Geology and Ground-Water Resources of Stanton County, Kansas

By

BRUCE F. LATTA

UNIVERSITY OF KANSAS PUBLICATIONS
STATE GEOLOGICAL SURVEY OF KANSAS
Bulletin 37

STATE GEOLOGICAL SURVEY OF KANSAS

BULLETIN 37

GEOLOGY AND GROUND-WATER RESOURCES OF STANTON COUNTY, KANSAS

By BRUCE F. LATTA

Analyses by ROBERT H. HESS

Prepared 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, Kansas State Board of Agriculture.

Printed by Authority of the State of Kansas
Distributed from Lawrence

UNIVERSITY OF KANSAS PUBLICATIONS

NOVEMBER, 1941

PRINTED BY KANSAS STATE PRINTING PLANT
W. C. AUSTIN, STATE PRINTER
TOPEKA 1941
19-277

STATE OF KANSAS

Payne H. Ratner, *Governor*

STATE BOARD OF REGENTS

Fred M. Harris, *Chairman*

Willis N. Kelly
Lester McCoy
Drew McLaughlin
W. T. Markham
Mrs. Donald Muir
Grover Poole
Mrs. Elizabeth Reigart
Oscar Stauffer

MINERAL INDUSTRIES COUNCIL

John Allison, *Chairman*
M. L. Breidenthal
Howard Carey
Anthony Folger
Lester McCoy
J. E. Missimer
Brian O'Brian, *Vice-Chairman*
Chester Scott
J. A. Schowalter
Kenneth Spencer
W. L. Stryker
B. O. Weaver

STATE GEOLOGICAL SURVEY OF KANSAS

Deane W. Malott, M. B. A., Chancellor of the University of Kansas and ex officio Director of the Survey

Raymond C. Moore, Ph. D., Sc. D., Director and State Geologist

John C. Frye, Ph. D., Asst. Director and Asst. State Geologist

Lea Drebing, Secretary

Stratigraphy, Paleontology, and Areal Geology
- John M. Jewett, M. A., Geologist
- Ralph H. King, M. S., Geologist*
- Walter H. Schoewe, Ph. D., Geologist
- Harold T. U. Smith, Ph. D., Geologist
- Ruth M. Dudley, M. A., Geologist
- Russell M. Jeffords, M. A., Geologist
- Arthur L. Bowsher, B. S., Geologist
- Edith Hicks Lewis, Stenographer

Subsurface Geology
- Raymond P. Keroher, B. A., Geologist
- Jacob E. Lemmons, B. A., Geologist
- Jewell J. Kirby, B. A., Geologist
- David McNair, Well sample curator, Wichita Branch

Mineral Resources
- George E. Abernathy, M. E., Ph. D., Geologist
- Robert M. Dreyer, Ph. D., Geologist
- Walter A. Ver Wiebe, Ph. D., Geologist
- Maurice H. Wallace, B. A., Geologist
- Norman Plummer, B. A., Ceramist
- John Romary, Ceramist
- John I. Moore, M. S., Petroleum Engineer
- E. D. Kinney, M. E., Metallurgist
- Clyde H. Wilson, Geophysicist
- Raymond F. Thompson, Chemist

Publications and Records
- Ralph H. King, M. S., Editor*
- Thomas G. Payne, M. S., Editor
- Donald E. Dowers, Draftsman*
- Glessner W. Reimer, Draftsman

Coöperative Projects with United States Geological Survey

Ground-Water Resources
- Stanley W. Lohman, M. S., Geologist in charge
- Herbert A. Waite, M. S., Geologist
- John C. Frye, Ph. D., Geologist
- Thad G. McLaughlin, Ph. D., Geologist
- Bruce Latta, B. A., Geologist
- Frank S. Byrne, Ph. D., Geologist
- Charles C. Williams, M. A., Geologist
- James J. Brazil, A. B., Geologist
- V. C. Fishel, B. S., Physicist
- Ellis Gordon, Well driller
- Perry McNally, B. A., Well driller
- Lawrence P. Buck, Well driller
- John B. LaDuex, B. A., Instrumentman
- Ruth A. Wilson, Stenographer
- G. H. von Hein, Well observer
- Woodrow Wilson, Well observer
- Melvin E. Scanlan, Engineer

Mineral Fuels Resources
- Wallace Lee, M. E., Geologist in charge
- Thomas G. Payne, M. S., Geologist
- Gene L. Maxwell, B. A., Geologist

Topographic Surveys
- Frank W. Hughes, Section chief
- J. P. Rydeen, Topographer
- Pierson Lyon, Topographer
- F. S. Bradshaw, Instrumentman

Special Consultants: Ray Q. Brewster, Ph. D., Chemistry; Claude W. Hibbard, Ph. D., Vertebrate Paleontology; John J. Jakosky, Sc. D., Geophysics; Eugene A. Stephenson, Ph. D., Petroleum Engineering.

Coöperating State Agencies: State Board of Agriculture, Division of Water Resources, George S. Knapp, Chief Engineer; Robert Smrha, Asst. Chief Engineer; **State Board of Health, Division of Sanitation,** Lewis E. Young, Acting Chief Engineer; Ogden S. Jones, Geologist.

* Absent on leave.

CONTENTS

ILLUSTRATIONS

GEOLOGY AND GROUND-WATER RESOURCES OF STANTON COUNTY, KANSAS

By Bruce F. Latta

ABSTRACT

This report describes the geography, geology, and ground-water resources of Stanton county, in southwestern Kansas. Stanton county has an area of about 685 square miles, and lies in the High Plains section of the Great Plains province. Most of the area is drained by Bear creek and Sand arroyo, which are ephemeral streams. The population of the county was 1,443 in 1940, and is principally rural. Johnson City, the county seat, is the largest community and in 1940 had a population of 524. Wheat farming is the chief industry. During the last several years the county has experienced partial or complete crop failure owing to drought conditions. The climate is the semiarid continental type, the average annual precipitation being about 17 inches.

The exposed rocks are sedimentary and range in age from late Cretaceous to Quaternary. Undifferentiated Pliocene (including the Ogallala formation) and Pleistocene sediments lie at or near the surface over nearly all of the county. They are overlain by a thin mantle of loess in the interstream areas, by thin deposits of alluvium in the stream valleys, and by dune sand south of Bear creek. The Cockrum sandstone (Upper Cretaceous) is the oldest formation exposed. Unexposed rocks beneath the Cockrum sandstone comprise the Kiowa shale and Cheyenne sandstone of early Cretaceous age, and rocks of the Triassic (?) and Permian systems. The pre-Tertiary strata in the northern part of the county form a buried trough, the north flank of which has been faulted in post-Tertiary time. The north flank of the buried trough is the south flank of the Syracuse anticline of southern Hamilton county.

The water table beneath Stanton county ranges in depth from less than 25 feet to 250 feet below the surface, and in general has an easterly slope. In the western part of the county, where the Cockrum sandstone is the principal water-bearing formation, the water table slopes as much as 60 feet to the mile, but in the eastern part of the county, where the Ogallala formation is the principal water bearer, the slope is very gentle and locally is as little as 4 feet to the mile. The difference in slope is due principally to the difference in permeability of the water-bearing materials in the two areas. The ground-water reservoir is recharged in three ways; by downward-percolating water that falls within or just west of the county, by influent seepage from Bear creek and possibly a small amount from Sand arroyo, and by water entering the Ogallala formation from the Cockrum sandstone at places where the latter formation thins between the Ogallala formation and the underlying impervious Kiowa shale. Water is discharged from the underground reservoir through wells and by lateral migration into areas to the east. All the public, railroad, and irri-

gation water supplies and most of the domestic and stock supplies are obtained from drilled wells.

At the time the investigation was made there were four active irrigation wells in the county, all of which obtained water from sands and gravels of the Ogallala formation. The most favorable place for future irrigation development is a roughly triangular area in the northeastern part of the county where the water table ranges from less than 50 feet to less than 100 feet below the surface.

The ground water is hard, but in general is of satisfactory quality for most purposes. In general the waters from the Ogallala formation and the Cockrum sandstone are slightly better than the water from the Cheyenne sandstone.

The Ogallala is the principal water-bearing formation in the county. It consists mostly of calcareous gravel, sand, and silt, which are consolidated locally to form conglomerate, sandstone, or siltstone. In Stanton county the Ogallala (including Pleistocene undifferentiated deposits) ranges in thickness from less than 50 feet to more than 400 feet. Most of the water is obtained from the sands and gravels of the formation. The Cockrum sandstone, which unconformably underlies the Ogallala formation, yields water to many wells in the western and southwestern parts of the county. It consists chiefly of fine- to medium-grained sandstones and light-colored shales or clays. It reaches 100 feet in thickness, but is absent locally. A few wells obtain water from the Cheyenne sandstone, which is made up of loose or cemented, fine to coarse sand and minor amounts of silty shale. It is about 50 feet thick in most places.

The basic field data upon which most of this report is based are given in tables, and include records of 147 wells, and chemical analyses of 38 samples of water from representative wells. Logs are given of 11 test holes drilled during the investigation and of several water wells in the county. The monthly water levels since August, 1939, in 17 unused wells are tabulated.

INTRODUCTION

Purpose and scope of the investigation.—An extensive program of ground-water investigations in the western part of the state was started in July, 1937, by the Geological Survey of the United States Department of the Interior and the Kansas State Geological Survey, with 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. In 1938 investigations were begun in parts of western Kansas where irrigation from wells is being carried on or where it is a possibility. This report presents the results of a study made during a part of the summer of 1939 to determine the availability and quality of ground water in Stanton county. The investigation was made under the general administration of R. C. Moore and K. K. Landes, state geologists, and O. E. Meinzer, geologist in charge of the Division of Ground Water of the Federal Geological Survey, and under the immediate 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 Stanton county, hence there is a definite need for a better understanding of the ground-water conditions. All public, railroad, domestic, and stock supplies in Stanton county are obtained from wells. Ground water is also being used to a small extent for irrigation, and it is likely that this practice will become more common in the future in order to insure the success of crops during periods of drought.

At the present rate of withdrawal there seems to be no danger of seriously depleting the ground-water supply, but as the number of large irrigation wells increases the problem of withdrawal may become more acute. It is desirable to have a better understanding of the ground-water conditions before extensive irrigation is begun. Accordingly a part of this report is devoted to the possibilities of developing additional water supplies from wells for irrigation.

At the beginning of the field work 17 unused wells were selected at strategic points in the county and monthly measurements of the water levels in them were begun in order to obtain information concerning the fluctuations in the quantity of water stored in the underground reservoir (Table 2).

Location and size of the area.—Stanton county, in southwestern Kansas, is in the second tier of counties north of Oklahoma and is bordered on the west by the state of Colorado (fig. 1). It lies between meridians 101°31′ and 102°2′ west longitude and parallels 37°25′ and 37°45′ north latitude. It has an area of about 685 square miles, is nearly square, and extends 24 miles north and south and about 28.5 miles east and west.

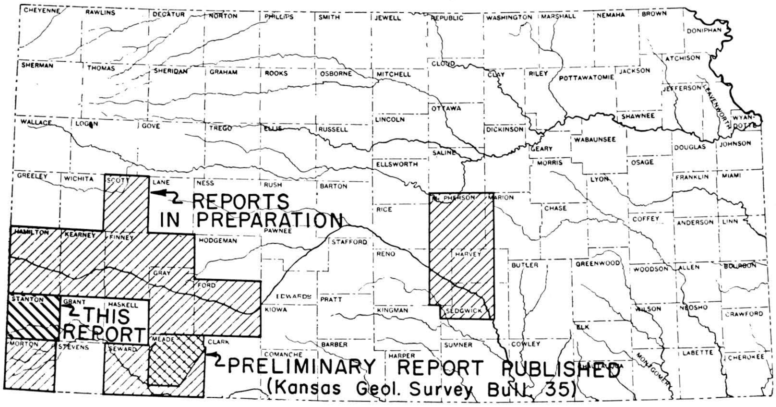


FIG. 1. Index map of Kansas showing area covered by this report and other areas for which coöperative ground-water reports are in preparation.

Previous geologic and hydrologic work.—The physiography of western Kansas was described by Haworth (1897, pp. 11-51) late in the 19th century. He includes in his report a detailed description of Bear creek and a north-south geologic cross section along the Kansas-Colorado line. W. D. Johnson (1901, pp. 601-741; 1902, pp. 631-669), a few years later, gave an interesting account of the occurrence of ground water in the High Plains, of which Stanton county is a part. In 1905 Darton (1905, pp. 318-319) made a preliminary survey of the geology and ground-water resources of the central Great Plains, and his report includes a brief paragraph on the possibility of obtaining artesian water in Stanton county. The same author (Darton, 1920) later published a somewhat detailed report on the geology and ground-water resources of the Syracuse-Lakin quadrangles, which includes about the northern two-thirds of Stanton county. Included in this report is a geologic map, a topographic map, and a map showing the depths to water level in the Syracuse and Lakin quadrangles. A very brief description of the availability of ground water in the county is given by Parker (1911, pp. 189-190) in a water-supply paper published in 1911.

In a report on well waters in Kansas published in 1913, Haworth (1913, p. 101) gives a short description of a water well in Stanton county and a map showing the depths to water level in western Kansas. The geology of Hamilton county, which adjoins Stanton county at the north, was studied and described by Bass (1926). He describes an anticlinal structure, the south flank of which extends into northern Stanton county. In 1935 Theis, Burleigh, and Waite (1935) described briefly the water-bearing formations and the availability of ground water in the entire southern High Plains. A report by Smith (1940) describes the Tertiary and Quaternary geology of southwestern Kansas, including Stanton county.

Methods of investigation.—The writer spent two months in Stanton county, from July 18 to September 18, 1939, obtaining data for this report. In the field a land-ownership map of the county was used to locate wells and to outline geologic outcrops. The total depth and the depth to water level in about 130 wells were measured. All measurements were made with a steel tape from a fixed measuring point at the top of each well. Information concerning the nature and thickness of the water-bearing material, yield of the wells, and the use and general character of the water was obtained from many farmers and drillers in the county. Samples of water were collected from 36 wells and chemical analyses of them were made by Robert H. Hess, chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health at Lawrence.

The altitudes of the measuring points of the wells in the southern half of the county and a few wells in the northern half were determined with a plane table and alidade by Delmar Branson and Everett Johnson in December, 1939, and January, 1940. The surface altitudes of most of the wells in the northern half of the county were taken from the topographic map of the Syracuse quadrangle.

In the winter and spring of 1940 eleven test holes (fig. 4) were drilled by Ellis D. Gordon and Perry McNally, using a portable hydraulic-rotary drilling rig owned by the state and federal geological surveys. Gordon and McNally were assisted for a short time by Laurence Buck. Samples from the test holes were collected and studied in the field by McNally and were again studied in the office by me. The test drilling gave information concerning the thickness and character of the water-bearing materials of the Ogallala formation and of the underlying Cretaceous and older beds. Landowners and drillers provided additional logs of wells drilled in the county.

A highway map of the county compiled by the State Highway Department was used in the office as a base map in preparing plates 1 and 2. The locations of the roads were corrected from notes taken in the field, and the drainage was corrected from aerial photographs obtained from the United States Department of Agriculture, Agricultural Adjustment Administration. The areal geology shown on plate 1 was taken in part from the state geologic map (Geologic map of Kansas, 1937) and modified by me from field observations and from the Stanton county soil map (Joel, 1937, map 5). Plate 2 shows the location of all the wells visited during the course of the investigation. The locations of wells within the sections are based upon speedometer distances. The upper number beside the well symbol is the number of the well and the lower number is the depth to the water level in the well in feet below the measuring point. Brackets around a well number indicate that the water has been sampled and that an analysis is given in this report. The wells are numbered in order by townships from north to south and by ranges from east to west. Within a township they are numbered in the same order as the sections. Well numbers on the map correspond to the well numbers used throughout the tables and text of this report.

Acknowledgments.—I am indebted to those farmers and ranchers in the county who so willingly supplied information concerning their wells, to Buell Scott and other drillers who provided well logs and other necessary information about wells, and to T. A. Blair, chief engineer for the Atchison, Topeka, and Santa Fe railway, for supplying a copy of the log of the railroad well at Manter. I also thank H. T. U. Smith and Frank Conselman for their helpful suggestions concerning the geologic problems.

The manuscript for this report has been critically reviewed by S. W. Lohman, and O. E. Meinzer, of the Federal Geological Survey; R. C. Moore and K. K. Landes, state geologists; Ralph H. King, editor, State Geological Survey of Kansas; George S. Knapp, chief engineer of the Division of Water Resources of the Kansas State Board of Agriculture; and Earnest Boyce, director of the Division of Sanitation of the Kansas State Board of Health. The illustrations were drawn by Donald E. Dowers and G. W. Reimer.

GEOGRAPHY

Topography and drainage.—Stanton county lies in the High Plains section of the Great Plains province. In general most of the county consists of gently rolling, nearly flat, upland plains (plate 3A) that slope toward the east at an average gradient of about 20 feet to the mile. The highest point in the county, north of Bear creek along the Colorado line, has an altitude of almost 3,700 feet. North Fork of Cimarron river leaves the southeastern corner of the county at an altitude slightly less than 3,100 feet, the lowest point in the county. The maximum relief, therefore, is about 600 feet.

The monotony of the nearly flat upland surface is broken by the effects of stream erosion in many places, by a prominent ridge in the northeastern part of the county, and by an area of dune sand south of Bear creek.

A prominent ridge, trending roughly northwest-southeast, extends from a point in northwestern Grant county across the northeastern part of Stanton county, through Hamilton county, and gradually merges with the High Plains surface in eastern Colorado. In southern Hamilton county the top of the ridge is broad and smooth, but the sides are cut deeply by streams. The ridge area in Stanton county is deeply dissected by tributaries of Bear creek.

There are no permanent streams in the county—only small ephemeral streams that flow only after heavy rains have fallen in the county or in southeastern Colorado. Bear creek, the most prominent of these small streams, originates 50 miles or more west of the state line in southeastern Colorado and enters Stanton county about 7 miles north of the southwest corner. It flows northeastward across the county and leaves at a point about 3 miles south of the northeastern corner. From there it flows a short distance eastward and then northeastward to a point about 10 miles south of Arkansas river in northern Grant county, where all traces of it gradually disappear. During times of heavy rains in southeastern Colorado and western Kansas, Bear creek carries a large quantity of water that is poured out on the plains in northern Grant county and into the sand hills south of Arkansas river. George S. Knapp, chief engineer of the Division of Water Resources, Kansas State Board of Agriculture, reports (personal communication) that—

> At times when Bear creek carries an unusually large quantity of water, the stream overflows to the south, the water going into Cimarron river near Ulysses.

The waters from Bear creek have never been known to reach Arkansas river. Some of the residents believe that an underground stream extends from Bear creek beneath the sand hills to the Arkansas valley. This, however, was disproved by Slichter (1906, pp. 20-21), who in 1904 established three underflow stations south of Arkansas river east of Hartland to determine whether or not there was any seepage from the direction of Bear creek toward the Arkansas valley. He found that—

> No ground water reaches either Clear lake or Arkansas river from the lost waters of Bear creek. Any seepage water approaching Arkansas valley from Bear creek must take up a generally easterly movement almost immediately upon entering the sand hills.

In the southwestern part of Stanton county Bear creek has cut a deep, locally steep-sided valley through the Ogallala formation, exposing the underlying Cockrum sandstone. In the northeastern part of the county the valley of Bear creek is shallow and in places almost unrecognizable. The average gradient of Bear creek as it crosses the county is about 9 feet to the mile. Little Bear creek follows closely the south side of the ridge in southern Hamilton county and enters Bear creek in the northern part of Stanton county about 1 mile south of the county line. A small area in the northwest part of the county is drained by an unnamed tributary of Little Bear creek.

Sand arroyo enters the county about 1 mile north of the southwest corner, flows in an easterly direction across the county, and leaves at a point about 7 miles north of the southeast corner. In the western part of its course it has cut a conspicuous, deep valley, but like Bear creek, through most of its course its valley is shallow and inconspicuous. After leaving Stanton county Sand arroyo joins North Fork of Cimarron river in southern Grant county. North Fork of Cimarron river crosses the extreme southeastern corner of Stanton county in a narrow but prominent valley.

A belt of dune sand about 19 miles long and as much as 2.5 miles wide extends along the south side of Bear creek in the central part of the county. The accumulated sand forms moderate slopes and hills that are separated by small basins. Some of the hills stand 40 feet or more above the depressions. In general, the area covered by dune sand has a more hilly or rolling surface than the surrounding land.

Population.—In 1940 Stanton county had the fewest residents of any county in the state. The population of the county has fluctu-

PLATE 3. A, Flat, featureless topography typical of the upland plains of Stanton county. View looking east from a point in sec. 10, T. 28 S., R. 41 W. B, Abandoned farm in Morton county, Kansas. Scenes like this are common in Stanton county. Note how the accumulated dust has almost completely buried the fence. Photograph by S. W. Lohman.

ated greatly since the first census was taken. The population in 1890 was 1,031; in 1900, 327; in 1910, 1,034; in 1920, 908; and in 1930, 2,152.

According to the 1940 census it was 1,443, an average of 2.1 persons to the square mile. Johnson City, the county seat, which is situated in the middle of the county, had a population of 524 in 1940, and Manter, located about 9 miles southwest of Johnson City, had a population of 133. Population figures are not available for Big Bow and Saunders. Big Bow is a small, unincorporated community in the east-central part of the county. Saunders, located near the state line in the southwestern part of the county, serves as a supply station for farmers and is a grain-shipping point. Early maps of the county show several small communities that have since been abandoned, including Fisher, Floto, and Fletcher.

Transportation.—Stanton county is served by a branch line of the Atchison, Topeka, and Santa Fe railway, which runs from Dodge City through Satanta to Prichett, Colo. It passes through all the communities in the county—Big Bow, Johnson City, Manter, and Saunders.

U. S. highway 160 passes from east to west through the middle of the county. It is graveled from Johnson eastward, but is not graveled west of Johnson. State highway 27 traverses the middle of the county from north to south and is graveled throughout. U. S. highway 270 follows state highway 27 from the north county line to Johnson and from there it follows U. S. highway 160 eastward. The highways and main county roads are kept in good condition and are passable throughout the year. Part of the county roads and section-line roads become temporarily impassable at different times of the year owing to drifting sand, snow, or mud, but in general the roads are good throughout the year and travel is not thus impeded.

Agriculture.—Stanton county was first settled by ranchers in the latter part of the nineteenth century because of the good grazing land and the abundant supply of good stock water. There was very little cultivation at first and such cultivation was chiefly incidental to the raising of livestock. After a time ranches gradually gave place to wheat farms, so that now there are no large cattle ranches left in the county. The most extensive farm development came after the World War, owing mainly to the large increase in the price of grain. In 1935, 74.4 percent of the total area of the county was under cultivation and only 14.1 percent was being used for pasture

(Joel, 1937, p. 16). The principal crops grown in Stanton county in 1935 were as follows (Joel, 1937, p. 65):

Crop distribution in Stanton county in 1935

	Acres
Wheat	97,787
Hay and forage	7,876
Grain sorghum	3,721
Barley	948
Corn	116

Since farming has been undertaken in the county, crop failures have been more common than crop successes, and each year since 1932 the county has experienced partial or complete crop failure. The chief causes of crop failure have been drought and wind erosion. Joel (1937, p. 14) states that the wind erosion was not serious until overgrazing depleted the native vegetation or cultivation destroyed it; that there was little wind erosion during extremely dry periods of the past such as that of 1893-'95. In the last 8 or 10 years the intensity and frequency of dust storms has become an extremely serious problem not only in Stanton county, but over the entire High Plains region.

Crop failures, the result of drought and wind erosion, along with lowered grain prices, have forced many farmers to abandon their farm homes (pl. 3B) and to live in other parts of the country. For those who remained these factors have resulted in a general lowering of the standards of living and in the necessity of government assistance. Almost half the farms in Stanton county are now worked by tenants and it is not uncommon to find several farms being worked by the same man. The average size of the farms has increased so that today the average farm consists of 845.3 acres (Joel, 1937, p. 66). Schoff (1939, p. 35), in writing about Texas county, Oklahoma, states that the increase in the size of farm units has been due to "the uncertain crop yield from year to year" and to "the flatness of the plains, which favors economical operation of large acreages by the use of tractors."

In summary, wheat raising is the chief industry of the county and only a small percentage of the land is devoted to the raising of cattle. Owing to low rainfall, paying crops are not raised every year, and the farmers have become accustomed to experiencing several crop failures for every good crop.

Climate.—The climate of Stanton county is the semiarid continental type involving slight precipitation, moderately high average wind velocity, and rapid evaporation. During the summer the days are hot, but the nights are, as a rule, cool and comfortable. The heat of the hot summer days in this part of the state is more easily endured than the heat in the eastern part of the state, owing to the lower relative humidity in the west. During most of the winter the weather is moderate and there are only occasional short severe cold periods. The average mean annual temperature at Johnson is 54.7° F. The average growing season, that is, the average interval be-

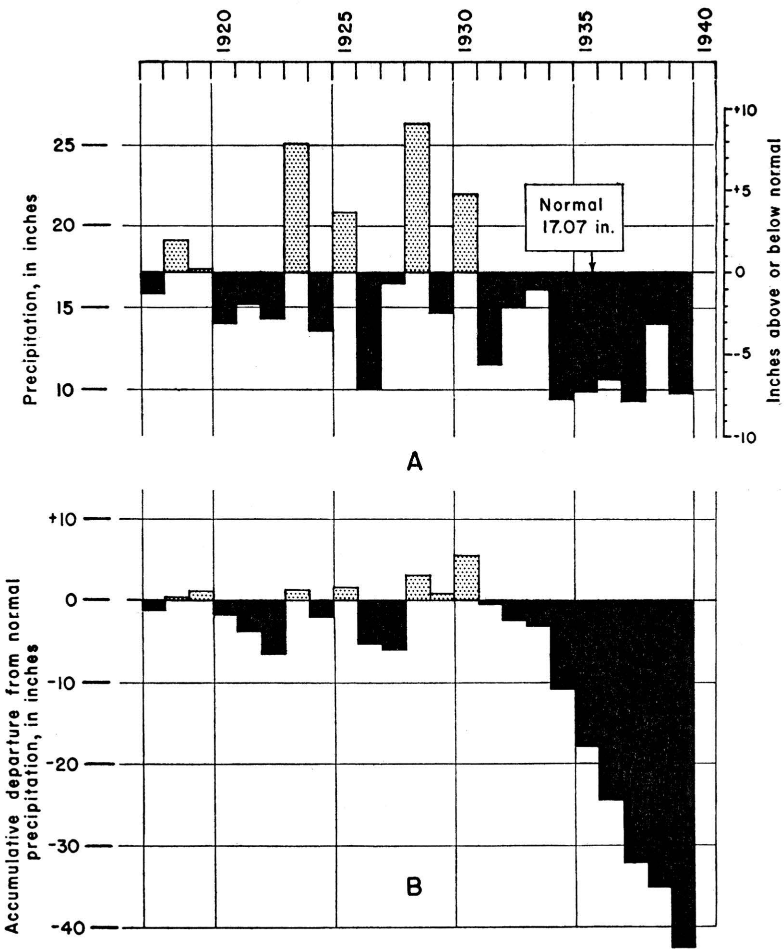


FIG. 2. Graphs showing (A) the annual precipitation at Johnson, Kan., and (B) the accumulative departure from normal precipitation at Johnson.

tween the last killing frost in the spring and the first killing frost in the fall, is about 176 days, and has ranged from a minimum of 156 days in one year to a maximum of 204 days in another year.

A large proportion of the moisture falls as torrential rains that are separated by long intervals of dryness. Most of the rain falls in the crop-growing season, which extends from March to September. The average mean annual precipitation at Johnson is 17.07 inches, and at Ulysses in Grant county it is 16.86 inches. The rainfall at Johnson has been below normal every year for the last 9 years. The annual precipitation and the accumulative departure from normal precipitation at Johnson and Ulysses are shown graphically in figures 2 and 3.

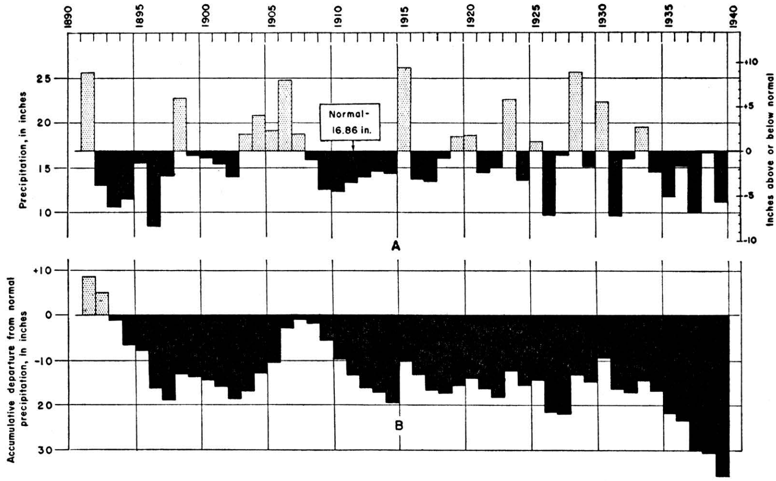


FIG. 3. Graphs showing (A) the annual precipitation at Ulysses, Grant county, Kansas, and (B) the accumulative departure from normal precipitation at Ulysses.

GEOLOGY

SUMMARY OF STRATIGRAPHY *

The rocks that crop out in Stanton county are all of sedimentary origin and range in age from early Upper Cretaceous to Recent. Outcrops of the formations are shown on plate 1. The oldest rocks exposed at the surface are shale and sandstone that have previously been called Dakota sandstone. For reasons given later (p. 79) this sandstone of early Upper Cretaceous age is named Cockrum sandstone in this report. This formation crops out in narrow belts along Bear creek and Sand arroyo in the southwestern part of the county. Calcareous sands, gravels, and silts of the Ogallala formation of Tertiary (Pliocene) age unconformably overlie the Dakota sandstone and lie at or near the surface over most of the county, except where they are covered by undifferentiated Pleistocene deposits. It is not possible to differentiate between the Pliocene and Pleistocene deposits so they are described in this report under the name Ogallala formation. Minor amounts of Quaternary loess, dune sand, or alluvium cover a large part of the surface.

Knowledge of the unexposed rocks that lie beneath Stanton county is at the best very general. The Kiowa shale and Cheyenne sandstone, both of early Cretaceous age, underlie the Cockrum sandstone in most or all of the county. The Morrison formation (Jurassic) may underlie the Cheyenne sandstone in the extreme western part of the county, but no direct evidence of this is available. Red shales and light-colored sandstones of Triassic age probably underlie the Cheyenne sandstone throughout most of the county. Beneath the Triassic (?) beds are thick deposits of red shale, hard blue shale, limestone, anhydrite, and gypsum belonging to the Permian system.

A generalized section of the geologic formations of Stanton county is given in Table 1.

GEOLOGIC HISTORY

The geologic history of Stanton county is the same in a general way as that of a large area of the central Great Plains. The rocks underlying the county comprise sediments of several types, including limestone, shale, sandstone, clay, sand, and gravel. The composition, appearance, and relations of these rocks indicate to the geologist the condition under which they were deposited.

