Geology, Mineral Resources, and Ground-Water Resources of Chase County, Kansas

PART 1
ROCK FORMATIONS OF CHASE COUNTY

by

RAYMOND C. MOORE, JOHN MARK JEWETT, AND HOWARD G. O'CONNOR

PART 2
MINERAL RESOURCES OF CHASE COUNTY

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PART 3
GROUND-WATER RESOURCES OF CHASE COUNTY

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FRANKLIN D. MURPHY, M.D.,
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Executive Director

RAYMOND C. MOORE, PH.D., SC.D.,
State Geologist and Director of Research, on leave

VOLUME 11

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GROUND-WATER RESOURCES OF CHASE COUNTY

Prepared by the State Geological Survey of Kansas and the United States Geological Survey, with the cooperation 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

By

HOWARD G. O'CONNOR

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PART 1
ROCK FORMATIONS OF CHASE COUNTY

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INTRODUCTION

This is the first of a series of reports on the stratigraphy, economic geology, and ground-water resources of eastern Kansas counties, consisting primarily of maps (Pls. 1, 2, and 3), but containing brief descriptive stratigraphy and discussions of ground water and other useful materials.

Location and Geography

The location of Chase County in Kansas is shown in Figure 1. The county lies in the approximate center of the eastern half of the State, including Ts. 18, 19, 20, 21, and 22 S. in Rs. 6, 7, 8, and 9 E. and the eastern tier of sections in Ts. 20, 21, and 22 S., R. 5 E., comprising approximately 774 square miles.

The population of Chase County is 5,020 (1950 census). The population of Cottonwood Falls, county seat, is 1,047, and of Strong City 724. Cattle raising is the principal industry; about 70 percent of the area is unplowed grassland.

Land surfaces in Chase County range from approximately 1,100 feet to 1,500 feet above sea level. The main topographic form is the Flint Hills escarpment and upland (Moore, 1930; Jewett, 1941, pp. 17-21; Schoewe, 1949, pp. 286-289), which is dissected by Cottonwood River and some of its tributary streams.

Field Work

Most of the field work on which this report is based was done in the summer of 1947 by Moore, Jewett, and O'Connor, who were assisted by James M. Parks and Edward J. Zeller. Ground-water investigations were made by O'Connor working more or less independently. Test drilling in alluvial deposits was done in the summer of 1948 under the supervision of O'Connor. Areal geology was mapped on air photographs (scale 1:20,000). Rock sections were measured in detail, using a rule, Locke level with stadia, and telescopic level with a 12-foot rod.

Previous Geologic Work

Most of Chase County is included in the Cottonwood Falls quadrangle (between 38° and 38° 30′ north latitude and 96° 30′ and 97° west longitude) the geology and topography of which were described by Prosser and Beede (1904). Outcropping rocks in the Flint Hills in Chase and other counties have been studied by several geologists and have been described in several publications (Moore, 1918; Fath, 1921; Bass, 1929; Condra and Upp, 1931; Jewett, 1941). Because of the interest aroused several years ago when Pre-Cambrian rocks were found at comparatively shallow depths in the Nemaha anticline, the subsurface geology of Chase County has been described rather widely (McClellan, 1930; Lee and others, 1946).

The geology of Chase County pertaining to oil and gas has been discussed by Jewett and Abernathy (1945), and by Jewett (1949); mineral resources were described briefly by Landes (1937, pp. 13-14).

Acknowledgments

Many citizens of Chase County were extremely helpful while field work was in progress. Their cooperation is greatly appreciated. Special thanks

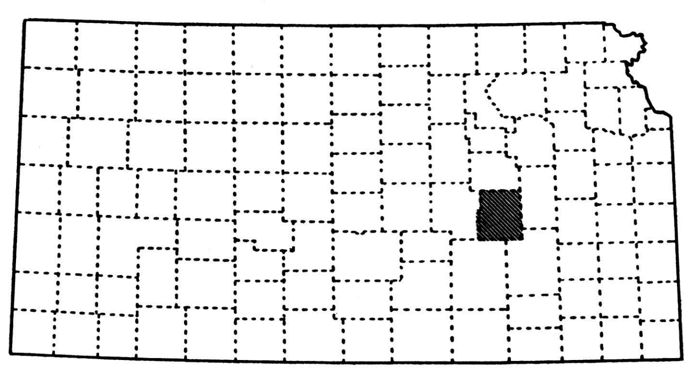


FIG. 1.—Index map of Kansas showing location of Chase County.

are expressed to several people who furnished information of various kinds. Among these are Willard Hilton, State Board of Health; N. D. Jackson, The Texas Company; Walter F. Kline, Elmdale Gas Company; William Wlivowsky, Strong City Gas Company; Earl J. Coulter, Cities Service Gas Company; and Hazen Bledsoe, driller. Plates 1, 2, and 3 were drafted by Alice White and W. W. Wilson.

STRATIGRAPHY OF OUTCROPPING ROCKS

Plate 1 is an areal geologic map of Chase County. With the exception of stream valley alluvium and terrace deposits, which are of Pleistocene and Late Tertiary (?) age, all exposed rocks in Chase County belong to the Permian System (Pl. 1). Most are of early Permian (Wolfcampian) age. In pages devoted to descriptions of the rock succession of Chase County, statement of thicknesses and distribution applies to this county only, unless otherwise indicated.

QUATERNARY SYSTEM

Pleistocene Series

Stream-Valley Alluvium

Stream-laid deposits of gravel, sand, silt, and clay as much as 55 or 60 feet in thickness occupy the valleys of Cottonwood River, South Fork of Cottonwood River, and Diamond Creek. Thinner accumulations which are more variable in lithology partly fill the valleys of smaller streams. In the valleys of the larger streams, coarser material, in deposits generally from about 3 to 18 feet thick, commonly is found in the lower parts of the accumulations.

Gravel and sand in these deposits contain fragments of limestone and mollusk shells rather freely intermingled with quartz and chert. The finer material, which occurs more commonly in the upper part of the alluvial accumulations, consists of silt and clay, generally sandy in the lower parts but commonly nearly free of sand in the upper parts. Colors, in general, are darker near the present land surface while variations of tan, buff, reddish buff, brown, gray, and gray green are seen in samples taken from bore holes. The lower parts of the deposits of finer materials generally are calcareous.

The extent of stream valley alluvium, except very narrow belts in small valleys, is shown on Plate 1.

Terrace Deposits

Stream-laid deposits of gravel, sand, silt, and clay and possibly volcanic ash occur in terraces at elevations lower than those of Tertiary (?) terraces. On the areal geologic map (Pl. 1) Pleistocene and probable Tertiary deposits that occur in terraces are undifferentiated.

The most prominent and extensive Pleistocene terrace occurs along the valleys of Cottonwood River and South Fork Cottonwood River. This terrace is here called the Emporia terrace because of its prominent development in the vicinity of Emporia, a few miles east of Chase County. The basal accumulations of the Emporia terrace lie on Permian rocks, generally 10 to 20 feet higher than the present alluvial flood-plain surface. Seemingly, however, where in contact with shale beds, the terrace deposits lie on an eroded surface almost as low as the present flood plain.

Material in the lower part of the Emporia terrace is well exposed in a gravel pit in the NE¼ SW¼ sec. 10, T. 19 S., R. 9 E. (Pl. 4A, 4B). It consists chiefly of coarse subrounded to subangular chert gravel, one-quarter to 3 inches in diameter. There is an intermingling of chert and quartz sand and a minor amount of silt and clay. The sorting is poor. This predominantly coarse material, which ranges in thickness from a few inches to about 15 feet, grades upward into tan and buff sandy silt, overlain by tan, buff, or reddish-brown silt and clay. The thickness of the finer material above the gravel ranges from a few inches to about 20 feet. Locally, various amounts of silt and clay have been removed and, except in the thicker deposits, calcareous matter has been leached.

Vertebrate remains, thought to be mid-Pleistocene in age, have been found in the Emporia terrace in Lyon County, and Pearlette volcanic ash has been reported above the basal sand and gravel and below about 40 feet of silt and clay in the terrace at Emporia (Frye, Swineford, and Leonard, 1948, pp. 508-510).

TERTIARY SYSTEM (?)
PLIOCENE SERIES (?)
Terrace Deposits

East of the Flint Hills in Chase County, belts of terraces border the major stream valleys at elevations ranging from 50 to 150 or more feet above the present flood plains. The materials comprising these high terraces were derived chiefly from cherty Lower Permian limestones that are exposed in the Flint Hills, and seemingly to a lesser extent from sandy beds in the Kiowa shale (Gulfian) somewhat farther west. The deposits consist chiefly of chert fragments, one-quarter to about 3 inches in diameter, with some smaller ones. Also there are sand grains of colorless quartz, mostly well rounded. Noncalcareous reddish clay occurs with the sand and gravel in amounts sufficient to bind it firmly together. The thickness of these alluvial accumulations ranges from a few inches to about 16 feet.

Topographic position of the high terrace deposits in Cottonwood River Valley, compared with that of similar gravel deposits which occur below Kansan or earlier glacial till in Kansas River Valley, suggests equivalent age. Furthermore, these deposits are higher, thinner, and more thoroughly dissected than those of the Emporia terrace, which is judged to be late Kansan in age. Although not studied in detail, high terrace chert gravels occur throughout most of eastern Kansas and have been described briefly in many geologic reports (Wooster, 1915; Todd, 1918, 1918a; Bass, 1929, pp. 104-108; Jewett, 1941, p. 19; 1945, p. 13; Moore and others, 1951, p. 20.).

PERMIAN SYSTEM
LEONARDIAN SERIES
SUMNER GROUP
Wellington Shale

A maximum of 40 to 50 feet of sediments, classified as the lower part of the Wellington shale, occurs in a small area in southwestern Chase County. Outcrops are not suitable for a measured section. In that area, about 2 feet of impure limestone was observed 40 feet above the base of the Wellington formation, and this limestone (mapped as the Hollenberg limestone by Moore and Landes, 1937) is the youngest Permian rock in the county. Gray, green, and red gypsiferous shale occurs between the Hollenberg (?) limestone and the underlying Herington limestone. The areal distribution of the Wellington formation is shown on Plate 1. It is not a source of ground water in this area.

WOLFCAMPIAN SERIES
CHASE GROUP
Nolans Limestone

The Nolans limestone, comprising two limestone members and a shale member, ranges in thickness from about 22 to 26 feet. Except possibly in the small area where overlain by Wellington shale this formation does not yield water to wells.

Herington limestone member.—Although parts of the Herington limestone are nonresistant, it contains some resistant beds that hold a prominent bench above the softer beds below. The upper and lower parts are more massive and more resistant than the middle part. The rock is largely dolomite.

The upper and lower parts of the Herington limestone are light-gray to buff hard sucroselike to dense dolomitic limestone, commonly containing sparse impure gray chert nodules and cauliflowerlike geodes. The middle part is light-brown to buff thin-bedded sucroselike dolomitic limestone. This part in weathered exposures is porous because of the leaching of abundant small gastropods and pelecypods.

Geodes of coarse-grained chalcedony or finely crystalline quartz or less commonly calcite, ranging from about an inch to about 10 inches in diameter, are scattered throughout the Herington limestone. The thickness of the member ranges from about 10 to 15 feet.

Paddock shale member.—The thickness of the Paddock shale ranges from about 6 to 9 feet. It is olive-gray and light drab-gray shale containing more or less calcareous zones in its middle part. Cauliflowerlike geodes of drusy or finely crystalline quartz and calcite occur plentifully in the upper part. The geodes range in diameter from about an inch to 10 inches. Some of them are at the top of the Paddock shale, partly embedded in the overlying limestone. Pelecypods, especially *Aviculopecten*, are locally abundant.

Krider limestone member.—The Krider member in Chase County is a dolomitic limestone which ranges in thickness from 2 to 4½ feet. Commonly the lower part comprises less than a foot of yellow to greenish-gray impure dolomitic limestone. This is overlain by gray-green shale, one-half to 2 feet thick. The upper part is gray to tan fossiliferous limestone, 1½ to 3 feet thick.

Odell Shale

The Odell shale ranges in thickness from 20 to 30 feet. The upper 3 to 8 feet is gray to gray-green and the middle and lower parts show shades of red, purple, and green. Locally, the lowermost few feet is gray and calcareous. Thin discontinuous to nodular impure limestone beds occur commonly in the upper and middle parts. Little or no ground water is obtained from the Odell shale.

Winfield Limestone

The Winfield limestone, comprising two limestone members and a shale member, ranges in thickness from about 20 to 24 feet. Small supplies of ground water are obtained from this limestone, principally from the Cresswell member, in a limited area.

Cresswell limestone member.—Light-gray to yellowish-gray mostly massive limestone comprises the largest part of the Cresswell limestone. As seen in some exposures, the upper part consists of yellowish-gray limestone bearing siliceous geodes and overlying limy shale or shaly limestone. The lower one-half to two-thirds of the member, however, is thick-bedded or locally somewhat slabby with thin shale partings. Chert is rather common. Purer chert occurs in small nodules with rudely concentric color bands that are darker in the central part. Less pure chert is brown or reddish and occurs in larger nodules, many of which are discoidal in shape. The thickness of the member ranges from about 9½ to 14½ feet.

Grant shale member.—The Grant shale ranges in thickness from 3 to 9 feet. The upper part comprises light-gray to yellowish-gray shaly limestone that weathers as shale, and the lower part gray calcareous shale. Locally, calcite geodes occur in the lower part. Fossils are sparse in most outcrops.

Stovall limestone member.—The Stovall limestone, lower subdivision of the Winfield formation, ranges from 1 to slightly more than 4 feet in thickness along its outcrop. Dark-gray chert nodules are present in some exposures, but are absent at others. The limestone is light gray but weathers yellowish to slightly rusty. At fresh exposures, the boundaries are sharply defined from overlying and underlying shale.

Doyle Shale

The thickness of the Doyle shale is everywhere about 62 feet. With soft limestone beds in the upper part of the Fort Riley limestone, it lies below long gentle slopes broken by a bench held by the Towanda limestone member. Lower beds of the Doyle are important sources of ground water in a considerable part of southwestern Chase County. Well water is obtained from these rocks at depths ranging from a few feet to more than 100 feet.

Gage shale member.—The upper part of the Gage shale consists primarily of yellow and gray calcareous shale bearing crinoid fragments, brachiopods, and pelecypods in one or more zones and locally coquinas of *Derbyia*. One to 4 feet of gray platy or splintery limestone occurs below the fossil zones. The lower and middle parts consist almost entirely of red, purple, and green shale with a minor amount of impure limestone in thin beds. The thickness of the member ranges from about 38 to 44 feet.

Towanda limestone member.—This member comprises 8 to 10 feet of gray hard platy limestone which weathers yellow to tan and locally contains brecciated zones. Thin shale breaks are common in the upper part.

Holmesville shale member.—These beds consist of unfossiliferous green and (less commonly) gray shale with thin beds of impure limestone and impure gypsum. Green shale is characteristic of the upper and lowermost parts. An easily recognized zone, consisting of 1 to 2½ feet of crystalline calcite "chains" 3 mm. in diameter in clayey matrix, occurs in the upper part. At long-weathered exposures the clay has been removed leaving porous boxworks of these tiny crystalline chains. The thickness of the Holmesville shale is about 8 to 12 feet.

Barneston Limestone

The Barneston limestone is about 80 feet thick. This limestone is the most important bedrock aquifer in this area and wherever it occurs extensively as it does in southwestern Chase County, it supplies water of good quality in quantities of 100 gallons a minute or more.

Fort Riley limestone member.—The upper beds of the Fort Riley limestone are massive but soft; in only a few places they form a distinct but not prominent topographic bench. They are light gray to light tan, and are chalky and platy. Fossils are sparse or absent. The middle limestone beds also are gray to light tan, platy, and chalky. Crinoid fragments, mollusks, and brachiopods are more or less plentiful. The lower part consists of massive beds of gray to buff porous fossiliferous limestone. This "rimrock" part, except in a few places, does not form a wall-like outcrop, as it does farther north in Kansas. Fossils in the lower part include abundant to sparse pelletlike algae, fusulines, echinoderm fragments, brachiopods, and mollusks. The thickness of the member commonly is about 40 feet.

Oketo shale member.—Gray to buff calcareous shale, containing echinoid and crinoid fragments, brachiopods (*Derbyia, Wellerella, Dictyoclostus, Composita*), and sparse gastropods, characterizes the Oketo shale. The member is everywhere thin or absent; locally it cannot be differentiated. The maximum thickness is about 3 feet.

Florence limestone member.—The Florence is a hard light-gray to yellowish-gray fossiliferous limestone containing abundant blue-gray chert nodules and beds (Pls. 4C, 5D). Almost everywhere it makes a well-defined bench in the topography. Commonly, two or more thin fossiliferous shale breaks occur in the lower part. The middle part is sparsely cherty limestone, which in many places is cellular and porous. Fossils include fusulines, bryozoans, corals, brachiopods, and mollusks. The thickness of the member is about 39 feet.

Matfield Shale

The three members of the Matfield shale are of about equal average thickness; the total amounts to about 57 feet. The formation generally yields little or no water to wells except for small supplies sometimes obtained from the middle member.

Blue Springs shale member.—The thickness of the Blue Springs shale is about 15 to 20 feet. It is divisible into persistent zones. Slightly less than the upper half of the member comprises gray, yellow, or olive shale containing thin discontinuous beds of limestone with sparse pelecypods. Below this zone and slightly above the middle, a 1-foot bed of molluscan limestone occurs. Olive and green shale comprise the middle and lower parts of the Blue Springs shale, and bright red, purple, and (less commonly) green shale constitutes a basal zone ranging from a few inches to about 6 feet in thickness.

Kinney limestone member.—The thickness of the Kinney limestone ranges from about 15 to 22 feet. Three major zones are persistent. They show marked variations in thickness and lithology, however.

The upper zone consists of limestone beds 2 to 6 feet thick. This unit commonly makes a prominent bench which is bordered by large rhomboidal blocks of limestone. Within distances as short as 100 yards, however, it may change from a single massive bed to several thin beds separated by shale partings; these thin limestones are inconspicuous and nonresistant to weathering. Thickness changes are abrupt. Ostracodes are characteristic of this rock and in some places they comprise almost the entire bed. Locally, the matrix material has been leached so as to produce a soft friable rock resembling sandstone; the "grains" are chiefly ostracode tests. Echinoderm fragments, brachiopods, and mollusks are rather plentiful in facies which lack numerous ostracodes.

Shale beds in the middle part of the Kinney limestone are gray, buff, and green. Most exposures include one or more calcareous zones or thin limestone beds. Fossils, including bryozoans, echinoid and crinoid fragments, *Derbyia, Composita,* and other brachiopods, are abundant, especially in the middle and lower parts.

The lower part, 2 to 7 feet thick, is occupied by one or more limestones, ranging from shaly beds to resistant hard rock that forms a prominent topographic bench. Echinoderm fragments, *Derbyia, Composita,* productids, and pelecypods are the common fossils in this part of the Kinney limestone.

Wymore shale member.—The thickness of the Wymore shale ranges from about 15 to 23 feet.

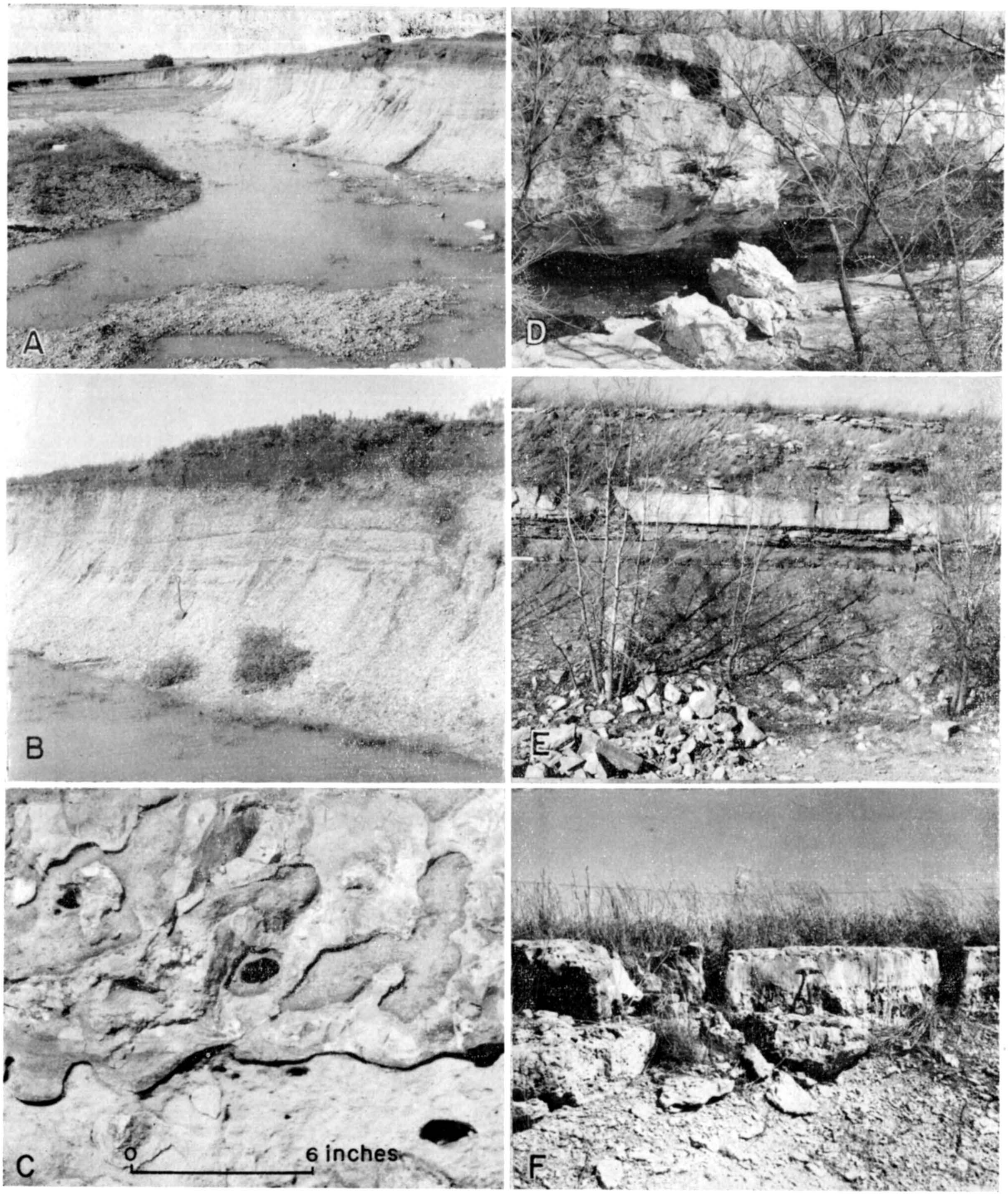


PLATE 4. **A,** Quarry in Pleistocene terrace gravel along Cottonwood River Valley, NE¼ SW¼ sec. 10, T. 19 S., R. 9 E. **B,** Close-up of quarry face shown in A. **C,** Chert nodules in lower part of Florence limestone, southern Chase County. **D,** Massive sparsely cherty outcrop of Threemile limestone showing large solution caves in lower part; along creek in Lot 10, sec. 19, T. 22 S., R. 8 E. **E,** Funston limestone, complete except for a small part of the upper limestone bed; exposed in face of quarry. Thin basal limestone is algal. SE¼ NW¼ sec. 3, T. 20 S., R. 6 E. **F,** Upper siliceous limestone bed of the Eiss limestone showing typical pitted weathering character. Along U. S. 50-S, SE¼ NW¼ sec. 17, T. 19 S., R. 8 E. (Photos by H. G. O'Connor.)

The upper part comprises gray and yellow shale with thin discontinuous limestone beds. The middle part consists of red, purple, and green shale which contains a lenticular impure limestone "boxwork" (secondary fillings along joints and bedding). Gray, yellow, and olive shale occurs generally in the lower part of the member.

Wreford Limestone

The Wreford limestone, including two limestone members and a shale member, has an average thickness of about 35 feet in Chase County.

Wherever this formation occurs beneath the surface at depths less than about 150 feet and is not intricately dissected, good supplies of ground water generally may be obtained from it.

Schroyer limestone member.—The thickness of the Schroyer limestone ranges from about 8 to 13 feet. The upper 3 or 4 feet is light gray and finely porous. It is more resistant to weathering than the remainder, which is similar in lithology except for abundance of chert nodules. Brachiopods are the most common fossils in this member; echinoderm fragments and bryozoans are less abundant. The Schroyer limestone does not produce a strong topographic bench, but with underlying shale beds, commonly lies below a gentle slope of considerable width.

