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

PART 1

ROCK FORMATIONS OF OSAGE COUNTY

By

HOWARD G. O'CONNOR

PART 2

MINERAL RESOURCES OF OSAGE COUNTY

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HOWARD G. O'CONNOR, WALTER H. SCHOEWE, EDWIN D. GOEBEL, AND NORMAN PLUMMER

PART 3

GROUND-WATER RESOURCES OF OSAGE COUNTY

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University of Kansas Publication

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State Geologist and Director

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GROUND-WATER RESOURCES OF OSAGE 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 OSAGE COUNTY

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INTRODUCTION

During the summer of 1947 the State Geological Survey of Kansas and the United States Geological Survey, in cooperation with the Division of Sanitation of the Kansas State Board of Health and the Division of Water Resources of the Kansas State Board of Agriculture, began a series of reports on the stratigraphy, economic geology, and ground-water resources of eastern Kansas counties. The reports consist chiefly of maps but contain brief descriptive stratigraphy, together with discussions of mineral and ground-water resources. The present status of these investigations is shown in Figure 1.

GEOGRAPHY

Osage County lies in central eastern Kansas as shown in Figure 1. It has an area of approximately 721 square miles or 20 townships.

According to the 1950 census, Osage County has a population of 12,811. The principal cities are Osage City, 1,919; Burlingame, 1,065; Lyndon, 729; Scranton, 487; Carbondale, 453; Overbrook, 387; Quenemo, 391; and Melvern, 389. Agriculture is the principal industry.

Physiographically the area is a part of the Osage Plains (Schoewe, 1949). The topography is that of a dissected plain developed on unequally resistant shale and limestone formations. This gives rise to a gently rolling topography of vales and escarpments with moderate to steep slopes adjacent to most of the river and creek valleys. Land surfaces range from about 875 feet to 1,300 feet above sea level.

Marais des Cygnes River and its tributaries drain about 90 percent of the county and the remaining 10 percent is drained by Wakarusa River.

Normal annual precipitation recorded at Lyndon, Kansas, is 34.76 inches. About 71 percent of the precipitation in this area falls during the usual 6-month growing season.

METHODS OF INVESTIGATION

Most of the field work on which this report is based was done by me assisted by James Conkin in the summer and fall of 1951. In 1949 Hubert Hall and Keith Lowell spent about 3 months in the field measuring rock sections in detail, using a rule, Locke level with stadia, and telescopic level with a 12-foot rod. In 1950 Ralph O'Connor and Raymond Boardman spent approximately 3 months continuing the stratigraphic studies. J. M. Jewett spent several days in the field during the stratigraphic investigations and aided in these studies.

Areal geology was mapped on air photographs (scale 1:20,000) and transferred by means of a Focalmatic desk projector to a base map (scale 1:40,000) adapted from a United States Department of Agriculture, Soil Conservation Service drainage and base map.

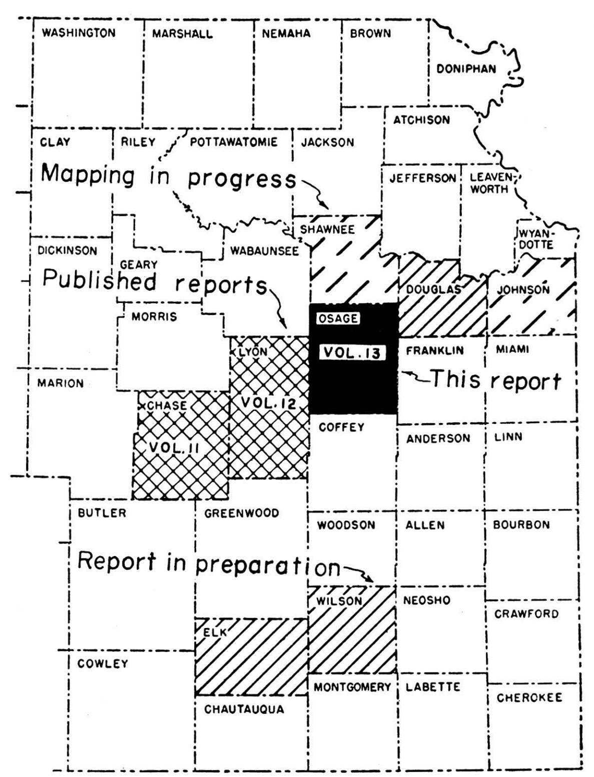


FIG. 1.—Index map of a part of eastern Kansas showing area covered by this report and other areas for which reports of this series have been published or are in preparation.

Test drilling was done in June 1951 and July and August 1953 with a portable hydraulic-rotary drilling machine owned by the State Geological Survey and operated by W. T. Connor, assisted at various times by Dick Connor, Warren Hodson, John Bashor, K. L. Walters, and C. K. Bayne. The altitude of the land surface at each test hole was determined by level parties headed by C. K. Bayne and W. W. Wilson.

PREVIOUS GEOLOGIC WORK

The sequence of rocks which crop out in Osage and other eastern Kansas counties has been studied and described by many geologists (Prosser, 1895; Hall, 1896; Beede, 1898; Moore, 1936; Moore and Landes, 1937; Moore, Frye, and Jewett, 1944; Moore and others, 1951; Mudge and Burton, 1950; O'Connor, 1953). Coal resources of the area have been studied by Haworth (1898); Whitla (1940); Bowsher and Jewett (1943); Schoewe (1946); and Abernathy, Jewett, and Schoewe (1947). A report on mineral waters, including some from Osage County, was published by Bailey (1902).

The subsurface geology has been described by McClellan (1930); Lee and others (1946); Lee, Leatherock, and Botinelly (1948); and Lee and Merriam (1954). The geology pertaining to oil and gas has been discussed by Jewett and Abernathy (1945) and by Jewett (1954). Named structures that have geographic application to Osage County have been listed by Jewett (1951).

ACKNOWLEDGMENTS

Appreciation is expressed to the many persons who furnished information on wells and water supplies, quarrying, and mining operations. Stratigraphic sections measured by nearly a dozen other members and former members of the Survey staff were utilized in preparation of this report and their help is acknowledged.

The manuscript of this report has been reviewed critically by several members of the Federal and State Geological Surveys; by Dwight Metzler, Director and Chief Engineer, and Willard O. Hilton, Geologist, Division of Sanitation, Kansas State Board of Health; and by R. V. Smrha, Chief Engineer, Division of Water Resources, Kansas State Board of Agriculture.

STRATIGRAPHY OF OUTCROPPING ROCKS

The rocks which crop out in Osage County range in age from Pennsylvanian to Quaternary and all are of sedimentary origin. Their areal extent is shown on Plate 1. In pages devoted to descriptions of the rock succession in Osage County, statements of thickness and distribution apply to this county only unless otherwise indicated.

QUATERNARY SYSTEM

Quaternary deposits in Osage County consist chiefly of fluvial deposits. In addition to the alluvium and low terraces (flood-plain complex) which comprise the modern flood plains of the present streams there are a series of successively older and higher terraces and terrace remnants along the principal valleys. Precise dating of these deposits has not yet been possible, age determinations being suggested by degree of weathering, physiographic position, and comparison with more conclusively dated terraces in the adjacent Cottonwood-Neosho River basin to the south and Kansas River basin to the north.

Loess and colluvial slope deposits occur as discontinuous and thin veneers along the valley slopes and some of the upland flats but are not mapped.

PLEISTOCENE SERIES

RECENT AND WISCONSINAN STAGES

Stream Valley Alluvium

Deposits of stream-laid gravel, sand, silt, and clay occur in the stream valleys and constitute the flood plains of the valleys. In general the alluvial fills grade upward from a gravel fill in the deeper part to a silt or clay at the surface. The maximum accumulations are about 40 feet thick in Marais des Cygnes River Valley and less in the smaller tributary valleys.

The coarse fraction is composed chiefly of chert, quartz, limestone, sandstone, and shale detritus derived from the Pennsylvanian, Permian, and Quaternary rocks which crop out in the Marais des Cygnes and Wakarusa River drainage basins. Descriptions of the alluvium are given in the record of test holes at the end of this report and are shown in cross section in Figure 3.

In the larger stream valleys two separate levels of alluvial deposits can be recognized locally as comprising the flood plain. The older and higher level averages perhaps 90 percent of the flood plain. This level occupies the entire flood plain in many areas of the valleys. In the wide parts of the valleys this surface is flat and poorly drained (cross section A-A′, Fig. 3). Valley width, depth of fill, gradient, and surface configuration of the flood plains are adjusted to and modified by the local bedrock of the area.

The younger and lower alluvial surface comprises perhaps 10 percent of the flood plain but ranges from 40 percent to little or none of the flood-plain complex locally. This surface is characterized by surface irregularities and scarring wherever it forms an appreciable part of the flood plain. It occurs 2 to 10 feet below the older, higher part of the flood plain.

The extent of stream-valley alluvium (flood plain), except very narrow belts in small valleys, is shown on Plate 1. It is an important source of ground water. Older Pleistocene terrace deposits are mapped with the alluvium in the small tributary valleys.

ILLINOIAN STAGE (?)

Terrace Deposits

An older and less extensive terrace occurring 10 to 15 feet above the flood plain can be recognized and mapped above the valley alluvium. This terrace rests on a bedrock surface 5 to 15 feet above the bedrock beneath the alluvium (cross section A-A′, Fig. 3). The sediments comprising these deposits are similar to those of the alluvium and have a maximum thickness of about 35 feet. A description of the lithology of these deposits is given in the log of test hole 18-14-9ac at the end of this report and its relation to older and younger terraces is shown in cross section A-A′ (Fig. 3).

The age of this terrace is not certain but it is thought to be equivalent to the Wiggam terrace along Neosho River (O'Connor, 1953, pp. 6-7) and of probable Illinoian age. The extent of these deposits is shown on Plate 1. Illinoian fluvial deposits in the area east of the Flint Hills and south of Kansas River have not yet been positively identified but are believed to be represented by the highest elements of the low terrace complex (Frye and Leonard, 1952, p. 112).

Illinoian (?) terrace deposits are an important source of ground water.

KANSAN STAGE (?)

Terrace deposits of probable Kansan age occur intermittently along the valley sides. The basal deposits of this terrace rest on an eroded surface 10 to 30 feet above the flood-plain surface. Maximum thickness of these deposits is 40 feet. The lithology of these Kansan (?) sediments is similar to that of the alluvium and Illinoian (?) terrace except for degree of weathering and consequent color changes. The log of test hole 15-15-35cc and the cross sections (Fig. 3) illustrate the nature of these deposits and the relation of this terrace to other Quaternary deposits.

Throughout most of their extent Kansan terrace deposits have only a thin or intermittent zone of saturation. Locally they are a source of small supplies of ground water.

QUATERNARY AND TERTIARY SYSTEMS

NEBRASKAN STAGE (?) AND PLIOCENE SERIES (?)

Remnants of three alluvial terraces occur at elevations 60 to 75, 80 to 95, and 140 to 160 feet above the present alluvial flood-plain surface in the Marais des Cygnes River Valley. The lowest of these is probably of Nebraskan age and the two higher levels are Pliocene or older in age.

These high-level terrace remnants are lithologically similar and consist of siliceous sand and gravel, principally chert, up to several inches in diameter and were derived chiefly from the Wolfcampian (Permian) rocks of the Flint Hills region. The brownish-red clay matrix which fills the interstices between gravels and the complete leaching of all calcareous material indicate that the deposits have been subjected to prolonged weathering. Thickness of these gravels ranges from a few inches to about 12 feet (Pl. 4A, 4E). The three terrace levels are not distinguishable on the basis of their lithology. Topographic position is the chief means of differentiating these high-level terrace gravels.

Cross section A-A′ (Fig. 3) and Plate 1 illustrate the relation of these gravels to the younger terrace deposits. As these terrace gravels are traced eastward along Marais des Cygnes River drainage their relative position in the local topography becomes higher.

They are generally above the water table and are not an important source of ground water.

PERMIAN SYSTEM

WOLFCAMPIAN SERIES

ADMIRE GROUP

Hamlin Shale

The Hamlin shale comprises three members, the Oaks shale, Houchen Creek limestone, and Stine shale. Only a few feet of weathered Stine shale occurs in one small area in Osage County. It is not an aquifer.

Stine shale member.—The complete thickness of the Stine shale member is about 50 feet in areas adjacent to the west. Only about 5 feet or less of the basal part is present on one hilltop in northwestern Osage County. In outcrops it is observed to be gray to olive, silty to sandy shale.

Five Point Limestone

The Five Point limestone is a gray fossiliferous limestone about 4 feet thick. Fossils include fusulinids, brachiopods, bryozoans, horn corals, and crinoids. It is not an aquifer.

West Branch Shale

Gray silty to sandy shale and sandstone about 25 feet thick comprise most of the West Branch shale. A thin coal generally less than 0.2 foot thick occurs in the upper 1 foot of the formation and is underlain by about 4 feet of gray shale and a thin sandy limestone containing pelecypods, bryozoans, brachiopods, and crinoid fragments. The middle and lower parts are chiefly fine-grained sandstone and sandy shale. It is not an important aquifer.

Falls City Limestone

The Falls City limestone comprises several thin gray limestones that weather light gray to cream and the included gray shale beds. The upper part consists of one or two thin gray limestones containing abundant fossils, chiefly mollusks and bryozoans. The lower part commonly comprises two thin molluscan gray limestones separated by a foot or two or gray shale. The formation has an approximate thickness of 12 feet. It is of little importance as an aquifer.

Hawxby Shale

Three measured sections of the Hawxby shale range from 11 to 14 feet in thickness. It comprises olive-green, gray, and red silty and micaceous or clayey shale, unfossiliferous or with a thin molluscan limestone.

It is not an aquifer.

Aspinwall Limestone

The Aspinwall limestone, comprising 2 to 5 feet of limestone or limestone and interbedded shale, is not a prominent bench-forming limestone. It contains mollusks and generally some productid brachiopods together with considerable ferruginous material locally. The limestone is light gray and weathers gray. It is of little importance as a source of ground water.

Towle Shale

The Towle shale ranges from about 8 to 13 feet in thickness in four measured sections of these beds in northwestern Osage County. The formation contains two members, an unnamed shale, and the Indian Cave sandstone which occurs locally in the lower part of the formation. Only the shale member was observed in the exposures studied. It is of little importance as a source of ground water.

Unnamed shale member.—Beds of gray, green, and red shale, in part clayey and in part silty or sandy, comprise the unnamed shale member. Red or red and green shale occurs near the middle or locally comprises almost the entire member.

PENNSYLVANIAN SYSTEM

VIRGILIAN SERIES

WABAUNSEE GROUP

Brownville Limestone

The Brownville limestone has an average thickness of about 2 feet. In fresh exposures it is a bluish-gray hard limestone in a single ledge or may have one or two thin partings. On weathering it becomes yellowish brown and the top surface is uneven. Typical fossils include *Marginifera*, *Chonetes*, bryozoans, crinoids, and fusulinids. Except for small supplies of water from shallow wells in the zone of weathering it is of little importance as an aquifer.

Pony Creek Shale

Measured sections of the Pony Creek shale range from 5 to 14 feet and average about 7 feet in thickness. It comprises gray to olive shale in the upper 3 feet which commonly is calcareous and, in the upper few inches, may be fossiliferous. Middle and lower parts are silty and sandy micaceous gray, green, and red shale. Locally a disconformity in the Pony Creek shale cuts out the upper part of the Caneyville limestone. It is of little importance as a source of ground water.

Caneyville Limestone

Two limestones and an unnamed separating shale comprise the Caneyville limestone. Where both the upper and lower limestones are recognizable the formation has a thickness of 12 to 14 feet. It is of little importance as an aquifer.

Grayhorse limestone member.—The Grayhorse member is a gray to gray-brown in part silty to sandy and partly coarsely crystalline brown-weathering limestone. Thickness ranges from 0.3 to about 2 feet where the member is identified. Thicker sections comprise two thin limestones and a gray shale bed. *Myalina* and other pelecypods, bryozoans, and algae are the common fossils. Locally the member is not present because of nondeposition or because of removal by erosion during Pony Creek deposition.

Unnamed shale member.—Middle Caneyville beds comprise about 10 or 11 feet of gray, green, and red silty and sandy shale and sandstone. As in areas to the northwest (Mudge and Burton, 1950) a disconformity originating in the Caneyville shale locally has cut out the Nebraska City limestone.

Nebraska City limestone member.—In much of its outcrop area in Osage County the Nebraska City limestone member is absent. Where it can be identified it is represented by a limy micaceous sandstone about 1 foot thick containing fragments of brachiopods and bryozoans.

French Creek Shale

The average thickness of the French Creek shale is about 30 feet. Where the Nebraska City limestone is absent and the upper boundary is indeterminate, the interval from the base of the Grayhorse to top of the Jim Creek limestone is about 41 to 44 feet. The Lorton coal, ranging from a featheredge to 0.6 foot in thickness, occurs in the upper 10 feet of the formation (at a few places two coals are separated by sandstone and gray shale). Gray shaly micaceous sandstone and sandy shale which weathers olive to tan form the predominant part of this formation. Locally, black carbonized plant remains are abundant. At some places brown limonitic concretions occur in the lower part.

Small supplies of ground water of variable quality are obtained locally from sandy zones at shallow depth.

Jim Creek Limestone

The Jim Creek limestone is a gray or brown and gray fine-grained hard limestone which occurs in a single ledge 0.5 to 1 foot thick. The bed weathers shelly and in many exposures the top surface is red or purple brown from limonite or hematite stains. Fossils include *Chonetes, Derbyia, Dictyoclostus, Enteletes,* small productid brachiopods, gastropods, bryozoans, *Allorisma, Nucula, Nuculana,* and *Myalina.* Fusulinids were not observed in any sections measured. Locally joints are much enlarged by solution.

The Jim Creek limestone is of little importance as an aquifer.

Friedrich Shale

Gray, olive, and green clayey to silty shale beds averaging 10 to 15 feet in thickness comprise most of the Friedrich shale. The weathered shale is brown to yellowish with streaks of brown limonite nodules and stains on bedding planes. Fossils are rare or absent.

The formation supplies little or no water to wells in this area.

Grandhaven Limestone

The Grandhaven limestone averages about 9 feet in thickness and normally comprises two limestones separated by a few feet of shale.

The upper limestone is light-gray algal limestone which weathers light tan to nearly white. Abundant large *Osagia* algae locally give the rock the appearance of a pebble conglomerate. Clams, bryozoans, brachiopods, crinoids, and fusulinids are also numerous in some exposures. Everywhere it is observed it is less than 2 feet in thickness, and locally the algal bed may be thin or absent.

Underlying silty to clayey shale beds averaging 4 to 8 feet in thickness are gray or olive and locally contain a red zone.

The lower limestone ranges from about 1 to 3 feet in thickness and comprises gray to yellow-brown limestone which weathers yellow brown. Fusulinids, crinoids, bryozoans, and brachiopods are abundant in most outcrops.

The Grandhaven limestone is not an important source of ground water. Locally, however, small supplies may be obtained from it at shallow depths.

Dry Shale

The Dry Shale comprises 7 to 18 feet of gray, green, and tan silty and calcareous shale. A nodular zone of limestone interbedded with gray-green shale occurs near the middle in some exposures. Crinoid fragments and a few brachiopods occur locally in the shale or the nodular limestone but the formation is mostly unfossiliferous. It is unimportant as an aquifer.

Dover Limestone

Exposures of the Dover limestone range in thickness from 1.5 to about 4 feet and average about 3 feet. It is light gray, especially the upper part, to light tan and weathers light gray tan. Large algal growths of the *Cryptozoon* type are numerous in the upper few inches of the limestone and robust fusulinids are abundant in the remainder of the bed. Horn corals, brachiopods, *Osagia,* and crinoid remains are also found in less abundance. Frequently the outcrop of the Dover and the slopes below it are covered with fusulinids which have weathered free. Because of its position and thickness the Dover generally makes the most prominent bench occurring between the Brownville and Tarkio limestones. The Dover limestone is of little importance as a source of ground water.

Langdon Shale

Gray and olive-gray, tan-weathering, blocky to thin-bedded sandy shale and gray, tan-weathering shaly sandstone comprise the Langdon shale. The upper foot or two is calcareous to sandy shale which, in southern outcrops, may contain fusulinids near the top. In other exposures the upper several feet of Langdon shale is sandy micaceous shale and thin-bedded to massive micaceous sandstone, parts of which are cemented with calcite. Middle and lower parts are thin-bedded silty and sandy shale containing scattered plant remains and ferruginous concretions.

A few wells obtain small supplies of ground water from sandy parts of the Langdon shale at shallow depths.

Maple Hill Limestone

The Maple Hill is a thin, medium-gray, brownish-gray weathering, hard limestone. It occurs as a single ledge and because of its widely spaced joints weathers out in large rhomb-shaped blocks. The top surface weathers reddish purple and the bed becomes shelly in many exposures. Small fusulinids, bryozoans, crinoids, and brachiopods are the most common fossils.

The Maple Hill limestone is of little importance as an aquifer.

Pierson Point Shale

Exposures of the Pierson Point shale average about 24 to 28 feet, thickening southward. At the top of the formation is a persistent thin coal or very carbonaceous streak and a thin gray underclay, together 2 feet or less in thickness. Next below is 8 to 15 feet of gray or greenish-gray, clayey to sandy shale containing one to three thin limy fossiliferous zones, the lowermost of which can be observed in most outcrops of this formation across Osage and Lyon Counties. North of Osage County the Pierson Point shale thins and in exposures in the vicinity of Maple Hill none of the fossiliferous limy zones are recognizable although the upper part contains scattered fossils. The lowermost of these limy fossiliferous zones, the Stormont limestone (O'Connor, 1953, p. 19), is identifiable across Osage and Lyon Counties and persists south of the area where typical algal-fusulinid Tarkio pinches out. The Stormont limestone averages about 2 feet in thickness and is variable in lithology, ranging from a sandy limestone to a limy sandstone or nodular very impure siltstone but everywhere is fossiliferous. The fauna contained includes fusulinids, numerous mollusks, brachiopods, bryozoans, crinoids, large algae, and in some exposures an abundant microfauna. It is generally nonresistant to weathering and makes little or no bench on hillsides. Unfossiliferous shale beds averaging 10 to 15 feet in thickness, comprising sandy or silty micaceous gray or gray-green shale in the upper part and blocky to thin-bedded blue-gray shale in the lower part, occur between the Stormont limestone and the algal bed at the top of the Tarkio limestone.

The Pierson Point shale is not important as an aquifer.

