Geology of Shawnee County, Kansas

GEOLOGICAL SURVEY BULLETIN 1215

Prepared in cooperation with the State Geological Survey of Kansas as a part of a U.S. Department of the Interior program for the development of the Missouri River basin

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By WILLIAM D. JOHNSON, JR., *and* W. L. ADKISON

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GEOLOGY OF EASTERN SHAWNEE COUNTY, KANSAS AND VICINITY

By WILLIAM D. JOHNSON, JR., and W. L. ADKISON

ABSTRACT

The eastern Shawnee County and vicinity study area, encompassing about 355 square miles of northeastern Kansas, was mapped as part of a study of Upper Pennsylvanian rocks. The area includes eastern Shawnee County and parts of southeastern Jackson, southwestern Jefferson, and westernmost Douglas Counties. Topographic coverage is provided by the Elmont, Grantville, Meriden, Richland, Topeka, and Wakarusa 7½-minute quadrangles and the northernmost parts of the Carbondale and Overbrook quadrangles.

The unexposed sedimentary rocks in the area range in age from Late Cambrian to Late Pennsylvanian and are as much as 2,700 feet thick. Biotite granite of the Precambrian basement complex has been penetrated in two wells.

Exposed sedimentary rocks in the area are about 725 feet thick and are in the Shawnee and Wabaunsee Groups, of Late Pennsylvanian (Virgil) age. Relatively thick shale formations of claystone, siltstone, and sandstone and alternating thinner limestone formations record a cyclic pattern of deposition. The shale formations were deposited largely under nonmarine conditions. The limestone units were deposited largely under marine conditions ranging from beach or extremely shallow water to deeper, fairly quiet water of normal salinity. The claystone and siltstone in the limestone formations were deposited in estuarine, shallow lagoonal, and normal-marine environments. The widespread Nodaway coal bed of the Howard Limestone was deposited during subaerial conditions. Local channels have eroded several formations, particularly the Topeka and Howard Limestones.

Scattered deposits of chert gravel of pre-Kansan age occur in the area but are too small to map. Kansan glacial drift, consisting mainly of unstratified and unsorted clay till, covers most of the area. Thick deposits of stratified glacial outwash occur along the Kansas and Wakarusa Rivers.

Alluvial material of Quaternary age fills the Kansas and Wakarusa River valleys and the valleys of the larger creeks. In the Kansas River valley, extensive deposits correlated with the Newman terrace of Wisconsin age occupy much of the valley floor, and a broad band of Recent alluvium borders the river In the Wakarusa River valley the alluvial fill is also correlated with the Newman terrace, but small terrace remnants, questionably correlated with the Buck Creek terrace of Illinoian age, locally occur along the valley sides.

The mapped area is in the western part of the Forest City basin. Outcropping rocks in the area strike about N. 20°–30° E. and dip northwest, generally 20–40 feet to the mile. The regional dip is interrupted by minor folds, a few of which have almost 20 feet of closure.

No oil or gas in commercial quantities has been discovered in the area, but in several test wells slight oil stains have been found in rocks in the part of the Hunton Formation that is of Devonian age and in the Simpson Group, of Middle Ordovician age. Coal was formerly mined from the Nodaway coal bed of the Howard Limestone at many localities, particularly around Topeka, but the mines are no longer in operation. Limestone and river sand and gravel are being quarried commercially.

INTRODUCTION

Shawnee County and parts of adjacent counties were mapped as part of a cooperative project between the U.S. Geological Survey and the State Geological Survey of Kansas. The objective of the project was to study in detail the stratigraphy of outcropping rocks of Upper Pennsylvanian and Lower Permian age. Data from the study contribute to the knowledge of the geology and mineral resources of the Missouri River basin and provide structural information that may aid in the search for oil and gas in the region.

The eastern Shawnee County and vicinity study area encompasses about 355 square miles of northeastern Kansas—eastern Shawnee County, and parts of southwestern Jefferson, southeastern Jackson, and extreme western Douglas Counties. Topographic coverage is provided by the Elmont, Grantville, Meriden, Richland, Topeka, and Wakarusa 7½-minute quadrangles and the northernmost parts of the Carbondale and Overbrook 7½-minute quadrangles (fig. 1). The area is in the Dissected Till Plains section of the Central Lowlands physiographic province (Fenneman, 1938).

This chapter describes the east half of the project area; western Shawnee County is discussed in "Chapter B" (Johnson and Wagner, p. 125–246) of this report.

This investigation was begun in the autumn of 1954 by H. C. Wagner, who mapped the southwestern part of the project area. In the autumn of 1955 W. D. Johnson, Jr., assumed direction of the project. H. J. Hyden assisted in the project during the autumn of 1957 and the spring of 1958, and W. L. Adkison was active on the project from the summer of 1958 to the completion of the fieldwork in the autumn of 1959.

The geology was plotted on aerial photographs at a scale of 1 : 17,000 and was transferred to topographic quadrangle maps by means of a vertical projector. The geologic map (pl. 1) was compiled on the combined topographic bases.

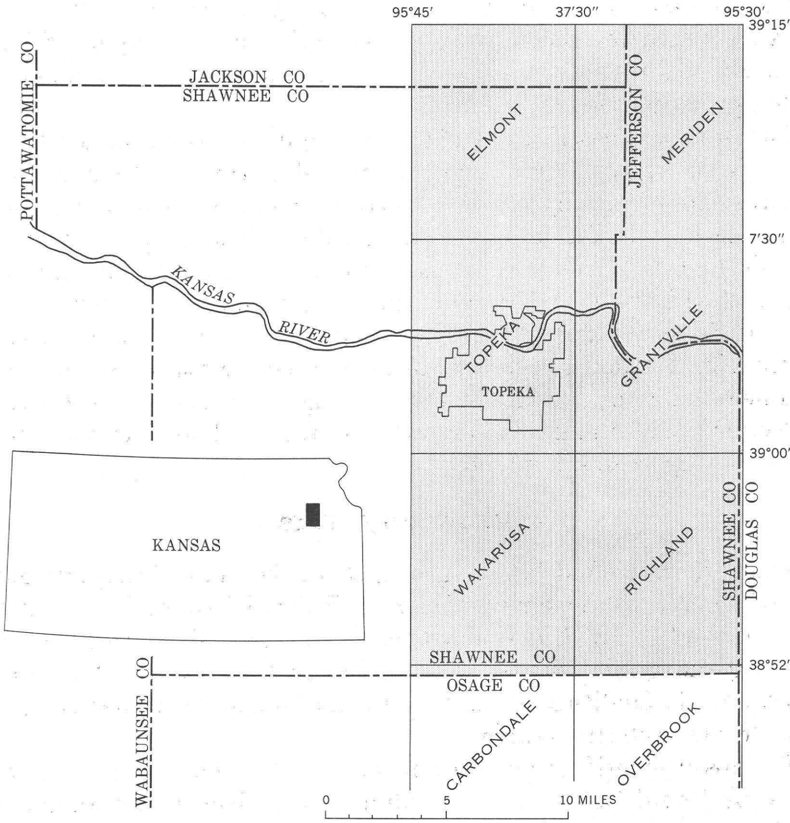

FIGURE 1.—Location of eastern Shawnee County, Kans. and vicinity.

Rock-color terms used in this report are those from the "Rock-Color Chart" (Goddard and others, 1948). The grade scale of Wentworth (1922) was used in classifying sand- and silt-sized detrital grains.

Rough-textured limestone is described as crystalline if crystal faces can be seen when observed with a hand lens; it is described as granular if crystal faces are absent. Smooth-textured limestone and chert are described as dense. Nonporous limestone is described as compact. Bedding structure is described as follows:

Laminated, less than 1/16 inch thick
Platy, 1/16–1/2 inch thick
Very thin bedded, 1/2–2 inches thick
Thin bedded, 2–4 inches thick
Medium bedded, 4–12 inches thick
Thick bedded, 1–3 feet thick
Massive, more than 3 feet thick

In the descriptions of subsurface stratigraphic units, the term "shale" is used for clastic rocks composed largely of clay or of fine- to medium-silt-sized particles of silicate minerals, regardless of bedding characteristics.

The lithologic descriptions of the outcropping formations are based on rock descriptions from many measured sections and outcrop exposures; however, only one or two stratigraphic sections representative of each of the formations are included in "Stratigraphic Sections" of this report. Reference to the appropriate stratigraphic sections is given with each stratigraphic unit. The faunas collected by the authors from the various units and reported on by E. L. Yochelson of the U.S. Geological Survey are so credited. Fusulinids that were retained and cataloged in the U.S. Geological Survey foraminiferal collection are also indicated, even though they had not been identified when this report was prepared.

ACKNOWLEDGMENTS

The authors are indebted to geologists of the State Geological Survey of Kansas, particularly to Dr. F. C. Foley, Director, for his active support, and to H. G. O'Connor for his several field conferences regarding the glacial deposits and older geologic units. The State Survey made facilities available to the authors and supplied samples from several wells in the area.

The fossil identifications were made by E. L. Yochelson, who was aided by David Delo, Jr., in consultation with Helen Duncan and S. H. Mamay, all of the U.S. Geological Survey. The authors' conclusions regarding depositional history of the area are based largely on the interpretations by E. L. Yochelson of the possible depositional environments of those strata represented in the fossil collections. The authors collected the fossils but sampled few localities exhaustively.

PREVIOUS WORK

The general geology of eastern Shawnee County and vicinity, particularly that near the Kansas River, has been known for many years. Previous authors who contributed to knowledge of the area were Meek and Hayden (1859), Swallow (1866), Prosser (1894), Haworth (1895), Bennett (1896), and Beede (1898). Smyth (1898) and Todd (1909, 1911, 1918) were previous authors on the glacial geology of this part of Kansas.

Revisions of the initial classification and description of Pennsylvanian rocks of Kansas were made by Moore (1932, 1936a, 1949), Moore, Frye, and Jewett (1944), Moore, Frye, Jewett, Lee, and O'Connor (1951), and by Moore and Mudge (1956).

Until publication of the geologic map of Kansas (Moore and Landes, 1937), only general reconnaissance maps of Shawnee County existed. Davis and Carlson (1952) described the geology and groundwater resources of the Kansas River valley between Topeka and Lawrence. The geology of Jackson County was studied in detail by Walters (1953). Part of the east edge of the mapped area was included in O'Connor's report (1960) on Douglas County. O'Connor (1955) also mapped Osage County which is adjacent to Shawnee County on the south.

The subsurface geology of this part of Kansas was described by Ockerman (1935) and by Lee (1940) in his study of the Mississippian rocks in Kansas. The stratigraphy and structural development of the Forest City basin, of which the mapped area is a part, were described by Lee (1943) and by Lee and others (1946). The eastern Shawnee County and vicinity study area was also included in the reports by Lee, Leatherock, and Botinelly (1948) and by Lee (1956) on the stratigraphy and structural development of the Salina basin, which lies west of the mapped area. Jewett (1954) summarized the oil and gas explorations in Shawnee and adjacent counties. Many other authors, some of whom are cited in this report, have described local aspects of the geology or mineral resources of eastern Shawnee County and vicinity.

STRATIGRAPHY

Sedimentary rocks of Paleozoic age and unconsolidated sediments of Quaternary age overlie the Precambrian basement complex in eastern Shawnee County and vicinity. White to pink biotite granite was penetrated in two wells.

The unexposed sedimentary rocks of Late Cambrian to Late Pennsylvanian age are as much as 2,700 feet thick and are lithologically described on the basis of sample logs prepared by W. L. Adkison (pl. 2). Supplemental data on the general distribution and thickness of these stratigraphic units were obtained from drillers' logs and electric logs of 15 other wells in the area. Rocks of Cambrian and Ordovician age—older than the Simpson Group—were drilled through their entire thickness in only two wells. The Toronto Limestone Member of the Oread Limestone is the youngest unexposed unit in the area.

The exposed sedimentary rocks, about 725 feet thick, are classified in the Shawnee and Wabaunsee Groups of Late Pennsylvanian (Virgil) age. The classification and nomenclature of these stratigraphic units are shown on plate 1.

Fairly thick shale formations of claystone, siltstone, and sandstone and alternating relatively thin resistant limestone formations (pl. 1) record a distinctive cyclic pattern of sedimentation (Moore, 1936a,

p. 26–34). The deposits of each sedimentary cycle are a cyclothem (Wanless and Weller, 1932, p. 1003), and each cyclothem contains a limestone formation and parts of the overlying and underlying shale formations. The cyclic succession of lithologic units is markedly exemplified in the limestone formations of the Shawnee Group by the repetition of three or four types of limestone and shale that appear in the same order in each of the four limestone formations of the group (pl. 1). The cyclic repetition in the Wabaunsee Group is less complex than that in the Shawnee; fewer limestone and shale members are present.

In this study the cyclothems were not mapped or described. Their boundaries were difficult to determine because many units of the theoretical cyclic sequence are missing and because the cyclothemic boundaries occur within the shales.

The unconsolidated sediments of Quaternary age include glacial till and outwash and more recent deposits of loess and colluvium. Stream valleys are filled with terrace deposits and alluvium.

CAMBRIAN SYSTEM

The Cambrian System in the study area comprises the Lamotte Sandstone and the Bonneterre Dolomite of the Upper Cambrian Series.

Lamotte Sandstone.—The Lamotte Sandstone (equivalent to the Reagan), about 5–25 feet thick, is composed chiefly of white fine to medium subangular to subrounded sand. The basal 5 feet which is probably "granite wash" is white to pink coarse to very coarse sand containing granules of angular quartz and granite.

Bonneterre Dolomite.—The Bonneterre Dolomite, about 85–125 feet thick, is medium-light-gray to medium-gray finely to medium-crystalline dolomite. It contains scattered fine to medium, in part frosted, sand and much glauconite and pyrite, especially in the lower half of the formation.

CAMBRIAN AND ORDOVICIAN SYSTEMS

The Cambrian and Ordovician Systems are represented in the mapped area by the Arbuckle Group of the Upper Cambrian and Lower Ordovician Series, the Simpson Group of the Middle Ordovician Series, the Viola Limestone of the Middle and Upper Ordovician Series, and the Maquoketa Shale of the Upper Ordovician Series.

Arbuckle Group.—The Arbuckle Group, 365–400 feet thick, consists primarily of medium-light-gray and pale- to moderate-yellowish-brown finely to medium-crystalline dolomite. In the upper part of the group the dolomite contains abundant white to medium-gray dense oolitic chert, and near the middle of the group it contains white and tripolitic chert. Quartz crystals also occur in the dolomite near the middle of the group. Several thin beds of medium-light-gray and greenish-gray glauconitic and pyritic shale are in the lower part, and several thin beds of white fine- to coarse-grained sandstone, composed of rounded and frosted grains, occur near the top and in the lower half. The position of the contact between rocks of the Arbuckle Group and the underlying Bonneterre Dolomite is questionable.

Simpson Group.—Rocks of the Simpson Group are about 70–125 feet thick and consist chiefly of white fine- to medium-grained sandstone in which the grains are rounded and frosted. The upper part of the Simpson contains brownish-gray to medium-dark-gray partly sandy fine- to medium-crystalline dolomite. The sandstone is dolomitic near the top of the group. A few thin beds mainly of gray, greenish-gray, and black shale occur near the top and base.

Viola Limestone.—The Viola Limestone, uniformly 110–120 feet thick, is mainly pale-yellowish-brown to brownish-gray (locally very pale orange and medium-gray) finely to medium-crystalline dolomite. The upper part of the unit contains very light gray to medium-gray dense opaque and partly spicular chert, some of which has black specks. The lower part locally contains chert and scattered fine to medium rounded and frosted sand.

Maquoketa Shale.—The Maquoketa Shale, which ranges in thickness from about 20 to 70 feet, is principally medium-light-gray to medium-gray partly dolomitic shale but includes some olive-gray shale. Locally the formation contains medium-light-gray to medium-gray dolomitic siltstone.

SILURIAN AND DEVONIAN SYSTEMS

The Silurian and Devonian Systems are represented in the mapped area by the 85- to 200-foot-thick Hunton Formation. The lower part of the Hunton is of Silurian age, and the upper part is of Devonian age.

The lower part is present with certainty only in the Murchison Federal Land Bank 1 well, in the SE cor. sec. 28, T. 10 S., R. 15 E., where it is 120 feet thick. The lower part may also be present as the lower 15 feet of the Hunton in the Forrester and others Hummer 1 well, in the SE¼NE¼SW¼ sec. 14, T. 11 S., R. 16 E. The lower part of the Hunton is mostly light-gray and very pale orange very finely to medium-crystalline dolomite. A few thin beds of medium-gray shale occur in the lower half of the formation, and some light-gray dense chert is present in the lower quarter.

The upper part of the Hunton Formation, about 85–115 feet thick, is primarily light-gray, very pale orange, and pale-yellowish-brown very finely to finely crystalline, in part sandy, dolomite containing sparse to abundant very light gray to medium-gray and pale-yellowish-brown dense opaque chert. The chert is concentrated in zones that seem to vary in position from well to well. The sand is fine to medium, rounded, and frosted. Clear quartz crystals are also present locally in the dolomite. That part of the Hunton which is of Devonian age also contains—generally in its upper beds—medium-gray shales and a few thin beds of light-gray to medium-light-gray very fine grained or finely to medium-crystalline, in some degree very dolomitic, limestone. Some white glossy fine- to medium-grained, in part limy and dolomitic, sandstone occurs in the lower half of the part that is of Devonian age.

DEVONIAN AND MISSISSIPPIAN SYSTEMS

The Chattanooga Shale, of Devonian-Mississippian age, is about 80–150 feet thick and is composed mainly of medium- to dark-gray shale but includes some greenish- and brownish-gray shale and, in its upper part, some medium-light-gray dolomitic siltstone. Shales in the lower part of the Chattanooga contain dark-brown to dark-gray spore cases. The basal unit of the formation, called the Misener sand by drillers, is about 2 feet thick; it is composed of light- to medium-gray fine- to coarse-grained pyritic limy, or dolomitic, sandstone. Locally the sandstone contains very light gray to medium-light-gray limy quartzose chert.

MISSISSIPPIAN SYSTEM

The Mississippian rocks in the area are those of the Lower Mississippian Series. These strata range in thickness from 205 to about 250 feet and are composed of limestone and dolomite. In the Murchison Federal Land Bank 1 well and in the J. J. Lynn Warner 1 well (pl. 2), these rocks were divided into those of Kinderhook age consisting, in ascending order, of the Chouteau Limestone, Sedalia Dolomite, and Gilmore City Limestone, and into those of Osage age consisting of the Burlington Limestone overlain by the Keokuk Limestone. The Burlington and Keokuk could not be differentiated in the J. J. Lynn Warner 1 well.

Chouteau Limestone.—The Chouteau Limestone, about 55–70 feet thick, is chiefly medium-light-gray to medium-gray and pale-yellowish-brown to brownish-gray very finely to finely crystalline limestone that is cherty in the upper half and dolomitic near the top. The chert is primarily light gray to medium gray, dense, and opaque. Locally some pale-yellowish-brown very finely crystalline cherty dolomite occurs at the top. Crinoid columnals are locally abundant in the lower part of the Chouteau.

Sedalia Dolomite.—The Sedalia, 10–15 feet thick, is chiefly medium-light-gray to medium-gray and pale-yellowish-brown very finely crystalline fossiliferous dolomite that is cherty in part. In the J. J.

Lynn Warner 1 well the lower part is medium-light-gray very fine grained slightly argillaceous dolomitic limestone. The chert is light gray to medium gray, dense, and opaque.

Gilmore City Limestone.—The Gilmore City Limestone, about 10–15 feet thick, is predominantly pale-yellowish-brown to medium-light-gray finely to medium-crystalline fossiliferous limestone. In the J. J. Lynn Warner 1 well (pl. 2), the limestone is dolomitic and in part glauconitic and contains some brownish-gray dense opaque spicular chert. Olive-gray very finely crystalline dolomite occurs at the top of the Gilmore City in this well.

Burlington Limestone.—The Burlington Limestone, the lower formation of Osage age, is about 35 feet thick and is mainly light-gray and very pale orange very finely crystalline to granular cherty limestone. It also includes cherty dolomite of the same color in its basal and upper parts. The chert is white to light gray, dense, and, commonly, opaque. Quartz crystals occur throughout the Burlington in the Murchison Federal Land Bank 1 well.

Keokuk Limestone.—The Keokuk Limestone, of Osage age, is about 90 feet thick in the Murchison Federal Land Bank 1 well. Its upper part consists of light-gray and pale-yellowish-brown very finely to finely crystalline partly dolomitic and glauconitic fossiliferous limestone that contains abundant white and light-gray dense chert and some spicular and tripolitic chert. Its lower part is mainly pale-yellowish-brown very finely to finely crystalline cherty dolomite but includes some dolomitic cherty limestone at the base. The chert in the dolomite resembles that in the limestone but is commonly darker. In the J. J. Lynn Warner 1 well, where the Keokuk and Burlington were not differentiated, the rocks are similar to those in the Federal Land Bank well except that the upper part is mainly cherty dolomite and lower part is limestone almost devoid of chert.

PENNSYLVANIAN SYSTEM

DES MOINES SERIES

The Pennsylvanian rocks of the Des Moines Series in the report area are divided into the Cherokee and Marmaton Groups.

Cherokee Group.—Rocks of the Cherokee Group, about 530–600 feet thick, consist primarily of medium-gray shale and siltstone but include olive- to greenish-gray shale and some dark-gray and black shale associated with many thin coal beds. Some thin beds of medium-dark-gray argillaceous limestone and dolomite are also present, particularly in the upper half of the group. White to light-gray very fine grained to medium-grained, partly limy or dolomitic sandstone is common in the lower half of the Cherokee, and beds as much as 30 feet

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thick occur in places. In the Murchison Federal Land Bank 1 well, a very light gray to very pale orange chert conglomerate 5 feet thick occurs at the base of the Cherokee. The chert is dense, quartzose, tripolitic, or spicular, and is imbedded in a siltstone matrix containing reddish-brown ironstone fragments, medium to very coarse quartz grains, glauconite, and pyrite.

Marmaton Group.—The Marmaton Group is about 120–140 feet thick and consists mainly of medium-gray, greenish-gray, and some dark-gray and black limy shale and siltstone and light-gray, very pale orange, and pale-yellowish-brown argillaceous partly dolomitic and generally fossiliferous limestone. Some light-gray to pale-yellowish-brown very fine grained sandstone and coal are also present. The limestone and greenish-gray shale are most abundant in the upper part of the Marmaton.

MISSOURI SERIES

The Missouri Series in the report area comprises the Pleasanton, Kansas City, and Lansing Groups. Both the Kansas City and Lansing Groups are divided into separate formations.

Pleasanton Group

In the mapped area rocks of the Pleasanton Group range in thickness from 85 to 140 feet. They consist predominantly of medium-gray to medium-dark-gray silty shale and siltstone but include some light-gray to medium-light-gray very fine grained silty, limy micaceous sandstone. The shale and siltstone are in part limy and slightly micaceous.

Kansas City Group

Rocks of the Kansas City Group are about 230–280 feet thick and are principally limestone but include a thick shale at the top. In the Murchison Federal Land Bank 1 well and in the J. J. Lynn Warner 1 well (pl. 2), the upper part of the Kansas City is divided, in ascending order, into the Iola Limestone, Lane Shale, Wyandotte Limestone, and Bonner Springs Shale. The part of the Kansas City below the base of the Iola Limestone is chiefly very pale orange, pale-yellowish-brown, and medium-gray very fine grained to very finely crystalline fossiliferous limestone but also contains thin beds of medium-gray, black, and some olive-gray shale that is partly limy. Some of the limestone is dolomitic, and some is cherty and oolitic. The chert is generally light gray to medium gray or pale yellowish brown and dense and has white specks.

Iola Limestone.—The Iola is 5–25 feet thick and is composed of very pale orange to pale-yellowish-brown dense to very finely crystalline partly fossiliferous limestone. Locally some dolomite of the same color is present at the base.

Lane Shale.—The Lane Shale, about 5–20 feet thick, is mainly medium-gray to medium-dark-gray partly limy shale and siltstone. It includes a persistent bed of black shale in its upper part and, locally, a bed of medium-gray argillaceous glauconitic fossiliferous limestone in its lower part.

Wyandotte Limestone.—The Wyandotte Limestone, 40–80 feet thick, is light gray, very pale orange, and pale yellowish brown, very fine grained to very finely crystalline, and fossiliferous; it contains a few thin beds of gray shale. In the upper part the limestone is dolomitic and locally very oolitic; in the lower part it contains light-gray to medium-dark-gray dense, in part spicular, chert.

Bonner Springs Shale.—The Bonner Springs Shale is 20 to about 100 feet thick and averages about 40 feet in thickness. It consists primarily of medium-gray partly limy and silty shale. At places medium-light-gray very fine to fine-grained limy micaceous sandstone occurs in the upper part.

Lansing Group

The Lansing Group in eastern Shawnee County and vicinity ranges in thickness from about 45 feet to possibly more than 120 feet and averages about 90 feet. The Lansing comprises, in ascending order, the Plattsburg Limestone, Vilas Shale, and Stanton Limestone.

Plattsburg Limestone.—The Plattsburg Limestone, about 30–55 feet thick, consists of medium-light-gray and pale-yellowish-brown fossiliferous limestone. The limestone is in part slightly argillaceous and dolomitic; that near the base contains some medium-light-gray to medium-dark-gray dense, in part spicular, chert. Gray shale occurs at places near the base.

Vilas Shale.—The Vilas Shale, generally 10–15 feet thick, is mainly medium-gray limy, partly silty shale that in places contains very pale orange slightly argillaceous limestone.

Stanton Limestone.—The Stanton Limestone is generally 45–75 feet thick but may be more than 120 feet thick in the Jenkins and Scott Asherman 1 well, in the NE¼NW¼NE¼ sec. 28, T. 10 S., R. 15 E. As indicated by the driller's log, the well ended in the Lansing Group and all the Lansing that was penetrated is considered to be Stanton Limestone. The Stanton is principally light-gray, brownish-gray, and very pale orange partly argillaceous fossiliferous limestone, but it includes thin beds of medium- and dark-gray to black shale and siltstone. Fairly thick beds of medium-light-gray very fine to fine-grained limy and dolomitic sandstone are locally present in the upper part.

VIRGIL SERIES

DOUGLAS GROUP

Strata between the Lansing and Shawnee Groups were previously divided into the Pedee Group (Missouri Series) and the overlying Douglas Group (Virgil Series). Stanton M. Ball, formerly of the State Geological Survey of Kansas, studied these rocks in detail from Iowa into Oklahoma; his recommended changes in the stratigraphic classification were adopted by the Kansas Survey (O'Connor, 1963, p. 1877, fig. 3). The authors have utilized the entire new classification of rocks between the Lansing and Shawnee Groups except the series and stage names. The U.S. Geological Survey regards the Missouri and Virgil as provincial series in Kansas and does not divide the series of the Pennsylvanian into stages. The State Geological Survey of Kansas classifies the Missourian and Virgilian as stages of the Upper Pennsylvanian Series. Changes in classification adopted in this report are as follows:

1. The Pedee Group is abandoned in Kansas, and the base of the Douglas Group is lowered to the top of the Lansing Group.
2. The base of the Stranger Formation (Douglas Group) is lowered to the top of the Stanton Limestone (upper formation of the Lansing Group).
3. The Iatan Limestone and Weston Shale, formerly formations of the Pedee Group, are reduced to members and are included as the two lower members of the Stranger Formation.
4. The Lawrence Shale is changed to the Lawrence Formation, and the base is lowered to the base of the Haskell Limestone Member; the Haskell Limestone Member and the overlying Robbins Shale Member were formerly included in the underlying Stranger Formation.
5. The boundary between the Missouri and the Virgil Series is placed at the base of the redefined Douglas Group.

In eastern Shawnee County and vicinity, the Douglas Group, composed of the Stranger and Lawrence Formations, ranges in thickness from about 180 to 275 feet. It consists predominantly of noncarbonate clastic rock.

Stranger Formation.—Sandstone, shale, and siltstone in widely varying amounts and totaling about 75–140 feet thick compose the Stranger Formation (pl. 2). The sandstone is mainly light gray to medium light gray, very fine grained, and micaceous; some is silty, limy, or slightly carbonaceous. The shale and siltstone are commonly gray and olive gray. A thin bed of coal occurs locally in the lower part of the formation.

Lawrence Formation.—The Lawrence Formation, about 90–140 feet thick, is chiefly medium-gray shale (pl. 2). The Haskell Limestone Member, at the base, is the most useful key unit in the Douglas Group. This member, which is commonly less than 5 feet thick, is brownish-gray, medium-gray, and reddish-brown very fine grained argillaceous limestone. The upper part of the Lawrence includes olive-gray and grayish-red limy shale, medium-light-gray siltstone, and a thin bed of brownish-gray very fine grained silty, dolomitic limestone.

SHAWNEE GROUP

The Shawnee, as originally defined as a formation by Haworth (1898, p. 93) from exposures in Shawnee County, Kans., included beds between the top of the Oread Limestone and the top of the Scranton Shale. The U.S. Geological Survey later recognized the Shawnee as a group (Fath, 1921, p. 39); Moore subsequently (1932, p. 93–94) redefined the boundaries of the Shawnee to include all beds from the base of the Oread Limestone to the top of the Topeka Limestone.

The Shawnee Group contains, in ascending order, the Oread Limestone, Kanwaka Shale, Lecompton Limestone, Tecumseh Shale, Deer Creek Limestone, Calhoun Shale, and Topeka Limestone.

OREAD LIMESTONE (strat. section 1)

The Oread Limestone was originally named by Haworth (1894, p. 123); however, he applied the name to only the lowermost limestone unit (now the Toronto Limestone Member). In 1895 Haworth extended the name to include an overlying thick limestone unit (now the Plattsmouth Limestone Member) and the intervening shales. The thin limestone unit—the Leavenworth—between the thick limestones was not recognized in early reports. Bennett (1896, p. 115) included a very fossiliferous platy limestone as the uppermost unit of the Oread, which was subsequently named the Kereford Limestone Member.

The Oread Limestone is composed, in ascending order, of the Toronto Limestone, Snyderville Shale, Leavenworth Limestone, Heebner Shale, Plattsmouth Limestone, Heumader Shale, and Kereford Limestone Members.

The youngest unexposed rocks in eastern Shawnee County and vicinity compose the Toronto Limestone Member, which consists of very pale orange to pale-yellowish-brown very fine grained to very finely crystalline, in part dolomitic, fossiliferous limestone that is about 10 feet thick.

All members of the Oread except the Toronto Limestone Member crop out in the south wall of the Wakarusa River Valley east of Richland; the Toronto underlies the alluvial fill in the valley. Outcrops are poor, but the limestone members locally form ledges along tributaries of the Wakarusa River. The Oread is about 45 feet thick in this general area; however, only about 35 feet is exposed in the mapped area. In the J. J. Lynn Warner 1 well, about 4 miles northwest of Richland, the Oread is about 65 feet thick. Within the study area the contacts between members of the Oread are conformable.

Snyderville Shale Member

The Snyderville Shale Member was named by Condra (1927, p. 38) for the shale between the Leavenworth Limestone Member and the Weeping Water Limestone Member (Toronto Limestone Member of Kansas) along Heebner Creek east of Snyderville quarry, a few miles west of Nehawka, Nebr.

Exposures of the Snyderville Shale Member are poor, and the basal part does not crop out in the study area. About 3 miles east of the area, in the W½NW¼ sec. 29, T. 13 S., R. 18 E., the Snyderville is about 6 feet thick and consists of olive-gray claystone containing many small irregular nodules of very light gray very finely crystalline argillaceous unfossiliferous limestone. Although fossils were not found in the Snyderville in or adjacent to the mapped area, locally in Douglas County (O'Connor, 1960, p. 40) the member contains marine fossils in the upper few feet.

Leavenworth Limestone Member

The Leavenworth Limestone Member was named by Condra (1927, p. 38) for exposures in a roadcut northwest of the Federal Penitentiary at Leavenworth, Kans. The member is composed of medium-gray to medium-dark-gray hard very fine grained limestone and occurs as a single vertically jointed bed about 1.5 feet thick. It weathers to large rectanguar blocks, which are medium light gray to moderate yellowish brown. The basal few inches of the Leavenworth is argillaceous and weathers to platy fragments. The upper 0.05 foot is also argillaceous and is stratified owing to the parallelism of fossil fragments. The weathered upper surface of the bed is irregular and pitted. The lower contact appears to be slightly gradational, but the upper contact is sharp and even.

Fossils present throughout the Leavenworth Limestone Member (but more abundant adjacent to the upper and lower contacts) include *Osagia*, fusulinids, horn corals, crinoid stems, and brachiopods, including *Hustedia* and *Chonetes*.

Heebner Shale Member

The Heebner Shale Member was named by Condra (1927, p. 37) for Heebner Creek and the Heebner farm, west of Nehawka, Nebr. The member, about 6 feet thick, is present in southeastern Shawnee

County but is not exposed. About 1 mile east of the area, in the NE¼NW¼ sec. 36, T. 13 S., R. 17 E., Douglas County, the Heebner consists of a lower part of brownish-black to black claystone about 2.7 feet thick overlain gradationally by olive-brown silty claystone 3.1 feet thick. The lower claystone weathers to hard fissile grayish-black to black laminae, and the upper part weathers light gray to light olive gray. Small ellipsoidal gray-brown phosphatic concretions are commonly present in the lower claystone (O'Connor, 1960, p. 41) but were not noted by the authors at the Douglas County locality. Conodonts occur in the black claystone of the Heebner, but no fossils were found in the upper part.

Plattsmouth Limestone Member

The name Plattsmouth was originally applied by Keyes (1898, p. 349–350) to a limestone unit 30 feet thick underlying the Platte Shale and overlying the Lawrence Shale near Plattsmouth, Nebr. This limestone apparently included all units of the Oread Limestone. Condra (1927, p. 37) restricted use of the name Plattsmouth to the thick "Upper Oread" limestone overlying the black shales of the Heebner Shale Member. Moore (1936a, p. 167), however, found that Condra's Plattsmouth also included the Kereford Limestone Member of the Oread and the lower beds of the overlying Kanwaka Shale. Consequently he further restricted the Plattsmouth to the limestone beds between the Kereford Limestone and Heebner Shale Members of the Oread.

The Plattsmouth Limestone Member—the best exposed member of the Oread Limestone—forms a bench in the south wall of the Wakarusa River valley and is well exposed along the north-flowing stream in the SW¼ sec. 27, T. 13 S., R. 17 E. The Plattsmouth is about 16 feet thick in a streambank in the SE cor. NW¼ sec. 27, T. 13 S., R. 17 E.; however, in Douglas County about half a mile southeast of the mapped area it appears to be only about 12 feet thick.

The member is medium-light-gray to medium-gray very fine grained hard dense limestone in thin to medium wavy beds. The individual beds are argillaceous immediately adjacent to the bedding planes and, where weathered, stand out in relief on the outcrop face. Thin layers of olive-gray very calcareous claystone are locally interbedded with the limestone; some layers in the uppermost part of the Plattsmouth are as much as 0.8 foot thick. The limestone weathers light yellowish gray or light gray to moderate yellowish brown. Irregular masses as much as 0.3 foot thick of medium- to brownish-gray dense fossiliferous chert occur in a conspicuous zone about 1 foot thick near the middle of the member. The contact of the Plattsmouth with the underlying Heebner Shale Member is gradational through a few inches of argillaceous limestone or very calcareous claystone.

Algae (*Cryptozoon?*), crinoid stems, and brachiopods are abundant in the Plattsmouth. Fusulinids are common, and bryozoans and pelecypods occur but are less common.

Heumader Shale Member

The Heumader Shale Member of the Oread Limestone was named by Moore (1932, p. 94, 96). The type locality is in the Heumader quarry in the bluffs above the Missouri River just north of St. Joseph, Mo.

The Heumader Shale Member is very poorly exposed in the Wakarusa River valley in southeastern Shawnee County, where it is present in the dip slope of the bench formed by the Plattsmouth Limestone Member. In an outcrop about half a mile southeast of the mapped area (strat. section 1, p. 92), the Heumader is about 4 feet thick and consists of weathered light-olive-gray slightly silty claystone that contains many pellets of light-gray argillaceous limestone. The upper 1 foot of the Heumader is medium-gray platy calcareous fossiliferous claystone in the streambank at the southeast corner of the area. Most of the Heumader in this area is virtually unfossiliferous, but Monger (1961, p. 76) found some specimens of *Syringopora* in the uppermost part at the locality of stratigraphic section 1.

Kereford Limestone Member

Kereford Limestone was the name applied by Condra (1927, p. 45) to one or more lenticular "dense, somewhat arenaceous, in part oolitic and quite fossiliferous" limestones in the lower part of the Kanwaka Shale near both Lecompton and Atchison, Kans., and at Amazonia, Mo. In 1932 Moore (p. 94) classified these beds as the uppermost member of the Oread Limestone. The type locality of the member is the Kereford quarry at the south edge of Atchison, Kans.

The entire Kereford Member is exposed along the stream that crosses the southeast corner of the area. It is partly exposed along the stream in the SE¼SW¼ sec. 27, T. 13 S., R. 17 E., and an unmapped exposure is in the north bank of the Wakarusa River just downstream from the bridge at Richland.

The Kereford, about 5–7 feet thick, consists of medium-light-gray to medium-gray and light-olive-gray to olive-gray argillaceous wavy very thin to thin-bedded very fossiliferous limestone. Most of the limestone is very finely crystalline, but the lower 2.5 feet and the upper 0.5 foot are very fine grained and contain abundant very small debris of fossils. Generally the limestone weathers to mottled dark-yellowish-orange, moderate-yellowish-brown, and light-olive-gray irregular flaggy beds on which well-preserved fossils stand out in relief. The 0.5-foot-thick limestone bed at the top weathers to a hard vertically jointed bed that has abundant fusulinids and small crinoid columnals in relief. A bed of claystone 0.7–1 foot thick underlies the capping limestone bed. The claystone is silty, calcareous, and fossiliferous; it weathers olive gray to olive brown and contains lenses of olive-gray argillaceous very fine grained limestone. The contact with the underlying Heumader Shale Member is poorly exposed, but, where observed, it is sharp and conformable.

The Kereford is characterized by its abundant and diverse fauna, which consists of *Osagia*, fusulinids, *Syringopora*, crinoid stems, fenestrate and ramose bryozoans, brachiopods (including *Dielasma*, *Marginifera*, *Derbyia*, *Composita*, *Juresania*, *Linoproductus*, and *Hustedia*), pelecypods (including *Aviculopecten*), gastropods, and sparse trilobites. E. L. Yochelson (written commun. 1960) reported on the following forms:

USGS fossil locality 19441–PC (f12989). In streambank in the SE¼SW¼ sec. 27, T. 13 S., R. 17 E., Shawnee County.

Fusulinids, undet. (abundant)
"*Dictyoclostus*" *portlockianus* (Norwood and Pratten)
Neospirifer dunbari R. H. King

Fusulinids from the upper limestone bed of the Kereford at this locality are retained in USGS foraminiferal collection f12988.

KANWAKA SHALE (strat. section 2)

The name Kanwaka Shale was originally proposed by G. I. Adams in an unpublished manuscript (Beede, 1902, p. 163) for the shale between the Oread and Lecompton Limestones. Condra (1927, p. 45) extended the lower boundary to include the present Kereford Limestone and the underlying Heumader Shale Members of the Oread. Moore (1932, p. 94) re-placed those limestone and shale units in the Oread, thus restricting the Kanwaka to the present usage. He divided the Kanwaka into, in ascending order, the Jackson Park Shale, Clay Creek Limestone, and Stull Shale Members. The Kanwaka was named for exposures in Kanwaka Township east of Stull, Douglas County, Kans., and is well exposed near the SE cor. sec. 26, T. 12 S., R. 18 E. (Moore, 1936a, p. 169).

All three members of the Kanwaka Shale crop out in the Wakarusa River valley, but to the north only the Stull Shale Member is exposed in the south wall of the Kansas River valley. Exposures are limited to roadcuts and streambanks. The Kanwaka is about 70–80 feet thick in the area. It rests conformably on the Oread Limestone, and the contact is sharp and slightly irregular. The contacts between the members of the Kanwaka also appear to be conformable.

Jackson Park Shale Member

The Jackson Park Shale Member was named by Moore (1932, p. 94); the type locality is Jackson Park, in southeastern Atchison, Kans. The member is about 47 feet thick about 1 mile east of Richland, and is 44 feet thick in the Murchison Federal Land Bank 1 well, about 2¼ miles southwest of Elmont. The member is mostly sandstone and siltstone but includes some claystone. All the rocks are light olive gray to light olive brown and micaceous. The sandstone is very fine grained and platy to very thin bedded. The silstone and claystone are clayey and silty, respectively, and both are laminated to platy. Some carbonized plant fragments occur on bedding planes in the upper part.

Clay Creek Limestone Member

The Clay Creek Limestone Member of the Kanwaka Shale was named by Moore (1932, p. 94) for exposures on Clay Creek about 1 mile west of Atchison, Kans. The Clay Creek consists of 3–4 feet of medium-gray to medium-olive-gray very finely crystalline argillaceous limestone in very thin to medium beds. The limestone generally weathers to light-olive-gray or yellowish-brown platy fragments and thin rubbly beds, but the lower part locally forms a hard vertically jointed bed. Some medium-dark-gray platy calcareous claystone occurs near the top of the member. Fusulinids are abundant, and crinoid columnals, fenestrate and ramose bryozoans, and shell fragments are fairly abundant.

Stull Shale Member

The upper beds of the Kanwaka Shale—from the Clay Creek Limestone Member to the base of the Lecompton Limestone—were named the Stull Shale Member by Moore (1932, p. 94). Exposures in the SE cor. sec. 26, T. 12 S., R. 18 E., near the village of Stull, Douglas County, Kans., constitute the type locality.

The thickness of the Stull in surface exposures ranges from about 35 feet, southeast of Richland, to about 23 feet, southwest of Richland. Southwest of Elmont the member is about 20 feet thick in the Murchison Federal Land Bank 1 well.

The Stull Shale Member is composed mostly of light-olive-gray to medium-gray laminated to platy micaceous, carbonaceous siltstone and claystone that weather light olive gray and, locally olive brown. The claystone is silty and is less abundant than the siltstone. Locally, light- to medium-gray very fine grained platy to very thin bedded micaceous sandstone is interbedded with the siltstone.

Very small plant fragments in the lower part were the only fossils noted in the member in eastern Shawnee County and vicinity. Just south of the area, in sec. 3, T. 14 S., R. 17 E., Osage County, a few gastropods and pelecypods were found about 8 feet below the top, and a few brachiopods were found at the top (H. G. O'Connor, written commun., 1951).

LECOMPTON LIMESTONE (strat. section 2)

Bennett (1896, p. 116) applied the name Lecompton to a series of three limestones and the intervening shales that crop out near Lecompton, Kans. Later Condra (1927, p. 45) included a fourth limestone (the Avoca) as the upper unit, and he applied a name to each subdivision. The Lecompton contains seven members, which are in ascending order, the Spring Branch Limestone, Doniphan Shale, Big Springs Limestone, Queen Hill Shale, Beil Limestone, King Hill Shale, and Avoca Limestone Members.

