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GEOLOGY AND GROUND-WATER RESOURCES OF SEWARD COUNTY, KANSAS

By FRANK E. BYRNE and THAD G. MCLAUGHLIN

with analyses by

ROBERT H. HESS

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

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GEOLOGY AND GROUND-WATER RESOURCES OF SEWARD COUNTY, KANSAS

By Frank E. Byrne and Thad G. McLaughlin

ABSTRACT

The report describes the geography, geology, and ground-water resources of Seward County in southwestern Kansas. The county has an area of 643 square miles and had a population of 6,593 in 1940. The area consists predominantly of flat to rolling upland plains which are broken only by the valley of the Cimarron River, which extends diagonally across the county. The climate is semiarid, the average annual precipitation being about 18 inches. The principal occupations in the area are farming and livestock raising.

The report includes a map showing the areas of outcrop of the rock formations (Pl. 1). The Meade and Kingsdown formations and dune sand underlie the upland areas and the Meade, Rexroad (?), and Laverne formations are exposed along the sides of Cimarron Valley. The floor and lower slopes of the valley are underlain by alluvium and colluvium. The report also contains a diagrammatic cross section of the area showing the distribution of the rock formations above the Permian redbeds as determined by extensive test drilling (Pl. 3).

The report contains a map of the area showing the depth to water level by means of shading (Pl. 2). The water table ranges in depth from less than 10 feet in parts of Cimarron Valley to more than 200 feet in parts of the upland. A map showing by contours the shape and slope of the water table is also included in this report. The contours show that ground water moves eastward through Seward County and that the gradient of the water table ranges from about 4 feet to the mile in the northeastern part of the county to about 40 feet to the mile in the southwestern part of the county.

The ground-water reservoir is recharged principally from precipitation that falls within the area, by percolation from intermittent streams, and by subsurface inflow from adjacent areas. Ground water is discharged from the ground-water reservoir by movement into adjacent areas, by evaporation and transpiration in areas of shallow water table, by seepage into Cimarron River, and by wells. All the domestic, public, industrial, and irrigation supplies and much of the stock supply are obtained from wells.

Ground water in Seward County is hard, but is suitable for most ordinary uses. Waters from the Laverne, Rexroad (?), and Meade formations are similar in composition and in hardness. Waters from the alluvium generally are of poorer quality.

The principal water-bearing formations in Seward County are the Rexroad (?), Laverne, and Meade formations, but a few domestic and stock wells

obtain water from alluvium in the Cimarron Valley. The character and water supply of each formation are discussed in the report.

The field data upon which most of the report is based are given in Table 10 and include records of 162 wells and chemical analyses of the waters from 20 representative wells. Logs of 35 test holes, water wells, and oil and gas wells in the area are given, including 23 test holes put down by the State and Federal Geological Surveys.

INTRODUCTION

Purpose and scope of the investigation.—The Geological Survey, United States Department of the Interior, and the Kansas Geological Survey started a program of ground-water investigations in the western part of Kansas in July 1937. In this program was enlisted the coöperation of the Division of Sanitation of the Kansas State Board of Health and the Division of Water Resources of the Kansas State Board of Agriculture. The execution of the program thus far has been concentrated largely in the western part of the State where ground-water problems have been deemed most pressing, although critical areas in central and eastern Kansas also have been investigated.

The investigation of the occurrence, quantity, and quality of ground water available in Seward County was undertaken during July and August of 1940 by Byrne. The project was under the immediate supervision of S. W. Lohman, Federal geologist in charge of ground-water investigations in Kansas, and was under the general administration of R. C. Moore, K. K. Landes, and J. C. Frye, State Geologists of Kansas, and O. E. Meinzer, Geologist in Charge of the Division of Ground Water of the Federal Geological Survey.

During the first field season, measurements of the water levels in more than 150 wells were made to determine the configuration of the water table in all parts of the county, the depth of the water table below the land surface, and the probable aquifers supplying the wells. Such data are accurate bases for comparative measurements of water levels in the same wells at some future time. Eleven wells were selected as observation wells, four of them being abandoned subsequently, and monthly water-level measurements were made by Richard B. Christy, Woodrow W. Wilson, Allan Graffham, and Howard Palmer. Samples of water were collected from 18 wells to determine the chemical quality of the water; the analyses were made by Robert H. Hess in the Water and Sewage Laboratory of the Kansas State Board of Health. Analyses of the municipal water supplies of Liberal and Kismet, the two incorporated cities in the county, were obtained from the files of the State Board of Health.

The field study also included an investigation of the geological formations exposed at the surface in the county with particular regard to their water-bearing qualities. Information relative to the underlying formations was obtained through the logs of water and gas wells already drilled and from the cuttings supplied from 17 test holes drilled by a portable hydraulic-rotary drilling machine (Pl. 4) owned by the State Geological Survey and operated in 1940 by Ellis Gordon, Perry McNally, and L. P. Buck, in 1942 by Ellis Gordon, James B. Cooper, and Oscar S. Fent, and in 1944 by Oscar S. Fent, Milford Klingaman, and Harold Rector.

The report was begun by Byrne and was partly completed when he entered the armed forces. In order to complete the report it was necessary for McLaughlin to do additional field work in that area to familiarize himself with the geologic and hydrologic problems. Additional field work, therefore, was done during the summer of 1943. Most of the base data had been collected during the first field season so that during the second field season special emphasis was placed on the geology in the Cimarron Valley in southeastern Seward County and southwestern Meade County. The report was then completed by McLaughlin. The section on Geologic formations and their water-bearing properties and the section on Recharge were prepared by McLaughlin; all other sections were prepared by Byrne.

Location and size of the area.—Seward County is situated in the southwestern part of the State of Kansas, in the first row of counties north of Oklahoma and in the third row of counties east of Colorado. The county is bounded on the north and south by parallels 37° 23′ and 37° 00′ north latitude, respectively, and on the east and west by meridians 100° 38′ and 101° 04′ west longitude (Fig. 1). The county has an area of 411,520 acres, or 643 square miles, is rectangular in outline, and measures 26.8 miles from north to south and 24 miles from east to west.

Previous geologic and hydrologic investigations.—In 1895, Hay undertook a water-resources study of a portion of the central Great Plains. Although the area studied did not include Seward County, Hay named several formations exposed in this area and advanced theories for their origin. Cragin (1896) described and named three formations of Meade and Clark Counties, these being of significance

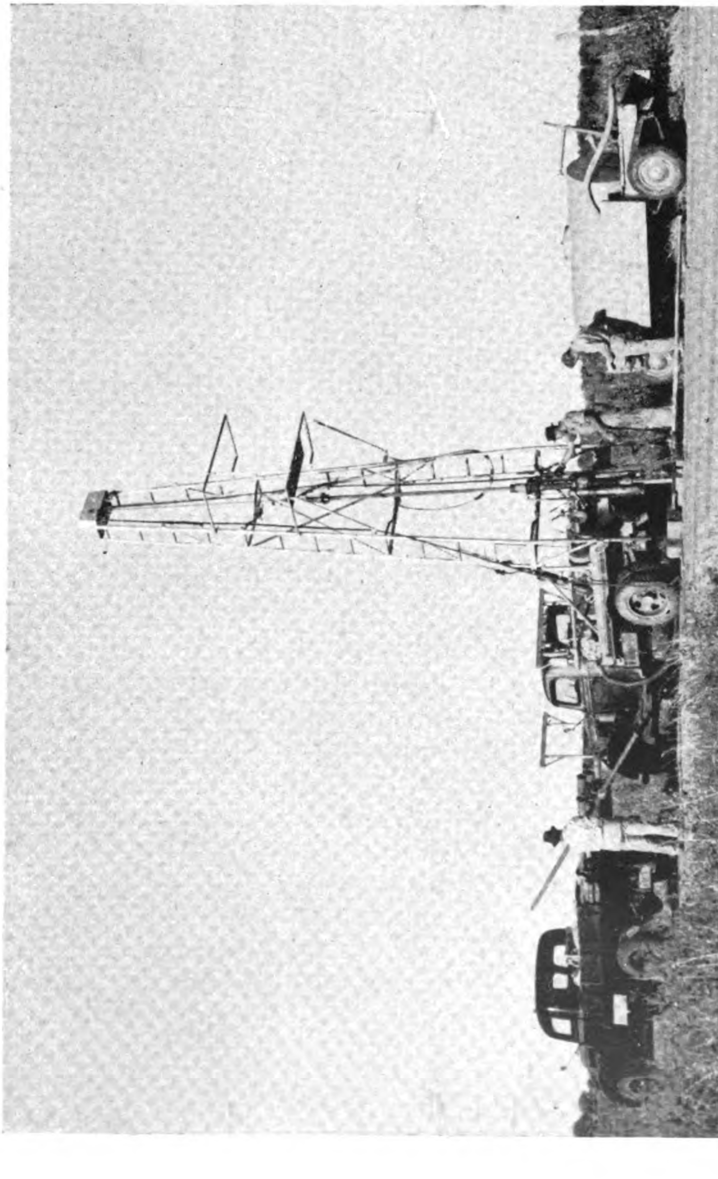

PLATE 4. Portable drilling machine used in drilling test holes in Seward County. Photograph by S. W. Lohman.

here because the same horizons have been encountered in Seward County.

Comprehensive treatment of the area was given by Haworth (1897; 1897b) when he described the physiography of western Kansas, including Seward County, and generalized on the occurrence of ground water. In a later section of the same volume (1897c), Haworth discussed the Tertiary geology of the region, the origin of sand dunes and surficial gravels, and cited the log of a State well drilled near Liberal as evidence bearing on the subsurface geology

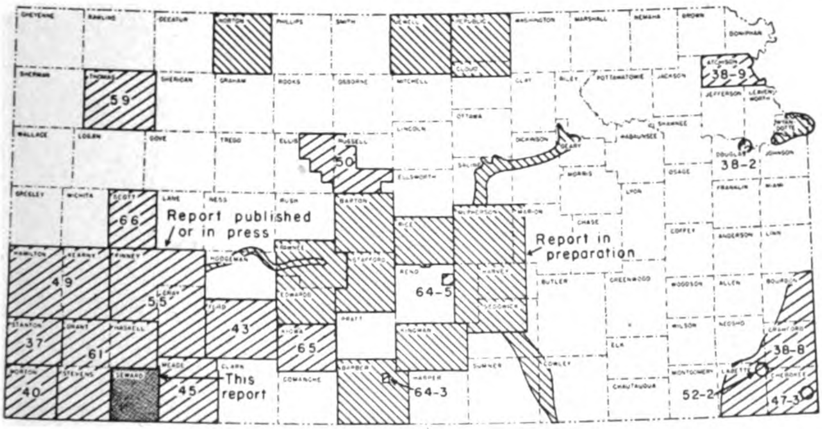

Fig. 1. Index map of Kansas showing area covered by this report and areas for which coöperative ground-water reports have been published or are in preparation. Bulletin numbers of ground-water reports published by State Geological Survey of Kansas are indicated.

of the area. In another paper the same author (Haworth, 1897a, facing p. 44) gave with considerable accuracy the depth to water in Seward County on a map of the general region.

Darton (1898, p. 734) named the Ogallala formation, which is extensively developed in southwestern Kansas, in his report on the geology and water resources of western Nebraska. The High Plains were described both geologically and hydrologically by Johnson (1901; 1902), following which he gave his conclusions as to the limits of their utilization. Darton (1905, pp. 288, 316, 317) described, as then known, the geology and hydrology of the county in his preliminary report on the central Great Plains. The log of a deep well at Liberal was included in the report.

Parker (1911, pp. 182-183, 305-311) discussed the hydrology of Seward County and gave tables indicating the chemical quality of the waters from eight local wells. Haworth (1913, pp. 57-68) summarized the ground-water resources of western Kansas in a nontechnical report prepared for the interested layman.

The report of a survey made by Theis, Burleigh, and Waite (1935) summarized the supplies of ground water available in the southern portion of the High Plains and described the principal aquifers. The results of a soil survey of the southern High Plains were published by Joel (1937) in a report that includes a useful soils map of Seward County. Smith (1940) published his studies on the Tertiary and Quaternary geology of Seward and other counties of southwestern Kansas. Frye and Hibbard (1941) made an important contribution to the detailed geology of the southwestern Kansas region in the report of their investigations in Meade County. Investigations have also been made of the geology and ground-water resources of areas adjacent to Seward County (Schoff, 1939; Frye, 1942; Latta, 1944; McLaughlin, 1946; and Schoff and Stovall, 1943).

Methods of investigation.—The highway map of Seward County issued by the Kansas State Highway Commission, in coöperation with the State Planning Board, was used as the base map for recording field observations and in the preparation of Plates 1 and 2. Revisions of roads and railroads were made on the base map as such changes were encountered in the field. The drainage lines were transposed from aerial photographs and mosaics obtained from the Agricultural Adjustment Administration of the United States Department of Agriculture.

The contacts of the geologic formations exposed at the surface were added to the base map directly from field observations and were checked against aerial photographs and the soils map of Seward County prepared by the Department of Agriculture, Soil Conservation Service. The areal distribution of the geologic formations and the form of the water table as indicated by water-table contours based on sea-level datum are shown on Plate 1.

The depth to water in all parts of Seward County is shown on Plate 2. The locations of the wells measured during the field season or for which reported measurements were recorded are indicated by small circles on this map. The position of each well within a section was determined by odometer reading. The wells from which water samples were taken for analysis are designated by brackets around the well numbers. The wells are numbered in order by ranges from east to west and by townships from north to south.

Within each township the order of well numbers follows the numbering of the sections.

Acknowledgments.—Much of the information included in this report was supplied by farmers, ranchers, county and municipal officials, and businessmen of Seward County. Their generous assistance was further implemented by Gene Harris, County Farm Agent; by H. W. Hillis, Chief Engineer of the Chicago, Rock Island, and Pacific Railway; and by officers of the Soil Conservation Service. Lee Larrabee of Liberal contributed considerable of his time and knowledge of Seward County. John C. Frye and Stuart L. Schoff, then of the United States Geological Survey, aided with their suggestions on problems of hydrology and geology.

The writers are greatly indebted to Claude W. Hibbard, formerly Curator of Vertebrate Paleontology of the Dyche Museum, University of Kansas, whose studies of the faunas of the Tertiary and Quaternary formations in southwestern Kansas have greatly facilitated the mapping of the geology of that area. Dr. Hibbard spent many weeks in the field in Seward County in 1940 and 1943 and assisted in mapping most of the geology in Cimarron Valley in the southeastern part of the county.

The illustrations included in this report were prepared under the supervision of Robyn Ashby Addis of the State Geological Survey. The manuscript was reviewed by members of the Federal Geological Survey; by R. C. Moore, State Geologist; by George S. Knapp, Chief Engineer of the Division of Water Resources of the Kansas State Board of Agriculture; and by Paul D. Haney, Director, and Ogden S. Jones, Geologist, of the Division of Sanitation of the Kansas State Board of Health. The manuscript was edited by Betty J. Hagerman of the State Geological Survey.

GEOGRAPHY

Topography and Drainage

Seward County lies entirely within the High Plains section of the Great Plains physiographic province. The principal part of the county consists of a slightly rolling upland plain, largely obscured by sand dunes in the southern half and traversed by the valley of Cimarron River from the northwestern corner to the southeastern corner.

The surface of Seward County slopes almost imperceptibly from the western border of the county to the southeastern corner. The highest point on the upland has an altitude of about 2,950 feet and the lowest point on the upland of about 2,680 feet. The slope of the upland, therefore, is about 11.1 feet to the mile toward the east and the southeast. The plain is of low relief, as is demonstrated by its typical expression in the northeastern quarter of the county. The upland hills are only slightly above the general surface of the plain and slope gently downward to the wide shallow basins that lie between them. Only in a few places, except for the areas immediately adjacent to Cimarron Valley, is the upland plain invaded by established drainage lines, these being long tributaries of the Cimarron. The surface runoff of the true upland, seemingly, is in the form of sheet wash, there being no evidence of gullying apparent in the soft materials underlying the upland. A part of the precipitation falling on the uplands descends as sheet wash to the low points of the upland surface where it collects in shallow pools. Because of the clayey character of the upland soil in many places, these pools may persist for some time after precipitation has ceased. The playas so formed have been called "buffalo wallows," although their association with buffaloes would seem a coincidental rather than a casual one. The imperviousness of the soil underlying a "wallow" may be in part due to the sheet wash transportation to the lowest part of the shallow basin of the very finest particles available on the gentle tributary slopes.

The typical upland plain topography is largely obscured in the southern half of the county except for an occasional "window" that shows through the concealing sand dunes. The upland sand dunes exhibit at least three magnitudes of expression as surface features. Most extensive are the dunes of low elevation that may be distinguished from the nonsandy upland surface only by their slightly hummocky topography. The sand in these areas contains a large admixture of silt, has a fairly well-developed soil profile, and can support "row crops." The dunes of the second type are less extensive, less silt is mixed in with the sand, and the hummocky topography is developed in moderate relief. The most typical sand dunes are those of the third type, actively blowing at the present time in many places. Such dunes project conspicuously above the otherwise subdued surface and constitute some of the highest points in the county. Dunes of the intermediate type support a good stand of scrub vegetation, but are not readily adapted to cultivation. The high dunes are only poorly protected by a thin covering of vegetation and resume their migration when the vegetal cover has been breached. A typical migrating dune is shown in Plate 5.

The several types of upland dunes exhibit what seems to be a consistent relationship to one another. Dunes of intermediate magnitude lie within more extensive areas of subdued dunes and the high dunes, if present, are to be found within more extensive areas of intermediate dunes.

The Cimarron River is the only well-established drainage line in Seward County. The river enters the county about 1.3 miles east of the northwest corner and leaves the county about 2.1 miles north of the southeast corner. Its diagonal course across the county is marked by moderate lateral undulations.

In about the southeastern half of its course, the Cimarron carries water throughout most of the year. In the northwestern half, however, water appears above the stream bed only during periodic flood stages. Heavy rains to the west of Seward County are reflected in sudden increases in the flow of the Cimarron. In a few hours the river may rise to bank-full stage after having been only a meager trickle of water meandering sluggishly across the stream bed (Pl. 5B). Such floods subside with equal rapidity.

The Cimarron Valley differs markedly in form in the northwestern and southeastern parts of the county. In the northwestern part, where generally there is no surface flow, the sand-covered stream bed occupies a wide shallow depression of the valley floor. The valley floor rises gently away from the stream and merges almost imperceptibly with the gently sloping valley walls. The materials exposed along the valley walls in this section are unconsolidated gravel and sand, and there is no sharp break demarking the valley walls from the upland.

The southeastern part of the valley is sharply contrasted from the above. Rivulets and pools of water are almost always to be found on the sandy stream bed, which occupies a steep-walled trench in the valley floor. The valley floor rises very gently away from the stream in a manner suggestive of a pediment. Then, abruptly, the gentle slope intersects the steep and moderately high valley wall. With equal abruptness, the valley wall intersects the general level of the upland plain. The materials exposed along the valley walls consist mainly of indurated gravel, sand, and clay that contain, in many places, two hard "mortar beds" and, at the top, a hard bed of caliche. The average relief is greater in this section of the valley and the transverse profile is distinctly more angular.

Most of the tributaries to the Cimarron in Seward County are short and have relatively high gradients. With only one exception, they carry water only during and shortly after rains. The one exception was noted at the Old Harwood Ranch (sec. 6, T. 33 S., R. 32 W.), now operated by W. L. Harvey, where a tributary is fed by two springs that now flow only occasionally. The average tributary

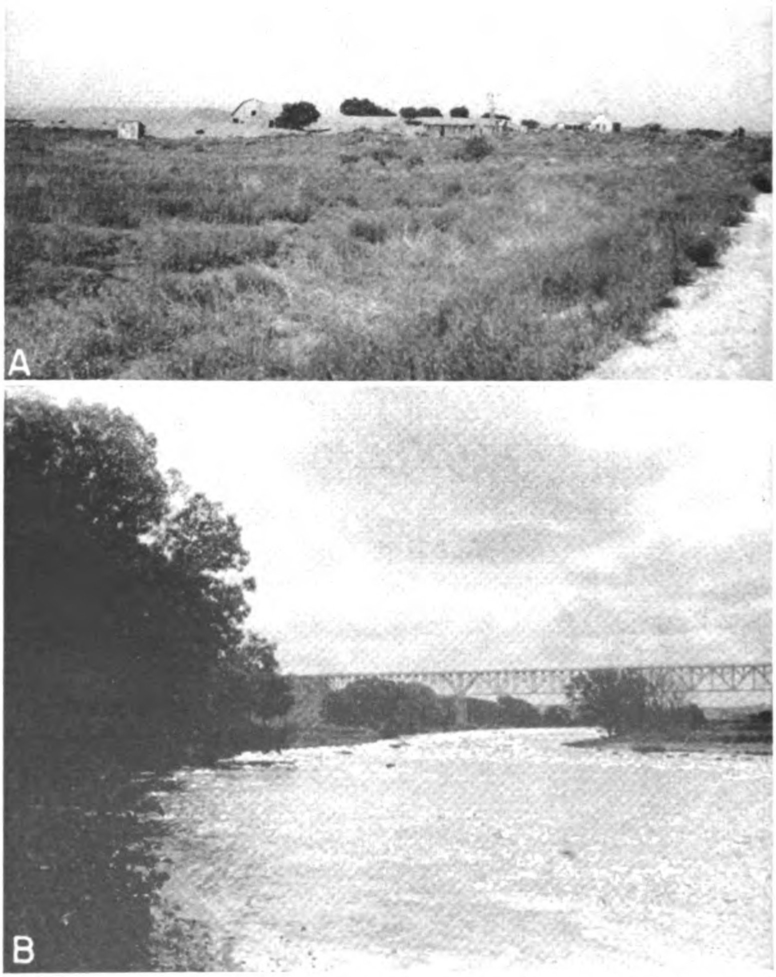

PLATE 5. *A*, Active sand dunes at NW corner sec. 3, T. 35 S., R. 31 W. *B*, Flash flood in Cimarron River. Photographs by Frank E. Byrne.

has a length of approximately two miles and occupies a steep-sided draw incised into the valley wall. The lower portion of the tributary consists of a sand wash cut into the pedimentlike slope of the valley floor.

The tributaries in the northwestern part of the county generally are much longer than the average and, consequently, have gentler gradients and shallower transverse profiles. Such tributaries cut into the harder underlying formations in only a few places, and their valleys might be termed "soft-rock" canyons as compared with the "hard-rock" draws to the southeast. Only the mouth of the longest of these canyons, Yarbo Canyon, is in Seward County; the remainder is in Stevens County to the west. Yarbo Canyon is about 5 miles long. A fairly typical example of a "soft-rock" tributary is found along the western border of T. 31 S., R. 33 W. An unusual "soft-rock" tributary lies in the east-central part of T. 32 S., R. 34 W. and the west-central part of T. 32 S., R. 33 W. This tributary parallels the Cimarron at a distance of about 2 miles to the southwest. In sec. 30, T. 32 S., R. 33 W., the tributary swings to the east and then to the northeast before it enters Cimarron Valley. Many shorter tributaries lie between its parallel course and the Cimarron, indicating the possibility of its capture by one or more of the shorter tributaries of the Cimarron at some future time. Perhaps such tributaries as this are remnants of an older drainage system not yet fully assimilated by the present-day Cimarron.

Climate

Seward County lies in a region of continental semiarid climate. Day temperatures during the summer are high, but discomfort is held to a minimum by the low relative humidity and the constant moderate winds. Irradiation is rapid so that the night temperatures, even in midsummer, are fairly low. Hot drying winds blow at irregular intervals during the summer and may cause appreciable crop damage.

The winter season is fairly cold and rather windy, but is accompanied by little snow. Occasional blizzards may be sufficiently severe and sufficiently sudden to cause considerable damage to livestock. The temperature ranges at Liberal, based on a 23-year period of record by the U. S. Weather Bureau, are given in Table 1.

TABLE 1.—*Monthly temperature ranges at Liberal, Kansas, in degrees Fahrenheit*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Average maximum temperature.....	47.4	52.9	61.5	69.9	77.5	88.2	93.3	91.9	85.2	73.0	60.4	47.7
Average minimum temperature.....	18.1	25.9	29.6	39.6	49.7	60.0	65.3	63.3	55.9	42.7	29.8	19.8

The average length of the growing season in the vicinity of Liberal during a 26-year period of record was 186 days, according to the Weather Bureau. The average date of the last killing frost in the spring is April 21 and the average date of the first killing frost in the fall is October 24. The latest recorded date of a killing frost is May 27 and the earliest date is October 8.

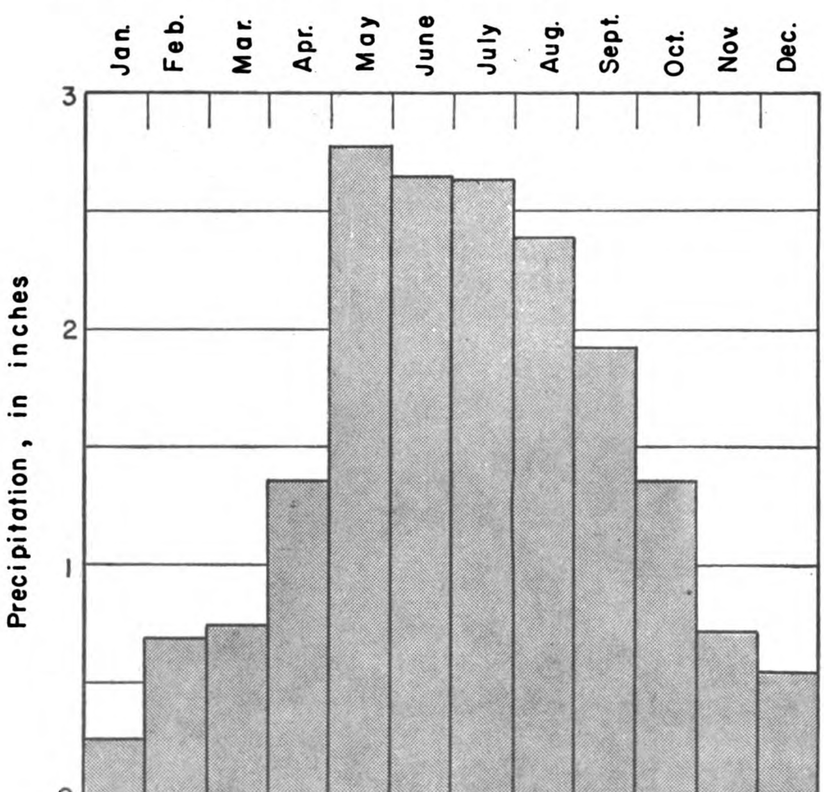

FIG. 2. Graph showing the average monthly distribution of precipitation in Seward County (based on records of the Weather Bureau stations at Liberal and near Kismet).

Precipitation data available for stations at Liberal and near Kismet are summarized in Figures 2, 3, and 4. The precipitation was below normal during most of the years between 1930 and 1941 resulting in the most severe drought since weather observations were begun in this area. The same is true for the station situated 12 miles northwest of Kismet (Fig. 4.) The years 1931, 1933, 1934, 1937, and 1939 were particularly dry near Kismet, and 1938 was

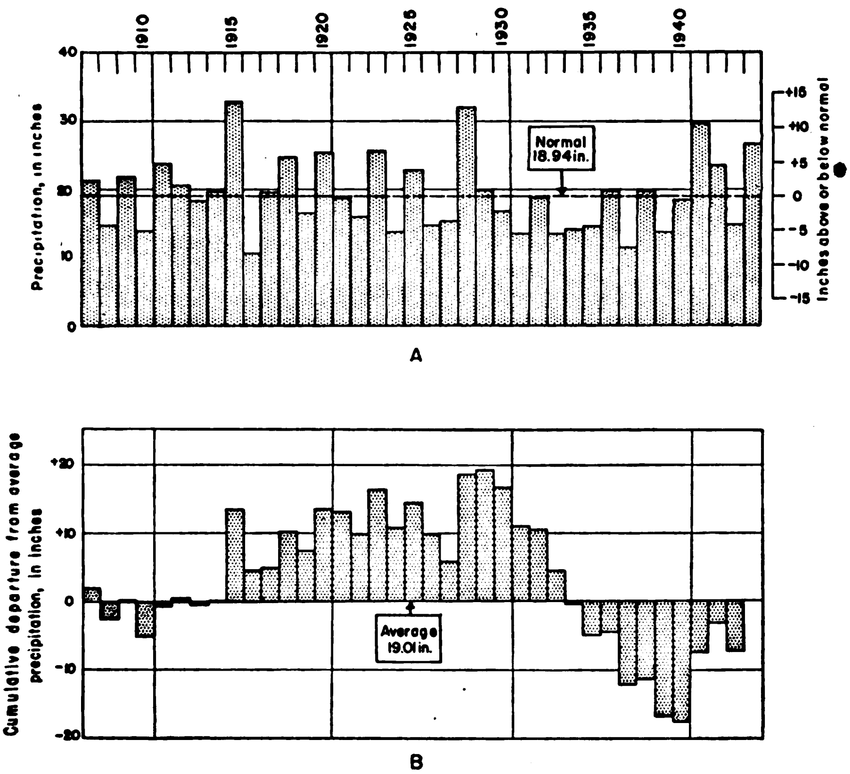

Fig. 3. Graphs showing (A) the annual precipitation at Liberal, Kansas, and (B) the cumulative departure from average precipitation at Liberal. (From records of the U. S. Weather Bureau.)

the only year, subsequent to 1928 and prior to 1941, in which the precipitation near Kismet exceeded normal although it was not much below normal in 1930.

About three-fourths of the annual rainfall generally falls during the growing season. Most of the precipitation falls in rather violent storms, sometimes of cloudburst proportions, separated by long dry intervals, but occasionally it falls slowly. The extremes of precipitation at Liberal are: least rainfall in a year, 10.25 inches in 1916; most rainfall in a year, 32.42 inches in 1915. The recorded extremes at the station near Kismet are: least rainfall in a year, 9.95 inches in 1937; most rainfall in a year, 28.67 inches in 1941.

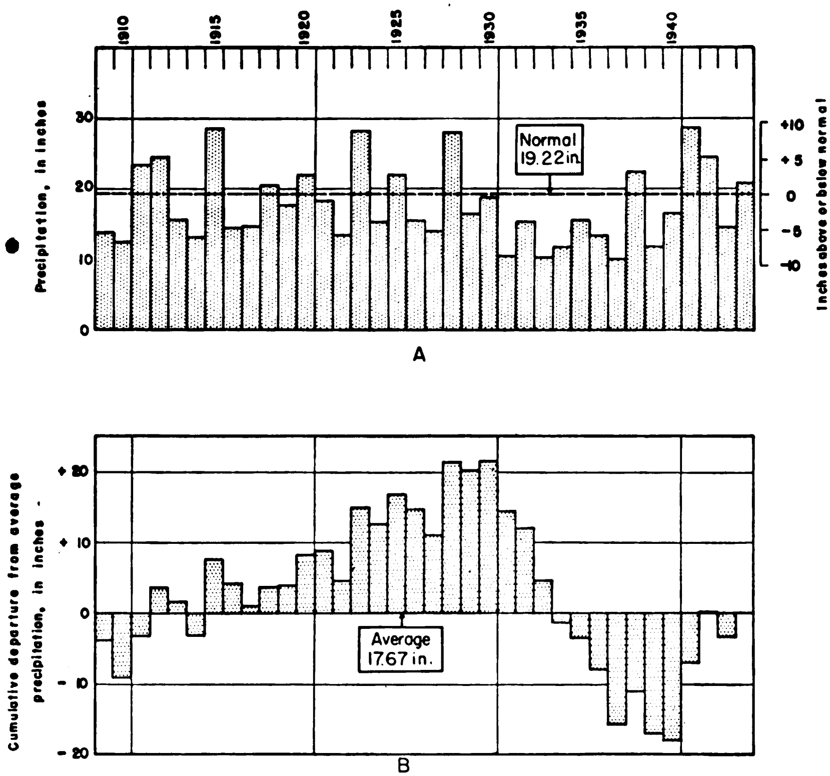

FIG. 4. Graphs showing (A) the annual precipitation near Kismet, Kansas, and (B) the cumulative departure from average precipitation near Kismet. (From records of the U. S. Weather Bureau.)

AGRICULTURE

The county was first settled by ranchers in about 1883, being formally organized in 1886 and named for W. H. Seward, the Secretary of State under President Lincoln. For many years, cattle raising remained the major industry in the county. Most of the ranches were located along Cimarron River, as they are at the present time. The upland was cultivated then only for winter feed. In recent years there has been a slow trend back toward the cattle industry (Table 2).

Table 2.—*Average number of livestock in Seward County, by five-year periods, 1910-1944*[1]

	1910-14	1915-19	1920-24	1925-29	1930-34	1935-39	1940-44
Milk cows..	2,767	2,751	1,791	1,564	1,487	1,713	1,776
Other cattle	5,722	9,785	8,874	6,853	8,085	6,055	13,784
Hogs.......	1,613	2,654	3,271	2,107	2,257	772	3,886
Sheep......	593	359	72	12	117	872	8,622
Hens.......	....	....	....	34,447	26,680	28,748	47,340
Horses.....	2,786	3,721	4,297	3,241	2,007	1,095	724
Mules......	879	1,284	1,735	1,265	418	133	52

1. Compiled by the Department of Agricultural Economics, Kansas State Agricultural Experiment Station, Manhattan, Kansas.

In the area northeast of the river, the grass and row-crop agriculture gave way to the raising of wheat in about 1922 to 1924. Several years later the same change affected the section around Liberal and wheat continues to be the most important agricultural product of the county (Table 3). In the five-year period, 1930-1934, the acreage of wheat harvested averaged 94,379 a year, but

Table 3.—*Average acreage of crops harvested in Seward County, by five-year periods, 1910-1944*[1]

	1910–14	1915–19	1920–24	1925–29	1930–34	1935–39	1940–44
Wheat harvested....	26,789	42,167	59,308	100,325	94,379	63,535	132,120
Wheat abandoned..	15,385	23,505	22,114	26,830	39,682	....	....
Corn..............	7,021	8,962	14,350	18,843	20,677	4,682	1,710
Oats..............	2,050	2,906	1,126	204	241	196	490
Barley.............	1,652	6,699	7,171	2,145	1,619	489	6,110
Grain sorghums....	24,471	46,318	41,457	34,817	....	30,551	25,966
Alfalfa............	327	75	20	....	....	....	....
Broomcorn	5,583	2,736	3,109	....	3,464	2,327	914

1. Compiled by the Department of Agricultural Economics, Kansas State Agricultural Experiment Station, Manhattan, Kansas.

during the same period an average of 39,682 acres of wheat was abandoned each year. During the same period the county produced each year an average of about 21,000 acres of corn, nearly 2,000 acres of barley, 25,000 to 45,000 acres of grain sorghums, and about 3,400 acres of broomcorn. At one time Liberal was reputed to be the largest grain-sorghum center in the world. The average individual crop yields, from 1922 to 1932, were: wheat, 10.6 bushels to the acre; corn, 13.2 bushels; barley, 13.4 bushels; kafir, 15.9 bushels; and milo, 17.1 bushels. The fluctuations in yield for all crops, in the same period, were 31 percent greater than the average for the State.

Drought and wind erosion have had a considerable influence on the agricultural practices within the county. Many farmers lost their farms as a result of the drought and left the county or remained as tenants, generally operating the farms under a cash-crop lease from an absentee owner (Table 4). The average size of the farm has been increased in the last several years by the practice of one person farming several properties previously operated by several individuals.