Tarkio Limestone

The Tarkio limestone ranges from about 7 feet in the north to a featheredge in the south, averaging 2 to 5 feet along most of its outcrop. It is a hard, massive, gray limestone which weathers a deep rich brown. Most of the bed contains an abundance of large fusulinids which weather into relief and are nearly white (Pl. 4H) in strong contrast to the brown-weathering matrix. The upper foot of limestone commonly contains abundant algae, mostly of the *Cryptozoon* type, but locally the algae are scattered through most of the formation. Crinoids, bryozoans, and brachiopods are present also. The Tarkio is unimportant as an aquifer.

Willard Shale

The Willard shale comprises 12 to 24 feet of gray to olive, silty, sandy, and clayey shale lying between the Tarkio and Elmont limestones. Locally it may contain thin zones of shaly sandstone. Fossils are not common but a few gastropods, pelecypods, and brachiopods are found locally in the upper part. In some places plant fragments occur in parts of the formation. Where the Tarkio limestone is absent in the south the Willard is included with the Pierson Point shale as the Pierson Point-Willard shale.

It is unimportant as an aquifer.

Elmont Limestone

The Elmont limestone ranges in thickness from about 1.5 to 7 feet. Typically it contains a thin molluscan or algal-molluscan limestone at the top separated by a few inches to 1 foot of gray calcareous shale. The next lower bed is a hard, dense, brittle, gray-blue limestone containing small inconspicuous fusulinids, *Cryptozoon* type algae of a slightly different color from the remainder of the bed, brachiopods, and crinoids. This bed is characterized by its close-spaced vertical joints. A thin conglomeratic limestone or zone of subrounded blue-gray pebbles marks the base of the Elmont limestone and is separated from the fusulinid bed by 1 to 4 feet of clayey and calcareous gray shale. The calcareous shale in several exposures contains *Derbyia, Chonetes,* and other brachiopods. The upper or lower limestone may be absent in some exposures.

The Elmont limestone is not an important source of ground water.

Harveyville Shale

Outcrops of the Harveyville shale range in thickness from about 2 to 10 feet. It is thin-bedded blue-gray to olive shale, which weathers tan. Locally it is slightly calcareous or sandy.

The Harveyville shale yields little or no water to wells.

Reading Limestone

The Reading limestone comprises one to three beds of limestone and a small amount of shale separating the limestones. It averages about 3 feet in thickness but is as much as 7 feet where shale partings between the limestones are prominent. The limestone is dark gray-blue, dense limestone which weathers yellow brown. The lower part contains abundant fusulinids as well as other fossils and at some places where a shale parting is present, two fusulinid-bearing limestones. Fusulinids are absent from the upper part of the formation. Bryozoans, crinoid fragments, and brachiopods are numerous in all the limestone beds. The shale beds are thin-bedded, gray to tan, and calcareous.

The Reading limestone ordinarily yields little or no water to wells. A few wells obtain small supplies from joints and fractures at shallow depths.

Auburn Shale

Strata, chiefly shale, sandstone, and soft limestones averaging 45 to 50 feet in thickness comprise the Auburn shale. Outcrops of the Auburn shale along the Shawnee-Osage County line are chiefly sandstone and sandy shale whereas outcrops along the Lyon-Osage County line are chiefly shale and limestone with little or no sandstone.

Near the top of the Auburn shale in many exposures is 2 to 10 feet of limy sandstone, or limy sandstone interbedded with sandy olive to gray shale. The limy sandstone is fossiliferous, algae and mollusks predominating. Locally carbonized plant remains in calcareous to clayey gray shale occur between the base of the Reading limestone and the limy sandstone in the upper part of the Auburn shale. Middle and lower beds, where not sandy, may contain one or two sparsely fossiliferous thin siltstones or soft limestones.

The Auburn shale, especially in areas where considerable sandstone is present, yields small supplies of water of variable quality to wells.

Wakarusa Limestone

The Wakarusa limestone ranges from about 3 to 8 feet in thickness. It comprises massive, thick- to medium-bedded limestone containing a variety of fossils. Large fusulinids, *Ottonosia,* brachiopods, crinoids, corals, and bryozoans are common. In thick sections the upper part is rather sandy algal molluscan or unfossiliferous limestone and weathers thin- to medium-bedded. In fresh exposures this limestone is bluish gray or mottled gray and brown and becomes light to dark brown in color when weathered.

It supplies small quantities of ground water to a few shallow wells chiefly from joints and fractures.

Soldier Creek Shale

Gray to olive, yellow-tan weathering silty to clayey shale 2 to 7 feet thick comprises the Soldier Creek shale. Locally calcareous nodules occur in the shale and in one exposure about 0.4 foot of coal was observed. It is unfossiliferous except for carbonized plant remains.

It yields little or no ground water to wells.

Burlingame Limestone

Thickness, lithology, and fossil content of the Burlingame limestone differ greatly from one outcrop to another because of differences in development of various parts of this stratigraphic unit. Measured sections of this limestone range from about 2 to 9 feet and average about 3 feet in thickness. Most commonly this formation is characterized by one or more massive-bedded, light-gray and buff limestones in which the matrix weathers buff to brown and the fossils weather light gray or tan. Small fusulinids are found in many outcrops and *Osagia* algae are abundant nearly everywhere. Locally limestone containing mollusks and the brachiopods *Juresania* and *Derbyia* occur in the lower part; elsewhere light-gray, brecciated algal-molluscan limestone up to several feet in thickness occurs in the upper part. Quarries in this brecciated, cross-bedded algal molluscan phase occur on the hilltops about 2 miles northeast of Burlingame and 2 miles southwest of Osage City (Pl. 2). Locally the limestone is conglomeratic. Bryozoans, crinoids, and brachiopods are generally associated with the fusulinid and algal beds.

The Burlingame yields small supplies of water of generally good quality to a few shallow wells.

Silver Lake Shale

Measured sections of the Silver Lake shale range from about 30 to 38 feet and average perhaps 35 feet. It comprises blue-green, olive, and blue-gray clayey and sandy shale. Shale in the upper part may be calcareous or contain impure calcareous siltstones. Yellowish-brown weathering sandstone and sandy micaceous shale are present in the middle and lower parts in many exposures. A thin coal bed ranging from a featheredge to about 0.4 foot thick occurs locally near the middle of the shale and carbonized plant remains are abundant. Except for land plants it is generally unfossiliferous.

Sandy parts of the Silver Lake shale yield small amounts of water to shallow wells locally.

Rulo Limestone

The Rulo is a thin but distinctive limestone 1.5 to 2 feet thick. Its position below the scarp making Wakarusa and Burlingame limestones and above the persistent Elmo coal together with its distinguishing lithologic characters make it readily recognizable.

It is blue gray and weathers drab yellow brown to dark gray with a slight mottled and knobby appearance caused by slightly different weathering characteristics of the fossiliferous and nonfossiliferous parts of the limestone. It comprises a single massive limestone having relatively widespaced joints. Upon weathering it tends to become shelly and break into small chips. Fossils are numerous and include *Dictyoclostus, Neospirifer, Derbyia, Myalina, Pinna,* horn corals, crinoids, bryozoans, and algae.

The Rulo is not important as an aquifer.

Cedar Vale Shale

The persistent Elmo coal occurs in the upper part of the Cedar Vale shale, generally within 1 foot of the Rulo limestone. It ranges from 0.1 to 0.5 foot in thickness and is commonly underlain by 0.2 to 0.4 foot of gray underclay. Beds of yellow-brown weathering sandstone occur in the upper part below the coal and underclay in a few exposures; elsewhere the remainder of the formation comprises gray or olive-green silty to sandy micaceous shale. Thickness of the unit ranges from about 10 to 28 feet and averages about 25 feet.

It yields small supplies of water to a few shallow dug wells.

Happy Hollow Limestone

The Happy Hollow limestone occurs as a thin relatively unfossiliferous detrital limestone in some outcrops and as two or three thin impure sandy to shaly fossiliferous limestones in other outcrops. It is a poor bench maker and good exposures are difficult to find.

Where several thin limestones and separating shales comprise the formation it is 4 to 9 feet thick. Top and base are marked by soft, shaly, or sandy, tan to gray-green molluscan-brachiopod limestones. Middle beds comprise chiefly gray to greenish silty and calcareous shale and soft molluscan limestones. Fusulinids may occur in the upper middle part but are not present in all outcrops.

In outcrops represented by detrital beds of limestone the formation comprises 1 to 4 feet of tan to yellow-brown limestone and may contain *Osagia*, brachiopods, crinoids, and mollusks.

The Happy Hollow ordinarily yields little or no water to wells.

White Cloud Shale

Gray, olive, and tan shale and sandstone beds averaging about 80 feet in thickness occurring between the Happy Hollow and Howard limestones comprise the White Cloud shale. In the area north of Dragoon Creek a considerable part of the formation consists of fine to very fine, gray, brown-weathering sandstone. Land plant remains occur in the sandy parts and locally a thin coal occurs in the upper part. Marine fossils are sparse or absent.

The White Cloud formation yields small supplies of ground water from beds of sandstone to many stock and domestic wells in part of Osage County. In areas lacking sandy zones it is not an important aquifer.

Howard Limestone

Measured sections of the Howard limestone range from about 20 to 35 feet, the average thickness being about 25 feet. It supplies small amounts of ground water to a few shallow wells.

Utopia limestone member.—The Utopia member consists of several limestones separated by thin shales. The upper bed, ranging from about 1 to 5 feet in thickness, is a light- to medium-gray "oatmeal"-textured limestone having abundant fusulinids and probably some algae in the upper part, grading downward into a limestone containing chiefly clams and snails. A thin gray calcareous shale ranging from a featheredge to 1.5 feet in thickness is underlain by 1.5 to 3 feet of thin unfossiliferous silty to fine sandy gray flaggy limestone.

According to Walter H. Schoewe (personal communication) these flaggy beds are the ones which contain abundant amphibian footprints, first noted by Mudge in 1873.

Below the flaggy beds 2 to 4 feet of thin-bedded fissile gray to dark-gray shale is present. Ostracods are abundant in parts of this shale. One or two thin impure limestones are present locally. The basal part of this member comprises 1.5 to 2.5 feet of blue-gray, light brown-gray weathering limestone containing abundant mollusks, especially *Nuculana, Myalina,* and several species of cephalopods.

Winzeler shale member.—The Winzeler shale member averages about 3 feet in thickness. Locally, however, less than a foot of shale separates the Utopia and Church limestones. It comprises gray to tan shale locally with one or two thin limy stringers.

Church limestone member.—The Church member averages 2 feet in thickness and occurs as a single massive bed of blue-gray, brown-weathering hard limestone. Crinoids, *Crptozoon* algae, and brachiopods are the most common fossils but bryozoans and mollusks are abundant locally.

Aarde shale member.—The average thickness of the Aarde shale member is 12 to 14 feet (area where Bachelor Creek member is identifiable). The upper part, above the Nodaway coal, is typically gray or blue-gray silty to calcareous shale underlain by dark-gray to nearly black fissile shale. Below the black fissile shale and above the Nodaway coal are 2 to 9 feet of gray clayey shale locally with a thin limestone similar in fauna and character to the Church limestone.

The Nodaway coal is a bituminous coal ranging in thickness from a featheredge to about 18 inches as observed in outcrops. Mine operators report as much as 36 inches of coal locally in mines (Schoewe, 1946, p. 24). Below the coal a thin sticky, structureless, gray underclay is present underlain by 1 to 4 feet of gray clayey and sandy shale. From the vicinity of Scranton northward the base of the Aarde is considered to be the base of the Nodaway coal as the Bachelor Creek limestone is not recognizable.

Bachelor Creek limestone member.—The basal member of the Howard limestone is a hard very sandy, gray to blue-gray, gray-brown weathering limestone. It ranges from about 2 to 8 feet and averages about 5 or 6 feet in thickness. Fossils are not abundant but include mollusks, bryozoans, crinoids, and brachiopod remains. In outcrops in northern Osage County, it becomes unrecognizable, grading into sandy shale or sandstone.

Severy Shale

Gray and olive clayey to sandy shale and gray fine- to very fine-grained micaceous sandstone averaging about 70 feet in thickness comprise the Severy shale. Carbonized plant remains occur in abundance locally and sparse brachiopods and bryozoans may occur near the top. As much as 40 feet of sandstone is present in the northern part. Thin platy calcareous siltstones are present locally in the basal part.

The Severy is an important source of ground water and supplies numerous stock and domestic wells with small quantities of water.

SHAWNEE GROUP

Topeka Limestone

The Topeka limestone is divided into four shale and five limestone members where it is fully developed. In Osage County the Coal Creek limestone and Holt and Iowa Point shales are not recognized. The two lower limestones comprise most of the formation. The Topeka limestone ranges from 13 to 26 feet and averages about 20 feet in thickness. At several localities in northern and central Osage County, the upper beds are cut out by overlying sandstone of the Severy shale.

A few wells obtain small supplies of water from the Topeka limestone, chiefly from joints and fractures at shallow depth.

Du Bois limestone member.—Light-gray, buff, or gray limestone, weathering tan, 0.5 to 1 foot thick probably represents the Du Bois member. It is fine-grained to finely crystalline hard limestone containing chiefly gastropods and pelecypods but also crinoid, echinoid, and bryozoan remains and a few brachiopods.

Turner Creek shale member.—Yellow-brown and greenish-gray clayey and calcareous shale beds about 2 feet thick are believed to correlate with the Turner Creek shale member. A thin (0.1 foot thick) impure limestone is observed near the middle locally.

Sheldon limestone member.—A fine-grained tan to yellow-brown limestone about 0.5 foot thick is thought to correlate with the Sheldon limestone member. Poorly preserved fusulinids, brachiopod fragments, and echinoderms are the observed fossils.

Jones Point shale member.—Yellow-brown limy nodular shale 1.5 to 2.5 feet thick containing *Chonetes, Meekella,* fusulinids, and bryozoans occurs in the upper part and is underlain by 1 foot or less of green to gray-green blocky unfossiliferous shale and probably represents the Jones Point shale member.

Curzon limestone member.—Interbedded limestone and limy shale 9 to 12 feet thick comprise the Curzon limestone member. Gray limestone 2 to 5 feet thick in the upper part nearly everywhere contains scattered chert nodules and a fauna of bryozoans, crinoids, and brachiopods. Middle and lower beds are interbedded gray limestone and shaly limestone, weathering yellow-brown to tan.

Composita, Neospirifer, Derbyia, Marginifera, bryozoans, and fusulinids are abundant. *Osagia* or other algae locally are present in the upper part. Near the middle of the member 1 to 2 feet of greenish shale is present.

Hartford limestone member.—The basal member of the Topeka limestone directly underlies the Curzon limestone (Iowa Point shale absent) and is represented by about 6 to 9 feet of mostly massive gray to blue-gray, deep yellow-brown weathering limestone. The upper part in some exposures is a brecciated-appearing limestone containing considerable free crystalline calcite and brown limonitic stains in the fractures and as replacement of fossils. The limestone is probably algal in origin but contains sparse fusulinids, crinoids, and brachiopods also. Middle beds are irregularly bedded limestone containing chiefly brachiopods and may seem silty and impure on weathering. Lower beds are gray to blue-gray massive hard limestone with abundant *Cryptozoon* and numerous large brachiopods.

Calhoun Shale

The Calhoun shale ranges in thickness from 35 to 55 feet and averages about 45 feet. The upper part consists chiefly of gray to olive, sandy and silty shale, locally with thin sandstone beds. Carbonized plant fragments are locally abundant.

Near or slightly above the middle a thin algal and molluscan limestone is observed in a few outcrops. At many places the lower beds are represented by several feet of gray very fine-grained micaceous sandstone underlain by a few feet of gray shale.

Beds of sandstone yield small supplies of variable quality water to many stock and domestic wells. Nonsandy beds yield little or no water.

Deer Creek Limestone

Thickness of the Deer Creek limestone ranges from 42 to 62 feet and averages about 50 feet. It is represented by three limestone and two shale members.

The Deer Creek limestone is not an important source of ground water, although a few wells obtain small supplies of water from it at shallow depths.

Ervine Creek limestone member.—The Ervine Creek member is composed almost entirely of light-gray to nearly white hard fine-grained limestone locally containing scattered chert nodules. The individual beds are thin and wavy bedded with several featheredge gray shale partings. Fossils include fusulinids, a variety of brachiopods, *Cryptozoon,* corals, bryozoans, crinoid fragments, ostracods, and mollusks. It ranges in thickness from about 8 to 22 feet.

Larsh-Burroak shale member.—Exposures of the Larsh-Burroak shale member range from 2 to 6 feet in thickness. The upper part is bluish-gray to tan thin-bedded clay shale. Hard black fissile shale comprises the lower part. The shale is unfossiliferous except for conodonts in the black shale.

Rock Bluff limestone member.—The Rock Bluff member is a single hard dense dark gray-blue limestone. On exposure the rock surface weathers to a light gray-tan or cream color. The rock is intersected by two nearly vertical prominent sets of joints. When broken the rock fragments break with sharp edges. Its thickness is uniformly 1 to 2 feet. Fusulinids are common in nearly all exposures. Brachiopods, bryozoans, crinoid fragments, and small mollusks are also present.

Oskaloosa shale member.—The Oskaloosa shale member ranges from 3 to 11 feet in thickness. Gray and yellow-brown clayey and calcareous shale comprises most of the member. Some exposures include a thin dense limestone or soft siltstone in the middle or lower part. Locally parts of the member are slightly sandy and micaceous. Fossils are absent or rare in most exposures.

Ozawkie limestone member.—The basal member of the Deer Creek limestone is the Ozawkie limestone which ranges from 10 to 17 feet in thickness. Typically the upper part comprises 2 to 6 feet of light-buff to yellow-brown somewhat impure massive limestone that weathers in irregular shelly slabs. It is not abundantly fossiliferous but contains sparse brachiopod, crinoid, and molluscan remains and locally fusulinids in the lower part.

Light-gray to tan clayey to slightly sandy shale 1 to 7 feet thick underlies the upper limestone and is underlain by 5 to 7 feet of light gray-white, gray, or blue-gray massive limestone. Some exposures of this part are mostly fusulinid-bearing limestone but elsewhere oölitic and algal limestone forms a prominent part of this ledge. Crinoid remains and brachiopods are also numerous in parts of these beds. One or two thin limy shales occur commonly in the lower or middle part of the lower ledge.

Tecumseh Shale

The Tecumseh shale thins from a maximum of about 55 feet in the north to 25 to 35 feet in the south. It is mostly clayey to silty and sandy blue-gray shale. A fairly persistent thin limestone 1 to 2 feet thick, or a limy shale zone 4 to 6 feet thick occurs in the upper or middle part. The fauna contained is locally chiefly mollusks and algae; in other outcrops especially in the south it consists of abundant fusulinids and brachiopods.

Shale below this limestone or limy zone is gray clay shale and sandy micaceous shale. In some exposures it contains pelecypods, brachiopods, and bryozoans.

The Tecumseh shale is not an important aquifer.

Lecompton Limestone

Measured sections of the Lecompton limestone range from 40 to 66 feet, the average thickness being about 43 feet. Four limestone and three shale members comprise this formation.

Shallow dug wells in the Lecompton limestone locally yield small supplies of ground water. Below the zone of weathering little or no water is obtained.

Avoca limestone member.—The Avoca member ranges from about 1 to 3.5 feet in thickness, averaging about 2 feet. It consists of one to three beds of gray-blue, dense, somewhat earthy limestone (Pl. 4B). Fusulinids are abundant in all outcrops. Algae, brachiopods, crinoids, and mollusks occur in parts of the member but are not everywhere abundant.

King Hill shale member.—The King Hill member is chiefly yellow, greenish, and gray clayey to calcareous shale and averages about 17 feet in thickness. A rather persistent yellow, soft, impure siltstone or "boxwork" limestone which weathers yellow brown occurs in the upper part (Pl. 4B). Locally another impure calcareous siltstone occurs in the lower part. Except for a few brachiopods and mollusks at the top of the member it is mostly unfossiliferous.

Beil limestone member.—The Beil limestone member averages 5 or 6 feet in thickness but where it includes considerable limy shale it is as much as 11 feet thick. In northern exposures the upper part consists of alternating beds of limy abundantly fossiliferous shale and thin flaggy to nodular limestone which weathers gray to tan. The lower part is more massive, irregular to wavy bedded, gray, fossiliferous limestone. Fusulinids, many brachiopods, bryozoans, mollusks, algae, and corals are abundant.

In central and southern outcrops it comprises 5 or 6 feet of gray, irregular to wavy bedded massive limestone characterized by its abundant corals, especially *Caninia torquia* and *Syringopora multattenuata* and many fusulinids. Its characteristic fauna and position above the black fissile shale of the underlying shale member serve to differentiate this member readily from other limestones of the Shawnee group.

Queen Hill shale member.—The Queen Hill shale member, which underlies the Beil limestone, averages about 3 feet in thickness and may be divided into two parts. The upper part is tan to gray, blocky to thin-bedded unfossiliferous clay shale. The lower 0.2 to 1.5 feet is hard, black, carbonaceous, fissile shale. Conodonts are found in the black shale.

Big Springs limestone member.—The Big Springs limestone, comparable to the Leavenworth and Rock Bluff limestone members of other Shawnee megacyclothems, is a dark gray-blue dense hard massive limestone bed. It has prominent vertical joints, the edges of which weather rounded. It commonly is about 1 foot thick, but is as much as 3 feet thick locally. Thicker sections may contain a thin shale break. Fusulinids are abundant, but algae, bryozoans, brachiopods, echinoderm fragments, and mollusks occur in the member also.

Doniphan shale member.—Shale beds ranging from 5 to 27 feet in thickness comprise the Doniphan member. The upper part, 2 to 12 feet thick, commonly is a gray clay shale, thin-bedded or blocky, in places much like an underclay. Locally it contains a few mollusks. Middle beds in southern outcrops contain a thin sandy or conglomeratic molluscan limestone, 3 or 4 feet of silty shale and siltstone, and another thin molluscan limestone. Lower beds in the south comprise 5 to 10 feet of gray or greenish blocky to thin-bedded shale.

Beds below the underclaylike shale in northern and central areas locally contain a thin zone of carbonized plant material with abundant ostracods underlain by 3 to 4 feet of gray shale and unfossiliferous siltstone. A thin conglomeratic molluscan limestone occurs locally at the base of these middle beds. In a few exposures the middle beds are chiefly gray calcareous shale.

Lower beds in northern and central outcrops comprise 2 to 4 feet of interbedded calcareous shale and shaly limestone containing abundant fusulinids directly overlying the massive Spring Branch limestone.

Spring Branch limestone member.—The basal member of the Lecompton formation is the Spring Branch limestone. This member is characterized by its abundant fusulinids in nearly all outcrops. Other fossils are less abundant. It is massive yellow-brown to brown ferruginous slightly wavy-bedded limestone locally somewhat sandy or silty. A thin parting or shale break occurs near the middle in many of the outcrops. Thickness of the member averages about 5 feet.