* The classification and nomenclature of the rocks described in this report have been adopted by the State Geological Survey of Kansas. They differ somewhat from the classification and nomenclature given in formal reports of the Federal Geological Survey.

TABLE 1.—*General section of the geologic formations of Stanton county*

System.	Subdivision.	Thickness (feet).	Character.	Water supply.
Quaternary	Alluvium.	(?)	Thin mantle of sand, gravel, and silt; covers the valleys of the larger streams.	Alluvium nearly everywhere lies above the water table. Supplies water to only a few shallow wells in the county. Serves as important catchment area for recharge of the underground reservoir.
	—unconformable on older formations—			
	Dune sand.	(?)	Composed principally of quartz sand, but contains some silt and clay. Covers large areas south of Bear creek.	Does not yield water to any wells in the county. Dunes serve as important catchment areas for recharge from local precipitation.
	—unconformable on older formations—			
	Loess.	0–10(?)	Unstratified, tan to buff clay and silt. Thin mantle covering interstream areas.	Relatively impermeable. Yields little or no water to wells and tends to resist the downward percolation of rainfall.
	—unconformable on older formations—			
Tertiary and Quaternary	Pliocene (including the Ogallala formation) and Pleistocene undifferentiated.	0–450+	Calcareous clay, silt, sand, and gravel, mainly unconsolidated. Hard conglomerate occurs at base in some places.	By far the most important water-bearing deposits in the county. Supplies water to stock, domestic, municipal, and irrigation wells. Water table at depths ranging from less than 50 to more than 200 feet below the surface.
	—unconformable on older formations—			
Cretaceous	Dakota group: Cockrum sandstone.	0–125+	Light tan to reddish brown. Massive to thin-bedded, fine-grained ferruginous sandstone and varicolored shale and clay shales.	Sandstones yield adequate supplies of water to stock and domestic wells at most places in the western part of the county. Water level at depths ranging from 50 to 250 feet below the surface. Water is under slight artesian pressure, but the pressure is not great enough to produce flows at the surface.
	Dakota group: Kiowa shale.	25–115+	Blue-gray to black, soft to hard clay-shale and shale. Not exposed in Stanton county.	Not known to yield water to wells.
	Dakota group: Cheyenne sandstone.	45–100+	Loose to cemented, fine to coarse, light-colored sand and some calcareous shaly silt.	Yields water to few wells in western part of county where the Cockrum supply is inadequate or entirely lacking.
	—disconformity (?)—			
Jurassic (?)	Morrison (?) formation.	(?)	Thought to be present in western Stanton county, but no evidence is available to substantiate this. Crops out about 25 miles west of this county and is found in drill holes in adjacent areas.	No data obtained.
	—disconformity (?)—			
Triassic (?)	Undifferentiated redbeds.	213+	Pink and buff calcareous sandstone and light-gray to red-brown clay.	Unimportant in Stanton county. Reported to yield artesian water in southwestern Morton county, some of which is highly mineralized.
Permian	Undifferentiated shale, limestone, anhydrite, and gypsum.	(?)	Red shale, hard blue shale, limestone, and some beds of sandstone, anhydrite, and gypsum. Encountered in gas test well south of Johnson.	Unimportant in Stanton county. Yields water to flowing wells at Richfield in central Morton county. Water is highly mineralized and unfit for ordinary uses.

Paleozoic Era

Very little is known of the conditions existing in the southwestern part of the state during the Paleozoic era. An oil test well drilled to a depth of 5,488 feet in southern Hamilton county penetrated thick beds of Mississippian and Pennsylvanian shales and limestones overlain by about 2,000 feet of Permian red shale and sandy shale containing beds of salt, anhydrite, gypsum, and limestone. A well drilled for gas about 1 mile south of Johnson penetrated Permian red shale and sandstone, limestone, gypsum, and anhydrite between depths of 880 feet and 3,005 feet below the surface. The limestones encountered in the two wells were deposited under marine conditions. The area probably was covered by great seas during most of the Paleozoic era except possibly during the Silurian and Devonian periods (Darton, 1906, pp. 45-46). Thick deposits of limestone, such as are found in the two deep wells mentioned, were deposited in these seas. It is not to be inferred that the land was covered continuously by a body of water, but rather that there were long periods of submergence separated by comparatively short intervals of emergence.

Permian period.—During the early part of the Permian period there was alternating submergence and emergence of the land, and during the latter part there was a widespread emergence that produced shallow basins and low plains. It was on this type of topography that the great mass of red clay and sand that forms the upper part of the Permian system in this region was laid down. Streams deposited the materials of the coarser beds; and the materials of the finer beds were laid down in shallow local basins or bayous and on wide mud flats. The climate seems to have been prevailing arid during the time these sediments were being deposited. The deposition of sand and clay was interrupted at different times by the chemical precipitation of almost pure gypsum, which is a product of evaporation in shallow bodies of water. Its relative purity indicates that the waters in which it was precipitated were probably very quiet, for if there had been much movement of the water the gypsum would probably contain a large amount of sand and clay. This summary of Permian history as applied to southwestern Kansas is largely based on a report by Darton (1907, p. 7).

Mesozoic Era

Triassic period.—The conditions that existed in late Permian time probably continued with little change into the Triassic period, for the sediments that were deposited in the central western states during the two periods are very similar. Most of the Triassic (?) sediments of southwestern Kansas are red shales and light-colored sandstones predominantly of continental origin. The sediments of the two periods differ in the amounts of gypsum they contain; the Permian contains a large amount of gypsum, but the Triassic has only a very small amount.

The entire Triassic period is not represented by rocks in Stanton county, indicating either that strata equivalent in age to all rocks known to comprise this system elsewhere were not deposited in this part of Kansas, or that some of the deposits were subsequently eroded after an uplift of the sea bottom in late Triassic (?) time.

Jurassic period.—Rocks representing the Jurassic system are not known to occur in Stanton county, but 160 feet of sediment (Morrison) crops out in southern Prowers county, Colorado, about 25 miles west of Stanton county (Saunders, 1934, p. 870), and a test hole drilled northwest of Richfield in Morton county (T. G. McLaughlin, personal communication) penetrated about 40 feet of blue-green marl, which is probably a part of the Morrison formation. If sediments of Jurassic age were deposited in Stanton county they seem to have been removed later by erosion except perhaps in the western part.

Cretaceous period.—The Cretaceous period began with the deposition of quartz sand forming the Cheyenne sandstone. The Cheyenne sandstone represents either shallow-water marine or stream deposition (Twenhofel, 1924, p. 19). After the deposition of the Cheyenne sands the land was submerged and covered by a moderately deep sea in which was deposited the dark clay forming the Kiowa shale. Next came a recurrence of conditions similar to those of Cheyenne time and nearly pure quartz sand was deposited, forming the Cockrum sandstone. The deposition of the Cockrum sand marks the beginning of late Cretaceous time. A thick series of younger Upper Cretaceous sediments was probably deposited over all or at least a part of Stanton county, but was entirely eroded prior to the deposition of the Ogallala (Pliocene) sediments.

Cenozoic Era

Tertiary period.—Early in the Tertiary period the land was uplifted and a long time of erosion began. All the late Cretaceous beds down to and in places including part of the Cockrum sandstone were stripped off, leaving an irregular topography. Sometime prior to the beginning of Pliocene time the strata in southern Hamilton county were arched or gently folded, resulting in what is now known as the Syracuse anticline (Bass, 1926, p. 77). The flank of this anticline dips southward to form a broad basin or trough in the northern part of Stanton county. The trough was probably very shallow at first, but was deepened by erosion before the beginning of Ogallala time. The present shape of the pre-Tertiary trough in cross section is shown by section AA′ on plate 4, and the areal shape is indicated in figure 4 by contour lines drawn on the pre-Tertiary surface. The

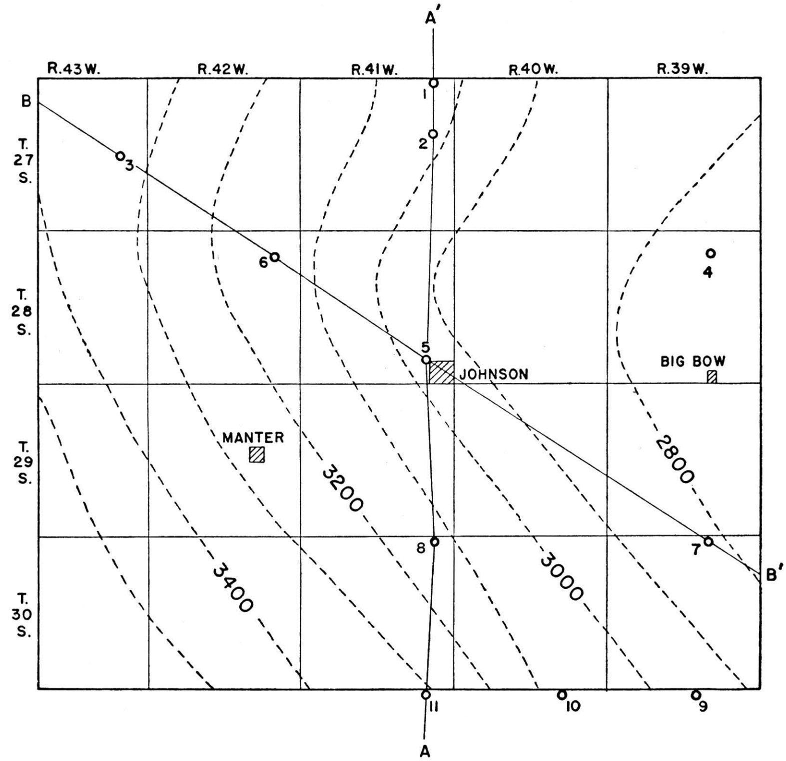


Fig. 4. Map of Stanton county showing the shape and slope of the pre-Tertiary surface by means of contours (dashed lines), location of test holes (numbered circles), and location of cross sections, shown on plate 4.

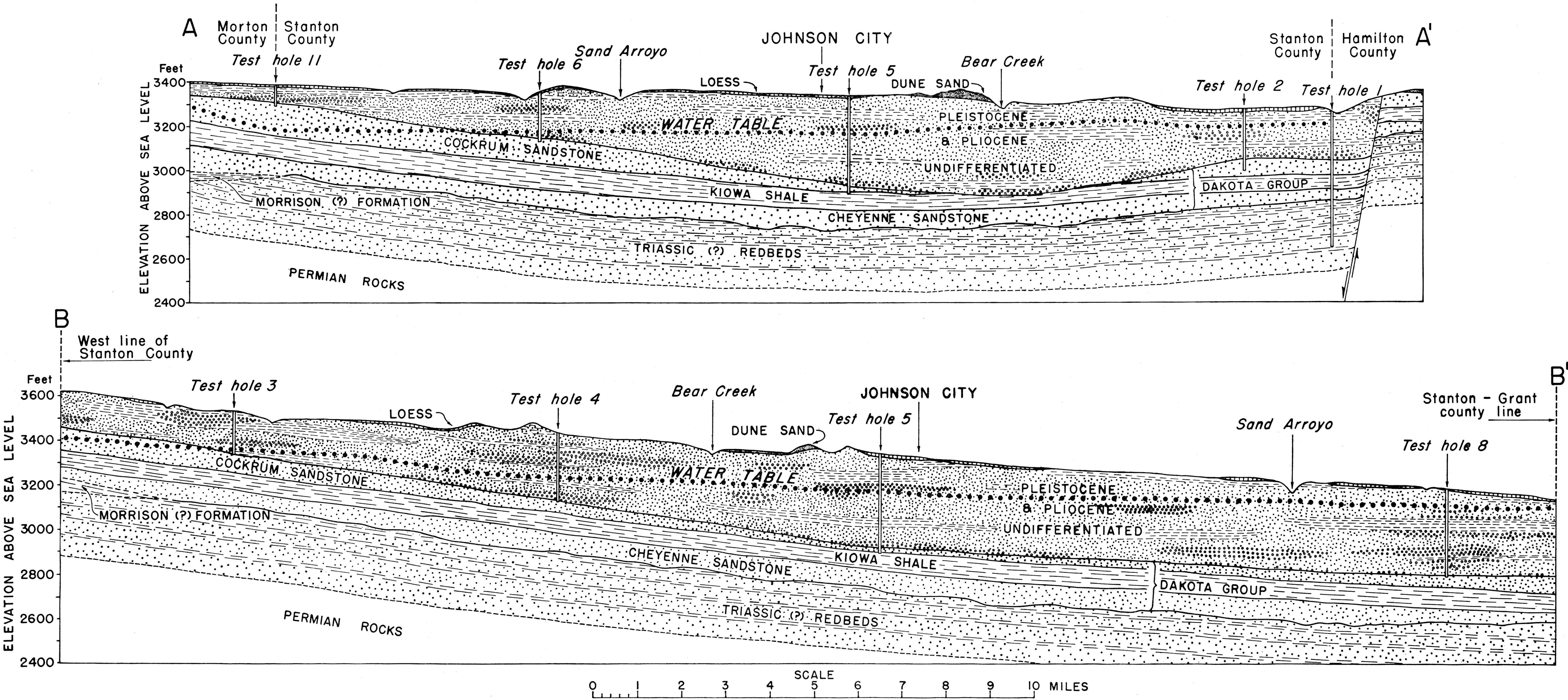


Plate 4. Geologic profiles through Stanton county, along lines AA′ and BB′ in figure 4.

axis of the trough is a short distance north of Johnson and trends roughly from northwest to southeast.

Late in Tertiary time, during the Pliocene epoch, there was a reversal of conditions, from stream erosion to stream deposition. Rock debris from the mountains to the west was deposited over the entire High Plains surface by widely shifting streams. These deposits, consisting of sand, gravel, clay, and silt, make up the Ogallala formation and the Pleistocene undifferentiated beds. The trough in Stanton county and the Syracuse anticline were both buried beneath a thick mantle of these sediments, leaving a flat and featureless surface.

Quaternary period.—Owing to a general uplift or to a change in climate in the Quaternary period, the streams again began to erode, resulting in the widespread denudation of the Tertiary and Pleistocene deposits. This period of erosion has continued to the present time and has progressed so far as to lay bare the rocks underlying the Tertiary beds in the southwest part of the county and at a few localities in adjacent areas.

During Quaternary time there was some additional folding and faulting of the Ogallala deposits and underlying Cretaceous strata on the south flank of the Syracuse anticlne. Smith (1941, pp. 136, 137) first suggested the presence of a fault on the south flank of the Syracuse anticline, basing his conclusions principally on physiographic evidence. During the course of the present investigation the Cockrum sandstone was encountered at an altitude of 3,039 feet in a test hole drilled on the Hamilton-Stanton county line. About 1⅛ miles north of this test well the Cockrum sandstone is exposed at an altitude of about 3,350 feet, more than 300 feet higher than in the test hole. It seems unlikely that this much difference in altitude can be attributed to folding and erosion alone; rather, the evidence indicates a normal fault that trends roughly northwest, and dips to the southwest. The Cretaceous strata seem to have been displaced vertically 250 to 300 feet, the downthrown side being the south side. North Branch of Bear creek follows in general the fault-line scarp. The combined faulting and crustal movement has produced the prominent ridge just north of the Stanton county line in southern Hamilton county, which ends within a short distance eastward in northwestern Grant county and southwestern Kearny county.

The streams in the southwestern part of the county are in a youthful stage of development, for downcutting is dominant and the valleys have relatively steep sides. In the eastern part of the county, however, the same streams have wide open valleys that have exceedingly gentle slopes, and they seem to be approaching base level, for they are aggrading their valleys instead of eroding them.

Within Quaternary time wind-blown sand has accumulated to form the dunes or sand hills south of Bear creek. At about the same time or perhaps before the formation of the sand hills a thin mantle of loess, mostly silt and clay, was deposited on the crests and slopes of the upland areas in the county. At the present time some areas of loess and sand dunes are sufficiently covered by vegetation so that the material is more or less permanently fixed, but in other large areas, where there is no protective vegetation, the fine surficial materials are being continually shifted and transported by the wind.

GROUND WATER

PRINCIPLES OF OCCURRENCE

The following discussion on the occurrence of ground water has been adapted from Meinzer (1923, pp. 2-102), and the reader is referred to his report for a complete discussion of the subject. A summary of considerations on this subject is given also in State Geological Survey Bulletin 27 (Moore, 1940).

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

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

The capacity of a rock to hold water is determined by its porosity, but its capacity to yield water is determined by its permeability. The permeability of a rock may be defined as its capacity for transmitting water under pressure, and is measured by the rate at which it will transmit water through a given cross section under a given difference of pressure per unit of distance. Rocks that will not transmit water may be said to be impermeable. Some deposits, such as well-sorted silt or clay, may have a high porosity, but because of the minute size of the pores will transmit water only very slowly. Other deposits, such as well-sorted gravel containing large openings that communicate freely with one another, will transmit water very readily. If a force greater than the force of gravity were applied to the water in the silt or clay it would probably move more readily. Part of the water in any deposit is not available to wells because it is held against the force of gravity by molecular attraction—that is, by the cohesion of the water itself and by its adhesion to the walls of the pores.

Below a certain level, which in Stanton county ranges from less than 25 feet to about 250 feet below the surface, the permeable rocks are saturated with water under hydrostatic pressure. These saturated rocks are said to be in the zone of saturation, and the upper surface of this zone is called the water table. Wells dug or drilled into the zone of saturation will become filled with ground water to the level of the water table.

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

ARTESIAN CONDITIONS

Ground water may be said to have normal pressure, subnormal pressure, or artesian pressure or pressure head. The static level of ground water under normal pressure is at the upper surface of the zone of saturation, and under subnormal pressure the static level is below this surface. Artesian water is ground water under sufficient pressure to rise above the zone of saturation. A well that flows at the land surface is known as a flowing artesian well.

Artesian conditions exist where a water-bearing bed is overlain by an impermeable or ralatively impermeable bed that dips from its outcrop to the discharge area (Sayre, 1937, p. 22). Water enters the water-bearing bed at the outcrop and percolates slowly downward to be held in the water-bearing bed by the overlying confining bed. Down the dip from the outcrop area the water exerts considerable pressure against the confining bed. When a well is drilled through the confining bed into the water-bearing bed the pressure is released and the water rises in the well. If the water is under sufficient pressure, and if the altitude of the land surface is lower than the altitude of the outcrop of the water-bearing bed, the water may rise high enough to flow at the surface. In places where there are lenses or beds of relatively impermeable clay or silt at the level of the water table, the water encountered below such lenses or beds will rise to the level of the surrounding water table, but such water is under normal pressure and is not artesian.

Although there are no known flowing wells in Stanton county, the water in the Cheyenne and Cockrum sandstones at many places in the western part of the county seems to be under slight artesian head. The water in the Ogallala formation, however, is in most places under normal pressure and therefore generally does not rise above the level at which it is first encountered. Cross section BB′ in plate 4 shows the Cheyenne sandstone to be confined below the Kiowa shale and indicates that artesian water might be obtainable from the Cheyenne sandstone. The gas test well south of Johnson is the only well that has tapped the Cheyenne sandstone in the eastern part of the county, and the water in it was cased off so that the drilling could proceed to the possible gas-bearing zones. No other wells are known to have been drilled into the Cheyenne sandstone in the eastern part of the county.

Darton (1920, p. 9), in discussing the Dakota sandstone in the Syracuse and Lakin quadrangles, says—

> This formation yields artesian flows from Coolidge westward up the Arkansas valley, but the head falls gradually and finally passes beneath the valley bottom a short distance east of Coolidge. Hence there is apparently no likelihood of finding flows within the area.

A well drilled in the SW¼ sec. 34, T. 29 S., R. 43 W., in Stanton county, encountered two sandstones separated by a bed of shale. The first sandstone, Cockrum, carried only a meager supply of water and therefore was cased off. It is reported that when the drill penetrated the second sandstone (Cheyenne), at a depth of 175 feet below the surface, the water rose in the well within 85 feet of the surface. In a small area surrounding Blaine, Colo., about 12 miles west of Stanton county, wells drilled into the Dakota and Cheyenne sandstones flow at the surface. There are reported to be approximately 60 flowing wells in the Blaine area, ranging in depth from about 200 to 500 feet. The Cheyenne sandstone or its equivalent, also yields flowing artesian water in a few wells near Coolidge, in west-central Hamilton county.

Water in the Triassic (?) redbeds is probably under slight pressure in Stanton county, but so far as is known the pressure is not great enough to cause the water to flow at the surface. Only one well (101) in the county is known to penetrate the Triassic (?) beds, and the water level in it stands 211 feet below the surface. A well 460 feet deep and thought to end in Triassic (?) beds was drilled many years ago at Elkhart in southwestern Morton county, and is reported to have flowed at the surface, but the water was so highly mineralized that it was cased off. Three flowing wells at Richfield, in central Morton county, obtain water from Permian beds, but the water is highly mineralized and cannot be used for most purposes.

THE WATER TABLE AND MOVEMENT OF GROUND WATER

Shape and Slope

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

The shape and slope of the water table in Stanton county are shown on plate 1, by means of contour lines drawn on the water table. Each point on the water table along a given contour line has the same altitude. These water-table contours show the configuration of the water surface just as topographic contours show the configuration of the land surface. The direction of movement of the ground water is at right angles to these water-table contour lines—in the direction of the greatest slope.

The map shows that the ground water beneath the plains moves through Stanton county in a general easterly direction, but that the direction of movement and the slope vary considerably in different places. The average gradient of the water table is about 18 feet to the mile, but as shown on the map the slope in the western part of the county is steep as compared with the more gentle slope in the eastern part. A short distance west of Manter the water table slopes as much as 60 feet to the mile, whereas southeast of Johnson the water table is nearly level, sloping as little as 4 feet to the mile.

Other things being equal, the slope of the water table in any area in general varies inversely with the permeability of the water-bearing material; that is, the water assumes a steeper gradient in flowing through fine material than through coarse material, providing the same quantity of water is moving through both types of material. This probably explains, at least in part, the great differences in the slope of the water table in eastern and western Stanton county. In the western part of the county, where the gradients are steep, the water in the upper part of the zone of saturation moves through the fine-grained Cockrum sandstone. As the water moves eastward it enters the coarser, more permeable sand and gravel of the Ogallala formation, and the gradient becomes greatly reduced. Some of the minor irregularities in the shape of the water table may be due to local differences in the permeability of the water-bearing formation.

Along Bear creek in the western part of the county the contour lines are flexed in a downstream direction, indicating the existence of a low ridge on the water table. Another, less discernible ridge on the water table is indicated by the downslope flexure of the contour lines in the northeastern part of the county. Influent seepage from Bear creek (p. 40) is the principal cause of these ridges on the water table. These ridges or areas are formed by water percolating downward because the frictional resistance offered by the small openings in the water-bearing material prevents the water from spreading out as rapidly as it would on the surface of a body of free water, such as a lake. As soon as the descending water reaches the water table it joins the main body of ground water and moves in an easterly direction to conform with the direction of movement of the ground water.

South of Manter a very prominent east-west trough or depression in the water table is indicated by the upslope flexture of the contour lines, and is the normal counterpart of the ridge to the north. On the south side of the ridge the water is moving in a southeasterly direction, whereas on the north side of the ridge it is moving in a northeasterly direction. East of Manter the waters gradually merge and move eastward in a common direction.

About 6 miles southeast of Johnson the downslope flexture of the 3,140-foot contour line indicates that a broad, relatively low mound has been built up on the water table. This is a low-lying area containing many shallow depressions that hold water after rains. Some of the water probably seeps downward to the underground reservoir, where it builds up a mound. A large part of the surface in Stanton county is mantled by loess—a very fine-grained, homogeneous material that resists the downward percolation of water because of its low permeability. The surface material in the relatively flat area southeast of Johnson, however, consists of sandy loam soils that allow the surface water to pass downward. Other minor irregularities in the shape of the water table also may be accounted for by the difference in the permeability of the soil—some taking in more water than others.

Relation to Topography

The water table and the land surface are similar in that they both slope in the same general direction and have approximately the same amount of total relief from west to east. On the map, plate 2, are shown the depths to the water level in Stanton county by the use of isobath lines—lines of equal depths to water level. In preparing this map the more general irregularities of the surface topography were taken into account by using aerial photographs and the available topographic maps. As shown on this map, the depth to water level ranges from less than 50 feet to 250 feet. Some inaccuracy has been introduced by small local irregularities on the land surface that are not shown on the topographic maps or aerial

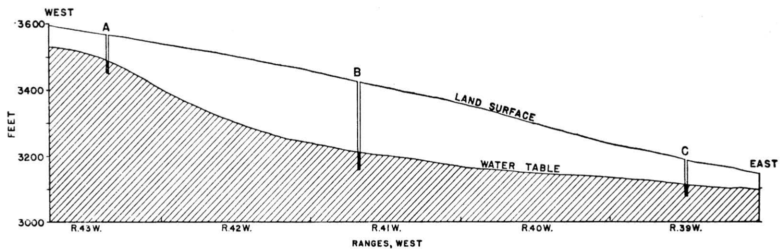


Fig. 5. East-west section across Stanton county along the south side of T. 29 S. showing the relation between the land surface and the water table.

photographs. It will be noted on the map that the depth-to-water lines are flexed both upstream and downstream along Bear creek and Sand arroyo. This lack of analogy between the depth to water and the surface slope results from the combination of an almost uniform slope of the land and a water table whose slope in the western part of the county is much steeper than it is in the eastern part. (p. 30.) The relation between the water table and the land surface from west to east across the county is shown in figure 5. Thus it can be seen that the depth to the water table is greater at B in the middle of the county than at either A in the western part, or at C in the eastern part.

For purposes of detailed descriptions of the ground-water conditions, Stanton county may be divided into several areas based upon the depths to the water level: (1) shallow-water areas, (2) deep-water areas, and (3) the Johnson area of intermediate depth to water. The shallow-water areas may in turn be subdivided into the northeastern area, the southeastern areas, and the southwestern areas.

Northeastern shallow-water area.—The northeastern shallow-water area is roughly triangular in shape and comprises parts of three townships, T. 27 S., R. 39 and 40 W., and T. 28 S., R. 39 W., which lie mainly south of Bear creek. In this area the depths measured ranged from 44 to 56 feet. All the wells in this area obtain water from sand and gravel of the Ogallala formation. In this area the zone of saturation ranges in thickness from 200 to 300 feet, and attains its greatest thickness in the southern part where the Ogallala formation occupies the pre-Tertiary trough described on page 24.

The relief of the surface is favorable for irrigation, and large quantities of water are available from wells. The possibilities of developing additional supplies for irrigation in this area are discussed on page 55.

Southeastern shallow-water areas.—There are two small areas in the southeastern part of the county in which the water table is less than 50 feet below the surface. One area is along the valley of Sand arroyo and the other is along the valley of North Fork of Cimarron river. Both areas include only the stream valleys and are, therefore, narrow, and are delineated by the 50-foot lines on plate 2. No wells were found in either area, but the water levels in the wells adjacent to these areas are only slightly more than 50 feet below the surface. The alluvium in the valleys lies above the water table, and hence will not yield water to wells, but water probably can be obtained from the underlying Ogallala formation, which supplies water to wells in adjacent areas.

Southwestern shallow-water areas.—There are two areas in the southwestern part of the county in which the water table is shallow. One of these areas comprises about 5 square miles along Sand arroyo in the southwestern corner of the county. The wells in this area (146) obtain water from the Cockrum sandstone and the water level in them is 50 feet or less below the surface.

The other area lies within the 50-foot line along Bear creek west of Manter. In the western part of this area Bear creek has cut through the Ogallala formation and exposed the Cockrum sandstone. Records of six wells in this area are given in the tables. Two of these wells (110 and 112) obtain water from the Cheyenne sandstone, two (109 and 113) obtain water from alluvium along Bear creek, one (98) obtains water from the Ogallala formation, and one (107) obtains water from the Cockrum sandstone. The depths of the wells range from 16 to 200 feet and the depths to water level in them range from about 12 feet to 40 feet.

Manter deep-water area.—The Manter deep-water area includes the southeastern half of T. 29 S., R. 42 W., and the western part of T. 29 S., R. 41 W. The wells in the western part of this area obtain water from the Cockrum sandstone and those in the eastern part obtain water from the Ogallala formation. The depth to the water level is everywhere more than 200 feet and in the SE¼ sec. 27, T. 29 S., R. 42 W., it is about 250 feet. The depths of most of the wells range from 215 to 256 feet, but the railroad well at Manter is 475 feet deep.

West-central deep-water area.—The west-central deep-water area, in which the water level lies more than 200 feet below the surface, comprises about 7 square miles in the central part of T. 28 S., R. 42 W. Records were obtained for only two wells (64 and 67) in this area, both of which obtain water from the Ogallala formation. The depths of wells in this area range from about 225 feet to more than 250 feet, and the depth to the water level ranges from about 200 feet to 244 feet.

Northwestern deep-water area.—The northwestern deep-water area is in the extreme northwestern corner of Stanton county and includes secs. 4, 5, 8, and 9 of T. 27 S., R. 43 W. The wells obtain water from the Cockrum sandstone and the depth to the water level ranges from about 200 feet to about 220 feet.

Johnson area of intermediate depth to water.—The Johnson area comprises an arcuate belt that extends from the north county line through Johnson to the south county line, near the middle of the county. The depth to the water level in this area ranges from about 100 to 200 feet, and all the wells obtain water from the Ogallala formation except a few in the southern part that obtain water from the Cockrum sandstone. The thickness of the Ogallala formation (including undifferentiated Pleistocene) ranges from about 80 feet in the southern part to more than 400 feet in the vicinity of Johnson, where the Ogallala occupies the pre-Tertiary trough described on page 24. In the southern part of the Johnson area the Ogallala formation is above the water table and therefore is dry. In the central and northern parts of the area the thickness of the saturated part of the Ogallala ranges from about 100 feet to more than 250 feet.

Fluctuations

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

The factors controlling the rise of the water table in Stanton county are the amount of rainfall within the county that passes through the soil and descends to the water table, the amount of seepage that reaches the underground reservoir from Bear creek and Sand arroyo, and the amount of water entering the county beneath the surface from areas farther west. All these factors depend upon precipitation either in or near the county. The relation between the amount of precipitation and the level at which the water stands in wells is complicated by several factors. After a long dry spell the soil moisture becomes depleted through evaporation and transpiration and when a rain does occur the soil moisture must be replenished before any water can descend to the water table. During the winter when the ground is frozen the water falling on the surface is hindered from reaching the water table, and during the hot summer some of the water that falls as rain is lost directly into the air by evaporation. Where the water table stands comparatively far below the surface, as it does in most of Stanton county, it fluctuates less in response to precipitation than it does where it is comparatively shallow.

The factors controlling the decline of the water table are the amount of water pumped from wells, the amount of water absorbed directly from the water table by plants (transpiration), the amount of water lost from the ground-water reservoir by evaporation, the loss of water from springs, and the amount of ground water passing beneath the surface into adjacent areas. The only escape of water from the ground-water reservoir in Stanton county seems to be through wells and by lateral movement out of the county. Owing to the deep-lying water table there is probably no loss of water from the ground-water reservoir through evaporation or transpiration in Stanton county, nor is there any discharge from springs. The last factor, the amount of ground water passing beneath the surface into adjacent areas, may or may not cause the water table to decline. Assuming that no water is withdrawn from wells, then if the amount of water leaving the county beneath the surface to the east is equal to the amount of water entering the county at the west, there will be no decline of the water table; however, if the amount of water leaving the county becomes greater than the amount entering the county, there will be a resulting decline of the water table.