The Lecompton Limestone crops out in the southeastern part of the area along the Wakarusa River and, to the north, along Deer Creek. The formation also crops out on the south side of the Kansas River; however, it is concealed on the north side by alluvium and glacial deposits. The limestone beds form prominent ledges in the valley walls, but the shale members are poorly exposed.

The formation ranges in thickness from about 40 feet in the Kansas River valley to about 46 feet in the Wakarusa River valley. The Lecompton is about 30 feet thick in the subsurface at the west edge of the area, southwest of Elmont. The Lecompton Limestone conformably overlies the Kanwaka Shale, and the contacts between the members of the Lecompton are conformble.

Spring Branch Limestone Member

The name Spring Branch was applied by Condra (1927, p. 47) to the basal limestone of his Lecompton Limestone Member of the Shawnee Formation. Moore (1932, p. 96) subsequently raised this unit to member status in the Lecompton Limestone of the Shawnee Group. According to Moore (1936a, p. 174), the interbedded thin limestones and shales now placed in the upper part of the Spring Branch were evidently considered by Condra to be part of the overlying Doniphan Shale Member. Because these limestone beds are elements of the same cyclothem as that of the Spring Branch, however, it is preferable to include them with the Spring Branch (Moore, 1936a. p. 174). The type locality is along Spring Branch, north of the village of Big Springs, Douglas County, Kans. The member is also well exposed east of the mapped area in the bluffs west of Lecompton near the NW cor. sec. 35, T. 11 S., R. 18 E., and in a roadcut near the center of the south line of sec. 36, T. 11 S., R. 17 E. (Moore, 1936a, p. 173).

The Spring Branch, about 7.4–14 feet thick, is composed of a lower, ledge-forming limestone unit 5.4–9 feet thick and an upper, less resistant unit of interbedded limestone, claystone, and siltstone about 2–7.5 feet thick. The lower unit is medium-light-gray to light-olive-gray very finely crystalline to very fine grained thick-bedded limestone that generally weathers to light-olive-gray or pale- to moderate-yellowish-brown vertically jointed beds. The limestone is generally slightly argillaceous, but the uppermost and lowermost few inches of this unit is locally very argillaceous. In the Wakarusa River valley a very thin light-olive-gray platy calcareous siltstone or claystone parting separates the two units of the member.

Limestone in the upper unit of the Spring Branch is similar to that in the lower unit except that it is very thin to medium bedded and has many interbeds of claystone and siltstone. Locally in the Wakarusa River valley, the limestone at the top is algal and oolitic. On weathering this bed appears to be banded and slightly crossbedded. Abundant minute iron-stained specks give the bed a speckled appearance. The claystone is medium light gray, silty, and platy; the siltstone is light olive gray to light olive brown. Both are calcareous and weather light olive gray, light yellowish orange, and light yellowish brown.

Fusulinids are very abundant throughout most of the member, and crinoid columnals are abundant. *Osagia* is locally very abundant in the upper unit, and gastropods and some ostracodes are common. Fusulinids from the Spring Branch from the locality at the center of the west line of the NW¼ sec. 36, T. 11 S., R. 17 E., about 1 mile east of the area, are retained in USGS foraminiferal collection f12987.

Doniphan Shale Member

The shale between the Spring Branch and Big Springs Limestone Members of the Lecompton was named the Doniphan by Condra (1927, p. 47) from exposures in northern Doniphan County, Kans. In eastern Shawnee County and vicinity, the Doniphan Shale Member is generally deeply weathered and forms a poorly exposed reentrant between the limestone members. The member ranges in thickness from about 2 feet, at the Kansas River, to 6 feet, locally in the Wakarusa River valley.

The Doniphan consists mostly of light-olive-gray and medium- to dark-gray laminated to platy claystone and siltstone that weather light olive gray to medium dark gray and olive brown. The claystone is slightly silty; in the Kansas River valley it is partly carbonaceous and, in some exposures shows poor fissility. Locally in the Wakarusa River valley, the Doniphan contains pellets less than 0.02 foot in diameter and thin beds of light-olive-gray to medium-light-gray argillaceous unfossiliferous limestone. The Doniphan conformably overlies the Spring Branch; the contact is placed at the top of the stratigraphically highest fossiliferous limestone bed of the Spring Branch. The only fossils noted were small pieces of carbonaceous material in outcrops in the Kansas River valley.

Big Springs Limestone Member

Big Springs is the name applied by Condra (1927, p. 47) to the single thick middle-limestone bed of the Lecompton. The type locality is near Big Springs, Douglas County, Kans., but the member is also typically exposed in a roadcut near the center of the south line of sec. 36, T. 11 S., R. 17 E., about 4½ miles west of Lecompton (Moore, 1936a, p. 175).

The thickness of the Big Springs Limestone Member ranges from 2 to 3 feet and averages about 2.8 feet. The limestone is light olive gray to medium gray, very finely crystalline, thin to thick bedded, and compact. Locally near Richland a thin olive-gray very calcareous claystone occurs in the lower 1 foot of the member. The limestone weathers to a light-olive-gray to light-gray vertically jointed ledge. At places in the Richland quadrange, yellowish-orange limonitic spots are abundant on the upper part of the weathered outcrop.

Fusulinids are abundant in the Big Springs, particularly in the lower half, and weather in relief. *Osagia*, crinoid columnals, bryozoans, and brachiopods are abundant. Fusulinids from the Big Springs from the locality at the center of the west line of the NW¼ sec. 36, T. 11 S., R. 17 E., about 1 mile east of the area, are retained in USGS foraminiferal collection f12986.

Queen Hill Shale Member

The shale above the Big Springs Limestone Member was named the Queen Hill by Condra (1927, p. 46) from exposures at Queen Hill, northeast of Rock Bluff, in T. 11 N., 14 E., Nebraska. The Queen Hill is 2.3–3.6 feet thick near the Wakarusa River, and to the north it is 3.3 feet thick along the Kansas River.

The Queen Hill is composed of a lower unit, slightly more than 1 foot thick, of grayish-black to brownish-black claystone and an upper unit of dark-gray claystone. Both claystones are slightly silty and laminated to platy. The lower unit weathers to dark-gray fissile plates that locally show iridescence; the upper unit weathers olive gray. The basal 0.05–0.1 foot of the lower unit is olive-gray to medium-gray silty calcareous claystone that weathers to a light-gray streak at the base of the overlying dark beds.

Conodonts are in the lower unit of the Queen Hill, and plant impressions are scattered throughout the upper unit. Shell fragments are locally abundant at the base of the Queen Hill in the Kansas River valley.

Beil Limestone Member

The Beil Limestone Member, named by Condra (1930, p. 48), overlies the Queen Hill Shale Member and underlies the King Hill Shale Member. The type locality, on the Beil farm, is in the bluffs of the Missouri River at the mouth of Kenosha Creek, south of Rock Bluff, Nebr. (Moore, 1936a, p. 176).

The lower part of the Beil crops out as a prominent ledge, but the upper part is exposed only in streambanks and roadcuts. The Beil, about 8.5–10 feet thick, is predominantly limestone with lesser amounts of siltstone and claystone. The limestone, dominant in the lower ½–⅔ of the member, is light olive gray, olive gray, and medium light gray, very finely crystalline to very fine grained, and argillaceous; it occurs in very thin to medium wavy beds. Laminae and very thin layers of olive-gray clayey platy calcareous siltstone are interbedded with the limestone in the lower part. The weathered outcrop is pale yellowish brown to light olive gray and shows the wavy bedding typical of the Beil.

The upper part of the Beil is characterized by alternating thin limestone and claystone beds. The claystone is olive gray to light olive brown, silty, platy, calcareous, and fossiliferous. In the Wakarusa River valley the top of the member is marked in places by a thin limestone bed that contains many dark-yellowish-orange limonitic inclusions, scattered limestone inclusions, and very abundant *Osagia* algae. The base of the Beil throughout the area is at the stratigraphically lowest fossiliferous limestone bed that overlies the dark-gray claystone of the Queen Hill.

Fossils are abundant in the Beil; fusulinids, crinoids, and brachiopods are the most abundant forms. Fusulinids are very abundant in the lower part but are less abundant to sparse in the upper part. Algae consists of *Osagia* and *Cryptozoon*-like forms. Some trilobite fragments were also found. The fauna of the Beil is represented in the following collection reported on by E. L. Yochelson (written commun., 1960):

USGS fossil locality 19442–PC (f12985). In old quarry in the center of the west line of the NW¼ sec. 36, T. 11 S., R. 17 E., about 1 mile east of the mapped area.

Fusulinids, undet.
Stereostylus sp.
Caninoid corals, undet.
Aulopora sp.
Crinoid stem and plate
Echinoid spines
Incrusting bryozoans
Fenestrate bryozoans
Rhomboporoid bryozoans

Derbyia crassa (Meek and Hayden)
Derbyia sp. indet.
Meekella striatocostata (Cox)
Chonetes graulifer Owen
Echinoconchus? sp. indet.
Juresania nebrascensis (Owen)
Reticulatia huecoensis (R. E. King)
Marginifera wabashensis (Norwood and Pratten)
Antiquatonia portlockianus (Norwood and Pratten)
Linoproductus cf. *L. prattenianus* (Norwood and Pratten)
Cancrinella boonensis (Swallow)
Neospirifer dunbari R. H. King
Composita subtilita (Hall)
Phricodothyris perplexa (McChesney)
"*Spiriferina*" *kentuckensis* (Shumard)
Hustedia mormoni Marcou
Dielasma bovidens (Morton)
Astartella sp. indet.
Straparollus (*Euomphalus*) cf. *S.* (*E.*) *plummeri* Knight

King Hill Shale Member

The name King Hill was applied by Condra (1927, p. 45) to the uppermost shale of the Lecompton from exposures in King Hill southeast of Rock Bluff, Nebr., in T. 11 N., R. 14 E.

The King Hill is about 8 feet thick in the Kansas River valley and about 11 feet thick in the southeastern part of the area. It is mostly olive-gray silty laminated to platy calcareous claystone, but near the middle it contains a thin-bedded unit of very argillaceous limestone 1.5–3.6 feet thick that weathers dark yellowish brown to light yellowish orange. The claystone generally weathers light olive gray, but in places the lower part weathers light greenish gray. Small limestone pellets and nodules occur in the claystone; the pellets in the claystone below the limestone weather light gray, and those above, yellowish brown. The limestone bed contains many fine stringers and small vugs filled with clear or light-brown crystalline calcite. The limestone weathers partly by exfoliation to punky slabs and platy rubble; locally it weathers to boxwork.

The contact between the King Hill Shale Member and the underlying Beil Limestone Member is at the top of the stratigraphically highest fossiliferous limestone that underlies the dark-yellowish-brown punky limestone of the King Hill. In many areas the rocks adjacent to the contact are deeply weathered and the exact position of the contact is difficult to determine.

The King Hill is sparsely fossiliferous. Fusulinids and brachiopods are most abundant near the upper contact. Some ostracodes and foraminifers occur in the upper half of the member in the Kansas River valley just east of the Shawnee County line (Purrington, 1948, p. 44).

Avoca Limestone Member

The upper member of the Lecompton Limestone, the Avoca, was named by Condra (1927, p. 45) from an exposure in South Fork Weeping Water Creek about 3 miles east of Avoca, Otoe County, Nebr. (T. 10 N., R. 12 E.).

The Avoca, 3–4 feet thick, is generally composed of two limestone beds separated by a thin parting of claystone or siltstone. The limestones are light olive gray to medium dark gray and very fine grained. The lower limestone is hard, hackly, and slightly argillaceous; it weathers to a light-olive-gray to pale-yellowish-brown vertically jointed ledge 2–3 feet thick. The upper part of the Avoca is made up of very argillaceous very thin bedded limestone that weathers to platy fragments. The claystone or siltstone is light olive gray and calcareous and locally contains small limestone inclusions that weather yellowish brown.

Fusulinids occur throughout the member and are very abundant in the lower part of the ledge-forming limestone bed. Other fossils include foraminifers, crinoid columnals, ramose bryozoans, brachiopods, pinnacid clams, ostracodes, and some *Osagia* and *Cryptozoon?* algae.

TECUMSEH SHALE (strat. section 3)

The Tecumseh Shale was named by Beede (1898, p. 28) for the thick shale underlying the Calhoun (Deer Creek) Limestone near Tecumseh, Shawnee County, Kans. The shale is well exposed in the SE¼ sec. 36, T. 11 S., R. 17 E. (Moore, 1936a, p. 178). Condra (1930, p. 52–53), on the basis of his work in Nebraska, divided the Tecumseh into three units—the Kenosha Shale, at the base; the Ost Limestone, in the middle; and the Rakes Creek Shale, at the top. Moore (1932, p. 96) extended the usage of these names into Kansas to designate the members of the Tecumseh Shale. Moore, Frye, Jewett, Lee, and O'Connor (1951, p. 66) subsequently decided that the Ost Limestone Member is not persistent enough to warrant any divisions of the Tecumseh in Kansas.

The Tecumseh Shale crops out in the Wakarusa River valley, along Deer Creek at the east edge of the area, and in the bluffs of the Kansas River valley. The formation generally weathers to grass- and tree-covered slopes and is exposed mainly on the steeper slopes and in streambanks. Outcrops in the Kansas River valley are poorly exposed.

The Tecumseh is about 60 feet thick in the Wakarusa River valley and along Deer Creek. Along the Kansas River the formation increases to about 70 feet in thickness and maintains that general thickness in the subsurface north of the river.

The Tecumseh is composed mainly of siltstone and claystone but has some thin beds of sandstone and limestone. The siltstone is light olive gray, pale olive, and medium gray and is laminated to very thin bedded; it weathers to olive-gray to yellowish-brown round, blocky or pencillike fragments that are locally stained reddish brown by iron oxide. The claystone is light olive gray to light olive brown. Both the siltstone and the claystone are finely micaceous and contain fine carbonaceous material. Light-olive-gray to light-olive-brown very fine grained micaceous sandstone occurs in beds less than half an inch thick in the upper part of the formation. A few thin beds of medium-light-gray argillaceous limestone are present in the upper part of the Tecumseh in the Wakarusa River and Kansas River valleys. One limestone contains granules and pebbles of light-yellowish-gray to light-olive-gray siltstone.

The basal part of the Tecumseh Shale contains crinoid columnals and a sparse microfauna of foraminifers and ostracodes (Purrington, 1948, p. 44). The remainder of the formation is mostly unfossiliferous except for scattered plant remains. Locally *Osagia*, crinoid columnals, bryozoans, a few *Chonetes* and other brachiopods, and some poorly preserved casts of pelecypods and gastropods are present in the upper 10 feet.

DEER CREEK LIMESTONE (strat. section 4)

The Deer Creek was originally defined by Bennett (1896, p. 117) as the Deer Creek System and included three limestones and the intervening shales. Haworth (1898, p. 94) modified the name to Deer Creek Limestone and included it as a member of the Shawnee Formation. From exposures in Nebraska and adjacent parts of Iowa and Kansas, Condra (1927, p. 50–51) divided the Deer Creek into five units, which are, in ascending order, the Rock Bluff Limestone, Larsh Shale, Haynies Limestone, Mission Creek Shale, and Ervine Creek Limestone. Moore (1936a, p. 183) recognized that the Rock Bluff was the stratigraphic equivalent of the "middle Deer Creek" limestone bed in Kansas and that the "lower Deer Creek" limestone bed in Kansas, which he named the Ozawkie (Moore, 1936a, p. 182), was not then identified in Nebraska. The Haynies Limestone either does not extend southward into Kansas, as was implied by Moore (1936a, p. 187), or it coalesces with the basal part of the Ervine Creek Limestone Member, owing to pinchout of the Burroak (formerly Mission Creek) Shale Member in southeastern Nebraska (Condra and Reed, 1943, p. 48). Condra and Reed (1937, p. 53–54) substituted the name Burroak for Mission Creek. The Deer Creek Limestone of Kansas is composed, in ascending order, of the Ozawkie Limestone Member, Oskaloosa Shale

Member, Rock Bluff Limestone Member, Larsh and Burroak Shale Members, and Ervine Creek Limestone Member. The type locality of this formation is along Deer Creek in eastern Shawnee County, Kans.

The Deer Creek Limestone forms a prominent escarpment in the Wakarusa River valley east of U.S. Highway 75 and in the Kansas River valley east of Topeka. The formation also crops out along Rock Creek on the east side of the Meriden quadrangle. The limestone members form ledges, but the shale members are poorly exposed.

The Deer Creek ranges in thickness from about 32 to 43 feet. The contact between the Deer Creek Limestone and the underlying Tecumseh Shale is sharp and conformable; contacts between the members of the Deer Creek are also conformable.

Ozawkie Limestone Member

The first published use of the name Ozawkie was by Condra (1935, p. 12), but Moore (1936a, p. 182) named the Ozawkie Limestone Member for exposures in a roadcut at Ozawkie, in the NE¼ sec. 31, T. 9 S., R. 18 E., Jefferson County, Kans. Previously the Ozawkie had mistakenly been correlated with the Rock Bluff Limestone in Nebraska (Moore, 1932, p. 96).

The Ozawkie Limestone Member is 6–10.1 feet thick and consists of two limestone beds separated (at most localities) by a thin claystone. The limestone is light gray to olive gray and brownish gray to pale yellowish brown, very finely crystalline to very fine grained, compact, and thin bedded to massive. Characteristically the limestone units weather to prominent dark-yellowish-orange to moderate-yellowish-brown vertically jointed ledges. The lower limestone, which is 2.8–6 feet thick, generally weathers to a granular texture because of the fossil debris present. The upper limestone is locally argillaceous and contains small pellets and irregular inclusions of greenish-gray claystone or siltstone, a few granules of light-brown limestone, small vugs filled with calcite crystals, and locally a few very small oolites. The upper bed ranges in thickness from 1.9 to 5.3 feet and has a granular or pseudo-oolitic texture.

The intervening claystone, 0.1–2 feet thick, is light olive gray to olive gray, silty, platy, calcareous, and fossiliferous. It weathers light olive gray to olive brown and contains very small pellets of light-olive-gray limestone.

Fusulinids are very abundant in the lower limestone bed and show in relief on weathered surfaces. *Osagia* is also abundant in the lower limestone bed and locally in the upper bed where it occurs along with pelletal algae. Crinoid columnals, echinoids, bryozoans, brachiopods, pelecypods, and gastropods are present in both limestones. Algae are abundant in the following collection from the member, reported on by E. L. Yochelson (written commun. 1960):

USGS fossil locality 19443–PC. In creekbed of south-flowing stream in the SE¼NW¼NE¼ sec. 16, T. 11 S., R. 17 E., Jefferson County.
Algae, undet. (abundant) pelletal
Osagia sp. indet.

Oskaloosa Shale Member

The Oskaloosa Shale Member was named by Moore (1936a, p. 184) from exposures near Oskaloosa, Jefferson County, Kans., but the first published use of the name was by Condra (1935, p. 12). The Oskaloosa is 6–8.5 feet thick and is primarily medium-light-gray to medium-gray, olive-gray, and light-greenish-gray to dark-greenish-gray slightly silty platy claystone. Locally the member contains sandy very thin bedded siltstone, and in places it has nodules less than 0.05 foot in diameter of light-gray limestone and of very fine grained sandstone.

The Oskaloosa generally is sparsely fossiliferous; crinoid columnals, brachiopods, pelecypods, and gastropods are the main fossils. A few fusulinids occur locally in the uppermost part.

Rock Bluff Limestone Member

The Rock Bluff, which is the middle limestone member of the Deer Creek Limestone in Kansas, was named by Condra (1927, p. 50) from exposures in the bluffs along the Missouri River northeast of Rock Bluff, Nebr. At the type locality the Rock Bluff is overlain by the Larsh Shale Member and underlain by the Tecumseh Shale; however, in Kansas the Oskaloosa Shale and Ozawkie Limestone Members of the Deer Creek separate the Rock Bluff from the Tecumseh.

The Rock Bluff is 1.8–2.8 feet thick and is a medium-light-gray to medium-gray and light-olive-gray very finely crystalline hard compact limestone that has a hackly or subconchoidal fracture. Characteristically the member weathers to a single light-olive-gray to moderate-yellowish-brown vertically jointed bed, although in many places it is thin to medium bedded. Locally the upper surface weathers to platy fragments. Fossils are abundant and include *Osagia*, fusulinids, crinoid columnals, brachiopods, and a few mollusks.

Larsh and Burroak Shale Members

The shale above the Rock Bluff Limestone Member in Kansas appears to be the stratigraphic equivalent of the Larsh Shale, Haynies Limestone, and Burroak (Mission Creek) Shale Members of the Deer Creek in Nebraska (Moore, 1936a, p. 187). Condra (1927, p. 49–50) named the Larsh, which overlies the Rock Bluff, from the Larsh farm, on Ervine Creek northeast of Union, Nebr. The Haynies overlies the

Larsh in Nebraska but is not recognized in Kansas. The shale overlying the Haynies and underlying the Ervine Creek in Nebraska was originally defined as the Mission Creek Shale (Condra, 1927, p. 49); however, because of previous miscorrelation it was renamed the Burroak Shale (Condra and Reed, 1937, p. 53–54). The type locality of the Burroak Shale Member is in roadcuts and ravines near Burr Oak School (E½ sec. 21, T. 71 N., R. 43 W., Mills County), about 6 miles south of Pacific Junction, Iowa (Condra and Reed, 1937, p. 53).

The Larsh and Burroak, together about 4 feet thick, are dominantly claystone that is readily divided into two units. The lower unit, about 1–2.6 feet thick, consists of medium-dark-gray to black, locally olive-black, slightly silty finely laminated to platy claystone that weathers to medium-dark-gray, brownish-black, or dark-olive-gray highly fissile pieces. At many localities the basal part of this unit is calcareous and weathers light olive gray. The upper unit, about 2–3.5 feet thick, consists of light-olive-gray to medium-dark-gray silty laminated to platy claystone and, locally, clayey siltstone that weather medium light gray to olive gray and olive brown. Very small nodules of pyrite, siltstone, and limestone occur in the upper unit at most places. The weathered outcrop of the Larsh and Burroak is conspicuous because of a dark band in its lower part and a lighter colored band in the upper part.

The lower, black claystone unit of the Larsh and Burroak Members contains conodonts, *Crurithyris* sp. indet., and possibly fish scales (E. L. Yochelson, written commun., 1960). Some pelecypods and possibly orbiculoid brachiopods were noted by the authors. The upper unit of the Larsh and Burroak locally has brachiopods, pelecypods, and a few high-spired gastropods.

Ervine Creek Limestone Member

The upper member of the Deer Creek Limestone, the Ervine Creek, was named by Condra (1927, p. 49) for exposures along Ervine Creek in Cass County, northeast of Union, Nebr. In 1933 Moore and Condra (Condra, 1933, p. 5) included the Jones Point Shale Member and the overlying Sheldon Limestone Member—previously defined erroneously as the lower two units of the overyling Calhoun Shale (Condra, 1930, p. 47)—in the upper part of the Deer Creek Limestone above the Ervine Creek. Condra (1935, p. 11) and Moore (1936a, p. 191) later replaced the lower two units in the Calhoun Shale, thus restricting the Ervine Creek to the present usage.

The Ervine Creek Limestone Member forms the upper part of the Deer Creek escarpment and in many places holds up a separate pronounced scarp. The upper, less resistant part of the member weathers to a gentle slope and is seldom exposed except in quarries. The Ervine

Creek ranges from about 13 to 18 feet in thickness and at most localities is divisible into two parts. The lower part, which is the more prominent and widespread and makes up the bulk of the member, is light-olive-gray to olive-gray, or medium-light-gray to medium-gray, dense to very finely crystalline limestone in thin to medium wavy beds. The limestone is very argillaceous adjacent to bedding planes. Laminae and very thin layers of medium-dark-gray very calcareous siltstone and claystone or very silty limestone are interbedded with the limestones at many localities. The lower part of the Ervine Creek characteristically weathers to a light-olive-gray to moderate-yellowish-brown ledge in which the wavy bedding is conspicuous (fig. 2).

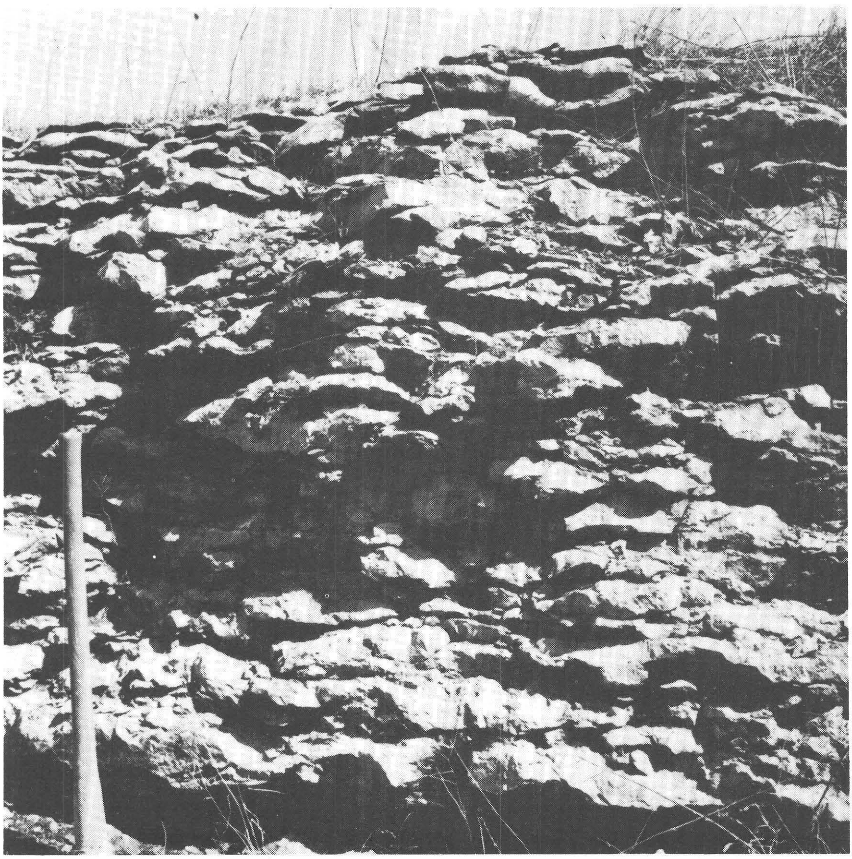

FIGURE 2.—Typical wavy beds in lower part of Ervine Creek Limestone Member of Deer Creek Limestone in roadcut on U.S. Highway 40 in NW¼NW¼ sec. 4, T. 12 S., R. 17 E. Pick handle is about 2½ feet long.

In the upper few feet of the Ervine Creek, the limestone is very argillaceous, and the bedding markedly differs from that in the lower part. This upper limestone is platy to medium bedded, generally not wavy bedded, and weathers to platy fragments or to rounded layers with shallow concave depressions on the surface; in places it is conquinoidal. Siltstone and claystone beds are thicker and more abundant than in the lower part. The limestone either rests directly on limestone of the lower part or is separated from it by a bed of siltstone or claystone.

The Ervine Creek Limestone Member is very fossiliferous, especially in the lower part; locally the upper part is unfossiliferous. Fusulinids are generally present throughout the lower part but are more abundant near the middle; except at a few localities they are sparse in the upper unit. The following collections, reported on by E. L. Yochelson (written commun. 1960), were taken from the Ervine Creek Limestone Member in the mapped area:

USGS fossil locality 19444–PC (f12984). In quarry in the NE¼SE¼ sec. 16, T. 11 S., R. 17 E., Jefferson County.

- Algae, undet.
- Fusulinids, undet.
- Horn coral, indet.
- Rhomboporoid bryozoan
- Fenestrate bryozoan
- *Derbyia crassa* (Meek and Hayden)
- *Linoproductus*? sp. indet.
- *Juresania nebrascensis* (Owen)
- Productoid brachiopod, indet.
- *Phricodothyris*? sp. indet.
- *Hustedia*? sp. indet.
- "*Spiriferina*" *kentuckensis* (Shumard)
- Bellerophontacean gastropod, indet.
- *Streptacis crenimarginatus* Knight

USGS fossil locality 19445–PC (f12993). In uppermost part of the member in railroad cut in the NW¼SW¼ sec. 14, T. 11 S., R. 16 E., Shawnee County.

- *Osagia*? sp. indet.
- Fusulinids, undet.
- Echinoid spine, indet.
- Rhomboporoid bryozoan
- *Derbyia crassa* (Meek and Hayden)
- *Derbyia* cf. *D. deercreekensis* Dunbar and Condra
- Productoid brachiopod, indet.
- *Neospirifer dunbari* R. H. King
- *Composita* n. sp?
- *Spiriferina*? sp. indet.
- Myalinid pelecypod, indet.
- High-spired gastropod, indet.

The locality also yielded the fusulinids in USGS foraminiferal collection f12994, as well as crinoid stems and a dictyoclostid brachiopod.

USGS fossil locality 19446–PC (f12983). At stratigraphic section 5.

Fusulinids, undet.
Fenestrate bryozoans
Derbyia cf. *D. deercreekensis* Dunbar and Condra
Juresania sp. indet.
Linoproductus? sp. indet.
Neospirifer dunbari R. H. King
Composita sp. indet.
Aviculopecten sp.

CALHOUN SHALE (strat. section 5)

The correlation and nomenclature of the rocks of the Calhoun Shale and the overlying Topeka Limestone in Kansas are intimately related to those in Nebraska. Many changes, summarized in table 1, have been made in both the nomenclature and the position of the contact between the two formations. The problems of correlation of the stratigraphic units in this part of the geologic column between Kansas and Nebraska are complicated by limited exposures, in part due to glacial deposits, geologic structure, and the rapid thinning of the shale units northward into Nebraska.

The Calhoun Shale was originally named the Calhoun Sandstone and Shale by Beede (1898, p. 29) for the beds overlying the Calhoun (Deer Creek) Limestone and underlying the Topeka Limestone. Haworth (1898, p. 94) modified the name to Calhoun Shale. Condra (1927, p. 51) mistakenly placed the Jones Point Shale, Sheldon Limestone, and Iowa Point Shale Members of the Topeka Limestone in the Calhoun Shale in Nebraska, and Moore (1936a, p. 190) concurred in this classification in Kansas. In 1937 Condra and Reed (p. 52) recognized previous errors in correlation and restricted the Calhoun in Nebraska to its present usage as the shale unit between the base of the Wolf River Limestone Member of the Topeka Limestone and the top of the Deer Creek Limestone. Moore, Frye, and Jewett (1944, p. 178) accepted this definition of the Calhoun, although the basal member of the Topeka is called the Hartford Limestone Member in Kansas. This usage has been accepted by the State Geological Survey of Kansas. The type locality of the Calhoun Shale is the "Calhoun Bluffs," on the north side of the Kansas River, in the S½ sec. 14, T. 11 S., R. 16 E., a short distance northeast of Topeka.

The Calhoun Shale crops out in the Kansas River valley generally east of Topeka, in the Wakarusa River valley east of Wakarusa, along Deer Creek north of Richland, and along Rock Creek southeast of Meriden. The formation underlies grass-covered and, in places, wooded slopes and is commonly exposed only in stream gullies and roadcuts.

The Calhoun commonly ranges in thickness from about 42 feet along Rock Creek to about 55 feet at its type locality in the Kansas River valley northeast of Topeka. South of the river the formation is about 45 feet thick on Tecumseh Creek at the Kansas Turnpike and about 60 feet thick 2 miles to the south along that creek. Locally, near the east side of the area, in the SE¼ sec. 33, T. 11 S., R. 17 E., the Calhoun is only about 30 feet thick. In the Wakarusa River valley the shale is about 50 feet thick. In the subsurface southwest of Elmont, it is about 40 feet thick.

The Calhoun consists principally of siltstone and sandstone and a small amount of claystone. Some limestone is locally present, and a thin coal bed occurs near the top. Locally sandstone makes up as much as two-thirds of the formation. The siltstone is light olive gray, olive brown, and medium to dark gray, finely sandy, laminated to very thin bedded, and locally micaceous. The sandstone is light yellowish gray, medium light gray, and light olive gray, very fine to fine grained, and generally laminated to thin bedded and locally has finely crossbedded layers. The sandstone contains abundant fine carbonaceous material, particularly on bedding planes and is also commonly micaceous. The weathered sandstone is generally light yellowish gray or light olive brown and, locally, is stained moderate yellowish brown from the ferruginous sandstone layers and concretions. Sandstone is most abundant in the upper part of the Calhoun, where it either is interbedded with siltstone or occurs as thick lenticular channel deposits. These channel sandstones are very conspicuous in the north wall of the Kansas River valley northeast of Topeka.

Claystone is common in the basal and uppermost parts of the Calhoun; locally in the Wakarusa River valley, it makes up more than half of the formation. The claystone is olive gray, medium to dark gray, and locally grayish black; it is silty, laminated to platy, and generally micaceous and locally contains fine carbonaceous material. The claystone weathers light olive gray to medium dark gray and at places has much iron stain on bedding planes.

Beds generally less than 1 foot thick of medium-gray to medium-dark-gray very fine grained platy to very thin bedded fossiliferous limestone are in the upper 20 feet of the Calhoun Shale in a small area in the Wakarusa River valley about 1 mile east of Wakarusa. A coal bed about 0.2 foot thick occurs at many localities in the upper 1.5–5.5 feet of the Calhoun Shale.

In general the overlying Calhoun Shale rests conformably on the Ervine Creek Limestone Member of the Deer Creek Limestone, but locally—in the railroad cut in the NW¼SW¼ sec. 14, T. 11 S., R. 16 E., and in a streambank in the SW¼NW¼ sec. 15, T. 10 S., R. 17 E.—

the uppermost beds of the Ervine Creek have been eroded, and channel sandstone of the Calhoun rests disconformably on them. Locally the contact between the Calhoun and the Deer Creek is gradational. Intraformational channeling of slight magnitude is also evident in the Calhoun Shale, particularly near Topeka.

A sparse fauna of brachiopods, pelecypods, and high-spired gastropods is present in the Calhoun Shale, particularly in the upper part. Carbonized plant fragments are abundant but are too small to identify. Limestone beds in the upper part contain many small shell fragments, and in some beds fusulinids, crinoid columnals, and bryozoans are abundant. Ostracodes are present locally in claystone beds. The fossils in the following list, reported on by E. L. Yochelson (written commun., 1960), were collected about 4 feet above the base of the Calhoun Shale:

Lingula sp. indet.
Aviculopecten sp. indet.
Myalinid indet.
Knightites (*Retispira*) sp. indet.
Organic indeterminate (possibly *Orbiculoidea*)

TOPEKA LIMESTONE (strat. section 6)

The Topeka Limestone—the upper formation of the Shawnee Group—was named by Haworth (1895, plate facing p. 290) and included three limestones and the intervening shales. The nomenclature of the Topeka, particularly of the rock units in the lower part, has been changed many times; these changes are summarized in table 1. Kirk (1896, p. 80) designated beds apparently equivalent to Haworth's Topeka as the Hartford Limestone from exposures in Coffey County, Kans. Hinds and Greene (1915, p. 188, 189), on the basis of their work in northwestern Missouri, included additional beds stratigraphically higher than those in Haworth's Topeka, but they did not name the various units. Condra (1927, p. 52) divided the Topeka in Nebraska into five units, which are, in ascending order, the Curzen Limestone, Turner Creek Shale, Du Bois Limestone, Holt Shale, and Coal Creek Limestone. Moore (1936a, p. 194) introduced Condra's divisions into Kansas but substituted the name Hartford for the Curzen. That same year Moore (1936b, p. 41) added two additional units to the lower part of the Topeka below the Hartford Limestone Member—the Jones Point Shale, and the Dashner Limestone Members at the base. In a restudy of the Calhoun Shale and Topeka Limestone, Condra and Reed (1937) recognized many miscorrelations of rock units, and they reclassified the beds of the Topeka Limestone into nine members, which are, in ascending order, the Wolf River Limestone, Iowa Point Shale, Curzen Limestone, Jones Point Shale, Sheldon Limestone, Turner

Creek Shale, Du Bois Limestone, Holt Shale, and Coal Creek Limestone Members. Except for the use of the name Hartford for the Wolf River and a slight change in spelling of the Curzon, this is the classification of the Topeka now used in Kansas (Moore, Frye, and Jewett, 1944, p. 177–178). The type locality of the Topeka Limestone is near Topeka, Kans., and all the members are well exposed along U.S. Highway 24 in the S½ sec. 14, T. 11 S., R. 16 E., a short distance northeast of the city.

The Topeka Limestone forms a prominent escarpment throughout much of the Wakarusa River and Kansas River valleys. North of the Kansas River the formation crops out mainly in the steep valley walls of Muddy and Rock Creeks. The lower part of the Topeka is the more resistant, and the upper part is seldom exposed except in quarries and roadcuts.

The Topeka ranges in thickness from about 10 feet, in the Wakarusa River valley northeast of Wakarusa, to 33 feet, east of Topeka on the Kansas Turnpike East Exchange Road. The wide range in thickness is the result of erosion of the upper part of the Topeka in the southern part of the area during deposition of the overlying Severy Shale in the northern part. In the Murchison Federal Land Bank 1 well, southwest of Elmont, the limestone is about 28 feet thick.

The Topeka Limestone is composed of nine members, which are, in ascending order, the Hartford Limestone, Iowa Point Shale, Curzon Limestone, Jones Point Shale, Sheldon Limestone, Turner Creek Shale, Du Bois Limestone, Holt Shale, and Coal Creek Limestone Members.

Hartford Limestone Member

The Hartford was named by Kirk (1896, p. 80) from exposures along the Neosho River in Coffey County, Kans., where it apparently included beds stratigraphically equivalent to the Topeka Limestone in the Kansas River valley, as originally defined by Haworth (1895, plate facing p. 290) (now designated as the Sheldon Limestone Member down through the Hartford Limestone Member). In Nebraska this part of the Topeka was designated as the Curzen Limestone by Condra (1930, p. 52), but he later (1935, p. 11) called it Hartford (Curzon). Moore (1936a, p. 196) applied the name Hartford to all beds of the Topeka below the Turner Creek Shale Member. Condra and Reed (1937, p. 6–7) recorrelated the units of the Topeka Limestone in the Kansas River valley and named the lowest limestone unit the Wolf River Limestone Member. In 1944 Moore, Frye, and Jewett (p. 178) changed the name to Hartford. The type locality of the Hartford Limestone Member is near Hartford, Kans., on the Lyon County–Coffey County line. The member is well exposed below the highway bridge at the north edge of town (Moore, 1936a, p. 195).

Over much of the area the ledge formed by the Hartford is the only part of the Topeka exposed. Where the member is concealed, its position is commonly marked by a slight bench on the hillside.

The Hartford ranges in thickness from 3.1 feet along Muddy Creek in sec. 1, T. 11 S., R. 16 E., to 8.2 feet, east of Topeka along the Kansas Turnpike East Exchange Road. The member is predominantly limestone, but it has a thin claystone bed less than 1 foot above its base. The limestone is medium light gray and light olive gray, very fine grained to very finely crystalline, hard, and thin bedded to massive. It is in part slightly silty or argillaceous, particularly in the upper few inches and locally near the base. In a few places the basal bed forms nodular blocks, the upper surfaces of which become platy to rubbly on weathering. The limestone characteristically weathers to small moderate-yellowish-brown subangular or lens-shaped blocks.

The claystone is medium gray to olive gray, silty, laminated to platy, and calcareous. It weathers light olive gray, olive brown, and moderate yellowish brown and forms a reentrant near the base of the Hartford ledge. Locally the claystone grades laterally to slightly sandy siltstone. The average thickness of the claystone bed is about 0.2 foot, but in places it is as much as 3 feet.

The Hartford contains an abundant and varied fauna of algae, fusulinids, lophophyllidid corals, crinoid columnals, echinoderm debris, bryozoans, brachiopods, pelecypods—including possibly *Aviculopinna*—and high-spired gastropods. The abundance of large fusulinids and large brachiopods facilitates the identification of this unit. The upper 1 foot is generally less fossiliferous, although at many localities it contains abundant *Osagia*. Fusulinids from the Hartford in stratigraphic section 6 compose USGS foraminiferal collections f12995 and f12999.

Iowa Point Shale Member

The Iowa Point was the name applied by Condra (1927, p. 51–52) to the 10-foot-thick shale underlying the Curzon Limestone Member and overlying the Meadow Limestone Member (now known as the Hartford Limestone Member) in the bluffs above the Missouri River near Iowa Point, Kans., but he mistakenly included this shale as the upper unit of the Calhoun Shale. The Iowa Point was miscorrelated northward into Nebraska by Condra (1930, 1935), and southward into the Kansas River valley by Moore (1936a). In 1937 Condra and Reed (p. 7, 51) recognized the true relation of the Iowa Point to the overlying and underlying limestone units, and in 1944 Moore, Frye, and Jewett (p. 178) formally defined the member in Kansas as the shale unit overlying the Hartford Limestone Member and underlying the Curzon Limestone Member of the Topeka. The type locality is in the bluffs above the Missouri River just southeast of the abandoned Iowa Point railroad station in Doniphan County, Kans. (Condra and Reed, 1937, p. 51).

The Iowa Point Shale Member crops out in a narrow and rather inconspicuous reentrant in the escarpment face formed by the lower limestone members of the Topeka Limestone. The thickness of the member averages about 1 foot, but ranges from about 0.1 to 1.5 feet. The Iowa Point is composed of medium-light-gray to olive-gray silty laminated to platy claystone and medium-light- to medium-dark-gray clayey to sandy platy siltstone. Thin beds of light-gray, medium-gray, and olive-gray fine-grained sandstone occur locally. The Iowa Point is generally micaceous and in part calcareous. In some localities the member contains thin beds and lenses of light-olive-gray to medium-light-gray fossiliferous limestone. The Iowa Point is light olive gray to olive gray on weathering.

Crinoids, bryozoans, and brachiopods are the principal fossils in the Iowa Point Shale Member. In places small carbonized plant fragments are abundant. The limestones are the most fossiliferous beds in the member.

Curzon Limestone Member

The name Curzon was originally used by Gallaher (1899, p. 57) in describing those beds in the lower part of the present Topeka Limestone in Missouri that lie below the Forest City Sand Rock (now the Turner Creek Shale Member). Condra (1927, p. 52) applied the name Curzen to beds in the lower part of the Topeka in Nebraska, but later he (Condra, 1935, p. 11) substituted the name Hartford. Condra and Reed (1937, p. 7) correlated the second limestone unit above the base of the Topeka in the Kansas River valley as the Curzen Limestone. This limestone had previously been included by Moore (1936a, p. 196) as an unnamed limestone bed in the Hartford Limestone Member of the Topeka. In 1944 Moore, Frye, and Jewett (p. 178) recognized the validity of the correlation of the Curzon Limestone Member as the unit overlying the Iowa Point Shale Member and underlying the Jones Point Shale Member. The correct spelling of the member name as Curzon was decided in 1943. The type locality of the Curzon Limestone Member is east of Curzon Station, southeast of Forest City, Holt County, Mo. (Condra and Reed, 1937, p. 51).