Kanwaka Shale

Shale beds ranging from 62 to 83 feet thick betwen the Oread and Lecompton limestones comprise the Kanwaka shale. It includes two shale and one limestone member. Beds of sandstone in the Kanwaka shale yield small supplies of ground water to several wells.

Stull shale member.—The Stull shale, upper member of the Kanwaka formation, averages

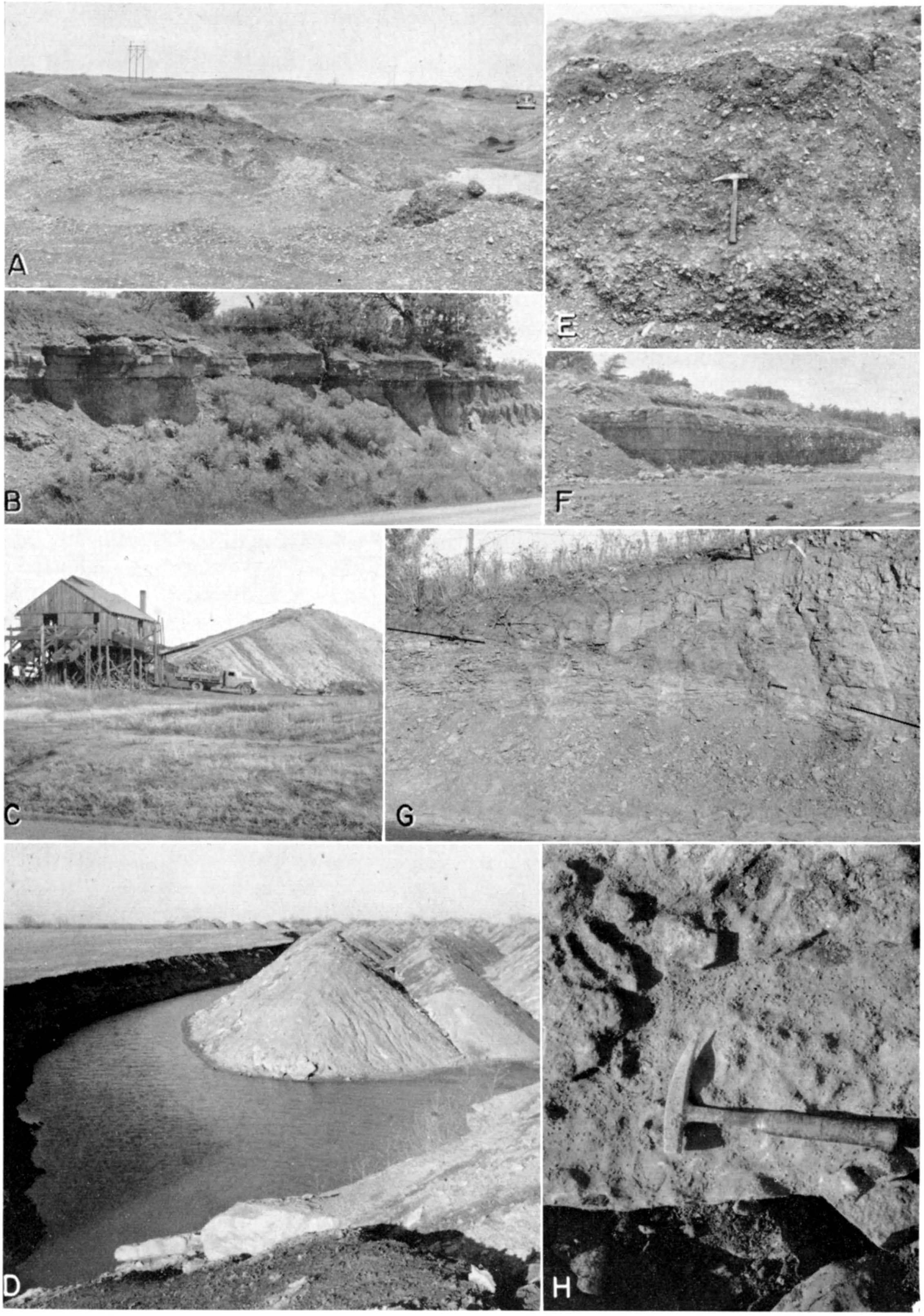


PLATE 4.—**A and E,** Chert gravel quarry in Pliocene (?) terrace deposits, sec. 27, T. 17 S., R. 14 E.; **B,** Avoca limestone and King Hill shale members of Lecompton limestone, NW¼ sec. 6, T. 18 S., R. 16 E.; **C,** Central Fuels Coal Company (Nodaway) coal mine, SW¼ sec. 23, T. 15 S., R. 14 E.; **D,** Oxbow Coal Company strip mine, SW¼ sec. 17, T. 16 S., R. 15 E.; **F,** Duesnbury quarry in Plattsmouth limestone member, sec. 3, T. 18 S., R. 16 E.; **G,** fault in Lawrence shale along K-31 in SW¼ NW¼ sec. 3, T. 17 S., R. 17 E.; **H,** Tarkio limestone with large fusulinids weathering in relief.

about 23 feet in thickness. It is chiefly blue-gray to gray clayey, silty, and sandy shale and very fine micaceous sandstone. *Derbyia, Leda, Yoldia, Pharkidonotus,* and *Bellerophon* occur in the upper part in northern and central outcrops. Carbonized plant remains and limonite nodules occur locally in middle and lower parts.

Clay Creek limestone member.—The Clay Creek member is a bluish-gray, gray-brown weathering fine-grained to granular limestone about 3 or 4 feet thick. It commonly is massive and dense and contains abundant fusulinids. Bryozoans, crinoid fragments, brachiopods, and *Osagia* are present in parts of the member. A thin crust of broken brachiopod, crinoid, and bryozoan fragments about 0.2 foot thick is common at the top of the member. In the upper middle part a thin shale parting is present. The shale parting expands southward. Along the Osage-Coffey County line about as much shale as limestone is present.

Jackson Park shale member.—The Jackson Park shale, lower member of the Kanwaka shale, averages 40 to 50 feet in thickness. Bluish-gray yellowish-tan weathering sandy and silty shale and gray tan-weathering fine-grained quartz sandstone comprise most of this unit. Carbonized land plant remains occur in the shale and locally it contains a thin coaly streak. As much as 30 feet of massive sandstone occurs locally in the lower part of the member.

Oread Limestone

The Oread formation is the lowermost and thickest of the scarp-forming Shawnee group limestones. Its average thickness is about 75 feet. The formation is divided into four limestone and three shale members. It is not an important aquifer, although shallow dug wells obtain small domestic and stock-water supplies locally.

Kereford limestone member.—The Kereford limestone member is the thickest of the Oread limestones, along most of its line of outcrop averaging about 16 feet in thickness but locally is as much as 25 feet. It is variable in lithology, the upper part being granular or oölitic algal-molluscan limestone in some exposures. Next lower is thin dense blue-gray flaggy limestone with many featheredge shale partings. The flaggy limestone is the predominant part of the member and is mostly void of conspicuous fossils. In the lower 5 or 10 feet a sequence, from the base of the platy unfossiliferous limestone downward, of molluscan and brachiopod limestone, fusulinid-bearing limestone, and algal-coral limestone is commonly observed. This part is generally somewhat wavy-bedded. Locally this fossiliferous part includes a thin shale or shaly limestone.

The Kereford makes a secondary bench above the massive Plattsmouth limestone throughout most of its outcrop area.

Heumader shale member.—The Heumader shale member averages 4 or 5 feet in thickness but locally is less than 1 foot thick. It is mostly clayey to silty gray or greenish shale, but may include a very thin brownish-red zone. Mollusks, bryozoans, or brachiopods are present at a few places but fossils are not abundant.

Plattsmouth limestone member.—Light bluish-gray to nearly white limestone that weathers light gray or tan comprises the Plattsmouth member. Average thickness is about 13 feet but as much as 22 feet has been measured (Pl. 4F). The member comprises dense fine-grained wavy-bedded limestone with scattered nodules of blue-gray chert. Fossils, many of which are replaced with clear crystalline calcite, are abundant and include brachiopods, bryozoans, crinoid fragments, corals, algae, mollusks, and fusulinids. Thin wavy featheredge shale partings are common.

Heebner shale member.—Similar in thickness and lithology and occupying the same cyclic position as the Larsh-Burroak and Queen Hill shale members is the Heebner shale member. It averages about 6 feet in thickness but has a range from about 3.5 to 10 feet. The upper part is blue-gray to olive-gray clay shale mostly unfossiliferous, underlain by 2 to 5 feet of black fissile conodont-bearing shale. Small grayish-brown phosphatic nodules occur sparingly in the black shale.

Leavenworth limestone member.—The Leavenworth limestone member ranges from 0.9 to 2.5 feet thick. It comprises a single massive bed of gray-blue, creamy-tan weathering, hard fine-grained vertically jointed limestone. Fusulinids are common; other fossils especially small mollusks are numerous also.

Snyderville shale member. — Predominantly shaly strata between the Leavenworth and Toronto limestone members is included in the Snyderville member. This unit exhibits large variations in lithology and thickness over short distances, ranging from less than 5 feet to about 40 feet, averaging perhaps 25 feet. Except in the thin exposures of Snyderville the sequence of beds is as follows. At the top, 1 to 5 feet of gray or tan-gray blocky clay is underlain by calcareous gray to yellow-tan shale, thin siltstone, and argillaceous limestone. Locally a thin conglomeratic limestone less than 1 foot thick is present near the middle. The lower shale beds may contain a thin impure limestone partly mudcracked and containing sparse mollusks and an algal limestone a few feet above the Toronto member.

Toronto limestone member.—The Toronto limestone is the lowermost member of the Oread formation. It ranges from a nodular light-gray rather weak limestone to a more typical massive, buff- to brown-weathering, hard limestone. A variety of fossils are present, fusulinids, brachiopods, and crinoid fragments being abundant in most exposures. Corals and mollusks are present in less abundance and locally the upper part is platy algal (?) limestone containing ostracods. Thickness of the member is commonly about 8 or 9 feet but may be as much as 13 feet.

DOUGLAS GROUP

Lawrence Shale

The two named members of the Lawrence formation, the Amazonia limestone and Ireland sandstone, crop out in southeastern Osage County although half or less of the formation is exposed at the surface.

That part of the formation occurring between the Toronto and Amazonia limestones ranges from about 5 to 32 feet in thickness and contains the Upper Williamsburg coal (Bowsher and Jewett, 1943). In addition to the coal, which ranges from 0.1 to 1.9 feet in thickness, beds of gray silty to sandy shale, a few inches of underclay, and less commonly a few feet of calcareous fine sandstone are present. The coal bed occurs from 0.5 foot to 30 feet below the Toronto limestone.

Sandstone in the Lawrence shale, chiefly the Ireland member, yields water to many wells in southeastern Osage County. It is an important aquifer.

Amazonia limestone member.—The Amazonia member is a thin gray to blue-gray dense laminated algal (?) limestone. Thin veinlets of greenish clay occur irregularly through the limestone. It ranges from 0.5 to about 2 feet in thickness and is relatively nonresistant to weathering. Brachiopods are sparse in a few exposures.

Ireland sandstone member.—The name Ireland sandstone member is applied to one or more beds of sandstone below the Amazonia limestone member. The sandstone is light gray when fresh but the small amounts of iron oxide present cause the sandstone to weather to various shades of tan, buff, and brown. The sandstone is unfossiliferous, chiefly fine to very fine quartz with a small percentage of mica and clay minerals. The sandstone grades laterally into sandy or silty shales.

Parts of the Lawrence shale between the Amazonia limestone member and the first beds of sandstone (Ireland) which underlie it are silty micaceous gray shale and locally include one or two thin sandy impure limestones.

STRUCTURAL GEOLOGY

No attempt was made to map structures in this investigation but the general structure of the surface rocks is shown on the areal map (Pl. 1). The dominant structure of the area is a gentle homocline dipping slightly north of west. Superimposed on this are many smaller synclinal and anticlinal structures, some of which are large enough to be recognizable on the areal geologic map without structural mapping.

Three faults are shown on the geologic map although at several other localities it is possible that small faults are present but the fault plane is not observable.

The fault in sec. 36, T. 18 S., R. 15 E. along the Osage-Coffey County line can be traced for at least a mile into Coffey County and has an estimated throw of 20 or 30 feet and was first noted by a geologist of the State Highway Commission mapping in that area.

The fault north of Quenemo along Salt Creek Valley (Pl. 4G) has a throw of 30 to 40 feet in sec. 3, T. 17 S., R. 17 E. and there is considerable evidence that it extends eastward some distance into Franklin County.

Small displacements along faults in parts of the Howard and Oread limestones have been reported in several mining operations.

The many sharp structures observable in the Oread limestone and to a lesser extent in the

Lecompton limestone in southeastern Osage County suggest considerable crustal unrest concurrent with the deposition of these late Pennsylvanian sediments. Rich (1932) has reported similar crustal movements and faulting in southern Douglas County.

PART 2

MINERAL RESOURCES OF OSAGE COUNTY

By

HOWARD G. O'CONNOR, WALTER H. SCHOEWE, EDWIN D. GOEBEL, AND NORMAN PLUMMER

INTRODUCTION

The known mineral resources of Osage County comprise coal, limestone, sandstone, shale, sand and gravel, silt, and clay. Ground water, also an important mineral resource, is discussed separately in Part 3 of this report. Coal has been mined since the 1860's and for many years Osage County ranked first among Kansas coal-mining counties. Clay resources have been used to a very small extent if at all. No commercial amounts of oil or gas have been produced. Limestone and chert sand and gravel have been produced for local use for many years, but large reserves remain.

Plate 2 is an economic map of Osage County. Locations of active and inactive gravel pits, rock quarries, and coal mines, names of exploited stratigraphic units, and test data on several of the limestones, shales, and clays are indicated on the map and in Tables 1, 2, and 3. Locations of all test wells drilled in search of oil or gas for which any information is available also are shown. The map shows the lowest stratigraphic depth reached and present status of all wells. Locations of roads, railroads, streams, oil and gas pipelines, pumping stations, and benchmarks are indicated.

ECONOMIC GEOLOGY OF OUTCROPPING ROCKS

Properties, sequence, and age of outcropping rocks are discussed in Part 1 of this report. Their distribution is shown on Plate 1.

LIMESTONE

Many of the outcropping limestones have economic importance because of their thickness, lithology, or composition. The principal uses for which these rocks are suitable include concrete and other aggregate, crushed rock for road metal, agricultural limestone, industrial limestone, riprap, subgrade and embankment material, and building stone. Because of specific chemical or physical properties some of the limestones are suitable for specialized uses. Chemical analyses of rock samples from some of the ledges are listed in Table 1. Location of the active and inactive or abandoned quarries together with the stratigraphic unit represented is shown on Plate 2.

CRUSHED ROCK AND RIPRAP

Many of the thicker ledges in Osage County are potential sources of rock for crushing and riprap material. Because of thickness, physical properties, and geographic distribution some of the ledges have been used extensively whereas others have not been quarried. No recommendations of beds for aggregate or riprap material are made because of the many specifications for aggregate for specialized uses and because no physical tests on any of the limestones were made.

Limestones known to have been quarried for crushed rock or riprap in the past 5 years (1949-1954) include the Tarkio and Reading limestones, the Utopia member of the Howard limestone, the Ervine Creek member of the Deer Creek limestone, and the Kereford and Plattsmouth members of the Oread limestone. The Duesnbury quarry (Pl. 4F) at Melvern is reported to have produced about 60,000 tons of rock, as aggregate, road metal, and agricultural lime, during 1953 and produces the largest annual tonnage of any quarry in Osage County (K. B. Duesnbury, personal communication). The principal stratigraphic unit quarried is the Plattsmouth limestone but smaller amounts of the Kereford limestone have been quarried also.

Projects requiring riprap for road, bridge, or railroad fill and embankment protection have

TABLE 1.—*Chemical analyses of selected outcropping limestones from Osage County*
(Analyzed under the supervision of Russell T. Runnels in State Geological Survey laboratories)

Stratigraphic unit, thickness, and type of sample	Location	SiO_2	*Al_2O_3	Fe_2O_3	CaO	MgO	P_2O_5	SO_3	Ignition loss	**Calculated $CaCO_3$	***Calculated $MgCO_3$
Ervine Creek ls., composite of 9.8 ft.	NE NW 32-14-17E	2.77	0.85	1.32	52.12	1.03	Trace	Trace	42.02	93.02	2.15
Tarkio ls., spot sample, lower 2.5 ft.	SE SE 12-15-13E	5.34	1.64	2.24	49.32	0.95	0.07	Trace	39.85	87.80	1.99
Curzon ls., composite of 6 ft. of bed	SE NE 27-15-15E	3.61	0.81	1.22	52.75	0.47	0.11	Trace	41.18	93.83	0.98
Ozawkie ls., composite of 11.7 ft. (without shale partings)	NW NE 4-15-17E	3.87	0.82	2.73	51.28	0.88	Trace	Trace	40.81	91.52	1.84
Upper Elmont ls., spot sample, 1.5 ft. bed	NW NE 23-16-13E	2.17	1.57	1.42	51.73	1.32	0.10	0.47	41.90	91.44	2.76
Middle Elmont ls., spot sample, 1.5 ft. bed	NW NE 23-16-13E	5.75	1.76	1.08	49.50	0.91	0.10	0.37	39.90	87.59	1.90
Lower Elmont ls., composite of 3.5 ft. bed	NW NE 23-16-13E	4.89	1.06	1.21	49.43	1.38	0.06	0.32	40.73	87.70	2.89
Hartford ls., composite of 5 ft. bed	NW SE 12-18-14E	0.74	0.24	0.53	54.37	0.51	0.07	....	43.13	96.81	1.07
Curzon ls., composite of 5.8 ft. bed	SE SW 14-18-14E	3.45	0.75	0.66	51.84	0.96	0.06	Trace	41.62	92.39	2.01
Hartford ls., upper 3.5 ft. of 8.5 ft. bed	SE SW 14-18-14E	2.88	3.89	5.01	30.77	13.54	0.20	0.13	42.59	54.30	28.14†
Hartford ls., lower 5 ft. of 8.5 ft. bed	SE SW 14-18-14E	0.82	0.25	0.67	54.56	0.53	0.08	....	43.07	97.11	1.11
Plattsmouth ls., composite of 20.2 ft. bed	NW SW 3-18-16E	3.89	1.04	1.32	49.59	2.15	Trace	0.16	41.24	88.31	4.50

*Includes MnO and TiO_2. †Calculated $FeCO_3$, 7.27.
**At 1,000°C.
***Not corrected for small percentages of Ca in phosphates and sulfates.

utilized the nearest local limestone available which occurred in suitable quantities and had the necessary physical requirements.

AGRICULTURAL LIMESTONE

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

Of 12 samples of limestone collected for chemical analysis all but one met minimum requirements for calcium carbonate equivalent (Table 1). Only those limestones that are thick enough to quarry profitably and are suitable for most uses have been exploited to any extent. These include the Plattsmouth and Ervine Creek limestone members.

STRUCTURAL STONE

Requirements for structural stone, or building stone, vary greatly with the intended use. In addition to durability and bearing strength, the color, both fresh and weathered, is an important consideration for some structural building stone.

The Tarkio, Reading, lower Topeka, Ozawkie, Utopia, Church, and Kereford limestones have been quarried and used locally as structural stone, but for various reasons have never become popular. The principal use of each of these limestones except the Utopia and Kereford limestones has been for farm buildings and minor engineering work, such as small bridge abutments, foundations, and walls. Both the Utopia and Kereford limstones have been quarried chiefly for flagging.

No plants utilizing diamond or gang saws have been established in Osage County for the production of cut or dimension stone or veneer stone. Structural stone production has been limited to intermittent operation of small quarries to produce hand-selected but uncut stone for the local market.

Flagging was shipped from Osage County quarries to Topeka and Emporia chiefly for use as paving sidewalks in the 1880's and 1890's.

CERAMIC MATERIALS

Shales from eight locations were tested to determine drying and firing characteristics. Samples from location OG-8 (Pl. 2) were taken by rotary drilling, and those from location OG-15 by core drilling. Shales sampled included White Cloud, Severy, Calhoun, Tecumseh, Stull member, Jackson Park member, and Heumader member.

The data given in Table 2 were obtained from standard ceramic tests, and indicate that all the shales tested are suitable for the production of heavy clay products such as brick, tile blocks, quarry tile, and drain tile. All samples fire to a shade of red, required firing or burning temperatures ranging from cone 04 (about 1920° F.) to cone 3 (about 2090° F.). The temperatures suitable for firing any of the shales extend over a range long enough for processing in the commonly used downdraft beehive kiln.