Change in the water level in wells records the fluctuation of the water table, which in turn records the recharge and discharge of the ground-water reservoir. In July, 1939, at strategic points in Stanton county 17 wells were selected and periodic measurements of the water levels in them were started, in order to determine the character and magnitude of fluctuations of the water table. The depths to water level in the wells were measured monthly beginning in August, 1939, and all measurements are given in table 2. All measurements prior to November 15, 1939, were made by me, those on and after that date were made by Richard B. Christy. The water levels in 13 of the 17 wells showed net gains of 0.01 foot to 0.84 foot from August, 1939, to July, 1940. The water levels in the other 5 wells showed net declines of 0.09 foot to 0.34 foot for the same period. In general, the water levels fluctuated very little during this period, and there seems to be no direct relation between the rainfall and the fluctuations in water level, owing to the lag between rainfall and recharge. The period of observation is too short to draw any conclusions regarding the trend of the water-table fluctuations. It is planned that the program of measuring water levels will be continued, for the longer the period of record the more reliable will be conclusions derived therefrom. All measurements through December acter and magnitude of fluctuations of the water table. The depths States Geological Survey for 1940, and additional measurements will be published annually in ensuing water-level reports.

RECHARGE

Recharge is the addition of water to the underground reservoir and may be accomplished in several different ways. All ground water within a practicable drilling depth beneath Stanton county is derived from the water that falls as rain or snow either within the county or on near-by areas west of the county. 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 Stanton county seems to be recharged by local rainfall within the county, by influent seepage from streams, and by subsurface inflow from areas west of the county.

TABLE 2.—*Water levels in observation wells in Stanton county, Kansas*, in feet below the measuring point*

(For location of wells refer to plate 2; for descriptions, refer to well tables, pages 89-99)

Well No.	1939.					1940.						
	Aug. 8.	Sept. 8.	Oct. 9.	Nov. 15.	Dec. 15-16.	Jan. 31.	Feb. 20-21.	Mar. 15.	Apr. 22-23.	May 14-15.	June 17-18.	July 17-18
4	55.92	55.87	55.89	55.82	55.86	55.81	55.81	55.79	†	†	55.79	55.77
13	51.53	51.60	52.44	52.45	52.57	52.65	52.67	52.72	52.83	52.82	52.82	52.52
29	100.34	100.33	100.43	100.41	100.38	100.43	100.45	100.44	100.44	100.44	100.44	100.43
35	179.07	179.03	179.12	178.98	179.00	178.84	179.04	178.92	178.99	178.94	178.89	178.80
47	70.91	70.91	70.92	70.94	70.91	70.92	70.91	70.92	70.88	70.10	70.91	70.89
48	78.25	78.29	78.28	78.34	78.29	78.28	78.30	78.30	78.30	78.27	78.28	78.38
54	102.55	102.44	102.58	102.51	102.51	102.48	102.53	102.52	102.52	102.52	102.49	102.68
57	150.49	150.39	150.52	150.34	‡150.90	150.91	150.30	150.17	150.25	150.12	150.06	150.01
62	140.73	140.72	140.65	140.39	140.39	140.26	140.44	140.18	140.18	140.30	139.89	139.89
68	138.03	138.02	137.94	137.89	137.90	137.83	137.90	137.83	137.73	137.73	137.64	137.60
84	60.43	60.46	60.53	57.97	60.61	60.66	60.67	60.67	60.66	60.72	60.69	60.77
93	....	176.39	176.60	176.44	176.42	176.43	176.42	176.38	176.36	176.31	176.37	176.26
117	63.95	63.91	63.93	63.93	63.92	63.92	63.92	63.90	63.90	63.68	63.87	63.85
124	138.80	138.79	138.85	138.78	138.70	138.79	138.76	138.73	138.78	138.79	138.78	138.73
128	182.43	182.45	182.35	182.42	182.21	182.23	182.48	182.42	182.47	182.36	182.33	182.24
141	153.11	153.15	153.04	153.02	152.89	152.84	153.15	153.04	152.89	153.09	152.97	152.80
146	46.73	46.74	46.76	46.76	46.77	46.77	46.79	46.78	46.80	46.80	46.80	46.67

* The descriptions and 1939 water-level measurements are being published in "Water Levels and Artesian Pressures in Observation Wells in the United States in 1939": U. S. Geol. Survey Water-Supply Paper (in press). Subsequent water levels will be published in future papers of this series.

† Well pumping.

‡ Well pumped just prior to measurement.

Recharge From Local Rainfall

The average annual precipitation in Stanton county is about 17 inches, but probably only a very small percent of this amount reaches the zone of saturation, owing to several complicating factors. Of the total precipitation, part is lost by evaporation into the air, part is lost through runoff, and part is used by growing plants.

The amount of water lost through evaporation into the air varies from one season to the other, the rate of evaporation being the greatest in the summer when temperatures are highest. In an average year more than half the total precipitation in the county comes during the summer from May through August, when the rate of evaporation is greatest. Although no figures are available regarding the exact annual amount of evaporation in Stanton county, it seems reasonable to assume that a large proportion of the annual precipitation returns to the atmosphere through evaporation.

A part of the precipitation that falls is used by plants, and the amount consumed in this way is obviously greatest during the growing season, which closely coincides with the period of the maximum rainfall.

The amount of water leaving the county by runoff in streams is probably very small, even though the local runoff in some places is large, for much of the local runoff is respread over the area by streams and does not leave the county. The duration and intensity of the rainfall, the slope of the land surface, and the type of soil and vegetation principally determine the amount of local runoff from precipitation. The runoff from a gentle rain as a rule is much smaller than the runoff from a heavy downpour, hence the amount of ground-water recharge from a gentle rain of long duration generally is greater than the recharge from a heavy downpour of short duration, providing all other factors are equal.

The slope of the land is an important factor in determining the amount of runoff, and in general the steeper the slope the greater the runoff. The slope of the surface in most places in Stanton county is gentle, hence this factor tends to hold at a minimum the loss of precipitation through runoff.

Runoff is greater in places where the soil is tightly compacted and consists of fine, relatively impermeable material than in places where the soil is sandy and loosely compacted. The latter type of soil allows a part of the water to percolate into the ground, thus decreasing the amount of surface runoff.

Vegetation on the surface tends to decrease the velocity of the runoff, thereby offering a better opportunity for the water to seep into the ground.

From the foregoing it can be seen that the proportion of the precipitation that reaches the water table may be relatively small. Theis, Burleigh, and Waite (1935, pp. 2-3) believe that—

> On the average over the High Plains only about half an inch of water a year escapes evaporation and absorption by the vegetation and percolates through the soil to the ground-water body.

The amount of recharge from precipitation in Stanton county is probably less than the average given for the entire High Plains, for about half the surface of the county is mantled by loess (plate 1), which greatly impedes if it does not prohibit the downward movement of water from the surface. The area of sand dunes south of Bear creek affords ample opportunity for a relatively large part of the precipitation to move readily downward beyond the influence of evaporation and the reach of plant roots. Other areas where the land lies low, the slopes are gentle, and the soils are sandy, are also favorable for recharge. Much of the rain that falls, particularly during heavy showers, will drain off into low places, or will stand on the surface for a time. A large proportion of the water will be lost through evaporation in either case, but some water will penetrate the soil and move downward toward the water table. The low area southeast of Johnson probably provides some recharge in this manner.

In many places the descending water will not recharge the underground reservoir directly beneath the area of intake, for the water, upon reaching a bed of impervious clay, silt, or caliche, must take a lateral course until it comes to an opening or pervious zone before continuing its downward course. In all probability the water follows a very irregular course from the surface to the water table.

Recharge from Streams

Two factors determine whether or not a stream is capable of supplying water to the underground reservoir; first, the water surface of the stream must be above the water table; and second, the material between the stream channel and the water table must be sufficiently permeable to permit water to percolate downward. If the water surface of the stream is lower than the water table and the material forming the sides of the channel are permeable, the process is reversed; that is, the ground-water reservoir will discharge water into the stream.

The ridges on the water-table contour map, described on page 32, indicate that along part of its course Bear creek is losing water to the ground-water reservoir. The channel of Bear creek lies above the water table throughout the county, and the deposits beneath the channel in most places allow the water to percolate downward. From a point in the SE¼ sec. 12, T. 29 S., R. 43 W., northeastward the alluvium forming the bed of Bear creek consists of highly permeable sand and gravel that will readily allow water to percolate downward. Southwest of this point, where Bear creek has cut into the Cockrum sandstone, the stream bed in many places is floored by relatively impermeable shales that probably allow little or no percolation. Where the channel has cut into sandstone, however, water may seep downward and ultimately reach the water table.

During times of heavy rains in eastern Colorado and western Kansas, Bear creek carries a large volume of water. Although most of this water is emptied out upon the high plains of northern Grant county, where it generally disappears in a few days partly by evaporation and partly by seepage into the ground (Darton, 1920, p. 3), a large part also seeps into the ground before reaching Grant county. Residents of Stanton county report that sometimes after moderate rains the water that flows in Bear creek sinks before it reaches the county line.

No evidence for recharge from Sand arroyo is shown on the water-table contour map, but this stream probably supplies some water to the underground reservoir. The drainage area of Sand arroyo is considerably smaller than that of Bear creek, hence Sand arroyo carries a much smaller volume of water, which accounts in part for the smaller amount of recharge derived from it.

From the foregoing discussion it can be seen that during and after rains seepage from Bear creek and possibly Sand arroyo supplies a large quantity of water to the ground-water reservoir in Stanton county.

Recharge From Outside of County

A part of the water that falls on the surface in southeastern Colorado probably passes underground and eventually reaches the underground reservoir beneath Stanton county. The Dakota (Cockrum) sandstone is exposed over wide areas in western Las Animas county, Colorado, and adjacent areas, and undoubtedly absorbs water directly from rainfall and from streams that cross the outcrops. It is likely that a part of the water thus absorbed by the sandstone travels down the dip into Kansas, and probably migrates into the overlying Ogallala formation in Stanton county at places where the two formations are in contact and especially where the Cockrum thins. This method of recharge is illustrated in plate 5 by an east-west cross section from Trinidad, Colo., through Johnson, to the Stanton-Grant county line.

West of Chacuaco creek the strata dip toward the west, and therefore any water absorbed by the Dakota sandstone west of Chacuaco creek probably travels westward and does not reach the underground reservoir in western Kansas. Water traveling down dip through the Dakota (Cockrum) sandstone does not migrate into the Ogallala formation until it reaches a line a few miles east of the Colorado-Kansas boundary, for the Ogallala formation west of this line lies entirely above the zone of saturation (pl. 4, B-B′). At places where the Cockrum sandstone does not have a confining bed above it and where the pressure head of the water in the Cockrum is greater than the head in the Ogallala formation, the water can move from the Cockrum into the Ogallala. Downward migration of the water from the Cockrum is unlikely because the underlying Kiowa shale is relatively impervious and will not permit water to move through it into the underlying Cheyenne sandstone.

The amount of recharge received in this manner is necessarily limited by the small rainfall in southeastern Colorado and by the capacity of the sandstone to transmit water laterally. The average annual rainfall in the intake area is probably about the same as that in Stanton county, but the area of Dakota sandstone exposed east of Chacuaco creek is much larger than the total area of Stanton county. Therefore, although the average annual precipitation is relatively low, considerable recharge could occur in the area of outcrop. The amount of water discharged from the Dakota sandstone in southeastern Colorado through seepage into streams or by pumping from wells is not known, but it is thought to be relatively small compared to the total amount of water contained in the sandstone.

The Dakota dips beneath the Ogallala formation at about the Las Animas-Baca county line in Colorado, east of which the Dakota (Cockrum) is exposed only in the small stream valleys. Some of the water that falls on the surface of the Ogallala formation in Baca county probably passes underground and in part enters the Dakota sandstone. The amount of water entering the Dakota sandstone in this manner is thought to be small as compared with the amount entering the sandstone in the area of outcrop.

The recharge area for the Cheyenne sandstone must be sought outside of Stanton county, because the Cheyenne is not exposed to rainfall in the county and is everywhere overlain by the relatively impervious Kiowa shale. The Cheyenne sandstone is probably recharged in areas of outcrop west of Stanton county in the same manner as the Dakota sandstone. The Purgatoire formation in Colorado is equivalent to the Cheyenne sandstone and Kiowa shale in Stanton county. The amount of water added annually to the Cheyenne sandstone in this manner is probably small, owing to the scanty rainfall in southeastern Colorado and to the small area of outcrop.

DISCHARGE

Transpiration and Evaporation

Water may be taken into the roots of plants directly from the zone of saturation or from the capillary fringe, and discharged from the plants by the process known as transpiration (Meinzer, 1923a, p. 48). The depth from which plants will lift ground water varies with different plant species and different types of soil. The limit of lift by ordinary grasses and field crops is not more than a few feet, but some types of desert plants have been known to send their roots 60 feet or more below the surface to reach the water table (Meinzer, 1923, p. 82).

The plant life in Stanton county consists mainly of short grasses and field crops and, as the water table nearly everywhere lies 50 feet or more below the surface, it is doubtful whether there is any great loss of water from the zone of saturation by the process of transpiration.

In areas where the water table is shallow some ground water from the zone of saturation evaporates directly into the atmosphere. In areas such as Stanton county, however, in which the zone of saturation and the capillary fringe lie at considerable depth, virtually no water is lost by evaporation from the zone of saturation.

Seepage into Streams

A stream that stands lower than the water table may receive water from the zone of saturation, but streams that stand above the water table, as do all the streams in Stanton county, cannot receive water from the zone of saturation. On the contrary, some of the streams in

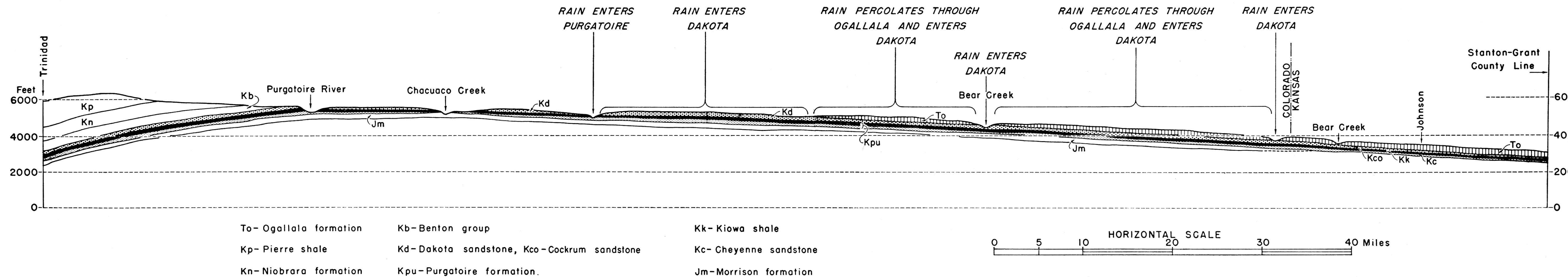


PLATE 5. East-west cross section from Trinidad, Colo., through Johnson, to the Grant-Stanton county line, illustrating recharge of the Purgatoire (equivalent in part to the Cheyenne) formation and the Dakota sandstone (equivalent to Cockrum sandstone). In parts of Stanton county the Ogallala formation receives recharge from the Cockrum sandstone. (Geology in Colorado was taken from the Geologic map of Colorado [U. S. Geol. Survey, 1935]; and elevations were taken from Darton [1906, pl. 6]).

Stanton county contribute water to the ground-water reservoir, as described on pages 39-40.

Springs

No springs that discharge water from the main zone of saturation were observed in Stanton county. The depth of the water table precludes the possibility of water-table springs, and artesian springs also are lacking. Many small seeps are found along Bear creek just east of the state line, but these seeps issue from small bodies of perched ground water rather than from the main ground-water reservoir. Here Bear creek has cut through the Ogallala formation, exposing shale and sandstone of the underlying Cockrum. Percolating ground water in the Ogallala formation encounters the impervious shale in the Cockrum, and as it cannot continue to move downward, it moves laterally and seeps out at places where the shale has been exposed by Bear creek.

Wells

From the foregoing discussion it can be seen that only a very insignificant amount of water, if any, is taken from the ground-water reservoir in Stanton county by natural processes, except the water that percolates slowly out of the county toward the east (p. 35). All or virtually all the water taken from the underground reservoir within the county is discharged through wells, as discussed below.

RECOVERY

Principles of Recovery

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

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

The specific capacity of a well is its rate of yield per unit of draw-down and is usually stated in gallons a minute per foot of draw-down. For example, well 78 is reported to yield 650 gallons a minute with a draw-down of 13 feet. Its specific capacity is, therefore, 50 gallons a minute per foot of draw-down.

When a well is pumped the water level drops rapidly at first and then more slowly, but it may continue to drop for several hours or days. In testing the specific capacity of a well, therefore, it is important to continue pumping until the water level remains approximately stationary. When the pump is stopped the water level rises rapidly at first, then more slowly, and may continue to rise long after pumping has ceased.

The character and thickness of the water-bearing materials have a definite bearing on the yield and draw-down of a well, and in turn on the specific capacity of a well. Draw-down increases the height that the water must be lifted in pumping a well, thus increasing the cost of pumping (p. 49). If the water-bearing material is coarse and of a fairly uniform size it will readily yield large quantities of water to a well with a minimum draw-down, but if the water-bearing material is fine and poorly sorted it will offer more resistance to the flow of water into a well, thereby decreasing the yield and increasing the draw-down. Other things being equal, the draw-down of a well varies inversely with the permeability of the water-bearing material.

The specific capacity of wells, particularly in unconsolidated materials, generally can be greatly increased by the employment of special methods of well construction, as described on pages 47-49.

In Stanton county ground water is recovered principally from drilled wells, but in part from dug wells. Descriptions of the types of wells employed in the county follow:

Dug Wells

Dug wells are wells that have been excavated by hand, generally with pick and shovel. In places where the walls will not stand alone, dug wells are cribbed with casings of wood, rock, concrete, or metal. As a rule dug wells are more subject to surface contamination than are properly constructed drilled wells. Moreover, as dug wells generally extend only a few feet below the water table, they are more likely to go dry during periods of drought than the deeper drilled wells.

There are only a few dug wells in Stanton county and they have all been abandoned in favor of drilled wells. Most of these wells were dug years ago by the early settlers of the county. The importance of water to these early settlers is illustrated by the time and hard labor they must have put into digging some of these wells. Several of the dug wells are more than 150 feet deep, are 3 to 5 feet in diameter, and are cribbed the entire depth.

Most of the dug wells in Stanton county have caved and are no longer in usable condition. Of the six dug wells found and inspected, only one (107) contained water and was equipped with a pump.

Drilled Wells

All the stock, domestic, railroad, municipal, and irrigation water supplies in Stanton county are obtained from drilled wells. Most of the wells were drilled by portable cable-tool drills mounted on trucks. This method of drilling consists in raising and lowering a heavy bit on the end of a steel cable, which is threaded over a sheave at the top of a tower or mast. The crushed material in the bottom of the hole is mixed with water and removed by means of a bailer.

Irrigation wells 19, 41, and 78 were drilled by the hydraulic-rotary method, the hole being made by the rapid rotation of a bit on the bottom of a string of drill pipe. In this method removal of the cuttings is accomplished by circulating mud-laden fluid down through the drill pipe and up through the annular space between the drill pipe and the hole. The cuttings are brought to the surface as fragments suspended in the mud. The mud also serves to plaster the materials around the hole, thereby preventing caving until the casing is installed. Wells 19 and 41 were drilled with a portable hydraulic-rotary drill rig (pl. 6A), which has all the drilling equipment except the derrick mounted on wheels. The derrick can be taken down joint by joint and transported to the next location by truck. Well 78 was drilled with a larger stationary drill rig (pl. 6B), of the type commonly used for drilling oil wells.

Most of the drilled wells in the county have galvanized-iron casing, but a few have wrought-iron casing. Wrought-iron casing is more expensive and more difficult to perforate, but will withstand more pressure and will last much longer than galvanized-iron casing. The diameter of the casing ranges from 5 or 6 inches in most domestic and stock wells to 18 inches or more in irrigation wells. Well 78 has 60-inch casing from the top to a depth of about 80 feet, and from there to the bottom it has 18-inch casing.

Wells in consolidated deposits.—Most of the wells in the western and southwestern parts of Stanton county obtain water from consolidated deposits (Cockrum or Cheyenne sandstone) and have been

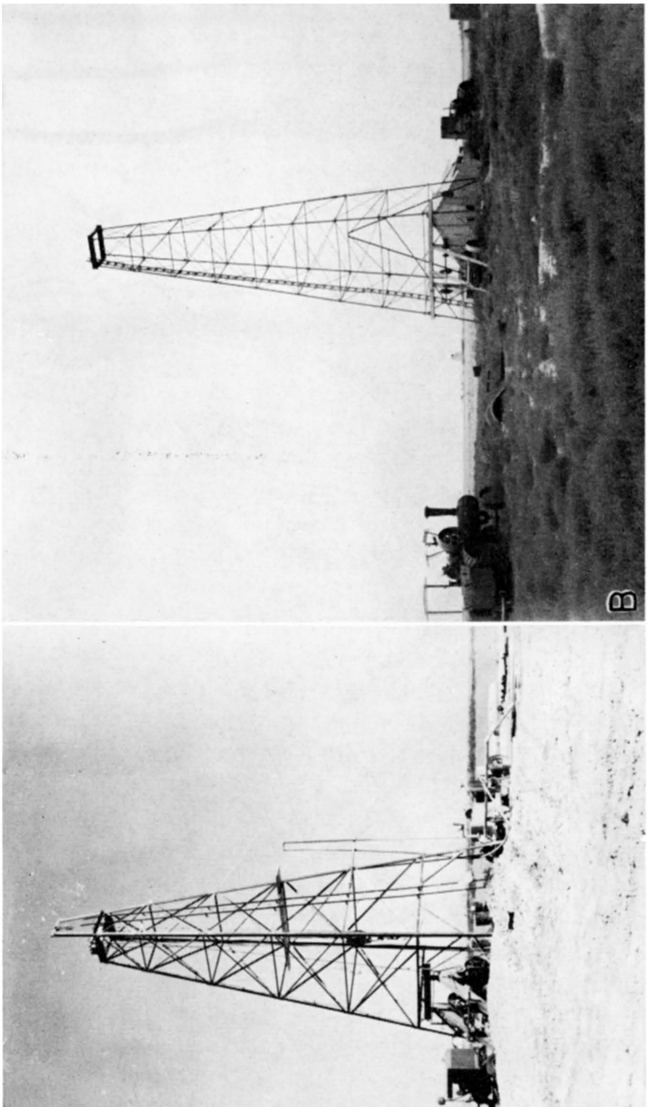


PLATE 6. Rotary well-drilling rigs used in Stanton county to drill irrigation wells. A, Well 41 being drilled by a portable rig. B, Stationary derrick at well 78.

drilled with portable cable-tool rigs. Many of the wells are open-end wells; that is, the hole is cased through the overlying Ogallala formation and a few feet into the consolidated rocks, but the lower part of the hole is not cased. Holes drilled into the bedrock formation below the Ogallala will as a rule stand open without casing. Well 112 was reported to have been drilled to a depth of 200 feet, but only the upper 30 feet was cased. Holes drilled into the consolidated formations will not always stand alone, so it becomes necessary in drilling some wells to case the holes from top to bottom. In such wells small perforations are sometimes cut in the casing opposite the water-bearing beds.

Wells in unconsolidated deposits.—About 70 percent of the wells observed in Stanton county obtain water from unconsolidated sands and gravel of the Ogallala formation. It is necessary to case these wells the full depth of the hole in order to prevent caving of the walls. In some wells the casing has been perforated in the lower part; in other wells the casing is open only at the bottom. Perforating the casing greatly increases the area of intake, and thus the specific capacity of the well is increased and the entrance velocity of the water is reduced. Well screens are used in some wells to prevent fine sand from entering the well and to increase the intake area.

The public-supply well at Johnson City and all the irrigation wells in the county are gravel-packed wells. In constructing this type of well, a hole of large diameter (48 to 60 inches) is first drilled and temporarily cased. A well screen or perforated casing of a smaller diameter than the hole (12 to 25 inches) is then lowered into place and centered opposite the water-bearing beds. Blank casing extends from the screen to the surface. The annular space between the inner and outer casings then is filled with carefully sorted gravel—preferably of a grain-size just slightly larger than the openings in the screen or perforated casing, and also just slightly larger than that of the water-bearing material. The outer casing is then withdrawn in order to uncover the screen and allow the water to flow through the gravel packing from the water-bearing material.

The logs of some of the test holes drilled during the investigation reveal that in some places the water-bearing materials are sufficiently coarse and well sorted that gravel-packed wells are not required in order to obtain large yields. In such places less expensive wells employing well screens or slotted casings, but without gravel packing, may be used satisfactorily. In places where the water-bearing materials are fine-grained, however, the gravel-packed wells have several advantages that offset the greater initial cost. The envelope of selected gravel that surrounds the screen increases considerably the effective diameter of the well, and hence decreases the velocity of the water entering the well. This reduction in velocity prevents the movement of fine sand into the well and increases the production of sand-free water. Owing to the increased effective area offered by this type of construction, the entrance friction of the water is reduced and hence the draw-down may be reduced appreciably. As stated above, a reduction in draw-down, at a given yield, increases the specific capacity and reduces the cost of pumping.

Assuming that a well of the best possible construction is employed, then the maximum amount of water that can be withdrawn from the well is fixed by nature and nothing can be done to make the well yield more than the water-bearing material will provide. The problem for the driller then is to construct each individual well in such a manner as to obtain the greatest yield with the smallest amount of draw-down that is possible under the existing conditions.

According to McCall and Davison (1939, p. 29) draw-down 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 used 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 draw-down than will increasing the diameter, so long as additional water-bearing formations are encountered.

A report (Davison, 1939) containing a description of different types of pumping plants, the conditions for which each is best suited, construction methods, and a discussion of construction costs is available from the Kansas State Board of Agriculture, Topeka, Kan., and the reader is referred to this publication for details of well construction.

The most important question to the farmer who is contemplating the construction of an irrigation well is whether or not the ground water can be developed and pumped to the surface at a cost low enough to permit a profit from the crops produced. The depth to water level determines in part the original cost of the well and the cost of operation. The height a given quantity of water must be lifted is a prime factor in determining the cost of operating a well. The economic success of an irrigation project often hinges on this point, for the cost of lifting water to the surface increases in proportion to the total pumping lift. It is generally not possible to state the limit of economical pumping lift in a given locality, for it depends on such factors as the cost of fuel for operating the pump, efficiency of the pump, kind and price of the crops being irrigated, and the skill and management of the individual. In 1902 Johnson (1902, p. 668) made the following statement:

> The economical pumping lift at Garden [Garden City, Kan.], under present conditions, can hardly be said to reach 20 feet. Under the more favorable conditions of future development and a local market this will probably not be increased by more than 50 percent. That is, 25 feet appears to be about the limit of height above the water plane at which irrigation farming from wells can profitably be conducted—at least on a commercial basis.

Since this statement was made the economical pumping lift in the vicinity of Garden City has increased more than 100 percent above the maximum figure given by Johnson, owing to modern developments in well construction, higher efficiency of modern pumps, type and increased price of crops being irrigated, and reduced cost of fuel for pumping.

The character and thickness of the water-bearing beds determine in part the original cost of constructing a well and the cost of operating the pumps after the well is completed. If the water-bearing beds are composed of somewhat fine materials it may be necessary to gravel-pack the well, and this increases the original cost. If the water-bearing materials are sufficiently coarse, less expensive wells employing well screens or perforated casings without gravel packing can be constructed.

Blowing wells.—Several so-called blowing wells were observed in Stanton county. In wells of this type air is alternately blown out of or sucked into the casing. This phenomenon was observed in wells 35 and 96. Lugn and Wenzel (1938, p. 64) describe blowing and sucking wells in south-central Nebraska and state that they are caused by changes in atmospheric pressure. There may be unsaturated sand and gravel above the water table and below an impervious layer of loess or silt. This unsaturated material is filled with air that is confined between the impervious layer and the water table. According to Lugn and Wenzel this air is subjected to compression and expansion by changes in atmospheric pressure, and this pressure change causes a flow of air into or out of the unsaturated sand and gravel through the well casing.

UTILIZATION OF WATER

All the water used in Stanton county is supplied by drilled wells. Records of 143 wells in the county and 4 outside the county were obtained and are tabulated on pages 89-99. Of the 143 wells in the county for which records are given, 136 are used for domestic and stock purposes, 4 are used for irrigation, 2 are used for public supplies, and 1 is used by a railroad.

Domestic and Stock Supplies

Domestic and stock water supplies in Stanton county are obtained from wells that range in depth from less than 50 feet to 256 feet and are 4, 5, 5½, or 6 inches in diameter. Most of them are 5½ or 6 inches in diameter.

The wells used for domestic or stock supplies generally are equipped with cylinder pumps operated by windmills. The most common type of cylinder pump consists of a vertical pipe 1½ to 3 inches in diameter equipped with a cylinder at the lower end, either above or below the surface of the water. The water is discharged through a short horizontal pipe connected by a T to the top of the vertical pipe. Six of the domestic and stock wells were equipped with hand-operated cylinder pumps and three were equipped with pumps that could be operated either by a windmill or by hand.

At the time of this investigation 69 of the 136 domestic and stock wells were no longer in use. Only the casing was left in 21 of these wells, the pump and pipe having been removed.

In Stanton county the ground water is hard, but generally is of satisfactory chemical character for domestic uses not affected by hardness and for use by stock.

Public Water Supplies

Only two communities in Stanton county have public water supplies—Johnson City and Manter, both of which are supplied from wells.

Johnson City is supplied from one drilled well (63), 223 feet deep, owned by the city. The well is cased with 10-inch steel casing, the lower 30 feet of which is perforated, and it is gravel-packed. It is equipped with a turbine pump operated by an electric motor rated at 20 horsepower, and is reported to yield 110 gallons a minute. The measured static water level was 163 feet below the land surface in August, 1939. No data are available on the draw-down. The water is pumped directly into the mains by the turbine in the well and the excess flows into an elevated steel tank, which has a capacity of 50,000 gallons. According to Elam Hilty, city water superintendent, the average daily consumption is 9,570 gallons, and the maximum daily consumption on record was 53,500 gallons used in July, 1939. Although the water is hard (analysis 63) it is in other respects satisfactory for all ordinary uses and is not treated.

Manter is supplied with water from a drilled well (100) owned by the city. The well is 278 feet deep and penetrates the Cockrum sandstone (for log see page 112). It is cased with 12-inch perforated steel casing and is equipped with a turbine pump operated by an electric motor rated at 30 horsepower. The yield of the well is reported to be 100 gallons a minute. The static level of the water is reported to be 240 feet below the surface, but the draw-down is not known. The water is pumped directly into the mains by the turbine and the excess flows into an elevated steel tank, which has a capacity of 15,000 gallons. The chemical character of the water is indicated by analysis 100. The water is not treated.