Generally the thickness of the member ranges from about 4.5 to 10.5 feet and averages about 8.5 feet. Locally northeast of Wakarusa, in the SE¼SW¼ sec. 19, T. 13 S., R. 16 E., the Curzon is only 2.3 feet thick and is overlain by channel sandstone of the Severy Shale. Channel sandstone of the Severy also rests on the eroded Curzon west of Watson in the NW¼ sec. 30, T. 12 S., R. 17 E.

The Curzon is predominantly limestone but has some thin beds of claystone near the middle. At most localities the Curzon is readily divisible into four limestone units, each of which is distinguishable from the others mainly by its weathered color and topographic expression. These units are varied in thickness, however, and their contacts are poorly defined.

The basal unit is medium-gray very finely crystalline very argillaceous limestone that weathers to thin moderate-yellowish-brown rubbly layers; it is generally less than 1 foot thick, and at many localities is not distinguishable from the overlying unit.

Overlying the basal unit is a ledge-forming unit of medium-light-gray to medium-gray very finely crystalline thin- to medium-bedded, compact limestone. Characteristically the upper 2 feet contains irregular masses of light-yellowish-brown, light-olive-brown, and brownish-gray to medium-dark-gray fossiliferous chert. The limestone is 4.5–6.5 feet thick and weathers light olive gray to moderate yellowish brown.

The third unit, 1–4 feet thick, consists of light-olive-gray and medium-light-gray to medium-gray very finely crystalline argillaceous to silty limestone interbedded with a lesser amount of light-olive-gray to medium-gray calcareous claystone. The limestone beds are very thin to thin, and the claystone is platy to very thin bedded. The mottled light-olive-gray and moderate-yellowish-brown appearance of the weathered rocks and the reentrant formed in the Curzon outcrop aid in distinguishing this unit.

The uppermost unit of the Curzon is 0.7–1.7 feet of light-olive-gray to olive-gray and medium-light-gray very finely crystalline argillaceous compact limestone that weathers moderate yellowish brown and forms a ledge. In places this ledge is vertically jointed, and the upper surface is platy and pitted.

Fossils are abundant in the Curzon and consist of algae, fusulinids, crinoid stems, echinoid debris, bryozoans, brachiopods, pelecypods, gastropods, and ostracodes. Fusulinids are abundant in the lower two units of the member, less abundant in the third unit of argillaceous limestone and claystone, and generally scattered in the uppermost limestone unit. Brachiopods and bryozoans are abundant in the middle units, and *Osagia* is commonly abundant in the upper unit. A composite list of forms from the Curzon Limestone Member in stratigraphic section 6, reported on by E. L. Yochelson (written commun., 1960), is as follows:

Osagia sp. indet.
Osagia? sp. indet.
Fusulinids, undet.
Crinoid plate and stem fragments

Echinoid spines
Rhomboporoid bryozoans
Ramose bryozoans
Fenestrate bryozoans (several genera)
Derbyia sp. indet.
Chonetes granulifer Owen
Neospirifer dunbari R. H. King
Composita subtilita (Hall)
Composita sp. indet.
Linoproductus sp. indet.
High-spired gastropod indet. (aff. "*Murchisonia*")

Fusulinids from the Curzon in stratigraphic section 6 compose USGS foraminiferal collections f12997 and f12998.

Jones Point Shale Member

The Jones Point was the name applied by Condra (1927, p. 51) to the shale below the Meadow (Sheldon) Limestone and above his Ervine Creek Limestone units at Jones Point, on the Missouri River east of Union, Nebr., but he mistakenly classified the Jones Point as the lower unit of the Calhoun Shale. Later work at Jones Point (Condra and Reed, 1937, p. 26) showed that this shale is not in the Calhoun and that the upper limestone beds of Condra's Ervine Creek are the Curzon Limestone Member, and therefore, that the Jones Point Shale Member at the type locality is between the Sheldon and Curzon Limestone Members. The correct position of the Jones Point in the Topeka Limestone in Kansas was also determined by Condra and Reed (1937, p. 6); previously Moore (1936a, p. 191) had included this shale in the Calhoun Shale. The type locality of the Jones Point Shale Member is in the bluffs on the west side of the Missouri River at Jones Point, east of Union, Nebr.

Except in a locality about 1½ miles northeast of Wakarusa and in the vicinity of Bauer Cemetery, about 1½ miles west of Watson, where the Severy Shale overlies the Curzon Limestone Member, the Jones Point Shale Member apparently occurs throughout the area. Outcrops, however, are limited to roadcuts, streambanks, and quarries.

The Jones Point is 2.4–5.8 feet thick; it is generally thicker in the northern part of its outcrop area. The member is light-olive-gray to medium-gray silty to locally finely sandy laminated to platy claystone that weathers light olive gray and olive brown. At some localities it is grayish-olive sandy siltstone containing stringers of fine-grained sandstone. Locally the member includes very thin lenses of olive-gray argillaceous limestone. A few brachiopods and pelecypods were noted locally; however, the member is apparently unfossiliferous in most exposures.

Sheldon Limestone Member

The Sheldon was the name proposed by Condra (130, p. 47) for the limestone bed in the Topeka Limestone that he (Condra, 1927, p. 51) had previously mistakenly correlated with the Meadow Limestone of the Lansing Group in Nebraska. Condra also mistakenly included the Sheldon as the middle unit of the Calhoun Shale above the Jones Point Shale and below the Iowa Point Shale Members. In 1933 Condra (p. 5) transferred the Sheldon Limestone and Jones Point Shale Members to the Deer Creek Limestone, but later both he (Condra, 1935, p. 11) and Moore (1936a, p. 191) returned to the original classification. Fieldwork by Condra and Reed (1937, p. 6) established that the correct position of the Sheldon is below the Turner Creek and above the Jones Point Shale Members; Moore, Frye, and Jewett (1944, p. 177) accepted this classification of the Sheldon for use in Kansas. The type locality of the Sheldon Limestone Member is in the Vilas Sheldon quarry, just east of Nehawka, Cass County, Nebr. (Moore, 1936a, p. 191).

The Sheldon ranges in thickness from 1.2 to 3.5 feet but commonly averages slightly less than 2 feet thick. The member is locally absent northeast of Wakarusa and along Tecumseh Creek west of Watson where the Severy Shale overlies rocks of the Topeka that are stratigraphically lower than the Sheldon.

The Sheldon is composed of light-olive-gray to medium-gray very finely crystalline very thin to thin-bedded hard compact limestone that is argillaceous in the lower 1 foot. It weathers light olive gray, dark yellowish orange, and moderate yellowish brown. The lower one-third of the member weathers to platy fragments, and the upper two-thirds forms a prominent ledge of knobby or tabular blocks. Much of the limestone has a pseudo-oolitic texture because of the small algae present. These textured zones are dispersed in the bed between zones of sublithographic limestone. Near Wakarusa small fragments of chert that weathers yellowish brown occur in the upper part.

The characteristic fossil of the Sheldon is *Osagia*, which is very abundant. Fragments of crinoids, echinoids, bryozoans, brachiopods, and gastropods are common. Fusulinids are sparse or absent in many areas of outcrop but they are fairly abundant southeast of Meriden and are very abundant in exposures along Rock Creek east of Meriden.

Turner Creek Shale Member

The Turner Creek was named by Condra (1927, p. 52) for the shale underlying the Du Bois and overlying the Curzon Limestone Members. Condra's Curzon apparently included all beds in the Topeka Limestone below the Turner Creek. In Kansas the base of the Turner Creek was placed at the top of the Hartford (Moore, 1936a, p. 197). Condra and Reed (1937) restudied the stratigraphic units in the Shawnee Group in Nebraska and adjacent States and reclassified the Sheldon Limestone Member as the unit underlying the Turner Creek Shale Member. In 1944 Moore, Frye, and Jewett (p. 177) accepted Condra and Reed's classification of the Turner Creek. The type locality of the member is along Turner Creek, southeast of Du Bois, Pawnee County, Nebr. (Condra and Reed, 1937, p. 48).

The Turner Creek Shale Member is 2.7–5.4 feet thick; however, in the areas northeast of Wakarusa, near Berryton, and near Watson, most or all of the member is absent, and the Severy Shale overlies beds stratigraphically lower in the Topeka. In the quarry immediately east of Forbes Air Force Base, as little as 0.6 foot of the member is present.

The Turner Creek is mainly claystone and siltstone but contains 2–5 thin limestone beds, principally in the middle and upper parts. Most of the claystone and siltstone is light olive gray to olive gray and laminated to very thin bedded. Locally both are slightly sandy and weather to small blocky fragments. At places the weathered claystone fragments are mottled by brownish-gray stain.

The limestone is light olive gray and medium gray to brownish gray, very finely crystalline to very fine grained, partly argillaceous, generally hard and compact, and in beds less than 0.1 foot thick to 0.5 foot thick. Very thin argillaceous limestone lenses occur in the claystone beds at some localities. The limestone is very fossiliferous, and well-preserved fossils are common on the upper surfaces of the beds. Thin beds of light-olive-brown silty platy sandstone occur in the Turner Creek near Lake Shawnee.

The limestone beds in the Turner Creek contain abundant brachiopods, gastropods, and pelecypods, as well as some specimens of *Osagia*, foraminifers(?), crinoid stems, and bryozoans. The claystone and siltstone beds are less fossilferous and contain mostly brachiopods and pelecypods. At a few localities the basal part of the Turner Creek Member contains abundant ostracodes and some minute carbonized plant remains. E. L. Yochelson (written commun., 1960) reported on the following fossils from this member:

Crinoid stem
Orbiculoidea sp. indet.
Derbyia sp. indet.
Chonetes? sp. indet.
Linoproductus sp. indet.
Juresania? sp. indet.
Numerous productoid spines
Myalinid pelecypod (cf. *Myalina* (*Orthomyalina*) sp. indet.)
High-spired gastropod, indet.
Ostracodes, undet.

Du Bois Limestone Member

The Du Bois Limestone Member was named by Condra (1927, p. 52) for exposures along Turner Creek southeast of Du Bois, Pawnee County, Nebr. Complete exposures of the Du Bois are sparse, but the upper part commonly crops out in pastures and on wooded slopes. Erosion during Severy time removed this member from much of the area from Wakarusa northeastward to Watson.

The Du Bois Limestone Member is generally a single vertically jointed bed 0.6–2.4 feet thick of olive-gray, medium-gray, and medium-dark-gray hard compact limestone. The limestone is very finely crystalline to very fine grained and locally slightly to very argillaceous. Streaks of dark-gray claystone occur in the upper 0.5 foot at many localities. The member weathers light olive gray, yellowish gray, and light yellowish brown and forms rectangular blocks that are platy at their tops. The rectangular blocks of compact limestone and the position of the member (underlying the black claystone of the Holt Shale Member) are characteristics which facilitate the identification of the Du Bois.

Osagia, bryozoans, brachiopods, pelecypods, and gastropods are abundant in the Du Bois. Crinoid stems, echinoid spines, and fusulinids are locally present though not common. At places fossil shells weather in relief along joints.

Holt Shale Member

The thin persistent dark claystone overlying the Du Bois Limestone Member and underlying the Coal Creek Limestone Member was called the Holt Shale Member by Condra (1927, p. 52) from the well-exposed rocks just below Forest City and northwest of Oregon, Holt County, Mo.

Exposures of the Holt show a dark band overlain by a lighter colored band. Dark fissile claystone fragments from the lower unit can be readily identified along streams and are thus an aid in locating the outcrop. Most or all of the Holt is missing over a broad area extending from the Osage County line southwest of Wakarusa northeastward to the vicinity of the Kansas Turnpike near the east border of the mapped area.

The Holt Shale Member, 1.7–3.5 feet thick, is composed primarily of claystone in two distinct units. The lower claystone, about 0.6–0.9 foot thick, is mainly medium dark gray to grayish black, but is in part olive gray to olive brown and is laminated to platy. Weathered claystone is fissile and medium dark gray, light olive gray, and dark yellowish brown. The upper, thicker unit is olive-gray to dark-gray slightly silty laminated to platy claystone that weathers light olive gray to olive brown. Along Deer Creek east of Topeka, a few very thin beds of medium-gray very fine grained argillaceous limestone occur in the upper claystone. At several localities near the Kansas River, the entire member is composed of dark-gray partly sandy laminated siltstone.

The lower claystone of the Holt contains some bryozoans, brachiopods, pelecypods, conodonts, and locally, ostracodes. The upper claystone contains abundant bryozoans, brachiopods, and pelecypods.

Coal Creek Limestone Member

The upper member of the Topeka Limestone was originally named the Union Limestone by Condra and Bengston (1915, p. 37), but, because that name was preempted, the name was changed to Coal Creek (Condra, 1927, p. 52). The type locality of the member is along Coal Creek about half a mile north of Union, Nebr.

The Coal Creek Limestone Member is absent from much of the outcrop belt of the Topeka Limestone south of the Kansas Turnpike owing to erosion in Severy time.

The Coal Creek, about 4.5 feet thick, consists of limestone interbedded with very thin layers of claystone and siltstone. The limestone is light olive gray, locally medium gray, very finely crystalline to very fine or fine grained, and argillaceous to silty. It occurs as very thin to thin beds that weather to nodular or platy fragments. Some limestone beds are composed primarily of shell fragments. The claystone and siltstone are light olive gray to olive gray, and calcareous and occur as beds generally less than 0.05 foot thick; however, a few beds are as much as 0.6 foot thick.

The abundance of fossils—particularly brachiopods—facilitates the identification of this member. The limestone beds contain the larger percentage of fossils. Crinoids and ramose, fenestrate, rhomboporoid, and incrusting bryozoans are also abundant; fusulinids are present locally. The Coal Creek Limestone Member contains the following fossils, reported by E. L. Yochelson (written commun., 1960):

USGS fossil locality 19447–PC (f12996). In stratigraphic section 6.

- Fusulinids, undet.
- Crinoid stems (large pieces)
- Fenestrate bryozoans
- Rhomboporoid bryozoans
- Incrusting bryozoans
- *Derbyia* cf. *D. crassa* (Meek and Hayden)
- *Cancrinella boonensis* (Swallow)
- *Juresania nebrascensis* (Owen)
- *Reticulatia huecoensis* (R. E. King)
- *Neospirifer dunbari* R. H. King
- *Composita subtilita* (Hall)
- "*Spiriferina*" *kentuckensis* (Shumard)
- *Hustedia mormoni* (Marcou)

USGS fossil locality 19448–PC. Along the Kansas Turnpike East Exchange Road in NE¼SW¼ sec. 3, T. 12 S., R. 16 E., Shawnee County.

Crinoid plate, indet.
Incrusting bryozoans
Ramose bryozoans
Juresania nebrascensis (Owen)
Reticulatia huecoensis (R. E. King)
Marginifera wabashensis (Norwood and Pratten)
Neospirifer dunbari R. H. King
Composita subtilita (Hall)
"*Spiriferina*" *kentuckensis* (Shumard)
Hustedia mormoni (Marcou)

WABAUNSEE GROUP

The Wabaunsee Group was originally called the Wabaunsee Formation by Prosser (1895, p. 688–697) and defined as the rocks between the base of the Cottonwood Limestone (now the lowest member of the Beattie Limestone of Permian age) and the top of the Osage coal (now the Nodaway coal bed of the Howard Limestone). Haworth (1898, p. 94) placed the base of the Wabaunsee at the top of the Scranton Shale, which is stratigraphically much higher than the Osage coal. Moore (1933, p. 94) redefined the group to include beds from the base of the Americus Limestone Member of the Foraker Limestone to the top of the Topeka Limestone. This change stratigraphically lowered both the upper and lower boundaries of the Wabaunsee. Condra (1935, p. 9) further restricted the Wabaunsee Group by placing its upper boundary at the top of the Brownville Limestone (now the upper member of the Wood Siding Formation); Moore (1936a, p. 200) concurred in this modification. The type locality of the group is Wabaunsee County, Kans.

That part of the Wabaunsee Group exposed in the mapped area comprises, in ascending order, the Severy Shale, Howard Limestone, Scranton Shale, Bern Limestone, Auburn Shale, Emporia Limestone, Willard Shale, Zeandale Limestone, Pillsbury Shale, and Stotler Limestone.

SEVERY SHALE (strat. section 7)

The name Severy Shale was first published by Haworth (1898, p. 66) on the basis of a proposal made by G. I. Adams in his field notes; the formation was named from exposures near Severy, Greenwood County, Kans.

The Severy underlies gently sloping country, but exposures are limited primarily to streambanks, roadcuts, and a few steep slopes. The Severy ranges in thickness from about 30 to 55 feet: near Meriden it is about 45 feet thick; in the subsurface southwest of Elmont, 40 feet thick; northeast of Topeka, 30–35 feet thick; and near the Wakarusa River about 55 feet thick.

The Severy Shale consists mainly of interbedded thin layers of claystone, siltstone, and sandstone, but it locally includes thick channel sandstones. Claystone and siltstone compose the bulk of the formation, but at some localities channel sandstone is the most conspicuous. The claystone and siltstone are generally light olive gray to olive gray and laminated to platy. The claystone is silty, and the siltstone is clayey to very finely sandy and micaceous. Both rock types contain minute particles of carbonaceous material and very small pyritic inclusions that weather moderate yellowish brown. A bed 0.2–1 foot thick light-olive-gray to olive-gray and medium-dark-gray silty to slightly sandy carbonaceous plastic indistinctly bedded claystone commonly occurs at the top of the Severy, in the position of an underclay, just beneath the Nodaway coal bed, which is the basal unit of the Howard Limestone in this area.

The sandstone in the Severy is light olive gray, yellowish gray, and medium dark to dark gray, very fine to fine grained, laminated to very thin bedded, and locally crossbedded. It is silty, micaceous, carbonaceous, and partly calcareous and contains many small pyritic nodules. Medium-light-gray siltstone and dark carbonaceous material commonly occur as fine laminae between the sandstone beds. The sandstone weathers light olive gray, light gray to light brownish gray, and pale to moderate yellowish brown and locally forms thick ledges, some containing large masses of crossbedded sandstone. A typical weathered outcrop of the formation is light olive gray and is covered with small hard yellowish-brown iron-stained fragments of siltstone and sandstone.

Channel deposits of the Severy Shale appear to be primarily sandstone, but some siltstone is present locally. The sandstone is similar in color and bedding to that in the normal stratigraphic sequence but generally is coarser grained and weathers to a pronounced brown color—olive brown, moderate yellowish brown, or reddish brown. The base of a channel deposit is generally evident, but because of poor exposures and the fact that the siltstone in the upper part of many channel fills is similar to that adjacent to the channel, the top could seldom be determined. A complete section of a major channel deposit could not be measured; however, a channel-sandstone unit south of Wakarusa is more than 20 feet thick. Channel deposits are most evident in the lower and uppermost parts of the Severy Shale but probably occur locally throughout the formation.

Except in areas of channeling, the Severy Shale rests conformably on the Topeka Limestone. A broad channel in the lower part of the Severy Shale extends northeastward for about 13 miles from Osage County to near the Kansas Turnpike, in the east-central part of the area (fig. 3). Along Towhead Creek, in the SE¼NW¼ sec. 35, near the south edge of the area, and along a road in the SE¼NW¼ sec. 36, T. 13 S., R. 15 E., channel sandstone rests directly on the Holt Shale Member of the Topeka Limestone. To the northeast, in the SE¼ sec. 25, T. 13 S., R. 15 E., the erosion extended into the Jones Point Shale Member of the Topeka; a short distance farther northeast, in the SW¼ sec. 19, T. 13 S., R. 16 E., the channel cut into the lower part of the Curzon Limestone Member. In the quarry just east of Forbes Air Force Base, the basal beds of the channel sandstone rest on strata ranging from the Holt Shale Member downward to within 0.6 foot of the base of the Jones Point Shale Member. Southeast of Lake Shawnee, in secs. 26 and 27, T. 12 S., R. 16 E., the channel appears to have cut stratigraphically down to the top of the Hartford Limestone Member. In a roadcut in the NW¼NW¼ sec. 30, T. 12 S., R. 17 E., the channel deposits overlie beds of the Curzon Limestone Member. A small channel in the upper part of the Severy Shale is exposed along the Kansas Turnpike in the SE¼ sec. 19, T. 12 S., R. 16 E.

Finely comminuted carbonaceous material occurs on many bedding planes throughout the formation. *Lingula* cf. *L. carbonari* (Shumard) was reported on by E. L. Yochelson (written commun., 1960) from a sandstone bed about 6 feet below the top of the Severy in the SW cor. sec. 22, T. 9 S., R. 17 E., Jefferson County (USGS fossil loc. 19450–PC).

HOWARD LIMESTONE (strat. sections 7, 8)

The name Howard Limestone was proposed by G. I. Adams in his field notes, but the first published usage of it was by Haworth in 1898 (p. 67). The type locality of the formation is near Howard, in Elk County, Kans., and the member is typically exposed in the NE¼ sec. 7, T. 29 S., R. 11 E. (Moore, 1936a, p. 204).

The Howard in the mapped area is composed, in ascending order, of the Aarde Shale, Church Limestone, Winzeler Shale, and Utopia Limestone Members. (In southern Kansas the basal member of the Howard is the Bachelor Creek Limestone.) Here the base of the Howard is placed at the base of the Nodaway coal bed of the Aarde Shale Member. Where the Nodaway coal is poorly exposed, the base of the Howard was mapped as at the base of the Church Limestone Member, which in most places is 2–4 feet above the base of the coal bed.

The Howard Limestone crops out in a belt that trends diagonally northeastward across the area. South of the Kansas River the Howard forms a distinct bench, but north of the river it is poorly exposed except near Meriden. The Howard is about 11–17 feet thick.

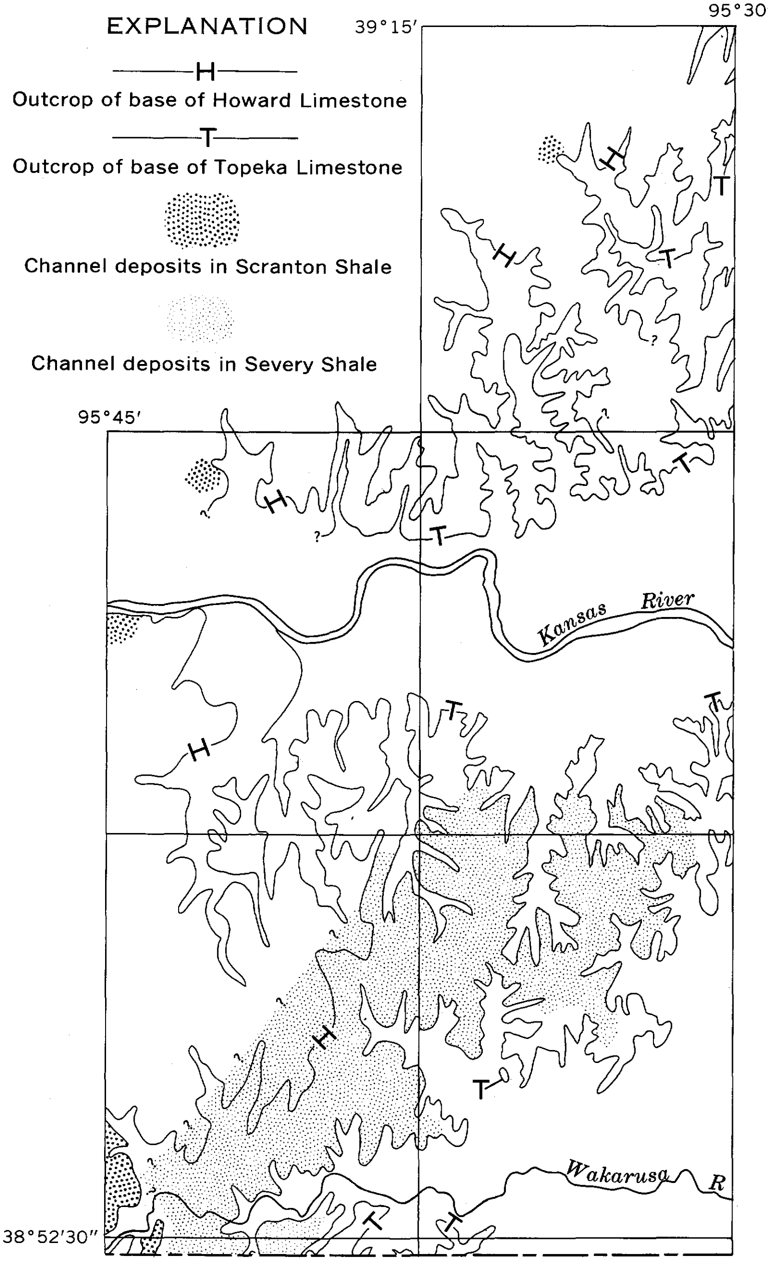

FIGURE 3.—Distribution of channel deposits in Severy and Scranton Shales relative to outcrops of Topeka and Howard Limestones in eastern Shawnee County and vicinity.

The Howard Limestone rests conformably on the Severy Shale throughout the area. At some localities the Howard is partly truncated, and near the southwest corner of the area is locally absent; where the Howard is absent, the overlying Scranton Shale rests on the underlying Severy Shale. The contacts of the members of the Howard Limestone are conformable.

Aarde Shale Member

The name Aarde was applied by Moore (1932, p. 94) to rocks cropping out on the Aarde farm, in sec. 4, T. 26 S., R. 11 E., Greenwood County, Kans. In the type area the Aarde comprises all beds between the top of the Bachelor Creek Limestone Member of the Howard Limestone and the base of the Church Limestone Member, including the very persistent Nodaway coal bed. Where the Bachelor Creek is missing, the Aarde Shale Member is restricted to those beds above the base of the Nodaway. Beede (1898, p. 29) applied the previously discarded name Shunganunga Shale to the few feet of beds between the top of the coal bed and the base of the Church Limestone Member.

The Aarde Shale Member is 0.8–8 feet thick, averaging about 3 feet thick, and consists of the Nodaway coal bed and the overlying claystone or siltstone. The Nodaway coal is brownish black to black and laminated to platy and has a hackly to subconchoidal fracture. Locally the lower part of the coal contains very thin partings of dark-gray to grayish-black finely laminated siltstone or claystone. Exposures of fresh coal are sparse; commonly only a thin coal smut marks the position of this bed. The Nodaway coal bed is 0.2–1.5 feet thick.

Most of the Aarde is light-olive- to dark-olive-gray, medium- to dark-gray, and grayish-black silty laminated to platy claystone. The claystone commonly weathers light olive gray to light olive brown or medium dark gray. A bed of dark-gray and dark-grayish-black to brownish-black claystone that weathers to conspicuous fissile slabs occurs near the middle of the member at many localities. Very thin stringers of coal occur locally above the Nodaway. In a few places the Aarde consists mainly of dusky yellow partly sandy siltstone. Along the Kansas Turnpike in the NW¼ sec. 25, T. 12 S., R. 15 E., the Aarde contains conspicuous lens-shaped bodies of siltstone (fig. 4) that lie 1 foot or more above the Nodaway coal bed. Locally the claystone in the upper part of the member contains small nodules and lenses of light-olive-gray to light-olive-brown clayey fossiliferous limestone. Just west of the area along Sixmile Creek, the Aarde includes several limestone beds about 1 foot thick.

Fossils are abundant in the Aarde at some localities and sparse at others. Crinoid stems, horn corals, bryozoans, and brachiopods are very abundant locally, but at other places the only fossils present are

FIGURE 4.—Lens-shaped siltstone deposits (L) in Aarde Shale Member of Howard Limestone along Kansas Turnpike in NW¼ sec. 25, T. 12 S., R. 15 E. Nodaway coal bed (N) at base of cut. Photograph by Ada Swineford, State Geological Survey of Kansas.

plant remains. The Aarde Shale Member includes the following forms, reported on by E. L. Yochelson (written commun. 1960):

USGS fossil locality 19449–PC (f12982). In roadcut in center of sec. 23, T. 10 S., R. 16 E., Shawnee County.

Small foraminifers, undet.
Fenestrate bryozoan fragments
Crurithyris planoconvexa (Shumard)
"*Spiriferina*" sp. indet.

Small foraminifers from the Aarde are also in USGS foraminiferal collection f12981, from stratigraphic section 8, and in f12980, from a streambank in the SE¼SE¼ sec. 2, T. 11 S., R. 15 E., Shawnee County. Additional forms from the Aarde, as reported on by Yochelson, include:

Horn corals, indet. (juvenile)
Crinoid stems, pieces
Orbiculoidea sp. indet.
Crurithyris cf. *C. planoconvexa* (Shumard)
Composita subtilita (Hall)
Chonetes sp. indet.

Marginifera cf. *M. wabashensis* (Norwood and Pratten)
Marginifera sp. indet.
Hustedia mormoni (Marcou)
Hustedia sp. indet.
Euphemites sp. indet.
Trilobite pygidium indet.

Church Limestone Member

The Church was named by Condra (1927, p. 54) from outcrops on the Church farm, on Turner Creek southeast of Du Bois, Nebr. The Church is the most resistant bed in the bench formed by the Howard Limestone. The member is 1.1–2.4 feet thick, and the limestone is light olive gray to olive gray and light gray to medium light gray, very finely crystalline, thin to thick bedded, hackly, hard, and compact. It generally weathers light to moderate yellowish brown or light olive gray and forms a single vertically jointed bed that commonly breaks into platy fragments in the upper 0.2–0.5 foot.

Crinoid stems, ramose and fenestrate bryozoans, brachiopods, and, locally, fusulinids and *Cryptozoon*-like algae are abundant in the Church. The following fossils from the Church Limestone Member were reported on by E. L. Yochelson (written commun., 1960):

USGS fossil locality 19451–PC. In stream in the NW¼NW¼ sec. 32, T. 10 S., R. 16 E., Shawnee County.
Algae? (*Cryptozoon*)
Crinoid stems
Fenestrate bryozoan
Chonetes granulifer Owen
Marginifera wabashensis (Norwood and Pratten)
"*Spiriferina*" cf. "*S*". *kentuckensis* (Shumard)
Aviculopecten sp. indet.
Neritacean gastropod, indet.
Ditomopyge? sp.

Yochelson also listed *Cryptozoon* and "oatmeal(?)," or platelet, algae and ostracodes collected from the Church in a roadcut on the west line of the NW¼SW¼ sec. 5, T. 10 S., R. 17 E.

Winzeler Shale Member

The Winzeler was named by Moore (1932, p. 94), and the type locality is on the Winzeler farm, in sec. 4, T. 26 S., R. 11 E., Greenwood County, Kans.

The member is 0.9–4.8 feet thick and averages about 3 feet thick. It is principally light-olive-gray silty laminated to platy claystone but includes light-olive-gray finely sandy micaceous siltstone. The claystone and siltstone weather light olive gray to light olive brown. One or more limestone beds as much as 1 foot thick occur mainly in the lower part at several localities. The limestone is light olive gray to medium light gray, clayey, platy to thin bedded, and fossiliferous.

It weathers light to moderate yellowish brown and light olive brown. The limestone bed in the basal part of the Winzeler along the Kansas Turnpike in the SE¼ sec. 26, T. 12 S., R. 15 E., is hard and compact and closely resembles the Church Limestone Member. A limestone bed showing cone-in-cone structure occurs locally in the upper 1 foot of the Winzeler near the Kansas River and southeast of Elmont.

Well-preserved fenestrate bryozoans are characteristic of the Winzeler, particularly of the lower part. The member also contains a sparse fauna of crinoid stems, ramose bryozoans, brachiopods, pelecypods, and ostracodes.

Utopia Limestone Member

The Utopia—the upper member of the Howard Limestone—was named by Moore (1932, p. 94), and the type locality is just east of the village of Utopia, in sec. 5, T. 25 S., R. 11 E., Greenwood County, Kans.

The Utopia, about 5–7 feet thick, is composed of a lower unit of limestone and claystone about 4 feet thick and an upper limestone unit 1.5–2 feet thick. The limestone beds crop out locally along streams. Limestone in the lower unit is mainly light olive gray to olive gray, light brownish gray, or medium to medium dark gray and very finely crystalline to very fine grained. It is argillaceous to silty, locally very finely sandy, and finely laminated to thin bedded. On weathering it becomes light olive gray to light yellowish gray and light olive brown to moderate yellowish brown.

Claystone occurs in beds as much as 0.8 foot thick in the middle and upper parts of the lower unit of the Utopia. The claystone is generally light olive gray, silty, and finely laminated to platy, and weathers light olive gray to light olive brown. Commonly a bed as much as 1 foot thick of dark-grayish-black to brownish-black claystone occurs near the middle of the lower unit. This bed weathers to hard fissile pieces and locally forms a thin ledge.

The upper limestone unit of the Utopia is generally light olive gray, very finely to finely crystalline, silty, platy to very thin bedded, and hard. It weathers light olive gray to light yellowish brown and in many places forms a thin ledge. Locally the uppermost part of the bed weathers to platy fragments, and along a tributary of South Branch Shunganunga Creek in the SE¼SW¼ sec. 36, T. 12 S., R. 15 E., the upper part weathers to hard concretionary masses 1.0–2.2 feet long and 0.5 foot thick. In a few places the upper unit of the Utopia contains many small subrounded ferruginous concretions that weather moderate yellowish brown.

The abundance of fusulinids and the paucity of other fossils are characteristic of the upper limestone unit of the Utopia. Fusulinids seem to be restricted to the upper unit. Abundant ostracodes and

Osagia are characteristic of the lower limestone and claystone beds, and carbonized plant fragments are common. The Utopia Limestone Member yielded the following fossils, which were reported on by E. L. Yochelson (written commun., 1960):

Upper limestone unit

Fusulinids, undet. (abundant). USGS colln. f12992, from stream in the NW¼NW¼ sec. 32, T. 10 S., R. 16 E., Shawnee County; f13000, from roadcut in the SE cor. sec. 21, T. 9 S., R. 17 E., Jefferson County; and f13001, from roadcut on the west line of the NW¼SW¼ sec. 5, T. 10 S., R. 17 E., Jefferson County.

- Crinoid stems
- Fenestrate bryozoans
- Rhomboporoid bryozoans
- *Derbyia*? sp. indet.
- *Composita* sp. indet.

Lower limestone unit

USGS fossil locality 19452–PC. In Rock Creek in the NW¼NW¼ sec. 6, T. 10 S., R. 17 E., Jefferson County.

- *Linoproductus* cf. *L. prattenianus* (Norwood and Pratten)
- *Composita* sp. indet.
- *Astartella* sp. indet.
- *Permophorus*? sp. indet.
- *Allorisma*? sp. indet.
- *Knightites* (*Retispira*) cf. *K.* (*R.*) *nodocostatus* (Gurley)
- *Glabrocingulum* sp. indet.
- *Glabrocingulum*? n. sp.
- *Stegocoelia* sp. indet.

The following forms were also collected from this locality but were not retained in the permanent collection:

- Algae? ("oatmeal" or pelletal)
- *Juresania* sp. indet.
- *Linoproductus prattenianus* (Norwood and Pratten)
- *Myalina* (*Orthomyalina*) cf. *M.* (*O.*) *subquadrata* (Shumard)
- Ostracodes, undet. (retained but not studied)

Other fossils listed by Yochelson from the Utopia are a bellerophontacean gastropod, a trilobite fragment, and inarticulate brachiopod fragments.

SCRANTON SHALE (strat. sections 8, 9, 10, 12)

The name Scranton was first proposed in 1907 by Bennett for the shale between the underlying Howard Limestone and the overlying Burlingame (now basal member of the Bern Limestone), according to Haworth and Bennett (1908a, p. 82); the name replaced the term "Burlingame Shale" that was previously applied to that stratigraphic unit. Moore (1936a, p. 210) discarded the name Scranton and raised the members of the Scranton to formational rank. In 1956 Moore and

Mudge (p. 2277) reintroduced the Scranton Shale as a formation. The name is derived from Scranton, Osage County, Kans., but, as no type section was designated when the formation was defined, Moore and Mudge (1956, p. 2277) designated a reference section along an eastward-flowing stream in the center of sec. 34, T. 12 S., R. 15 E., Shawnee County. The lower part of the formation, however, is not exposed at this locality.

The Scranton Shale comprises, in ascending order, the White Cloud Shale, Happy Hollow Limestone, Cedar Vale Shale, Rulo Limestone, and Silver Lake Shale Members. The Happy Hollow and Rulo were mapped in areas of good exposures, but they were not traced across the entire outcrop belt of the Scranton.

The lower part of the Scranton underlies low rolling country, and exposures commonly are poor. Generally the upper part is exposed in gullies in the steep slope of the escarpment capped by the overlying Bern Limestone.

The Scranton is about 140 feet thick west of Forbes Air Force Base. About 130 feet of the formation was measured in the south bluff of the Kansas River valley just west of the mapped area. The shale is 165 feet thick in the Murchison Federal Land Bank 1 well, southwest of Elmont. The Scranton is about 145 feet thick in a well just north of the mapped area, about 2½ miles northwest of the village of Rock Creek.

The formation is composed mainly of claystone and siltstone but includes a lesser amount of sandstone and some limestone. Throughout most of the area the Scranton Shale rests conformably on the Howard Limestone; however, channeling in the White Cloud Shale Member of the Scranton has locally removed part or all of the Howard. The contacts between the various members of the Scranton apparently are conformable.

White Cloud Shale Member

The White Cloud Shale Member, as originally defined by Condra (1927, p. 58), included all beds from the top of the Howard Limestone to the base of the Rulo Limestone Member and contained, in the upper part, the Happy Hollow Limestone Member. In 1930 Condra (p. 53) restricted the White Cloud to the beds between the Howard and the base of the Happy Hollow. The type locality is west of White Cloud, Doniphan County, Kans.

A complete section of the White Cloud was not measured in the area, but the thickness of the member is estimated to be 80–105 feet. More than 40 feet of the lower part of the member is exposed on the south side of the Kansas River valley in secs. 27 and 28, T. 11 S., R. 15 E.

The White Cloud is principally light-olive-gray to olive-gray and medium-gray silty platy claystone and light-olive-gray, light-brownish-gray, and medium-gray to medium-dark-gray sandy laminated to very thin bedded siltstone. Locally, light-gray to light-olive-gray fine-grained platy to very thin bedded sandstone constitutes a large percentage of the member. The sandstone is commonly micaceous and contains much finely comminuted carbonaceous material. In places the claystone and siltstone contain many small medium-dark-gray very fine grained hard compact sideritic concretions and pellets of pyrite; both the concretions and pellets weather moderate yellowish brown. Outcrops of the White Cloud are generally light olive gray to light olive brown. The outcrop is commonly broken by many very thin vertical fractures filled with siltstone that weathers to hard moderate-yellowish-brown chips.

Channel deposits in the White Cloud Shale Member are exposed at four localities, and others are undoubtedly present in the area but concealed. In some places near the southwest corner of the area, channeling has removed all the Howard Limestone, but in other places small remnants of the Church Limestone and Aarde Shale Members of the Howard remain. The channel appears to trend from Sixmile Creek in secs. 21 and 22, T. 13 S., R. 15 E., southward into Osage County (fig. 3). The west limit of the channel is roughly delineated by outcrops of the Howard Limestone; the east limit is not known but was probably east of Sixmile Creek. Outliers of the lower part of the Howard in the center of sec. 34, T. 13 S., R. 15 E., are apparently located within or close to the edge of the channel. The channel fill appears to consist primarily of interbedded claystone and sandy siltstone. Where the Howard Limestone is absent, the deposit could not be distinguished from similar beds in the upper part of the Severy Shale. The contact between the Scranton and Severy Shales was arbitrarily drawn on the map at the projected horizon of the base of the Howard Limestone.

A channel in the basal part of the White Cloud is excellently exposed along the south side of the Kansas River valley in the W½ sec. 27 and along the east edge of sec. 28, T. 11 S., R. 15 E. At the east end of the exposure, the base of the channel is about 22 feet above the top of the Howard Limestone; however, to the west the channel cuts to within 1 foot of the base of the Utopia Limestone Member of the Howard. Locally the base of the channel is marked by conglomeratic limestone as much as 1 foot thick composed of subangular to subrounded pebbles of weathered olive-gray to moderate-yellowish-brown hard compact very finely crystalline limestone in a matrix of light-olive-gray sandy micaceous limestone. The bed contains much pyrite and carbonaceous material, and a very thin coal stringer locally occurs at or near the base. In the deepest part of the channel a unit 15 feet thick of interbedded olive-gray sandy platy siltstone and very fine grained silty platy to medium-bedded sandstone directly overlies the conglomerate. Many very small mudstone chips occur on the bedding planes. Above this unit is more than 25 feet of very light gray to light-gray fine-grained calcareous sandstone in ledge-forming beds as much as 6 feet thick. The sandstone contains much mica and carbonaceous material. In this exposure the channel fill is overlain by sandstone that is stratigraphically higher in the White Cloud and that contains many thin discontinuous conglomerates composed mainly of ironstone fragments.

North of the Kansas River a channel in the basal part of the White Cloud is exposed in a roadcut in the NE cor. sec. 11, T. 11 S., R. 15 E. The base of the channel is marked by a conglomerate as much as 1.2 feet thick. The conglomerate is composed of pebbles and small cobbles of sideritic ironstone that weathers dark reddish brown and moderate yellowish brown and of granules and pebbles of light-greenish-gray claystone, embedded in a matrix of very fine grained sandstone containing much pyrite and carbonaceous material. This conglomerate lies about 12 feet above the top of the Howard Limestone. The rest of the exposed channel fill is interbedded laminated to very thin bedded siltstone and sandstone.

The channel deposit in the basal part of the White Cloud exposed in a streambank of Rock Creek north of Meriden in the NW¼NW¼ sec. 6, T. 10 S., R. 17 E., rests on the lower limestone unit of the Utopia Limestone Member of the Howard Limestone. The channel fill is made up of light-gray to light-yellowish-gray fine- to medium-grained very thin to thin-bedded sandstone which is very micaceous and contains much carbonaceous material. A very thin conglomeratic sandstone containing subangular pebbles of light-olive-gray dense ironstone that weathers dark reddish brown to moderate yellowish brown occurs at the base of the channel. Fossils are sparse in the White Cloud and are mainly carbonized plant remains; also, a few small pelecypods occur in the basal 1 foot.

Happy Hollow Limestone Member

The Happy Hollow was named by Condra (1927, p. 58), who included it as a bed in the White Cloud Shale Member. In 1930 Condra (p. 53) placed the top of the White Cloud at the base of the Happy Hollow, and recognized the Happy Hollow as a separate unit of the Scranton Shale. Moore (1936a, p. 209) discarded the name Scranton Shale and considered the Happy Hollow to be a formation, but later he and Mudge (1956, p. 2277) reintroduced the name Scranton Shale and included the Happy Hollow as a member. The type locality is in the bluffs at the mouth of Happy Holly Creek, in northeastern Doniphan County, Kans.

Outcrops of the Happy Hollow Limestone Member are sparse. The member was mapped with certainty only near the Kansas Turnpike close to the west edge of the area, where it crops out in streambanks and roadcuts. The Happy Hollow was not definitely recognized north of the Kansas River.