Most of the shales contain enough silt or sand to make them somewhat lean or short when pugged with water for molding or extrusion. For

TABLE 2.—*Ceramic data on shale samples from Osage county*

PLASTIC AND DRY PROPERTIES

Sample no.	Location	Stratigraphic position	Thickness sampled, feet	Water of plasticity, percent	Drying shrinkage, percent
OG-8*	SE SW 17-16-15E	Aarde-Severy	47	19.00	0.87
OG-8-A	do	do	8	19.74	2.19
OG-8-B	do	do	10	17.73	1.10
OG-8-C	do	do	9	18.21	0.88
OG-8-D	do	do	10	17.97	1.45
OG-8-E	do	do	10	20.85	0.72
OG-9	SW SE 8-14-17E	Tecumseh	17	21.84	2.94
OG-10	SE SE 35-16-14E	Severy (middle)	37	20.07	1.57
OG-11	SW SW 4-17-15E	Calhoun	12	25.78	4.09
OG-12	NW SW 22-17-13E	White Cloud	27	22.91	2.05
OG-13	NW SE 19-16-16E	Calhoun	12	27.36	2.95
OG-14	SW NE 7-16-16E	Tecumseh (lower)	12	27.15	6.60
OG-15-C**	SE SW 14-16-14E	Severy (upper)	24	18.82	1.87
OG-15-D	do	Severy (middle)	18	18.92	2.07
OG-15-E	do	Severy (lower)	18	18.86	2.61
OG-15-F	do	Calhoun (upper)	7	19.55	2.31
OG-15-J	do	Tecumseh	15	19.09	3.63
OG-15-K	do	Stull	14	19.84	3.70
OG-15-N	do	Jackson Park (lower)	29	19.08	3.57
OG-15-O	do	Heumader	13	22.47	5.26

FIRED PROPERTIES

Sample no.	Fired to cone	Fired color	Linear shrinkage, percent	Total linear shrinkage, percent	Percent absorption: 24 hours cold water	Percent absorption: 5 hours boiling water	Saturation coefficient
OG-8	06	Red	***0.58+	0.29	17.30	23.33	0.74
OG-8-A	04	do	2.16	4.35	13.69	16.79	0.82
	01	do	5.11	7.30	7.49	10.76	0.70
	2	Dark red	6.79	8.98	4.11	6.96	0.59
OG-8-B	04	Red	0.14	1.24	14.83	20.57	0.72
	01	do	1.27	2.37	12.32	18.39	0.67
	2	Dark red	2.59	3.69	9.74	15.84	0.61
OG-8-C	04	Red	0.23+	0.65	15.95	22.28	0.72
	01	do	0.89	1.77	14.10	20.66	0.68
	2	Dark red	2.49	3.37	10.19	16.58	0.61
OG-8-D	04	Light red	0.29+	1.16	16.15	22.28	0.72
	01	Red	0.84	2.29	13.80	20.49	0.67
	2	Dark red	2.41	3,86	10.41	16.90	0.62
OG-8-E	04	Red	0.09	0.81	20.12	26.37	0.76
	01	do	1.90	2.62	16.71	22.82	0.73
	2	Dark red	3.65	4.14	12.90	18.58	0.69

OG-9	05	do	3.12	6.06	11.64	14.54	0.80
	02	Weak red	6.00	8.94	5.23	7.87	0.66
	3	Red	8.09	11.03	1.56	2.99	0.52
OG-10	05	Orange red	2.30	3.87	14.26	17.21	0.83
	02	Weak red	5.20	6.77	7.77	11.26	0.69
	3	Red	8.04	9.61	2.68	5.08	0.53
	4	Dark red	8.63	10.20	0.67	1.15	0.58
OG-11	05	Orange red	4.46	8.55	10.23	12.44	0.82
	02	Weak red	7.62	11.71	3.39	4.31	0.79
OG-12	05	Orange red	3.38	5.83	12.25	15.03	0.82
	02	Red	6.45	8.50	6.31	9.25	0.68
	3	do	8.94	10.99	1.59	2.58	0.62
OG-13	05	Orange red	6.84	9.79	9.16	10.85	0.84
	02	do	9.68	12.63	1.08	2.47	0.44
OG-14	05	do	5.89	12.49	3.86	5.53	0.70
	02	Red	7.81	14.48	0.22	1.31	0.17
OG-15-C	05	Pale red	0.19	2.06	15.26	20.92	0.73
	1	Light red	2.01	3.88	11.67	17.49	0.67
	3	Red	5.04	6.91	5.46	11.05	0.49
OG-15-D	05	Light red	0.31	2.38	16.15	20.66	0.78
	1	Pink buff	1.83	3.90	12.29	17.07	0.72
	3	Red	4.98	7.05	6.34	11.22	0.57
OG-15-E	05	Orange red	0.66+	1.95	18.53	23.20	0.80
	1	Pinkish yellow	0.17+	2.44	16.97	22.45	0.76
	3	Yellow red	1.54	4.15	11.69	17.75	0.66
OG-15-F	05	Orange red	0.42+	1.89	15.17	20.28	0.75
	1	do	0.85	3.16	12.76	18.46	0.69
	3	Red	3.65	5.96	7.41	13.12	0.56
OG-15-J	05	Orange red	1.11	4.74	11.88	14.61	0.81
	1	do	2.05	5.68	10.29	13.51	0.76
	3	Yellow red	3.77	7.40	3.83	6.91	0.55
OG-15-K	05	Pale red	4.69	8.39	6.93	9.04	0.77
	1	Weak red	6.92	10.62	2.48	4.36	0.57
OG-15-N	05	Light red	2.71	6.28	10.36	12.78	0.81
	1	Reddish pink	4.56	8.13	6.37	8.90	0.72
	3	Red	7.52	11.09	1.21	3.25	0.37
OG-15-O	05	Pale red	7.15	12.41	5.95	7.30	0.82
	1	Weak red	7.02	12.28	1.01	2.00	0.51

*OG-8 is a composite of samples OG-8-A through OG-8-E, which are successive samples taken by drilling. OG-8-A represents the upper 8 feet, etc.

**Samples OG-15-C through OG-15-O were taken from drilling cores from the same test hole.

***(+) Indicates expansion.

most this should be considered an advantage because shales of this type can be dried rapidly without danger of cracking or warping.

The shales were also tested for their suitability as a raw material for producing lightweight concrete aggregate by the rotary kiln method of bloating. The test kiln used is a small batch type. Samples tested in this kiln were preheated to about 1000° F. before being charged into the rotary kiln. Total bloating time ranged from 4 to 9 minutes. The results of these tests are given in Table 3. Unit weights were determined on samples crushed through rolls set three-sixteenths inch apart. This produced an aggregate with maximum sizes slightly more than three-eighths inch in diameter. Unit weights of the crushed samples ranged from 28.40 to 55.00 pounds per cubic foot. This is well within the limit of 75 pounds per cubic foot set by the American Society for Testing Materials (1949) for lightweight aggregate.

TABLE 3.—*Results of lightweight aggregate bloating tests on Osage County shales*

		Firing temperatures, degrees F.				
Sample no.*	Time in kiln, minutes	Initial softening	Formed soft roll	Maximum attained	Unit weight, lbs. per cu.ft.	Color of crushed aggregate
OG-9	8	2220	2240	2240	54.30	Dark gray
OG-10	5	2170	2230	2260	47.73	Dark gray
OG-11	4	2260	2270	2290	43.80	Dark gray
OG-12	9	2200	2240	2240	47.73	Dark gray
OG-13	6	2220	2260	2260	43.55	Red and dark gray
OG-14	5	2220	2240	2240	28.40	Red and gray
OG-15-C	6	2230	2250	2260	49.10	Tan and dark gray
OG-15-D	6	2170	2190	2210	48.10	Dark gray
OG-15-E	6	2180	2230	2260	48.80	Dark gray
OG-15-F	5	2120		2180	55.00	Black and tan
OG-15-J	5	2100	2140	2180	38.10	Dark gray
OG-15-K	5	2160	2170	2190	41.40	Black and tan
OG-15-N	5	2100	2110	2190	41.90	Black and tan
OG-15-O	5	2140	2160	2180	44.10	Black and tan

*Stratigraphic position and location given in Table 2.

Unit weights ranging from 40 to 50 pounds per cubic foot are usually considered desirable. Ten of the shales tested fall within this range.

GRAVEL, SAND, AND SANDSTONE

Extensive deposits of gravel and sand composed of chert occur in the terraces of Kansan age and older (Pl. 4A, 4E). These gravel deposits have been used without washing or sizing as road metal on county and township roads for many years. The red clay matrix which fills the voids in the sand and gravel serves as a binder when used as road surfacing material, but limits the uses to which the sand and gravel may be suitable without washing and cleaning.

Gravel and sand in the alluvium and low terrace deposits are not well suited for commercial production because the deposits are poorly sorted and contain varying amounts of hard (limestone, chert, and quartz) and soft (shale, siltstone, and sandstone) rocks. Because it is generally necessary to remove considerable overburden of silt and clay to obtain the sand and gravel and because of the poor quality of material, these deposits likely will remain of little importance as a source of sand or gravel. Locally, small amounts of this material have been removed directly from stream beds for use as an inexpensive but poor quality road metal.

Deposits of fine to very fine (0.25-0.0625 mm) quartz sandstone occur in several of the outcropping shale formations. Individual quartz grains are angular to subangular. Associated with the quartz are scattered mica flakes, glauconite, and pyrite. The sandstones range from well cemented to friable, soft sandstone on the outcrop and grade laterally into sandy shale and shale. One small quarry in the Severy shale (NW¼ sec. 1, T. 14 S., R. 15 E.) has been worked recently for sandstone for use as a road material.

COAL

At least nine separate coals have been identified in outcrops in Osage County (stratigraphic column, Pl. 2), but only two, the Nodaway and upper Williamsburg, have been mined to any extent. Schoewe (1946) presents data on the history, location of mines, production, and reserves of coal in the Wabaunsee group. Bowsher and Jewett (1943) compiled similar data on coals of the Douglas group.

The following additional information on mining and coal reserves was compiled as of January 1, 1954.

Two coals, the upper Williamsburg of the Douglas group and the Nodaway of the Wabaunsee group, have been mined in Osage County. Of these two coals, the Nodaway is the only one currently mined and is the one of greatest commercial importance. Cumulative Nodaway coal production of Osage County from 1869 to 1953 inclusive is 11,733,692 tons. Although Osage County at present ranks 5th in production of coal among the Kansas coal mining counties, it formerly ranked first. The period from 1885 to 1892 marked the greatest development of the Osage County mining industry. In 1889, Osage County had 118 coal mines which employed 2,271 men and produced almost 400,000 tons of coal. Seventy-five mines employing 2,917 men were operated in 1891, whereas in 1953, there were only 4 strip and 3 shaft mines mining coal, employing 85 men and producing less than 15,000 tons of coal. The Nodaway coal averages 18 inches in thickness and is mined at the surface by stripping (Pl. 4D) and in shaft mines (Pl. 4C) to a depth of 120 feet. The upper Williamsburg coal averages 12 inches in thickness and lies from 12 to 50 feet beneath the surface in the Quenemo mining area. Production of the Williamsburg coal was never great. As of January 1, 1954, the measured Nodaway coal reserves of Osage County are estimated at 55 million tons of which approximately 35 million tons are within strippable depths, whereas 20 million tons constitute the deep coal. Of the strippable coal 75 percent (or 26,250,000 tons) is considered recoverable coal whereas 50 percent of the deep coal (or 10 million tons) is recoverable. The total recoverable measured Nodaway coal therefore amounts to 36,250,000 tons. The indicated Nodaway coal reserves underlie 49.5 square miles, average 18 inches in thickness, and total 85,536,000 tons of coal. The inferred Nodaway coal is estimated at 142,800,000 tons. The upper Williamsburg coal reserves are estimated at 3,720,000 tons for the measured and indicated reserves and 7,200,000 tons for the inferred reserves.

SUBSURFACE ROCKS

STRATIGRAPHY AND STRUCTURE

Osage County lies in the southwestern part of the Forest City basin. Subsurface conditions along a north-south line through the central part of the county are shown on Figure 2. Major rock units are differentiated.

The surface rocks generally dip west by northwest, but the pre-Chattanooga subsurface units dip more northerly into the North Kansas basin.

A brief discussion of the stratigraphy of the major rock divisions present in the subsurface of Osage County is given in the following paragraphs.

PENNSYLVANIAN ROCKS

Pennsylvanian rocks in Osage County have a maximum thickness of about 2,250 feet. The west by northwest dipping Pennsylvanian rocks do not have a constant thickness due to slight lateral changes in the thickness of the units, and because some have been removed from the eastern part of the county by erosion.

The Wabaunsee rocks are well exposed in western and northwestern Osage County. The thickness of Wabaunsee rocks in the county is about 500 feet. The group of rocks is composed of thin fusulinid-bearing limestone and clayey and sandy shale.

The Shawnee group consists of less than 350 feet of clayey and sandy shales ranging up to about 80 feet in thickness, and limestones generally less than 20 feet thick. The Douglas-Pedee group is composed mostly of clastic material and discontinuous thin beds of limestone and shale. They have a maximum thickness of 275 feet. The Lansing-Kansas City group comprises predominantly limestones. The combined groups have a total average thickness of about 375 feet. The Pleasanton shale averages about 130 feet in thickness in the county. The Marmaton group, about 140 feet thick, is characterized by limestones separated by thin shales. The "Cherokee" rocks are made up of about 500 feet of shales with some thin discontinuous limestones and sandstones.

MISSISSIPPIAN ROCKS

The undifferentiated Mississippian rocks in Osage County consist of an uninterrupted sequence of characteristically cherty limestones. They range from 250 to 400 feet in thickness (Lee and others, 1946, sheet 5). The Chattanooga black shale ranges in thickness from 50 to nearly 150 feet. The greater thickness is in the northwestern part of the county.

PRE-CHATTANOOGA ROCKS

The Chattanooga shale overlaps the upper part of the "Hunton" limestone, the Maquoketa shale, and the beveled beds of the Viola limestone in northwestern Osage County. Along the line of the cross section (Fig. 2) the "Hunton" limestone ranges from a featheredge to about 35 feet. Silurian rocks are believed to be absent in the county (Lee, 1943, fig. 13). Some Maquoketa shale (uppermost Ordovician) is present in the northern part of the county (wells 1 and 2, Fig. 2). The Viola limestone ranges from 50 to 100 feet in thickness along the line of the cross section. The Simpson rocks consist of sandstones which range in thickness from 10 to 50 feet. The interval between the top of Pre-Cambrian rocks and the top of the St. Peter sandstone ranges from about 400 feet in northwestern Osage County to almost 800 feet in the southeastern corner (Lee and others, 1946, sheet 1).

Keroher and Kirby (1948) indicate that (1) the Jefferson City-Cotter rocks in Osage County range from 100 feet in the northwest corner to more than 250 feet in the southern part, (2) the Roubidoux rocks have an average thickness of 100 feet, (3) the Van Buren-Gasconade strata range in thickness from less than 50 to more than 100 feet from west to east across the county, (4) the Eminence dolomite is absent in southwestern Osage County and ranges from a featheredge to more than 50 feet in thickness northeastward, (5) the Bonneterre dolomite, more than 50 feet thick, lies on Pre-Cambrian rocks throughout the county.

OIL AND GAS EXPLORATION

No commercial quantities of oil or gas have been reported from Osage County. The Pomona gas pool (now inactive), located in Franklin County, just east of the eastern Osage County line, produced from the "Squirrel sand" in the upper part of the "Cherokee" group. Gas wells have

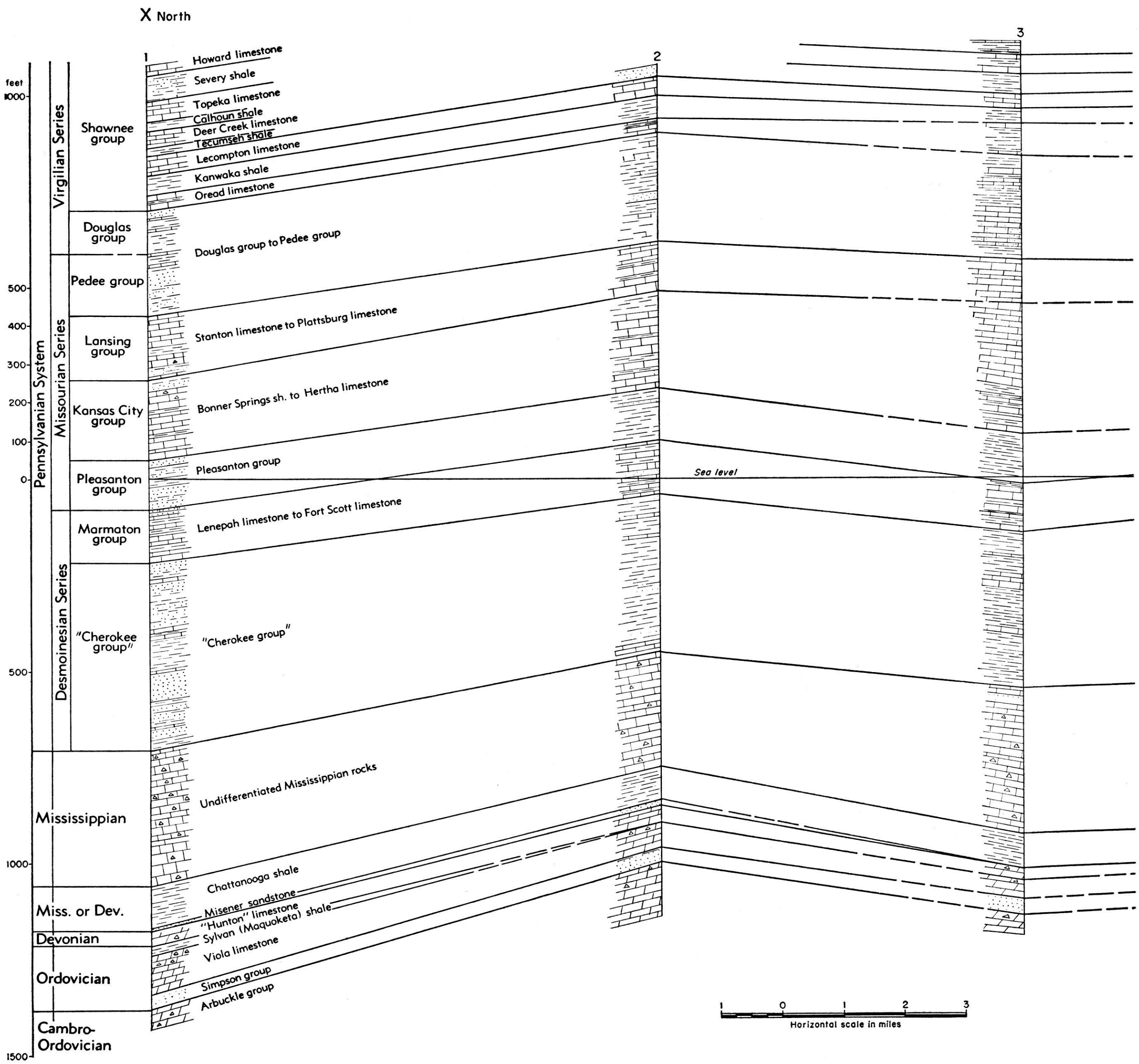
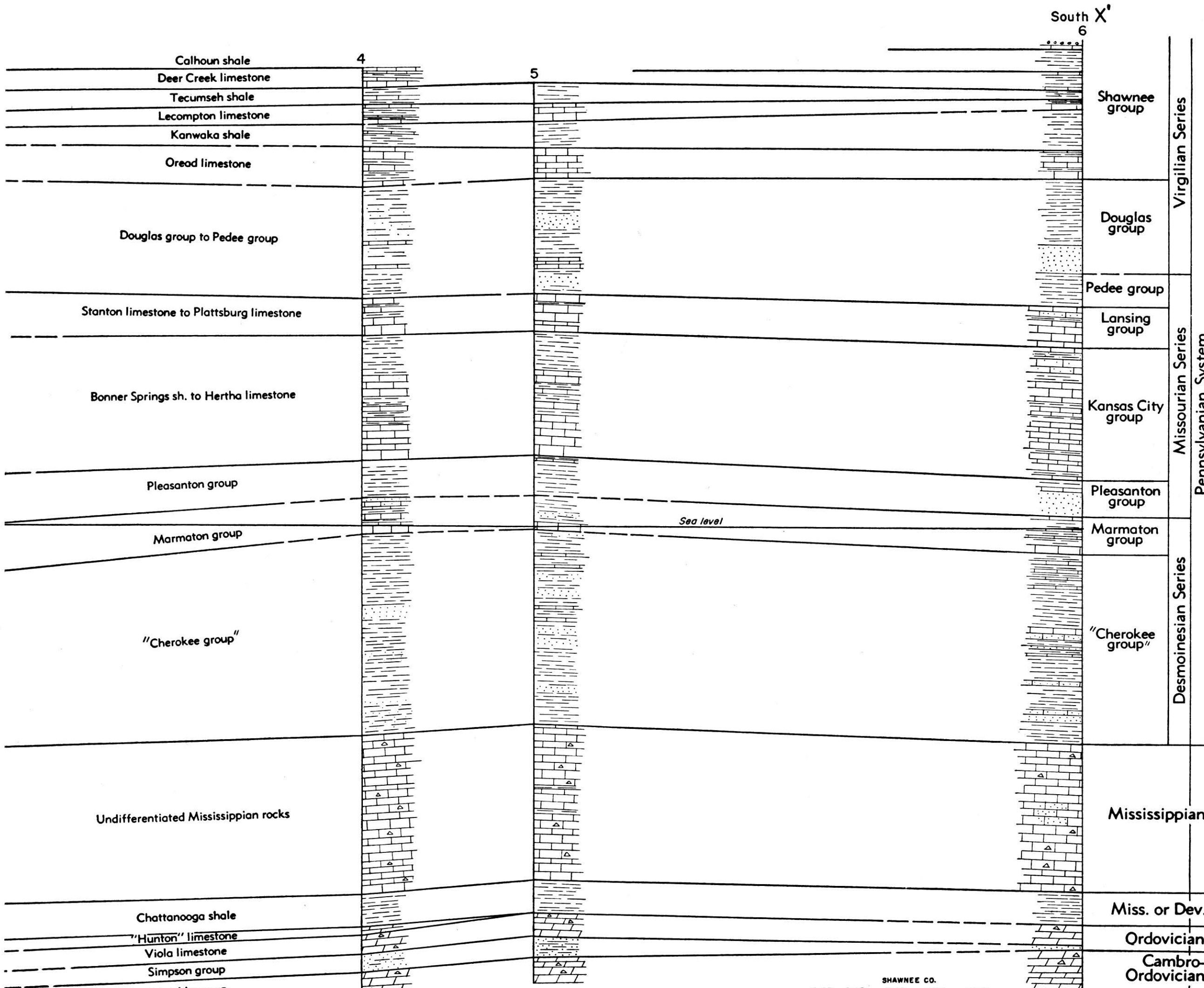
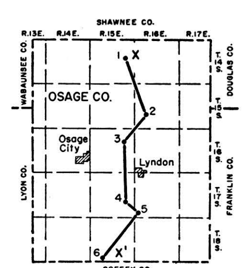


FIG. 2.—Geologic cross section showing conditions along a north-south line



NO.	LOCATION	FARM	COMPANY
1	Sec. 14, T.14S., R.15E.	Oberle	Woods Oil and Gas Co.
2	Sec. 20, T.15S., R.16E.	Peterson	Gulf Oil Corp.
3	Sec. 14, T.16S., R.15E.	Hyde	Orlando Petroleum Co.
4	Sec. 23, T.17S., R.15E.	Sturdy	G.N. Rupe
5	Sec. 31, T.17S., R.16E.	Vanderslice	Smith and Cameron
6	Sec. 32, T.18S., R.15E.	Woodbury	Empire Gas and Fuel Co.



through the central part of Osage County, differentiating major rock units.

been reported in sec. 16, T. 16 S., R. 17 E. and in sec. 5, T. 17 S., R. 17 E.; however, production has not been substantiated.

The Geological Survey has records of 64 exploratory tests in Osage County (Pl. 2). Although the tests geographically extend throughout most of the county, few were drilled deeper than the top of Mississippian strata. Because of this, the possibility of commercial production from Osage County should not be precluded.