Havensville shale member.—The average thickness of the Havensville shale is about 10 feet. It comprises gray, buff, and olive shale interbedded with thin lenticular beds of limestone. Echinoderm fragments, bryozoans, brachiopods, and pelecypods are abundant.

Threemile limestone member.—Measured sections of the Threemile limestone range from 14 to 23 feet. An easily differentiated upper zone comprises gray, more or less porous chalky limestone with abundant chert. The chert is arranged in bands or in some places is scattered; it is more abundant in the upper and lower parts, and locally chert is absent in the middle part. The sparsely cherty middle part forms a strong prominent bench over most of its line of outcrop (Pls. 4D, 6C). A zone of gray fossilferous shale, commonly 1 to 2 feet thick, but locally much thinner or absent, separates the two limestone zones of this member. The basal part of the member is a blocky gray limestone generally containing two bands of chert. The thickness of this part ranges from 1 to 4 feet. Brachiopods are the most abundant fossils in the Threemile limestone, but sparse fusulines, bryozoans echinoderm fragments, and a few mollusks also are present.

COUNCIL GROVE GROUP

Speiser Shale

The thickness of the Speiser shale is commonly about 18 feet, but it ranges from about 13 to 20 feet. The upper 1 to 6 feet in all exposures studied consists of gray calcareous abundantly fossiliferous shale with a thin limestone locally at its base. Bryozoans, echinoderm fragments, and brachiopods—especially *Chonetes, Composita,* and *Derbyia*—occur in this zone. The middle and most of the lower part of the Speiser shale comprise unfossiliferous red and purple shale and lesser amounts of green shale. The Speiser shale is unimportant as a source of ground water.

Funston Limestone

The Funston limestone is characteristically about 17 feet thick, but ranges from 13 to 25 feet (Pl. 4E). It comprises an upper and lower limestone, separated by shale. The upper limestone is gray when newly exposed to weathering but in time it becomes buff or brown. Its upper part is decidedly platy and the lower part massive. In many places it bears chert nodules or quartz-lined geodes.

The shale between the two limestones is gray, gray-black, or green and silty in the upper part, and commonly a thin limestone bed occurs in the middle or lower part. Locally, it contains thin lenses or stringers of porous chert near the top. The lower part of the shale is gray to black and at some exposures bears bryozoans, brachiopods, and mollusks; in places it is nearly barren of fossils. At an exposure near the Cen. sec. 1, T. 21 S., R. 7 E., the lower part of the shale is represented by slabby limestone consisting almost entirely of bryozoans. At the same place, the middle part is gypsiferous and the upper middle part contains stringers of chert.

Both the upper and lower limestone beds of the Funston formation are composed largely of mollusks. Calcareous algae occur, at least locally, in all parts of the formation, although most commonly in the lower part.

A few shallow wells obtain small supplies of ground water from the Funston limestone. However, wells in this formation are generally of low yield, variable in quality, and not dependable.

Blue Rapids Shale

The average thickness of the Blue Rapids shale is 15 to 17 feet; locally it is much thinner. Gray, green, and red shale comprises almost the entire formation, although there are some thin limestone beds and zones of limestone nodules and calcareous "boxwork" (secondary filling along bedding and joint planes). It supplies little or no water to wells in this area.

Crouse Limestone

The Crouse limestone comprises an upper and lower limestone separated by shale. The combined thickness commonly is about 16 feet.

The upper Crouse limestone is divisible into two lithologic units. The uppermost part, about 1 to 3 feet thick, is conspicuous because of its very platy structure. It is light to dark gray or buff. In some places this part has the appearance of platy calcareous shale. Gray or buff massive limestone, which forms a prominent topographic bench and furnishes large detached blocks of rock along its outcrop, comprises the lower part of the upper Crouse limestone (Pl. 5B). This part ranges in thickness from about 1½ to 3 feet. Locally it contains siliceous nodules or geodes and is characterized by rusty-weathering, small high-spired gastropods, and small clams. "Osagia"-type algae are abundant in some parts of the upper Crouse limestone.

The shale of the Crouse limestone also is divisible into two distinct lithologic units. The upper part, 5 to 10 feet thick, is gray or buff unfossiliferous clay shale. The lower part, ranging from about 1 to 5 feet in thickness, is gray and abundantly fossiliferous, containing microfossils, byrozoans, echinoderm fragments, and brachiopods.

The lower part of the Crouse is a gray or buff mottled silty limestone which has a rather slabby structure. Commonly it is a molluscan limestone, but locally it contains a varied assemblage of mollusks, bryozoans, and brachiopods. The thickness range is between about 0.8 and 2.5 feet.

A few shallow wells obtain small supplies of ground water from the Crouse limestone. Deeper wells penetrating this limestone generally obtain little or no water from this zone.

Easly Creek Shale

Measured sections of the Easly Creek shale range from 12 to 18 feet in thickness. Predominantly the formation comprises green clayey and calcareous shale, with two zones of bright red or purple material occurring near the middle or in the lower part. A zone of nodular limy material or "boxwork" occurs in some outcrops near the base. It supplies little or no ground water to wells in Chase County.

Bader Limestone

The average thickness of the Bader limestone is about 28 feet. Locally this formation, principally the lower member, is a source of small supplies of ground water for domestic and stock wells.

Middleburg limestone member.—The upper Middleburg limestone member of the Bader formation is divisible into four lithologic units. The total thickness commonly is about 7 feet. At the top is 1 to 2 feet of light-gray platy to slabby limestone commonly containing small high-spired gastropods. This uppermost limestone unit is underlain by 1 to 2 feet of black or dark-gray platy shale. Next below is a zone of dark-gray slabby limestone or calcareous shale, about 0.5 to 2 feet thick. The lowermost unit is light-gray massive to slabby or nodular limestone, 1 to 3 feet thick. It commonly contains small snails and clams; locally, however, it bears crinoid fragments, bryozoans, and productid brachiopods.

Hooser shale member.—Green and gray shales with a marly "boxwork" zone in the middle part comprise the Hooser shale. In places, beds of red shale are observed in the middle and lower parts. The thickness typically is about 6 feet but ranges from 3 to 7 feet.

Eiss limestone member.—The thickness of the Eiss limestone is about 16 feet. It is divisible into three distinct units.

The upper part is a gray siliceous bench-making limestone (Pl. 4F), which becomes characteristically pitted when weathered. Coarse crystalline fossils stand out in relief on weathered surfaces. The thickness ranges from 1 to 2½ feet. The middle part comprises several feet of gray and olive shale commonly with abundant crinoid and echinoid fragments, bryozoans, and brachiopods occurring in the lower part.

The lower unit, ranging in thickness from 3 to 12 feet, is dark-gray to nearly black shaly limestone. The basal part is molluscan, but higher in the rock crinoid fragments, bryozoans, and the brachiopods *Meekella, Chonetes,* and *Composita* mingle with small snails and clams.

Stearns Shale

The average thickness of the Stearns shale is about 7 feet. It is gray, black, and green in the upper part and gray green or locally calcareous and cream-colored in the lower part. Red shale occurs near the middle in some places. It is of little importance as a source of ground water.

Beattie Limestone

The Beattie limestone comprises two massive limestones averaging about 5 feet in thickness, separated by about 12 feet of shale. It is one of the principal aquifers of the Council Grove group and supplies many stock and domestic wells with ground water.

Morrill limestone member.—The Morrill limestone ranges in thickness from about 3½ to 6 feet. It exhibits various lithologic characters in different beds, which commonly are separated by thin shale. The upper part may be either soft or dense limestone, gray to yellowish brown, fossiliferous, with calcite vugs and geodes. The middle and lower parts are mostly molluscan or algal.

Florena shale member.—Measured sections of the Florena shale range from 8 to 15 feet in thickness. The upper 1 to 5 feet is unfossiliferous or only very sparsely fossiliferous. This part, which is gray, yellow, or black, commonly contains calcitic and siliceous vein fillings and geodes. In places, gypsum is associated with the geodes. The lower 6 to 9 feet is dark gray to black or gray and is abundantly fossiliferous. The brachiopod *Chonetes* is the most common fossil, but *Derbyia,* productids, and *Composita* are common. Echinoid and crinoid fragments and bryozoans are found locally. Small trilobites are sparsely present.

Cottonwood limestone member.—The Cottonwood limestone ranges in thickness from about 3 to 6½ feet. Commonly it is a massive gray to creamy buff limestone that weathers light gray. There are one or more very thin shale partings. Abundant slender fusulines are characteristic (Pl. 6D). The fusulines are abundant only in the upper half or less of the Cottonwood member, and they are absent in the lower part except for very sparse specimens locally near the top of this lower division. The lower part generally carries echinoderm fragments, bryozoans, and brachiopods and more or less commonly irregularly platy algal material. This lower part may be massive or slabby.

A rather decided facies change is observed in the Cottonwood limestone in tracing the unit from north to south across Chase County. South of Cottonwood River, in the drainage area of Jacobs Creek, it loses its characteristic massiveness and does not occur in conspicuous outcrops, as farther north (Pl. 5C). In the drainage area of Verdigris River, in southern Chase County, it is 3 to 5 feet thick. Sparse to abundant siliceous nodules are characteristic there; in some outcrops the upper fusuline zone consists of limy shale and the lower algal part is massive to slabby limestone.

Eskridge Shale

Measured sections of the Eskridge shale show a thickness range from 23 to 38 feet and furnish record of marked changes in lithology. In an exposure in the NE¼ sec. 19, T. 18 S., R. 7 E., 37 feet of red, green, and purple partly gypsiferous shale is exposed. The base of the formation is covered. No fossils were seen. In the N½ SW¼ sec. 3, T. 22 S., R. 9 E., the formation is 24½ feet thick. The upper part is gray and green; a thin bed of pelecypod-bearing limestone occurs in red and green shale in the middle part, and a bed of lignitic platy material, nearly 1 foot thick, occurs 5½ feet above the base. The Eskridge shale is not an important source of ground water; however, a few wells do obtain small supplies of water from it at shallow depths.

Grenola Limestone

The thickness of the Grenola limestone is about 45 feet. It is the chief aquifer for many wells in Chase County. The Neva limestone member is the most important aquifer.

Neva limestone member.—The upper unit of the Neva limestone is an algal and molluscan limestone bed, 1 to 6 feet thick. Locally it is a coquina of small shells, fossil fragments, and algal material. It is separated from the "main ledge" by gray fossiliferous shale, which ranges in thickness from a featheredge to as much as 9 feet. Echinoid spines and brachiopods are abundant in this part which in the southern part of the county is very calcareous shale or shaly limestone. The middle or main ledge is a gray massive limestone containing echinoderm fragments, brachiopods, and locally fusulines in the upper part and fusulines in the lower part. It appears brecciated and pitted in weathered exposures (Pl. 6E). It ranges in thickness from about 3½ to 8 feet. Next below is a thin bed of gray to nearly black fusuline-bearing shale overlying about 1 foot of brownish-gray fusuline limestone that commonly has an upper crust composed principally of the brachiopod *Crurithyris*. A few inches of shale, locally containing algal material, lies above a pitted algal limestone, about one-half to a foot thick, which comprises the lower unit of the Neva member.

Salem Point shale member.—The average thickness of the Salem Point shale is about 9 feet. Buff limy nodular shale occurs in the upper part as a zone from one-half to 3 feet thick. The lower 5 to 7 feet is gray to gray-green or black thin-bedded to fissile shale.

Burr limestone member.—The Burr limestone comprises several limestone beds separated by shales. As seen in most exposures there is a limestone bed 0.3 to 1½ feet thick at the top; this is underlain by 1 to 5 feet of gray-green or gray shale that seemingly is without fossils. The middle part is characterized by extremely platy limestone (Pl. 5E). This part is light gray or bluish and weathers light tan or yellow. At some outcrops there are shale partings in this zone and locally a thin layer rich in ostracodes is included. The lower part of the Burr limestone is gray and mottled shaly to slabby limestone, 2½ to 7 feet thick, and containing an abundance of clams. Locally, several shale partings occur in this lower part. The average thickness of the member is about 12 feet.

Legion shale member.—Commonly the upper few inches of the Legion shale is black, platy, and carbonaceous. Locally a thin limestone is exposed; it contains crinoid fragments, bryozoans, brachiopods, and pelecypods in the upper part. Mostly, however, this member of the Grenola formation comprises gray seemingly unfossiliferous shale. In places gray-green or buff colors are seen in the lower part. The overall thickness range is between about 3 and 8 feet.

Sallyards limestone member.—Gray platy to shaly limestone and gray shale characterize the Sallyards limestone. The thickness ranges from about 1 to 5 feet. Where thin the member commonly contains only pelecypods, but where thicker crinoid fragments, bryozoans, gastropods, and pelecypods are common.

Roca Shale

Measured sections of the Roca shale are uniformly about 16 feet thick. Approximately the upper half is gray or green shale, calcareous or with limy nodules. The lower part commonly contains two or three thin limestone beds separated by red, green, and purple shale. In a few places there is a small amount of gray clay in this lower part. In general the limestones are seemingly without fossils, but locally they contain small snails.

The Roca shale is of little importance as a source of ground water.

Red Eagle Limestone

The average thickness of the Red Eagle formation (Pl. 5F), which comprises two limestone members and a shale member, is about 14½ feet. It is the principal aquifer for numerous wells where it is not too deeply buried below younger rocks.

Howe limestone member.—The upper division of the Red Eagle (Howe limestone) is gray or gray-brown oölitic, algal, or foraminiferal limestone. In most places, part is earthy or chalky and soft. Commonly it does not form a conspicuous outcrop. The thickness ranges from about 1 to 3 feet.

Bennett shale member.—The thickness of the Bennett shale ranges from about 3½ to 12 feet. In thicker facies the upper part is greenish gray to buff and is sandy. Where the Bennett is thinner, the upper part commonly is gray. The lower part is light to dark gray and calcareous. The Bennett shale is abundantly fossiliferous. Fossils include echinoid and crinoid fragments, bryozoans, and many common Lower Permian brachiopods.

Glenrock limestone member.—Measured sections of the Glenrock limestone range from 2¾ to 7½ feet. Mostly the rock is light-gray to nearly white limestone and is chalky and brecciated. Cavernous weathering is characteristic. Generally the lower part comprises thin limestone and shale beds. The shale partings are gray, yellow, and nearly black. Fusulines are characteristic of the basal part and locally conodonts are abundant.

Johnson Shale

Light to dark-gray and greenish shale generally containing two or three thin limestone beds comprises the Johnson shale. The common thickness is about 22 feet. Generally the upper part is dark gray and carbonaceous. The middle part contains thin limestone beds of several textural types. The gray to green shale that occurs in the lower part contains a thin bed of nodular to well-bedded limestone, and in places gypsum occurs in this lower part.

The Johnson shale generally yields little or no water to wells; however, the lower part occasionally yields small supplies of ground water from gypsiferous or geodiferous zones.

Foraker Limestone

The Foraker formation is approximately 39 to 42 feet thick. Although the middle and lower members are unimportant as sources of ground water, the Long Creek limestone is an important aquifer, the upper geodiferous and cavernous part generally being very permeable.

Long Creek limestone member.—The Long Creek limestone comprises light-gray to yellow massive to slabby soft limestone and some shale. At most weathered outcrops the limestone is cavernous and vesicular-appearing. It is not resistant to weathering and forms an inconspicuous bench. Fresher exposures show geodiferous to somewhat cavernous rock. Colorless to pink or reddish-orange crystals of quartz and coarse-grained chert, generally associated with crystalline celestite or less frequently barite, characterize the top of the Long Creek limestone. In places there are nodules of pyrite and chalcopyrite that cause dark reddish-brown staining. Small clams and *Osagia*-like algae are somewhat sparse. Measured sections range from about 4 to 9 feet in thickness.

Hughes Creek shale member.—At measured exposures, the Hughes Creek shale ranges in thickness from about 18 to 25 feet. It is predominantly gray calcareous shale with a subordinate amount of limestone and is characterized by abundant fusulines throughout most of the thickness. A shaly to massive fusuline limestone 2 to 3 feet thick occurs commonly a short distance from the top. A shale zone containing bryozoans, brachiopods, and pelecypods occurs next above the "Thrall limestone bed" (Bass, 1936, p. 36) which is in about the middle of the Hughes Creek. The Thrall limestone is gray blocky fusuline-bearing limestone, commonly slightly more than 1 foot thick. Another rather persistent but thinner fusuline limestone occurs in the lower part of this member.

Americus limestone member.—The lowermost member (Americus) of the Foraker formation comprises an upper and lower limestone, separated by about 6 feet of bluish-black shale, rich in brachiopods. The upper limestone commonly is blue gray in its upper part and yellow in the lower. The common thickness is between 1 and 1½ feet. Fusulines, crinoid fragments, and brachiopods are the common fossils. In the lower part, gray shaly to platy limestone about 2 feet thick containing brachiopods is underlain by less than a foot of black brachiopod-bearing shale below which is the Americus "main ledge," gray blocky limestone containing brachiopods and fusulines and about 1½ feet thick. The total thickness of the Americus member is 11 feet or slightly more.

ADMIRE GROUP

Hamlin Shale

The Hamlin shale is about 56 feet thick. It is of little importance as a source of ground water in this area.

Oaks shale member.—Exposed in only a few places, the Oaks shale is mostly gray to black. Measured sections range from 5 to 10 feet in thickness.

Houchen Creek limestone member. — Where measured, the Houchen Creek limestone ranges from 1 to 3 feet in thickness. This rock has distinctive lobate bedding (Pl. 5A), because it is composed partly of calcareous algae. Weathered outcrops display yellow-brown sandy-appearing "honeycomb" rock and dense gray algal limestone.

Stine shale member.—In its few exposures in Chase County, the Stine shale comprises gray, red, and green shale and locally one or two thin limestone beds in its middle and lower parts. *Lingula* and other fossils are more or less common in places and sandy phases contain plant remains. Measured thicknesses range from 46 to 50 feet.

Five-Point Limestone

The Five Point limestone has been found only at one place in Chase County; this is along the east county border in the Verdigris River Valley. Several near-by exposures in Lyon County indicate that its properties are rather persistent. It is gray to brown massive commonly dense limestone. Well-preserved brachiopods, pelecypods, crinoids, and bryozoan fragments occur in a thin crust at the top of the bed together with numerous sharks teeth and fusulines. The thickness is about 2 feet. It is not an aquifer.

West Branch Shale

The West Branch shale is the oldest stratigraphic unit at the surface in Chase County. Along the Chase-Lyon County line in Verdigris River Valley it is from 25 to 30 feet thick. Coal or a carbonaceous streak and underclay occur generally near the top. The upper part is sandy and locally contains some sandstone or thin siltstone beds. There is a thin calcareous fossiliferous zone near the middle part and the lower part is tan to gray with a limy zone near the base. No wells obtain ground water from the West Branch shale. In all except a very small area it is too deeply buried to contain potable water.

PART 2
MINERAL RESOURCES OF CHASE COUNTY

By

HOWARD G. O'CONNOR, JOHN MARK JEWETT, AND R. KENNETH SMITH

INTRODUCTION

The known mineral resources of Chase County comprise oil in the southeastern part, gas in the central and northwestern part, and deposits of limestone, clay (shale), gravel, sand, and silt. Ground water, also an important mineral resource, is discussed separately in Part 3 of this report. Limestone, gravel, and sand have been exploited for many years but extensive reserves remain. Oil and gas have been produced for several years but rocks below those of Pennsylvanian age have been inadequately explored for petroleum. Clay resources have been utilized to a very small extent or not at all.

An economic geologic map of Chase County is given in Plate 2. Locations of active and inactive pits and quarries and the names of exploited stratigraphic units and some important test data on limestones and clays (shales) are shown on the map. Locations of all wells that have been drilled for oil or gas for which any information is available also are indicated. The map shows the lowest stratigraphic depth reached and the present status of all wells. Areas of oil and gas fields and locations of roads, railroads, oil and gas pipe lines, and pumping stations are indicated.

ECONOMIC GEOLOGY OF OUTCROPPING ROCKS

Properties and the sequence of outcropping limestones and shales and surficial deposits of gravel, sand, and silt are discussed in Part I of this report. Their distribution is shown on Plate 1.

LIMESTONE

Several limestones occurring in the exposed portion of the geologic column are of economic importance because of their thickness and qualities. The more common uses for which these rocks are suitable include concrete and other aggregate, crushed rock for road metal and other uses, agricultural limestone, riprap, and building stone. Some of them, because of chemical composition, may be suited to more specialized uses. Chemical analyses of rock taken from the more important ledges are listed in Table 1. Data on limestone quarries are listed in Table 2.

AGRICULTURAL LIMESTONE

Limestone having a calcium carbonate equivalent of 80 percent or more occurring in ledges sufficiently thick to allow economical quarrying is regarded as potential material for agricultural limestone. Physical requirements for agricultural limestone largely are dependent on processing and are not considered here.

Limestones which are potential sources of agricultural limestone include: Herington, Cresswell (locally), Towanda, Fort Riley, Crouse, Cottonwood, a limestone in the lower part of the Eskridge shale (locally), Neva, Glenrock, and Long Creek.

Because of the chert content in the Florence, Shroyer, and Threemile ledges, these rocks are not regarded as sources of agricultural limestone.

Dolomitic limestones, such as the Herington and Long Creek, are of special interest as sources of agricultural limestone as they meet minimum requirements for calcium carbonate equivalent of 80 percent or more and have other desirable properties, namely (1) a slower rate of neutralization and (2) they supply soluble magnesium which is now known to be beneficial to plant growth. The Cottonwood limestone, a limestone in the Eskridge shale, and the Neva limestone have been utilized for agricultural limestone in the county.

TABLE 1.—*Chemical analyses of selected outcropping limestones from Chase County*

Stratigraphic unit, thickness, and type of sample	Location	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	P_2O_5	SO_3	Ignition loss	Calculated $CaCO_3$*	Calculated $MgCO_3$
Herington ls., composite of 4 spot samples	NW NE 3-22-6E	13.35	1.71	1.37	0.55	25.50	18.83	0.17	tr.	38.93	45.47	39.39
Krider ls., spot sample of 0.8-foot bed in upper part	NW NE 3-22-6E	10.27	1.62	1.32	0.77	26.68	18.72	0.09	tr.	40.49	47.57	39.16
Cresswell ls., composite of complete member (12.8 ft.)	SW NW 16-22-6E	6.34	0.85	0.76	0.21	50.04	1.89	0.14	....	40.01	89.23	3.95
Cresswell ls., composite of lower 5.6 feet	NE NW 17-22-7E	5.30	1.72	0.14	0.56	50.06	0.68	0.20	0.26	41.01	89.26	1.42
Towanda ls., composite of 10 spot samples of ls. beds of member	SW SW 24-21-6E	2.84	1.11	0.27	0.17	52.59	0.65	0.03	tr.	41.88	93.78	1.36
Ft. Riley ls., composite of 8.85 ft. lower part of member	NW NE 6-22-6E	5.69	1.65	0.65	0.15	50.18	0.66	tr.	tr.	40.44	89.48	1.38
Threemile ls., composite of upper 13.3 ft. without chert	NW NE 18-19-8E	1.72	0.30	0.32	tr.	54.56	0.48	tr.	nil	42.92	97.29	1.00
Crouse ls. (upper) composite of lower massive 2.75 ft. of bed	NW NW 4-18-9E	4.94	0.85	1.49	0.45	50.83	0.28	tr.	tr.	40.46	90.64	0.59
Crouse ls., (lower) composite of all 3.10 ft. of lower Crouse limestone	NW NW 4-18-9E	4.41	0.83	0.58	0.41	51.48	0.74	tr.	tr.	41.20	91.80	1.55
Cottonwood ls., composite of ±5 ft. (complete member)	SE SE 30-19-7E	5.50	1.74	0.49	0.69	50.09	0.65	0.15	0.32	40.71	89.32	1.36
Cottonwood ls., composite of ±5 ft. (complete member)	NE NW 36-19-8E	4.75	0.98	0.28	**	50.55	1.35	0.17	tr.	41.13	90.14	2.82
Cottonwood ls., composite of 3.2 ft. (complete bed)	NW SW 3-22-9E	6.85	1.18	0.59	**	49.53	1.78	0.20	tr.	40.24	88.32	3.72
Eskridge sh. (lower ls. bed) 3.9 ft., composite of complete bed	SW NW 23-19-8E	1.62	1.30	0.36	....	52.78	0.57	0.12	0.12	42.96	94.11	1.19
Upper Neva, composite of complete upper bed, 5.1 ft.	SW NW 23-19-8E	5.09	1.03	0.42	**	50.97	0.56	0.11	0.21	41.38	90.89	1.17
Middle Neva, composite of complete middle Neva, 3.8 ft.	SW NW 23-19-8E	6.05	2.31	0.21	**	50.04	0.75	0.09	0.22	37.04	89.23	1.56
Glenrock ls., composite of upper 5.95 ft.	SE NW 26-19-7E	2.85	0.76	0.32	**	52.89	1.05	0.14	tr.	42.07	94.31	2.20
Long Creek ls., composite of lower 9.75 ft. of member	NW SE 24-21-9E	13.69	1.53	0.38	0.23	41.66	4.22	0.06	†	37.20	74.29	8.88

* Not corrected for small percentages of calcium in phosphates and sulfates.