The Happy Hollow Limestone Member, 0.3–0.6 foot thick, is brownish gray to medium gray, very fine to fine grained, and very argillaceous to sandy. Commonly it weathers to moderate- to dark-yellowish-brown rough pitted cobbles; however, in some exposures it breaks into platy fragments. Locally the upper surface appears brecciated, and the bed contains many small masses of ferruginous limestone. A bed about 3.2 feet thick of light-olive-gray to olive-gray very argillaceous very thin to thin-bedded limestone, which may be equivalent to the Happy Hollow, caps a small hill in the NW cor. SW¼ sec. 35, T. 9 S., R. 16 E. The bed weathers light olive gray to moderate yellowish brown and contains many coaly and carbonaceous plant remains and, also, abundant *Chonetes*, *Marginifera*, and other brachiopods, crinoid stems, and gastropods. South of the Kansas River the member contains many crinoid stems, ramose bryozoans, small brachiopods, and pelecypods.

Cedar Vale Shale Member

The Cedar Vale was named by Condra (1930, p. 53) from exposures east of Cedar Vale, Chautauqua County, Kans. Moore (1936a, p. 212) stated that it is exposed in the east bluff of the Caney River in sec. 12, T. 34 S., R. 8 E.

The Cedar Vale is about 30–35 feet thick in the vicinity of the Kansas Turnpike near the west edge of the area. The complete thickness of the member north of the Kansas River could not be determined. In the Murchison Federal Land Bank 1 well, southwest of Elmont, the combined thickness of the Cedar Vale and White Cloud Shale Members is about 140 feet.

The Cedar Vale is primarily siltstone and some claystone. Both rocks are mainly light olive gray and medium light to medium gray and laminated to platy and weather light olive gray and light olive brown to moderate yellowish brown. The claystone is silty, and the siltstone is clayey to sandy, micaceous, and in part calcareous. In a few localities thick beds of light-olive-gray to medium-dark-gray very fine grained platy to very thin bedded sandstone occur in the member, but generally sandstone makes up only a small part. A few thin beds of brownish-gray fine-grained argillaceous fossiliferous limestone are also present.

A coal bed about 0.3 foot thick—the Elmo—occurs in the upper 1 foot of the Cedar Vale at most localities south of the Kansas River. The coal was not seen in outcrops north of the river, probably because of poor exposures; but a coal bed correlated with the Elmo was cut by the Murchison Federal Land Bank 1 well, southwest of Elmont.

Crinoid stems, fenestrate bryozoans, small brachiopods, pelecypods, and gastropods are locally abundant in the Cedar Vale, particularly in the limestone beds and in the beds above the Elmo coal. Well-preserved plant leaf and stem imprints are present on many bedding planes in the upper part.

Rulo Limestone Member

The Rulo was originally defined by Condra and Bengston (1915, p. 14) as the lowest member of the Nemaha Formation. Later Condra (1927, p. 58) considered the Rulo to be in the upper part of the Scranton Shale. Moore (1936a, p. 213) discarded the name Scranton Shale and raised the shale members—including the Rulo—to formational rank. Later he and Mudge (1956, p. 2277) returned to the usage of Condra, in which the Rulo is considered to be a member of the Scranton. The type locality is about 2.5 miles north of Rulo, Richardson County, Nebr.

The Rulo was mapped only in the southwestern part of the area and in a small area north of the Kansas River southwest of Elmont. Exposures are generally confined to streambanks and roadcuts. In places the Rulo forms a minor bench on the hillside, and hard limestone fragments are scattered on the outcrop. In the southwestern part of the area, the Rulo is 1.4 feet thick. North of the Kansas River the Rulo, apparently mostly limestone concretions, is only 0.2–0.4 foot thick; in a streambank in the SE¼SE¼ sec. 15, T. 10 S., R. 15 E., it is locally 4.1 feet thick.

The Rulo is olive-gray and medium-gray to medium-dark-gray very finely crystalline silty hard fossiliferous limestone that weathers light olive gray, light olive brown, or moderate yellowish brown. The upper and lowermost beds are very argillaceous and weather to platy fragments. Part of the Rulo weathers to hard concretions that have subconchoidal fracture. In much of the northern third of the area, a bed of concretions occurs about 20 feet below the top of the Scranton Shale and appears to be stratigraphically equivalent to the Rulo. The concretions are composed of silty limestone, are in part septarian, and have veins of light-gray and dark-brown calcite.

Brachiopods are generally abundant in the Rulo and are particularly evident on the surface of the limestone concretions. Crinoid stems, bryozoans, pelecypods, and gastropods are also common. The following is a list of fossils, by E. L. Yochelson (written commun., 1960), from the Rulo Limestone Member:

USGS fossil locality 19453–PC. In streambank in the SE¼SE¼ sec. 15, T. 10 S., R. 15 E., Shawnee County.

Crinoid stems
Fenestrate bryozoans
Chonetes granulifer Owen
Reticulatia huecoensis (R. E. King)
Marginifera cf. *M. wabashensis* (Norwood and Pratten)
Neospirifer dunbari R. H. King
Composita sp. indet.
Hustedia mormoni (Marcou)
Astartella sp.

These additional forms were also identified from the member by Yochelson:

Rhomboporoid bryozoans
Linoproductus prattenianus (Norwood and Pratten)
Linoproductus sp. indet.
Pelecypod, indet.
Platyceras sp. indet.
Low-spired gastropod, indet.
Cf. *Donaldina* indet.
Ostracodes, indet.

Silver Lake Shale Member

The Silver Lake, as originally defined by Beede (1898, p. 30), included the beds from the top of the Elmo coal bed (now defined as part of the Cedar Vale Shale Member) to the base of the Burlingame Limestone Member of the Bern Limestone; the Rulo Limestone Member was included in this unit. Condra (1927, p. 58) applied the name Silver Lake only to the beds between the top of the Rulo Limestone Member and the base of the Burlingame Limestone Member and designated the shale as the upper unit of the Scranton Shale. Moore (1936a, p. 214) discarded the name Scranton Shale and considered the Silver Lake to be a formation; however, he and Mudge (1956, p. 2277) later reintroduced the name Scranton Shale and included the Silver Lake as its upper member. The type area is near Silver Lake, Shawnee County, Kans.

The Silver Lake Shale Member crops out in the slope directly below the escarpment formed by the Bern Limestone and is the best exposed part of the Scranton Shale. The Silver Lake, about 19–26 feet thick, is composed of various proportions of interbedded claystone, siltstone, sandstone, and some limestone. In general, claystone is the principal rock, and siltstone and sandstone occur in roughly equal, but lesser, amounts. The claystone and siltstone are mainly light olive gray and medium light to medium dark gray and are generally laminated to platy. On weathering they become light olive gray, light gray, olive brown, and moderate yellowish brown. The claystone is silty and partly calcareous and in places contains thin lenses of limestone. The siltstone is clayey to sandy and generally micaceous. Locally the lower part of the member contains dense limestone concretions.

Sandstone in the Silver Lake is light olive gray to medium light gray, very fine grained, silty, micaceous, platy to thin bedded, and locally massive. Some layers show indistinctly formed crossbedding. A thick bed of sandstone occurs 5–8 feet below the top of the member northwest of Meriden. The sandstone forms a prominent face more than 13 feet high in the side of a butte in the SW¼NW¼ sec. 2, T. 10 S., R. 16 E.

Limestone beds as much as 3 feet thick are common in the upper part of the member but also occur locally in other parts. The limestone is generally light olive gray to olive gray or brownish gray, very finely to finely crystalline, and silty. It is very thin to thin bedded, locally forms hard compact concretions, and weathers light olive gray, olive brown, or dark yellowish brown.

Fossils in the Silver Lake Shale Member occur primarily in the limestone beds and include mainly crinoid stems, brachiopods, pelecypods, gastropods, and some specimens of *Osagia* and other algae. Some plant fragments are also present. E. L. Yochelson (written commun., 1960) reported on the following fossils collected by the authors:

USGS fossil locality 19454–PC. In roadcut in the center of the W½W½ sec. 26, T. 9, S., R. 16 E., Jackson County.

Algal growth (coating shells)
Myalina (*Orthomyalina*) *subquadrata* Shumard
Euphemites vittatus (McChesney)

USGS fossil locality 19455–PC. In stratigraphic section 12.

Crinoid stems
Echinoid plates
Brachiopod fragments, indet.
Bellerophon (*Pharkidonotus*) *percarinatus* (Conrad)
Paleostylus (*Pseudozygopleura*) sp. indet.
Ostracodes, undet.

BERN LIMESTONE (strat. sections 10, 11, 12)

The Bern Limestone was named by Moore and Mudge (1956, p. 2276–2277) and defined as the beds overlying the Scranton Shale and underlying the Auburn Shale. The formaton is named after the town of Bern, in northern Nemaha County, Kans., and the type section is in a roadcut in the SE¼SE¼ sec. 7, T. 1 S., R. 13 E., about half a mile north and 1 mile west of Bern. The Bern Limestone comprises, in ascending order, the Burlingame Limestone, Soldier Creek Shale, and Wakarusa Limestone Members.

The Bern Limestone caps outliers and forms a prominent escarpment south of the Kansas River along the west edge of the area, north of the river near Elmont, and northwest of Meriden. The limestone members form benches, which are separated by the covered slope underlain by the shale member.

In eastern Shawnee County and vicinity the Bern ranges in thickness from about 12 to 24 feet; it attains maximum thickness near Elmont. The Bern Limestone rests conformably on the Scranton Shale, and at most localities the contact is sharp and even. A transitional zone a few inches thick of very argillaceous limestone or very calcareous claystone occurs locally. The contacts between the members of the formation also are conformable.

Burlingame Limestone Member

The name Burlingame was applied by Hall (1896, p. 105) to the thick limestone that directly overlies the Scranton Shale. Moore and Haynes (1917, p. 106) classified the Burlingame as a member of the Wabaunsee Formation. Later Moore (1936a, p. 200, 215) raised the Wabaunsee to group rank and included the Burlingame as a formation. Moore (1936a, p. 215–216) also pointed out that the overlying Soldier Creek and Wakarusa had previously been included by various authors in the Burlingame, but he restricted the Burlingame to include only the lower limestone, seemingly in accord with Hall's original description. In 1956 Moore and Mudge (p. 2277) classified the Burlingame as the lower member of the newly defined Bern Limestone. The type locality is in Burlingame, Kans., where the member forms a fairly prominent escarpment through the western part of town.

Thickness of the Burlingame Limestone Member varies markedly from place to place. At the north edge of the area, north of Meriden, the Burlingame is only 1.6 feet thick, but along U.S. Highway 75 in the SE cor. sec. 31, T. 9 S., R. 16 E., it is 11.8 feet thick.

The Burlingame is generally a single bed composed of two distinct limestone lithologies. Over much of its outcrop area north of the Kansas River, it is composed of irregular, generally elongate, subangular to subrounded fragments of light-gray to light-olive-gray very finely crystalline hard compact sparsely fossiliferous limestone in a matrix of very fine grained argillaceous compact limestone (fig. 5). The fragments may be jumbled or arranged in irregular layers and are generally alined with the convex side down (fig. 6). They have subconchoidal fracture, and each is generally partly rimmed with a dark very thin algal(?) layer. The fragments weather dark yellowish brown, the matrix weathers pale yellowish orange to pale yellowish brown, and the outcrop is generally mottled light olive gray to moderate yellowish brown. The limestone is in thin to medium uneven beds.

In areas where the Burlingame shows little or no brecciation, as south of the Kansas River, northwest of Meridian, and at localities

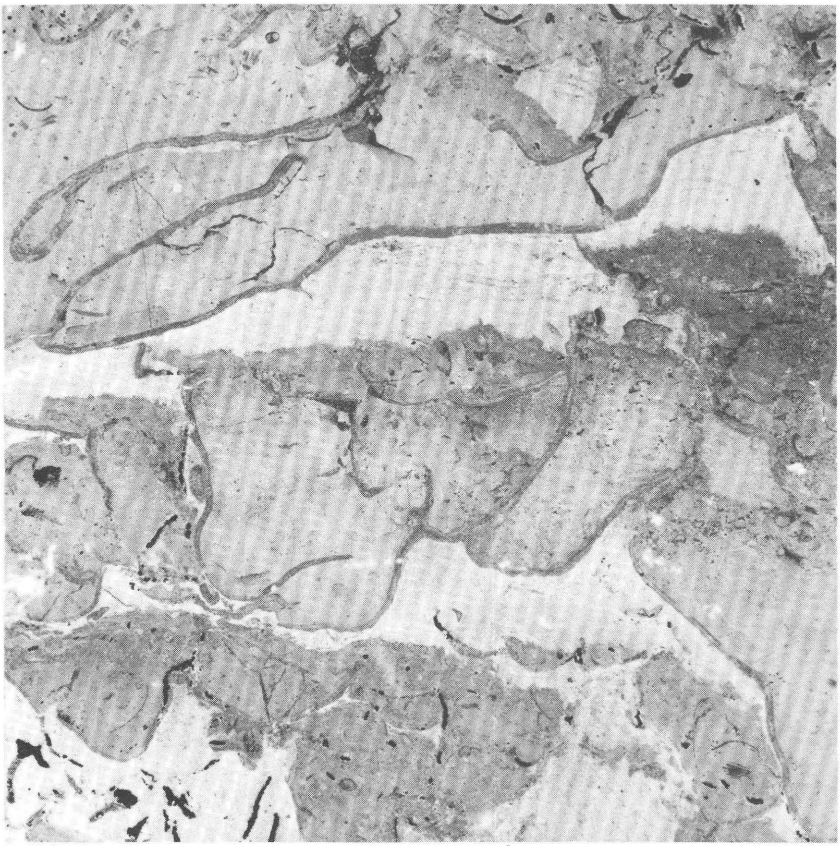

FIGURE 5.—Brecciated part of Burlingame Limestone Member of Bern Limestone in quarry in NW¼SE¼ sec. 14, T. 10 S., R. 15 E. Note dark algal(?) layer beneath limestone fragments. Light-colored matrix of very fine grained limestone. Vertical peel print, × 2, courtesy of D. E. Owen.

southeast of Hoyt, the limestone is generally light olive gray and medium light gray to medium gray, very finely crystalline, slightly argillaceous, thin to thick bedded, hard, compact, and very fossiliferous. Locally the lower 0.2 foot is more argillaceous and weathers to rubble. Where both limestone lithologies occur in the same outcrop, the brecciated limestone always forms the upper part.

At several localities a light-gray silty very calcareous claystone is present in the lower 1 foot of the Burlingame. The upper and lower contacts of the claystone are uneven and gradational, and laterally this unit probably grades to limestone. The claystone is poorly exposed in the SE cor. sec. 31, T. 9 S., R. 16 E., where it is 0.8 foot thick, and is well exposed in a roadcut in the SE¼SW¼ sec. 34, T. 10 S., R. 15 E., where it is 0.2 foot thick.

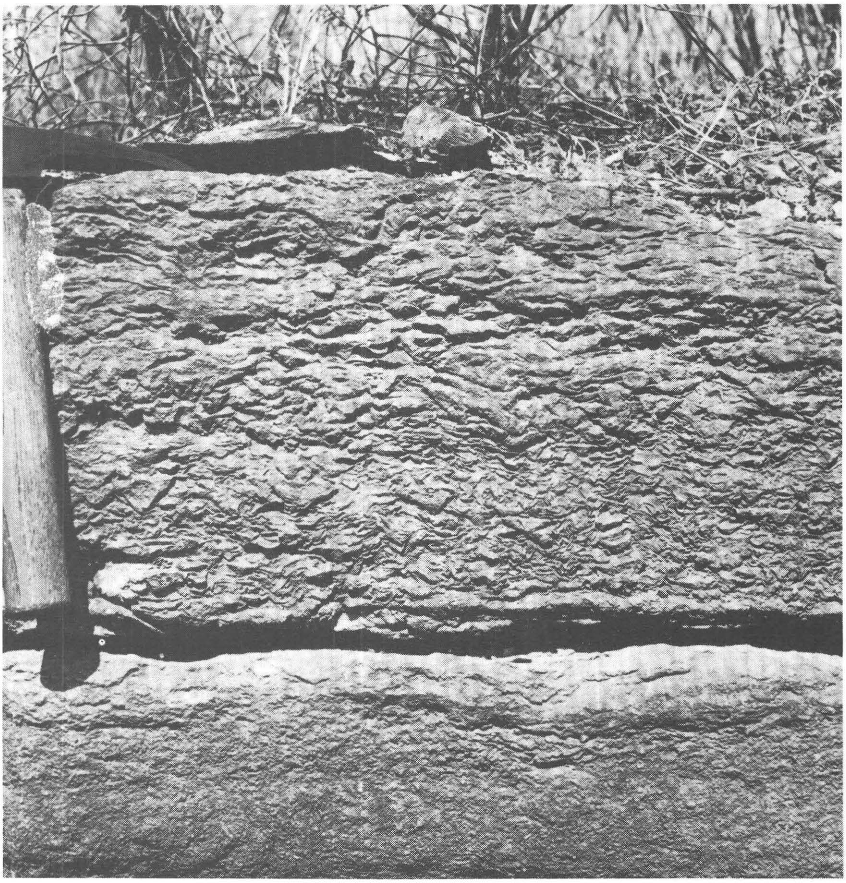

FIGURE 6.—Weathered brecciated part of Burlingame Limestone Member of Bern Limestone in roadcut in NW¼NE¼ sec. 36, T. 10 S., R. 14 E., about 3 miles west of mapped area.

Fossils are common but not abundant in the brecciated part of the Burlingame, and abundant in the nonbrecciated part. Fusulinids and *Osagia* are particularly abundant in the nonbrecciated part. In places small gastropods are abundant in the basal part of the member. The Burlingame Limestone Member includes the following fossils, reported on by E. L. Yochelson (written commun., 1960):

Osagia (or a similar algal growth)
Fusulinids, undet. (abundant)
Dibunophylloides sp.
Crinoid stems
Echinoid spines
Fenestrate bryozoan fragments
Rhomboporoid bryozoans

Neospirifer dunbari R. H. King
Composita subtilita (Hall)
Derbyia crassa (Meek and Hayden)
Chonetes granulifer Owen
Chonetes sp. indet.
Linoproductus sp. indet.
Productid brachiopods, indet.
Enteletes? sp. indet.
Abundant shell fragments, indet.

Fusulinids from the Burlingame are retained in the following USGS foraminiferal collections: f12976, from stratigraphic section 10; f12978, from a roadcut on the west line of the NW¼SW¼ sec. 19, T. 9 S., R. 17 E., Jefferson County; and f12979, from a railroad cut in the SE¼SW¼ sec. 2, T. 10 S., R. 15 E., Shawnee County.

Soldier Creek Shale Member

The name Soldier Creek was applied by Beede (1898, p. 30) to the shale between the top of his Stanton Limestone and the base of his Wakarusa. According to Moore (1936a, p. 219), however, Beede's original Wakarusa Limestone is the unit now called the Reading Limestone Member of the Emporia Limestone, and the Wakarusa Limestone Member of the Bern Limestone of the present usage was in the upper part of Beede's Stanton Limestone. Condra (1927, p. 77) unintentionally transposed the name Wakarusa to the first limestone above the top of the Burlingame and designated as the Soldier Creek the shale between the two limestones. Condra's usage had widespread application, and Moore (1936a, p. 218–220) recognized the error of the correlations with the Wakarusa and the Soldier Creek at their type areas but argued that usage rather than priority should be followed in applying names to those two units. Thus the present application of the names Wakarusa and Soldier Creek is modified from that of Beede, but the sequence of units is the same. No type locality for the Soldier Creek Shale Member was designated, although Moore (1936a, p. 218) stated that it is presumably on Big Soldier and Little Soldier Creeks about 3 miles from Silver Lake, Shawnee County, Kans. (west of the mapped area).

In the Soldier Creek, pronounced differences in thickness occur within short distances; the range in thickness is from 2.6 to 15.2 feet. Southwest of Elmont the Soldier Creek is 7.4 feet thick in a quarry in the NW¼ sec. 26, T. 10 S., R. 15 E., but it abruptly thickens to 15.2 feet in a quarry in the northeast quarter of the section. The Soldier Creek is thinnest in the NE cor. sec. 6, T. 10 S., R. 16 E., where the Burlingame Limestone Member attains its maximum thickness.

The Soldier Creek is composed mainly of claystone, but one or two beds of limestone are generally present in the middle or upper parts.

The claystone is typically light olive gray to olive gray and medium gray; however, some is light greenish gray and medium dark gray to dark gray. It is partly silty, laminated to platy and partly calcareous and weathers to shades of olive gray mottled with light olive brown. Some very calcareous claystone weathers to yellowish-orange boxwork.

Limestone of the Soldier Creek is mainly light olive gray and medium light gray, very finely crystalline, very argillaceous in part, and very thin to medium bedded. Some beds are coquinoidal; others are dense very argillaceous unfossiliferous limestone that weathers to olive-gray or yellowish-orange rubble, some of which is nodular or cellular.

Locally along the Kansas Turnpike, moderate-yellowish-orange to dark-yellowish-orange and moderate-yellowish-brown very fine grained silty sandstone is present in the upper part of the member and is interbedded with siltstone in the lower part. A very thin streak of coal occurs in the member in a quarry in the SE¼ sec. 14, T. 10 S., R. 15 E.

Fossils in the Soldier Creek are confined primarily to the limestone and claystone beds in the basal and uppermost parts. Pelecypods and gastropods, some of which may be bellerophontacean forms (E. L. Yochelson, written commun., 1960), are very abundant in some beds; *Osagia*, crinoid stems, bryozoans, brachiopods, and carbonized plant material are also present.

Wakarusa Limestone Member

The name Wakarusa was originally given by Beede (1898, p. 30) to a limestone bed about 40 feet above the top of his Stanton (Burlingame Limestone Member) Limestone. Subsequent fieldwork showed, however, that Beede's Wakarusa was actually the present Reading Limestone Member of the Emporia Limestone (Moore, 1936a, p. 219), and the Wakarusa, as used by Condra (1927, p. 77) and other authors, is equivalent to the upper part of Beede's Stanton Limestone. Because Condra's use of the name Wakarusa had been applied extensively in publications, Moore (1936a, p. 218–220) believed that it would be desirable for usage to take precedence over priority of definition in application of the name. In present usage, therefore, the Wakarusa Limestone Member of the Bern Limestone is the first thick limestone above the top of the Burlingame Limestone Member and is underlain by the Soldier Creek Shale Member.

The Wakarusa is present along the Wakarusa River just south of Auburn (west of the mapped area), at the type locality of the Wakarusa Limestone as defined by Beede; however, its exposures are better along the North Branch Wakarusa River about 1 mile west of Auburn. The Wakarusa forms a narrow inconspicuous bench on the hillside above the ledge or escarpment of the Burlingame Limestone Member. In good exposures the Wakarusa crops out as a dual ledge, in which the upper bed is the thicker and more prominent.

The Wakarusa is 3–4.3 feet thick and generally consists of two limestone beds separated by claystone. The limestone is typically light olive gray, although it is medium gray to brownish gray locally. It is very finely crystalline, very thin to medium bedded, hard, and compact and generally weathers various shades of olive gray, yellowish brown, or yellowish orange. The lower limestone is typically a single bed 0.4–2 feet thick; generally it is less than 1 foot thick. In some localities a thin claystone parting occurs in the upper part of the lower limestone. The upper limestone, about 2 feet thick, is vertically jointed, and weathers to large angular blocks. Locally the uppermost part of the upper limestone weathers to platy fragments.

Claystone of the Wakarusa is light olive gray to olive gray, silty, laminated to platy, and calcareous and weathers light olive gray and, locally, yellowish brown or yellowish orange. Thin lenses of argillaceous fossiliferous limestone occur at many localities. The claystone is 0.3–1.3 feet thick and has upper and lower contacts that are generally uneven and gradational. In a few places along the Kansas Turnpike, yellowish-gray sandstone is present between the limestone beds of the Wakarusa.

Fossils are abundant and varied. The lower limestone is characterized by small fusulinids, crinoid stems, and *Osagia* and other incrusting algae. The upper limestone contains two distinct fossil zones: the lower 1 foot (one zone) is characterized by an abundance of crinoid remains (mainly stems) and the absence of fusulinids; the upper part (the second zone) is characterized by an abundance of large fusulinids. Brachiopods are numerous in all beds and *Cryptozoon*-like algae are conspicuous in relief on the weathered upper limestone. Small fossil fragments, particularly in the upper limestone, are light reddish brown, probably from an algal coating. The Wakarusa Limestone Member contains the following fossils, reported on by E. L. Yochelson (written commun., 1960):

USGS fossil locality 19457–PC (f12975). In stratigraphic section 10.

- Fusulinids, undet. (abundant)
- Crinoid stems
- Fenestrate bryozoans, indet.
- *Derbyia* cf. *D. crassa* (Meek and Hayden)
- *Chonetes granulifer* Owen
- *Reticulatia huecoensis* (R. E. King)
- *Marginifera wabashensis* (Norwood and Pratten)
- *Composita subtilita* (Hall)
- "*Spiriferina*" *kentuckensis* (Shumard)
- *Hustedia mormoni* (Marcou)

Additional forms (not from locality 19457–PC) include:

Lamellar algae (of *Ivanovia* type)
Algae (*Cryptozoon*? type)
Rhomboporoid bryozoan
Composita cf. *C. subtilita* (Hall)
Hustedia sp. indet.
Wellerella? sp. indet.
Pectenoid? pelecypod, indet.
Cephalopod?, indet.

In addition to collection f12975 (loc. 19457–PC) just mentioned, fusulinids from the Wakarusa are retained in USGS foraminiferal collections f12973, from a quarry in the center of the NW¼ sec. 26, T. 10 S., R. 15 E., Shawnee County; f12977, from a roadcut on the west line of the NW¼SW¼ sec. 19, T. 9 S., R. 17 E., Jefferson County (east of the mapped area); and f12990, from stratigraphic section 12.

AUBURN SHALE (strat. section 12)

The Auburn Shale was named by Beede (1898, p. 30) for the shale overlying his Wakarusa Limestone and underlying the Elmont Limestone, but, because Beede's Wakarusa is equivalent to the present Reading Limestone Member of the Emporia Limestone, the term Auburn was originally applied to the present Harveyville Shale Member of the Emporia. Condra (1927, p. 78) applied the name Auburn to the shale underlying the Reading and overlying the Wakarusa of present usage, and this definition has been generally accepted. Although Beede did not designate a type locality, undoubtedly it is near Auburn, Kan. There are good exposures of the Auburn Shale along the Kansas Turnpike in the NE¼SW¼ sec. 35, T. 13 S., R. 14 E., southwest of Auburn.

Typically, the Auburn Shale forms a fairly steep vegetation-covered slope, in which exposures are confined to stream gullies and roadcuts. Along the west side of the area, south of Topeka, a limestone bed in the upper part forms a pronounced hillside bench. The Auburn is about 25–30 feet thick north of the Kansas River and about 45 feet thick south of the river. The Auburn rests conformably on the Wakarusa Limestone Member of the Bern Limestone, and its basal contact is sharp and even.

The Auburn is primarily claystone but includes some thin beds of siltstone and limestone. The claystone is generally light olive gray to olive gray, silty, finely laminated to platy, and partly calcareous. The blocky fragments on the weathered outcrop are light olive gray to light yellowish gray. A dark-gray to grayish-black finely laminated to platy hard siltstone that is generally 0.7–0.9 foot thick occurs 11–13 feet below the top of the formation. This siltstone weathers to fissile plates and forms a hard bed that, together with an underlying light-colored claystone, is very conspicuous. Thin beds and lenses of light-olive-gray to light-yellowish-gray very finely crystalline argillaceous very fossiliferous limestone are present in the upper 10 feet of the Auburn Shale. The beds are generally less than 0.2 foot thick, but near the edge of the area, northwest of Elmont, they are as much as 1.3 feet thick.

Fossils in the Auburn Shale are confined mainly to the dark siltstone and overlying limestone and claystone in the upper part. The siltstone contains very abundant ostracodes and many small brachiopods, probably *Lingula*. Crinoid stems, bryozoans, *Chonetes*, *Neospirifer*, and other brachiopods and myalinid pelecypods are abundant in the overlying beds. E. L. Yochelson (written commun., 1960) reported on the following forms from these beds:

USGS fossil locality 19456-PC. In stratigraphic section 12.
Crinoid stems
Linoproductus prattenianus (Norwood and Pratten)
Cancrinella cf. *C. boonensis* (Swallow)

EMPORIA LIMESTONE (strat. sections 12, 13)

The Emporia Limestone was named by Kirk (1896, p. 80) from exposures at Emporia, Kans., but considerable ambiguity existed as to just what limestone beds Kirk intended to include in the Emporia. So, Condra (1927, p. 78) redfined the Emporia as the limestone unit underlain by the Auburn Shale and overlain by the Willard Shale. The Emporia Limestone consists, in ascending order, of the Reading Limestone, Harveyville Shale, and Elmont Limestone Members. The type section of the Emporia was not clearly defined by Kirk, but the formation is well exposed along U.S. Highway 50 a few miles east of Emporia (Mudge and Burton, 1959, p. 17).

The Emporia forms a low escarpment or hillside bench, but exposures are confined mainly to streambanks and roadcuts. Thickness of the formation is uniform and ranges from about 16 to 20 feet. The contact between the Emporia and the underlying Auburn Shale is conformable and even. The contacts between the members of the Emporia are also conformable.

Reading Limestone Member

The Reading was originally designated by Smith (1903, p. 100) as the Emporia Blue Limestone, but he later renamed it the Reading Blue Limestone (1905, p. 150). Moore (1936a, p. 224) deleted the term "blue" from the name and regarded the Reading as the lower formation of the Emporia Limestone. In 1956 he and Mudge (p. 2276) reduced the Reading in rank to that of lower member of the Emporia. The type locality is near Reading, Lyon County, Kans., according to Moore (1936a, p. 224), who listed excellent exposures in a roadcut near the NW cor. sec. 33, T. 17 S., R. 13 E., about 1 mile northwest of the town.

The Reading Limestone Member is 1.8–2.6 feet thick and is typically medium gray, very finely crystalline, thin to thick bedded, hard, and compact and, in part, has subconchoidal fracture. The member consists of two or three beds, the upper of which is a 0.3-foot-thick bed of slightly argillaceous limestone that weathers moderate to dark yellowish brown and forms a step that is set back slightly from the outcrop face. Characteristically the weathered limestone blocks of the Reading are mottled light olive gray and moderate yellowish brown, and the zone of weathering extends deep into the rock. Dark limonite stains are generally conspicuous on the upper surface. Locally, small inclusions of light-red barite are in the Reading. In the SW¼NE¼ sec. 10, T. 10 S., R. 15 E., an intraformational breccia about 0.4 foot thick occurs approximately 1.8 feet above the base.

The Reading is characterized by an abundance of crinoid stems that weather white and stand out in relief. Brachiopods are also abundant, and large fusulinids are common but are generally not conspicuous. Fossils from the Reading Limestone Member, reported on by E. L. Yochelson (written commun., 1960), include:

Fusulinid, indet. (probably USGS colln. f12956A, from strat. section 12)
Lophophyllidid coral
Crinoid stem
Rhomboporoid bryozoan
Echinoconchus moorei Dunbar and Condra

Harveyville Shale Member

The first to formally describe the Harveyville was Moore (1936a, p. 226), although Condra (1935, p. 10) was the first to publish the name. Condra classified the Harveyville as the middle member of his Preston (now known to be the Emporia) Limestone, but Moore gave the shale formational rank. Moore and Mudge (1956, p. 2276) reduced the Harveyville to member rank in the Emporia Limestone. The type locality, according to Moore (1936a, p. 226), is near Harveyville, southeastern Wabaunsee County, Kans. Mudge and Burton (1959, p. 18) stated that the member is not exposed in that part of the county, but according to Moore (1936a, p. 226), it is exposed in sec. 25, T. 15 S., R. 13 E., in Osage County.

The Harveyville Shale Member crops out in the northwestern part of the area, where it is 10.5–14.4 feet thick. South of the Kansas River only the basal part of the Harveyville is present.

The member is composed of light-olive-gray to olive-gray silty claystone that weathers to light-olive-gray blocky fragments. At most localities the claystone contains abundant very small nodules of very light gray, very light olive gray, or light-olive-brown limestone. Ferruginous siltstone is present locally in very thin lenses and pellets that weather moderate yellowish brown. Except for a few shell fragments in the upper part, the Harveyville is unfossiliferous.

Elmont Limestone Member

Beede (1898, p. 30) named the Elmont, and Condra (1935, p. 10) included it as the upper member of his Preston (Emporia) Limestone. Moore (1936a, p. 226–227) classified the Elmont as a formation, but later he and Mudge (1956, p. 2276) redefined the Elmont as a member of the Emporia Limestone. The type locality is near Elmont, in northern Shawnee County, Kans.

The Elmont, 3.3–4.6 feet thick, is predominantly limestone but in places contains thin claystone partings. The basal 0.5–1 foot consists of pale-olive, light-brownish-gray, or light-yellowish-brown very finely crystalline very thin to thin-bedded algal-molluscan limestone. A few angular to round dark-gray limestone pellets are present, particularly in the upper part of this basal limestone. Overlying the algal-molluscan limestone at many localities is a medial bed of argillaceous unfossiliferous limestone about 2 feet thick that weathers to light-olive-gray to light-yellowish-gray blocks containing many inclusions of light-yellowish-brown and light-yellow calcite. In places a thin light-olive-gray to light-greenish-gray silty claystone is also present in this medial part. Near the north edge of the area, the medial part contains a medium-gray to light-brownish-gray hard dense partly conglomeratic limestone 1.2–1.3 feet thick which overlies the argillaceous limestone. The conglomeratic limestone consists of very small angular to subrounded pebbles of light-olive-gray to dark-gray dense limestone. The upper unit of the member is a single vertically jointed light-olive-gray very finely crystalline hard compact fossiliferous limestone bed about 1 foot thick. The upper 0.1 foot of this bed is slightly argillaceous and weathers to platy fragments.

Distinct faunal assemblages in the various parts of the Elmont aid in identifying this member. Algae, pelecypods, and some bryozoans and foraminifers are present in the basal bed, ostracodes and pelecypods occur near the middle, and small fusulinids and brachiopods are characteristic of the upper bed. The fossil fragements in the upper limestone are commonly reddish brown—a characteristic which aids in identifying the bed. The few fossils collected by the authors from the Elmont Limestone Member were identified by E. L. Yochelson (written commun., 1960) as follows:

Algae (lamellar)
Algae? (pelletal or "oatmeal")
Myalina (*Orthomyalina*) sp. indet.

Septimyalina? sp. indet.
Shell fragments, indet.
Ostracodes, undet.

WILLARD SHALE (strat. sections 12, 13)

The name Willard Shale was applied by Beede (1898, p. 31) to the shale that overlies the Elmont Limestone Member of the Emporia Limestone and underlies the Tarkio Limestone Member of the Zeandale Limestone. The type locality is near Willard, on the Shawnee County–Wabaunsee County line, and exposures are good in cutbanks along Post Creek south of the town.

The Willard Shale forms a relatively steep slope between the Emporia and Zeandale Limestones, but is well exposed only along streams and in roadcuts. The Willard is 40–47 feet thick. Claystone forms the major part of the formation, but thick sandstones are also present (principally in the upper part), and in places siltstone is interbedded with the claystone. The claystone is generally light olive gray, silty, and platy and weathers light olive gray to light olive brown. The siltstone is sandy, and micaceous and similar in color to the claystone. Weathered outcrops are covered with pencil-shaped siltstone fragments and are broken by narrow nearly vertical fractures filled with siltstone. Sandstone of the Willard is light yellowish gray to light olive gray, very fine grained, partly silty, and micaceous. Locally it contains concentric-weathering ferruginous concretions as much as 0.6 foot in diameter. Bedding planes are markedly stained by limonite. The weathered outcrop is light olive gray mottled with pale to moderate yellowish brown.

The Willard Shale rests conformably on the Emporia Limestone, and the contact is sharp and even. Except for a few crinoid stems locally present in the lower few feet, the Willard is unfossiliferous.

ZEANDALE LIMESTONE (strat. sections 13, 14)

The Zeandale Limestone was named by Moore and Mudge (1956, p. 2276) for the town of Zeandale, in southeastern Riley County, Kans. The type section is in the SE¼NE¼NE¼ sec. 28, T. 10 S., R. 9 E., along a north-south farm-access road a quarter of a mile south of Zeandale (Mudge and Burton, 1959, p. 21). The Zeandale Limestone is divided into three members, which are, in ascending order, the Tarkio Limestone, Wamego Shale, and Maple Hill Limestone Members.

The Zeandale Limestone, 15–18 feet thick, forms a fairly low but distinct bench in much of its outcrop area in the northwestern part of the mapped area. Exposures of the lower part of the formation are generally good, but the upper part crops out only in roadcuts and along steep gullies.

The Zeandale Limestone rests conformably on the Willard Shale, and the basal contact is sharp and slightly uneven. The contacts between the individual members of the Zeandale are also conformable.

Tarkio Limestone Member

The Tarkio was originally termed the "Chocolate limestone" (Swallow, 1867, p. 67). Calvin (1901, p. 420, 430) applied the name Tarkio to a limestone exposed in Tarkio Creek, north of Coin, Page County, Iowa. Condra and Bengston (1915, p. 8) assigned the name Tarkio to the upper limestone of their Nemaha Formation and listed the next lower limestone of that formation as the Preston (Emporia). Later Condra (1927, p. 63–64, 71) stated that the Tarkio was the "Chocolate limestone" in Kansas and that it overlies the Willard Shale, but in 1934 Condra (Moore, 1936a, p. 229), after studying the type locality of Calvin's Tarkio, concluded that the Tarkio was correlative to the beds in Kansas called the Emporia Limestone. Because the type locality on Tarkio Creek in Page County, Iowa, does not contain beds now described as the Tarkio, Moore (1936a, p. 230) designated as the type section the exposures of the Tarkio noted by Swallow (1867, p. 67) on Mill Creek, southwest of Maple Hill, Wabaunsee County, Kans.

The prominent ledge formed by the Tarkio is broken by widely spaced vertical joints, and commonly, weathering produces many large holes in the limestone blocks. The Tarkio is 1.8 to about 4.5 feet thick and commonly comprises two limestone units separated at many places by a claystone about 0.3 foot thick. The limestone is light olive gray, very finely crystalline, slightly argillaceous, thin to medium bedded, hard, and compact. It weathers light olive gray to yellowish brown and, where deeply weathered, forms wedge-shaped slabs. At many localities the upper limestone unit has a brecciated appearance because of fine joints and fractures filled with light-colored calcite, and at others it is compact and sparsely fossiliferous; it everywhere shows a wide range in thickness. Characteristically, abundant large fusulinids weather in relief on the lower limestone. The claystone is light olive gray, slightly silty, and platy and contains abundant very small limestone inclusions.

The Tarkio is characterized by the presence of the large robust fusulinid *Triticites ventricosus* (Moore, 1936a, p. 230) in the lower limestone. The upper limestone also contains fusulinids, but generally they are less abundant and locally are restricted to the lower part of the upper limestone. Fusulinids from the Tarkio are included in USGS foraminiferal collections f12991, from stratigraphic section 12, and f12968, from stratigraphic section 14. Brachiopods and crinoid stems are common to abundant, and some horn corals, bryozoans, and echinoids are also present. *Cryptozoon*-like algae occur in the upper limestone in a few places.

Wamego Shale Member

The Wamego was named by Condra and Reed (1943, p. 42) to replace the name Pierson Point that had previously been assigned by Condra (1927, p. 80) to the strata between the top of the Tarkio Limestone Member and the base of the Maple Hill Limestone Member. The name Pierson Point was discarded because at its type locality, it included beds between the Dover and Tarkio, not just those between the Maple Hill and the Tarkio. The Pierson Point Shale was classified as a formation in Kansas (Moore, 1936a, p. 232) and was retained by the State Geological Survey of Kansas until Moore and Mudge (1956, p. 2276) substituted the name Wamego for the middle member of the Zeandale Limestone. The type locality of the Wamego is in the bluffs north of U.S. Highway 40 about 4 miles west of Wamego, Pottawatomie County, Kans. (Condra and Reed, 1943, p. 42).

The Wamego, about 12 feet thick, is composed primarily of claystone containing a few interbeds of limestone and sandstone in the lower half. The claystone is light olive gray, silty, and platy and weathers light olive gray to light olive brown. Locally very thin to thin beds of very fine grained silty ferruginous sandstone that weathers light olive brown are interbedded with the claystone. Along the west edge of the area, a bed as much as 3.5 feet thick of sandy thin-bedded limestone that weathers moderate yellowish brown occurs 3–5 feet above the base of the Wamego. In places this limestone contains many small argillaceous limestone pellets. The upper 0.2 foot of the bed is a mass of shell fragments, but the rest contains only scattered fossils.

Brachiopods are the most common fossils in the Wamego Shale Member; they occur in the limestone beds together with crinoid stems, bryozoans, and pelecypods.

Maple Hill Limestone Member

The Maple Hill was named by Condra (1927, p. 80) for exposures along Maple Creek (now known as Mill Creek), southwest of Maple Hill, Kans. Condra classified the unit as a bed in his McKissick Grove Shale Member of the Wabaunsee Formation. This limestone had previously been included as part of the Emporia Limestone (Adams, Girty, and White, 1903, p. 52) and also as part of the Admire Group (Haworth and Bennett, 1908b, p. 114). Moore (1936a, p. 233) defined the Maple Hill as a formation, but later he and Mudge (1956, p. 2276) reclassified it as the upper member of the Zeandale Limestone. The type locality is along Mill Creek south of Maple Hill, in the

NW¼SE¼ sec. 26, T. 11 S., R. 12 E., Wabaunsee County (Mudge and Burton, 1959, p. 25).

The Maple Hill is a single stratum 1.3–2.4 feet thick of light-olive-gray to medium-gray very finely crystalline thin-bedded hard limestone. It weathers light olive gray mottled with moderate yellowish brown and dark brown, especially on the upper surface. Commonly the upper surface is limonite stained and has a conspicuous red color. Between widely spaced vertical joints the bed weathers to large rectangular blocks that break into thin slabs.

The fauna of the Maple Hill is characterized by abundant small slender fusulinids, some of which are in USGS foraminiferal collection f12971, from stratigraphic section 13. Brachiopods and crinoid stems are also abundant, and bryozoans, horn corals, and echinoid plates are common. *Cryptozoon*-like algae are common in the upper part.

PILLSBURY SHALE (strat. section 14)

The Pillsbury Shale was included as an unnamed shale in both the Emporia Limestone (Adams and others, 1903, p. 52) and the Admire Group (Haworth and Bennett, 1908b, p. 114). In 1927, Condra (p. 80) named this shale the Table Creek of the McKissick Grove Shale Member of the Wabaunsee Formation. In 1943 he and Reed (p. 42) discarded the name Table Creek, because the type locality included three other formations, and introduced the name Langdon Shale for the beds underlying the Dover and overlying the Maple Hill. At its type section, however, the Langdon is correlative to the Wamego Shale Member of the Zeandale Limestone (Moore and Mudge, 1956, p. 2275); consequently, the name Langdon was abandoned and the name Pillsbury was assigned by those authors to the beds between the Dover and Maple Hill Limestone Members. The formation was named from Pillsbury Crossing, a ford across Deep Creek in the NE¼NW¼ sec. 5, T. 11 S., R. 9 E., Riley County, Kans. (Moore and Mudge, 1956, p. 2275). The type exposure is in a roadcut in the SE¼NE¼NE¼ sec. 28, T. 10 S., R. 9 E., Riley County.