PART 3

GROUND-WATER RESOURCES OF OSAGE COUNTY

By

HOWARD G. O'CONNOR

INTRODUCTION*

Nearly all the rural population and about 70 percent of the total county population depend entirely or in part on ground water for domestic water supplies. A brief discussion of the general principles of the occurrence of ground water and data on the occurrence, quality, quantity, and availability of ground water in various parts of Osage County are given in this report. Information upon which this report is based was obtained from records of 171 wells, records of many drillers logs, logs and samples of 15 test holes in Marais des Cygnes River Valley, Dragoon Creek Valley, and the Carbondale area, and chemical analyses of 33 samples of ground water (28 complete analyses and 5 chloride and nitrate analyses). General information was obtained from many residents concerning water-bearing formations, well yields, and quality of water in many areas of the county.

Jungmann Brothers, Lon Dietrich, and W. D. Wilson, water well drillers, were especially helpful in supplying information on wells that they had drilled in the area.

This investigation was made under the general direction of A. N. Sayre, chief of the Ground Water Branch of the United States Geological Survey, and under the immediate supervision of V. C. Fishel, district engineer of the Ground Water Branch in charge of the cooperative ground-water studies in Kansas.

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 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, a well in the NW¼ NE¼ sec. 10, T. 16 S., R. 17 E., would be numbered 16-17-10ab.

* 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.

SOURCE, OCCURRENCE, AND MOVEMENT OF GROUND WATER

The discussion of the occurrence of ground water in Osage County is based partly on the detailed treatment of the principles of occurrence of ground water by Meinzer (1923). A general discussion of the principles of ground-water occurrence, with special reference to Kansas, has been given by Moore and others (1940). The interested reader is referred to these publications for a more detailed discussion of the occurrence of ground water.

Ground water is the part of the water below the surface of the land that supplies water to wells and springs. It is derived largely from precipitation falling as rain or snow, some of which reaches the zone of saturation by percolation downward through the soil and subsoil.

The rocks in the outer crust of the earth's surface are not solid but contain many openings or voids that contain air, water, or other fluids. Generally, the rock formations below a certain level are saturated with water.

The upper surface of the zone of saturation is not a level surface, nor a static surface, but has many irregularities, which on a modified scale are generally similar to the irregularities of the surface topography. Normally, the small part of the precipitation that reaches the zone of saturation moves slowly toward the rivers and creeks or their tributaries and discharges into them or is lost by transpiration and evaporation in the valley areas.

Water in the zone of saturation available to wells in Osage County may occur unconfined or confined. Unconfined, or free, ground water is water in the zone of saturation that does not have a confining or impermeable body restricting its upper surface. The upper surface of unconfined water is called the water table. Shallow wells constructed in the near-surface weathered shale, limestone, and sandstone, the alluvial fill in stream valleys, and the colluvial slope deposits generally obtain unconfined ground water. Ground water is said to be confined if it occurs in permeable zones between relatively impermeable confining beds. Most of the deeper drilled wells constructed in the Pennsylvanian and Permian bedrock obtain confined ground water.

GROUND-WATER RECHARGE AND DISCHARGE

The addition of water to the underground reservoir is called recharge and may be effected in several ways. The most important source of recharge is local precipitation. For the shallow upland wells in bedrock local precipitation is the only source of recharge. Lesser amounts are contributed elsewhere by influent seepage from streams and ponds and by subsurface inflow from adjacent areas. Locally, however, influent seepage from streams may contribute important amounts of recharge to adjacent alluvial deposits and to bedrock where streams cut across permeable zones in bedrock.

Recharge is seasonal in the midwest, including Osage County. Generally the water levels of wells have been lowered by natural drainage into streams during the winter, when soil is frozen and precipitation is small. During the spring months precipitation is fairly abundant and transpiration and evaporation demands are low, resulting in considerable recharge. Recharge may occur in other seasons, also, whenever precipitation is sufficient to overcome the soil moisture deficiency built up during the preceding dry period.

Ground water moves through the permeable rocks in accordance with the character and structure of the rocks, from points of higher to points of lower elevation. It may discharge directly into a stream as a spring or seep or may be discharged by evaporation or transpiration where the water table is near the surface. A part of the total ground water is discharged from wells, but in Osage County the amount is very small compared with other means of discharge.

Over a long period of time approximate equilibrium exists between the amount of water that is added annually to ground-water storage and the amount that is discharged annually by natural means.

AVAILABILITY OF GROUND-WATER SUPPLIES

The quantity, quality, and availability of ground-water supplies in Osage County depend largely on the geology.

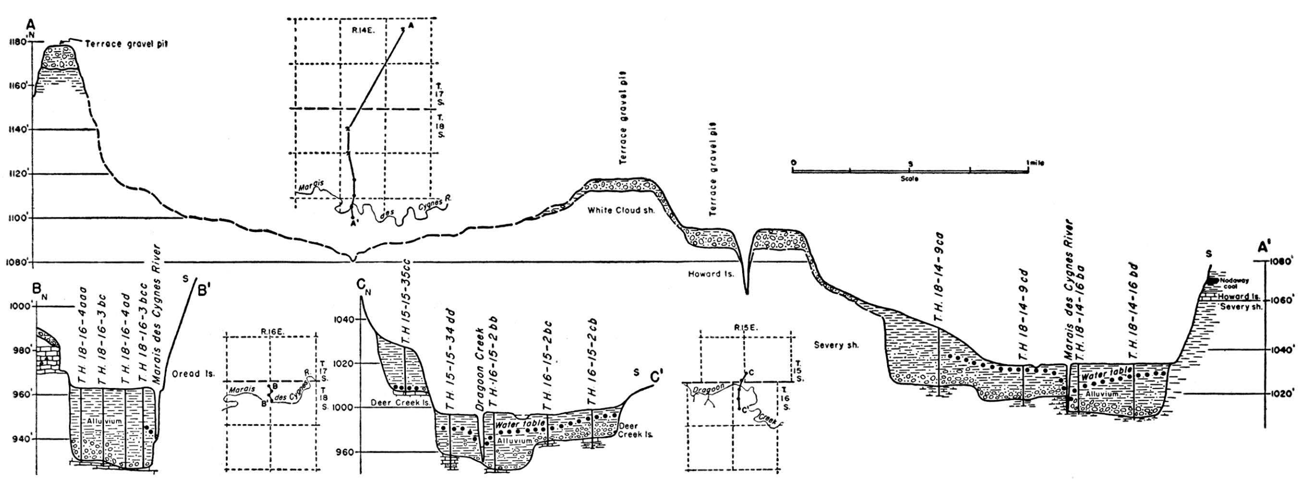


FIG. 3.—Geologic cross sections across Dragoon Creek and Marais des Cygnes River Valleys.

Wells 25 to 40 feet deep constructed in the alluvium and the deposits of the low terraces in the valleys are capable of furnishing excellent stock and domestic supplies, and in the major valleys they furnish small industrial and municipal supplies. Yields of 10 to 50 gallons a minute can be developed in parts of the valleys of the Marais des Cygnes River, Salt Creek, Dragoon Creek, and One Hundred and Ten Mile Creek. Smaller yields can be obtained in the tributary valleys. During prolonged dry periods, the yield of heavily pumped wells in alluvial deposits may be much reduced, and if located in areas of thin alluvial deposits the wells may fail.

Bedrock aquifers yield small to moderate water supplies to wells in two areas of the county. Many wells constructed in the Ireland sandstone member of the Lawrence shale have yields of 1 to 10 gallons a minute. A few wells yield as much as 35 or 40 gallons a minute. These wells range from about 80 to about 350 feet in depth. Because of the large areal extent of the Ireland and consequent large volume of water in storage, water levels in wells obtaining water from it are not noticeably affected by temporary periods of deficient precipitation.

In another bedrock area the White Cloud and Severy shales yield water to many wells at the rate of 1 to 10 gallons a minute. Locally yields may be as much as 20 gallons a minute or as little as 300 gallons a day, however. Wells obtaining water from sandstone beds in these aquifers range in depth from 30 to about 240 feet. The water levels in the deeper wells are little affected by brief periods of deficient precipitation.

Wells that obtain water from other bedrock aquifers develop yields of only a few gallons a day to, in rare instances, as much as 25 gallons a minute. The geographic areas in which the aquifers occur and the range of yields that can be expected are shown on Plate 3 and are discussed in the section describing the ground-water regions.

UTILIZATION OF GROUND WATER

Ground water is obtained from hundreds of stock and domestic wells, records of 161 of which are included in this report, and several public-supply wells.

PUBLIC SUPPLIES

CARBONDALE

The Carbondale water supply is derived from two wells. One well (15-14-24db) near the intersection of Main Street and the Atchison, Topeka, and Santa Fe Railroad is a large dug well 12 feet in diameter and 71 feet deep. It is cased with concrete to a depth of 54 feet and has a natural rock wall the remainder of the depth. It is equipped with a cylinder pump and a 5-horsepower electric motor. In November 1953 the well was yielding less than half a gallon a minute.

The second well (15-14-24dc), about 0.5 mile south of the first, is reported to be a 6-inch drilled well 110 feet deep. It is equipped with a cylinder pump powered by a three-quarters horsepower electric motor set to pump continuously at a rate of one-half gallon a minute. Water from this well is pumped into the large dug well (15-14-24db) from which water is pumped to a 55,000 gallon elevated steel reservoir for distribution.

During most of 1953 the two wells did not supply adequately more than one-fourth to three-fourths of the municipal water requirements, the remainder being hauled by railroad tank car from Topeka, Kansas.

A chemical analysis of the water is given in Table 4.

OVERBROOK

The City of Overbrook is supplied by two drilled wells about 4½ miles east of the city in adjoining Douglas County. The east well (15-17-lacl), 507 feet deep, is cased with 412.5 feet of 6¼-inch iron casing and has a natural rock wall (is uncased) for the remainder of the depth. Water is obtained from about 75 feet of the Tonganoxie sandstone member (Stranger formation). The west well (15-17-lac2), 497 feet deep, is cased with 417 feet of 6¼-inch iron casing and has a natural rock wall for the remainder of the depth. The Tonganoxie is the aquifer in this well also.

During the construction and testing of these wells, the east well is reported to have delivered 50 gallons a minute in a 36-hour pumping test with tubing set 200 feet from the bottom of the well, and the west well delivered 50 gallons a minute at the same pump setting in a 24-hour test. Each well is now equipped with a submersible turbine pump powered by a 7½-horsepower electric motor, set to pump 35 gallons a minute. Water is pumped from the wells to an elevated 50,000-gallon steel reservoir at the east edge of town.

The water is of good quality, although slightly high in iron, as shown by the chemical analysis given in Table 4.

QUENEMO

The water supply of Quenemo is obtained chiefly from two drilled wells completed in 1951 (17-17-10cc1 and 17-17-10cc2). Each well is reported to be 33 feet deep and to obtain water from about 6 feet of alluvial sand and gravel. The wells are cased with 8-inch iron casing and are equipped with electric turbine pumps. Each well yields about 35 gallons a minute.

One other city well (17-17-9da1) is available for emergency use. This well is an 8-inch drilled well 175 feet deep and obtains water from several feet of the Ireland sandstone member (Lawrence shale). It is equipped with a cylinder pump and a 5-horsepower electric motor. The capacity of the pump is greater than the capacity of the well; thus it can be pumped intermittently only and for short periods.

Two other city wells have been abandoned, one (17-17-9da2) because of low yield and the other (17-17-9dd) because the water is salty (Table 4).

Water is pumped from the well field to an elevated 38,000-gallon steel storage tank at the west edge of town.

A chemical analysis of the untreated water from well 17-17-10cc2 is given in Table 4.

CHEMICAL CHARACTER OF GROUND WATER

The chemical character of the ground water in Osage County is shown in Table 4 by the analyses of 33 samples of water collected from wells and test holes. The analyses are given in parts per million. Factors for converting parts per million of mineral constituents to equivalents per million are given in Table 5. These water samples were collected from the principal water-bearing formations and from different parts of the county as evenly distributed as possible. Table 4 includes analyses of three public water supplies. All 33 samples of water were analyzed by Howard A. Stoltenberg, Chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health.

DISSOLVED SOLIDS

When water is evaporated, the residue consists mainly of the dissolved mineral constituents but may contain a little organic matter and water of crystallization. Water containing less than 500 parts per million of dissolved solids generally is satisfactory for domestic use, except for difficulties resulting from its hardness, or in some places, excessive iron content. Water containing more than 1,000 parts per million of dissolved solids 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 28 samples of ground water from Osage County ranged from 278 to 70,900 parts per million (Table 4); about one-third of the samples for which dissolved solids were determined contained less than 1,000 parts per million.

HARDNESS

Hardness of water is commonly recognized by its effects when soap is used with the water. Calcium and magnesium cause nearly all the hardness of water and are the active agents in the formation of the greater part of scale formed in steam boilers and other vessels in which water is heated or evaporated.

In addition to the total hardness, the table of analyses shows the carbonate and noncarbonate hardness. Carbonate, or temporary, hardness can be removed almost entirely by boiling. 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. (The two types of hardness have the same reaction when the water is used with soap.)

Water having a hardness of less than 60 parts per million is rated as soft and is seldom treated to remove hardness. Hardness between 60 and 120 parts per million increases the consumption of soap but does not seriously interfere with the use of water for most purposes. Hardness above 120 parts per million can be noticed by anyone, and if the hardness is about 200 parts per million or more the water is sometimes softened for household use or cisterns are installed to collect soft rain water. Where municipal supplies are softened, the hardness is generally reduced to between 80 and 100 parts per million.

The hardness of 28 samples of ground water collected in Osage County ranged from 22 to 12,200 parts per million (Table 4).

Iron

Iron is generally dissolved in small quantities in most natural ground water. If water contains much more than about 0.1 part per million of iron, part of the iron may precipitate as a reddish sediment. Iron in excess of 0.3 part per million is undesirable as it may cause stains on cooking utensils, bathroom fixtures, and clothing or give a disagreeable taste to the water.

The iron content of 28 samples of ground water collected in Osage County ranged from 0.05 to 11.0 parts per million. All but 4 of the samples contained more than 0.1 part per million; about half the samples contained 0.3 part per million or less.

Fluoride

The fluoride content of water to be drunk by children should be known because of the effect excessive fluoride may have on their teeth. The dental defect known as mottled enamel may appear on the teeth of children who drink water containing excessive amounts of fluoride during the period of formation of their teeth. Teeth affected with mottled enamel have white chalky spots on them or in severe cases may have brown stains or may be pitted.

Water containing 1.7 to 1.8 parts per million of fluoride is likely to produce mottled enamel in about half the children continuously using such water, but the mottling would be largely of the very mild and mild types (Dean, 1936). Fluoride contents up to 1.5 parts per million cause little difficulty, and for that reason the U.S. Public Health Service (1946) has set that figure as its limit. The optimum fluoride content is about 1 part per million (Dean, 1938).

The quantity of fluoride in ground water in Osage County, except some of the ground water obtained from sandstone, is generally less than 1.5 parts per million (Table 4).

Nitrate

In Kansas many of the individual domestic water supplies have dissolved nitrates (NO_3) in concentrations large enough to cause cyanosis of infants if the water were used in the preparation of a baby's formula. For this reason the nitrate

TABLE 4.—*Analyses of water from typical wells in Osage 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	Noncarbonate
14-14-15bb	NW NW 15-14-14E	18.1	Terrace alluvium	7-17-52	....	2,640	16	0.36	430	64	303	353	1,350	93	0.6	204	1,340	290	1,040
14-15-13aa	NE NE 13-14-15E	31.1	Topeka ls. and/or Severy sh.	3-26-47	....	878	14	0.15	185	22	49	354	186	63	0.4	106	552	290	262
14-15-16ba2	NE NW 16-14-15E	172	Calhoun sh.	5-22-52	58									470		239			
14-15-19aa	NE NE 19-14-15E	180	White Cloud sh.	5-22-52	....									80		7.5			
14-15-24ba[b]	NE NW 24-14-15E	495	Ireland ss.	8-29-53	....	8,490	13		418	167	2,450	198	1,700	3,640	1.2	1.1	1,730	162	1,570
14-15-24db	NW SE 24-14-15E City of Carbondale	71	Calhoun sh.	3-10-53	....	1,040	17	1.6	133	34	167	429	351	82	0.6	2.1	472	352	120
14-15-35db	SE NW 35-14-15E	200	Severy and Calhoun sh.	5-22-52	....									322		43			
14-16-18bb	NW NW 18-14-16E	18+	Severy sh.	2-11-47	....	2,750	10	0.05	57	31	944	459	532	980	1.7	5.8	270	270	0
14-16-19ad[c]	SE NE 19-14-16E	643	Tonganoxie ss.	4-20-54		70,900	5.8	11.0	3,010	1,160	22,700	76	1,640	42,400			12,200	62	12,200

14-17-17ba	NE NW 17-14-17E	58.6	Tecumseh sh. and/or Deer Creek ls.	5-22-52	54	1,200	6.0	1.4	286	26	46	332	169	114	0.3	385	820	272	548
15-13-25ba	NE NW 25-15-13E	17.2	Pierson Point and/or Willard sh.	5-21-52	55	1,160	8.2	0.30	215	31	135	382	376	141	0.2	66	664	313	351
15-14-21cd	SE SW 21-15-14E	20.7	Terrace alluvium	5-21-52	....	1,040	14	0.22	206	30	86	262	183	173	0.2	217	638	215	423
15-15-6ab	NW NE 6-15-15E	200	White Cloud sh.	5-21-52	58	672	7.2	0.67	45	13	188	423	170	24	1.0	15	166	166	0
15-16-15ab	NW NE 15-15-16E	23.7	Deer Creek ls. and/or Calhoun sh.	7-17-52	....	1,090	7.0	1.4	151	55	106	342	145	53	0.2	407	602	280	322
15-17-1ac2[d]	SW NE 1-15-17E City of Overbrook	497	Tonganoxie ss.	4- 1-53		604	9.0	0.62	40	15	176	350	37	154	0.8	0.3	162	162	0
15-17-33dc	SW SE 33-15-17E	110	Kanwaka sh.	7-17-52	....	875	7.6	0.07	4.5	2.8	342	517	81	179	1.5	2.0	22	22	0
16-15-5cb	NW SW 5-16-15E	21.5	White Cloud sh.	7-17-52	....	656	1.6	0.07	129	31	51	309	60	94	0.2	137	450	254	196
16-16-18cc	SW SW 18-16-16E	50	Calhoun sh.	7-17-52	....	775	2.8	0.23	185	26	32	295	172	75	0.5	137	568	242	326
16-16-23ba	NE NW 23-16-16E	25.1	Deer Creek ls. and/or Tecumseh sh.	7-17-52	....	1,380	2.2	0.91	340	31	47	252	382	184	0.3	266	976	206	770
16-17-10ab	NW NE 10-16-17E	345	Ireland ss.	5-22-52	....									131		540			
16-17-17cc	SW SW 17-16-17E	34	Terrace alluvium	5-22-52	56	278	12	0.37	78	4.0	14	209	30	13	0.2	24	211	172	39
17-14-10aa	NE NE 10-17-14E	34.5	White Cloud sh. and/or Howard ls.	7-15-52	....	3,440	16	0.56	373	76	642	398	1,560	364	0.6	217	1,240	326	917
17-14-18bc	SW NW 18-17-14E	32.4	Auburn sh.	5-21-52	....	1,840	11	0.23	241	163	86	281	909	75	0.4	217	1,270	230	1,040
17-16-20aa	NE NE 20-17-16E	297	Ireland ss.	5-21-52	58	719	6.2	3.3	140	39	54	390	167	58	0.4	62	510	320	190
17-16-26aa	NE NE 26-17-16E	250	do	5-22-52	58									146		106			
17-16-33dd	SE SE 33-17-16E	120	do	7-17-52	....	1,760	9.0	0.16	7.0	5.0	688	615	72	670	3.6	0.9	38	38	0
17-17-9dd[e]	SE SE 9-17-17E City of Quenemo	167	do	2-25-43	....	369	18	0.18	98	16	18	390	13	9.0	0.3	2.2	310	310	0
17-17-9dd[e]	SE SE 9-17-17E City of Quenemo	228	Tonganoxie ss.	3- 4-36	....	11,700	9.2	4.3	259	141	3,720	146	0	6,510	2.4	8.4	1,220	120	1,110
17-17-10cc2	SW SE 10-17-17E City of Quenemo	33	Terrace alluvium	9-10-52	....	824	16	0.11	159	23	55	359	143	60	0.2	102	491	294	197
17-17-17cb	NW SW 17-17-17E	255	Ireland ss.	5-22-52	57	1,840	7.8	0.27	19	8.0	702	633	98	685	6.0	3.8	80	80	0
18-14-10cc	SW SW 10-18-14E	22.4	Terrace alluvium	5-21-52	....	546	4.0	0.07	94	22	67	336	93	29	0.3	71	325	276	49
18-16-14dd1	SE SE 14-18-16E	170	Ireland ss.	7-17-52	....	514	2.6	0.44	139	14	31	410	93	22	0.1	10	404	336	68
18-16-30bc	SW NW 30-18-16E	14.7	Terrace alluvium	5-21-52	57	1,080	12	0.20	191	32	124	407	485	16	0.3	21	608	334	274
18-17-28cc	SW SW 28-18-17E	20	Kereford ls. and/or Jackson Park sh.	7-17-52	....	438	2.6	0.22	112	14	19	357	64	19	0.2	21	362	292	70

[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] Sample not representative of Ireland sandstone water, includes much drilling water lost to permeable zones penetrated by the test hole.

[c] Sampled after 18 hrs. of continuous pumping at 4 gpm. Sample represents chiefly water from Tonganoxie sandstone but includes some water from Calhoun shale and some drilling water lost to the permeable zones penetrated by the test hole. Chlorides were still increasing and sulfates decreasing at the time this sample was taken.

[d] Overbrook municipal wells located in Douglas County—omitted from tabulated data.

[e] Two analyses listed for this well. One sample when well drilled to 167 feet (Ireland sandstone member of Lawrence shale) and second sample when well deepened to 228 feet (Tonganoxie sandstone member of Stranger formation).

TABLE 5.—*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

content of water to be used by infants should be known. 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 formula preparation. Metzler and Stoltenberg (1950, p. 194) state:

> The nitrates are converted to nitrites and absorbed by the blood, where they destroy its oxygen carrying properties. The blood becomes chocolate brown, the skin develops a blue color, and death may result from oxygen starvation.

Concentrations of nitrate found in ground water generally do not cause cyanosis in older children or adults but may have other adverse effects (Young, 1911).

Because of the soluble nature of natural nitrate minerals and the special conditions necessary for their accumulation, it seems likely that little nitrate is derived from nitrate-bearing rocks in the water-bearing formations. Soil nitrogen in the form of nitrate and ammonia salts probably are the chief source of nitrates found in ground water. Other sources of nitrate are barnyards, cesspools, and privies, which may also contribute dangerous bacteria to ground water.

Shallow dug wells are generally more susceptible to nitrate contamination than are deeper drilled wells. Nitrate concentrations seem to show seasonal variations, being highest in the winter season and lowest during the growing season of late spring and summer (Metzler and Stoltenberg, 1950, p. 202).