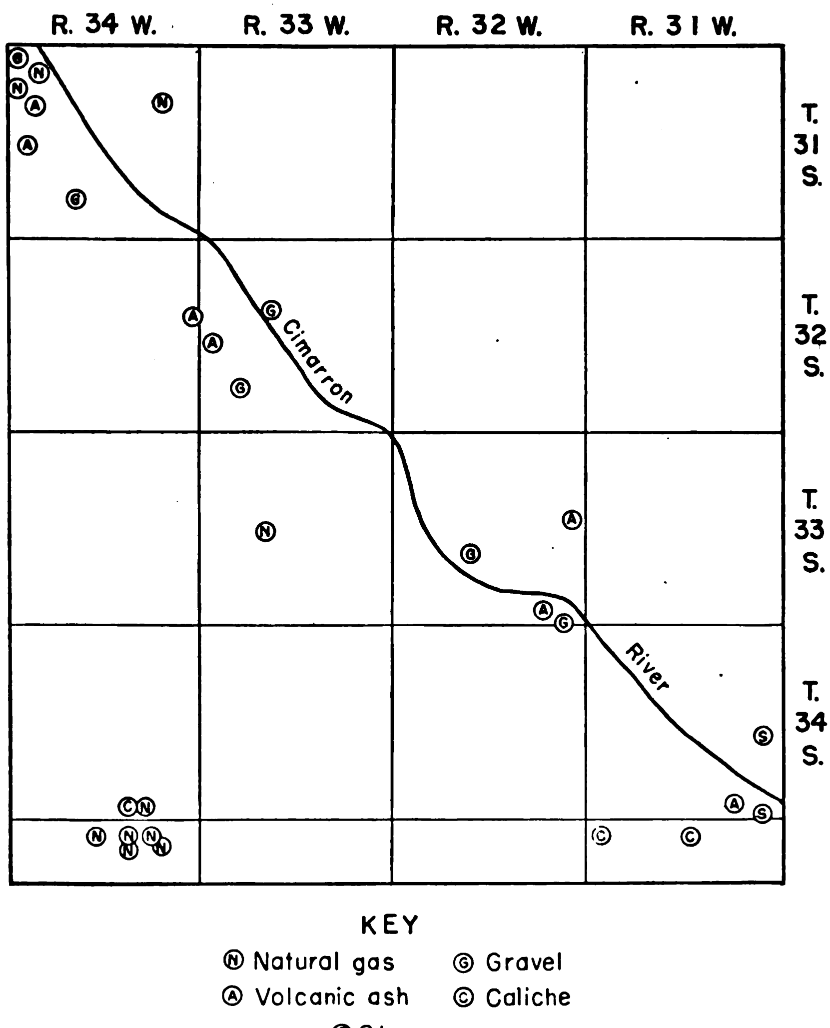

FIG. 5. Map of Seward County showing locations of mineral deposits.

TABLE 4.—*Tenure of farms in Seward County in 1930, 1935, and 1940, in percentage of total acreage farmed*[1]

	Owner	Part owner	Manager	Tenant
1930	17.8	36.8	0.2	45.2
1935	22.5	28.8	0.2	48.6
1940	20.7	24.5	0.2	54.6

1. Compiled by the Department of Agricultural Economics, Kansas State Agricultural Experiment Station, Manhattan, Kansas.

The type of soil determines the crops that are raised. Loam and silt soils are seeded primarily to wheat, grain being a secondary cash crop. Fine sandy loams are devoted, about half and half, to the cultivation of wheat and row crops. Sandy loams are utilized for the same crops as the fine sandy loams, but are subject to blowing and probably should be reserved for cover crops and pasture (Gene Harris, County Farm Agent in 1940). The dune phase of the sandy loam soils generally is in pasture, but row crops and wheat are grown on some of it. These areas were once covered by bluestem but are now covered largely by sagebrush and other desert plants. The clayey lake bottoms, known also as buffalo wallows (p. 14) can be farmed, but are subject to drowning-out because of poor subsurface drainage. The alluvial sandy soils in Cimarron River Valley formerly were covered by excellent hay meadows, but the widening channel of the Cimarron has destroyed most of them.

MINERAL RESOURCES

Several mineral deposits of economic value occur in Seward County, including natural gas, volcanic ash, gravel, caliche, and stone. Most of them are produced in relatively small quantities, however, and are used only locally. The locations of these deposits are shown in Figure 5.

Gas.—Several producing gas wells, gas test wells, and oil test wells have been drilled in Seward County. The logs of several of these are given at the end of this report. The Boles no. 1 well was the first oil test drilled in southwestern Kansas. A strong flow of gas was encountered between depths of 2,716 and 2,755 feet. Deepening the well to 2,919 feet produced only salt water. The well was plugged back to shut out the water and was finished as a gas well on July 20, 1920. This well is the "discovery" well of the southwestern Kansas gas-producing district, generally called the Hugoton field.

The Sealy no. 1 test well which was drilled during 1925 is now capped, but is said to be capable of production. The Pyle no. 1 and Hitch no. 1 test wells were not productive. There were 10 producing gas wells in Seward County at the end of 1944. Landes (1937, p. 88) states, "It is reasonable to assume that all of western Seward County, at least, is underlain by gas-bearing strata." The Liberal Gas Company derives its supply of natural gas from several wells in the vicinity of the discovery well. Production seemingly comes from at least three limestones in the Chase group (Wolfcampian series, Permian system).

Volcanic ash.—Volcanic ash, known also as pumice or pumicite, crops out at several localities along Cimarron Valley, mainly along the southwestern side. The material is exposed only on the valley wall generally within 75 feet of the upland surface. Only a few of the deposits were being exploited in 1940. The volcanic ash is found in isolated beds in the Meade formation. The color is roughly determined by the degree of purity, the ash with essentially no extraneous material being white or light gray. The addition of clay alters the color to medium or dark gray. In one locality, some of the ash is brown owing to the addition of limonite. The ash breaks up readily into a fine gritty powder composed of very angular particles. The material shows little or no induration except that imparted to it by the angularity of its constituent particles. The beds, which average about 4 feet in thickness, generally display well-developed bedding, the planes being horizontal in general, but in some places the beds exhibit the oscillatory type of cross-bedding found in materials deposited in lakes or ponds. Irregular calcareous concretions, variable in both size and shape, are a common feature of the ash.

Chemically, the volcanic ash consists predominantly of "rock glass," a solution of solidified silicates, and a minor amount of soda and potash feldspars. No chemical analyses of the ash collected from Seward County were made, but an analysis of a similar deposit found only a few miles to the northwest in Grant County (Western Spar Products Company mine) has been published by Landes (1928, p. 15).

Volcanic ash has many uses. Probably its chief use is as a scouring agent, although such a usage of it is made by only a few residents of the county. There is no commercial production of the

Seward County deposits for this purpose at the present time. The pits now being exploited furnish volcanic ash for road-building purposes. The material may be used as a part of the fill of a soft-surfaced road or may be used as a binder in the construction of black-top roads, adding much, it is said, to the ability of such roads to stand up under heavy traffic. Road-building uses are entirely local and only occasional. Following are descriptions of the ash deposits visited by Frank Byrne in 1940.

A small ash pit is located on the west side of the road in the SE¼ SE¼ sec. 7, T. 31 S., R. 34 W. The ash is relatively impure and is used only as road fill.

A moderately large pit that seemingly has not been worked for several years is located on the north wall of Yarbo Canyon in the SW¼ NE¼ sec. 19, T. 31 S., R. 34 W. The ash rests on a clay floor and its basal part contains an admixture of clayey impurities. The next 2 feet of material is finely bedded and of greater purity. The top 4 feet comprises a single massive layer that is quite pure except for the uppermost 1.5 feet, which is somewhat clayey. Small tubular concretions are common in the bedded part. The beds appear to dip at an angle of about 15 degrees to the south.

A large pit on the Burg Ranch in the SW¼ sec. 19, T. 32 S., R. 33 W. once was extensively worked, the ash having been used in the construction of "black top" roads. The material is in a relatively pure bed about 5 feet thick that becomes clayey near the top. Bedding is well-developed throughout the mass and in one horizon there is strongly marked cross-bedding (Pl. 11B). Large irregular concretionary masses are found throughout the upper part. Soft tan nodules of impure ash as large as 6 inches in diameter occur in a few places. The volcanic ash overlies a massive brown sand.

The Sunflower Mineral Mine in the SW¼ NE¼ sec. 13, T. 33 S., R. 32 W., is the largest ash pit in the county (Landes, 1928, p. 43). It was opened by T. C. Perry and has not been worked since 1926. The Rock Island Railroad built a short spur to the pit. The floor is a gray clay, above which is a massive bed of relatively pure ash about 8 feet thick. The immediate overburden is a layer of brown sandy volcanic ash containing nodules of caliche. The bedding planes show a low-angle primary dip (Pl. 11C). A textural analysis for this material (given by Landes, 1928, p. 44) indicates that only 7 percent of the material passed through a 300-mesh screen, but that 99 percent of the material passed through a 20-mesh screen.

An outcrop in the NW¼ sec. 35, T. 33 S., R. 32 W. contains a bed of relatively pure volcanic ash about 5 feet thick that seems never to have been worked. Gastropod shells were found in the ash.

An unworked outcrop of volcanic ash occurs in the SE¼ SE¼ sec. 35, T. 34 S., R. 31 W. The bed is about 8 feet thick of which about 4 feet is exposed.

Caliche.—Caliche is used within the county as a road-surfacing material. It is applied directly to the top of the road, binding the road gravel firmly, thereby increasing the intervals between gradings. The caliche is taken from shallow pits excavated in the uppermost part of the Meade formation. Pits so used were found at the following localities: (1) three pits in the S½ sec. 34, T. 34 S., R. 34 W.; (2) two pits in the NW¼ sec. 6, T. 35 S., R. 31 W.; and (3) NE¼ sec. 3, T. 35 S., R. 31 W. The caliche is disseminated throughout a brown sandy silt or occurs as nodules in the same material. The uncalcified overburden is thin and is easily removed with a drag.

Gravel.—Gravel is worked from several localities along Cimarron Valley. All the pits investigated were excavated in the gravelly lower part of the Meade formation or from terrace deposits. These were located as follows:

(1) NW¼ sec. 28, T. 31 S., R. 34 W., a very extensive pit operated for gravel and sand for road materials; (2) sec. 17, T. 32 S., R. 33 W., several pits that were worked extensively in 1943; (3) NE¼ NW¼ sec. 6, T. 31 S., R. 34 W., a fair-sized pit worked for road materials; (4) SW¼ NE¼ sec. 29, T. 32 S., R. 33 W., not now being worked; (5) E½ SE¼ sec. 21, T. 33 S., R. 32 W., an extensive pit operated by Mrs. G. A. Correll. The basal 5 feet of gravel is heavily calcified, but the upper 4 feet is clean-washed. The gravel is quite coarse and consists of fragments of sandstone, scoriaceous felsite, graphic granite, petrified wood, mortar bed, and other fragments in less abundance; (6) NW¼ SW¼ sec. 36, T. 33 S., R. 32 W., a gravel pit operated by the Panhandle Eastern Pipeline Company, about three-quarters the distance up the west wall of Cimarron Valley.

Building stone.—Two beds of rock provide building stone for local use. One of these, the so-called "saw-rock" bed in the Laverne formation, was quarried at about the beginning of this century from an exposure of the Laverne in sec. 24, T. 34 S., R. 31 W. The local name refers to the softness of the material which permits the sawing of it into desired shapes and sizes. The rock was used in the construction of some of the buildings at Arkalon and of a few of the ranch buildings in the valley. Despite its softness, the stone seems to be quite durable, perhaps because of the case-hardening of the surface that takes place after the removal of the rock from its natural ledge.

A mortar bed in the Meade formation was quarried in the NE¼ SE¼ sec. 36, T. 34 S., R. 31 W. for stone to be used in the construction of the county fair ground at Liberal. The rock is as hard as good limestone and must be quarried by hard-rock methods.

Population

Seward County is one of the less populous of the Kansas counties, ranking 76th in 1940. The census of 1880, the first for the county, lists 5 residents for the county and indicates that they were probably there for the hunting season. In that year, however, there was a postoffice located at Adobe (sec. 5, T. 34 S., R. 31 W., on the east side of the Cimarron), a settlement since abandoned.

In 1883, the State Legislature added the unorganized counties of Kansas, Stevens, and a portion of Meade, to the unorganized county of Seward. The temporarily enlarged county measured 90 miles east to west and 27 miles north to south. The population was then estimated to be 500. In 1885 the population had increased to 713.

Seward County, in its present size, was formally organized in June 1886, at which time the population had increased to 2,551. Fargo Springs (secs. 25 and 26, T. 32 S., R. 33 W.) was established as the county seat. In 1888, the county seat was removed to Springfield (sec. 4, T. 32 S., R. 33 W.) where it remained until 1896 when it was again removed, this time to Liberal, its present site. The cities of Fargo Springs and Springfield (population of more than 300 persons in 1889) have been abandoned.

The population of the county declined from 2,620 in 1889, to its minimum as an organized unit, 663 in 1897. Then followed a steady increase to 1,493 in 1906, followed by a sudden increase to 3,018 in 1907. The population grew at a fairly constant rate to 5,053 in 1916. Again there came a sudden increase to 6,087 in 1917. Since 1917 the population has fluctuated between 5,990 (1925) and its maximum of 7,768, which was reached in 1939 (Table 5). The population increased greatly during the war as a result of the establishment of an Army air base at Liberal.

Of the 1940 population, 90.0 percent were native whites born of native parents, 8.7 percent were native whites born of foreign-born parents, 1.2 percent were foreign-born whites, and 0.1 percent were Negro.

The well-being of agriculture seems to be the determining factor insofar as the county's population is concerned. The sudden increase in population in 1906 and 1907 might possibly reflect the time of the real opening of the southwest to crop agriculture rather than livestock agriculture. The rapid upswing in 1916 and 1917 possibly indicates the influence of World War I on the wheat market and the consequent expansion of the wheat-growing areas in the western part of the State. The recent fluctuations in population seem to be related directly to the crop success or failure for any one year.

TABLE 5.—*Population of Seward County, 1880-1940*[1]

Year	Population	Year	Population	Year	Population	Year	Population
1880	5	1897	663	1914	4,178	1931	6,637
1881	(2)	1898	685	1915	4,498	1932	6,135
1882	(2)	1899	721	1916	5,053	1933	7,318
1883	500	1900	804	1917	6,087	1934	6,980
1884	(2)	1901	865	1918	6,006	1935	7,212
1885	713	1902	803	1919	6,239	1936	6,816
1886	2,551	1903	824	1920	6,327	1937	7,052
1887	(2)	1904	978	1921	6,265	1938	7,061
1888	2,250	1905	1,035	1922	6,306	1939	7,768
1889	2,620	1906	1,493	1923	6,203	1940	6,593
1890	1,575	1907	3,018	1924	6,040	1941	6,448
1891	1,047	1908	3,520	1925	5,990	1942	6,406
1892	929	1909	3,846	1926	6,058	1943	8,016
1893	1,000	1910	3,858	1927	6,191	1944	8,004
1894	826	1911	4,333	1928	6,089		
1895	(2)	1912	4,228	1929	6,586		
1896	688	1913	4,074	1930	6,954		

1. Compiled from the Biennial Reports of the Kansas State Board of Agriculture.
2. Not reported.

Liberal has long been the principal city in the county. At the present time there is only one other incorporated city, Kismet, which was founded in 1930. The distribution of population within the county is shown in Table 6. The percentage of rural inhabitants has declined in recent years, probably because of drouth and the subsequent dust storms which made farming an unprofitable enterprise during at least some of the years.

TABLE 6.—*Urban and rural population of Seward County, 1931-1940*[1]

	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940
Liberal..........	4,099	3,416	4,575	4,314	4,653	4,509	4,848	5,075	5,615	4,513
Kismet..........	232	244	195	197	225	245	237	189	286	213
Rura	2,306	2,475	2,548	2,469	2,334	2,062	1,967	1,797	1,867	1,867
Total.......	6,637	6,135	7,318	6,980	7,212	6,816	7,052	7,061	7,768	6,593

1. Compiled from the records in the office of the Seward County Clerk.

Transportation

The main line of the Chicago, Rock Island, and Pacific Railway Company runs approximately east and west through the southern part of Seward County. The Amarillo branch line of the same railway joins the main line at Liberal. At one time Liberal was a division point on the Rock Island and the railway still maintains rather extensive yards there. Liberal serves as an important loading center for wheat and livestock.

The county is traversed by four Federal Highways, US 54, US 83, US 160, and US 270, all surfaced with black-top. The county roads are kept in good repair wherever they are still in use. Some roads in the least-populated sections are being allowed to deteriorate. The county roads carrying most of the local traffic are either graveled or are improved by the addition of caliche or volcanic ash to the road bed.

GEOLOGY

Summary of Stratigraphy

The geologic formations that have been recognized in Seward County either through surface outcrops or through the identification of the cuttings from test holes drilled by the Federal and State Geological Surveys are indicated in Table 7. The presumed relationships of the several stratigraphic units involved are indicated diagrammatically in Plate 3. The oldest geologic formations penetrated by the test holes were the redbeds of the Permian system. These do not crop out within the county, but are at the surface in Meade County. Several producing gas wells and oil- and gas-test wells (logs 12, 17, and 18) have been drilled to depths ranging from about 0.5 mile to almost 1 mile below the surface. The shallower of these either found production or drilling was stopped in formations near the base of the Permian system. The log of the deepest test well drilled

TABLE 7.—*Generalized section of the geologic formations in Seward County, Kansas.*

System	Series	Formation	Thickness (feet)	Physical Character	Water-supply
Quaternary	Recent	Colluvium	0–30	Sand, gravel, silt, and clay	Does not yield water to wells in this area
		unconformable on older formations			
		Alluvium	0–75 (?)	Coarse sand and gravel; contains silt and clay	Yields adequate supplies of relatively hard water to domestic and stock wells
		unconformable on older formations			
		Dune sand	0–60±	Medium-grained sand containing fine-grained sand and silt	Does not yield water to wells in this area, but assists in recharge of underlying formations
		unconformable on older formations			
	Recent and Pleistocene	Terrace deposits	0–20 (?)	Coarse sand and gravel	Does not yield water to wells in this area
		unconformable on older formations			
		Kingsdown silt	0–40±	Silt and fine sand containing nodules of caliche	
		disconformity			
	Pleistocene	Meade formation	75–100 (?)	Sand and gravel at base; sand, silt, clay, and caliche in upper part. Locally contains volcanic ash	Yields moderately hard water to a few wells in the western part of Seward County
		unconformable on older formations			

TABLE 7.—*Generalized section of the geologic formations in Seward County, Kansas—Concluded*

System	Series	Formation	Thickness (feet)	Physical Character	Water-supply
Tertiary	Pliocene	Rexroad (?) formation*	15–150 (?)	Sand and gravel at base; sand, silt, clay, and caliche in upper part. Sand and gravel in part cemented with calcium carbonate	Yields abundant supplies of moderately hard water to domestic, stock, and public-supply wells
		unconformable on older formations			
		Laverne formation	300-500 (?)	Sand, gravel, silt, and clay in lower part; micaceous sand, calcareous sandstone, silt, clay, caliche, and limestone in upper part	Yields water to very few wells in the southeastern part of this area. An important potential source of ground water
		unconformable on older formations			
Cretaceous	Gulfian**	Dakota formation	0–100	Brown, yellowish-brown, reddish-brown, buff and tan fine-grained sandstone, and varicolored clay	Locally is a potential source of ground water, but is practically unexploited in this area owing to its considerable depth
		disconformity			
Permian	Guadalupian** and Leonardian	Undifferentiated redbeds	1,500±	Brick-red sandstone and siltstone containing salt, gypsum, anhydrite, and dolomite	Locally is a potential source of ground water, but is practically unexploited in this area owing to its considerable depth and its generally high mineral content

* The fauna of the Rexroad (?) formation is believed to be equivalent of the Blanco fauna of Texas. The Kansas and Nebraska Geological Surveys have adopted the term Blancan to include the deposits in the Central High Plains that contain the Blanco fauna and faunas of equivalent age. At present there is not general agreement among paleontologists as to whether the Blancan is late Pliocene or early Pleistocene. We correlate the Seward County Rexroad (?) beds with the type Rexroad deposits in Meade County.

** The classification of Permian series is not adopted by the U. S. Geological Survey as applied to Kansas.

to date is not now available so that no valid conclusions can be drawn as to what still older geologic systems are present below the Permian.

The Cretaceous formations which overlie the Permian redbeds do not crop out in Seward County, but have been found in surface exposures not far to the west in Morton County (McLaughlin, 1942), to the northwest in Stanton County (Latta, 1941), and to the south in Texas County, Oklahoma (Schoff, 1939). The nearest Cretaceous outcrops to the east are found in Clark County.

The oldest surface rocks in the county belong to the Laverne formation. Outcrops of the Laverne are restricted to the lower valley slopes along the southeasternmost part of Cimarron Valley in Seward County, but occur also in the adjacent part of Meade County and in Oklahoma. The Laverne formation is separated from the overlying Rexroad (?) formation by a prominent unconformity. Evidence to be presented later indicates that the geologic age of the Laverne is early Pliocene, but the exact age of the Rexroad (?) is still in doubt. The sediments here included in the Rexroad (?) formation crop out principally along the wall of the lower Cimarron Valley, but outcrops of beds as far west as Morton County are believed by us to belong to this formation. Both the Laverne and Rexroad (?) probably underlie all of Seward County.

It was not found practicable to separate the Meade formation from the somewhat younger Kingsdown silt; hence they were mapped as a single undifferentiated unit. The gravel and sand of the Meade crop out extensively along Cimarron Valley. The sand and silt of the Kingsdown directly underlie much of the upland surface north of Cimarron River except where they are concealed beneath relatively thin deposits of dune sand. Paleontologic evidence from this county and from Meade County confirms the Pleistocene age of the Meade formation and the Pleistocene and Recent age of the Kingsdown silt.

The youngest geologic formations in the county—alluvium, colluvium, and dune sand—are primarly Recent in age although part of the dune sand may be older. The alluvium is restricted to the valley bottoms, and the dune sand covers limited areas in Cimarron Valley and large parts of the upland surface.

The areal distribution of the exposed formations is shown in Plate 1, and all of the formations are described in greater detail in the section on geologic formations and their water-bearing properties.

Geologic History

PALEOZOIC ERA

The early episodes in the geologic history of Seward County are obscured by the depth to which rocks formed have been buried beneath the deposits laid down in more recent geologic time. Paleozoic and younger rocks rest on the eroded surface of formations of pre-Cambrian age. The configuration of that surface, as well as the lithologic character of the rocks themselves, can be determined only after the results of deep test drilling over the county are known. From the logs of wells drilled in adjacent areas, it is thought that predominantly marine formations, ranging in age from the Cambrian to the Pennsylvanian (with the possible exception of Silurian and Devonian), lie over the pre-Cambrian floor and have an aggregate thickness of more than 6,000 feet. A deep test drilled near the southwest corner of Meade County in 1944 was drilled to the pre-Cambrian granite. Specific data on this well are not available.

As mentioned above, the production of gas comes from reservoirs in the Chase group of the Wolfcampian series which comprises part of the Permian system. Assuming that the gas produced in this county is from the same beds that supply gas to wells in Stevens County (Ver Wiebe, 1941, p. 98), there is basis for believing that a shallow extension of what is now the Gulf of Mexico covered Seward County in early Permian time. Both marine and shore facies are represented in the strata then laid down. Shortly after the time of deposition of the Chase group, the shallow sea withdrew toward the south and subsequent Permian deposition was of the nonmarine type, including such lagoonal deposits as the salt and gypsum beds of the Sumner and Nippewalla groups (Leonardian series). It is thought that the Permian redbeds reached by the Survey test holes belong to the Guadalupian series, also of nonmarine origin.

MESOZOIC ERA

Triassic and Jurassic periods.—With the cessation of Permian deposition in this area, there ensued a long interval in which erosion was preponderant over deposition. The occurrence of nonmarine beds of Triassic (?) and Jurassic age in Morton County (McLaughlin, 1942, pp. 26-27) might justify the inference that formations of comparable age and character had been deposited in Seward County as well. If so, such deposits have since been removed completely by erosion or are so thin or discontinuous as to have escaped recognition in the test holes thus far drilled in the county.

Cretaceous period.—Deposits laid down during the early part of the Cretaceous period underlie the northwestern corner of the county and adjacent areas. In nearby areas where they are better known they comprise two nonmarine sandstones (Cheyenne sandstone and Dakota formation) separated by a dark marine shale (Kiowa shale). Of these, only the Dakota formation extends into Seward County. In many parts of Kansas these rocks are overlain by younger marine Cretaceous formations. Had these been deposited in this area, they subsequently must have been eroded completely inasmuch as the well logs studied give no indication of their present existence beneath the surface of Seward County.

CENOZOIC ERA

Tertiary period.—No deposits laid down during the earlier epochs of the Tertiary period, the Paleocene, Eocene, Oligocene, and Miocene have been recognized in the county, either at the surface or in the subsurface. During this long geologic time interval, therefore, the processes of erosion seem to have had greater net effect than the processes of deposition.

During early Pliocene time, the area once again became one of deposition. In this interval the Laverne formation was deposited primarily by streams but also in lakes of relatively limited extent. Soon after deposition, the strata of the Laverne were involved in a deformative movement of the rocks of the area that caused the strata to be inclined locally as much as 15 degrees from the horizontal. The exact nature of the deformation is conjectural because the limited area of outcrop of the Laverne formation makes it difficult to determine the details of the structure produced or the source of the force responsible. The structure was caused at least in part by solution and collapse.

After the deposition of the Laverne formation there may have been a period of erosion. In middle Pliocene time the silt, sand, gravel, and caliche of the Ogallala formation were deposited over much of western Kansas, but these beds were removed from some areas of southwestern Kansas by a later period of erosion. The date of this period of erosion is not known because the exact age of the Rexroad (?) formation has not been determined. The nearest estimate that can be made at present is that the erosion took place between the close of the middle Pliocene and the early part of the Pleistocene. The erosion during this period may have removed most of the Ogallala formation between Point of Rocks in Morton County and Crooked Creek in Meade County.

In late Pliocene or early Pleistocene the deposits that comprise the Rexroad (?) formation were laid down over all of Seward County and adjacent areas. These beds consist of sand and gravel at the base and silt, sand, clay, and caliche in the upper part. These beds are unconformably overlain by the lithologically similar deposits of the Meade formation and were deposited primarily by streams flowing eastward from the Rocky Mountains.

Quaternary period.—Near the end of the Tertiary period or in the early part of the Quaternary period (after the deposition of the Rexroad (?) beds) there was folding and faulting in parts of southwestern Kansas. This period of erosion and deformation produced the major faulting in the Meade Basin in Meade County (Frye and Hibbard, 1941), and is represented by the unconformity between the Meade and Rexroad formations. The period was followed by the deposition of the stream-laid silt, sand, and gravel comprising the Meade formation.

During late Pleistocene time, aggrading streams flowing at the upland level spread fine sand and silt over their flood plains. These sediments, which comprise a part of the Kingsdown silt, probably were laid down over all of Seward County. Subsequent erosion removed much of the water-laid part of the Kingsdown silt from the southern part of the county. Deposits of loess were laid down over part of Seward County in late Pleistocene or Recent time and comprise the uppermost part of the Kingsdown silt.

During late Pleistocene and Recent time the high terrace deposits of Cimarron River were laid down, the valley was deepened nearly to its present level, and the alluvium was deposited. More recently (since 1914) the channel of Cimarron River has widened greatly throughout its course in Seward County. The widening has destroyed much bottom land and has caused accelerated erosion in many of the small tributaries in this area.

Other events in Recent time included the deposition of dune sand over large areas along Cimarron River, the deposition of colluvium in Cimarron Valley, and the formation of sink holes in many places in the upland areas.

As mentioned in describing the topography, there seem to have been three generations of dunes formed primarily during Recent time, perhaps related to cyclical climatic changes. The three types of dunes seem to be autochthonous in origin—that is, their distribution and form are evidence that they were shaped from loose sands in their present immediate vicinities. There is no indication of the sand having been derived from the present valley of the Cimarron. The "windows" between dune areas (as in secs. 4, 5, 6, 8, 9, etc., T. 35 S., R. 34 W.) seem to contradict the possibility that the sand was moved by the wind from some more-or-less remote external region.

A fourth type of sand dune, unrelated to the upland types, is found in the Cimarron Valley and represents wind-concentrated sand of alluvial origin. Such dunes are small and are much more abundant in the northwestern half of the valley than they are in the southeastern half. In one place (secs. 3, 4, 9, and 10, T. 31 S., R. 34 W.) there is evidence that some dunes that originated in the valley have since migrated northeastward and upward onto the upland surface.

During much of Pliocene, Pleistocene, and Recent time, there was major subsidence along Cimarron River in southeastern Seward and southern Meade Counties. It is believed that the course of Cimarron River from southeastern Seward County to the Ashland Basin in Clark County has been determined largely by solution and collapse. Much of the structure of the Laverne strata has been caused by subsidence in the area of outcrops of that formation. The overlying Rexroad (?) formation has also been strongly tilted in several places in southwestern Meade County. In both Meade and Seward Counties the Meade formation in several places dips toward Cimarron River. In southwestern Meade County a large block containing deposits of the Meade formation has dropped to stream level which is nearly 200 feet below its original position. As indicated by the above, the subsidence has been either continuous or recurrent since the deposition of the Laverne formation.

GROUND WATER

Principles of Occurrence

This discussion of the principles governing the occurrence of ground water takes account of conditions in Seward County. Preparation of the discussion has been based chiefly on the authoritative and detailed treatment of the occurrence of ground water by Meinzer (1923), to which the reader is referred for more extended consideration. A general discussion of the principles of ground-water occurrence, with special reference to Kansas, has been published by Moore (1940).

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

The interstices or voids in rocks range in size from microscopic openings to the huge caverns found in some limestones. The open spaces generally are connected so that water may percolate from one to another, but in some rocks these open spaces are isolated and the water has little chance to percolate. In Seward County, the rocks from which most of the ground water is obtained are poorly consolidated sand and gravel. Generally the sand and gravel of the Tertiary and Quaternary deposits contain many interstices through which water percolates freely; locally these interstices may be filled with calcium carbonate, clay, or other materials that make the rock relatively impermeable. Much of the silt, sand, and gravel of the Tertiary and Pleistocene deposits is poorly sorted and the finer particles fill a part of the space between the larger particles, thereby decreasing the amount of space available to ground water. The sandstones of the Dakota formation are cemented with iron oxide or calcium carbonate. The cement occupies a part of the spaces between sand grains, but enough voids are left to contain some water.

The porosity of a rock is 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 or other liquid and the porosity is then practically the percentage of the total volume of rock that is occupied by water. The porosity of a rock determines only the amount of water a given rock can hold, not the amount it may yield to wells. Some rocks may be highly porous, but will not yield an appreciable amount of water to a well. The specific yield of a water-bearing formation is defined as the ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume. It is a measure of the yield when it is drained by a lowering of the water table. The permeability of a water-bearing material is defined as its capacity for transmitting water under hydraulic head, and is measured by the rate at which it will transmit water through a given cross section under a given difference of head per unit of distance. A rock containing very small interstices may be very porous, but it would not be very permeable, whereas a coarser-grained rock, although it may have less porosity, generally is much more permeable. Some water is held in rocks by the force of molecular attraction, which, in fine-grained rocks, is sufficiently great to make the rock relatively impermeable.

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

Artesian Conditions

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

In some rock formations, relatively permeable strata such as sand and gravel alternate with relatively impermeable strata such as clay or shale. If these beds have a slope, then water that falls on the area of outcrop of a permeable bed moves down the dip of the bed between the confining layers of relatively impermeable material and saturates the permeable stratum. Wells drilled to the saturated bed encounter water under artesian head. Artesian water has been encountered in many wells in Seward County but nowhere in this area has the artesian head been sufficient to cause them to flow.

The Water Table

The water table, defined above as the upper surface of the zone of saturation, is not a static level surface, but rather it generally is a sloping surface that may exhibit hills and valleys similar to those of the land surface. Figure 6 demonstrates diagrammatically some general relationships of the water table to the land surface and to bodies of surface water. Other irregularities may be caused by differences in permeability of water-bearing materials or by unequal additions of water to the ground-water reservoir at different places.

Water in the zone of aeration, once it has penetrated below the soil zone, seeps vertically downward until it reaches the zone of saturation, unless it encounters an inclined layer of relatively impermeable rock. Within the zone of saturation the direction in which the water moves is determined by the hydraulic gradient, and generally is toward streams or lakes or areas of lower altitude. In some places the usual direction of percolation may be reversed, as in the vicinity of a stream that is losing water to the materials over which it is flowing or in the vicinity of an artificial lake in which the water level has been raised above the local water table.

The rate at which ground water percolates is relatively slow as

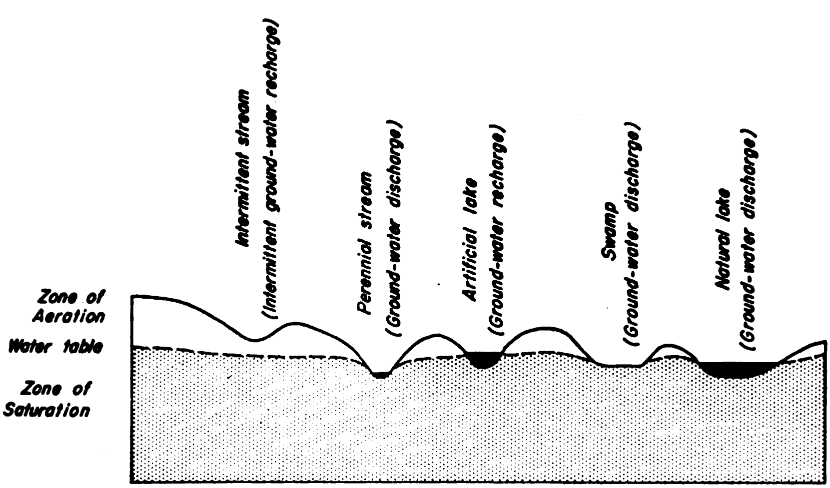

FIG. 6. Diagram showing the relation of the water table to the land surface and to bodies of surface water.

compared with the velocity of water in surface streams. The frictional resistance encountered by ground water as it percolates through the interstices of the rocks is far greater than that created by surface water as it flows over the land. Hydrostatic head and permeability are the important factors determining ground-water velocity.

SHAPE AND SLOPE

The shape and slope of the water table in Seward County are shown on the map (Pl. 1) by contour lines drawn on the water table. All points on the water table on a given contour line have the same altitude. These water table contours show the configuration of the water surface just as topographic contour lines show the shape of the land surface. The direction of movement of the ground water is at right angles to the contour lines in the direction of the downward slope.

The map (Pl. 1) shows that the general movement of the ground water in Seward County is east-southeastward, but that the slope and the direction of movement of the ground water vary considerably from one part of the county to the other. The maximum slope is in the area of closely-spaced contours in the southwestern part of the county and is nearly 40 feet to the mile, whereas the minimum slope is in the northeastern corner of the county and is about 4 feet to the mile. The average slope along the north line of the county is 5.5 feet to the mile and the average slope along the south line of the county is 16.7 feet to the mile.

The shape and slope of the water table, which determine the rate and direction of movement of ground water, are controlled by several factors. Irregularities in the shape and slope of the water table in Seward County appear to be caused by: (1) the shape and slope of the underlying bedrock floor; (2) discharge of ground water into streams; (3) recharge of the ground-water reservoir by ephemeral streams; and (4) local differences in the permeability of the water-bearing materials. The effect of these factors on the shape and slope of the water table will be discussed separately in the following paragraphs.

The shape and slope of the bedrock floor (the Dakota formation and the Permian redbeds) probably have little or no effect on the configuration of the water table but probably are among the chief factors affecting the general slope of the water table. The slope of the water table in Seward County and in adjacent areas is approximately in the same direction and degree as that of the bedrock floor.

The discharge of ground water into streams is one of the principal factors affecting the shape and slope of the water table in Seward County. Below the point where the 2,710-foot contour line crosses Cimarron River (Pl. 1) the channel of the river has been cut lower than the water table in areas adjacent to the river. The ground water moves toward the river from adjacent areas and discharges into the Cimarron Valley causing a depression of the water table which is indicated by the upstream flexure of the water-table contours. The relation of the water to the stream channel is shown in Figure 6. The greatest upstream flexure of the contours is in the southeastern corner of the county. The flexure diminishes in degree upstream as the difference between the levels of the stream channel and the adjacent water table diminish.

The recharge of the ground water by an ephemeral stream has caused a slight downstream flexure of the water-table contours in the northwest corner of the county. The channel of the river in this area is above the level of the water table, hence water moves downward through the stream bed to create a ridge in the water table.

Local differences in permeability of the water-bearing materials probably is the principal factor causing the steep slope of the water table in the western part of the county. This zone of closely spaced contours extends northwestward through northeastern Stevens County and southeastern Grant County. On both sides of this zone the water table is relatively flat. In the zone of closely-spaced contours the upper part of the zone of saturation probably is in relatively impermeable silt and clay whereas on either side it probably is in more permeable deposits of sand and gravel.

RELATION TO TOPOGRAPHY

Plate 2 shows the relation of the water table to the land surface in Seward County by means of isobath lines which are lines of equal depth to water level. All points on the 50-foot isobath, for example, are points at which the water table lies 50 feet below the land surface. In areas between the 50-foot and 100-foot isobaths the depth to water is more than 50 feet but less than 100 feet. In the preparation of this map an effort was made to take into account the major irregularities of the land surface.