** Reported with Al_2O_3.

† $S + SO_4 = 0.12$; $FeS_2 = 0.97$.

BUILDING STONE

Nearly all the thicker and more massive limestone ledges in Chase County have been used as sources of building stone. Although rough dimension blocks can be obtained from all of them, the Fort Riley, Cottonwood, and Americus limestones are especially well adapted for cut stone. Other limestones regarded as possible sources of rock for building stone include parts of the Towanda, Kinney, Funston, Crouse, Neva, and the Glenrock limestones. Factors considered include durability, thickness of ledges and individual beds, spacing of joints, and color on weathering.

TABLE 2.—*Locations of limestone quarries in Chase County*

Location where quarried	Thickness of quarried part, feet	Total thickness of member, feet
NOLANS LIMESTONE		
Herington limestone member		
SE¼ SE¼ sec. 14, T. 21 S., R. 6 E.	3 (upper)	10-15
NE¼ sec. 28, T. 21 S., R. 6 E.	3 (upper)	10-15
NW¼ NE¼ sec. 35, T. 21 S., R. 6 E.	3 (upper)	10-15
WINFIELD LIMESTONE		
Cresswell limestone member		
NE¼ SE¼ sec. 18, T. 22 S., R. 6 E.	10	10-14
NW¼ NW¼ sec. 20, T. 22 S., R. 6 E.	10-13	10-14
DOYLE LIMESTONE		
Towanda limestone member		
NW¼ SW¼ sec. 5, T. 22 S., R. 7 E.	8-10	8-10
BARNESTON LIMESTONE		
Ft. Riley limestone member		
SE cor. sec. 27, T. 20 S., R. 7 E.	8-10 (lower)	±40
SE¼ NW¼ sec. 1, T. 21 S., R. 5 E.	8-10 (lower)	±40
NE¼SW¼ sec. 1, T. 21 S., R. 5 E.	8-10 (lower)	±40
NW¼ SE¼ sec. 12, T. 21 S., R. 5 E.	8-10 (lower)	±40
Cen. N½ SE¼ sec. 13. T. 21 S., R. 5 E.	2- 8 (upper)	±40
NW¼ SE¼ sec. 13, T. 21 S., R. 5 E.	2- 8 (upper)	±40
Cen. E. line sec. 19, T. 22 S., R. 7 E.	±8 (upper)	±40
MATFIELD SHALE		
Kinney limestone member		
NE¼ NW¼ sec. 1, T. 21 S., R. 5 E.	....	±19
NE¼ NW¼ sec. 7, T. 22 S., R. 8 E.	....	±14
NW¼ SE¼ sec. 18, T. 22 S., R. 8 E.	±3 (upper)	±19
NW¼ NE¼ sec. 19, T. 22 S., R. 8 E.	±3 (upper)	±19
WREFORD LIMESTONE		
Threemile limestone member		
NW¼ SE¼ sec. 16, T. 19 S., R. 8 E.	....	14-21
NE¼ sec. 18, T. 19 S., R. 8 E.	±13	14-21
FUNSTON LIMESTONE		
NE¼ NW¼ sec. 31, T. 18 S., R. 8 E.	....	±19
NW¼ SW¼ sec. 29, T. 18 S., R. 9 E.	....	±19
Cen. W½ SW¼ sec. 29, T. 18 S., R. 9 E.	....	±19
SE¼ sec. 10, T. 19 S., R. 6 E.	....	±20
SE¼ NW¼ sec. 11, T. 19 S., R. 6 E.	....	±20
NE¼ SE¼ sec. 7, T. 19 S., R. 8 E.	....	±18
SE¼ NW¼ sec. 3, T. 20 S., R. 6 E.	±6 (lower)	±25
NE¼ NE¼ sec. 15, T. 20 S., R. 6 E.	±5 (upper)	±22
NE¼ sec. 22, T. 20 S., R. 6 E.	±5 (upper) ±6 (lower)	±22
CROUSE LIMESTONE		
SE cor. sec. 2, T. 18 S., R. 9 E.	±3 (upper)	±16
NW cor. sec. 3, T. 18 S., R. 9 E.	±3 (upper)	±16
Cen. W½ NW¼ sec. 4, T. 18 S., R. 9 E.	±3 (upper)	±16
Cen. W½ W½ sec. 33, T. 18 S., R. 9 E.	±3 (upper)	±16
NW¼ NW¼ sec. 14, T. 19 S., R. 8 E.	±3 (upper)	±16
SE¼ NW¼ sec. 15, T. 19 S., R. 8 E.	±3 (upper)	±16
NE¼ NW¼ sec. 16, T. 19 S., R. 8 E.	±2 (upper)	±16
Cen. E½ sec. 30, T. 19 S., R. 8 E.	±2 (upper)	±16
N½ sec. 32, T. 19 S., R. 8 E.	±3 (upper)	±16
NE¼ SE¼ sec. 33, T. 19 S., R. 8 E.	±3 (upper)	±16
SE¼ NW¼ sec. 3, T. 20 S., R. 6 E.	±2 (upper)	±16
SW¼ NW¼ sec. 4, T. 20 S., R. 8 E.	±2 (upper)	±16
Cen. N½ N½ sec. 4, T. 20 S., R. 8 E.	±2 (upper)	±16
SW¼ SW¼ sec. 29, T. 20 S., R. 8 E.	±2 (upper)	±16
BADER LIMESTONE		
Eiss limestone member		
NW¼ NW¼ sec. 23, T. 20 S., R. 6 E.	±2 (upper)	±18
BEATTIE LIMESTONE		
Morrill limestone member		
NE¼ NE¼ sec. 16, T. 19 S., R. 8 E.	±4	3.4-6
Cottonwood limestone member		
SW¼ SW¼ sec. 32, T. 18 S., R. 8 E.	±5	4-6.5
SW¼ SW¼ sec. 14, T. 19 S., R. 8 E.	±5	4-6.5
NE¼ NE¼ sec. 16, T. 19 S., R. 8 E.	±5	4-6.5
NW¼ SW¼ sec. 16, T. 19 S., R. 8 E.	±5	4-6.5
SE¼ NW¼ sec. 17, T. 19 S., R. 8 E.	±5	4-6.5
Lot 9 sec. 18, T. 19 S., R. 8 E.	±5	4-6.5
SW¼ NE¼ sec. 22, T. 19 S., R. 8 E.	±5	4-6.5
Cen. W½ NW¼ sec. 23, T. 19 S., R. 8 E.	±5	4-6.5
NE¼ NW¼ sec. 23, T. 19 S., R. 8 E.	±5	4-6.5
SW cor. sec. 26, SE¼ sec. 27, N½ sec. 34, NW cor. sec. 35, T. 19 S., R. 8 E.	±5	4-6.5
Cen. S½ sec. 28, T. 19 S., R. 8 E.	±5	4-6.5
NW¼ SW¼ sec. 28, T. 19 S., R. 8 E.	±5	4-6.5
SE¼ NW¼ sec. 29, T. 19 S., R. 8 E.	±5	4-6.5
Cen. E½ SW¼ sec. 33, T. 19 S., R. 8 E.	±5	4-6.5
SE¼ NE¼ sec. 34, T. 19 S., R. 8 E.	±5	4-6.5
NE¼ NW¼ sec. 36, T. 19 S., R. 8 E.	±5	4-6.5
SW¼ SE¼ sec. 11, T. 20 S., R. 6 E.	±5	4-6.5
SE¼ SW¼ sec. 14, T. 20 S., R. 6 E.	±5	4-6.5
NE¼ NE¼ sec. 27, T. 20 S., R. 8 E.	±5	4-6.5
NW¼ NE¼ sec. 28, T. 20 S., R. 8 E.	±5	4-6.5
ESKRIDGE SHALE		
Unnamed limestone member		
S½ NW¼ sec. 23, T. 19 S., R. 8 E.	3.9	
GRENOLA LIMESTONE		
Neva limestone member		
SE¼ NE¼ sec. 22, T. 19 S., R. 8 E.	±5 (upper)	±13
S½ NW¼ sec. 23, T. 19 S., R. 8 E.	±9 (upper and middle)	±13
SE¼ SE¼ sec. 31, T. 19 S., R. 9 E.	....	±13
SE¼ NW¼ sec. 7, T. 20 S., R. 7 E.	....	14-17
RED EAGLE LIMESTONE		
Glenrock limestone member		
SE¼ NW¼ sec. 5, T. 20 S., R. 7 E.	±5	± 5
FORAKER LIMESTONE		
Long Creek limestone member		
SE¼ NE¼ sec. 12, T. 20 S., R. 9 E.	....	± 6
Americus limestone member		
SE¼ NE¼ sec. 24, T. 19 S., R. 9 E.	1.5 (lower)	±14

The principal uses of the limestones regarded as of minor importance as building stone are for construction of local bridge foundations and abutments, foundations for small buildings, and in construction of farm buildings and other relatively small structures.

Fort Riley limestone.—The Fort Riley limestone has not been quarried extensively in Chase County, but is an important source of material for cut stone in Cowley and Geary Counties. Parts of this rock are light and uniform in color, uniform in texture, easily cut, and have bedding and joint planes spaced to allow quarrying of large blocks. The durability of the Fort Riley limestone, taken from elsewhere in Kansas, has been demonstrated in many buildings.

Cottonwood limestone.—The Cottonwood limestone for a long time has been an important source of building stone. Early in the century six or more commercial quarries produced cut stone in Chase County (Prosser and Beede, 1904, p. 5). The rock is massive, nearly white in color, even-textured, durable, and commonly remarkably free from jointing. Blocks of stone 3 feet or more thick and of much greater length and width can be taken from the ledge. The crushing strength is reported as 6,800 pounds per square inch, the weight 161.6 pounds per cubic foot, and the specific gravity 2.59 (Prosser and Beede, 1904, p. 5). One commercial quarry is now operating in the county about 2 miles east of Cottonwood Falls.

Americus limestone.—The lower part, or "main ledge," of the Americus limestone is regarded as a potential source of commercial building stone because of properties that allow quarrying of large blocks uniformly about 1½ feet thick. The rock is gray in color and has no tendency to become slabby after long exposure.

CRUSHED ROCK AND RIPRAP

All the thicker limestone ledges in Chase County are potential sources of rock for crushing and for riprap material. Many have been used for road metal or aggregate material. No recommendations of individual ledges for aggregate material are made because of the many current sets of specifications for aggregate for specialized uses and because no physical tests were made.

Wreford limestone.—The importance of the Wreford limestone as a source of crusher rock has been recognized for many years. According to Prosser and Beede (1904, p. 6): "This rock [Wreford limestone] was extensively quarried for ballast at the Crusher Hill quarry, one mile northwest of Strong." Chert in the Wreford and Florence limestones may cause them to be undesirable for crushing or for some uses.

Other limestones.—Other comparatively thick limestone ledges that are important sources of road metal and crushed stone for other uses include the Herington, Cresswell, Towanda, Fort Riley, Funston, Crouse, Eiss, Morrill, Cottonwood, limestone in the Eskridge shale locally, Neva, Glenrock, Long Creek, Americus, and Five Point limestones. All the limestones mentioned in this section are regarded as potential sources of riprap material for various uses.

CERAMIC MATERIALS

Ceramic data from firing tests on several samples of clay from Permian shales and from Pleistocene alluvial deposits were obtained in the Geological Survey Ceramic Laboratory by Norman Plummer. Ceramic data are listed in Tables 3 and 4. The paragraphs below were prepared in part by Plummer.

CLAY FOR STRUCTURAL PRODUCTS

Most of the shales have a very short firing and maturing range when being made into brick or other ceramic products because of their high content of lime. The lime content, however, has the property of neutralizing red colors of iron oxides and buff and greenish colors are produced. Data (Table 3) indicate that brick and tile can be produced from the Florena shale if the firing temperature is controlled to within 30°F. of cone 1 (about 2100°F.). The Blue Springs shale also is usable for making brick and tile but an even closer control of firing temperature is necessary. Other shales that were tested are unsatisfactory or of doubtful value for structural clay products (Table 3).

A ceramic analysis was run on a composite sample of 18 feet of alluvial clay from the bank of Cottonwood River, NE¼ NE¼ sec. 35, T. 19 S., R. 8 E. (CS-15). It was first tested by mixing with water and extruding from a de-airing brick machine (CS-15). Working properties were excel-

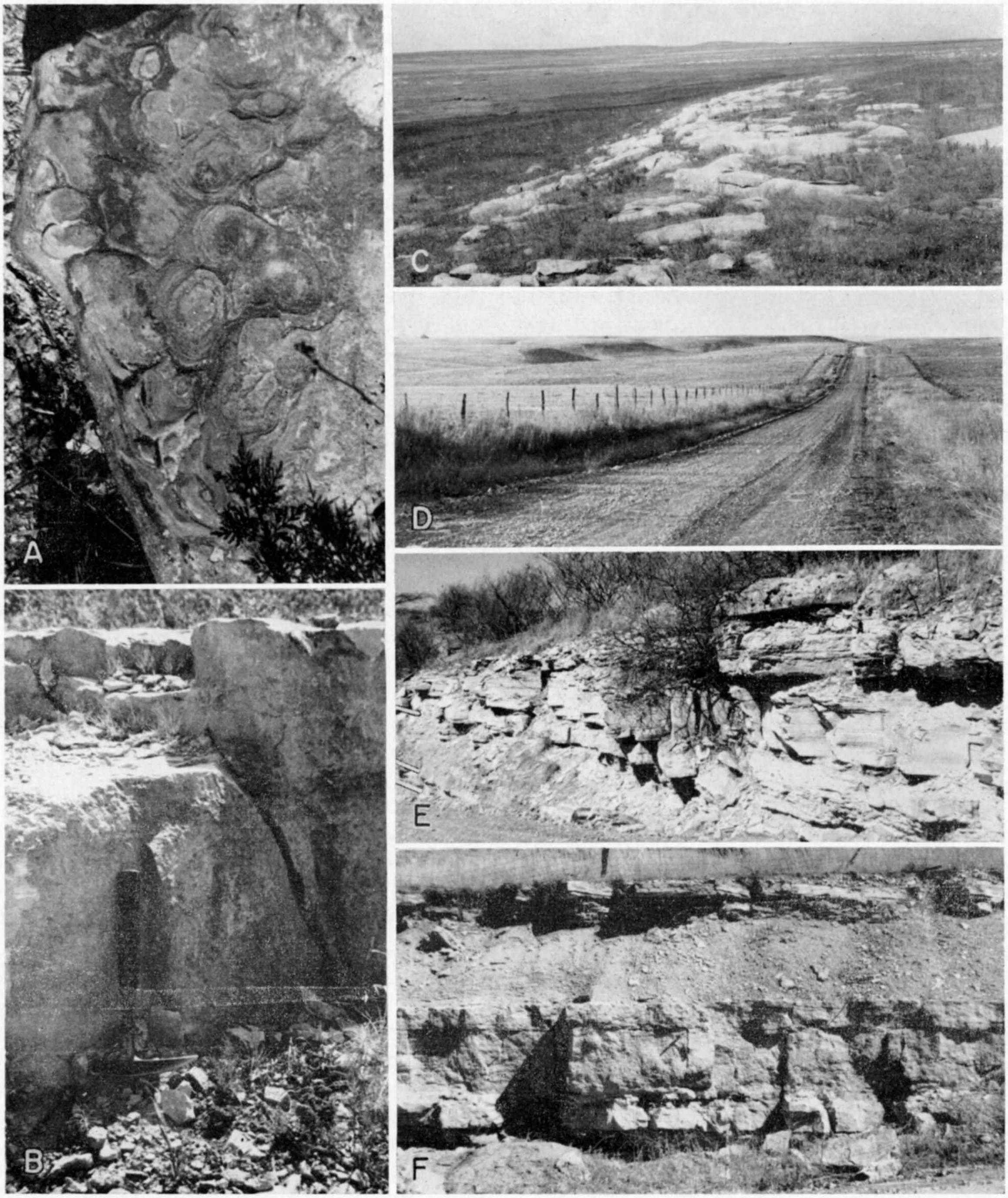


PLATE 5. **A,** Typical lobate-bedded algal Houchen Creek limestone, NE¼ SE¼ sec. 2, T. 20 S., R. 9 E. **B,** Lower part of the upper limestone bed, the "quarry rock" of the Crouse. **C,** Characteristic conspicuous outcrop of the Cottonwood limestone north of Cottonwood River along highway K-150 in sec. 30, T. 19 S., R. 7 E. **D,** Characteristic strong rounded bench formed by the Florence limestone, SE¼ sec. 2, T. 21 S., R. 6 E. **E,** Burr limestone (a) showing platy porcelaneous middle part, (b) Legion shale, and (c) Sallyards limestone. Near Cen. sec. 26, T. 19 S., R. 7 E. **F,** Red Eagle limestone showing characteristic development of each member; Elmdale hill, sec. 26, T. 19 S., R. 7 E. (Photos: A, by R. I. Jindra; B, C, D, E, and F, by H. G. O'Connor.)

TABLE 3.—*Ceramic data on samples of Permian shales from Chase County**

Sample No.	Stratigraphic position	Thickness sampled, feet	Water of plasticity, percent	Shrinkage water, percent	Pore water, percent	Volume shrinkage, percent	Measured linear shrinkage, percent	Calculated linear shrinkage, percent
			PLASTIC AND DRY PROPERTIES					
CS-10	Roca sh.	5	21.68	7.40	14.28	14.07	3.85	4.94
CS-6	Eskridge sh.	7	21.58	9.40	12.18	18.25	5.15	5.76
CS-5	Florena sh.	4	25.05	9.20	15.85	16.97	5.31	5.37
CS-13	Blue Springs sh.	7	23.26	9.72	13.54	18.42	5.29	6.55
CS-38	do	5	19.26	4.76	14.50	9.15	3.13	2.97
CS-14-A	Gage sh. (upper)	6	27.44	14.83	12.61	29.29	7.94	8.94
CS-14-B	Gage sh. (lower)	6	25.31	9.33	15.98	17.09	5.29	5.40

FIRED PROPERTIES

Sample No.	Ignition loss, percent	Firing range, cones	Fired to cone	Color	Volume shrinkage, percent	Linear shrinkage, calculated, percent	Percent absorption 24 hrs., cold water	Percent absorption 5 hrs., boiling water	Saturation coefficient
CS-10	14.49	4-5	04	pink-buff	5.95	1.96		18.05	
			3	white & brown	9.93	3.42	11.65	17.19	0.68
CS-6	19.79	3-4(?)	04	cream	0.09	0.03		26.22	
			7	green	30.76	17.31	5.54	7.76	0.77
CS-5	8.86	01-2	04	orange-buff	7.22	2.46		17.40	
			3-4	brown	25.08	9.18	3.65	4.33	0.84
CS-13	12.08	1-3	04	pink-buff	2.39	0.79		26.60	
			3	green	18.60	6.63	4.15	8.02	0.52
CS-38	14.66	2-4(?)	04	yellow	1.21	0.40		24.52	
			3	green	10.13	3.47	13.05	17.44	0.75
CS-14-A	16.82	?	04	yellow	(disintegrated in water—no data)				
CS-14-B	22.61	2-4	04	cream	0.64	0.20		28.92	
			7	green	37.11	14.32	2.49	4.14	0.60

* Sample locations are given in Table 5 and shown on Plate 2.

lent but cracks formed in the bricks in drying. The clay was then mixed with 15 percent river sand for one test (CS-15-5) and was preheated to 600°F. before forming into bricks for another test (CS-15-C). In both cases the working characteristics were good and no cracking occurred in drying. Results of the tests are given in Table 4. The color after firing ranged from orange red to brick red and the clay proved satisfactory for use in any type of structural clay product. The firing range of about 120°F. is sufficiently long. At the maximum temperature attained in the test (2030°F.) there were no symptoms of overfiring. The low saturation coefficient of the fired sample indicates that the brick or tile made from the clay will withstand severe weathering (Table 4).

SHALES FOR CERAMIC CONCRETE AGGREGATE AND RAILROAD BALLAST

Several tests have been made on Permian shale samples to determine their suitability for use in the production of a sintered railroad ballast (ceramic slag) by means of heating to a high tempera-

TABLE 4.—*Ceramic data on three methods of using an alluvial clay from Chase County*

Sample No.	Thickness sampled, feet	Water of plasticity, percent	Linear shrinkage, percent	Drying behavior
		PLASTIC AND DRY PROPERTIES		
CS-15	18	23.67	6.97	cracked
CS-15-S	18	25.83	9.40	slight warping
CS-15-C	18	26.15	6.04	satisfactory

FIRED PROPERTIES

Sample No.	Ignition loss, percent	Firing range, cones	Fired to cone	Color	Linear shrinkage, percent	Percent absorption 24 hours, cold water	Percent absorption 5 hours, boiling water	Saturation coefficient
CS-15	3.81	04-01	05	red-orange	0.67	11.26	13.68	0.82
CS-15-S	3.72	05-01	05	red-orange	0.04-	10.17	13.58	0.75
			01	red	4.24	3.16	6.18	0.46
CS-15-C	3.31	04-01	05	red-orange	0.71	13.79	16.46	0.84
			01	red	6.86	3.07	5.40	0.57

TABLE 5.—*Data on firing and physical properties of "ceramic slag" produced from Chase County shales*

Sample No.	Stratigraphic position	Thickness, feet	Location	Temp., degrees F.	Absorption* 5 hours boiling			Sat. coefficient	Bulk spec. gravity	Form of testing	Remarks
					Max.	Min.	Avg.				
CS-5	Florena sh.	4	26-19-7E	2100	4.82	3.31	4.33	0.84	2.22	Bars	Good material
CS-6	Eskridge sh.	4	18-19-8E	2210	8.00	7.40	7.76	0.77	2.00	Bars	Too calcareous
CS-6	do	4	18-19-8E	2220	9.91	2.82	6.05	....	2.07	Lumps	Calcareous, not uniform
CS-10	Roca sh.	5	SW 23-19-9E	2110	18.13	16.51	17.19	0.68	1.79	Pressed	Fairly good material
CS-10	do	5	SW 23-19-9E	2150	....	....	....	....	....	Lumps	Highly calcareous, not uniform
CS-13	Blue Springs sh.	7	SE 2-21-6E	2120	1.38	0.34	0.86	....	2.14	Pressed	Not uniformly fired in lump form
CS-13	do	7	SE 2-21-6E	2100	8.76	7.27	8.02	0.52	2.04	Bars	Fairly good material
CS-14-A	Gage sh. (upper)	6	SW 8-21-6E	2280	....	....	....	....	....	Lumps	Calcareous, not uniform
CS-14-B	Gage sh. (lower)	6	SW 8-21-6E	2210	5.67	3.36	4.14	0.60	2.10	Bars	Some limestone pocks
CS-38	Blue Springs sh.	5	SE 28-19-6E	2165	....	....	....	....	....	Lumps	Not fired uniformly
CS-38	do	5	SE 28-19-6E	2100	18.51	16.24	17.44	0.75	1.83	Bars	Too calcareous
CS-38	do	5	SE 28-19-6E	2120	....	....	3.02	....	2.19	Pressed	Fairly good material

* Absorption after 24 hours submersion in cold water equals average absorption after 5 hours submersion in boiling water multiplied by the saturation coefficient.

ture in a rotary kiln (Plummer and Hladik, 1948). The same shales were used in these tests as for the regular ceramic tests reported in Table 4. Sample CS-5 which proved to be best for brick and tile was also best for railroad ballast or heavy concrete aggregate manufacture. Samples CS-10, CS-13, and CS-38 are also satisfactory raw materials for the manufacture of these products, but should be ground, mixed, and pelleted before firing in order to eliminate slaking of calcareous portions (Table 5).

Subsequent tests on the same materials in an attempt to produce a lightweight concrete aggregate similar to Haydite indicate that a bloated shale product cannot be manufactured from these Permian shales by the rotary kiln method, but that any one of the various sintering or moving hearth methods is well adapted to materials like the Florena and the Roca shales (Plummer and Hladik, 1951).