The Pillsbury, about 40 feet thick, underlies stream divides in the northwestern part of the area, but a few roadcuts offer the only good exposures. The formation is mainly light-olive-gray silty platy claystone; in the upper third the claystone is interbedded with clayey siltstone that weathers light olive gray to moderate yellowish brown. The siltstone is limonite stained on the bedding planes. The uppermost part of the Pillsbury is very calcareous and contains thin lenses of light-olive-gray fossiliferous limestone. Where the contact was observed the Pillsbury rests conformably on the Zeandale Limestone. Scattered fusulinids, crinoid columnals, and small brachiopods occur in the claystone immediately beneath the Dover Limestone Member of the Stotler Limestone.

STOTLER LIMESTONE (strat. section 14)

The Stotler Limestone was named by Moore and Mudge (1956, p. 2275) for the old Stotler Post Office, which was in the SW¼ sec. 10, T. 16 S., R. 13 E., Lyon County, Kans. The type section is in the spillway and along the south side of a pond in the SE¼ sec. 13, T. 16 S., R. 12 E., which is north of U.S. Highway 56 and about 2 miles west of Miller (Moore and Mudge, 1956, p. 2275). The Stotler contains three members, which are, in ascending order, the Dover Limestone, Dry Shale, and Grandhaven Limestone Members.

Rocks in the Dover Limestone Member and in the lower part of the Dry Shale Member are the uppermost beds of Pennsylvanian age exposed in the mapped area. The rest of the Stotler Limestone and part of the overlying Root Shale are probably present beneath the glacial drift near Hoyt. Only the lower 4 feet of a total thickness of about 7 feet of Stotler is exposed. The Stotler Limestone rests conformably on the Pillsbury Shale, and the contact is gradational through about 0.5 foot of very calcareous slightly resistant claystone.

Dover Limestone Member

The Dover was named by Beede (1898, p. 31) from exposures near Dover, Shawnee County, Kans. This limestone was included in the Emporia Limestone by Adams, Girty, and White (1903, p. 52), in the Admire Shale (now the Admire Group) by Haworth and Bennett (1908b, p. 114), and in the McKissick Grove Shale Member of the Wabaunsee Formation by Condra (1927, p. 80). Moore (1936a, p. 235) classified the Dover as a formation that underlies the Dry Shale and overlies the Table Creek (Pillsbury) Shale. Moore and Mudge (1956, p. 2275) reduced the Dover to the rank of member of the Stotler Limestone.

The Dover Limestone Member is not present at Dover but is well exposed about 1½ miles west of Dover along State Route 10 in the NW¼SW¼ sec. 34, T. 12 S., R. 13 E., Wabaunsee County, and about 1½ miles east of Dover in a roadcut in the SW¼NW¼ sec. 31, T. 12 S., R. 14 E., Shawnee County.

The Dover crops out at only two localities; it occurs as a small outlier on a ridge in the SE¼ sec. 22 and SW¼ sec. 23, T. 9 S., R. 15 E., and it is partly exposed in a roadcut on the west line of the SW¼ sec. 24, T. 9 S., R. 15 E. Elsewhere, as near Hoyt, the member is concealed by glacial drift.

The Dover is 2–2.4 feet thick and is composed of light-olive-gray very finely crystalline argillaceous hard compact limestone that weathers light olive gray and has a brown tint. Thin partings of calcareous claystone are interbedded in the lower 0.6 foot of the member. The Dover forms a vertically jointed ledge in which the limestone weathers to small irregular rubbly blocks and plates.

Very abundant large fusulinids and abundant *Crytozoon*-like algae and brachiopods are characteristic of the Dover Limestone Member; hence, they are a very useful aid in identifying it. The fusulinids are particularly abundant in the lower part, where they weather in relief on the rock surface. The algae are concentrated in the upper part and weather out as biscuit-shaped masses. Horn corals are also common. The Dover Limestone Member contains the following fossils, which were reported on by E. L. Yochelson (written commun., 1960):

Algae (*Cryptozoon*)
Small foraminifers, undet. } (USGS colln. f12967, from strat. section 14)
Fusulinids, undet. (abundant) }
Crinoid stems
Echinoid spines
Marginifera cf. *M. histricula* Dunbar and Condra
Hustedia sp. indet.

Dry Shale Member

The Dry was defined as a formation by Moore (1936a, p. 236), although it had first been recognized and named in a stratigraphic section by Moore, Elias, and Newell (1934). In 1956 Moore and Mudge (p. 2275) classified the Dry as the middle member of the Stotler Limestone. The type locality is on Dry Creek southwest of Emporia, in sec. 5, T. 20 S., R. 11 E., Lyon County, Kans. (Moore, 1936a, p. 236).

About 2 feet of an estimated thickness of 4 feet of the Dry Shale Member is exposed in a roadcut in the SE¼SE¼ sec. 22, T. 9 S., R. 15 E. In this small exposure the Dry consists of light-olive-gray platy calcareous claystone that weathers light olive gray mottled with light olive brown. Unfossiliferous limestone nodules as much a 1 foot long and 0.5 foot thick that weather light olive brown are abundant. The member is unfossiliferous at this locality.

QUATERNARY SYSTEM

Overlying the Pennsylvanian rocks is extensive unconsolidated material deposited by streams, glacial ice, wind, and slope wash. Stream-laid deposits occur as terraces or as alluvium along all major streams and their tributaries. Glacial drift, chiefly till and melt-water sediments, covers much of the mapped area. Because the till and melt-water sediments (glacial outwash) are poorly exposed, these deposits were not mapped separately. Eolian loess mantles many stream divides. Because the loess is generally thin and poorly exposed, it was included in mapping with either the glacial drift or the underlying Pennsylvanian rocks. About 10 feet of loess is exposed in a railroad cut just north of Tecumseh, where it overlies silts and gravels of Illinoian age (Davis and Carlson, 1952, p. 228). Colluvial deposits—principally clay, silt, and very fine sand—occur over much of the area; however, they are generally too thin to map and were included with the underlying bedrock or the glacial drift. In many valleys, colluvium has accumulated on stream terraces at the base of valley walls, and these deposits have markedly modified the terrace forms. No contact is evident between the colluvial and terrace deposits, so the colluvium was included with the terrace material when mapped.

Chert gravel.—In late Tertiary or early Pleistocene time, chert gravel derived from the west—primarily from the Wreford and Barneston Limestones of Early Permian age—was deposited in the valleys of the Kansas and Wakarusa Rivers. Subsequent erosion has left remnants of these deposits topographically isolated high above the present flood plains. During the Pleistocene Kansan Glaciation, ice overrode most deposits and incorporated the chert gravel in the till and glacial outwash. The few deposits remaining in eastern Shawnee County and vicinity are too small to be indicated on the geologic map.

The deposit in an old gravel pit in the SW¼NE¼ sec. 18, T. 11 S., R. 17 E., is composed of subangular to subrounded granules and pebbles of light-gray and pale-yellowish-brown chert and light-yellowish-gray and dark-brown limestone in a matrix of moderately cemented light-yellowish-gray to medium-gray fine to medium quartz sand. A few limestone cobbles as much as 0.25 foot long also occur in the deposit. The best exposure of chert gravel is in an old pit in the NW¼NW¼ sec. 7, T. 11 S., R. 16 E., where chert comprises over 98 percent of the deposit and no glacial erratics are present (Davis, 1951, table 3). Chert gravel is scattered on the ridge in the south-central part of sec. 23, T. 13 S., R. 15 E., and on the interstream divide in the SE¼ sec. 29, T. 13 S., R. 17 E. Locally, as in a roadcut in the SE cor. sec. 23, T. 13 S., R. 16 E., a thin layer of moderate-yellowish-brown subangular to subrounded chert gravel underlies the till.

GLACIAL DRIFT

In early Pleistocene time the main drainage in eastern Shawnee County and vicinity was to the east, virtually as it is at the present time. During part of the Kansan Glaciation, almost all the area was occupied by ice that caused major temporary changes in the drainage pattern. The Kansas River was dammed at St. George, Pottawatomie County (Mudge and Burton, 1959, p. 10), and from there was diverted southeastward through a series of channels across northern Wabaunsee County and into the North Branch Wakarusa River in western Shawnee County. From there the water flowed by way of the Wakarusa River back into the Kansas River east of Lawrence.

The southern limit of the ice advance was at the Wakarusa River. Ice possibly did not override the east-facing escarpment formed by the Bern Limestone in the southwestern part of the area, for no glacial debris was found there. The ice front was established along a line extending from Shunganunga Creek, on the west side of the area, southeastward through Pauline and along Lynn Creek, to the north side of the Wakarusa River. A terminal moraine was deposited from Shunganunga Creek to near Pauline; elsewhere, melt water from the ice sheet laid down thick deposits of glacial outwash. After the withdrawal of the ice north of the Kansas River valley, the river resumed, in general, its previous course, and its major tributaries reoccupied their old valleys. Diversion channels are evident at several places where melt water from the retreating glacier spilled over stream divides or interfluves. Melt water flowed southward through a diversion channel in the E½ sec. 33, T. 9 S., R. 17 E., into the drainage basin of Rock Creek; and a temporary channel, possibly through Meriden, may have connected Rock and Muddy Creeks. Certainly other diversion channels existed but have since been destroyed or so modified by erosion that they were not recognized.

The glacial drift ranges markedly in thickness in eastern Shawnee County and vicinity. It is thickest in the slopes north of the Kansas River. Test holes drilled in the SE¼ sec. 9 and in the E½ sec. 10, T. 11 S., R. 15 E., penetrated 32–76 feet of stratified clay, sand, pebbles, and boulders. On the uplands south of the river, the drift (which is chiefly till) ranges from a very thin veneer to about 20 feet in thickness and probably averages less than 10 feet thick. A test hole drilled about 1 mile east of the area penetrated 48 feet of drift (O'Connor, 1960, p. 142). Near the Wakarusa River the glacial-outwash deposits are locally as much as 25 feet thick.

The glacial drift is predominantly unstratified unsorted till but includes, particularly in the terminal area, deposits of stratified glacial outwash. Because the till and outwash are poorly exposed, they were not differentiated, and in many localities it was difficult to identify the glacial drift beneath the mantle of loess and soil. Consequently, the identification of glacial drift depended largely on the presence of erratics. The distribution of glacial drift shown on the geologic map (pl. 1) probably represents the minimum rather than the maximum extent, because many small areas covered by a thin veneer of drift probably were not mapped.

Till

The till is composed principally of clay, but rock particles of silt, sand, granule, pebble, cobble, and boulder size are also abundant. Most of the till was derived from claystones and limestones that crop out in this part of Kansas, and only a small amount of the till is composed of rock fragments moved there from the northern part of the country. Most fragments of pebble size or larger are limestone, but some are igneous or metamorphic rock, chert, sandstone, ironstone, quartz, or shale. Most boulders are less than 2 feet long; the largest erratic measured—a conglomeratic quartzite—is 23 by 11 by 8 feet, and only part of it is exposed. Pink quartzite cobbles and boulders are conspicuous but make up only a small percentage of the coarse fraction of the till. The weathered till is light brown or pale reddish brown; no fresh till was observed.

Glacial outwash

The glacial outwash includes stratified clay, silt, sand, small gravel, and abundant random cobbles and boulders deposited by melt water from the Kansan ice sheet during its advance and retreat. The outwash deposited during the advance of the ice is classified as the Atchison Formation by the State Geological Survey of Kansas; deposits of the retreatal phase are included in the Grand Island and Sappa Formations. The composition of the outwash deposits is complex and variable, and seldom can the Atchison and Grand Island Formations be definitely separated on the basis of lithology in this part of Kansas. In fact, the Atchison is recognized with reasonable certainty only where it is overlain by Kansan till. The Sappa Formation, overlying the Grand Island, is made up chiefly of silt of glaciofluvial and glaciolacustrine origin. No attempt was made to differentiate the glacial outwash of the three formations in mapping.

The proglacial outwash, the Atchison Formation of the State Geological Survey of Kansas (Moore and others, 1951, p. 15), commonly consists of indistinctly crossbedded gravels interstratified with medium to coarse sand. Locally lenses of gravel are tightly cemented by calcite. In places the pebble-sized rock fragments are chiefly limestone and chert, although some are shale and sandstone; only a very small amount of glacial erratics is present (Davis and Carlson, 1952, p. 222). At other localities the Atchison contains a large percentage of glacial erratics and is indistinguishable from the Grand Island Formation. The similarity between the two formations is particularly evident in the terminal area of the ice sheet, near the Wakarusa River. Commonly, as in an old gravel pit in the SE¼NW¼ sec. 16, T. 11 S., R. 16 E., as much as 15 feet of well-sorted yellowish-gray finely sandy silt overlies the gravel of the Atchison Formation and underlies Kansan till (Davis and Carlson, 1952, p. 221).

Most gravel deposits in the area consist of glacial outwash of the Grand Island Formation (Lugn, 1935, pp. 103–104). These deposits are particularly thick and abundant in the terminal area of the ice sheet near the Wakarusa River and along the north side of the Kansas River valley. The Grand Island is well exposed in an old gravel pit in a moraine in the SW¼SW¼ sec. 11, T. 12 S., R. 15 E.; in a quarry in the SE¼ sec. 10, T. 13 S., R. 16 E.; and in a pit in the SW¼NW¼ sec. 24, T. 13 S., R. 16 E.

At many localities the glacial outwash of the Grand Island closely resembles till which is poorly bedded and from which much of the clay and silt has been removed. Locally till is interbedded with the outwash. Some exposures in the SW¼NW¼ sec. 24, T. 13 S., R. 16 E., show indistinctly crossbedded moderately well cemented lenses of sand and gravel interbedded with beds of fine to coarse friable sand. In a quarry in the NE¼SE¼ sec. 16, T. 11 S., R. 17 E., the outwash consists of a basal deposit about 3 feet thick of yellowish-brown very fine to medium very micaceous sand containing abundant subrounded pebbles of limestone, igneous rock, ironstone, and yellowish-brown chert. Overlying the sand is a layer of cobbles and small boulders of limestone, sandstone, and igneous rock, and, in turn, a zone 1.3 feet thick of light-gray silty to slightly sandy clay containing scattered limestone pebbles. The upper 22 feet of the outwash is interbedded sand and silt showing deltaic bedding. The sand is moderate yellowish brown and fine to medium grained; it is made up mainly of quartz but contains some feldspar and many pebbles of limestone, igneous rock, and ironstone. The silt, which is more abundant in the lower half, is light yellowish gray to olive gray and sandy. It contains scattered small pebbles and weathers light yellowish brown. Part of this deposit may be equivalent to the Sappa Formation.

North of the Kansas River valley, the outwash is not as thick, although several large deposits were observed. The outwash capping the ridge in the SE¼ sec. 28, T. 9 S., R. 15 E., contains a high percentage of large boulders and may be partly morainal. The coarse sand and gravel of the deposit capping the ridge in E½NE¼ sec. 4, T. 10 S., R. 15 E., are partly cemented by calcite. Outwash also occurs along the stream in the W½NW¼ sec. 15, T. 10 S., R. 17 E.

Extensive deposits of pale-yellowish-brown to pale-red clayey to sandy silt and very fine sand are present in the Kansas River valley, particularly on the north side. The silt is massive and contains many granules and pebbles. It is more than 40 feet thick in places and extends northward beyond the valley as much as 1 mile. These deposits, which are in the Sappa Formation (Condra, Reed, and Gordon, 1947, p. 12, 22), could not be accurately delineated, for they are generally concealed by soil and loess; consequently, they were not mapped separately from the glacial drift. Good exposures of the Sappa occur along the north side of Soldier Creek in the SW¼ sec. 12, T. 11 S., R. 15 E.; in an old gravel pit in the SE¼NW¼ sec. 16, T. 11 S., R. 16 E.; and along Whetstone Creek in the NE¼ sec. 32, T. 11 S., R. 17 E.

BUCK CREEK(?) TERRACE DEPOSITS

Small remnants of terrace deposits of post-Kansan age occur at several localities in the Wakarusa River valley; they consist mainly of reddish-brown clayey silt with scattered pebbles and lie about 5–10 feet above adjacent terrace deposits of Wisconsin age. These topographically higher deposits are questionably correlated with the Buck Creek terrace deposits of Illinoian age in the Kansas River valley east of the mapped area (Davis and Carlson, 1952, p. 213). In a railroad cut just north of Tecumseh, an unmapped deposit correlated with the Buck Creek terrace includes, from its base upward, at least 12 feet of gravel, 10 feet of silt, and a well-developed soil profile of the Sangamon Interglaciation (Davis and Carlson, 1952, p. 228). This Buck Creek deposit is overlain by about 10 feet of loess of more recent age.

The largest remnants of the Buck Creek(?) terrace are in the Wakarusa River valley upstream from Wakarusa. The terrace, at the common corner of secs. 26, 27, 34, and 35, T. 13 S., R. 15 E., probably overlies beds of the upper part of the Topeka Limestone. The small deposit east of Richland, in the SW¼NE¼ sec. 27, T. 13 S., R. 17 E., rests on the Plattsmouth Limestone Member of the Oread Limestone. Remnants of Buck Creek(?) terrace deposits are probably more widespread in the area than is shown by the geologic map, but they are partly concealed by loess or colluvium and were not recognized.

NEWMAN TERRACE DEPOSITS

Extensive alluvial deposits of Wisconsin age occupy much of the bottom land in the Kansas River and Wakarusa River valleys and in the valleys of the major tributaries. In the Kansas River valley the deposits underlie a flat poorly drained terrace surface—the Newman—which is 20–40 feet above the river. The width of the terrace ranges from less than 100 feet, near Tecumseh, to about 1¾ miles, at the east edge of the area. The Newman is best preserved on the north side of the Kansas river. Together, the Newman terrace and the alluvium form the flood plain of the Kansas River; however, only severe floods inundate the terrace, and the high points remain above flood level.

On the basis of test borings, Davis and Carlson (1952, p. 229) reported that the Newman terrace deposits in the Kansas River valley are locally almost 90 feet thick. The lower part of the deposits consists of coarse sand, gravel, and numerous cobbles, but these materials grade upward to clay, silt, and fine sand in the upper 40 feet. The sediments in the upper part are similar to those now being transported by the Kansas River (Davis and Carlson, 1952, p. 229).

Newman terrace deposits form most of the flood plain of the Wakarusa River and the flood plains of major creeks in the area. Ordinary floods cover these deposits. The Wakarusa River has incised 20–25 feet below the level of the flood plain on the Newman deposits. The thickness and composition of the Newman terrace deposits along the Wakarusa River within the mapped area are not known; however, about 5½ miles to the east, the deposits are about 65 feet thick and consist mainly of silty and sandy clay that is underlain by 1–3 feet of medium sand and very coarse gravel composed of chert, limestone, sandstone, and quartz (O'Connor, 1960, p. 143–144).

ALLUVIUM

The belt of alluvium along the Kansas River ranges in width from about ¾ mile to more than 2½ miles and, together with the Newman terrace, forms the flood plain of the river. The alluvial surface is irregular and marked by meander scars that in places contain small ponds. A scarp marks the contact between the alluvium and the Newman terrace. At the surface the alluvium consists of coarse silt and fine sand that grade downward to fine to coarse gravel; fine silt and clay are confined to meander scars (Davis and Carlson, 1952, p. 230).

The belt of alluvium along the narrow channel of the Wakarusa River is less than 150 feet wide; hence, it was not mapped separately from the Newman terrace deposits. The alluvium along the major tributaries of the Kansas River is generally narrow, and the scarp separating it from the Newman terrace deposits is commonly less than 5 feet high and in many places is obscure. Near the mouths of the creeks, the alluvium grades to that in the Kansas River valley, but upstream along some creeks it merges with the Newman terrace surface.

DEPOSITION OF EXPOSED UPPER PENNSYLVANIAN STRATA

The Upper Pennsylvanian rocks in eastern Shawnee County and vicinity were deposited during alternating marine and nonmarine conditions. Sedimentation in the Late Pennsylvanian sea was cyclic; the depositional sequence of marine beds in both the Shawnee and Wabaunsee Groups was in a definite order, although the order is different in the two groups.

The Late Pennsylvanian sea advanced from the southwest (Wanless, 1950, p. 20). The depth of water was estimated by E. L. Yochelson (written commun., 1960) to have been not more than 50–75 feet, and by Moore (Wanless, 1950, p. 26) to have been less than 100 feet. Elias (1937, p. 421) estimated that the maximum depth of the late Paleozoic sea in Kansas was about 180 feet. The sediment supplied to the sea was derived mainly from an upland to the east and south (Moore, 1929, p. 483).

The lower part of the Snyderville Shale Member of the Oread Limestone, the oldest exposed bedrock in the area, may have been deposited in a nonmarine environment, but the upper few feet of the Snyderville was laid down in a shallow sea, as indicated by a marine fauna. The depth of the sea probably increased gradually, for the abundance of fusulinids in the middle part of the Leavenworth suggests deposition in quiet water, in an environment similar to that postulated by E. L. Yochelson (written commun., 1960) for the Big Springs Limestone Member of the Lecompton Limestone. Partly on the basis of the abraded appearance of the fossils, however, Dixon (1960, p. 36) suggested that the middle part of the Leavenworth was deposited in more turbulent and probably shallower water than other parts of the limestone.

The lower part of the overlying Heebner Shale Member accumulated as black mud, probably in very shallow water, under reducing conditions favorable for the growth of conodonts and the formation of phosphatic nodules. These conditions were similar to those that prevailed during deposition of the Chattanooga Shale (Late Devonian in central Tennessee (Conant and Swanson, 1961, p. 56, 62). The gray marine shale in the upper part of the Heebner indicates that a well-aerated and, presumably, gradually deepening sea persisted during deposition of the Plattsmouth Limestone Member of the Oread Limestone. The abundant fauna (dominantly brachiopods), wavy bedding (possibly due to currents), and many thin claystone partings seem to indicate that deposition occurred in a relatively shallow-water environment in which the depth of water, position of the strand line, and, probably, the source of sediment varied repeatedly. The overlying Heumader Shale Member presumably was deposited mainly near shore in a retreating sea. The sparse marine fauna locally present in the uppermost part of the shale outside eastern Shawnee County and vicinity indicates a minor readvance, or at least a temporary halt, in the general regressive phase of the sea during which the Kereford Limestone Member of the Oread was deposited. Monger (1961, p. 49) concluded that the lower part of the Kereford was deposited during quiescent marine conditions and that the upper part was deposited above wave base, which resulted in the sorting of fossil fragments and the winnowing of calcareous ooze.

After deposition of the Oread Limestone, the accumulation of a thick section of nonmarine clastics formed the Kanwaka Shale. The readvance of the sea, during which the thin fossiliferous Clay Creek Limestone Member was deposited, temporarily interrupted these nonmarine conditions. The Late Pennsylvanian sea returned to this general area before deposition of the Lecompton Limestone, as indicated by the occurrence of a sparse molluscan fauna in the upper part of the Kanwaka.

Strata were deposited in the same cyclic sequence, probably under very similar environmental conditions, during Lecompton time as were the beds of the Oread Limestone. The initial unit of the Lecompton Limestone—the lower part of the Spring Branch Limestone Member—contains abundant fusulinids and a few other fossils and probably was deposited in quiet water that was perhaps deeper than normal marine but was certainly shallow enough for food to be abundant (E. L. Yochelson, written commun., 1960). The presence of algae, gastropods, and some ostracodes in the upper part of the Spring Branch indicates that the water became shallower. Carbonaceous material in the overlying Doniphan Shale Member suggests nonmarine or perhaps estuarine conditions, which were followed by a deepening of the sea and the deposition of the fusulinid-bearing Big Springs Limestone Member. The presence of algae in the upper part of the Big Springs may indicate a shallower water environment in late Big Springs time. The Queen Hill Shale Member, which consists of black claystone overlain by gray claystone, accumulated under conditions similar to those that existed during Heebner time. Abundant fusulinids, echinoderm debris, large pieces of bryozoans, and abundant and varied brachiopods in the Beil Limestone Member of the Lecompton indicate normal-marine fairly quiet water (E. L. Yochelson, written commun., 1960). The local occurrence of algae and the alternating beds of limestone and claystone, particularly in the upper part of the Beil, bear record of variations in the depth of water and in the types of available sediment. The sea was withdrawing from this part of the State in early King Hill time, and the area may have been emergent for at least part of that time. Ostracodes and foraminifers in the upper part of the King Hill Shale Member show that there was a return of shallow marine waters. The water became deeper during accumulation of the lower fusulinid-bearing part of the Avoca Limestone Member but again became more shallow as the upper part was deposited.

As the sea continued to retreat, the foraminifer- and ostracode-bearing basal few feet of the Tecumseh Shale was deposited. During most of the Tecumseh time, subaerial conditions existed, as indicated by the presence of a thick section of clastics containing plant remains but no marine fossils. A transgressing sea moved into this area in late Tecumseh time, as recorded by the marine fauna in the upper part of the formation.

During Deer Creek time the transgressive and regressive movements of the sea, the environments of deposition, and the resulting strata were virtually identical to those during Oread and Lecompton time and occurred in about the same order. After deposition of the lower, fusulinid-bearing part of the Ozawkie Limestone Member of the Deer Creek Limestone, conditions rapidly changed to a beach or extremely shallow-water environment in which the dominantly algal limestone in the upper part of the Ozawkie was formed (E. L. Yochelson, written commun. 1960). The sea retreated briefly in early Oskaloosa time, but returned in late Oskaloosa time and remained all of Rock Bluff time. The reducing marine environment that existed earlier in Heebner and Queen Hill times recurred in early Larsh and Burroak time. Deepening of the Late Pennsylvanian sea reestablished normal marine conditions, under which the upper part of the Larsh and Burroak Shale Members and the Ervine Creek Limestone Member accumulated.

Gradual withdrawal of the sea at the end of Ervine Creek time resulted in estuarine or very shallow water near-shore marine conditions in earliest Calhoun time, as indicated by the presence of *Lingula* and algal-coated myalinid pelecypods in the basal part of the Calhoun Shale (E. L. Yochelson, written commun., 1960). Eastern Shawnee County and vicinity was largely emergent during deposition of the noncarbonate clastics of the Calhoun; plant remains, interformational channeling, and rapid lateral variations in types of sediment suggest that flood-plain conditions existed. In late Calhoun time swamp conditions locally prevailed for a short time, as shown by the presence of a thin coal bed near the top of the formation. Thin fossiliferous limestone beds locally present in the upper part of the Calhoun indicate that some parts of the area were not emergent during Calhoun time.

Strata of the Topeka Limestone are dominantly marine. The lower two limestone members of the Topeka—the Hartford and the Curzon—probably were deposited under generally similar conditions in an environment that varied from normal marine with fairly quiet water to one in which the water was shallower and the circulation more vigorous (E. L. Yochelson, written commun. 1960); the more vigorous circulation is suggested by the presence of bioclastic limestone in part of the Curzon. The presence of algae in both the Hartford and the Curzon indicates that the water was shallow enough for photosynthesis to take place (E. L. Yochelson, written commun. 1962). The intervening Iowa Point Shale Member probably is largely marine, but the presence of abundant carbonized plant fragments suggests that estuarine conditions may have existed locally. The few brachiopods and pelecypods locally present in the Jones Point Shale Member suggest marine deposition, but there is no evidence to indicate the depositional environment of the unfossiliferous parts. The presence of abundant algae suggests that during Sheldon time the sea must have been relatively shallow, and probably clear. A fresh-water pool or swamp environment in which ostracodes and plants were dominant may have existed at least locally in the area when the basal part of the Turner Creek Shale Member of the Topeka Limestone was laid down. A change to a marine environment is indicated by the presence of brachiopods and pelecypods in the rest of the Turner Creek, and the sea remained in the area during deposition of the Du Bois Limestone Member. The black claystones in the lower part of the Holt Shale Member probably were deposited in very shallow poorly oxygenated waters. The sea progressively readvanced over the area in late Holt time, and marine conditions prevailed during deposition of the very fossiliferous limestones of the Coal Creek Limestone Member of the Topeka.

This part of Kansas was emergent at the end of Topeka time, and the nonmarine Severy Shale was deposited. The initial Severy deposits as well as beds of the underlying Topeka Limestone were removed from part of the area by stream channeling. Recurrent erosion is also recorded by the presence of channel deposits stratigraphically higher in the Severy.

A sparse marine fauna in the upper part of the Severy records a marine invasion of short duration, but the marine conditions soon were replaced by widespread swamp conditions favorable to the accumulation of carbonaceous materials, notably the Nodaway coal bed at the base of the Howard Limestone. Conditions were transitional from marine to estuarine (E. L. Yochelson, written commun. 1960) during deposition of the overlying Aarde Shale Member, which contains small foraminifers, *Crurithyris*, *Hustedia*, and other brachiopods, but none of the larger productids. The Church Limestone Member was deposited in fairly deep quiet water; however, the presence of algae and ostracodes indicates that the water became shallower near the end of Church time. Although conditions varied, the marine environment persisted until the end of Howard time: during deposition of the Winzeler Shale Member, many fenestrate bryozoans were preserved; during early Utopia time a very shallow water near-shore sublittoral environment is indicated by the presence of algal-coated myalinid pelecypods, but a more open sea (possibly with a firm bottom and swift currents) is suggested by the occurrence of *Linoproductus*, gastropods, and abundant ostracodes (E. L. Yochelson, written commun. 1960); and the fusulinid-bearing upper part of the Utopia Limestone Member probably represents a deposit in quieter water.

The sea retreated after Utopia time and left a thin accumulation of shallow-water near-shore marine sediments, which comprise the lowermost part of the White Cloud Shale Member of the Scranton Shale. Lithologic heterogeneity of the rocks, crossbedded sandstones, and channel deposits suggest that much of the Scranton, particularly the White Cloud, was probably deposited as a flood plain. Erosion in White Cloud time locally removed the entire Howard Limestone and an undetermined amount of the Severy Shale. Although minor re-advances of the sea are recorded in the Happy Hollow and Rulo Limestone Members of the Scranton, conditions were dominantly nonmarine, and for a short period preceding deposition of the Rulo, part of the mapped area was a swamp in which coal formed. Algal-coated myalinid pelecypods and abundant ostracodes in the uppermost part of the Scranton indicate sublittoral to near-shore marine conditions which accompanied another widespread advance of the sea.

Deposits of the Wabaunsee Group above the Scranton Shale indicate a marked change in the rhythmic oscillations of the sea. The cyclic succession of lithologic units is less complex than in the Shawnee Group, and the limestone formations in the upper part of the Wabaunsee Group are composed of two limestone units separated by a claystone or siltstone unit.

The fauna indicates that most of the Burlingame Limestone Member of the Bern Limestone probably accumulated in water of normal salinity that at times was fairly quiet but at other times was vigorously circulated (E. L. Yochelson, written commun. 1960). The presence of algae and, locally, mollusks in the basal part suggests that the water was shallow in early Burlingame time.

The sea withdrew from this part of Kansas during deposition of the lower part of the Soldier Creek Shale Member of the Bern Limestone, and a swamp in which coal formed was present in part of the area. A marine fauna in the upper part of the Soldier Creek indicates a return of the sea—which remained in the area throughout Wakarusa time—but the complexity of the fauna indicates variations in depth of water, hardness of bottom, and velocity of currents.

Nonmarine rocks compose most of the Auburn Shale in eastern Shawnee County and vicinity. The sea advanced into the area in late Auburn time and remained during deposition of the overlying Reading Limestone Member of the Emporia Limestone. A partial or perhaps total withdrawal of the sea occurred during at least part of Harveyville time; the presence of well-preserved plants and abundant smooth ostracodes in the member a short distance west of the mapped area suggests a fresh-water pool or swamp environment (E. L. Yochelson, written commun., 1960). Algae, ostracodes, and myalinid pelecypods indicate that the sea was extremely shallow at the beginning of Elmont time; however, the water was deeper during deposition of the upper fusulinid-bearing part of the Elmont Limestone Member of the Emporia.

All strata of the Willard Shale except those in the basal few feet seem to be of nonmarine origin; thus, a rapid retreat of the sea at the end of Elmont time is indicated. The apparent lack of marine sediments at the top of the Willard and the lack of a near-shore fauna in the basal part of the overlying Tarkio Limestone Member of the Zeandale Limestone suggest a rapid advance of the sea. Most of the Tarkio is fusulinid-bearing limestone that probably was deposited in quiet water. A marine fauna in thin limestone beds in the lower part of the overlying Wamego Shale Member of the Zeandale indicates that a shallow sea covered this area during most, if not all, of Wamego time. The bioclastic limestone of the overlying Maple Hill Limestone Member, with its many fusulinids, crinoid debris, brachiopods (but no productids), small fragments of bryozoans, and algae, suggests deposition in relatively shallow water in which current action was vigorous but not strong enough to give the fusulinids a preferred orientation (E. L. Yochelson, written commun., 1960).

A change to nonmarine conditions after Maple Hill time is postulated for deposition of most of the Pillsbury Shale; however, the sea returned near the end of Pillsbury time, and fusulinid-bearing claystones were deposited immediately below the Dover Limestone Member of the Stotler Limestone. The Dover contains abundant fusulinids, horn corals, and biscuit-shaped algal masses. The marine conditions continued to prevail at least through deposition of the lower part of the overlying Dry Shale Member of the Stotler—the youngest exposed rocks in the mapped area.

STRUCTURE

Eastern Shawnee County and vicinity lies in the western part of the Forest City basin—a structural basin east of the Nemaha uplift in the northeastern part of Kansas and neighboring parts of Missouri, Nebraska and Iowa—that formed mainly after Mississippian time (Lee, 1943, p. 13). The mapped area is east of the axis of the basin. Outcropping rocks strike approximately N. 20°–30° E. and dip northwest, generally 20–40 feet per mile. The northwestward dip is interrupted slightly by minor folds that generally trend northwestward. The structural relief is about 500 feet. A few small structures occur with less than 20 feet of closure. The structure pattern in the area is shown on the geologic map (pl. 1) by contours drawn at 20-foot intervals on the base of the Topeka Limestone.

ECONOMIC GEOLOGY

OIL AND GAS

Eighteen wells have been drilled for oil or gas in eastern Shawnee County and vicinity, but no shows of oil or gas have been reported (Jewett, 1954, p. 336). The well locations are shown on the geologic map (pl. 1). Oil in adjacent Wabaunsee County, which is also in the Forest City basin, has been found primarily on small anticlinal structures (Smith and Anders, 1951; Hilpman, 1958; Goebel and others, 1962); the oil is mainly from porous zones in carbonate rocks of the Viola Limestone (Middle and Upper Ordovician) and the Hunton Formation (Silurian and Devonian). In a few wells oil has been obtained from sandstone in the Simpson Group (Middle Ordovician) and from limestone in the Kansas City Group (Upper Pennsylvanian). In the abandoned McLouth gas and oil field in Jefferson County, about 18 miles east of the mapped area, gas and oil were obtained from sandstone in the Cherokee Group (Middle Pennsylvanian) and from limestone and dolomite of Mississippian age (Lee and Payne, 1944).

The rocks that yield oil or gas in various fields adjacent to Shawnee County are in the subsurface of the mapped area. Zones of pinhole porosity are present in both the Viola Limestone and the Hunton rocks in the Murchison Federal Land Bank 1 well in the SE cor. sec. 28, T. 10 S., R. 15 E., and in the J. J. Lynn Warner 1 well in the center of the SE¼NW¼ sec. 5, T. 13 S., R. 17 E. (pl. 2). Very slight oil stains occur in the upper few feet of the Hunton and in Simpson rocks in the J. J. Lynn Warner 1 well and in Simpson rocks in the Murchison Federal Land Bank 1 well.

Several small anticlinal folds with less than 20 feet of closure are reflected by the structure contours drawn at an interval of 20 feet on the base of the Topeka Limestone, but no detailed information is available about the relation of these folds to the structure of older rocks at depth. Zones of porosity and oil staining in the Viola Limestone and in rocks of the Hunton and Simpson suggest the possibility that stratigraphic traps may be present in these rocks.

COAL

Thin beds of coal occur locally in rocks of the Shawnee and Wabaunsee Groups in eastern Shawnee County and vicinity, but only the Nodaway coal bed, at the base of the Howard Limestone, is of sufficient thickness to have been mined for domestic and commercial uses. Schoewe (1946) described the coal resources of the Wabaunsee Group in detail; most data presented herein are from that publication. Previously, Whitla (1940) had described the coal resources of all post-Cherokee rocks in Kansas.

The Nodaway coal bed in the mapped area ranges in thickness from 0.2 to 1.5 feet and is bituminous in rank, banded, shiny, brittle, and moderately hard. Analyses of coal from 10 mines in adjacent Osage County and nearby parts of Jefferson County show an average of 10.2 percent moisture, 35.7 percent volatile matter, 43.5 percent fixed carbon, 10 percent ash, 7.6 percent sulfur, 11,093 Btu per pound as received, and 13,843 Btu per pound on a moisture-matter-free basis (Schoewe, 1946, table 3).

The Nodaway was mined at 25 known mines in Shawnee County; 3 were strip mines, 5 were shaft mines, and the rest were small drift mines (Schoewe, 1946, p. 129). Coal was mined at Topeka by the early settlers; but by 1908 most mining in the county had ceased, and no mining activity was reported after 1927. The mines were located in four areas: west of Meriden, along Muddy Creek near State Route 4; north of Topeka, along a tributary of Halfday Creek in secs. 2 and 12, T. 11 S., R. 15 E.; on the west edge of Topeka, near Gage Park and the State Hospital; and in the southwestern part of Topeka, along Shunganunga Creek in the S½ sec. 10, in the SW¼ sec. 13, and along South Branch Shunganunga Creek in the NE¼ sec. 26, T. 12 S., R. 15 E.

Schoewe (1946, p. 133) reported that the total amount of coal produced in Shawnee County probably exceeded 80,000 tons, most of which was from the Nodaway. He estimated that the proved reserves of coal in the Nodaway are approximately 10,290,000 tons. The Nodaway is of little economic value now because of the thinness of the coal, the amount of overburden, and the position of the bed under part of the city of Topeka.

LIMESTONE

Limestone quarried in the eastern part of Shawnee County and adjacent parts of Jefferson County is used primarily as concrete aggregate and road metal, although in 1959 some was quarried for riprap material for the new channel of Soldier Creek around North Topeka.

The Ervine Creek Limestone Member of the Deer Creek Limestone and the Burlingame and Wakarusa Limestone Members of the Bern Limestone are the principal beds quarried in the mapped area. Rock from the Hartford and Curzon Limestone Members of the Topeka Limestone is quarried immediately east of Forbes Air Force Base.

Quarrying of the Bern Limestone centers around the town of Elmont. The Burlingame Limestone Member is the principal source in these quarries, but the Wakarusa is also taken where it is not deeply weathered. Quarries in the Ervine Creek Limestone Member are located east of Topeka along Tecumseh and Stinson Creeks, in the Wakarusa River valley about 2 miles east of Wakarusa, and about 2 miles northeast of Grantville. Where quarried, the Ervine Creek is 14–18 feet thick, the Hartford and Curzon Limestone Members of the Topeka are 6.2 and 10.4 feet thick, respectively, and the Burlingame is 5–10 feet thick. Chemical analyses of rock from these and from two other limestone members are given in table 2.

No dimension stone is produced in this area, but several limestone members have been quarried along their outcrops for local use as building stone. Near Topeka, rock from the Hartford Limestone Member of the Topeka has been used in construction of houses, barns, and small bridges. This limestone is difficult to saw because of its hardness, but it can be hand dressed without difficulty (Riser, 1960, p. 110). Near Richland, rock from beds in the Lecompton Limestone is locally used for building stone. Small amounts of stone have also been quarried for local use from the Maple Hill and Tarkio Limestone Members of the Zeandale Limestone and from the Reading Limestone Member of the Emporia Limestone.

SAND AND GRAVEL

All sand and gravel currently (1961) produced commercially in Shawnee County is from the alluvium along the Kansas River. Most of the sand is used for building, for paving, and as fill, although small amounts are used as engine and blast sand. The building industry utilizes most of the gravel, but some is used in paving and as fill.

Deposits of glacial sand and gravel of Kansan age have been quarried at several localities in the mapped area, especially south of the Kansas River. A fairly large amount of material was dug from a morainal deposit along the south side of Shunganunga Creek in the SW¼SW¼ sec. 10, T. 12 S., R. 15 E.; also, a large pit was formerly operated in the SW¼SW¼ sec. 24, T. 13 S., R. 16 E. Because these deposits are poorly sorted and contain cemented zones, the pits were probably difficult to operate. Material from both pits was probably used mainly as road metal. North of the Kansas River small deposits, mainly of chert gravel, were quarried in the SW¼NW¼ sec. 7, T. 11 S., R. 16 E. and in the SW¼NE¼ sec. 18, T. 11 S., R. 17 E. Small de-

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TABLE 2.—*Chemical analyses of selected limestones in eastern Shawnee County and adjacent parts of Douglas County, Kans.*

[In percent by weight. Tr., trace. Adapted from Runnels and Schleicher, 1956]

Formation	Member	Sample locality: Section	Sample locality: Township	Sample locality: Range	Sample locality: County	Thickness (ft.)	Lab. No.	$CaCO_3$ [a]	$MgCO_3$ [a]	$CaCO_3$ [a] equivalent	CaO	MgO	L.O.I. [b]	SiO_2	Al_2O_3 [c]	Fe_2O_3 [d]	K_2O	Na_2O	SO_3	S [e]	P_2O_5	Total [f]
Bern Limestone	Burlingame Limestone.	NE¼NW¼ 26	10 S.	15 E.	Shawnee	4.5	53210	87.86	1.86	90.34	49.29	0.89	39.75	4.71	1.47	2.91	----	----	Tr.	0.19	0.05	99.07
Topeka Limestone	Curzon Limestone	Center 16	11 S.	16 E.	do	4.0	49454	85.19	3.33	88.82	47.91	1.59	39.08	9.04	.87	1.93	----	----	0	----	.14	100.56
Do	do	SE¼SW¼ 11	12 S.	17 E.	Douglas	3.0	54369	91.38	.61	92.04	51.27	.79	40.50	4.66	1.62	1.15	----	----	Tr.	----	.06	100.05
Do	Curzon and Hartford Limestones.	SW¼SW¼ 4	13 S.	16 E.	Shawnee	13.0	53211	76.44	7.32	85.86	43.03	3.50	37.78	10.12	2.06	2.64	0.25	0.12	.11	.07	.10	99.71
Do	Hartford Limestone	Center 16	11 S.	16 E.	do	3.0	49445	83.60	4.58	88.61	47.05	2.19	38.99	5.40	1.51	5.53	----	----	.14	----	.08	100.89
Deer Creek Limestone.	Ervine Creek Limestone.	SE¼ 14	11 S.	16 E.	do	10.0	49455	93.56	1.07	93.93	52.53	.51	41.33	4.08	.87	1.37	----	----	0	----	.08	100.77
Do	do	SE¼NW¼ 4	12 S.	17 E.	do	6.9	53213	92.83	1.36	93.25	52.05	.65	41.03	3.54	.87	1.65	----	----	0	Tr.	.03	99.82
Do	do	SE¼SE¼ 10	13 S.	16 E.	do	8.8	53214	91.08	2.72	94.48	51.15	1.30	41.57	3.63	.93	1.15	----	----	.12	.08	.03	99.88
Do	Ozawkie Limestone	SE¼(?) 36	11 S.	17 E.	Douglas	----	50554	95.07	----	95.18	53.27	----	41.88	2.11	.71	.89	----	----	0	0	Tr.	98.86
Lecompton Limestone.	Spring Branch Limestone.	NE¼NW¼ 36	11 S.	17 E.	do	6.8	53216	73.94	12.41	90.91	41.63	5.93	40.00	6.29	1.55	4.22	----	----	.10	.01	.08	99.80

[a] Calculated.
[b] Net loss of weight on ignition from 105° to 1000°C.
[c] Includes MnO, ZrO_2, V_2O_5, and TiO_2 when present.
[d] Total iron expressed as Fe_2O_3.
[e] Omitted in computing total, because included in loss on ignition (L.O.I.).
[f] Does not include amounts shown for $CaCO_3$, $MgCO_3$, and $CaCO_3$ equivalent.

posits of glacial sand and gravel, such as that in the creekbank in the W½NW¼ sec. 15, T. 10 S., R. 17 E., probably supplied the needs of local residents.

