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

PART 1

ROCK FORMATIONS OF ELK COUNTY

By

GEORGE J. VERVILLE:

Abstracted for this report by John M. Jewett

PART 2

MINERAL RESOURCES OF ELK COUNTY

By

ROBERT KULSTAD, NORMAN PLUMMER, WALTER H. SCHOEWE,
AND EDWIN D. GOEBEL

PART 3

GROUND-WATER RESOURCES OF ELK COUNTY

By

CHARLES K. BAYNE

University of Kansas Publication

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Chancellor of the University, and ex officio Director of the Survey

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State Geologist and Director

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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

CHARLES K. BAYNE

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PART 1

ROCK FORMATIONS OF ELK COUNTY

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GEORGE J. VERVILLE

Abstracted for this report by John M. Jewett

ABSTRACT

The surface of Elk County, in southeastern Kansas, is underlain by bedrock of Virgilian (Pennsylvanian) and Wolfcampian (Permian) age. There are local, relatively thin Pleistocene (Quaternary) deposits and accumulations of gravel that are probably of late Tertiary age. Subsurface rocks in descending order are Permian, Pennsylvanian, Mississippian, Devonian (?), Ordovician, Cambrian, and Precambrian.

Mineral resources that are being utilized include oil, gas, and limestone. Clay and a very small amount of coal are available for exploitation. Ground water that is not mineralized is not plentiful. It is present in valley alluvium and at shallow depths in some of the bedrock formations in quantities sufficient to meet the needs for domestic and stock water.

INTRODUCTION

This is the fourth in a series of reports on the stratigraphy, economic geology, and ground-water resources of eastern Kansas counties, consisting primarily of maps (Pl. 1, 2, and 3) but containing brief descriptive stratigraphy and discussions of oil and gas, ground water, and other useful geologic materials. Previously published reports in the series are on Chase County (Moore and others, 1951), Lyon County (O'Connor and others, 1952), and Osage County (O'Connor and others, 1954).

LOCATION AND GEOGRAPHY

Figure 1 shows the location of Elk County in Kansas. Locations of counties that are the subjects of previously published reports in this series and areas in which studies are in progress are shown in the same figure.

Elk County lies in southeast Kansas, the second county from the southern state boundary and fourth from the eastern boundary. The county comprises the south ½ of Township 28,

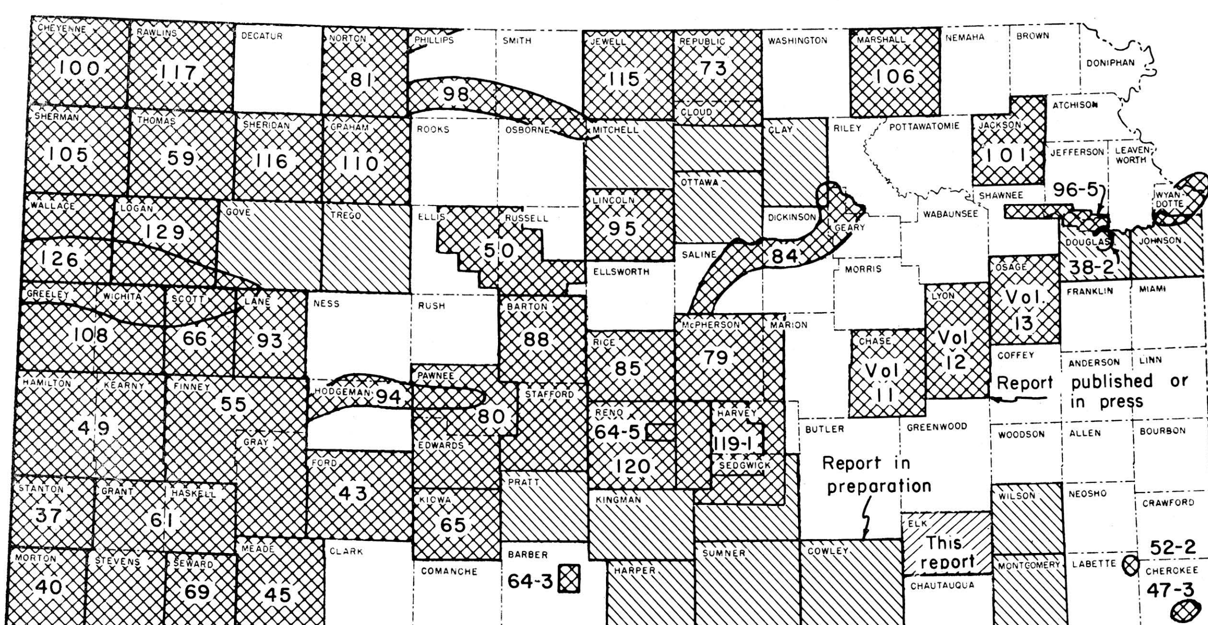

FIG. 1—Index map of Kansas showing area discussed in this report and areas for which ground-water reports have been published or are in preparation.

and all of Townships 29, 30, and 31 South, in the east ½ of Range 8, Ranges 9, 10, 11, and 12, and the west ⅔ of Range 13 East. The latitude of the county's northern boundary is 37° 36′ 15″ north, and the longitude of the eastern boundary is 95° 58′; the area is 651 square miles.

According to the 1950 Federal census, the population of Elk County was 6,679; of Howard, the county seat, 1,149; of Moline, 871; and of Longton, 478. Farming, cattle raising, and oil production are the chief industries of the county.

The altitude of the land surface in Elk County ranges from approximately 850 feet to 1,600 feet above sea level; the surface slopes eastward from the Flint Hills escarpment, which lies along the western boundary. The county lies in the Arkansas River basin and is drained principally by Elk River and its tributaries.

FIELD WORK

Field work on which the stratigraphic part of this report principally is based was done in the summers of 1949 and 1950 by George Verville, who was assisted in 1949 by Bruce Walker and in 1950 by Elliott Riggs. Several years ago R. C. Moore spent considerable time studying the outcropping rocks in Elk County. Results of his studies, including a 1-inch areal geologic map, were used by Verville. Ground-water investigations were carried on by Charles K. Bayne, who supervised test drilling in alluvial deposits. A very large part of the data concerning oil and gas exploration and development was obtained by Frank Moffitt, who did field work in Elk County in the summer of 1951. The field studies of Verville and his assistants and of Moffitt were done under the general supervision of J. M. Jewett, who with the cooperation of Robert O. Kulstad did some field work on economic geology and other phases of the investigation. William R. Atkinson supplemented Moffitt's work by adding development statistics through 1955.

Areal geology of Paleozoic rocks was mapped by Verville on air photographs (scale 1:20,000). For measuring rock sections in detail he used a rule, hand level with stadia, or telescopic level and 12-foot rod. Pleistocene deposits were mapped by Bayne.

PREVIOUS GEOLOGIC WORK IN THE AREA

Knowledge of the geology of Elk County and other Kansas counties has accumulated over a period of many years; many geologists have contributed to the store of data that is available when new work is undertaken in any area. General descriptions of rocks that crop out in Elk County are included in several reports (Condra and Upp, 1931; Moore, 1936, 1949, and 1951; Moore, Frye, and Jewett, 1944; Moore and others, 1951). Exposures of some of the beds were described by Condra and Busby (1933) and by O'Connor and Jewett (1952). Mineral resources of the county were discussed by Landes (1937), and oil and gas by Jewett and Abernathy (1945) and by Jewett (1949, 1954). Oil and gas developments in Elk County and other oil and gas producing counties are discussed in the annual oil and gas development reports of the State Geological Survey, the latest of which is Bulletin 128 (Goebel and others, 1957). Subsurface geology in Elk County relative to oil and gas has been described by several geologists and especially by Ley (1924). The areal and structural geology of that small part of Elk County which is included in the Fredonia quadrangle was mapped by Wagner (1954, Pl. 1).

ACKNOWLEDGMENTS

Most of the stratigraphic data included here were abstracted by Jewett from a detailed report on Pennsylvanian and Permian stratigraphy of Elk County submitted by George J. Verville to the faculty of the University of Wisconsin in partial fulfillment of the requirements for the Doctor of Philosophy degree. Thanks are expressed here to M. L. Thompson, formerly of the University of Wisconsin and now of the Illinois State Geological Survey, who was Verville's advisor during the progress of the field studies and preparation of the report. Data on unconsolidated beds were obtained from Charles K. Bayne, who investigated the post-Paleozoic deposits of the area in connection with groundwater studies.

The splendid cooperation of many people who live in Elk County or who have interests there is gratefully acknowledged. Here should be mentioned Lester Stryker and Morris Stryker of

Fredonia; J. E. Brinegar, W. H. Denton, Carl Morrow, and J. E. Perkins of Howard; Harry Brandenburg, William Hall, Tom Henrickson, Harry Jones, Cecil Marshall, and Holly Schappel of Moline; W. A. Colvin of Madison; Frank Anderson and Hal Redmon of Wichita; C. W. Studt and Thomas Lee of Independence; Bib Murry of Grenola; C. E. Whittaker and Dave Morgan of Eureka; Fred Osborne of Elk Falls; and A. E. Basinger of Bartlesville, Oklahoma.

Thanks are also expressed to Holly Wagner, U. S. Geological Survey, for his cooperation in several phases of the investigations, and to Wallace Lee for his help regarding subsurface formations.

Raymond C. Moore's unpublished geologic map of Elk County and many stratigraphic sections were especially useful during progress of the mapping.

Drafting of maps and figures was done under the supervision of Sally Asbury.

The manuscript has been read by Frank C. Foley, R. C. Moore, V. C. Fishel, Howard G. O'Connor, and W. D. Johnson, Jr.

STRATIGRAPHY OF OUTCROPPING ROCKS

Plate 1 is an areal geologic map of Elk County. Stream valley alluvium and terrace deposits are of Pleistocene and late Tertiary (?) age, but most of the area is occupied by more strongly consolidated rocks of late Pennsylvanian and early Permian age. On this and following pages, where the rock succession in Elk County is described, statements of thickness and distribution apply to this county only unless otherwise indicated. Exposures of most of the outcropping Paleozoic rocks in the county are represented graphically in Figures 2, 3, 4, 5, and 6.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

Stream Valley Alluvium

Stream-laid deposits of gravel, sand, silt, and clay as much as 40 feet thick occupy the valleys of Elk and Fall Rivers. Thinner accumulations partly fill the valleys of smaller streams. In the larger valleys coarse material, predominantly chert, limestone, and sandstone gravel, commonly is found in a lower zone ranging from a fraction of an inch to 8 feet in thickness. Sand is intermingled with the pebbles, some of which are 2 to 3 inches in diameter. The upper part of the deposit consists mostly of clay and silt but grades downward into more sandy material. Colors generally are darker near the present land surface, but variations of tan and buff predominate in the lower parts.

The position of present stream valley alluvium, except very narrow belts in small valleys, and the position of the lowest recognizable terrace are shown together on Plate 1.

The thicker deposits of alluvium constitute the most important fresh-water-bearing formation in Elk County.

Terrace Deposits

Stream-laid deposits of clay, silt, sand, and gravel, of Pleistocene age, occur in terraces at elevations lower than those of material believed to have been deposited by streams in Late Tertiary time. Three terraces are recognized along parts of Elk River valley near Longton. The lowest one is narrow and discontinuous. In lithology and thickness the material of this terrace is similar to the alluvium below the present floodplain, and its position in reference to the river valley suggests correlation with the Wiggam terrace along Cottonwood and Neosho Rivers farther north in Kansas (O'Connor, 1953, p. 6).

The most prominent and extensive Pleistocene terrace lies a few feet above the lowest terrace and about 15 to 20 feet above the present floodplain. The material of this terrace is similar to that of the lower and younger valley fills. The position of this intermediate terrace suggests correlation with the Emporia terrace in Chase and Lyon counties (Moore and others, 1951, p. 6; O'Connor, 1953, p. 7). The Emporia terrace is judged to be late Kansan in age.

The third and highest Pleistocene terrace is recognized only in the vicinity of Longton, where it is 20 to 25 feet above the intermediate level. Material below this terrace consists of a thin zone

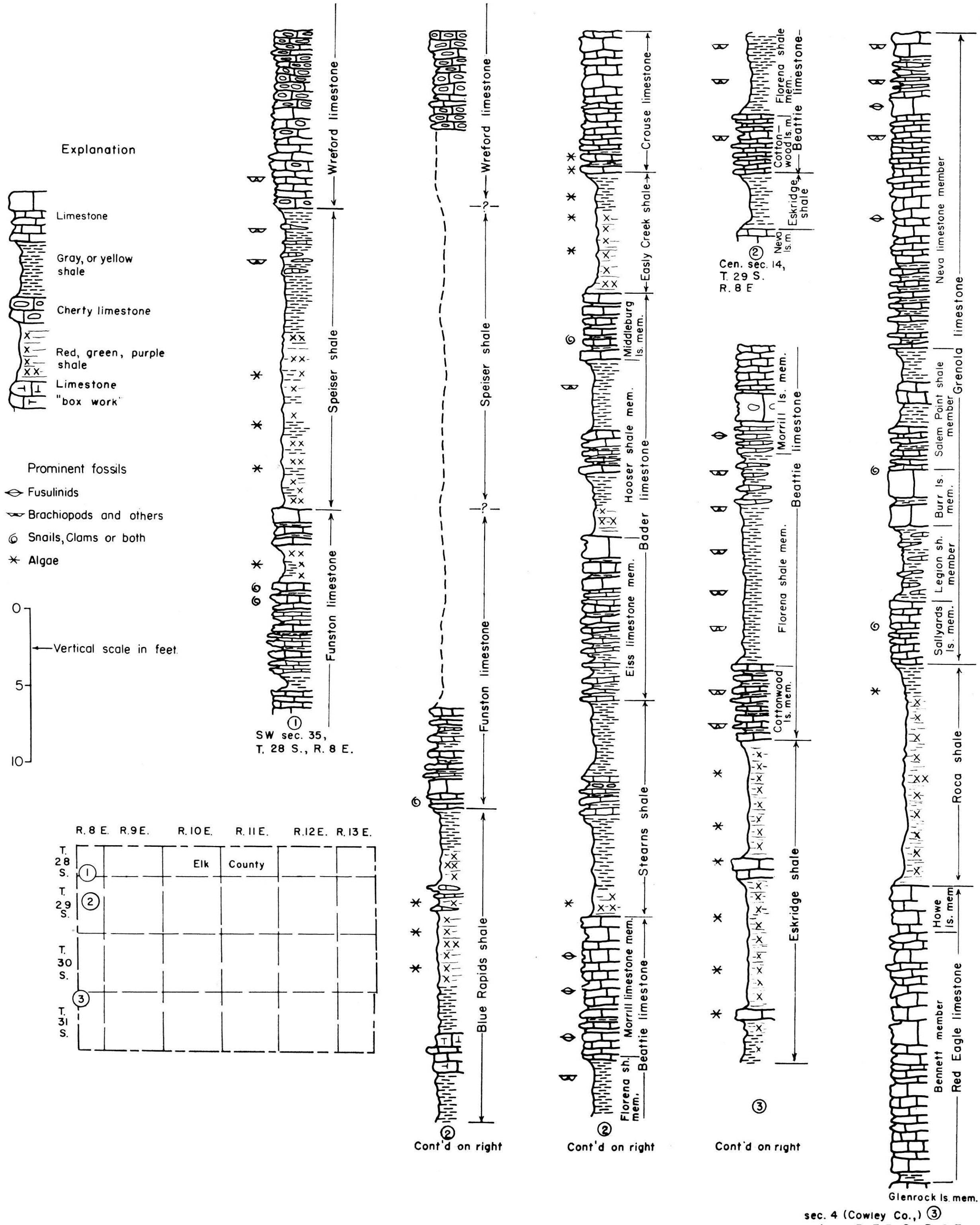

FIG. 2—Diagrammatic representation of outcropping middle Wolfcampian (Permian) rocks.

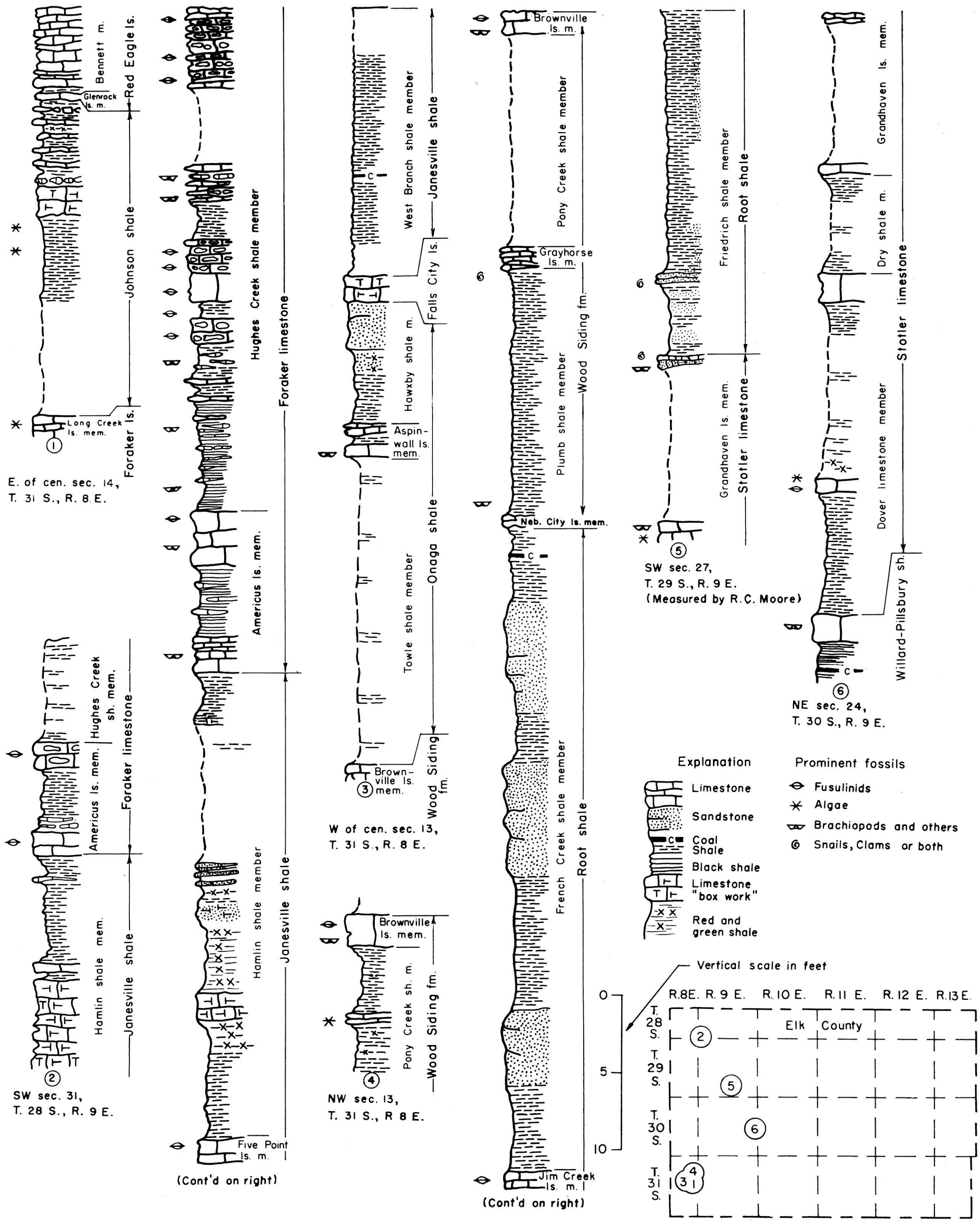

FIG. 3—Diagrammatic representation of outcropping lower Wolfcampian (Permian) and upper Virgilian (Pennsylvanian) rocks.

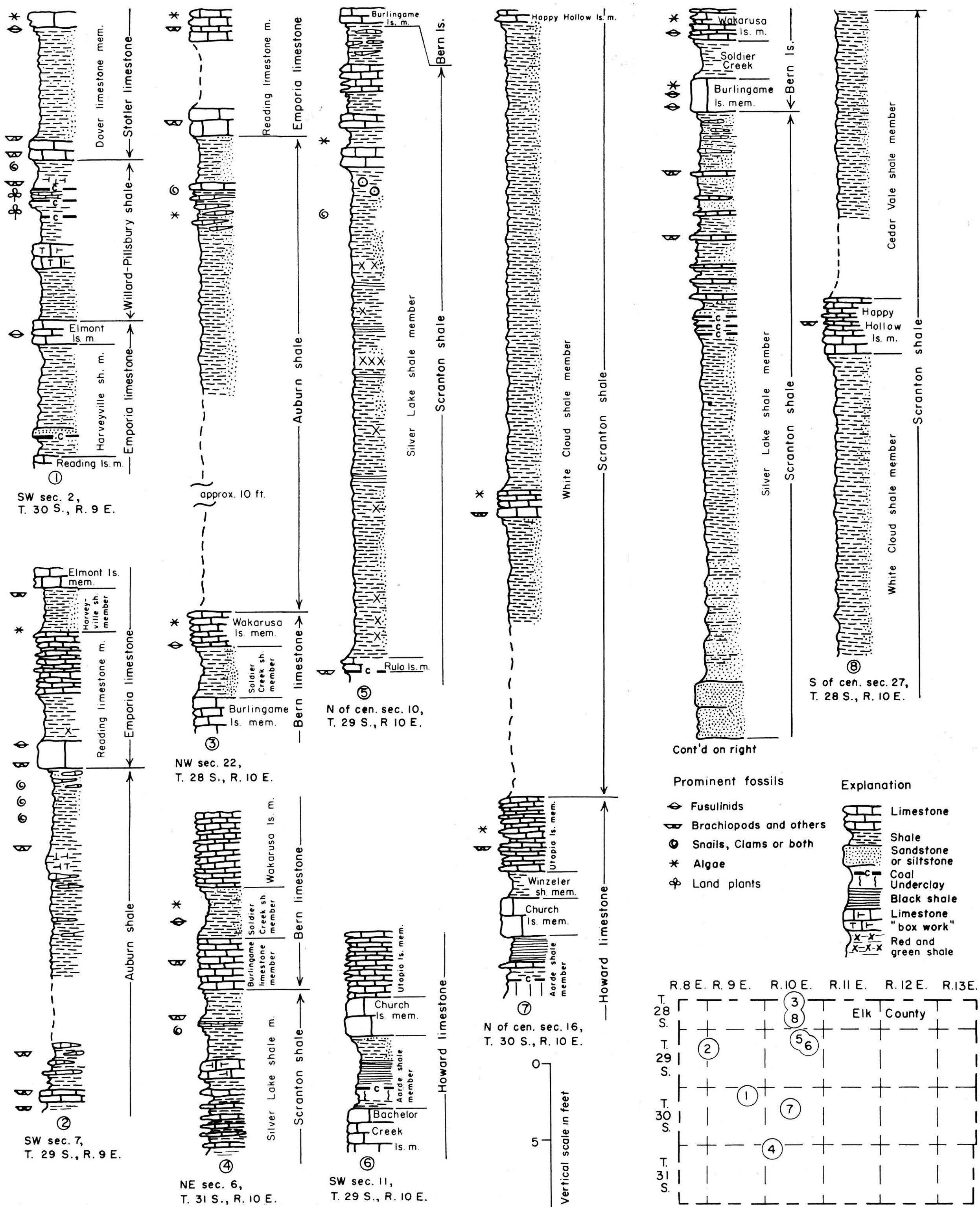

FIG. 4—Diagrammatic representation of outcropping upper Virgilian (Pennsylvanian) rocks.

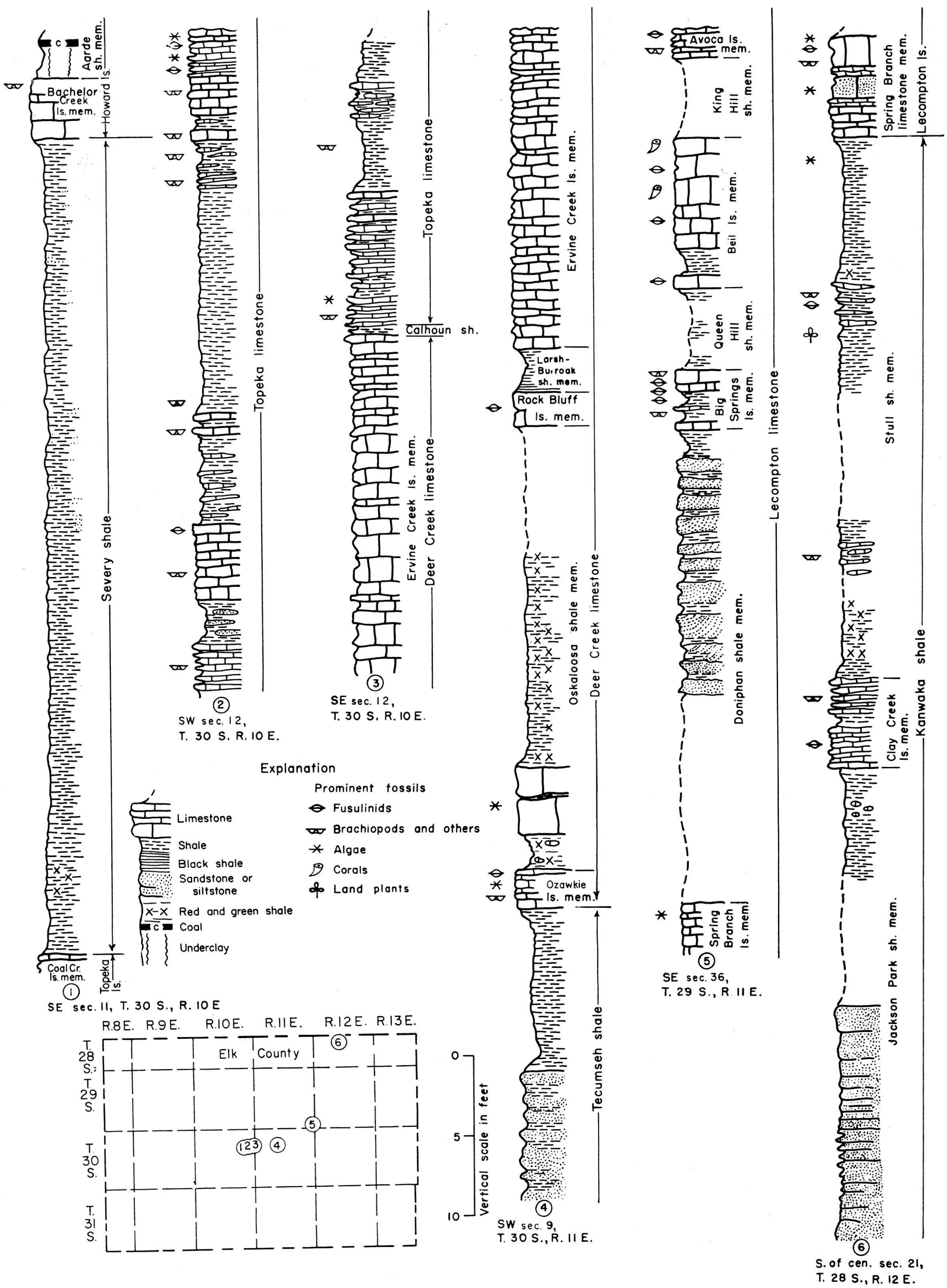

FIG. 5—Diagrammatic representation of outcropping middle Virgilian (Pennsylvanian) rocks.