MATERIAL FOR ROCK WOOL

Although no specific tests have been run with Chase County samples, a number of Permian shales proved satisfactory for the production of rock wool in a series of tests run several years ago (Plummer, 1937). Sample CS-14-B, from the Gage shale included in this report, is sufficiently calcareous to produce a rock wool without additions. The Grant shale as sampled in Cowley County and also in Riley County is a natural wool rock.* Rock wool produced from the Cowley County sample was excellent in quality. Parts of the Eskridge and Holmesville shales are sufficiently calcareous to be classed as wool rocks, but in general small additions of limestone would be necessary in order to increase the fusibility. A material suitable for the production of rock wool should have a calcium carbonate plus magnesium carbonate content of 50 to 65 percent. The balance should consist largely of silica, with some alumina and other oxides. Usually a shale having an ignition loss ranging from 22 to 30 percent can be used for the production of rock wool.

GRAVEL AND SAND

Extensive accumulations of chert gravel together with chert and quartz sand occur in the terrace deposits and alluvium in the stream valleys. One washing and screening plant which utilizes terrace deposits of sand and gravel is located north of Bazaar along the Atchison, Topeka, and Santa Fe Railway.

The locations of the Bazaar and other pits most of which are operated intermittently and the disposition of gravel deposits of commercial importance are shown on Plate 2; the materials are described in Part 1 of this report. The reserves of gravel and sand in Chase County are large.

* A wool rock is defined as a rock having a composition such that no additional material need be added to prepare it for processing into rock wool.

SUBSURFACE ROCKS

STRATIGRAPHY AND STRUCTURE

Conditions along an east-west line through the northern part of Chase County are shown in Figure 2. Major rock units are differentiated.

The Nemaha anticline, the buried crystalline core of which sometimes is called the granite ridge, is the dominant structural element in Chase County. Its axis extends in a north-northeast south-southwest direction through a point near Elmdale. Movement that formed this anticline, which extends entirely across Kansas and well into Nebraska and Oklahoma, occurred chiefly in early Pennsylvanian time. Erosion removed great thicknesses of rock from the anticline, and in Chase County as elsewhere along the fold, Pennsylvanian sediments overlap and overstep rocks ranging in age from Pre-Cambrian to Mississippian. Pre-Cambrian crystalline rocks lie next below middle Pennsylvanian rocks in the northern and southwestern parts of Chase County in higher parts of the anticline.

As indicated in Figure 2, rocks generally dip less steeply westward from the Nemaha anticline than eastward from the uplift, although locally the condition may be reversed. The part of Chase County east of the Nemaha anticline is regarded as being in the Forest City basin, and the western part of the county is on the west flank of the anticline or on the east flank of the Salina basin.

The stratigraphy of the major rock divisions encountered in the subsurface in Chase County is discussed in the following paragraphs.

PENNSYLVANIAN ROCKS

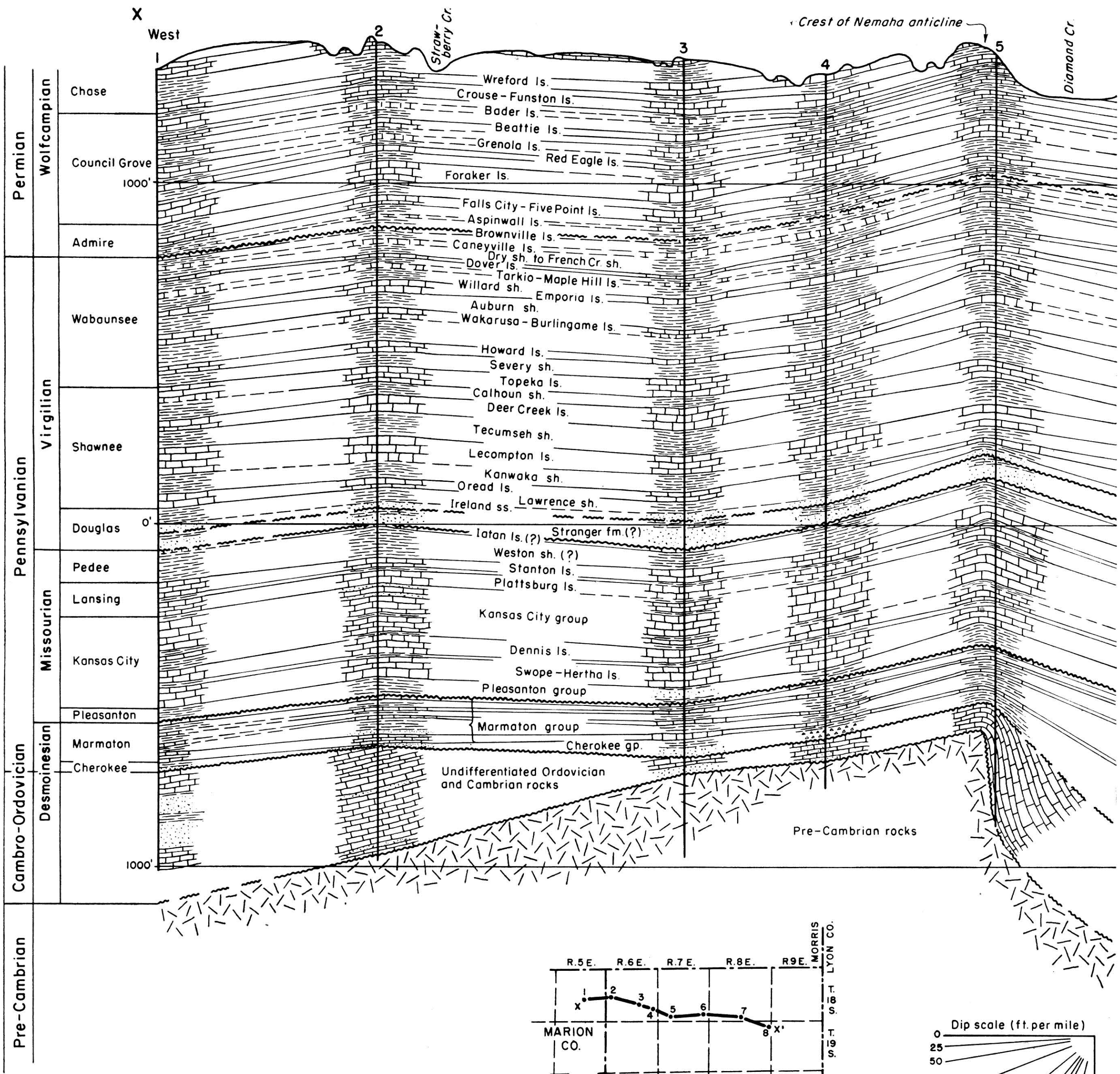
Pennsylvanian rocks in Chase County have an average thickness of about 2,000 feet. The Wabaunsee and Shawnee groups are characterized by shale and relatively thin limestone beds. The thickness of the Wabaunsee section is about 475 feet and of the Shawnee about 500 feet. The Oread limestone, the basal formation of the Shawnee group, is about 75 feet thick. The Douglas group consists almost entirely of clastic materials, but a persistent limestone occurs approximately 100 feet below the top. This is probably the Haskell limestone. The thicknesses of Douglas rocks differ from place to place, which indicates that 50 or more feet of Missourian rocks was eroded locally before deposition of Douglas sediments. Sandstone, ranging from about 200 to 250 feet in thickness, commonly occurs in the basal part of the Douglas section. In places where the Douglas rocks are relatively thin, 30 feet or more of rocks identified as belonging to the Pedee group is present. The combined Lansing and Kansas City groups comprise approximately 400 feet of nearly solid limestone. The Pleasanton shale is approximately 100 feet thick. Slightly more shale than limestone is present in the Marmaton section. About 350 feet of Cherokee shale is present in most of Chase County. The Cherokee is thin or absent in the Nemaha anticline area. Pennsylvanian beds lie upon Pre-Cambrian rocks in the vicinity of Elmdale.

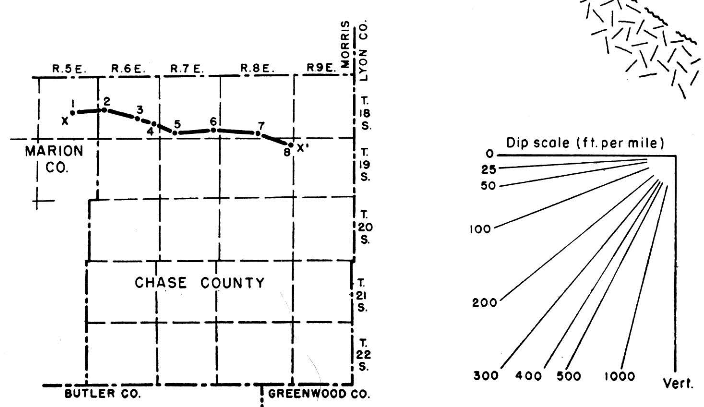
MISSISSIPPIAN ROCKS

Mississippian limestone formations and the Chattanooga shale have been removed by post-Mississippian erosion from the Nemaha anticline area in the northwestern part of Chase County (Lee, 1939, pl. 1; 1940; Jewett and Abernathy, 1945, pl. 3; Lee, Leatherock, and Botinelly, 1948, pl. 13; and Jewett, 1949, p. 115). The total thickness of Mississippian limestones in the county ranges from a featheredge to slightly more than 400 feet. The maximum thickness of the Chattanooga shale is about 150 feet.

PRE-CHATTANOOGA ROCKS

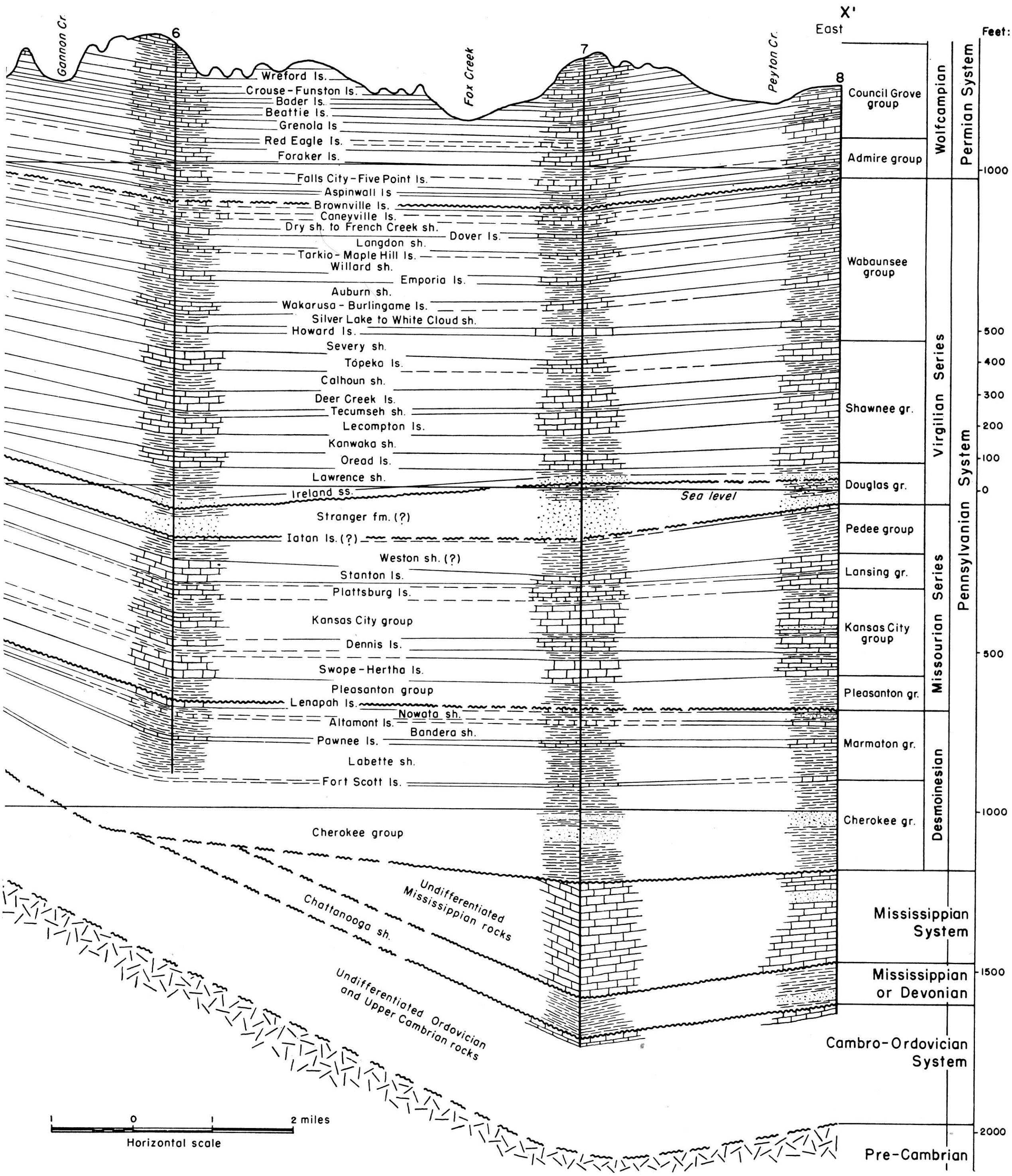
The "Hunton" limestone and the Maquoketa shale seemingly are absent from most of Chase County. The Viola limestone and other rocks as old as some part of the Arbuckle limestone have been eroded from most of the Nemaha anticline in the county (McClellan, 1930; Ockerman, 1935, fig. 2). Lee, Leatherock, and Botinelly (1948, pl. 13) show the pre-Chattanooga section in Chase County east of the Nemaha anticline as comprising (1) Kimmswick limestone, (2) Simpson formation, (3) Arbuckle dolomite, and (4) Lamotte sandstone. Bonneterre dolomite and Lamotte sandstone were found high on the upthrown side of the Nemaha fold in the Drummond well, sec. 15, T. 20 S., R. 7 E. Keroher and Kirby (1948, fig. 3) did not recognize Lamotte sandstone in Chase County but show Roubidoux dolomite occurring





NO.	LOCATION	FARM	COMPANY
1	Sec. 22, T. 18 S., R. 5 E.	Svoboda	Empire Gas and Fuel Co.
2	Sec. 19, T. 18 S., R. 6 E.	J. B. Chase	National Refining Co.
3	Sec. 27, T. 18 S., R. 6 E.	L. J. Lipps	Urschel et al
4	Sec. 25, T. 18 S., R. 6 E.	L. J. Lipps	Preston and Pasewalk
5	Sec. 32, T. 18 S., R. 7 E.	L. J. Lipps	Preston and Pasewalk
6	Sec. 36, T. 18 S., R. 7 E.	Mulvane	Mississippi Valley Oil Co.
7	Sec. 33, T. 18 S., R. 8 E.	Altemus	E. W. Marland, Inc.
8	Sec. 1, T. 19 S., R. 8 E.	J. H. Quinn	Munsey Oil Co.

FIG. 2.—Geologic cross section showing conditions along an east-west line



through the northern part of Chase County, differentiating major rock units.

next above the Pre-Cambrian surface except in the northeast part of the county where Bonneterre dolomite is shown as being in contact with the basement rocks. According to Keroher and Kirby (1948, figs. 4, 8, and 9) the Jefferson City-Cotter section ranges from about 125 to 400 feet in thickness in the county, the Roubidoux dolomite ranges from slightly less than 100 to more than 150 feet in thickness, and the Bonneterre dolomite is present only in the northeastern part of the county where its maximum thickness is less than 50 feet.

OIL AND GAS

EXPLORATION AND PRODUCTION

Oil and gas have been found sparsely distributed over Chase County. The county as a whole has been inadequately explored. Oil has been found only in the southeastern corner in extensions of pools from Greenwood and Lyon Counties. Gas has been discovered at several places within the county, but mostly on the Nemaha anticline. Previously, more gas was produced than was used within the county and it was piped to towns in Morris and Lyon Counties. Now, however, it is used only locally. According to available records, 356 holes have been drilled in Chase County for oil and gas. Of this total, 37 have produced oil and 142 have produced gas in the past, or are producing at present.

Producing formations.—The rocks in which gas has been found include the Ireland sandstone in the Lawrence shale and the Langdon shale, both of Late Pennsylvanian age. Gas is also produced from the Indian Cave sandstone member of the Towle shale, the West Branch shale, and the Hamlin shale, all of Early Permian age. Oil is produced from the "Bartlesville sand" in the Cherokee shale of Middle Pennsylvanian age.

Although 117 holes have been drilled into rocks of Mississippian age and older, no oil or gas has yet been found in rocks older than Pennsylvanian in age. Survey files contain records of 24 holes drilled into the Pre-Cambrian granite. Locations of oil and gas wells and dry holes and their stratigraphic depths are shown on Plate 2.

Drilling activity in recent years.—In 1948 four wells were reported drilled in the county. One dry wildcat, the K. T. Anderson et al. No. 1 Diggs well in the SE¼ SE¼ NE¼ sec. 13, T. 18 S., R. 9 E. was completed in June 1948 and abandoned in the Arbuckle dolomite at 3,340 feet. Two dry wells were drilled in sec. 13, T. 18 S., R. 9 E. near the Pixlee field in Greenwood County. One dry hole was drilled in the Chase County part of the Atyeo field.

In 1949 ten wells were reported for oil and gas. Six of these holes were stratigraphic test holes drilled by the Amerada Petroleum Corporation. All six were reported as dry and abandoned. A dry wildcat, the Aladdin Petroleum Company No. 1 Altemus in the SE¼ SE¼ NE¼ sec. 26, T. 18 S., R. 8 E., was completed in July 1949 and abandoned in the Arbuckle at 3,252 feet. Another dry wildcat was the Alyward and Seibel No. 1 Hindren well in the S½ SW¼ SW¼ sec. 15, T. 21 S., R. 6 E. completed in November 1949 and abandoned in Ordovician rocks at 3,497 feet. One dry well was drilled in Mississippian rocks in the Atyeo field. One dry shallow well was drilled in the Davis gas field in 1949.

Six dry holes were drilled in Chase County in 1950. One of these wells was drilled into Mississippian rocks to a depth of 2,570 feet in the Atyeo field. Mississippian rocks were also reached in a well in sec. 14, T. 20 S., R. 9 E. The four remaining wells drilled in 1950 were drilled to the Arbuckle dolomite. Two of these wells are in the northwestern part of the county in sec. 29, T. 18 S., R. 6 E., and in sec. 7, T. 19 S., R. 6 E. The remaining Arbuckle wells were drilled in the eastern part of the county in sec. 21, T. 21 S., R. 8 E., and in sec. 22, T. 18 S., R. 9 E.

GAS FIELDS

Altemus field.—The Altemus gas field, sec. 26, T. 18 S., R. 8 E., has one producing well, but no log is available. The well is located through oral communication with the inhabitants of the farm on which it is situated. The gas produced is for local farm use only.

Davis field.—The Davis gas field, in secs. 19, 29, and 30, T. 18 S., R. 8 E., is by far the largest gas-producing area in the county today. The first producing gas well was drilled in 1929 with an initial production of 681,000 cubic feet. Most of the wells were drilled from 1940 to 1944, however. The field was discovered by the drilling of a well in sec. 19, T. 18 S., R. 8 E. which had an initial production of a few barrels of oil a day. This well was abandoned shortly after it was drilled but upon further extensive drilling for the same oil zone abundant quantities of gas were found in the Indian Cave sandstone and a sand in the Hamlin shale, both of Early Permian age, at depths that ranged from 260 to 439 feet. The initial volume of gas in each well ranged from 50 to 1,000 thousand cubic feet per day. Three of the 36 drilled in this field have been dry. Three wells are abandoned gas wells, one is an abandoned oil well, and the remaining 29 wells are still producing gas today. The gas from this field is piped approximately 5 miles south into Strong City for use in that town. Part of the gas is piped a mile farther south into Cottonwood Falls for local use in that town. During the winter months the production is not high enough to supply the total needs of the two towns and as a result the supply must be supplemented by gas from the Cities Service pipe lines.

The Davis gas field is the only field in the county on which open flow figures are recorded. In 1948 a total of 42,845,000 cubic feet of gas was produced and in 1949, 49,276,000 cubic feet was produced.

Elk field.—The Elk gas field is in secs. 15, 20, 21, 22, 27, and 28, T. 19 S., R. 6 E. The earliest producing well of which the Survey has a record was drilled in January 1930 with an initial production of 786,000 cubic feet of gas per day. Two more wells were drilled in June of the following year and the other producing wells were drilled in a period extending from 1933 to 1939. The producing formation in this field is a sandy zone in the Hamlin shale (Admire group) of Early Permian age at an average depth of 500 feet. The only dry hole of 18 holes drilled in this field extended to Pre-Cambrian granite. Nine wells have produced gas in the past but are now abandoned. Eight of the wells have gas in them today but are capped and not in production. As a result there is no production at the present time from the Elk field. Gas from this field was formerly piped to Florence, approximately 15 miles to the southwest in Marion County. This was abandoned in 1945, however.

Elmdale field.—The Elmdale gas field, in secs. 20, 26, 27, 28, 33, 34, 35, and 36, T. 19 S., R. 7 E. and in secs. 1, 2, and 3, T. 20 S., R. 7 E., has only five producing wells today. The field is said to have been discovered in the early 1920's but the year is uncertain. Forty-one wells produced gas in the past but are now abandoned. Six wells drilled in the field have been dry. None of these dry holes was drilled to the Pre-Cambrian granite at depths ranging from 1,805 to 2,810 feet. The Survey has no record of any of the producing or abandoned gas wells. They were located through the aid of Mr. W. F. Kline of Elmdale, and according to him two of the producing wells are approximately 500 feet deep and two are approximately 800 feet deep. The producing formations in this case would probably lie within the Wabaunsee group of Late Pennsylvanian age. No open flow measurement is kept on these wells but the gas is piped into Elmdale for use within that town. Their supply is supplemented by three producing wells in the Lipps field to the north. These three wells together with the five wells in the Elmdale field produced an estimated total of 10,500,000 cubic feet of gas in 1949.

Hymer field.—The Hymer gas field, secs. 17 and 18, T. 18 S., R. 7 E., has only two producing wells, neither of which the Survey has any record, but which were located through oral communication with the inhabitants of Hymer. Both wells are used for local farm use only.

Lipps field.—The Lipps gas field is located in secs. 25 and 36, T. 18 S., R. 6 E. and in secs. 29, 30, 31, and 32, T. 18 S., R. 7 E. The discovery well was drilled in September 1925 in sec. 32, T. 18 S., R. 7 E. The other wells were drilled in 1926 and 1927. The initial daily production ranged from 2,000 to 4,261,840 cubic feet of gas. The producing formation is the Ireland sandstone member of the Lawrence shale of Pennsylvanian age at an average depth of 1,200 feet. Two of the 37 holes drilled in the field penetrated the Pre-Cambrian granite. Of the 37 holes drilled, 11 were dry, 19 have produced gas in the past but are now abandoned, and 6 wells are producing gas today. The Cities Service Gas Company formerly piped the gas produced from this field to Emporia for use in that city. Now, however, gas from three of the producing wells is piped into Elmdale and the gas from the three remaining producing wells is for local farm use.

Neva field.—The Neva gas field, secs. 14 and 15, T. 19 S., R. 7 E., has only one producing well today. There are three other wells which formerly produced gas but are now abandoned. The Survey has no record of any of these wells and they were located through the courtesy of Mr. W. F. Kline of Elmdale. The gas from the producing well is piped into Elmdale via the pipe line that connects the Lipps field with Elmdale.

Strong City field.—The Strong City gas field, in secs. 13 and 24, T. 19 S., R. 7 E. and sec. 19, T. 19 S., R. 8 E., formerly produced gas from the Langdon shale of Pennsylvanian age as well as the West Branch shale and the Hamlin shale of Early Permian age. The largest producer was the Langdon shale at an average depth of 450 feet. The first well was drilled in 1925 but no initial production figures are available. The other wells were drilled in a period extending from 1937 to 1940. Of the 19 wells drilled in this field, 7 were dry and 12 have produced gas in the past but are now abandoned. Two of the dry holes are stratigraphic test holes drilled in 1949 by the Amerada Petroleum Corporation.

OIL FIELDS

Atyeo field.—The Atyeo field, mainly in Lyon and Greenwood Counties, has a westward extension into Chase County in secs. 24, 25, and 36, T. 21 S., R. 9 E., and in sec. 1, T. 22 S., R. 9 E. The producing formation is the "Bartlesville shoestring sand" at an average depth of 2,250 feet. The daily initial production was from 15 to 60 barrels per well. Discovery was made in 1926. Of 13 holes drilled in the field 8 were dry and 5 produced oil; only 2 wells now produce in the Chase County portion of the Atyeo field. In 1948 these two wells produced a total of 1,666 barrels of oil. In 1949 their total production was 5,780 barrels of oil. The production in 1950 was 9,283 barrels of oil.