For purposes of detailed descriptions of the ground-water conditions, Seward County may be divided into several areas based upon the depths to water level: (1) Cimarron Valley area, (2) Liberal area, (3) Kismet area, (4) Hayne area, (5) western area, (6) northwestern area, (7) northeastern area, and (8) southwestern area. A brief description of each area follows.

Cimarron Valley area.—The Cimarron Valley area includes the flood plain of Cimarron River and the gentle valley slopes adjacent to the flood plain. The depth to water level is less than 50 feet along the deeper part of the valley and ranges from 50 to 100 feet along two narrow sloping belts that border the valley. The shallowest well in the county (80), which has a depth to water level of only 9.5 feet, is in this valley.

Wells in this area obtain water from the alluvium of Cimarron Valley, the Rexroad (?) and Laverne formations, and possibly also from the sand and gravel of the Meade formation. All of the stock ranches in the county are situated in this area. Most of the wells that supply these ranches are on the flood plain and have water levels within 50 feet of the surface.

In 1940 there was one irrigation well which obtained water from the alluvium in this area. The alluvium is capable of supplying abundant quantities of water for irrigation. The height the water must be lifted to the surface is slight, the topography in some places is suited to irrigation, and the soil in many places is not too sandy. It would seem that a well-water irrigation project would have a better chance for success in this area than in any other part of Seward County.

Liberal area.—The Liberal area includes approximately 25 square miles of land immediately to the west of Liberal in which the depth to water level ranges from about 75 feet to 100 feet. The ground water probably is obtained from the lower part of the Meade formation and perhaps in part from the Rexroad (?) formation.

The Liberal deep-well irrigation project, discussed later in some detail, was undertaken just outside this area and was not deemed entirely successful, owing mainly to the large drawdown of the water level in the well during pumping. This increased the height it was necessary to lift the water to the surface and added materially to the cost of operation. It is possible that similar difficulty would be encountered in other parts of this area.

Kismet area.—The Kismet area includes the City of Kismet, in which the depth to water level is more than 200 feet. A maximum depth to water level of 212 feet was encountered in well 65 in this area. The water is obtained from the Rexroad (?) or Laverne formation. The area roughly coincides with a belt of fairly high sand dunes.

Hayne area.—The Hayne area, in which the water level is more than 200 feet below land surface, is the most extensive of the four deep-water areas in the county and, as is true of the others, it coincides with an area of fairly high sand dunes. Its extent is about 43 square miles. The deepest water level found in the county, 249 feet (well 118), is in this area. The water probably is obtained from the Laverne or Rexroad (?) formation.

Western area.—The western area includes only about 5 square miles along the western border of Seward County (secs. 17, 18, and 20, T. 32 S., R. 34 W. and parts of the adjacent sections), in which the depth to water level is more than 200 feet. In well 58 in this area the water table is 215 feet below land surface. The Rexroad (?) formation probably supplies water to most of the wells in this area.

Northern area.—The northern area comprises slightly more than 3 square miles in the northwestern part of the county in which the depth to water level is more than 200 feet. It extends northward into Haskell County. The water in this area is obtained primarily from the sand and gravel of the Rexroad (?) formation.

Northeastern area.—The northeastern area comprises nearly half the county and almost all of the county north of Cimarron River. In this area, the depth to water level ranges from 100 to 200 feet. From the upper edge of Cimarron Valley the area extends northward into Haskell County and eastward into Meade County. Enclosed within it are the Kismet and the northern deepwater areas. Most of the wells in this area obtain their supplies of water from the Rexroad (?) formation and a few wells probably obtain water from the Meade formation.

Southwestern area.—The southwestern area includes all of the area south of Cimarron Valley in which the depth to water level ranges from 100 to 200 feet. The water in this area probably is obtained primarily from the Rexroad (?) formation. The Hayne, western, and Liberal areas lie within this more extensive area.

FLUCTUATIONS IN WATER LEVEL

The water table in any area does not remain stationary 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 principal factors controlling the rise of the water table in Seward County are the amount of precipitation that passes through the soil and moves downward to the water table, the amount of water added to the ground-water reservoir by seepage from Cimarron River, and the amount of water entering the area by subsurface inflow from areas to the west and north. The principal factors controlling the decline of the water table in this area are the amount of water discharged by effluent seepage into Cimarron River, the amount of water lost through transpiration and evaporation where the water table is shallow, the discharge of water through springs, the amount of water pumped from wells, and the amount of water leaving the area by subsurface flow into the areas to the east and south.

Fluctuations of the water table are reflected directly in changes in the water levels in wells. In order to record such changes on a monthly basis, 11 representative wells in Seward County were selected as observation wells. The water levels in these wells were measured in July and August, 1940, during the compilation of the well inventory, were measured by Byrne later in August, 1940, and were measured at monthly intervals thereafter by Richard C. Christy, Woodrow W. Wilson, Allen Graffham, and Howard Palmer. These measurements were tabulated by Meinzer and Wenzel (1943, pp. 146-148; 1944, pp. 167-168; 1945, pp. 150-151).

TABLE 8.—*Observation wells in Seward County*

Well number in this report	Well number in Water-Supply Paper 938, 946, and 988	Well number in this report	Well number in Water-Supply Paper 938, 946, and 988
3	155	85	60
17	165	104	66
23	108	112	52
53	15	128	8
56	106	158	159
64	122		

Ground-water Recharge

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

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

RECHARGE FROM PRECIPITATION

The average annual precipitation in Seward County is about 19 inches, but only a part of this water reaches the zone of saturation owing to evaporation, transpiration, and surface runoff. The amount of water added to or discharged from the ground-water reservoir is reflected in the fluctuations of the water levels in wells. Periodic measurements of water levels in wells 23, 53, 56, 64, and 158 have been made since August 1940. The fluctuations of the water levels in these wells are shown in Figure 7. Well 53 is a shallow well in Cimarron Valley whereas the other wells are on the upland and have depths to water level ranging from about 96 feet to more than 209 feet. The water levels in all of the observation wells in Seward County were higher at the end of 1944 than they were at the beginning of record. The water level in most wells rose during 1941, 1942, and 1944 which were years of above-normal precipitation, whereas the water level in most wells declined during 1943, a year of below-normal precipitation.

The fact that the water level in some deep wells fluctuates only slightly does not necessarily mean that there is no recharge, for the water level will rise only when the rate of recharge exceeds the rate of ground-water discharge. The recharge in such areas probably is more or less continuous and is about equal to the natural discharge. Although the annual net rise in water levels in the four deep wells is small, the cumulative rise may be relatively large. The average cumulative rise of water levels in these wells ranged from 0.48 foot in 1943 to 2.00 feet in 1944.

From the beginning of 1941 to the end of 1944 the water levels in three upland wells (56, 64, and 158) rose an average of 0.22 foot a year. If the specific yield of the upper part of the zone of saturation in this area were known, the amount of the annual gain in storage of ground water could be estimated. If it were assumed that the specific yield is 15 percent, then the annual gain in storage would amount to about 0.4 inch and the gain in storage for the four years (1941-1944) would amount to about 1.6 inches. A gain in ground-water storage of 1.6 inches would amount to about 83 acre-feet (27,000,000 gallons) per square mile.

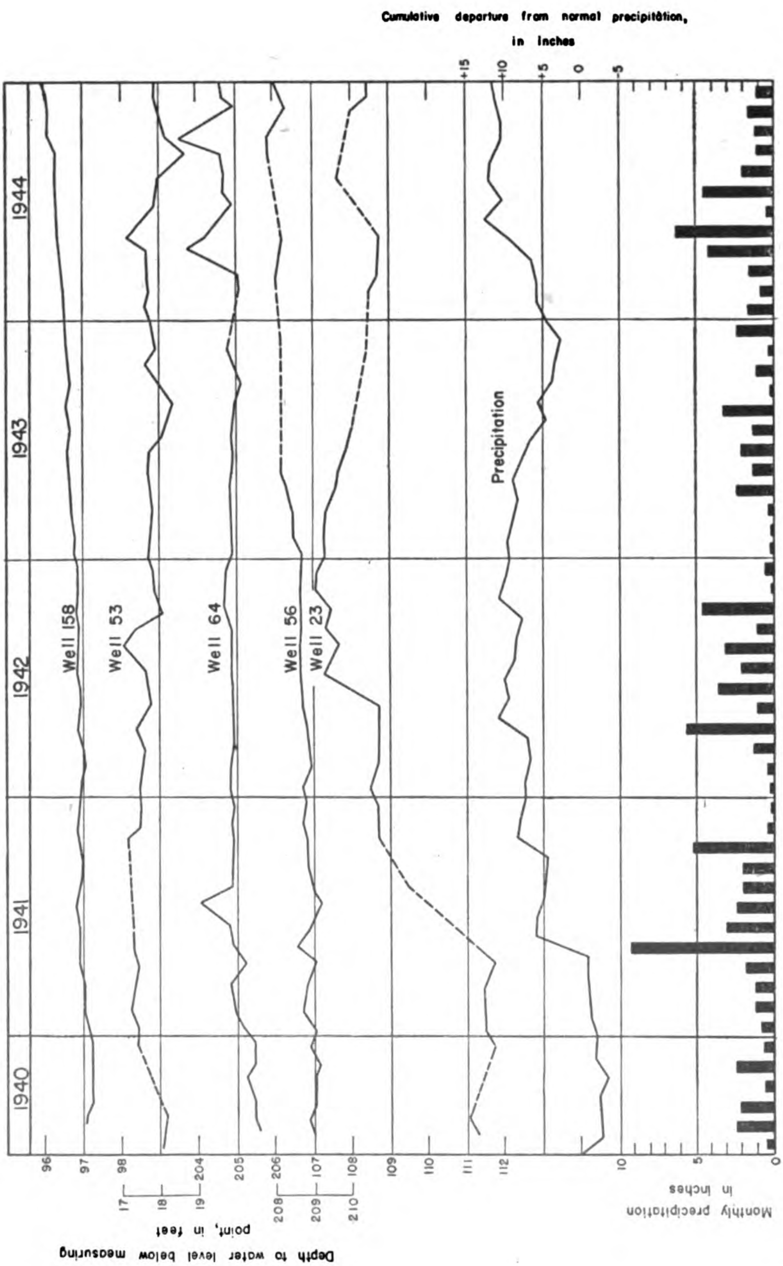

FIG. 7. Hydrographs showing the fluctuations of the water levels in five wells in Seward County, the cumulative departure from normal monthly precipitation at Liberal, and the monthly precipitation at Liberal.

RECHARGE FROM SEEPAGE

Some water is contributed to the ground water reservoir by seepage from streams and depressions. Cimarron River is a losing stream in the northwestern part of Seward County. In this part of the course of the Cimarron some of the flood water moves downward to the zone of saturation. This has caused a mound on the water table near the northwest corner of the county (Pl. 1).

Well 23 is located about 0.5 mile from the flood plain of Cimarron River. During a flood in 1941 the flood water extended from bluff to bluff. It is believed that seepage during this and subsequent floods produced much of the rise shown for well 23 in Figure 7.

RECHARGE BY SUBSURFACE INFLOW

Ground water moves into Seward County by subsurface inflow from Stevens County on the west and Haskell County on the north. The water moves across the county in a general southeasterly direction into Meade County, Kansas, and Texas and Beaver Counties, Oklahoma.

Discharge of Subsurface Water

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

DISCHARGE BY TRANSPIRATION AND EVAPORATION

Water may be taken into the roots of plants directly from the zone of saturation or from the capillary fringe, and discharged from the plants by the process known as transpiration. In most of Seward County the depth to the water table is so great that there is no transpiration or evaporation from the zone of saturation or from the capillary fringe. In Cimarron Valley, however, the water table is shallow and much ground water is discharged by these processes.

DISCHARGE BY SPRINGS AND SEEPS

A relatively small amount of ground water is discharged by springs in Seward County. The only spring noted in the county was in the S½ sec. 6, T. 33 S., R. 32 W. Residents reported that there were formerly several springs in that vicinity. The water from the spring is ponded in a small tributary to Cimarron River by a small dam. The water seemingly does not flow from the principal zone of saturation but from a perched body of water overlying a relatively impermeable mortar bed. A similar spring was observed in Wolf Canyon in Meade County a few yards east of the E. line sec. 12, T. 35 S., R. 31 W. The water there also is flowing from a perched body of water.

The seepage of water into Cimarron River is one of the principal processes of discharge of ground water in Seward County. In most of Seward County the channel of Cimarron River is lower than the level of the water table in the adjacent upland areas; hence the ground-water moves toward the river and discharges into the stream channel. Toward the southeast the rate of discharge increases because the difference between the altitude of the stream channel and the altitude of the water table in adjacent areas increases.

DISCHARGE BY SUBSURFACE FLOW

Much ground water is discharged from this area by subsurface flow into adjacent areas toward the east and south. This is indicated by the slope of the water table (Pl. 1), which indicates that the water moves into Meade County and into Texas and Beaver Counties, Oklahoma.

DISCHARGE BY WELLS

Another method of discharge of water from the ground-water reservoir is the discharge of water from wells. All domestic, industrial, railroad, and municipal supplies of water and much of the livestock supply of water in Seward County are derived from wells. The amount of water discharged from wells for these purposes, however, is relatively small. The recovery of ground water from wells is discussed in the next section.

RECOVERY

PRINCIPLES OF RECOVERY

The discharge from a well is produced by a pump or some other lifting device or by artesian head (for a more detailed discussion of the principles of recovery see Meinzer, 1923a, pp. 60-68). When water is being discharged from a well there is a resulting drawdown or lowering of the water level, or, in a flowing artesian well, an equivalent reduction in artesian head. The water table is lowered in an area around the well to form a depression resembling an inverted cone. This depression of the water table is known as the cone of depression, and the distance that the water level is lowered at the well is called the drawdown. In any well, the greater the rate of pumping, the greater will be the drawdown.

When water is withdrawn from a well, the water level declines rapidly at first and then more slowly until it finally becomes nearly stationary. Conversely, when the withdrawal ceases, the water level rises rapidly at first and then more slowly until it eventually resumes its original position (Fig. 8).

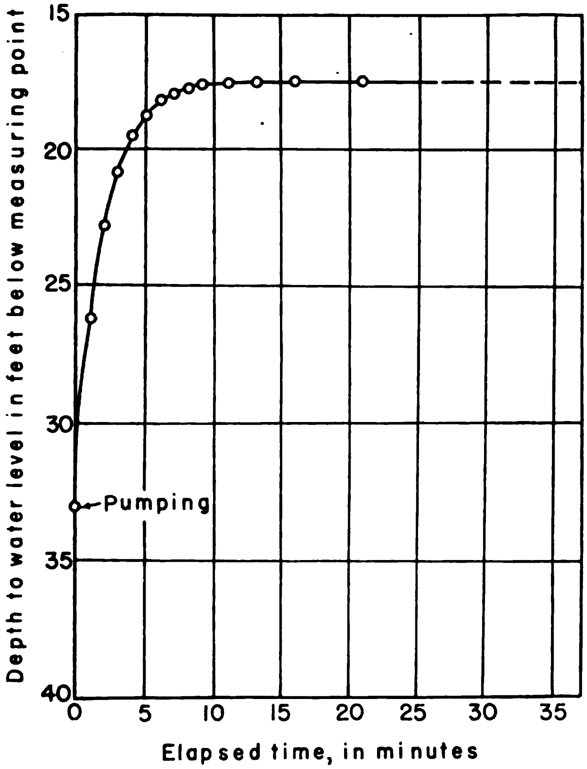

FIG. 8. Graph showing the recovery of water level in well 53. (Measurements by Woodrow W. Wilson.)

CONSTRUCTION OF WELLS

All but one of the wells listed in Table 10 are drilled wells. Well 22 consists of a battery of two dug wells used to supply water for irrigation. One driven well was observed during the course of the investigation but it could not be measured.

Drilled wells are excavated by means of a percussion or rotary drill. They generally are 4 to 6 inches in diameter although the railroad, industrial, and municipal wells may be much larger. The domestic and stock wells generally are cased with galvanized-iron casing but a few are cased with wrought-iron casing. Most of the large-diameter wells are cased with wrought iron.

Almost all wells in Seward County obtain water from unconsolidated deposits, principally the Rexroad (?) and Meade formations. Wells in these deposits generally are cased to the bottom of the hole to prevent caving. In most of the domestic and stock wells the water enters only through the open end of the casing but in the larger wells the casing generally is perforated below the water table to provide greater intake facilities. The size of the perforations is an important factor in the construction of a well and the capacity or even the life of the well may be determined by it. If the perforations are too large fine material may filter through and fill in the well; if the perforations are too small they may become clogged so that water is prevented from entering the well freely.

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

Gravel-wall wells generally are effective for obtaining large supplies of water from relatively fine-grained unconsolidated deposits and are widely used for irrigation in the upland areas of western Kansas. In constructing a well of this type, a hole of large diameter, 30 to 60 inches, is drilled and is temporarily cased with unperforated pipe. A well screen or perforated casing of smaller diameter than the hole is then lowered into place and centered in the larger pipe opposite the water-bearing beds. Unperforated casing extends from the screen to the surface. The annular space between the inner and outer casings is then filled with sorted gravel. The outer casing is then withdrawn part way to uncover the screen and allow the gravel packing to come in contact with the water-bearing material.

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

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

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

BLOWING WELLS

Several wells in Seward County, such as no. 77, are reported to be blowing wells—that is, air blows into or out of the well at irregular intervals causing a whistling or sighing noise. The phenomenon is not an uncommon one and its explanation by Lugn and Wenzel (1938, p. 64) is satisfactory. They indicate that the phenomenon is related to changes in atmospheric pressure and occurs in those wells in which there is an unsaturated layer of relatively permeable material above the water table but beneath some relatively impermeable bed. During an interval of high atmospheric pressure the air above the water table is compressed causing the air to escape through the well casing. The air is sucked into the well when the atmospheric pressure declines rapidly.

METHODS OF LIFT AND TYPES OF PUMPS

The stock- and domestic-supply wells in Seward County almost without exception employ lift or force pumps to raise the water to the surface. Both types of pumps have cylinders or working barrels attached to the lower end of the drop pipe and placed in the well about at the level of the water table. A wooden or metal jet rod connects the plunger of the working barrel with the source of power, usually a windmill but sometimes a hand jack. Unlike a force pump, a lift pump cannot raise the water above the pump head.

The drop pipe, which generally is about 2 inches in diameter, is commonly supported by wooden or metal clamps of various designs that are supported in turn by the top of the casing or by some specially constructed device such as blocks of wood, brick, or concrete. Most of the wells in the county are equipped with sheet-metal covers placed between the clamp and the top of the casing to prevent small objects from falling into the well.

The wells supplying water to the railroad, to municipalities, to industries, or for irrigation are generally equipped with turbine or centrifugal pumps. These may be operated by electric motors, by steam engines, or by internal-combustion engines utilizing oil, natural gas, or gasoline for fuel. Turbine pumps are installed when the depth to water level, including drawdown, exceeds the effective suction limit of the centrifugal pump. The report by Davison (1939, pp. 23-44) contains descriptions of different types of pumping plants, the conditions for which each is best suited, construction methods, and a discussion of cost of construction.

Utilization of Water

The records of the wells in Seward County that were measured during July and August, 1940 are given in Table 10. The water obtained from these wells, almost all of which are drilled, is used for domestic, stock, municipal, railroad, industrial, and irrigation supplies.

DOMESTIC AND STOCK SUPPLIES

Water for domestic and stock uses comes from wells ranging in depth from about 13 feet to 257 feet. The shallowest depth to water level found in Seward County, 9 feet, was that of well 80 which is not in use. The deepest water level, 249 feet, was in well 118. Almost all domestic and stock wells are cased with either 4-inch wrought-iron casing or 5-inch galvanized-iron casing. Many of the wells have spigots for drawing water from the pipe directly at the well head and most of them are equipped with drains which may be opened to drain water from the pipe above the winter freezing line. The water is moderately hard but is suitable for most domestic and stock uses.

MUNICIPAL SUPPLIES

Both Liberal and Kismet, the two organized communities in the county, have public-supply systems utilizing water from municipally owned wells.

The water supply for Liberal is obtained from five wells drilled in the city park in the northern part of the city. City well 1 was drilled with a hydraulic-rotary drilling machine and was completed in 1931 at a reported depth of 418 feet. The well is cased with 18-inch steel casing and is equipped with a turbine pump powered by a 50-horsepower electric motor. The reported water level was 120 feet in 1940. The well is reported to yield 420 gallons a minute with a drawdown of 83 feet.

City well no. 2 was drilled in 1931 to a depth of 506 feet and was cased to a depth of 185 feet with 18-inch steel casing and from 185 feet to 506 feet with 12-inch steel casing. The well is equipped with a turbine pump powered by a 135-horsepower 6-cylinder natural-gas engine. The well formerly yielded 750 gallons a minute with a drawdown of 126 feet after 24 hours of pumping. In 1944 the well yielded 435 gallons a minute with a drawdown of 115 feet after 4 hours of pumping.

City well no. 3 was drilled in 1919 to a depth of 345 feet and was cased with 18-inch steel casing in the upper part and 15-inch steel casing in the lower part. The casing is finished with a perforated screen. The 14-stage turbine pump has a rated capacity of 250 gallons a minute and is operated by a 50-horsepower electric motor. The well is reported to yield 250 gallons a minute with a drawdown of 14 feet after one hour of pumping.

City well no. 4 was drilled to a depth of 565 feet and was cased with 12-inch steel casing. The well is equipped with a turbine pump powered by a Diesel engine. The well is reported to yield 320 gallons a minute. The static water level is 117 feet below land surface.

City well no. 5 was drilled in 1943 to a depth of 533 feet. The static water level was 121 feet below land surface when the well was completed in December 1943 but had declined to 155 feet below land surface by August 1944. The well is equipped with a turbine pump powered by an electric motor. The well is reported to yield 220 gallons a minute and to have a drawdown in excess of 195 feet after 10 hours of pumping.

Water is stored in two reservoirs having a combined capacity of 750,000 gallons, and is pumped from the reservoirs into the mains by one turbine pump and three centrifugal pumps having a combined capacity of 3,650 gallons a minute. Pressure is maintained by an elevated storage tank having a capacity of 85,000 gallons. In addition to the municipally owned reservoirs, the nearby Army air base has a 250,000-gallon reservoir in which water purchased from the city of Liberal is stored.

The average daily consumption of water, which was about 500,000 gallons in 1940, had increased to approximately 2,000,000 gallons in 1944.

The residents of Kismet purchased water from the Chicago, Rock Island, and Pacific Railway Company until about 1935 when a municipal water-supply system was installed. The city-owned well was drilled to an estimated depth of 250 feet. The casing is open at the bottom only, is 6 inches in diameter, and is made of galvanized iron. Gravel is reported to be the chief aquifer. The pump, which also lifts the water to the storage tank, is a 250-gallon-a-minute vertical centrifugal pump powered by a 7½-horsepower electric motor. The reservoir is a 37,500-gallon tank elevated 80 feet above the land surface. The water is distributed by gravity. The consumption is estimated by Zed Coffey, the city marshal, to average 100,000 gallons a month in winter and 500,000 gallons a month in summer. The total cost of the system, including the well, is placed at $4,000. A chemical analysis of the water is listed in Table 9.

RAILROAD SUPPLIES

The Chicago, Rock Island, and Pacific Railway Company maintains water-supply wells at Kismet and at Liberal. Similar wells were maintained at Arkalon until that community was cut off from the railroad by the construction of a cut-and-fill designed to reduce grade and to eliminate curves in crossing Cimarron Valley.

The City of Kismet was formerly supplied with water obtained from the railroad's well, as previously mentioned. The well is reported to be 245 feet deep and is cased with 12-inch wrough-iron casing. The aquifer is a coarse sand. The surface pump, a plunger type with a capacity of 85 gallons a minute, is operated by a 60-horsepower steam engine and also lifts the water to the 38,000-gallon elevated storage tank.

The same railroad has three locomotive-supply wells (railroad nos. 5, 7, and 8) and one stockyard well in its Liberal yards. No. 5, the one farthest west, is reported to be about 169 feet deep and to yield 150 gallons a minute with a drawdown of 7.5 feet. The well is equipped with a turbine pump. Railroad well no. 7, intermediate in position between the other two, is reported to be 200 feet deep, to have a capacity of 60 gallons a minute, and to be equipped with a single-action pump jack operated by a 15-horsepower internal-combustion engine.

Railroad well no. 8, the easternmost locomotive-supply well, was drilled in 1923 and is reported to be 300 feet deep. It is cased with 12-inch steel casing to a depth of 268 feet. The bottom of the casing is finished with a 60-foot strainer. The aquifer is a coarse sand extending from 270 to 300 feet below land surface. The double-action plunger pump has a capacity of 116 gallons a minute and is operated by a 15-horsepower oil engine. The stockyards well is reported to be 183 feet deep. The water from the wells is lifted to elevated tanks by the surface pumps.

INDUSTRIAL SUPPLIES

Two natural-gas pipeline compressor stations have been constructed in Seward County and both rely upon supplies of well water. The station of the Northern Natural Gas Company was in process of construction during the period of this investigation. The following information was supplied by Frank Rabb, the company's resident construction engineer. Two wells were drilled in June 1940, the west one to a depth of 266 feet and the east one to a depth of 264 feet. The logs of the two wells are essentially alike and only one of them is included in the section on well logs. The wells were cased with 10-inch steel casing to a depth of 251 feet, the bottom 30 feet having been perforated with 216 1 by 6 inch holes and protected by 12-inch copper gravel guard. The wells were gravel-packed to the top, the gravel particles ranging from ¾-inch to 1½ inches in diameter. The static water level was 184 feet below land surface. Two electrically driven turbine pumps having capacities of 50 gallons a minute each were to be installed. Pumping tests indicated a yield of 100 gallons a minute with a drawdown of 6 feet after 10 hours of pumping. The water is stored in an elevated steel tank.

The Panhandle Eastern Pipeline Company has constructed a compressor station in the Cimarron Valley near Arkalon. The station is supplied with water obtained from five wells, four of which were drilled in 1930 and 1931 and the fifth in 1937. Information relative to the most recently drilled well was given by H. H. Duff of the company's resident staff. This well was drilled to a depth of 147 feet. The aquifer is a clean water sand encountered between the depths of 93 and 145 feet. The bottom 104 feet of the 13-inch casing was perforated with 72 holes to the foot. The lower 131 feet of the hole was walled with ¼- to 1-inch gravel, the top 16 feet having been walled with clay. The well is equipped with a vertical centrifugal pump having a rated capacity of 200 gallons a minute and operated by a 10-horsepower electric motor. The water is stored in a 75,000-gallon elevated metal storage tank (standing about 40 feet above the land surface). Booster pumps also are employed in lifting the water to the storage tank. No information on the older wells was available at the local office.

POSSIBILITIES OF FURTHER DEVELOPMENT OF INDUSTRIAL SUPPLIES FROM WELLS

Abundant supplies of natural gas and ground water are available in Seward County for the development of industries. Seward County is underlain by thick deposits of water-bearing material that would yield moderate to large quantities of water to wells (Pl. 3). Industrial wells could be developed in almost any part of the area provided preliminary test drilling indicated an adequate thickness of coarse-grained water-bearing material. The area in which industrial supplies could be developed is much larger than the area in which irrigation supplies could be developed because industry would not be as limited by the type of soil and by the pumping lift.

IRRIGATION SUPPLIES

The deficiency of precipitation during the past decade (1931-1940) has occasioned a considerable interest among the residents of the county in the possibilities of irrigation with water from wells. Two irrigation projects have been attempted to date, the earlier one now abandoned and the later one still in the proving phase of its operation (Pl. 6). The wells (128 and 22) are listed and described in Table 10, but in view of the general interest, more complete accounts are given below.

Liberal Deep-Well Irrigation Company project.—The Liberal Deep-Well Irrigation Company project (Lee Larrabee, who supplied most of the following information, President, and Willard Mayberry, Secretary-Treasurer) was the result of an effort to demonstrate the feasibility of small-scale irrigation with water obtained from deep wells. The supply well (128) was drilled in 1937 on the C. M. Light farm a short distance north of Liberal. The well was reported to be 350 feet deep and the chief aquifer was a coarse sand from 175 to 225 feet below the land surface. A 15-inch steel casing was installed and was enclosed within a gravel envelope 12 inches thick. A 200-foot section of the casing was perforated with shutter-type apertures. The well was equipped with a 7-stage turbine pump having a capacity of 1,000 gallons a minute and operated by a 96-horsepower natural gas engine. The well was reported to yield 256 gallons a minute with a drawdown of 126 feet. Schoff (1939, p. 124) cites the following expenses in its construction: cost of well, including casing and gravel envelope, $3,000; cost of pump, $2,100; cost of engine, $1,200; and total cost, $6,300.

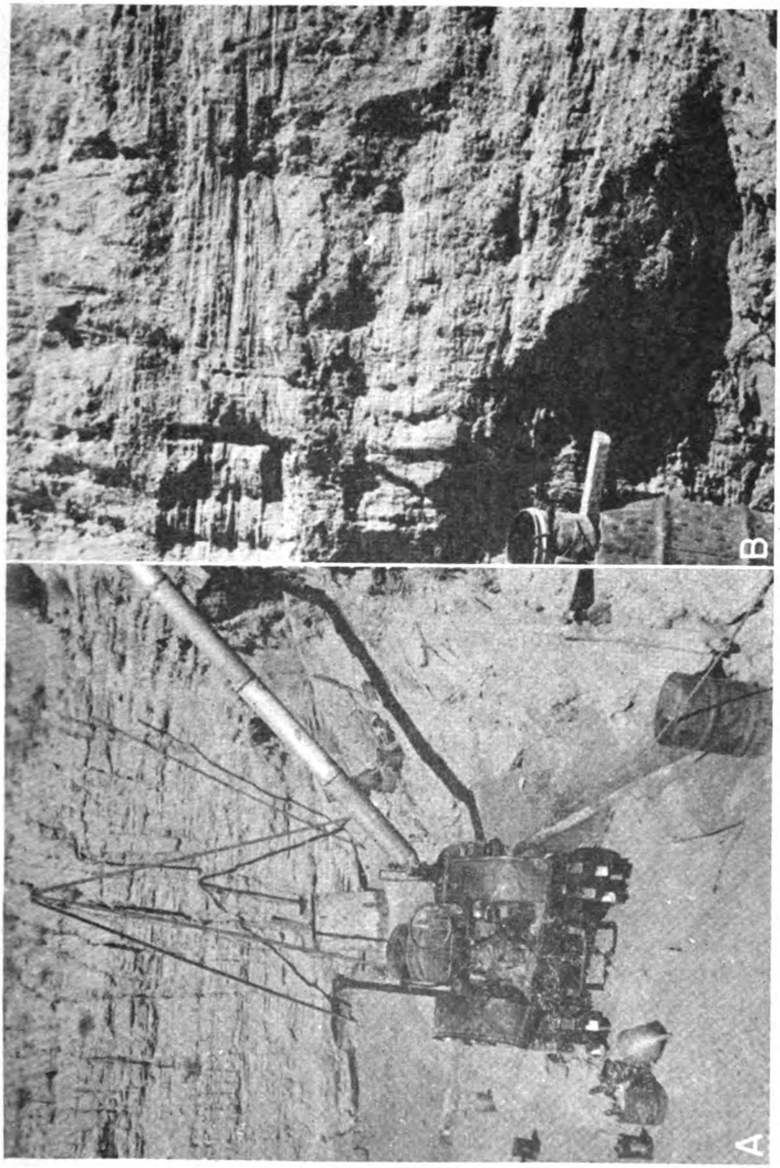

PLATE 6. *A*, The Harlow irrigation well. *B*, Wall of Harlow irrigation pit showing bedding. Photographs by Frank E. Byrne.

The equipment was installed too late in the summer of 1937 for a crop to be irrigated. In 1938, 60 acres of land was seeded to diversified garden truck. The crop that was grown was satisfactory but market prices were below normal and the income from the sale of the produce was less than the expenses of operation. No effort was made to produce a crop in 1939 and in 1940 the project was abandoned.

Harlow irrigation project.—This project (well no. 22) was undertaken by R. Y. Harlow in the late spring of 1940 on the Harlow farm in sec. 5, T. 31 S., R. 34 W. The farm lies part way up the valley slope on the east side of Cimarron River at the north boundary of the county. The project was completed on July 25, 1940, all the necessary work having been done by Mr. Harlow and his son.

Using a team and a slip, the Harlows excavated a rectangular pit (Pl. 6) to a depth of about 34 feet. Two wells were then dug into the floor of the pit by means of a sand bucket, the east well to a depth of 13.6 feet through sand and fine gravel and the west well to a depth of 15.7 feet through the same material. The layers of sand, gravel, and silt that were penetrated are thin-bedded and some of the seams of gravel and sand are strongly cross-bedded (Pl. 6B). Occasional cobbles of hard rock and boulders of soft clay are visible in the walls of the pit. The sediments are not indurated although there are thin zones of caliche.

Open-end oil barrels were then installed as casings, these being irregularly perforated by means of hammer and chisel. Two 6-inch supply lines are connected to a vertical centrifugal pump having a capacity of 1,000 gallons a minute. The pump is driven by a 4-cylinder gasoline engine connected with the pump by a belt drive. An inclined 10-inch discharge pipe carries the water from the pump to the earthen reservoir at the surface. The rate of discharge is estimated by Mr. Harlow to be 450 gallons a minute and is limited by the drawdown in the shallower east well.

The project supplies water for the irrigation of about 15 acres of sandy silt soil planted to cane and garden truck. The water moves from the reservoir to the fields in open ditches. No evaluation of the success of this project could be made at the time of this investigation. An earlier irrigation effort was made about 25 years ago by Mr. Harlow, the water then having been supplied by two windmill wells. The earlier experiment is reported to have produced good crops.

POSSIBILITIES OF FURTHER DEVELOPMENT OF IRRIGATION SUPPLIES FROM WELLS

The water table in most of Seward County lies too far below the land surface for water to be pumped economically for irrigation. The only place where the water table is near the land surface is in Cimarron Valley where most of the level bottom land has been removed by the widening channel of Cimarron River.

The only place on the upland areas of Seward County where the water table is less than 100 feet below land surface is an area of about 28 square miles between Liberal and the Stevens County line (Pl. 2). A large part of this area, however, is underlain by dune sand and is not suitable for irrigation. It was in this area that the first gas well in the Hugoton field was drilled; hence there is an abundant supply of low-cost fuel available for use in pumping water for irrigation where the depth to water is not excessive and where the soil and slope are suitable. Inasmuch as only small areas are suitable for irrigation the quantity of water available should be adequate to supply all the wells that may be drilled.

Quality of Water

The chemical character of the ground water utilized in Seward County is shown by the 20 analyses of water listed in Table 9. All samples, except those of wells 63 and 130, were collected by Frank E. Byrne during August 1940. The other two samples were collected from public-supply wells at Kismet and Liberal by the Kansas State Board of Health earlier in the same year. The analyses were made by Robert H. Hess, then chemist in the Water and Sewage Laboratory of the Kansas State Board of Health. The analyses, in general, do not indicate the sanitary condition of the waters as they show only the dissolved mineral contents. The constituents listed were determined by the methods used by the U. S. Geological Survey.

CHEMICAL CONSTITUENTS IN RELATION TO USE

The following discussion of the chemical constituents of ground water in relation to use was adapted from publications of the U. S. Geological Survey.