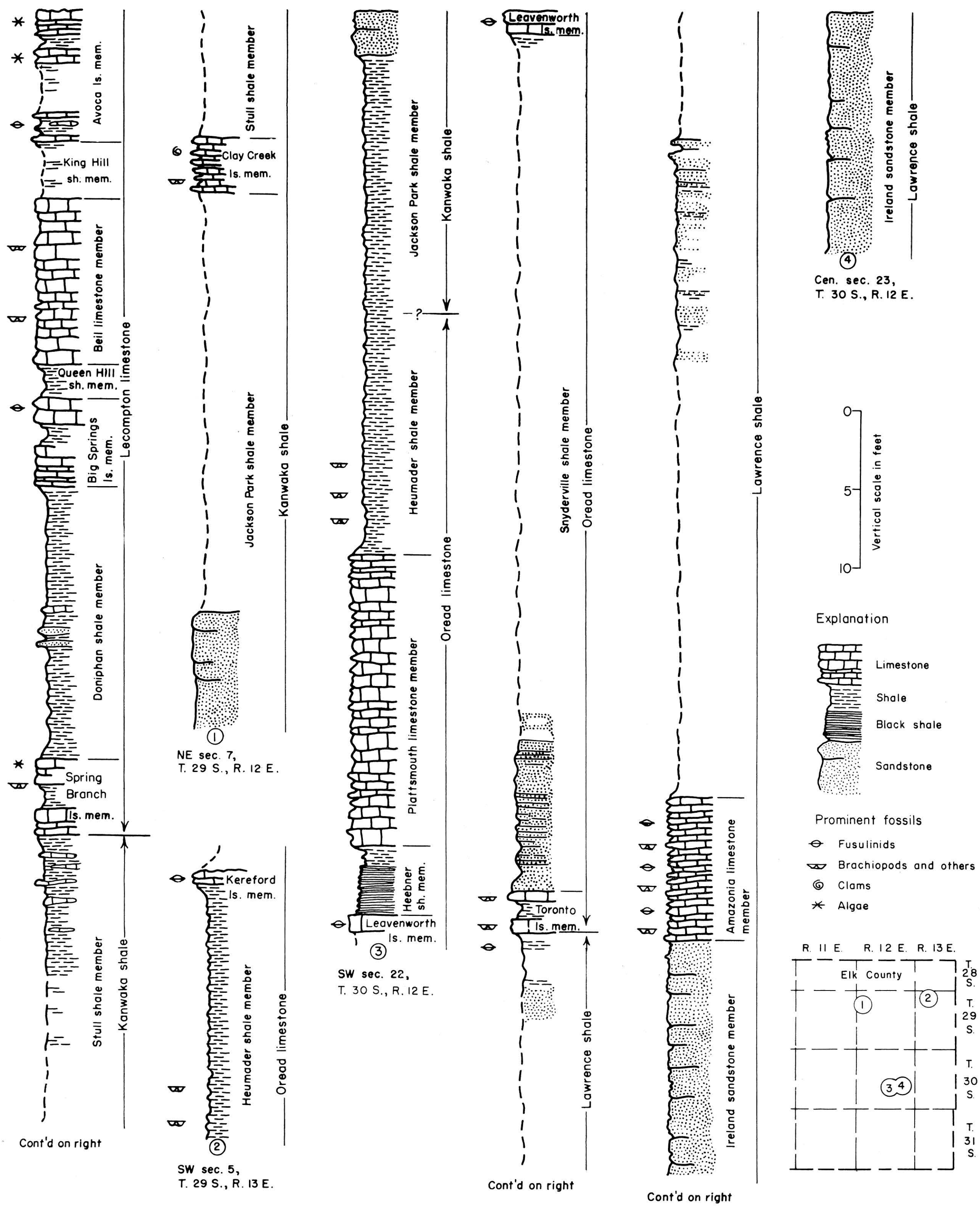

FIG. 6—Diagrammatic representation of outcropping lower Virgilian (Pennsylvanian) rocks).

of fine material underlain chiefly by chert gravel. Material in the two lower terraces yields considerable water to wells. The uppermost terrace, however, generally is above the water table.

TERTIARY (?) SYSTEM

PLIOCENE (?) SERIES

Terrace Deposits

Remnants of a terrace ranging from about 100 to 150 feet above the river valley occur in isolated locations in the Fall River watershed. The deposits constituting the terrace are composed mainly of coarse chert gravels and are, probably at least in part, of late Tertiary age. The average thickness is a few feet. In a few places these chert gravels yield a small amount of water to shallow wells.

PERMIAN SYSTEM

WOLFCAMPIAN SERIES

CHASE GROUP

Barneston Limestone

The lowermost member of the Barneston formation, the Florence limestone member, is the youngest consolidated rock in Elk County. It caps two small hills in the extreme northwestern part, hence is of little importance as an aquifer.

Florence limestone member.—Exposures of the Florence limestone are poor and are covered mostly with fragmental chert weathered from higher parts of the rock. Only the lower few feet of this extremely cherty limestone occurs in Elk County.

Matfield shale

Present only in the extreme northwestern part of the county, the Matfield shale has a thickness of 55 to 60 feet.

Blue Springs shale member.—The thickness of the Blue Springs shale is about 25 feet. Exposures in Elk County do not allow exact measurements or descriptions, but in neighboring parts of Cowley County this unit contains some thin-bedded fossiliferous limestone interbedded with gray shale in the upper part and about 2 feet of gray-green limestone about 6 feet from the base. The rest is bluish-gray and bright-red shale. The formation is unimportant as an aquifer.

Kinney limestone member.—The Kinney limestone holds two fairly prominent benches in the extreme northwestern part of Elk County, where the unit is believed to comprise two limestones separated by a few feet of shale. The total thickness is about 15 feet.

Wymore shale member.—The Wymore shale is covered by soil in the small areas of its outcrop in northwestern Elk County. In neighboring parts of Cowley County it is about 9 feet thick and consists of gray and red shale and includes some lavender limestone in its lower middle part.

Wreford Limestone

Like higher beds, the Wreford limestone is poorly exposed. Measurable exposures in the western part of the county are limited to only a few feet of cherty limestone, which occurs in the lower part of the formation, and they are not suited for differentiating the members of the formation. The upper beds generally are reduced to cherty rubble, which blankets the bench held by the formation. The thickness probably is between 30 and 35 feet. The formation is an important aquifer.

COUNCIL GROVE GROUP

Speiser Shale

The thickness of the Speiser shale is commonly about 28 feet, but one section containing only 19 feet was measured. The upper part consists of thin, gray and buff, nodular limestone and shale beds. There is considerable red and green material in the lower part. The upper part is abundantly fossiliferous, and large specimens of *Derbyia* are plentiful. The formation is of little or no importance as a source of ground water.

Funston Limestone

Where measured, the Funston limestone ranges in thickness from 11 to 13 feet and consists of two limestones separated by 4.5 to 7 feet of buff, gray, and red shale. Locally, the shale is calcareous and contains nodular, partly fossiliferous limestone. The upper limestone, about 2 to 4 feet thick, is dense and platy to massive. The lower limestone, about 1.5 to 2.5 feet thick, is bluish and commonly contains fossil mollusks and algal remains. The formation is of little or no importance as an aquifer.

Blue Rapids Shale

The average thickness of the Blue Rapids shale is about 23 feet. Thin, locally cherty limestone is fairly characteristic, especially of the upper part. Colors of the shale are gray, greenish, and red. Locally, specimens of the large brachiopod *Juresania* are common in the upper part, and sparse algal remains occur in the middle and lower parts. Little if any ground water is obtained from the formation.

Crouse Limestone

The Crouse limestone is about 9 feet thick and in most exposures consists (in descending order) of: 2 to 3 feet of yellowish, thin-bedded, platy limestone; 3 to 4 feet of bluish-gray, dense, massive, locally cherty limestone; and about 3 feet of irregular, thin-bedded to nodular limestone, which characteristically contains discoidal fossil algal colonies (*Ottonosia*), which at least in part are coatings on clam shells. The more massive upper and middle parts of the formation hold a prominent topographic bench along the line of outcrop. A few wells derive water from the Crouse limestone.

Easly Creek Shale

The average thickness of the Easly Creek shale is about 10 feet. The formation is characterized by its distinct brown and red colors and the presence of small white algal masses. This formation is of little or no importance as a source of ground water.

Bader Limestone

About 28 feet is the average thickness of the Bader formation in Elk County, where it is composed of bluish and greenish-gray, thin-bedded limestone and gray, buff, yellow, brown, green, and red shale. Boundaries of members are defined with some difficulty. Little or no ground water is derived from the Bader formation.

Middleburg limestone member.—The Middleburg limestone is about 6 feet thick and consists of gray to greenish, thin-bedded limestone that weathers whitish and is interbedded with gray to greenish shale. The dense, tough limestone commonly contains fossil pelecypods. Its position is marked by a low indistinct bench below the more deeply weathered Easly Creek shale.

Hooser shale member.—About 11 feet is the average thickness of the Hooser shale. In descending order it consists of: about 4.7 feet of buff to yellow shale; 0.2 foot of greenish-gray, molluscan limestone; 2.5 feet of interbedded dark-blue to greenish, nodular, fossiliferous limestone and buff shale; and 4.1 feet of varicolored, algal shale, which commonly is poorly exposed.

Eiss limestone member.—The thickness of the Eiss limestone is about 11 feet. The upper 2 feet is blue-gray, massive limestone, commonly conspicuously pitted and faded to light gray by weathering. It is underlain by about 2 feet of red and green shale. The rock in the lower part (about 7 feet) is buff and gray thin-bedded limestone, the lowermost part of which is nodular and contains fossiliferous gray shale.

Stearns Shale

The Stearns shale is about 13 feet thick. It is well exposed in only a few places, but where seen it consists of about 5 feet of gray shale overlying about 6 feet of red and brown shale, which is underlain by about 2.5 feet of bluish to dark-gray shale and nodular limestone. The more brightly colored shale contains small bodies that are believed to be fossil algae. The brachiopods *Meekella* and *Juresania* and the pelecypod *Aviculopecten* occur in the nodular limestone and associated shale. The formation is of no importance as an aquifer.

Beattie Limestone

The Beattie formation consists of two limestone members and a shale member, and it ranges in thickness from about 15 to 29 feet. The formation is of little or no importance as a source of ground water.

Morrill limestone member.—The thickness of the Morrill limestone averages about 9 feet, but may be as little as 7 feet locally. The upper part is buff to whitish, irregularly thin bedded limestone, and the next lower unit, commonly about 2 feet thick and 3 to 5 feet below the top, is buff to bluish, massive limestone that weathers with an irregular, pitted, light-gray surface. The lower part is buff to yellowish, thin-bedded, nodular limestone interbedded with yellow fossiliferous shale. Fusulinids and sea-urchin plates and spines are abundant in the massive and lower, shaly parts. Material believed to be of algal origin covers many of the sea-urchin fragments.

Florena shale member.—The average thickness of the Florena shale is about 8 feet; a maximum of 14 feet was measured near the Elk-Cowley County boundary between sections 3 and 4, T. 31 S., R 8 E. This unit consists of gray, brownish, and bluish clay shale that is abundantly fossiliferous. Light-gray, argillaceous, nodular limestone in discontinuous beds occurs locally in the upper part where the Florena shale is thicker. The brachiopod *Chonetes* is the most plentiful fossil, but there is an abundance of other forms, including fusulinids, conodonts, mollusks, bryozoans, echinoderms, and trilobites.

Cottonwood limestone member.—The Cottonwood limestone is bluish-gray limestone, interbedded with buff and gray shale, and its average thickness is about 5 feet. Fusulinids are fairly common in the upper part, and gastropods, pelecypods, and productid brachiopods are common in the lower part.

Eskridge Shale

The average thickness of the Eskridge shale is about 23 feet. Gray and red shale and some purplish and greenish limestone are characteristic. The formation commonly is concealed under a grass-covered slope marked by a bench held by distinctive massive limestone beds in its middle part. The Eskridge shale is of no practical importance as an aquifer.

Grenola Limestone

The thickness of the Grenola limestone is about 45 feet. The Neva limestone, uppermost member of the formation, is the most conspicuous part. A few springs issue from the Grenola, and probably a few shallow wells produce water from it.

Neva limestone member.—The Neva limestone is about 20 feet thick. There is some shale in the lower part, especially in the southern part of adjacent Greenwood County, but to some extent it grades into nodular and thin-bedded limestone in southern Elk County. The upper part of the unit is composed of massive and thin-bedded limestone. Light gray is the prevailing color. Fusulinids are plentiful.

Salem Point shale member.—The thickness of the Salem Point shale averages about 7 feet. Gray to brown shale is the prevalent rock. Some bluish-buff limestone occurs in the upper part, and the middle part is characteristically marked by "limestone box work", a network of calcite veins. A thin, dense, pelecypod-bearing limestone occurs in the lower part.

Burr limestone member.—The Burr limestone is about 4 feet thick and consists of two massive, blue-gray to dark-gray dense limestones separated by about 0.2 foot of shale. Fossils include ostracodes, the pelecypod *Myalina,* and small snails.

Legion shale member.—About 5 feet is the common thickness of the Legion shale. It comprises gray to buff shale and a few limestone stringers. This rock is sparsely fossiliferous, containing a few pelecypods and the brachiopod *Juresania.*

Sallyards limestone member.—Measured sections of the Sallyards limestone show a thickness of 3.5 to 4.1 feet. Where best exposed it consists of bluish-gray massive to platy, irregularly bedded limestone that weathers dark gray. Pelecypods, crinoid fragments, and bryozoans are common.

Roca Shale

The Roca shale is about 15 feet thick. The upper few feet is gray to brown shale that in some places contains small white to cream-colored nodules, which are believed to be fossil algae. The rest of the formation commonly is red to purplish shale, but in some exposures the lowermost part is green, gray, or brown. This formation commonly is concealed under a grass-covered slope. The formation is of little or no importance as a source of ground water.

Red Eagle Limestone

The Red Eagle limestone is about 19 feet thick. The formation consists almost entirely of limestone, but members recognized farther north in Kansas and in southern Nebraska are differentiated (O'Connor and Jewett, 1952). Exposures in Elk County are sparse; an outcrop in sec. 4, T. 31 S., R. 8 E., affords the best opportunity for study. The formation is of little or no importance as an aquifer.

Howe limestone member.—The Howe limestone is 2.5 feet thick. It is buff and chalky and occurs as a massive bed. Recognizable fossils are minute foraminifers and minute gastropods.

Bennett shale member.—The Bennett shale is represented almost entirely by a limestone facies. The measured thickness of the member is 19.9 feet. All except the lower 0.3 foot of the unit is coarsely crystalline gray limestone that weathers buff. It occurs in irregular well-jointed beds a few inches thick, and the lower part is somewhat nodular. The lowest 0.3 foot is gray, silty shale, containing rusty-brown fragments of *Orbiculoidea.*

Glenrock limestone member.—The lowermost member of the Red Eagle formation is a silty, nodular, gray, fusulinid-bearing limestone 0.2 foot thick.

Johnson Shale

The thickness of the Johnson shale is about 20 feet. Where best exposed the upper 7 feet is bluish-black shale including several thin, blue, dense, nodular limestone beds. This is underlain by 1.9 feet of yellowish, vuggy, earthy limestone, containing a profusion of variously oriented calcite veins, which stand out in relief on weathered surfaces producing a honeycomb, or "boxwork", effect. In the upper part, ostracodes, pelecypods, and productid brachiopods are abundant, and other fossils are common.

Foraker Limestone

The Foraker limestone is a cherty limestone and shale formation about 55 feet thick carrying a prolific fusulinid fauna. This formation is the main aquifer in the northwest part of Elk County.

Long Creek limestone member.—The Long Creek limestone is about 6 feet thick. The upper part, about 1 foot, is gray to tan, tough limestone that weathers nearly white to bright yellow orange and is believed to be mostly algal. At exposures in southern Greenwood County, the middle part of the unit is seen to consist of brown and gray shale that is platy in its lower part. The lower part is dark-gray to bluish, fusulinid-bearing limestone and includes a thin algal zone at the top. In Elk County the Long Creek limestone is commonly present on gentle slopes at a considerable distance west of the escarpments held by thicker limestones in the same formation. Consequently, exposures are generally poor.

Hughes Creek shale member.—The Hughes Creek shale is about 40 feet thick and consists mainly of dense, gray, massive, cherty, fusulinid-bearing limestone and dark-gray, blue-gray, and yellow-gray, fossiliferous shale. About one-half of the thickness of the unit is shale. The limestone, unlike the shale, is fairly well exposed and bears abundant fusulinids in both the chert nodules and the calcareous matrix. Other fossils include ostracodes, crinoid fragments, bryozoans, brachiopods, pelecypods, and conodonts.

Americus limestone member.—The thickness of the Americus limestone ranges from about 7.5 to 11 feet. The unit comprises two limestones separated by shale. In the northern part of the county, the upper limestone is about 1.6 feet thick, blue gray, massive, and cherty. The separating shale is about 4.5 feet thick, bluish to yellow, and contains some platy to nodular limestone beds in the lower part. The lower limestone is about 1.4 feet thick. It is bluish gray and consists of two beds, the lower of which contains thin zones of gray to tan limy pebbles. In the southern part of Elk County, the upper part consists of blue-gray, massive limestone about 3.5 feet thick. The shale, in the middle part of the unit, is about 4.5 feet thick and is blue gray to black. Locally, it is almost coaly. A few blue limestone stringers are in the shale. The lower limestone, about 2 feet thick, is bluish gray, massive, and contains tan and gray limy pebbles in the lower part. In the upper part it has irregular thin beds, and fusulinids are abundant.

ADMIRE GROUP

Janesville Shale

In Elk County the Janesville shale is about 70 feet thick. It comprises two shale members separated by a limestone member in the middle part.

Formerly, strata now recognized as the Janesville shale (Moore and Mudge, 1956, page 2273 and fig. 1) were classed as three separate formations (Hamlin shale, Five Point limestone, and West Branch shale) that now are regarded as members of the Janesville formation.

Hamlin shale member.—The Hamlin shale is about 35 feet thick. It comprises two shale units separated by a limestone near the top. The upper part is the Oaks shale bed, which ranges from about 3 to 7 feet in thickness and averages about

6 feet. There are few exposures of this part of the Hamlin shale in Elk County, but where seen it is brownish in the upper part grading through yellowish into dark gray or nearly black; or the persistent brown part is underlain by thin, yellow-gray limestone, which overlies yellow and bluish platy shale. In turn, this latter is separated from greenish shale below by a thin bed of limestone. Small white nodules in the brown shale in the upper part of the Hamlin are believed to be fossil algae.

A limestone bed is the middle unit in the Hamlin shale. This unit is believed to be the Houchen Creek limestone. Its thickness is about 3.5 feet. It is buff to orange yellow, earthy, and shaly, and it is characteristically marked by well-developed calcite veinwork, which stands out in relief as pronounced "boxwork" where weathered.

The lower part of the Hamlin shale was formerly known as the Stein shale member of the Hamlin formation. The strata have a thickness of about 32 feet. Where best exposed, they grade from gray to yellow shale in the upper few feet to the green and red material that constitutes most of the unit. The lower part consists of yellow to orange and gray shale overlying greenish-gray, blocky shale. Locally, there is a well-developed "boxwork" of calcite and some silty, crinkly, thin-bedded limestone in the middle part.

Five Point limestone member.—This limestone is about 2 feet thick, dark to brownish gray, and weathers to yellow orange. It is massive and at the outcrops commonly is broken down into two or three irregular beds. Fusulinids are abundant, and brachiopods and bryozoans are common.

West Branch shale member.—Measured sections of the West Branch shale range from about 20 to 36 feet in thickness. A thin bed of coal occurs about 8 to 14 feet below the top. The upper part of the formation is greenish-gray shale, which grades downward into bluish-gray to black shale containing some greenish material. Yellow to tan calcite "boxwork" and limestone stringers occur locally in the lower part.

Falls City Limestone

The Falls City limestone is 2 to 3 feet thick. It is earthy to dense, dark-blue to yellowish-gray limestone containing numerous joints filled with calcite. In some places, the lower part is massive and the upper part is nodular; in other places, the unit consists of three or more nearly uniform beds. Most of the fossils are fragmentary. *Composita, Meekopora,* bellerophontid gastropods, and crinoids are most common.

Onaga Shale

The Hawxby shale, Aspinwall limestone, and Towle shale formerly were classed as individual formations, but according to present classification (Moore and Mudge, 1956), they are regarded as members of the Onaga shale, which in Elk County has an average thickness of about 20 feet.

Hawxby shale member.—The thickness of this unit ranges from about 6 to 8 feet. The upper part is gray and locally contains micaceous sandstone. The lower part is red, purple, green, and yellow. Locally, a thin, bluish-gray, nodular limestone, believed to be algal, is present next below the upper gray part.

Aspinwall limestone member.—The average thickness of the Aspinwall limestone is 2 feet. Locally, about 0.6 foot of shale occurs between the upper and lower parts. Exposures in Elk County are poor, but where best seen the unit is thin-bedded to slabby and dark gray. It contains a mixed molluscan-bryozoan-brachiopod fauna.

Towle shale member.—The Towle shale has an average thickness of about 20 feet. It commonly consists of yellow to gray micaceous shale, which weathers greenish gray. Locally, the upper part contains several thin bluish limestone beds interbedded with gray and tan shale. Physical evidence of disconformity at the base of the Towle shale was not observed in Elk County.

The Admire group of rocks is of only minor importance as aquifers. Locally, small amounts of water are obtained from relatively shallow dug wells.

PENNSYLVANIAN SYSTEM

VIRGILIAN SERIES

WABAUNSEE GROUP

Wood Siding Formation

As defined by Moore and Mudge (1956, p. 2273), the Wood Siding formation comprises beds formerly assigned to the Brownville, Pony Creek, and Caneyville formations. The first two of these units (two uppermost) were retained by Moore and Mudge as members of the Wood Siding formation.

In Elk County, the Wood Siding formation has an average thickness of about 40 feet. The formation is of little importance as an aquifer.

Brownville limestone member.—The Brownville limestone ranges from about 1 to 2 feet in thickness. It commonly is a single massive bed of gray limestone that weathers yellow or brown. Its outcrop is persistent. The rock is characterized by an abundance of fusulinids and the brachiopods *Chonetes* and *Marginifera*. It also contains crinoid fragments, echinoid spines, and bryozoans.

Pony Creek shale member.—The average thickness of the Pony Creek shale is about 18 feet. Gray brown in the upper part, the shale grades downward into bluish green and yellowish gray. A thin coal bed occurs about 9 feet below the top of the formation. Pelecypods and ostracodes have been observed in the shale.

Grayhorse limestone member.—This unit is slightly more than 1 foot thick. It consists of dark-gray massive limestone that weathers buff to yellowish and breaks down into thin wedge-shaped slabs, giving the ledge a distinct cross-bedded appearance. Locally, it is a coquina of small fragments of pelecypods, *Myalina* being the most common.

Plumb shale member.—Plumb is a new stratigraphic name introduced by Moore and Mudge (1956, p. 2275) for shale that formerly was regarded as the middle unit of the Caneyville formation.

This part of the Wood Siding formation ranges in thickness from about 17 to 30 feet. It is bluish-gray to yellowish, micaceous shale, which locally contains some sandstone and thin limestone beds. In the southern part of Elk County, the upper part of the unit contains three limestone beds. The upper one is 0.5 foot thick, dark gray, weathering yellow to rusty, and contains fusulinids. The middle limestone is a 1-foot bed of dark-blue, brownish-weathering limestone crowded with small snails, brachiopods, and bryozoans. The lower limestone is lenticular, dense, and blue, and contains small siltstone pebbles in its lower part. *Myalina* is abundant in shale above the thin limestones in that area.

Nebraska City limestone member.—The Nebraska City limestone is about 1 foot thick. It consists of bluish-gray, dense, locally somewhat impure, massive limestone that weathers buff to orange. Observed fossils include fusulinids, the pelecypod *Aviculopinna*, crinoid fragments, and small brachiopods.

Root Shale

Moore and Mudge (1956, p. 2275) have defined the Root shale as a formation comprising strata formerly assigned to (in descending order): French Creek shale, Jim Creek limestone, and Friedrich shale formations; these units now are regarded as members of the Root formation. In Elk County this formation is about 70 feet thick.