Teeter field.—The Teeter oil field, in the southeastern corner of Chase County in secs. 25, 35, and 36, T. 22 S., R. 9 E., is the most important oil-producing area of the county. It is a northward extension of the major part of the field in Greenwood County. Discovery was made in 1925. The producing formation is the "Bartlesville shoestring sand" at an average depth of 2,500 feet. Initial daily production ranged from 6 to 515 barrels per well, the average being about 100 barrels. Of 48 holes drilled in the pool, 17 were dry and 31 have produced oil, 21 of which are still producing oil. In 1948 the total production of the Chase County part of the Teeter field was 18,551 barrels, in 1949 it was 31,138 barrels, and in 1950 it was 28,311 barrels.

PART 3
GROUND-WATER RESOURCES OF CHASE COUNTY

By

HOWARD G. O'CONNOR

GROUND-WATER RESOURCES*

SOURCE

Ground water is the water below the surface of the land that supplies water to wells and springs. In Chase County, ground water is derived largely from precipitation falling as rain or snow. Part of the water falling as rain or snow finds its way into the soil zone and percolates downward to the zone of saturation, part of the water enters the soil but is returned to the atmosphere by evaporation or transpiration without becoming a part of the ground-water body, and part of the water is carried away as surface runoff by streams.

The ground water percolates slowly through the rocks in a direction determined by the topography and geologic structure until it is discharged through wells or springs, through seeps directly into streams, or by evaporation and transpiration in the valley areas.

PRINCIPLES OF OCCURRENCE

The rocks and surficial deposits that form the outer crust of the earth are not solid throughout, but contain numerous voids or interstitial openings which may contain air or water. The number, size, shape, and arrangement of these openings in

* Although the ground-water section of this report is a cooperative product of the State Geological Survey of Kansas and the United States Geological Survey the stratigraphic nomenclature used is that of the State Geological Survey of Kansas.

the different kinds of rocks vary greatly, and the water-bearing characteristics of rocks vary accordingly. The mode of occurrence of ground water in any area, then, is primarily dependent upon the geology of the region.

According to their origin, the interstices of a rock may be classified as primary or secondary. Primary interstices are those which came into existence at the time the rocks were being formed. Secondary interstices are those developed by processes that affected the rocks after they were formed.

Secondary interstices, comprising joints, other fracture openings, and solution openings, are of primary importance in the consolidated rocks, whereas the primary or original interstices are of greater importance in the unconsolidated rocks with respect to water supplies, in Chase County as generally elsewhere.

The amount of water that can be stored in a rock is determined by the porosity of the rock. Porosity is the percentage of the total volume of a rock that is occupied by interstices. A rock is said to be saturated when all its interstices are filled with water or other liquids. The amount of water that a saturated rock formation will yield is known as the specific yield and may be defined as the ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume. Because some water is left behind, held by capillarity, the specific yield is always less than the porosity.

The amount of water a rock formation may hold is determined by its porosity, but the rate at which it will yield water is determined by its permeability. The permeability of a rock formation is defined as its capacity for transmitting water under a hydraulic head and is measured by the rate at which the formation will transmit water through a given cross section under a given difference in head per unit of distance. A stratum of clay may have a porosity equal to that of a strata of sand, but, because of the small size of the interstices of the clay and the force of molecular attraction in fine-grained rocks, the clay may be almost impermeable under ordinary hydraulic gradients; however, a stratum of sand having an identical porosity may have a high permeability because of the relatively large interconnecting interstices which permit water to move through easily under the same hydraulic gradient.

Below a certain level in the earth's crust the permeable rocks generally are saturated with water under hydrostatic pressure and are said to be in the zone of saturation. The upper surface of the zone of saturation is called 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.

UNCONFINED WATER

Unconfined or free ground water is ground water in the zone of saturation that does not have an impermeable or confining body restricting its upper surface and the upper surface of which is the water table. This surface is not a static level but is a sloping surface that shows irregularities on a subdued scale similar to those of a land surface. Changes in permeability and unequal amounts of recharge to and discharge from the ground-water reservoir also cause irregularities in the water table. In fine-grained granular materials the small openings above the water table are generally filled by capillary water for a distance of several inches to several feet above the water table, but the position of the water table is shown by the level at which water will stand in a well. In rock formations containing unconfined ground water in fissures, fractures, or solution channels the zone of capillary water above the water table is generally thin.

CONFINED WATER

Ground water is said to be confined if it occurs in permeable zones between relatively impermeable confining beds. Slightly permeable confining beds are probably much more abundant than impermeable confining beds and considered over a wide area it is probable that no bed is strictly impermeable.

In areas where water is confined by alternating permeable and impermeable beds, a well may pass through several zones of saturation, each of which has sufficient permeability to supply water to a well. Confined water in permeable formations tends to move in the direction of dip of the formation. The quality and the quantity of water obtainable from these confined beds varies considerably, even in short distances, because of changes

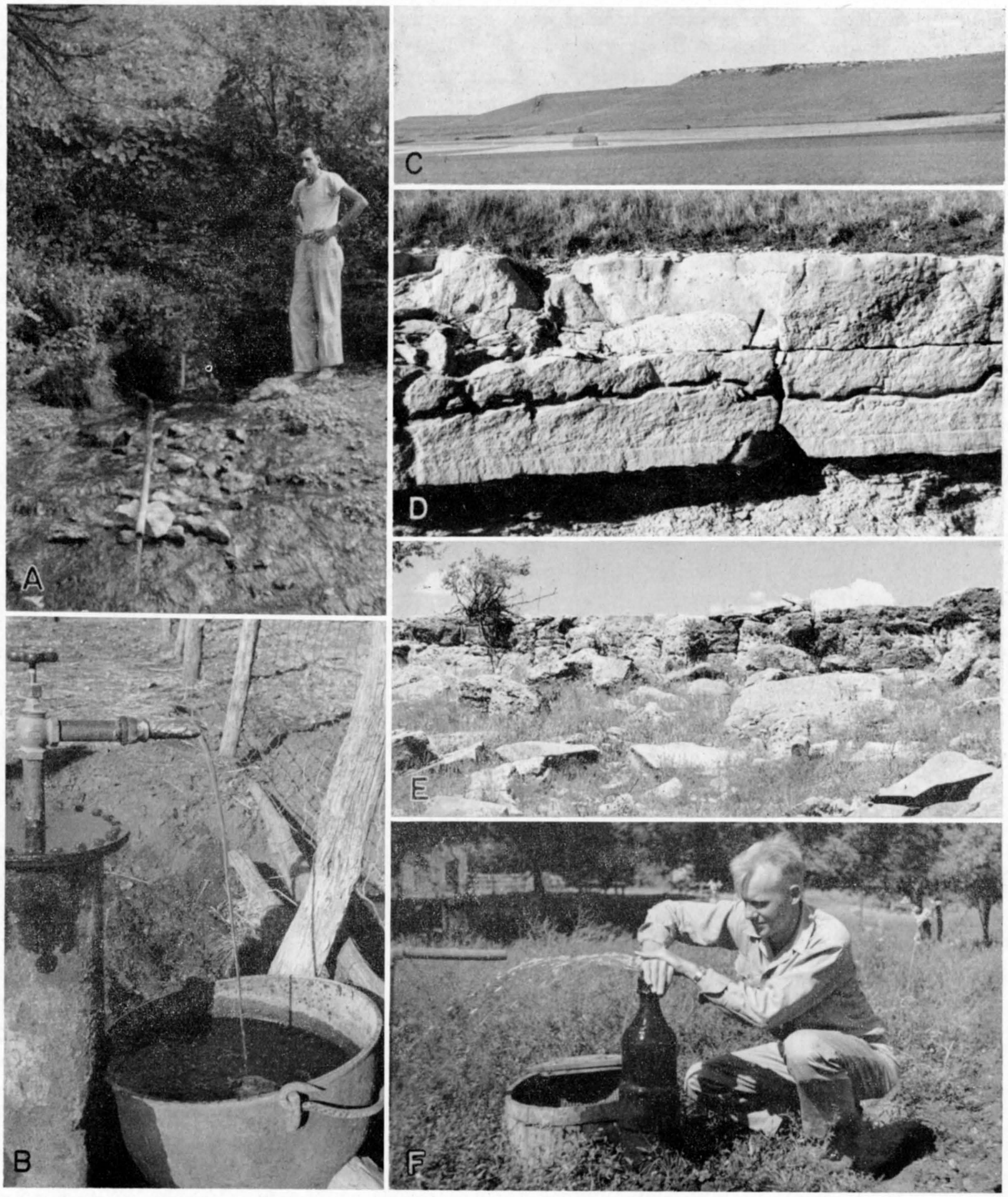


PLATE 6. **A,** Jack Spring, a "large" spring in the Florence limestone. **B,** Morse flowing artesian well, SE¼ SE¼ sec. 27, T. 22 S., R. 6 E. **C,** Escarpment of the Threemile limestone, south side of Cottonwood River near Clements, Kansas. **D,** Cottonwood limestone along highway K-150 showing solution channel developed along a joint. Few or no fusulines below parting. Sec. 30, T. 19 S., R. 7 E. **E,** "Main bed" of Neva limestone at type locality showing wall-like outcrop, sec. 13, T. 19 S., R. 7 E. **F,** Flowing artesian well (no. 20-7-27-da3) on William Selves ranch. (Photos: A, B, and D, by H. G. O'Connor; C and E, by R. I. Jindra; F, by A. R. Leonard.)

in lithology and degree of weathering, and in the amount of fracturing and solution that have occurred.

Artesian conditions.—The level at which water stands in wells may be called the piezometric or pressure-indicating surface. Where the top of the zone of saturation occurs in a permeable formation the piezometric surface coincides with the water table, and the water is said to be under normal pressure. If water is confined between relatively impermeable beds and the level at which water will stand in a well is below the top of the zone of saturation, the water is said to be under subnormal pressure; but if the level at which water will stand in a well is above the zone of saturation, the water is said to be under artesian pressure. An artesian well that flows at the land surface is a flowing artesian well.

Areas of artesian flow.—In Chase County there are two known areas where flowing artesian wells occur.

In one area three flowing wells were drilled in 1922, to a depth of somewhat more than 100 feet, on the William Selves ranch in the NE¼ SE¼ sec. 27, T. 20 S., R. 7 E. The northeasternmost, No. 20-7-27da3 (Pl. 6F), of the three wells had sufficient head to flow water to the second story of a farmhouse adjacent to the well. Wells 20-7-27da3 and 20-7-27da2 each flow less than 1 gallon a minute and are not used. Well 20-7-27da1, the southeasternmost of the three flowing wells, is used to supply water for all domestic purposes at the Selves ranch. Table 6 includes a chemical analysis of the water from this well. The artesian flow from the well through a one-half inch pipe was measured as slightly more than 3 gallons per minute by A. R. Leonard and H. G. O'Connor. The total discharge from the three flowing wells in 1947 was approximately 500,000 gallons.

There are two flowing wells about 1¼ miles south of the Selves ranch on the James C. McNee ranch in the SW¼ SE¼ sec. 34, T. 20 S., R. 7 E., and NE¼ NE¼ sec. 3, T. 21 S., R. 7 E. These wells are reported by their owner to be approximately 100 feet deep.

There is one flowing well on the Mildred Morse farm in the SE¼ SE¼ sec. 27, T. 22 S., R. 6 E. This well is reported to be 20 to 30 feet in depth and to have been drilled about 1937. The initial hydrostatic head was reported sufficient to force water approximately 13 feet above the land surface. In the fall of 1947 this well was flowing an estimated 5 gallons a minute through the well casing and was leaking around the outside of the casing, the discharge by leakage accounting for most of the flow (Pl. 6B).

Prior to the drilling of the Morse well, a well owned by School District No. 45 of Burns, Kansas, in the SW¼ SW¼ sec. 26, T. 22 S., R. 6 E., had flowed, but it ceased to flow when the Morse well was drilled. A chemical analysis of the water from the school well (22-6-26cc) is given in Table 7.

GROUND-WATER RECHARGE

Recharge is the addition of water to the underground reservoir and may be accomplished in several ways. In Chase County local precipitation is the principal source of recharge, and lesser amounts are contributed by influent seepage from streams and ponds and by subsurface inflow from adjacent areas.

RECHARGE FROM PRECIPITATION

In Chase County the normal annual precipitation is about 32 inches. The greatest amount occurs in the months of April to September, inclusive, during the growing season. The normal annual precipitation amounts to more than 500,000,000 gallons of water per square mile, but only a small part of this quantity reaches the zone of saturation. Of the precipitation, a part runs off directly, a part is discharged by evaporation and transpiration, and a part is added to (recharges) the ground-water reservoir, later being discharged into streams or by evaporation and transpiration.

Runoff, including both direct runoff and ground-water discharge into streams, accounts for only a small part of the precipitation except after prolonged or very heavy rains. According to records of the Division of Water Resources of the Kansas State Board of Agriculture, the annual net runoff in the drainage area of the Cottonwood River above Cottonwood Falls, Kansas, during the 5 years 1939 to 1943, inclusive, ranged from 0.96 inch in 1940 to 11.59 inches in 1941, and the average for the 5-year period was 3.47 inches. If related to the precipitation records at Cottonwood Falls for the same period of time, a runoff of approximately

11 percent of the precipitation is indicated; this figure is probably somewhat higher than the average for a longer period of time because of the exceptionally high precipitation and runoff in 1941.

The amount of water lost by transpiration and evaporation depends upon the temperature, humidity, vegetative covering, wind velocity, depth to the water table below land surface, and the length of time the processes of evaporation have access to moisture. In Chase County the bulk of the water that does not run off into the streams, averaging probably a little less than 29 inches, is lost by transpiration and evaporation.

Seepage from Streams and Ponds

Streams contribute recharge to the unconsolidated alluvial material during times when stream level is above the level of the adjacent water table. After periods of flood, the water table in the alluvium of Cottonwood River Valley and its major tributaries is frequently several inches to several feet higher than before the flood. The water, however, discharges rather quickly back into the streams after their levels decline.

Intermittent tributary streams, where they cross exposed permeable strata in the upland areas, contribute to the recharge of the stratified Permian rocks where structural conditions are suitable—that is, where the permeable strata dip away from, rather than toward, the contributing stream.

Ponds and lakes in the upland areas contribute small amounts of recharge, mostly to the surficial permeable rocks below the pond or lake but to some extent to permeable stratified rocks. The amounts contributed to the stratified rocks, however, are small.

Percolation from Outside the Area

Ground-water recharge by subsurface percolation in either the consolidated stratified rocks or unconsolidated rocks, or both, enters Chase County from adjacent areas. The amount of ground water added to the subsurface reservoirs by this means, however, is small. Also, it probably is balanced by water leaving the county in the same way.

DISCHARGE OF SUBSURFACE WATER

Discharge of subsurface water has been divided by Meinzer (1923, pp. 48-56) into ground-water discharge (discharge of water from the zone of saturation) and vadose-water discharge (discharge of soil water not derived from the zone of saturation. Ground water also moves out of Chase County by subsurface percolation in both the consolidated and unconsolidated rocks, eventually to be discharged by evaporation or transpiration or through springs and seeps or wells.

Evaporation and Transpiration

Water is lost to the atmosphere directly from the soil zone and zone of vadose water by evaporation. Also through the process of transpiration, plants discharge large quantities of water to the atmosphere from the vadose zone. The use of soil water is of great importance to agriculture for crops in most areas of Chase County are dependent on this type of water for growth, but significant amounts of ground water from the capillary fringe and, to a lesser extent, from the zone of saturation, are discharged by transpiration in all the valley areas by trees, alfalfa, and other plants.

In the upland areas considerable amounts of water from water-bearing limestone beds are transmitted into surficial slope deposits where the water is removed by evaporation and transpiration. Little or no ground water is lost to plants in the upland areas except by seepage along the outcrop of water-bearing limestones, as the uplands are almost entirely devoid of trees or other deep-rooted plants, the vegetative cover consisting almost entirely of native grasses.

Springs and Seeps

The flow of Jack Spring in sec. 25, T. 22 S., R. 7 E. (Table 6, Pl. 6A) was measured on October 29, 1947, during a low flow stage by W. W. Wilson and determined to be discharging ground water at the rate of 95 gallons per minute, or about 50 million gallons per year. During much of the year the rate of discharge is considerably more than 95 gallons per minute. This was the largest spring measured in Chase County, but numerous other springs, mostly of smaller size, were noted. The rocks included within the Chase group, especially in the southwest quarter of the county, supply

TABLE 6.—*Yields of four of the largest springs in Chase County*

Name	Location	Flow, gallons per minute	Aquifer
Palmer Spring	SW¼ NE¼ sec. 7 T. 18 S., R. 8 E.	75*	Wreford limestone
Rock Spring	SE¼ NE¼ sec. 9, T. 21 S., R. 7 E.	34**	Barneston limestone
Jack Spring†	SW¼ NW¼ sec. 25, T. 22 S., R. 7 E.	95**	do
Perkins Spring†	Lot 6 sec. 19, T. 22 S., R. 8 E.	70**	Wreford limestone

* Estimated flow Sept. 20, 1947.
** Measured by W. W. Wilson, Oct. 29, 1947.
† Chemical analysis of water given in Table 7.

water to the largest, most dependable springs. Springs in other sections of the county emerging from rocks of the Admire and Council Grove groups, as a rule, are not as large or dependable. Throughout the county certain limestone formations are characterized by a line of shrubs and green vegetation along their line of outcrop. This growth is made possible by the seepage water that emerges along the line of outcrop, thus providing a steady, dependable water supply for the plants. A short distance above and below the limestone outcrop only native grasses are present.

DISCHARGE BY WELLS

A third means of discharge of water from the ground-water reservoir is that by pumping or artesian flow from wells, which disposes of water not accounted for by the methods of discharge discussed in the preceding pages.

PUBLIC WATER SUPPLIES

Cottonwood Falls and Strong City are the only cities in Chase County having public water supplies; they are supplied from wells penetrating the alluvium of the Cottonwood River Valley.

Cottonwood Falls.—The water supply of Cottonwood Falls is obtained from several wells tapping the alluvium of the Cottonwood River Valley northwest of the town (secs. 19 and 20, T. 19 S., R. 8 E.). The oldest wells, completed in 1923, known as Mercer Nos. 1, 2, 3, and 4, are combination dug and drilled wells about 30 feet deep and 30 feet apart. They are connected by laterals and pumped by one electrically powered pump. Three drilled wells 50 to 60 feet deep known as Rufner Nos. 1, 2, and 3 were added to the well field between 1925 and 1934 to augment the municipal water supply. In 1940 a 12-inch drilled well 47 feet deep, known as the Gates No. 1, was completed for use, and in 1948 a ninth well, Gates No. 2, was added to the well field (Pl. 3).

Water is pumped from the well field to an elevated steel standpipe in the south part of town. The standpipe is 15 feet in diameter and 65 feet in height and has a capacity of 85,000 gallons.

A chemical analysis of the water is given in Table 7. A cross section of the alluvium near this well field is shown in Figure 3.

Strong City.—Strong City derives its water supply from one dug well, No. 19-8-20aa, 15 feet in diameter and 54 feet deep, completed in 1914 (Pl. 3). The well penetrates 6 feet of coarse water-bearing sand and gravel in the lower part of the alluvium. Casing of brick and concrete rests on an iron shoe at the bottom, under and through which water enters the well.

Water is pumped from the well to the adjacent water plant by two 150-gallons-per-minute low-service turbine pumps. It is there treated for hardness. After treatment, the water is pumped by two 150-gallon-per-minute high-service pumps to an elevated 69,000-gallon covered concrete reservoir on a hilltop east of town.

A chemical analysis of the untreated water is given in Table 7.

INDUSTRIAL SUPPLIES

There are no industrial users of ground water in Chase County. The Atchison, Topeka, and Santa Fe Railway Company and the Matfield pumping station of the Cities Service Gas Company utilize surface water for their operations.

AVAILABILITY OF LARGE GROUND WATER-SUPPLIES

In no part of the county can large supplies of ground water be developed, but moderate supplies such as are used by the cities of Cottonwood Falls and Strong City can be developed in the alluvium of Cottonwood River, the lower portion of Diamond Creek, and the South Fork of the Cottonwood River.

Twenty-five test holes were drilled on five lines across the three principal stream valleys in the county in June 1948 with the hydraulic-rotary drilling machine owned by the State Geological Survey of Kansas. The location of the test holes is

Table 7.—*Analyses of water from typical wells and springs in Chase County*
Analyzed by H. A. Stoltenberg.—Dissolved constituents given in parts per million[a]

Well No.	Location	Depth feet	Geologic source	Date of collection	Temperature °F	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium & potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$ Total	Carbonate	Non carbonate
	T. 18 S., R. 6 E.																		
18-6-12 da	NE¼ SE¼ sec. 12	32.6	Easly Creek shale and Bader limestone	4-16-48	....	414	9.2	1.8	112	19	9.4	333	32	27	0.3	41	358	273	85
	T. 18 S., R. 7 E.																		
18-7-33 aa	NE¼ NE¼ sec. 33	35	Cottonwood limestone	6-24-48	....	501	8.6	0.05	130	24	19	438	61	11	0.1	31	423	359	64
	T. 18 S., R. 8 E.																		
18-8-1 ca	NE¼ SW¼ sec. 1	42.9	Speiser shale Funston limestone	4-17-48	58	1,147	12.0	0.38	254	58	17	403	102	108	0.1	398	872	330	542
	T. 18 S., R. 9 E.																		
18-9-25 cc	SW¼ SW¼ sec. 25	17.4	Burr limestone and Sallyards limestone	4-17-48	....	1,306	7.2	0.33	288	41	37	267	190	94	0.3	518	887	219	668
18-9-32 da	NE¼ SE¼ sec. 32	45.6	Bader limestone	6-25-48	....	610	7.0	1.9	110	52	28	411	95	32	0.4	84	488	337	151
	T. 19 S., R. 6 E.																		
19-6-29 cc	SW¼ SW¼ sec. 29	99.1	Florence limestone	6-24-48	58	948	8.8	3.8	95	70	143	522	93	139	0.3	142	524	428	96
	T. 19 S., R. 7 E.																		
19-7-22 ac	SW¼ NE¼ sec. 22	50.3	Foraker limestone	4-16-48	....	1,220	13.0	1.4	68	51	324	371	64	490	0.7	26	379	304	75
	T. 19 S., R. 8 E.																		
19-8-5 ba	NE¼ NW¼ sec. 5	37.9	Alluvium	6-24-48	....	310	7.6	0.44	98	9.4	7.4	331	15	5.5	0.2	4.4	283	272	11
19-8-13 cb	NW¼ SW¼ sec. 13	91.4	Grenola limestone	4-17-48	....	522	10.0	0.16	130	32	8.7	388	136	5.5	0.3	8	456	318	138
19-8-18 (1)	Lot *10* of sec. 18	43	Cottonwood limestone	6-24-48	59	470	7.2	0.08	113	33	16	454	41	12	0.1	24	418	372	46
	City of Cottonwood Falls, Kans.[b]		Alluvium	7-25-47	....	539	12.0	0.33	122	32	29	482	70	17	0.1	7.1	436	395	41
19-8-29 aa	City of Strong, Kas.		Alluvium	6-15-48	....	484	7.0	0.03	44	28	59	52	130	105	0.2	4.9	225	67	158
19-8-29 bc 2	SW¼ NW¼ sec. 29	80	Eskridge Shale and Grenola limestone	4-14-48	....	1,869	14.0	1.9	217	108	220	315	1,121	17	1.1	16	986	258	728
	T. 19 S., R. 9 E.																		
19-9-3 cc	SW¼ SW¼ sec. 3	37	Long Creek limestone	4-17-48	....	521	11.0	1.4	99	27	49	349	22	70	0.3	71	358	286	72
19-9-6 ad	SE¼ NE¼ sec. 6	65.0	Beattie limestone	4-17-48	....	913	13.0	1.6	126	77	73	432	369	28	0.3	14	631	354	277
19-9-15 bb	NW¼ NW¼ sec. 15	17.2	Terrace alluvium	6-25-48	58	520	10.0	0.60	94	22	70	383	61	67	0.2	7.1	325	314	11
	T. 20 S., R. 7 E.																		
20-7-27 da	NE¼ SE¼ sec. 27	112	Wreford limestone	4-14-48	58	357	9.8	0.02	74	36	13	405	14	8.5	0.1	26	332	332	0
	T. 20 S., R. 8 E.																		
20-8-2 bd	SE¼ NW¼ sec. 2	21.1	Alluvium	4-16-48	....	631	9.0	1.3	122	26	64	409	147	20	0.2	42	412	336	76
20-8-16 aa 2	NE¼ NE¼ sec. 16	32.4	Beattie limestone	4-16-48	....	618	9.2	0.56	118	45	24	349	115	28	0.4	106	480	286	194
20-8-26 da	NE¼ SE¼ sec. 26	27.9	Grenola limestone	6-25-48	56	603	7.8	0.30	107	39	48	368	82	54	0.4	84	428	302	126
20-8-31 (1)	Lot *17* of sec. 31	49.6	Bader limestone	4-14-48	....	576	11.0	0.16	129	31	29	405	29	51	0.1	97	450	332	118
	T. 21 S., R. 5 E.																		
21-5-12 ca	NE¼ SW¼ sec. 12	51.9	Florence limestone	4-14-48	59	818	10.0	3.1	168	13	72	329	56	49	0.4	288	472	270	202