Dissolved solids.—When water is evaporated the residue consists mainly of the mineral constituents listed in Table 9 and generally includes a small quantity of organic material and a little water of crystallization. Waters containing less than 500 parts per million

Table 9.—*Analyses of water from typical wells in Seward county, Kansas*
(Analyzed by Robert H. Hess. Parts per million[1] and (in italics) equivalents per million.[2])

Well No. on plate 2	Location, Depth, Geologic Horizon	Date of collection, 1940	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)[2]	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness (calculated as $CaCO_3$)		
														Total	Carbonate	Noncarbonate
	T. 31 S., R. 32 W.															
8	NW NE sec. 4, 185 feet, Plioce e and Pleistocene undifferentiated..........	Aug. 18	62	0.19 *.01*	53 *2.64*	17 *1.40*	33 *1.43*	203 *3.33*	82 *1.71*	9.5 *.27*	0.9 *.05*	6.6 *.11*	304	203	166	37
	T. 31 S., R. 34 W.															
22	NE NE sec. 5, 48 feet, Recent alluvium..	do......	61	.00	69 *3.44*	20 *1.64*	39 *1.71*	237 *3.89*	108 *2.25*	11 *.31*	.6 *.03*	19 *.31*	385	254	194	60
23	NE SE sec. 6, 114 feet, Pliocene and Pleistocene undifferentiated..........	do......	61	.03 *.03*	46 *2.30*	15 *1.23*	41 *1.80*	236 *3.87*	45 *.94*	11 *.31*	.6 *.03*	11 *.18*	288	177	177[3]	0
24	NW NE sec. 14, 205 feet, Pliocene and Pleistocene undifferentiated..........	Aug. 17	64	.2	61 *3.04*	18 *1.48*	33 *1.44*	233 *3.82*	84 *1.75*	9.5 *.27*	.6 *.03*	5.3 *.09*	328	226	191	35
	T. 32 S., R. 31 W.															
31	NE SE sec. 12, 178 feet, Pliocene and Pleistocene undifferentiated..........	Aug. 18	61	.19 *.01*	49 *2.45*	14 *1.15*	26 *1.13*	192 *3.15*	57 *1.19*	9 *.25*	.7 *.04*	6.2 *.10*	258	181	157	24
	T. 32 S., R. 33 W.															
53	SE SW sec. 21, 153 feet, Recent alluvium	Aug. 20	60	.08	56 *2.79*	31 *2.55*	44 *1.90*	231 *3.79*	139 *2.89*	14 *.39*	1.2 *.06*	6.6 *.11*	407	267	189	78
	T. 33 S., R. 31 W.															
63	SE SW sec. 4, 150 feet, Pliocene and Pleistocene undifferentiated..........	Feb. 13[4]	tap	.6	63 *3.14*	20 *1.64*	38 *1.66*	232 *3.80*	99 *2.06*	13 *.37*	.0 *.0*	13 *.21*	389	239	190	49
69	SE SE sec. 23, 225 feet, Pliocene and Pleistocene undifferentiated..........	Aug. 18	64	.19 *.01*	64 *3.19*	23 *1.89*	40 *1.73*	220 *3.61*	133 *2.77*	13 *.37*	.8 *.04*	1.5 *.02*	286	255	180	75
	T. 33 S., R. 33 W.															
78	NW NE sec. 4, 152 feet, Pliocene and Pleistocene undifferentiated..........	do......	63	.43 *.02*	58 *2.89*	25 *2.06*	32 *1.37*	232 *3.80*	91 *1.89*	14 *.39*	.6 *.03*	13 *.21*	350	249	59	190
	T. 33 S., R. 34 W.															
96	SE NW sec. 23, 112 feet, Pliocene and Pleistocene undifferentiated..........	do......	63	.79 *.03*	62 *3.09*	22 *1.81*	29 *1.27*	242 *3.97*	74 *1.54*	17 *.48*	.4 *.02*	10 *.16*	336	247	198	49

TABLE 9.—*Analyses of water from typical wells in Seward County, Kansas—Concluded*

Well No. on plate 2	Location, Depth, Geologic Horizon	Date of collection, 1940	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)[2]	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness (calculated as $CaCO_3$)		
														Total	Carbonate	Noncarbonate
	T. 34 S., R. 31 W.															
100	NE SW sec. 5, 29 feet, Recent alluvium..	Aug. 18	62	.0	71 *3.54*	19 *1.56*	41 *1.80*	216 *3.54*	134 *2.79*	14 *.39*	.8 *.04*	8.4 *1.4*	396	255	177	78
102	NE NE sec. 27, 34 feet, Recent alluvium	do......	62	.07	74 *3.69*	21 *1.73*	67 *2.90*	215 *3.53*	72 *1.50*	111 *3.13*	.6 *.03*	8 *.13*	461	271	176	95
	T. 34 S., R. 32 W.															
105	NE SE sec. 8, 270 feet, Pliocene and Pleistocene undifferentiated..........	do......	62	1.8 *.06*	61 *3.04*	17 *1.40*	17 *.75*	220 *3.61*	49 *1.02*	17 *.48*	.3 *.02*	3.5 *.06*	277	225	180	45
113	SE SE sec. 23, 216 feet, Pliocene and Pleistocene undifferentiated..........	do......	......	.7 *.03*	64 *3.19*	19 *1.56*	27 *1.18*	212 *3.48*	76 *1.58*	24 *.68*	.5 *.03*	10 *.16*	327	239	174	65
	T. 34 S., R. 33 W.															
118	SW SW sec. 3, 257 feet, Pliocene and Pleistocene undifferentiated..........	do......	62	.12	66 *3.29*°	19 *1.56*	19 *.84*	203 *3.33*	82 *1.71*	15 *.42*	.3 *.02*	13 *.21*	316	243	166	77
130	SW NE sec. 32, 506 feet, Pliocene and Pleistocene undifferentiated..........	Jan. 13	tap	.07	50 *2.50*	22 *1.81*	28 *1.20*	217 *3.56*	70 *1.46*	9 *.25*	.0 *.0*	15 *.24*	338	216	178	38
	T. 34 S., R. 34 W.															
133	NE NW sec. 7, 130 feet, Pliocene and Pleistocene undifferentiated..........	Aug. 18	63	1.3 *.05*	66 *3.29*	14 *1.15*	21 *.92*	233 *3.82*	33 *.69*	23 *.65*	.3 *.02*	11 *.18*	286	225	191	34
141	SW SW sec. 33, 93 feet, Pliocene and Pleistocene undifferentiated..........	do......	62	1.9 *.07*	56 *2.79*	22 *1.81*	14 *.59*	225 *3.69*	34 *.71*	18 *.51*	.7 *.04*	15 *.24*	274	234	184	50
	T. 35 S., R. 31 W.															
146	SE NE sec. 15, 211 feet, Pliocene and Pleistocene undifferentiated..........	Aug. 19	63	1 *.04*	70 *3.49*	24 *1.97*	75 *3.27*	234 *3.84*	60 *1.25*	122 *3.44*	.7 *.04*	10 *.16*	480	275	192	83
	T. 35 S., R. 33 W.															
157	SW NW sec. 15, 180 feet, Pliocene and Pleistocene undifferentiated..........	do......	61	.08	38 *1.90*	32 *2.63*	16 *.71*	211 *3.46*	54 *1.12*	12 *.34*	3 *.16*	9.7 *.16*	270	227	173	54

1. One part per million is equivalent to 1 pound of substance per million pounds of water or 8.33 pounds per million gallons of water.
2. Calculated.
3. Total alkalinity, 193 parts per million; excess alkalinity, 16 parts per million.
4. 1939.

of dissolved solids generally are entirely satisfactory for domestic use, except for difficulties resulting from their hardness or occasional excessive content of iron. Waters containing more than 1,000 parts per million are likely to include enough of certain constituents to produce a noticeable taste or to make the water unsuitable in some other respects.

The dissolved solids did not exceed 500 parts per million in any of the samples of water that were collected in Seward County. Consequently, all waters that were sampled can be considered suitable for most ordinary uses. Three of the samples of water (from wells 53, 102, and 146) contained between 400 and 500 parts per million of dissolved solids, 11 of the samples contained between 300 and 400 parts per million, and the 6 samples contained between 200 and 300 parts per million.

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

In addition to the total hardness, the table of analyses shows the carbonate hardness and the noncarbonate hardness. The carbonate hardness is that due to the presence of calcium and magnesium bicarbonates and can be almost entirely removed by boiling. In some reports this type of hardness is called temporary hardness. The noncarbonate hardness is due to the presence of sulfates or chlorides of calcium and magnesium; 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 generally is rated as soft, and its treatment for the removal of hardness under ordinary circumstances is not necessary. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for most purposes; however, it does slightly increase the consumption of soap, and its removal by a 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 in some areas 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 range in hardness in the water samples from Seward County was from 258 to 480 parts per million. The supplies for Kismet (389 parts per million) and Liberal (338 parts per million) are not softened before being discharged into the mains but may be softened in the home or in industry before consumption. All waters used in the locomotives of the Chicago, Rock Island, and Pacific Railway Company are treated before use.

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

Two of the water samples collected from wells in Seward County contained no iron (22 and 100). Five wells (23, 53, 102, 130, and 156) yielded water containing less than 0.1 part per million of iron and nine samples (8, 24, 31, 63, 69, 78, 96, 113, and 118) contained more than 0.1 part per million but less than 1.0 part per million. Samples taken from wells 105, 113, 141, and 146 contained 1.0 part per million or more of iron. The iron content of the water from well 141 was the highest of all those sampled, 1.9 parts per million.

Fluoride.—Although determinable quantities of fluoride are not so common as fairly large quantities of the other constituents of natural water, it is desirable to know the amount of fluoride present in water that is likely to be used by children. Fluoride in water has been shown to be associated with the dental defect known as mottled enamel, which may appear on the teeth of children who, during the period of formation of the permanent teeth, drink water containing fluoride. It has been stated that waters containing one part per million or more of fluoride are likely to produce mottled enamel, although the effect of one part per million is not usually very serious (Dean, 1936). If the water contains as much as four parts per million of fluoride, 90 percent of the children drinking the water are likely to have mottled enamel, and 35 percent or more of the cases will be classified as moderate or worse. Small quantities of fluoride, not sufficient to cause mottled enamel, are likely to be beneficial by decreasing dental caries (Dean, Arnold, and Elvove, 1942).

Only two of the water samples collected in Seward County contained fluoride in excess of one part per million. Well 53 contained 1.2 parts per million of fluoride and 156 contained 3.0 parts per million.

Water for irrigation.—The suitability of water for use in irrigation is commonly believed to depend mainly on the total quantity of soluble salts and on the ratio of the quantity of sodium to the total quantity of sodium, calcium, and magnesium. The quantity of chloride may be large enough to affect the use of the water and in some areas 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) states 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. 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 sodium to 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 and the crops, on the manner of use, and on the drainage that no definite limits can be adopted.

The mineral content of the samples of water collected in Seward County did not exceed any of the limits of suitability for irrigation as determined by Scofield; hence, ground water from any part of Seward County probably would be suitable for irrigation.

SANITARY CONSIDERATIONS

The analyses of water given in Table 9 show only the amounts of dissolved mineral matter in the water and do not indicate the sanitary quality of the water. An abnormal amount of certain mineral matter, such as nitrate, however, may indicate pollution of the water.

About one-third of the prewar population of Seward County was dependent upon private water supplies from wells and every precaution should be taken to protect these supplies from pollution. A well should not be located where there are possible sources of pollution, such as barnyards, privies, and cesspools, and every well should be tightly sealed down to a level somewhat below that of the water table. As a general rule, dug wells are more subject to contamination from surface water than are drilled wells, chiefly because they generally are not effectively cased or sealed at the surface. Drilled wells generally are well protected by the casing, although many are poorly sealed at the top.

QUALITY OF WATER IN RELATION TO WATER-BEARING FORMATIONS

The general character of water from the principal water-bearing formations in Seward County is indicated in Figure 9 and is discussed below.

Pliocene and Pleistocene formations.—The Laverne, Rexroad (?), and Meade formations yield water to most of the wells in Seward County. The Rexroad (?) is the principal water-bearing formation in the area because in most places the water table is near or below the base of the Meade formation and because ground water in the Laverne formation generally is not utilized owing to its considerable depth. Because of the lithologic similarity of the coarse water-bearing materials in these formations and because a large number of wells probably obtain water from more than one formation, the quality of the water from the three formations will be discussed in one section.

Samples of water from these deposits ranged in hardness from 177 to 275 parts per million, the average being 231 parts per million. The amount of dissolved solids ranged from 258 to 480 parts per million and averaged 333 parts per million. The average fluoride content of these waters was 0.7 parts per million.

Alluvium.—Water from the Recent alluvium of Cimarron River is generally of poorer quality than that from the water-bearing formations mentioned above. Three samples of water were collected

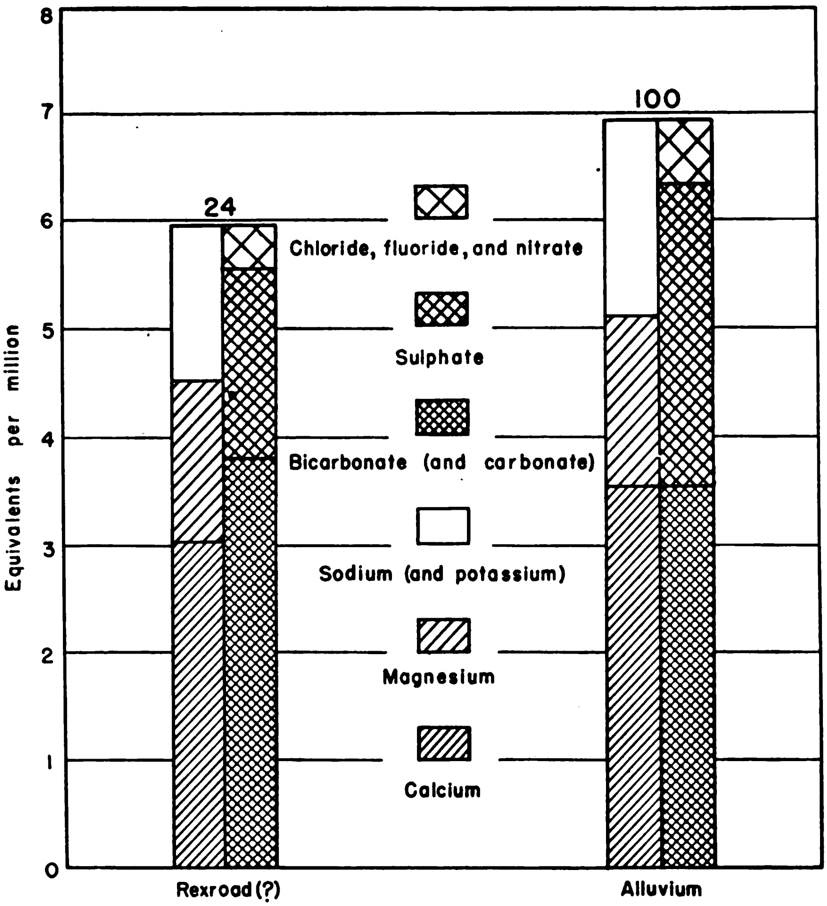

FIG. 9. Analyses of waters from the principal water-bearing formations in Seward County.

from wells ending in these deposits. The average hardness of these waters was 259 parts per million. The amount of dissolved solids averaged 396 parts per million and the fluoride content averaged 0.9 part per million.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Permian System

UNDIFFERENTIATED REDBEDS

Character.—The undifferentiated redbeds of Permian age do not crop out in Seward County; hence the only available data concerning these beds are the logs of gas wells that have been drilled in the Seward County part of the Hugoton gas field. The redbeds encountered in these wells consist principally of red shale, siltstone, and sandstone containing interbedded salt, gypsum, anhydrite, and dolomite.

Distribution and thickness.—The Permian redbeds underlie all of Seward County but they do not crop out. The nearest outcrop of these deposits is in southeastern Meade County about 14 miles east of Seward County. The thickness of redbeds exposed in Meade County is more than 100 feet (Frye, 1942, p. 93). Because there is an erosional unconformity between the Permian redbeds and the overlying sediments of Cretaceous age or younger, the thickness of the redbeds in this area is variable. Most of the gas wells in this and adjacent areas penetrate between 1,200 and 1,600 feet of redbeds.

Water supply.—No wells in Seward County obtain water from the Permian redbeds owing to their considerable depth. These beds yield highly mineralized water to a few artesian wells in Morton County. Potable water is reported to have been encountered in several gas wells in the Hugoton field but no chemical analyses of these waters are available.

Cretaceous System

GULFIAN SERIES

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

Dakota Formation

Character.—The character of the Dakota formation in Seward County was determined by a study of the cuttings from two test holes in the northwestern part of the county (logs 3 and 4). The formation consists principally of buff and brown sandstone and varicolored clay. The sandstone generally consists of very fine- to medium-grained quartz sand. The clay ranges from gray to various shades of brown, red, and purple and generally contains very fine- to fine-grained quartz sand. Where the Dakota formation crops out in southwestern Kansas the sandstone generally is poorly bedded, and in some places it is strongly ripple-marked and cross-bedded. The cementing material in the sandstone generally is iron oxide.

Distribution and thickness.—The Dakota formation underlies only the northwestern corner of Seward County (Pl. 3). The formation also underlies most of southwestern Kansas. It is absent in parts of Morton, Stevens, Seward, Meade, and Haskell Counties.

The thickness of the Dakota formation in Seward County ranges from a featheredge at its southern limit to approximately 100 feet at the northwest corner of the county. Only one test hole (4) penetrated the entire thickness of the Dakota formation in Seward County. The formation at that point was 72 feet thick. In adjacent areas to the northwest the formation is 100 to 150 feet thick, and in north-central Kansas the formation is more than 300 feet thick (Plummer and Romary, 1942, p. 330).

Water supply.—No wells obtain water from the Dakota formation in Seward County because adequate quantities of potable water are available from the overlying Tertiary and Quaternary deposits. Water from the Dakota formation in adjacent areas generally is of poorer quality than water from the overlying deposits.

Tertiary System

PLIOCENE SERIES

Laverne Formation

The Laverne formation was named and described from a locality in Harper County, Oklahoma, by V. V. Waite in an unpublished manuscript which was quoted by Gould and Lonsdale (1926). These beds were studied in 1889 by Cragin (1891) who correlated them with the "Loup Fork beds." Case (1894) made a collection of the flora of these beds in 1893. Adams (1902) described similar rocks in Cimarron Valley in southeastern Seward County and suggested that they were of Tertiary age and that they were equivalent to the beds previously described by Cragin in Oklahoma. The flora and fauna of the Laverne formation in Beaver County, Oklahoma, were described more recently by Chaney and Elias (1936, pp. 16-

23). Detailed studies of the Laverne formation in Kansas have been made recently by Frye and Hibbard (1941), Frye (1942), and McLaughlin (1945).

Character.—The Laverne formation exposed in Cimarron Valley in Meade and Seward Counties consists primarily of steeply dipping beds of shale, chalky sandstone, sand, and gravel containing caliche and thin-bedded limestone. Test holes drilled in that area indicate that the lower part of the formation consists principally of sand and gravel containing interbedded clay or shale (Pls. 7 and 8).

The sand and gravel is made up of materials derived from igneous rocks and consists principally of quartz and feldspar although mica is abundant at some horizons. The beds of sand and gravel where exposed generally are moderately well sorted, in part cross-bedded, and in places cemented with calcium carbonate to form "mortar beds."

The clay and shale generally are light gray to dark blue gray but locally may be light green, pink, or maroon. The clay in many places contains fine quartz sand and mica. The shale is thinly bedded and the clay generally is massive, blocky, and poorly bedded.

The calcareous or chalky sandstone is soft, friable, poorly bedded, very porous, and is fine-grained to very fine-grained. These beds are known locally as "sawrock" inasmuch as they can be cut easily with a saw and have been quarried locally for building stone (Pl. 9B). These beds generally are cream-colored to buff but they weather to brown, dark gray, and nearly black. They contain abundant ostracodes and some remains of fish. Sections of the Laverne formation measured by Claude W. Hibbard and Thad G. McLaughlin are given below and on page 74.

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

	Thickness, feet
TERTIARY—Pliocene	
Laverne formation	
15. Sandstone, fine to coarse, light tan to buff	2
14. Shale, gray, poorly bedded	5
13. Caliche, sandy, very hard, white. Weathers to smooth round boulders	.5
12. Shale, thin-bedded, varicolored. Predominantly yellowish near base, gray in middle, and pink to maroon near top	6.1
11. Sandstone, fine-grained, compact, hard. Forms prominent ledge. Weathers to large disc-shaped blocks having pitted surface. Top 4 inches contains caliche	3

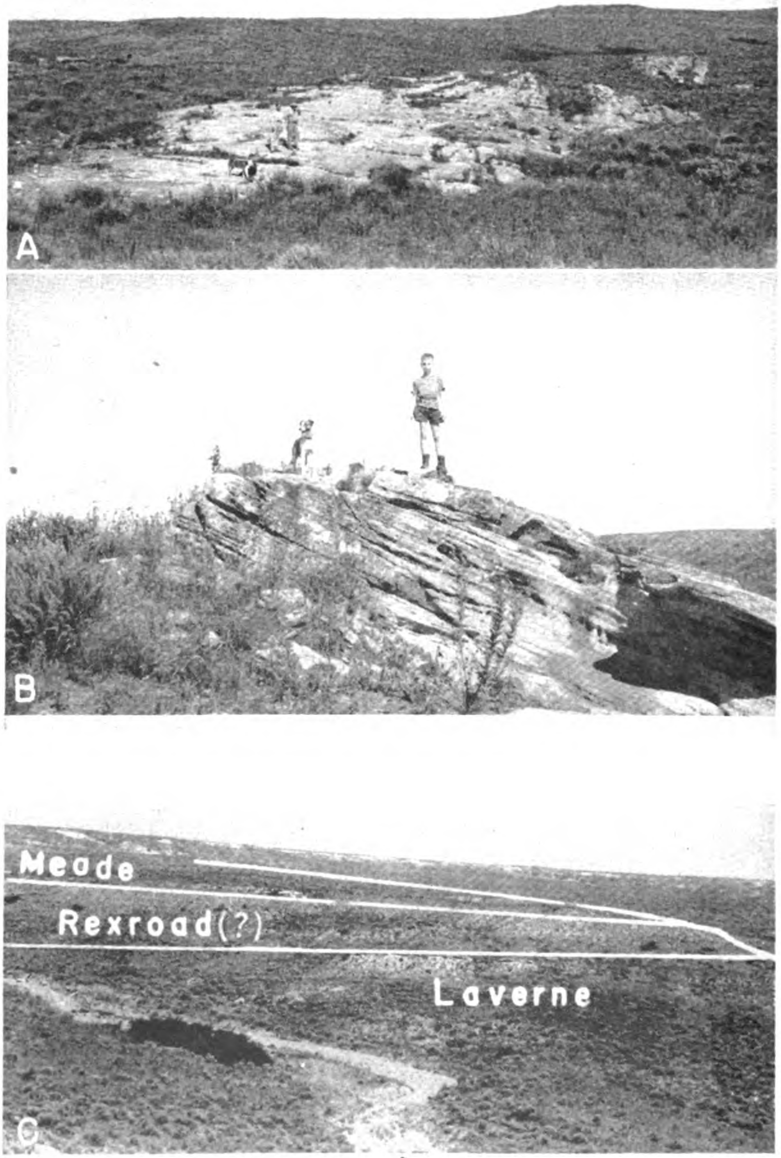

PLATE 8. *A,* Tilted beds of the Laverne formations in NE¼ NW¼ sec. 32, T. 34 S., R. 30 W., Meade County. Photograph by S. W. Lohman. *B,* Close-up view of the above picture. Photograph by S. W. Lohman. *C,* Meade, Rexroad (?), and Laverne formations in SW¼ SW¼ sec. 13, T. 34 S., R. 31 W., Seward County. Photograph by Thad G. McLaughlin.

10.	Alternating thin beds of gray, tan, and green shale and buff friable sandstone. Beds contain a few white limy zones. Abundant crystals of gypsum in upper part.....	19.2
9.	Shale, dark gray; contains lenses of thin buff sandstone.	1.3
8.	Sandstone, medium-grained, white; contains thin partings of dark-gray shale	.6
7.	Caliche, dense, hard, white...........................	.3
6.	Shale, massive, light gray to blue gray..................	3.6
5.	Sand, fine to coarse, yellowish buff to rusty brown, and fine gravel; unconsolidated to moderately well consolidated. Forms massive ledge when consolidated.........	12
4.	Silt, sandy, and clay..................................	12
3.	Sandstone, fine-grained and very fine-grained, very porous, highly calcareous, even-bedded, cream colored to light tan; contains silt and lesser amounts of medium sand and clay. In places it is case-hardened. Locally known as "sawrock." Contains abundant ostracodes....	21
2.	Shale, silty, calcareous, diatomaceous, light buff to yellow tan; contains sand	20–30
1.	Clay, blue gray	20
	Thickness of Laverne formation exposed................	126.6–136.6

Distribution and thickness.—The Laverne formation crops out in Meade and Seward Counties, Kansas, and in Beaver and Harper Counties, Oklahoma, but the subsurface extent of the formation probably is much greater than is indicated by the limited areas of outcrop. These beds probably underlie much of Seward, Haskell, Stevens, and Grant Counties, Kansas, as well as large areas in Oklahoma. They are absent in part of Morton, Stanton, and Hamilton Counties where the Cretaceous or older bedrock crops out or is overlain by the Ogallala formation. Similarly, they probably do not extend east of Crooked Creek in Meade County where the Permian redbeds are exposed or are overlain by the Ogallala formation. The northern and southern limits of these deposits are not known.

The thickness of the Laverne formation is not known inasmuch as the base of the formation is nowhere exposed. About 80 feet of these beds have been measured near the mouth of Wolf Canyon in sec. 7, T. 35 S., R. 30 W., Meade County, and about 135 feet have been measured in sec. 25, T. 34 S., R. 31 W., Seward County. Test holes in Meade and Seward Counties (16, 18, and 20) that were begun on Laverne strata penetrated from 301 to 464 feet of material before entering the Permian redbeds. All of this material is believed to be a part of the Laverne formation. The test hole that penetrated 464 feet of material (20) was begun on a ledge of "sawrock" (bed 4 in measured section on page 75); hence, the total thickness of these beds may exceed 500 feet.

Water supply.—Relatively few wells in Seward County obtain all their water from the Laverne formation because adequate quantities of water generally can be obtained in the overlying Rexroad (?) formation. Many of the deep wells that obtain most of their water from the Rexroad (?) formation may also obtain some water from the Laverne. Some of the municipal wells at Liberal, for example, penetrate all water-bearing materials that lie above the Permian redbeds.

Test holes drilled in this area indicate that in many places the Laverne formation contains thick deposits of sand and gravel and therefore is an important potential source of large quantities of ground water.

Ogallala Formation

The Ogallala formation does not crop out in Seward County and whether or not it is present in the subsurface cannot be determined at present. Where the Cimarron Valley has been cut below the base of the Rexroad formation in southeastern Seward County and southwestern Meade County, it has been found that the Rexroad beds overlie the Laverne formation and that the Ogallala formation is absent. The absence of the Ogallala in these places can be explained in two ways: 1. The more resistant beds of the Laverne formation formed "high" areas over which the Ogallala sediments were not deposited. 2. The post-Ogallala erosion removed much or all of the Ogallala formation in this area before the Rexroad sediments were laid down.

The beds in the upper part of the Laverne formation are, in general, more resistant than those of the other Cenozoic formations of this area. On the Nieland Ranch, for example, the tilted Laverne beds formed a "high" during most of Rexroad time and are overlain only by the uppermost beds of the Rexroad. This indicates that the upper beds of the Laverne formation in this area are sufficiently resistant to have remained above the level of deposition during Ogallala time.

The principal evidence that much or all of the Ogallala formation was removed from this area during the interval of erosion between Ogallala time and Rexroad time is that all beds that are known to be Rexroad and those believed to be Rexroad lie at an elevation below that of a line projected from the base of the Ogallala in Morton County to the base of the Ogallala along Crooked Creek in Meade County. The position of the Rexroad beds in relation to that of the Ogallala beds could be accounted for in parts of the Meade Basin by faulting and by subsidence but there is no evidence of either faulting or subsidence between southeastern Seward County and Point of Rocks in Morton County.

Inasmuch as the Ogallala formation does not crop out in Seward County and as there is strong evidence that erosion removed much or all of the Ogallala beds in this area, the Ogallala formation is herein considered absent in Seward County.

Rexroad (?) Formation

The Rexroad formation was named by Smith (1940, pp. 95-99) from exposures along tributaries of Crooked Creek on the Rexroad Ranch in sec. 22, T. 33 S., R. 29 W., Meade County, Kansas. In 1941 Frye and Hibbard (1941, p. 407) designated these beds the Rexroad member (upper Pliocene) of the Ogallala formation. Subsequently these beds have been classified as the Rexroad formation. In this report the term Rexroad (?) is used for those deposits in Seward County that are believed by us to correlate with the Rexroad formation in Meade County.

Character.—The Rexroad (?) formation consists of sand and gravel in the lower part, silt to coarse gravel containing nodules and stringers of caliche in the middle, and silt and clay containing caliche in the upper part (Pl. 7).

The basal sand and gravel deposit lies in channels in the underlying deposits. For this reason there is wide variation in its thickness. In at least one place the sand and gravel deposit is absent (NW¼ sec. 24, T. 34 S., R. 31 W.). At this place the Laverne formation lies about 15 feet below the base of the Meade formation. The tilted Laverne strata were high erosional remnants that were not covered until near the close of Rexroad (?) deposition.

The sand and gravel consist of materials derived from igneous rocks. The gravel consists of fragments of feldspar, quartz, and some chalcedony, and the sand is made up principally of quartz. In most places at least part of this deposit has been cemented with calcium carbonate to form "mortar beds" which form prominent ledges in some places along Cimarron Valley. The "mortar beds" in the Rexroad (?) formation differ markedly from those in the Ogallala formation in adjacent areas. They are coarser-grained, contain less calcium carbonate, and weather to a smoother surface.

The "mortar beds" of the Rexroad (?) resemble more closely those of the Meade formation. Those in the Meade formation generally are coarser-grained but this cannot be used as a criterion for distinguishing them.

The middle part of the Rexroad (?) formation represents a transition from the coarse sand and gravel in the lower part to the fine sand, silt, and clay in the upper part. The middle part consists of an admixture of reddish clay, silt, sand, and gravel containing, in many places, abundant nodules and stringers of caliche giving the rock a mottled red and white appearance. The top and bottom of this part of the formation is not sharply defined inasmuch as it grades into the upper and lower parts. The middle part is very poorly sorted and is moderately well indurated.

The upper part of the formation generally consists primarily of silt, fine sand, and clay containing a few beds of caliche. Near the top of the formation is a 2-foot bed of hard cherty caliche that weathers to irregular, rough, pitted boulders. In most places, this bed has been removed by the deep-channeling preceding the deposition of the overlying Meade formation. The upper part of the formation generally is brown and gray in various shades. A thick bed of dark-brown blocky clay has been found at most places where the Rexroad (?) formation crops out.

Several sections of the Rexroad (?) formation that were measured by Claude W. Hibbard and Thad G. McLaughlin are listed below. The first was measured in one of the very few places where both the top and bottom of the Rexroad (?) formation are exposed, although in this section a few of the upper beds appear to have been removed by channeling.

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

	Thickness, feet
QUATERNARY—Pleistocene	
Meade formation	
19. Sand and gravel; coarse, locally cemented with calcium carbonate to form "mortar beds"	11
TERTIARY—Pliocene	
Rexroad (?) formation	
18. Silt, fine sandy, buff red; contains caliche	13.5
17. Silt, sandy, light brown to red; contains caliche. The caliche near the top is nodular and cherty	14
16. Silt, fine sandy, buff red to red; contains caliche. Material near the middle cemented with calcium carbonate	14
15. Caliche, siliceous, massive, very hard, white	2

14. Sand, fine to coarse, tan to buff red; contains irregular nodules and bands of caliche and much silt. Becomes finer toward top. Most of the silt and caliche are in the upper part	20
13. Sand and gravel, coarse, moderately well sorted, cross-bedded. The pebbles are predominantly igneous rocks but some are abraded fragments of caliche. The upper two-thirds of the bed is cemented with calcium carbonate to form "mortar beds." The "mortar beds" form prominent ledges that cap several low mesas and that have been eroded into long rectangular blocks	22.5
Laverne formation	
12. Clay, brown; contains lenses of rust-stained quartz sand. Weathers to gray green. Contains fragments of fossil camel,	17
11. Sand, fine to medium, gray to yellow, cemented with calcium carbonate to form "mortar beds." Bed dips eastward	15
10. Sand and gravel, unconsolidated, yellow to rusty	5.5
9. Clay, silty, blocky, tan, sandy at top	2.5
8. "Mortar beds," thin, crinkly; contains fine to medium sand,	0.2
7. Sand, fine, and silt; pinkish	1
6. Sand, fine to medium, yellowish tan; contains a few pebbles of coarse sand and gravel. Upper part cemented with calcium carbonate to form "mortar beds." Dips west-southwestward	5
5. Clay, gray	8
4. Sandstone, massive, soft, friable, highly calcareous, very porous, tan to buff; contains very fine sand, silt, and a few grains of medium sand. Contains abundant remains of ostracodes. Locally known as "sawrock"	21
3. Clay and silt; contains fine sand	2
2. Sand, fine to coarse, yellow to rusty	2
1. Sand, fine, tan	1
Thickness of Rexroad (?) formation exposed	86
Thickness of Laverne formation exposed	80.2

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

	Thickness, feet
TERTIARY—Pliocene	
Rexroad (?) formation	
8. Caliche, cherty, very hard, white. Forms prominent bench,	2
7. Unexposed. Covered by caliche rubble from above. Gentle slope indicates silt or clay	10
6. Clay, silty and fine sandy, gray brown to buff; contains thin discontinuous layers of caliche	21
5. Clay and silt, fine sandy, buff to pink; contains nodules and thin stringers of caliche	16.5

4. Sand and gravel; contains abraded pebbles of caliche and small lenses of clay	7.5
3. Clay, light brown	2
2. Clay, blue gray; contains caliche. Weathers to rusty brown,	2
1. Sand and gravel, coarse. Pebbles are predominantly igneous rocks but some are abraded caliche. Base not exposed	9–25
Thickness of Rexroad (?) formation exposed	70–86

Section of Quaternary and Tertiary deposits in SE¼ sec. 35 and SW¼ sec. 36, T. 32 S., R. 33 W., Seward County, Kansas

	Thickness, feet
QUATERNARY—Pleistocene	
Terrace deposits	
8. Sand and gravel, coarse; contains cobbles as large as 5 inches in diameter	3
Meade formation	
7. Sand and gravel, coarse; cemented near base with calcium carbonate to form "mortar beds"	20
TERTIARY—Pliocene	
Rexroad (?) formation	
6. Clay, blocky, gray green and brown. Grades upward into fine-grained micaceous sand. The sand is cemented in some places to form 4-inch "mortar bed"	3.8
5. Shale, calcareous, thin-bedded, white; contains fine sand and remains of ostracodes	0–0.5
4. Silt, fine sandy, tan at base to green at top. Varies from massive at base to blocky in middle to thin-bedded at top. Top part grades laterally into a varved diatomaceous marl,	4
3. Clay, blocky, in part sandy, brown to gray	4
2. Sand, fine, and silt; poorly sorted, consolidated, tan to reddish brown; contains nodules of caliche. Lower 5 feet is mostly fine sand containing clay as a binder. Middle 4 feet mostly tan to brown silt containing irregular nodules of caliche which give the rock a mottled appearance. Upper 4 feet predominantly massive fine-grained poorly consolidated tan to red brown sand	13
1. Sand and gravel; coarse	15
Thickness of Rexroad (?) formation exposed	40.3

Distribution and thickness.—The Rexroad (?) formation crops out in many places in the Cimarron Valley between central Seward County and southwestern Meade County and along tributaries of Crooked Creek in west-central Meade County. It crops out also in Cimarron Valley in the NW¼ sec. 35, T. 30 S., R. 37 W., Grant County, in secs. 20 and 29, T. 31 S., R. 38 W., Stevens County, and in sec. 35, T. 32 S., R. 40 W., in Morton County.

Between central Seward County and northwestern Stevens County the channel of Cimarron River has been cut to approximately the level of the contact between the Rexroad (?) formation and the overlying Meade formation. Where the sand and gravel of the Meade formation are thick, the contact is below the stream level and where they are thin it is above stream level. Recent pediment-like deposits cover much of the valley slopes and mask the bedrock except in a few places where such deposits have been removed by the widening channel of Cimarron River or by the deepening channels of some of its tributaries.

The Rexroad (?) formation underlies much of Grant, Haskell, Stevens, and Seward Counties and parts of Meade, Morton, and Stanton Counties. It is absent east of Crooked Creek in Meade County and north and west of Point of Rocks in Morton County. It extends southward into Beaver County, Oklahoma, but its northern and southern limits are not known. The thickness of the Rexroad (?) formation is shown in the measured sections listed in the preceding pages.