Railroad Supplies

The Atchison, Topeka and Santa Fe railway has a drilled well (101) at Manter that supplies water for locomotive boilers. The well is 475 feet deep and is cased with 12½-inch steel casing to a depth of 87.5 feet; the rest of the hole is cased with 8-inch steel casing that is perforated from a depth of 195.4 feet to the bottom. The well is equipped with a lift pump operated by an electric motor. The static water level is reported to stand 211 feet below the surface. No data are available regarding the yield or draw-down. The well is interesting because it is drilled through the bedrock formations into the top of Triassic (?) redbeds. A reported log of the well is given on page 112.

Irrigation Supplies

Interest in irrigation has increased among Stanton county farmers during the last several years as a result of nearly a decade of drought. A few attempts have been made to use surface water for irrigating small tracts of land along the streams. Fred Collingwood irrigates a part of the SW¼ sec. 22, T. 27 S., R. 40 W. by pumping water from Bear creek (pl. 7C). He operates his pump 3 or 4 times a year during high-water stages. Charles Winger has a similar plant for pumping water from Bear creek in the SE¼ sec. 22, T. 27 S., R. 40 W. There are no perennial streams in the county, hence surface water is available only after heavy rains have fallen and none is available during dry periods when it is most needed.

The use of ground water for irrigation has been barely started. At the present time there are four drilled irrigation wells in the county, descriptions of which are given in the well tables and in more detail in the following paragraphs.

Brown well.—The irrigation well (78) of H. H. Brown (R. P. Dotzour, lessee) is on the upland plain 1 mile south of Big Bow in the SE corner SW¼ sec. 2, T. 29 S., R. 39 W. It is 330 feet deep and is cased with 60-inch steel casing from the surface to a depth of about 80 feet, and with 18-inch steel casing from there to the bottom. The casing was perforated with a cutting torch and covered with a copper screen such as that used for doors and windows. The well is not gravel-packed. The static water level in the well stands about 56 feet below the surface. Brown, in a personal communication, reports:

> The formation is a fine to medium-sized sand and gravel with some 27 different water strata to the bottom of the well with alternate layers of clay.

The well is equipped with a turbine pump, which has a capacity of 2,000 gallons a minute. Originally the pump was operated by a 75-horsepower Diesel engine, but it is now driven by a tractor. The reported yield of the well, when a tractor is used for power, is 650 gallons a minute with a draw-down of 13 feet.

The well was drilled in 1930 and was used for 3 years by Brown to irrigate 100 acres of sugar beets and potatoes. From 1933 to 1936 the well was not used. In 1937 Dotzour pumped water from it to irrigate about 20 acres of wheat, after which the well again was idle until the fall of 1939, when Dotzour used the well to irrigate wheat. He reports that there was plenty of water available for irrigation between 1937 and 1939, but that the ground was not in suitable condition during this period, owing to blowing dust.

Molz well.—The irrigation well of M. P. Molz (6) is in the shallow-water area south of Bear creek, in the SE corner NE¼ sec. 27, T. 27 S., R. 39 W. (pl. 7B). It is reported to be 83 feet deep, and is cased with 18-inch steel casing, the lower 32 feet of which is perforated. Water enters the well from sand and gravel at a depth of 56 to 76 feet. The reported water level is 56 feet below

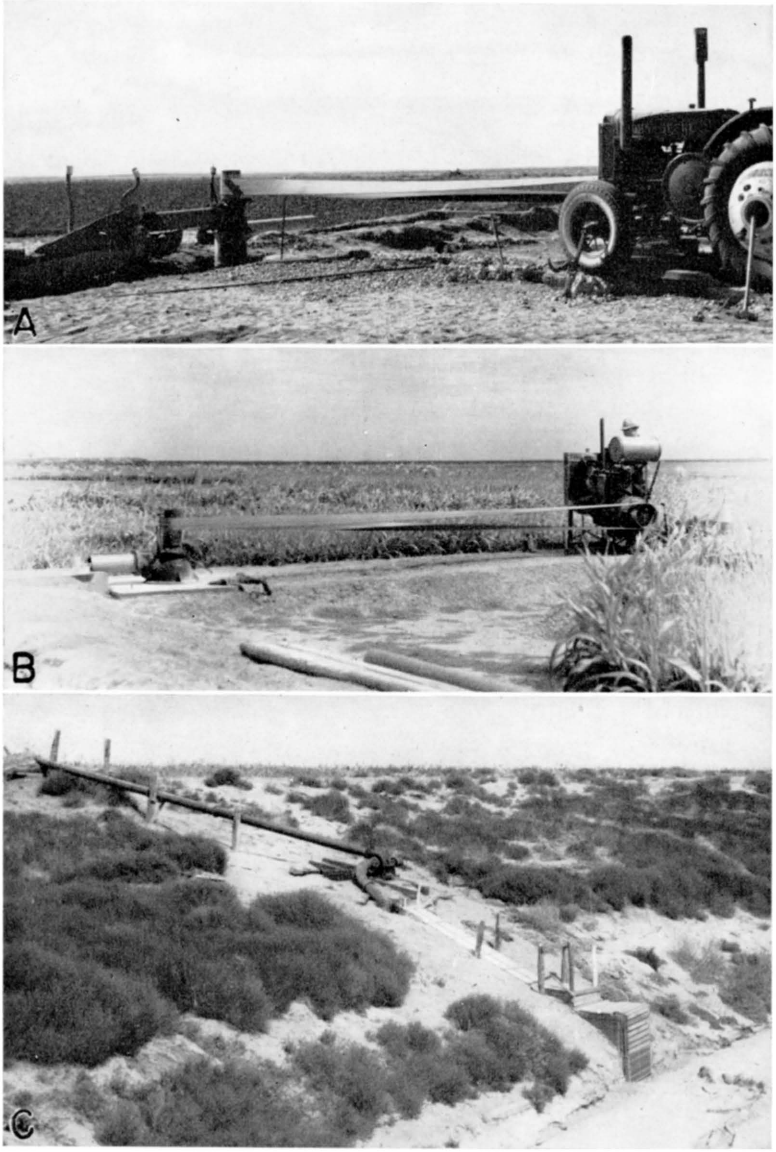


PLATE 7. A, Irrigation well (19) in the NW corner NE¼ sec. 35, T. 27 S., R. 40 W., owned by Clarence Winger; B, Irrigation well (6) in the SE¼ sec. 27, T. 27 S., R. 39 W., owned by M. P. Molz; C, Surface-water pumping plant in the SW¼ sec. 22, T. 27 S., R. 40 W., owned by Fred Collingwood.

the land surface. The well is equipped with a turbine pump operated by a stationary 20-horsepower combine engine, and is reported to yield 450 gallons a minute with a draw-down of 25 feet. Molz believes that the yield could be increased and the draw-down decreased by drilling the well deeper. The well was drilled in 1936 by the owner. In 1939, wheat and feed crops on 52 acres of land were irrigated with water from the well.

Clarence Winger well.—The irrigation well (19) of Clarence Winger, in the NW corner NE¼ sec. 35, T. 27 S., R. 40 W., was drilled in the fall of 1939 by Buell Scott, who used a rotary drill (pl. 7A). The depth of the well is 182 feet. The lowest 120 feet of the 16-inch galvanized-iron casing is perforated. It is a gravel-packed well and obtains water from sand and gravel (see log of test hole on page 111). The water level in the well is reported to be 63 feet below the surface. The well is equipped with a turbine pump operated by a tractor, and yields about 800 gallons a minute with a draw-down of 27 feet after pumping for 6 hours.

Charles Winger well.—The irrigation well of Charles Winger, (41), in the NW corner NW¼ sec. 5, T. 28 S., R. 39 W., was drilled by Buell Scott in the fall of 1939, soon after the completion of Clarence Winger's well. It is 160 feet deep, is gravel-packed, and is cased with 18-inch galvanized-iron casing, the lowest 100 feet of which is perforated. The water comes from sand, and the water level in the well is reported to stand 52 feet below the land surface. A pump had not yet been installed when I visited the well in October, 1939, but the owner planned to install a turbine pump and some type of stationary engine. A log of the well is given on page 111.

Possibilities of Developing Additional Irrigation Supplies

The amount of water that can be pumped from an underground reservoir without causing excessive permanent lowering of the water table depends on the capacity of the reservoir and on the amount of annual recharge. The quantity of water in storage in the Ogallala formation in Stanton county seems to be large, but the amount of annual recharge to this underground reservoir is relatively small (pp. 36-42). The largest quantity of water could be pumped without excessive lowering of the water level if the irrigation wells were distributed evenly over Stanton county. Conditions seem to be favorable for irrigation in only a small part of the county, however; in other parts the depth to water is likely to be too great or the surface too irregular for the development of irrigation.

The most favorable area for the use of water from wells for irrigation in Stanton county is the northeastern shallow-water area (p. 33), which is roughly that area northeast of a line drawn from the point where state highway 27 intersects the Stanton-Hamilton county line to the point where Sand arroyo leaves Stanton county. The four existing irrigation wells are located in this area. The water table is everywhere less than 100 feet below the surface, and south of Bear creek, in the eastern part of the area, the water table is less than 50 feet below the surface. The land surface in most places is relatively flat and in that respect is suitable for irrigation.

The water-bearing formation in this area, the Ogallala, ranges in thickness from more than 200 feet to about 350 feet. The water-bearing materials in the Ogallala range in texture from fine sand to coarse gravel, but the character and thickness of these materials vary greatly from place to place even within a short distance, so that some wells encounter more and better water-bearing materials than other wells. If the drilling of an irrigation well is comtemplated it is wise to drill several test holes of small diameter first, in order to determine whether or not saturated materials of the proper character and thickness are available. The information gained from the test holes should indicate what type of well should be constructed, whether gravel packing is necessary (p. 47), and if not, what size screen should be used or what size perforations should be made in the casing.

The thickness of the saturated part of the Ogallala ranges from about 150 feet in the northwestern part of this area to about 300 feet in the eastern part. Coarse water-bearing sands and gravels have been found in most of the wells already drilled in this area, and as a rule the coarser, more permeable materials are found near the base of the Ogallala formation, although this is not everywhere true. Relatively large yields probably can be obtained from properly constructed wells at most places in this area.

In an area south of the area described above and east of the 100-foot depth-to-water lines as shown on plate 2, the conditions are similar, but the water table is in general farther below the surface. The water table is less than 100 feet and more than 60 feet below the surface in this area.

The surface relief in the southwestern shallow-water areas (p. 33) is in general too great for successful irrigation, and it is doubtful whether the Cockrum or Cheyenne sandstones would yield sufficient water.

Ground water has been used for irrigation at other places on the uplands in the High Plains where the water level lies as deep as it does in the northeastern part of Stanton county. On the upland plains in the vicinity of Garden City sugar beets are grown by means of irrigation with water from wells. In that area the wells obtain water from the Ogallala formation and are generally between 200 and 300 feet deep, and the water level generally stands about 40 or 45 feet below the surface, but is as much as 70 feet in a few wells.

Based on records of the Division of Water Resources of the Kansas State Board of Agriculture, approximately 12,000 acres of land was irrigated with water pumped from wells in the so-called Scott county shallow-water area in 1939. H. A. Waite, in a personal communication, reports that the depth to water level in this area ranges from about 20 to 90 feet. An irrigation well on the uplands northeast of Ensign in southeastern Gray county is reported by Lohman (1938a, p. 4) to be 200 feet deep and the water level, as measured in November, 1937, 165.5 feet below the land surface. According to W. N. White (written communication, January 15, 1941), an area of about 230,000 acres was irrigated with water from about 1,700 wells on the High Plains of Texas near Plainview, Lubbock, Muleshoe, Hereford, and Texline in 1939. He reports that the wells are 100 to 300 feet deep and the water level in the irrigated areas ranges from about 20 feet to 100 feet or more below the surface. Most of the wells are equipped with turbine pumps operated by automobile engines, and yield 300 to 2,000 gallons a minute, the average being about 700 gallons a minute.

QUALITY OF WATER

The chemical character of the well waters in Stanton county is shown by the analyses of water from 38 representative wells given in table 3. The samples of water were collected by me and analyzed by Robert H. Hess, chemist, in the water and sewage laboratory of the Kansas State Board of Health. The analyses show only the dissolved mineral content of the waters and do not in general indicate the sanitary condition of the waters.

The fluoride content of the waters was determined by the Modified Sanchis method, and the other constituents given were determined by the methods used by the U. S. Geological Survey.

TABLE 3.—*Analyses of water from wells in Stanton county, Kansas*

(Analyzed by Robert H. Hess. Quantities are expressed in parts per million.* Equivalents per million are shown in italics)

Well No. Plate 2.	Location, depth, geologic horizon.	Date of collection, 1939	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)	Total dissolved solids †	Hardness (calculated as $CaCO_3$): Total	Hardness: Carbonate	Hardness: Noncarbonate
	T. 27 S., R. 39 W.															
2	NW corner sec. 2. 96 feet, Ogallala	Oct. 21	60	0.08	44 *2.20*	17 *1.40*	23 *.99*	232 *3.80*	12 *.25*	7.0 *.20*	1.6 *.08*	16 *.26*	237	180	‡180	0
7	NE corner SE¼ sec. 29, 80 feet, Ogallala	Oct. 21	59	.76	66 *3.39*	30 *2.47*	33 *1.43*	177 *2.90*	177 *3.68*	16 *.45*	1.4 *.07*	12 *.19*	427	295	145	150
	T. 27 S., R. 40 W.															
8	NE corner SE¼ SW¼ sec. 1, 150 feet, Ogallala	Oct. 21	59	.04	54 *2.69*	13 *1.07*	16 *.68*	215 *3.53*	26 *.54*	6.0 *.17*	1.1 *.06*	8.8 *.14*	232	188	176	12
12	NW¼ SW¼ sec. 17, 71 feet, Ogallala	Oct. 21	59	1.50	71 *3.54*	22 *1.81*	33 *1.42*	185 *3.03*	156 *3.24*	11 *.31*	1.0 *.05*	8.8 *.14*	397	270	152	118
19	NW corner NE¼ sec. 35, 182 feet, Ogallala	Oct. 25	60	.03	66 *3.29*	19 *1.56*	24 *1.03*	174 *2.85*	122 *2.54*	9.0 *.25*	.9 *.05*	12 *.19*	340	243	143	100
	T. 27 S., R. 41 W.															
20	SW corner SW¼ sec. 3, 117 feet, Ogallala	Oct. 30	59	.10	76 *3.79*	23 *1.89*	30 *1.32*	181 *2.97*	167 *3.47*	12 *.34*	1.1 *.06*	10 *.16*	410	284	148	136
21	SW corner SE¼ sec. 15, 123.5 feet, Ogallala	Oct. 24	60	.18	66 *3.29*	20 *1.64*	28 *1.21*	172 *3.82*	120 *2.50*	18 *.51*	1.0 *.05*	16 *.26*	355	247	141	106
24	SE corner SW¼ SW¼ sec. 31, 172 feet, Ogallala	Oct. 24	60	.20	52 *2.59*	13 *1.07*	25 *1.10*	172 *2.82*	75 *1.56*	7.0 *.20*	.7 *.04*	8.8 *.14*	268	184	141	43
	T. 27 S., R. 42 W.															
26	NE¼ NE¼ sec. 8, 138 feet, Ogallala	Oct. 25	60	.39	64 *3.19*	20 *1.64*	29 *1.28*	178 *2.92*	129 *2.68*	12 *.34*	.8 *.04*	8.0 *.13*	352	242	146	96
	T. 27 S., R. 43 W.															
34	NE corner SE¼ NE¼ sec. 15, 199 feet, Cockrum	Oct. 20	61	1.7	50 *2.50*	13 *1.07*	24 *1.02*	185 *3.03*	56 *1.16*	7.0 *.20*	.8 *.04*	9.7 *.16*	255	182	152	30
37	NE corner NE¼ sec. 33, 120.5 feet, Cockrum (?)	Oct. 20	61	11	49 *2.45*	14 *1.15*	26 *1.12*	161 *2.64*	79 *1.64*	9.0 *.25*	.9 *.05*	8.4 *.14*	278	200	132	68
	T. 28 S., R. 39 W.															
39	NE corner SE¼ sec. 3, 65.5 feet, Ogallala	Oct. 25	59	5.0	75 *3.74*	39 *3.21*	67 *2.90*	189 *3.10*	278 *5.78*	25 *.71*	2.0 *.11*	9.2 *.15*	595	357	155	202
42	SE corner SW¼ sec. 8, 79.5 feet, Ogallala	Oct. 21	59	1.3	73 *3.64*	30 *2.47*	35 *1.52*	256 *4.20*	139 *2.89*	14 *.39*	1.3 *.07*	4.9 *.08*	427	308	210	98

Table 3.—Analyses of water from wells in Stanton county, Kansas—*Continued*

Well No. Plate 2.	Location, depth, geologic horizon.	Date of collection, 1939	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)	Total dissolved solids †	Hardness (calculated as $CaCO_3$). Total	Carbonate	Noncarbonate
	T. 28 S., R. 40 W.															
53	NW corner NW¼ sec. 35, 102 feet, Ogallala	Oct. 25	59	3.5	55 *2.74*	17 *1.40*	27 *1.19*	167 *2.74*	93 *1.93*	16 *.45*	.9 *.05*	10 *.16*	306	214	137	**77**
55	NW corner NW¼ sec. 1, 117 feet, Ogallala	Oct. 24	60	1.3	51 *2.54*	17 *1.40*	23 *1.00*	232 *3.80*	28 *.58*	3.0 *.08*	.9 *.05*	27 *.43*	267	200	190	**10**
60	NE corner SW¼ sec. 23, 193 feet, Ogallala	Oct. 25	61	1.6	46 *2.30*	13 *1.07*	25 *1.09*	183 *3.00*	50 *1.04*	7.0 *.20*	.6 *.03*	12 *.19*	247	172	150	**22**
63	SE¼ NE¼ SW¼ sec. 36, 223 feet, Ogallala	June	......	0	50 *2.50*	18 *1.48*	26 *1.13*	181 *2.97*	81 *1.68*	10 *.28*	1.0	11 *.18*	317	199	148	**51**
	T. 28 S., R. 42 W.															
64	NW Corner SW¼ sec. 9, 248.5 feet, Ogallala	Oct. 25	62	.87	53 *2.64*	13 *1.07*	18 *.78*	148 *2.43*	77 *1.60*	8.5 *.24*	.7 *.04*	11 *.18*	256	187	121	**66**
65	NE corner SW¼ SW¼ sec. 13, 213 feet, Ogallala	Oct. 20	59	4.2	46 *2.30*	19 *1.56*	27 *1.17*	190 *3.12*	72 *1.50*	9.0 *.25*	.9 *.05*	7.1 *.11*	280	201	156	**45**
69	NE corner SE¼ SE¼ sec. 32, 68 feet, Ogallala (?)	Oct. 20	59	.04	47 *2.35*	5.8 *.48*	12 *.54*	154 *2.53*	25 *.52*	3.5 *.10*	.5 *.03*	12 *.19*	183	142	126	**16**
	T. 28 S., R. 43 W.															
71	NW corner sec. 12, 173 feet (?)	Oct. 20	62	2.4	51 *2.54*	12 *.99*	23 *1.01*	181 *2.97*	59 *1.23*	7.0 *.20*	.6 *.03*	7.1 *.11*	253	181	148	**33**
74	SW corner SE¼ sec. 27, 213 feet, Cockrum	Oct. 20	61	13	35 *1.75*	19 *1.56*	42 *1.81*	183 *3.00*	74 *1.54*	12 *.34*	2.0 *.11*	8.0 *.13*	297	189	150	**39**
	T. 29 S., R. 39 W.															
78	SE corner SW¼ sec. 2, 330 feet, Ogallala	Oct. 25	61	0	58 *2.89*	21 *1.73*	33 *1.43*	176 *2.89*	123 *2.56*	12 *.34*	1.0 *.05*	13 *.21*	349	231	144	87
80	SW corner SE¼ SW¼ sec. 5, 92 feet, Ogallala	Oct. 25	59	.53	59 *2.94*	18 *1.48*	30 *1.30*	188 *3.08*	103 *2.14*	9.0 *.25*	.7 *.04*	13 *.21*	327	222	154	68
85	NW corner sec. 30, 94 feet, Ogallala	Oct. 25	60	3.3	42 *2.10*	20 *1.64*	35 *1.53*	188 *3.08*	83 *1.73*	8.0 *.23*	1.3 *.07*	9.7 *.16*	296	193	154	39
	T. 29 S., R. 41 W.															
92	SE corner sec. 11, 201 feet, Ogallala	Oct. 24	61	.30	43 *2.15*	12 *.99*	19 *.82*	173 *2.84*	38 *.79*	3.0 *.08*	1.3 *.07*	11 *.18*	214	158	142	16
96	NE¼ SE¼ sec. 35, 209 feet, Ogallala	Oct. 21	63	.68	48 *2.40*	20 *1.64*	21 *.90*	198 *3.25*	58 *1.21*	7.5 *.21*	1.6 *.08*	12 *.19*	268	203	162	41

Table 3.—Analyses of water from wells in Stanton county, Kansas—*Concluded*

Well No. Plate 2.	Location, depth, geologic horizon.	Date of collection, 1939	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)	Total dissolved solids †	Hardness (calculated as $CaCO_3$). Total	Carbonate	Noncarbonate
	T. 29 S., R. 42 W.															
100	NW¼SW¼ sec. 14, 278 feet, Cockrum	Oct.	......	0	66 *3.29*	18 *1.48*	4 *.16*	190 *3.12*	72 *1.50*	9.0 *.25*	1.0	3.7 *.06*	335	239	156	83
106	SE¼ NW¼ SW¼ sec. 34, 215 feet, Cockrum	Oct. 21	62	.18	49 *2.45*	18 *1.48*	23 *1.01*	204 *3.35*	52 *1.08*	7.0 *.20*	3.0 *.16*	9.2 *.15*	263	197	167	30
	T. 29 S., R. 43 W.															
110	NW corner SW¼ SW¼ sec. 14, 108 feet, Cheyenne	Oct. 24	58	.24	74 *3.69*	21 *1.73*	50 *2.16*	220 *3.61*	158 *3.29*	18 *.51*	1.2 *.06*	6.6 *.11*	439	272	180	92
114	SE corner SW¼ SW¼ sec. 33, 160 feet, Cheyenne	Oct. 20	59	1.9	106 *5.29*	27 *2.22*	46 *1.98*	229 *3.76*	232 *4.83*	27 *.76*	1.0 *.05*	5.3 *.09*	561	379	188	191
	T. 30 S., R. 39 W.															
119	SW corner NW¼ sec. 20, 114 feet, Ogallala	Oct. 25	60	3.5	43 *2.15*	29 *2.38*	38 *1.67*	212 *3.48*	102 *2.12*	14 *.39*	2.3 *.12*	5.3 *.09*	343	233	174	59
122	SW corner sec. 25, 81 feet, Ogallala	Oct. 25	59	.71	45 *2.25*	32 *2.63*	33 *1.43*	227 *3.72*	95 *1.98*	12 *.34*	3.0 *.11*	9.7 *.16*	343	246	186	60
	T. 30 S., R. 41 W.															
134	NW corner SE¼ sec. 33, 189 feet, Cockrum	Oct. 24	60	.90	32 *1.60*	23 *1.89*	39 *1.70*	204 *3.35*	60 *1.25*	9 *.25*	2.8 *.15*	12 *.19*	281	176	167	9
	T. 30 S., R. 42 W.															
136	SE corner SW¼ SW¼ sec. 4, 177.5 feet, Cheyenne	Oct. 21	60	.68	46 *2.30*	21 *1.73*	26 *1.13*	207 *3.39*	66 *1.37*	7.0 *.20*	1.8 *.09*	6.6 *.11*	279	203	170	33
138	NW corner SE¼ sec. 11, 207 feet, Cheyenne	Oct. 24	61	.20	47 *2.35*	23 *1.89*	33 *1.42*	220 *3.61*	76 *1.58*	7.0 *.20*	3.0 *.16*	6.6 *.11*	306	213	180	33
139	NE¼ NE¼ sec. 29, 176 feet, Cockrum	Oct. 21	59	.37	44 *2.20*	24 *1.97*	32 *1.41*	220 *3.61*	74 *1.54*	7.0 *.20*	2.3 *.12*	6.6 *.11*	300	209	180	29
140	NW¼ SW¼ SE¼ sec. 33, 149.5 feet, Cockrum	Oct. 24	60	.96	52 *2.59*	28 *2.30*	39 *1.69*	234 *3.84*	98 *2.04*	15 *.42*	2.6 *.14*	8.8 *.14*	361	246	192	54

* One part per million is equivalent to 1 pound of substance per million pounds of water and is equal to 8.33 pounds per million gallons.
† Calculated.
‡ Total alkalinity, 190 parts per million; excess alkalinity, 10 parts per million.

Chemical Constituents in Relation to Use

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

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

The ground waters from most of the wells sampled in Stanton county contain less than 400 parts per million of dissolved solids, and are entirely satisfactory for most ordinary purposes. The waters from four of the wells sampled (7, 20, 42, and 110) contained between 400 and 500 parts per million of dissolved solids and the waters from two other wells (39 and 114) contained more than 500 parts.

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 virtually all the hardness of ordinary waters. These constituents are also the active agents in the formation of the greater part of the scale formed in steam boilers and in other vessels in which water is heated or evaporated.

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

Water having a hardness of less than 50 parts per million is generally 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, but it does slightly increase the consumption of soap, and its removal by a softening process is profitable for laundries or other industries using large quantities of soap. Waters in the upper part of this range of hardness will cause considerable 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 to soften water for household use or to install cisterns to collect soft rain water. Where municipal water supplies are softened, an attempt is generally made to reduce the hardness to 60 or 80 parts per million. The additional improvement from further softening of a whole public supply is not deemed worth the increase in cost.

The ground waters of Stanton county are all hard, the samples ranging in hardness from 142 to 379 parts per million. Three samples had more than 300 parts per million of hardness (analyses 39, 42, and 114), 21 samples had 200 to 300 parts, 13 samples had 150 to 200 parts and only 1 sample had less than 150 parts (analyses 69). Neither of the two municipal water supplies in the county is treated; however, many of the residents of the two municipalities use one of the several manufactured products on the market for softening the water before it is used for washing.

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 separate out and settle as a reddish sediment. Iron, which may be present in sufficient quantity to give a disagreeable taste and to stain cooking utensils, may be removed from most waters by simple aeration and filtration, but a few waters require the addition of lime or some other substance.

Seven of the 38 samples of water from Stanton county contained 0.1 part per million or more of iron. All but three of the samples had less than 4 parts per million; the water from well 65 had 4.2 parts; the water from well 39 had 5.0 parts; and the water from well 74 had 13 parts.

Fluoride.—Although determinable quantities of fluoride are not so common as fairly large quantities of the other constituents of natural waters, it is desirable to know the amount of fluoride present in waters that are likely to be used by children. Fluoride in water has been shown to be associated with the dental defect known as mottled enamel, which may appear on the teeth of children who drink water containing fluoride during the period of formation of the permanent teeth. It has been stated that waters containing 1 part per million or more of fluoride are likely to produce mottled enamel, although the effect of 1 part per million is not usually very serious. (Dean, 1935, pp. 1269-1272). If the water contains as much as 4 parts per million of fluoride, 90 percent of the children exposed are likely to have mottled enamel and 35 percent or more of the cases will be classified as moderate or worse.

Of the 38 samples of ground water collected in Stanton county, 25 contained 1.0 part or more per million of fluoride, and of these 19 contained 1.0 to 2 parts, and 6 contained more than 2 parts. The samples from wells 106 and 138 contained the largest concentrations of fluoride—3.0 parts per million.

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

All the waters for which analyses are given in table 3 come well within the limits suggested by Scofield for waters safe for use in irrigation.

Sanitary Considerations

The analyses of water given in tables show only the amounts of dissolved mineral matter in the water and do not indicate the sanitary quality of the water.

It is well recognized that every precaution should be used to protect domestic and public water supplies from pollution by organic material. About 70 percent of the population of Stanton county is dependent on private water supplies from wells, and it rests chiefly with the drillers and individual well-owners to observe precautions to insure a safe and wholesome water supply. It is obvious that a well should not be located where there are possible sources of pollution nor where surface water can descend to the water table. The drainage from cesspools and privies is particularly dangerous. Every well should be so constructed as to seal off all surface water. As a general rule dug wells are more subject to contamination from surface water than are drilled wells, owing mainly to the fact that generally they are not effectively sealed at the surface.

Relation to Stratigraphy

The typical quality of water in the three principal water-bearing formations in Stanton county is shown by figure 6. In general the waters from the Ogallala formation and the Cockrum sandstone are similar. The comparatively few analyses of water from the Cockrum fall in the middle range of concentration of the waters from the Ogallala. Two of the waters from the Cheyenne fall in this same range, but the other two fall in the upper range of concentration of waters from the Ogallala. The concentration of the waters from the same formation varies considerably, however, which makes it difficult to establish any definite relationships. The largest concentrations of iron are found in two samples from the Cockrum sandstone, but other samples from this sandstone contained only negligible amounts of iron. The greatest fluoride content found was 3.0 parts per million in samples of one Cockrum water (106) and one Cheyenne water (138). Only 3 samples of water from the Ogallala formation contained as much as 2.0 parts per million of fluoride.

The water samples analyzed from the Ogallala formation contained 142 to 357 parts per million of hardness, the Cockrum waters 176 to 246 parts, and Cheyenne waters 203 to 379 parts. Because of the small number of samples from the Cheyenne formation, however, it is difficult to draw any conclusions as to the general range of hardness to be expected in these waters.

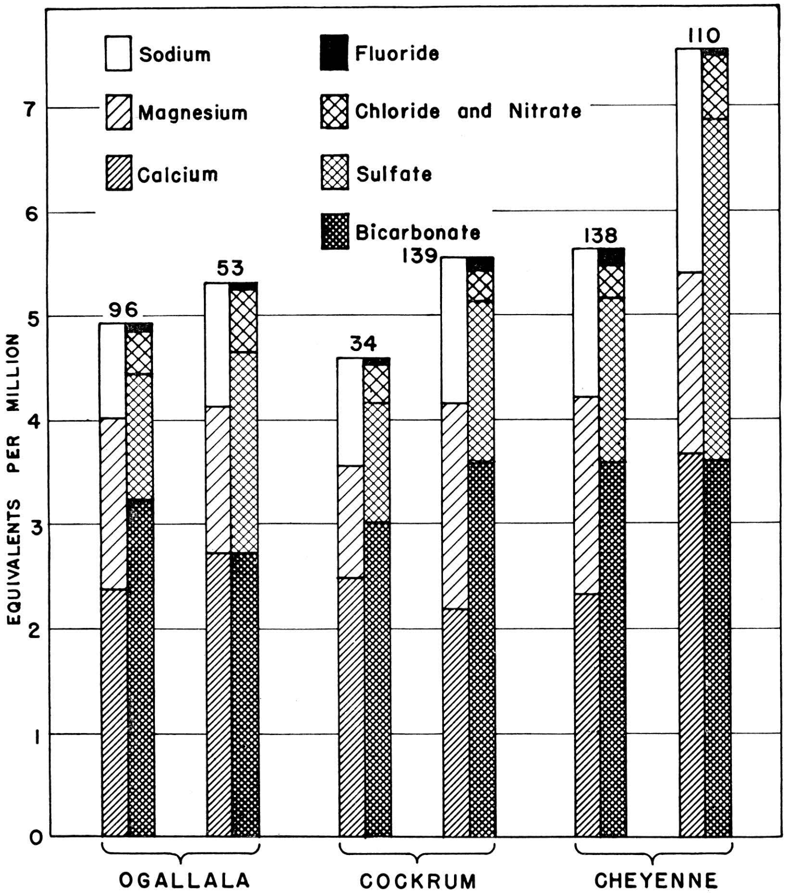


FIG. 6. Analyses of typical waters from the three principal water-bearing formations in Stanton county. Numbers refer to analyses in table 3.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

PERMIAN SYSTEM

The oldest rocks encountered by deep drilling in the county belong to the Permian system. They do not crop out in the county and only one hole has been drilled deep enough to penetrate these beds—a gas test well drilled to a depth of 3,005 feet by the Western Production Company in the middle of the NE¼ sec. 11, T. 29 S., R. 41 W. (log 22).