	T. 21 S., R. 7 E.																		
21-7-21 bb	NW¼ NW¼ sec. 21	101.7	Towanda and Fort Riley limestones	4-16-48	57	395	12.0	1.8	85	31	19	390	24	14	0.4	18	340	320	20
	T. 21 S., R. 8 E.																		
21-8-15 ba	NE¼ NW¼ sec. 15	64	Cottonwood limestone	6-24-48	....	435	8.2	0.30	70	47	21	346	99	16	0.4	3	368	284	84
	T. 22 S., R. 6 E.																		
22-6-18 dc	SW¼ SE¼ sec. 18	56.6	Winfield limestone	4-14-48	57	375	13.0	0.18	64	33	28	332	47	18	0.5	8.8	295	272	23
22-6-26 cc	SW¼ SW¼ sec. 26	29. (?)	Towanda and Fort Riley limestones	4-16-48	....	577	15.0	2	82	44	59	336	165	44	2	0.88	386	276	110
	T. 22 S., R. 7 E.																		
22-7-8 cb	NW¼ SW¼ sec. 8	41.8	Fort Riley limestone	4-16-48	....	412	10.0	0.88	107	21	15	384	35	10	0.2	25	354	315	39
22-7-25 bc	SW¼ NW¼ sec. 25	spring	Florence limestone	4-16-48	55	327	9.6	0.03	91	16	11	346	13	10	0.2	6.2	293	284	9
22-7-35 cb	NW¼ SW¼ sec. 35	94.1	Barnestone limestone	4-16-48	56	339	10.0	0.80	71	28	21	376	8.2	13	0.5	2	292	292	0
	T. 22 S., R. 8 E.																		
22-8-7 aa	NE¼ NE¼ of sec. 7	58.9	Bader limestone	6-24-48	....	2,116	14.0	0.30	210	118	345	184	748	585	0.8	4.1	1,009	151	858
22-8-9 cd	SE¼ SW¼ sec. 9	61.0	Cottonwood limestone	4-16-48	55	4,157	15.0	0.66	348	198	778	128	1,650	1,090	1.3	14	1,682	105	1,577
22-8-18 (1)	Lot 10 of sec. 18	spring	Wreford limestone	4-16-48	54	262	6.4	0.13	72	13	9.4	268	18	9	0.2	2.2	233	220	13
22-8-20 ca	NE¼ SW¼ sec. 20	25.3	Crouse limestone	4-16-48	....	1,075	14.0	0.47	178	37	113	355	152	109	0.1	297	596	291	305
22-8-22 dc	SW¼ SE¼ sec. 22	44.6	Crouse and Middle-burg limestones	6-24-48	58	413	4.8	0.83	87	19	31	304	26	15	0.2	80	295	250	45

a. One part per million is equivalent to one pound of substance per million pounds of water or 8.33 pounds per million gallons of water.
b. Water sample from municipal distribution system. Wells in secs. 19 and 20, T. 19 S., R. 8 E.

shown on Plate 3 and graphic cross sections along the five lines are shown in Figure 3.

Individual wells properly located so as to penetrate the maximum thickness of saturated alluvial material in the Cottonwood River Valley should be capable of supplying 75 to 200 gallons a minute. The area of alluvium above the dam on Cottonwood River at Cottonwood Falls is probably the best area for wells of maximum yield. The dam creates a considerable body of water extending 2 to 3 miles upstream, thus maintaining a high water table and contributing effectively to the recharge of the ground-water reservoir in the area. Smaller quantities of water can be obtained from the other stream valleys in which the alluvium is not as extensive or thick.

The southwest part of the county is the only area in which wells penetrating stratified Permian rocks are capable of supplying moderately large quantities of water. Wells near the western edge of the county below the long dip slopes of the Barneston and Wreford limestones generally yield 5 to 10 gallons a minute and in some places yield 50 to 100 gallons a minute. Much ground water, which now is allowed to discharge through springs and seeps along the low areas where the formations crop out, could be utilized in this area.

CHEMICAL CHARACTER OF WATER

The chemical character of the ground waters in Chase County is shown by the 34 analyses of water given in parts per million in Table 7. Factors for converting parts per million of mineral constituents to equivalents per million are given in Table 8. These water samples were collected from wells distributed as evenly as practicable within the county and among the principal water-bearing formations. Table 7 includes analyses of the two public water supplies. The samples of water were analyzed by Howard A. Stoltenberg, Chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health.

Total Dissolved Solids

When water is evaporated, the residue consists mainly of the dissolved mineral constituents and usually a little water of crystallization. Waters containing less than 500 parts per million of dissolved solids generally are satisfactory for domes-

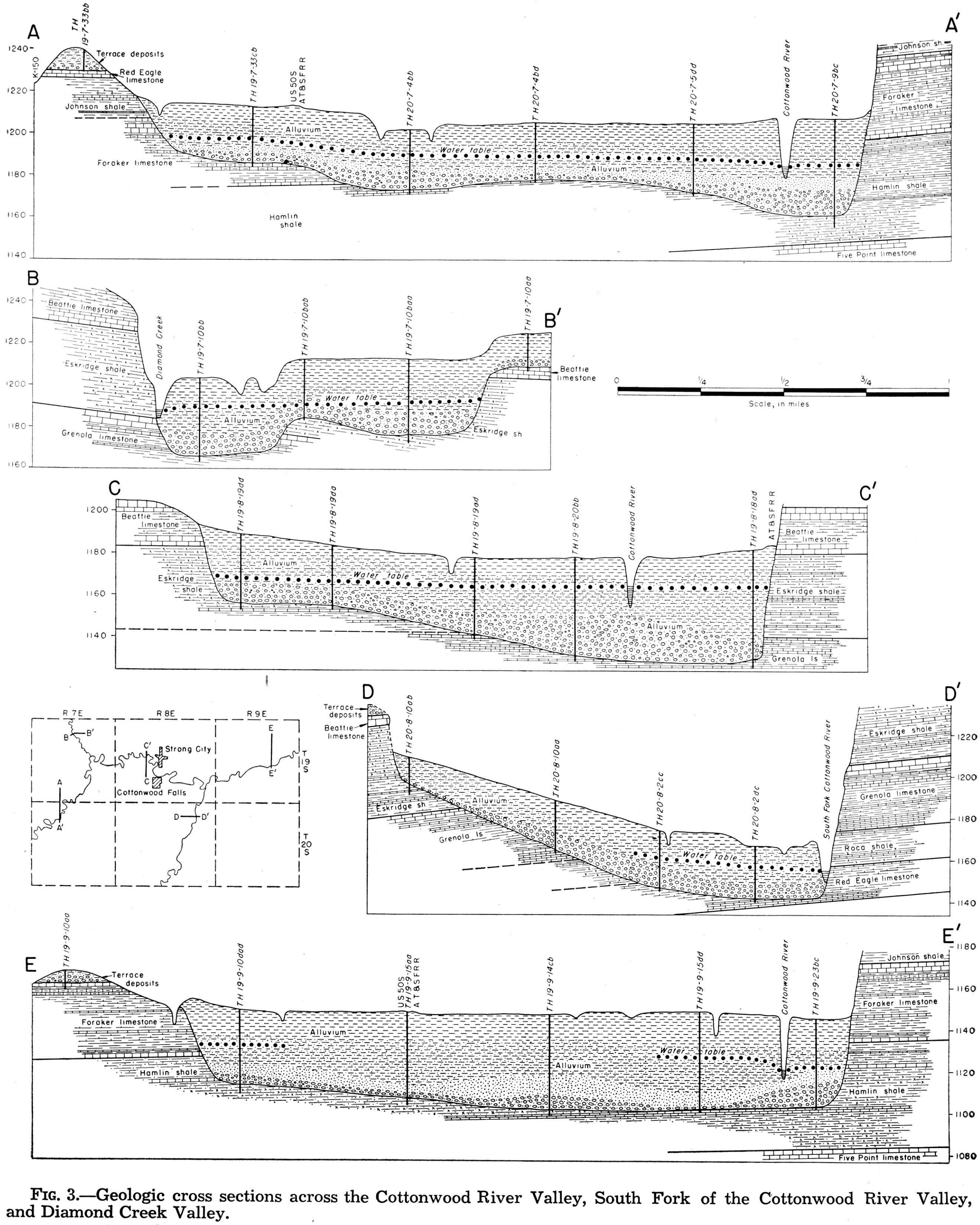


FIG. 3.—Geologic cross sections across the Cottonwood River Valley, South Fork of the Cottonwood River Valley, and Diamond Creek Valley.

TABLE 8.—*Factors for converting parts per million of mineral constituents to equivalents per million*

Cation	Conversion factor	Anion	Conversion factor
Ca^{++}	0.0499	HCO_3^-	0.0164
Mg^{++}	0.0822	SO_4^{--}	0.0208
Na^+	0.0435	Cl^-	0.0282
		NO_3^-	0.0161
		F^-	0.0526

tic use, except for difficulties resulting from their hardness or occasional excessive content of iron. Waters containing more than 1,000 parts per million may include enough of certain constituents to produce a noticeable taste or to make the water unsuitable in some other respect. The amount of dissolved solids in the 34 samples of ground water collected in Chase County is indicated in Table 9.

HARDNESS

Hardness of water is the property that generally receives the most attention and in washing is recognized by the increased quantity of soap required to produce lather. Calcium and magnesium are the constituents that cause practically all the hardness of water and are the active agents in the formation of the greater part of the scale formed in steam boilers and in other vessels in which water is heated or evaporated.

In addition to the total hardness, the table of analyses shows the carbonate hardness and the noncarbonate hardness. The carbonate hardness is due to the presence of calcium and magnesium bicarbonate and can be removed almost entirely by boiling. This type of hardness is sometimes 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 is sometimes called permanent hardness. So far as use with soaps is concerned, there is no difference between the carbonate and noncarbonate hardness. Noncarbonate hardness generally forms harder scale in steam boilers.

TABLE 9.—*Dissolved solids in water samples from wells and springs in Chase County*

Dissolved solids, parts per million	Number of samples
300 or less	1
301- 400	6
401- 500	6
501- 600	7
601- 700	4
701- 800	0
801- 900	1
901-1,000	2
1,001-2,500	6
2,501-5,000	1

TABLE 10.—*Hardness of water samples from wells and springs in Chase County*

Hardness, parts per million	Number of samples
200 or less	0
201- 250	2
251- 300	5
301- 400	9
401- 500	10
501- 600	2
601- 700	1
701-1,000	3
More than 1,000	2

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 appreciably increase the consumption of soap. The use of water in the upper part of this range of hardness will result in the formation of a considerable amount of scale in steam boilers. Hardness above 150 parts per million can be noticed by anyone, and if the hardness is 200 or 300 parts per million or more it is common practice to soften the water for household use or to install cisterns to collect soft rain water. Where municipal water supplies are softened, the hardness generally is reduced to 60 or 80 parts per million. The additional improvement from further softening of a whole public supply generally is not deemed worth the increase in cost.

The hardness of 34 water samples of ground water collected in Chase County is indicated in Table 10.

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 in waters from the same formation. If a water contains much more than 0.1 part per million of iron, the excess may precipitate as a reddish sediment. Iron, where present in sufficient quantity to give a disagreeable taste and to stain cooking utensils, may be removed from most waters by simple aera-

TABLE 11.—*Iron content of water samples from wells and springs in Chase County*

Iron, parts per million	Number of samples
Less than 0.1	5
0.1-1.0	18
1.1-2.0	9
2.1-3.0	0
3.1-4.0	2

tion and filtration, but a few waters must be treated by the addition of lime or by passing the water through resinous substances having a high affinity for iron.

Table 11 shows the iron content of the water samples analyzed.

FLUORIDE

Although the quantities of fluoride are generally much less than the quantities of 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 1.5 parts per million or more of fluoride are likely to produce mottled enamel (Dean, 1936). If water contains as much as 4 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.

Recent investigations indicate that small quantities of fluoride in water are beneficial for the development of teeth, and that the incidence of tooth decay is less when such quantities of fluoride are present in the water used for drinking than when there is none. All but three of the 34 samples analyzed contained from 0.1 to 1.0 part per million fluoride. Three samples contained 1.1 to 2.0 parts per million.

NITRATE

The significance of nitrate in drinking water has received considerable attention in recent years since the discovery that high concentrations of nitrate in water used in preparing baby formulas may cause cyanosis of infants ("blue babies").

A concentration of 90 parts per million of nitrate as NO_3 in drinking water is considered by the Kansas State Board of Health as being dangerous to infants, and some authorities recommend that water containing more than 45 parts per million should not be used for preparation of formulas. Cyanosis is not produced in adults or older children by these concentrations of nitrate.

Nitrate found in well waters in Chase County may be derived from two sources: (1) nitrate minerals naturally occurring in the rocks from which a well derives water or (2) organic action. The second of these two possibilities is the more probable, inasmuch as no nitrate minerals are known in any of the rocks at or near the surface in Chase County. Bacterial decomposition of organic material, either plant or animal, in the topsoil produces nitrate. Especially during the early spring and late summer, when plants are relatively dormant, large concentrations of nitrate can be built up in the soil. Barnyards are also sources of organic material high in nitrate. Of the 32 water samples (excluding municipal supplies) from wells in Chase County that were analyzed, 19 percent of the drilled wells and 33 percent of the dug wells contained more than 90 parts per million of nitrate. The maximum amount determined was 518 parts per million, from a dug well (18-9-25cc), and the minimum determined was 0.88 part per million from a drilled well (22-6-26cc).

SANITARY CONSIDERATIONS

The analyses of water shown in Table 7 show only the amounts of dissolved mineral matter and do not indicate the sanitary quality of the water. However, an abnormal amount of certain mineral matter, such as nitrate, may indicate pollution of the water.

Dug wells and shallow springs are more likely to become contaminated than properly constructed drilled wells, generally because they are not effectively protected from surface waters at the well or spring opening. Drilled wells are generally protected by the casing, although many are not properly sealed at the top. A well should not be located near possible sources of pollution such as barnyards, privies, and cesspools.

GROUND-WATER REGIONS IN CHASE COUNTY

Ground-water resources in various parts of Chase County may best be discussed by dividing the county into several ground-water regions and areas in which ground water occurs under similar conditions. These are discussed below. The symbol used for each on Plate 3 is given in parentheses after the name.

BLUESTEM UPLAND REGION (B)

The Bluestem Upland region is characterized by undulating to gently rolling topography with a few rounded to flat-topped buttes. This region is developed on rocks of the Chase group, principally those above the escarpment-making Florence limestone, but it includes some land developed on adjacent uplands formed by the Wreford limestone and Matfield shale. Much of this region is bluestem grassland. Most of the wells in the region are drilled wells 40 to 150 feet deep, except for a few shallow dug wells along stream valleys.

The chief aquifers in the region, the Barneston and Wreford limestones, yield fresh water except where deeply buried. The Towanda and Cresswell limestones are good aquifers locally. Occasionally a well will derive water from the Kinney limestone or a permeable zone in one of the shales.

CEDAR CREEK AREA (Bc)

This area, drained principally by Cedar Creek and its tributaries, comprises the largest division of the Bluestem Upland region in Chase County. The area is structurally a large basin, the center of which is near Wonsevu, in sec. 9, T. 22 S., R. 6 E. East of Wonsevu long dip slopes, 5 to 7 miles in width, are developed on the Doyle shale and Barneston limestone. North, south, and west of Wonsevu the dip slopes developed on the alternating limestone and shale formations have smaller areal extent.

Ground water is obtained by wells from the rocks of the Chase group at depths ranging from less than 5 feet to as much as 150 feet. Both confined and unconfined water are obtained. Springs are abundant, and small marsh spots occur in several places along streams where the water table intersects the land surface. The quality of the ground water is generally good (Table 7). Yields of 5 to 10 gallons per minute are common, but some wells yield 100 gallons or more per minute. Small supplies of water are obtained from thin alluvial deposits along the principal creeks.

SOUTH ELMDALE AREA (Bs)

The South Elmdale area is similar in many respects to the Cedar Creek area. Ground water is obtained from limestone aquifers of the Chase group, chiefly the Barneston and Wreford limestones. Ground water in the Barneston limestone occurs almost entirely as unconfined water in this area, but water in the Kinney and Wreford limestones occurs primarily as confined artesian water that has considerable head in parts of the area. There are several flowing artesian wells in the area.

The water is of good quality (Table 7). Yields of wells are small to moderate, ranging from less than 1 gallon per minute to as much as 75 gallons per minute. Wells obtain water at depths of a few feet to as much as 150 feet. Springs and seeps are common along the creeks in the eastern part of this area.

This area constitutes the southeast flank of the Elmdale anticline, a "high" area along the buried Nemaha anticline of the subsurface. The dip of the rock strata is to the south and east.

MIDDLE CREEK AREA (Bm)

An upland developed on rocks of the Chase group and drained in part by Middle Creek constitutes a third ground-water area of the Bluestem Upland region.

Well water is obtained from rocks of the Chase group at depths ranging from a few feet to approximately 150 feet. The water is of good quality for stock and domestic use. Springs and seeps are numerous where the creeks have cut through the water-bearing limestone beds. Success in obtaining a good well is dependent on finding local structural lows and permeable zones in the water-bearing beds, especially around the marginal areas adjacent to the Elmdale area.

Well yields range from less than 1 gallon per minute to as much as 50 gallons per minute. The quality of water is generally good (Table 7).

FOX CREEK AREA (Bf)

The Fox Creek area along the north boundary of the county, drained in part by Fox Creek, is the border of a large upland developed on rocks of the Chase group in Morris County. Most of this area in Chase County is fairly well dissected, only small tracts remaining where rocks of the Barneston limestone are present and undissected.

For the most part wells are rather sparse in this area. Springs, however, are abundant along the creeks and together with numerous ponds supply most of the stock water in the Fox Creek area. Nearly all the area is bluestem pasture land. The yields of wells and the character of the ground water are similar to those in the Middle Creek area (Bm).

THURMAN AREA (Bt)

The Thurman area, in the southeast corner of the county, is a small upland between tributaries of the Verdigris River and tributaries of the Cottonwood River. Drainage is dominantly westward to the South Fork of the Cottonwood River. The general dip of the rocks in the area is to the west also.

Wells obtain water from the Barneston, Kinney, and Wreford limestones and from thin patchy deposits of alluvium along some of the creeks. Most of the wells are 50 feet or less in depth and have only small yields. The quality of the water is similar to that in the other areas of the Bluestem Upland region.

DISSECTED BLUESTEM REGION (D)

The major part of Chase County is included in the ground-water region designated the Dissected Bluestem region. This region is developed almost entirely on rocks belonging to the Council Grove group, but it includes small hilly dissected areas developed on rocks included in the lower part of the Chase group. Rocks of the Admire group in Chase County and adjacent areas to the east are distinctly of lesser value as reservoirs of ground water, but inasmuch as these rocks occur at the surface in only three small areas in Chase County, they are included in this region for purposes of discussion in this report.

The chief aquifers are the Beattie, Grenola, Red Eagle, and Long Creek limestones. The Eiss limestone yields small supplies of water to wells locally. Other limestones of the Council Grove group are only occasionally the principal aquifer supplying a well.

A relatively minor part of the water obtained from the wells is derived from permeable zones in the shale beds separating the limestones.

The Admire group in Chase County consists chiefly of shale and sandy shale and minor amounts of sandstone and limestone. Good water supplies are not obtainable from these rocks in the county.

Many of the wells in this region are dug wells constructed in the surficial weathered limestones and shales. These wells are relatively shallow, generally ranging from 12 to 40 feet in depth. Many of them have been successful and adequate for the purpose they serve, mainly because of the large reservoir capacity of dug wells, although the water-bearing beds they tap are of low yield. However many of the shallow dug wells are inadequate in spite of their storage capacity. The static level in these wells fluctuates considerably.

Drilled wells in the region are generally deeper than the dug wells, commonly 30 to 60 feet deep and a few 100 feet or more. These wells frequently obtain confined water from joints, bedding planes, solution channels, or cavernous zones in the limestones; the productivity of the well is primarily dependent on the number and size of these openings penetrated in the zone of saturation. Periods of deficient rainfall affect the deeper wells and water-bearing zones less than they do the shallow wells.

The ground water is much more variable in chemical quality in this region than in the Bluestem Upland region (Table 7).

ROCK CREEK AREA (Dr)

Abundant springs characterize a narrow strip of land drained by Rock Creek and other eastward-flowing tributaries along the west side of South Fork Cottonwood River. The area is used principally for grazing, and normally, spring-fed creeks supply most of the necessary stock water. Stock and domestic wells are relatively few. The wells generally have small yields, and the water varies considerably in chemical character. Some wells as shallow as 30 feet yield water too highly mineralized for domestic or stock use, whereas some other wells as deep as 80 or 100 feet obtain water of good quality.

North of Rock Creek the strata have a considerable easterly dip in places and in the area west of Spring Creek some of the water-bearing beds contain water under considerable head. Strata ranging from the Neva limestone to the Wreford limestone are exposed in the area centered around sec. 36, T. 19 S., R. 7 E. and dip eastward 100 to 160 feet in a distance of 3 or 4 miles. No flowing wells were observed in this area, however.

Many ponds have been constructed to supplement springs and wells as sources of stock water supply.

ELMDALE AREA (De)

A considerable area south, west, north, and northeast of Elmdale is included in the Elmdale area. The area lies on or adjacent to the crest of the buried Nemaha ridge. Except along the valleys, the land is almost entirely devoted to native grassland and wells are not abundant. Stock-water supplies are obtained in large part from creeks and springs, supplemented by stock ponds. With few exceptions the best wells are adjacent to the main drainage lines in the lower parts of the valleys. Yields of wells range from less than 500 gallons a day to as much as 100 gallons per minute, for example well 18-7-33aa. Quality of water is variable. Wells range in depth from a few feet to more than 100 feet.

BUCKEYE-PEYTON CREEK AREA (Db)

The Buckeye-Peyton Creek area northeast of Strong City and north of Saffordville is essentially like the Elmdale section except for somewhat less relief and more areas of low cultivated slopes. In most of this area the best water-bearing beds of the Council Grove group, the Beattie, Grenola, Red Eagle, and Long Creek limestones, are near the surface and contain fresh water. Although a considerable number of shallow wells, for the most part less than 50 feet deep, are often inadequate as stock and domestic wells, there are many dependable wells of small to moderate yields in the area. Fresh water may be obtained at depths ranging from a few feet to approximately 150 feet. The quality of the water is variable but generally good (Table 7).

VERDIGRIS-BLOODY CREEK AREA (Dv)

A large area in the southeastern part of Chase County is drained in part by Verdigris River and in part by Bloody Creek. The dip of the rock strata is to the west and northwest; otherwise this area is essentially like the Elmdale area. Most wells are along the valleys of the tributary creeks and streams and are 30 to 50 feet deep, a few being as deep as 100 feet. Yields of wells are generally small and in many instances are inadequate for domestic or stock needs. This is especially true of the area southeast of Matfield Green where water-bearing rocks above the Cottonwood limestone furnish inadequate supplies of water to wells. In this area the Cottonwood limestone contains abundant water, but the water is too highly mineralized to be usable for stock or domestic supplies (Table 7, well 21-8-15ba).

Quality of water varies from good to poor in this area (Table 7).

ALLUVIAL FLOOD-PLAIN REGION (A)

The alluvial flood-plain deposits of Cottonwood River and its principal tributaries contain large quantities of hard but otherwise good water. The thickness of the alluvium ranges from a few feet to a maximum of 55 or 60 feet in the Cottonwood River Valley and is as much as 25 to 40 feet thick in the principal tributaries (Fig. 3).

Wells properly constructed in the areas of maximum thickness of alluvium are capable of yielding 75 to 200 gallons of water per minute without excessive drawdown. Correspondingly smaller supplies are available from the alluvial deposits of the smaller tributaries. The municipal supplies of Strong City and Cottonwood Falls are obtained from wells in alluvium of the Cottonwood River Valley (Pl. 3).