Water Supply.—The Rexroad (?) is the principal water-bearing formation in Seward County. These beds supply all or part of the water to most of the wells in the county. The coarse sand and gravel at the base of the formation, where adequately thick, is capable of yielding large quantities of water to wells. The middle part of the formation consists of poorly sorted materials and the upper part consists of fine-grained materials; hence they will not yield large quantities of water to wells but may yield sufficient water for domestic and stock uses. Water from the Rexroad (?) formation generally is moderately hard but is suitable for most uses.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

Meade formation

The Meade formation was recognized by Cragin (1896, p. 53) as the *Meade gravels* which was the name proposed by him for the lowest of three "terranes" in the vicinity of the old Vanhem post office in sec. 13, T. 30 S., R. 23 W., Clark County (Hibbard, 1944b, p. 709). Cragin also gave the name *Pearlette ash* to the deposits of volcanic ash in that region. Smith (1940, pp. 100-111) assigned the names *Odee formation, Equus niobrarensis beds*, and *Jones Ranch beds* to Pleistocene deposits in Meade County and adjacent areas. The Meade formation was redefined by Frye and Hibbard

(1941, pp. 411-419) to include Cragin's *Meade gravels* and *Pearlette ash,* Smith's *Odee formation, Equus niobrarensis beds,* and *Jones Ranch beds,* and all other beds of Pleistocene age above the Rexroad and below the Kingsdown silt. Additional paleontologic studies by Hibbard* indicate that the *Jones Ranch beds* are equivalent to a part of the Kingsdown silt and therefore should not be considered a part of the Meade formation.

Character.—The uppermost beds of the Meade formation do not crop out in Seward County. The *Odee formation* and *Equus niobrarensis beds* are local deposits that apparently were laid down in sink holes and therefore do not extend into Seward County. The Meade formation as exposed in Seward County (called the lower Meade by Frye and Hibbard) is very nearly an exact duplication of the Rexroad (?) formation. It consists of a deposit of coarse sand and gravel at the base, a zone of transition in the middle consisting of poorly sorted silt, sand, and gravel containing abundant nodules and stringers of caliche, and an upper zone consisting of fine sand, silt, clay, and beds of caliche (Pl. 7). Volcanic ash is found in a few places in the upper zone. Measured sections of the Meade formation are given on the following pages:

Section of Meade formation in sec. 21, T. 33 S., R. 28 W., Meade County, Kansas (Frye, 1942, p. 98)

	Thickness, feet
QUATERNARY—Pleistocene	
Meade formation	
18. Silt, sand, and some clay; tan to buff brown, massive; contains sandy beds and caliche cobbles	14.8
17. Sand and silt; gray to gray tan	5.4
16. Clay with some silt and sand; light gray, massive. Breaks with a conchoidal fracture when dry	4.5
*15. Volcanic ash, pearl gray, lenticular, somewhat impure	1.6
14. Silt, clay, and some sand; gray, massive; contains a few calcareous nodules. (Borchers fauna, where present, occurs at top of this bed)	6.4
13. Volcanic ash (Pearlette member), pearl gray, thin-bedded, cross-bedded	7.1
12. Clay, silt, and some sand; tan gray and brown gray, massive. Grades upward into yellowish gray-green sand and contains some mottled yellow-brown silt. Contains a few thin beds of ash and calcareous nodules. (Cudahy fauna occurs at top of this bed, where present	9.5

* Personal communication.

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

11. Sand, silt, and coarse gravel; brown; contains abundant nodules. Grades upward into red-brown to tan-maroon sand and silt	8.8
10. Sand, coarse and well sorted at base, grading upward into finer, more poorly sorted sand. Calcareous nodules at top	10.1
Ogallala formation	78.0
Thickness of Meade formation exposed	68.2

Section of Meade formation in secs. 28 and 33, T. 34 S., R. 31 W., Seward County, Kansas

	Thickness, feet
QUATERNARY—Pleistocene	
Meade formation	
9. Caliche, white. Weathers to coarse rubble	3
8. Clay, buff and gray; contains fine sand	12
7. Caliche, crumbly, white, impersistent. Forms ledge in some places	1
6. Clay, light gray	6
5. Caliche, white, fairly persistent. Forms ledge	0.5
4. Clay, gray to greenish gray, fossiliferous	5
3. Sand, fine to medium; contains gravel at the base	5
2. Sand, fine, and silt; red; contains numerous nodules and bands of caliche. In many places caliche is very hard and is more resistant to erosion than the silt and clay. In other places the caliche is soft and the rock has a red and white mottled appearance. Forms vertical walls where cut by small streams and gullies. Where caliche is resistant it accumulates in rubble on the surface	15
1. Sand and gravel, coarse; contains "mortar beds" about 20 feet below the top. Base not exposed	30
Thickness of Meade formation exposed	77.5

Section of Quaternary and Tertiary deposits in NW¼ sec. 35, T. 33 S., R. 32 W., Seward County, Kansas. (Measured by Claude W. Hibbard and John C. Frye.)

	Thickness, feet
QUATERNARY—Pleistocene	
Terrace deposit	
10. Sand and gravel, coarse, poorly sorted. Pebbles consist of granite, felsite, vesicular basalt, quartzite, sandstone, and chert. Pebbles are as large as 7 inches in largest diameter	12
Meade formation	
9. Volcanic ash interbedded with light-tan silty clay and fine-grained sand	10
8. Sand, fine to coarse, and silt; pale buff	5
7. Silt and clay, thin-bedded	2.1
6. Sand and gravel, grading upward into medium sand	8
5. Sand and gravel cemented with calcium carbonate to form "mortar bed"	1.2
4. Sand and gravel, cross-bedded. Pebbles are as large as 2 inches in diameter	3.3

disconformity

TERTIARY—Pliocene

Rexroad (?) formation

3.	Sand and silt, poorly sorted, tan and dirty pink; contains nodules and bands of caliche	5.2
2.	Silt and clay, gray and tan; contains bands of nodular caliche. Massive zone of caliche at the top	2.6
1.	Sand, silty, buff tan to gray	8.1
	Thickness of Meade formation exposed	29.6
	Thickness of Rexroad (?) formation exposed	15.9

The basal deposit of sand and gravel in the Meade formation consists primarily of material derived from igneous rocks but may also contain many water-worn pebbles of calithe and "mortar beds" derived from older sedimentary rocks. The sand and gravel generally is cross-bedded and the individual beds are moderately well sorted. A part of the deposit generally is cemented with calcium carbonate to form "mortar beds" which erode to prominent ledges in many places along Cimarron Valley and which form the cap rock of several buttes in Cimarron Valley near the Meade-Seward County line.

The sand and gravel of the Meade formation generally is coarser than the sand and gravel at the base of the Rexroad (?) formation. It contains a greater abundance of water-worn pebbles of caliche and "mortar beds" and appears to contain more chalcedony. The sand and gravel of the Meade formation differs markedly from that of the Ogallala formation. The Ogallala formation in Meade and Clark Counties contains abundant pebbles of fine-grained sandstone, gray quartzite, and ironstone which probably were derived from the Dakota formation and other Cretaceous deposits (Smith, 1940, p. 42). Pebbles of this type are rare in the Meade formation. In addition, the Ogallala formation contains relatively few water-worn pebbles of caliche and "mortar beds."

The middle or transition zone of the Meade formation consists of poorly sorted reddish silt, sand, and gravel containing abundant nodules and stringers of caliche (Pl. 10). The material is moderately well indurated and forms steep slopes in some places. The caliche generally is harder than the rest of the material, forming a rough surface on steep slopes and abundant rubble on gentle slopes. The gravel becomes more abundant near the base and generally is absent in the upper part. The zone has a characteristic mottled red and white appearance. This deposit is well exposed in many places along Cimarron Valley from northwestern Stevens County to

PLATE 9. *A,* Old-age dune sand overlying the Meade formation in railroad cut just west of Kismet. Note the bedding in the dune sand and the abundant caliche in the red transitional phase of the Meade formation. *B,* Tilted beds of the Laverne formation ("sawrock" horizon) in southeastern Seward County. Photographs by H. T. U. Smith.

A

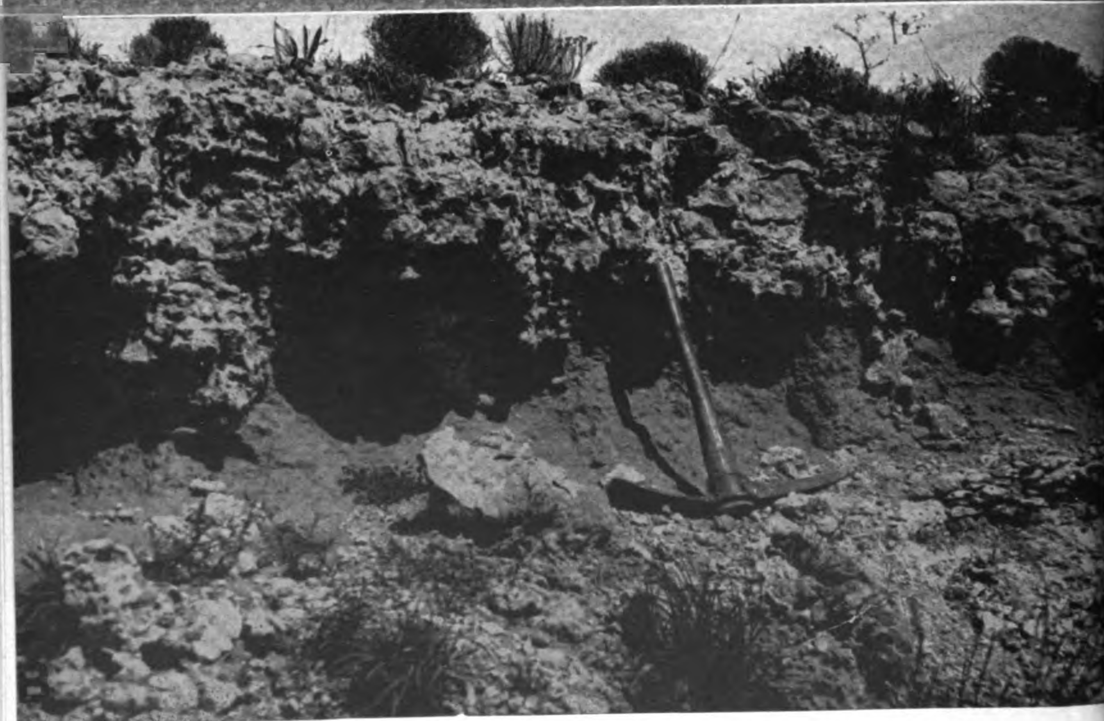

PLATE 10. *A*, Red transitional phase of the Meade formation in road cut along U. S. Highway 54 in NW¼ sec. 19, T. 33 S., R. 31 W. *B*, Close-up view of the red transitional phase of the Meade formation at the same locality. Note

central Meade County. It is particularly well exposed in the railroad cut north of the Arkalon railroad bridge.

The upper part of the Meade formation in Seward County consists of beds of clay, silt, fine sand, and caliche containing volcanic ash in some places (Pl. 11A). Locally there is a few feet of sand and gravel at the base. This sand and gravel thickens eastward and is widespread in Meade County (Claude W. Hibbard, personal communication). The silt and clay generally is light gray to greenish gray but may be light brown, brown, buff, or pinkish buff. The caliche occurs in beds ranging in thickness from a few inches to nearly 4 feet. The uppermost bed generally is thickest and has been quarried in a few places for road metal. The volcanic ash crops out in many places in Meade County but has been found in only a few isolated places in Seward County. Its occurrence has been described in more detail under mineral resources.

Distribution and thickness.—The Meade formation is widespread in southwestern Kansas. It underlies most of the area in Kansas south of the Arkansas River and west of Meade. It has also been observed in the panhandle of Oklahoma. The formation was deposited over all of Seward County and is absent only where Cimarron River has eroded down to the underlying formations. In most of Seward County it is underlain by the Rexroad (?) formation and overlain by the Kingsdown silt or by dune sand.

The thickness of the Meade formation is variable depending primarily upon the thickness of the basal sand and gravel (Pl. 7). The measured thickness at the type locality (measured section on page 78) is approximately 68 feet but at this point the basal sand and gravel are very thin. Its average thickness in Seward County probably is between 75 and 100 feet. Toward the west the basal sand and gravel seems to thicken whereas some of the upper beds pinch out or have been removed by erosion.

Water supply.—The Meade formation yields water to a part of the wells in the western half of Seward County. In Cimarron Valley in the western half of Seward County the contact of the Meade and Rexroad formations is approximately at the level of the stream which represents approximately the level of the water table in adjacent upland areas. Most of the Meade formation, therefore, lies above the water table but the lowermost part of the formation may be saturated with water and may yield water to wells. Wells in western Seward County probably obtain most of their

6—7070

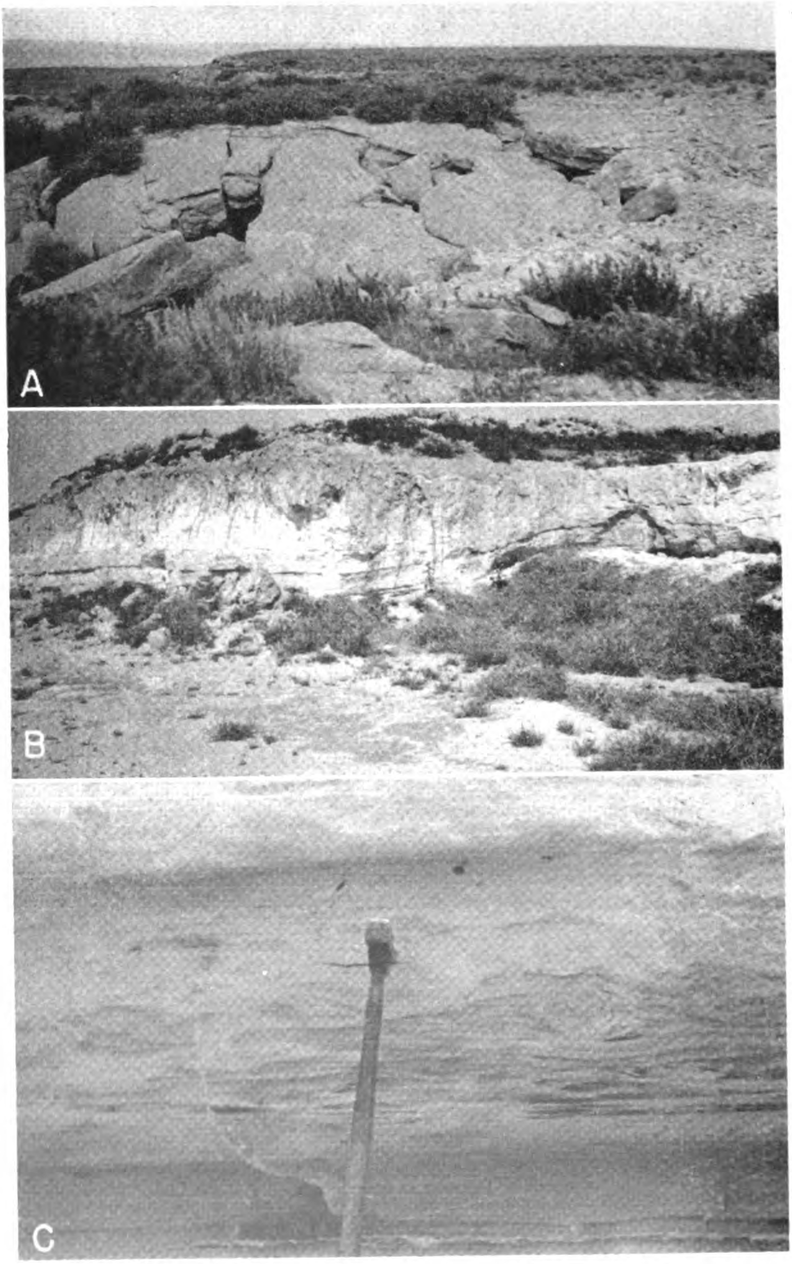

PLATE 11. *A,* Mortar bed at the base of the Meade formation near the center of the west line of sec. 36, T. 34 S., R. 31 W. *B,* Volcanic ash at the Sunflower Mineral Mine in SW¼ NE¼ sec. 13, T. 33 S., R. 32 W. Note the dip displayed by the bedding planes. *C,* Volcanic ash exhibiting bedding, cross-bedding, and concretions. Burg Ranch deposit, SW¼ sec. 19, T. 32 S., R. 33 W. Photographs by Frank E. Byrne.

water from the Rexroad (?) formation but many may obtain part of their water from the Meade formation. Few, if any, wells obtain water from the Meade formation in the eastern half of Seward County.

PLEISTOCENE AND RECENT SERIES

Kingsdown silt

The *Kingsdown marl* was described by Cragin (1896, p. 54) from outcrops southwest of Kingsdown in Ford County and along Bluff Creek in northern Clark County. He did not designate a type locality for these beds but they are typically exposed in the vicinity of the old Vanhem post office in sec. 13, T. 30 S., R. 23 W., Clark County. Cragin believed that the *Kingsdown marl* might be Pliocene. These deposits were redefined as the *Kingsdown formation* by Smith (1940, pp. 111-116) who designated as the type locality an outcrop that he measured in sec. 13, T. 30 S., R. 23 W., Clark County. Frye and Hibbard (1941, pp. 419-420) redefined these beds as the Kingsdown silt and included the overlying loess of uppermost Pleistocene and Recent age. Hibbard (1944b, pp. 745-752) has recognized two phases of the Kingsdown silt in Clark County which he has called lower and upper Kingsdown. The Kingsdown silt exposed in Seward County probably is equivalent to the upper Kingsdown as defined by Hibbard.

Character.—The Kingsdown silt in Seward County consists of fine sand in the lower part grading upward into sandy silt, silt, and loess. The upper part may contain many small nodules of caliche. The lower sand is thin-bedded and the upper silt and loess are massive and have been eroded to form vertical cliffs in some places. These beds range from light tan to buff.

Distribution and thickness.—The Kingsdown silt underlies much of southwestern Kansas. It covers much of Grant, Haskell, Meade, Clark, and Ford Counties and the northern part of Seward County. These beds are thin or absent south of Cimarron River in Seward County where the Meade formation is at the surface or is overlain by dune sand.

The Kingsdown silt is thickest in northern and northeastern Seward County. The thickness ranges from a featheredge near Cimarron River to approximately 40 feet in the northeastern part of the county.

Water supply.—The Kingsdown silt lies above the water table in Seward County; hence it does not yield water to wells. The lower part of the formation is saturated with water in a few places in Meade County where it yields small quantities of water to a few wells (Frye, 1942, p. 110).

Terrace deposits

There are at least two and possibly three terraces along Cimarron River in southwestern Kansas (Smith, 1940, pp. 126, 153; Frye and Hibbard, 1941, p. 420; and McLaughlin, 1946, pp. 132-134). The most prominent terrace is about 50 feet below the level of the upland which in southeastern Seward and southwestern Meade Counties is more than 200 feet above the level of the stream. The terrace generally is level with the top of the red transition zone in the Meade formation and the underlying sand and gravel generally lie in channels in the basal sand and gravel of the Meade formation. The sand and gravel underlying the highest terrace includes abundant cobbles of sandstone apparently derived from Mesozoic rocks, and cobbles of reddish light vescicular basalt probably derived from the beds of lava along the headwaters of Cimarron River.

A second terrace which is about 50 to 75 feet above the level of the stream has been observed in southeastern Seward County and southwestern Meade County. The sand and gravel underlying this terrace mantles the hills formed by the tilted strata of the Laverne formation.

A third terrace at a level of about 20 feet above the stream bed was noted in Stevens and Seward Counties by Smith (1940, pp. 126 and 153) and in Morton County by McLaughlin (1946, pp. 132-133). This terrace is not well preserved in most of Seward County owing to the mask of colluvium that covers the lower valley slopes.

Frye and Hibbard (1941, p. 420) report that teeth of *Paraelephas columbi* (Falconer) have been taken from the high-terrace deposits in Cimarron Valley south of Meade. The remains of fossils and the fact that the highest terrace deposits are in channels cut into the Meade formation indicate that this terrace was formed during late Pleistocene time and therefore that almost all the downcutting in Cimarron Valley was during late Pleistocene and Recent time. The terrace deposits lie above the water table in Seward County and do not yield water to wells.

RECENT SERIES

Alluvium

Alluvium occurs only along the floor of Cimarron Valley in Seward County (Pl. 1). It consists primarily of sand and gravel containing lesser amounts of silt and clay. The thickness of the formation in Seward County is not known but test holes drilled through the alluvium in adjacent areas indicate a thickness of about 70 feet.

The alluvium in Seward County has been covered in many places by recent pediment-like deposits and in other places has been partly removed by the widening channel of Cimarron River. As a result, very little bottom land remains and the broad sandy channel of Cimarron River occupies most of the valley floor.

Alluvium yields water to many domestic and stock wells in Cimarron Valley, but the yield of these wells generally is small. Water in the alluvium generally is hard but can be used for most domestic and farm purposes (see analyses 22, 53, 100, and 102).

Dune sand

Most of the area south of Cimarron River and part of the area north of Cimarron River is underlain by dune sand (Pl. 1). It overlies the Meade formation south of the river and the Meade and Kingsdown formations north of the river. In the northwestern part of the county it extends into Cimarron Valley and is in contact with the alluvium. The sand consists of fine- to medium-grained well rounded quartz sand containing some silt.

Smith (1940, pp. 159-165) described an ideal dune cycle in his discussion of sand dunes in southwestern Kansas. The cycle consists of two phases: (1) An eolian or active phase during which the dune is built up, and (2) an eluvial or passive phase during which vegetation prevents further growth and the dune is subdued by weathering and creep. He divides the eluvial phase into stages of youth, maturity, and old age. In the youth stage, the soil zone is formed and slopes are reduced. The dune becomes mature when its profile is smooth and regular and when its soil becomes thicker and more stable. Old age is reached when the dune form is indistinguishable. He states that the eluvial phase in any stage may be interrupted by rejuvenation. These stages account for the varied topography discussed on pages 14 and 36.

The thickness of the dune sand may be as much as 40 or 50 feet where the dunes are still in the youthful stage but it is relatively thin between the higher dunes and in areas where the dunes have reached the old-age stage of the erosion cycle.

Most of the dune sand probably is of Recent age because it was deposited over the terraces and the alluvium which are late Pleistocene to Recent. Some of the dune sand in Seward County, however, appears to be much older (Pl. 9A). In the railroad cut southwest of Kismet there is a deposit of moderately well indurated dune sand that is separated from overlying younger less consolidated dune sand by a well defined soil zone. The older dune sand may be Pleistocene.

The dune sand lies wholly above the water table in Seward County and does not yield water to wells. The dune-sand areas are poorly drained and form ideal catchment areas which assist in the recharge of the ground-water reservoir.

*Colluvium**

Frye and Smith (1942, pp. 215-221) reported pediment-like slopes along Smoky Hill River in Logan and Gove Counties and along Cimarron River in southeastern Seward County. These slopes are particularly well developed in Cimarron Valley between the highway bridge north of Liberal and the Forgan bridge in southwestern Meade County. The pediment-like slopes in this area are in part mantled with alluvial detritus or colluvium, consisting of a poorly sorted admixture of sand, gravel, silt, and clay. The deposits are composed of material derived from the Meade and Rexroad (?) formations which form the valley walls.

Character.—The colluvium in most places consists primarily of sand and gravel containing silt and clay, but in a few places the finer materials are predominant. The larger pebbles may be fragments of igneous rocks derived from the basal sand and gravel of either the Meade or the Rexroad (?) formation or they may be rough fragments of caliche, "mortar beds," siltstone, or clay derived from the middle and upper parts of these formations. The deposits generally are structureless, display no sorting, and are slightly indurated. The silt and clay bind the pebbles so that the deposit erodes to a vertical bluff in a few places. Soil zones were observed in these deposits near the highway bridge north of Liberal.

Since 1914 the channel of Cimarron River has been widening

* Term applied to heterogeneous aggregates of rock detritus, such as talus and avalanches, resulting from the transporting action of gravity.

rapidly and apparently has also lowered. This has caused recent accelerated erosion in the tributary streams that traverse the colluvium. The surface of the colluvium, therefore, is very irregular and the land underlain by it generally is unsuitable for any use other than grazing.

Distribution and thickness.—The colluvium mantles much of the lower slopes in Cimarron Valley throughout Seward County (Pl. 12). As stated above, it is most widespread in the southeastern part of the county where it generally extends from a point at or near the channel of the river almost up to the high terrace deposits. The material ranges in thickness from a featheredge near the edge

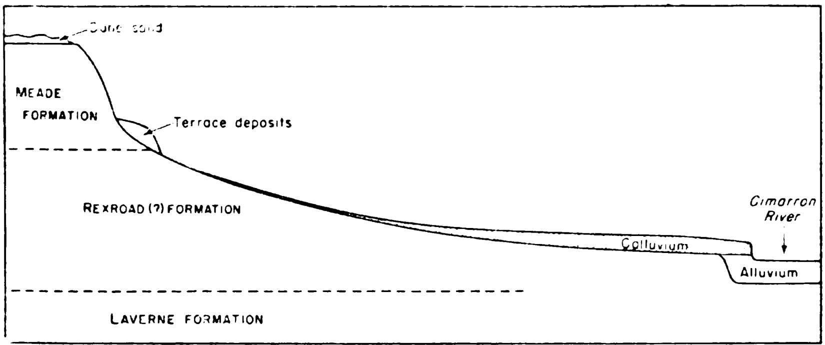

FIG. 10. Diagrammatic profile of Cimarron Valley in southeastern Seward County.

of the valley to approximately 30 feet in some places near the river. The idealized transverse section of Cimarron Valley shown in Figure 10 illustrates the mode of occurrence of the colluvium.

Water supply.—The colluvium lies above the water table; hence it does not yield water to wells in Seward County.

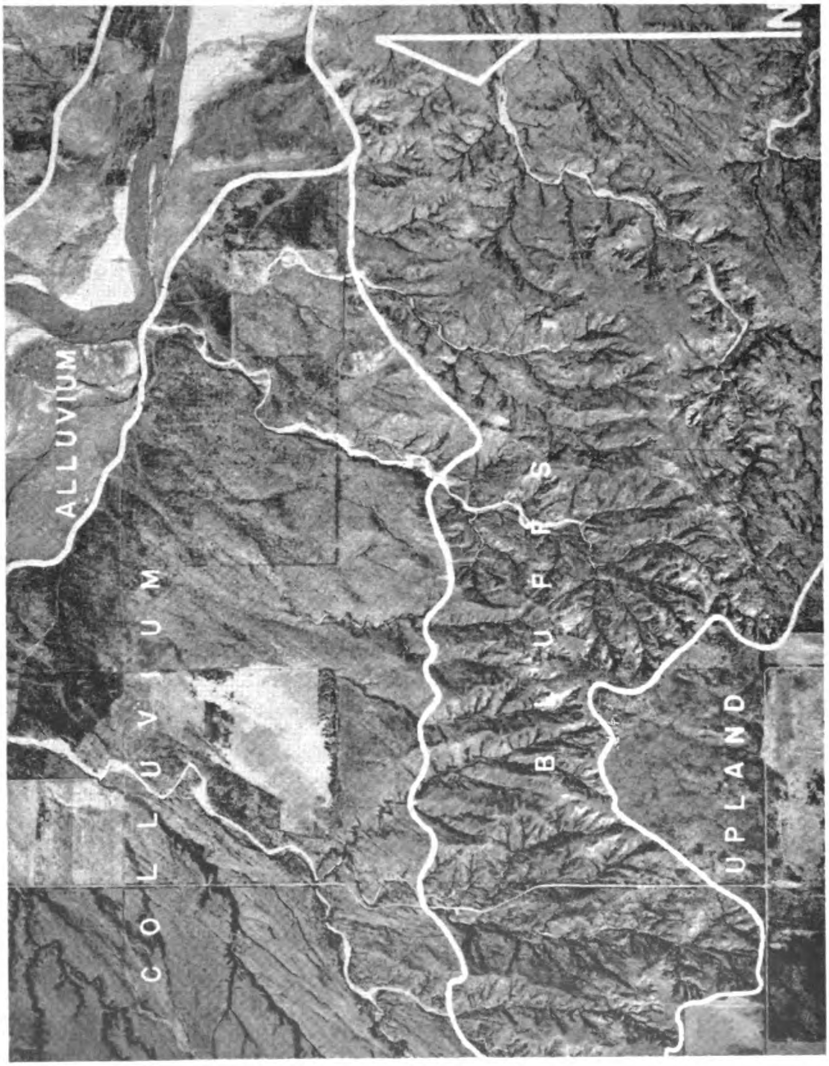

PLATE 12. Aerial photograph of a part of southeastern Seward County adjacent to Cimarron River showing the distribution of the colluvium in relation to the valley flat and to the bluffs and upland. Note how the colluvium pinches out toward the eastern part of the area where the steeply dipping beds of the Laverne formation form prominent ridges that extend to the edge of the channel. Photograph from U. S. Soil Conservation Service, March 13, 1939.

WELL RECORDS

Information pertaining to water wells in Seward County is tabulated in Table 10. The numbers in the first column correspond to the well numbers on the map (Pl. 2) and in the table of analyses (Table 9). The numbers in the first column that are in parentheses indicate wells from which samples of water were taken for analysis. 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. The measured depths to water level are given to the nearest 0.01 foot, whereas reported depths are given only to the nearest foot and are subject to error.

TABLE 10.—*Records of drilled wells in Seward County, Kansas*

[illegible]	Location	Owner or tenant	Topographic position	Depth of well (feet)	Diameter of well (inches)	Principal water-bearing horizon	Method of lift[2]	Use of water[3]	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water below measuring point (feet[4])	Date of measurement, 1940	Remarks
	T. 31 S., R. 31 W.													
	NE NE sec. 2	E. D. Beisinger	Upland plain	160+	5	Pliocene and Pleistocene undifferentiated	C, W	N	Notch on top of casing, west side.	+ 0.7	2,808.2	153.23	Aug. 14	Premises unoccupied.
2	NW NE sec. 8	J. A. Fleming	do	182	5	do	C, W	D, S	Top of bottom collar clamp north-northwest side.	+ .3	2,824.1	162.09	do	Well repaired after Aug. 14 by inserting 3-inch casing inside old casing.
3	SE SE sec. 11	F. Collingwood	do	161.3	5	do	C, W	N	Low point on top of casing north side.	+ .4	2,805.8	157.55	do	Well in process of repair.
[illegible]	SE SE sec. 21	Palmer	do	165+	5	do	C, W	D	Top of casing, west side	+ 1.2	....	159.07	do	Used only occasionally.
[illegible]	SW NW sec. 32	Keith Rosson	do	180	5	do	C, W	D, S	Top of casing, southwest side.	+ .5	2,811.8	162.12	do	
[illegible]	SE NE sec. 36	Winters	do	149+	5	do	C, W	N	Top of clamp bolt, west-southwest side.	+ .3	2,780.6	145.50	Aug. 12	Pump not in working order; well and house abandoned
	T. 31 S., R. 32 W.													
[illegible]	NW NW sec. 2	Mrs. Ray Roberts	do	180+	5	do	C, W	N	Top of casing, north side	+ .6	2,846.8	158.62	Aug. 16	Well abandoned but in usable condition.
[illegible]	NW NE sec. 4	Alliance Life Ins. Co.	do	185±	4	do	C, W	D, S	Top of casing, east side	.0	2,875.5	164.76	do	
[illegible]	NE NW sec. 12	C. A. Kocher	do	175	4	do	C, W	D, S	Top of casing, northwest side.	+ .4	2,831.9	160.57	Aug. 14	
[illegible]	SW SE sec. 13	R. A. Garten	do	175±	4	do	C, W	D, S	Top of casing, north side	+ .1	2,835.1	171.50	do	Well used only occasionally
[illegible]	NW SW sec. 14	Griffith & Baughman	do	195+	5	do	C, W	D, S	Top of casing, south-southeast side.	.0	2,853.9	182.55	Aug. 16	
[illegible]	NW NW sec. 16	Cecil Davis	do	175+	5	do	C, W	D	Top of casing, north side	+ 1.1	2,869.1	172.48	do	
[illegible]	SE NE sec. 25	C. H. Kirtley	do	200±	6	do	C, W	D, S	Top of casing, south side	+ .1	2,845.0	187.38	Aug. 14	
[illegible]	NW SW sec. 31	L. H. Hatfield	do	175	5	do	C, W	N	Top of casing, south-southeast side.	— 1.8	....	168.32	Aug. 17	House and well abandoned

	T. 31 S., R. 33 W.													
15	NW NW sec. 10	L. B. Becker	do	195+	5	do	C, W	D, S	Notch on top of casing, northeast side.	+ 5	2,911.9	189.77	Aug. 18	
16	NE NW sec. 12	P. L. Miller	do	200±	5	do	C, W	D, S	Top of metal cover, west side.	+ .5	2,883.8	174.35	Aug. 19	
17	SE SW sec. 14	Griffith & Baughman	do	180	5	do	N	N	Top of casing, south side	+ .5	2,877.4	168.11	Aug. 17	Observation well.
18	SE SW sec. 17	I. R. Salley	do	200±	5	do	C, W	D, S	Top of casing, south side	.0	2,900.3	174.89	do	
19	NE NE sec. 28	H. B. Hamilton	do	180	5	do	C, W	D, S	Top of casing, east side	+ 1.3		174.66	do	
	T. 31 S., R. 34 W.													
20	SW SE sec. 1	J. R. Thomas	do	230±	4	do	C, W	D, S	Top of casing, northeast side.	+ 1.8	2,941.8	201.50	Aug. 19	Well ends in gravel.
21	NE SE sec. 3	S. H. McCutcheon	Low dune	215±	(?)	do	N	N	Top of cover against pipe, northwest side.	+ 2.0		203.45	do	House and well abandoned.
(22)	NE NE sec. 5	R. Y. Harlow	Valley slope	13.6	23	do	T, G	I	Top of casing, southwest side.	−34.0±		3.17	Aug. 21	East well of a battery of two. Estimated aggregate yield 450 gallons a minute. Well ends in sand and fine gravel.
(23)	NE SE sec. 6	C. D. Day	do	114	5	do	C, W	D, S	Top of cover next to pipe, northwest side.	+ 1.0		111.33	Aug. 1	Observation well.
(24)	NW NE sec. 14	Lucille Jones	Upland plain	205±	5	do	C, W	D, S	Top of steel clamp, west side.	+ 1.2	2,936.6	192.96	Aug. 17	
25	NW SW sec. 17	A. Rhoads et al	Valley slope	135	5	do	N	N	Top of casing, west side	.0		123.30	Aug. 1	Well and property abandoned; no well.
26	SW SW sec. 19	A. Johnson	do	146	5	do	C, W	N	do	+ .2		135.18	do	Property abandoned.
27	SE NE sec. 22	Federal Land Bank	Sand dune	163	5	do	N	N	Top of concrete base, north side.	− .4		154.50	Aug. 27	Property abandoned; well not in usable condition.
	T. 32 S., R. 31 W.													
28	SW SE sec. 4	John Malone	Upland plain	190±	4	do	C, W	D, S	Top of casing, south-southeast side.	+ .6		157.84	Aug. 12	
29	SW SW sec. 6	W. J. Hill	do	184+	5	do	C, W	D, S	Top of casing, west side	+ .6	2,826.2	181.16	do	
30	NE NW sec. 11	Matt Dreitz	do	184±	4	do	C, W	D, S	Top of casing, south-southwest side.	+ 1.2	2,786.4	157.14	do	
(31)	NE SE sec. 12	J. H. Williamson	do	178±	5	do	C, W	D, S	Top of casing, south-southeast side.	+ .2	2,774.7	156.06	Aug. 9	
32	SW SW sec. 13	E. Richardson	do	170+	4	do	C, W	S	Top of casing, east side	+ 1.9	2,782.6	167.50	Aug. 7	
33	SE SE sec. 18	H. D. Masson	do	155+	5	do	C, W	S	Top of casing, north side	− .3	2,792.1	153.55	do	
34	NE NE sec. 22	J. E. Hebisen	do	175+	5	do	N	N	Top of casing, southwest side.	.0	2,790.0	172.77	do	House abandoned.
35	NE SE sec. 26	E. Richardson	do	186+	4	do	C, W	S	Top of casing, east-southeast side.	+ 2.0	2,778.4	175.09	do	
36	SE SE sec. 28	Mrs. M. Collingwood	do	181+	5	do	C, W	N	Top of casing, west side	+ .1		175.70	Aug. 9	Abandoned stock well.
37	SE NE sec. 30	Mrs. Anna Stoll	do	172.5	4	do	C, W	D, S	Top of casing, east side	+ .5	2,783.0	167.78	Aug. 7	