CLAY

Claystone immediately beneath the Nodaway coal bed of the Howard Limestone was formerly dug from a pit on the west side of Topeka in the SE¼NE¼ sec. 27, T. 11 S., R. 15 E., for the manufacture of brick. Digging operations ceased at this pit in the 1930's, and no clay or shale is currently being dug in Shawnee County for ceramic use. Claystone was dug from the Calhoun Shale along the east side of Deer Creek in the SW¼ sec. 3, T. 12 S., R. 16 E., for several years (around 1950) and was blended with clay from the Dakota Formation (Lower Cretaceous) of central Kansas for the manufacture of small pottery objects.

A sample from near the middle of the Calhoun Shale in the center of the N½SW¼ sec. 15, T. 11 S., R. 16 E., produced a lightweight aggregate with a density of 48.5 pounds per cubic foot (Plummer and Hladik, 1951, p. 60). If this sample was representative, the clayey parts of the Calhoun Shale probably are usable for the production of lightweight aggregate.

STRATIGRAPHIC SECTIONS

Each geologic formation or member that crops out in eastern Shawnee County and vicinity is represented, at least in part, in one or more of the measured sections that follow. No complete stratigraphic sections of the Kanwaka, Severy, and Scranton Shales are included, and the section of the Oread Limestone was measured in Douglas County a short distance east of the mapped area. Approximately half the sections were measured by W. D. Johnson, Jr., and W. L. Adkison. The rest were measured by Johnson, assisted at one locality by H. W. Miller of the State Geological Survey of Kansas. Lists of fossils in the U.S. Geological Survey Permian and Carboniferous fossil collection (for example, 19441–PC) and foraminiferal collection (for example, f12995) noted in the measured sections are shown in the text under the proper stratigraphic unit. Those fossil identifications not credited are field identifications made by the authors.

1. *Composite section of the Oread Limestone*

[Kereford Limestone Member through Plattsmouth Limestone Member, measured along road in the SW cor. SE¼ sec. 35; Heebner Shale Member in the NE¼NW¼ sec. 36, T. 13 S., R. 17 E.; Leavenworth Limestone Member and Snyderville Shale Member in the W½NW¼ sec. 29, T. 13 S., R. 18 E., Douglas County]

Oread Limestone:

	Feet
Kereford Limestone Member:	
Limestone, light-olive-gray, argillaceous; irregular beds as much as 0.2 ft thick; weathers in part to small light-gray to light-olive-gray cobbles; scattered small moderate-brown iron-rich masses; abundant fusulinids, *Derbyia*, *Marginifera*, and other brachiopods; poorly exposed; upper contact arbitrarily chosen	5.1
Heumader Shale Member:	
Claystone (deeply weathered), light-olive-gray, slightly silty; many light-gray argillaceous limestone pellets as much as 0.02 ft long; upper contact irregular	4.2
Plattsmouth Limestone Member:	
Limestone, medium-light-gray to medium-gray, very fine grained, hard, compact; thin to medium wavy beds; probably very argillaceous along bedding planes; weathers light yellowish gray to light gray and moderate yellowish brown; irregular masses as much as 0.3 ft thick of medium-gray to brownish-gray dense fossiliferous chert in zone 1 ft thick about 5 ft above base; very abundant brachiopods and abundant algae (*Cryptozoon*?) and crinoids; base not exposed	11.4+
Heebner Shale Member:	
Claystone, olive-brown, silty, laminated to platy; weathers light gray to light olive gray; grades into overlying unit	3.1
Claystone, brownish-black to black, finely laminated; weathers to fissile grayish-black to black laminae; upper 0.1 ft gradational into overlying claystone; conodonts	2.7
Thickness of Heebner Shale Member	5.8
Leavenworth Limestone Member:	
Limestone, medium-gray to medium-dark-gray, very fine grained, hard, compact; weathers to medium-light-gray to moderate-yellowish-brown vertically jointed bed; upper surface irregular, pitted; abundant *Osagia*, fusulinids, horn corals, crinoid columnals, and *Meekella*, *Hustedia*, *Chonetes*, and other brachiopods, particularly at top of bed; forms ledge	1.6
Snyderville Shale Member:	
Claystone, olive-gray; weathers light olive gray; abundant irregularly shaped nodules 0.01–0.08 ft in diameter of very light gray very finely crystalline argillaceous unfossiliferous limestone that weathers light yellowish gray; upper part poorly exposed; upper contact estimated	6.3
Thickness of exposed Oread Limestone	34.4

2. *Basal part of the Tecumseh Shale down into the Jackson Park Shale Member of the Kanwaka Shale*

[Lower two-thirds measured along road in the NE¼NE¼ sec. 33; upper one-third measured in pasture in the center of the SW¼NE¼ sec. 33, T. 13 S., R. 17 E., Shawnee County]

	Feet
Tecumseh Shale:	
Claystone, light-gray, laminated to platy, silty; weathers light olive gray; many beds as much as 0.03 ft thick of hard siltstone that weathers dark yellowish brown especially in lower 3 ft; top not present	9.0
Lecompton Limestone:	
Avoca Limestone Member:	
Limestone, medium-gray, very fine grained, very thin bedded, slightly argillaceous; weathers to light-olive-gray plates; top of unit weathers dark reddish brown; very abundant shell fragments; abundant crinoids; fusulinids much less abundant than in underlying bed	1.3
Limestone, medium-dark-gray, very fine grained, hard; weathers medium light gray to light olive gray; very abundant fusulinids in relief; abundant fine shell hash; forms ledge	2.2
Thickness of Avoca Limestone Member	3.5
King Hill Shale Member:	
Claystone, light-olive- to light-greenish-gray, silty, laminated; abundant light-gray argillaceous limestone pellets as much as 0.1 ft long; partly covered	3.4
Limestone (deeply weathered), pale-yellowish-orange to moderate-yellowish-brown, very argillaceous; weathers to cellular and pitted blocks	1.0
Covered interval	1.1
Limestone (deeply weathered), moderate-yellowish-brown, very argillaceous; forms nodular layer	.2
Claystone, light-olive-gray, laminated	.4
Limestone, light-olive-gray, very thin bedded; argillaceous, especially in lower 0.3 ft, compact; weathers pale yellowish orange to light yellowish brown; upper part weathers to oval plates	.9
Claystone, light-olive-gray, calcareous; weathers pale yellowish orange; grades into overlying unit	1.5
Claystone, light-olive-gray to light-greenish-gray, laminated; many light-gray argillaceous limestone pellets 0.01–0.1 ft long—most less than 0.03 ft long	2.1
Thickness of King Hill Shale Member	10.6

2. *Basal part of the Tecumseh Shale down into the Jackson Park Shale Member of the Kanwaka Shale*—Continued

	Feet
Lecompton Limestone—Continued	
Beil Limestone Member:	
Limestone, light-gray to very light brownish gray, very fine grained, hard; weathers light olive gray; many small inclusions of light-greenish-gray argillaceous limestone; very abundant small *Osagia;* very abundant fine fragments of brachiopods; forms single resistant bed	0.4
Claystone, light-gray to light-olive-gray, silty; weathers light olive gray; abundant very small light-yellowish-orange specks; lower half poorly exposed	3.4
Limestone, medium-light-gray, very finely crystalline; weathers to thin light-yellowish-brown to light-olive-gray wavy beds; fusulinids, corals, bryozoans, *Derbyia* and other brachiopods	2.2–2.4
Limestone, medium-light-gray to light-olive-gray, very argillaceous, platy to very thin bedded; both upper and lower contacts gradational, irregular; fusulinids, *Composita* and other brachiopods; on weathering, forms reentrant	0.1–0.5
Limestone, medium-light-gray, very finely crystalline, argillaceous; weathers pale yellowish brown; abundant fusulinids, crinoid columnals, bryozoans, and brachiopods	3.0–3.2
Thickness of Beil Limestone Member	9.1–9.9
Queen Hill Shale Member	
Covered interval	1.2
Claystone, dark-gray, platy; weathers brownish gray; upper contact covered	.8
Claystone, grayish-black, finely laminated; weathers to fissile fragments that show fine iridescence	.2
Claystone, medium-gray, very silty; weathers brownish gray	.1
Thickness of Queen Hill Shale Member	2.3
Big Springs Limestone Member:	
Limestone, medium-light-gray, very finely crystalline; weathers to light-gray bed; upper contact sharp, even; abundant fusulinids and brachiopods in upper part; very abundant grayish-red fusulinids in lower 1.1 ft	2.0
Claystone, olive-gray, very calcareous; very abundant fusulinids; forms reentrant	.2
Limestone, medium-light-gray, very finely crystalline, slightly argillaceous; weathers light olive gray; basal contact sharp, even; very abundant grayish-red fusulinids	.6
Thickness of Big Springs Limestone Member	2.8

2. *Basal part of the Tecumseh Shale down into the Jackson Park Shale Member of the Kanwaka Shale*—Continued

	Feet
Lecompton Limestone—Continued	
Doniphan Shale Member:	
Claystone, medium-gray; slightly silty; weathers olive gray	0.8
Covered interval	1.2
Siltstone (deeply weathered), medium-light-gray to light-olive-gray, clayey; abundant light-gray limestone pellets less than 0.02 ft long; unfossiliferous	3.0
Limestone, light-olive-gray, argillaceous, thin-bedded; medium-light-gray dense limestone in upper 0.2 ft; subconchoidal fracture; weathers moderate yellowish brown to olive brown	.8
Claystone (deeply weathered), light-olive-gray	.2
Thickness of Doniphan Shale Member	6.0
Spring Branch Limestone Member:	
Limestone, yellowish-brown, argillaceous; weathers moderate yellowish brown; scattered fusulinids, crinoid columnals, and brachiopods	0.2
Claystone, medium-light-gray, silty, platy; weathers light olive gray to light yellowish orange; very abundant fusulinids	.4
Limestone, light-olive-gray, argillaceous; very abundant fusulinids	.4
Claystone, medium-light-gray, silty, platy; weathers light olive gray to light yellowish orange; very abundant fusulinids	.3
Limestone, light-olive-gray, argillaceous; fusulinids	.3
Claystone (deeply weathered); probably medium light gray, silty, platy; weathers light olive gray to light yellowish orange; very abundant fusulinids	.4
Limestone, medium-gray, very finely crystalline, thick-bedded; forms two beds on weathering, separated by claystone parting 0.05 ft thick 2.8 ft above base; basal contact sharp, even; very abundant fusulinids, crinoid columnals and brachiopods; forms prominent ledge	5.4
Thickness of Spring Branch Limestone Member	7.4
Thickness of Lecompton Limestone	41.7–42.5

2. *Basal part of the Tecumseh Shale down into the Jackson Park Shale Member of the Kanwaka Shale*—Continued

	Feet
Kanwaka Shale:	
Stull Shale Member:	
Siltstone, medium- to medium-light-gray, micaceous; 0.1 ft light-gray very fine grained micaceous sandstone near middle	1.7
Covered interval	17.9
Siltstone, medium-gray, micaceous; weathers light olive gray; oval concentric-weathering ironstone concretions that weather moderate yellowish brown in layer about 0.1 ft thick 0.1 ft below top	1.2
Covered interval; probably siltstone	.9
Siltstone, medium-gray, micaceous; weathers light olive gray; olive-gray very fine grained sandstone bed 0.05 ft thick about 0.3 ft above base	1.9
Claystone, silty, platy, micaceous; weathers light olive gray mottled with olive brown; scattered carbonaceous material	5.0
Covered interval; probably claystone	4.5
Claystone, medium-gray, slightly silty, platy to very thin bedded; weathers light olive gray	1.8
Thickness of Stull Shale Member	34.9
Clay Creek Limestone Member:	
Limestone, olive-gray, very argillaceous, very thin bedded; weathers moderate olive brown; capped by olive-gray silty limestone layer 0.02 ft thick; abundant fragments	0.2
Claystone, medium-dark-gray, platy, calcareous; weathers olive gray with patches of olive brown; crinoid columnals	.2
Limestone, medium-gray, argillaceous, very thin bedded; weathers to yellowish-brown to olive-gray platy to rubbly beds; a more resistant bed 1.2 ft thick about 1 ft above base; abundant small fusulinids	3.5
Thickness of Clay Creek Limestone Member	3.9
Jackson Park Shale Member:	
Siltstone, light-olive-gray, platy, very finely micaceous; upper contact sharp; base not exposed	0.8+
Thickness of exposed Kanwaka Shale	39.6

3. *Ozawkie Limestone Member of the Deer Creek Limestone down into the King Hill Shale Member of the Lecompton Limestone*

[Along creek and along old farm road in the NE¼SE¼ and SE¼SE¼ sec. 27, T. 12 S., R. 17 E., Shawnee County]

	Feet
Deer Creek Limestone:	
Ozawkie Limestone Member:	
Limestone (deeply weathered); large moderate-yellowish-brown blocks; base not exposed; abundant *Osagia;* very abundant fusulinids	2.7+
Tecumseh Shale:	
Siltstone (deeply weathered), pale-olive, clayey; poorly exposed	5.0
Siltstone, medium-gray, very finely sandy, laminated to platy; weathers olive gray	1.5
Siltstone, medium-gray, clayey	.5
Sandstone, light-olive-gray to olive-brown, very fine grained, platy, micaceous	.4
Siltstone, medium-gray to pale-olive, clayey, platy	.7
Sandstone, pale-olive, very fine grained, silty, platy to very thin bedded, micaceous; limonite enrichment at top; carbonaceous material on bedding planes	.8
Siltstone, pale-olive, laminated to platy	.3
Siltstone, olive-gray, laminated; iron stain on bedding planes	.1
Siltstone, medium-gray to light-olive-gray, laminated to platy; scattered carbonaceous material on bedding planes	.6
Sandstone, light-olive-gray, very fine grained, platy, micaceous; carbonaceous material on bedding planes	.4
Limestone, hard, conglomeratic; weathers moderate yellowish brown; abundant light-yellowish-gray to light-olive-gray argillaceous limestone granules and pebbles as much as 0.04 ft long; forms resistant ledge	.7
Covered interval	5.5
Siltstone, moderate-olive-brown to light-olive-gray clayey; bedding indistinct; weathers to spheroidal or pencillike fragments; reddish-brown iron stain on joints and bedding planes; scattered plant fragments	27.5
Covered interval; probably claystone	15.5
Claystone, light-olive-gray, platy; weathers light gray to light yellowish gray; small pyrite inclusions; basal contact sharp, even; few small crinoid columnals	2.7
Thickness of Tecumseh Shale	62.2

3. *Ozawkie Limestone Member of the Deer Creek Limestone down into the King Hill Shale Member of the Lecompton Limestone*—Continued

	Feet
Lecompton Limestone:	
Avoca Limestone Member:	
Limestone, medium-light-gray (with olive tint), argillaceous; in two very thin wavy beds 0.3 ft thick; scattered fusulinids, crinoid columnals, bryozoans, small brachiopods, and few cephalopods	0.6
Claystone (deeply weathered), medium-dark-gray; exposed along creek	.4
Limestone, medium-gray, very finely crystalline, very thin to thin-bedded; weathers to moderate-yellowish-brown vertically jointed bed; basal contact sharp, irregular; very abundant fusulinids; some brachiopods; forms ledge that causes a waterfall	2.5
Thickness of Avoca Limestone Member	3.5
King Hill Shale Member:	
Siltstone, medium-gray, clayey, platy; abundant brachiopods; only uppermost part exposed below waterfall on Avoca Limestone Member	0.5+
Thickness of exposed Lecompton Limestone	4.0

4. *Composite section of the Deer Creek Limestone*

[Ervine Creek Limestone Member in quarry in the SE¼SE¼ sec. 20; middle members and upper part of the Ozawkie Limestone Member in roadcut on south line of the SW¼SW¼ sec. 21; and lower part of Ozawkie Limestone Member in roadcut in the SW cor. NW¼NW¼ sec. 27, T. 13 S., R. 16 E., Shawnee County]

	Feet
Calhoun Shale:	
Claystone, medium-gray, silty, platy; weathers light olive gray to moderate yellowish brown; scattered carbonaceous material on bedding planes in lower 1.5 ft; top not exposed	8.0+
Deer Creek Limestone:	
Ervine Creek Limestone Member:	
Limestone, brownish-gray to olive-gray, very argillaceous; abundant crinoid columnals, bryozoans, shell fragments, and productid(?) spines	0.2
Claystone, laminated, very calcareous; weathers light olive gray to pale yellowish brown	.4
Limestone, medium-gray, very argillaceous, thin- to medium-bedded; weathers to light-olive-gray smoothly rounded layers; subconchoidal fracture; upper contact gradational; scattered brachiopods and pelecypods	8.5
Limestone, medium-light-gray to medium-gray, very finely crystalline; thin to medium wavy beds as much as 0.9 ft thick; very argillaceaus adjacent to bedding planes; weathers light olive gray to moderate yellowish brown; abundant fusulinids, horn corals, crinoid columnals, bryozoans, and brachiopods	9.0
Thickness of Ervine Creek Limestone Member	18.1

4. *Composite section of the Deer Creek Limestone*—Continued

	Feet
Deer Creek Limestone—Continued	
Larsh and Burroak Shale Members:	
Claystone, medium-gray, slight silty, laminated to platy; weathers olive gray to olive brown; scattered pelecypod(?) casts	3.5
Claystone, black, laminated, very finely micaceous; weathers to brownish-black to dark-olive-gray fissile fragments; orbiculoid brachiopods(?), small pelecypods, conodonts	1.2
Claystone, calcareous; weathers olive gray; small brachiopods; other fossil fragments	.1
Thickness of Larsh and Burroak Shale Members	4.8
Rock Bluff Limestone Member:	
Limestone, medium-gray, very finely crystalline, thin- to medium-bedded; weathers olive gray to moderate yellowish brown; subconchoidal fracture; crystalline calcite fills shell casts; lower contact sharp, undulating; upper contact sharp, regular; abundant *Osagia*, fusulinids, crinoid columnals, and brachiopods; forms prominent vertically jointed ledge	2.8
Oskaloosa Shale Member:	
Claystone, medium-gray, slightly silty, platy; weathers olive gray; light-gray limestone pellets less than 0.05 ft in diameter in upper 0.2 ft; abundant very small pyritic inclusions; scattered brachiopods and pelecypods	6.8
Ozawkie Limestone Member:	
Limestone, very fine grained, slightly argillaceous, massive; weathers pale to moderate yellowish brown; small greenish-gray claystone inclusions; crystalline-calcite-filled fossil casts; crinoid columnals; some fine *Osagia*	4.2
Claystone, very calcareous; weathers moderate yellowish brown in basal 0.3 ft and olive gray above; abundant light-olive-gray to yellowish-brown limestone fragments in upper 1 ft; upper contact sharp, slightly irregular	2.0
Limestone, very fine grained; weathers moderate yellowish brown to brownish gray; scattered small hard irregular ferruginous limestone masses on weathered surfaces; fusulinids generally very abundant, sparse in upper 0.3 ft; crinoid columnals, *Composita*, *Juresania*, and other brachiopods; some bryozoans; forms prominent ledge	3.9
Thickness of Ozawkie Limestone Member	10.1
Thickness of Deer Creek Limestone	42.6

4. *Composite section of the Deer Creek Limestone*—**Continued**

	Feet
Tecumseh Shale:	
Claystone, medium-dark-gray, silty, platy, micaceous; weathers olive gray; upper contact sharp, even; scattered *Chonetes* and other brachiopods and pelecypods	1.8
Limestone, medium-light-gray, fine-grained, argillaceous; weathers light gray to pale yellowish brown; abundant *Osagia*, crinoid columnals, bryozoans, fine shell hash, and productid(?) spines	1.2
Claystone; weathers olive gray to moderate yellowish brown; moderate-yellowish-brown nodular limestone 0.15 ft thick in the middle; upper contact sharp, even	.7
Limestone, medium-dark-gray, very fine grained, clayey to very silty; weathers to two olive-gray to moderate-yellowish-brown beds of equal thickness; some cellular-weathering limestone in upper 0.3 ft; abundant secondary-calcite stringers	.6
Claystone, medium-dark-gray to olive-gray, silty, platy; abundant light-olive-gray siltstone laminae; bedding indistinct in upper 1 ft	3.6
Siltstone, laminated to platy, micaceous; weathers olive gray to olive brown; scattered very fine carbonaceous material on bedding planes; base not exposed	5.5+
Thickness of exposed Tecumseh Shale	13.4

5. *Hartford Limestone Member of the Topeka Limestone down into the Ervine Creek Limestone Member of the Deer Creek Limestone*

[Along road in the center of the N½N½N½ sec. 27, T. 10 S., R. 17 E., Jefferson County]

	Feet
Topeka Limestone:	
Hartford Limestone Member:	
Limestone (deeply weathered), moderate-yellowish-brown, very finely crystalline, hard; abundant fusulinids, crinoid columnals, and brachiopods; ledge poorly exposed	4.7
Calhoun Shale:	
Sandstone, light-olive-gray, very fine grained, platy to very thin bedded; sandy siltstone partings; partly covered	9.8
Siltstone, light-olive-gray, sandy; grades upward into sandstone	5.0
Sandstone, calcareous, ferruginous; weathers to light-brown to reddish-brown concretions	.2
Siltstone, light-olive-gray; silty sandstone layer 0.2 ft thick near middle	3.2
Sandstone, olive-gray, very fine grained, silty; capped by very thin layer that weathers yellowish orange	.4
Siltstone, olive-gray, sandy	1.4
Siltstone, light-olive-gray, sandy; capped by calcareous concretionary sandstone bed 0.1 ft thick that weathers yellowish orange	2.4
Sandstone, light-olive-gray, very fine grained, silty, platy; capped by layer 0.05 ft thick that weathers yellowish orange	.4
Siltstone, light-olive-gray; upper part more sandy	2.4
Sandstone, very fine grained, calcareous, concretionary; weathers light brown	.1

5. *Hartford Limestone Member of the Topeka Limestone down into the Ervine Creek Limestone Member of the Deer Creek Limestone*—Continued

	Feet
Calhoun Shale—Continued	
Siltstone, light-olive-gray, clayey to sandy, finely laminated; weathers light olive gray	0.6
Sandstone, light-olive-gray, very fine grained, laminated to platy, micaceous; weathers to hard light-olive-gray finely crossbedded layers; some ripple-marked layers; interbedded with light-olive-gray sandy siltstone; unit capped by layer of calcareous sandstone concretions as much as 0.15 ft in diameter that weather light brown; black carbonaceous material on bedding planes	4.1
Siltstone, olive-gray; clayey to sandy in upper part; weathers light olive gray to light olive brown; upper contact gradational	3.3
Claystone, olive-gray, silty, platy to very thin bedded; weathers to light-olive-gray blocky to pencillike fragments; upper contact gradational	3.2
Sandstone, olive-gray, calcareous, micaceous, fossiliferous; weathers light olive gray; moderate-yellowish-brown iron stain on joints	1.9
E. L. Yochelson (written commun., 1960) reported on the following forms present in this sandstone:	
Lingula sp. indet.	
Aviculopecten sp. indet.	
Myalinid indet.	
Knightites (*Retispira*) sp. indet.	
Organic indeterminate (possibly *Orbiculoidea*)	
Siltstone, light-olive-gray, slightly clayey, platy; weathers light olive gray to light olive brown	.7
Siltstone, olive-gray, coarse-grained, hard; weathers light olive gray; light-reddish-brown stain on joints; beds 0.2 ft thick	.4
Siltstone, light-olive-gray to light-olive-brown, clayey	.6
Claystone, light-olive-gray to light-olive-brown, silty; basal contact sharp, slightly irregular; upper contact gradational; few crinoid columnals and echinoid spines in basal 0.1 ft	1.6
Thickness of Calhoun Shale	41.7
Deer Creek Limestone:	
Ervine Creek Limestone Member:	
Limestone, olive-gray, silty, very fossiliferous; forms ledge that caps underlying unit	0.4
Limestone, olive-gray, very finely crystalline, silty, very fossiliferous; weathers to moderate-yellowish-brown porous beds	1.7
Limestone, light-olive-gray, very finely crystalline, hard, compact, fossiliferous; weathers to light-olive-gray to moderate-yellowish-brown thin to medium wavy beds; some layers very silty; a few siliceous hackly layers about 2 ft below top; base not exposed	7.9
USGS fossil loc. 19446–PC (f12983). From entire member.	
Thickness of exposed Ervine Creek Limestone Member	10.0
Thickness of exposed Deer Creek Limestone	10.0

6. *Topeka Limestone and uppermost part of the Calhoun Shale*

[Along U.S. Highway 24 in the N½S½ sec. 14, T. 11 S., R. 16 E., Shawnee County]

	Feet
Till.	
Topeka Limestone:	
Coal Creek Limestone Member:	
Limestone, light-olive-gray, silty; weather to nodular beds less than 0.2 ft thick; interbeds less than 0.05 ft thick of light-olive-gray calcareous siltstone; member capped by hard limestone bed 0.6 ft thick, underlain by siltstone bed 0.6 ft thick that contains a few limestone lenses; USGS fossil loc. 19447–PC (f12996)	4.4
Holt Shale Member:	
Siltstone, dark-gray, laminated; weathers to medium-dark-gray fissile fragments; upper contact slightly irregular; rhomboporoid bryozoans, brachiopods (cf. *Crurithyris*), conodonts(?); identifications by E. L. Yochelson (written commun. 1960)	2.1
Du Bois Limestone Member:	
Limestone, medium-dark-gray, very finely crystalline, hard, compact; weathers to light-olive-gray to light-yellowish-gray vertically jointed bed; abundant brachiopods and gastropods	0.8
Turner Creek Shale Member:	
Siltstone, light-olive-gray; pelecypods	0.4
Limestone, light-olive-gray, very finely crystalline; weathers to hard light-olive-gray bed; brachiopods, productid spines, gastropods	.2
Siltstone, light-olive-gray, slightly sandy, platy	.5
Limestone, medium-gray, very fine grained, hard; weathers medium light gray to light olive gray; abundant brachiopods, productid spines, and gastropods	.1
Siltstone, light-olive-gray, slightly sandy; fossil fragments	.5
Limestone, medium-dark-gray, hard; abundant very small pyrite and limestone pellets; very abundant fossil fragments	.1
Siltstone, medium-light-gray, slightly sandy, platy; weathers light olive gray; scattered shell fragments	1.1
Thickness of Turner Creek Shale Member	2.9
Sheldon Limestone Member:	
Limestone, light-gray to light-olive-gray; weathers light olive gray to very light yellowish brown; silty in lower 0.9 ft; forms ledge; base is generally poorly exposed; very small fossil fragments	3.5
Jones Point Shale Member:	
Claystone, olive-gray, silty to very finely sandy; weathers light olive gray; micaceous on bedding planes	2.7

6. *Topeka Limestone and uppermost part of the Calhoun Shale*—Continued

	Feet
Topeka Limestone—Continued	
Curzon Limestone Member:	
Limestone, light-yellowish-brown to olive-gray, very finely crystalline, hard; weathers to moderate-yellowish-brown vertically jointed bed; scattered *Osagia*, fusulinids, echinoid spines, fenestrate and ramose bryozoans, *Linoproductus* and other brachiopods, high-spired gastropods (aff. "*Murchisonia*"); identifications by E. L. Yochelson (written commun. 1960)	1.2
Limestone, light-olive-gray, silty; interbedded with light-olive-gray claystone; limestone weathers to thin irregular beds and lenses; fusulinids (USGS colln. f12998), crinoid plate and stem fragments, echinoid spines, rhomboporoid, ramose, and fenestrate bryozoans, *Derbyia*, *Chonetes granulifer* Owen, *Neospirifer dunbari* R. H. King, and *Composita subtilita* (Hall); identifications by E. L. Yochelson (written commun., 1960)	1.8
Limestone, medium-light-gray, very finely crystalline, hard, compact, hackly; beds 0.4–1.3 ft thick; medium-light-gray silty limestone interbeds 0.3–0.5 ft thick; brownish-gray fossiliferous chert in irregular masses as much as 0.3 ft thick mainly in zone about 1 ft below top; some masses scattered in upper 2 ft; *Osagia*?, fusulinids (USGS colln. f12997), crinoid stems, bryozoans, *Composita*	4.9
Thickness of Curzon Limestone Member	7.9
Iowa Point Shale Member:	
Claystone, medium-gray to olive-gray, silty, laminated, micaceous; weathers medium light gray; some shell fragments	1.4
Hartford Limestone Member:	
Limestone, light-olive-gray, very finely crystalline; silty in upper half; weathers moderate yellowish brown; weathers to irregular blocks in upper 2.7 ft; single hard vertically jointed bed that has sharp edges and "cable markings" in lower 2.8 ft; upper contact gradational through about 0.1 ft of silty limestone; abundant fusulinids throughout (USGS colln. f12999); algae, crinoid stems, lophophyllidid corals, brachiopods, and possibly pelecypods in lower part	5.5
Siltstone, olive-gray, slightly sandy, laminated to platy; weathers light olive gray; crinoid columnals	.2
Limestone, light-olive-gray, very finely crystalline, hard; weathers yellowish gray to moderate yellowish brown; forms resistant ledge at base of Topeka; abundant fusulinids (USGS colln. f12995), crinoid columnals, echinoderm debris, bryozoans, brachiopods, and a high-spired gastropod	.5
Thickness of Hartford Limestone Member	6.2
Thickness of Topeka Limestone	31.9

6. *Topeka Limestone and uppermost part of the Calhoun Shale*—Continued

Calhoun Shale:	*Feet*
Siltstone, olive-gray, sandy; upper contact sharp	1.2
Coal, brownish-black, hard, brittle, hackly	.2
Clay, olive-gray; structureless	.1
Siltstone, medium-gray to olive-gray, sandy, laminated to platy, micaceous; weathers yellowish gray to light olive gray; base not exposed	4.0+
Thickness of exposed Calhoun Shale	5.5

7. *Howard Limestone and upper part of the Severy Shale*

[Along the Kansas Turnpike and in the bank of Shunganunga Creek in the NE¼SE¼ sec. 26, T. 12 S., R. 15 E., Shawnee County]

Howard Limestone:	*Feet*
Utopia Limestone Member:	
Limestone, light-olive-gray, hard; weathers light olive gray with dark-yellowish-orange stains; very abundant fusulinids; some crinoid columnals and brachiopods	1.4
Limestone, light-olive-gray; irregular thin beds; weathers light olive gray with dark-yellowish-orange stains; very abundant fenestrate bryozoans, crinoid columnals, echinoid spines, and brachiopods	.9
Siltstone, pale-yellowish-brown to light-olive gray, laminated to platy; weathers yellowish gray with pale-brown tint; medium-dark-gray siltstone laminae on bedding planes; olive-gray coarse-grained siltstone lenses as much as 0.13 ft thick; ostracodes very abundant in dark siltstone laminae and lenses; small pelecypods, fine shell fragments, carbonaceous material	1.3
Limestone, light-brownish-gray to light-olive-gray, slightly sandy, thin-bedded; weathers to thin yellowish-gray to pale-yellowish-orange nodular beds; very abundant *Osagia;* abundant crinoid columnals, brachiopods, and pelecypods	2.5
Thickness of Utopia Limestone Member	6.1
Winzeler Shale Member:	
Siltstone, light-olive-gray, sandy, laminated to platy; weathers yellowish gray; ferruginous specks that weather moderate yellowish brown; fenestrate and ramose bryozoans and brachiopods in basal part	3.4
Limestone, medium-light-gray, thin-bedded, hard, dense; weathers moderate yellowish brown; crinoid columnals, brachiopods	1.0
Siltstone, yellowish-gray to light-gray, finely sandy, laminated	.2
Thickness of Winzeler Shale Member	4.6
Church Limestone Member:	
Limestone, medium-light-gray, hard, dense, hackly; weathers to single moderate-yellowish-brown bed; abundant crinoid columnals and brachiopods	2.2

7. *Howard Limestone and upper part of the Severy Shale*—Continued

	Feet
Howard Limestone—Continued	
Aarde Shale Member:	
Siltstone, dark-gray, slightly sandy, laminated to platy; weathers medium gray; brachiopods	2.4
Coal (Nodaway), black, laminated to platy; weathers to blocky fragments; dark-gray to grayish-black fissile siltstone in lower 0.2 ft	1.4
Thickness of Aarde Shale Member	3.8
Thickness of Howard Limestone	16.7
Severy Shale:	
Clay, medium-dark-gray, sandy, plastic; weathers medium light gray; dusky-yellow sandstone specks; carbonaceous material just below overlying coal bed	0.7
Sandstone, very light olive gray to yellowish-gray; medium dark gray in upper part; fine grained, platy to thin bedded, micaceous; weathers pale yellowish brown, mottled with moderate yellowish brown; abundant pyrite nodules; a few vertical joints as much as 0.07 ft wide filled with harder sandstone; base not exposed	13.7
Thickness of exposed Severy Shale	14.4

8. *Lower part of the White Cloud Shale Member of the Scranton Shale down into the uppermost part of the Severy Shale*

[In railroad cut and bluff in the SW¼NW¼ sec. 27, T. 11 S., R. 15 E., Shawnee County]

	Feet
Scranton Shale:	
White Cloud Shale Member:	
Sandstone, light-gray to very light olive gray, fine-grained, quartzose, calcareous, slightly crossbedded; layers 0.01–0.05 ft thick; abundant mica and carbonaceous material in soft basal 0.5 ft; crops out in ledges as much as 5.5 ft thick in bluff; only lower part measured	21.0+
Siltstone and sandstone (channel); olive-gray finely sandy siltstone layers less than 0.01–0.04 ft thick; siltstone weathers light olive gray; interbeds of very light olive gray to light-yellowish-brown very fine grained silty sandstone in layers ranging in thickness from less than 0.01 ft to more than 0.5 ft; many very small chips of mudstone along bedding planes; minute pyrite specks in sandstone; crops out in lower part of bluff	15.0
Limestone, light-olive-gray, finely sandy, micaceous, conglomeratic; subangular to subrounded pebbles generally less than 0.1 ft in diameter, but some range in diameter from 0.02–0.2 ft of hard compact very finely crystalline limestone that weathers olive gray to moderate yellowish brown; abundant pyrite and carbonized plant material; coal stringer 0.01 ft thick locally at or near base; conglomerate absent in places at base of channel	0–0.8

8. *Lower part of the White Cloud Shale member of the Scranton Shale down into the uppermost part of the Severy Shale*—Continued

	Feet
Scranton Shale—Continued	
White Cloud Shale Member—Continued	
Thickness of exposed White Cloud Shale Member	36. 0–36. 8
Thickness of exposed Scranton Shale	36. 0–36. 8
Disconformity.	
Howard Limestone:	
Utopia Limestone Member:	
Limestone, light-olive-gray, very finely crystalline, silty, very thin bedded; weathers moderate yellowish brown and platy at top; upper surface eroded; *Osagia*, crinoid columnals; small algal(?)-encrusted shells of brachiopods and pelecypods; forms (with the overlying conglomeratic limestone) prominent ledge in bluff	0. 9–2. 0
Siltstone, medium-dark-gray to olive-gray; clayey, laminated; weathers olive gray; some carbonaceous material and fine shell fragments	. 2
Limestone, olive-gray, very finely crystalline, silty; *Osagia*, crinoid columnals, fine shell fragments	. 1
Thickness of Utopia Limestone Member	1. 2–2. 3
Winzeler Shale Member:	
Claystone, medium-dark-gray, silty, laminated; weathers light olive gray to olive gray	1. 4
Church Limestone Member:	
Limestone, light-olive-gray, very finely crystalline, hard, compact; weathers to vertically jointed moderate-yellowish-brown ledge; platy in upper 0.2 ft; abundant crinoid columnals, ramose and fenestrate bryozoans, and brachiopods	2. 1
Aarde Shale Member:	
Claystone, light-olive-gray, silty, platy; weathers light olive gray, partly mottled with light olive brown; a few very small black carbonaceous or phosphate specks; abundant shell fragments	1. 7
Claystone, dark-gray, slightly silty; laminated to platy; weathers to dark-olive-gray fissile fragments; few *Lingula*?; visible dark band in railroad cut	. 2
Claystone, light-olive-gray, very calcareous; a few clayey limestone lenses; very abundant brachiopods and abundant bryozoans	2. 4

8. *Lower part of the White Cloud Shale Member of the Scranton Shale down into the uppermost part of the Severy Shale*—Continued

	Feet
Howard Limestone—Continued	
Aarde Shale Member—Continued	
E. L. Yochelson (written commun. 1960) reported on the the following forms:	
Small foraminifers, undet. (USGS colln. f12981)	
Horn coral, indet. (juvenile)	
Crinoid stem, pieces	
Marginifera cf. M. wabashensis (Norwood and Pratten)	
Composita subtilita (Hall)	
Crurithyris planoconvexa (Shumard)	
Hustedia mormoni (Marcou)	
Coal (Nodaway), black, hackly, glistening; principally light-brownish-gray carbonaceous siltstone containing coal stringers as much as 0.05 ft thick in upper 0.17 ft; mostly grayish-black carbonaceous claystone containing coal stringers in lower 0.4 ft; very thin light-yellow jarosite streaks throughout	1.4
Thickness of Aarde Shale Member	5.7
Thickness of Howard Limestone	10.4–11.5
Severy Shale:	
Claystone, light-olive-gray; fine carbonaceous material fills vertical fractures	0.2
Claystone and siltstone; olive-gray silty laminated claystone interbedded with very light olive gray very finely sandy micaceous siltstone laminae; outcrop weathers light olive gray, streaked by moderate yellowish brown; very small pyritic inclusions that weather moderate yellowish brown; finely disseminated carbonaceous material; base not exposed	5.0+
Thickness of exposed Severy Shale	5.2

9. *Upper part of the Silver Lake Shale Member down into the upper part of the White Cloud(?) Shale Member of the Scranton Shale*

[Along the Kansas Turnpike in the SE¼SE¼ sec. 4, T. 13 S., R. 15 E., Shawnee County]

	Feet
Scranton Shale:	
Silver Lake Shale Member:	
Limestone, silty, thin-bedded; weathers moderate yellowish brown. Unit not measured.	
Siltstone, medium-light-gray to light-olive-gray, platy; weathers light olive gray to moderate yellowish brown	8.8
Claystone, medium-dark-gray, laminated to platy	10.8
Thickness of exposed Silver Lake Shale Member	10.6

9. *Upper part of the Silver Lake Shale Member down into the upper part of the White Cloud (?) Shale Member of the Scranton Shale*—Continued

	Feet
Scranton Shale—Continued	
Rulo Limestone Member:	
Limestone, medium-gray, very fine grained; very argillaceous especially in basal and uppermost parts; hard slightly concretionary limestone layer 0.7 ft thick about 0.15 ft above base; abundant crinoid columnals, ramose and fenestrate bryozoans, and brachiopods	1.4
Cedar Vale Shale Member:	
Claystone, medium-dark-gray, laminated to platy; grades upward into Rulo	0.6
Coal (deeply weathered) (Elmo), black; grayish-black laminated claystone 0.05 ft thick in the middle	.3
Claystone, medium-gray; in part stained yellowish brown; bedding indistinct	1.0
Siltstone, medium-light-gray, very finely sandy, laminated to platy, micaceous	4.7
Sandstone, light-gray, very fine grained, platy to very thin bedded; weathers olive gray to olive brown; very silty in upper 1.5 ft	1.8
Siltstone, medium-gray, clayey, laminated to platy, micaceous; weathers olive gray to yellowish brown; grades into overlying sandstone	2.1
Claystone, medium-dark-gray, laminated; weathers olive brown; abundant crinoid columnals and pelecypods	.2
Limestone, brownish-gray, fine-grained, argillaceous; medium-dark-gray claystone pebbles and stringers as much as 0.01 ft thick; abundant fossile fragments	.4
Siltstone, very thin bedded, very calcareous, soft; weathers to pale-yellowish-brown to moderate-yellowish-brown cellular blocks; abundant very thin calcite stringers	1.2
Claystone, medium-gray to olive-gray, silty, platy to very thin bedded; weathers medium light gray to light olive gray; upper contact sharp, even	12.8
Siltstone, medium-light-gray, micaceous, soft; weathers medium brownish gray to olive brown	.5
Siltstone, medium-light-gray; weathers moderate yellowish brown; some small brown-weathering pyritic siltstone masses	.3
Siltstone, medium-light-gray, micaceous; weathers medium brownish gray to olive brown	.2
Siltstone, medium-light-gray, very calcareous; weathers to single bed of moderate-yellowish-brown hard round masses	1.5
Siltstone, medium-light-gray, micaceous; calcareous in upper 1.5 ft; weathers brownish gray to olive brown; much iron stain in upper 1.5 ft	2.1
Claystone; weathers olive gray	1.5
Thickness of Cedar Vale Shale Member	31.2

9. *Upper part of the Silver Lake Shale Member down into the upper part of the White Cloud (?) Shale Member of the Scranton Shale*—Continued

	Feet
Scranton Shale—Continued	
Happy Hollow (?) Limestone Member:	
Limestone, brownish-gray, very fine grained, very argillaceous; weathers to rough pitted moderate-yellowish-brown cobbles; abundant ferruginous limestone nodules as much as 0.1 ft thick; abundant crinoid columnals, bryozoans, pelecypods, and unidentified spines; forms inconspicuous bed	0.5
White Cloud (?) Shale Member:	
Siltstone, medium-gray to medium-dark-gray, laminated to very thin bedded; weathers light olive gray to moderate yellowish brown; claystone interbeds of same color; abundant siltstone chips and plates on weathered outcrop; base not exposed	5.5+
Thickness of exposed Scranton Shale	58.2