The material from a depth of 880 feet to the bottom of the hole is here assigned to the Permian system. These rocks at a depth of 880 to 2,200 feet are principally red shales, but there are minor amounts of anhydrite, gypsum, and limestone; the rocks from 2,200 feet to the bottom of the hole consist mainly of limestone and hard blue shale, but also include in the upper part, beds of anhydrite and gypsum. No attempt is here made to differentiate these rocks into smaller geologic divisions, owing to the lack of detail in the log. An oil well in sec. 30, T. 25 S., R. 41 W., in southern Hamilton county, encountered about 1,850 feet of material belonging to the Permian system (Norton, 1939, p. 1764) including beds from the Taloga formation down to the Herington limestone.

Beds of Permian age probably underlie most or all of Stanton county at depths beneath the reach of water wells. A few flowing wells at Richfield in central Morton county obtain water from the upper part of this system of rocks. The water is highly mineralized, however, and is therefore unfit for ordinary uses. A more detailed description of these wells may be found in a forthcoming report by T. G. McLaughlin (in press). In writing on the Permian in the High Plains, Theis, Burleigh, and Waite (1935, p. 4) state—

> It [upper part of the Permian] consists of compact gypsiferous red shale. It is relatively impermeable, and the water available from it is in general highly mineralized and not potable.

TRIASSIC (?) SYSTEM

Undifferentiated Redbeds

Character.—Triassic(?) rocks are not exposed at the surface in the county, but have been encountered in a few drill holes. They consist chiefly of fine-grained buff, pink, red, and white sandstones and red clays, and also include some beds of light-gray to yellow-gray and red silty clay or clayey siltstone. The sandstones in large part are composed of well-rounded to sub-angular quartz grains, and are generally calcareous.

Distribution and thickness.—Only three holes have been drilled in the county deep enough to encounter Triassic(?) rocks; namely, the Western Production Company's gas test well (log 22), the railroad well at Manter (log 18), and the test hole in the NW corner sec. 1, T. 27 S., R. 41 W. (log 1). Nothing can be told about the Triassic(?) rocks from the log of the gas test well because it is general and lacks detail. According to the log of the railroad well at Manter, red shales and light-colored sandstones were encountered at a depth of 410 to 475 feet, the bottom of the hole. These rocks are all thought to be Triassic(?) in age. The rocks at a depth of 412 feet to the bottom (617 feet) in test hole 1 are also regarded as Triassic(?). Triassic(?) beds crop out at Two Buttes dome in southern Prowers county, Colorado, about 25 miles west of Stanton county; along Cimarron river in southwestern Morton county, Kansas; and in the panhandle of Oklahoma in central Texas county and northwestern Cimarron county. The subsurface evidence in Stanton county and the relative nearness of areas of outcrop indicate that Triassic(?) beds are probably present beneath most or all of the county.

The upper surface of the Triassic(?) beds in Stanton county is probably very uneven, for it is an erosional surface, and because it is uneven the thickness of the beds may vary from place to place. The thickness of these beds in the county probably ranges from 200 to 300 feet or more. Test hole 1 penetrated 205 feet of Triassic(?) rock and did not reach the base. The Triassic(?) exposed at Two Buttes dome is reported to be about 280 feet thick, and in Cimarron county, Oklahoma, the total thickness is 575 feet (Sanders, 1934, p. 865).

The Triassic(?) rocks exposed in southwestern Morton county is 42 feet thick, and a test hole drilled at the outcrop revealed another 200 feet of similar beds below the base of the exposure (McLaughlin, in press), thus giving a total thickness of 242 feet.

Age and correlation.—The age of these beds is uncertain because all the evidence available is based on drill cuttings, and no identifiable fossils were found in the cuttings. The rocks have been assigned a Triassic(?) age because stratigraphically they overlie Permian redbeds and because they are lithologically similar to known Triassic rocks that are exposed in other areas. Frank Conselman (personal communication), subsurface geologist for the Gulf Oil Corporation, believes that there is a close lithologic similarity between these beds and the Dockum (Upper (?) Triassic) of Texas and Oklahoma.

Water supply.—Only one well (101) in the county is known to obtain water from Triassic(?) beds, and the well also obtains water from water-bearing formation above the Triassic(?). The Triassic(?) is unimportant as a water-bearing formation, as sufficient quantities of good water can be obtained from higher zones.

A few wells in southwestern Morton county are reported to obtain moderate supplies of water from Triassic(?) rocks, and artesian water has been found in these beds along Cimarron river at depths of 200 to 212 feet. Most of the water from the Triassic(?) in this area is highly mineralized and of poor quality.

JURASSIC(?) SYSTEM

MORRISON(?) FORMATION

Jurassic rocks are not exposed in Stanton county, nor have they definitely been encountered in wells. Sanders (1934, p. 865) reports that there is 160 feet of Morrison beds exposed at Two Buttes dome, and Darton (1906, pl. 7) in a cross section shows the Morrison extending to the Colorado-Kansas line beneath younger strata. Morrison strata are also known to be exposed in the deeper valleys in eastern Las Animas county, Colorado, in Cimarron county, Oklahoma, and in Union county, New Mexico. A test hole at the SE corner sec. 36, T. 31 S., R. 42 W., in Morton county, about 6 miles south of Stanton county, is reported to have penetrated 28 feet of blue-green clay and marl and 12 feet of blue-green, light-gray, and brown sandstone, all of which is thought to belong to the Morrison formation (McLaughlin, in press). Although there is no substantiating evidence available, it seems possible that rocks of Jurassic age might be present beneath the Cretaceous rocks in the western part of Stanton county, but it is altogether possible that the Morrison pinches out somewhere west of the Kansas-Colorado line, and that the beds referred to the Morrison in the test hole in northern Morton county represent an outlier of the formation.

CRETACEOUS SYSTEM

Dakota Group

Only those Cretaceous sandstones and shales that lie below the Graneros shale are found in Stanton county. In the past this series of sandstones and shales in Kansas and adjacent areas has been described under various classifications.

One of the earliest complete classifications was given by Cragin (1886, 1889, 1895), in which he classified the Cretaceous strata of southern Kansas into the Cheyenne sandstone, Kiowa shale, and Dakota sandstone, named in upward order. Several local subdivisions of these rocks were also named by Cragin. The upper part of the Comanche series in central Kansas was designated by Cragin (1895, p. 162) as the Mentor formation.

A few years later Gould (1898) divided these strata into the Cheyenne sandstone, Kiowa shale, Medicine beds, and Dakota sandstone. In 1920, Twenhofel (1920, pp. 281-297) discarded the term Medicine beds and treated the Kirby clay and Reeder sandstone—units named by Cragin that were included as members of the Medicine beds by Gould—as members of his "Dakota" formation. Twenhofel (1924, pp. 12-30) later classified the Cretaceous strata in southern Kansas as the Cheyenne sandstone, Belvidere formation, and "Dakota" formation. He retained the name Kiowa for the lowest member of the Belvidere formation. In the same report Twenhofel assigned to the Belvidere and "Dakota" formations all the Cretaceous strata below the Graneros shale in central and northern Kansas. Wing (1930, pp. 31-35) described all rocks below the Graneros shale and above the Permian shales in Cloud and Republic counties as the Dakota formation, and Ockerman (1930, pp. 30-31) described the equivalent strata in Mitchell and Osborne counties as the "Dakota" sandstone.

Darton (1920, p. 2) subdivided the Cretaceous strata below the Graneros in western Kansas into three formations, the Cheyenne sandstone, the Kiowa shale, and the Dakota sandstone. Stose (1912, p. 3) subdivided the equivalent strata in eastern Colorado into two formations, the Purgatoire formation below, and the Dakota sandstone above. This classification was also used by Sanders (1934, pp. 862-865) in eastern Colorado and by Rothrock (1925, pp. 47-49), DeFord (1927, pp. 753-755), and Schoff (1939, pp. 54-57) in the Oklahoma panhandle. Lee (1927, p. 17) correlates the Dakota and Purgatoire formations in southeastern Colorado with rocks designated by him as the Dakota group at the Bellvue section in northern Colorado. Bass (1926, pp. 59, 73-76) used the name Dakota sandstone for strata between the Graneros shale and the Permian in Hamilton county, but stated that possibly it includes representatives of the Purgatoire formation. Elias (1931, p. 28; 1937, p. 10) grouped the same beds in western Kansas into the Dakota group as did Landes and Keroher (1939, p. 24).

Tester (1931, p. 234), after studying the Dakota at the type locality in eastern Nebraska, suggested that the sandstone and shale succession there found beneath the Graneros and overlying the Pennsylvanian or older rocks (contact concealed) be called the Dakota stage. Reasons were given for use of the term stage instead of group. He (Tester, 1931, p. 283) stated that—

> The Washita-Kiowa-Mentor series belongs to the same general sequence as the Dakota stage of the type area. Also, because of the close relationships and the similar physical history of the "Dakota" (using the term in a narrow sense) rocks of Kansas and the Kiowa-Mentor series of Kansas, it seems impractical to make a systematic separation in that part of the geologic column.

Tester therefore placed the Washita-Kiowa-Mentor-"Dakota" rocks of Kansas in a stage at the base of the Cretaceous system as developed in this region and indicated that this stage may be regarded as a part of the Comanche series. He (Tester, 1931, p. 284) stated further that—

> The Dakota of the type area may be in part younger than the oldest part of the stage in southern Kansas. . . . It is at least as old as the Mentor member of Kansas, and apparently is closely equivalent to the entire Kansas section.

Although the Belvidere formation of Kansas contains deposits (Marquette sandstone) that correspond to the Dakota in mode of origin (Tester, 1931, pp. 268, 272), it seems to be regarded as older than the type Dakota, but Tester found no practicable means of drawing a lower boundary for the Dakota so as to exclude Comanchean beds of similar lithologic character.

In 1937 the Kansas Geological Survey (Moore and Landes, 1937) used the term Dakota group to include all Cretaceous strata below the Graneros. At a conference of survey geologists in Lawrence in January, 1941, a decision was reached by the state geologists to continue the use of the term Dakota group as interpreted by Tester (1931) from studies in the type locality of the Dakota and subsequently accepted in Kansas reports (Moore and Landes, 1937; Moore, 1940, p. 40). The Dakota group as thus defined includes all the strata from the base of the Cheyenne sandstone to the base of the Graneros shale. The Dakota group is also used in this sense by the Nebraska Geological Survey and many oil geologists (Kansas Geol. Society Guidebook, 1940, pp. 14, 55), but the name Dakota is also used by them to designate the upper sandstone division of this group. It is not desirable usage to employ the same name in these two very different applications. Accordingly, under conditions of present knowledge it seems best to recognize the Dakota group as including the somewhat variable, partly undifferentiated succession of clastic deposits of Cretaceous age below the Graneros shale and to use local names for the subdivisions of the group in those areas where it is possible to subdivide the Dakota group.

All Cretaceous strata in Stanton county belong to the Dakota group. They comprise the Cheyenne sandstone, Kiowa shale, and an upper sandstone (formerly called Dakota) that is here named the Cockrum sandstone.

Cheyenne Sandstone

Character.—The Cheyenne sandstone does not crop out in Stanton county, but in many wells it has been encountered beneath dark shales that separate the Cheyenne sandstone from the Cockrum sandstone. The nearest outcrop of the sandstone is at Two Buttes dome in southern Prowers county, Colorado, where, according to Sanders (1934, p. 862) the Cheyenne consists of massive to cross bedded white friable sandstone that is generally conglomeratic and porous. He says it is the chief aquifer of southeastern Colorado. Described on the basis of test hole cuttings and reports of well drillers, the Cheyenne in Stanton county consists of loose or cemented, fine to coarse, light-gray to white, and light-yellow sand and minor amounts of silty shale. The sandstones are composed mainly of well-rounded quartz grains, are generally calcareous, and contain scattered crystals of pyrite.

Distribution and thickness.—The Cheyenne sandstone is known to overlie unconformably Triassic (?) beds over a large part of Stanton county, and it might possibly rest upon the Morrison (?) formation in the western part, but no evidence has been brought forth to substantiate this hypothesis. Several wells in the southwestern part of the county have encountered the Cheyenne sandstone at depths ranging from about 150 feet to 250 feet and test hole 1 at the Stanton-Hamilton county line penetrated the Cheyenne sandstone at a depth of 356 feet. It is not known whether or not the sandstone is present in the eastern part of the county. It is present in the northwestern part of Morton county, but is thought to be absent in the eastern part of that county. West of Stanton county the Cheyenne sandstone crops out at Two Buttes and is believed to underlie the greater part of southeastern Colorado.

The Cheyenne sandstone was deposited on an uneven erosional surface, and its thickness, therefore, probably varies greatly even in short distances. Its thickness in test hole 1 was 56 feet, and drillers report a thickness of about 60 feet in the southwestern part of the county. About 2 miles south of Stanton county in northwestern Morton county a well penetrated 125 feet of white sandstone between the Kiowa shale and the underlying redbeds, the greater part of which is believed to be the Cheyenne (McLaughlin, in press). About 8 miles southeast of this well the Cheyenne sandstone is reported to be absent. The formation at Two Buttes, in Colorado, is 30 to 45 feet thick (Sanders, 1934, p. 865), and in Cimarron county, Oklahoma, DeFord (1927, p. 754) reports 15 to 50 feet of white sandstone at the base of the Purgatoire formation, which probably can be correlated with the Cheyenne sandstone. In Kiowa and Comanche counties, Kansas, the Cheyenne is 10 to 55 feet thick.

Age and correlation.—The sandstone underlying the Kiowa shale in Stanton county is correlated with the Cheyenne sandstone of adjacent areas on lithologic and stratigraphic evidence. The sandstone is very similar lithologically to the Cheyenne exposed in adjacent areas, from which identifiable fossils have been taken. In all areas where it has been studied the Cheyenne sandstone is found below a varying thickness of dark shale (Kiowa), and this is also true of the sandstone in Stanton county. As the sandstone in this county resembles so closely the Cheyenne of other areas and as its stratigraphic position agrees, its correlation with the Cheyenne sandstone is believed to be correct.

Fossils collected from this sandstone in Texas county, Oklahoma, and in other areas were identified and found to be Washita (Lower Cretaceous) in age (Schoff, 1939, p. 55).

Origin.—Owing to the lack of outcrops and to the meager well log data, it is impossible to discuss adequately the origin of the Cheyenne sandstone in Stanton county. Schoff (1939, p. 55) found marine pelecypods in this sandstone in Texas county, Oklahoma, which he says is conclusive evidence of marine origin. He also states that—

The fine- to medium-grained sand of which the sandstone is composed suggests deposition in moderately shallow water off shore, rather than on or near the beach, where wave activity is ordinarily greatest.

The discontinuity of bedding, the cross-lamination, the assortment of the sands, the presence of land plants, and the absence of shells of marine animals in the sandstone in south-central Kansas suggested a continental stream origin to Twenhofel (1924, pp. 18-20). It is altogether possible that both writers are correct in their interpretations, and that the origin of the Cheyenne sandstone or its equivalent is not everywhere the same, but that at some places it may be continental and at others marine.

Water supply.—At most places in Stanton county moderate supplies of water are obtained from formations above the Cheyenne sandstone, but at a few places in the southwestern part of the county the formations above the Cheyenne contain very little water and it is necessary to penetrate this sandstone in order to obtain an adequate supply. In seven wells in the county all or a part of the water is obtained from this sandstone. The wells range in depth from 108 feet to 207 feet. Sanders (1934, p. 865) reports that the Cheyenne sandstone is the chief water-bearing formation in southeastern Colorado.

Well drillers report that this sandstone is coarser than the Cockrum sandstone and that the water from it moves into wells more freely than the water from the Cockrum sandstone. The water is generally under sufficient head to rise to about the level of the water in the Cockrum sandstone. The four samples of water from the Cheyenne that were analyzed are hard, calcium bicarbonate waters that range in mineral content from 280 to 560 parts per million. They contain moderate amounts of sulphate, but not much chloride. They are satisfactory for most ordinary purposes. Analyses of two samples of water from the Cheyenne sandstone are shown in figure 6.

Kiowa Shale

Character.—A bed of shale of variable thickness separates the Cheyenne sandstone from the Cockrum sandstone. It is designated in this report as the Kiowa shale. This shale is blue gray to gray black, fossiliferous, and contains considerable pyrite and gypsum. The shale encountered in test hole 1 was very argillaceous and in part calcareous. C. G. Streeter, former well driller, reports (oral communication) that the shale below the Cockrum sandstone in southwestern Stanton county generally is blue, soft, and sticky in the upper part, but in the lower part it is almost black, is very hard (almost slaty), and contains considerable pyrite.

Distribution and thickness.—The Kiowa shale probably underlies all parts of Stanton county. It has been found in wells in the western and central parts of the county and probably extends eastward past the Stanton-Grant county line. The shale crops out at Two Buttes in Colorado, in Kiowa and Comanche counties, Kansas, and in the panhandle of Oklahoma.

The thickness of this shale member in test hole 1 in northern Stanton county was 67 feet, and drillers report a maximum thickness of 115 feet in the southwestern part of the county. According to McLaughlin (in press) the Kiowa shale underlies most of the northern third of Morton county, and its thickness ranges from 35 to 85 feet, being greatest in the western part of the county. Darton (1920, p. 2) says that the shale is 125 to 150 feet thick in central-southwestern Kansas. It probably reaches its maximum thickness of 150 feet at its type locality in Kiowa county, Kansas.

Age and correlation.—This shale does not crop out in Stanton county, and the only source of information concerning the shale has been the cuttings from test hole 1 and reports of well drillers. The Kiowa shale in Stanton county is lithologically more similar to the Kiowa of southeastern Colorado than it is to the Kiowa of the type area. Frank Conselman, in discussing the Kiowa shale in Stanton county, states that—

> Perhaps the "Kiowa" would be more properly regarded as the upper part of undifferentiated Purgatoire, as it is lithologically different from normal Kiowa.

The shale lies stratigraphically above the Cheyenne sandstone, therefore it is at the horizon of the Kiowa shale of other areas.

Water supply.—The materials making up the Kiowa shale are relatively impermeable and supply little or no water to wells.

Cockrum Sandstone

The Cockrum sandstone, a name here introduced to designate the sandstone that overlies the Kiowa shale, is named from outcrops along Cockrum branch of Bear creek in the S½ sec. 9, T. 29 S., R. 43 W. and from outcrops along Bear creek in southwestern Stanton county. It is classed as the uppermost division of the Dakota group and includes beds that have formerly been designated under the name Dakota sandstone. It represents the oldest formation exposed (Late Cretaceous) in Stanton county.

In Stanton county the Cockrum sandstone is overlain disconformably by the Ogallala formation (Tertiary). The nearest exposures of the upper part of the Cockrum sandstone are in secs. 8 and 22, T. 26 S., R. 41 W., in southern Hamilton county, where the Graneros shale lies conformably on the Cockrum sandstone. The lower contact of the Cockrum sandstone is concealed in Stanton county, but is exposed along Two Butte creek in the southern part of T. 27 S., R. 45 W., in southern Prowers county, Colorado. Good exposures of the middle part of this formation are found along Bear creek and Sand arroyo in southwestern Stanton county, particularly in secs. 14, 15, and 21, T. 29 S., R. 43 W. The base of the Cockrum sandstone was encountered in test holes 1 and 5.

Character.—The Cockrum sandstone is composed of fine- to medium-grained, light-tan, buff, brown, or reddish-brown sandstone that is commonly ferruginous, and light-colored shale or clay. Sandstone is predominant and at the outcrops constitutes 40 to 70 percent of the formation. In general the sandstones are composed of fine, subangular to angular quartz grains. Iron oxide is the principal cementing agent and imparts to the sandstone the brown or reddish-brown color. In some places the sandstones are hard and tightly cemented and at other places they are soft and loosely cemented. Some of the sandstone has been cemented with a calcareous cement, and in Morton county some of the sandstone is reported to have been recemented with silica to form steel-gray dense quartzite (McLaughlin, in press). In some outcrops the sandstone layers are thin bedded and alternate with layers of shale or clay; in other outcrops they are massively bedded (pl. 8A). The individual beds range in thickness from less than 1 foot to 10 feet. The alternate beds consist of sandy clay, clay-shale, or shale that is generally gray or yellow, but in some places is reddish or purplish.

Probably the most striking feature of this formation, at least at the outcrops, is the abundance of ferruginous material. Much of the sandstone is cemented by iron oxide and may also contain numerous small ironstone concretions. A thin layer of "ironstone" (term used by Darton, 1920, p. 4) 1 to 6 inches thick is exposed at several places along Bear creek southwest of Johnson, one of which is shown in plate 8B. This "ironstone" contains very little sand, has a dark-red color, is extremely hard, and generally forms small ledges on the outcrops. Large disk-shaped iron concretions were found embedded in the yellow and gray shale directly below the Ogallala-Cockrum

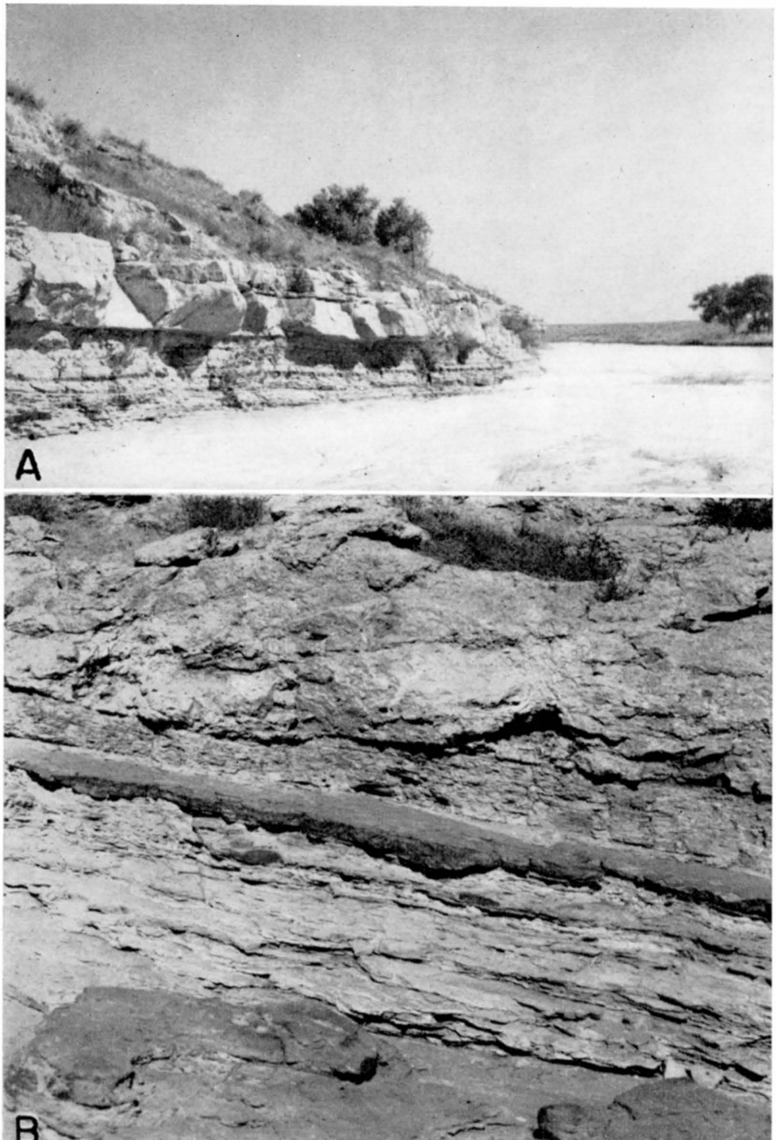


PLATE 8. A, Ledge of Cockrum sandstone along Bear creek in the SE¼ sec. 21, T. 29 S., R. 43 W. B, Outcrop of shale in the Cockrum sandstone on north side of Bear creek in the SW¼ sec. 15, T. 29 S., R. 43 W., capped by cemented sands and gravels of the Ogallala formation. Note the thin, dark layer of ironstone several inches below the contact. Beds do not dip as steeply as shown.

contact at the exposure in the SW¼ sec. 15, T. 29 S., R. 43 W. (pl. 9A). These disk-shaped concretions are dark red and are as much as 3 feet in diameter.

The following measured sections indicate the lithology of the Cockrum sandstone at the outcrops:

Section along Bear creek in the SW¼ sec. 15, T. 29 S., R. 43 W.

	Thickness, in feet
Ogallala formation:	
4. Conglomerate, tightly cemented, hard, containing small to large fragments of the material from the Cockrum sandstone.	
(Unconformity.)	
Cockrum sandstone:	
3. Shale, soapy, yellow and gray, contains disk-shaped iron concretions as much as 3 feet in diameter	3.0
2. "Ironstone," hard, dark red	0.5
1. Shale, soapy, yellow and gray, contains iron concretions similar to those in bed 3	5.0
Total thickness of Cockrum exposed	8.5

Section of Cockrum sandstone along Bear creek in the NW¼ sec. 14, T. 29 S., R. 43 W. (Darton, 1920, p. 4.)

	Thickness, in feet
5. Sandstone, soft	3.0
4. Sandstone, hard, massive, brown to buff	4.0
3. Clay, light gray, sandy, containing thin beds of brown sandstone,	6.0
2. Sandstone, hard, massive	4.6
1. Clay, gray, shaly, containing 6-inch ironstone layer near base	12.0
Total thickness exposed	29.6

Section of Cockrum sandstone along Bear creek in the NW¼ sec. 14, T. 29 S., R. 43 W. (Darton, 1920, p. 5.)

	Thickness, in feet
6. Sandstone, thin bedded	6.0
5. Sandstone, massive	10.0
4. Shale, dark	3.0
3. Clay, thin sandstone, and ironstone	8.0
2. Sandstone and shale, thin bedded	4.0
1. Sandstone, gray, in part massive	8.0
Total thickness exposed	39.0

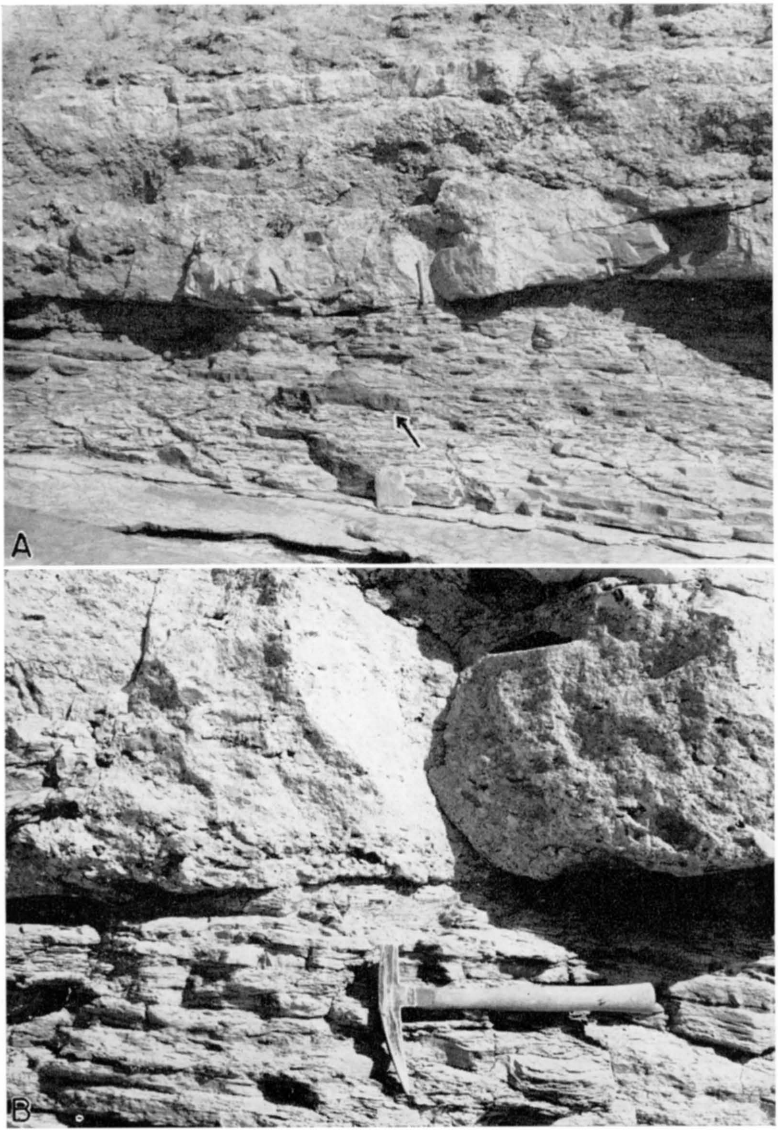


PLATE 9. Base of the Ogallala formation resting unconformably on eroded shale in the Cockrum sandstone in the SW¼ sec. 15, T. 29 S., R. 43 W. A. The sharp contact between the Cockrum and Ogallala may be seen just above the head of the pick. The arrow points to one of the numerous iron concretions in the shale of the Cockrum. B. Close-up view of the contact, showing the conglomeratic nature of the material at the base of the Ogallala. (Photographs by S. W. Lohman.)

In southern Hamilton county the Cockrum sandstone is overlain by a gray-black, fissile clay shale (Graneros). The topmost beds of the Cockrum sandstone grade into the overlying shale so that there is no sharp contact between the two. According to Bass (1926, p. 73) lenses of sandstone interfinger with the shale in the basal part of the Graneros.

The Cockrum sandstone is underlain conformably by the blue-black to gray-black Kiowa shale.

Distribution and thickness.—The Cockrum sandstone crops out along Bear creek and Sand arroyo in southwestern Stanton county, as shown in plate 1, along a tributary of North Fork of Cimarron river in northern Morton county, and in draws and along the lower slopes on the southern side of the ridge in southern Hamilton county, and it was encountered in all the test holes drilled in Stanton county. It may therefore be assumed that the Cockrum sandstone is present either at the surface or below the surface nearly everywhere in the county. During the period of erosion that preceded the deposition of Tertiary sediments great quantities of Cretaceous sediments were eroded away, and this may account for the probable absence of the Cockrum in the bottom of the trough in northern Stanton county (cross section AA′, plate 4). Test hole 5 at Johnson encountered only 20.5 feet of the Cockrum sandstone before penetrating the Kiowa shale, which is good evidence that the Cockrum might be entirely lacking in the deeper part of the trough 1 or 2 miles north of Johnson.