ALLUVIAL TERRACE REGION (T)

Alluvial terrace deposits occur along the valleys of the principal streams as deposits of unconsolidated sediments similar in character to but higher in altitude than the alluvial flood-plain deposits. Because they are above stream level, only a small part of the terrace deposits shown on Plate 3 are sufficiently thick and undissected to contain a permanent zone of saturation. The parts of the terraces that do contain a permanent zone of saturation yield small to moderate quantities of good water to wells (Table 7).

Because of the position of terraces above the flood plains of the principal streams, many of the wells penetrate unsaturated terrace material and are dug or drilled into the underlying Permian bedrock in order to obtain water from permeable saturated zones in the limestone or shale beds. Generally these wells are successful; possibly the terrace deposits, though not containing water themselves, aid in the recharge of the bedrock aquifers by absorbing water and feeding it into openings in the bedrock.

WELL-NUMBERING SYSTEM

The well and test-hole numbers used in this report give the location of wells and test holes according to the General Land Office Surveys and according to the following formula: township, range, section, 160-acre tract within that section, and the 40-acre tract within that quarter section. If two or more wells are located within a 40-acre tract, the wells are numbered according to the order in which they were inventoried. The 160-acre and 40-acre tracts are designated a, b, c, or d in a counterclockwise direction, beginning in the northeast quarter. For example, a well located in the NE¼ SE¼ sec. 10, T. 19 S., R. 7 E., would be numbered 19-7-10da. Wells in the strip of oversized sections in R. 8 E. are located in the same manner, except that the lot number is used where a well is in an area divided into lots.

RECORD OF WELLS

Information pertaining to water wells in Chase County is given in Table 12. The well numbers used in this report give the location of wells according to the General Land Office Surveys as described in the preceding paragraph. The measured depths of water levels are given to the nearest 0.01 foot, whereas reported depths are given only to the nearest foot and are subject to error. Similarly measured depths of wells are given to the nearest 0.1 foot, reported depths are given only to the nearest foot and are subject to error.

TABLE 12.—*Records of wells and springs in Chase County*

Well No. (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, in. (4)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Feet above land surface	Depth to water level, feet (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 18 S., R. 6 E.														
18-6-1 cd	SE SW sec. 1	C. C. Roniger	Du	56.3	48	R	Limestone and shale	Bader ls.	Cy, H	D, S	Top of concrete cover	1.0	52.13	9-13-47	Can be pumped dry in half an hour
18-6-12 da	NE SE sec. 12	D. L. Carpenter	Du	32.6	32	R	do	Easly Creek sh. and Bader ls.	Cy, H	D	do	1.0	28.97	9-13-47	
18-6-20 ba	NE NW sec. 20	William Amick	Dr	93.1	7½	I	Limestone	Wreford ls.	N	S	Top of casing	4.0	20.43	9-16-47	
18-6-20 bb	NW NW sec. 20	do	Du	14.9	42	R	Silt, sand and gravel	Alluvium	N	N	Top of wooden box cover	1.8	7.89	9-16-47	Abandoned, formerly a stock well
	T. 18 S., R. 7 E.														
18-7-17 bc	SW NW sec. 17	Atchison, Topeka & Santa Fe Ry	Dr	31	(?)	(?)	Gravel	Alluvium	(?)	S	Land surface	0	22	....	Reported yield 4
18-7-33 aa	NE NE sec. 33	Joe Crawford	Dr	35	6	GI	Limestone	Cottonwood ls.	T, E	D, S	Land surface	0	10	....	Reported to yield +100
	T. 18 S., R. 8 E.														
18-8-1 ab	NW NE sec. 1	A. M. Eldred	Dr	40.4	6	GI	Silt, sand and gravel	Alluvium	Cy, H	D	Top of casing	0.1	8.81	10- 2-47	
18-8-1 ca	NE SW sec. 1	G. A. Holm	Dr	42.9	6	GI	Shale and limestone	Speiser sh. & Funston ls.	Cy, H	D, S	do	0.5	11.95	10- 2-47	
18-8-7 ac	SW NE sec. 7	R. O. Palmer	Sp	....	....	....	Limestone	Wreford ls.	....	D, S	....	....	......	9-20-47	Palmer Spring, Estimated yield 75
18-8-18 da	NE SE sec. 18	Kerwin Parks	Dr	34.2	6½	I	Shale and limestone	Funston ls. (?) & Speiser sh (?)	Cy, H	D	do	0.8	24.10	9-20-47	Reported to yield less than 1

18-8-26 ad	SE NE sec. 26	Park Maderly	Dr	?	6½	I	Limestone	Crouse ls. (?)	Cy, N	N	do	0.7	18.50	10- 2-47	Formerly a stock well
18-8-32 ba	NE NW sec. 32	James Robertson	Du	30.7	35	R	Shale and limestone	Eskridge sh.	Cy, H	D	Top of wooden cover	3.0	22.54	9- 9-47	
18-8-36 cb	NW SW sec. 36	Robert Watchous	Dr	40.0	7	GI	Limestone and shale	Beattie ls.	Cy, W, H	D, S	Top of concrete cover	0.2	24.08	10- 2-47	
	T. 18 S., R. 9 E.														
18-9-1 db	NW SE sec. 1	G. R. Evans	Dr	60.7	7½	GI	Limestone	Grenola or Red Eagle ls.	Cy, W	S	Top of casing	3.5	17.21	10- 2-47	
18-9-14 aa	NE NE sec. 14	Frank and Hugo Haucke	Dr	33.5	6½	GI	Shale and limestone	Eskridge sh.	Cy, H	D	do	0	17.73	10- 2-47	
18-9-16 ab	NW NE sec. 16	Fred Umberger	Du	22.4	24	R	Limestone	Eiss ls.	Cy, H	D	Top of rock curbing	0.9	15.07	10- 3-47	
18-9-16 cd	SE SW sec. 16	William Brown	Du	25.0	36	R	Shale and limestone	Eskridge sh.	Cy, H	D	Top of 2- by 6-inch board cover	1.0	22.59	10- 3-47	
18-9-18 da	NE SE sec. 18	Mary Erickson	Du	23.6	30	R	Limestone and shale	Eiss ls.	Cy, H	D	Top of stone cover	0.4	13.02	10- 3-47	
18-9-23 dd	SE SE sec. 23	Bert Birkell	Du	20.6	30	R	Limestone	Burr and Sallyards ls.	Cy, W	D, S	Top of board cover	1.3	14.98	10- 2-47	
18-9-25 cc	SW SW sec. 25	B. E. Sayer	Du	17.4	30	R	Limestone	Burr and Sallyards ls.	Cy, H	D	Top of east 2- by 6-inch board	3.0	18.80	10- 3-47	
18-9-27 aa	NE NE sec. 27	P. A. Blender	Du	22.8	30	R	Limestone	Grenola ls.	Cy, W	S	Top of iron rim curbing	0.5	17.26	10- 3-47	Reported inadequate
18-9-27 db	NW SE sec. 27	L. L. Ramy	Dr	38.9	7	GI	Limestone	Red Eagle ls. (?)	Cy, W	D, S	Top of casing	0.3	24.24	10- 3 47	
18-9-29 cc	SW SW sec. 29	Peak and Hatcher Co.	Dr	33.3	8½	GI	Limestone and shale	Easily Creek sh or Bader ls.	Cy, H	D	do	0.3	24.93	10- 3-47	
18-9-32 cc	SW SW sec. 32	Asa Pendergraft	Du	14.2	36	R	Silt, sand and gravel	Alluvium	Cy, W	S	Top of board cover	3.0	8.73	9-27-47	
18-9-32 da	NE SE sec. 32	Wayne L. Roady	Dr	45.6	8	N	Limestone and shale	Easily Creek sh. and Bader ls.	Cy, W	D	do	0	22.38	10- 4-47	
18-9-33 ca	NE SW sec. 33	Fred Murdock	Dr	41.5	6(?)	I	Limestone and shale	Beattie ls.	Cy, W	S	Top of 3-way elbow pipe joint	2.0	21.34	10- 4-47	
18-9-35 dc	SW SE sec. 35	H. J. Petford	Dr	60.3	6	I	Limestone and shale	Foraker ls.	Cy, W	S	Top of 2- by 6-inch board under pump	1.0	39.72	10- 3-47	
	T. 19 S., R. 6 E.														
19-6-1 ac	SW NE sec. 1	Sophonia Stenzel	Du	27.3	47	R	Limestone	Beattie ls.	Cy, H	D, S	Bottom of concrete cover	0.1	20.74	9-15-47	
19-6-9 bd	SE NW sec. 9	May and Rolla Pracht	Dr	20.6	7½	I	Limestone and shale	Funston ls. or Blue Rapids sh.	Cy, H	D	Top of casing	1.4	dry	9-15-47	Not adequate Reported dry
19-6-18 da	NE SE sec. 18	C. R. Koegeboehn	Du	17.7	32(?)	R	Sand and gravel	Alluvium	Cy, E	D, S	Top of board top over well	0.3	10.60	9-16-47	Reported adequate, used as Community well in 1935, 1936
19-6-29 cc	SW SW sec. 29	H. E. Bowers	Dr	99.1	6	GI	Limestone	Florence ls.	Cy, H	N	Top of casing	0	43.50	6-24-48	Abandoned, formerly a school well
19-6-29 dd	SE SE sec. 29	Mamie J. Ward	Du	12.0	30	R	Limestone	Kinney ls.	Cy, W	S	Top of wooden frame over well	3.5	8.60	9-16-47	
19-6-36 bb	NW NW sec. 36	G. T. Dawson, Jr.	Dr	73.4	8½	N	Limestone and shale	Wreford ls. or Speiser sh.	N	S	Land surface	0	32.20	9-16-47	Abandoned well
	T. 20 S., R. 5 E.														
20-5-13 cb	NW SW sec. 13	Joseph Kroupa	Dr	69.5	7	I	Limestone	Barneston ls.	Cy, W	D, S	Top of casing	1.3	33.55	9-16-47	
	T. 20 S., R 6 E.														
20-6-5 bc	SW NW sec. 5	C. Lalowette	Dr	145.3	7½	I	Limestone	Wreford ls.	Cy, W	S	do	1.7	101.30	9-16-47	Not in use
20-6-14 bd	SE NW sec. 14	W. V. Haarshman	Dr	149.9	6½	I	Sand and gravel	Alluvium (?)	Cy, W	S	do	1.0	25.20	9-17-47	Reported adequate
20-6-23 dc	SW SE sec. 23	C. R. Park	Dr	67.2	8	I	Sand and gravel	Alluvium	Cy, W	D, S	do	1.3	26.13	9-17-47	Reported adequate
20-6-31 bd	SE NW sec. 31	B. S. Thompson	Dr	42.5	6½	I	Limestone	Wreford ls.	Cy, W	N	do	0.7	24.75	9-23-47	Not in use
	T. 20 S., R. 7 E.														
20-7-1 cb	NW SW sec. 1	C. D. Bower	Du	14.4	36	R	Limestone	Eiss ls.	Cy, W	N	Top of R.R. tie	1.1	9.98	9- 8-47	Abandoned, formerly a stock well

TABLE 12.—*Records of wells and springs in Chase County—Continued*

Well No. (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, in.	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Feet above land surface	Depth to water level, feet (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
20-7-7 bd	SE NW sec. 7	Geo. T. Dawson	Du	28.8	(?)	(?)	Limestone	Red Eagle ls.	Cy, H	D, S	Top of board cover	1.0	20.34	9-17-47	
20-7-12 bc	SW NW sec. 12	Pearl H. Stauffer	Dr	62.1	5½	GI	Limestone and shale	Beattie ls. and Eskridge sh.	N	N	Top of casing	0	37.09	9- 8-47	Abandoned, formerly a domestic well
20-7-13 cb	NW SW sec. 13	Geo. W. Starkey	Du	55.0	48	R	Limestone	Barneston ls.	N	N	Top of concrete cover under pump	0.6	15.54	9- 8-47	
20-7-22 dd	SE SE sec. 22	C. K. Jones	Dr	46.2	6	I	Limestone	Florence ls.	Cy, W	S	Top of casing	1.5	24.11	9-11-47	
20-7-23 ba	NE NW sec. 23	J. V. Schwilling	Dr	59.8	12	I	Limestone	Florence ls.	Cy, W	D, S	do	0.8	18.83	9-11-47	Reported adequate for domestic
20-7-27 ad	SE NE sec. 27	William Selves	Dr	44.4	6½	GI	Limestone	Florence ls.	N	N	do	1.0	34.51	9-11-47	
20-7-27 da1	NE SE sec. 27	do	Dr	112	6	OW	Limestone	Wreford ls.	F	D	....	....	....	....	Measured flow, +3
20-7-27 da2	NE SE sec. 27	do	Dr	130.0	6	OW	Limestone	Wreford ls.	F	S	....	....	....	....	Not in use
20-7-27 da3	NE SE sec. 27	do	Dr	108	6	OW	Limestone	Wreford ls.	F	D, S	....	....	....	....	Estimated flow, 1±. Not in use
20-7-28 cd	SE SW sec. 28	Frank Gaddie, Jr.	Dr	43.4	9	GI	Limestone	Wreford ls.	Cy, H	N	Top of casing	0.5	22.80	9-11-47	Abandoned, formerly a domestic well
20-7-32 ac	SW NE sec. 32	William Studer	DD	52.6	6(?)	GI	Limestone	Wreford ls.	Cy, H	N	Top of board on which pump sets	0.2	32.93	9-11-47	
20-7-34 dc	SW SE sec. 34	James C. McNee	Dr	51.2	6¼	I	Limestone	Wreford ls. (?)	F	S	Top of casing	3.8	....	9-10-47	Well reported originally ±100 ft. deep. Yield ±1
	T. 20 S., R. 8 E.														
20-8-2 bd	SE NW sec. 2	School District	Dr	21.1	5	GI	Sand and gravel	Alluvium	Cy, H	N	Top of board under pump	0.4	10.42	9-26-47	Reported adequate
20-8-3 dc	SW SE sec. 3	A. J. McCabe	Du	35.5	36-45	R	Limestone	Neva ls.	Cy, W	D	Top of pump base	0.2	25.93	9-26-47	
20-8-4 ad	SE NE sec. 4	Maxine Carrier	Du	7.8	3×2 ft.	R	Limestone and shale	Eiss ls.	Cy, H	S	Top of casing	3.0	3.52	9- 8-47	Similar to an enclosed, low yield spring
20-8-10 ba	NE NW sec. 10	W. R. Blackburn	Dr	99.5	7	GI	Limestone	Neva ls.	N	S	do	0.6	19.99	9-26-47	Reported yield, ½
20-8-16 aa1	NE NE sec. 16	Gerald Brough	Du	17.3	48	R	Limestone and shale	Eiss ls. and Stearns sh.	Cy, H	D	Top of concrete platform	1.0	13.02	9-26-47	
20-8-16 aa2	NE NE sec. 16	do	Dr	32.4	7	GI	Limestone and shale	Beattie ls.	Cy, W	D	Top of casing	0.8	11.37	9-26-47	Reported adequate
20-8-18 Lot 22	Lot 22 sec. 18	Howard Craney	Du	47.0	48-40	R	Limestone	Florence ls.	Cy, H	S	Top of wooden cover	1.5	33.57	9-10-47	
20-8-22 bb	NW NW sec. 22	W. G. and M. L. Patton	Dr	27.0	6½	(?)	Sand and gravel (?)	Alluvium	Cy, H	S	Top of casing	1.0	13.61	9-25-47	
20-8-26 bb	NW NW sec. 26	Miss S. Norton	Du	26.7	(?)	R	Limestone	Grenola ls.	Cy, G	S	Top of rock curbing	1.0	25.60	9-26-47	Reported adequate
20-8-26 da	NE SE sec. 26	W. F. and J. R. Norton	Du	27.9	48	R	Limestone	Grenola ls.	N, H	D	Top of stone cover	0.5	22.84	9-26-47	Reported adequate
20-8-30 db	NW SE sec. 30	F. & G. Roniger	DD	33.4	(?)	R	Limestone and shale	Bader ls.	Cy, H	S	Top of board cover	2.3	14.08	9- 9-47	
20-8-30 Lot 7	Lot 7 sec. 30	Arthur Wilson	Dr	134.6	8	I	Limestone	Wreford ls.	Cy, W	D, S	Top of concrete cover	0.4	33.08	9- 9-47	Reported adequate
20-8-31 Lot 17	Lot 17 sec. 31	A. J. Burton	Dr	49.6	7	GI	Limestone	Bader ls.	N	D	Top of casing	1.3	26.70	9-12-47	Reported yield ±1
20-8-32 ab	NW NE sec. 32	Wilber Stout	Du	6.7	54	R	Limestone	Bader ls.	Cy, W	S	Top of center wooden beam	0.6	3.29	9- 9-47	Reported adequate
20-8-33 dd	SE SE sec. 33	L. Barnesberger	Du	27.4	30-36	(?)	Sand and gravel	Alluvium	Cy	S	Top of board cover	1.2	23.44	9-25-47	Reported inadequate for stock
	T. 20 S., R. 9 E.														
20-9-1 cc	SW SW sec. 1	Art Thomason	Du	28.4	36	R	Shale.	Hamlin sh.	Cy, H	D	Top of wooden platform	0.6	16.99	9- 4-47	Reported inadequate
20-9-8 bb	NW NW sec. 8	E. T. Anderson	Du	20.2	48(?)	R	Sand and gravel	Alluvium	Cy, W	D, S	Top of concrete cover	1.0	17.92	9-26-47	Reported adequate

20-9-14 aa	NE NE sec. 14	Floyd Eidman	Du	±40	36	Br	Limestone	Long Creek ls.	Cy, H	D	Top of casing	0	20.40	9- 4-47	Not in use
20-9-26 ab	NW NE sec. 26	E. W. Bell	Dr	54.1	5½	I	Limestone and shale	Grenola ls.	Cy, W	S	Top of **wooden** cover	0.2	28.22	9- 4-47	
20-9-26 dd	SE SE sec. 26	do	Dr	28.6	7	GI	Limestone and shale	Crouse ls.	N	D	Top of **concrete** slab	0.2	15.89	9- 4-47	
20-9-30 cb	NW SW sec. 30	School District	Dr	50.6	6	GI	Limestone and shale	Beattie ls.	Cy, H	N	Top of casing	0.2	20.57	9-26-47	
	T. 21 S., R. 5 E.														
21-5-12 ca	NE SW sec. 12	Dave Wheeler	Du	51.9	30	R	Limestone	Florence ls.	Cy, H	D	do	0.9	46.50	9-23-47	Not adequate. Haul water in dry years.
	T. 21 S., R. 6 E.														
21-6-8 bc	SW NW sec. 8	John Crissup	DD	28.5	42 & 6	R	Limestone and shale	Matfield sh.	Cy, W	S	Top of concrete curbing around well	1.3	21.72	9-23-47	
21-6-21 ad	SE NE sec. 21	F. K. Harshman	Dr	84.3	7	GI	Limestone	Towanda ls.	Cy, W	D, S	Top of casing	1.0	50.73	9-23-47	
21-6-22 aa	NE NE sec. 22	M. S. Ludwig	Dr	100.0	7	I	Limestone	Towanda ls. and/ or Winfield ls.	Cy, W	S	do	1.1	66.40	9-23-47	
21-6-28 ab	NW NE sec. 28	H. E. Williams	Dr	97.2	7	GI	Limestone	Winfield ls.	Cy, W	S	do	1.5	77.28	9-23-47	
21-6-28 dd	SE SE sec. 28	Geo. Whitcomb	Dr	67.4	6½	I	Limestone	Winfield ls.	Cy, W	D, S	Top of concrete cover	0.7	58.54	9-19-47	
21-6-29 cb	NW SW sec. 29	Dave Little	Dr	49.3	8	GI	Limestone	Towanda ls. and Gage sh.	Cy, W	S	Top of casing	2.3	36.70	9-19-47	Reported adequate
21-6-30 bb	NW NW sec. 30	Cora F. Griffith	Dr	50.8	6½	I	Limestone	Barneston ls.	Cy, H	D, S	do	0.1	31.58	9.23-47	Reported adequate
21-6-35 bb	NW NW sec. 35	Lloyd Thompson	Dr	89.6	8	I	Limestone	Winfield ls. and/ or Towanda ls.	Cy, W	D, S	do	1.0	59.46	9-23-47	Reported adequate. Yield +5
21-6-36 cc	SW SW sec. 36	C. P. Thompson	Dr	68.3	10	GI	Limestone	Fort Riley ls.	Cy, W	D, S, I	do	1.0	44.88	9-19-47	Reported yield +5
	T. 21 S., R. 7 E.														
21-7-3 aa	NE NE sec. 3	James C. McNee	Dr	......	6½	I	Limestone	Wreford ls. (?)	F	S	do	2.7	....	10-29-47	Well reported originally ± 100 ft. deep. Yield ±1
21-7-8 dd	SE SE sec. 8	C. B. Cowley	Dr	108.4	6½	GI	Limestone	Barneston ls.	Cy, W	S	do	0	21.12	9-17-47	Reported adequate, yield +10
21-7-9 ad	SE NE sec. 9	L. C. Elder	Sp	......	....	....	Limestone	Florence ls.	....	S	....	....	....	10-29-47	Rock Spring. Measured yield, 34
21-7-11 cb	NW SW sec. 11	George Meiser	Dr	40.0	8	GI	Limestone and shale	Matfield sh.	Cy, H	D	Top of casing	0	17.04	9-12-47	Reported adequate. Yield +4
21-7-17 aa	NE NE sec. 17	George Pierce	Dr	59.7	7	GI	Limestone	Towanda ls. and Fort Riley ls.	Cy, W	N	do	1.0	34.06	9-17-47	Not in use
21-7-18 cc	SW SW sec. 18	Comm. of Ins. State of Kansas	Dr	97.2	7	I	Limestone	Barneston ls.	Cy, W	D, S	do	1.1	29.98	9-19-47	Reported adequate
21-7-19 ad	SE NE sec. 19	Orvis O'Dell	Dr	82.2	6	GI	Limestone	Barneston ls.	Cy, W	D, S	do	1.8	23.07	9-18-47	Estimated yield 10+
21-7-21 bb	NW NW sec. 21	Guy Rosebraugh	Dr	101.7	7½	I	Limestone	Towanda ls. and Fort Riley ls.	Cy, W	D, S	do	0.3	53.50	9-17-47	Pumped continuously 7 hrs. previous to W.L. measurement
21-7-21 cc	SW SW sec. 21	Stella Moore	Dr	98.3	7	I	Limestone	Towanda ls .	Cy, W	S	do	1.3	70.64	9-17-47	
21-7-32 bb	NW NW sec. 32	Doris Stevens	Dr	105.7	8½	I	Limestone	Towanda ls. and Fort Riley ls.	Cy, W	D, S	do	1.3	72.52	9-18-47	Estimated yield, 5+
21-7-33 da	NE SE sec. 33	Glen W. Baker	Dr	+100.	5-6	GI	Limestone	Towanda ls. and Fort Riley ls.	Cy, W	D, S	do	0.2	82.50	9-12-47	Not in use
	T. 21 S., R. 8 E.														
21-8-15 ba	NE NW sec. 15	Jay P. Sharp	Dr	64	8	GI	Limestone and shale	Beattie ls.	Cy, W	D, S	do	0	28	6-23-48	Estimated yield 2±
21-8-15 da	NE SE sec. 15	W. Pinkstone	Du	31.2	45	R	Sand and gravel	Alluvium	Cy, H	D, S	Top of concrete cover	1.5	17.34	9-25-47	Dry in 1913, low in 1936
	T. 22 S., R. 5 E.														
22-5-13 dc	SW SE sec. 13	F. G. Burdorf	Dr	49.2	5	GI	Limestone	Towanda ls. &/or Fort Riley ls.	Cy, W	S	....	0	17.64	9-19-47	
	T. 22 S., R. 6 E.														
22-6-5 dc	SW SE sec. 5	Walter Berends	Du	56.8	24	R	Limestone	Winfield ls.	Cy, W	D, S	Top of concrete cover	1.3	26.07	9-19-47	Reported adequate
22-6-11 cc	SW SW sec. 11	Margaret Smith	Dr	85.5	5½	GI	Limestone	Barneston ls.	Cy, W	S	Top of casing	0.3	8.25	9-23-47	
SW SE sec. 18	22-6-18 dc	T. B. Sidner	Dr	56.6	7	GI	Limestone	Winfield ls.	Cy, H	D	do	0	27.32	9-19-47	Reported adequate