Of the 33 samples analyzed, 17 contained more than 45 and 14 contained more than 90 parts per million of nitrate (NO_3). The nitrate content of the 33 samples ranged from 0.3 to 540 parts per million.

SULFATE

Sulfate (SO_4) in ground water is derived chiefly from gypsum and the oxidation of iron sulfides. Sulfate occurring in ground water as magnesium sulfate (Epsom salts) and sodium sulfate (Glaubers salts) in excess of about 500 parts per million may have a laxative effect on persons not accustomed to drinking water containing large amounts of sulfate.

CHLORIDE

Chloride in ground water may be dissolved in small quantities from sedimentary rocks, from connate waters in the sediments, or from sewage. Chloride has little effect on the suitability of water for ordinary use unless the quantity is enough to give the taste of salt. Chloride in excess of about 250 or 300 parts per million can be detected by persons having a sensitive taste. Water high in chloride is corrosive to many metal surfaces.

Sodium chloride is the chief constituent of the ground water in deep aquifers (200 feet or more in depth), which prevents use of otherwise adequate supplies of ground water in some parts of the county.

SANITARY CONSIDERATIONS

The analyses of water (Table 4) show only the amounts of dissolved minerals and do not indicate the sanitary quality of the water. Well water may contain mineral matter that gives the water an objectionable taste, but may be free from harmful bacteria and safe for drinking. Other well water, good tasting and seemingly pure, may contain harmful bacteria. Excessive amounts of certain dissolved minerals, such as chloride or nitrate, may indicate pollution.

A dug well generally is more likely to become contaminated than a properly constructed drilled well, because the opening at the top of a dug well may not be covered adequately and, therefore, not as effectively protected from surface water. A well should not be near possible sources of pollution such as privies, septic tanks, sewer drains, and barnyards.

Recommended sanitary types of construction and suggestions for locations and pump installations for cisterns and dug and drilled wells can be obtained from the Kansas State Board of Health.

GROUND-WATER REGIONS IN OSAGE COUNTY

Ground-water regions in Osage County are determined primarily by the underlying rock materials, the structure of the area, and the climate. The quality of water in the principal aquifers is also a factor considered. On this basis the county is divided into several regions in which ground water occurs under similar conditions. The region boundaries are necessarily generalized and within each region the discussion is not applicable to some wells.

REGION A

Region A (Pl. 3) includes the valley areas underlain by clay, silt, sand, and gravel of the alluvium and low terrace deposits (chiefly Illinoian or younger). In the Marais des Cygnes River Valley and parts of Salt Creek, Dragoon Creek, and One Hundred and Ten Mile Creek Valleys, wells having yields of 10 to 50 gallons a minute can be developed. Water is obtained from sand and gravel in the basal parts of the deposits. The thickness of the fluvial deposits ranges from a maximum of about 40 feet in the Marais des Cygnes River Valley to about 5 feet in small tributary valleys.

In parts of the county where other ground-water resources are available, wells in alluvial deposits are preferred because of their greater reliability during drought periods, larger yields, and better chemical quality of the water. Excellent stock and domestic wells and, locally, small municipal supplies can be developed in most of this region.

REGION B

Areas in which rocks of the Admire and Wabaunsee groups of early Permian and late Pennsylvanian age are the chief source of well water are included in Region B (Pl. 3). Because of differences in depths and yields of wells and quality of water, this region is divided into two parts for purposes of discussion.

Area B1.—In Area B1 of Region B the principal water-bearing beds are the thin sandstones and sandy zones in the shales. The sandstones are composed chiefly of very fine to medium sand grains generally containing enough silt and clay to make them low in permeability. Sandy zones occur locally in nearly all the shale formations, but the zones are not individually extensive or thick. Locally, some of the limestone beds have enough porosity and permeability to yield small supplies of water to shallow wells for domestic or stock use. In other places they yield little or no water to wells.

Throughout most of this area an adequate and dependable supply of water of good quality is difficult to obtain. Most wells are 30 feet or less in depth, although a few are as deep as 60 feet. Ground water obtained from depths greater than 30 to 60 feet generally contains enough of certain dissolved mineral constituents to make it unsatisfactory for domestic use, and in some places water at depths of less than 30 feet is unsatisfactory.

Large-diameter shallow dug wells are the predominant type of well in this area. Yields are generally small and the storage space provided by large-diameter wells is desirable. During dry seasons many wells are inadequate or go dry. Some of the farms in this area have no wells but depend on large cisterns for domestic water supplies and ponds or creeks for stock-water supplies. Ponds and cisterns are important supplements to ground-water supplies in this area.

Area B2.—In Area B2 of Region B many farms have drilled wells which range in depth from about 60 to 240 feet. These wells derive water chiefly from beds of sandstone in the White Cloud shale and the Severy shale. (Some of the wells have been reported to penetrate as much as 40 feet of sandstone.) Yields of drilled wells in this area are reported to range from half a gallon a minute to as much as 20 gallons a minute. Most wells probably yield 2 to 5 gallons a minute. The quality of water from these wells is generally good (well 15-15-6ab, Table 4). Along the western margin of this area chloride generally increases and may limit the usefulness of the water.

Shallow wells comparable in quality of water, depth, and yield to those of Area B1 are also found in the remainder of Area B2.

REGION C

Region C (Pl. 3) includes the area in which wells obtain ground water chiefly from Pennsylvanian rocks of the Shawnee group.

Dug wells, generally 15 to 60 feet deep, obtain small supplies of water from fractures in the limestones and shales. Beds of sandstone, especially in the Calhoun and Kanwaka shales, are the principal source of water for both dug and drilled wells in some localities. Drilled wells obtain water suitable for domestic and stock use at depths ranging from 40 feet to 150 feet. Because the sandstones occur as erratic channel deposits or lenticular beds that grade laterally into shale, wells drilled into these beds are not always successful (14-17-16ab, Table 6).

Water obtained from the sandstones of the Shawnee group is generally a sodium bicarbonate water moderately high in dissolved solids. Chloride is generally the constituent that determines the usefulness of the water. Shallow wells constructed in the weathered limestones and shales generally yield a much harder calcium bicarbonate water.

Wells in this region yield from only a few gallons a day to a maximum of 10 gallons a minute. During years of normal precipitation the average well in this region would probably yield 1 gallon a minute.

Many farms use cisterns to supplement the domestic ground-water supplies and for soft water and have ponds for stock-water supplies.

Water from deeper aquifers in this region is too mineralized for stock or domestic use.

Region D

Pennsylvanian rocks of the Douglas group are the principal aquifers in Region D (Pl. 3). The Ireland sandstone member of the Lawrence shale is extensive in this region, attaining a maximum thickness of 60 to 80 feet. Nearly all the wells in Osage County that tap the Ireland sandstone member are drilled wells that range in depth from about 80 to 350 feet. Yields of these wells range from 1 to 40 gallons a minute.

Local residents report that in a small area in the southeast corner of the county wells drilled to the depth that should penetrate the Ireland sandstone member are not successful because the sand is "dry" or because no sandstone is present. This area includes parts or all of secs. 21, 22, 27, 28, 33, and 34, T. 18 S., R. 17 E. Two Kansas Emergency Relief Committee (K.E.R.C.) wells in sec. 10, T. 18 S., R. 17 E., drilled into the Ireland sandstone member during the drought years of the 1930's, were reported as dry also.

The water obtained from the Ireland sandstone member ranges from a soft sodium bicarbonate water to a somewhat harder calcium bicarbonate water. As in other parts of Osage County where wells obtain water from sandstone, the fluoride content has a wide range of concentration and in many places is more than the recommended maximum of 1.5 parts per million (Table 4). The amount of chloride in some of the wells in the Ireland sandstone member is enough to give a salty taste to the water.

Records were obtained for one well and one test hole drilled into the Tonganoxie sandstone member of the Stranger formation in Osage County (14-16-19ad and 17-17-9dd). The water in each instance was highly mineralized and not suitable for domestic or stock use.

From the data available in Osage County and adjacent counties, it is known that the quality of water in both the Ireland sandstone member and Tonganoxie sandstone member changes from usable to unusable within short distances.

The west boundary of Region D (Pl. 3) depicts as accurately as possible from the data available, the area in which water of suitable quality for domestic or stock use can be obtained from the Ireland sandstone member. Where wells penetrating the Ireland are sparse, the boundary may be in error by one-half to 2 miles.

RECORDS OF WELLS

Information pertaining to water wells in Osage County is given in Table 6. Measured depths to water levels are given to the nearest 0.01 foot, whereas reported depths are given only to the nearest foot. Similarly, measured depths of wells are given to the nearest 0.1 foot whereas reported depths are given only to the nearest foot.

TABLE 6.—*Records of wells in Osage County*

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; drawndown in ft.)
14-13-2cd	SE SW 2-14-13E	....	Dr	421	8	N	Sandstone	Cedar Vale and/or White Cloud sh.	N	N					K.E.R.C. well. Reported salty. No water reported in log between surface and 350 ft.
14-13-13dc	SW SE 13-14-13E	J. E. George	Du	30	±42	R	Shale	Colluvium and/or French Creek sh.	N	N	Land surface	0	2.0	10-25-51	Adequate for stock in drought years of 1933-1936.
14-13-35dc	SW SE 35-14-13E	Edward Ross	Du	17.7	±48	R	Shale or sand & gravel	Langdon sh. or terrace alluvium	Cy, H	D, S	Top of concrete curbing	1.0	10.41	10-25-51	Inadequate in dry years.
14-14-1bc	SW NW 1-14-14E	Tom Shogren	Dr	85	6?	GI	Sandstone or shale	Silver Lake and/or Cedar Vale sh.	Cy, H	D	Land surface	0		5-14-52	Reported slightly brackish.
14-14-10bb	NW NW 10-14-14E	Fairplain Grange	Dr	37.2	5¼	GI	Sandstone	Langdon or Pierson Point sh.	Cy, H	D	Top of concrete curbing	0.2	12.60	10-26-51	
14-14-12cb	NW SW 12-14-14E	Carl Shogren	Dr	60	6	GI	Shale or sandstone	Auburn sh.	Cy, H	D, S	Land surface	0	8	5-14-52	Soft water, low yield.
14-14-15bb	NW NW 15-14-14E	John E. Cochran	Du	18.6	±42	R	Sand and gravel	Terrace alluvium	Cy, H	D, S	Top of concrete curbing	0.5	9.40	10-26-51	Reported adequate in drought years of 1934-36.
14-14-22ad	SE NE 22-14-14E	Harry Carl	Du	25.2	±48	R	Shale or sandstone	Auburn sh.	Cy, H	D	Base of metal pump base	1.4	4.92	10-26-51	
14-14-22ba	NE NW 22-14-14E	Homer Tucker	Du	16.3	±36	R		Pierson Point sh.	Cy, H	S	Top of 2x6 board cover	1.0	8.64	10-25-51	Reported very low yield; inadequate in dry years.
14-14-24ad	SE NE 24-14-14E	Ernest P. Cook	Dr	160	6	GI	Sandstone	White Cloud sh.	N	D, S	Top of GI casing	1.2	10.83	5-15-52	Reported yield +6 from sand at 100-160 ft. Sodium bicarbonate water.
14-14-24cc	SW SW 24-14-14E	Otto Montgomery	Dr	233			do	do	Cy, E	D, S	Land surface	0		5-14-52	Has slight chloride and sodium bicarbonate taste.
14-14-25cc	SW SW 25-14-14E	Leonard Reick	Dr	+200	6?		do	do	Cy, E	D, S				5-14-52	do
14-14-27cc	NE SW 27-14-14E	H. F. Diver	Du	9.6	±48	R	do	Willard sh.	Cy, W	D, S	Top of concrete curbing	1.1	1.23	10-26-51	Reported adequate for stock and domestic in dry years.
14-15-1aa	NE NE 1-14-15E	E. L. Kitchen	Dr	100	9¾	N			N	N				7-20-53	Reported yield, 8 gal./24 hrs.
14-15-2bb	NW NW 2-14-15E	D. S. Robb	Du	29.5	±48	R	Shale or sandstone	Severy sh.	J, E	D	Top of steel rim in curbing	2.7	20.02	5-23-52	Reported adeq. for domestic in dry years of 1934-36.
14-15-4cd	SE SW 4-14-15E	C. Troudner	Du	20	60-90	R	do	Silver Lake sh.	Cy, H	N				5-23-52	Use cistern for domestic. Well not now in use.
14-15-5ab	NE NW 5-14-15E	Claudia Matthews	DD	110	30-6?	R, N	do	Silver Lake and/or White Cloud sh.	N	N	Top of rock curbing	0.8	10.61	5-14-52	Reported adequate but very hard.
14-15-11ac	SW NE 11-14-15E	James Timson	Du	60	±42	R	Sandstone	Severy sh.	J, E	D	Top of concrete curbing	0.7	23.68	5-23-52	Reported adequate.
14-15-11ba	NE NW 11-14-15E	James Timson	DD	105	±84-6?	R, N	do	do	Cy, E	D, S	Land surface	0	20	5-23-52	do
14-15-13aa	NE NE 13-14-15E	Mable Carroll	Du	33.3	±25	T	Shale or limestone	Topeka ls. and/or Severy sh.	Cy, G	S	Top of tile casing	2.2	15.5	3-26-47	
14-15-16ba1	NE NW 16-14-15E	W. C. Wehrle	Du	19.2	±60	R	Shale or sandstone	White Cloud sh.	Cy, H	D	Top of concrete curbing	0.5	6.12	5-15-52	Since 1928 dry twice—in 1934 and 1936.
14-15-16ba2	NE NW 16-14-15E	W. C. Wehrle	Dr	172	6?	GI	Sandstone	Calhoun sh.	Cy, W	D, S	do	1.8	15.45	5-15-52	Yield +5. Sandstone at 160-172 ft. Slight sodium bicarbonate and chloride taste.

TABLE 6.—*Records of wells in Osage 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.)
14-15-17bb	NW NW 17-14-15E	A. L. Arron	Du	60	±48	R	Shale or sandstone	Silver Lake sh.	J, E	D	Top of 2x12 board cover	2.5	2.94	5- 6-52	Reported inadequate in dry years.
14-15-19aa	NE NE 19-14-15E	Harold Urish	Dr	180	8	GI	Sandstone	White Cloud sh.	Cy, W	D, S	Top of concrete curbing	0.6	103.26	5-14-52	Reported adequate. Soft water.
14-15-21da	NE SE 21-14-15E		Dr	254	8		do	Severy sh.			Land surface	0			K.E.R.C. well. Reported yield +8 of "mineral" water from 18 ft. sandstone.
14-15-24ac	SW NE 24-14-15E	City of Carbondale	Dr	327	8		do	Calhoun sh.	Cy, H	D	do	0			K.E.R.C. well. Reported yield 1 from 14 ft. sandstone.
14-15-24dc	SW SE 24-14-15E	City of Carbondale	Dr	110	6	I	do	do	Cy, E	P	do	0			
14-15-24db	NW SE 24-14-15E	City of Carbondale	Du	71	144	C, N	do	do	Cy, E	P	do	0	21	6-15-52	
14-15-27cb	NW SW 27-14-15E	Albert Oberle	Dr	215	5½	GI	do	Calhoun sh.?	Cy, E	S	do	0			Water too saline for horses.
14-15-28bb	NW NW 28-14-15E	Leo Bodine	Du	19.0	±60	R	Sand and gravel	Alluvium	N	N	Base of concrete curb at manhole	0.3	2.63	5-14-52	Former school well.
14-15-28bc	SW NW 28-14-15E	Leo Bodine	Dr	210	6?	GI	Sandstone	Severy sh.	Cy, E	D, S	Land surface	0	10-20	5-14-52	
14-15-28dc	SW SE 28-14-15E	Preston Rutty	Dr	206	6	GI	do	do	Cy, W	S	do	0			Reportedly has noticeable chloride taste.
14-15-31ad	SE NE 31-14-15E	N. J. Mabon	Dr	170	8	GI	do	White Cloud sh.	Cy, W	D, S	do	0			Top of "water sand" at 140 ft.
14-15-35bd	SE NW 35-14-15E	Lou Urish	Dr	200	8	GI	do	Severy and Calhoun sh.	Cy, W	D, S	Top of concrete curbing	0.8	58.19	8-28-51	Reported yield 2. Water at 75 and 200 ft.
14-15-35cb	NW SW 35-14-15E	E. Urish	Du	23.1	±30	R	Sand and gravel	Alluvium	Cy, W		Top of 2x12 board cover	1.3	6.37	8-28-51	
14-16-13bc	SW NW 13-14-16E	Wilson Karnes	Du	9.5	±96	R	Shale or limestone	Calhoun sh. and/ or Deer Creek ls.	J, E	D	Top of concrete curbing	0.5	5.1	5-23-52	Reported adequate.
14-16-22cb1	NW SW 22-14-16E	R. R. Metzler	Du	18	±36	R	Sandstone	Calhoun sh.	B, H	D	Land surface	0			Reported not adequate in dry years.
14-16-22cb2	NW SW 22-14-16E	R. R. Metzler	Du	32	±72	R	Limestone	Ervine Creek ls.	Cy, H	S	Inside rim of concrete curbing at manhole	0.8	4.80	5-23-52	
14-16-34bb	NW NW 34-14-16E	W. W. Knight	Dr	63.4	6?	T	Limestone or sandstone	Topeka ls. and/or Severy sh.	Cy, H	D	Top inside rim of tile casing	0.4	4.60	5-23-52	Reported adequate.
14-16-35dd	SE SE 35-14-16E	E. N. Weiler	Du	54.3	±60	R	Limestone	Topeka ls.	Cy, H	N	Top of concrete curbing	1.4	6.48	5-12-52	Reported not adequate in dry weather.
14-17-3cc	SW SW 3-14-17E	Charles Johnson	Du	30	24	R	Limestone	Deer Creek ls.	Cy, H	D, S		0.8	14.66	11-15-51	Reported dry once in last 65 years.
14-17-10cd	SE SW 10-14-17E	Carl Schimer	Du	24.3	±30	R	do	do	Cy, H	D, S	Bottom of metal pump base	2.0	13.89	6- 2-52	Reported adequate except in very dry years.
14-17-16ab	NW NE 16-14-17E	Charles Desque	Dr	295	6	N			N	N	Land surface	0			Reported as dry hole.
14-17-17ba	NE NW 17-14-17E	Ada Hupp	Du	60	±48	R	Shale or limestone	Tecumseh sh. and/ or Deer Creek ls.	Cy, H	D	Top of 3x12 board cover	1.4	22.50	11-15-51	Reported adequate except one year since 1918.
14-17-21bc	SW NW 21-14-17E	Roy Simmon	Du	35	±48	R	Limestone	Deer Creek ls.	Cy, H	D, S	Land surface	0			
14-17-22dc	SW SE 22-14-17E	C. M. Krouse	Dr	107	6?	GI, I	Sandstone	Kanwaka sh.	Cy, H	D, S	Top of iron casing	0.3	9.70	6- 2-52	Low yield sodium bicarbonate water.
15-13-25ba	NE NW 25-15-13E	Charles Monroe	Du	17.7	±48	R	Shale and/or sandstone	Pierson Point and/ or Willard sh.	Cy, H	D, S	Top of concrete curbing	0.5	6.56	10-25-51	Reported low yield, not adequate in dry years.
15-14-3da	NE SE 3-15-14E	R. D. Terrill	Du	19.7	±96	R, N	Sand and gravel	Terrace alluvium	J?, E	D, S		1.0	11.79	10-26-51	Reported adequate since 1925.

15-14-5da	NE SE 5-15-14E	Albert Smith	Du	14.1	±48	R	Shale or limestone	Willard sh. and/ or Elmont ls.	Cy, W	S	Top of concrete and rock curbing	1.2	5.43	10-25-51	Reported to go dry in dry years, has slick taste.
15-14-17bb	NW NW 17-15-14E	E. W. Stromer	Du	30	±72	R	Shale or sandstone	Silver Lake sh.	Cy, W	D, S	Land surface	0	24	10-25-51	Reported adequate for domestic and 150 head of stock year around.
15-14-21cd	SE SW 21-15-14E	Tom Fisher	Du	21.0	±36-42	R	Sand and gravel	Terrace alluvium	J, E	D, S	Top of concrete curbing	0.3	6.50	10-25-51	Reported adequate.
15-14-27bb	NW NW 27-15-14E	Robert Mings	Du	23.1	±42	R	do	Alluvium	Cy, H	D	Top of 1x4 board flush with concrete curbing	0.5	4.74	10-24-51	do
15-14-29ba	NE NW 29-15-14E	Earl Kimble	Du	22	±60	R	Sandstone or shale	Cedar Vale sh.	J, E	D, S	Land surface	0	6	10-25-51	Reported adequate except in very dry years.
15-15-6ab	NW NE 6-15-15E	Ralph Vandevord	Dr	200	6	GI	Sandstone	White Cloud sh.	Cy, G	D, S	Base of 4x5 board over well fit	0.4	69.98	5- 6-52	Reported adequate, yield approximately 2 or 3.
15-15-6bb	NW NW 6-15-15E	Sam Bell	Du	32.9	±48	R	Shale	Silver Lake sh.	J, E	D	Top of concrete curbing	0.4	7.29	5- 6-52	Reported to go dry in dry years.
15-15-7cb	NW SW 7-15-15E	Clarence Hekstrom	Du	16.7	±24	R	Sandstone or shale	White Cloud sh.	Cy, H	D	do	1.0	3.98	5- 6-52	
15-15-7dc	SW SE 7-15-15E	David Love, Sr.	Du	48.0	±48	R, N	do	do	Cy, W	S	do	1.2	13.28	5-15-52	
15-15-12da	NE SE 12-15-15E	James Heberly	Dr	+80	6	GI	Sandstone?	Calhoun sh. (?)	Cy, H	N	do	0	3.39	5-12-52	Reported salty, not usable for dom. or stock.
15-15-15cb	NW SW 15-15-15E	Alec McIntosh	Du	32	±84	R	Limestone	Utopia ls.	Cy, W	S	Land surface	0	16	5-15-52	Reported adequate.
15-15-18ab	NW NE 18-15-15E	A. D. Tindell	Du	40	±60	R	Sandstone	White Cloud sh.	Cy, W	S	Top of 2x12 board cover	2.2	17.52	5-15-52	Reported adequate since 1907.
15-15-19ad	SE NE 19-15-15E	Earl Thompson	Du	38.0	60-72	R	Sandstone or shale	do	J, E	D, S	Top of concrete and rock curbing	2.0	5.80	10-31-51	Reported not adequate in parts of 1934-36.
15-15-29bc	SW NW 29-15-15E	Grant Watson	Du	35	±60	R	do	Severy sh.	C, E	D, S	Land surface	0	29	10-31-51	Reported adequate, yield approx. 2.
15-16-7cc	SW SW 7-15-16E	School Dist. No. 5	Du	30.2	±36	R	Limestone	Topeka ls.	Cy, H	D	Top of concrete curbing	0.8	4.66	5-12-52	
15-16-11dd	SE SE 11-15-16E	Ulice Butel	Dr	399	8		Sandstone	Ireland ss.		N	Land surface	0			K.E.R.C. well. Reported salty. Water sand at 395-399.
15-16-15ab	NW NE 15-15-16E	Jack Wells	Du	24.5	±96	R	Limestone or shale	Deer Creek ls. and/or Calhoun sh.	Cy, H	D, S	Top of steel rim in concrete cover	0.8	7.97	12-13-51	Not dry in 1934 or 36, but not used much.
15-16-29ab	NW NE 29-15-16E	Jestine Leeper	Du	14.4	±48	R	Sand and gravel	Terrace alluvium	Cy, H	S	Top of concrete curbing	2.8	9.40	12-13-51	
15-17-1ac1	SW NE 1-15-17E	City of Overbrook	Dr	507	6¼	I, N	Sandstone	Tonganoxie ss.	T, E	P	Land surface	0	210	4- 1-53	Reported yield approx. 45 with 100 ft. drawdown Tonganoxie ss. from 420-490 ft.
15-17-1ac2	SW NE 1-15-17E	City of Overbrook	Dr	497	6¼	I, N	do	do	T, E	P	do	0	210	4- 1-53	Reported yield approx. 45 with 100 ft. drawdown Tonganoxie ss. from 395-485.
15-17-16aa	NE NE 16-15-17E	Leslie Greenfield	Du	18	±36	R	Shale or limestone	Tecumseh sh. and/ or Lecompton ls.	Cy, H	D	Top of concrete curbing	0.4	6	6- 2-52	Reported inadequate in drought years.
15-17-22bb	NW NW 22-15-17E	Walter Lassen	Du	26	±72	R	Shale	Tecumseh sh.	Cy, H	D, S	Land surface	0			Reported inadequate in dry years, very low yield.
15-17-33dc	SW SE 33-15-17E	Harold Supple	Dr	110	6	GI	Sandstone	Kanwaka sh.	J, E	D, S	do	0	50	6- 1-50	Water sand from approx. 94-109. Reported yield +¾.
15-17-34cd	SE SW 34-15-17E	E. E. Howard	Dr	110	6?		do	do	Cy, W	D, S	do	0			Reported yield approx. 1/10.
16-13-14dc	SW SE 14-16-13E	C. J. Lowman	Du	16.1	±36	R	Limestone or shale	Burlingame ls. and/ or Silver Lake sh.	Cy, H	D	Top of concrete curbing	0.3	11.07	8-14-51	Reported adequate.
16-14-7ad	SE NE 7-16-14E	Oscar Gustafson	Dr	90	8	I?	Shale or sandstone	Auburn and/or Silver Lake sh.	Cy, H	D	Land surface	0	20	10-23-51	Reported adequate yield less than ½.