French Creek shale member.—The average thickness of the French Creek shale is about 37 feet; as much as 42 feet was measured in the northern part of the county. The member comprises gray and greenish to bluish shale and gray to brown sandstone. Locally, the sandstone fills channels. In the northern part of the county, a thin coal bed lies near the top of the unit.

Sandstone in the French Creek shale yields small amounts of water in a few places.

Jim Creek limestone member.—The Jim Creek limestone is about 1 foot thick. It is dark blue to bluish gray and massive. The rock weathers purplish, making identification easy. Fusulinids are common and pelecypods are sparse.

Friedrich shale member.—The Friedrich shale is about 30 feet thick and consists of gray to bluish shale, which becomes more micaceous and sandy southward in the county. A thin bed of coal occurs about 1 foot below the top of the member. A sandstone ranging from a featheredge to as much as 10 feet thick commonly is seen below the coal bed, but locally the position of the sandstone is ocupied by sandy shale. In the northern part of the county, one or more thin pelecypod-bearing limestones occur in the lower part of the formation. Locally, small quantites of water are obtaned from the Friedrich shale.

Stotler Limestone

Moore and Mudge (1956, p. 2275) have defined the Stotler limestone as a formation comprising the Grandhaven limestone, the Dry shale, and the Dover limestone as members; these units formerly were regarded as individual formations. In Elk County the Stotler formation averages about 38 feet thick.

Grandhaven limestone member.—The average thickness of the Grandhaven limestone is about 10 feet. The unit consists of two or three thin limestones separated by gray and brown shale beds 4 to 11 feet thick. Locally, there is a thin coal bed in the shale. The lowermost limestone bed of the member is dark gray and weathers brown and is less than 1 foot thick. The uppermost limestone is bluish and weathers to a rusty brown. It averages about 1 foot in thickness and contains "*Osagia*", small brachiopods, and crinoid fragments. *Crurithyris,* rhomboporid and fenestellid bryozoans, and crinoid fragments are abundant in the shale portion.

Dry shale member.—The Dry shale averages about 7 feet thick and consists of gray and brown shale, which is fossiliferous, containing ostracodes, pelecypods, gastropods, bryozoans, and crinoid fragments. A thin coal bed lies in the upper part of the member. The Dry shale carries very little water.

Dover limestone member.—The Dover limestone is about 21 feet thick, and it consists of three thin limestones separated by gray, brown, and greenish-gray shale beds. The separating shales are locally fossiliferous. The upper limestone is 2 to 3 feet thick. It is bluish-gray, brown-weathering thin-bedded limestone composed mostly of algal material, "*Osagia*". The middle limestone is a single bed of dark-gray limestone that characteristically weathers into slabs and contains an abundance of black cryptozoans and slender specimens of *Triticites*. The lower limestone averages about 1.7 feet in thickness; it is dark blue, dense, and massive, and weathers buff to bright orange. The brachiopod *Chonetes* is abundant in this lower bed.

Weathered parts of the Dover limestone locally are sources of some water in wells.

Willard-Pillsbury Shale

Moore and Mudge (1956, p. 2275) have introduced the name Pillsbury as the name of strata between the Dover and Maple Hill limestones.

Because the Maple Hill and Tarkio limestones and the intervening Wamego shale have not been identified as far south as Elk County, strata between the Dover limestone (above) and the Elmont limestone are classed as Willard-Pillsbury. In Elk County the thickness of this part of the section averages about 9 feet and diminishes southward in the county. Lithologically the unit is variable, but one or more thin coal beds are present in all exposures studied. Thin-bedded or slabby limestone, in places overlain and underlain by coal deposits, seemingly is persistent in the northern and central parts of the county, and locally there is a limestone "boxwork" in the lower middle part of the section. The shale commonly is buff to greenish gray. Plant remains are present in the limestone beds that are associated with coal seams, and an assemblage of bryozoans, brachiopods, pelecypods, echinoderm fragments, and ostracodes is characteristic of the upper part of this stratigraphic unit.

Locally, the formation yields some water.

Emporia Limestone

Moore and Mudge (1956, p. 2276) revived the name Emporia limestone. The formation, as defined by Kirk (1896, p. 78-85), includes the Elmont limestone, the Harveyville shale, and the Reading limestone, units that for most of the intervening time were regarded as individual formations. In Elk County the Emporia formation has a thickness of about 22 feet.

Elmont limestone member.—The maximum thickness of the Elmont limestone is slightly more than 5 feet. This unit changes markedly in lithology, faunal content, and thickness across the county. At exposures in the northern part, it is slightly less than 2 feet thick, and is bluish-gray, buff-weathering, somewhat massive limestone containing an abundance of small, slender fusulinids. Farther south it is about 5 feet thick, bluish gray, slightly cross-bedded, somewhat conglomeratic, and crinoidal. The Elmont limestone is the source of water in some relatively deep wells.

Harveyville shale member.—The average thickness of the Harveyville shale is about 9.5 feet. Gray, micaceous, silty and sandy shale, which contains algal pellets in the upper part and limonitic concretions in the lower and which is streaked with orange, grades southward into bluish- and greenish-gray and reddish clay shale. A thin bed of coal lies in the lower part of the unit in the northern part of the county.

Reading limestone member. — The Reading limestone averages 6 feet thick, but in the northern part of the county about 10 feet has been measured where two or three thin limestones separated by shale are present below the more persistent part. This persistent part is a bluish-gray, massive, vertically jointed limestone, about 2.5 feet thick. Locally, as much as 4 feet of thin-bedded, algal limestone lies above the main, massive unit. The shale parts are gray and bluish gray to bluish black. Fusulinids are abundant in the main massive ledge. The lower limestones commonly are abundantly fossilferous, containing fusulinids, bryozoans, ostracodes, and algal remains.

Auburn Shale

The Auburn shale averages slightly less than 40 feet thick. The formation is variable in lithology, consisting of red, gray, brown, and blue-green, clayey to sandy shale containing thin blue limestones, gray bedded to nodular siltstones, and buff to brown limestone "boxwork". Some of the thin limestones in the middle and lower parts of the Auburn shale are fossiliferous. This formation is unimportant as an aquifer.

Bern Limestone

The Bern limestone (Moore and Mudge, 1956, p. 2276) includes the Wakarusa limestone, Soldier Creek shale, and Burlingame limestone, formerly classed individually as formations. In Elk County the Bern formation is about 12 feet thick.

Wakarusa limestone member.—The average thickness of the Wakarusa limestone is about 5 feet but 7.7 feet was measured in the southern part of the county and only 2 feet in the northern part. Light bluish-gray fusulinid- and algal-bearing limestone is characteristic. Where thickest, the member includes about equal amounts of gray shale and limestone. The shale occurs in the middle part. The Wakarusa limestone locally yields some water.

Soldier Creek shale member.—The Soldier Creek shale is commonly slightly less than 3 feet thick and consists of bluish- and greenish-gray clay shale locally streaked with yellow. It is sparingly fossiliferous, crinoid fragments and ostracodes being the most plentiful forms.

Burlingame limestone member.—The Burlingame limestone averages about 3 feet thick. It is thinner and somewhat more massive in the northern part of the county than in the southern part. The rock is commonly brown, algal in its upper par, and fusulinid bearing in the lower part. Locally, in the southern part of the county, the two parts are separated by slightly less than 1 foot of gray, calcareous, algal shale. In addition to "*Osagia*" in the upper part and small fusulinids in the lower, echinoid fragments, bryozoans, brachiopods, and pelecypods are fairly common fossils in the formation.

Scranton Shale

Strata between the base of the Burlingame limestone and (downward) the top of the Howard formation (Utopia limestone) are included in the Scranton shale (Moore and Mudge, 1956, p. 2277). In Elk County the Scranton formation has a thickness of about 125 feet.

Silver Lake shale member.—The Silver Lake shale averages about 40 feet thick. The member consists of gray shale and includes thin, platy, impure, pelecypod-bearing limestone beds in the upper part. The lower part is sandy and micaceous and contains thin sandstone lenses and sandy concretions. Vertical jointing is common in the lower part. In the northern part of the county, there is a thin coal bed about 15 feet below the top of the member. Locally, channel-filling sandstones carry some water.

Rulo limestone member.—The Rulo limestone averages slightly less than 1 foot in thickness. It is dark gray and weathers brown and platy. Its upper part, at least locally, is algal. Fossils are not plentiful in the Rulo limestone, but the alga "*Osagia*", productid and spiriferid brachiopods, gastropods, and echinoderm fragments are present. Seemingly the Rulo limestone has been removed locally by intraformational erosion (Fig. 4, stratigraphic section 8).

Cedar Vale shale member.—About 30 feet is the average thickness of the Cedar Vale shale. The member is poorly exposed; it, with the overlying Silver Lake shale, almost everywhere is concealed by long, grass-covered slopes. The position of the separating Rulo limestone is marked by a slight bench about midway between the Burlingame and Happy Hollow limestones. Almost all of the upper part (about 1 foot) of the Cedar Vale is gray shale containing marine fossils in the upper part and sparse land plant fossils in the lower part. Next below is a thin coal bed, the Elmo. Sandy shale or thin-bedded sandstone, below the Elmo coal, grades downward into more clayey, gray and yellow shale. Locally, sandstone in the Cedar Vale shale carries some water.

Happy Hollow limestone member.—The thickness of the Happy Hollow limestone ranges from about 2 to 10 feet and most commonly is about 3 feet. In most exposures the member comprises one or more massive beds of pinkish-brown, massive limestone containing abundant large fusulinids. The member is unusually thick in sec. 8, T. 30 S., R. 10 E., where it consists of 11 feet of light-gray to buff limestone, massive in the lower part but irregularly bedded in the upper part. The increase in thickness is due to accumulation of algal material.

White Cloud shale member.—The thickness of the White Cloud shale is about 50 feet. Where best exposed, approximately 30 feet in the upper part is gray to yellowish brown, finely laminated, and micaceous; the uppermost part is sandy. The lower part of the White Cloud member comprises dark gray to black shale and limestone beds ranging from a featheredge to a few inches in thickness. Algal remains, corals, ostracodes, and brachiopods are present as fossils in the limestone and shale beds in the lower part of the unit. Sandy parts of the White Cloud carry some water.

Howard Limestone

In Elk County the Howard limestone is 11 to 12 feet thick. The formation includes three limestone and two shale members. A persistent coal bed is present in the lower shale member. A few shallow wells obtain water from weathered parts of the formation.

Utopia limestone member.—The average thickness of the Utopia limestone is about 5 feet. The rock is dark bluish gray and weathers rusty brown, buff, or bright orange. Locally, it is nearly a coquina of shell fragments and algal remains. Thin bedding is characteristic of the ledge.

Winzeler shale member.—In all exposures where studied, the Winzeler shale is less than 2 feet thick, and in several places the unit was observed to be little more than a thin shale parting between the overlying and underlying limestones. In the thicker sections the Winzeler shale is yellowish brown and clayey.

Church limestone member.—The Church limestone averages only about 2 feet thick, but inasmuch as it is massive and resistant to weathering, it is the most prominent part of the Howard formation. The rock is dark bluish gray, hard, and dense. Weathered surfaces are bright brown to buff. Fusulinids are common, and other fossils are fairly plentiful.

Aarde shale member.—In measured sections the Aarde shale ranges from 1.6 to about 5 feet in thickness. It comprises gray and black fissile shale in the upper part and a thin coal bed (the Nodaway), gray shale, and underclay in the lower part. Locally, south of T. 30 S., a thin bed of dark-gray limestone occurs a short distance above the coal bed.

Bachelor Creek limestone member.—The Bachelor Creek limestone averages slightly less than 3.5 feet thick. It is light to dark bluish-gray limestone that weathers dark gray and buff. The rock is silty and impure and contains echinoderm fragments, pelecypods, and brachiopods.

Severy Shale

The Severy shale averages about 70 feet in thickness; it is composed of gray to buff, silty and sandy, micaceous shale, the upper part of which locally contains lenses and nodules of hard, bluish-gray siltstone and sandstone. The lower part commonly is laminated gray silty and sandy shale including yellowish and bluish streaks. Vertical jointing is common in the lower part, which locally contains some red clay. South of the town of Howard, hills that lie east of the Howard limestone escarpment are capped with bluish-gray siltstone in the upper part of the Severy. The Severy shale does not carry important amounts of water.

SHAWNEE GROUP

Topeka Limestone

In Elk County the Topeka limestone has a thickness of 40 to 50 feet. Of the nine members recognized within the formation farther north in Kansas, only the upper and lower ones are differentiable in Elk County.

Coal Creek limestone member.—The uppermost division of the Topeka formation in Elk County is a persistent fusulinid-rich limestone that, according to R. C. Moore (personal communication), is traceable into the Turkey Run limestone of the Pawhuska formation in northern Oklahoma. It is here called Coal Creek limestone, however, because it occupies the position of the topmost member of the Topeka formation farther north. Its thickness in Elk County ranges from about 5 to 8.5 feet. The rock mainly is dark to brownish gray and weathers buff to gray. The ledge is thin and wavy bedded. It is characterized by abundant, large fusulinids. Algae are numerous in places at the top. Common fossils include "*Osagia*", *Triticites*, rhomboporid bryozoans, brachiopods, and echinoderm fragments. Several species of pelecypods and a small, high-spired gastropod are present in the lower part.

Undifferentiated shale and limestone. — The middle part of the Topeka formation in Elk County, comprising shale and limestone about 35 feet thick, is not classifiable in terms of member divisions recognized in northern Kansas and Nebraska. Hence, in this report strata between the Coal Creek member and the bottom limestone member (identified as Hartford) are undifferentiated. They correspond in stratigraphic position to the members that in the north have been named (in downward order) Holt shale, Du Bois limestone, Turner Creek shale, Sheldon limestone, Jones Point shale, Curzon limestone, and Iowa Point shale. It is pointless to describe features that distinguish these units farther north because they are all foreign to the middle Topeka succession in Elk County.

The upper part of the undifferentiated Topeka beds as just defined consists of 15 to 23 feet of predominantly shaly strata characterized by the abundance and variety of invertebrate fossils found at most outcrops. These include especially abundant *Chonetes* shells and very slender small fusulinids (*Triticites*), which may lie closely together in alignment on thin limestone plates; common *Neospirifer*, *Echinoconchus*, *Dictyoclostus*, *Juresania*, and other brachiopods; and a profusion of well-preserved small gastropods and pelecypods. Crinoid remains and ammonoids are less common. A zone of abundant slender ramose bryozoans (*Rhombopora*) occurs commonly at the top of the shale, just below the Coal Creek limestone. Most of the shale is light ash gray in fresh exposures; but some layers are yellowish, and weathered outcrops are gray to brownish. Earthy to silty limestone occurs as plates, as nodules, and in thin beds a fraction of an inch thick. Some beds are calcereous fossiliferous siltstone, which breaks with irregular conchoidal fracture. According to Moore (personal communication), this shaly division of the Topeka formation is widely distributed in Chautauqua and Greenwood counties, to the south and north of Elk County, respectively.

Next below the fossiliferous shaly unit is a fairly persistent brown-weathering limestone, which is blue gray to dark blue in fresh exposures. The topmost bed is massive and hard, has an even upper surface, and contains abundant "*Osagia*". Lower beds lack "*Osagia*" but carry brachiopods and, in places, fairly numerous robust fusulinids. This division, about 3 to 5 feet thick, which may represent the Curzon member, overlies light-tan, fine-grained sandstone or very sandy shale at some outcrops, especially in the vicinity of Moline, and this sandy zone aids in distinguishing the limestone.

Beneath the sandstone is 3 to 5 feet of bluish silty to clayey unfossiliferous shale. Generally this is a covered zone. It is the basal division of the undifferentiated Topeka beds.

Hartford limestone member.—The lowermost Topeka member in Elk County consists of thin-bedded, fine-grained, blue-gray to dark-blue limestone, the basal 0.5 to 1 foot of which is characterized especially by adundance of large algal colonies (*Ottonosia*) associated with the chambered sponge *Amblysiphonella*. The thin-bedded strata locally contain fusulinids, but in some outcrops search fails to discover these fossils. The *Ottonosia-Amblysiphonella* bed is an extremely persistent marker, which has been identified by Moore from northern Kansas to Oklahoma, and it serves to define the lower boundary of the Topeka formation.

Calhoun Shale

In Elk County the Calhoun shale is almost nonexistent, for the maximum thickness of shaly strata between the basal Topeka *Ottonosia-Amblysiphonella* bed and the "*Osagia*"-bearing, easily identified top of the Ervine Creek limestone (uppermost member of the Deer Creek formation) is barely 5 feet. This section is not commonly exposed. Where well exposed, this sequence is seen to consist of unfossiliferous dark-blue to drab, silty to clayey shale. Near Moline and east of Howard, this shale is less than 0.5 foot thick, and locally it is absent.

The Calhoun shale is of no importance as an aquifer.

Deer Creek Limestone

The Deer Creek limestone is 55 to 70 feet thick. The formation includes three limestone and two shale members. The upper member, the Ervine Creek limestone, caps a pronounced escarpment across the east-central part of Elk County.

The Deer Creek formation is an important aquifer in a large area where it lies at shallow depth. Springs are present along its outcrop.

Ervine Creek limestone member.—The Ervine Creek limestone in Elk County is about 15 to 25 feet thick. Where best exposed, in a quarry northeast of Moline, it consists of 23 feet of nearly uniform fossiliferous light-gray limestone. The top is a massive osagite bed having an even upper surface. The member is darker gray near the top and lighter gray and somewhat uneven bedded in the lower part. There are numerous very thin, dark shale partings that separate the massive beds. The member is characterized by robust fusulinids. Other marine invertebrates are also well represented.

Larsh-Burroak shale member.—The Larsh-Burroak shale averages about 3 feet in thickness. It is gray and bluish gray in the upper part and black and fissile in the lower part.

Rock Bluff limestone member.—The Rock Bluff limstone ranges in thickness from 1.5 to 2 feet. It is dark-bluish, hard, brittle limestone occurring commonly in one vertically jointed bed. The rock weathers into sharp, angular blocks. Fusulinids are the most numerous and characteristic fossils.

Oskaloosa shale member.—The thickness of the Oskaloosa shale averages about 28 feet, but as much as 34 feet was measured. The member is mostly red to green and purplish shale containing sandstone lenses and plates. Locally, sandstone in the upper middle part is cross bedded, and it may be thick enough and hard enough to be prominent topographically. In some exposures there is a 4-foot bed of greenish to dark-gray algal limestone about 2.5 feet above the base.

Ozawkie limestone member.—The lower member of the Deer Creek formation averages about 2.5 feet thick. It comprises two or three beds of limestone separated by gray-brown, yellowish, or locally red and green shale. Bluish-gray, mottled algal and fusulinid limestone is characteristic.

Tecumseh Shale

The Tecumseh shale consists mostly of sandy and silty gray shale, red, green, and bluish-gray shale, and sandstone. Its average thickness is about 45 feet. Locally, the upper 15 to 20 feet consists of thin to fairly massive, cross-bedded layers of gray sandstone, which weathers buff and reddish. A thin bed of limestone occurs about 12 feet above the base of the formation. The shale below this limestone is more clayey than that above. It contains occasional calcareous nodules, and pelecypods are common in its upper part. Sandstones in the Tecumseh formation, in an area south and west of Elk Falls, yield considerable amounts of ground water.

Lecompton Limestone

The thickness of the Lecompton limestone is about 55 feet. The formation contains four limestone and three shale members. Small supplies of water are obtained locally from the weathered upper part of the formation.

Avoca limestone member.—The Avoca limestone averages about 8.5 feet in thickness. The upper part, commonly less than 1 foot thick, is dark-gray shelly limestone underlain by less than 1 foot of gray-brown fossiliferous shale. The most persistent and characteristic part lies next below. It is a limestone bed about 1 foot thick, hard, dense, brittle, vertically jointed and containing abundant cryptozoans (*Ottonosia*), which always are associated with *Amblysiphonella.* Thus, this unit duplicates characters of the basal Topeka (Hartford member) bed. The lower part consists of about 1.6 feet of gray, clayey, fossiliferous shale underlain by about 4 feet of blue-gray, wavy-bedded limestone that weathers brown and contains abundant fusulinids. Other marine invertebrates also are well represented in the Avoca member.

King Hill shale member.—The thickness of the King Hill shale ranges from about 5 to 10 feet.

The member contains a considerable amount of red and greenish-gray clay, but where thin it is composed principally or wholly of gray and bluish shale.

Beil limestone member.—The Beil limestone has an average thickness of about 9 feet. In some exposures about 7 feet of gray to cream, yellow-weathering, massive to thin-bedded limestone is separated below by about 1.5 feet of gray shale from 1 foot of bluish-gray, dense limestone. In other places there is 2 feet of thin, irregularly bedded, yellow-weathering limestone underlain by about 9 feet of light-gray, cream-weathering limestone that is especially massive in its upper part. Corals, characteristic of the Beil in many places, are not particularly abundant in Elk County. Somewhat common fossils are robust fusulinids, corals, bryozoans, and brachiopods.

Queen Hill shale member.—The average thickness of the Queen Hill shale is about 3.5 feet. The unit thickens southward, and the greatest thicknesses were measured in localities where the underlying Big Springs limestone and Doniphan shale are unusually thin. This member is composed principally of dark-gray clayey shale. Black, fissile shale occurs in the middle part of the member in Chautauqua County, and although not observed in southern Elk County, it is probable that this lithology extends that far.

Big Springs limestone member. — The Big Springs limestone has an average thickness of about 4.5 feet. The upper part is massive, dense, and vertically jointed. The lower part commonly is composed of one or more thin beds of limestone and thin shale layers. Locally, the lowermost part is a calcareous sandstone, and in all places where studied it is somewhat sandy. Fossils include fusulinids, ostracodes, and rhomboporid and fenestellid bryozoans.

Doniphan shale member.—The thickness of the Doniphan shale averages about 23 feet but in measured sections ranges from 18 to 28 feet. This unit comprises gray to buff, silty and sandy shale and sandstone. In places the upper part is mainly greenish-gray, slightly cross-bedded sandstone, and locally the middle part contains several thin sandstone beds. In some places, sandstone is thick, hard, massive, and topographically prominent.

Spring Branch limestone member.—The average thickness of this lowermost member of the Lecompton formation is slightly more than 4 feet. In general, there is a slight decrease in thickness southward across the county. At some exposures the unit consists of three massive limestone beds separated by thin layers of slabby or nodular limestone. This facies comprises an upper bluish-gray, dense, algal and fusulinid limestone; a middle bed of sandy impure limestone that weathers brown or orange; and a lower massive, algal limestone that weathers into irregular slabs. In other places there is an upper bed less than 2 feet thick that is mottled light gray and contains abundant "*Osagia*", and a lower bed of bluish-gray sandy limestone about 1.5 feet thick. These two beds are separated by about 1.5 feet of gray shale.

Kanwaka Shale

In southern Elk County and in neighboring parts of Chautauqua County, the section between the base of the Lecompton formation and the top of the Plattsmouth limestone is 125 to 135 feet thick. Seemingly, this section includes beds that are equivalent to the Kereford limestone and Heumader shale, which farther north are classed as the upper two members of the Oread formation, but which have not been identified in this area. Furthermore, the Clay Creek limestone, which farther north separates the upper member, the Stull shale, from the Jackson Park shale, has not been identified in southern Elk County. In northeastern Elk County, where the three members of the Kanwaka formation have been identified, the thickness of the formation is about 90 to 100 feet. Sandstone is quantitatively important in the formation in both parts of the county. The Elgin sandstone, in the lower part of the formation, is one of the most important aquifers in Elk County.

Stull shale member.—The average thickness of the Stull shale in northeastern Elk County is about 30 feet. In an exposure in sec. 21, T. 28 S., R. 12 E., the member is about 35 feet thick. The following units are differentiated and are regarded as somewhat characteristic for the area: 8 feet of greenish-gray clay shale containing a zone of red clay in the middle part; 6 feet of thin, buff, fossiliferous limestone interbedded with gray shale containing fossil plants; and 21 feet of shale, orange and buff in the upper part, but grading downward through bluish-gray, pelecypod-bearing shale into green and red or bluish and buff shale and including a few thin beds of limestone about 7 or 8 feet from the base. These beds of limestone contain *Chonetes*.

Clay Creek limestone member.—In northeastern Elk County, the Clay Creek limestone has an average thickness of about 4.5 feet. The upper part consists of as much as 3 feet of thin, gray, slabby, coquinoid limestone interbedded with gray shale. The lower part consists of as much as 3 feet of thin-bedded, buff to orange, fusulinid-bearing limestone, interbedded with gray and buff shale. Elsewhere in the area the member is thinner and comprises gray, pelecypod-bearing limestone and shale. The lower part of the unit characteristically is sandy. Seemingly, the Clay Creek limestone pinches out in southern Elk County, or inasmuch as the lower part becomes increasingly sandier southward, more probably the rock is represented by one of several thin sandstone beds that lie about 30 feet below the top of the Kanwaka formation.

Jackson Park shale member.—The Jackson Park shale in northeastern Elk County ranges from 40 to 50 feet in thickness. The upper part consists of bluish-gray or reddish clay and is underlain by buff to yellowish-gray or gray, massive, cross-bedded sandstone. The lower part of the sandstone body locally fills channels. At some exposures the base of the channels is near the top of the Kereford limestone, and in some places the base of sandstone beds lies only a few feet above the Plattsmouth limestone, suggesting that the Kereford limestone and a part of the Heumader shale were removed by erosion before deposition of the sand. In places where the channels are less deep, the lower part of the Jackson Park shale consists of gray to tan, silty and sandy shale and thin sandstone beds.

In southern Elk County, where the Stull and Jackson Park shales are not differentiated, sandstone 50 to 75 feet thick extends downward nearly to the top of the Plattsmouth limestone. This is the Elgin sandstone, which is believed to be properly regarded as a part of the Jackson Park member.