The base of the Cockrum sandstone is not exposed at any of the outcrops in the county, so the maximum thickness of the formation was estimated from the logs of test holes and wells, and was found to exceed 100 feet. In some places, however, the Cockrum is less than 100 feet thick and at other places it is absent entirely, as indicated above.

Age and correlation. — The Cockrum sandstone is Late Cretaceous in age and is equivalent to the Dakota sandstone of southeastern Colorado. Darton (1906, p. 25) and other early workers in eastern Colorado used the terms Dakota sandstone or Dakota formation to include all the rocks above the Morrison formation and below the Graneros shale, but these rocks are now included in the Purgatoire formation and Dakota sandstone. Darton at that time recognized that rocks of different ages were being included under the one name, and in 1920 he restricted the name Dakota sandstone in western Kansas to include only the rocks above the Kiowa shale and below the Graneros shale (Darton, 1920). Because Dakota is here used as a group name for the Cretaceous rocks below the Graneros shale, the name Cockrum is used to designate those rocks that were formerly called the Dakota sandstone.

Water supply.—The Cockrum sandstone is the most widely used water-bearing formation below the Ogallala formation in Stanton county. The Ogallala formation in the western and southwestern parts of the county is in places nearly barren of water so that in such places it is necessary to drill through the Ogallala formation into the Cockrum sandstone in order to obtain a sufficient supply of water for domestic or stock use.

The Cockrum sandstone is reported by well drillers to be of finer texture than the deeper Cheyenne sandstone, but in most places the Cockrum is sufficiently permeable to yield adequate quantities of water to wells. In a few places where the Cockrum is thin or tightly cemented it is necessary to drill to the underlying Cheyenne sandstone to obtain an adequate supply of water. Only seven of the recorded wells in Stanton county have been drilled through the Cockrum sandstone to the deeper lying Cheyenne sandstone, however. The Dakota (Cockrum) sandstone yields water to flowing artesian wells in the vicinity of Blaine in southeastern Colorado. In Stanton county the water in the Cockrum generally is under some artesian head, but the head is not sufficient to produce flowing wells.

Almost a fourth of the recorded wells in Stanton county obtain water from the Cockrum sandstone. Most of these are domestic or stock wells, but one well (100) supplies water to the city of Manter. The wells are 62 to 278 feet deep and the depth to water level ranges from 53 to 242.5 feet below the surface. All the wells that obtain water from the Cockrum sandstone are located in the western or southwestern part of the county.

Eight analyses indicate that water from the Cockrum sandstone is moderately hard calcium bicarbonate water, and contains a moderate amount of sulphate and only a small amount of chloride. It is similar in quality to water from the Ogallala formation. Representative analyses are shown in figure 6.

TERTIARY AND QUATERNARY SYSTEMS

Pliocene (including the Ogallala formation) and Pleistocene undifferentiated

The material below the loess, dune sand, and alluvium and above the Cretaceous bedrock in Stanton county probably represents deposits of more than one age. This material is here referred to the Pliocene (including the Ogallala formation) and Pleistocene undifferentiated. A discussion of the age is given below.

For simplicity, because it has not been possible to distinguish the Pleistocene from the Pliocene in this area, and owing to the probability that Pleistocene deposits do not occur everywhere in Stanton county, the Pliocene and Pleistocene undifferentiated are included throughout this report under the name Ogallala formation.

Character.—The Ogallala formation consists chiefly of calcareous sands, gravels, and silts, the proportions of which may differ greatly from place to place. The materials making up the formation generally are poorly sorted, and gradations from one lithologic type to another may take place within short distances, both laterally and vertically. The sands, gravels, or silts form lenses that overlap one another irregularly (pl. 4). The materials are generally but not altogether unconsolidated. Some of the beds of sand and gravel have been loosely cemented with calcium carbonate and resemble old mortar (pl. 9B). At an exposure in sec. 15, T. 29 S., R. 43 W., the base of the Ogallala consists of gray, hard and compact conglomerate (pl. 9B). The conglomerate is composed of small to large fragments or blocks of sandstone, iron concretions, clay, shale, and lesser amounts of several kinds of igneous rocks—all tightly cemented with calcium carbonate. Most of the material seems to have been derived from Cretaceous formations. Some of the blocks derived from the Cockrum sandstone exceed 12 inches in their greatest dimension. Loosely consolidated beds of sand, gravel, and silt overlie the conglomerate.

The finer materials of the Ogallala formation are composed mostly of silt and include only very small amounts of clay. No beds of clay were found at the outcrops or in the test holes. Lenses of sandy silt ranging in thickness from a few inches to more than 50 feet are common and are likely to be encountered in any part of the formation. The color of the silt is tan, brown, yellow, yellow-brown, or reddish-tan, or shades of gray. Many of the lenses are very calcareous and are white to gray. Test hole 4 in the northeastern part of the county encountered light-gray to white soft clay and volcanic ash at a depth of 80 to 94 feet.

The sands in the Ogallala range in texture from very fine to coarse grained and generally contain scattered pebbles. Well-rounded to subangular quartz grains are dominant in the sands, but there are a few grains of feldspar and of dark minerals. Some of the sand is brown or red-brown, but most of it is tan.

The coarser materials are composed of fine to very coarse gravel. Gravels may be found in almost any part of the formation, but in general they are most abundant and coarsest in the lower part. Smith (1940, pp. 42, 43) has described two distinct facies of gravels and conglomerates on the Ogallala formation based upon the lithology of the pebbles. According to Smith, the one facies occurs only at the base of the formation and is composed chiefly of sandstone, ironstone, and quartzite pebbles that were derived from Cretaceous formations. The other facies occurs above the base of the formation and is composed chiefly of granite, feldspar, felsite, quartzite, and quartz pebbles derived from crystalline igenous and metamorphic rocks. These two facies were recognized in outcrops and in a few of the test holes in Stanton county. The conglomerate at the base of the formation in sec. 15, T. 29 S., R. 43 W., was used by Smith to illustrate the "sandstone, ironstone, and quartzite" facies.

The pebbles making up the gravels are well rounded to angular, and are white, gray, brown, yellow, red, or red brown. The gravels are rarely clean, but generally have considerable sand or silt mixed with them.

Caliche in the form of nodular calcium carbonate may be found mixed with the silt, sand, or gravel throughout the Ogallala formation. These nodules are white to gray and as a rule are fairly soft. A bed of hard caliche 5 feet thick was encountered in test hole 4 at a depth of 311 to 316 feet. A hard, crystalline, grayish-white limestone marked with pinkish irregularly concentric bands crops out near the middle of T. 30 S., R. 43 W. It is only a few inches thick and is broken into irregular blocks of different sizes. This limestone probably represents the cap rock of the Ogallala formation, and may be equivalent to the "algal limestone" of other areas.

Distribution and thickness.—The Ogallala formation is present everywhere in Stanton county except in the southwestern part where Bear creek and Sand arroyo have cut through it into the underlying

Cockrum sandstone (pl. 1). In about half the county it is covered by a thin mantle of loess, and south of Bear creek in the central part of the county it is covered by dune sand.

The thickness of the formation in Stanton county ranges from less than 50 feet to more than 400 feet. The great range in thickness is due chiefly to the uneven surface on which these sediments were deposited.

The Ogallala attains its greatest thickness in the buried trough in the northern part of the county (plate 4, section AA′). Test hole 5 at Johnson, which is near the deepest part of the trough, penetrated 417 feet of the Ogallala formation before reaching the Cockrum sandstone. The bedrock floor rises toward the north so that the thickness of the Ogallala is only 226 feet at the Hamilton-Stanton county line (test hole 1). About 1⅛ miles north of the county line the Ogallala is only a few feet thick and the Cockrum sandstone is exposed at the surface, owing to post-Ogallala faulting and erosion. From Johnson southward and southwestward the bedrock floor again rises, and in the southwestern part of the county it is exposed in the stream valleys. At Manter, the thickness of the Ogallala is about 200 feet and just east of Saunders it is less than 50 feet. Six miles south of Johnson the thickness is 216 feet (test hole 8) and at the Stanton-Morton county line south of Johnson, the thickness is only 81 feet (test hole 11). East of this point the Ogallala thickens. At a point about 6 miles east of State highway 27 on the Stanton-Morton county line, 191 feet of the Ogallala was penetrated in test hole 10 and, at a point about 5 miles farther east, 261 feet was penetrated in test hole 9. In northwestern Stanton county 297 feet of the Ogallala was drilled in test hole 6, and 182 feet in test hole 3, indicating that the formation thins toward the northwest. In the eastern part of the county the Ogallala probably attains its maximum thickness near Big Bow. The thickness of the formation was 329 feet in test hole 4, about 5 miles north of Big Bow, and 383 feet in test hole 7, which is 6 miles south of Big Bow. The thickness of the Ogallala is probably greater in the lowest part of the trough, which is somewhere between these two test holes.

Origin.—The materials of the Ogallala formation were deposited by widely shifting streams that originated in the Rocky Mountains (Johnson, 1900, p. 638). This manner of deposition explains the lenticular character of the materials and the many other irregular features of the formation. The sands and gravels probably represent channel deposits and the silts probably represent flood plain deposits. Johnson (1900, p. 638) briefly summarizes the origin of the High Plains as follows:

> The original smooth plain . . . was alluvial, *i. e.*, stream-built. It was spread, in substantially its present position as to elevation and inclination, by widely shifting, heavily loaded, and depositing streams from the mountains. Shifting deposition, burial, and plain building constitute the normal habit of desert streams. . . . Virtually the same mountain streams are at present cutting away and degrading where formerly they made broad fan-form deposits and built up.

Smith (1940, p. 79) believes that the silts and clays in the Ogallala were derived from soils and weathering products in the mountain area, and that the abundant limy material was derived from weathering of Paleozoic limestones and of calcic minerals in the crystalline rocks of the mountain area, but that some of the limy material may have been provided by weathering *in situ* after deposition. According to Theis, Burleigh, and Waite (1935, p. 1) the coarse sediments in the Ogallala "were laid down by streams, but the structureless material appears to have been deposited by the wind."

Age and correlation.—Although very little evidence is available, it seems certain that the material described above represents deposits of both Pliocene and Pleistocene age. Heretofore these deposits have been described as belonging to the Ogallala formation (Pliocene), which is so widespread in the western part of the state (Darton, 1920, p. 6). It now seems, however, that a part is of Pleistocene age.

A fossil gastropod taken from test hole 4 (fig. 4) at a depth of 100 to 109 feet was identified by Calvin Goodrich (written communication) as *Succinea avara* Say. According to Hibbard (personal communication) this form is commonly found in undoubted Pleistocene deposits of Meade county, Kansas. Other evidence suggesting a Pleistocene age for some of the surficial deposits in Stanton county is the occurrence, in sec. 13, T. 26 S., R. 41 W., Hamilton county, only about 3.5 miles north of the Hamilton-Stanton county line, of volcanic ash, which is described by both Landes (1928, p. 25) and Bass (1926, p. 60) as probably belonging to the Pleistocene. The ash is underlain by 2 feet of soil that rests directly on the Cockrum sandstone. This ash may be correlative with ash in Meade county that contains undoubted Pleistocene fossils (Hibbard, personal communication).

Water supply.—The sands and gravels of the Ogallala formation are by far the most productive source of ground water in Stanton county.* About 70 percent of the domestic and stock wells, one of the two municipal wells, and all the irrigation wells draw water from this formation.

The finer materials of the formation are generally porous and hold considerable water but are not permeable enough to yield water freely, but the coarser materials, the gravels in particular, are very good water bearers and generally yield abundant supplies of water. Beds of water-bearing sand and gravel may be found at almost any depth in the formation, but as a rule are thicker and more permeable in the lower part. Beds of sand and gravel ranging in thickness from a few feet to about 50 feet were drilled in the test holes. The Ogallala is especially thick and permeable in the buried trough. The four irrigation wells are located over this trough and yield 450 to 800 gallons a minute. The city well at Johnson (63) is reported to yield 110 gallons a minute with a total lift of more than 165 feet.

The Ogallala formation is a large underground reservoir that is only partly filled with water. The upper part is dry because the recharge of the reservoir is not sufficient to fill it. In the southwestern and extreme western parts of the county the Ogallala is relatively thin and lies entirely above the water table, and, therefore, will not yield water to wells. The thickness of saturated material in the Ogallala increases toward the east, being greatest near the county line. The thickness of saturated material in the Ogallala is shown by cross sections AA′ and BB′ on plate 4. Logs of the test holes indicate that more than half of the saturated zone in the Ogallala is composed of sand and gravel, so the amount of water available is large.

Twenty-four analyses indicate that the waters in the Ogallala are moderately hard, calcium carbonate waters. With few exceptions the samples contain 170 to 300 parts per million of hardness and 150 to 250 parts per million of bicarbonate. The chloride content is uniformly low (less than 25 parts per million). The sulphate, fluoride, and iron content are very variable. Representative analyses are shown graphically in figure 6.

* The saturated part of the Pliocene and Pleistocene undifferentiated probably is entirely within the Ogallala.

QUATERNARY SYSTEM

Loess

Much of the upland area in Stanton county is covered by a thin mantle of buff to brown loess. The areas mapped as loess on plate 1 correspond to the areas mapped as "soil group 1" by the Soil Conservation Service (Joel, 1937, map 5). The soils of this group were found by McLaughlin (oral communication) to represent loess or loessial materials, and are described by Joel (1937, p. 11) as consisting of—

> Silt loams, clay loams, and silty clay loams with also some clays, and are underlain by heavy clay subsoils somewhat lighter in color than the topsoils.

The loess is composed chiefly of silt, but contains minor amounts of clay and very fine sand. Analyses in table 4 give the mechanical composition of samples of loess collected in Stanton county by Smith (1940, p. 122).

The loess occurs only on the uplands in the interstream areas. Its thickness is not known definitely but is thought to range from a foot or less to about 10 feet. The loess was found to be 8 feet thick in a pit dug at Johnson.

The loess is relatively impermeable and lies above the zone of saturation and therefore does not yield any water to wells. The upper part of the loess absorbs much of the rainfall and returns it to the atmosphere by evaporation or through the growing vegetation,

Table 4.—*Mechanical analyses of loess from Stanton county, Kansas*
(Analyzed by H. T. U. Smith)

Location.	Depth of sample (feet)	Mechanical composition (percentage by weight).					
		More than 0.5 mm	0.5-0.25 mm	0.25-0.125 mm	0.125-0.062 mm	0.062-0.031 mm	Less than 0.031 mm
NW¼ sec. 12, T. 27 S., R. 41 W.,	3	0	0.3	4.0	37.7	36.0	22.0
SW¼ sec. 30, T. 28 S., R. 42 W.,	4	0.03	0.4	3.5	21.1	58.5	16.6
NE¼ sec. 24, T. 29 S., R. 41 W.,	3	0	0.3	4.5	30.8	48.0	16.0

and not much of the rainfall percolates through the loess soil to the ground-water reservoir. A large part of the precipitation that falls on its surface in heavy storms is lost by surface run-off.

Dune Sand

Dune sand covers the Ogallala formation in a belt about 19 miles long and less than 1 mile to about 2.5 miles wide south of Bear creek. It is composed chiefly of fine- to medium-grained quartz sand and contains smaller amounts of silt, clay, and coarse sand. The sand has been accumulated by the wind to form small, moderately steep hills, some of which are 40 to 50 feet high, and low mounds.

No wells obtain water from the dune sand in Stanton county for it is everywhere above the water table, but owing to the fact that the sand is loose and highly permeable, it probably serves as an important catchment area for ground-water recharge from local rainfall.

Alluvium

Alluvium has been deposited in most of the stream valleys, and consists of sand, gravel, silt, and clay derived mainly from the Ogallala formation but in part from the Cretaceous formations into which the streams have cut. Its thickness is not known but in general it is thought to be relatively slight and in some stream channels there is no alluvium. Most of the alluvium occupies the bottoms of the present channels, and lies directly upon the Ogallala formation except in the southwest part of the county in the channels of Bear creek and Sand arroyo where the alluvium overlies Cretaceous shale (Cockrum).

Two of the recorded wells in the county end in alluvium (109 and 113). Both wells are shallow and have been abandoned. Most of the alluvium lies above the water table and hence does not supply water to wells. Where the alluvium lies on impervious material it might possibly contain small bodies of perched ground water that are not connected with the main body of ground water. The amount of water held in such small reservoirs probably would not be sufficient to supply wells, however, and probably would be depleted rapidly under conditions of drought.

BIBLIOGRAPHY

BASS, N. W., *1926,* The geology of Hamilton county, Kansas: Kansas Geol. Survey Bull. 11, part 2, pp. 53-83, figs. 13-26, pls. 5-6.

COLLINS, W. D., *1928,* Notes on practical water analysis: U. S. Geol. Survey Water-Supply Paper 596-H, pp. 235-261, pl. 14.

CRAGIN, F. W., *1886,* Further notes on the Dakota gypsum of Kansas: Washburn Coll. Lab. of Nat. Hist., vol. 1, no. 4, pp. 166-168.

———, *1889,* Contributions to the paleontology of the plains: Washburn Coll. Lab. of Nat. Hist., vol. 2, no. 10, pp. 65-68.

———, *1895,* The Mentor beds, a central Kansas terrane of the Comanche series: Am. Geologist, vol. 16, pp. 162-165.

DARTON, N. H., *1905,* Preliminary report on the geology and underground water resources of the central Great Plains: U. S. Geol. Survey Prof. Paper 32, pp. 1-409, figs. 1-18, pls. 1-72 (including maps).

———, *1906,* Geology and underground waters of the Arkansas Valley in eastern Colorado: U. S. Geol. Survey Prof. Paper 52, pp. 1-85, figs. 1-2, pls. 1-27 (including maps).

———, *1920,* Description of the Syracuse and Lakin quadrangles: U. S. Geol. Survey Geol. Atlas, Syracuse-Lakin folio (no. 212), pp. 1-10, figs. 1-7, pls. 1-6, maps.

DAVISON, M. H., *1939,* Irrigation pumping plants, construction and costs: Kansas State Board of Agriculture, Div. of Water Resources, Bull. 231-C, pp. 1-52, figs. 1-17, June.

DEAN, H. T., *1936,* Chronic endemic fluorosis: Jour. Amer. Med. Assoc., vol. 107, pp. 1269-1272.

DEFORD, R. K., *1927,* Areal geology of Cimarron county, Oklahoma: Am. Assoc. Petroleum Geologists Bull. 11, pp. 753-755.

ELIAS, M. K., *1931,* The geology of Wallace county, Kansas: Kansas Geol. Survey Bull. 18, pp. 1-252, figs. 1-7, pls. 1-42.

———, *1937,* Geology of Rawlins and Decatur counties, Kansas: Kansas Geol. Survey Mineral Resources Circ. 7, pp. 1-25, figs. 1-4.

GOULD, C. N., *1898,* On a series of transition beds from the Comanche to the Dakota Cretaceous: Am. Jour. Sci., 4th ser., vol. 5, pp. 169-175.

HAWORTH, ERASMUS, *1897,* Physiography of western Kansas: Kansas Univ. Geol. Survey, vol. 2, pp. 11-49, fig. 1, pls. 1-8.

———, *1913,* Special reports on well waters in Kansas: Kansas Geol. Survey Bull. 1, pp. 1-110, figs. 1-9, pls. 1-6.

JOEL, A. H., *1937,* Soil conservation reconnaissance survey of the southern Great Plains wind-erosion area: U. S. Dept. Agri., Tech. Bull. 556, pp. 1-59, figs. 1-2, pls. 1-14, maps 1-20.

JOHNSON, W. D., *1901,* The High Plains and their utilization: U. S. Geol. Survey 21st Ann. Rept., part 4, pp. 601-741, figs. 300-329, pls. 113-156.

———, *1902,* The High Plains and their utilization: U. S. Geol. Survey 22d Ann. Rept., part 4, pp. 631-669, figs. 236-244, pls. 51-65.

LANDES, K. K., *1928,* Volcanic ash resources of Kansas: Kansas Geol. Survey Bull. 14, pp. 1-58, figs. 1-3, pls. 1-5.

———, and KEROHER, R. P., *1939,* Geology and oil and gas resources of Logan, Gove, and Trego counties, Kansas: Kansas Geol. Survey Mineral Resources Circ. 11, pp. 1-45, figs. 1-8, pls. 1-4.

———, and OCKERMAN, J. W., *1930,* The geology of Mitchell and Osborne counties, Kansas: Kansas Geol. Survey Bull. 16, pp. 1-54, fig. 1, pls. 1-15.

LEE, W. T., *1927,* Correlation of geologic formations between east-central Colorado, central Wyoming and southern Montana: U. S. Geol. Survey Prof. Paper 149, pp. 1-80, figs. 1-5, pls. 1-35.

LOHMAN, S. W., *1938,* Ground water in south-central Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W-5, pp. 1-315, figs. 1-11, pls. 1-17 (including maps).

———, *1398a,* Water supplies from wells available for irrigation in the uplands of Ford county, Kansas: Kansas Geol. Survey, Mineral Resources Circ. 9, pp. 1-10.

LUGN, A. L., and WENZEL, L. K., *1938,* Geology and ground-water resources of south-central Nebraska: U. S. Geol. Survey Water-Supply Paper 779, pp. 1-242, figs. 1-21, pls. 1-16 (including maps).

MCCALL, K. D., and DAVISON, M. H., *1939,* Cost of pumping for irrigation: Kansas State Board of Agriculture, Div. of Water Resources, Bull. 234, pp. 1-55, figs. 1-14.

MCLAUGHLIN, T. G., in press, Geology and ground-water resources of Morton county, Kansas: Kansas Geol. Survey Bull. 40.

MEINZER, O. E., *1923,* The occurrence of ground water in the United States, with a discussion of principles: U. S. Geol. Survey Water-Supply Paper 489, pp. 1-321, figs. 1-110, pls. 1-31 (including maps).

———, *1923a,* Outline of ground-water hydrology, with definitions: U. S. Geol. Survey Water-Supply Paper 494, pp. 1-71, figs. 1-35.

MOORE, R. C., and others, *1940,* Ground-water resources of Kansas: Kansas Geol. Survey Bull. 27, pp. 1-112, figs. 1-28, pls. 1-34, (includes chapter, Ground-water investigations in the Stanton district, southwestern Kansas, by T. G. McLaughlin and B. F. Latta).

———, and LANDES, K. K., *1937,* Geologic map of Kansas, Kansas Geol. Survey. 1:500,000.

NORTON, G. H., *1939,* Permian redbeds of Kansas: Am. Assoc. Petroleum Geologists Bull. 23, pp. 1751-1815, figs. 1-24.

PARKER, H. N., *1911,* Quality of the water supplies of Kansas: U. S. Geol. Survey Water-Supply Paper 273, pp. 1-375, map.

ROTHROCK, E. P., *1925,* Geology of Cimarron county, Oklahoma: Okla. Geol. Survey Bull. 34, pp. 7-92, figs. 1-18, pls. 1-3 (including map).

SANDERS, C. W., *1934,* Geology of Two Buttes dome in southeastern Colorado: Am. Assoc. Petroleum Geologists Bull. 18, pp. 860-870, figs. 1-6 (including geologic map).

SAYRE, A. N., *1937,* Geology and ground-water resources of Duval county, Texas: U. S. Geol. Survey Water-Supply Paper 776, pp. 1-116, figs. 1-3, pls. 1-8 (including map).

SCHOFF, S. L., *1939,* Geology and ground-water resources of Texas county, Oklahoma: Oklahoma Geol. Survey Bull. 59, pp. 1-248, figs. 1-13, pls. 1-5, (including map).

SCOFIELD, C. S., *1933,* Quality of irrigation waters: California Dept. of Public Works, Div. Water Resources, Bull. 40.

SLICHTER, C. S., *1906,* The underflow in Arkansas Valley in western Kansas: U. S. Geol. Survey Water-Supply Paper 153, pp. 1-90, figs. 1-24, pls. 1-3.

SMITH, H. T. U., *1940,* Geologic studies in southwestern Kansas: Kans. Geol. Surevy Bull. 34, pp. 1-212, figs. 1-22, pls. 1-34.

STOSE, G. W., *1912,* Description of the Apishapa quadrangle: U. S. Geol. Survey Geol. Atlas, Apishapa folio (no. 186), pp. 1-12, maps.

TESTER, A. C., *1931,* The Dakota stage of the type locality: Iowa Geol. Survey, vol. 35, pp. 199-332, figs. 25-44, pls. 3-4.

THEIS, C. V., BURLEIGH, H. P., and WAITE, H. A., *1935,* Ground water in the southern High Plains: U. S. Dept. Interior Memorandum for the Press, pp. 1-4, map, Oct. 30.

TWENHOFEL, W. H., *1920,* The Comanchean and Dakota strata of Kansas: Am. Jour. Sci., 4th ser., vol. 49, pp. 281-297.

———, *1924,* Geology and invertebrate paleontology of the Comanchean and "Dakota" formations of Kansas: Kansas Geol. Survey Bull. 9, pp. 1-135, pls. 1-23 (including maps).

WING, M. E., *1930,* The geology of Cloud and Republic counties, Kansas: Kansas Geol. Survey Bull. 15, pp. 1-49, figs. 1-2, pls. 1-18.

TABLE OF WELL RECORDS

Descriptions of the wells visited in Stanton county are given in the following table (table 5). The wells are listed in order by townships from north to south and by ranges from east to west. Within a township the wells are listed in the order of the sections. All information classed as "reported" was obtained from the owner, tenant, or driller. Depths of wells not classed as "reported" are measured and given to the nearest tenth of a foot below the measuring point described in the table, and depths to water level not classed as "reported" are measured and given to the nearest hundredth of a foot.

TABLE 5.—*Records of Drilled Wells in Stanton County, Kansas*

Well No. Plate 2.	LOCATION.	Owner.	Topographic position.	Depth of well (feet)[1]	Diameter of well (inches)	Principal water-bearing bed. Character of material.	Principal water-bearing bed. Geologic subdivision.	Method of lift ([2])	Use of water ([3])	Measuring point. Description.	Measuring point. Height above (+) or below (—) land surface (feet)	Measuring point. Height above sea level (feet)	Depth to water level below measuring point (feet)[4]	Date of measurement, 1939	Remarks.
	T. 26 S., R. 39 W.[5]														
1	SW corner SW¼ sec. 32	(?)	Valley slope	141.8	6	(?)	Ogallala	C,W	N	Top of casing, east side	+0.8	....	128.79	Aug. 10	Domestic and stock well.
	T. 27 S., R. 39 W.														
2	NW corner NW¼ sec. 2	Fegan Ranch	Upland flat	96.0	6	Sand and gravel	do.	C,W	D, S	Top of casing, south west side.	0	....	87.53	Aug. 10	Can be pumped dry. See analysis.
3	NW¼ NW¼ sec. 14	C. Molz & Son	Bottom of draw	82.0	6	do.	do.	C,W	S	Top of board covering casing.	+1.0	....	69.24	Aug. 31	
4	SE¼ SE¼ sec. 17	G. L. Warner	Upland slope	66.0	5.5	(?)	do.	C,W	N	Top of casing, north side.	+1.0	....	55.92	July 25	Domestic well.
5	SE¼ SW¼ NE¼ sec. 23	R. M. Mater	Undulating upland	69.0	6	(?)	do.	C,H	D	Lower edge of pump base, east side.	0	....	44.15	Aug. 5	
6	SE¼ NE¼ sec. 27	Pete Molz	do.	83	18	Sand and gravel	do.	T,G	I	Land surface	0	3,154.3	56	....	See log. Casing perforated, 51-83 feet. Reported to yield 450 gallons a minute with a draw-down of 25 ft.
7	NE corner SE¼ sec. 29	H. Reynolds	Upland flat	80.5	6	do.	do.	C,W	D, S	Top edge of east pipe clamp.	+ .5	....	63.29	Aug. 31	See log. Water reported to be slightly hard. See analysis.
	T. 27 S., R. 40 W.														
8	NE cor. SE¼ SW¼ sec. 1.	S. J. Oliver	Hillside	150	4	Sand	do.	C,W	D, S	Land surface	0	....	110	....	See analysis.
9	SW cor. SE¼ SW¼ sec. 5.	E. J. Guldner	Valley flat	78	6	Sand and gravel	do.	C,W	D, S	Lower west edge of pump base.	+1.5±	....	53.49	Aug. 22	See log. Main supply 58-69 feet. Water-bearing sand and gravel, 25-32 feet, 35-42 feet, 73-78 feet.
10	SW cor. NW¼ NW¼ sec. 10	J. Plummer	Valley slope	60.0	(?)	(?)	do.	C,W	S	Land surface	0	....	50±	Sept. 2	Water dripped on tape from side of casing—only approximate depth to water obtainable.
11	SW corner NW¼ sec. 15	do.	do.	68.5	6	(?)	do.	C,W	S	Top edge of pipe clamp.	+ .5	....	57.23	do.	
12	NW corner SW¼ sec. 17	G. R. Carrithers	Upland flat	72.0	5.5	(?)	do.	C,W	D, S	Top edge of pipe coupling.	+1.0	....	56.19	Aug. 22	See analysis.