TABLE 10.—Record of drilled wells in Seward County, Kansas—*Continued*

No.[1]	Location	Owner or tenant	Topographic position	Depth of well (feet)	Diameter of well (inches)	Principal water-bearing horizon	Method of lift[2]	Use of water[3]	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water below measuring point (feet[4])	Date of measurement, 1940	Remarks
	T. 32 S., R. 31 W.													
	SW SW sec. 32	Sherer	Upland plain	195+	(?) 4	Pliocene and Pleistocene undifferentiated	C, W	D, S	Top of casing, east side	+ .2	....	192.86	Aug. 5	Casing leaks.
)	NE SE sec. 33	Mrs. M. H. Sherer	do	214±	5	do	C, W	D, S	Top of casing, south side	+ .7	....	188.40	do	
)	NE NE sec. 36	Mrs. J. W. McVey	do	175+	5	do	C, W	D, S	East point on brick at top of casing, north side.	+ 1.0	2,767.0	171.70	do	
	T. 32 S., R. 32 W.													
1	SE SE sec. 4	L. G. Wesler	do	165	5	do	C, W	N	Top of casing, east side	.0	....	162.01	Aug. 12	do
2	SE SW sec. 12	E. S. Krause	do	174	4	do	C, W	D, S	do	+ .8	2,812.6	168.94	Aug. 8	
3	SE SE sec. 14	R. E. Cotton	do	200±	4	do	C, W	D, S	Top of casing, south-southeast side.	+ .4	2,811.8	169.34	Aug. 12	
4	NW NW sec. 17	Roy Jones	do	180±	4	do	C, W	D, S	Top of casing, north side	.0	2,945.1	175.01	Aug. 8	
5	SW SW sec. 24	Oscar Reiss	do	188	4	do	C, W	D, S	do	+ .6	2,803.8	184.40	Aug. 9	
6	SE SW sec. 26	J. P. Fellers	do	217±	5	do	C, W	D, S	Top of casing, south side	+ .5	2,804.2	179.87	do	
7	SE SW sec. 30	J. W. Baughman	Crest of divide	81.5	5	do	N	N	Top of bucket, south side	+ .2	....	81.16	Aug. 20	Abandoned.
8	NW NW sec. 33	May Massoni	Upland plain	193	5	do	C, W	N	Top of casing, southeast side.	+ .3	....	188.57	do	Houses unoccupied but windmill in working order.
	T. 32 S., R. 33 W.													
9	SW NW sec. 1	North. Natl. Gas Co.	do	264	10	do	....	....	Land surface	.0	....	184.00	July 10	East well of battery of two; gravel packed; well ends in coarse gravel, see log.
0	NW NW sec. 10	Sam Specht	do	200+	5	do	C, W	D, S	Top of casing, east-northeast side.	+ .5	2,882.3	187.15	Aug. 17	
1	SE SW sec. 12	A. L. Morgan	do	184	4	do	C, W	N	Top of casing, north side	+ .2	2,858.3	180.59	Aug. 8	Mill broken; house unoccupied.
2	NW SE sec. 15	Mrs. Edna Scott	Edge of valley wall	183	5	do	C, W	D	Top of small steel clamp northwest side.	+ 1.2	2,844.2	162.47	Aug. 12	
3)	SE SW sec. 21	H. Burg	Floodplain	53	5	Recent alluvium.	C, W	D, S	Top of casing at lowest point.	+ 1.3	2,796.6	18.02	July 10	

54	NW SW sec. 31	Vida Corrigan	Sand dune	175	5	Pliocene and Pleistocene undifferentiated	C, W	N	Top of iron clamp, east side	+ .5	....	163.67	July 31	House destroyed.
55	NE NW sec. 36	Mrs. S. N. Kneeland	Floodplain	56±	5	Recent alluvium	C. W	D	Top of cover, south side	+ .5	....	17.18	Aug. 20	Well ends in gravel.
	T. 32 S., R. 34 W.													
56	SW SW sec. 8	Kansas City Life Insurance Co.	Upland plain	212	5	Pliocene and Pleistocene undifferentiated	C, W	N	Top of casing, west-southwest side.	+ .9	2,950.6	209.04	Aug. 1	Premises unoccupied.
57	NE SW sec. 9	J. H. Evans	do	196	5	do	C, W	N	Top of casing, south side	+ .1	2,919.8	184.06	do	
58	SE NE sec. 19	S. Edwards	Undulating upland	222	4	do	C, W	N	Top of casing, northeast side.	+ .3	....	214.83	do	
59	SE SW sec. 21	Laura B. Mills	Sand dune	202+	5	do	C, W	N	Top of casing, west-southwest.	.0	2,929.4	200.18	July 31	
60	NW SW sec. 29	Della Keating	do	173+	(?) 5	do	C, W	N	Top of south block, east side of pipe.	+ 1.0	2,929.5	174.04	do	
61	SW NW sec. 35	G. W. Marteney	do	189+	4	do	C, W	N	Top of south wooden clamp, east side of pipe.	+ 1.0	2,899.3	183.23	do	
	T. 33 S., R. 31 W.													
62	SW NE sec. 4	C. R. I. & P. R. R.	Upland plain	248.5±	12 to 8	do	C, S	R	Land surface	.0	....	190.00	do	Water level eported as of 10-20-30; measured yield 10-20-30, 196 gallons a minute; well ends in gravel and coarse sand.
(63)	SE SW sec. 4	City of Kismet	do	150±	6	do	T, E	P	do	.0	....	100±	July 5	Reported yield, 250 gallons minute; well ends in gravel.
64	NE SE sec. 9	Mrs. Flora Atwell	Sand dune	213	5	do	C, W	N	Top of casing, west side	+ 2.0	....	205.63	Aug. 5	Premises occupied but well not in use.
65	SE NE sec. 11	Mary Elliott Estate,	do	228±	5	do	C, W	D, S	Inside edge of tractor drum, northeast side.	+ .4	2,770.0	212.71	Aug. 9	
66	NE NW sec. 18	E. R. Dudrey	Sand dune blowout	184	4	do	C, W	N	Inside edge of iron collar southeast side.	.0	2,750.7	176.07	Aug. 9	Premises abandoned.
67	NE NE sec. 20	Cent. Life Assur. Soc.; A. L. Handy, tenant.	Sand dune	193	(?) 5	do	C, W	D, S	Top of casing, north-northwest side.	+ .2	....	186.34	Aug. 2	
68	NW NE sec. 22	F. T. Ellsaesser	do	197	5	do	C, W	N	Top of casing, south side	+ .2	....	187.48	do	Only building foundations remain.
(69)	SE SE sec. 23	Claude Wheatley	do	225	5	do	C, W	D, S	Notch on top of casing, east side.	+ .8	2,739.3	201.77	do	
70	NE SW sec. 31	Willa B. Davis	Floodplain	41	5	Recent alluvium	C, W	S	Top of casing, north side	+ 1.2	2,544.7	19.71	Aug. 5	
71	SW NW sec. 34	C. E. Andrews	Sand dune	212+	5	Pliocene and Pleistocene undifferentiated	C, W	N	Top of casing, south-southwest side.	.0	2,724.5	198.94	Aug. 2	Premises unoccupied.
72	NE NE sec. 35	Augusta Guldner	Upland plain	210+	5	do	C, W	D, S	Top of casing, southwest side.	+ .7	2,720.7	197.75	Aug. 3	
73	NE SE sec. 36	W. A. Carter Estate,	Sand dune	190+	5	do	C, W	D, S	Top of casing, east side	+ 1.2	2,705.6	181.59	Aug. 2	
	T. 33 S., R. 32 W.													
74	NE NE sec. 11	G. L. Anderson	do	214+	5	do	C, W	D, S	Top of casing, south side	.0	2,786.7	213.16	Aug. 7	

TABLE 10.—Record of drilled wells in Seward County, Kansas—*Continued*

No. on pl. 2[1]	Location	Owner or tenant	Topographic position	Depth of well (feet)	Diameter of well (inches)	Principal water-bearing horizon	Method of lift[2]	Use of water[3]	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water below measuring point (feet[4])	Date of measurement, 1940	Remarks
	T. 33 S., R. 32 W.													
75	SW SW sec. 12	Cent. Life Assur. Soc.	Sand dune	220±	5	Pliocene and Pleistocene undifferentiated	C, W	D, S	Metal protector around casing, north side.	+ .2	2,886.0	220.53	Aug. 9	
76	SW NW sec. 24	Panhandle Eastern Pipeline Co.	Valley slope	147	13	do	C	N	Land surface	.0	2,700±	21.00	....	Four other wells in battery; well ends in sand, see log; water level reported as of 5-17-32.
77	SE SW sec. 30	Mrs. J. L. Gurn	Sand dune	217±	5	do	C, W	D, S	Top of casing, east side	+ 1.4	2,811.9	206.45	July 31	
	T. 33 S., R. 33 W.													
(78)	NW NE sec. 4	George Cook	Rim of valley	152	6	do	C, W	D, S	Top of casing, south side	+ .4	2,806.9	138.18	July 23	
79	NE SE sec. 8	Seward County	Sand dune	146	5	do	C, W	D, S	Top of metal cover, south-southeast side.	+ .1	2,907.8	134.56	Aug. 12	Stock and school supply.
80	NW NE sec. 12	Roy Pyle	Floodplain	13+	6	Recent alluvium	N	N	Bottom of notch in casing, west side.	+ 1.5	....	11.09	July 23	
81	NW NW sec. 16	John Thompson	Sand dune	176±	5	Pliocene and Pleistocene undifferentiated	C, W	D, S	Top of casing, south side	+ .7	2,846.8	174.90	July 20	
82	SE SE sec. 18	Mrs. E. Thompson	do	191	5	do	C, W	D, S	Top of casing, east-southeast side.	+ 1.1	2,863.9	185.55	July 30	
83	SE SE sec. 19	A. H. Thompson	do	199	5	do	C, W	N	Top of casing, east side	.0	2,873.9	194.40	do	Premises abandoned.
84	SE SE sec. 20	Morgan Brothers	do	203	(?) 5	do	C, W	N	Top of casing, east-northeast side.	+ 1.0	2,849.0	178.44	July 20	do
85	NW NE sec. 21	Lee Swan	do	202±	5	do	C, W	D, S	Top of casing, west side	+ .2	2,843.4	182.40	July 23	
86	NW NE sec. 23	Roy Pyle	do	212±	5	do	C, W	D, S	Top of union, west side	+ 1.2	2,832.1	194.60	do	
87	NE NE sec. 26	A. B. Harvey Estate,	do	195	5	do	C, W	D, S	Top of casing, south-southeast side.	— .4	2,817.9	190.20	July 22	
88	NE SE sec. 27	E. Jennison	do	195	5	do	C, W	D, S	Top of casing, northwest side.	.0	2,825.2	189.71	do	One joint perforated casing lowered inside 5-inch casing
89	SE NE sec. 33	J. H. Salley	Upland plain	177+	5	do	C, W	D, S	Top of hole in flange, south-east side.	+ .5	2,827.7	175.32	July 11	

90	SW SW sec. 33	J. H. Salley	do	191	5	do	C, W	N	Top of casing, west-northwest side.	− .2	2,841.8	173.55	July 10	Premises unoccupied.
91	NW SW sec. 36	C. W. Bryant	Sand dune	195	(?) 5	do	C, W	D, S	Top of casing, north-northwest side.	+ .4	2,820.0	184.44	July 22	
	T. 33 S., R. 34 W.													
92	SW SW sec. 7	Anna Lazenby	do	163	(?) 5	do	C, W	D, S	Top of north clamp, west side.	+ 1.9	2,858.6	133.87	July 30	
93	NE NE sec. 12	Mrs. K. M. Lee	do	148	5	do	C, W	D, S	Top of union, southeast side.	+ .8	....	141.33	July 31	
94	SE NE sec. 19	Stephens and Keating	do	153	(?) 5	do	C, W	S	Top of metal cover, southeast side.	+ .6	2,940.1	108.32	July 30	Premises unoccupied.
95	SE SW sec. 21	Cont'l Assur. Society	do	121	5	do	C, W	S	Top of casing, east side	+ 1.0	....	115.34	do	do
(96)	SE NW sec. 23	G. Marcellus	do	112	5	do	C, W	D, S	Top of iron clamp, east side.	+ .1	....	106.48	do	Situated in a low place among sand dunes.
97	SW SW sec. 30	John Fuller	do	114+	5	do	C, W	D, S	Top of casing, northeast side.	+ .4	2,958.3	112.59	do	
98	SW SW sec. 32	S. W. Hopewell	Upland plain	114	5	do	C, W	N	Top of casing, south-southwest side.	+ .4	2,973.6	111.02	do	Elevator dismantled.
99	SW SW sec. 36	C. M. Cox Estate	Sand dune	143	(?) 5	do	C, W	N	Top of casing, west-southwest side.	+ 1.6	2,909.2	131.97	July 29	Premises unoccupied.
	T. 34 S., R. 31 W.													
(100)	NE SW sec. 5	McClure Estate	Floodplain	[illegible]0+	5	Recent alluvium	C, W	D, S	Top of bucket, south-southeast side.	+ .9	2,535.0	26.47	Aug. 5	
101	NW NE sec. 9	R. M. Hayes	do	125	5	Pliocene and Pleistocene undifferentiated	C, H	D	Top of casing, west side	+ .7	2,513.8	17.46	do	do
(102)	NE NE sec. 27	Mrs. M. York	do	34+	5	Recent alluvium	C	D, S	Top of casing, north side	+ 2.0	....	34.10	Aug. 13	
103	SW SW sec. 28	John Long	Sand dune	226+	5	Pliocene and Pleistocene undifferentiated	C, W	S	Top of casing, north-northeast side.	+ .3	....	222.72	July 24	
104	NW SW sec. 35	Federal Land Bank	do	221	5	do	C, W	D, S	Top of sheet-metal cover, north-northeast side.	+ 1.1	....	217.45	do	
	T. 34 S., R. 32 W.													
(105)	NE SE sec. 8	Grant Black	do	270±	5	do	C, W	D, S	Notch in casing, north side	+ 1.0	....	232.12	July 19	
106	SW SW sec. 10	Lydia Augerot	Upland plain	211+	5	do	C, W	N	Low point on casing, south-southeast side.	+ .4	2,771.8	207.06	July 9	do
107	SW SW sec. 12	J. R. P. Carr	do	213	5	do	C, W	N	Top of cement block, east-southeast side.	+ .2	2,745.7	208.37	do	do
108	SE SE sec. 13	Bert Dubois	do	225+	5	do	C, W	D, S	Low point in top of casing, east side.	+ 1.0	2,737.5	211.91	July 20	
109	SE SE sec. 14	Della Buckles	do	212+	5	do	C, W	N	Top of casing, east side	+ .4	2,743.1	207.44	July 8	do
110	SE SW sec. 17	Pennington Estate	Sand dune	222+	5	do	C, W	N	do	+ .1	2,798.5	218.43	July 19	
111	SW SW sec. 19	Anna Marsh	do	193+	5	do	C, W	N	Top of iron clamp, southwest side.	.0	2,795.9	176.52	July 18	do

TABLE 10.—Record of drilled wells in Seward County, Kansas—Continued

No. on Pl 2[1]	LOCATION	Owner or tenant	Topographic position	Depth of well (feet)	Diameter of well (inches)	Principal water-bearing horizon	Method of lift[2]	Use of water[3]	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water below measuring point (feet[4])	Date of measurement, 1940	Remarks
	T. 34 S., R. 32 W.													
112	NW NW sec. 22	Federal Farm Mort.	Sand dune	213	(?) 5	Pliocene and Pleistocene undifferentiated	C, W	N	Top of union above wood clamp, northeast side.	+ 1.2	2,766.9	208.97	July 22	Premises unoccupied.
(113)	SE SE sec. 23	Bert Dubois	do	216	5	do	C, W	D, S	Top of casing, south side	.0	2,740.1	204.35	Aug. 3	
114	NW SW sec. 30	Alfred Cady	do	190±	5	do	C, W	D, S	Top of casing, south-southeast side.	+ .4	....	157.93	July 18	
115	SW SW sec. 32	C. Wick	do	180	4	do	C, W	N	Top of iron plate, north side.	+ .3	....	172.04	July 20	do
116	NE SE sec. 34	A. S. Neff	do	214+	5	do	C, W	N	Top of casing, south side	+ .6	2,750.6	211.95	July 8	do
	T. 34 S., R. 33 W.													
117	SW SE sec. 2	G. E. Ingle	Upland plain	240±	5	do	C, W	D, S	Top of casing, west side	+ 1.0	....	217.64	July 13	
(118)	SW SW sec. 3	Mrs. A. Thompson	High sand dune	257	5	do	C, W	D, S	Top of handle flange on bucket over casing.	+ .4	....	249.11	July 12	
119	SE NE sec. 7	J. H. Gentzler Estate	Sand dune	148	5	do	C, W	D, S	Top of casing, east side	+ .9	2,880.8	136.78	July 29	Reported depth 180 feet.
120	NW NE sec. 14	L. O. Weidensaul and Mrs. O. Blakemore	Upland plain	208±	5	do	C, W	D, S	Top of metal cover, northwest side.	.0	....	200.65	July 12	
121	SW SE sec. 15	Mrs. D. E. Eubank	do	175±	5	do	C, W	D, S	Top of casing, south side	.0	....	144.88	do	
122	SW SE sec. 17	Mrs. H. E. Burns	do	166±	5	do	C, W	D, S	Top of casing, southwest side.	+ .3	....	106.78	July 11	
123	SE NE sec. 20	Mrs. L. W. Stevenson	do	155	5	do	C, W	N	Top of union, west-northwest side.	+ 1.2	2,856.7	112.13	do	Premises unoccupied.
124	SW SE sec. 22	C. F. Hertlein	Sand dune	137+	5	do	C, W	D, S	Top of clamp, north-northeast side of pipe.	+ 1.2	....	128.39	July 12	Leaky casing, measurement may be inaccurate.
125	NE NW sec. 24	Wilby McAhren	Upland plain	205	5	do	C, W	D, S	Top of metal cover, west-southwest side.	+ 1.3	2,831.6	197.62	do	
126	SW SW sec. 26	Mrs. J. Stamps	Sand dune	171	5	do	C, W	D	Top of casing, east-northeast side.	.0	2,807.5	127.40	July 19	
127	NE NW sec. 27	A. McCord	Upland plain	150+	5	do	C, W	N	Top of iron clamp, west-southwest side.	+ .4	2,832.4	143.00	July 12	Premises unoccupied.
128	NW NE sec. 32	Liberal Deep Well Co.	do	350+	15	do	T, NG	N	Top of air vent, south side,	+ .4	2,854.8	124.02	Aug. 15	Abandoned irrigation well

129	NW NW sec. 32	*M. L. Grover*	do	118	5	do	C, W	D, S	Top of iron clamp, northeast side.	+ 1.2	2,858.6	115.15	July 27	
130)	*SE NE sec. 32*	*City of Liberal*	*do*	*506±*	*18 to 12*	*do*	*T, NG*	*P*	*Land surface*	.0	....	120.00	....	Well No. 2 of battery of 3 wells; water level measured by H. A. Waite, 5-7-34; see log.
31	SW SW sec. 35	Judge Light	do	150+	5	do	C, W	D, S	Top of casing, southeast side.	+ .7	....	138.32	July 18	
32	*T. 34 S., R. 34 W.* SE SE sec. 4	Homer Krieble	do	145	6	do	C, W	D, S	do	+ 1.4	2,935.4	119.33	July 29	
33)	NW NW sec. 7	B. F. Packer	Sand dune	130±	5	do	C, W	D, S	Top of wooden clamp, east side.	+ 1.1	2,962.3	116.87	do	
34	SW SW sec. 10	H. Krieble	do	114	5	do	N	N	Low point on top of casing, southwest side.	+ .4	2,929.2	107.73	do	Premises unoccupied; pipe withdrawn from well.
35	NE NE sec. 11	Keating and Stevens	Upland plain	133	(?) 5	do	C, W	D, S	Top of wooden clamp, west side.	+ 1.1	....	120.96	July 29	
36	NE NW sec. 17	T. Printz	Sand dune	127	5	do	C, W	D, S	Top of 2 x 4, east side	+ 1.5	....	107.44	do	
37	SE SE sec. 23	Mrs. Gassaway	Upland plain	105+	5	do	C, W	D, S	Top of casing, southwest side.	+ .6	....	101.59	July 27	
38	NW SW sec. 26	W. R. Green	Sand dune	109	5	do	C, W	N	Top of casing, south-southeast side.	+ 1.2	....	87.78	do	Premises unoccupied.
39	NW NE sec. 28	O. L. Gartung	do	123	6	do	C, W	D, S	Top of casing, southwest side.	+ .3	2,938.6	107.68	July 29	
40	SE NE sec. 31	W. A. Heston	do	106+	5	do	C, W	D	Top of casing, east side	+ 1.3	2,945.1	100.14	July 27	
141)	SW SW sec. 33	Seward County	Upland plain	93	(?) 5	do	C, W	D	Top of iron clamp, east side.	+ 1.0	2,910.6	75.28	July 25	Supplies Wideawake schools.
42	SE SW sec. 36	Maude Gaines et al.	do	95	(?) 5	do	C, W	N	Top of metal cover, south side.	.0	....	86.56	do	Premises unoccupied.
43	*T. 35 S., R. 31 W.* NW SW sec. 5	Federal Land Bank	Sand dune	208	5	do	C, W	D	Top of casing, south-southwest side.	− .3	....	194.99	July 24	
44	NE NW sec. 11	C. Ferguson	do	228	5	do	C, W	N	Top of casing, north-northwest side.	+ 1.2	2,683.8	208.42	do	do
145	SW NE sec. 13	G. Blucher	do	229+	5	do	C, W	D, S	Low point on top of casing, west-southwest side.	+ 1.2	2,675.2	221.23	do	
146)	SE NE sec. 15	Federal Land Bank	do	211	(?) 5	do	C, W	D, S	Top of casing, northeast side.	+ .5	2,683.6	200.04	do	
147	NE NW sec. 18	Illinois Life Ins. Co.	do	217±	5	do	C, W	D, S	Top of bucket, northwest side.	.0	2,703.3	185.74	July 23	
148	*T. 35 S., R. 32 W.* NE SE sec. 2	Elmo Lodge of Perfection.	do	189	5	do	C, W	N	Top of rim of iron wheel, west side.	+ 1.0	2,736.3	185.72	July 20	do
49	NW NW sec. 6	J. W. Preifert	do	155+	5	do	C, W	N	Top of casing, west side	+ .5	....	150.98	July 18	do
50	SW SE sec. 6	Federal Land Bank	do	145+	5	do	C, W	D, S	Top of casing, north-northeast side.	+ 1.1	2,764.6	141.40	July 19	
51	NW SW sec. 13	A. N. Heitschmidt, tenant; H. F. Witt, owner.	do	217	5	do	C, W	N	Top of casing, east side	+ 1.5	2,733.6	205.92	July 22	Land farmed but buildings unoccupied; well used occasionally.
52	NW NW sec. 16	E. Thompson	do	188+	5	do	C, W	D, S	Top of union, south side	+ 1.3	2,746.7	183.10	July 18	

TABLE 10.—Record of drilled wells in Seward County, Kansas—*Concluded*

No. on pl. 2[1]	Location	Owner or tenant	Topographic position	Depth of well (feet)	Diameter of well (inches)	Principal water-bearing horizon	Method of lift[2]	Use of water[3]	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water below measuring point (feet[4])	Date of measurement, 1940	Remarks
	T. 35 S., R. 33 W.													
53	NW NE sec. 2	L. D. Weidensaul	Sand dune	148+	5	Pliocene and Pleistocene undifferentiated	C, W	N	Top of casing, south side	+ .2	....	141.62	July 8	Premises unoccupied.
54	NW NE sec. 4	R. Hoskins	Upland plain	150±	5	do.	C, W	D	Top of bolt, east side	+ .1	....	122.62	July 18	
55	NE NW sec. 4	C. R. I. & P. R. R.	do.	168.6	10	do.	(?) T, S	R	Land surface	.0	....	124.00	....	One of several railroad wells; reported to yield 150 gallons a minute with drawdown of 7.5 feet.
56	SW NW sec. 5	J. Lloyd	do.	140±	5	do.	C, W	D	Top of casing, north-northeast side.	+ .2	....	86.36	July 25	Well temporarily out-of-order.
57	SW NW sec. 15	E. Snyder	do.	180±	5	do.	C, W	D, S	Top of casing, east-northeast side.	.0	2,828.0	129.10	July 22	
	T. 35 S., R. 34 W.													
58	NW NE sec. 3	Liberal Gas Co.	Sand dune	162.5	12	do.	N	N	Notch in top of casing, northwest side.	+ 1.7	2,922.8	97.08	Aug. 15	Used only to provide water for drilling gas wells.
59	SW SE sec. 6	F. Boles	do.	111+	5	do.	C, W	D, S	Top of casing, west side	+ .3	2,948.5	105.39	July 25	
60	NW NE sec. 13	E. Hall	do.	101	5	do.	C, W	D, S	Top of iron clamp, north-west side.	+ .7	2,875.5	88.83	do.	
61	NW SE sec. 15	M. M. Trexler	do.	108	(?) 5	do.	C, W	N	Top of wooden clamp, east side.	+ .1	2,900.5	95.55	do.	Premises unoccupied.
62	NE SE sec. 17	Cora Richardson	do.	116+	(?) 5	do.	C, W	N	Break in cover, north side of pipe.	— .2	2,924.6	100.66	do.	do

1. Number in parenthesis indicates that analysis of water is given in Table 9.
2. Pumps: C, cylinder; N, none; T, turbine. Power: W, wind; H, hand; E, electric motor; G, gasoline engine; NG, natural gas engine; S, steam engine.
3. D, domestic; I, irrigation; N, not in use; P, public supply; R, railroad; S, stock.
4. Measured water levels given in feet, tenths, and hundredths; reported water levels given in feet.

WELL LOGS

Listed in the following pages are the logs of 35 test holes and wells in Seward County, including 23 test holes drilled by the State Geological Survey. The locations of these test holes are shown in Plate 3.

1. *Sample log of test hole 1 at the NW cor. sec. 6, T. 31 S., R. 30 W., Meade County, drilled by State Geological Survey, 1940. Surface altitude, 2,795± feet.* (Samples studied by Perry M. McNally and John C. Frye.)

	Thickness, feet	*Depth, feet*
Soil, brown	1	1
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Silt and sand, fine, gray tan	7	8
Sand, fine to medium, brown	4	12
Sand, fine, and silt; contains gray-tan caliche	79	91
Sand and silt, brown, cemented with caliche	6	97
Sand and gravel, brown	11	108
Silt, fine sand, and caliche	2	110
Sand and gravel, brown and tan	232	342
Sand, fine, silt, and caliche; gray	18	360
Silt, fine sand, and caliche; gray	31	391
Sand, gray	21	412
Sand, fine, silt, and caliche; pink tan	8	420
Sand, brown	11	431
Sand and some silt; cemented with caliche	19	450
Silt, fine sand, and caliche; tan	20	470
Sand, fine, silt, and caliche; gray; contains remains of plants	20	490
Silt, caliche, and fine sand; tan and gray	23	513
Caliche, silt, and fine sand; yellow; contains thin beds of sandstone and pink-red beds of clay	17	530

2. *Sample log of test hole 2 at the SW cor. sec. 36, T. 30 S., R. 32 W., Haskell County, drilled by State Geological Survey, 1943. Surface altitude, 2,837 feet.* (Samples studied by James B. Cooper, Oscar S. Fent, and Thad G. McLaughlin.)

	Thickness, feet	*Depth, feet*
Soil, sandy, gray black	1.5	1.5
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Silt, micaceous, soft, yellow gray	3.5	5
Silt, micaceous, soft, red brown; contains fine sand and caliche	5	10
Silt, compact, buff and tan; contains fine to coarse sand, caliche, and fine gravel	39	49
Sand, medium to fine; contains soft tan silt and caliche	6	55
Clay, compact, light buff; contains fine sand	9	64

	Thickness, feet	*Depth, feet*
Silt, compact, red tan; contains fine to coarse sand, fine gravel, and caliche	18	82
Sand and gravel, coarse to fine; contains soft gray to tan and yellow-brown silt and caliche	50	132
Silt, soft, yellow brown	3	135
Gravel, fine to coarse, and medium to coarse sand	5	140
Silt, clayey, soft, yellow buff; contains coarse to fine sand and caliche	14	154
Sand and gravel, coarse to fine; contains soft buff and yellow-gray silt	63	217
Silt, soft, gray; contains medium to fine sand	9	226
Sand, coarse to fine; contains fine to medium gravel and soft gray silt	24	250
Clay and silt, soft, blue gray; contains fine sand	23	273
Sand, coarse to fine, gray; contains medium to fine gravel	5	278
Clay and silt, compact, partly laminated, blue gray to gray and buff; contains fine sand	67	345
Sand, coarse to fine, and medium to fine gravel; contains caliche	31	376
Silt, soft, white to pink; contains coarse to fine sand and caliche	14	390
Caliche and soft light-brown silt; contains medium to fine gravel and coarse to fine sand	27	417
Clay, compact, tan; contains fine to medium sand and pyrite	27	444
Sand, fine-grained, consolidated; contains caliche	26	470
Silt, fine sandy, partly consolidated, cream to tan; contains caliche	25	495
Sand, fine to medium, partly cemented; contains a little silt	21	516
PERMIAN—Guadalupian		
Siltstone, brick red	14	530

3. *Sample log of test hole 3 at the SW cor. sec. 31, T. 30 S., R. 32 W., Haskell County, drilled by State Geological Survey, 1943. Surface altitude, 2,897 feet.* (Samples studied by James B. Cooper, Oscar S. Fent, and Thad G. McLaughlin.)

QUATERNARY AND TERTIARY—Pleistocene and Pliocene	*Thickness, feet*	*Depth, feet*
Silt, clayey to sandy, dark brown to red brown; contains caliche	8	8
Silt, soft, white and gray; contains fine to medium sand	9	17
Silt, sandy, compact, dark tan and gray; contains fine gravel	4	21
Silt, soft, brown; contains fine to medium sand	2	23
Silt, compact, white and gray; contains caliche	4	27

	Thickness, feet	*Depth, feet*
Silt, gray to light tan and brown; contains fine to medium sand and caliche	10	37
Sand, red brown; contains fine to coarse gravel and silt	11	48
Silt, red brown and gray; contains very fine sand and caliche	3	51
Sand, red brown; contains fine gravel and silt	5	56
Silt, soft, red brown; contains fine to medium sand	4	60
Sand and gravel, coarse to fine	28	88
Silt, compact, gray; contains coarse gravel and caliche,	8	96
Sand, yellow brown; contains fine to coarse gravel	4	100
Gravel, fine to coarse; contains silt	10	110
Sand, coarse to fine; contains fine to medium gravel	13	123
Sand, coarse to fine; contains fine to medium gravel and silt	117	240
Gravel, fine to coarse, and coarse to medium sand; contains soft light-gray silt	6	246
Silt, soft, light gray; contains coarse to medium sand,	2	248
Gravel, medium to fine, and coarse to medium sand	9	257
Silt, soft, yellow gray; contains coarse to fine sand	3	260
Gravel, fine to coarse, and coarse to medium sand; contains silt, soft, gray and tan	13	273
Silt, clayey, soft, yellow brown and light gray; contains medium to fine sand	7	280
Sand and gravel, coarse to fine; contains a little silt and caliche	113	393
Silt, soft, white and gray to buff and brown; contains fine to coarse sand and gravel and nodules of caliche	47	440
Clay, blocky, tan; contains caliche	10	450
Silt, soft, white, and fine gravel; contains fine to coarse sand and tan blocky clay	10	460
Sand, coarse to medium, consolidated; contains soft light-gray silt	11	471
Silt, soft, blue gray to gray buff and yellow buff; contains fine to coarse sand	24	495
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, soft, yellow, and very fine sand; contains fine-grained yellow and brown sandstone	5	500
No sample recovered	10	510

4. *Sample log of test hole 4 at the SE cor. sec. 25, T. 31 S., R. 35 W., Stevens County, drilled by State Geological Survey, 1943. Surface altitude, 2,967 feet.* (Samples studied by Oscar S. Fent and Thad G. McLaughlin.)

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

	Thickness, feet	Depth, feet
Sandstone, fine-grained, soft, and silt, compact; white and yellow; contains ironstone	10	490
Silt, light yellow and white; contains very fine-grained white sandstone	7	497
Sandstone, fine-grained to very fine-grained, hard, and silt, soft; white and yellow	3	500
Siltstone, in part clayey, soft, and sandstone, fine-grained to very fine-grained; white to yellow; contains ironstone	17	517
Clay, varicolored; contains yellow and red siltstone and very fine-grained sandstone	29	546
PERMIAN—Guadalupian		
Redbeds		
Clay, dark red	4	550
Shale, hard, dark red; contains a little blue-gray shale,	10	560

5. *Sample log of test hole 5 at the SE cor. sec. 24, T. 32 S., R. 35 W., Stevens County, drilled by State Geological Survey, 1943. Surface altitude, 2,974 feet.* (Samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Dune sand		
Sand, medium to fine; contains light to dark-gray silt,	6	6
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Silt, in part clayey, soft, buff to greenish gray and gray; contains a little caliche and fine to medium sand	20	26
Sand, medium to fine; contains soft gray-white silt and a little caliche	3	29
Silt, soft, buff and light tan; contains fine to coarse sand and a little caliche	21	50
Sand, medium	3.5	53.5
Clay, silty, yellow gray	6.5	60
Sand, coarse to fine; contains fine gravel and soft gray silt	6	66
Silt, soft, yellow gray; contains fine to medium sand..	10	76
Sand, coarse to fine, and silt, soft, gray; contains caliche	4	80
Sand and gravel; coarse to fine	13	93
Silt, clayey, buff; contains fine sand, pink-buff clay, and caliche	17	110
Clay, silty, buff	7	117
Gravel and sand; coarse to fine; contains a little soft white silt	19	136
Silt, clayey, buff; contains fine sand and a little caliche	4	140
Silt, compact, buff and pink; contains fine to coarse sand and caliche	35	175

	Thickness, feet	Depth, feet
Gravel, medium to fine; contains soft buff silt and fine to coarse sand	14.5	189.5
Silt, gray; contains fine gravel, fine to coarse sand, and caliche	10.5	200
Gravel, medium to fine, and sand, coarse; partly consolidated	20	220
Gravel, medium to fine, and sand, coarse; consolidated,	3	223
Silt, soft, gray brown; contains fine to coarse sand...	11	234
Sand, coarse to medium, and gravel, fine	5	239
Silt, soft, yellow gray to tan and buff; contains fine to medium sand and caliche	31	270
Clay, compact, blocky, brown and blue gray; contains caliche	10	280
Silt, clayey, buff to yellow gray and tan; contains very fine to medium sand and caliche	30	310
Clay, compact, laminated, light blue gray; contains soft tan silt and a little caliche	70	380
Silt, soft, buff and tan; contains fine sand	40	420
Sand, coarse to fine; contains yellow-buff silt, fine to medium gravel, and caliche	30	450
Silt, gray and buff; contains fine to medium sand and a little caliche	20.5	470.5
Gravel, fine, and sand, coarse to fine	6.5	477
Silt, soft to compact, light pink to buff; contains fine to coarse sand and a little caliche	15	492
Silt, clayey, red and buff; contains sand and caliche...	5	497
PERMIAN—Guadalupian		
Redbeds		
Siltstone, clayey, dark red	13	510

6. *Sample log of test hole 6 at the NE cor. sec. 30, T. 33 S., R. 30 W., Meade County, drilled by the State Geological Survey, 1940. Surface altitude, 2,721 feet.* (Samples studied by Perry McNally, John C. Frye, and Charles C. Williams.)