10. *Basal part of Auburn Shale down into the Silver Lake Shale Member of the Scranton Shale*

[Along the Kansas Turnpike in the SW¼SE¼ sec. 34, T. 12 S., R. 15 E., Shawnee County]

	Feet
Auburn Shale:	
Claystone, laminated; weathers olive gray to olive brown; small cellular masses of light-gray limestone; top not exposed	2.0+
Bern Limestone:	
Wakarusa Limestone Member:	
Limestone, medium-gray, very fine grained, slightly argillaceous, thin- to medium-bedded; weathers olive gray to moderate yellowish brown; weathers to rubbly plates in upper 0.2 ft; abundant fusulinids (especially in upper part) and *Osagia*?; forms prominent ledge; USGS fossil loc. 19457–PC (f12975)	2.4
Claystone, olive-gray, platy, calcareous; crinoid columnals, brachiopods	.7
Limestone, medium-gray to brownish-gray, very fine grained; weathers pale yellowish brown to moderate yellowish brown; abundant *Osagia*, fusulinids, and crinoid columnals	.7
Thickness of Wakarusa Limestone Member	3.8
Soldier Creek Shale Member:	
Claystone, medium-gray; weathers olive gray; abundant limonitic spots and streaks that weather moderate yellowish brown	2.8
Limestone, medium-light-gray, very fine grained, very argillaceous; weathers light gray to pale yellowish brown; weathers to rubbly slope	2.2
Claystone, medium-gray, calcareous; weathers olive gray; scattered medium-light-gray argillaceous limestone beds as much as 0.1 ft thick	1.4
Limestone, medium-light-gray to medium-gray, very fine grained, very argillaceous, very thin to thin-bedded; weathers light olive gray; interbedded with medium-gray claystone layers, especially in upper part; scattered pyritic inclusions 0.01 ft in diameter	1.9

10. *Basal part of Auburn Shale down into the Silver Lake Shale Member of the Scranton Shale*—Continued

	Feet
Bern Limestone—Continued	
Soldier Creek Shale Member—Continued	
Claystone, medium-dark-gray to dark-gray, laminated to platy; a few *Lingula*? and other brachiopods at base; pectinoid pelecypods in upper half	1.8
Thickness of Soldier Creek Shale Member	10.1
Burlingame Limestone Member:	
Limestone, medium-light-gray, very fine grained, thin- to medium-bedded; argillaceous in lower 0.2 ft; weathers pale yellowish brown; many *Osagia;* E. L. Yochelson (written commun. 1960) reported abundant fusulinids (USGS colln. f12976), crinoid stems, rhomboporoid bryozoans, *Derbyia crassa* (Meek and Hayden), *Enteletes*?; *Chonetes granulifer* Owen, *Linoproductus, Neospirifer dunbari,* R. H. King, and *Composita subtilita* (Hall); forms prominent ledge	2.1
Thickness of the Bern Limestone	16.0
Scranton Shale:	
Silver Lake Shale Member:	
Claystone, medium-gray to medium-dark-gray; very small limestone grains in upper half; silty in lower half; thin medium-gray limestone lenses in upper 0.5 ft; upper contact sharp, undulating; brachiopod fragments in upper 0.5 ft	2.3
Siltstone, medium-light-gray, very sandy	.9
Sandstone, medium-light-gray, very fine grained, silty, very thin to thin-bedded, soft, micaceous; weathers light gray to moderate yellowish brown; lower 1 ft poorly exposed; forms ledge elsewhere along outcrop	3.0
Siltstone, medium-light-gray, sandy, very thin to thin-bedded, very calcareous; in part ripple marked; weathers light gray mottled with grayish red	2.0
Sandstone, medium-light-gray, very fine grained, very thin to thin-bedded, very calcareous; weathers to hard irregular beds that are light gray mottled with grayish red; scattered very small pyritic inclusions; grades into overlying siltstone; abundant fucoidal marks on bedding planes; scattered bryozoans and pelecypods	3.5
Siltstone, medium-gray, clayey, laminated to platy, micaceous; olive-gray calcareous siltstone 0.05 ft thick in the middle	.6
Limestone, medium-gray, very fine grained, very silty to very finely sandy, pyritic; weathers olive brown to reddish brown; basal contact irregular; very abundant pelecypods	.1
Claystone, medium-dark-gray, silty, laminated; interbedded with some medium-light-gray siltstone	1.2

10. *Basal part of Auburn Shale down into the Silver Lake Shale Member of the Scranton Shale*—Continued

	Feet
Scranton Shale—Continued	
Silver Lake Shale Member—Continued	
Siltstone, medium-light-gray to medium-gray, laminated to platy, micaceous; interbedded with medium-dark-gray silty claystone; finely sandy in upper half; abundant oval pyrite nodules as much as 0.4 ft long and 0.07 ft thick; some carbonaceous material on bedding planes	4.0
Claystone, silty, laminated to platy; weathers olive gray; a few very thin limonitic siltstone beds; pyritic siltstone concretions as much as 0.06 ft long and 0.03 ft thick; base not exposed	1.5+
Thickness of exposed Silver Lake Shale Member	19.1
Thickness of exposed Scranton Shale	19.1

11. *Bern Limestone*

[Along U.S. Highway 75 in the SE¼SE¼ sec. 31., T. 9 S., R. 16 E., and the NE¼NE¼ sec. 6, T. 10 S., R. 16 E., Jackson and Shawnee Counties]

	Feet
Bern Limestone:	
Wakarusa Limestone Member:	
Limestone, light-olive-gray, very finely crystalline, hard, compact; weathers to a mottled light-olive-gray and dark-yellowish-brown vertically jointed bed; small *Cryptozoon*-type algae; abundant large fusulinids, horn corals, crinoid columnals, and brachiopods	1.8
Claystone, light-olive-gray, silty, platy; weathers light olive gray; fossiliferous limestone lens 0.1 ft thick near the middle; crinoid columnals, shell fragments	.4
Limestone, light-olive-gray, very finely crystalline, clayey; weathers light olive gray; two beds; abundant brachiopods; scattered fusulinids	.2
Claystone, light-olive-gray, silty; very thin clayey limestone lenses; abundant shell fragments	.2
Limestone, light-olive-gray, very finely crystalline; weathers light olive brown to light olive gray; abundant crinoid columnals, bryozoans, and brachiopods	0.4
Thickness of Wakarusa Limestone Member	3.0
Soldier Creek Shale Member:	
Claystone, olive-gray, slightly silty, platy; weathers light olive gray mottled with light olive brown; abundant pyritic limestone inclusions less than 0.01 ft in diameter that weather moderate yellowish brown; lower half not exposed	2.6
Burlingame Limestone Member:	
Limestone, pale-yellowish-orange, very fine grained, argillaceous; weathers to pale-yellowish-orange bed; upper and lower contacts uneven, gradational	0.7

11. *Bern Limestone*—Continued

	Feet
Bern Limestone—Continued	
Burlingame Limestone Member—Continued	
Limestone, pale-yellowish-brown to light-olive-gray, very finely crystalline, hard, compact, brecciated; thin to medium irregular beds; a few thick beds; weathers pale yellowish orange in upper part; weathers light olive gray in rest of unit; lower contact irregular, gradational; abundant large fusulinids, crinoid columnals, bryozoans, and brachiopods in upper 1 ft; fossils throughout rest of unit are sparse—primarily *Osagia* and brachiopods	9.8
Claystone, medium-light-gray, platy calcareous; weathers yellowish gray; lower contact uneven, gradational; brachiopods	0.8
Limestone, light-olive-gray, very finely crystalline, hard; weathers to pale-yellowish-brown bed; lower contact uneven; *Osagia*, crinoid stems, ramose and fenestrate bryozoans, brachiopods, pelecypods, gastropods	.5
Thickness of Burlingame Limestone Member	11.8
Thickness of Bern Limestone	17.4

12. *Tarkio Limestone Member of the Zeandale Limestone down into the Cedar Vale(?) Shale Member of the Scranton Shale*

[Along road in the SW¼SE¼ and on south line of the SW¼ sec. 19, T. 9 S., R. 16 E., Jackson County]

	Feet
Till.	
Zeandale Limestone:	
Tarkio Limestone Member:	
Limestone, light-olive-gray, very fine grained, slightly clayey, thin-bedded; abundant large fusulinids and crinoid stems; only lower part exposed; USGS colln. f12991	1.6+
Willard Shale:	
Claystone, light-olive-gray, silty	2.5
Sandstone, light-yellowish-gray to light-olive-gray, very fine grained, silty, micaceous, soft; weathers light olive mottled with moderate yellowish brown	6.0
Claystone, silty; weathers mottled light olive gray to light olive brown; light-olive-gray very finely sandy micaceous siltstone interbeds as much as 0.06 ft thick; siltstone (more abundant in upper part) grades into overlying sandstone	14.0
Covered interval	18.6
Thickness of Willard Shale	41.1

12. *Tarkio Limestone Member of the Zeandale Limestone down into the Cedar Vale (?) Shale Member of the Scranton Shale*—Continued

	Feet
Emporia Limestone:	
Elmont Limestone Member:	
Limestone, light-olive-gray, very fine grained, hard, compact, hackly; forms single vertically jointed bed; scattered small fusulinids; many small brachiopods	1. 0
Limestone, medium-gray, very fine grained, thin-bedded, hard, compact; weathers light brownish gray to light olive gray; hackly to subconchoidal fracture; light-olive-gray and dark-gray dense angular limestone fragments less than 0.03 ft in diameter in upper 0.7 ft; dark-brown ostracodes visible	1. 2
Limestone, light-olive-gray, very finely crystalline, argillaceous; weathers to small rounded light-olive-gray to light-yellowish-gray blocks; abundant light-yellowish-brown calcite inclusions; fossils not identifiable	1. 3
Limestone, medium-gray, very finely crystalline; small angular light-olive-gray clayey limestone inclusions	. 2
Limestone, light-yellowish-brown, finely crystalline, very thin to thin-bedded; weathers moderate yellowish brown; granular texture on weathered surface; upper contact slightly uneven; abundant fossils, mostly as fine fragments; lamellar algae, fenestrate bryozoans, pelecypods	. 7
Thickness of Elmont Limestone Member	4. 4
Harveyville Shale Member:	
Claystone, light-olive-gray, silty; weathers to light-olive-gray blocky to subconchoidal fragments; scattered irregular oval nodules 0.08–0.15 ft long and 0.05–0.08 ft thick of very light gray to very light olive gray finely crystalline limestone	10. 5
Reading Limestone Member:	
Limestone, medium-gray, finely crystalline, hard; beds 0.6 ft thick; weathers moderate yellowish brown; capped by argillaceous limestone layer 0.35 ft thick that weathers mottled light olive gray and dark yellowish orange; limestone layer forms step set slightly back from outcrop face; upper and lower contact sharp, even; scattered light-red barite inclusions less than 0.01 ft in diameter; abundant large crinoid stems in relief; many brachiopods	2. 4
Fossils from the Reading, reported on by E. L. Yochelson (written commun. 1960), includes fusulinids (probably USGS colln. f12956A), a lophophyllidid coral, crinoid stem, rhomboporoid bryozoan, and *Echinoconchus moorei* Dunbar and Condra.	
Thickness of Emporia Limestone	17. 3

12. *Tarkio Limestone Member of the Zeandale Limestone down into the Cedar Vale (?) Shale Member of the Scranton Shale*—Continued

	Feet
Auburn Shale:	
Claystone; light-olive-gray in lower part to medium-light-gray in upper part; slightly silty; weathers to light-olive-gray blocky fragments; light-olive-gray to light-yellowish-gray clayey limestone in many irregular beds 0.02–0.09 ft thick; limestone weathers to hard fragments; limestone more abundant in upper part; claystone and limestone beds fossiliferous; USGS fossil loc. 19456–PC	10.9
Siltstone, dark-gray, hard, finely laminated to platy; weathers to medium-dark-gray ledge; very abundant ostracodes; a few *Lingula*?	.9
Claystone, light-olive-gray, slightly calcareous; weathers light yellowish gray; forms conspicuous light-colored outcrop	1.9
Covered interval	11.2
Claystone, light-olive-gray, silty; weathers to light-olive-gray blocky to subconchoidal fragments; brownish-gray stain on bedding planes and joints	2.2
Thickness of Auburn Shale	27.1
Bern Limestone:	
Wakarusa Limestone Member:	
Limestone, light-olive-gray, very finely crystalline, medium-bedded, hard; weathers moderate yellowish brown; weathers light yellowish brown and is more resistant in upper 1.5 ft; scattered pyritic inclusions generally 0.02–0.07 ft in diameter (some as much as 0.2 ft) that weather dark brown; inclusions weather out of upper surface and leave pits; abundant fusulinids (USGS colln. f12990); horn corals, crinoid stems, fenestrate bryozoans, brachiopods, pelecypods; a possible cephalopod	3.1
Soldier Creek Shale Member:	
Claystone, light-olive-gray; weathers light olive gray, light greenish gray, and light olive brown; very abundant pelecypods and gastropods	0.6–1.4
Limestone, light-olive-gray, very finely crystalline, silty, medium-bedded, coquinoidal; weathers light olive gray to light yellowish gray; scattered medium-dark-gray dense subrounded limestone pebbles 0.02–0.07 ft long; upper contact very irregular; very abundant pelecypods and gastropods; some *Osagia*	1.6
Claystone, light-greenish-gray; weathers mottled light olive gray and light olive brown; small calcareous claystone inclusions that weather light yellowish gray; partly covered	1.3

12. *Tarkio Limestone Member of the Zeandale Limestone down into the Cedar Vale (?) Shale Member of the Scranton Shale*—Continued

	Feet
Bern Limestone—Continued	
Soldier Creek Shale Member—Continued	
Limestone, light-olive-gray, very finely crystalline, clayey, compact; beds 0.1–0.2 ft thick; weathers light yellowish brown to moderate yellowish brown; crinoid columnals, brachiopods, spines, pelecypods	1.0
Claystone, light-greenish-gray; weathers light greenish gray to light olive gray with light-olive-brown specks	2.1
Thickness of Soldier Creek Shale Member	6.6–7.4
Burlingame Limestone Member:	
Limestone, light-olive-gray, very finely crystalline, hard, compact, medium- to thick-bedded; brecciated in upper half; weathers dark yellowish orange to moderate yellowish brown; irregular pattern of calcite-filled joints in upper part; basal contact sharp, slightly uneven; fossils, including small fusulinids, crinoid stems, ramose bryozoans, and brachiopods are not readily evident; forms prominent ledge	5.4
Thickness of Bern Limestone	15.1–15.9
Scranton Shale:	
Silver Lake Shale Member:	
Claystone, light-olive-gray, calcareous, platy; light-olive-gray finely crystalline irregular limestone lenses as much as 0.07 ft thick containing *Osagia*, crinoid columnals, and brachiopod spines in upper 0.8 ft; clayey nonfossiliferous limestone beds less than 0.07 ft thick that weather dark yellowish gray in lower half	3.8
Limestone, light-gray to very light olive gray, finely crystalline, silty; irregular beds 0.02–0.07 ft thick; weathers pale yellowish brown to moderate yellowish brown; interbedded with irregular light-olive-gray calcareous silty claystone layers as much as 0.03 ft thick; a few medium-gray dense limestone beds as much as 0.1 ft thick; abundant light-gray secondary calcite on bedding planes and joints	5.8
Claystone, light-olive-gray, slightly silty, platy; scatttered oval light-olive-gray hard dense fossiliferous limestone concretions as much as 0.33 ft thick and 2.5 ft long that weather pale yellowish brown; USGS fossil loc. 19455–PC	9.1
Thickness of Silver Lake Shale Member	18.7

12. *Tarkio Limestone Member of the Zeandale Limestone down into the Cedar Vale (?) Shale Member of the Scranton Shale*—Continued

	Feet
Scranton Shale—Continued	
Rulo (?) Limestone Member:	
Limestone, medium-gray to olive-gray, very finely crystalline, silty, hard, compact, pyritic; in part concretionary; weathers light olive gray to light olive brown; poorly formed cone-in-cone structures at top of bed. Concretions, 0.45 ft thick and 1.4–2 ft long, have fractures filled with light-gray and dark-brown calcite in their outer 0.1 ft; crinoid stems and *Linoproductus* and other brachiopods are present on exterior of concretions	0.2–0.4
Cedar Vale (?) Shale Member:	
Claystone, light-olive-gray, silty, laminated to platy; weathers to light-olive-gray blocky fragments; interbedded with light-olive-brown sandy micaceous siltstone layers less than 0.02 ft thick that weather to hard light-yellowish-orange to pale-yellowish-brown fragments; carbonized plant leaves and stems well preserved on bedding planes	7.0+
Thickness of exposed Scranton Shale	25.9–26.1

13. *Pillsbury Shale down to the base of the Emporia Limestone*

[In streambank and along road in the NW¼SE¼ and SW¼SE¼ sec. 21, T. 9 S., R. 15 E., Jackson County]

	Feet
Pillsbury Shale:	
Claystone (partly covered), light-olive-gray; upper part not present	9.0
Zeandale Limestone:	
Maple Hill Limestone Member:	
Limestone, light-olive-gray, very finely crystalline, thin-bedded, hard; weathers light olive gray mottled with moderate yellowish brown and dark brown, especially on upper surface; very abundant small fusulinids (USGS colln. f12971); abundant crinoid columnals, echinoid plates and brachiopods; forms ledge	2.4
Wamego Shale Member:	
Covered interval	11.4
Limestone, light-olive-gray, clayey	.2
Claystone, light-olive-gray, platy; many flat limestone inclusions less than 0.01 ft long	.6
Thickness of Wamego Shale Member	12.2
Tarkio Limestone Member:	
Limestone, very finely crystalline, slightly clayey, thin-bedded, hard, compact; weathers light olive brown to pale yellowish brown; thin claystone parting possibly present near base; scattered large fusulinids; partly covered	1.8

13. *Pillsbury Shale down to the base of the Emporia Limestone*—Continued

	Feet
Zeandale Limestone—Continued	
Tarkio Limestone Member—Continued	
Limestone. light-olive-gray, very finely crystalline, hard, compact; weathers light olive gray to light yellowish gray; very abundant fusulinids	1.7
Thickness of Tarkio Limestone Member	3.5
Thickness of Zeandale Limestone	18.1
Willard Shale:	
Sandstone, very fine grained, micaceous; weathers pale yellowish brown to light olive gray; concentric-weathering ferruginous sandstone concretions as much as 0.6 ft long; much iron stain on bedding planes; upper contact poorly exposed	9.6
Claystone, light-olive-gray, silty, platy; interbedded with platy very finely sandy siltstone beds; claystone and siltstone weather light olive brown; siltstone shows "pencil" weathering; scattered round siltstone pellets as much as 0.02 ft in diameter; outcrop broken by nearly vertical joints as much as 0.5 ft wide; grades upward into sandstone	15.0
Mostly covered interval; light-olive-gray slightly silty claystone in lower 2 ft; crinoid columnals	22.8
Thickness of Willard Shale	47.4
Emporia Limestone:	
Elmont Limestone Member:	
Limestone, light-olive-gray, very finely crystalline, hard, compact; single vertically jointed bed; very thin layers of grayish-black clayey limestone in upper 0.1 ft; reddish-brown fossil fragments; abundant small fusulinids and brachiopods	0.8
Limestone, light-brownish-gray, very finely crystalline, conglomeratic; beds 0.03–1.5 ft thick; light-olive-gray to medium-dark-gray subangular to subrounded dense limestone pebbles generally less than 0.03 ft in diameter (some as much as 0.15 ft); much finely comminuted shell hash; probably pelecypods	1.8
Claystone, light-olive-gray to light-greenish-gray, silty, blocky	.2
Limestone, light-brownish-gray, very finely crystalline, hard, compact; weathers to single light-olive-gray bed; very thin film of light-olive-gray claystone on bedding planes; a few dark-gray subrounded limestone pellets less than 0.01 ft in diameter; irregularly spaced layers of abundant fossil fragments; abundant pelecypods	.5
Fossils from the Elmont, reported on by E. L. Yochelson (written commun., 1960), include algae? (pelletal or "oatmeal"), *Myalina* (*Orthomyalina*) sp. indet., and *Septimyalina*? sp. indet.	
Thickness of Elmont Limestone Member	3.3

13. *Pillsbury Shale down to the base of the Emporia Limestone*—Continued

	Feet
Emporia Limestone—Continued	
Harveyville Shale Member:	
Claystone, light-olive-gray, silty, blocky; abundant flat light-olive-brown limestone nodules less than 0.01 ft long; some fossil fragments in upper part; partly covered	3.8
Covered interval	10.0
Claystone, light-olive-gray	.6
Thickness of Harveyville Shale Member	14.4
Reading Limestone Member:	
Limestone, medium-gray, very finely crystalline, hard, compact; weathers moderate yellowish brown; upper bed 0.4 ft thick; middle bed 1.35 ft thick; lower bed 0.85 ft thick; beds weather to rectangular plates 0.1–0.2 ft thick; many large fusulinids, crinoid columnals, and brachiopods	2.6
Thickness of Emporia Limestone	20.3

14. *Dry Shale Member of the Stotler Limestone down into the Tarkio Limestone Member of the Zeandale Limestone*

[In streambank and along road on the east line of the SE¼ sec. 22, T. 9 S., R. 15 E., Jackson County]

	Feet
Soil.	
Stotler Limestone:	
Dry Shale Member:	
Claystone, light-olive-gray, platy; weathers light olive gray mottled with light olive brown; abundant light-olive-gray dense limestone nodules as much as 1.0 ft long and 0.5 ft thick that weather light olive brown	1.8+
Dover Limestone Member:	
Limestone, light-olive-gray, very finely crystalline, argillaceous, hard, compact; weathers light olive gray with brown tint interbedded with calcareous fossiliferous claystone in lower 0.55 ft; very abundant large fusulinids; abundant *Cryptozoon*-type algae, crinoid stems, and brachiopods; forms vertically jointed ledge that weathers to rubbly blocks and plates	2.4

E. L. Yochelson (written commun. 1960) reported on the following fossil forms from the Dover:

Algae-*Cryptozoon*
Small foraminifers, undet.
Fusulinids, undet. (abundant) } (USGS colln. f12967)
Crinoid stems
Echinoid spines
Marginifera cf. *M. histricula* Dunbar and Condra
Hustedia sp. indet.

Thickness of exposed Stotler Limestone	4.2

14. *Dray Shale Member of the Stotler Limestone down into the Tarkio Limestone Member of the Zeandale Limestone*—Continued

	Feet
Pillsbury Shale:	
Claystone, light-olive-gray, silty; light-olive-gray clayey siltstone interbeds less than 0.02 ft thick that weather light olive gray to moderate yellowish brown; ironstain on siltstone layers; thin light-olive-gray limestone lenses and scattered fusulinids, crinoid columnals, and small brachiopods in upper 0.65 ft; grades into overlying limestone	14.6
Claystone (partly covered), light-olive-gray, silty, platy	16.2
Thickness of exposed Pillsbury Shale	30.8
Lower part of the Pillsbury Shale and upper part of the Zeandale Limestone, undifferentiated:	
Covered interval	15.5
Zeandale Limestone:	
Wamego Shale Member:	
Claystone, light-olive-gray, silty; weathers mottled light olive gray and light olive brown; ferruginous very thin bedded silty very fine grained sandstone layers as much as 0.3 ft thick that weather light olive brown; top not exposed	7.8
Tarkio Limestone Member:	
Limestone, light-olive-gray, very finely crystalline, slightly clayey, thin- to medium-bedded, hard, compact; weathers light olive gray to pale yellowish brown; fine joints and fractures filled with light-colored calcite give a brecciated appearance; scattered fusulinids in lower part; forms resistant layer that caps ledge	2.6
Claystone, light-olive-gray, slightly silty; platy; abundant light-yellowish-gray limestone inclusions less than 0.01 ft long; some fossil fragments	.3
Limestone, light-olive-gray, very finely crystalline, thin-bedded; weathers light olive gray; very abundant large fusulinids (USGS colln. f12968); base not exposed	1.5+
Thickness of exposed Tarkio Limestone Member	4.4
Thickness of exposed Zeandale Limestone	12.2

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Geology of Western Shawnee County, Kansas and Vicinity

By WILLIAM D. JOHNSON, Jr., *and* H. C. WAGNER

GEOLOGY OF SHAWNEE COUNTY, KANSAS

GEOLOGICAL SURVEY BULLETIN 1215-B

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GEOLOGY OF WESTERN SHAWNEE COUNTY, KANSAS, AND VICINITY

By WILLIAM D. JOHNSON, JR. and H. C. WAGNER

ABSTRACT

The western Shawnee County and vicinity study area, encompassing about 358 square miles of northeastern Kansas, was mapped as part of a study of Upper Pennsylvanian and Lower Permian rocks. The area includes western Shawnee County and parts of eastern Wabaunsee and southwestern Jackson Counties.

Subsurface sedimentary rocks range in age from Late Cambrian to Late Pennsylvanian and are as much as 3,300 feet thick. Granite of the Precambrian basement complex has been penetrated in one well.

The exposed sedimentary rocks, about 600 feet thick, are in the Wabaunsee Group, of Late Pennsylvanian age, and in the Admire and Council Grove Groups, of Early Permian age. Relatively thick units of claystone, siltstone, and sandstone and alternating thinner units of fossiliferous limestone record a cyclic pattern of deposition that occurred throughout Late Pennsylvanian and Early Permian time. Local channels have eroded several formations, particularly the Wood Siding Formation, which is the uppermost unit of Pennsylvanian age.

Scattered deposits of brown chert gravel of pre-Kansan age are present locally but are too small to map. Kansan glacial drift covers much of the northern two-thirds of western Shawnee County and vicinity. Thick stratified glacial-outwash deposits locally occur across the southern part of the area and, to the north, along the Kansas River valley.

The Kansas River and Wakarusa River valleys and the larger creek valleys are filled with alluvial material of Quaternary age. In the Kansas River valley extensive deposits making up the Newman terrace of Wisconsin age occupy much of the valley floor, and a broad deposit of Recent alluvium borders the river. The alluvial fill in the Wakarusa River valley is correlated with the Newman terrace. Terrace remnants correlated with the Buck Creek terrace of Illinoian age are in the Kansas River valley near the west edge of the area and along many of the larger tributaries of that river.

The area studied is in the western part of the Forest City basin. Outcropping rocks in the area strike about N. 15°–30° E. and dip to the northwest, generally 15–30 feet per mile. The regional dip is interrupted by a few small folds that have less than 20 feet of surface closure.

Commercial quantities of oil and gas have not been found in the area, but traces of oil have been reported from sandstone in the Cherokee Group (Middle Pennsylvanian) and from dolomite in the Simpson Group (Middle Ordovician). Oil stains have been noted on rock samples from the part of the Hunton Forma-

tion that is of Devonian age, from the Viola Limestone (Middle and Upper Ordovician), and from the Simpson Group (Middle Ordovician). Drillers' logs have reported shows of gas from rocks in the Wabaunsee, Douglas, Kansas City, and Pleasanton Groups of Late Pennsylvanian age, and the Marmaton and Cherokee Groups of Middle Pennsylvanian age.

INTRODUCTION

Shawnee County and parts of adjacent counties were mapped as part of a cooperative project between the U.S. Geological Survey and the State Geological Survey of Kansas. The objective of the project was to study in detail the stratigraphy of outcropping rocks of Upper Pennsylvanian and Lower Permian age. Data from the study contribute to the knowledge of the geology and mineral resources of the Missouri River basin, and may aid in the search for oil and gas in the region.

The western Shawnee County and vicinity study area encompasses about 358 square miles of northeastern Kansas. Topographic coverage is provided by the entire Auburn, Dover, Grove, Rossville, Silver Lake, and Willard 7½-minute quadrangles and by small parts of the Burlingame, Harveyville, Maple Hill, and St. Marys 7½-minute quadrangles (fig. 7). The area is in the Central Lowlands physiographic province (Fenneman, 1938); the northern two-thirds of the area is in the Dissected Till Plains section, and the rest is in the Osage Plains section. Eastern Shawnee County and vicinity is discussed in "Chapter A" (Johnson and Adkison, of this volume).

This study was begun by H. C. Wagner, who mapped the Dover quadrangle and the west half of the Auburn quadrangle (fig. 7) in the autumn of 1954 and spring of 1955; additional work was done later by W. D. Johnson, Jr., to define Upper Pennsylvanian and Lower Permian channels in these quadrangles. Johnson mapped the rest of the area, between the autumn of 1955 and the summer of 1957. H. J. Hyden assisted in mapping of the Willard quadrangle in the summer of 1957, and W. L. Adkison measured additional stratigraphic sections during the field season of 1959.

The geology was plotted on aerial photographs at a scale of 1:17,000 and was transferred to topographic quadrangle maps by means of a vertical projector. The geologic map (pl. 3) was compiled on the combined topographic bases.

Rock-color terms used in this report for exposed sedimentary rocks are those from the "Rock-Color Chart" (Goddard and others, 1948). The grade scale of Wentworth (1922) was used in classifying sand- and silt-sized detrital grains.

Rough-textured limestone is described as crystalline if crystal faces can be seen with a hand lens; it is described as granular if crystal faces

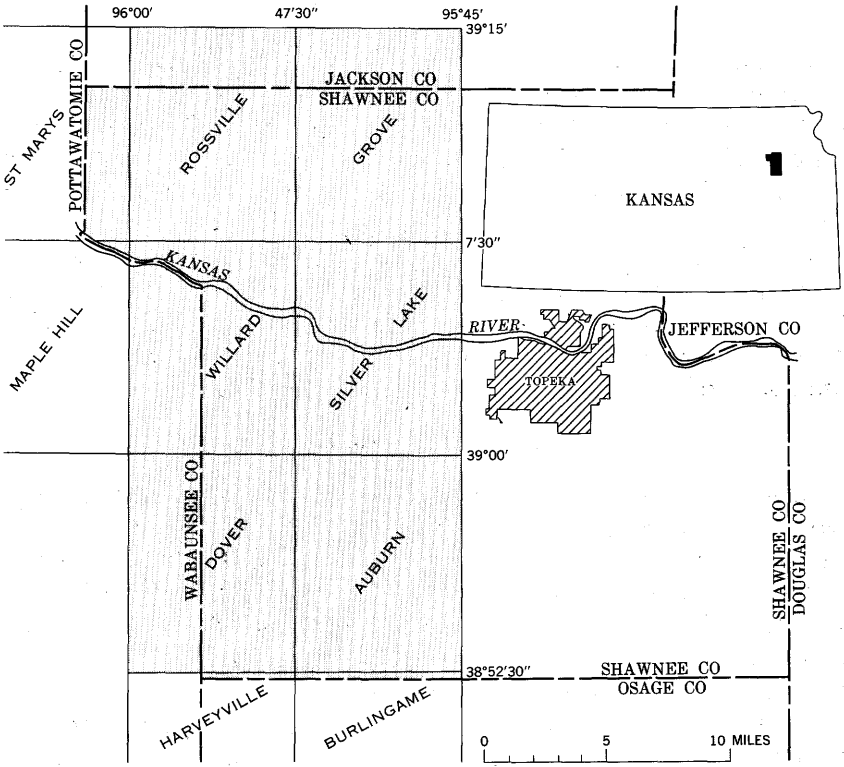

FIGURE 7.—Location of western Shawnee County, Kans., and vicinity.

are absent. Smooth-textured limestone and chert are described as cryptocrystalline or dense. Nonporous limestone is described as compact. Bedding structure is described as follows:

Laminated, less than 1/16 inch thick
Platy, 1/16–1/2 inch thick
Very thin bedded, 1/2–2 inches thick
Thin bedded, 2–4 inches thick
Medium bedded, 4–12 inches thick
Thick bedded, 1–3 feet thick
Massive, more than 3 feet thick

"Cable markings," the conspicuous indentations in the outcrop face of limestone beds, are due to partial solution activity along incipient bedding planes.

Stratigraphic sections in which the various outcropping formations are best represented, either in whole or in part, make up the last part of this chapter. Appropriate stratigraphic sections are referred to with the description of each formation.

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The authors express sincere appreciation to Frank C. Foley, Director, State Geological Survey of Kansas, for the use of the facilities of that organization, and to J. M. Jewett and H. G. O'Connor, State Geological Survey of Kansas, for their advice in the field regarding stratigraphic problems and the recognition and distribution of channel deposits.

The Kansas Sample Log Service extended the courtesy of permitting reproduction of the sample logs of three wells in western Shawnee County and vicinity. D. E. Owen allowed the authors to publish several peel prints of rock units in the Bern Limestone from his unpublished M.S. thesis from the University of Kansas.

PREVIOUS WORK

Geologic reconnaissance in western Shawnee County and vicinity, particularly along the Kansas River, was done by Meek and Hayden (1859), Swallow (1866), Prosser (1894), Haworth (1895), Bennett (1896), and Beede (1898). The glacial geology in this part of Kansas was studied by Smyth (1898) and by Todd (1909, 1911, 1918a). The early Pleistocene geomorphic history of Wabaunsee County and adjacent areas was described by Mudge (1955).

Revisions in the initial classification and descriptions of Pennsylvanian and Permian rocks in Kansas were made by Moore (1932, 1936a, 1949), Moore, Frye, and Jewett (1944), Moore and others (1951), and by Moore and Mudge (1956). Mudge and Yochelson (1962) studied the stratigraphy and paleontology of the uppermost Pennsylvanian and lowermost Permian rocks in Kansas and investigated the placement of the systemic boundary.

The geologic map of Kansas (Moore and Landes, 1937) shows the bedrock geology in western Shawnee County and vicinity in considerable detail. In 1952 Davis and Carlson included a small part of the area in their study of the geology and ground-water resources of the Kansas River valley from Topeka to Lawrence. The groundwater resources of the river valley from Topeka westward to Wamego were described by Beck (1959). In 1959 Mudge and Burton described the geology and evaluated the construction materials in Wabaunsee County. The geology and ground-water resources of Jackson County was studied by Walters (1953). O'Connor (1955) mapped Osage County, which joins this report area on the south, and Scott, Foster, and Crumpton (1959) mapped Pottawatomie County, which borders the area on the northwest. Johnson and Adkison (chap. A, this report) described the geology of the eastern part of Shawnee County and the contiguous parts of Jackson and Jefferson Counties.

Subsurface rock units of northeastern Kansas were studied by Ockerman (1935). Description, correlation, and distribution of Mississippian rocks in Kansas were discussed by Lee in 1940. The stratigraphy and structural development of the Forest City basin were described by Lee (1943) and by Lee and others (1946). Although Shawnee County lies east of the Salina basin, the county was included in the area studied by Lee, Leatherock, and Botinelly (1948) and by Lee (1956) in working out the stratigraphy and structural development of the Salina basin. Oil and gas exploration in Shawnee County and adjacent counties was summarized in 1954 by Jewett. Other geologists, some of whom are cited elsewhere in this chapter, have described various aspects of the geology or mineral resources of the area, especially in field-trip guidebooks and unpublished theses.

STRATIGRAPHY

Sedimentary rocks of Paleozoic age and unconsolidated sediments of Quaternary age overlie the Precambrian basement complex in western Shawnee County and vicinity. Granite was penetrated in one well.

The unexposed sedimentary rocks of Late Cambrian to Late Pennsylvanian age, as much as 3,300 feet thick, were lithologically described by use of sample logs from five wells in the north half of the area (pl. 4). Supplemental data on the general distribution and thickness of these stratigraphic units were obtained from drillers' logs of 12 other wells in the area. Rocks of the Arbuckle Group (Upper Cambrian and Lower Ordovician) were drilled through their entire thickness in only one well; the upper part of the Arbuckle was drilled in three other wells. The lower part of the Severy Shale contains the youngest unexposed strata in the area. The color terms used to describe the unexposed sedimentary rocks are those used in the sample logs and do not necessarily conform to those of the "Rock-Color Chart."

The exposed sedimentary rocks in the mapped area are about 600 feet thick and are classified in the Wabaunsee Group of Late Pennsylvanian (Virgil) age and in the Admire and Council Grove Groups of Early Permian age. The nomenclature and classification of the stratigraphic units are shown on plate 3. The derivation of the nomenclature and the specific location of the type locality of each formation and its members were discussed in detail by Mudge and Burton (1959, p. 16–58) and by Johnson and Adkison (chap. A, this report); only reference to the first use of each name is included in this chapter.

In the Wabaunsee Group, fairly thick shale formations of claystone, siltstone, and sandstone and alternating relatively thin resistant limestone formations (pl. 3) record a distinctive cyclic pattern of sedimentation (Moore, 1936a, p. 25–26). The Lower Permian rocks also show cyclic sedimentation (Jewett, 1933; Elias, 1937). In those rocks the lithologic units are similar to those of the Wabaunsee Group except that sandstone and coal are less abundant and red and green mudstones are more abundant. The deposits of each sedimentary cycle are a cyclothem (Wanless and Weller, 1932, p. 1003), and each cyclothem contains a limestone formation and parts of the overlying and underlying shale formations.

In this study the cyclothems were not mapped or described. The boundaries of the cyclothems were difficult to determine because many units of the theoretical cyclic sequence are missing and because the cyclothemic boundaries occur within the shale members or formations.

The unconsolidated sediments of Quaternary age include glacial till and outwash and more recent deposits of loess and colluvium that mantle much of the northern two-thirds of the mapped area. Stream valleys are filled with terrace deposits and alluvium.

CAMBRIAN AND ORDOVICIAN SYSTEMS

The Cambrian and Ordovician Systems are represented in the mapped area by the Arbuckle Group of the Upper Cambrian and Lower Ordovician Series, the Simpson Group of the Middle Ordovician Series, the Viola Limestone of the Middle and Upper Ordovician Series, and the Maquoketa Shale of the Upper Ordovician Series.

Arbuckle Group.—Rocks of the Arbuckle Group were drilled in the Musgrove Heiland 1 well, where they are 28 feet thick. Thirty-three feet of the Arbuckle was drilled in the W. M. McKnab Fritz 1 well, in the NW¼ sec. 4, T. 12 S., R. 14 E. The Arbuckle is generally pale-yellowish-brown, gray, or buff finely to coarsely crystalline, in part slightly sandy, dolomite. The dolomite contains much white to medium-light-gray dense chert and oolitic chert. In the Murchison Federal Land Bank 1 well, a thin medium-gray to greenish-gray shale occurs near the top of the Arbuckle.

Simpson Group.—The Simpson Group is about 90–125 feet thick. The lower two-thirds of the group is mainly white to gray fine- to medium-grained sandstone that has rounded frosted grains, and the upper third is mainly brown medium-crystalline partly sandy and vuggy cherty dolomite, limestone, and shale. A few very thin layers and stringers of green and dark-gray to black shale are intercalated in the sandstone. In the Musgrove Heiland 1 well, the sandstone and shale in the lower half of the Simpson are overlain by slightly sandy, dolomitic limestone. Dark-gray, greenish-gray, and in part black platy subwaxy shale occurs at or near the top of the Simpson in some wells and at the base of the Simpson in others.

Viola Limestone.—The Viola Limestone, about 75–115 feet thick, is mostly brownish-gray to pale-yellowish-brown very finely to medium-crystalline dolomite commonly containing abundant very light gray to medium-gray dense opaque somewhat spicular chert in its upper part. Near the northwest corner of the area, mottled gray coarsely crystalline limestone occurs at the base. Locally the upper part has a few very thin beds of medium-gray shale.

Maquoketa Shale.—The Maquoketa Shale, about 60–90 feet thick, is dominantly medium- to dark-gray and gray-green commonly dolomitic shale but contains a few thin beds of shaly dolomite. In the Kaiser-Francis and Shawver-Armour Adams "A" 1 well, however, the dolomite beds are thicker and more numerous; some are slightly cherty (pl. 4).

SILURIAN AND DEVONIAN SYSTEMS

The Silurian and Devonian Systems are represented in the mapped area by the Hunton Formation. The Hunton ranges in thickness from 125 to 285 feet and is thickest in the northwestern part of the area. According to Lee (1943, p. 44, 45, 51), the lower part of the Hunton is of Early Silurian age, and the upper part is of Middle Devonian age. Light-gray to medium-light-gray and buff-gray finely to medium-crystalline dolomite, in places containing light-gray dense chert and a few thin beds of medium-gray and gray-green shale, composes the lower 55–235 feet of the Hunton.

The upper part of the Hunton Formation, about 55–85 feet thick, is light-gray, buff, or very pale orange very finely to finely crystalline partly sandy dolomite containing sparse to abundant chert. The chert is light gray to medium light gray and pale yellowish brown, dense, and opaque; it occurs in zones that differ in stratigraphic position from well to well. The sand is fine to medium, rounded, and frosted. Euhedral quartz occurs in the dolomite locally. Some medium-gray shale is interbedded with the upper beds of the Hunton in the northeastern part of the area.

DEVONIAN AND MISSISSIPPIAN SYSTEMS

The Chattanooga Shale of Devonian and Mississippian age ranges from about 130 to 260 feet in thickness but averages about 150 feet thick. The shale is mainly medium to dark gray in the eastern part of the area and greenish gray in the western part. In places dolomitic siltstone and shaly dolomite occur near the top. Most well samples from the lower part of the Chattanooga contain abundant dark-brown to dark-gray spore cases. The basal unit of the formation—the Misener sand of economic usage—is recognized only in the eastern part of the area. It may occur elsewhere but, because it probably does not exceed 2 feet in thickness, it was not recognized by drillers. The sandstone is light to medium gray, fine to coarse grained, dolomitic, and pyritic. Locally it contains very light gray to medium-light-gray calcareous quartzose chert.

MISSISSIPPIAN SYSTEM

The Mississippian rocks in the area are those of the Lower Mississippian Series. The strata, which range in thickness from about 210 to 290 feet and average about 235 feet thick, are composed mainly of thick units of limestone and dolomite in nearly equal amounts. The Lower Mississippian rocks in eastern Shawnee County (chap. A, this report) were divided into formations, but those formations could not be recognized with certainty in western Shawnee County and vicinity. The Lower Mississippian limestone is pale yellowish brown, light to medium gray, or brownish gray, and is very finely to coarsely crystalline. Crinoid fragments are common throughout, and white to light-gray chert is commonly present in the upper part. Euhedral quartz is locally abundant in limestone near the middle of the unit, and glauconite occurs in some beds in the upper part. The dolomite is pale yellowish brown, very pale orange, grayish brown, or buff; it is very finely to finely crystalline and commonly contains abundant light- to medium-gray and white dense chert. Thin black shale beds are locally intercalated in the limestone and dolomite, and white fine- to medium-grained cherty sandstone occurs in the upper part in the Kaiser-Francis and Shawver-Armour Adams "A" 1 well (pl. 4).

PENNSYLVANIAN SYSTEM

DES MOINES SERIES

The Pennsylvanian rocks of the Des Moines Series are represented in the report area by the Cherokee and Marmaton Groups.