TABLE 12.—*Records of wells and springs in Chase County—Continued*

Well No. (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, in.	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Feet above land surface	Depth to water level, feet (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
22-6-21 ab	NW NE sec. 21	George Carley	Dr	17.0	6	GI	Limestone	Towanda ls.	N	D	do	2.3	9.79	9-19-47	
22-6-26 bb	NW NW sec. 26	P. Scharemberg	Du	44.8	(?)	R	Limestone	Towanda ls.	Cy, W	S	Top of concrete cover	1.3	28.98	9-18-47	Reported adequate. Yield +10
22-6-26 cc	SW SW sec. 26	Sch. Dist. 45	Dr	29(?)	6	I	Limestone	Towanda and/or Fort Riley ls.	Cy, H	P	Top of casing	1.0	8.(?)	4-26-48	Reported to be adequate. Flowing well for several years.
22-6-27 ad	SE NE sec. 27	R. L. Edmonds	Dr	47.5	5½	GI	Limestone	Towanda and Fort Riley ls.	Cy, W	S, I	do	0.7	21.56	9-19-47	
22-6-27 dd	SE SE sec. 27	Mildred Morse	Dr	29(?)	7	I	Limestone	Towanda and/or Fort Riley ls.	F	S	do	1.0	....	9-19-47	Flowing well—Original reported head, approx. 13 feet.
22-6-34 aa	NE NE sec. 34	B. E. Melson	Dr	48.0	4½	GI	Limestone	Towanda ls.	Cy, W	S	do	0.9	40.20	9-18-47	
	T. 22 S., R. 7 E.														
22-7-5 bc	SW NW sec. 5	L. E. Pike	Dr	46.3	10½	GI	Limestone	Fort Riley ls.	Cy, H	D	do	1.0	18.58	9-18-47	
22-7-8 cb	NW SW sec. 8	Chas. C. Deering	Dr	41.8	6½	I	Limestone	Fort Riley ls.	Cy, H	D	do	0.7	26.80	9-18-47	
22-7-18 dd	SE SE sec. 18	Ada S. Walker	Dr	63.7	6	GI	Limestone	Barneston ls.	Cy, W	S	Top of galvanized sheet around top of hole	1.1	17.03	9-18-47	Reported adequate. Yield +10
22-7-25 bc	SW NW sec. 25	Wayne Rogler	Sp	......	....	....	Limestone	Florence ls.	....	S	....	....	....	10-29-47	Jack Spring, Measured yield 95.
22-7-25 cd	SE SW sec. 25	do	Dr	76.1	6	I	Limestone	Barneston ls.	Cy, W	S	Top of casing	1.2	32.17	9- 5-47	Reported adequate. Yield +10
22-7-31 ba	NE NW sec. 31	Geo. P. Poter	Dr	74.8	7½	I	Limestone	Towanda ls. and Fort Riley ls.	Cy, W	S	do	0.5	43.56	9-18-47	Reported adequate. Yield +10
22-7-35 cb	NW SW sec. 35	Wayne Rogler	Dr	94.1	5	I	Limestone	Barneston ls.	Cy, W	S	do	1.3	48.91	9- 5-47	Reported adequate. Yield +10
	T. 19 S., R. 7 E.														
19-7-2 cc	SW SW sec. 2	O. T. Pierson	Dr	58.8	6½	GI	Limestone and shale	Neva ls. and/or Eskridge sh.	N	N	Top of casing	0.7	33.52	9-13-47	Abandoned, formerly a stock well
19-7-10 da	NE SE sec. 10	H. T. Drake	Du	22.7	42	R	Sand and gravel	Alluvium	Cy, W	N	Top of concrete curbing	1.0	11.51	4-14-48	Abandoned, formerly a domestic and stock well
19-7-12 cb	NW SW sec. 12	Dewey Childs	Du	26.1	36	R	Limestone	Grenola ls.	Cy, H	D	do	0.5	21.65	9-20-47	
19-7-18 ac	SW NE sec. 18	Neal McCallum	Du	38.7	34	R	Limestone and shale	Red Eagle ls.	Cy, H	D, S	Top of wooden covering	1.0	35.90	9-15-47	
19-7-21 dc	SW SE sec. 21	Duncan McAlpine	Du	31.3	40	R	Shale and limestone	Hughes Creek sh & Americus ls.	N	D, S	Top of casing	3.0	29.80	9-15-47	
19-7-22 ac	SW NE sec. 22	Ray Whitlock	Dr	50.3	8	GI	Shale and limestone	Hughes Creek sh. & Americus ls.	Cy, H	D	do	0.8	27.60	9-15-47	Not adequate. Yields approx. 150 gallons per day
19-7-25 ad	SE NE sec. 25	E. C. Crofoot	Du	13.8	38	I	Limestone	Threemile ls.	Cy, W	S	do	+3.7	6.40	9- 5-47	
19-7-28 aa	NE NE sec. 28	Ruth A. Bell	Du	25.9	72	R	Sand and gravel	Alluvium	Cy, W	D, S	Top of angle iron on cover	0.8	11.48	9-15-47	
19-7-30 dc	SW SE sec. 30	Chas. H. Davis	Du	15.1	54	R	Shale and limestone	Eskridge sh.	Cy, W	S	Top of wooden cover	1.5	8.96	9-16-47	
19-7-32 ab	NW NE sec. 32	do	Du	38.6	36	R	Limestone and shale	Red Eagle ls.	Cy, H	D	do	0.8	31.90	9-16-47	
19-7-35 ac	SW NE sec. 35	Carl S. and Roy S. Breese	Dr	97.0	8½	I	Limestone and shale	Red Eagle ls. &/ or Long Cr. ls.	Cy, W	S	Top of casing	2.1	85.06	9- 5-47	
	T. 19 S., R. 8 E.														
19-8-2 dd	SE SE sec. 2	W. J. Wilson	Dr	44.6	6½	GI	Limestone and shale	Eiss ls.	Cy, H	D, S	do	0.1	26.68	10- 2-47	Estimated yield, 1-2
19-8-5 ba	NE NW sec. 5	George Davis	Du	37.9	117	R	Sand and gravel	Alluvium	T, E	D, S	Top of concrete floor pump house	1.0	19.90	9- 9-47	Adequate, use about 5,000 gals. per day
19-8-11 dc	SW SE sec. 11	A. Bjorklund	Dr	26.4	9	I	Limestone and shale	Beattie ls.	Cy, H	D, S	Top of concrete porch	0.4	6.91	9-27-47	Estimated yield, 1-2. Reported adequate

19-8-13 cb	NW SW sec. 13	J. E. Stout	Dr	91.4	6	GI	Limestone and shale	Burr & Sallyards ls.—Roca sh.	Cy, W	D, S, I	Top of concrete cover	0	72.42	9- 2-47	Adequate. Reported yield +5
19-8-16 ad	SE NE sec. 16	J. E. Danford	Du	37.4	48	R	Limestone and shale	Beattie ls.	Cy, H	D, S	Top of 2- by 10-inch board under pump	0.6	21.56	9-27-47	Reported adequate
19-8-16 bc	SW NE sec. 16	Joe Johnson	Du	13.2	24	R	Limestone	Cottonwood ls.	N	D	Top of board enclosure	5.0	12.51	9-20-47	Reported adequate
19-8-17 bd	SE NW sec. 17	Atchison, Topeka & Santa Fe Ry	Dr	30	6	(?)	Sand and gravel	Alluvium	(?)	S	Land surface	0	22	11- 4-48	Reported yield 6
19-8-18 Lot 10-b	Lot 10 sec. 18	H. L. Roberts	Dr	43	6	GI	Limestone and shale	Eskridge sh. and Cottonwood ls.	Cy, E	D	do	0	30	6-24-48	Reported adequate
19-8-18 Lot 10-a	Lot 10 sec. 18	Nelson Simmons	Dr	97.5	6½	I	Limestone	Grenola ls.	Cy, E	D, S	Top of concrete cover	+0.5	36.63	9-20-47	Reported adequate
19-8-24 ab	NW NE sec. 24	C. F. Littler	Dr	39.3	6	C	Limestone	Red Eagle ls.	Cy, H	D	do	0.5	22.27	10- 1-47	
19-8-27 dc	SW SE sec. 27	Helen Sayer	Du	27.2	36	R	Limestone and shale	Cottonwood ls. & Eskridge sh.	Cy, H	D, S	Top of stone cover over well	1.4	19.77	9-26-47	
19-8-29 bc1	SW NW sec. 29	Carl Cowley	Du	26.9	48	R	Shale and limestone	Eskridge sh.	Cy, H	D, S	Base of pump	0.3	25.39	9- 5-47	Not used
19-8-29 bc2	SW NW sec. 29	Burley Starks	Dr	80	6	I	Shale and limestone	Eskridge sh. and Grenola ls.	Cy, H	D	Land surface	(?)	27	9- 5-47	Reported yield, 10 gallons per hour
19-8-30	Lot 3 sec. 30	Iva E. Cowley	Dr	41.1	7	I	Limestone and shale	Eiss and Beattie ls.	Cy, W	S	Top of casing	0.9	10.9	9- 5-47	
19-8-31	Lot 14 sec. 31	S. J. Barrett	Du	15.7	30	R	Limestone and shale	Crouse ls. (?)	Cy, H	D	Top of iron rim of well cap	1.2	10.79	9-11-47	
	T. 19 S., R. 9 E.														
19-9-3 ad	SE NE sec. 3	R. J. Reyer	Du	20.8	36	R	Limestone and shale	Foraker ls.	Cy, H	D	Top of 2- by 6-inch board cover	0.8	14.05	10- 4-47	Reported adequate
19-9-3 cc	SW SW sec. 3	Will Richey	Du	37.0	48	R	Limestone	Long Creek ls.	Cy, W	D, S	Top of stone cover over well	1.2	36.45	10- 1-47	Reported adequate Yield +5
19-9-4 dc	SW SE sec. 4	Jeff Griffith	Dr	47.7	6	T	Limestone and shale	Johnson sh. and Long Creek ls.	Cy, W	S	Top of casing	0.3	30.89	10- 1-47	
19-9-6 ad	SE NE sec. 6	Fred E. Murdock	Dr	65.0	6½	I	Limestone and shale	Beattie ls.	Cy, W	S	do	1.3	27.01	10- 4-47	
19-9-7 aa	NE NE sec. 7	Earl C. Fleming	Dr	36.5	6	I	Limestone	Neva ls.	Cy, W	S	do	1.0	8.97	9-27-47	
19-9-10 da	NE SE sec. 10	Martin Wittker	Du	39.8	42	Br	Sand and gravel	Alluvium	Cy, W	D	Top of 4- by 4-inch board at top of casing	1.9	27.04	9- 4-47	
19-9-15 bb	NW NW sec. 15	Bill Imasche	Du	17.2	36	R	Sand and gravel	Terrace Alluvium	P, H	D, S	Top of concrete platform	1.0	12.94	6-25-48	Reported adequate
19-9-23 aa	SE NW sec. 23	G. A. Zumbrunn	Du	47.5	36	R	Sand and gravel	Alluvium	Cy, E	D, S	Top edge of concrete, west side	0.2	32.42	9- 4-47	Reported adequate
19-9-23 bc	SW NW sec. 23	F. J. McDaniel	Du	43.0	54	R	Sand and gravel	Alluvium	Cy, H	(?)	Top of casing, southeast corner	0	31.30	9- 4-47	
19-9-24 ba	NE NW sec. 24	Martin Adler	Dr	37.3	(?)	(?)	Shale and sandstone	Hamlin sh.	Cy, H, W	D, S	Top edge of 2- by 10- inch board platform	0.4	28.61	9- 4-47	
19-9-24 dc	SW SE sec. 24	Wm. R. Edie	Dr	45.3	8	GI	Limestone and shale	Foraker ls. and Hamlin sh.	Cy, N	N	Top of pile of 2- by 10-inch boards	1.0	23.35	9- 4-47	Abandoned, formerly a stock well
19-9-25 cc	SW SE sec. 25	D. L. Crawford	Du	18.3	48	R	Limestone and shale	Foraker ls.	Cy, W	S	Top of wooden platform at hole in southwest side	2.0	10.43	9- 4-47	
19-9-30 cc	SW SW sec. 30	E. E. Andrews	Dr	64.6	8½	GI	Limestone and shale	Red Eagle ls.	Cy, H	D	Top of casing	0.5	40.37	9-26-47	Not in use
19-9-31 da	NE SE sec. 31	Jack Campbell	Du	33.0	(?)	R	Limestone and shale	Red Eagle ls. and Johnson sh.	Cy, H	D, S, I	Top of stone covering	1.0	28.17	9-26-47	Reported adequate, Yield +5
	T. 22 S., R. 8 E.														
22-8-1 ab	NW NE sec. 1	E. C. Crofoot	Du	15.6	48	R	Sand and gravel	Alluvium	Cy, W	S	Top of concrete cover	2.0	10.05	9-25-47	
22-8-7 aa	NE NE sec. 7	Jess E. Bailey	Dr	58.9	6(?)	N	Limestone and shale	Bader ls.	N	D	Top of 2-inch board over well	0.2	38.44	9- 5-47	New well; casing not installed. Yield ±1
22-8-7 da	NE SE sec. 7	C. L. Underwood	Du	15.6	24	R	Limestone and shale	Crouse ls.	N, H	D, S	Top of board covering	3.0	15.00	9-24-47	Reported adequate. Yield less than ¼
22-8-9 cd	SE SW sec. 9	E. Talkington	DD	61.0	24 & 6	R	Limestone	Cottonwood ls.	N	N	Top of concrete curbing	2.0	24.62	3-26-48	Highly mineralized water. Yield +25

TABLE 12.—*Records of wells and springs in Chase County—Concluded*

Well No. (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, in.	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Feet above land surface	Depth to water level, feet (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
22-8-10 dd	SE SE sec. 10	Mrs. T. S. Jones	Du	13.6	36	R	Sand and gravel	Alluvium	Cy, W	N	Top of board cover	0	9.24	9-25-47	Reported inadequate. Goes dry at times
22-8-11 da	NE SE sec. 11	Henry T. Reidel	Du	±13	168	R	Shale and limestone	Speiser sh. and Colluvium	Cy, W	S	Top of hole in pump base	2±	10.28	9-25-47	Reported inadequate in dry years. Yield less than ¼
22-8-16 ab	NW NE sec. 16	R. H. Underwood	Dr	75(?)	6	I	Limestone	Cottonwood ls.	Cy, H	N	Top of casing	0.8	±25(?)	9-25-47	Highly mineralized water
22-8-16 ad	SE NE sec. 16	Audrey Decker	Dr	99.9(?)	8	I	Limestone and shale	Beattie ls. (?)	Cy, H	D	do	1.0	34.05	9-24-47	Not in use
22-8-17 cb	NW SW sec. 17	M. E. Pierce	Du	33.8	32	R	Limestone and shale	Crouse ls.	N, H	D	Top of concrete curbing	0.2	16.06	9-24-47	
22-8-18 Lot 10	Lot 10 sec. 18	C. S. Lips	Dr	34.4	6	I	Limestone and shale	Crouse ls. and Blue Rapids sh.	Cy, W	N	Top of casing	1.9	22.14	9- 5-47	Abandoned, formerly a domestic and stock well
22-8-19 Lot 6	Lot 6 sec. 19	J. A. and Ruth Banks	Sp	......	....	....	Limestone	Threemile ls.	....	D, S		....	....	10-29-47	Perkins Spring. Measured yield 70
22-8-20 ca	NE SW sec. 20	Robert White	Du	25.3	30	R	Limestone and shale	Crouse ls.	Cy, H	D	Top of 2- by 4-inch board curbing	0.5	20.73	9-24-47	Reported inadequate in dry years
22-8-22 dc	SW SE sec. 22	J. R. Lackey	Dr	44.6	7	I	Limestone and shale	Crouse ls. and Middleburg ls.	Cy, H	D	Top of casing	0.8	34.80	9-24-47	Reported inadequate
22-8-25 bb	NW NW sec. 25	A. M. Johnson	Du	24.5	30-36	R	Limestone	Wreford ls.	N, H	D	Top of board around top of well enclosure	2.7	18.50	9-24-47	Reported adequate
22-8-29 ad	SE NE sec. 29	R. D. McCallum	Du	18.5	40	R	Sand and gravel	Alluvium	Cy, W	D, S	Top of board top over well	2.0	16.74	9-24-47	Reported adequate. Yield ±20
22-8-34 ad	SE NE sec. 34	John Sampler	Du	35.0	24	R	Limestone and shale	Crouse ls.	N, H	S	Top of 2- by 4-inch board	1.0	35.87	9-24-47	Reported inadequate. Yield less than ¼
22-8-34 bb	NW NW sec. 34	F. D. Swanson	Du	21.3	45	R	Limestone and shale	Crouse ls. and Blue Rapids sh.	Cy, H	D	Top of concrete covering	0.5	19.94	9-24-47	Reported inadequate. Yield less than ¼
	T. 22 S., R. 9 E.														
22-9-8 cc	SW SW sec. 8	Vona I. Channell	Du	38.0	42	R	Limestone	Florence ls.	N	N	Top of rock cover	0.7	15.28	9-25-47	Abandoned, formerly a school well
22-9-18 ab	NW NE sec. 18	Alice North	Du	10.7	36	R	Sand and gravel	Alluvium and/or Colluvium	Cy, W	S	Base of 2- by 4-inch brace	2.0	6.54	9-25-47	Reported inadequate
22-9-19 dc	SW SE sec. 19	E. V. Johnson	Dr	27.8	8	I	Sand and gravel	Alluvium	Cy, H	D	Top of casing	1.0	9.80	9-24-47	
22-9-31 ac	SW NE sec. 31	J. D. McDowell	Du	16.8	36(?)	R	Limestone	Wreford ls.	Cy, H	S	Top of board cover over well	1.8	15.30	9-24-47	

1. Location number: Well numbers give the location of wells according to General Land Office surveys and according to the following formula: Township—Range—Section, 160-acre tract within that section, and the 40-acre tract within the quarter section. If two or more wells are located within a 40-acre tract, the wells are numbered serially according to the order in which they were inventoried. The 160-acre and 40-acre tracts are designated a, b, c, or d in a counterclockwise direction beginning in the northeast quarter. For example: well 18-6-1cd is located in the SE¼ SW¼ sec. 1, T. 18 S., R. 6 E.
2. DD, dug and drilled well; Dr, drilled well; Du, dug well; Sp, spring.
3. Reported depths below the land surface are given in feet; measured depths are given in feet and tenths below measuring points.
4. Br, brick; C, concrete; GI, galvanized sheet iron; I, iron; N, none; OW, oil-well casing; R, rock; T, tile.
5. Method of lift: Cy, cylinder; F, natural flow; N, none; P, pitcher pump; T, turbine. Type of power: E, electric; G, gas engine; H, hand operated; N, none; W, windmill.
6. D, domestic; I, irrigation; N, not being used; S, stock; P, public supply.
7. Measured depths to water level are given in feet, tenths, and hundredths; reported depths to water level are given in feet. All depths are below measuring point.

REFERENCES

BASS, N. W. (1929) The geology of Cowley County, Kansas, with special reference to the occurrence of oil and gas: Kansas Geol. Survey, Bull. 12, pp. 1-203, figs. 1-23, pls. 1-12.

——— (1936) Origin of the shoestring sands of Greenwood and Butler Counties, Kansas: Kansas Geol. Survey, Bull. 23, pp. 1-135, figs. 1-10, pls. 1-21.

CONDRA, G. E., AND UPP, J. E. (1931) Correlation of the Big Blue Series in Nebraska: Nebraska Geol. Survey, Bull. 6, 2d ser., pp. 1-76, figs. 1-15.

DEAN, H. T. (1936) Chronic endemic dental fluorosis: Am. Med. Assoc. Jour., vol. 107, pp. 1269-1272.

FATH, A. E. (1921) Geology of the Eldorado oil and gas field: Kansas Geol. Survey, Bull. 7, pp. 1-187, figs. 1-9, pls. 1-19.

FRYE, J. C., SWINEFORD, ADA, AND LEONARD, A. B. (1948) Correlation of Pleistocene Deposits of the central Great Plains with the glacial section: Jour. Geology, vol. 56, no. 6, pp. 501-525, figs. 1-3, pls. 1-2.

JEWETT, J. M. (1941) The geology of Riley and Geary Counties, Kansas: Kansas Geol. Survey, Bull. 39, pp. 1-164, figs. 1-2, pls. 1-17.

——— (1945) Stratigraphy of the Marmaton group, Pennsylvanian, in Kansas: Kansas Geol. Survey, Bull. 58, pp. 1-148, pls. 1-4.

——— (1949) Oil and gas in eastern Kansas with special reference to developments from 1944 to 1948: Kansas Geol. Survey, Bull. 77, pp. 1-308, figs. 1-53, pls. 1-4.

JEWETT, J. M., AND ABERNATHY, G. E. (1945) Oil and gas in eastern Kansas: Kansas Geol Survey, Bull. 57, pp. 1-244, figs. 1-21, pls. 1-4.

KEROHER, R. P., AND KIRBY, J. J. (1948) Upper Cambrian and Lower Ordovician rocks in Kansas: Kansas Geol. Survey, Bull . 72, pp. 1-140, figs. 1-13, pls. 1-6.

LANDES, K. K. (1937) Mineral resources of Kansas counties: Kansas Geol. Survey, Min. Res. Circ. 6, pp. 1-110.

LEE, WALLACE (1939) Relation of thickness of Mississippian limestones in central and eastern Kansas to oil and gas deposits: Kansas Geol. Survey, Bull. 26, pp. 1-42, figs. 1-4, pls. 1-3.

LEE, WALLACE, LEATHEROCK, CONSTANCE, AND BOTINELLY, THEODORE (1948) The stratigraphy and structural development of the Salina basin of Kansas: Kansas Geol. Survey, Bull. 74, pp. 1-155, figs. 1-11, pls. 1-14.

LEE, WALLACE, AND OTHERS (1946) Structural development of the Forest City basin of Missouri, Kansas, Iowa, and Nebraska: U.S. Geol. Survey, Oil and Gas Investi., Prelim. Map 48, sheets 1-7.

MCCLELLAN, H. W. (1930) Subsurface distribution of pre-Mississippian rocks of Kansas and Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. 14, no. 12, pp. 1535-1556, figs. 1-3.

MEINZER, O. E. (1923) Outline of ground-water hydrology, with definitions: U. S. Geol. Survey, Water-Supply Paper 494, pp. 1-71, figs. 1-35.

MOORE, R. C. (1918) The environment of Camp Funston: Kansas Geol. Survey, Bull. 4, pp. 1-81.

——— (1930) Geologic map of Kansas (with descriptive text): Kansas Geol. Survey, scale 1 inch = 40 miles.

MOORE, R. C., AND LANDES, K. K. (1937) Geologic map of Kansas: Kansas Geol. Survey, scale 1:500,000.

MOORE, R. C., AND OTHERS (1951) The Kansas rock column: Kansas Geol. Survey, Bull. 89, pp. 1-132, figs. 1-52.

OCKERMAN, J. W. (1935) Subsurface studies in northeastern Kansas: Kansas Geol. Survey, Bull. 20, pp. 1-78, figs. 1-4, pls. 1-13.

PLUMMER, NORMAN (1937) Rock wool resources of Kansas: Kansas Geol. Survey, Min. Res. Circ. 5, pp. 1-74, figs. 1-25.

PLUMMER, NORMAN, AND HLADIK, W. B. (1948) The manufacture of ceramic railroad ballast and constructional aggregates from Kansas clays and silts: Kansas Geol. Survey, Bull. 76, pt. 4, pp. 53-112, fig. 1, pls. 1-8.

——— (1951) The manufacture of lightweight concrete aggregate from Kansas clays and shales: Kansas Geol. Survey, Bull. 91, pp. 1-100, figs. 1-4, pls. 1-7.

PROSSER, C. S., AND BEEDE, J. W. (1904) Description of the Cottonwood Falls quadrangle: U. S. Geol. Survey, Geol. Atlas of the U. S., Folio 109, pp. 1-6, figs. 1-2.

SCHOEWE, W. H. (1949) The geography of Kansas: Part 2, Physical geography: Kansas Acad. Sci. Trans., vol. 52, no. 3, pp. 261-333, figs. 12-55.

TODD, J. E. (1918) Kansas during the ice age: Kansas Acad. Sci. Trans., vol. 28, pp. 33-47.

——— (1918a) History of Kaw Lake: Kansas Acad. Sci. Trans., vol. 28, pp. 187-199, figs. 1-3.

WOOSTER, L. C. (1915) The chert gravels of eastern Kansas: Kansas Acad. Sci. Trans., vol. 27, pp. 58-62.