Oread Limestone

The Oread formation is about 120 feet thick in Elk County. All of the four limestone and three shale members are represented, and all but the upper two members are well exposed. The Plattsmouth and Snyderville members are of some importance as aquifers.

Kereford limestone member.—The Oread formation crops out in northeastern and southeastern Elk County, but only in the northeastern part has the Kereford limestone been recognized. In the area where it has been identified, the Kereford limestone is slightly less than 1 foot thick and consists of dark-gray shaly limestone weathering buff and gray that occurs in two beds separated by gray shale. Both limestone and shale contain fusulinids.

Heumader shale member. — In localities in northeastern Elk County where the Heumader shale has been identified, it is about 16 feet thick. The upper part is light gray, is silty to sandy, and contains numerous well-preserved specimens of the small pelecypod *Astartella*. The lower part, ranging from about 2 to 8 feet in thickness, is fossiliferous gray shale, locally containing a thin, fusulinid-bearing limestone bed. In southern Elk County, fossiliferous shale above the Plattsmouth limestone may be the Heumader shale member of the Oread formation.

Plattsmouth limestone member.—The Plattsmouth limestone averages about 15 feet in thickness, but as much as 18 feet was measured. It consists of light-gray limestone in irregular beds. The upper few feet consists of wavy beds of soft, impure limestone separated by thin shales. The middle part is bluish gray, brittle, and dense but becomes more crystalline and lighter in color downward. The lower 4 or 5 feet consists of dense gray limestone that weathers buff or brown. These lithologic units are not sharply defined but grade into one another. The Plattsmouth limestone contains a mixed fauna of marine invertebrates including fusulinids.

Heebner shale member.—The Heebner shale is about 4.6 feet in thickness. The upper part is characteristically gray or brownish, and the lower part is black and fissile. The black part is about 3 feet thick in all exposures studied in Elk County. Marine invertebrate fossils occur in the zone of transition between the gray and black parts.

Leavenworth limestone member.—The thickness of the Leavenworth limestone averages about 1.3 feet and ranges from 1.0 to 1.8 feet. This unit is a single, massive bed of dark-blue, dense, brittle limestone that has prominent vertical joints. Weathering produces a buff or orange veneer. The most numerous fossils are small fusulinids. Small brachiopods and fragments of echinoderms are less plentiful.

Snyderville shale member.—In measured sections the Snyderville shale ranges in thickness from about 60 to 68 feet. The unit comprises principally red, green, and bluish shale, greenish-gray siltstone, and sandstone. In the northeastern part of the county, this member is red, buff, and light-gray shale and includes about 12 feet of buff to yellow sandstone in the upper part and a few sandstone lenses and ironstone concretions scattered through the lower 45 feet. In the southeastern part, approximately the lower half of the Snyderville is gray, thin-bedded and cross-bedded, fine-grained, micaceous sandstone containing a small amount of sandy shale.

Toronto limestone member.—The thickness of the Toronto limestone ranges from about 6 feet in northeastern Elk County to 2 feet or less in the southeastern part. In the northern area, the member consists of thin beds of limestone separated by shale partings. A molluscan bed is near the top, and the other beds bear fusulinids. In the southern area, where the Toronto is less than 2 feet thick, it consists of two molluscan limestones separated by a bed of bluish-gray shale.

DOUGLAS GROUP

Lawrence Shale

The thickness of the Lawrence shale ranges from 90 to 170 feet. Units definitely recognized in Elk County are: a clay shale in the upper part, the Amazonia limestone, and the Ireland sandstone in the lower part. The Ireland sandstone is one of the most important aquifers in Elk County.

Unnamed shale unit.—A sequence of 60 to 65 feet of rock, mostly beds of shale, lies below the Toronto limestone and above the Amazonia. Exposures of this part of the stratigraphic section are poor. In general, the sequence comprises gray to buff, silty or sandy shale, and a small amount of gray, greenish-gray, and buff sandstone. A thin coal bed lies about 2 feet below the top of the formation. Shale above the coal is crowded with fusulinids in the upper part and contains a prolific pelecypod fauna in the lower part.

Amazonia limestone member.—The Amazonia limestone averages slightly less than 5 feet thick, but as much as 9 feet was measured. The thickness decreases southward. Where the rock is thickest, it consists of thin, slabby, irregular beds of dark-gray to bluish-gray, light-weathering, extremely fossiliferous limestone. Elsewhere it is reduced to a bed of fusulinid-bearing limestone less than 2 feet thick. In some places the unit is shaly and sandy in its lower part. Common fossils in the Amazonia are marine invertebrates and algae.

Ireland sandstone member.—In this part of Kansas, the Ireland sandstone is regarded as including beds that lie next below the Amazonia limestone; in some other places, an unnamed shale lies between the Amazonia and Ireland members. The thickness of the Ireland sandstone ranges from about 30 to perhaps as much as 100 feet. The sandstone is interpreted as being a deposit that accumulated on an irregular erosional surface and as consisting of a series of channel fills that grade laterally into a more extensive but thinner sheetlike deposit that lies above divides between channels. In the deeper channels the measurable thickness is about 80 feet. The rock consists principally of gray to reddish or buff, fine- to medium-grained sandstone. Where the sandstone fills channels, the contact with the underlying Robbins shale is sharp; elsewhere it is less well marked.

Stranger Formation

The Stranger formation ranges in thickness from about 65 to 130 feet. It includes two limestone, one sandstone, and two shale members. Small supplies of ground water are obtained from the formation.

Robbins shale member.—The thickness of the Robbins shale ranges from 65 to 112 feet. In localities where the Ireland sandstone is relatively thin and seemingly is a sheetlike deposit over divides on the post-Robbins erosional surface, the Robbins shale is thick; the contact between the Ireland and Robbins may not be sharply defined, however. Throughout the area of outcrop, the two units have a uniform combined thickness of about 150 feet. The Robbins shale consists of gray to bluish, clayey to silty, blocky shale in its lower part but grades upward into silty and sandy shale and gray to yellowish to reddish-gray sandstone.

Haskell limestone member.—The Haskell limestone is a persistent, massive limestone and has an average thickness of about 1.5 feet. The thickness decreases southward. This rock is about 2.6 feet thick in neighboring parts of Wilson County (east of Elk County) and about 0.8 foot thick in northeastern Chautauqua County. The Haskell is dark bluish-gray, hard limestone that weathers buff. Abundant dark-gray to black, irregularly layered bodies are believed to be algal colonies.

Vinland shale member.—The Vinland shale averages about 18 feet in thickness. It thickens southward, from about 4 feet in west-central Wilson County to about 35 feet in northeastern Chautauqua County. The upper part is composed of yellowish and gray shale that grades downward into greenish gray. Poorly preserved specimens of the pelecypod *Myalina* are present in the upper part of the unit in southeastern Elk County; in the northeastern part of the county, the unit is more calcareous and more abundantly fossiliferous, carrying fenestellid bryozoans, small brachiopods, and crinoid fragments.

Westphalia limestone member. — The Westphalia is a discontinuous, dark-gray, sandy to shaly, fusulinid-bearing, algal limestone and has an average thickness of slightly less than 3 feet. It is slightly thicker in the northeastern part of the county than it is in the southeastern part. In the northern area the thickness ranges from a featheredge to nearly 5 feet; but locally the limestone is absent, and about 15 feet of gray, yellow, and greenish shale lies between the Haskell limestone and the Tonganoxie sandstone. The Westphalia, although fusulinid bearing, contains a relatively large amout of clastic material, including fragments of coaly material, mica flakes, silt, and fine sand. Fossils other than fusulinids include algae, fragments of crinoids and other fossils, and productid and spiriferid brachiopods.

Tonganoxie sandstone member.—The thickness of the Tonganoxie sandstone ranges from about 2 to 40 feet. In the southeastern part of Elk County, the unit is thin, greenish gray, brown weathering, and calcareous. Worm borings and castings are numerous. Only the upper part of the Tonganoxie sandstone is exposed in the northeastern part of the county, but the member is thicker there. The thin veneer of sandstone in the southeastern part probably was deposited on a divide between channels, and it is probable that shale, equivalent in age to a part of the Tonganoxie member, rests directly on some part of the Weston shale.

MISSOURIAN SERIES

PEDEE GROUP

Weston Shale

The maximum measured thickness of the exposed part of the Weston shale, oldest outcropping rock in Elk County, is about 22 feet. The rock is gray to greenish-gray, clayey to silty shale, bearing small limonitic concretions.

PART 2

MINERAL RESOURCES OF ELK COUNTY

By

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INTRODUCTION

The known useful mineral resources in Elk County include oil, gas, limestone, shale and clay, sandstone, and gravel. Ground water, another important mineral resource, is discussed in Part 3 of this report. Natural gas has been produced in the county since 1901 and oil since 1902 (Jewett, 1954, p. 202). Both hydrocarbons still are important there. The county has very large reserves of limestone, sandstone, shale and clay, and gravel. Although several thin beds of coal occur here, there is no coal mining. Locations of limestone quarries are shown on Plate 1, which is primarily an areal geologic map. Oil and gas developments in the county are shown on Plate 2, which map shows locations of all wells drilled for oil and gas of which the State Geological Survey has record, the status of each well, the location of pipe lines, and the outlines of established oil and gas fields as of 1956. For all wells known to be producing, the producing zone is indicated, and the age of the oldest rock penetrated is indicated for all dry holes. Geographic and cultural features are also shown on this map.

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

Limestone crops out extensively in Elk County. The separate beds have been quarried at several places in the county. The limestone quarry operating near Moline is one of the largest of its kind in central United States; therefore, limestone constitutes one of the county's most valuable natural resources. The locations of the Moline quarry and of the several inactive quarries are shown on Plate 1.

The potential value of a limestone deposit depends on numerous factors: the quality of the rock, the thickness of the bed, the availability of a market, and the expense necessary to quarry the rock. One of these factors could outweigh all others under special circumstances; therefore, any of the many limestone beds exposed in Elk County might have value at some time. There are some beds, however, that because of quality and thickness seem more likely to become valuable than others and therefore are discussed further.

THE PLATTSMOUTH LIMESTONE

In Elk County the Plattsmouth limestone member of the Oread formation averages approximately 15 feet thick. It has uniformly thin wavy beds and a relatively high content of calcium carbonate (Table 1). Detailed description of the Plattsmouth is found elsewhere in this report. No physical test of this limestone in Elk County is included in this report, but this limestone is quarried extensively for commercial purposes in other parts of the state. There are several small abandoned quarries in the Plattsmouth limestone in the county.

THE ERVINE CREEK LIMESTONE

The Ervine Creek member of the Deer Creek formation and closely associated overlying limestone beds in the Topeka formation form a deposit approximately 40 feet thick in Elk County. The Ervine Creek is about 20 feet thick and is wavy bedded much like the Plattsmouth limestone. The Ervine Creek is the rock quarried at Moline. The overlying limestone beds, assigned to the Topeka formation, contain some shale beds but consist mostly of thick-bedded blocky limestone. Under present quarrying procedure, the Topeka beds are treated as overburden. Detailed descriptions of this total thickness of limestone can be found elsewhere in this report.

Chemical data of the Ervine Creek and associated beds, as shown in Table 1, reveal a relatively high content of calcium carbonate. Physical tests of the Ervine Creek and the overlying Topeka beds were made by the Kansas State Highway Commission in 1946 on samples obtained from the face of the quarry operating near Moline. Figure 7, which shows the results of these tests, indicates the specific gravity, Los Angeles and soundness numbers, and the place where each of the samples was taken in the quarry. The specific gravity of the rock is the ratio of its weight to the weight of an equal volume of water. It gives some indication of the porosity of the rock. The Los Angeles number indicates a degree of resistance to abrasion. A detailed description of this test is found in American Society for Testing Materials Standards for 1955; nevertheless, some description seems necessary here. The Los Angeles testing machine itself is essentially a rotating barrel containing several baffles. After the sample is crushed to the size of coarse aggregate, a specified amount is placed in the machine. The machine is then run at a specified speed for a specified number of revolutions. The size of the aggregate is measured on screens both before and after the test. The loss in weight, expressed as percentage of the original weight, is the Los Angeles number. A high number would therefore indicate a soft rock, and a low number a hard one. The soundness number is an expression of the resistance of the rock to freezing and thawing. Various tests have been devised to measure this property of construction materials. One of these is actual freezing and thawing of the rock aggregate a specified number of times under circumstances comparable to weather conditions. The soundness is expressed as a decimal part of 1, which number would indicate a perfect specimen.

Rock from the Moline quarry is used as aggregate in road paving and airplane runways, as railroad ballast, road metal, and agricultural limestone. In late 1955, officials of the company operating the quarry reported that the quarry employed about 40 people and that it had an average daily production of approximately 6,000 tons. The production capacity, of course, exceeds this figure. Approximately 95 percent of the production of the quarry is transported by rail. The quarry serves a small local market but chiefly supplies many parts of the state where rock suitable for construction materials is not available.

Several pictures of the Moline quarry may be seen in Plate 4. As of 1956, the average thickness of the overburden was 25 feet. Much of it is limestone; consequently, its removal is a quarrying operation in itself. After the removal of the overburden, a bed of rock (the Ervine Creek limestone) 20 to 22 feet thick is available for production (Pl. 4A). Vertical shot holes are made with wagon drills from the top of the exposed ledge of quarried rock. These are loaded and shot. Blasted rock is loaded with power shovels into trucks (Pl. 4B) that transport it to the primary crusher located near the quarry face (Pl. 4C). A series of belts transports the crushed rock from the primary crusher over a considerable distance to the rest of the plant, where it undergoes further crushing, screening, and washing (Pl. 4A, D). Finished rock products either are loaded directly for transportation or are stockpiled (Pl. 4E). The plant makes extensive use of conveyor belts for both its loading and stockpiling.

THE RED EAGLE LIMESTONE

The Red Eagle formation constitutes a third limestone of potential value. The formation consists of a lower member, the Glen Rock limestone; a middle member, the Bennett shale; and an upper member, the Howe limestone. According to O'Connor and Jewett (1952), however, in southern Greenwood County and farther south, the Red Eagle consists almost entirely of limestone. Where the Red Eagle crops out in western

TABLE 1.—*Chemical analyses of limestone from Elk County*
(Analyzed by R. T. Runnels, State Geological Survey)

Name and thickness of member	Location	Lab no.	Calc. $CaCO_3$	Calc. $MgCO_3$	Calc. $CaCO_3$ Equiv.	Chemical analysis, percent												
						CaO	MgO	L.O.I.*	CO_2†	SiO_2	Al_2O_3‡	Fe_2O_3§	K_2O	Na_2O	SO_3	S	P_2O_5	Total
Red Eagle 19 ft.	W½ 3-31-8E	5622	94.38	0.30	94.66	52.88	0.54	0.68	41.65	2.39	0.19	1.15	0.15	0.06	nil	......	Trace	99.69
Foraker 30 ft.	NE SE 15-31-8E	5610	85.86	nil	85.41	48.11	0.44	0.65	37.58	11.94	0.56	0.75	0.05	0.06	Trace	Trace	0.08	100.22
Foraker 35 ft.	Center SE 36-28-8E	569	83.35	0.31	83.66	46.86	0.56	0.78	36.81	13.23	0.91	0.62	0.07	0.06	0.06	nil	0.10	99.97
Wakarusa 5 ft.	NE 6-31-10E	5376	79.42	2.38	82.18	44.58	1.37	36.16	....	11.58	2.65	3.08	0.23	0.06	nil	nil	0.06	99.77
Burlingame 5 ft.	NE 6-31-10E	5378	88.18	2.18	89.95	49.53	1.04	39.58	....	6.24	1.22	2.07	0.07	0.04	nil	nil	0.09	99.78
Bachelor Creek 4 ft.	SE 11-30-10E	5379	43.21	1.76	45.27	24.34	0.84	20.25	....	41.52	8.03	2.93	0.98	0.98	nil	nil	0.10	100.06
Coal Creek 6 ft.	NE 23-30-10E	5380	86.17	3.01	89.68	48.28	1.79	39.46	....	6.18	1.67	2.48	0.08	0.04	nil	nil	Trace	99.98
Topeka 4.1 ft.	NW SW 12-30-10E	5381	31.36	2.13	33.86	17.62	1.02	15.30	....	61.21	2.28	2.07	0.29	0.11	nil	0.08	0.04	99.94
Topeka 10 ft.	C S Line NE 12-30-10E	5611	78.28	2.82	81.57	43.97	2.07	0.98	35.89	11.71	2.83	1.37	0.36	0.14	0.02	0.40	0.07	99.32
Ervine Creek 20 ft.	SE SW NE 12-30-10E	5612	92.97	2.30	95.66	52.21	1.63	0.69	42.08	2.12	0.52	0.92	0.02	0.06	0.12	0.07	0.03	100.40
Ervine Creek 12 ft.	SW 9-30-11E	5383	96.95	0.75	97.02	54.33	0.36	42.69	....	1.37	0.39	0.55	0.03	0.02	nil	Trace	0.01	99.75
Biel 9.5 ft.	C 21-30-11E	5382	64.86	4.14	71.02	36.38	1.98	31.25	....	22.38	4.26	2.77	0.36	0.13	nil	nil	0.03	99.54
Plattsmouth 12 ft.	NE 3-30-12E	5377	94.32	1.15	95.66	52.89	0.55	42.09	....	2.63	0.74	0.67	0.03	0.03	nil	nil	0.03	99.66
Plattsmouth 9 ft.	SE NE SE 21-29-13E	52361	96.06	0.82	96.98	53.83	0.94	42.67	....	1.62	0.51	0.62	......	......	nil	Trace	0.01	100.20
Haskell 1.3 ft.	SE NE 21-31-13E	5374	94.02	2.57	95.64	52.75	1.23	42.08	....	1.70	0.71	1.44	0.03	0.04	nil	nil	0.06	100.04

* L.O.I. Net loss on ignition at 1000° C.
† CO_2 Carbon dioxide—where determined the remaining loss of H_2O, etc., is reported as L.O.I. (600° C.).
‡ Al_2O_3 Includes manganese oxide, titania, vanadium oxide, and zirconium oxide if present.
§ Fe_2O_3 Total iron expressed as Fe_2O_3.

Sample No.	Specific Gravity	Los Angeles	Soundness
14-1	2.62	30.5	0.96 0.91
14-2	2.56	37.7	0.97 0.94
14-3	2.51	45.4	0.97 0.95
14-4	2.54	41.8	0.96 0.95
14-5	2.55	35.9	0.94 0.92

Sample No.	Specific Gravity	Los Angeles	Soundness
13-1	2.52	34.8	0.95 0.9
13-2	2.62	27.9	0.96 0.91
13-3	2.47	43.4	0.96 0.94
13-4	2.54	62.2	0.96 0.95
13-5	2.54	37.1	0.95 0.92

Sample No.	Specific Gravity	Los Angeles	Soundness
12-1	2.54	31.5	0.96 0.96
12-2	2.60	27.6	0.96 0.95
12-3	2.57	39.6	0.96 0.92
12-4	2.50	46.6	0.92 0.89
12-5	2.60	36.0	0.91 0.96
12-6	2.55	32.4	0.96 0.93
12-7	2.61	33.8	0.9 0.93

Sample No.	Specific Gravity	Los Angeles	Soundness
Position of Shale Bed			
11-1	2.61	32.8	0.96 0.94
11-2	2.58	33.8	0.98 0.95
11-3	2.49	40.7	0.99 0.98
11-4	2.58		0.94 0.92
11-5	2.57	42.9	0.98 0.96
11-6	2.57	36.4	0.86 0.83
11-7	2.50	38.5	0.88 0.82

Continued on left below

Sample No.	Specific Gravity	Los Angeles	Soundness
10-1	2.55	35.4	0.96 0.93
10-2	2.53	40.0	0.95 0.96
10-3	2.54	40.1	0.97 0.95
10-4	2.60		0.97 0.98
10-5	2.50	40.4	0.96 0.91

Sample No.	Specific Gravity	Los Angeles	Soundness
Position of Shale Bed			
9-1	2.58	35.6	0.88 0.81
9-2	2.61	32.8	0.91 0.88
9-3	2.54		0.98 0.96
9-4	2.57	37.7	0.96 0.93
9-5	2.56	34.9	0.97 0.97

Sample No.	Specific Gravity	Los Angeles	Soundness
8-1	2.67	27.3	0.91 0.86
8-1B	2.70	27.7	0.93 0.90
8-2	2.63	27.7	0.92 0.89
8-3	2.60	32.7	0.80 0.79
8-4	2.59	29.9	0.95 0.96
8-5	2.52	38.3	0.96 0.97
8-6	2.53	49.6	0.96 0.93
8-6B	2.37	43.7	0.96 0.95
8-7	2.55	34.3	0.97 0.96

Sample No.	Specific Gravity	Los Angeles	Soundness
7-1	2.65	29.9	0.85 0.81
7-1B	2.57	35.3	0.86 0.77
7-2	2.63	28.6	0.90 0.88
7-3	2.61	31.0	0.85 0.80
7-4	2.57	37.0	0.97 0.95
7-5	2.48	43.1	0.93 0.92
7-6	2.56	39.4	0.97 0.94
7-7	2.50	56.6	0.93 0.88

Continued on left below

Sample No.	Specific Gravity	Los Angeles	Soundness
6-1	2.68	28.3	0.93 0.86
6-2	2.66	28.2	0.95 0.93
6-3	2.62	31.2	0.80 0.77
6-4	2.60	32.2	0.95 0.96
6-5	2.54	48.7	0.95 0.94
6-6	2.54	43.6	0.96 0.90
6-7	2.55	37.1	0.96 0.92

Sample No.	Specific Gravity	Los Angeles	Soundness
5-1	2.66	30.4	0.89 0.87
5-2	2.66		0.93 0.86
5-3	2.59	31.3	0.81 0.73
5-4	2.57		0.95 0.95
5-5	2.61	32.4	0.93 0.89
5-6	2.59	39.9	0.97 0.92
5-7	2.59	34.4	0.96 0.92

Sample No.	Specific Gravity	Los Angeles	Soundness
Position of Shale Bed			
4-4	2.57	33.0	0.98 0.90
4-5	2.58	39.4	0.97 0.93
4-6	2.62	39.1	0.98 0.97
4-7	2.54	39.0	0.96 0.91

Sample No.	Specific Gravity	Los Angeles	Soundness
3-1	2.64	26.7	0.87 0.81
3-2	2.64	29.0	0.89 0.83
3-3	2.57	35.2	0.84 0.70
3-4	2.61	30.0	0.98 0.95
3-5	2.52	49.5	0.97 0.94
3-6	2.47	52.1	0.94 0.93
3-7	2.54	35.0	0.96 0.92

FIG. 7—Physical properties of rock at Moline Quarry (Courtesy of State Highway Commission).

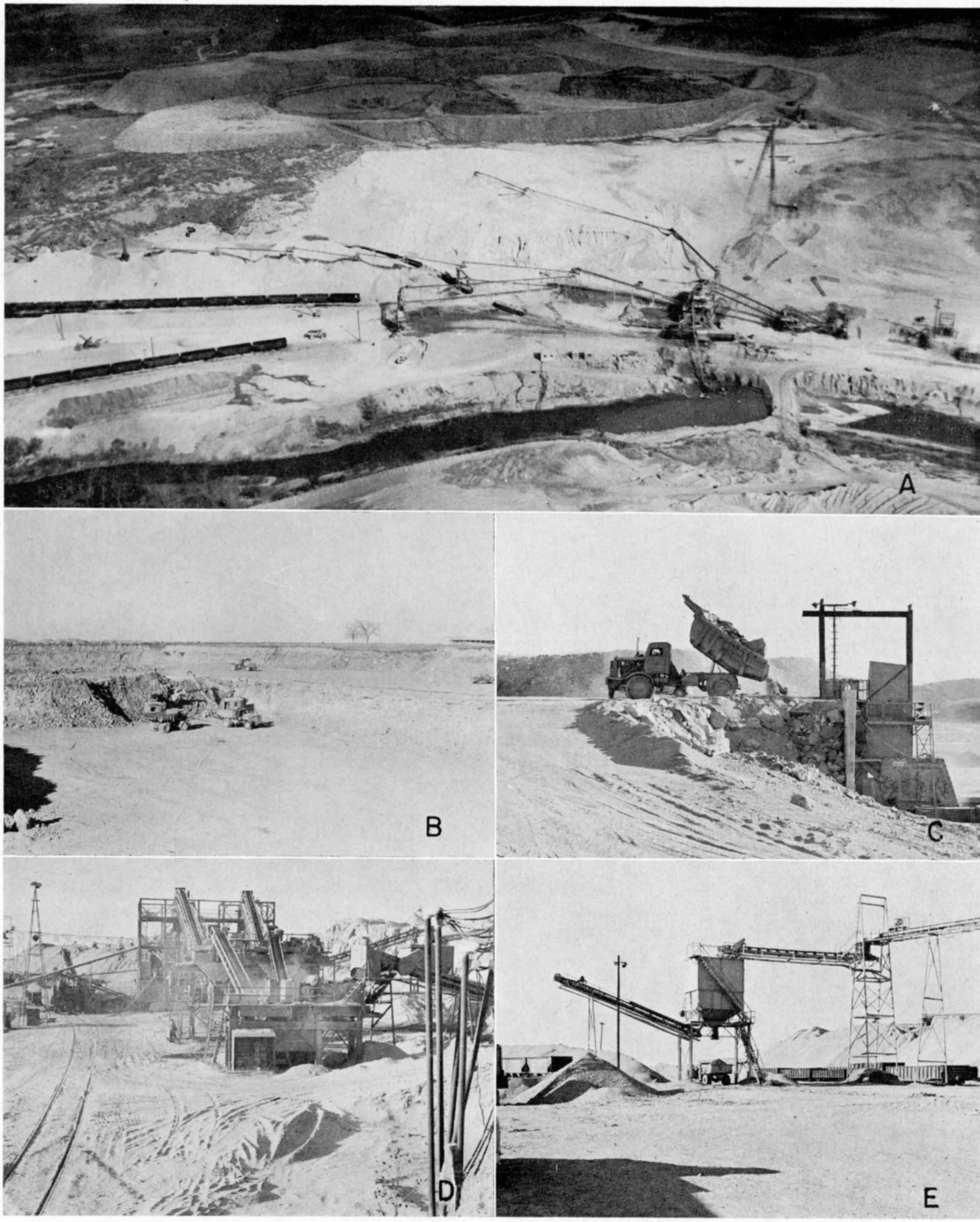


PLATE 4.—The Moline Quarry of Concrete Materials and Construction Co. **A**. Aerial view of quarrying, crushing, and loading operations. (Picture courtesy of Max F. Oelschlaeger.) **B**. Loading trucks at quarry face. **C**. Unloading truck at primary crusher. **D**. Subsequent crushing, screening, and washing operations. **E**. Loading and stockpiling of the finished product.