13	NE corner SE¼ sec. 21	L. Y. Carrithers	do	56.0	5	(?)	do	C,W	N	Top of concrete platform.	+1.0	3,236.2	52.33	July 25	Domestic well.
14	SW corner SE¼ sec. 24	J. A. Floyd	do	(?)	6	Sand and gravel	do	C,W	D	Top of casing, south side.	+ .2	3,231.3	81.43	Aug. 10	
15	SE corner SE¼ sec. 26	Audrey Schulz	do	(?)	6	Sand	do	C,W	N	Top edge of pipe clamp, south side.	+ .5	....	59.86	Aug. 19	Do.
16	SE corner SE¼ sec. 29	M. C. Williamson	Upland slope	105.0	6	(?)	do	C,W	N	Top of casing, northwest side.	0	....	65.09	do	Do.
17	NW corner NW¼ sec. 30	O. E. Josserand	Upland flat	93.0	6	(?)	do	C,W	S	Top of casing, north side.	0	....	87.85	Aug. 22	
18	SE cor. SW¼ SW¼ sec. 32.	J. L. Cross	Upland slope	119.5	6	Sand	do	C,W	D, S	Top of east pipe clamp, west side.	0	....	114.70	Sept. 6	
19	NW corner NE¼ sec. 35	Clarence Winger	Upland flat	182	16	Fine sand to coarse gravel.	do	T, G	I	Land surface	0	....	63	....	See log. Lower 120 feet of casing perforated. Reported to yield 800 gallons a minute with a drawdown of 27 feet after 6 hours pumping. Depth to water reported for October, 1939. See analysis.
	T. 27 S., R. 41 W.														
20	SW corner SW¼ sec. 3	J. A. Stone	Upland flat	117.0	6	....	do	C,W	S	Top of casing, east side.	0	....	75.63	Aug. 22	Gravel packed. Tan, fine sandstone (probably Ogallala) reported from depth of 110-135 feet. Reported that water from sandstone rose 35 feet. Reported depth 135 feet when drilled in 1906. See Analysis.
21	SW corner SE¼ sec. 15	G. Raney	Upland flat	123.5	6	(?)	do	C,W	S	Top of casing, north side.	0	....	98.56	Sept. 6	See analysis.
22	SE corner SE¼ sec. 17	J. P. McNabb	do	122.5	6	(?)	do	C,W	N	Top of west pipe clamp, east side.	+ .5	....	118.13	Aug. 22	Domestic well.
23	NE corner SE¼ sec. 30	Nellie Yinger	do	158.5	6	(?)	do	C,W	N	Lower edge of pipe coupling.	+2.5±	....	143.65	Aug. 30	Do.
24	SE cor. SW¼ SW¼ sec. 31.	W. M. Ihloff	do	172	6	Sand and gravel	do	C,W	D, S	Land surface	0	....	161	....	Casing set on hard, yellow clay. Temperature 60° F. See analysis.
25	SE corner NE¼ sec. 33	H. Hammond	do	145.0	6	(?)	do	N	N	Top of pipe coupling, east side.	+4.5	....	129.06	Aug. 18	Stock well.
	T. 27 S., R. 42 W.														
26	NE¼ NE¼ sec. 8	J. W. Reynolds est.	do	138.0	6	(?)	do	C,W	D, S	Top of casing, east side.	0	....	122.98	Aug. 25	See analysis.
27	NW cor. SW¼ SE¼ sec. 10	M. L. Gillum	do	147.5	6	Sand and gravel	do	C,W	D, S	Top of casing, north side.	0	....	115.60	Sept. 6	Casing set on clay.
28	SE corner SE¼ sec. 11	J. E. Williams	do	128.0	6	(?)	do	C,W	N	Top of casing, west side.	0	....	116.85	do	Domestic well.
29	SE corner NE¼ sec. 12	W. Ward	do	130.0	5.5	(?)	do	N	N	Top of casing, northeast side.	0	....	100.33	July 24	Abandoned, formerly a domestic well.
30	SE corner NE¼ sec. 21	Collingwood Ld.Co.	do	194.3	6	(?)	(?)	C,W	D, S	Top of west pipe clamp, east side.	+ .3	....	157.75	Sept. 5	

TABLE 5.—Records of Drilled Wells in Stanton County, Kansas (*Continued*)

Well No. Plate 2.	LOCATION.	Owner.	Topographic position.	Depth of well (feet)[1]	Diameter of well (inches)	Principal water-bearing bed. Character of material.	Principal water-bearing bed. Geologic subdivision.	Method of lift ([2])	Use of water ([3])	Measuring point. Description.	Measuring point. Height above (+) or below (—) land surface (feet)	Measuring point. Height above sea level (feet)	Depth to water level below measuring point (feet)[4]	Date of measurement, 1939	Remarks.
31	SE corner SW¼ sec. 33	C. McCune	Upland flat	174.3	6	(?)	Ogallala	C,W	N	Top of north pipe clamp, south side.	+ .3	....	169.09	do	Domestic well.
32	SW corner SW¼ sec. 36	W. H. Teas	do	203.0	6	(?)	do	N	N	Top of casing, north side.	0	....	189.92	Aug. 25	Abandoned, formerly a domestic well.
	T. 27 S., R. 43 W.														
33	NE cor. SE¼ SE¼ sec. 5	J. S. Little	do	221.3	6	(?)	Cockrum	C,W	N	Top of pipe coupling, west side.	+ .3	....	212.85	Aug. 31	Domestic well.
34	NE cor. SE¼ NE¼ sec. 15	S. A. Schmidt	Valley slope	200.0	6	(?)	do	C,W	D, S	Top of pipe coupling, west side.	+1.0	....	183.36	do	See analysis.
35	NE corner SE¼ sec. 26	H. S. Weir	Upland flat	236.5	5.5	(?)	do	N	N	Top of bucket covering casing.	+ .5	3,542.9	179.06	July 29	Abandoned.
36	NW cor. NE¼ NW¼ sec. 27	E. C. Berkley	do	200.0	6	(?)	do	C,W	N	Top of casing, east side.	0	....	186.32	Aug. 31	Domestic and stock well.
37	NE corner NE¼ sec. 33	J. B. Cockrum	do	130.5	6	Fine sand	Cockrum (?)	C,W	D, S	Top of south pipe clamp, north side.	0	....	125.89	Sept. 13	Very small yield reported. Water has reddish color due to high iron content. See analysis.
38	SE¼ NE¼ sec. 34	H. N. Mendenhall	Valley slope	118.0	6	Sand	do	C,W	D, S	Top of casing, west side.	+1.0	....	115.7	do	Very small yield reported.
	T. 28 S., R. 39 W.														
39	NE corner SE¼ sec. 3	R. I. Montgomery	Upland flat	65.8	6	(?)	Ogallala	C,H	P	Top of casing, east side.	+ .3	3,151.9	53.74	Aug. 31	Supplies rural school. See analysis.
40	NW corner NE¼ sec. 5	C. R. Winger	do	59.5	6	Sand	do	C,W	N	Top of casing, north side.	+1.0	....	45.89	Aug. 10	Stock well.
41	NW corner NW¼ sec. 5	do	do	160	18	do	do	T,G	I	Land surface	0	....	52	....	See log. Lower 100 feet of casing perforated. Depth to water reported for October, 1939. No data of yield available.
42	SE corner SW¼ sec. 8	W. F. Belcher	do	79.5	6	(?)	do	C,W	D, S	Top of north pipe clamp, south side.	+1.0	....	64.73	Aug. 31	See analysis.
43	NW cor. NE¼ NE¼ sec. 12	R. P. Pinegar	Undulating upland	56.5	6	(?)	do	N	N	Top of casing, north side.	0	....	55.30	do	Abandoned, formerly a domestic well.
44	SW corner SW¼ sec. 14	Eyman & Kearney	Upland flat	52.0	5.5	(?)	do	N	N	Top of casing, north side.	0	3,151.3	46.13	Aug. 5	Abandoned, formerly a stock well.

45	SW corner SW¼ [illegible]	J. G. Neufeldt	do.	119.5	6	(?)	do.	C,H	N	Top of west bolt hole in pump base.	+ .5	....	78.43	Aug. 7	Domestic well.
46	NE cor. NW¼ NW¼ sec. 29	A. Ross	do.	67.5	5.5	(?)	do.	C,W	N	Top of casing, north side.	+1.5	....	63.90	Aug. 3	Do.
47	NW¼ NE¼ sec. 35	Southwestern Col,	do.	87.8	5.5	(?)	do.	N	N	Top of casing, east side.	+ .3	....	70.89	July 25	Abandoned, formerly a domestic well.
	T. 28 S., R. 40 W.														
48	SE corner NE¼ sec. 13	J. Snyder	do.	97.5	5.5	(?)	do.	C,W	N	Top of north bolt hole in pump base.	+ .5	....	78.32	July 28	Domestic well.
49	NW corner SW¼ sec. 15	C. H. Beckett	do.	99.0	5.5	(?)	do.	C,H	N	Top of north bolt hole in pump base.	0	....	90.99	Aug. 10	Do.
50	SW corner SE¼ sec. 21	J. A. Ramsey	Upland flat	128.5	6	(?)	do.	C,W,H	D, S	Top of opening in side of casing.	—2.5±	....	118.31	Sept. 6	
51	SE corner SE¼ sec. 30	O. L. Stockman	do.	157.0	5.5	Sand and gravel	do.	C,W	D, S	Lower edge of pump base, northwest side.	—1.5	....	145.62	Aug. 19	
52	NW corner NE¼ sec. 33	C. E. Van Meter	Top of hill	146.5	6	Coarse sand	do.	C,W	D, S	Top of casing, northwest side.	0	....	130.99	Aug. 16	Lower 18 feet of casing perforated.
53	NW corner NW¼ sec. 35	B. Wolfe	Upland flat	102.0	5.5	Loose sand	do.	C,W	D, S	Land surface	0	....	81	....	See analysis.
54	NW corner NE¼ sec. 36	L. R. Smith	Hilltop	125.5	5.5	(?)	do.	C,W	N	Top of casing, east side.	0	....	102.62	July 21	Domestic well.
	T. 28 S., R. 41 W.														
55	NW corner NW¼ sec. 1	E. H. Tallman	Valley slope	117.0	6	(?)	do.	C,W	S	Top of south bolt hole in pump base.	0	3,304.1	80.97	Aug. 30	See analysis.
56	SE corner SE¼ sec. 3	H. Witt	Upland flat	177.5	6	(?)	do.	C,H	N	Top of casing, east side.	+ .5	....	144.23	Sept. 6	Domestic well.
57	NW corner NE¼ sec. 13	J. Wilson	do.	164.5	(?)	(?)	do.	C,W	N	Lower edge of pump base.	+ .5	....	150.55	July 24	Do.
58	NE cor. SE¼ SE¼ sec. 16	O. E. Josserand	Hilltop	207.0	6	(?)	do.	C,W	S	Top of casing, northwest side.	0	....	189.25	Sept. 9	
59	SW corner SE¼ sec. 17	H. Bearman	Valley slope	165.0	(?)	(?)	do.	C,W	S	Lower edge of pump base.	0	....	152.6	Aug. 30	
60	NE corner SW¼ sec. 23	G. E. Bearman	Upland flat	195.0	6	(?)	do.	C,W	D, S	Top of board covering well.	0	....	183.28	do.	See analysis.
61	SE¼ SE¼ sec. 26	O. Cockreham	do.	185.5	5.5	Sand and gravel	do.	C,W	D, S	Top of metal flange around pipe.	0	3,350.4	182.30	Aug. 18	
62	SW corner SW¼ sec. 29	H. Bearman	do.	156.0	6	(?)	do.	C,W	N	Top of casing, north side.	0	....	140.53	July 22	Domestic well.
63	SE¼ NE¼ SW¼ sec. 36	City of Johnson City.	do.	223.0	12-10	Coarse gravel	do.	T, E	P	Top of opening, north side of pump.	+2.0±	....	165.13	Aug. 16	Supplies city of Johnson City. 24-inch gravel-packed well, lower 30 feet of casing perforated. Coarse gravel from 182 to 223 feet. Reported to yield 110 gallons a minute. See analysis.
	T. 28 S., R. 42 W.														
64	NW corner SW¼ sec. 9	Schribner	Hilltop	248.5	6	(?)	do.	C,W	D, S	Top of board platform.	0	....	244.28	Sept. 7	Reported small yield, well pumps dry. See analysis.
65	NE cor. SW¼ SW¼ sec. 13	Ed McKee	Upland flat	213.0	6	Gravel	do.	C,W	D, S	Top of lower 2- by 4-inch board.	+ .8	....	187.23	Sept. 11	Moderate yield reported. Temperature 59° F. See analysis.

TABLE 5.—Records of Drilled Wells in Stanton County, Kansas (*Continued*)

Well No. Plate 2.	LOCATION.	Owner.	Topographic position.	Depth of well (feet)[1]	Diameter of well (inches)	Principal water-bearing bed.		Method of lift (2)	Use of water (3)	Measuring point.			Depth to water level below measuring point (feet)[4]	Date of measurement, 1939	Remarks.
						Character of material.	Geologic subdivision.			Description.	Height above sea level (feet)	Height above (+) or below (—) land surface (feet)			
66	SE cor. SE¼ SE¼ sec. 24	Laseter & Mendenhall.	Valley slope	115.0	5.5	(?)	Ogallala	C,W	D, S	Top of north pipe clamp, south side.	0	....	94.1	Aug. 26	
67	NE cor. NW¼ NW¼ sec. 27	L. Stanton	Upland flat	232.0	6	Coarse gravel	do.	C,W	D, S	Land surface	0	....	207	....	Coarse gravel from 205 to 232 feet. Casing set on clay.
68	SW corner SW¼ sec. 29	C. D. Wartman	do.	169.3	5.5	(?)	Cockrum (?)	N	N	Top of upper rivet inside casing.	+ .3	3,544.6	137.98	July 29	Abandoned, formerly a stock well.
69	NE cor. SE¼ SE¼ sec. 32	Pierson est	Valley slope	68.0	6	(?)	Ogallala (?)	C,W	N	Lower edge of coupling, west side.	0	3,489.3	60.18	Sept. 7	Domestic well. See analysis.
70	SW¼ NW¼ sec. 35	O. Robison	do.	137.0	6	(?)	Ogallala	C,W	D, S	Land surface	0	3,449.0	119	....	
	T. 28 S., R. 43 W.														
71	NW corner NW¼ sec. 12	Collingwood Ld. Co.	Upland flat	173.3	(?)	(?)	(?)	C,W	D, S	Top of north pipe clamp, south side.	+ .3	3,570.6	169.94	Sept. 7	See analysis.
72	NE cor. NW¼ NE¼ sec. 13	Fed. Farm Mort. Corp.	Upland slope	223.0	6	(?)	Cockrum	N	N	Top of casing, west side.	0	....	189.16	Aug. 31	Abandoned, formerly a domestic well.
73	SE cor. SW¼ SW¼ sec. 15	C. Williams	Upland flat	244.0	6	(?)	do.	C,W	D, S	Top of south bolt hole in pump base.	0	....	193.13	do.	
74	SW corner SE¼ sec. 27	M. Beardsley	do.	213.0	6	(?)	do.	C,W	D	Lower edge of south pipe clamp.	0	....	207.9	Aug. 25	Very small yield reported. Casing set in blue clay. See analysis.
	T. 28 S., R. 41 W.[6]														
75	SW¼ SW¼ sec. 28	(?)	do.	98.0	5.5	(?)	Ogallala	N	N	Top of casing, southwest side.	—1.0	3,657.5	93.93	Aug. 1	Abandoned, formerly a domestic and stock well.
	T. 29 S., R. 38 W.[7]														
76	SW¼ NW¼ sec. 30	(?)	Upland slope	94.0	6	(?)	do.	C,W	N	Top of pipe coupling, southeast side.	+1.0	....	68.39	Aug. 9	Domestic well.
	T. 29 S., R. 39 W.														
77	SE corner SW¼ sec. 2	H. H. Brown	Upland flat	74.0	5.5	Sand	do.	C,H	N	Top of casing, west side.	0	3,157.8	56.97	Aug. 3	See log of well 76.

78	SE corner SW¼ sec. 2	do	do	330.0	60-18	Sand and gravel	do	T,G	I	Top of pulley wheel, north side.	+4.0±	3,161.2	60.35	Aug. 7	See log. 60-inch casing to depth of 80 feet, 18-inch casing 80-330 feet, perforated to depth of 330 feet. Reported to yield 650 gallons a minute with a draw-down of 13 feet. See analysis.
79	SE corner SE¼ sec. 4	G. L. Henry	do	84.0	6	(?)	do	C,W	D, S	Land surface	0	3,191.9	80	....	
80	SW cor. SE¼ SW¼ sec. 5	do	do	94.0	5.5	(?)	do	C,W	D, S	Lower edge of pipe coupling.	+2.0	3,213.4	77.79	Aug. 7	See analysis.
81	SW cor. NW¼ SW¼ sec. 6	V. A. Sherer	do	105.5	6	(?)	do	C,W	S	Top of northwest hole in pump base.	0	....	93.65	Aug. 23	
82	SE corner SE¼ sec. 9	R. P. Dotzour	do	88.5	5.5	(?)	do	C,W	S	Top of tin plate covering casing.	0	3,198.5	81.16	do	
83	SE corner SE¼ sec. 18	J. C. Hainer	do	101.5	(?)	(?)	do	C,W,H	N	Top of flange over casing.	+ .5	3,231.1	93.79	Aug. 7	Domestic well.
84	NW corner SW¼ sec. 23	J. C. Jones	Upland slope	65.0	(?)	(?)	do	C,W	N	Top of pipe coupling, west side.	+3.5±	3,168.4	60.44	July 21	Do
85	NW corner NW¼ sec. 30	W. C. Jones	Upland flat	94.5	5.5	(?)	do	C,W	D, S	Top of south pipe clamp, north side.	+ .5	3,228.1	87.21	Aug. 18	Water rose .06 foot in 7 minutes after pumping stopped. No additional rise was noted. See analysis.
	T. 29 S., R. 40 W.														
86	SW corner SE¼ sec. 6	Leonard Norlin	do	189.0	6	Coarse gravel	do	C,W	D	Top of pipe coupling, north side.	+ .5	....	149.15	Aug. 23	Coarse gravel, 180-190 feet. Moderate yield reported.
87	SW corner SE¼ sec. 19	J. Carter	do	158.0	(?)	(?)	do	C,W	N	Top of casing, west side.	0	3,311.4	153.1	do	Domestic well.
88	NW corner NW¼ sec. 22	Delcie Ihinger	do	133.5	5.5	(?)	do	C,W	N	Top of west bolt hole in pump base.	+2.0	....	124.88	Aug. 18	Do
89	SE cor. SW¼ NE¼ sec. 26	Art Nickerson	do	112.5	6	Sand and gravel	do	C,W	D, S	Top of casing, northwest side.	0	....	105.63	Sept. 12	Moderate yield reported.
90	SW corner SW¼ sec. 33	F. Staker	do	193.5	6	(?)	do	C,W	N	Top of casing, southeast side.	+ .5	3,308.1	154.05	Aug. 9	Domestic well.
	T. 29 S., R. 41 W.														
91	SW corner SW¼ sec. 9	Santa Fe	do	238.5	5.5	(?)	do	C,W	N	Top of casing, north side.	+ .5	3,418.4	211.42	Aug. 23	Do
92	SE corner SE¼ sec. 11	Glen Arnold	do	201	6	Gravel	do	C,W	D, S	Top of casing, south side.	0	3,356.4	184.25	Aug. 24	Lower 15 feet of casing perforated. See analysis.
93	Cent. NE¼ sec. 11	J. Plummer	do	235.0	8	Coarse gravel	do	N	N	Top of casing, south side.	+1.0	3,349.7	176.45	Aug. 24	See log. Supplied water for drilling test well for gas.
94	SE corner SE¼ sec. 20	C. F. Hobbs	Gentle slope	187.5	6	(?)	do	C,W	N	Lower edge of east pipe clamp.	0	3,383.7	173.80	Aug. 28	Domestic well.
95	SW cor. NW¼ NW¼ sec. 25	Santa Fe	Terrace	172.5	6	(?)	do	C,W	D	Top of casing, north side.	+ .5	3,323.9	153.03	Aug. 24	
96	NE corner SE¼ sec. 35	H. L. Collers	Upland flat	209.2	5.5	Gravel	do	C,W	D	Top of west bolt hole in pump base.	+ .2	3,375.6	202.07	do	Moderate supply reported. See analysis.
	T. 29 S., R. 42 W.														
97	NW cor. SW¼ NW¼ sec. 2	C. D. Wartman	Hillside	85.0	6	Coarse gravel	do	C,W	D, S	Land surface	0	3,445.3	78	....	Moderate supply reported.
98	Ce ter sec. 4	do	Valley slope	37.0	6	Gravel	do	C,W	D, S	Land surface	0	3,459.3	28	....	Do

TABLE 5.—Records of Drilled Wells in Stanton County, Kansas (*Continued*)

Well No. Plate 2.	LOCATION.	Owner.	Topographic position.	Depth of well (feet)[1]	Diameter of well (inches)	Principal water-bearing bed.		Method of lift ([2])	Use of water ([3])	Measuring point.			Depth to water level below measuring point (feet)[4]	Date of measurement, 1939	Remarks.
						Character of material.	Geologic subdivision.			Description.	Height above sea level (feet)	Height above (+) or below (—) land surface (feet)			
99	NE¼ SE¼ sec 10	C. A. Plank	Hilltop	182.0	6	(?)	do	C,W	N	Top of casing, north side.	0	3,513.2	152.28	Aug. 23	Domestic well.
100	NW¼ SW¼ sec. 14	City of Manter	Upland flat	278.0	12	Sandstone (?)	Cockrum	T,E	P	Land surface	0	3,488.4	240	....	See log. Supplies city of Manter. "Soft sand rock," 215-255 feet. Reported to yield 100 gallons a minute.
101	SW¼ SW¼ sec. 14	Santa Fe R. R.	do	475.0	12.5-8	"Pack sand"	Ogallala-Triassic (?)	C,E	R	Land surface	0	3,492.6	211	....	See log.
102	NE corner SE¼ sec. 18	C. H Bilbery	Hillside	141.5	6	(?)	Cockrum	N	N	Top of casing, south side.	+1.5	3,555.2	98.75	Aug. 25	Abandoned.
103	SE corner SE¼ sec. 27	E. T. Flowers	Hilltop	256.0	6	(?)	do	C,W	N	Land surface	0	3,504.2	250	Aug. 9	Domestic and stock well.
104	SW¼ SW¼ sec. 27	do	Upland flat	253.0	(?)	(?)	do	C,W	D	Lower edge of pump base.	+1.0	3,512.5	242.5	Sept. 9	
105	NE corner SE¼ sec. 30	A. W. Johnson	do	234.5	6	(?)	do	C,W	N	Top of pipe clamp, north side.	0	3,553.3	230.20	do	Domestic well.
106	SE cor. NW¼ SW¼ sec. 34	W. J. Pizel	Hillside	215.0	6	Sandstone	do	C,W	D, S	Land surface	0	3,492.6	203	....	Casing set in shale. See analysis.
	T. 29 S., R. 43 W.														
107	NW corner SE¼ sec. 9	Cora Lococo	Terrace	21.0	36	(?)	do	C,W	N	Top of west pipe clamp.	0	3,588.5	19.76	Aug. 26	Dug domestic well, about 100 feet from creek bed.
108	NE cor. SE¼ NE¼ sec. 10	Fay Green	Upland slope	100.0	6	Sandstone	do	C,W	N	Top of casing, south side.	+1.0	3,597.4	84.24	Aug. 25	Domestic and stock well.
109	SW corner NE¼ sec. 14	Fed. Land Bank	Valley flat	20.0	6	(?)	Alluvium (?)	N	N	Top of casing, north side.	+1.5	3,515.9	12.90	Aug. 26	One of six windmills formerly used to irrigate small plot of land.
110	NW cor. SW¼ SW¼ sec. 14	Johnson St. Bank	do	108.0	5.5	Sandstone	Cheyenne	C,W	D, S	Top of east pipe clamp.	+ .2	3,533.5	28.45	Aug. 25	See analyses.
111	NE corner NW¼ sec. 15	Renfrew Inv. Co.	Valley slope	74.0	(?)	do	Cockrum	C,W	N	Top of tin plate over casing.	+1.0	3,577.5	61.89	Aug. 26	Domestic and stock well.

112	SE cor. SW¼ SW¼ sec. 15	Stanton county	do	200	6	do	Cheyenne	N	N	Top of casing, south side.	+1.0	3,572.7	41.30	Aug. 25	Cased to depth of 30 feet. Measured depth, 63 feet. Was to be used during building of Stanton Co. dam.
113	NW corner SE¼ sec. 21	J. B. Cockrum	do	18.0	(?)	Sand and gravel	Alluvium	N	N	Top of pipe clamp, east side.	+2.0±	3,558.5	14.40	Aug. 29	Water was pumped from this and other wells in valley to upland for irrigation.
114	SE cor. SW¼ SW¼ sec. 33	J. A. Stewart	Upland flat	160	6	Sandstone	Cheyenne	C,W	D, S	Land surface	0	....	145	....	See analysis.
	T. 30 S., R. 39 W.														
115	SE corner SW¼ sec. 4	F. Shore	do	92.0	5.5	(?)	Ogallala	N	N	Top of casing, west side.	+1.0	3,203.5	81.28	Aug. 4	Abandoned, formerly a stock well.
116	NW corner NE¼ sec. 6	A. R. Swindler	do	110.0	5.5	(?)	do	C,W	N	Top of casing, northeast side.	+1.0	3,229.5	96.52	Aug. 2	Domestic well.
117	NE corner NW¼ sec. 14	Z. B. Nicholas	do	78.0	6	(?)	do	C,W	N	Top of pipe clamp	0	3,171.6	63.91	July 20	Do
118	NE corner NE¼ sec. 18	O. Shore	do	104.0	6	(?)	do	N	N	Top of pipe coupling	+1.0	3,220.4	92.54	Aug. 4	Abandoned, formerly a domestic well.
119	SW corner NW¼ sec. 20	M. Collingwood	do	114.0	6	(?)	do	C,W	D, S	Top of casing, west side.	0	3,207.8	78.12	Aug. 18	See analysis.
120	NW corner SW¼ sec. 22	L. C. Aller	do	93.0	6	(?)	do	C,W	D	Top of board covering casing.	0	3,184.5	72.92	Aug. 4	
121	SW corner NW¼ sec. 24	J. Shore	do	92.5	6	(?)	do	C,W	N	Top of 4- by 4-inch wooden clamp.	+ .5	3,156.9	57.07	do	Stock well.
122	SW corner SW¼ sec. 25	C. R. Lucas	do	81.4	6	(?)	do	C,W	D	Top of west pipe clamp, east side.	+ .4	3,170.6	72.48	do	See analysis.
123	NE cor. SE¼ SE¼ sec. 32	I. McAnatney	do	111.0	6	(?)	do	C,W	N	Top of casing, east side.	0	3,227.1	101.08	Aug. 2	Domestic well.
	T. 30 S., R. 40 W.														
124	SE corner SE¼ sec. 3	F. H. Staker	Upland slope	147.0	(?)	(?)	do	C,W	N	Top of lower pipe coupling.	+1.0	3,283.9	138.83	July 28	Domestic well.
125	SE corner SE¼ sec. 14	J. Herrick	Upland flat	115.0	6	(?)	do	N	N	Top of casing, north side.	0	3,244.3	106.23	Aug. 24	Abandoned, formerly a domestic well.
126	SW cor. NW¼ NW¼ sec. 17	P. H. Moore	do	166.5	5.5	(?)	do	C,W	N	Top of west bolt hole in pump base.	+ .5	3,314.8	152.84	do	Domestic well.
127	NE cor. NW¼ NE¼ sec. 36	C. H. Reese	do	125.5	5.5	(?)	do	C,W	N	Top of casing, west side.	+ .5	3,244.6	108.91	Aug. 4	Do
	T. 30 S., R. 41 W.														
128	SW corner SE¼ sec. 8	A. J. Doughty	do	196.0	5.5	(?)	Cockrum (?)	C,W	N	Top of casing, north side.	+1.0	3,406.8	182.47	July 28	Domestic well.
129	SE cor. NE¼ SE¼ sec. 11	W. H. Smoot	do	217	6	Sand and gravel	Ogallala	C,W	D, S	Land surface	0	3,364.4	170	....	
130	SW corner NW¼ sec. 18	S. Eliz. Davis	do	200	6	Fine sand	Cockrum	N	N	Top of casing, southeast side	0	3,452.0	170	....	Domestic well.
131	SE corner NE¼ sec. 21	E. Hilty	Upland slope	206.5	6	(?)	do	C,W	N	Top of north bolt hole in pump base.	0	3,409.4	200.32	Sept. 7	Domestic and stock well.
132	SW corner NW¼ sec. 23	J. N. Beauchamp.	Upland flat	188.0	6	(?)	do	C,W	N	Top of pipe coupling, east side.	+1.0	3,372.0	171.85	Aug. 3	Do

TABLE 5.—Records of Drilled Wells in Stanton County, Kansas (*Concluded*)

Well No. Plate 2.	LOCATION.	Owner.	Topographic position.	Depth of well (feet)[1]	Diameter of well (inches)	Principal water-bearing bed. Character of material.	Principal water-bearing bed. Geologic subdivision.	Method of lift ([2])	Use of water ([3])	Measuring point. Description.	Measuring point. Height above sea level (feet)	Measuring point. Height above (+) or below (—) land surface (feet)	Depth to water level below measuring point (feet)[4]	Date of measurement, 1939	Remarks.
133	NW cor. SW¼ NW¼ sec. 30	H. D. Reed	Upland flat	207.0	6	(?)	Cockrum	C,W	N	Top of north pipe clamp, south side.	0	3,446.8	188.10	Sept. 7	Domestic and stock well
134	NW corner SE¼ sec. 33	L. Tucker	do.	189.0	6	(?)	do.	C,W	D, S	Top of north bolt hole in pump base.	0	3,405.8	181.35	Aug. 30	See analysis.
135	NE¼ SE¼ sec. 35	J. A. Hendrickson	do.	196	6	Sandstone	do.	C,W	D, S	Land surface	0	3,378.4	194	....	
	T. 30 S., R. 42 W.														
136	SE cor. SW¼ SW¼ sec. 4	I. Shepard	do.	177.7	6	(?)	Cheyenne	C,W	D, S	Lower edge of pipe coupling.	+ .2	3,511.4	165.47	Sept. 7	See analysis.
137	SE corner SE¼ sec. 9	Sarah Rorick	do.	194.5	6	Sandstone	do.	C,W	N	Top of pipe coupling, north side.	+ .5	3,515.0	181.50	Aug. 28	Brown sandstone reported, 160-194 feet.
138	NW corner SE¼ sec. 11	G. J. Wartman	do.	207.0	6	(?)	do.	C,W	D	Top of north pipe clamp, south side.	0	3,481.1	193.30	Sept. 7	See analysis.
139	SE cor. NE¼ NE¼ sec. 29	C. D. Weaver	do.	176.0	6	(?)	Cockrum	C,W,H	D	Lower edge of pump base.	0	3,542.4	154.89	Sept. 11	See analysis.
140	NW¼ SW¼ SE¼ sec. 33	T. F. Shumate	do.	150.0	6	"Sand rock"	do.	C,W	D, S	Top of north pipe clamp north side.	+ .5	3,532.9	118.44	Aug. 30	See analysis.
	T. 30 S., R. 43 W.														
141	SE¼ SW¼ sec. 2	C. F. Wendf	Upland slope	162.5	6	(?)	Cheyenne	C,W	N	Top of west bolt hole in pump base.	+ .5	3,644.2	153.05	July 19	Domestic and stock well.
142	NW corner SE¼ sec. 13	Baker Bros	Valley side	84.5	5.5	(?)	Cockrum	C,W	N	Top of south pipe clamp, north side	0	3,542.1	66.80	Aug. 28	Domestic well.
143	NE corner SE¼ sec. 20	C. F. Royce	Upland flat	72.5	6	(?)	do.	C,W	N	Top of tin plate covering casing.	+ .5	3,668.4	64.92	Aug. 29	Do.
144	NE corner NE¼ sec. 22	E. Stires	do.	63.5	6	(?)	do.	C,W	S	Top of casing, southeast side.	+1.5	3,596.0	52.58	do.	
145	SW cor. SE¼ SE¼ sec. 24	W. L. Sharp & Co.	Valley side	(?)	6	(?)	(?)	N	N	Top of casing, south side.	+1.0	3,580.2	77.88	Sept. 11	Do.

146	SW corner SE¼ sec. 27....	C. M. Harrison...	Upland flat.......	55.5	5.5	(?)............	Cockrum...	C,W	N	Top of pipe coupling, east side.	+ .5	3,615.2	46.73	July 21	Do......
	T. 30 S., R. 41 W.[6]														
147	NW corner NE¼ sec. 9....	(?)...............	do...............	164.0	6	(?)............	Cheyenne...	C,W	N	Top of casing, north side.	+2.0±	3,681.2	143.19	Aug. 29	Do......