	Thickness, feet	Depth, feet
Soil, sandy, brown	3	3
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Silt and fine sand, yellow brown	5	8
Sand, fine to medium, brown		
Sand, fine to medium, and silt; light gray; contains caliche	11.5	19.5
Clay, limy, light gray to white, and caliche	7.5	27
Sand, fine, and silt, limy; contains caliche	6	33
Silt, limy, and sand, fine	10	43
Sand, fine, consolidated, brown	6	49
Sand, fine, light brown to brown; contains caliche and silt	31	80

	Thickness, feet	Depth, feet
Silt, tan, calcareous, and sand, fine; contains tan blocky clay	13	93
Sand, medium, to gravel, coarse; brown	54.5	147.5
Sand, medium; contains silt and clay	7.5	155
Sand, fine to coarse, gray to brown	35	190
Sand, fine to medium, brown and gray, and silt, limy, gray	10	200
Silt, fine sandy, gray	9	209
Sand and gravel; contains fine sand	50	259
Sand, fine, yellow brown	2	261
Clay, sandy, light gray	7	268
Silt, blue gray, and clay, sandy	11	279
Sand, fine to medium, brown, and silt	3.5	282.5
Silt, clay, and fine sand, light gray to brown	16.5	299
Sand, fine to coarse, brown	3	302
Clay, silty, blue gray, and fine sand	4	306
Silt, fine sand, and caliche	3	309
Sand, fine, to gravel, medium	17	326
Clay, blue gray, and silt	2	328
Sand, fine, to gravel, medium; contains silt and caliche	49	377
Clay, silty to fine sandy, blue gray to tan	4.5	381.5
Sand, tan	3.5	385
Clay, silty to fine sandy, blue gray and tan; contains sand	24	409
Sand, fine, to gravel, medium; gray and brown	55	464
Clay, silty to fine sandy, blue gray to buff and brown; contains tan to buff silt	31	495
Sand, fine to coarse; contains silt and clay	14	509
Silt, buff, and sand, fine	19	528
Sand, fine, and silt, limy; contains caliche	22	550
Sand, poorly sorted, silt, and caliche	12	562
Sand, medium, to gravel, fine; brown	10	572
PERMIAN—Guadalupian		
Redbeds		
Siltstone, maroon to brick red	8	580

7. *Sample log of test hole 7 at the SE cor. sec. 15, T. 33 S., R. 31 W., drilled by the State Geological Survey, 1940. Surface altitude, 2,743 feet.* (Samples studied by James B. Cooper and Frank E. Byrne.)

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Dune sand		
Sand, fine, brown	14	14
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Caliche and clay, light gray, silty, calcareous	6	20
Caliche, white to light gray	4	24
Sand, fine, calcareous, brown, clay, silty, and caliche,	12	36

	Thickness, feet	Depth, feet
Sand, fine, calcareous, brown	7	43
Sand, medium, to gravel, fairly coarse; brown, poorly sorted	7	50
Sand, fine, calcareous, brown and gray; contains caliche and gravel	9	59
Silt, sand, and gravel, medium; brown, poorly sorted,	3.5	62.5
Sand, fine, gray, very calcareous	4.5	67
Sand and gravel; contains thin zones of caliche	4	71
Sand and gravel, poorly sorted; contains waterworn pebbles of caliche; interbedded with fine calcareous brown sand	9	80
Sand and gravel, poorly sorted, brown	10	90
Sand, medium, to gravel, fine; brown	20	110
Sand and gravel, poorly sorted; interbedded with fine calcareous sand and with thin mortar beds in basal part	39.5	149.5
Sand, medium and coarse, greenish brown, calcareous; contains fine sand and silt	2.5	152
Sand, medium, to gravel, fine; brown	25	177
Sand, fine, to gravel, coarse; brown, calcareous; contains hard beds of caliche	13	190
Clay, silty and fine sandy, greenish brown	10	200
Clay, fine sandy, calcareous, gray; contains sand, gravel, and brown silty clay; three thin mortar beds interbedded	20	220
Sand, medium, to gravel, fine; brown; contains silty clay	50	270
Sand and gravel, brown; contains fine calcareous sand and silt	10	280
Sand, medium, to gravel, fine; brown	7	287
Clay, silty to fine sandy, light blue gray	3	290
Sand, fine, to gravel, medium; brown	8.5	298.5
Clay, silty to fine sandy, light blue gray	8.5	307
Sand, medium, to gravel, medium; brown	55	362
Shale, silty, blue gray, and clay, silty to fine sandy; contains hard limestone at top	8	370
Sand, coarse, to gravel, medium; interbedded with blue-gray thin-bedded shale	60	430
Shale, silty, dull green gray	10	440
Shale, silty, dull green and gray; interbedded with limonite-stained sandstone	10	450
Shale, silty, dull green gray, and sandstone, concretionary, thin-bedded	30	480
Shale, green gray and blue gray, interbedded with sandstone, concretionary, rusty brown; contains some gravel	9	489
Shale, silty, blue gray, green gray, and yellow; contains chips of black carboniferous material	19	508

8. *Sample log of test hole 8 in the SE¼ SW¼ sec. 18, T. 33 S., R. 31 W., drilled by the State Geological Survey, 1940. Surface altitude 2,752± feet.* (Samples studied by James B. Cooper and Frank E. Byrne.)

	Thickness, feet	*Depth, feet*
Road fill	3	3
QUATERNARY—Recent		
Dune sand		
Sand, fine, dark brown	2	5
Sand, fine, brown, calcareous	2	7
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Caliche and clay, brown; contains fine sand	11	18
Silt and fine sand, light gray to greenish white, calcareous	9	27
Clay, silty, and sand, fine; purple brown	11	38
Caliche, tan	5	43
Sand, fine, pink brown, calcareous; contains pebbles of caliche near base	17	60
Caliche, coarse sand, and gravel; contains fine sandy clay near base	16.5	76.5
Sand and gravel, brown; contains thin "mortar beds" at 94 and 96 feet and thin bed of caliche at 130 feet	66.5	143
Sand, fine, brown, calcareous, and caliche, soft	4	147
Caliche	3	150
Sand, medium, to gravel, coarse; brown	20	170
Sand, fine to coarse, brown; contains fine sandy clay	10	180
Sand, medium, to gravel, medium; brown	33	213
Sand, fine, to gravel, medium; calcareous, white	1	214
Sand, medium, to gravel, medium; brown	5.5	219.5
Sand, medium, to gravel, fine; calcareous, white	1.5	221
Sand, fine, to gravel, fine; brown; contains thin zone of caliche near base	9	230
Sand, fine, to gravel, fine; calcareous, brown; contains blocky pink-brown silt	11	241
Sand, medium, to gravel, fine; brown	9	250
Sand, medium, to gravel, medium; brown	30	280
Sand, medium, to gravel, fine; brown	10	290
Sand, fine, calcareous, brown; contains thin zone of caliche in upper part and scattered gravel and blocks of clay near base	30	320
Sand, calcareous, light gray to gray; contains fine gravel and caliche	30	350
Silt and sand, fine; calcareous, gray brown; contains thin zone of caliche near top	8	358
Mortar bed, coarse sand, and fine brown-gray gravel,	3	361
Sand, calcareous, hard, yellow to yellow brown	1.5	362.5
Silt, pink red, and clay, varicolored; interbedded, fairly hard	7.5	370

	Thickness, feet	Depth, feet
Caliche, calcareous clay, and pinkish red silt; hard ..	4.5	374.5
Sand and gravel, loose; contains caliche and pink-red silty clay	15.5	390
Clay, silty, varicolored, and limestone, thin-bedded; contains gravel near base	30	420
Clay, mottled or varicolored, and limestone, thin-bedded; contains gravel and sand in basal part ..	40	460
Sand and gravel interbedded with gray and pink clay; contains hard "mortar beds," and reworked fragments of sandstone	20	480
Clay, silty, pink red and gray; contains thin bed of limestone near middle	30	510
Silt and sand, fine; calcareous, rusty brown; contains fine gravel	10	520
Shale, blue gray, and gravel	10	530
Sand, silty, rusty brown, in part consolidated	10	540

9. *Sample log of test hole 9 at the NE cor. sec. 21, T. 33 S., R. 32 W., drilled by the State Geological Survey, 1942. Surface altitude, 2,681 feet.* (Samples studied by James B. Cooper and Frank E. Byrne.)

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Dune sand		
Sand, fine, and silt; gray brown	2	2
Sand, fine to coarse, grayish brown	5	7
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Silt and sand, coarse; calcareous, brownish gray; contains fine gravel	8	15
Sand, fine, to gravel, fine; light brownish gray	5	20
Clay, silt, and sand, coarse; tan; contains fragments of caliche	6	26
Sand, fine to coarse, and gravel, fine; slightly calcareous, light brownish gray	4	30
Sand, medium, to gravel, fine; tan gray	30	60
Sand, medium, to gravel, coarse; calcareous, light brownish gray	10	70
Sand, fine, to gravel, medium; brownish gray	130	200
Sand, fine to coarse, brownish gray	22	222
Sand and gravel, brown gray, and compact gray and tan shale	32.5	254.5
Shale, compact, gray and tan, interbedded with fine-grained tan sandstone	11.5	266
PERMIAN—Guadalupian		
Redbeds		
Sandstone, fine-grained, calcareous, gray red	4	270
Shale, silty and fine sandy, calcareous, red to reddish gray, contains gray sandstone	40	310

10. *Sample log of test hole 10 in the NW¼ sec. 19, T. 33 S., R. 32 W., drilled by the State Geological Survey, 1942. Surface altitude, 2,659 feet.* (Samples studied by James B. Cooper and Frank E. Byrne.)

	Thickness, feet	*Depth, feet*
Soil, sandy, brown; contains coarse gravel from 6 to 10 inches below land surface	2	2
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Sand, coarse, and silt, lime-cemented, light brownish gray; contains coarse gravel	13	15
Sand, fine, to gravel, medium; grayish brown	8.5	23.5
Sand, fine, to gravel, medium; lime-cemented, light brown	6.5	30
Sand, fine, silt, and clay; calcareous, yellowish gray brown	2	32
Clay, silt, and sand, fine; calcareous, tan gray	4	36
Sand, fine to coarse, calcareous, tan gray	4	40
Sand, fine, to gravel, medium; gray brown	100	140
Sand, fine, to gravel, medium; calcareous, light brownish gray; contains silt and clay	20	160
Silt and clay, calcareous, brownish gray	10	170
Silt and clay, calcareous, brownish gray; contains sand and medium gravel	10	180
Sand, silt, and clay; calcareous, light brownish gray	10	190
Sand, medium, to gravel, medium; gray brown	5	195
Sand and silt, lime-cemented, gray brown; contains clay and fine gravel	15	210
Clay, sandy, calcareous, gray brown; contains sand and gravel	30	240
Sand, fine to coarse, hard at top	10	250
Sand and shale, compact, brown	10	260
Clay, silty and fine sandy, pink, and sandstone, hard; contains brown shale	10	270
Clay, sandy; contains caliche	10	280
Sand, fine, to gravel, coarse; contains clay	30	310
Sand, fine, to gravel, coarse; contains clay in lower part	71	381
Clay, compact, soft, pink to light gray	6	387
PERMIAN—Guadalupian		
Redbeds		
Shale, light red; contains siltstone	33	420
Shale and siltstone, red; contains inclusions of fine-grained calcareous gray sandstone	10	430

11. *Sample log of test hole 11 at the NW cor. sec. 23, T. 33 S., R. 33 W., drilled by the State Geological Survey, 1942. Surface altitude, 2,816 feet.* (Samples studied by James B. Cooper and Frank E. Byrne.)

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Dune sand		
Sand, fine, and silt; medium brown	1	1
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Sand, fine to coarse, calcareous, gray red; contains silt,	5	6
Sand, fine to coarse, gray red; contains silt	4	10
Sand, fine, to gravel, medium; contains brown silt	12	22
Sand, silt, and clay; calcareous, gray red	3	25
Sand, medium, to gravel, medium; brownish gray	7	32
Clay at top to sand at base; calcareous, gray brown	18	50
Sand, medium, to gravel, fine; brownish gray	9	59
Silt and sand, calcareous, light brown gray; contains clay	21	80
Caliche, dense, white	5	85
Sand, fine, to gravel, medium; brownish gray; contains silt and clay	5	90
Sand, fine, to gravel, medium; brownish gray	30	120
Sand, fine, to gravel, medium; calcareous, brownish gray	5	125
Sand and gravel, fine and medium, calcareous, tan gray	4	129
Clay, sandy, yellow brown	1	130
Sand, fine, to gravel, fine; grayish brown	21	151
Sand, fine, to gravel, fine; lime-cemented, yellow gray,	6	157
Sand, fine, to gravel, fine; grayish brown	13	170
Sand, fine, to gravel, fine; calcareous, tan gray	10	180
Sand, fine, to gravel, medium; brown gray	60	240
Sand and gravel interbedded with silt and clay; calcareous, pink and gray brown	20	260
Sand, fine gravel, and silt; calcareous, pink and gray brown	10	270
Sand, medium, to gravel, coarse; brown gray	21	291
Sand, silt, and clay; calcareous, tan gray	9	300
Sand, medium, to gravel, fine; grayish brown	15	315
Sand and gravel, calcareous, brownish gray; contains silt and clay	7	322
Sand, medium, to gravel, fine; grayish brown	37	359
Sand, silt, and clay; calcareous, light yellowish brown; contains brown shale	6	365
Gravel, medium, and sand, medium; brownish gray	15	380
Clay, sand, and shale interbedded; calcareous, tan gray	20	400
Shale, soft, buff gray, and clay, sandy, compact, tan gray	10	410

	Thickness, feet	Depth, feet
Clay, sandy, greenish gray, interbedded with shale, compact, dark tan and gray	50	460
Shale, compact, dark green gray and buff, interbedded with sandy clay	10	470
Shale, compact, dark green gray and buff	20	490
Shale, compact, dark green gray and gray	10	500
Shale, compact, dark red brown; contains fine sandy clay; interbedded with green gray shale	30	530
Shale, silty, compact, gray	10	540
Shale, gray; interbedded with compact red shale	20	560
Shale, gray and red; contains sandy clay	10	570
Shale, dense, medium gray, and shale, silty, red	20	590
Shale, calcareous, gray and red, and siltstone, compact, red	10	600
Shale, silty, medium gray, and shale, red	10	610
Shale, dense, dark gray	20	630
Shale, silty, medium gray, and shale, red	12	642
PERMIAN—Guadalupian		
Redbeds		
Siltstone, red; contains calcareous gray sandstone	8	650
Siltstone, red; contains large inclusions of medium-grained highly calcareous sandstone	10	660
Siltstone, red, and shale, gray, dense	10	670

12. *Sample log of test hole 12 at the SW. cor. sec. 17, T. 33 S., R. 33 W., drilled by the State Geological Survey, 1942. Surface altitude, 2,862 feet.* (Samples studied by James B. Cooper and Frank E. Byrne.)

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Dune sand		
Sand, fine to coarse, brown; contains silt	5	5
Sand, coarse to fine, reddish brown; contains silt	5	10
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Sand, fine to coarse, reddish brown; contains silt and clay	17	27
Silt and clay, calcareous, red gray	13	40
Sand, coarse, to gravel, coarse; gray brown	7	47
Silt, clay, and sand; calcareous, brown gray	13	60
Caliche, light gray; contains fine sand	10	70
Clay, brownish gray; calcareous; contains silt and sand	10	80
Caliche, brownish gray; contains silt and clay	10	90
Caliche, brownish gray; contains sand and silt	10	100
Sand and gravel, fine; lime-cemented, brown gray	10	110
Sand, coarse, to gravel, medium; light brown	12	122
Gravel, fine and medium, and sand; lime-cemented, hard	6	128
Sand, medium, to gravel, medium; light brown	57	185

	Thickness, feet	Depth, feet
Sand, medium, to gravel, medium; lime-cemented, gray	3	188
Sand, fine, to gravel, medium; calcareous, light brown	22	210
Sand, coarse, silt, and clay; calcareous, tan and yellow tan	10	220
Sand, medium, to gravel, coarse; brownish gray	35	255
Sand and gravel, brownish gray, slightly calcareous; contains silt and clay	5	260
Sand and gravel, brownish gray, calcareous	20	280
Gravel, fine, to sand, medium; brownish gray; contains silt and clay	10	290
Gravel, medium, to silt; highly calcareous, tan	10	300
Gravel, medium, to sand, fine; brown gray	40	340
Sand, coarse to fine, grayish brown, and gravel, fine; interbedded with compact gray, tan, and yellow-brown shale	84	424
Shale, compact, dark yellowish gray, and clay, sandy,	6	430
Shale, sandy, dark gray	10	440
Shale, silty, dark gray, and shale, sandy, soft, yellow gray	20	460
Shale, dark gray	10	470
Shale, sandy, gray, rusty, and dark gray	10	480
Shale, sandy, soft, dark brown gray	21.5	501.5
Shale, calcareous, hard, blue gray	1.5	503
Shale, compact, brown gray, and shale, sandy, yellow brown	7	510
Sand, coarse, brownish gray; contains gravel	11	521
PERMIAN—Guadalupian		
Redbeds		
Shale, bright red; contains calcareous silt	22	543
Shale, silty, calcareous, bright red; contains yellow-gray sandstone	7	550

13. *Sample log of test hole 13 at the NE cor. sec. 22, T. 33 S., R. 34 W., drilled by the State Geological Survey, 1942. Surface altitude, 2,888 feet.* (Samples studied by James B. Cooper and Frank E. Byrne.)

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Dune sand		
Sand, fine and medium, light brown; contains silt	1.5	1.5
Sand, fine and medium, reddish brown; contains silt	5.5	7
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Silt, clay, and sand; calcareous, brownish gray	3	10
Sand, coarse, to silt; calcareous, gray brown	13	23
Sand, silt, and clay; calcareous, reddish brown to dark gray	7	30
Sand, silt, and clay; highly calcareous, tan gray	6.5	36.5

	Thickness, feet	*Depth, feet*
Sand, coarse to fine, calcareous, brownish gray; contains caliche	2.5	39
Silt, clay, and fine sand; calcareous, gray red	6	45
Sand, fine to coarse, brownish gray; contains fine gravel	11	56
Clay, silty, gray red	3	59
Silt, clay, and sand; highly calcareous, tan to brown gray	11	70
Clay, calcareous, tan to brownish gray; contains silt and fragments of caliche	11	81
Caliche, sandy, tan to light gray; contains reddish-gray silt and clay	9	90
Silt, sand, and gravel, fine to medium; highly calcareous, tan gray	20	110
Sand and gravel, reddish gray; highly calcareous; contains silt and clay	11	121
Caliche, hard, white to light brownish gray	9	130
Sand, coarse, to gravel, medium; brownish gray	9	139
Sand and gravel, consolidated, gray	9.5	148.5
Gravel, fine to coarse, pink gray, slightly cemented; contains coarse sand	1.5	150
Silt and sand, highly calcareous, buff gray; contains clay	6	156
Sand, fine, and gravel; calcareous, light brownish gray,	4	160
Sand, coarse, and gravel, fine; light brownish gray; contains silt	20	180
Silt, sand, and clay; calcareous, tan gray	10	190
Sand, medium, to gravel, medium; grayish brown	40	230
Sand and gravel; contains silt	25	255
Shale, silty to fine sandy, slightly calcareous, compact, medium gray and yellow buff	18	273
Shale, calcareous, compact, dark gray to yellow gray	17	290
Sand, coarse, gray brown, and shale, calcareous, dark gray to yellow gray	10	300
Sand, coarse to fine, gray brown; contains gray and buff shale	10	310
Sand, fine to coarse, gray brown	20	330
Sand, light brown, and shale, calcareous, compact, dark gray	20	350
Sand, light brown, and shale, compact, gray	10	360
Sand, light brown; interbedded with compact gray and pink shale	60	420
Clay, sandy, and shale; varicolored; contains much sand from 480 to 500 feet	80	500
Permian—Guadalupian		
Redbeds		
Siltstone, calcareous, pink to pinkish gray; contains red shale	20	520

14. *Sample log of test hole 14 at the SW corner sec. 16, T. 33 S., R. 34 W., drilled by the State Geological Survey, 1942. Surface altitude, 2,904 feet.* (Samples studied by James B. Cooper and Frank E. Byrne.)

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Dune sand		
Sand and silt, brown	5	5
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Silt and clay, calcareous, reddish gray; contains nodules of caliche	5	10
Silt and clay, calcareous, gray	11	21
Caliche, sandy, light brownish gray to white	8	29
Caliche, fine sandy, grayish white	2	31
Sand, medium, to gravel, coarse; brownish gray	15	46
Silt and clay, calcareous, rusty gray; contains fine sand,	4	50
Silt to sand, medium; calcareous, light brownish gray; contains clay	8	58
Sand, medium, to silt; calcareous, gray brown; contains gravel at base and fragments of caliche	12	70
Silt, sand, and beds of caliche; light gray	20	90
Caliche, sandy, tan gray	20	110
Sand and silt; contains caliche	37	147
Sand, fine, to gravel, fine; calcareous, brownish gray	4	151
Gravel and sand, consolidated	6	157
Gravel, coarse, to sand, fine; brown	13	170
Sand, fine to coarse, light brown	40	210
Sand and gravel, fine, light brown	50	260
Gravel, fine to coarse; contains a little gray brown clay,	70	330
Sand and gravel, gray brown	30	360
Sand, fine to coarse, light brownish gray	23	383
Shale, compact, pink, and clay, sandy, white to gray	7	390
Shale, sandy, compact, pink gray, tan, and gray green	25	415
Sand and gravel, light brown	27	442
Shale, compact, greenish gray, tan, and red	8	450
Shale, in part sandy, compact, tan, gray, and red	20	470
Shale, compact, varicolored	26.5	496.5
PERMIAN—Guadalupian		
Redbeds		
Shale, brick red	13.5	510

15. ***Sample log of test hole 15 at the SW corner sec. 18, T. 33 S., R. 34 W., drilled by the State Geological Survey, 1942. Surface altitude, 2,936 feet.*** **(Samples studied by James B. Cooper and Frank E. Byrne.)**

	Thickness, feet	*Depth, feet*
QUATERNARY—Recent		
Dune sand		
Sand, fine to medium, brown; contains silt	6	6
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Sand, silt, clay, and fine gravel; calcareous, pinkish gray	4	10
Sand, fine to coarse, calcareous, gray brown, coarser toward base; contains fine gravel	17	27
Clay, silt, and sand, coarse; calcareous, brown gray	3	30
Sand, medium and coarse, brownish gray	10	40
Sand, silt, clay, and fine gravel; calcareous, pink brown, becoming much coarser in basal part	20	60
Gravel, coarse, to sand, coarse; gray brown	10	70
Sand, fine, to gravel, medium, contains numerous fragments of caliche	25	95
Gravel, medium, to sand, fine; lime-cemented	5	100
Sand, silt, and clay; gray brown, highly calcareous; contains a little fine gravel	10	110
Sand and some silt; lime-cemented, tan to pinkish gray,	30	140
Sand, coarse, to silt, gray brown	10	150
Sand and some silt; lime-cemented, tan to pinkish gray,	10	160
Silt, sand, and clay; tan to pinkish gray	10	170
Silt, clay, and some sand; gray brown, highly calcareous	4	174
Sand, fine, to gravel, medium; calcareous, light brown	16	190
Gravel, fine, and sand, coarse; light brown	30	220
Sand, fine to coarse, light brown, slightly calcareous; contains a little fine gravel	20	240
Sand, coarse, and gravel, fine; light brown	20	260
Sand, fine to coarse, slightly calcareous, tan gray; contains a little fine gravel	10	270
Sand, fine to coarse, slightly calcareous, brownish gray,	20	290
Sand, coarse, and gravel, fine; brownish gray	20	310
Sand and gravel, reddish gray	10	320
Sand, fine to coarse, light brownish gray; contains a little gravel	10	330
Sand and a little gravel, reddish gray	10	340
Silt, clay, and sand; tan brown to yellow gray	13	353
Sand, medium, to gravel, fine; light brownish gray	27	380
Silt and clay; tan brown	3	383
Sand, medium, to gravel, fine; light brownish gray	7	390
Sand and gravel; contains small fragments of ironstone,	10	400
Sand, medium, and gravel, fine	10	410
Sand, medium, to gravel, fine; light brownish gray	46	456
Shale, compact, tan brown and red	4	460

	Thickness, feet	Depth, feet
Sand and gravel, brownish gray	20	480
Shale, compact, tan, brown, red, and gray green	10	490
Sand and gravel, brownish gray	20	510
Sand, light brown, and shale, red and brown; interbedded	17	527
Shale, compact, hard, brown	3	530
Sand, brownish gray, and shale, compact, brown and red; interbedded	90	620
Shale, compact, tan brown	78	698
PERMIAN—Guadalupian		
Redbeds		
Shale, silty, slightly calcareous, bright red	22	720

16. *Sample log of test hole 16 in the NE¼ SW¼ sec. 31, T. 34 S., R. 30 W., Meade County, drilled by the State Geological Survey, 1944. Surface altitude, 2,444 feet.* (Samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Silt, gray brown; contains sand and gravel	3	3
Silt and clay, buff and greenish gray; contains sand and gravel	2	5
TERTIARY—Pliocene		
Laverne formation		
Clay, light buff and light blue gray; contains crystalline gypsum	5	10
Clay, light gray to light blue gray; contains fine to coarse sand at depth of 12 feet	2.5	12.5
Caliche, hard, light gray to greenish gray; contains sand and clay	13.5	26
Shale, thin-bedded, dark blue gray	21	47
Caliche, light blue gray; contains sand, clay, and gravel	19	66
Clay, silty, light blue gray	14	80
Clay, in part silty, light gray; contains fine to medium sand and crystals of gypsum	40	120
Clay, light gray; partly cemented by gypsum and contains many crystals of gypsum	18	138
Caliche, hard, light gray; contains fine to coarse sand and crystals of gypsum	12	150
Clay, silty, in part thin-bedded, gray; contains gypsum	50	200
Clay, in part thin-bedded, light blue gray	12	212
Sand, fine, to gravel, medium; contains yellow and white clay and limonite	25	237
Clay, light tan; contains fine to coarse sand and a little caliche	6	243
Silt, pink buff; contains fine to medium sand	2	245
Clay, light tan; contains a little sand and gravel	2	247

	Thickness, feet	Depth, feet
Sand, fine, to gravel, medium	28	275
Silt, pink buff to yellow buff; contains sand and gravel	4	279
Gravel, fine, and sand	5	284
Silt, pink buff; contains fine to medium sand and zones of caliche	12	296
Gravel, fine to medium, and sand; contains caliche and pink-buff silt in lower part	10	306
PERMIAN—Guadalupian		
Redbeds		
Shale, brick red	4	310

17. *Sample log of test hole 17 in the SE¼ NE¼ sec. 33, T. 34 S., R. 30 W., Meade County, drilled by the State Geological Survey, 1944. Surface altitude, 2,655 feet.* (Samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, silty, tan	4.5	4.5
QUATERNARY—Pleistocene		
Meade formation		
Silt, light gray to light brown; contains caliche and fine to coarse sand	23.5	28
Silt, light buff, and caliche, buff; sandy	5	33
Silt, clayey, light brown	4	37
Sand, coarse to fine, and gravel, medium to fine	3	40
Gravel, coarse, to sand, fine	15	55
Silt, light gray; contains caliche	3	58
Sand to gravel, coarse; contains caliche	12	70
TERTIARY—Pliocene		
Rexroad (?) formation		
Silt, white and light buff; contains caliche and fine to coarse sand	25	95
Silt, clayey, light brown and white	15	110
Silt, clayey, gray brown to light brown; contains sand and fine gravel	10	120
Gravel, fine to medium, sand, and silt, light brown and white; contains caliche	7	127
Silt, clayey, dull yellow and light blue gray	12	139
Sand, coarse to fine, and gravel, medium to fine; contains a little greenish-gray and buff silt	61	200
Sand, coarse to fine, and gravel, fine	30	230
Sand, coarse to fine, and silt, light greenish gray	22	252
Laverne formation		
Silt, soft, light gray to light tan; contains fine to medium sand	8	260
Silt, clayey, light gray, light buff, and light blue gray	20	280
Clay, thin-bedded, blue gray; contains fine sand	20	300
Clay, light blue gray	20	320

	Thickness, feet	*Depth, feet*
Clay, silty, blocky, dull greenish gray	6	326
Silt and clay, brittle, gray	4	330
Silt and clay, gray and blue gray; contains very fine sand	23	353
Silt, green; contains fine to very fine sand	7	360
Clay, silty, light green gray and blue gray	10	370
Clay, soft, light gray	50	420
Clay, soft, light gray; contains thin beds of caliche and a little sand	25	445
Sand, coarse to fine, and gravel, fine	47	492
Clay, silty, white to pink buff	5	497
Sand, coarse to fine; contains white and buff silt	23	520
Sand, coarse to fine, and gravel, fine	80	600
Sand, coarse to fine, and gravel, fine; in part cemented; contains light-buff and pink silt in lower part	14	614
PERMIAN—Guadalupian		
Redbeds		
Shale, silty, dull red	11	625

18. *Sample log of test hole 18 in the SW¼ NW¼ sec. 13, T. 34 S., R. 31 W., drilled by the State Geological Survey, 1944. Surface altitude, 2,594 feet.* (Samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	*Depth, feet*
Sand and silt, gray brown	2	2
TERTIARY—Pliocene		
Laverne formation		
Clay, blocky, gray green	2	4
Sand and gravel, coarse to fine, in part cemented	5	9
Clay, yellow buff	4	13
Sand, fine, to gravel, medium; in part cemented	4	17
Clay, yellow buff and light blue gray; contains a little caliche	13	30
Gravel, fine, and sand; contains blue-gray clay	6	36
Clay, light blue gray; contains silt in upper part, sand in the middle, and caliche at base	8	44
Silt, micaceous, soft, brown	3	47
Clay, compact, blue gray	3	50
Silt, brownish gray; contains fine to coarse sand	3	53
Clay, green gray, blue gray, and yellow buff; contains sand in upper part	25	78
Silt, clayey, yellow gray; contains sand and gravel	8	86
Gravel, fine to medium, and sand	4	90
Sand, coarse to fine, and gravel, medium to fine; contains yellow silt in upper part	10	100
Gravel, coarse to fine, and sand	58	158

	Thickness, feet	Depth, feet
Silt, yellow brown; contains fine to medium sand	2	160
Gravel, medium to fine, and sand	17	177
Clay, light gray	3	180
Silt, micaceous, yellow	2	182
Clay, yellow buff	5	187
Gravel, medium to fine, and sand; contains yellow-gray silt	8	195
Silt, buff; contains fine to medium sand	2	197
Gravel, medium to fine, and sand	3	200
Silt, micaceous, yellow gray to yellow	6	206
Clay, blue gray	14	220
Clay, silty, light blue gray and yellow gray; contains fine to medium sand	5	225
Gravel, fine, and sand	6	231
Silt, buff; contains fine to coarse sand	3	234
Gravel, fine, and sand	2	236
Silt, buff; contains fine to coarse sand	1	237
Gravel, fine, and sand	8	245
Silt, buff; contains fine to coarse sand	1	246
Gravel, fine, and sand; contains yellow-gray and buff silt in lower part	24	270
Caliche, hard, white and pink; contains fine to medium sand	3	273
Silt, yellow gray; contains fine to coarse sand	2	275
Gravel, fine to medium, and sand	15	290
Gravel, medium to fine, and sand; contains a few thin beds of light-gray, yellow-gray, and pink-buff silt	100	390
Sand, coarse to fine, and gravel, medium to fine; contains pink-buff silt in lower part	30	420
Gravel, medium to fine, and sand	12	432
Silt, white to light brown and gray green; contains fine to coarse sand	32	464
PERMIAN—Guadalupian		
Redbeds		
Shale, brick red and white	16	480

19. *Sample log of test hole 19 in the SW¼ SW¼ sec. 13, T. 34 S., R. 31 W., drilled by the State Geological Survey, 1944. Surface altitude, 2,611 feet.* (Samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Sand, coarse to fine, and gravel, medium to fine; contains brown silt	3	3
Sand, coarse to fine, and gravel, medium to fine; cemented with calcium carbonate to form "mortar beds"	4	7

	Thickness, feet	Depth, feet
TERTIARY—Pliocene		
Rexroad (?) and Laverne formations		
Clay, light gray, contains a little coarse to fine sand...	4	11
Sand, coarse to fine, and silt, clayey, light greenish gray and pink buff; contains fine to medium gravel,	7	18
Gravel, fine, and sand	8	26
Sand, medium to fine, consolidated	4	30
Sand, coarse to fine, and gravel, medium to fine; contains light-brown silt and gray-green clay	53	83
Caliche, gray white; contains fine to medium sand	1	84
Sand, coarse to fine, and gravel, medium to fine	26	110
Gravel, medium to fine, and sand	63	173
Caliche, hard, white; contains fine to medium sand	1	174
Gravel, fine, and sand; contains gray-green and yellow clay	6	180
Gravel, fine, and sand; in part cemented; contains blue-gray and light gray-green clay in lower part	20	200
Sand, coarse to fine, and gravel, fine	63	263
Silt, soft, light yellow buff and light gray	5	268
Sand, coarse to fine, and gravel, fine	30	298
Clay, soft, buff; contains fine to coarse sand	7	305
Gravel, fine, and sand	135	440
Clay, light yellow brown, light greenish gray, light pink buff, and brown; contains fine to medium sand	28	468
PERMIAN—Guadalupian		
Redbeds		
Shale, dull red	12	480

20. *Sample log of test hole 20 in the NE¼ SW¼ sec. 24, T. 34 S., R. 31 W., drilled by the State Geological Survey, 1944. Surface altitude, 2,520 ± feet.* (Samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, gray brown	1	1
TERTIARY—Pliocene		
Laverne formation		
Clay, blocky, gray green	2	3
Limestone, hard, light gray; contains fine to coarse sand	1	4
Marl, porous, yellow to gray white	14	18
Clay, light gray green	8	26
Gravel, fine to medium, and sand; cemented by limonite,	4	30
Sand, coarse to fine, and gravel, medium to fine	13	43
Clay, light gray green	3	46
Limestone, hard, light gray	1	47
Silt and clay, thin-bedded, in part cemented, gray and brown	11	58
Gravel, coarse, to sand, fine, yellow	46	104

	Thickness, feet	Depth, feet
Clay, silty, light gray green and light brown	2	106
Gravel, medium to fine, and sand	32	138
Clay, partly cemented, white	1	139
Marl, hard, yellow to gray white; contains fine to coarse sand and fine gravel	11	150
Silt, thin-bedded, blue gray and green gray, contains fine sand	47	197
Shale, laminated, gray to green gray; contains blue-gray silty clay	9	206
Sand, medium to fine	3	209
Clay, blue gray	9	218
Gravel, medium to fine, and sand; contains light-gray clay, and light-gray and pink-buff silt	22	240
Gravel, medium to fine, and sand	110	350
Gravel, medium to fine, and sand; contains dark-buff silt	25	375
Silt, pink buff to reddish buff; contains fine to medium sand	48	423
PERMIAN—Guadalupian		
Redbeds		
Shale, brick red	7	430

21. *Sample log of test hole 21 in the SW¼ NW¼ sec. 36, T. 34 S., R. 31 W., drilled by the State Geological Survey, 1940. Surface altitude, 2,585 feet.* (Samples studied by James B. Cooper and Frank E. Byrne.)