Elk County (Pl. 1), it averages about 20 feet thick. Chemical data pertaining to the Red Eagle, as shown in Table 1 from one sample, show a high content of calcium carbonate. A more detailed description of this limestone unit is found elsewhere in this report.

GRAVEL

Cherty limestones, especially the Florence, Wreford, and Foraker, of the upper part of the Elk County stratigraphic section crop out in the western part of the county. Upon weathering, these limestones yield great quantities of chert fragments that accumulate in creek beds throughout the vicinity of the outcrop area. These chert gravel deposits have provided considerable material for secondary roads in the county.

CERAMIC MATERIALS

Shales from five localities were tested to determine their general ceramic properties and their bloating characteristics in the production of lightweight concrete aggregate. Sample EK-1 represented all of the clayey portion (22 feet) of the Robbins shale; sample EK-2 the entire thickness (32.5 feet) of the Heumader-Jackson Park shale; sample EK-3 the upper 17 feet of the French Creek shale; sample EK-4 the upper 31 feet of the White Cloud shale; and sample EK-5 the upper 22 feet of the Severy shale. All these shales except the Severy are predominantly clayey. The Severy is somewhat silty, as indicated by a silica content of 62.50 percent (Table 4).

The data obtained from standard ceramic tests

TABLE 2.—*Ceramic data on shale samples from Elk County*

PLASTIC AND DRY PROPERTIES

Sample no.	Location	Stratigraphic position	Thickness sampled, feet	Water of plasticity, percent	Drying shrinkage, percent
EK-1	SW SW 22-31-13E	Robbins	22	25.25	5.87
EK-2	E Cen. SW 22-30-12E	Heumader-Jackson Park	32.5	24.34	6.64
EK-3	SW SW 7-31-9E	French Creek (upper)	17	23.72	4.55
EK-4	Cen. N½ 16-30-10E	White Cloud	31	24.31	3.71
EK-5	SW NW 2-30-10E	Severy (lower)	15	19.50	1.92

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
EK-1	06	Red	5.93	11.80	3.78	4.97	0.76
	04	do	7.20	13.07	0.68	2.81	.24
EK-2	06	Red	2.69	9.33	9.36	10.58	.88
	04	do	5.11	11.75	4.88	5.93	.82
EK-3	06	Red	3.52	8.07	10.18	12.26	.83
	04	do	4.39	8.94	8.27	10.73	.77
EK-4	05	Bright Red	3.37	6.57	11.43	13.70	.83
	02	Red	5.98	9.18	5.63	8.12	.69
	2	Dark Red	8.29	11.75	0.68	2.59	.26
EK-5	06	Red	1.57	3.49	13.83	16.59	.83
	04	do	2.89	4.81	11.05	13.82	.80
	02	Dark Red	4.58	6.50	7.31	10.00	.73
	2	do	8.20	10.12	1.05	3.56	.29

TABLE 4.—*Chemical analyses of Elk County shales*

Sample no.	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	P_2O_5	SO_3	K_2O	Na_2O	Ignition loss
EK-1	54.20	19.87	6.37	0.98	3.20	2.04	0.18	0.14	3.12	0.49	8.32
EK-2	59.55	20.00	5.23	1.70	1.41	1.69	0.03	nil	3.03	0.28	7.07
EK-3	58.85	18.91	8.38	0.99	1.29	1.59	0.19	0.02	3.19	0.88	5.58
EK-4	59.17	19.05	8.40	1.30	0.42	1.52	0.12	nil	3.05	0.93	5.48
EK-5	62.50	16.95	6.61	1.08	0.68	2.24	0.19	0.01	2.88	1.75	4.56

(Table 2) indicate that all the shales tested are suitable for the production of heavy clay products such as brick, hollow tile, quarry tile, and drain tile. All the samples tested fired to some shade of red. Optimum firing temperatures range from cone 07 (about 1780°F) for sample EK-1 to cone 02 (about 2015°F) for sample EK-5. The optimum temperature for sample EK-2 is cone 05 (about 1890°F), and for EK-3 and EK-4 cone 03 (about 1990°F).

All the shales except the Severy would require some care in drying because the high clay content tends to produce warping. These same shales would also have to be fired somewhat slowly because they are "tight" and as a consequence do not oxidize easily.

The bloating tests for lightweight aggregate were made in a batch-type rotary kiln (Plummer and Hladik, 1951). The samples were fired to incipient fusion, and unit weights were determined on samples crushed through rolls set 3/16 inch apart. This crushing produced an aggregate of slightly more than 3/8 inch maximum diameter. Unit weights of the crushed samples ranged from 42.3 pounds per cubic foot for sample EK-1 to 61.3 for sample EK-2 (Table 3). This is below the limit of 75 pounds per cubic foot set by the American Society for Testing Materials for lightweight bloated shale aggregate, but unit weights in the range of 40 to 50 pounds per cubic foot are usually regarded as more desirable. This limitation would exclude samples EK-2 and EK-4 from the more desirable shales for use in the production of lightweight aggregate.

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

Sample no.	Time in kiln, minutes	Firing temperature, degrees F. Initial softening	Formed soft roll	Maximum attained	Unit weight, lb. per cu. ft.	Color of crushed aggregate
EK-1	9	2130	2190	2200	42.3	Dark gray
EK-2	9	2190	2210	2260	61.3	Gray
EK-3	8	2160	2170	2250	53.2	Dark gray
EK-4	10	2180	2220	2240	59.8	Dark gray
EK-5	9	2110	2180	2260	44.6	Gray

The five shales tested do not represent all the Elk County shales having possible ceramic value, but they do represent a quantity of good grade shale in excess of any probable demand of the future.

COAL

Coal occurs at several horizons in Elk County, but as far as is known only the Nodaway and Elmo coals, both in the Wabaunsee group of rocks (stratigraphic column, Pl. 1), have been mined. Schoewe (1946) presents data on the history, location of mines, production, and reserves of coal in the Wabaunsee group.

The Nodaway coal occurs in the Howard limestone formation above the Bachelor Creek limestone and below a limestone bed 4 to 5 inches thick, which is separated by about 1 foot of black fissile and gray shale from typical massive, well-jointed Church limestone above. The coal crops out at places along the edge of the Howard limestone escarpment, especially between Howard and Mound Branch of Elk River. The Nodaway coal is thin, and as far as known it was mined in a drift mine in the SE¼ sec. 21, T. 30 S., R. 10 E., where according to Whitla (1940, p. 36) the coal is 18 inches thick. About 4.5 miles north of Howard, in sec. 11 and 12, T. 29 S., R. 10 E., it is probably no more than 5 inches thick where a very small amount of coal was taken from several shallow pits.

Most of the coal mined in Elk County was the Elmo coal, which occurs just below the Rulo limestone (stratigraphic column, Pl. 1). The Elmo coal mines, four strip and one shaft, are in the valley of Mound Branch less than 5 miles southwest of Howard, in sec. 20 and 21, T. 30 S., R. 10 E. The coal ranges from 16 to 18 inches in thickness and was reported mined last in 1922.

According to published data, the cumulative coal production from Elk County totaled 3,615 tons from 1894 to 1902. It is known that coal was mined in the county for local domestic use as early as 1877; mining activity was discontinued in 1922. Total cumulative production of coal in the county is estimated at 10,000 tons, most of which was Elmo coal.

Elk County contains approximately 544 acres of land underlain by an 18-inch Nodaway coal bed. This amounts to about 1,220,000 tons of coal, of which at least 50 percent, or 610,000 tons, is recoverable. The amount of land underlain by Elmo coal that is 18 inches thick is 986 acres (1.4

square miles) and contains 2,020,000 tons of coal, of which 75 percent, or 1,515,000 tons, is recoverable. Elk County, therefore, has a total recoverable measured coal reserve of 2,125,000 tons.

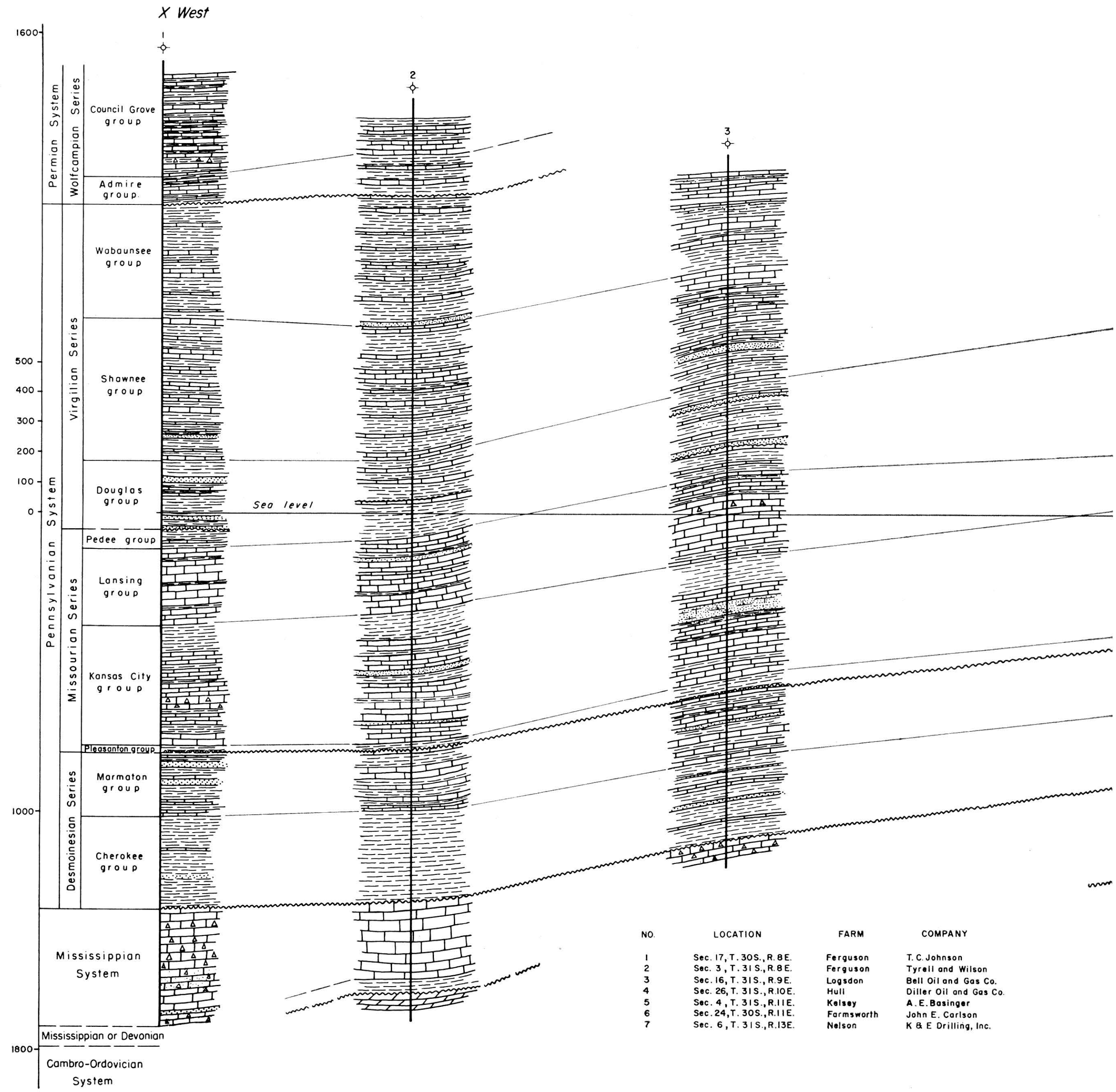
SUBSURFACE ROCKS

Stratigraphy and Structure

Conditions along an east-west line through the southern part of Elk County are shown on Figure 8. Major rock units are differentiated.

Elk County lies on the Prairie Plains monocline, which constitutes the western flank of the Ozark uplift and involves extensive regions in western Missouri, eastern Kansas, and northeastern Oklahoma, where the strata dip at low angle generally westward. Elk County also lies on the western flank of what is commonly known as the Cherokee basin.

The subsurface rocks of Elk County reflect a history of oscillation, repeated emergence being



NO.	LOCATION	FARM	COMPANY
1	Sec. 17, T. 30S., R. 8E.	Ferguson	T. C. Johnson
2	Sec. 3, T. 31 S., R. 8E.	Ferguson	Tyrell and Wilson
3	Sec. 16, T. 31S., R. 9E.	Logsdon	Bell Oil and Gas Co.
4	Sec. 26, T. 31S., R. 10E.	Hull	Diller Oil and Gas Co.
5	Sec. 4, T. 31S., R. 11E.	Kelsey	A. E. Basinger
6	Sec. 24, T. 30S., R. 11E.	Farmsworth	John E. Carlson
7	Sec. 6, T. 31 S., R. 13E.	Nelson	K & E Drilling, Inc.

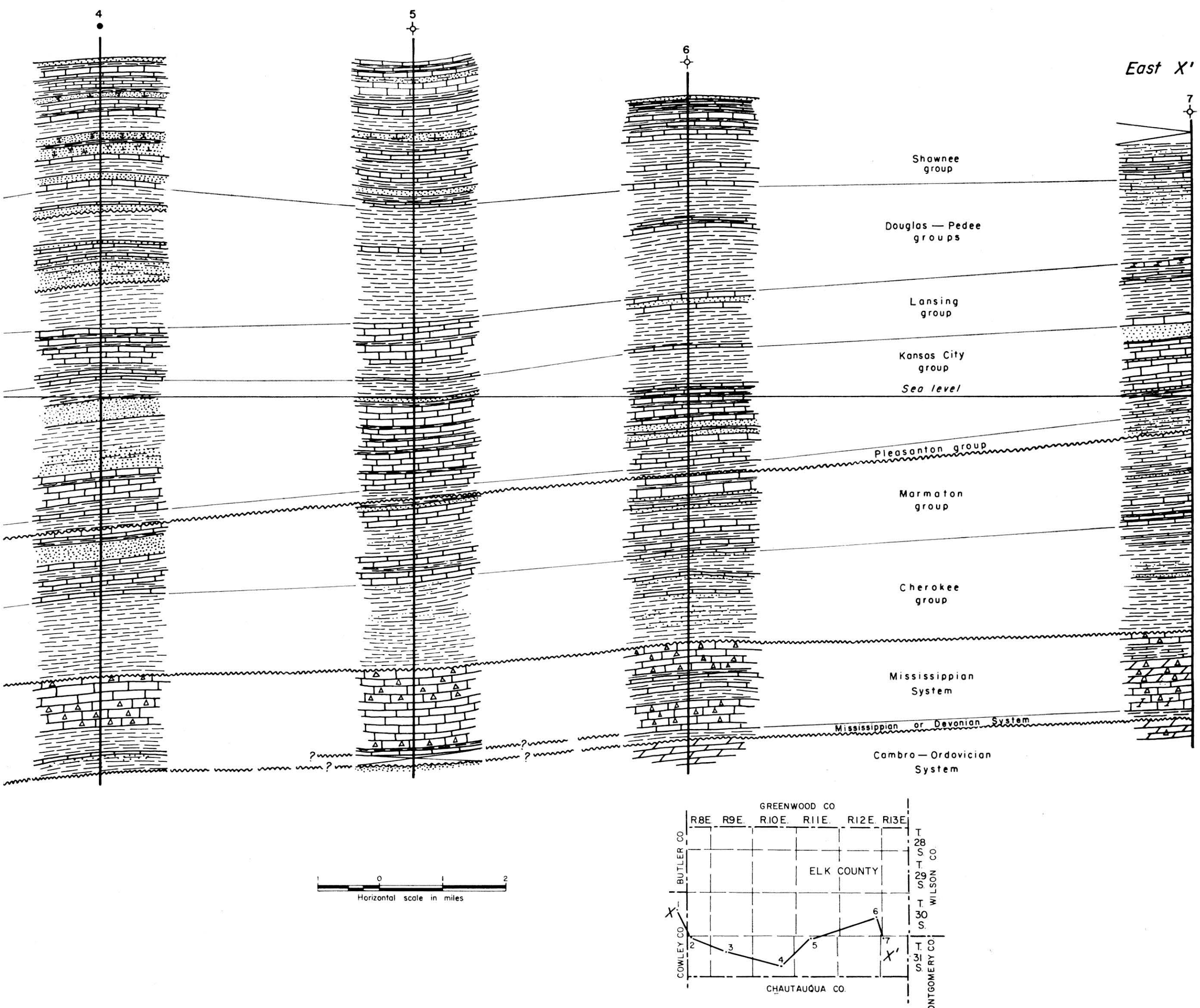
FIG. 8—Geologic cross section showing conditions along an east-west line

shown by numerous unconformities separating Paleozoic formations. Erosion seems to have been widespread from late Ordovician to early Mississippian time, from the close of Mississippian to early Pennsylvanian time, and since Permian time.

The most striking local feature in Elk County is the Longton ridge, which extends into Chautauqua County to the south and is about 25 miles long. The highest part of the ridge is found in sec. 33, T. 31 S., R. 12 E.

Generally, in the surface strata there is only slight evidence of various Mississippian folds. The folds of the surface strata seem to be reflections of subsurface structural features, but not all surface folds are located over or near subsurface structures.

On the Prairie Plains monocline the prevailing attitude of the strata is locally modified by



through southern part of Elk County, differentiating major rock units.

departures from the westward dip. The differences range from steepening to reversal. Several of the more important oil fields have been developed on the structural features formed by these local variations upon the Prairie Plains monocline.

PERMIAN ROCKS

Thickness of the Council Grove group in Elk County is about 125 feet. The group consists principally of limestones and shales. Rocks of the Admire group consist of shales, thin beds of limestones, and some coal. They have a total thickness of about 90 feet in the county.

PENNSYLVANIAN ROCKS

The Wabaunsee group consists of shale, sandstone, and thin beds of limestone. In Elk County it has a total thickness of about 300 feet. The Shawnee group here is about 425 feet thick, and it is characterized by thick limestone beds and distinctive cyclic sedimentation. The Douglas group has a total thickness of about 300 feet and consists chiefly of clastic rocks—shale and sandstone. The thickness of Douglas rocks differs in different parts of the county, as shown by Figure 8. The Lansing group in Elk County is about 225 feet thick. It consists principally of two limestones separated by a thin shale. The Kansas City group, consisting chiefly of limestones, is about 440 feet thick in the county. The underlying Pleasanton rocks consist chiefly of shale and sandy shale and are about 60 feet thick. Marmaton rocks, consisting of alternating beds of shale and limestone but including some sandstone and coal beds, are 250 feet thick. The Cherokee group is about 300 feet thick and consists mostly of shales but includes some thin limestones and sandstones.

MISSISSIPPIAN ROCKS

Pre-Pennsylvanian rocks are in unconformable contact with the Cherokee group throughout Elk County. Undifferentiated Mississippian limestones in Elk County range from 150 to 300 feet in thickness (Lee, 1939, plate 1). The formations are the "Warsaw", Keokuk, Burlington, Reed Springs, and St. Joe limestones and Northview-Compton (undivided shale and limestone) (Lee, 1940). The Chattanooga shale in Elk County is about 50 feet thick.

PRE-CHATTANOOGA ROCKS

The Cambro-Ordovician rocks in Elk County have not been completely subdivided. The Cotter dolomite unconformably underlying the Chattanooga shale is the youngest Ordovician rock in Elk County. The Cambro-Ordovician rocks range from about 750 to 1,165 feet in thickness and are principally cherty dolomites and limestones.

OIL AND GAS

INTRODUCTION

Data on oil and gas wells in Elk County were collected in the field during the summer of 1951 by Frank Moffitt. Compilation of information from the reference file of drillers logs and allied oil and gas information in the Oil and Gas Division of the State Geological Survey was completed by R. Kenneth Smith, Edwin D. Goebel, William R. Atkinson, and P. Lorenz Hilpman. Considerable data on Elk County wells were given to the authors by the following individuals and agencies: H. E. Redmon, C. W. Studt, E. P. Trout, Kansas Well Log Bureau, and the Conservation Division of the Kansas Corporation Commission.

The Geological Survey has no logs for many of the wells located on the oil and gas field map, Plate 2. Wherever substantial evidence existed that a well had been drilled, a well symbol has been put on the map, even though exact locations, records of stratigraphic zones, or drillers logs of many of the holes are not available. Probably a few of the wells drilled in Elk County are not represented on the map, but there has been reasonable diligence in the compilation.

EXPLORATION AND PRODUCTION

Oil was first discovered in Elk County near Longton in 1902. The southwestern part of the county is the principal oil-producing area. Elk County's first reported gas well is the one completed in 1901 near Elk Falls. Gas production has been relatively important since about 1921, and the southern half of the country is the principal gas-producing area.

Producing formations.—Oil and gas are produced from three sandstones in the Vilas shale in the Lansing group, which is Pennsylvanian in age (Jewett, 1954, p. 203). The uppermost of these sandstones is known as the "Bush-Denton" (or "Ferguson"), the middle is the "Longton" (or "Webb"), and the lowermost is the "Encill" sand. Production is also known from the "Stalnaker" in the Lansing group. The "Layton" sandstone in the upper part of the Kansas City group yields oil and gas. Oil and gas in the Marmaton group come from the "Old Red" or "Wayside" sand in the Nowata shale, the "Weiser" sand in the Bandera shale, the "Peru" sand in the Labette shale, and the Little Osage shale of the Fort Scott formation. Oil and gas sands of the Cherokee group include the "Bartlesville" about 180 feet below the top and the "Burgess" near the base. The productive part of the Mississippian rocks is a weathered zone in the upper part. The Cotter dolomite of the Arbuckle group, Ordovician, produces oil from a porous zone in the upper part. Goebel and others (1957, page 170) report the depths to the tops of the various producing rocks in Elk County.

The peak year for oil production in Elk County was 1927, when more than 895,000 barrels was reported. Production during 1955 amounted to more than 304,000 barrels from approximately 281 wells. Cumulative reported oil production from the county amounts to approximately 14.5 million barrels, as of 1956.

SECONDARY RECOVERY

The earliest secondary recovery project in Elk County was in the New Albany field. In 1927 air under pressure was applied to the oil reservoir. The oil-producing formation in the field was the "Wayside" sandstone encountered at a depth of about 560 feet. Air under pressure was applied until 1937; natural gas was then substituted for air as the driving medium (Grandone, 1944).

The Longton field is the only other major field in Elk County to which secondary recovery methods have been applied. Commencing in 1947, fresh water from shallow wells was injected into the "Longton" shallow sand at a depth of 570 feet. On several other smaller fields pilot water-flood studies have been made. As of January 1, 1956, no secondary recovery operations were reported in the county.

The calculated water-flood reserves as of January 1, 1948, were more than 1,860,000 barrels of oil (Sweeney, 1949, p. 11).

PART 3

GROUND-WATER RESOURCES OF ELK COUNTY*

By

CHARLES K. BAYNE

INTRODUCTION

The rural population of Elk County depends almost entirely on ground water for a water supply. During the summer of 1950, a study of the ground water in Elk County was made by 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. During the well inventory, records were collected on 161 wells. The inventory included for each well a measurement of its depth, the depth to water, and identification of the principal aquifer penetrated. Six test holes were drilled in the valley of Elk River to determine the thickness and character of the alluvial deposits. General information on yields of wells, water-bearing formations, and quality of water was obtained from many residents in the area.