1. Reported depths below the land surface are given in feet; measured depths, in feet and tenths below measuring points.
2. C, cylinder pump; E, electric motor; G, gasoline engine; H, hand operated; N, none; T, turbine pump; W, windmill.
3. D, domestic; I, irrigation; N, not being used; P, public supply; R, railroad; S, stock.
4. Measured depths to water level are given in feet, tenths, and hundredths; reported depths to water level, in feet.
5. Hamilton county, Kansas.
6. Baca county, Colorado.
7. Grant county, Kansas.

WELL LOGS

On the following pages are given the logs of several wells and test holes in Stanton county. The logs are divided into the three following groups; logs of test holes, logs of water wells, and the log of a gas test well. The logs in each group are listed in order by townships from north to south and by ranges from east to west. Numbers 1 to 8 are logs of the test holes drilled in Stanton county by the coöperative well-drilling machine, and numbers 9 to 11 are logs of similar test holes drilled in Morton county just south of the Stanton county line. The locations of the test holes are shown in figure 4. Numbers 12 to 21 are logs of water wells and number 22 is the log of the gas test well in sec. 11, T. 29 S., R. 41 W.

1. Log of test hole 1 at the NW corner, sec. 1, T. 27 S., R. 41 W., drilled by the State and Federal Geological Surveys, 1940. Surface altitude, 3,265 feet. (Authority, samples studied by Perry McNally, Frank Conselman, and Bruce F. Latta.)

	Thickness (feet)	Depth (feet)
Ogallala formation:		
Silt, fine sandy, tan to gray	25	25
Silt, fine sandy, and clayey, gray	11	36
Sand and gravel, gray to brown	8	44
Silt, sandy, light brown	26	70
Sand, medium, to coarse gravel, tan	10	80
Silt, sand, and gravel, tan	10	90
Sand, fine, to medium gravel, tan	11	101
Silt, light gray and brown, and clay	9	110
Silt and clay, blue gray	10	120
Silt, fine sandy, brown	4	124
Sand, fine to coarse, tan	16	140
Sand, fine, to coarse gravel, tan	10	150
Sand, coarse, to coarse gravel, tan	19	169
Silt, sandy, brown	16	185
Sand, coarse, to coarse gravel, tan	18	203
Silt and clay, sandy, brown	14	217
Sand, medium, to medium gravel, tan	9	226
Cockrum sandstone:		
Sandstone, yellow brown and red brown	4	230
Clay, soft, light gray and blue	2.5	232.5
Sandstone, light brown, yellow, and red brown	5	237.5
Sandstone, red brown, and alternating clay, yellow and gray,	6.5	244

Clay, yellow, gray, and blue	6	250
Sandstone, soft, yellow to light brown	20	270
Clay, sandy, gray green to yellow	19	289
Kiowa shale:		
Shale, clayey, blue gray	16	305
Shale, sandy, hard, blue gray	10	315
Shale, clayey, soft, blue gray	15	330
Shale, hard, blue gray	26	356
Cheyenne sandstone:		
Sandstone, fine to medium grained, gray	14	370
Shale, clayey, blue gray, and hard fine-grained sandstone	24	394
Sandstone, soft, light gray	10	404
Sandstone, hard, buff	8	412
Triassic (?):		
Clay, red and light gray	5	417
Sandstone, buff	2	419
Clay, red, and soft, yellow-brown sandstone	5	424
Clay, red and light gray	3	427
Sandstone, hard, light brown to buff	14	441
Clay, red brown and light gray	22	463
Sandstone, light gray to buff	30	493
Siltstone, hard, red	5	498
Clay, gritty, light gray to white	6.5	504.5
Sandstone, light brown to buff	515	510
Clay, silty, red brown, light gray, and gray green	13	523
Sandstone, buff to gray brown	65	588
Sandstone, hard, fine grained, buff, blue green, gray	25	613
Clay, silty, light gray and blue gray	4	617

2. Log of test hole 2 at NW corner, sec. 13, T. 27 S., R. 41 W., drilled by State and Federal Geological Surveys, 1939. Surface altitude, 3,275 feet. (Authority, samples studied by Perry McNally and Bruce F. Latta.)

	Thickness (feet)	Depth (feet)
Road fill	4	4
Ogallala formation:		
Soil, silty, brown to black	4	8
Silt, limy, gray	5	13
Sand, medium, tan	6	19
Silt, limy, gray	8	27
Silt, sandy, brown, and fine sand	12	39
Sand, fine, to coarse gravel, tan	3.5	42.5

Silt, sandy, light brown	7.5	50
Sand, fine to coarse, tan	7	57
Clay, silty, brown and gray	9	66
Sand and gravel, poorly sorted, tan	42.5	108.5
Silt, sandy, brown to gray	24.5	133
Sand, medium, to fine gravel, tan	1.5	134.5
Silt, sandy, tan, and some caliche	35.5	170
Sand, medium, to coarse gravel, angular, tan	20	190
Sand, gravel, and silt, alternating beds of	10	200
Silt, sandy, limy, brown, and caliche	5	205
Sand, medium, to coarse gravel, poorly sorted	9	214
Silt, sandy, tan, and some caliche	6	220
Gravel, fine to coarse, poorly sorted, containing abundant pebbles of Dakota sandstone	8	228
Cockrum sandstone:		
Clay, sandy and silty, yellow to brown	5	233
Clay, sandy, yellow, and sandstone, very fine grained, red brown	7	240

3. Log of test hole 3 at NE corner, sec. 23, T. 27 S., R. 43 W., drilled by State and Federal Geological Surveys, 1939. Surface altitude, 3,527.4 feet. (Authority, samples studied by Perry McNally and Bruce F. Latta.)

	Thickness (feet)	Depth (feet)
Road fill	2	2
Ogallala formation:		
Silt, limy, light brown (loess)	2	4
Sand, fine, brown, containing caliche fragments	5	9
Silt, sandy, brown, and some caliche	14	23
Sand, fine, and coarse gravel, poorly sorted, tan	16	39
Silt, gritty, limy, soft, creamy brown	3	42
Sand, medium, to medium gravel, tan	3	45
Gravel, very coarse, angular, tan	9	54
Silt, light brown	6	60
Sand, medium, to fine gravel, angular, tan	7	67
Silt, sandy, brown	11	78
Sand, fine, to fine gravel, tan	10	88
Silt, sandy, brown to gray green	12	100
Silt, sandy, tan, sandstone fragments, soft, and a few gastrapod fragments	9	109
Sand, medium, to medium gravel, angular, tan	6.5	115.5
Silt, sandy, hard, brown, and caliche	8.5	124
Sand, medium, to medium gravel, angular, tan	5	129

Silt, sandy, brown, caliche, and a few hard limestone fragments	4	133
Sand, fine, to coarse gravel, tan	23	156
Silt, sandy, red brown	2	158
Sand, fine to coarse, red brown, and clay balls	12	170
Sand, fine to coarse, tan	5	175
Silt, clayey, sandy, brown and gray, and caliche	7	182
Cockrum sandstone:		
Clay, soft, red buff, containing dark-brown iron nodules	2	184
Clay, brown, yellow brown, and red	6	190
Clay, varicolored, and sandstone, soft, light gray	10	200

4. Log of test hole 4 at SW corner, sec. 2, T. 28 S., R. 39 W., drilled by State and Federal Geological Surveys, 1939. Surface altitude, 3,152 feet. (Authority, samples studied by Perry McNally and Bruce F. Latta.)

	Thickness (feet)	Depth (feet)
Top soil, tan	2	2
Ogallala formation:		
Soil, gray, limy streaks	2	4
Silt, sandy, light brown	10	14
Silt, sandy, brown, and sand, loose, red brown	10	24
Silt, sandy, light gray, brown, and white	26	50
Sand, fine to medium, tan	5	55
Silt, sandy, limy, brown	17	72
Sand, fine to coarse, tan, water-bearing	8	80
Clay and volcanic ash, intermixed, soft, white	14	94
Silt, light brown and gray, and some caliche	23	117
Silt, sandy, limy, brown and gray	41	158
Silt, sandy, light brown, and scattered sand, gravel, and caliche	22	180
Clay, silty, sticky, tan	28.5	208.5
Silt, sandy, tan, and sand lenses	15.5	224
Silt, sandy, tan	10	234
Silt, limy, tan, light gray, and white	5	239
Gravel, medium to very coarse, tan, water-bearing	27.5	266.5
Clay, silty, sticky, tan	8.5	275
Sand and silt, limy, gray, interbedded	3	278
Sand, fine to coarse, tan	3	281
Silt, sandy, limy, tan	5	286
Sand, fine, tan and gray	5	291
Silt, sandy, limy, light brown	4	295
Sand, fine to coarse, tan	6	301

Silt, sandy, limy, light brown and gray	4	305
Sand, fine to coarse, tan, and caliche	6	311
Caliche, hard	5	316
Sand, loose, and caliche	7.5	323.5
Silt, gritty, limy, light gray to white tan	6	329.5
Cockrum sandstone:		
Sandstone fragments, maroon brown	3.5	333
Clay, sandy, yellow and gray (drilled hard)	17	350

5. Log of test hole 5 at NE corner, sec. 35, T. 28 S., R. 41 W., drilled by State and Federal Geological Surveys, 1939. Surface altitude, 3,346.6 feet. (Authority, samples studied by Perry McNally and Bruce F. Latta.)

	Thickness (feet)	Depth (feet)
Road fill	2	2
Ogallala formation:		
Silt, sandy, gray, and caliche	5	7
Silt, sandy, tan to brown, and caliche	33	40
Sand, medium, to coarse gravel, tan	16.5	56.5
Silt, sandy, brown, and some caliche	5.5	62
Sand, fine to coarse, tan	3	65
Silt, brown, containing thin sand lenses and caliche	5	70
Sand and gravel, tan, containing beds of thin silt	58	128
Silt, sandy, brown	18	146
Silt, limy, gray, and caliche	9	155
Sand, fine, to medium gravel, tan	6	161
Silt, sandy, brown and gray	9	170
Sand, fine, to coarse gravel, tan	28	198
Silt, sandy, light gray	7	205
Sand, medium, to coarse gravel, tan	42	247
Silt, sandy, gray tan	7	254
Gravel, medium to coarse, tan	35	316
Silt, sandy, yellow brown and gray	27	343
Sand, fine, to coarse gravel, tan	7	350
Silt, sandy, brown, gray, and gray green	13	363
Sand, medium, to coarse gravel, tan	19	382
Silt, Sandy, brown and gray	16	398
Sand, medium, to coarse gravel, tan	2	400
Silt, sandy, brown	17	417
Cockrum sandstone:		
Sand, fine, brown, and clay, light gray to yellow brown	20.5	437.5
Clay-shale, sandy, silty, dark gray to blue gray	2.5	440

6. Log of test hole 6 at SE corner, sec. 2, T. 28 S., R. 42 W., drilled by State and Federal Geological Surveys, 1939. Surface altitude, 3,434.1 feet. (Authority, samples studied by Perry McNally and Bruce F. Latta.)

	Thickness (feet)	Depth (feet)
Top soil, black, loamy	1.5	1.5
Ogallala formation:		
Silt, soft, buff, somewhat limy (loess)	7.5	9
Silt, limy, light brown to gray	9	18
Silt, limy, light gray to creamy white	4	22
Silt, sandy, hard, tan	9	31
Silt, sandy, red brown	9	40
Silt, sandy and limy, tan, containing some caliche	5	45
Sand, fine, to coarse gravel, angular, tan	2	47
Silt, sandy, tan to red brown	25	72
Sand, fine to coarse, tan	4	76
Silt, sandy, tan	5	81
Sand, medium, to coarse gravel, angular, tan	10	91
Silt, sandy, brown, and caliche	11	102
Sand, fine, to coarse gravel, tan	31	133
Silt, limy, light gray, and some caliche	17	150
Sand, fine, to medium gravel, tan	10	160
Silt, hard, brown, containing limonitic streaks	10	170
Silt, sandy, brown	15	185
Sand, fine, to coarse gravel, angular, tan	5	190
Silt, sandy, brown	10	200
Clay, silty, light brown to gray	16	216
Sand, fine, to medium gravel, gray to tan	1.5	217.5
Clay, silty, light brown to gray	8.5	226
Silt, sandy, limy, light brown to gray	21	247
Sand, fine to coarse, tan	3	250
Silt, sandy, brown	5	255
Sand, coarse, tan, and clay balls, sandy	5	260
Sand, fine, and fine gravel, tan, and clay balls, sandy	10	270
Sand, gravel, and silt, interbedded	27	297
Cockrum sandstone:		
Sandstone, very fine grained, soft, friable, brown	9	306
Clay, silty, light gray, yellow, and red	12	318
Clay, soft, dark gray	8	326
Sandstone, soft, friable, red brown	1	327
Clay, shaly, soft, dark gray to black	3	330

7. Log of test hole 7 at NW corner, sec. 2, T. 30 S., R. 39 W., drilled by State and Federal Geological Surveys, 1939. Surface altitude, 3,187.6 feet. (Authority, samples studied by Perry McNally and Bruce F. Latta.)

	Thickness (feet)	Depth (feet)
Soil, loamy, gray	4	4
Ogallala formation:		
Silt, sandy, soft, light brown	6	10
Silt, sandy, red tan to light brown	10	20
Silt, hard, light brown	18.5	38.5
Silt, gritty, limy, tan and white, and caliche	11.5	50
Silt, gray tan	10	60
Sand, fine, tan, and silt, white, brown, and yellow brown	4	64
Silt, limy, brown and gray	6	70
Silt, sandy, light brown to light gray	15	85
Sand and gravel, poorly sorted, tan	2	87
Silt, sandy, brown and yellow brown	7	94
Sand, fine to coarse, tan	8	102
Silt, sandy, tan	4.5	106.5
Sand, coarse, to coarse gravel, tan	3.5	110
Silt, sandy, brown to gray, containing thin layer of caliche,	46	156
Sand, fine, to fine gravel, tan	20	176
Silt, sandy, light brown, containing thin sand lenses	8	184
Sand, fine, to medium gravel, tan	24	208
Silt, sandy, light brown, and caliche	12	220
Sand, fine, to fine gravel, tan	6	226
Silt, sandy, brown and yellow brown	4	230
Sand, gravel, and sandy silt	4	234
Silt, sandy, limy, and caliche	3	237
Sand, gravel, and silt, interbedded, tan	11	248
Sand and gravel, tan (major grade is fine gravel)	48	296
Silt, hard, tan	5	301
Sand, fine, to medium gravel, angular, tan	17	318
Silt, hard, tan	6	324
Sand, fine, to medium gravel, tan	26	350
Silt, hard, brown and gray	11	361
Sand, fine to coarse, tan	22.5	383.5
Cockrum sandstone:		
Sandstone, very fine grained, red brown	6.5	390
Sandstone, fine grained, red brown and light gray	30	420

8. Log of test hole 8 at NW corner, sec. 1, T. 30 S., R. 41 W., drilled by State and Federal Geological Surveys, 1939. Surface altitude, 3,359.1 feet. (Authority, samples studied by Perry McNally and Bruce F. Latta.)

	Thickness (feet)	Depth (feet)
Ogallala formation:		
Soil, sandy, gray	4	4
Silt, soft, brown	6	10
Silt, light brown to light gray, containing calcareous nodules	6	16
Silt, sandy, brown	11	27
Silt, sandy, limy, tan	4	31
Sand, medium to coarse, tan	3	34
Silt, limy, tan	14	48
Sand, fine, to coarse gravel, tan	6	54
Silt, sandy, brown	5	59
Silt, sandy, limy, tan, and caliche	14	73
Silt, sandy, limy, light gray and brown, containing some caliche	11	84
Sand, fine to medium, brown	3	87
Silt, limy, light gray, and caliche	7	94
Gravel, coarse, poorly sorted, brown	3	97
Silt, sandy, limy, gray, and caliche	12	109
Silt, sandy, limy, brown, and caliche	30	139
Caliche, hard	0.5	139.5
Silt, sandy, gray, gray green, and brown, and some caliche,	26.5	166
Sand, fine, to coarse gravel, angular, tan	22	188
Silt, sandy, hard, brown	6	194
Sand, fine, to coarse gravel, angular, tan	5	199
Silt, sandy, brown and gray	3.5	202.5
Sand, fine, to coarse gravel, angular, brown	14	216.5
Cockrum sandstone:		
Clay, sandy, light gray and brown, containing a few thin beds of sandstone	15.5	232
Clay, gray, yellow, and red	3	235
Clay, gray, and sandstone, very fine grained, brown	5	240

9. Log of test hole 9 at the NW corner, sec. 4, T. 31 S., R. 39 W., Morton county, drilled by the State and Federal Geological Surveys, 1940. Surface altitude, 3,192.7 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness (feet)	Depth (feet)
Ogallala formation:		
Loam, brown to black	3	3
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, fine sandy, light gray	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 and silt, fine, 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
Sand and gravel	11.5	248.5
Silt, brown, sandy	7.5	256
Silt, sand, and gravel	5.5	261.5
Cockrum sandstone:		
Sandstone, brown, and clay, varicolored	8.5	270

10. Log of test hole 10 at the NW corner, sec. 3, T. 31 S., R. 40 W., Morton county, drilled by State and Federal Geological Surveys, 1940. Surface altitude, 3,266.2 feet. (Authority, samples studied by Perry McNally and Bruce F. Latta.)

	Thickness (feet)	Depth (feet)
Ogallala formation:		
Loam, brown to black	4	4
Silt, sandy, brown	5	9
Sand, fine, brown, and clay	18	27
Caliche, gray, and sand	10	37
Silt, sandy, brown	4	41
Sand, fine, and clay	2	43
Silt, brown, and sand	7	50
Sand, fine to medium, brown	10	60
Silt, sandy, brown	5	65
Sand, fine to medium, brown	5	70
Sand, fine, and gravel, coarse	25	95
Clay, silty, brown	1.5	96.5
Sand and gravel, brown	18	114.5
Silt, sandy, brown	16.5	131
Silt, caliche and sand	7	138
Silt, limy, brown	4	142
Silt, limy, gray, containing sand and gravel	3	145
Sand, fine to coarse, brown	23	168
Silt, limy, light brown	6	174
Silt, brown, and sand	2	176
Sand and gravel, brown (predominantly fine gravel)	4	180
Sand and gravel	11	191
Cockrum sandstone:		
Clay, varicolored	9	200

11. Log of test hole 11 at the NE corner, sec. 4, T. 31 S., R. 41 W., Morton county, drilled by the State and Federal Geological Surveys, 1940. Surface altitude, 3,387.8 feet. (Authority, samples studied by Perry McNally and Thad McLaughlin.)

	Thickness (feet)	Depth (feet)
Ogallala formation:		
Loam, black	2	2
Silt, brown, soft	6	8
Silt, sandy, brown	3	11
Silt, limy, light gray	6	17
Silt, pink	8	25
Silt, limy, gray	6	31
Silt, gray, and sand	2	33

Sand, fine, brown, and clay	2	35
Silt and caliche	3	38
Sand and gravel, coarse	2	40
Silt and sand	12	52
Sand and gravel, medium, brown	10	62
Silt, light brown	1.5	63.5
Sand, fine, reddish brown	5.5	69
Silt, limy, gray	2	71
Silt, sandy, pink	2	73
Clay, limy, light gray	8	81
Cockrum sandstone:		
Sandstone, fine grained, yellowish brown, gray, and maroon,	9	90

12. Log of well (6) of Pete Molz in SE¼ sec. 27, T. 27 S., R. 39 W. Surface altitude, 3,154.3 feet. (Authority, Pete Molz, owner and driller.)

	Thickness (feet)	Depth (feet)
Ogallala formation:		
Soil, clay, and sand	56	56
Fine sand, to coarse gravel	14	70
Fine sand	6	76
Sand rock	0.5	76.5
Fine sand	6.5	83
Coarse sand and gravel	—	—

13. Log of well (9) of E. J. Guldner at SW corner, SE¼ SW¼ sec. 5, T. 27 S., R. 40 W. (Authority, owner.)

	Thickness (feet)	Depth (feet)
Ogallala formation:		
Soil	16	16
Sand, consolidated	2	18
Clay	7	25
Gravel, water-bearing	7	32
Clay	3	35
Sand, coarse	7	42
Clay	16	58
Sand, coarse	11	69
Clay	4	73
Sand, coarse	5	78
Clay	—	—

14. Log of test hole of Clarence Winger at NW corner, NE¼ sec. 35, T. 27 S., R. 40 W. Well (19) finished at a depth of 182 feet. (Authority, Buell Scott, driller.)

Ogallala formation:	Thickness (feet)	Depth (feet)
Soil	16	16
Clay, yellow	18	34
Rock	3	37
Clay, yellow	9	46
Sand, very fine	14	60
Water sand, fine	20	80
Water sand, medium	75	155
Rock	2	157
Sand and gravel, water-bearing	18	175
Clay, brown	1	176
Gravel, coarse	10	186
Clay	38	224
Water sand, good	46	270

15. Log of test hole of Charles Winger at NW corner, sec. 5, T. 28 S., R. 39 W. Well (41) finished at a depth of 160 feet. (Authority, Buell Scott, driller.)

Ogallala formation:	Thickness (feet)	Depth (feet)
Soil	18	18
Clay and "gyp"	42	60
Sand, fine	12	72
Clay and sand	28	100
Sand	41	141
Clay and sand	19	160
Clay	37	197
Sand	38	235

16. Log of well (78) of H. H. Brown at SE corner, SW¼ sec. 2., T. 29 S., R. 39 W. Surface altitude, 3,157.2 feet. (Authority, driller, through W. H. Smoot.)

Ogallala formation:	Thickness (feet)	Depth (feet)
Surface soil and sand	54	54
Clay and sand, water-bearing	40	94
Sand rock, water-bearing	100	194
Shale	60	254
Quicksand, water-bearing	30	284
Shale	20	304
Coarse gravel, water-bearing	16	320

17. Log of city well (100) at Manter, Kan., NW¼ SW¼ sec. 14, T. 29 S., R. 42 W. (Authority, Bill Williams, driller.)

	Thickness (feet)	Depth (feet)
Soil	2	2
Clay, sandy	23	25
Clay	35	60
Clay, hard, and shell	45	105
Clay, soft, yellow	25	130
Shale, sticky, blue	25	155
Clay, hard, sand and gravel	5	160
Missing	45	205
Clay	10	215
Sand rock, soft	40	255
Rock, solid	12	267
Shale, block	10	277

18. Log of well (101) of the Atchison, Topeka and Santa Fe Railway at Manter, Kan., NE corner, SW¼ SW¼ sec. 14, T. 29 S., R. 42 W. (Authority, driller.)

	Thickness (feet)	Depth (feet)
Soil and clay	45	45
Sand, dry	23	68
Sand rock	2	70
Clay and "gyp"	10	80
Sand, pack	7	87
Rock, hard	7	94
Clay	2	96
Shale	16	112
Shale, hard	3	115
Shale streak, soft and hard	35	150
Rock, hard, blue	2	152
Shale streak, soft and hard	23	175
Rock, very hard	1	176
Clay	4	180
Rock, hard	3	183
Shale, soft and hard	19	202
Sand rock and shale	2	204
Magnesia and white sand, cemented	18	222
Sand, pack	8	230
Sand, pack, and sand rock in thin layers	16	246
Sand rock, soft	8	254
Sand, very fine	19	273
Boulders	2	275

Clay	3	278
Shale, soft and hard, in thin layers	31	309
Sand rock, hard	5	314
Shale, blue	12	326
Rock, hard	1	327
Shale, soft	4	331
Sand rock, hard	18	349
Pack sand	35	384
Shale, hard	6	390
Magnesia	14	404
Sand rock, extra hard	6	410
Shale, red	6	416
Sand rock, white	12	428
Shale, red	4	432
Sandstone, soft	18	450
Sandstone, extra hard	6	456
Pack sand, soft	18	474
Shale, red	1	475

19. Log of abandoned water well in NE¼ sec. 32, T. 30 S., R. 41 W. (Authority, T. F. Shumate.)

	Thickness (feet)	Depth (feet)
Soil, sand, gravel, and clay	110	110
Soapstone	30	140
Sand rock, white	50	190
Quicksand, very fine	5	195
Shale, black	2	197

20. Log of abandoned water well in SW¼ sec. 34, T. 29 S., R. 43 W. (Authority, C. G. Streeter, driller.)

	Thickness (feet)	Depth (feet)
Clay, sand, gravel, and conglomerate	25	25
Sandstone, brown	35	60
Shale, sticky, soft, blue in upper part and hard, pyritic, black in lower part	115	175
Sandstone, coarser than sandstone above, water under pressure	41	216

21. Log of test hole in SE¼ sec. 2, T. 27 S., R. 41 W. (Authority, Buell Scott, driller.)

	Thickness (feet)	Depth (feet)
Ogallala formation:		
Soil and clay	18	18
Gyp, hard	3	21
Clay, some pebbles	42	63
Sand, medium, water-bearing, gray	37	100
Clay, brown	15	115
Clay, and some gravel	10	125
Sand and clay, interbedded	35	160
Gravel, coarse, containing limy pebbles	15	175
Sand rock, fairly hard, brown	3	178
Gravel, coarse (larger than peas)	33	211

22. Log of gas test well of Western Production Company at center of NE¼ sec. 11, T. 29 S., R. 41 W. Surface altitude, 3,348.7 feet. (Authority, driller.)

	Thickness (feet)	Depth (feet)
Surface sand	20	20
Sand and gravel	30	50
Sand and shale	160	210
Sticky shale	250	460
Sand and gravel	190	650
Sticky shale	100	750
Sand and gravel	130	880
Anhydrite and gyp	37	917
Red shale	743	1,660
Anhydrite	8	1,668
Anhydrite and lime	22	1,690
Red shale, containing streaks of anhydrite	135	1,825
Red shale	35	1,860
Red shale and gyp	317	2,177
Red shale	23	2,200
Blue sticky shale	34	2,234
Hard blue shale and anhydrite	56	2,290
Anhydrite and gyp	30	2,320
Blue and red hard shale	51	2,371
Hard lime	4	2,375

INDEX

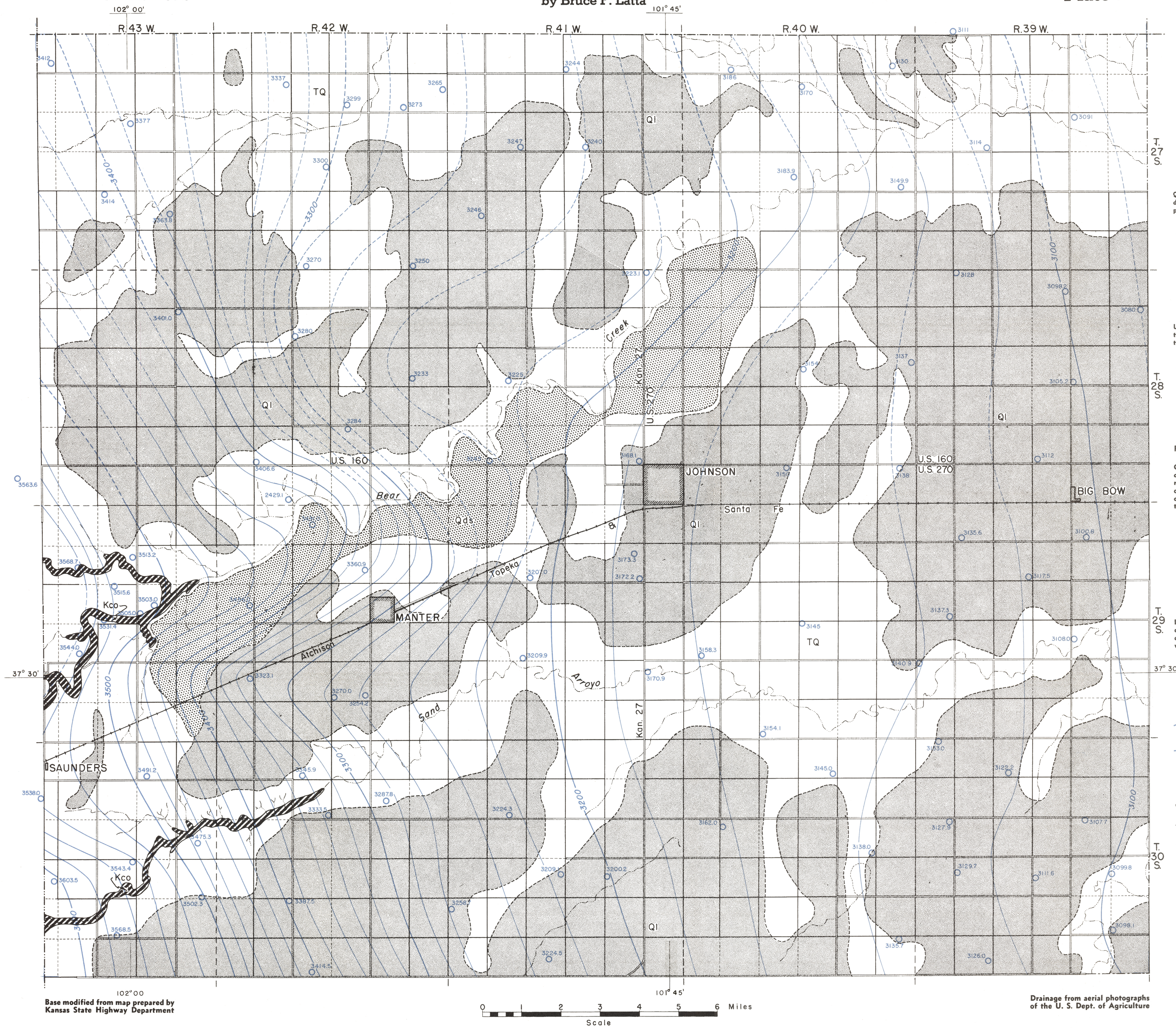
□

State Geological Survey of Kansas

MAP OF STANTON COUNTY
Showing Geology and Water-Table Contours, 1939

by Bruce F. Latta

Bulletin 37
Plate 1



Base modified from map prepared by Kansas State Highway Department

0 1 2 3 4 5 6 Miles
Scale

Drainage from aerial photographs of the U. S. Dept. of Agriculture

EXPLANATION

QUATERNARY

Qds — **Dune sand**
Quartz sand. Sand dunes are above water table and do not furnish water directly to wells, but are important catchment areas for ground-water recharge.

Ql — **Loess**
Unstratified clay and silt. Yields little or no water to wells and tends to resist the downward percolation of rainfall.

TERTIARY AND QUATERNARY

TQ — **Pliocene (including the Ogallala formation) and Pleistocene undifferentiated**
Calcareous sand, gravel, silt, and clay, mainly unconsolidated. Most productive water-bearing formation in Stanton County. Supplies adequate water of good quality to wells that range in depth from about 50 feet to more than 200 feet. Supplies water to irrigation wells in parts of the county.

CRETACEOUS

Kco — **Cockrum sandstone**
Light tan to reddish-brown, fine-grained sandstone and varicolored shale and clay-shale. Furnishes adequate supplies of good water to domestic and stock wells in western part of county.

Contour interval 20 feet

3100 — Water-table contours based on instrumental levels

3400 — Water-table contours based on altitudes taken from topographic map

3284 — Well location. Number refers to altitude of water level

Federal, State, or County road

Township road

Section line (no road)

MAP OF STANTON COUNTY

Showing the depths to Water Level and the Location of Wells for which Records are given

by Bruce F. Latta

1940

State Geological Survey of Kansas

Bulletin 37
Plate 2