TABLE 6.—*Records of wells in Osage 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.)
16-14-18dc	SW SE 18-16-14E	Carol Anstrom	Du	13.3	±84	R	Shale?	Colluvium and/or Cedar Vale sh.	Cy, H	S	Land surface	0		8-14-51	Estimated flow at surface 1. Dry in 1913 and 1934.
16-14-20cc1	SW SW 20-16-14E	Albert Lundgren	Du	35 or 40	±48	R, N	Sand and gravel	Terrace alluvium	Cy, E	D, S	do	0	5	10-24-51	Reported adequate, low yield.
16-14-20cc2	SW SW 20-16-14E	Albert Lundgren	Du	29.6	±48	R	do	do	N	N	Top concrete curbing east side of opening	0.8	10.96	10-24-51	
16-14-21dc	SW SE 21-16-14E	Jim Ryan	Du	18	±36	R	do	do	Cy, H	D, S	Land surface	0	6	10-23-51	Reported adequate.
16-14-32bd	SE NW 32-16-14E	John W. Walker	Du	45	±60	R	Shale or limestone	Auburn sh. and/ or Wakarusa ls.	Cy, H	D, S	do	0	39	10-23-51	do
16-15-5cb	NW SW 5-16-15E	W. M. Regenold	Du	24.9	±54	R	Shale or Sandstone	White Cloud sh.	J?, E	D	Top of wooden enclosure 2.4 ft. above concrete curbing	3.4	11.32	10-31-51	Reported adequate.
16-15-8bc	SW NW 8-16-15E	Harry Davenport	Du	4.5	±54	R	Limestone	Howard ls.	Cy, H	D, S	Top of rock cover over well inside storm cellar	—5.	4.0	10-31-51	
16-15-20dc1	SW SE 20-16-15E	Bert Davenport	Dr	58.2	4	I	Sandstone or limestone	Calhoun sh. and/ or Topeka ls.	Cy, H	D	Top of iron casing	0.9	12.43	11- 7-51	Reported yield ½ to 1.
16-15-20dc2	SW SE 20-16-15E	Bert Davenport	Du	20?	±48	R	Sand and gravel	Alluvium	J, E	S	Land surface	0	3	8- 1-50	
16-15-36cc	SW SW 30-16-15E	C. B. Gilliland	Du	20	±96	R	Shale or limestone	Tecumseh sh. and/ or Lecompton ls.	Cy, W	D, S	do	0	4	11- 7-51	Reported adequate since dry in 1936.
16-16-5dc	SW SE 5-16-16E	J. P. Bryson	Du	28.6	±120	R	Sand and gravel	Alluvium	Cy, G	D, S	Top of inset in concrete well cover	3.4	4.55	12-13-51	K.E.R.C. well. Reported yield 25 in 10 hr. test from 4 ft. sand and gravel.
16-16-6db	NW SE 6-16-16E	Ada Neihart	Du	30	±54	R	do	Terrace alluvium	Cy, W	S	Land surface	0	5	12-13-51	Reported adequate.
16-16-18cc	SW SW 18-16-16E	Louis Meyers	Du	50	36	R	Sandstone or shale	Calhoun sh.	Cy, E	S	do	0	20	12-13-51	Reported not adequate in dry years.
16-16-18cd	SE SW 18-16-16E	Louis Meyers	Du	64	±48	R	do	do	Cy, W	S	do	0	15	12-13-51	do
16-16-22cc	SW SW 22-16-16E	Clyde Neilson	Du	25.4	±30	R	Limestone	Deer Creek ls.	Cy, H	S	Top of R.R. tie cover	1.0	6.40	11- 8-51	Reported yield less than 1.
16-16-23ba	NE NW 23-16-16E	Harold Woodard	Du	26.0	±54	R	Limestone or shale	Deer Creek ls. and/ or Tecumseh sh.	Cy, H	D	Top of concrete curbing	0.9	14.51	12- 8-51	
16-16-24aa	NE NE 24-16-16E	R. C. Bauck	Du	30	60	R	do	Lecompton ls. and/ or Kanwaka sh.	Cy, H	S	Top of 2x6 board frame under board cover	0.2	4.40	12- 8-51	Reported not adequate in drouth years.
16-16-36ca1	NE SW 36-16-16E	O. J. Schendel	Du	23.6	±96	R	do	Plattsmouth ls. and/or Heebner sh.	Cy, H	D, S	Top of concrete curbing	0.4	7.78	11- 8-51	
16-16-36ca2	NE SW 36-16-16E	O. J. Schendel	Dr	120	7?	I	Sandstone	Ireland ss.	Cy, W	S	Land surface	0			Reported adequate, has sodium bicarbonate and chloride taste.
16-17-3dd	SE SE 3-16-17E	H. F. Whitlatch	Dr	60	8	GI	Limestone and shale	Kanwaka sh.	Cy, E	D, S	do	0	30	12-13-51	Reported not adequate in dry years. Yield ¼ to ½.
16-17-8bb	NW NW 8-16-17E	W. B. Schneidewind	Du	20	48	R	Shale	do	Cy, H	S	do	0	1.5	12-13-51	Reported adequate only in normal or wet years.

16-17-10ab	NW NE 10-16-17E	A. S. Lee	Dr	345±5	6?	GI	Sandstone	Ireland ss.	Cy, E	D, S	do	0	145	7- 1-30	Drilling stopped 15 ft. into water-bearing sandstone.
16-17-10da	NE SE 10-16-17E	G. W. Gingerich	Dr	274	6	I?	do	do	Cy, G?	D, S	do	0			K.E.R.C. well. Reportedly will yield +16 from 48 ft. of sandstone.
16-17-15cc	SW SW 15-16-17E	Charles Crable	Du	22	±48	R	Limestone	Kereford ls.	Cy, H	D	do	0	6	12-12-51	Reported not adequate in dry years.
16-17-17cc	SW SW 17-16-17E	John Ashwell	Dr	34	6?	GI	Sand and gravel	Terrace alluvium	Cy, E	D, S	do	0	9	12- 8-51	Reported adequate.
16-17-21ad	SE NE 21-16-17E	John Ogle	Dr	195	6	GI	Sandstone	Ireland sandstone	Cy, E	D, S	do	0	100	7- 1-49	do
16-17-30dc	SW SE 30-16-17E	H. O. Miller	Du	28	48	R	Limestone or shale	Lecompton ls. and/or Stull sh.	Cy, H	D	do	0	22	12-11-51	Reported not adequate in dry years.
16-17-34cc1	SW SW 34-16-17E	Roy Driver	Dr	230	6	GI	Sandstone	Ireland ss.	Cy, W	S	do	0	100	12-11-51	Reported adequate. Brackish water usable for all stock.
16-17-34cc2	SW SW 34-16-17E	Roy Driver	Du	18.9	±48	R	Limestone and shale	Oread ls.	Cy, H	D	Top of concrete curbing	1.0	9.96	12-11-51	Reported not adequate in dry years.
16-17-34cd	SE SW 34-16-17E	New Hope School	Du	17.1	±36	R	Sand and gravel	Alluvium	Cy, H	D	do	1.2	5.91	12-11-51	Reported adequate in dry years of 1934-36.
17-13-24dd	SE SE 24-17-13E	Henry Price	Du	13.6	±120	C, R	Sand and gravel	do	Cy, H	D, S	do	2.0	6.07	10-22-51	K.E.R.C. well, originally 18 ft. deep.
17-13-35cd	SE SW 35-17-13E	Charles Schlobohm	Du	22.4	±36	R	do	do	J?, E	D, S	Top of steel rim in curbing	1.7	4.74	10-22-51	Reported adequate.
17-14-1aa	NE NE 1-17-14E	Harley J. Bower	Du	30	±30	R	do	do	Cy, H	D, S	Land surface	0	6.5	11- 7-51	do
17-14-8dd	SE SE 8-17-14E	D. W. Crant	Du	25	±42	R	Shale or sandstone	Silver Lake sh.	J, E	D, S	do	0	7	10-22-51	do
17-14-10aa	NE NE 10-17-14E	Floyd Williams	Du	35.0	±36	R	Shale or limestone	White Cloud sh. and/or Howard ls.	Cy, H	S	Top of concrete curbing	0.5	5.20	10-19-51	Reported low yield, not adequate in dry years, very hard, bitter taste.
17-14-15aa	NE NE 15-17-14E	Will Bishop	Du	38.8		R	Limestone or shale	Howard ls. and/or Severy sh.	Cy, W	S	Top of 2x12 board cover	1.2	7.43	10-19-51	Reported low yield, not adequate in very dry years.
17-14-18bc	SW NW 18-17-14E	Glen Private	Du	34.8	36-42	R	Shale	Auburn sh.	Cy, H	D, S	Top of board cover	2.4	9.33	10-22-51	
17-14-22ad	SE NE 22-17-14E	Otto Kiwitter	Du	19	72	R	Sandstone and shale	White Cloud sh.	Cy, H	S	Land surface	0	2	10-19-51	Reported adequate, very hard.
17-14-34ba	NE NW 34-17-14E	John R. Jones	Du	25	±60	R	Shale and sandstone	do	B, H	S	do	0	11	10-19-51	
17-14-36da	NE SE 36-17-14E	Elda Staniford	Du	20	±96	R	Limestone and shale	Topeka ls.	Cy, H	D, S	do	0	3	11- 6-51	
17-15-5da	NE SE 5-17-15E	H. H. Smith	Du	21.5	±48	R	Sand and gravel	Terrace alluvium	Cy, H	D, S	Top of 2x6 casing	0.5	6.07	11- 7-51	Reported adequate.
17-15-6bb	NW NW 6-17-15E	Clarence Lindberg	Dr	60	6?		Shale or sandstone	Calhoun sh.	Cy, H	D	Land surface	0			
17-15-6bc	SW NW 6-17-15E	Pleas. Valley School	Dr	56.4	5½		do	do	Cy, H	D, S	Top of concrete curbing	1.3	31.70	11- 7-51	Reported low yield ¼ to ½.
17-15-13aa	NE NE 13-17-15E	H. C. Bibbee	Du	15.4	±48	R	Limestone and shale	Topeka ls.	Cy, H	D	do	1.1	5.41	11- 7-51	
17-15-24ba	NE NW 24-17-15E	Walter Ellis	Du	16 or 18	±42	R	Shale and ilmestone	Colluvium and/or Deer Creek ls.	Cy, H	D	Land surface	0	6	11- 7-51	
17-15-35bb	NW NW 35-17-15E	Lynn Michaels	Du	25 or 30		R	Limestone	Deer Creek ls.	Cy, H	D	do	0	6	11- 7-51	Reported not adequate in dry years.
17-16-4ab	NW NE 4-17-16E	Raymond Goldsmith	Du	18.1	±30	R	Sand and gravel	Alluvium	J, E	D, S	Top of concrete curbing	1.5	7.93	11- 8-51	Reported adequate.
17-16-14bb	NW NW 14-17-16E	J. C. Fulton	Dr	220	6	GI	Sandstone	Ireland ss.	Cy, H	D, S	Land surface	0			Reported adequate, has slight chloride taste.
17-16-20aa	NE NE 20-17-16E	M. R. Bronson	Dr	297	5	GI	do	do	Cy, H	D, S	do	0	150	1-10-50	Water sand at 256-296. Reported adequate.
17-16-25bc	SW NW 25-17-16E	F. G. Rice	Dr	258	6	GI	do	do	Cy, W	D, S	Top of GI casing	1.0	10.87	11-12-51	Reported adequate.
17-16-26aa	NE NE 26-17-16E	John Plowman	Dr	250	6	GI	do	do	Cy, W	D, S	do	1.0	84.54	11-12-51	do

TABLE 6.—*Records of wells in Osage 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.)
17-16-28dd	SE SE 28-17-16E	H. R. Failor	Du	25.2	±48	R	Shale or sandstone	Kanwaka sh.	Cy, H	D, S	Top of concrete and rock curbing	1.5	19.44	11- 8-51	Reported not adequate in dry weather.
17-16-30ad	SE NE 30-17-16E	Mae Whitney	Du	23.3	60-120	R	Limestone	Deer Creek ls.	Cy, H	D, S	Top of 1x4 curbing under board manhole cover	1.8	9.29	11- 8-51	Reported adequate.
17-16-33cc	SW SW 33-17-16E	Kenneth Elder	Dr	160	6	GI	Sandstone	Ireland ss.	J, E	D, S	Top of concrete curbing	0.7	45.85	11- 9-51	do
17-16-33dd	SE SE 33-17-16E	Don Everst	Dr	120	6?	GI	do	do	J, E	D, S	Land surface	0	60	11- 9-51	do
17-17-6dc	SW SE 6-17-17E	B. A. Frost	Dr	169	6	GI	do	do	Cy, W	D, S	Top of GI casing	0.5	82.26	12-11-51	do
17-17-9da1	NE SE 9-17-17E	City of Quenemo	Dr	175	8?	I	do	do	Cy, E	P	Land surface	0			Present well yield less than capacity of pump.
17-17-9da2	NE SE 9-17-17E	City of Quenemo	Dr	175?	8	I	do	do	N	N	do	0			Not now in use, yield too low.
17-17-9dd	SE SE 9-17-17E	City of Quenemo	Dr	228	8	I	do	Tonganoxie ss.	N	N	do	0			Originally 167 ft. Ireland ss. mem. well. Deepened to 228 and got very salty water.
17-17-10cc1	SW SW 10-17-17E	City of Quenemo	Dr	33	8	I	Sand and gravel	Terrace alluvium	T, E	P	do	0			
17-17-10cc2	SW SW 10-17-17E	City of Quenemo	Dr	33	8	I	do	do	T, E	P	do	0			
17-17-15cc	SW SW 15-17-17E	J. M. Leabo	Du	20	±24	R	do	do	Cy, H	D	Top of 2x8 board box under pump	2.5	10.25	12- 7-51	Reported adequate.
17-17-15cd	SE SW 15-17-17E	J. M. Leabo	Du	17.2	48	R	do	Alluvium	Cy, W	S	Top of 2x12 board cover	2.3	4.65	12- 7-51	do
17-17-17cb	NW SW 17-17-17E	Van B. Cade	Dr	255	6	GI	Sandstone	Ireland ss.	Cy, E	D, S	Land surface	0	88	7-12-49	do
17-17-21bb	NW NW 21-17-17E	Ernest A. Casten	Dr	150	6	GI	do	do	Cy, H	D, S	do	0	15 or 20	12-11-51	Reported adequate. Water from 68 ft. sandstone.
18-13-11aa	NE NE 11-18-13E	Frank Fagen	Du	19.5	84	R	Sand and gravel	Alluvium	Cy, G	D, S	Top of 3x12 board cover over well	2.0	6.83	10-22-51	Reported adequate.
18-13-36cc	SW SW 36-18-13E	J. P. Monroe	Du	13.9	±96	R	Shale	White Cloud sh.	Cy, H	D	Top of concrete curbing	0.5	7.33	10-22-51	Reported not adequate in dry years.
18-14-5bb	NW NW 5-18-14E	Howard Roland	Du	31.4	±48	R	Shale or sandstone	do	Cy, W	D, S	do	0	23.71	10-22-51	do
18-14-7aa	NE NE 7-18-14E	George Ford	Du	30	±42	C, R	Sand and gravel	Alluvium	Cy, H	D, S	Land surface	0	6	10-19-51	Reported adequate.
18-14-10cc	SW SW 10-18-14E	R. L. Leurs	Du	23.4	±48	R	do	Terrace alluvium	Cy, H	D, S	Top of concrete curbing	1.0	12.78	10-19-51	do
18-14-15cb	NW SW 15-18-14E	Bertha Jones	Du	18.8	±36	R	Limestone	Topeka ls.	J, E	D, S	do	1.7	3.58	10-19-51	do
18-14-25cc	SW SW 25-18-14E	Donald Edwards	Du	24.5	±60	R	Shale or limestone	Severy sh.	Cy, H	D, S	do	1.0	8.21	11- 6-51	
18-14-30bb	NW NW 30-18-14E	L. C. Lynch	Du	22.0	±36	R	Shale or sandstone	Cedar Vale sh.	B, H	D, S	Top of board enclosure around well opening	2.5	12.63	10-19-51	Reported to go dry in dry years.
18-15-3cd	SE SW 3-18-15E	G. R. Evans	Du	19.0	±96	R	Sand and gravel	Terrace alluvium	C, E	S	Top of concrete and rock curbing	2.5	11.67	11- 6-51	Reported adequate.
18-15-28aa	NE NE 28-18-15E	Robert Waugh	Du	24.1	±48	R	Limestone or sandstone	Topeka ls. and/or Calhoun sh.	Cy, H	D, S	Top of 2x12 board cover	0.8	5.15	11- 6-51	
18-15-34dd	SE SE 34-18-15E	Russel Schrader	Du	17.2	±36	R	Shale	Tecumseh sh.	Cy, H	D	Top of concrete curbing	0.5	13.14	11- 6-51	Reported not adequate in dry years.
18-16-5ab	NW NE 5-18-16E	Lloyd White	Du	30.2	±48	R	Sand and gravel	Terrace alluvium	Cy, E	D, S	Top of borad cover	0.5	5.37	11- 9-51	Reported adequate.
18-16-8ba	NE NW 8-18-16E	Kenneth Criss	Du	18.6	±36	R	Limestone and shale	Lecompton ls.	Cy, H	D, S	Top of concrete curbing	0.4	6.78	11- 9-51	

18-16-14dc	SW SE 14-18-16E	T. G. Edwards	Du	16.2	±48	R	Shale	Kanwaka sh.	Cy, H	D	Base of metal pump	1.9	7.49	11-13-51	Reported to go dry in dry years.
18-16-14dd1	SE SE 14-18-16E	T. G. Edwards	Dr	170	6	GI	Sandstone	Ireland ss.	Cy, E	D, S	Land surface	0	100	11-13-51	Reported adequate.
18-16-14dd2	SE SE 14-18-16E	Walter White	Dr	168	6	GI	do	do	Cy, H	D	Top of GI casing	0.1	101.83	11-13-51	Reported adequate, soft water.
18-16-19ab	NW NE 19-18-16E	Ed Phelon	Du	24.7	±36	R	Sand and gravel	Terrace alluvium	N	N	Top of rock curbing	0.2	15.32	11- 9-51	Reported adequate.
18-16-21ba	NE NW 21-18-16E	P. B. Weis	Dr	200	6	GI	Sandstone	Ireland ss.	Cy, H	D, S	Land surface	0	100	7- 1-50	do
18-16-24aa	NE NE 24-18-16E	A. E. Patterson	Dr	100	8	GI	do	do	N	N	Top of GI casing	0.5	25.34	11-13-51	New well not yet in use.
18-16-26dc	SW SE 26-18-16E	J. Weeker	Dr	300	8?	I?	do	do	Cy?	D, S	Land surface	0			K.E.R.C. well. Old gas test plugged back to 300 ft.
18-16-27cd	SE SW 27-18-16E	C. T. McNabb	Dr	212	6	GI	do	do	Cy, W	D, S	do	0	10	11- 1-50	Reported adequate.
18-16-29dd	SE SE 29-18-16E	P. W. Haworth	Dr	140	6	GI	do	Kanwaka sh.	Cy, G	S	Top of GI casing	1.2	7.54	11- 9-51	Reported yield approx. 4.
18-16-30bc	SW NW 30-18-16E	George Henry	Du	15.7	32-72	R	Sand and gravel	Terrace alluvium	Cy, H	D, S	Top of concrete curbing	1.0	6.63	11- 9-51	Reported adequate.
18-16-34cc	SW SW 34-18-16E	B. C. Gillmore	DD	300			Sandstone	Ireland ss.	Cy, W	D, S	Land surface	0			
18-16-35dd	SE SE 35-18-16E	Cary Lackey	Dr	170 or 180	6	GI	do	do	Cy, W	D, S	do	0			Reported as soft sodium bicarbonate water.
18-17-5ac	SW NE 5-18-17E	D. D. McMilian	Dr	220	8	I	do	do	Cy, ?	D, S	do	0			K.E.R.C. well. Reported yield 800 gal./hr.
18-17-5ba	NE NW 5-18-17E	Dode McMilian	Dr	208	6	GI	do	do	Cy, W	D, S	do	0	100	11-14-51	Reported adequate.
18-17-10cc	SW SW 10-18-17E	Nellie West	Dr	265	8				N	N	do	0			K.E.R.C. well reported as dry hole. Reported 20 ft. Ireland ss. no water.
18-17-10da	NE SE 10-18-17E	J. Riggs ?	Dr	180	8				N	N	do	0			K.E.R.C. well. Reported as dry hole.
18-17-15da	NE SE 15-18-17E	M. F. Martin	Dr	197 or 189	6?	GI	Sandstone	Ireland ss.	Cy, E	D, S	do	0			Reported to have enough chloride to taste.
18-17-28cc	SW SW 28-18-17E	George Hull	Du	20	±72	R	Limestone or shale	Kereford ls. and/or Jackson Park sh.	Cy, H	D, S	do	0	5	11-13-51	Reported adequate for dom. only in drought years.
18-17-31dc	SW SE 31-18-17E	William Kruger	Dr	275	6	GI	Sandstone	Ireland ss.	Cy, G	D, S	do	0			Reported adequate.
18-17-32cc	SW SW 32-18-17E	W. F. Shilling	Du	25.9	±96	R	Limestone or shale	Kereford ls. and/or Jackson Park sh.	Cy, H	S	Top of concrete curbing	1.0	7.85	11-14-51	Reported not adequate in drought years of 1934-36.