WELL-NUMBERING SYSTEM

The wells and test holes included in this report (Table 11) are numbered according to the following formula, using the General Land Office classification system. The number is designated according to township, range, section, quarter sec-

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

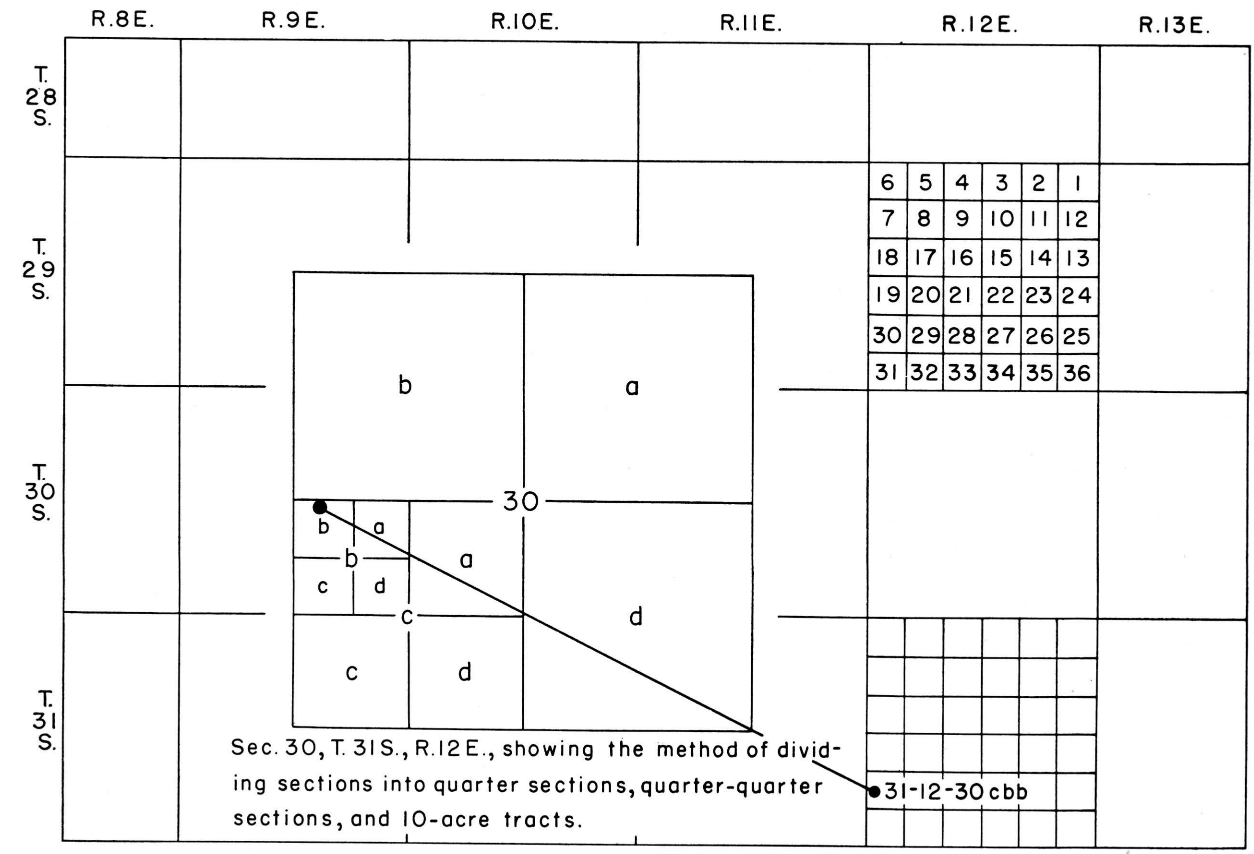


FIG. 9—Map of Elk County illustrating well-numbering system used in this report.

tion, quarter-quarter section, and 10-acre tract within the quarter-quarter section. The quarter sections, the quarter-quarter sections, and the 10-acre tracts are designated a, b, c, and d in a counterclockwise direction, beginning in the northeast quarter. For example, the well in the NW¼ NW¼ SW¼ sec. 30, T. 31 S., R. 12 E., is numbered 31-12-30cbb, as shown in Figure 9.

PRINCIPLES OF OCCURRENCE

The following discussion of the principles of the occurrence of ground water applies specifically to Elk County. For a more detailed discussion of the occurrence of ground water the reader is referred to Meinzer (1923). A discussion of the occurrence of ground water as applied to Kansas is given by Moore and others (1940).

The rocks that directly underlie the surface of Elk County include open spaces that contain gases or liquids. The number, size, shape, and arrangement of these openings are controlled by the character of the rock; thus, the occurrence of ground water is determined by the geology of the county. The openings range from microscopic pores to large solution channels. If the openings are connected, water may move from one to another. In general, water moves freely in rocks having large openings, and such rocks yield more water to wells than do rocks having smaller openings.

In Elk County the source of ground water is precipitation that falls as rain or snow. A part of the precipitation percolates downward to the zone of saturation and becomes ground water. The rest of the precipitation runs off directly over the surface, evaporates, or is transpired from the soil by plants.

Where porous permeable rock extends some distance above the zone of saturation, the upper surface of the saturated zone is called the *water table*. In Elk County, the ground water in the alluvium of the stream valleys and parts of the upland areas is in the zone of saturation beneath the water table. If the upper surface of the zone of saturation is restricted beneath impermeable rock, the water table is absent, and the water is under artesian conditions, and in a well will rise above the top of the bed in which it is confined. The level to which the water would rise when under artesian conditions is called the *piezometric surface*. In Elk County the piezometric surface is above the land surface only in one area of about 160 acres in the valley of Painterhood Creek in sec. 1, T. 30 S., R. 12 E., near the community of Busby. Wells here obtain water from the Ireland sandstone member of the Lawrence shale at a depth of about 40 feet. Records were obtained on several of the wells, and the artesian head was measured. The maximum head measured was that of well 30-12-1ba, which was 4.60 feet above the land surface (Table 11).

GROUND-WATER RECHARGE

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

In Elk County the normal annual precipitation is 35.09 inches. Approximately 65 percent of the precipitation occurs in the growing season, from April through September. The normal annual precipitation amounts to about 2.9 acre-feet, or slightly less than 1 million gallons per acre.

A minimum value for the quantity of ground water recharged may be estimated from the amount discharged from ground-water bodies into streams, as the pumpage is probably nearly constant and is relatively small. The true value would be larger by the amount of ground water evaporated and transpired, but this amount was relatively small at the times when the analyses of surface flow were made.

GROUND-WATER DISCHARGE

The amount of ground water discharged into the streams was obtained by separating the base flow from the total discharge of Elk River at the gaging station near Elk City in Montgomery County, only a few miles downstream from the boundary of Elk County. Elk River drains about 64 percent of the area of Elk County. Flows for November, December, and January were used in calculating the base flow, as evapotranspiration is low during these months, and periods were selected when there was no direct surface runoff from precipitation; therefore, the flow of the stream represented essentially ground-water discharge. A curve representing base flow or ground-water discharge was drawn from hydrographs prepared from records for several years. Assuming that the base flow is nearly constant throughout the year, the annual ground-water discharge for the basin was computed to be about 27,000 acre-feet, which is equivalent to about 5.5 percent of the annual precipitation (2 inches). Extending this figure to cover the whole county, the total ground-water runoff would be about 42,000 acre-feet.

Discharge of subsurface water has been divided by Meinzer (1923) into ground-water discharge (discharge from the zone of saturation) and vadose-water discharge (discharge of soil water or other water not derived from the zone of saturation). In Elk County, water is discharged from the zone of saturation by seeps and springs, evapotranspiration, and withdrawal from wells. Ground water is also discharged from Elk County by percolation through consolidated and unconsolidated rocks into adjacent areas, although this quantity is probably offset by the amount gained by percolation into the county from outside areas.

DISCHARGE BY EVAPORATION AND TRANSPIRATION

The quantity of ground water discharged from an aquifer by evaporation and transpiration depends on the climate, type of vegetation, depth to the water table, and type of rocks and soil above the water table. In most of Elk County the water level is too deep for much discharge of ground water by evaporation and transpiration; these processes are most active in the valleys, where the water table is shallow.

The total discharge of water from the area by evapotranspiration, of which the discharge of ground water makes up only a small part, can be estimated by subtracting the total runoff from the total precipitation on the area when ground-water storage remains about constant and pumpage is small. In Elk County the precipitation was about normal in 1946. The total runoff was about 116,000 acre-feet, or about 15 percent of the precipitation; hence, about 85 percent was discharged

Table 5.—*Analyses of water from typical wells in Elk County*

Dissolved constituents given in parts per million[a] and equivalents per million[b]

Well no. and location	Depth, feet	Geologic source	Date of collection	Temperature (°F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$: Total	Carbonate	Noncarbonate
28-8-33dd	100.0	Wreford and Crouse limestones	1-16-51	53	426	8.8	2.1	97 4.84	26 2.14	20 .88	337 5.53	49 1.02	28 .79	0.3 .02	31 .50	349	276	73
28-9-36da	180.0	Wakarusa limestone	1-16-51	55	684	20	0.17	129 6.44	41 3.37	41 1.79	332 5.44	256 5.32	24 .68	0.6 .03	8.0 .13	490	272	218
28-11-24cd	26.0	Deer Creek limestone	1-16-51	54	5,130	15	.23	498 24.85	304 24.99	661 28.76	368 6.04	2,080 43.20	565 15.93	.6 .03	832 13.40	2,492	302	2,190
28-13-27ba	50.0	Terrace and alluvium	1-16-51	53	225	22	.08	37 1.85	7.2 .59	29 1.27	149 2.44	37 .77	15 .42	.1 .01	4.4 .07	122	122	0
28-13-30ba	65.0	Ireland sandstone	1-16-51	54	913	21	.23	118 5.89	34 2.79	93 4.05	117 1.92	25 .52	99 2.79	.1 .01	465 7.49	434	96	338
29-10-1dd	18.0	Howard limestone and Severy shale	1-16-51	52	409	9.6	.07	72 3.59	21 1.73	50 2.18	346 5.67	28 .58	24 .68	.4 .02	34 .55	266	266	0
29-12-8bb	50.5	Elgin sandstone	1-16-51	53	1,280	10	1.2	326 16.27	23 1.89	100 4.34	356 5.84	204 4.24	439 12.38	.1 .01	2.1 .03	908	292	616
29-12-32cd	22.0	Doniphan shale	1-15-51	52	1,580	7.4	2.2	8.8 .44	5.4 .44	619 26.92	1,040c 17.54	184 3.83	208 5.86	9.0 .47	6.2 .10	44	44	0
30-8-24bd	Spring	Foraker limestone	1-16-51	56	352	8.8	.12	87 4.34	22 1.81	17 .74	366 6.00	21 .44	14 .39	.3 .02	2.2 .04	308	300	8
30-10-11aa	60.0	Topeka and Deer Creek limestones	1-16-51	53	468	9.2	.09	100 4.99	22 1.81	39 1.69	371 6.08	54 1.12	25 .70	.1 .01	36 .58	340	304	36
30-10-28cd	50.0	White Cloud shale	1-16-51	54	351	5.6	.38	56 2.79	22 1.81	37 1.59	229 3.76	75 1.56	13 .37	1.0 .05	28 .45	230	188	42
30-11-26bb	26.0	Lecompton limestone	1-15-51	53	967	11	13	95 4.74	23 1.89	211 9.16	366 6.00	377 7.84	67 1.89	.4 .02	2.2 .04	332	300	32
30-12-1bd	46.0	Ireland sandstone	1-15-51	56	635	9.8	.07	8.4 .42	3.4 .28	242 10.50	386d 6.70	40 .83	129 3.64	.4 .02	.9 .01	35	35	0
30-12-31dc	21.0	Oread limestone	1-15-51	53	352	10	.08	73 3.64	5.8 .48	39 1.70	192 31.5	75 1.56	19 .54	.2 .01	35 .56	206	158	48
31-8-35aa	30.0	French Creek shale	1-16-51	53	877	8.0	3.2	157 7.83	40 3.29	78 3.37	373 6.12	144 3.00	89 2.51	.2 .01	177 2.85	556	306	250
31-9-8cd	60.0	Elmont limestone	1-16-51	53	757	8.2	.08	107 5.34	12 .99	124 5.40	205 3.36	233 4.85	61 1.72	.1 .01	111 1.79	316	168	148
31-10-34dd	18.0	Topeka limestone	1-14-51	52	565	13	.21	127 6.34	19 1.56	32 1.38	289 4.74	71 1.48	37 1.04	.3 .02	124 2.00	395	237	158
31-11-34aa	144.0	Tecumseh shale	1-14-51	55	383	6.6	1.7	108 5.39	6.4 .53	28 1.21	354 5.80	43 .89	14 .39	.2 .01	2.5 .04	296	290	6
31-12-1ac	30.0	Ireland sandstone	1-15-51	54	677	12	1.8	97 4.84	33 2.71	57 2.47	94 1.54	54 1.12	104 2.93	.2 .01	274 4.41	378	77	301
31-12-9bc	29.0	Alluvium and terrace	1-15-51	52	549	16	.52	86 4.29	16 1.32	57 2.47	161 2.64	29 .60	45 1.27	.3 .02	221 3.56	280	132	148
31-12-30cb	48.0	Elgin sandstone	1-14-51	54	324	10	.11	86 4.29	14 1.15	12 .50	256 4.20	50 1.04	22 .62	.2 .01	4.1 .07	272	210	62
31-12-33bd	23.0	Oread limestone	1-14-51	53	635	9.8	.23	154 7.68	23 1.89	30 1.30	307 5.03	42 .87	110 3.10	.4 .02	115 1.85	478	252	226
31-12-36bd	97.0	Ireland sandstone	1-15-51	54	493	14	.34	82 4.09	23 1.89	63 2.76	332 5.44	113 2.35	32 .90	.4 .02	2.0 .03	299	272	27
31-13-21dd	21.0	Alluvium	1-15-51	54	1,980	12	.24	441 22.01	57 4.68	64 2.77	264 4.33	45 .94	352 9.93	.2 .01	885 14.25	1,334	216	1,118

[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] An equivalent per million is a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing the concentration in parts per million by the chemical combining weight of the substance or ion.

[c] Includes equivalent of 28 parts per million of carbonate (CO_3).

[d] Includes equivalent of 22 parts per million of carbonate (CO_3).

by evapotranspiration. The manner in which precipitation falls will cause considerable variation in the quantity of water discharged by evapotranspiration. The precipitation in Elk County in 1946 and 1947 was 35.37 and 36.63 inches, respectively, but the distribution in the two years was different. Total evapotranspiration during 1946 and 1947 was about 85 and 60 percent, respectively.

DISCHARGE BY SEEPS AND SPRINGS

Most of the ground-water discharge in Elk County takes place through seeps and springs along the outcrops of the aquifers. The base flow of all perennial streams in the county is maintained by seeps and springs. The total discharge by these means was computed to be about 42,000 acre-feet per year.

DISCHARGE FROM WELLS

All municipal and large industrial water supplies in Elk County are obtained from surface-water sources. Ground water is withdrawn from wells for domestic and stock use. Domestic and stock wells are generally drilled or dug, but a few wells in the alluvium of Elk and Fall Rivers are driven. The yearly pumpage from wells in the county is about 110 million gallons, or about 338 acre-feet. The yield of domestic wells in Elk County ranges from as much as 50 gallons a minute for some wells in the Wreford limestone in the northwest corner of the county and in the alluvium of Elk and Fall Rivers to only a few gallons an hour from some wells in sandy shales and massive limestones.

CHEMICAL CHARACTER OF WATER

The chemical character of the ground water in Elk County is indicated by the 24 analyses of water given in Table 5. The water samples were collected from typical wells and springs in the principal aquifers and were taken from places spaced as evenly as practicable within the county.

The samples were analyzed by Howard A. Stoltenberg, chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health in Lawrence.

DISSOLVED SOLIDS

The residue left after a natural water is evaporated consists of rock minerals and minor amounts of organic material and water of crystallization.

Water containing less than 500 parts per million of dissolved solids is generally regarded as satisfactory for domestic use, except for difficulties resulting from hardness or excessive iron content. Water containing more than 1,000 ppm of dissolved solids may contain enough of certain constituents to cause a noticeable taste or to make the water unsuitable for use in some other respects. The amount of dissolved solids in the 24 samples collected in Elk County is given in Table 6.

The water from 10 wells of a total of 24 that were sampled in Elk County had less than 500 ppm of dissolved solids and is suitable for most domestic uses. Ten samples had between 500 and 1,000 ppm of dissolved solids, and the water from 4 wells contained more than 1,000 ppm. Well 28-11-24cd had the highest concentration of dissolved solids, 5,130 ppm.

TABLE 6.—*Dissolved solids in water samples from wells and springs in Elk County*

Dissolved solids (parts per million)	Number of samples
Less than 300	1
300 to 499	9
500 to 749	6
750 to 999	4
1,000 or more	4

HARDNESS

Hardness is the property of water that generally receives the most attention, because of its effect when soap is used with the water. Nearly all the hardness in water is caused by calcium and magnesium, which also cause most of the scale in boilers.

In addition to total hardness, Table 5 gives the carbonate and noncarbonate hardness. The carbonate hardness is due to the presence of calcium and magnesium bicarbonates and may be almost completely removed by boiling. The noncarbonate hardness is caused by the presence of sulfates and chlorides of calcium and magnesium. The carbonate hardness is sometimes called *temporary hardness,* and the noncarbonate hardness is called *permanent hardness.*

Water having a hardness of 50 ppm or less is soft; hence, treatment for softening water of this type is not ordinarily necessary. Water having a hardness of 50 to 150 ppm is suitable for most uses, but does increase the use of soap; therefore industries such as laundries, which are large users of soap, find it profitable to soften the water. The fact that hard water causes scale in boilers is an additional reason for industry to do this. Hardness of more than 150 ppm can be noticed by almost anyone, and when the hardness reaches

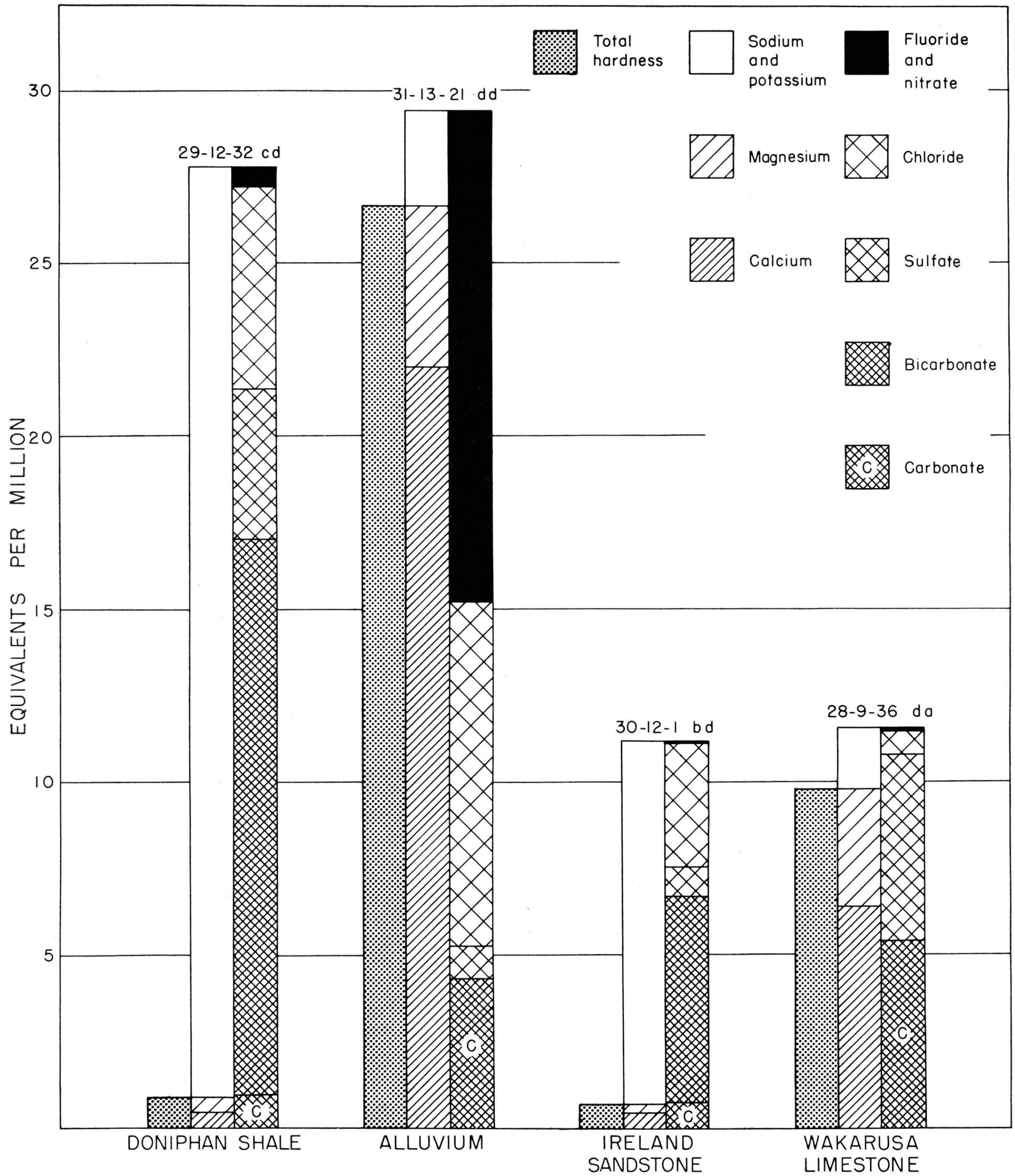


FIG. 10—Graphical representation of analyses of water from wells in principal water-bearing formations in Elk County.

200 ppm, it requires reduction for most uses. Where municipal water supplies are softened, the hardness is generally reduced to 80 to 100 ppm. The improvement of the water by further softening is not generally thought to be worth the increased cost.

Of 24 samples of water collected from wells in Elk County, two had a hardness of less than 50 ppm, one had a hardness between 150 and 300 parts, and 14 had a hardness of more than 300 parts, including two that had a hardness of more than 1,000 ppm. The two samples in which the water had a hardness of less than 50 ppm were of the sodium bicarbonate type; that is, they had a very large percentage of sodium and bicarbonate and carbonate but a small percentage of calcium and magnesium. The relation between sodium, calcium, and magnesium content and hardness is shown in Figure 10, which is a diagram of the analyses of two soft and two hard waters. The hardness of the 24 samples of water collected in Elk County is given in Table 7.

TABLE 7.—*Hardness of water from typical wells in Elk County*

Hardness as $CaCO_3$ (parts per million)	Number of samples
Less than 50	2
50 to 149	1
150 to 299	7
300 to 499	10
500 to 999	2
1,000 or more	2

IRON

Iron is a common troublesome constituent of ground water. The quantity of iron in the water may vary greatly from place to place, even within the same formation. If iron is present in ground water in quantities in excess of about 0.3 ppm, the excess iron will precipitate upon exposure to air. Generally where iron is present in sufficient quantity to cause a disagreeable taste or to stain cooking utensils and textiles, it may be removed by aeration and filtration. In some waters the addition of other chemicals is necessary to remove the iron. Table 8 indicates the iron content in the 24 samples of water from wells and springs in Elk County.

TABLE 8.—*Iron content of water samples from wells and springs in Elk County*

Iron (parts per million)	Number of samples
Less than 0.1	6
0.10 - 0.29	8
0.30 - 0.99	3
1.0 - 1.9	3
2.0 or more	4

FLUORIDE

Generally only a small amount of fluoride is present in ground water. Fluoride in water consumed by children is closely related to dental health. Water containing more than about 1.5 ppm of fluoride may cause mottling of tooth enamel, the severity of the mottling increasing with the fluoride content. Small quantities of fluoride, not sufficient to cause mottled enamel, may reduce tooth decay (Dean, 1936; Dean, Arnold, and Elvove, 1942).

In Elk County only one sample of water (well 29-12-32dc) had a fluoride content greater than 1 ppm; this had a fluoride concentration of 9 ppm.

NITRATE

The range of nitrate content in waters in Elk County is great. The source of nitrate in well water in Kansas is not definitely known. One possible source is nitrate-bearing rocks within the aquifers, although such rocks have not been found in Kansas in association with well waters containing excessive nitrate. Another source is contamination of the well by surface water containing high concentrations of nitrate. These surface waters may derive the nitrate from barnyards, artificial fertilizers, or nitro-biological activity associated with certain legumes that increase the nitrate in the soil.

Dug wells are more susceptible to contamination than drilled wells, because they are more difficult to seal at and just below the surface than drilled wells, in which the casing generally serves as a good seal against contamination. Table 9 compares nitrate contents in 9 dug and 14 drilled wells sampled in Elk County.

TABLE 9.—*Comparison of nitrate in dug and drilled wells in Elk County*

Nitrate (parts per million)	Number of samples	
	Dug wells	Drilled wells
Less than 25	1	8
25 to 49	2	3
50 to 99	0	0
100 to 199	3	1
200 or more	3	2

Excessive nitrate in well water may cause infant cyanosis ("blue baby") when the water is used in the preparation of formulas. The Kansas State Board of Health regards water containing more than 90 ppm (as NO_3) as unsafe for use in infant feeding and regards water containing less than 50 ppm as safe. The nitrate in well water cannot be removed by boiling, as that only concentrates the nitrate; and its removal by chemical means cannot be done practically.

In Elk County 14 of the 23 samples of water contained less than 50 ppm of nitrate and were in the safe range. Nine samples had a nitrate content of more than 100 ppm. The highest nitrate content was in water from well 31-13-21dd in alluvium. This water contained 885 ppm of nitrate (Table 5).

CHLORIDE

Chloride is abundant in sea water and oil-field brines and is dissolved in small quantities from many rock materials. Chloride where concentrated is corrosive to steam boilers.

In Elk County only four samples of water had more than 150 ppm of chloride. The highest, 565 ppm, was in the sample from well 28-11-24cd. Water containing 550 ppm of chloride tastes salty to most persons; as little as 250 ppm can be detected by some persons.

SANITARY CONSIDERATIONS

The analyses of the water from wells in Elk County (Table 5) indicate only its mineral constituents and do not show its sanitary condition. Concentrations of certain minerals, however, such as chloride or nitrate, may indicate possible pollution.

In Elk County nearly all the rural population is dependent on wells for a water supply. In construction of wells, therefore, care should be taken to prevent pollution. A well should not be constructed near possible sources of pollution, such as barnyards, cesspools, or privies. The well should be so constructed that surface water drains away from the well rather than toward it. If it is necessary to drill a well where drainage will be toward it, the well should be finished with earth mounded around it as a barrier against surface water. Drilled wells are generally protected by the casing, which forms a seal, but in some areas, wells must be dug to obtain adequate storage capacity.

GROUND-WATER REGIONS IN ELK COUNTY

For the purpose of discussing the availability of ground water, Elk County has been divided into regions coinciding with the outcrops of different geologic formations. Although the regions cannot be sharply delimited, they were selected because of similarities of aquifers or of wells within a region. The name selected for a region is the name of the geologic formation where only one formation is present and the hyphenated names of the upper and lower formations or members where more than one is included. The names of the ground-water regions and the letters designating the regions on the ground-water map (Pl. 3) are given in Table 10.