	Thickness, feet	Depth, feet
Soil, fine sandy, brown; contains caliche	2	2
QUATERNARY—Pleistocene		
Meade formation		
Sand, medium, to gravel, coarse; brown	3	5
Sand, medium, to gravel, coarse; consolidated	1.5	6.5
TERTIARY—Pliocene		
Sand, fine, calcareous, light gray	1.5	8
Silt and fine sand, calcareous, pink tan	5	13
Caliche, soft, white to light gray	3.5	16.5
Caliche and clay, yellow	2.5	19
Caliche, hard, light gray, white and yellow	5	24
Sand, fine, calcareous, yellow orange	3	27
Sand, fine, silt, and caliche; light gray	3	30
Clay, silty to fine sandy, light gray	1	31
Sand, medium, to gravel, fine; brown and orange	16	47
Silt and fine sand, calcareous, gray orange and brown.	3	50
Sand, fine and medium, brown	24	74
Silt and fine sand, calcareous, light gray and orange,	2.5	76.5
Sand, fine and medium, brown	6.5	83
Sand, fine and medium, brown and orange brown	7	90

	Thickness, feet	Depth, feet
Sand, fine to coarse, brown; contains yellow silt and a little gravel	30	120
Sand, medium, to gravel, fine; brown; contains caliche,	42	162
Clay, silty to fine sandy, light gray	12	174
Clay, silty, blue gray, alternating with sand, fine and medium, gray	7	181
Sandstone, soft, calcareous, buff	10.5	191.5
Sand, fine and medium, buff to yellow brown	12.5	204
Sand, medium, to gravel, medium; brown	36	240
Sand, medium, to gravel, medium; orange brown	15	255
Sand, medium, to gravel, medium; brown	20	275
Clay, silty, light gray	6	281
Sand, medium, to gravel, fine; brown	9	290
Sand, medium and coarse, orange brown	5	295
Sand, medium to coarse, and gravel; hard, brown	46	341
Clay, fine sandy, highly calcareous; contains caliche,	2	343
Sand, medium, to gravel, medium; brown; contains siltstone	7	350
Sand, medium, to gravel, fine; brown	51	401
Clay, sand, and gravel; contains caliche at top and in lower half	16	417
Sand, coarse, and gravel, fine; consolidated	5	422
Gravel, fine and coarse, brown; contains silty blue-green clay	24	446
Silt and sand, pink brown, interbedded with silty blue-green clay	5	451
Sand and gravel, interbedded with blue-green clay	16	467
Sand, fine, brown; contains silty blue-green shale and brown siltstone. Contains gravel in basal part	33	500
PERMIAN—Guadalupian		
Redbeds		
Shale, silty, light gray to red brown, and siltstone, red brown	20	520

22. *Sample log of test hole 22 at the SE cor. sec. 36, T. 34 S., R. 35 W., Stevens County, drilled by the State Geological Survey, 1943. Surface altitude, 2,950± feet.* (Samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Dune sand		
Sand, medium to fine; contains soft gray to gray-black silt	5	5
Sand, medium to fine, red	9	14
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Silt, soft, buff; contains medium to fine sand	4	18
Silt, clayey, green; contains medium to fine sand	5	23
Silt, soft, buff to white; contains medium to fine sand and caliche	7	30

	Thickness, feet	Depth, feet
Sand, medium to fine, and silt, soft, buff	4	34
Silt, soft, light gray; contains medium to fine sand	4	38
Sand, coarse to fine	22	60
Silt, soft, buff to gray white; contains medium to fine sand and caliche	10	70
Silt, compact, light yellow tan; contains medium to fine sand and caliche	20	90
Sand, coarse to fine; contains soft buff and white silt,	14	104
Silt, clayey, buff; contains coarse to fine sand and caliche	2	106
Gravel and sand, coarse to fine	29	135
Silt, soft, buff; contains medium to fine sand and a little gravel	10.5	145.5
Silt, compact, light tan; contains medium to fine sand and caliche	14.5	160
Silt, soft, white and buff; contains coarse to fine sand and caliche	30	190
Silt, clayey, buff and light tan; contains coarse to fine sand and caliche	15	205
Silt, soft, gray and buff; contains fine to coarse sand, fine gravel, and caliche	15.5	220.5
Gravel, fine, to sand, medium	2.5	223
Silt, soft, light brown; contains medium to fine sand and caliche	6	229
Sand to gravel, fine; contains caliche	23	252
Silt, soft, tan; contains medium to fine sand and caliche	28	280
Sand, coarse to fine	20	300
Silt, soft, tan; contains fine sand and caliche	4	304
Silt, soft, light greenish gray and brown, and sand, very fine	6	310
Silt, soft, white to greenish gray and light gray buff; contains coarse to fine sand and a little caliche	50	360
Silt, clayey, white to yellow and brown; contains dense blue-white caliche	20	380
Silt, very soft, gray white and yellow brown, and sand, fine; contains hard white to yellow-brown sandstone and concretions of hard brown siltstone	50	430
Silt, very soft, gray white and yellow brown; contains concretions of sandy hard brown siltstone	38	468
Gravel, fine, to sand, medium	2	470
Silt, very soft, light buff to yellow brown and gray white; contains coarse to very fine sand	100	570
Silt, soft, gray buff to blue gray, and sand, medium to fine; contains concretions of ironstone	20	590
Silt, soft, light gray and yellow brown; contains medium to fine sand	10	600

	Thickness, feet	Depth, feet
Silt, very soft, gray buff and yellow brown; contains coarse to fine sand and fine gravel	20	620
Silt, soft, light gray buff; contains medium to fine sand	60	680
Gravel, fine, to sand, medium	8	688
PERMIAN—Guadalupian		
Redbeds		
Silt, blocky, light orange red	2	690
Silt, clayey, light orange red	30	720

23. *Sample log of test hole 23 at the NW cor. NE¼ sec. 13, T. 35 S., R. 31 W., drilled by the State Geological Survey, 1940. Surface altitude, 2,662 feet.* (Samples studied by James B. Cooper and Frank E. Byrne.)

	Thickness, feet	Depth, feet
QUATERNARY—Recent		
Dune sand		
Sand, fine, brown	7	7
QUATERNARY—Pleistocene		
Meade formation		
Sand, fine, pinkish tan	4	11
Sand and gravel; fine to coarse	8	19
Silt and sand, fine; calcareous, brown	2	21
Caliche, gray to buff, basal part hard	9	30
Caliche, hard, gray to white; contains fine quartz sand,	10	40
Caliche and clay, tan; contains silt	9	49
Silt and sand, fine; calcareous, brown; contains fine gravel	3	52
Caliche, soft, and clay, silty and limy, tan	5	57
Sand, fine, calcareous, brown to yellow brown; contains silt	3	60
Silt and sand, fine; calcareous, brown	6	66
Sand, medium, to gravel, coarse; brown	3.5	69.5
Sand, medium, to gravel, fine; consolidated	4.5	74
Sand, medium, to gravel, medium; brown	6	80
Sand, coarse, consolidated	2.5	82.5
TERTIARY—Pliocene		
Rexroad (?) formation		
Clay, silt, and fine to medium sand; gray to brown; contains caliche	17.5	100
Silt and sand, fine; calcareous, hard, gray	5	105
Clay, silty to fine sandy, very calcareous, hard	11	116
Caliche and clay, interbedded, brown to buff, contains silt and a little sand	4.5	120.5
Sand, fine, brown, and silt; calcareous	4.5	125
Clay, silty to fine sandy, calcareous, light gray	5	130
Clay, silt, and sand, fine; interbedded, calcareous, light gray and brown	7	137
Sand, fine to medium, calcareous, hard, brown	9	146

	Thickness, feet	Depth, feet
Sand, fine, to gravel, medium; brown; contains clay in upper part	10	156
Sand, fine, to gravel, medium; brown; contains caliche	42	198
Laverne formation		
Clay, silty to fine sandy, calcareous, light gray	4	202
Silt and sand, fine; light cream gray to brown and yellow; contains caliche	6	208
Clay, silty, blue gray; contains caliche	19	227
Sandstone, calcareous, fairly hard, blue gray; contains gypsum in lower part	13	240
Shale, sandy clay, and sandstone; calcareous, blue gray	10	250
Sand, fine, blue gray, and silt; contains thin beds of silty white limestone in lower part	30	280
Silt, calcareous, blue gray, and sand, fine; contains thin beds of gypsum	40	320
Shale, silty and fine sandy, blue gray; contains gypsum	28	348
Shale, silty, earth brown, and shale, blue gray; interbedded; contains gypsum in basal part	32	380
Gypsum, hard, and sandstone, dense, dark gray to black	6	387
Shale, blue gray; contains thin layers of gypsum near base	23	410
Shale, silty, and fine sandy, blue gray, and shale, hard, yellow green	24	434
Sand, medium, and gravel, fine; partly cemented; brown	142	576
PERMIAN—Guadalupian		
Redbeds		
Siltstone, red	14	590

24. *Drillers log of test hole drilled for the City of Liberal in NW¼ NE¼ sec. 32, T. 34 S., R. 33 W., 1944.* (Layne-Western Company, driller.)

	Thickness, feet	Depth, feet
Soil	2	2
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Clay, sandy	8	10
Sand	3	13
Clay, sandy, and caliche	77	90
Sand, gravel, and clay	20	110
Clay, sandy, red (static water level, 121 feet)	13	123
Clay, hard, white	33	156
Rock	2	158
Sand, medium coarse	3	161
Rock and sand	3	164
Rock, hard	5	169

	Thickness, feet	Depth, feet
Clay, sandy	28	197
Sand, medium coarse	4	201
Clay, sandy	115	316
Clay, blue	14	330
Clay; contains streaks of sand	7	337
Sand, medium coarse	32	369
Clay, blue	39	408
Clay, sandy	47	455
Sand, fine, and clay	11	466
Sand, fine	39	505
Sand, medium coarse, and gravel	35	540
Sand, very fine	50	590
PERMIAN—Guadalupian		
Redbeds		
Shale, red	11	601

25. *Drillers log of test hole of the Deep Well Irrigation Company in the NW cor. sec. 32, T. 34 S., R. 33 W.* (Log furnished by Perry Keller, Liberal city engineer.)

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Clay	5	8
Sand	10	18
Clay	12	30
Sand	25	55
Clay	5	60
Sand	20	80
Clay	15	95
Sand	25	120
Clay	5	125
Sand	5	130
Clay	5	135
Sand, very fine	7	142
Clay	23	165
Sand, medium; contains caliche	5	170
Rock, soft	3	173
Rock, hard	7	180
Sand, medium to coarse	84	264
Clay	7	271
Sand	4	275
Clay	7	282
Sand	19	301
Sand and gravel	14	315
Sand	12	327
Gravel and clay	10	337
Sand, coarse	10	347
Clay	9	356

26. ***Drillers log of the municipal supply well of the City of Kismet in the SE¼ SW¼ sec. 4, T. 33 S., R. 31 W. Surface altitude, 2,785± feet.*** **(J. Doty, driller.)**

	Thickness, feet	*Depth, feet*
Soil	4	4
Clay, sandy	16	20
Gyp, hard	40	60
Sand and gravel	38	98
Sand rock, soft	3	101
Sand	6	107
Sand rock, soft	2	109
Sand	12	121
Sand rock, soft	3	124
Clay	14	138
Sand, dirty	12	150
Sand and gravel	98	248

27. *Drillers log of railroad well at Liberal in the NW¼ sec. 4, T. 35 S., R. 33 W.*

	Thickness, feet	*Depth, feet*
Soil	2	2
Clay, white, and gypsum	40	42
Clay, blue	50	92
Clay, white, and sand	35	127
Sand, white	2	129
Clay, yellow	38	167
Shale and sand, white	10	177
Sand, white	13	190
Shale, white	2	192

28. *Drillers log of railroad well at Liberal in the NE¼ sec. 32, T. 34 S., R. 33 W. Surface altitude, 2,840± feet.* (Darton, 1905, p. 317.)

	Thickness, feet	*Depth, feet*
Clay, hard	6	6
Sand	35	41
Sandstone, soft	22	63
Sandstone, coarse	12	75
Sand	10	85
Sandstone, soft	100	185
Sand and clay	80	265
Sandstone, hard	5	270
Sand, coarse to fine, and gravel	45	315
Sand and sandstone	130	445
Sand, coarse, and gravel	40	485

29. *Drillers log of well of Panhandle Eastern Pipeline Company near Arkalon in the NW¼ SW¼ sec. 24, T. 33 S., R. 32 W. Surface altitude, 2,610± feet.* (Well Works Manufacturing Company, Garden City, Kansas, driller.)

	Thickness, feet	Depth, feet
Soil, sandy	14	14
Sand	13	27
Clay	7	34
Sand, fine	4	38
Clay, tough	25	63
Sand	8	71
Clay, blue	4	75
Clay, sandy	11	86
Sand rock, soft	6	92
Sand	11	103
Clay, blue	9	112
Sand rock, soft	2	114
Sand	21	135
Clay, blue	4	139
Sand, fine	7	146
Clay, blue	3	149
Sand and gravel	19	168

30. *Drillers log of well no. 1 of the Northern Natural Gas Company in the SW¼ NW¼ sec. 1, T. 32 S., R. 33 W.* (Buell Scott, driller.)

	Thickness, feet	Depth, feet
Soil	8	8
Clay; contains caliche and streaks of fine sand	12	20
Clay, brown, and sand	5	25
Caliche	3	28
Clay, brown	4	32
Sand, fine	6	38
Clay and caliche	2	40
Caliche	2	42
Clay	4	46
Caliche and clay	4	50
Caliche and fine sand	2	52
Rock	2	54
Caliche	3	57
Caliche and sand	18	75
Sand and clay	10	85
Sand and red clay	5	90
Caliche	2	92
Caliche and sand	3	95
Clay, red, and sand	10	105
Sand, coarse	22	127
Clay and sand	2	129
Sand	20	149

	Thickness, feet	*Depth, feet*
Clay	1	150
Sand	20	170
Sand and caliche	6	176
Sand	7	183
Clay	2	185
Sand	5	190
Clay and sand	2	192
Sand	12	204
Clay	1	205
Clay and sand	2	207
Sand	17	224
Clay	2	226
Sand, fine	11	237
Sand, coarse	19	256
Sand	10	266

31. *Drillers log of the Traders Oil Corporation No. 1 Boles in the NE¼ NE¼ sec. 3, T. 35 S., R. 34 W.* (Harry McQuigg, driller.)

	Thickness, feet	*Depth, feet*
Sand and clay, soft	50	50
Caliche and clay	55	105
Clay, sandy	10	115
Sand	17	132
Clay, brown and yellow	18	150
Sand	6	156
Clay, sticky	4	160
Caliche and clay	58	218
Clay, sticky, brown	7	225
Sand, fine, brown; contains streaks of soft sticky clay,	100	325
Caliche, white	4	329
Sand; contains shale and clay	271	600
Clay and lime	40	640
Clay, sticky, blue	19	659
Clay, red	101	760
Sand lime, light-colored	5	765
Clay, red	185	950
Shale, red	80	1,030
Clay, blue and red, and gypsum, white	35	1,065
Clay, soft, blue	37	1,102
Clay, red, and shale	38	1,140
Sandstone, soft, and salt	93	1,233
Clay, red	102	1,335
Shale, sandy, brown	12	1,347
Shale, red	113	1,460
Shale, blue	2	1,462
Shale, red, and rock, hard	168	1,630
Sandstone, brown	15	1,645
Sand, hard	45	1,690

	Thickness, feet	*Depth, feet*
Clay, red	10	1,700
Shale, blue	2	1,702
Shale, red	15	1,717
Shale, soft, red	8	1,725
Lime, hard	25	1,750
Clay and shale, red	100	1,850
Sand, hard	2	1,852
Clay and shale, red	78	1,930
Shale, red	18	1,948
Shell, hard	3	1,951
Shale, blue	1	1,952
Shale, red	80	2,032
Shell, hard, red	2	2,034
Clay, red, contains gypsum	21	2,055
Clay, blue	5	2,060
Shale, red	17	2,077
Shale, hard	2	2,079
Shale, red	23	2,102
Shale, blue	6	2,108
Clay, red, and shale	52	2,160
Rock, red	8	2,168
Shale, blue	77	2,245
Shale, blue, and sharp shells, gritty	2	2,247
Shale, blue	17	2,264
Shale, blue, and sandy lime shells	26	2,290
Shale, blue	10	2,300
Shale, blue, and sandy lime shells	72	2,372
Shell, hard	8	2,380
Shale, blue	20	2,400
Lime shells and shale, blue	5	2,405
Shell, lime	5	2,410
Shale, blue	11	2,421
Lime, hard	11	2,432
Lime, softer	2	2,434
Shell, lime	41	2,475
Shale, white and pink	10	2,485
Shale, blue, and streaks of lime	16	2,501
Lime shell, hard	8	2,509
Shale, blue	29	2,538
Lime, hard, gray	7	2,545
Shale, blue	25	2,570
Lime shell, hard	4	2,574
Shale, blue	7	2,581
Lime, sandy, changing to sand	4	2,585
Shale, blue	15	2,600
Lime, white	10	2,610
Shale, blue	40	2,650
Shale, sandy, greasy	30	2,680

	Thickness, feet	Depth, feet
Lime, hard, gray	25	2,705
Slate, black, and shale	11	2,716
Sand, gas	39	2,755
Shale, brown	15	2,770
Shale, hard	12	2,782
Sand, water	2	2,784
Lime	10	2,794
Shale, blue	20	2,814
Lime, hard	11	2,825
Shale, sandy	20	2,845
Lime, hard	2	2,847
Sand; contains salt water	55	2,902
Shale, blue	17	2,919

32. *Drillers partial log of the Liberal Gas Company No. 4 Boles in the NE¼ sec. 4, T. 35 S., R. 34 W.*

	Thickness, feet	Depth, feet
Lime and streaks of blue shale	31	2,066
Sand lime and streaks of red bed	34	2,100
Hard sandy lime	35	2,135
Lime and blue shale	295	2,430
Lime and anhydrite	202	2,632
Dolomite, light gray, and white anhydrite	10	2,642
Dolomite, light gray	11	2,653
Dolomite, anhydrite, and shale; light gray	10	2,663
Dolomite and shale, light gray	7	2,670
Dolomite, light gray, white anhydrite, and white translucent chert	10	2,680
Shale, light gray	30	2,710
Limestone, light gray mottled (gas producing horizon),	35	2,745
Red rock	4	2,749
Dolomite, dense, white	5	2,754

33. *Drillers partial log of the No. 1 Pyle in the NE¼ NE¼ sec. 13, T. 33 S., R. 33 W.*

	Thickness, feet	Depth, feet
Cellar	20	20
Sand	258	278
Gravel	4	282
Sand	22	304
Gravel	6	310
Sand	155	465
Red rock	5	470
Sand	20	490
Red rock and sand	40	530
Red rock	132	662
Sand	8	670
Red rock	588	1,258

34. Drillers log of Seward County Oil and Gas Company No. 1 Sealy in the NE¼ sec. 20, T. 33 S., R. 33 W.

	Thickness, feet	Depth, feet
Clay, sandy, brown	135	135
Sand	50	185
Clay, sandy	20	205
Sand	50	255
Clay, brown	15	270
Sand	45	315
Clay	34	349
Sand, fine, gray	31	380
Clay, yellow	20	400
Mud, blue	40	440
Sand	5	445
Red bed	425	870
Sand, red	10	880
Red bed	48	928
Lime or white chat	12	940
Red bed	15	955
Lime, hard	10	965
Red rock	5	970
Lime or white chat	30	1,000
Mud, blue	5	1,005
Red rock	95	1,100
Sand, fine, red	150	1,250
Red bed	350	1,600
Sand, red, and lime	55	1,655
Mud, blue	5	1,660
Red bed	10	1,670
Mud, blue	10	1,680
Red bed	85	1,765
Sand	45	1,810
Red bed	125	1,935
Shale, blue	5	1,940
Red bed	145	2,085
Shale, blue	15	2,100
Lime, sandy, gray	10	2,110
Shale, blue	60	2,170
Shale and lime	12	2,182
Shale, blue	18	2,200
Shale, gray, and lime	50	2,250
Sand and lime	5	2,255
Shale, blue and gray	20	2,275
Shale, blue	12	2,287
Lime, sandy, gray	6	2,293
Shale, blue	7	2,300
Lime, gray	6	2,306
Shale, blue	4	2,310
Lime, sandy, gray	50	2,360
Lime, sandy, blue	35	2,395

	Thickness, feet	Depth, feet
Shale, blue	5	2,400
Lime, sandy, gray	10	2,410
Shale, blue	5	2,415
Sand and lime	12	2,427
Lime, gray	10	2,437
Slate, black	7	2,444
Lime, gray	16	2,460
Shale, blue	41	2,501
Lime, gray	14	2,515
Shale, blue	45	2,560
Lime, hard, gray	25	2,585
Rock, pink	10	2,595
Lime, blue	15	2,610
Shale, blue	35	2,645
Sand	9	2,654
Lime, white	25	2,679
Sand	10	2,689
Shale, blue	5	2,694
Shale, red	9	2,703
Lime, gray	24	2,727
Sand	22	2,749
Shale, blue and brown	6	2,755
Red rock	7	2,762
Lime, gray	2	2,764

35. *Drillers log of Vickers and McGinley No. 1 Hitch at the Cen. SW¼ sec. 33, T. 32 S., R. 34 W.* (Stearns and Streeter Company, drillers.)

	Thickness, feet	Depth, feet
Sand, fine	380	380
Shale, blue	35	415
Shale, light-colored	32	447
Red rock	3	450
Shale, red	140	590
Red rock	167	757
Sand, red	18	775
Red rock	142	917
Shale, red	12	929
Sand, light-colored	6	935
Shale, red	25	960
Lime, hard, white	12	972
Shale, red	5	977
Lime, white	8	985
Shale, red	5	990
Lime, hard, white	5	995
Shale, soft, red	15	1,010
Lime, white	33	1,043
Sand, gray	5	1,048
Shale, sandy, brown	27	1,075

	Thickness, feet	*Depth, feet*
Sand, red	5	1,080
Shale, sandy, brown	15	1,095
Shale, red	45	1,140
Sand	90	1,230
Sand, red	76	1,306
Shale, red	329	1,635
Shale, blue	5	1,640
Shale, red	35	1,675
Lime, hard, white	20	1,695
Shale, red	71	1,766
Lime	4	1,770
Shale, red	100	1,870
Lime, sandy	5	1,875
Shale, red	5	1,880
Shale, blue	8	1,888
Shale, red	43	1,931
Lime, white	7	1,938
Shale, varicolored	12	1,950
Shale, red	205	2,155
Shale, blue	55	2,210
Lime, blue	20	2,230
Lime and shale	30	2,260
Shale, blue	5	2,265
Lime, white	33	2,298
Shale, blue	21	2,319
Lime, white	6	2,325
Lime	38	2,363
Lime, white	32	2,395
Shale	35	2,430
Lime, white	5	2,435
Shale, blue	3	2,438
Lime, white	32	2,470
Lime	25	2,495
Shale, blue	10	2,505
Lime, blue	37	2,542
Lime	48	2,590
Shale, blue	18	2,608
Lime, gray	34	2,642
Sand, dark	73	2,715
Shale, brown	15	2,730
Lime, white	28	2,758
Sand, gray	14	2,772
Sand	2	2,774
Lime, sandy	51	2,825
Lime, white	41	2,866
Shale, brown	7	2,873
Lime	22	2,895
Lime, sandy	25	2,920

	Thickness, feet	*Depth, feet*
Lime, white	29	2,949
Sand, gray	21	2,970
Lime	20	2,990
Lime, white	55	3,045
Shale, brown	10	3,055
Sand, gray	2	3,057
Lime, white	30	3,087
Lime, gray	53	3,140
Lime, white	60	3,200
Shale, blue	4	3,204
Shale, red	11	3,215
Lime, white	20	3,235
Shale, blue	6	3,241
Lime, white	33	3,274
Lime, blue	38	3,312
Shale, blue	4	3,316
Lime, white	25	3,341
Sand	39	3,380
Lime, white	2	3,382
Sand	8	3,390
Lime, white	35	3,425
Sand	20	3,445
Sand, gray	30	3,475
Sand, white	5	3,480
Lime, white	15	3,495
Shale, blue	2	3,497
Lime	12	3,509
Lime, hard, white	7	3,516
Sand	5	3,521
Sand, white	4	3,525
Lime, white	57	3,582
Sand	9	3,591
Lime, white	9	3,600
Lime	24	3,624
Lime, hard, white	61	3,685
Sand, white	5	3,690
Lime, hard, white	45	3,735
Lime, soft, blue	10	3,745
Lime, white	45	3,790
Lime, blue	5	3,795
Lime, white	40	3,835
Lime, blue	15	3,850
Lime, black	20	3,870
Lime, blue	40	3,910
Shale, blue	7	3,917
Lime, black	20	3,937
Lime, blue	25	3,962
Lime, brown	38	4,000
Lime, black	15	4,015

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INDEX

21-7070

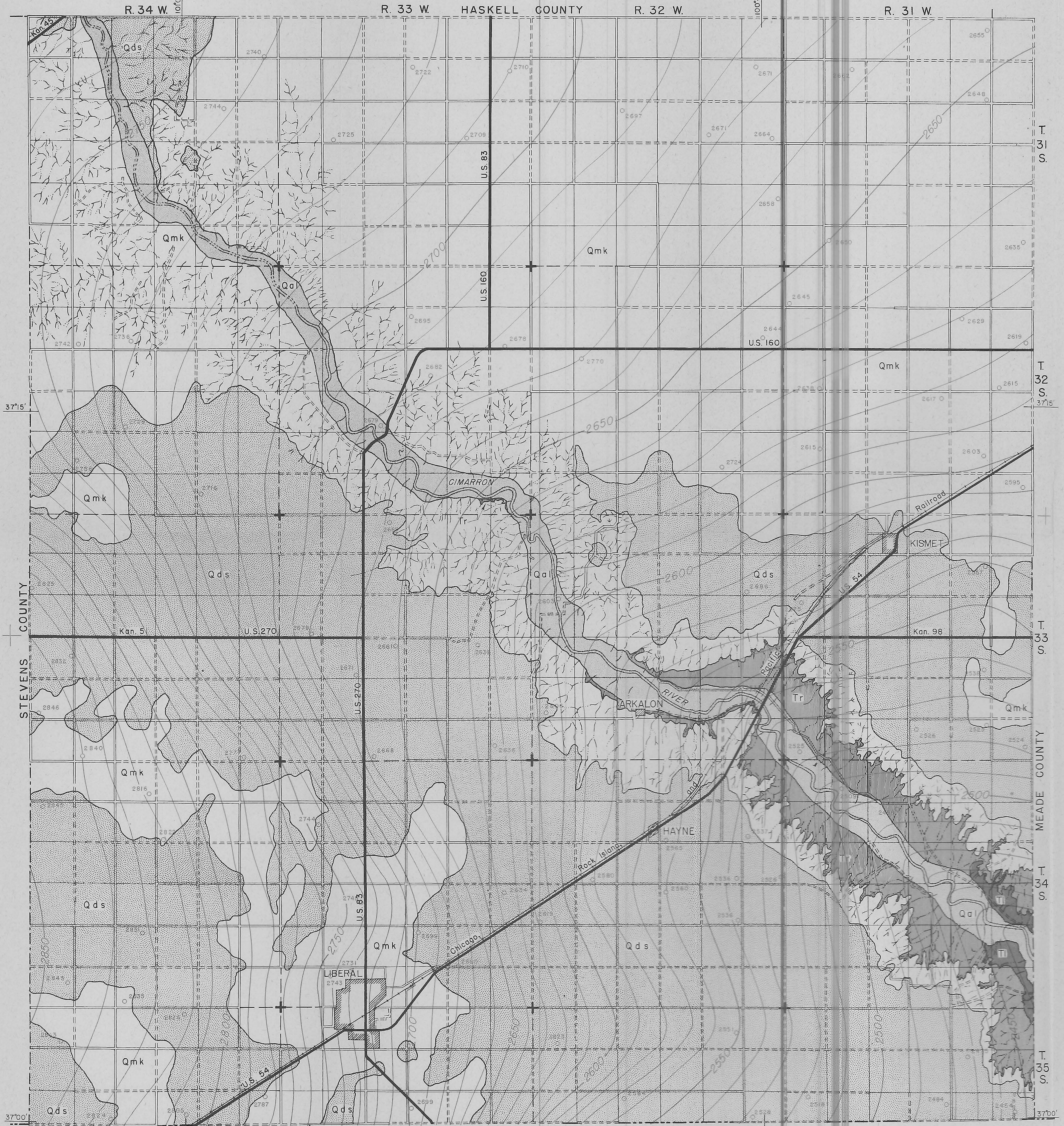
MAP OF SEWARD COUNTY

Showing Geology and Water-Table Contours, 1940

By Thad G. McLaughlin and Frank E. Byrne

State Geological Survey of Kansas

Bulletin 69
Plate 1



Base modified from map prepared by Kansas State Highway Department

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

0 1 2 3 4 5 6

Scale in miles

EXPLANATION

Qal — **Alluvium**
Gravel, sand, and silt. Yields moderate quantities of water to domestic and stock wells.

Qds — **Dune sand**
Fine eolian sand. Sand dunes are above the water table and do not yield water to wells. Important catchment areas for recharge of the ground-water reservoir.

(RECENT — QUATERNARY)

Qmk — **Meade and Kingsdown formations**
Sand, gravel, silt, clay, and caliche. Lower part of Meade supplies water to a few domestic and stock wells.

(PLEISTOCENE — QUATERNARY)

Tr — **Rexroad (?) formation**
Sand, gravel, silt, clay, and caliche. Yields moderate to abundant supplies of water to domestic, stock, municipal, and industrial wells in Seward county.

(PLIOCENE OR PLEISTOCENE — TERTIARY OR QUATERNARY)

Tl — **Laverne formation**
Shale, clay, sand, gravel, caliche, and limestone. Yields moderate supplies of water to a few wells in southeastern Seward county and to deep wells in other parts of the county. Important potential source of ground water.

(PLIOCENE — TERTIARY)

Contour interval 10 feet

2500 — Water-table contours based on instrumental levels

2496 — Well location. Number refers to altitude of water level

Federal or State highway

Graded road

Ungraded road

Section line (no road)

Township line (no road)

Railroad

Perennial stream

Intermittent stream

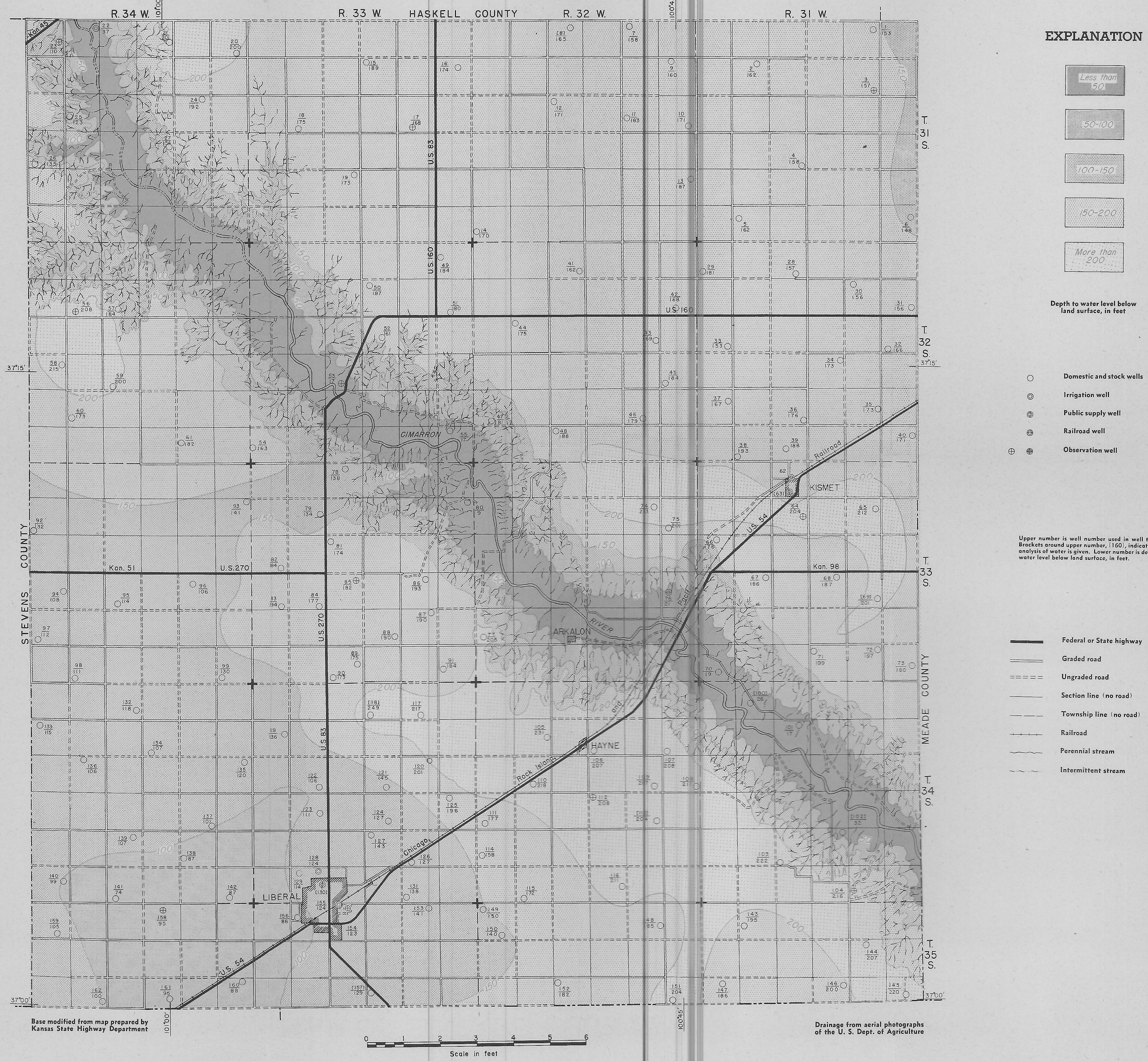
MAP OF SEWARD COUNTY

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

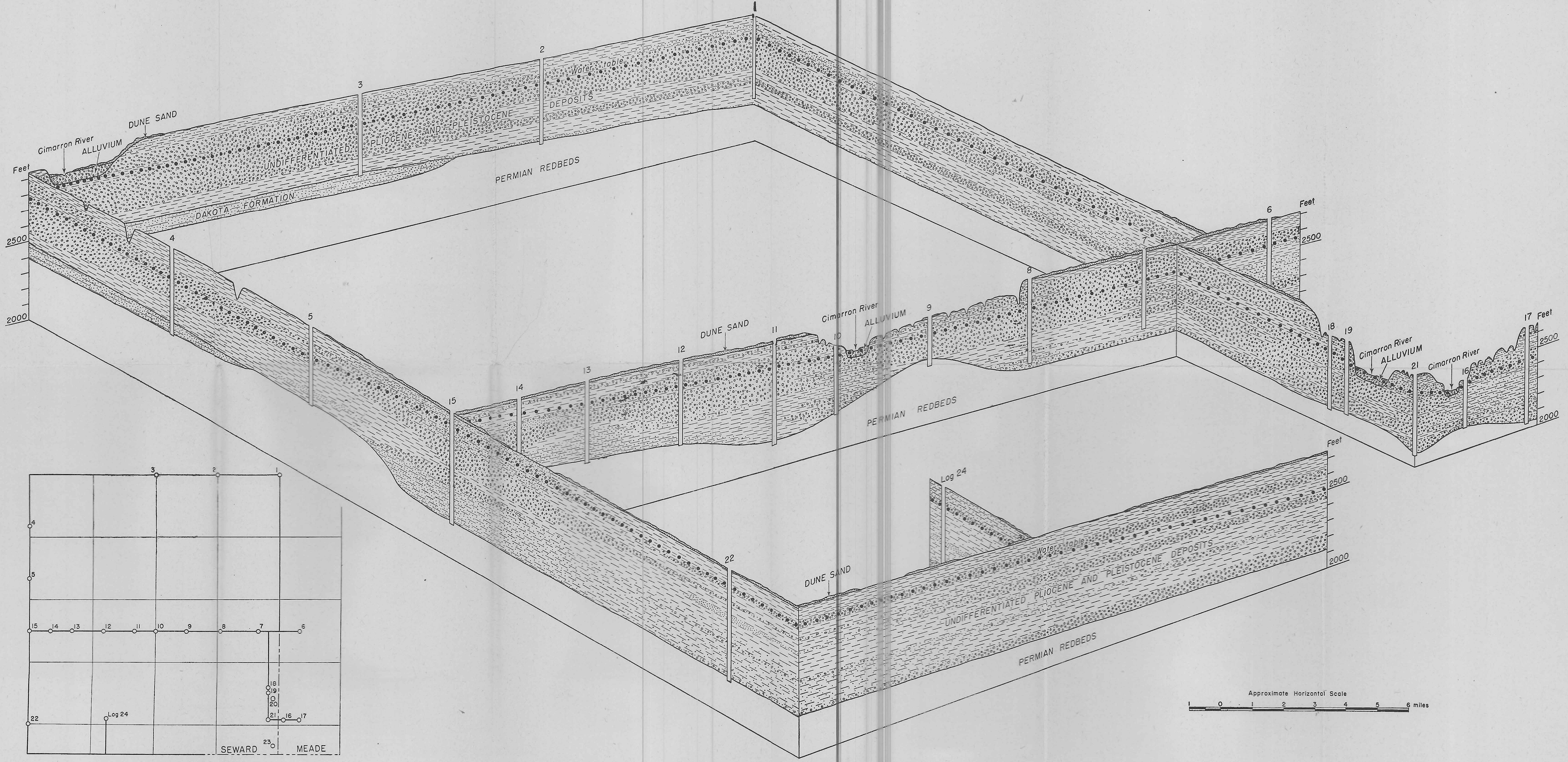
State Geological Survey of Kansas

By Frank E. Byrne
1940

Bulletin 69
Plate 2



DIAGRAMMATIC CROSS SECTION OF SEWARD COUNTY, KANSAS



STRATIGRAPHIC SECTIONS IN MEADE AND SEWARD COUNTIES, KANSAS

State Geological Survey of Kansas

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