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.
3. Reported depths below the land surface are given in feet; measured depths are given in feet and tenths below measuring points.
4. C, concrete; GI, galvanized sheet iron; I, iron; N, none; R, rock; T, tile.
5. Method of lift: Cy, cylinder; N, none; T, turbine; J, jet; C, centrifugal; B, bucket and rope. Type of power: E, electric; G, gas engine; H, hand operated; N, none; W, windmill.
6. D, domestic; 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.

LOGS OF TEST HOLES AND WELLS

Given on the following pages are the logs of 15 test holes drilled by the State Geological Survey in Osage County (Pl. 3), and logs of test holes or wells obtained from drillers and other sources. Samples from the test holes were studied by me and are the basis for the geologic cross sections (Fig. 3).

14-13-2cd Drillers log of K. E. R. C. well in the SE cor. SW¼ sec. 2, T. 14 S., R. 13E., Osage County; drilled 1934.

	Thickness, feet
Soil and clay	15
Gray shale	3
Limestone	4
Gray shale	8
Red bed	3
Light shale	14
Limestone	3
Sandy shale	5
Gray shale	17
Limestone	7
Light shale	11
Limestone	2
Red bed	3
Limestone	3
Gray shale	7
Dark shale	6
Limestone	8
Sandy shale	28
Limestone	3
Gray shale	34
Limestone	5
Gray shale	11
Limestone	4
Gray shale	6
Limestone	5
Gray shale	13
Limestone	6
Gray shale	6
Limestone	5
Light shale	20
Limestone	6
Gray shale	4
Limestone	3
Gray shale	9
Limestone	2
Gray shale	16
Limestone	2
Gray shale	12
Limestone	7
Light shale	14
Sandy shale	10
Sand ("salt" water)	10
Gray shale	20
Sandy shale	41
Total depth of well	421

14-15-21da Drillers log of K.E.R.C. well in the NE¼ SE¼ sec. 21, T. 14 S., R. 15 E., Osage County; drilled in 1934.

	Thickness, feet
Gravel	7
Clay	10
Gray shale	80
Limestone	6
Gray shale	30
Sandy shale	40
Limestone	3
Shale	2
Limestone	2
Shale	3
Limestone	17
Gray shale	14
Sand	6
Broken sand	10
Sand (water)	18
Gray shale	7
Total depth of well	255

Reported yield 5,000 gallons in 10 hours

14-15-24ac Drillers log of K.E.R.C. well in the SW¼ NE¼ sec. 24, T. 14 S., R. 15 E., Osage County; drilled in 1934.

	Thickness, feet
Soil	4
Clay	16
Gray shale	5
Limestone	19
Gray shale	20
Sand (water)	14
Gray shale	7
Limestone	19
Shale	4
Limestone	4
Gray shale	9
Limestone	20
Light shale	3
Limestone	3
Dark shale	30
Limestone	19
Shale	2
Limestone	15
Shale	6
Limestone	6
Gray shale	25
Limestone	4
Gray shale	46
Limestone	10
Gray shale	7
Limestone	17
Total depth of well	334

Reported yield 600 gallons in 10 hours

14-15-24ba Log of test hole in the NE¼ NW¼ sec. 24, T. 14 S., R. 15 E., about 30 feet west of center line of N-S road and 200 feet north of fence on quarter section line; drilled July-August 1953. Surface altitude, 1,085.9 feet. Commenced drilling at 315 feet over existing open hole.

	Thickness, feet
PENNSYLVANIAN-Virgilian	
Oread limestone	
Limestone	1
Shale, gray	7
Limestone, light-gray; contains several hard chert zones	13
Shale, fissile, black	3.5
Limestone, hard, gray	2.5
Shale	9
Limestone	2
Shale	9
Limestone	10
Lawrence shale	
Shale, gray; coal bed in upper part	13.5
Limestone	4
Shale, gray	30.5
Shale, sandy, gray	13
Sandstone, fine to very fine, gray	15
Shale, sandy, gray	12
Sandstone, fine to very fine, gray	6
Shale, sandy, gray	8
Sandstone, fine, gray	10
Siltstone and sandstone, gray	10
Stranger formation	
Limestone, gray, hard	1.5
(Stopped in limestone)	
Total depth of test hole	495.5

14-16-19ad Sample log of test hole in the SE¼ NE¼ sec. 19, T. 14 S., R. 16 E., drilled January-March 1954. Surface altitude, 1,149.2 feet.

	Thickness, feet
Rubble	2.5
PENNSYLVANIAN-Virgilian	
Howard limestone-Aarde shale member	
Coal (Nodaway)	1
Severy shale	
Clay and clay shale, light-gray	16.5
Limestone	1.5
Shale, blue-gray	31.5
Shale, dark-gray	2
Shale, slightly micaceous, light-gray	1
Shale, calcareous, fossiliferous (bryozoans), medium-gray	2
Topeka limestone	
Limestone, fossiliferous, light-gray	20.5
Calhoun shale	
Shale, silty, slightly micaceous, medium-gray	29.5
Sandstone, fine to very fine, micaceous, light-gray; contains carbonized plant fragments	10
Shale, slightly calcareous, medium-gray	19
Deer Creek limestone	
Limestone, light gray-white with clear or white crystalline fossil fragments	13
Shale, slightly calcareous, medium dark-gray	4
Limestone, slightly sandy, fossiliferous, gray to brown	3
Shale, gray	5
Shale, calcareous, light-gray	11
Shale, light-gray; contains thin limestone stringers	6
Shale, calcareous, light-gray	4
Limestone, fossiliferous, light-gray	5
Tecumseh shale	
Shale, slightly calcareous, gray	38
Lecompton limestone	
Limestone, fine-grained, light-gray; contains coarse, crystalline fossil fragments	6
Shale, medium-gray	6
Limestone, light- to medium-gray; contains pyrite, abundant fusulinids, and brachiopods	8
Shale, fissile, black	2.5
Limestone, hard; medium-gray, dark-gray around abundant fusulinids	1.5
Shale, silghtly calcareous, gray	3
Limestone, light gray-white; fusulinids abundant	14
Kanwaka shale	
Shale, slightly calcareous, dark-gray	24
Limestone, fossiliferous, gray-brown	5
Shale, silty, micaceous, slightly calcareous, gray	21
Shale, silty, micaceous, gray; contains carbonaceous plant fragments	15
Shale, silty to sandy, micaceous, gray	9
Oread limestone	
Limestone, pyritic, hard, medium-gray; fusulinids abundant	6
Shale, silty, calcareous, slightly micaceous, medium-gray	7.5
Limestone, hard, light-gray	22.5
Shale, noncalcareous, black	6
Limestone, brittle, light-gray	2.5
Shale, argillaceous, gray	8
Limestone, light-gray	13.5
Lawrence shale	
Shale, gray with red streak	25
Shale, gray; contains sandy limestone streak	10
Shale, agillaceous to silty, gray	76
Stranger formation	
Limestone, slightly sandy, medium light-gray	3.5
Shale, silty to fine sandy, gray	13
Shale (sample lost)	4
Sandstone, very fine-grained, partly calcite cemented, light gray-white	15.5
Shale, silty to very fine sandy, gray	29.5
Shale, silty to very fine sandy, micaceous, partly calcareous, gray	40
Shale, sandy, gray	19.5
Total depth of test hole	643

15-15-34dd Sample log of test hole in the SE¼ SE¼ sec. 34, T. 15 S., R. 15 E., 100 feet east of intersection of roads, 200 feet west of windmill on north side of road; drilled June 1951. Surface altitude, 997.2 feet.

	Thickness, feet
QUATERNARY-Pleistocene	
Alluvium	
Soil, gray-black	5
Silt and clay, slightly sandy, brown-tan	5
Clay and silt, soft, yellow-green	1.5
Silt and clay, calcareous, green; contains a small amount of sand and gravel	5.5
Clay, calcareous, yellow-green; contains a small amount of sand and gravel	1.5
PENNSYLVANIAN-Virgilian	
Deer Creek limestone	
Limestone, shaly, yellow	2
Limestone, chalky, light-gray; contains clear crystalline calcite spots	4
Total depth of test hole	24.5

15-15-35cc Sample log of test hole in the SW¼ SW¼ sec. 35, T. 15 S., R. 15 E., on east road shoulder, 200 feet south of quarter section line; drilled June 1951. Surface altitude, 1,027.7 feet.

	Thickness, feet
QUATERNARY-Pleistocene	
Terrace deposits	
Soil, reddish-tan	5
Silt and clay, slightly sandy, tan with reddish cast	10
Silt and clay, slightly sandy, tan-gray	2
Silt and clay, soft, sandy, yellow-tan	2
Sand and gravel, predominantly chert, quartz, and limestone	1.5
PENNSYLVANIAN-Virgilian	
Deer Creek limestone	
Limestone, hard, light-gray	1
Total depth of test hole	21.5

15-16-11dd Drillers log of K.E.R.C. well in the SE¼ SE¼ sec. 11, T. 15 S., R. 16 E., Osage County; drilled in 1934.

	Thickness, feet
Soil and clay	7
Limestone	4
Dark shale	5
Limestone	4
Gray shale	6
Limestone	6
Gray shale	4
Limestone	9
Gray shale	40
Limestone	7
Light shale	3
Limestone	5
Gray shale	2
Limestone	18
Dark shale	8
Limestone	7
Gray shale	20
Limestone	5
Gray shale	45
Limestone	8
Light shale	21
Limestone	21
Gray shale	12
Limestone	4
Dark shale	40
Light shale	49
Sandy shale	35
Sand (salt water)	4
Total depth of well	399

16-15-2bb Sample log of test hole in the NW¼ NW¼ sec. 2, T. 16 S., R. 15 E., on west road shoulder, 200 feet south of bridge; drilled June 1951. Surface altitude, 997.9 feet

	Thickness, feet
QUATERNARY-Pleistocene	
Alluvium	
Soil, black to dark-gray	4
Silt and clay, noncalcareous, dark-tan	12
Gravel and sand, predominantly chert; contains considerable gray and tan silt and clay	6.5
Clay, soft, calcareous, blue-gray	2
Sand and gravel, predominantly sandstone and chert; contains black shale, limestone and mollusk shell detritus	1.5
PENNSYLVANIAN-Virgilian	
Deer Creek limestone	
Limestone, hard, gray	0.5
Total depth of test hole	26.5

16-15-2bc Sample log of test hole in the SW¼ NW¼ sec. 2, T. 16 S., R. 15 E., on west side of road, 3-2/3 power poles south of bridge over creek; drilled June 1951. Surface altitude, 996.4 feet.

	Thickness, feet
QUATERNARY-Pleistocene	
Alluvium	
Soil, dark-gray	3
Clay and silt, gray	1
Silt and clay, mottled yellow-brown and gray	2.5
Silt and clay, yellow-brown and gray; contains gravel size shale detritus	3.5
Sand and gravel; chiefly limestone, chert, and shale	1.5
PENNSYLVANIAN-Virgilian	
Deer Creek limestone	
Limestone, medium hard, yellow-brown	2
Limestone, light-gray	0.5
Total depth of test hole	14

16-15-2cb Sample log of test hole in the NW¼ SW¼ sec. 2, T. 16 S., R. 15 E., on west road shoulder, 2-1/3 power poles south of half-mile line; drilled June 1951. Surface altitude, 998.7 feet.

	Thickness, feet
QUATERNARY-Pleistocene	
Alluvium	
Soil, gray-brown	3
Clay and silt, yellow-brown; contains some sand and gravel	3
Sand and gravel; chert, shale, limestone, and quartz detritus	6.5
PENNSYLVANIAN-Virgilian	
Deer Creek limestone	
Limestone and thin shale breaks, very fossiliferous, yellow-brown	2
Shale, very fine sandy, calcareous, blue-green	2.5
Total depth of test hole	17

16-16-5dc Drillers log of K.E.R.C. well in the SW¼ SE¼ sec. 5, T. 16 S., R. 16 E., Osage County; dug in 1934.

	Thickness, feet
Black gumbo	5
Yellow clay	16
Quicksand	1.5
Gravel	2.5
Limestone	—
Total depth of well	25

Reported yield 15,000 gallons in 10 hours from 4 feet ot sand and gravel

16-17-10da Drillers log of K.E.R.C. well in the NE¼ SE¼ sec. 10, T. 16 S., R. 17 E., Osage County; drilled in 1934.

	Thickness, feet
Soil	5
Clay	5
Gravel	4
Limestone	10
Gray shale	18
Limestone	20
Dark shale	10
Limestone	3
Gray shale	75
Sandy shale	15
Dark shale	35
Light shale	17
Sand (water)	48
Gray shale	7
Limestone	2
Total depth of well	274

Reported yield 10,000 gallons in 10 hours from 48 feet of sandstone

17-13-24dd Drillers log of K.E.R.C. well in the SE¼ SE¼ sec. 24, T. 17 S., R. 13 E., Osage County; dug in 1934.

	Thickness, feet
Black gumbo	3.5
Clay	10
Gravel	1.5
Shale	3
Total depth of well	18

18-14-9ca Sample log of test hole in the NE¼ SW¼ sec. 9, T. 18 S., R. 14 E., on east road shoulder, west side of road, 100 yards north of farm house; drilled May 1951. Surface altitude, 1,048.7 feet.

	Thickness, feet
Road fill	5
QUATERNARY-Pleistocene	
Terrace deposits	
Clay and silt, gray to mottled gray-brown	2
Silt and clay, slightly sandy and micaceous, friable, yellow-brown	3
Silt, yellow-brown; contains considerable sand and gravel	11
Gravel and sand, predominantly brown chert	4.5
PENNSYLVANIAN-Virgilian	
Severy shale	
Shale, clayey, dark-gray	2
Shale, thin-bedded, silty, micaceous, gray; contains thin hard calcareous fossiliferous siltstone beds	2
Total depth of test hole	29.5

18-14-9cd Sample log of test hole in the SE¼ SW¼ sec. 9, T. 18 S., R. 14 E., on west side of road, 150 feet south of windmill; drilled May 1951. Surface altitude, 1,033.3 feet.

	Thickness, feet
Road fill	5
QUATERNARY-Pleistocene	
Alluvium	
Clay, motled yellow-tan and light-gray	5
Silt and clay, light tan-brown	3
Sand and gravel, predominantly chert; contains quartz sand, limestone, and shale detritus	3
PENNSYLVANIAN-Virgilian	
Severy shale	
Shale, gray-blue; contains thin hard calcareous siltstone beds	3
Total depth of test hole	19

18-14-16ba Sample log of test hole in the NE¼ NW¼ sec. 16, T. 18 S., R. 14 E., on west side of road, 200 feet south of Marais des Cygnes River bridge; drilled May 1951. Surface altitude, 1,033.2 feet.

	Thickness, feet
Road fill	4
QUATERNARY-Pleistocene	
Alluvium	
Clay and silt, dark-tan to gray-tan	2
Silt and clay, slightly sandy, friable, gray-tan	10
Sand and gravel, predominantly chert; contains considerable quartz and brown sandstone detritus	5.5

	Thickness, feet
PENNSYLVANIAN-Virgilian	
Severy shale	
Shale, hard, silty to fine sandy, calcareous, gray	1
Total depth of test hole	22.5

18-14-16bd Sample log of test hole in the SE¼ NW¼ sec. 16, T. 18 S., R. 14 E., on east side of road grade, 0.25 mile south of Marais des Cygnes River bridge; drilled May 1951. Surface altitude, 1,033.7 feet.

	Thickness, feet
Road fill	5
QUATERNARY-Pleistocene	
Alluvium	
Silt and clay, gray to gray-brown	5
Silt and very fine sand, light-brown	11
Gravel and sand, predominantly brown chert; contains considerable brown silt	3.5
PENNSYLVANIAN-Virgilian	
Severy shale	
Siltstone or very fine sandstone, hard, calcareous, medium gray	1
Total depth of test hole	25.5

18-16-3bc Sample log of test hole in the SW¼ NW¼ sec. 3, T. 18 S., R. 16 E., in field east of road, 20 feet north of roadway; drilled June 1951. Surface altitude, 962.3 feet.

	Thickness, feet
Road fill	5
QUATERNARY-Pleistocene	
Alluvium	
Clay and silt, gray	2
Clay and silt, dark-tan	10
Clay and silt, gray-tan to gray	4
Clay, sandy, blue-gray and tan	2.5
Sand and gravel, predominantly chert; contains limestone and quartz detritus	8
PENNSYLVANIAN-Virgilian	
Oread limestone	
Limestone, hard, fossiliferous, finely crystalline, light-gray	3
Total depth of test hole	34.5

18-16-3bcc Sample log of test hole in the SW¼ SW¼ NW¼ sec. 3, T. 18 S., R. 16 E., at entrance to farm field north of Melvern bridge, 20 feet east of east road shoulder edge; drilled June 1951. Surface altitude, 963.7 feet.

	Thickness, feet
QUATERNARY-Pleistocene	
Alluvium	
Soil, black	4
Silt and clay, tan	12
Silt and clay, friable, tan	4
Clay, slightly sandy, dark-green	4
Clay, very sandy, green	9.5
Gravel and sand, predominantly chert; contains quartz, limestone, and black shale detritus	3.5
PENNSYLVANIAN-Virgilian	
Oread limestone	
Limestone, very hard, fossiliferous, light-gray	0.75
Total depth of test hole	37.75

18-16-4aaa Sample log of test hole in the NE¼ NE¼ NE¼ sec. 4, T. 18 S., R. 16 E., on road shoulder, halfway between first and second telephone poles south of rock quarry on west side of road, north side of valley; drilled June 1951. Surface altitude, 962.8 feet.

	Thickness, feet
Road fill	4
QUATERNARY-Pleistocene	
Alluvium	
Clay, hard, slightly mottled gray and tan	12
Clay and silt, gray and tan-gray	2
Clay and silt, soft, gray	4
Clay, silty, mottled green and gray	1
Sand and gravel, predominantly chert and black shale	9.5
PENNSYLVANIAN-Virgilian	
Oread limestone	
Limestone, very hard, light-gray	1
Total depth of test hole	33.5

18-16-4ad Sample log of test hole in the SE¼ NE¼ sec. 4, T. 18 S., R. 16 E., on west road shoulder, 150 feet south of north end of hedge row on east side of road, 100 yards north of southernmost test hole in line; drilled June 1951. Surface altitude, 961.9 feet.

	Thickness, feet
Road fill	4
QUATERNARY-Pleistocene	
Alluvium	
Clay and silt, medium-gray	2.5
Clay and silt, tan	8.5
Silt and clay, slightly sandy, friable, tan	4
Sand and silt; contains a small amount of gravel	1
Silt and clay, light-gray to yellow-gray	10
Sand and gravel, chiefly chert and black shale; contains limestone, quartz, brown sandstone detritus	2.5
PENNSYLVANIAN—Virgilian	
Oread limestone	
Limestone, soft, light-gray	2.5
Limestone, very hard	0.1
Total depth of test hole	35.1

18-16-26dc Partial drillers log of gas well in the SW¼ SE¼ sec. 26, T. 18 S., R. 16 E., plugged back to 300 feet for use as a K.E.R.C. water well.

Soil	4
Sand	8
Limestone	12
Shale	8
Limestone	73

Shale	35
Water sand	35
Shale	15
Sandy shale	15
Shale	45
Shale, white	20
Shale	140
Limestone	35

18-17-5ac Drillers log of K.E.R.C. well drilled in the SW¼ NE¼ sec. 5, T. 18 S., R. 17 E., Osage County; drilled in 1934.

	Thickness, feet
Soil	5
Clay	8
Gray shale	2
Limestone	20
Black shale	5
Limestone	2
Gray shale	9
Limestone shells	31
Limestone	12
Light shale	12
Limestone	3
Sand	15
Limestone	2
Sand	10
Coal	3
Gray shale	12
Broken sand	10
Shale	3
Sand	7
Limestone	2
Sand (water)	48
Total depth of well	221

Reported yield 8,000 gallons in 10 hours

18-17-10da Drillers log of K.E.R.C. well in the NE¼ SE¼ sec. 10, T. 18 S., R. 17 E., Osage County; drilled in 1934.

	Thickness, feet
Clay and boulders	15
Limestone	6
Gray shale	19
Dark shale	4
Limestone	1
Gray shale	12
Limestone	7
Gray shale	45
Sand	5
Gray shale	24
Limestone	1
Gray shale	24
Limestone	3
Gray shale	4
Limestone	1
Sand	4
Gray shale	3
Limestone	2
Total depth of well	180

Reported as a dry hole

18-17-10cc Drillers log of K.E.R.C. well in the SW¼ SW¼ sec. 10, T. 18 S., R. 17 E., Osage County; drilled in 1934.

	Thickness, feet
Soil and boulders	6
Limestone	8
Blue shale	5
Dark shale	8
Limestone	5
Sandy shale	130
Limestone	4
Gray shale	59
Sand (dry)	20
Dark shale	20
Total depth of well	265

Reported as a dry hole

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