TABLE 10.—*Names of ground-water regions in Elk County and designating symbols used on Plate 3*

Region or area	Symbol used on Plate 3
Wreford-Americus region	WA
Hamlin-Dry region	HD
Dover-Burlingame region	DB
Silver Lake-Severy region	SS
Topeka-Lecomton region	TL
Tecumseh area	TLt
Kanwaka region	K
Oread region	O
Ireland region	I
Stranger region	S
Alluvium-Terrace region	AT

WREFORD-AMERICUS REGION

The westernmost region in Elk County is the Wreford-Americus region designated by the symbol WA on Plate 3. The rocks in this region are a sequence of shales and limestones. The limestones are relatively thick, and many of them contain chert. The topography of the region is typical of the Flint Hills. The Americus limestone member of the Foraker limestone forms a lower escarpment recognized over much of the southern part of the outcrop; the Wreford limestone forms an upper escarpment; and the intervening limestones form a series of terracelike benches.

The chief aquifers of this region are the Wreford and Foraker limestones. Water is yielded to wells through joints and solution channels in the cherty members of these formations. Other aquifers in the area are the Crouse, Bader, Beattie, and Grenola limestones. The Neva limestone member of the Grenola yields water to springs over a part of its outcrop in Elk County, but of the wells inventoried none was obtaining water from the Neva limestone. In Cowley County, however, the Neva yields water to many wells and springs (Bass, 1929).

Wells in the Wreford-Americus region are generally drilled wells ranging in depth from 20 to 125 feet. Most of the wells in the area yield adequate and dependable supplies of water, but during the drought period 1933 to 1939, because many wells failed, many ponds were constructed or water had to be hauled. The yield from wells in this area ranges from as much as 50 gallons a minute from the Wreford limestone to only a few gallons an hour from other aquifers (Table 11). Many springs and seeps issue from rock in this area, which is the headwater area of Elk River and Caney Creek—both spring-fed streams.

Water from the aquifers in this region is generally good except for hardness, which is mostly of the carbonate type and can be removed by relatively simple treatment. Samples were collected from two wells in the Wreford-Americus region. Well 28-8-33dd yields water from the Wreford and Crouse limestones. This water has a total hardness of 349 ppm. The carbonate, or temporary, hardness of the water from this well is 276 parts. Well 30-8-24bd yields water from the Foraker limestone; this water has a total hardness of 308 ppm, of which 300 ppm is carbonate, or temporary, hardness.

HAMLIN-DRY REGION

The Hamlin-Dry region, designated by the symbol HD on Plate 3, is a relatively narrow belt lying below the escarpment of the Foraker limestone. In this area sandstone and sandy shales of the Admire group and upper part of the Wabaunsee group yield water to wells. The wells are typically shallow dug wells, many of which yield small supplies inadequate for stock water.

The water from wells in this region is generally hard. The noncarbonate hardness generally is high because of the high sulfate content. The analysis of water from well 31-8-25aa in this region is given in Table 5.

DOVER-BURLINGAME REGION

The Dover-Burlingame region, designated by the symbol DB on Plate 3, was defined because of similarities in the limestones. The limestones in this region form escarpments, although the escarpments are not nearly so pronounced as those in the Wreford-Americus region. The limestones are thin but persistent and uniform in thickness, and from them water is obtained through joints and solution channels within the formations. The shales in some parts of this region are sandy or contain channel sandstones that yield small amounts of water to wells. Wells in the Dover limestone are generally shallow dug wells and yield small amounts of water. The Dover limestone does not yield water in this area to wells drilled below the weathered zone. The Elmont limestone does not yield water to wells at shallow depths, but several wells obtain water from depths of 75 feet or more. Yields of wells in the Elmont are small, probably not more than 1 or 2 gpm. The Wakarusa limestone and Burlingame limestone are separated by the thin Soldier Creek shale, and it is difficult to determine which of the two is the principal source of water in many wells. Most wells in the Wakarusa and Burlingame limestones yield small amounts of water, but they may yield as much as 10 ppm. A spring in a road cut in the SW¼ sec. 23, T. 27 S., R. 10 E., Greenwood County, in the Burlingame limestone had an estimated flow of 10 gpm.

The water in the Dover-Burlingame region is generally hard.

SILVER LAKE-SEVERY REGION

The Silver Lake-Severy region, designated by the symbol SS on Plate 3, is underlain predominantly by shale and sandy shale. The only escarpment-forming limestone is the Howard, which yields small amounts of water to wells in some areas where it has been altered near the surface by weathering. Most wells in this region obtain water from sandy shales or sandstones of the upper part of the Cedar Vale shale, the middle part of the White Cloud shale, or the upper part of the Severy shale. The yield of wells in this area is generally small, a few gallons an hour, and generally not enough for stock-water supplies. Wells drilled through a large thickness of the Severy shale into the Topeka or the Deer Creek limestone generally yield poor water. Most wells in this area are shallow dug wells, although a few are drilled as much as 100 feet deep.

The water in the shallow wells in this region is generally good but is somewhat hard. The hardness is mostly carbonate. The water from well 29-10-1dd in the Howard limestone or the upper part of the Severy shale had a total hardness of 266 ppm, which was carbonate hardness. The water from well 30-10-28cd in a sandstone in the White Cloud shale had a hardness of 230 ppm, of which 188 parts was carbonate (Table 5).

TOPEKA-LECOMPTON REGION

The Topeka-Lecompton region, TL on Plate 3, is the largest limestone region in Elk County. It includes outcrops of the Topeka, Deer Creek, and Lecompton limestones and also the Tecumseh shale, the extent of which is shown separately on Plate 3 as an area and designated by the symbol TLt. The limestones in this region are relatively thick and are similar in their ground-water characteristics in that they yield water from the top members of the formations. The Topeka limestone yields small supplies generally from dug wells from the "Red" limestone, which probably is equivalent to the Coal Creek limestone member. The Deer Creek limestone, which is probably the best aquifer in the Topeka-Lecompton region, yields supplies to wells penetrating the Ervine Creek limestone member. Many small springs issue from this rock along the outcrop. The Avoca limestone member and Beil limestone member of the Lecompton limestone yield small supplies to wells in some areas. In the northern part of its outcrop the Doniphan shale member contains more sand than in the southern part and is the best aquifer of the formation. Most of the wells producing from the Lecompton limestone have small yields. Wells obtaining water from the Doniphan member are as deep as 125 feet.

TECUMSEH AREA

In the Tecumseh area, TLt on Plate 3, wells obtain water from the Tecumseh shale. In the area south and west of Elk Falls it is sandy and resembles in part locally a channel-filling sandstone. Farther north the Tecumseh does not contain enough sandstone to yield appreciable amounts of water. Most wells inventoried in this region are drilled wells and yield water from depths of as much as 140 feet.

The water in the Topeka-Lecompton region is generally hard. Most of the hardness is carbonate, but well 28-11-24cd yields, from the Deer Creek limestone, water that has a noncarbonate hardness of 2,190 ppm and contains 832 ppm of nitrate, which indicates contamination. Water from well 29-12-32dc is a sodium bicarbonate water containing much sodium, bicarbonate, and carbonate, and is very soft. This well yields water from the Doniphan shale member of the Locompton limestone, which is sandy in this area. The analyses of the water from wells in the Topeka-Lecompton region are given in Table 5.

KANWAKA REGION

In the Kanwaka region, designated by the symbol K on Plate 3, water is obtained from wells in the Kanwaka shale, which is divided into three members: in descending order the Stull shale, the Clay Creek limestone, and the Jackson Park shale.

In the Stull shale member, a lenticular or channel-filling sandstone yields water to wells. In Elk County, this sandstone reaches a thickness of about 30 feet. Wells in this sandstone yield adequate supplies of good water.

A channel-filling sandstone (Elgin) whose top is a few feet below the top of the Jackson Park shale reaches a thickness in Elk County of about 35 feet, and in places it lies directly on the Kereford limestone member of the Oread limestone. In Chautauqua County near Elgin, it reaches its maximum thickness of 150 feet. In Elk County, wells penetrating this sandstone yield adequate supplies of water for stock and domestic use.

The quality of water from the Kanwaka region differs from place to place. The northern part of the aquifer generally yields poorer water than the southern part.

Drillers report areas where salt water is present in this region. The analyses of water samples also indicate that the ground water in parts of the region is strongly mineralized. The water in well 29-12-8bb had 439 ppm of chloride and 1,279 ppm of dissolved solids. The total hardness of this water was 908 parts, of which 292 parts was carbonate hardness. The water in well 31-12-30cb, in the southern part of the region, had only 22 ppm of chloride and 324 parts of dissolved solids. The total hardness was 272 parts, 210 parts of which was carbonate hardness (Table 5).

OREAD REGION

The Oread region, designated on Plate 3 by the symbol O, lies just east of the Kanwaka region and comprises the outcrop areas of units of the Oread limestone. Wells in this region yield water from the Plattsmouth limestone member and the Snyderville shale member of the Oread limestone. The yield of wells in the Plattsmouth member is generally small, and the rock may provide only enough water for domestic wells. Wells in the Snyderville shale member yield water from sandy zones and generally yield slightly more than the wells in the Plattsmouth.

The water from the Oread region is generally hard; most of the hardness is carbonate (Table 5).

IRELAND REGION

The Ireland region, designated by the symbol I on Plate 3, is the largest of the sandstone regions in Elk County. It is underlain by beds of the Lawrence shale, of which the Ireland sandstone member is the best aquifer. Wells in the Ireland sandstone member are either dug or drilled. The best wells are drilled and range from 40 to 160 feet in depth. The quantity of water derived from the Ireland by wells ranges from about 1 to 10 gpm and averages about 2 gpm.

Near the community of Busby in sec. 1, T. 30 S., R. 12 E., in an area of about a quarter of a square mile, artesian water flows from wells that penetrate the Ireland sandstone member to an average depth of about 40 feet. The yields from these wells range from an estimated 0.5 gpm in some wells to about 3 gpm in well 30-12-1ba. The artesian head of this well was 4.60 feet above the land surface (Table 11). In other wells in the region the water rises above the aquifer, but the static level is below the land surface.

The water from wells in this region is relatively hard, but the hardness is generally carbonate. Well 30-12-1ba yields a sodium bicarbonate water in which the calcium and magnesium content is low and the sodium content is high. This well yields water from the Ireland sandstone member and is a flowing artesian well. Water in some wells in the northern part of the region is reported by drillers to be salty.

STRANGER REGION

The Stranger region, designated on Plate 3 by the symbol S, is the area of outcrop of beds of the Stranger formation, which extend from the base of the Ireland sandstone member downward through the Tonganoxie sandstone member of the Stranger formation. Wells yield water from sandy shale and sandstone of the Robbins and Vinland shale members and from the Tonganoxie sandstone member of the Stranger formation. The Tonganoxie sandstone probably yields water to wells in the southeast part of the county and to a few wells in the northeast part of the county. The yield of most of the wells is not large, and where the Tonganoxie is found at a depth of more than 100 feet the water is generally slightly salty. The quality of the water in the Stranger region is similar to that in the Ireland region.

ALLUVIUM-TERRACE REGION

The Alluvium-Terrace region, designated by the symbol AT on Plate 3, consists of areas underlain by unconsolidated alluvium and terrace deposits along the valleys of Elk and Fall Rivers. The area of these deposits is not large, but the deposits yield water to wells in larger quantities than any other aquifer in the county.

The terrace deposits do not yield as much water to wells as the alluvium, because generally the water table is near the base of the terrace deposits. The coarse gravels are generally thinner in the terraces than in the alluvium. A cross section of the alluvium of Elk River along a line extending from about 150 feet south of the NE cor. SE¼ sec. 5, T. 31 S., R. 12 E., to about 150 feet south of the NE cor. SE¼ sec. 17, T. 31 S., R. 12 E., is shown as B-B′ in Figure 11. This cross section shows three terraces. The first is a low, discontinuous terrace in which the ground-water characteristics are similar to those in the alluvial floodplain and which is therefore mapped as alluvium and is included in the discussion of the alluvium. The second terrace lies about 17 feet higher than the low terrace. The second terrace is about 0.5 mile wide, and its deposits are not so good an aquifer as are those at the low terrace. The gravels are thinner than in the low terrace,

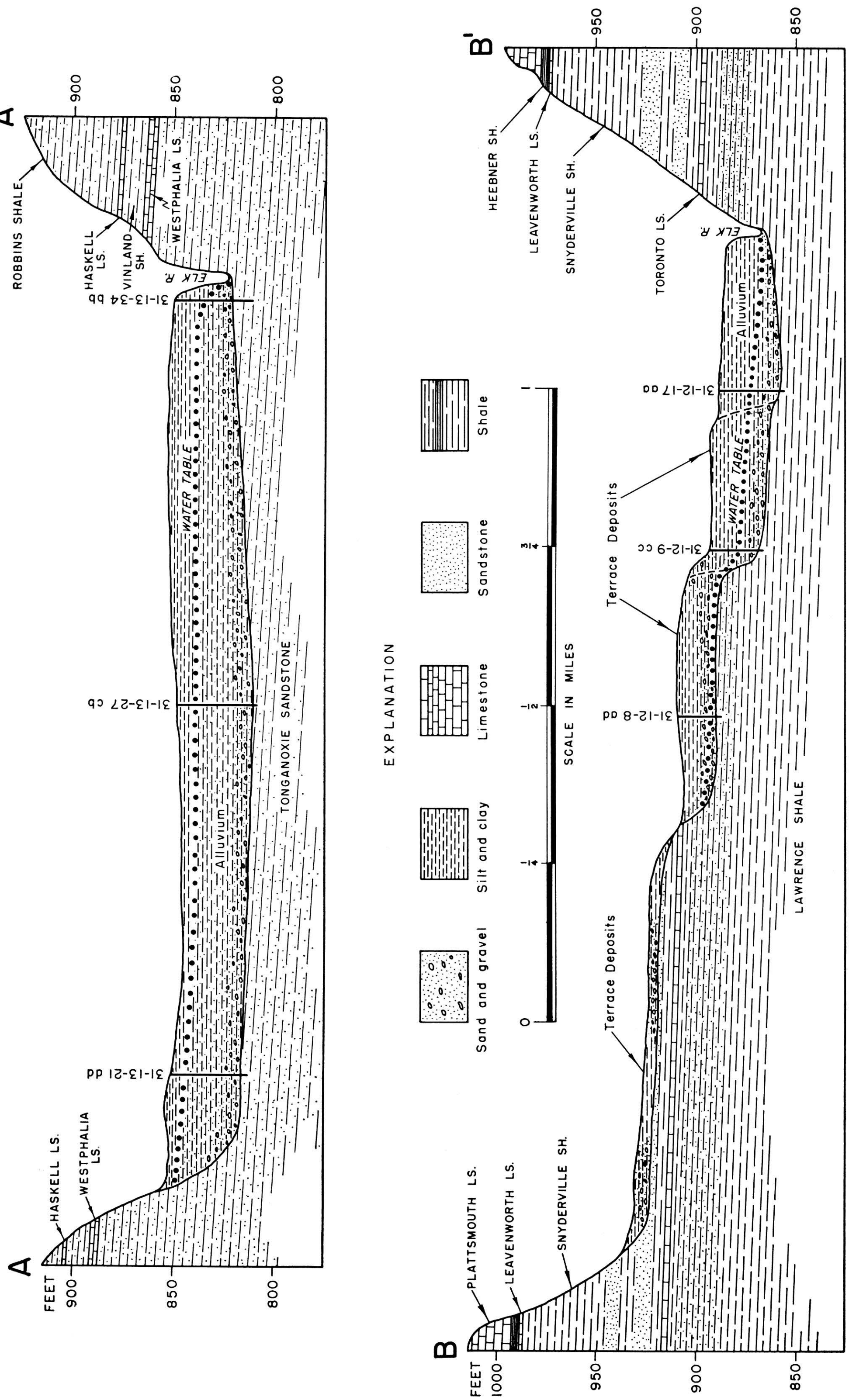


FIG. 11—Geologic cross sections across Elk River valley in Elk County, along lines A-A' and B-B'.

and the water table is near the base of the terrace deposits. Wells in this terrace area generally yield adequate supplies for stock or domestic use, but large supplies could not be developed. The third terrace lies about 20 feet above the second and overlies the bench made by the resistant Toronto limestone member of the Oread limestone. At its widest part this terrace is about 0.75 mile wide. The terrace gravels are thin and lie above the level of the water table in the floodplain. The wells in this area are small because they depend on seepage water from the shales in the valley sides and on infiltration in seasons of heavy rainfall.

The terrace area in the northeast part of the county along Fall River is similar to the second terrace along Elk River.

The alluvium along Elk River provides moderate supplies from the east county line westward, upstream, to an area just below Elk Falls. Upstream from Elk Falls the alluvium thins and is not an important aquifer, although it yields water to a few wells. The wells in the alluvium below Elk Falls obtain water from chert gravels and sands that are not continuous over the entire valley but, where present, yield water to wells freely. These chert gravels and sands, as indicated by test drilling and logs of wells, are generally about 5 feet thick and are not more than 10 feet thick in any of the test holes.

Upstream from the eastern edge of the outcrop of the Oread limestone the valleys of Elk and Fall Rivers are narrow. Downstream from the eastern edge of the outcrop the valleys widen as the stream crosses the softer shales of the Lawrence and Stranger formations. East of the Elk County line the valleys continue to widen for a distance of about 5 miles, to the western edge of the outcrop of the Stanton limestone. Below this point the valleys again narrow.

Valley widths are shown by cross sections A-A′ and B-B′ in Figure 11. Cross section A-A′ is across the Elk River valley 1 mile west of the Elk-Montgomery County line, and cross section B-B′ is about 7 miles west of cross section A-A′ near Longton.

Where gravel is present in the alluvium, wells yield as much as 50 gpm. Even where gravel is absent, the silts are generally so sandy that very good stock wells can be developed.

Water from the alluvium and terrace area of the Fall River valley is generally good. It is relatively soft and the hardness is carbonate. The water from the alluvium and terrace area of the Elk River valley is not so good as that in the Fall River valley. The chloride content is greater, and the water has a greater total hardness. The samples of water from wells in the alluvium of Elk River were high in nitrate, probably owing to local contamination.

RECORDS OF TYPICAL WELLS

Descriptions of wells visited in Elk County are given in Table 11. Information classed as "reported" was obtained from the owner or tenant. Depths of wells not classed as "reported" were measured and are given to the nearest tenth of a foot below the measuring point. Depths to water level not classed as "reported" were measured and are given to the nearest hundredth of a foot.

TABLE 11.—*Records of wells in Elk County*

Well no. and location (1)	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 (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
28-8-22bb	G. P. Farrell	Sp				Limestone	Crouse limestone	F	S			F	8-31-50	Yield 5
28-8-22cd	do	do				do	Bader limestone	F	S			F	8-31-50	Yield 10
28-8-27ab	do	do				do	Cottonwood limestone	F	D, S			F	8-31-50	Yield 10. Flows continuously in dry weather with little decrease in flow
28-8-27ba	do	Dr	250.0	6	GI	do	do	Cy, W	S	Top of casing	0.8	39.5	8-31-50	Yield 1
(28-8-33dd)	do	Dr	100.0	6	GI	do	Crouse and Bader limestones	Cy, W	S	do	0.5	38.6	8-31-50	Yield 1
28-8-34ac	do	Du	150.0	6	GI	do	Wreford limestone	Cy, W	S	do	0.9	26.5	8-31-50	Yield 1
28-9-23cb	V. Spardling	Sp				do	Hughes Creek shale	F	S			F	8-31-50	Yield 1
(28-9-36da)	T. Farney	Dr	180.0	8	GI	do	Wakarusa and Burlingame limestones	Cy, E	D, S	Top of casing	0.8	123.0	8-19-50	Small supply
28-10-19cc	R. J. Dryer	Du	18.0	30	R	do	Elmont limestone	B, H	D, S	Top of rock curb	0.6	4.60	8-31-50	Small supply
28-10-22dd	R. P. Jacobs	Du	16.0	36	R	Sandstone	Cedar Vale shale	Cy, H	D, S	Top of board cover	0.5	5.60	8-31-50	
28-10-32dd	E. J. Petty	Dr	60.0	8	GI	Limestone	Wakarusa and Burlingame limestones	Cy, H	D, S	do	0.8	52.0	8-19-50	Yield about 1
28-11-21dd	C. E. Clogston	Dr	60.0	6	GI	do	Deer Creek limestone	N	N	Top of casing	0.6	56.0	9-11-50	Very small supply
(28-11-24cd)	J. A. Maken	Du	26.0	96	R	do	Ervine Creek limestone	Cy, H	S	Top of board cover	1.3	4.6	9-11-50	Very small supply
28-11-28aa	E. Tull	Du	18.0	36	R	do	Topeka limestone	Cy, H	D, S	do	1.0	10.6	9-11-50	Very small supply
28-11-28cd	Gibson	Dr	120	8	GI	Sandstone	Deer Creek limestone	Cy, H	S	Top of casing	1.0	13.80	9-11-50	Estimated yield 10
28-11-30bc	R. A. Dungar	Du	32.0	30	R	Limestone	Howard limestone	Cy, H	S	Base of pump	1.6	16.80	8-31-50	
28-12-21cc	G. Fultzenloger	Dr	125.0	8	GI	Sandstone	Jackson Park shale	Cy, H	S	do	1.1	56.70	9-8-50	Salt water at 225 feet in upper Lawrence shale
28-12-24ad	Glenn Taggart	Dr	225	6	GI	do	Ireland sandstone	Cy, W	D, S	Top of casing	0.6	98.6	9-8-50	Water from Tonganoxie sandstone is slightly salty
28-12-25da	R. L. Alspaugh	Dr	70.0	6	GI	do	do	Cy, H	D, S	do	1.0	12.10	9-8-50	
28-13-21dd	T. S. Bewley	Du	20.0	36	R	Gravel	Alluvium (terrace deposits)	Cy, W	S	Top of board cover	0.2	14.00	8-26-50	
28-13-22bc	Chandler and Oaks	Dr	70.0	6	GI	do	do	Cy, H	D, S	Top of casing	1.0	12.30	9-9-50	Good well, 40 feet of alluvium. Sandstone below 40 feet
(28-13-27ba)	A. L. Broderick	Dr	125.0	6	GI	do	do	Cy, H	D, S	do	1.2	18.6	9-8-50	Salt water at 125 feet, probably local pollution from oil wells
(28-13-30ba)	J. Huges	Dr	65.0	6	GI	Sandstone	Ireland sandstone	Cy, H	D, S	Base of pump	0.6	28.8	9-8-50	
28-13-31cb	E. Donley	Dr	60.0	6	GI	Gravel and sandstone	Alluvium and Ireland sandstone	Cy, H	D, S	do	1.2	14.8	9-8-50	
28-13-34ad	H. O. Boucher	Dr	55.0	6	GI	Sandstone	Ireland sandstone	Cy, H	D, S	do	1.0	20.60	9-10-50	
29-8-1ab	Helen P. Youngmeyer	Sp				Limestone	Hughes Creek shale and Americus limestone	F	S			F	8-31-50	Good supply; yield ±3
29-8-3bb	G. P. Farrell	Dr	50	6	GI	do	Wreford limestone	Cy, W	S	Base of pump	1.5	10.55	8-31-50	Yield 1
29-8-13bd	H. P. Youngmeyer	Du	35.0	30	R	do	Hughes Creek shale and Americus limestone	Cy, W	S	do	0.5	12.64	9-1-50	
29-8-15cb	Cora Hoard	Sp				do	Wreford limestone	F	S			F	9-1-50	Yield ±1
29-9-6ab	A. C. Barnes	Du	35.0	36	R	Sandstone	Pony Creek shale	B, H	D, S	Top of well curb box	2.8	15.60	8-31-50	Poor well
29-9-9dd	C. C. Rader	Dr	75.0	8	GI	Limestone	Elmont limestone	Cy, H	D, S	Top of casing	0.3	60.85	8-19-50	do
29-9-14dc	W. H. Wilich	Dr	74.0	8	GI	do	Burlingame limestone	Cy, E	D, S	do	0.6	54.06	8-19-50	Fair well in sandstone in Cedar Vale shale, salt water at 86 feet

29-9-16bc	J. C. Rader	Du	38.0	36	R	Sandstone	Pony Creek shale	Cy, H	S	Top of board cover	0.8	7.96	9-1-50	
29-9-34bb	F. D. Smith	Du	35.5	36	R	do	Friedrich shale	Cy, H	N	do	0.6	21.0	9-1-50	
29-10-1ab	L. J. Hurd	Du	25.0	40	R	do	White Cloud shale	Cy, H	S	Top of curb	0.6	16.10	8-30-50	Fair well
(29-10-1dd)	J. A. Heisler	Du	18.0	36	R	Limestone	Howard limestone	B, H	D, S	do	0.5	12.06	8-31-50	do
29-10-2ab	G. Jones	Dr	103.0	8	GI	Sandy shale	Severy shale	Cy, H	S	Top of casing	0.4	46.03	8-30-50	
29-10-3cd	O. Styler	Dr	305.0	6	N	Limestone and sandstone	Howard limestone and Severy shale	N	N	Ground surface	0.0	20.60	9-9-50	Yield 1/20 at 22 feet. No water below 22 feet
29-10-7cb	W. F. Davey	Dr	62.0	8	GI	Sandstone	Cedar Vale shale	Cy, H	S	Top of casing	0.8	6.82	8-19-50	Weak well, probably yields water from Wakarusa, Burlingame in wet weather
29-10-11bb	Bowman	Dr	100.0	6	GI	Sandy shale and limestone	White Cloud shale and Howard limestone	Cy, H	D, S	do	0.6	25.20	9-8-50	
29-10-22cd1	F. C. Atkinson	Du	16.0	40	R	Limestone	Howard limestone	Cy, H	S	Base of pump	0.9	11.38	8-30-50	Does not yield large amount of water but does not fail in drought
29-10-22cd2	do	Du	35.0	30	R	do	do	Cy, W	S	do	0.5	9.55	8-30-50	do
29-11-3cb	C. Snowden	Du	26.0	36	R	do	Topeka and Ervine Creek limestones	Cy, H	S	do	0.3	10.88	9-11-50	
29-11-11da	J. P. McCormick	Du	28.0	38	R	do	Ervine Creek limestone	Cy, W	D, S	do	0.6	7.50	9-11-50	Small supply
29-11-16dd	G. C. Morehead	Du	18.0	36	R	do	Topeka limestone	Cy, H	D, S	do	0.5	10.12	9-11-50	do
29-11-24ab	E. B. Nix	Dr	125.0	8	GI	Limestone and sandy shale	Deer Creek limestone and Tecumseh shale	Cy, H	S	do	0.8	36.73	9-8-50	do
29-11-32aa	C. Glasco	Dr	75.0	8	GI	Limestone	Ervine Creek limestone	Cy, H	S	do	0.5	13.86	8-21-50	do
29-11-34cd	R. C. Madison	Du	16.0	48	R	do	do	Cy, H	S	do	0.6	6.24	9-7-50	do
29-11-36cb	R. F. Jones	Dr	160.0	8	GI	Limestone and sandstone	Lecompton limestone and Elgin sandstone	Cy, E	D, S	do	0.9	65.28	8-21-50	Fair supply
29-12-1dc	Dodson Bros.	Dr	55.0	6	GI	Gravel	Alluvium	Cy, H	D, S	do	1.0	10.65	9-7-50	Very good well; 27 feet of gravel
29-12-3bd	Martin	Dr	25.0	6	GI	Sandstone	Jackson Park shale	Cy, H	D, S	do	1.6	13.68	9-8-50	Fair well
29-12-6bd	Add Burrton	DD	128.0	8	GI	do	do	Cy, W	D, S	do	0.7	32.69	8-25-50	Good well
29-12-8ba	A. J. Gorges	Dr	55.0	8	GI	do	Elgin sandstone	Cy, E	S	Top of casing	0.6	18.86	9-8-50	do
29-12-8bb1	do	Dr	60.0	8	GI	do	do	J, E	D, S	do	1.3	18.35	8-25-50	Fair well
(29-12-8bb2)	School district	Dr	50.5	6	GI	do	do	Cy, H	P	do	0.8	12.97	8-25-50	Good well
29-12-8dc	M. Thompson	Dr	50.0	8	GI	do	Doniphan shale	Cy, H	S	do	1.8	21.89	8-25-50	do
29-12-9bb	E. A. McBee	Dr	65.0	6	GI	do	Elgin sandstone	Cy, H	S	do	0.5	30.06	9-8-50	do
29-12-10ab	E. Taylor	Dr	160.0	6	GI	do	Ireland sandstone	Cy, H	D, S	do	0.8	48.38	9-8-50	Slightly salty
29-12-17bb	L. Baumgartner	Sp				do	Doniphan shale	F	S			F	8-25-50	Flow 3; diminishes in dry weather
29-12-18dd	H. H. Nekels	Dr	100.0	6	N	Limestone	Ervine Creek limestone	N	N		0.0	—	8-30-50	Very little water—abandoned as dry
29-12-20dd	H. Dotter	Dr	90.0	6	GI	Sandstone	Tecumseh shale	Cy, H	D, S	Top of casing	0.5	25.46	9-8-50	Good well
29-12-25ac	School district	Dr	100.0	8	GI	do	Ireland sandstone	Cy, H	P	do	0.6	14.46	8-26-50	Good well; abandoned
29-12-28ba	H. Dodds	Dr	50.0	6	GI	do	Doniphan shale	Cy, H	S	do	0.8	29.76	9-8-50	Fair well
(29-12-32cd)	R. C. Harner	Du	22.0	36	R	do	do	Cy, H	D, S	Base of pump	1.2	9.65	9-7-50	
29-12-34cc	R. R. Parsons	Dr	42.0	6	GI	Sandstone and limestone	Jackson Park shale and Plattsmouth limestone	Cy, H	D, S	do	0.8	16.82	9-7-50	Abandoned
29-13-4db	C. E. Hall	Dr	65.0	6	GI	Sandstone	Ireland sandstone	Cy, H	D, S	do	0.6	22.60	9-10-50	
29-13-30ba	F. Guyat	Dr	65.0	8	GI	do	do	Cy, W	S	do	1.2	27.83	8-26-50	
(30-8-24bd)	T. C. Corey	Sp				Limestone	Foraker limestone	F	D, S			F	8-30-50	Good spring; yield 10
30-9-12cc	P. Brown	Du	16.0	60	R	do	Dover limestone	Cy, H	S	Ground surface	0.0	4.10	8-30-50	
30-9-12cd	H. Brown	Du	14.0	40	R	Limestone and shale	do	N	N	do	0.0	8.26	8-30-50	Very poor well
30-9-17db	T. C. Corey	DD	107.0	8	GI	Limestone and sandy shale	Foraker limestone and West Branch shale	Cy, H	S	Base of pump	0.9	7.86	8-30-50	Good well
30-9-25dc	E. F. Street	Du	21.0	36	R	Limestone	Dover limestone	Cy, H	S	do	0.6	13.72	8-26-50	

TABLE 11.—*Records of wells in Elk County, continued*

Well no. and location (1)	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: Geological source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Feet above land surface	Depth to water level	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
30-9-31dd	C. Stockdale	Du	17.0	36	R	do	Caneyville limestone	N	N	Top of cover	0.2	13.68	8-30-50	
30-9-33dc	E. Terry	Du	18.0	36	R	Sandy shale	Dry shale	Cy, H	D, S	Base of pump	0.5	7.96	8-27-50	Poor well
30-10-5cd	P. Daughty	Dr	80.0	8	GI	do	Cedar Vale shale	Cy, E	D, S	do	0.6	34.28	8-20-50	Good well; yield 1¼. Water comes in below Rulo. in sandy shale or sandstone
(30-10-11aa)	C. A. Russell	Dr	60.0	8	GI	Limestone	Topeka and Ervine Creek limestones	N	N	Top of casing	0.4	15.62	7-28-50	Good well; yield 1⅔
30-10-13dd	School district	Dr	50.0	6	GI	do	Ervine Creek limestone	Cy, H	P	do	0.3	13.21	9-6-50	Abandoned
30-10-16cd	do	Du	35.0	40	R	Sandstone	White Cloud shale	Cy, H	P	Base of pump	0.5	4.83	8-30-50	Abandoned
(30-10-28cd)	R. Nigh	Dr	50.0	8	GI	do	do	Cy, H	D, S	do	0.6	22.38	8-21-50	Yield 1/6
30-10-33bb	C. Douglas	Dr	397	8	GI	do	White Cloud shale and Elgin sandstone	Cy, H	D, S	do	0.8	18.35	8-21-50	do
30-10-35cb	O. Williams	Du	30	36	R	do	Severy shale	Cy, E	D, S	do	0.3	18.62	8-27-50	Good well
30-10-36da	E. W. Lindley	Du	17.0	36	R	Limestone	Ervine Creek limestone	Cy, H	D, S	do	0.8	11.25	9-6-50	
30-11-8db	R. Forsyth	Du	24.0	36	R	Gravel	Alluvium	Cy, H	S	do	0.8	14.36	9-7-50	
30-11-12dc	R. Perkins	Du	18.6	30	R	Sandstone	Doniphan shale	P, H	D, S	Top of board cover	0.6	7.82	9-6-50	
30-11-19aa	G. Sherman	Du	16.0	48	R	Limestone	Ervine Creek limestone	Cy, W	S	do	1.3	8.23	9-6-50	
30-11-20ad	Fred Strachen	Dr	125.0	8	GI	Sandstone	Doniphan shale and Elgin sandstone	Cy, W	D, S	Top of casing	0.8	37.80	8-21-50	Fair well
(30-11-26bb)	H. E. Gibson	Du	16.2	36	R	Limestone	Lecompton limestone	P, H	S	Base of pump	2.6	5.42	9-6-50	Poor well
30-11-31bc	J. D. James	Du	16.0	36	R	do	Ervine Creek limestone	Cy, H	D, S	do	1.0	10.83	9-6-50	Reported very hard water. Poor well
30-11-35cc	O. E. Buchanan	Dr	112.0	8	GI	Sandstone	Elgin sandstone	Cy, E	D, S	do	0.7	31.46	8-22-50	Good well
30-11-35dc	B. Ransom	Dr	80.0	8	GI	do	do	Cy, W	S	do	1.3	39.65	8-22-50	do
30-12-1ac	B. Foote	Dr	42.0	8	GI	do	Ireland sandstone	F	D, S	Top of pipe	1.5	+3.10	8-26-50	Flow 1
30-12-1ba	Cash McDonald	Dr	66.0	6	GI	do	do	F	S	do	2.3	+4.80	8-26-50	Flow 4
(30-12-1bd)	School district	Dr	46.0	6	GI	do	do	F	P	do	3.1	+2.60	8-26-50	Flow 1
30-12-1dc	T. Ryan	Dr	80.0	8	GI	do	do	Cy, H	D	Base of pump	0.6	6.87	8-26-50	Very little water
30-12-20aa	Reece McGee	Sp				do	Jackson Park shale	F	D, S			F	9-6-50	Flow 15
30-12-23ba	J. M. Clark	Dr	100.0	6	GI	do	Ireland sandstone	Cy, H	D, S	Base of pump	0.8	18.96	8-26-50	Good well
30-12-23cb	R. C. Patterson	Dr	160.0	6	GI	do	do	Cy, W	S	do	0.5	12.73	8-26-50	do
30-12-23dc	do	Dr	60.0	6	GI	do	do	Cy, H	D, S	do	0.6	23.67	8-26-50	do
30-12-24cb	Emery Moore	Dr	42.0	8	GI	do	do	Cy, H	D, S	do	0.8	12.48	8-26-50	do
(30-12-31dc)	E. Persinger	Du	21.0	36	R	Limestone	Toronto limestone	Cy, H	D, S	do	0.6	12.81	9-6-50	
30-13-8ba	Z. E. Hearn	Du	28	50	R	Sandstone	Ireland sandstone	P, H	D, S	Top of board cover	0.9	13.96	9-7-50	Yield 4
30-13-10bc	C. E. Ward	Dr	60.0	8	GI	do	do	Cy, W	S	Top of casing	0.6	24.38	8-26-50	
30-13-16cc	G. Barnaby	Du	16.0	36	R	do	do	Cy, H	S	Top of cover	0.9	11.36	9-7-50	
30-13-27cd	F. D. Warren	Dr	48.0	6	GI	do	do	Cy, H	D, S	Base of pump	0.5	18.38	9-7-50	
30-13-29bc	Grange Hall	Dr	44.0	6	GI	do	do	Cy, H	D	Top of casing	0.3	20.80	9-7-50	Yield ⅔
30-13-30cd	G. J. Sharp	Dr	48.0	6	GI	do	do	Cy, H	D, S	do	0.6	26.36	9-7-50	
31-8-12aa	A. D. Arbuckle	Dr	26.2	8	GI	Gravel	Alluvium	Cy, H	D, S	do	0.3	10.14	8-18-50	Good well
31-8-25cc	O. C. Ealey	Du	30.0	30	R	Sandstone	Pony Creek shale	N	N	Ground surface	0.0	12.10	8-27-50	
(31-8-35aa)	do	Du	30.0	30	R	Sandy shale	French Creek shale	Cy, H	D, S	Top of cover	0.6	11.22	8-27-50	
31-9-7ba	Loren VanSickle	Dr	150.0	10	GI	Limestone	Elmont limestone	N	N	Top of casing	0.3	9.48	7-11-50	Yield ⅓
(31-9-8cd)	J. F. Deal	Dr	60.0	8	GI	Cy, H D, S	do	do		do	0.2	18.68	7-11-50	
31-9-16aa	E. E. Rathbone	Dr	100.0	6	GI	Sandstone and limestone	Willard and Langdon shales, Wakarusa and Burlingame limestones	Cy, W	D, S	do	0.5	38.86	8-18-50	Good well; yield 4

31-9-19dc	E. Neubaker	Du	22.0	48	R	do	Dover limestone	P, H	D, S	Top of cover	0.9	9.17	8-27-50	
31-9-21ab	L. Stiles	Dr	105.0	8	GI	do	Wakarusa and Burlingame limestones	Cy, H	D, S	Top of casing	0.6	67.36	8-18-50	
31-9-27ad	School district	Du	22.0	36	R	do	Elmont limestone	N	N	Ground surface	0.0	6.80	8-27-50	Abandoned
31-10-3bc	R. W. Wilson	Du	30.0	36	R	Sandstone	Severy shale	Cy, W	S	Top of cover	0.8	8.75	8-27-50	
31-10-4da	do	Du	20.0	48	R	Gravel and sandstone	Alluvium and Severy shale	Cy, H	S	Base of pump	4.2	9.82	8-26-50	
31-10-7bb	School district	Du	28.0	36	R	Sandy shale	Harveyville shale	Cy, H	P	do	0.5	12.20	8-26-50	
31-10-12bd	Concrete Materials Co.	Dr	214	8	GI	Sandstone	Jackson Park shale	T, E	In	Ground surface	0.0	80	8-21-50	Good well
31-10-25aa	C. J. Blough	Du	11.0	72	R	Limestone	Ervine Creek limestone	N	N	do	0.0	7.1	9-6-50	
31-10-27dd	H. C. Mills	Du	23.0	36	R	do	Topeka limestone	Cy, W	S	Top of cover	0.6	4.42	8-27-50	
31-10-30dd	R. Larkin	Du	29.5	36	R	Sandy shale	White Cloud shale	Cy, H	D, S	do	0.3	26.92	8-27-50	
(31-10-34dd)	I. B. Walker	Du	18.0	48	R	Limestone	Topeka limestone	Cy, H	D, S	Base of pump	0.3	7.67	8-27-50	Good house well
31-11-3aa	C. A. Bird	Dr	65.0	8	GI	Sandstone	Jackson Park shale	Cy, H	D, S	do	0.6	50	8-22-50	Good well
31-11-3cc	F. E. Royce	Dr	100.0	8	GI	do	Elgin sandstone	Cy, H	D	do	0.2	38.02	8-21-50	Yield about 1
31-11-3cd	School district	Dr	200	8	GI	Sandstone and limestone	Elgin sandstone and Plattsmouth limestone	T, E	D	Ground surface	0.0	48	9-21-50	
31-11-3dd	M. Frakes	Dr	45.0	10	GI	Gravel	Alluvium	N	N	Top of casing	0.8	18.80	8-22-50	
31-11-7da	Knabe Bros.	Du	32.0	36	R	Sandstone	Tecumseh shale	Cy, H	S	Top of cover	0.3	8.92	9-6-50	Good well
31-11-10ca	Frank Whitmer	Dr	200	6	GI	Gravel and sandstone	Alluvium (terrace), and Kanwaka shale	Cy, H, E	D, S	Base of pump	0.6	23.62	8-22-50	do
31-11-11ca	Konstant Kassen	DD	90	36-6	R, GI	Sandstone	Elgin sandstone and Jackson Park shale	Cy, W	D, S	do	0.5	18.67	8-23-50	do
31-11-13bd	Fred Freeman	Dr	46.0	8	GI	do	Elgin sandstone	Cy, E	D, S	do	0.9	18.89	8-23-50	do
31-11-21cc	R. W. McAllester	Du	20.0	48	R	Limestone	Ervine Creek limestone	B, H	D, S	Ground surface	0.0	18.20	9-6-50	Yield 6
31-11-30cc	J. Hogan	Dr	230	8	GI	Limestone and sandstone	Ervine Creek limestone and Kanwaka shale	Cy, H	S	Top of casing	1.2	17.80	9-6-50	Good well
31-11-32cd	P. Cunningham	Du	14.8	48	R	Limestone	Ervine Creek limestone	Cy, H	D, S	Top of cover	0.3	7.96	9-6-50	
(31-11-34aa)	R. F. Mullendore	Dr	144.0	6	GI	Sandstone	Tecumseh, Doniphan, and Stull shales	Cy, H	D, S	Base of pump	0.6	12.62	9-6-50	Good well
31-11-35ba	do	Dr	148.0	6	GI	do	do	Cy, W	S	do	0.9	20.67	9-6-50	do
(31-12-1ac)	N. Russell	Du	30.0	48	R	do	Ireland sandstone	Cy, H	D, S	do	0.3	8.97	9-7-50	do
31-12-4db	E. Roden	Dr	192.0	10	N	do	Ireland sandstone and Vinland shale	N	N	Ground surface	0.0	23.67	8-23-50	Good well, oil well supply
31-12-4dc	G. L. Freeman	Dr	90.0	8	GI	do	Ireland sandstone	Cy, W	D, S		0.3	22.43	8-23-50	
(31-12-9bc)	J. H. McCann	Dr	29.0	8	GI	Gravel	Terrace	Cy, H	D, S	Base of pump	0.4	12.36	8-23-50	Good well
31-12-10ad	Fred Osborn	Dr	157.8	10	S	Gravel and sandstone	Alluvium, Ireland sandstone, and Tonganoxie sandstone	N	N	Ground surface	0.0	16.7	8-24-50	40 feet of alluvium; drilled for oil well
31-12-13ad	F. A. Finley	Dr	56	6	GI	Sandstone	Ireland sandstone	Cy, H	D, S	Top of casing	0.6	36.37	9-7-50	
31-12-16ad	Loren Vestal	Dr	140.0	8	GI	do	Ireland sandstone and Robbins shale	Cy, E	D, S	do	0.8	26.83	8-24-50	
31-12-25db	C. W. Clymer	Dr	169.0	8	GI	do	Ireland sandstone and Stranger formation	Cy, E	D, S	do	1.2	48.77	8-24-50	
31-12-27aa	H. D. Plummer	Du	26.0	36	R	Sandy shale	Snyderville shale of Oread limestone	Cy, H	S	Base of pump	0.5	13.62	9-7-50	Poor well
31-12-28ac	L. E. St. John	Dr	150.0	6	GI	Sandstone	Ireland sandstone	Cy, H	D, S	do	0.6	28.60	8-24-50	do
(31-12-30cb)	C. Vestal	Dr	48.0	8	GI	do	Kanwaka shale	Cy, H	D, S	do	0.8	30.22	8-24-50	
(31-12-33bd)	Frank Smith	Du	23.0	36	R	Sandy shale	Snyderville shale of Oread limestone	B, H	D, S	Top of well curb	1.2	12.62	9-7-50	
31-12-33cb	A. Stephens	Dr	140	6	GI	Sandstone	Ireland sandstone	N	N	Top of casing	1.0	15.67	9-7-50	Oil well supply
(31-12-36bd)	R. M. Brown	Dr	97.0	8	GI	do	Cy, H D, S			do		do		1.2 52.38 8-24-50

TABLE 11.—*Records of wells in Elk County, continued*

Well no. and location (1)	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: Geological source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Feet above land surface	Depth to water level	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
31-13-3ca	C. V. Haines	Dr	36.0	6	GI	do	do	Cy, H	S	do	0.6	16.66	9-7-50	
31-13-8ba	R. L. Piper	Du	28.0	36	R	do	Vinland shale	Cy, H	D, S	Base of pump	1.2	11.82	9-7-50	
31-13-17ca	B. S. Stewart	Dr	36.8	6	GI	do	Ireland sandstone	Cy, H	D, S	do	0.7	22.83	9-7-50	
31-13-20bb	H. M. Duryea	Dr	37.0	8	GI	Gravel	Alluvium	Cy, H	D, S	do	0.3	14.92	8-25-50	Gravel 18 to 37 feet, sandstone at 37. Good well
(31-13-21dd)	H. Cox	Du	21.0	48	R	do	do	Cy, W	S	do	1.3	4.77	9-7-50	Good well
31-13-34aa	B. C. Bryant	Dr	42.0	6	GI	do	do	Cy, H	D, S	do	0.6	9.86	9-7-50	
31-13-27cbc	J. M. Cox	Du	19.0	48	R	Sand and gravel and sandy silt	do	N	N	Top of well curb	1.5	12.10	12-14-50	Yield about 7
31-13-27cc	E. Ballinger	Du	23.0	40	R	do	do	N	N	do	0.3	13.50	12-14-50	
31-13-32db	F. Stark	Du	35.0	36.0	R	Sandstone	Ireland sandstone	Cy, H	D, S	Base of pump	0.9	16.88	9-7-50	
31-13-34bd	B. C. Bryant	Dr	42.0	6	GI	do	Vinland shale	Cy, G	D, S	do	0.3	12.78	9-7-50	Good well
31-13-34dd	C. H. Holland	Dr	75.0	6	GI	do	Stranger formation	Cy, H	D, S	do	0.6	26.38	9-7-50	do

1. Well number in parentheses indicates that analysis of water is given in table.
2. DD, dug and drilled well; Dr, drilled well; Du, dug well; Sp, spring.
3. Reported depths below the land surface are given in feet; measured depths are given in feet and tenths below measuring points.
4. GI, galvanized sheet iron; N, none; R, rock.
5. Method of lift: CY, cylinder; F, natural flow; N, none; P, pitcher pump; T, turbine; B, bucket; J, Jet.
Type of power: E, electric; H, hand operated; W, windmill.
6. D, domestic; In, industrial; N, not being used; S, stock.
7. Measured depths to water level are given in feet, tenths, and hundredths; reported depths to water level are given in feet.

LOGS OF TEST HOLES

Sample logs of six test holes drilled in the valley of Elk River are given on the following pages. These test holes were drilled in November 1950. Samples were collected and studied by Charles K. Bayne.

31-12-8ad. Sample log of test hole in SE cor. NE¼ sec. 8, T. 31 S., R. 12 E., 25 feet north of half-section line and 8 feet west of section line. Drilled 1950. Surface altitude, 908.5 feet. Depth to water, 16.1 feet.

	Thickness, feet	Depth, feet
Road fill	3.5	3.5
QUATERNARY-Pleistocene		
Terrace deposits		
Silt and clay, yellow to tan	4.5	8
Silt and clay, yellow to tan, and some very fine sand	5	13
Silt and clay, tan; contains much fine sand and some chert gravel	5	18
Gravel, chert, and fine quartz sand	2.5	20.5
PENNSYLVANIAN		
Lawrence shale		
Sandstone, very fine grained, yellow green to olive	2	22.5

31-12-9ccb. Sample log of test hole in NW cor. SW¼ SW¼ sec. 9, T. 31 S., R. 12 E., on east road shoulder 60 feet south of hedge. Drilled 1950. Surface altitude, 891.0 feet. Depth to water, 17.0 feet.

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY-Pleistocene		
Terrace deposits		
Silt and clay, tan	5	8
Silt and clay, tan, and some fine sand	5	13
Silt and clay, tan-red, and fine sand	5.5	18.5
Gravel, chert, clayey, tan	6.5	25
PENNSYLVANIAN		
Lawrence shale		
Shale and sandstone, laminated, yellow green; alternating hard and soft layers	1.5	26.5

31-12-17aa. Sample log of test hole in NE cor. sec. 17, T. 31 S., R. 12 E., 15 feet south and 25 feet west of section corner in field. Drilled 1950. Surface altitude, 886.0 feet. Depth to water, 14.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY-Pleistocene		
Alluvium		
Silt, black	3	3
Silt and clay, dark gray to tan	5	8
Silt and clay, tan; contains some dark-gray clay and shells	5	13
Silt and clay, tan to brown; contains shells	10	23
Silt and clay, gray to blue gray	2	25
Gravel, chert and sandstone, fine quartz sand, and shells	6.5	31.5
PENNSYLVANIAN		
Lawrence shale		
Shale, sandy, laminated, thin hard zones, blue gray to blue green	2	33.5

31-13-21cc. Sample log of test hole in SW cor. sec. 21, T. 31 S., R. 13 E., 100 feet south of school, 25 feet west of road, in school yard. Drilled 1950. Surface altitude, 850.9 feet. Depth to water, 7.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY-Pleistocene		
Alluvium		
Silt, gray black	3	3
Silt and clay, yellow, gray mottling	5	8
Silt and clay, yellow, gray mottling; contains some fine sand	5	13
Silt and clay, yellow, gray mottling; contains much fine sand	11	24
Silt and clay, gray to blue	6	30
Gravel, chert and sandstone, and fine quartz sand	5	35
PENNSYLVANIAN		
Tonganoxie sandstone		
Shale, laminated, light gray	3	38

31-13-27cb. Sample log of test hole in NW cor. SW¼ sec. 27, T. 31 S., R. 13 E., in field 50 feet east of section line, 25 feet south of half-section line. Drilled 1950. Surface altitude, 847.3 feet. Depth to water, 10.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY-Pleistocene		
Alluvium		
Silt, gray black	3.5	3.5
Silt and clay, tan	4.5	8
Silt and clay, tan, some gray mottling	10	18
Silt and clay, tan, mottled gray; contains some fine sand	11	29
Clay, blue, and chert gravel; contains some fine quartz sand	10	39
PENNSYLVANIAN		
Tonganoxie sandstone		
Shale, blue, sandy, hard	1	40

31-13-34bb. Sample log of test hole in NW¼ NW¼ sec. 34, T. 31 S., R. 13 E., 200 feet east and 600 feet south of section corner, in field 150 feet north of river. Drilled 1950. Surface altitude, 847.7 feet. Depth to water, 11.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY-Pleistocene		
Alluvium		
Silt, clayey, gray, mottled tan	7	7
Silt, tan	12	19
Silt, tan; contains some fine sand and shells	5	24
Silt, tan; contains some fine quartz sand and chert gravel, and shells	5	29
PENNSYLVANIAN		
Tonganoxie sandstone		
Shale, blue to blue green	5	34
Shale, soft, blue green	4	38
Shale, hard, blue green	2	40

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