Cherokee Group.—Rocks of the Cherokee Group of Middle Pennsylvanian age are about 480–625 feet thick. They consist mainly of medium- to dark-gray shale and siltstone but also include lesser amounts of greenish-gray and red shale. Black shale is commonly associated with thin coal beds. White to light-gray fine- to medium-grained, in part limy or dolomitic, sandstone occurs throughout; some sandstone beds are as much as 30 feet thick (pl. 4). Thin beds mainly of buff or medium-dark-gray, in part argillaceous, limestone and dolomite occur throughout the group but are most abundant in the upper half. The basal unit of the Cherokee—called the Pennsylvanian basal conglomerate by drillers—consists of conglomeratic sandy siltstone, sandstone, or sandy shale 4–5 feet thick and contains pyrite, glauconite, fragments of very light gray to very pale orange chert and reddish-brown ironstone, and quartz grains. The chert is dense, quartzose, tripolitic, or spicular.

Marmaton Group.—Rocks of the Marmaton Group, the upper unit of the Des Moines Series, are 115–155 feet thick. Drillers' logs of several wells indicate, however, that the group may locally range from 85 to 165 feet in thickness. The contact between the Marmaton and Cherokee Groups is difficult to identify, especially in drillers' logs, because limestone beds in the lower part of the Marmaton Group and upper part of the Cherokee Group apparently lack lateral continuity. Rocks of the Marmaton Group are mainly medium-gray, pale-yellowish-brown, or buff argillaceous limestone, but they also include abundant medium-gray, greenish-gray, or dark-gray to black partly calcareous shale. The limestone is dolomitic in the eastern part of the area. Light-gray to pale-yellow-brown very fine grained argillaceous sandstone and coal occur in small amounts.

MISSOURI SERIES

The Missouri Series in the report area comprises the Pleasanton, Kansas City, and Lansing Groups. Rocks in the upper part of the Kansas City Group and in the Lansing Group were divided into formations in eastern Shawnee County (chap. A, this report). However, the formations of only the Lansing Group could be recognized with certainty in western Shawnee County and vicinity.

Pleasanton Group.—The lowest unit of the Missouri Series (Upper Pennsylvanian), the Pleasanton Group, is about 70—115 feet thick. It is mainly medium- to dark-gray shale and siltstone. The upper half contains beds of medium-light-gray and grayish-brown very fine grained silty calcareous micaceous sandstone and a few beds of brown and gray dense to finely crystalline limestone (pl. 4).

Kansas City Group.—Rocks of the Kansas City Group, about 230–265 feet thick, are primarily limestone but include a fairly thick widespread shale bed at the top. The limestone is very pale orange, pale yellowish brown, buff, or medium gray, dense to very fine grained and very finely crystalline, and in part argillaceous. Locally the uppermost and lowermost limestone units are dolomitic. Several thin zones of oolitic and oolicastic limestone are commonly present in the upper and the "lower-middle" parts. Light- to medium-gray or pale-yellowish-brown dense partly spicular chert characterizes several limestone units. Much of the limestone is fossiliferous, and some is glauconitic.

Thin units of medium-gray to medium-dark-gray partly calcareous shale and of dark-gray to black partly coaly shale are interbedded with the limestone; the black shales are widespread. The shale unit at the

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top contains various amounts of light-gray to medium-light-gray very fine to fine-grained calcareous micaceous sandstone; in the northwestern part of the area, it is made up entirely of sandstone.

Lansing Group.—Rocks of the Lansing Group, about 80–100 feet thick, are composed, in ascending order, of the Plattsburg Limestone, Vilas Shale, and Stanton Limestone. The Plattsburg Limestone, about 15–30 feet thick, is medium light gray to very pale orange or pale yellowish brown, dense to very fine grained and very finely crystalline, and generally fossiliferous. Medium-light-gray to medium-dark-gray dense spicular chert is sparse to moderately abundant. The Vilas Shale, about 10–30 feet thick, is medium to dark gray and partly calcareous, and it contains one or more thin beds of fossiliferous limestone. The Stanton Limestone, about 35–55 feet thick, is primarily light-gray or buff dense to very fine grained fossiliferous limestone, although locally it contains black, partly coaly shale near its base and a thin bed of gray partly calcareous and partly dolomitic sandstone near its top.

VIRGIL SERIES

DOUGLAS GROUP

Rocks between the Lansing and Shawnee Groups, formerly divided into the Pedee Group (Missouri Series) and the overlying Douglas Group (Virgil Series), were reclassified by the State Geological Survey of Kansas (O'Connor, 1963) as a result of detailed work by Stanton M. Ball. Except for the series and stage names, this new classification was adopted by the U.S. Geological Survey in the report on eastern Shawnee County and vicinity (Johnson and Adkison, chap. A, this report). As redefined, the Douglas Group includes all strata from the top of the Lansing Group to the base of the Shawnee Group and comprises the Stranger Formation and the overlying Lawrence Formation. The Douglas ranges in thickness from about 225 to 265 feet and consists mainly of noncarbonate clastic rock (pl. 4).

Stranger Formation.—The Stranger Formation, about 95–135 feet thick, consists dominantly of light-gray to medium-light-gray very fine to fine-grained micaceous sandstone and medium- to dark-gray, olive-gray, and grayish-red partly sandy shale. Some sandstone beds include fine fragments of carbonaceous material. A thin coal bed occurs near the base of the Stranger in the Murchison Federal Land Bank 1 well.

Lawrence Formation.—Rocks of the Lawrence Formation are about 125–140 feet thick and are chiefly medium-gray shale. At the base the Haskell Limestone Member, generally about 5 feet thick, consists of one or two beds of brownish-gray, reddish-brown, and medium-gray very fine grained argillaceous slightly fossiliferous limestone. This member is the most useful marker in the Douglas Group. In the eastern part of the area, the upper part of the Lawrence contains olive-gray and grayish-red limy shale and medium-light-gray siltstone. In the western part, sandstone and siltstone compose about half of the formation; individual units are locally as much as 40 feet thick.

SHAWNEE GROUP

Thickness of the Shawnee Group is fairly uniform, ranging from 320 to 350 feet. The group consists of seven formations, which are, in ascending order, the Oread Limestone, Kanwaka Shale, Lecompton Limestone, Tecumseh Shale, Deer Creek Limestone, Calhoun Shale, and Topeka Limestone. The limestone formations are 25–65 feet thick, and the shale formations 35–85 feet thick. The Shawnee Group crops out in eastern Shawnee County and was described in detail by Johnson and Adkison (chap. A, this report).

The limestone formations consist mainly of three to five beds of limestone that is medium gray, pale yellowish brown, buff, or very pale orange, dense to very fine grained and finely crystalline, partly argillaceous, and fossiliferous. A zone of medium-dark-gray to brownish-gray dense fossiliferous chert occurs in the upper part of the Oread Limestone and in the lower part of the Topeka Limestone. The limestone beds in each limestone formation are separated by medium-light-gray to medium-gray partly calcareous shale. A thin perisistent black shale is present near the middle of each limestone formation.

The shale formations are principally medium-gray shale and medium-light-gray siltstone. The Kanwaka and Calhoun Shales contain beds of medium-light-gray very fine grained silty partly calcareous sandstone, and the Kanwaka has a thin continuous bed of fossiliferous limestone—the Clay Creek Limestone Member—in its upper half.

WABAUNSEE GROUP

SEVERY SHALE (strat. section 1)

The Severy Shale (Haworth, 1898, p. 66), the oldest unit exposed in western Shawnee County and vicinity, is mostly covered along the east edge of the area, where it occurs in the south bluff of the Kansas River valley. Along Sixmile Creek in the southeastern part of the area and in the south bluff of the Wakarusa River valley, the Severy crops out below the ledge formed by the overlying Howard Limestone.

The lower part of the Severy Shale, the basal formation of the Wabaunsee Group, constitutes the youngest unexposed rocks in western Shawnee County and vicinity. This part of the Severy is mainly medium-gray partly sandy shale and siltstone and locally includes some very shaly sandstone.

About 30 feet of the Severy Shale is exposed; it is 42–50 feet thick in engineering test holes drilled on the north side of the Kansas River valley near Golden Rule School, at the east border of the area. Along the Wakarusa River the Severy is mainly moderate-yellowish-brown fine-grained finely laminated to platy very micaceous sandstone, some of which is crossbedded. Laminae of medium-light-gray siltstone are intercalated with the sandstone, and carbonaceous material is abundant on the bedding planes. A few beds of medium-light-gray sandy limestone are also present. The upper part of the formation along Sixmile Creek is light-olive-gray to olive-gray laminated to platy very silty claystone and, in places, very finely sandy micaceous siltstone. Both lithologies weather light olive gray to light yellowish gray. Weathering of pyrite stains the outcrop pale yellowish brown. Finely disseminated carbonaceous material occurs throughout the formation. Brachiopods, crinoid stems, and bryozoans are locally present in the upper 0.9 foot (strat. section 1).

HOWARD LIMESTONE (strat. section 1, 2)

The Howard Limestone (Haworth, 1898, p. 67) is composed, in ascending order, of the Aarde Shale Member, Church Limestone Member, Winzeler Shale Member, and Utopia Limestone Member. In southern Kansas the Bachelor Creek Limestone Member forms the basal unit of the formation (Moore, 1936a, p. 205), but it is absent from this area. The base of the Howard is placed at the base of the Nodaway coal bed of the Aarde Shale Member in this report.

The Howard Limestone crops out in the southeastern part of the area along the Wakarusa River and Sixmile Creek, where it forms ledges and waterfalls in the stream channels. The Howard forms a narrow outcrop band on timbered slopes along the south side of the Kansas River valley near the east edge of the area.

The Howard is about 25 feet thick along the Wakarusa River, 5.4–7 feet thick along Sixmile Creek, and 7–15 feet thick in the Kansas River valley. The differences in thickness along the Kansas River valley are apparently the result of local erosion during deposition of the overlying Scranton Shale. The Howard is conformable on the Severy Shale and at places has a gradational contact with the Severy. The contacts between the members of the Howard Limestone are conformable.

Aarde Shale Member

At the type locality of the Aarde Shale Member in Greenwood County, Kansas (Moore, 1932, p. 94), this member consists of the beds between the top of the Bachelor Creek Limestone Member of the Howard and the base of the Church Limestone Member and contains the very widespread Nodaway coal bed. In western Shawnee County and vicinity, the Bachelor Creek is absent, and the base of the Aarde Shale Member is therefore designated as at the base of the Nodaway.

The Aarde Shale Member ranges in thickness from 0.7 foot locally along Sixmile Creek to 5.5 feet at the Kansas River immediately east of the mapped area. The Nodaway coal bed, at the base, is overlain by siltstone in the southern part of the area and mainly by claystone to the north, in the Kansas River valley. The Nodaway consists principally of black hard brittle vitreous coal in the Kansas River valley; however, in the southern part of the area it contains much grayish-black to black finely laminated very carbonaceous claystone that weathers brownish black owing to iron stain and is veined with secondary gypsum. Along Sixmile Creek the coal bed also contains very thin lenses of medium-gray to brownish-gray very argillaceous very fossiliferous limestone. The Nodaway is 0.4–1.4 feet thick.

The siltstone in the Aarde Shale Member is mainly light olive gray, laminated, carbonaceous, and, in part, sandy or calcareous. In places it contains interbeds of medium-dark-gray to grayish-black siltstone that weathers to very fissile plates. Locally along Sixmile Creek the siltstone grades into medium-light-gray to light-olive-gray very silty laminated to platy fossiliferous limestone and, at places, into olive-gray platy calcareous sandstone. The claystone is mainly light olive gray, silty, and laminated to platy; in some places it is calcareous and grades into argillaceous limestone.

The abundance of fossils in the Aarde Shale Member varies widely from outcrop to outcrop. Crinoid stems and brachiopods are the most abundant forms, although bryozoans are also present.

Church Limestone Member

The Church Limestone Member (Condra, 1927, p. 54) is 0.3–2.2 feet thick; abrupt increases in thickness occur locally. The member is composed mainly of light-olive-gray and medium-light-gray very fine grained to very finely crystalline limestone that is slightly silty, thin to thick bedded, hard, and compact. It generally weathers to a moderate-yellowish-brown vertically jointed ledge, the upper part of which in places weathers platy or has wavy bedding. Locally the member contains hard nodules of algal (?) deposits as much as 0.15 foot long.

The Church contains abundant *Osagia*, *Cryptozoon*-like algae, crinoid stems, and brachiopods. Fusulinids are locally abundant; elsewhere they are sparse or absent. Horn corals and gastropods are common.

Winzeler Shale Member

The Winzeler Shale Member (Moore, 1932, p. 94), 0.6–6.2 feet thick, is dominantly medium-dark-gray or dark-gray laminated siltstone and claystone that weather light olive gray to olive gray. In places the claystone is silty and the siltstone is sandy. The siltstone locally weathers to hard dark fissile fragments. Exposures of the member are restricted to streambanks in the southern part of the area. Along the Wakarusa River (strat. section 2) the Winzeler is mainly yellowish-gray and medium-gray finely crystalline silty partly very thin bedded hard limestone that weathers yellowish gray to light gray and, in places, is moderately resistant to erosion. The limestone locally contains hard nodular lenses as much as 1.5 feet long.

In a few places the dark siltstones of the Winzeler contain abundant ostracodes; elsewhere they are unfossiliferous. The limestone beds contain a few brachiopods and crinoid stems.

Utopia Limestone Member

The Utopia Limestone Member (Moore, 1932, p. 94) is well exposed in the channel of the Wakarusa River in the NE¼NE¼ sec. 32, T. 13 S., R. 15 E. The Utopia, 2–12 feet thick, is composed of a lower limestone and siltstone unit 0.6–9.3 feet thick and an upper limestone unit 1–2.8 feet thick. The limestone of the lower unit is light to medium gray with a brown hue, generally very finely to medium crystalline, silty, very thin to thin bedded, and partly coquinoidal and weathers to light-gray and light-olive-gray rubbly wavy beds. Very thin beds of light-olive-gray to olive-gray claystone are interbedded with the limestone in places. At many localities the upper 1–2 feet of the lower unit is dark-gray finely laminated siltstone that weathers to hard light-gray very fissile plates. Thin argillaceous limestone beds occur locally in the siltstone.

The limestone of the upper unit is light olive gray and medium light gray to medium gray, very finely to finely crystalline, partly silty, and very thin to thin bedded. It weathers generally light gray to light grayish yellow and forms a ledge. Locally, as in the bottom of Sixmile Creek in the SE¼NW¼ sec. 16, T. 13 S., R. 15 E. (strat. section 1), the upper 1 foot of the unit weathers to oval concretionary masses, some of which are as much as 2–3 feet long and 0.3 foot thick.

The lower unit of the Utopia Limestone Member contains abundant *Osagia*, crinoid stems, fenestrate and ramose bryozoans, echinoid spines, brachiopods, pelecypods, gastropods, ostracodes, and, locally, amphibian tracks. The siltstone at the top of this lower unit contains abundant ostracodes and a few inarticulate brachiopods. The upper unit of the Utopia is characterized by abundant fusulinids, but at many places it also contains abundant *Osagia*, ramose and fenestrate bryozoans, brachiopods, pelecypods, and, in the lower 0.7 foot, gastropods.

SCRANTON SHALE (strat. section 3)

The Scranton Shale (see Moore and Mudge, 1956, p. 2277) consists, in ascending order, of the White Cloud Shale, Happy Hollow Limestone, Cedar Vale Shale, Rulo Limestone, and Silver Lake Shale Members. The Happy Hollow and Rulo Limestone Members were mapped in areas of good exposures but were not traced across the entire outcrop belt of the Scranton. The Scranton is poorly exposed along the Wakarusa River and its tributaries in the southeastern part of western Shawnee County and vicinity and along the Kansas River and its tributaries in the central, eastern, and northeastern parts of the area.

The Scranton ranges in thickness from about 130 feet, in the south bluff of the Kansas River, to 165 feet, in the Murchison Federal Land Bank 1 well (pl. 4) just east of the area. The formation is composed mainly of siltstone and claystone but also contains some sandstone and limestone. The Scranton rests conformably on the Howard Limestone except where the Howard is absent owing to channeling during deposition of the lower member of the Scranton. The contacts between the members of the Scranton are apparently conformable.

White Cloud Shale Member

The White Cloud Shale Member (Condra, 1927, p. 58; 1930, p. 53) is estimated to be 50–60 feet thick in the southeastern part of the area. The member may exceed that thickness if the channel of the White Cloud east of the mapped area (Johnson and Adkison, chap. A, this report) extends into the southeast corner of the western Shawnee County area. On the west edge of the area, in the Kaiser–Francis and Shawver–Armour Adams "A" 1 well the White Cloud is estimated to be 55 feet thick (pl. 4).

The White Cloud is mainly light-olive-gray slightly sandy laminated partly micaceous siltstone. It locally includes much yellowish-gray and light-olive-gray very fine to fine-grained sandstone that is generally silty, platy to very thin bedded, and micaceous. Thin beds of dusky-yellow and dark-gray sandy laminated claystone and light-olive-gray to light-brownish-gray fine-crystalline partly sandy platy to thin-bedded limestone are also present. The sandstone and limestone commonly contain abundant finely comminuted carbonaceous material and many minute pyrite crystals. Locally in the southeastern part of the area (strat. section 3), a coal bed as much as 0.4 foot thick is present in the upper 2–7 feet of the member.

The White Cloud Shale Member is conformable on the underlying Howard Limestone throughout most of the area, but the contact may be disconformable near the southeast corner of the area owing to a channel of the White Cloud. In engineering test wells just north of the Kansas River valley near the east edge of the area, a conglomerate reportedly overlies Howard Limestone that is of less than normal thickness. This conglomerate probably marks the base of the channel deposit that is exposed about half a mile east of the area in the south bluff of the Kansas River. The upper contact of the White Cloud was determined only where the Happy Hollow Limestone Member was identified.

Carbonized plant fragments are the most abundant fossils in the White Cloud; however, a few crinoid stems, brachiopods, and pelecypods occur in some of the limestone beds.

Happy Hollow Limestone Member

The Happy Hollow Limestone Member (Condra, 1927, p. 58) is poorly exposed in the area and was traced with certainty only near the Wakarusa River and along Sixmile Creek where it forms a thin ledge in the valley walls. This member, about 0.4–3.4 feet thick, is mainly light-brownish-gray and greenish-gray finely crystalline coquinoidal limestone that is partly sandy, thin bedded, hard, and compact. It generally weathers to nodular pitted blocks whose surfaces are stained with iron oxide and appear mottled dark yellowish orange, moderate yellowish brown, and, in places, grayish red.

Test drilling by the State Highway Commission along the Kansas Turnpike in the NW¼NE¼ sec. 17, T. 13 S., R. 15 E., revealed a narrow channel that has locally removed the Happy Hollow Limestone Member. The channel (too small to be shown on the geologic map) was tentatively assigned to the Soldier Creek Shale Member of the Bern Limestone.

The Happy Hollow Limestone Member generally contains many very small fragments of fossils; the fossils include crinoid stems, fenestrate, ramose, and encrusting bryozoans, brachiopods, gastropods, and, locally, pelecypods. *Osagia* and *Cryptozoon*-like algae are sparse; a few small fusulinids were noted at one locality.

Cedar Vale Shale Member

The Cedar Vale Shale Member (Condra, 1930, p. 53) is 25 feet thick in the southern part of the area and more than 29 feet thick in an incomplete section in a railroad cut in the SE¼SW¼ sec. 36, T. 10 S., R. 14 E.

The member is mostly sandstone, but claystone is abundant in the upper half; limestone and fairly thick siltstone beds occur locally. A coal bed is present near the top of the member throughout the area.

The sandstone is either yellowish gray to grayish yellow or pale olive to very light gray. It is very fine to fine grained, commonly silty, platy to thin bedded, and micaceous and has abundant carbonaceous material on the bedding planes. In places the sandstone contains thin hard calcareous crossbedded lenses that are moderately resistant.

The claystone is mainly medium light gray and medium gray; however, adjacent to the coal bed near the top of the member, it is yellowish gray to grayish black and carbonaceous and, in places, contains coaly streaks. Most of the claystone is silty to sandy and platy to very thin bedded.

The siltstone is light olive gray to medium gray, partly clayey to finely sandy, laminated to platy, and micaceous. At several localities, light-greenish-gray and medium-gray silty to sandy platy to very thin bedded fossiliferous limestone beds occur in the lower half of the member. A resistant limestone bed crops out about 10 feet below the top of the Cedar Vale along the north side of the Wakarusa River valley near Auburn. The bed is 0.3–1 foot thick and is composed largely of pelecypods; it contains cone-in-cone structures of calcite at the top.

The Elmo coal bed, about 0.2–0.6 feet thick, generally occurs in the upper 1 foot of the member, but at a few places it is about 3 feet below the top. A brownish-black to black generally clayey coal bed questionably correlated with the Elmo crops out in a railroad cut in the SE¼SW¼ sec. 36, T. 10 S., R. 14 E.; it is 1.6 feet thick and occurs about 11 feet below the top of the Cedar Vale.

The most abundant fossils in the Cedar Vale Shale Member are plant remains, although most of the limestone beds and, locally, the uppermost claystone beds contain abundant pelecypods and some *Osagia*, crinoid stems, ramose and fenestrate bryozoans, brachiopods, productoid spines, ostracodes, and fucoidal markings.

Rulo Limestone Member

The Rulo Limestone Member (Condra and Bengston, 1915, p. 14) is best exposed as a narrow ledge in streambanks and roadcuts south of the Kansas River; only small localities were mapped north of the river (pl. 3). The member, 0.6–3.6 feet thick, is composed mainly of limestone; however, at several localities it contains a middle claystone and sandstone unit as much as 2.6 feet thick. The limestone is medium light gray to medium dark gray, very fine grained and finely crystalline, and in part very argillaceous. The member is platy to thin bedded, partly concretionary, hard, and compact. It weathers yellowish gray, yellowish orange, and shades of yellowish brown. The lower part commonly weathers to very thin plates, whereas the upper part forms subrounded concretionary masses that have subconchoidal fracture and are generally fossil encrusted. The claystone of the Rulo is medium gray to medium dark gray, silty, and platy; the sandstone is grayish yellow, very fine grained, and platy.

Abundant crinoid stems, ramose and fenestrate bryozoans, brachiopods, and myalinid pelecypods characterize the fauna of the Rulo Limestone Member. Gastropods are less abundant throughout, and horn corals, trilobites, and cephalopods are sparse. The upper part of the member is more fossiliferous than the lower part and, at some localities, also contains carbonized plant material.

Silver Lake Shale Member

The Silver Lake Shale Member (Beede, 1898, p. 30) crops out in the slope beneath the escarpment of the Bern Limestone. Its outcrop is generally yellowish gray and is commonly covered with hard yellowish-orange and moderate-yellowish-brown siltstone fragments. This member is about 20 feet thick north of the Kansas River and thickens southward; east of Auburn it reaches its maximum thickness, 36 feet.

The member is composed of various proportions of sandstone, siltstone, and claystone. Some thin limestone beds occur in the upper third of the member. At many places sandstone makes up about half of the member; at a few places sandstone composes almost all the Silver Lake. Elsewhere the member is mainly claystone and siltstone. In general, the sandstone is yellowish gray and dusky yellow, very fine grained, laminated to very thin bedded, and micaceous. Some layers show indistinct crossbedding. Locally, ferruginous nodules and carbonaceous material occur on the bedding planes.

The claystone is commonly medium gray to medium dark gray, slightly silty to sandy, and laminated to platy. At a few places it is partly calcareous and contains small limestone nodules. The siltstone is medium gray (locally light gray and light greenish gray), laminated to very thin bedded, micaceous, and in places pyritic. The limestone is mainly light gray to medium dark gray, very finely crystalline and very fine grained, very argillaceous to sandy, and micaceous.

Fossils are moderately abundant in the limestone beds and, at a few places, in the siltstone and claystone beds. Brachiopods and pelecypods are the most abundant forms, but a few crinoid stems, ramose bryozoans, and gastropods are also present. The sandstone generally contains carbonized plant fragments, and in places, abundant fucoidal marks that may be worm tracks.

BERN LIMESTONE (strat. section 4)

The Bern Limestone (Moore and Mudge, 1956, p. 2276) comprises, in ascending order, the Burlingame Limestone, Soldier Creek Shale, and Wakarusa Limestone Members. The formation forms prominent ledges in valley walls through much of the eastern half of the mapped area; in places it underlies a low escarpment. The Bern ranges in thickness from about 13 to 25 feet; its maximum thickness is south of Auburn along the Kansas Turnpike. The Bern rests conformably on the Scranton Shale, and at most localities the contact is sharp. Locally, however, the contact is gradational through a few inches of very argillaceous limestone or very calcareous claystone.

Burlingame Limestone Member

The Burlingame Limestone Member (Hall, 1896, p. 105) generally forms a prominent ledge at the base of the escarpment or bench formed by the Bern Limestone. At most places the member weathers to large tabular blocks separated by well-formed vertical joints. The thickness of the member ranges from 1 to 7 feet and averages about 3 feet.

The Burlingame is composed mainly of two distinct types of limestone that were recognized previously by Moore (1936a, p. 216). The member contains thin claystone beds in places. The lower part of the Buringame is light- to medium-gray thin- to thick-bedded dense to very fine grained hard very fossiliferous limestone. At many localities the lower 0.2–1 foot of the member is very argillaceous and weathers to rubble. At several places the lowest bed contains very small subangular to subrounded dense limestone pebbles that are tightly cemented in the limestone matrix (fig. 8). On fracturing, the limestone breaks across the pebbles.

The upper part of the Burlingame is composed of irregular and generally elongate subangular to subrounded fragments of light- to medium-gray and light-brownish-gray very fine grained hard dense sparsely fossiliferous limestone in a matrix of dense or very fine grained argillaceous limestone (fig. 9) of the same color. The fragments may be jumbled or arranged in irregular layers and are generally alined with the convex sides down. The fragments have subconchoidal fracture, and each fragment generally is partly rimmed with a very thin dark colored algal(?) layer. The limestone is thin to thick bedded and partly argillaceous and locally contains pyrite and very small calcite-filled geodes. The weathered limestone is mottled light olive gray and pale yellowish brown and has fragments weathered in relief on its exposed surfaces (fig. 10). The brecciated limestone composes most of the member north of the Kansas River.

An olive-gray and yellowish-gray calcareous sparsely fossiliferous claystone occurs in the lower or middle part of the Burlingame along Blacksmith Creek (strat. section 4) and north of the Kansas River east of Messhoss Creek. This claystone is 0.1–9.7 feet thick, laminated to

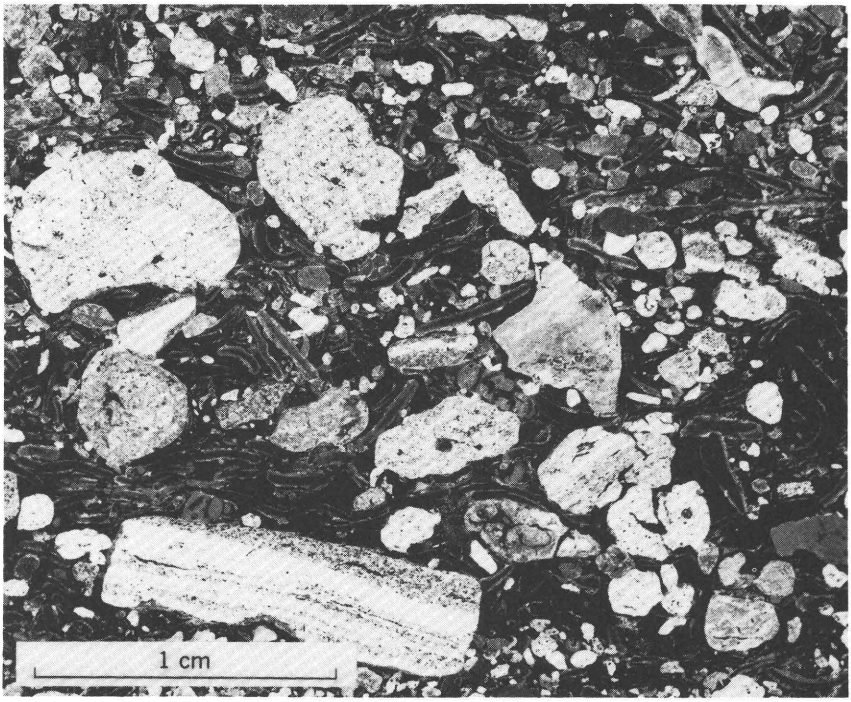

FIGURE 8.—Conglomeratic limestone in basal part of Burlingame Limestone Member of Bern Limestone. Light-colored fragments are limestone; many darker fragments are algal-coated fossil debris. NW¼NW¼ sec. 34, T. 11 S., R. 14 E. Vertical peel print, × 4, courtesy of D. E. Owen.

very thin bedded, and locally slightly silty to sandy. Very thin claystone partings also occur in the Burlingame at some localities south and east of Auburn.

The Burlingame Limestone Member has been eroded from a small area along the Kansas Turnpike in the center of the W½ sec. 17, T. 13 S., R. 15 E., by a channel deposit tentatively assigned to the Soldier Creek Shale Member of the Bern.

The Burlingame contains three fossil zones, but all three zones are not present everywhere (Moore, 1936a, p. 217; Owen, 1959). The basal 1–2 feet of the member throughout much of the east-central part of the area is characterized by abundant pelecypods, particularly *Aviculopecten*, small gastropods, brachiopods, and the alga, *Osagia.* Less abundant are crinoid stems, ramose and fenestrate bryozoans, and fusulinids. Much of the fossil debris is very small.

Overlying the mollusk zone and comprising the entire member at many localities south of the Kansas River is a zone characterized by abundant fusulinids and *Osagia* (fig. 11). Generally the fusulinids

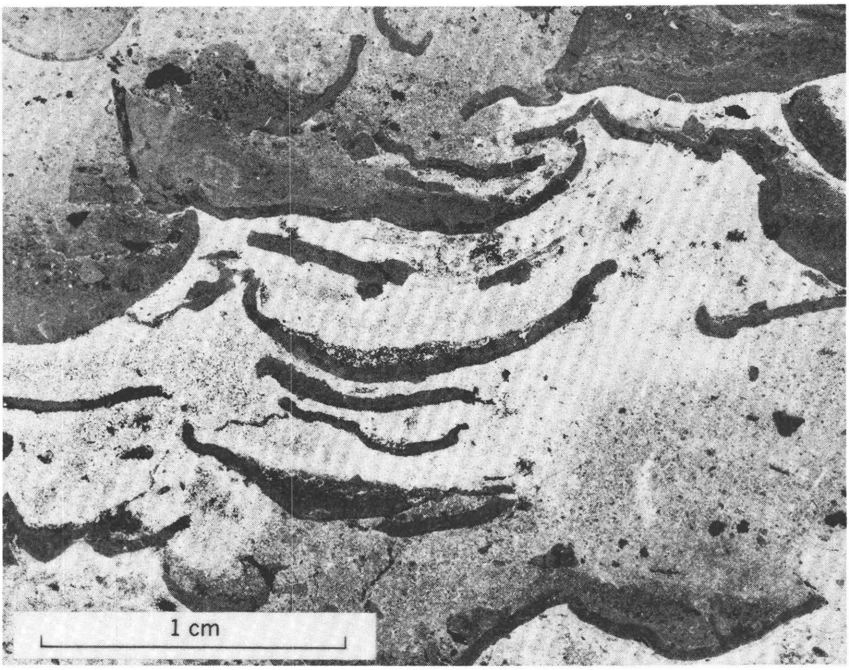

FIGURE 9.—Brecciated part of Burlingame Limestone Member of Bern Limestone from quarry in SE¼NE¼ sec. 29, T. 10 S., R. 15 E. Note dark algal(?) layer beneath limestone fragments. Light-colored matrix is dense limestone. Black spots are air bubbles. Vertical peel print, × 4, courtesy of D. E. Owen.

increase in abundance upward in the zone, and the *Osagia* are more abundant in the lower part and sparse to absent in the upper part. Brachiopods are abundant and varied; crinoid stems, ramose and fenestrate bryozoans, and gastropods are numerous; and pelecypods and *Cryptozoon*-like algae occur at some localities.

The upper fossil zone—the brecciated limestone—contains a sparse fauna of crinoid stems, brachiopods, and gastropods and a few fusulinids and ramose bryozoans. Most of the fossils occur in the lower part of the brecciated limestone. E. L. Yochelson (written commun., 1960) reported *Linoproductus prattenianus* (Norwood and Pratten), *Dielasma*? sp. indet., and a pleurotomariacean gastropod from the brecciated limestone. The claystone bed contains a few fusulinids, crinoid stems, and brachiopods.

Soldier Creek Shale Member

The Soldier Creek Shale Member (Beede, 1898, p. 30) is 6.6–15 feet thick; it is thickest along the Kansas Turnpike south of Auburn. This member is mainly claystone with a lesser amount of limestone,

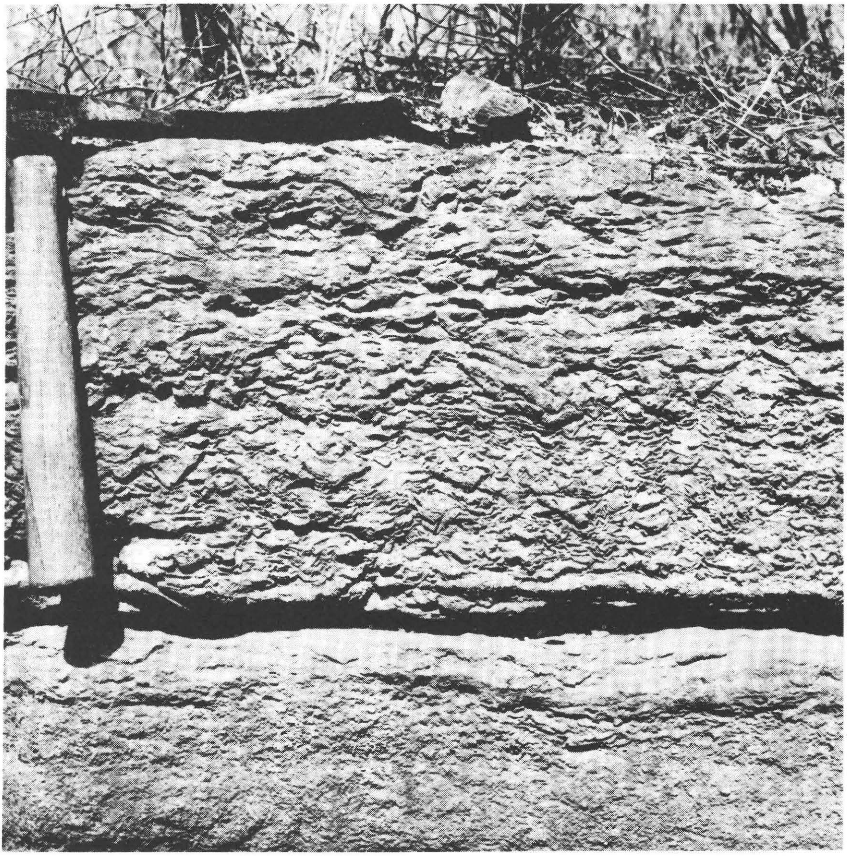

FIGURE 10.—Weathered brecciated part of Burlingame Limestone Member of Bern Limestone in roadcut in NW¼NE¼ sec. 36, T. 10 S., R. 14 E.

but at places south of Auburn it is almost entirely limestone. Some beds of siltstone and sandstone occur in the southern part of the outcrop area, and a thin coal bed is present locally.

The claystone is mainly medium gray and olive gray, slightly silty to slightly sandy, noncalcareous to very calcareous, and laminated to thin bedded. At places it contains abundant small nodules of argillaceous limestone. The weathered claystone is light olive gray, yellowish brown, or olive brown. The very calcareous claystone commonly weathers to hard yellowish-orange or grayish-orange platy or nodular rubble.

A very thin dark-gray to grayish-black claystone bed that may grade laterally into coal occurs near the base of the member in the SW¼ NE¼ sec. 11, T. 11 S., R. 14 E. A coal bed 0.3 foot thick is present about 10 feet below the top of the Soldier Creek Shale Member in the

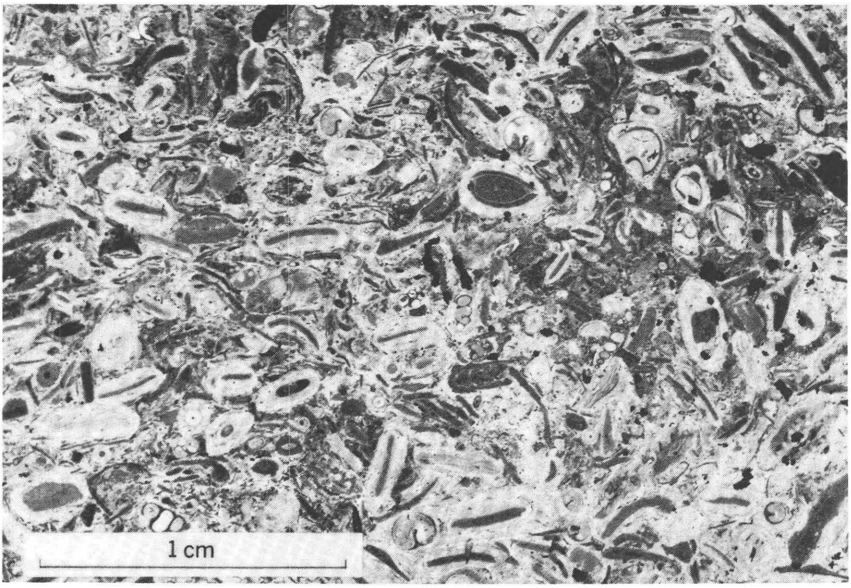

FIGURE 11.—Burlingame Limestone Member of Bern Limestone. Granular texture is due to presence of dark-colored fossil debris coated with light-colored *Osagia* algae. SE¼NE¼ sec. 27, T. 13 S., R. 14 E. Vertical peel print, × 4, courtesy of D. E. Owen.

bank of Vassar Creek in the NW¼NW¼ sec. 30, T. 11 S., R. 14 E.

One or more beds of light- to medium-gray and yellowish-orange very finely crystalline to fine-grained very argillaceous generally unfossiliferous limestone are present in the middle or upper part of the Soldier Creek Shale Member. The limestone is generally laminated to thin bedded and weathers to conspicuous grayish-orange or pale-yellowish-brown platy or nodular fragments and, locally, to boxwork. Commonly the limestone is interbedded with layers of claystone, and the contacts with the claystone beds are generally gradational. At some localities the limestone contains stringers and veinlets of brown calcite. Along the east edge of the area north of the Kansas River, the limestone in the Soldier Creek is very pyritic and fossiliferous.

South of Auburn the very argillaceous unfossiliferous limestone of the Soldier Creek grades fairly rapidly into a bioherm composed mainly of yellowish-gray to light-olive-gray finely to coarsely crystalline very thin to medium-bedded coquinoidal limestone. The bioherm, centered along the Shawnee County–Osage County line, is well exposed in the south bluff of South Branch Wakarusa River and along the Kansas Turnpike. According to Owen (1959, fig. 62), the bioherm trends northwestward and is about 5 miles long and more than 3 miles wide; its original width is unknown. It is thickest, 10.5 feet, along the Kansas Turnpike in the NW¼SW¼ sec. 25, T. 13 S., R. 14 E. From there the reef wedges out within less than 1 mile to the northwest. The main-reef facies, exposed along the Kansas Turnpike, is characterized by coquinoidal limestone of unbroken or large fragments of fossils in a matrix of clear crystalline calcite (fig. 12). Owen (1959, p. 84) reported that the insoluble residue of the main-reef facies averages only about 1.5 percent and consists of subangular to angular quartz sand, clay and silt aggregates, and a very small amount of muscovite. Locally along the Kansas Turnpike, a parting 0–1.5 feet thick of olive-gray to dark-gray calcareous pyritic claystone occurs in the lower part of the bioherm. The fore-reef facies, in the SE cor. NE¼ sec. 34, T. 13 S., R. 14 E., is characterized by very small fossil debris and by having considerably more clastic material, mainly subangular to angular quartz sand (Owen, 1959, p. 84), than the main-reef facies.

The reef limestone is generally overlain by dusky-yellow slightly sandy calcareous claystone. Locally, in the NE cor. SW¼ sec. 35, T. 13 S., R. 14 E., however, the bioherm is overlain by a 0.4-foot-thick light-brownish-gray limestone bed (possibly of algal origin), which, in turn, is overlain by a 0.2-foot-thick dense limestone bed that weathers

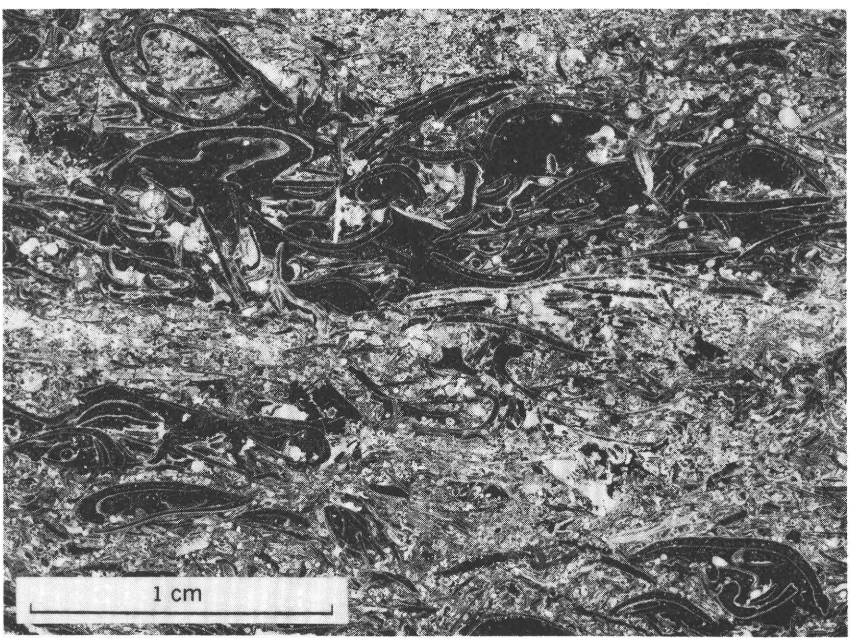

FIGURE 12.—Main-reef facies of bioherm in Soldier Creek Shale Member of Bern Limestone in NW¼SW¼ sec. 25, T. 13 S., R. 14 E. Vertical peel print, × 4, courtesy of D. E. Owen.

dark yellowish brown and that contains fusulinids. Above these beds is claystone, at the top of the member.

Siltstone in the Soldier Creek is mainly medium gray to light brownish gray and locally clayey or slightly sandy, laminated to platy, and unfossiliferous. Parts of it are calcareous and micaceous and contain yellowish-gray limestone nodules less than 0.1 foot to about 0.3 foot long. Near the Kansas Turnpike about 2 miles northeast of Auburn, a yellowish-gray very fine grained silty laminated micaceous limestone occurs at or near the base of the member.

Throughout most of the area the Soldier Creek rests conformably on the Burlingame Limestone Member. South of Auburn, however, an unconformity between the bioherm in the member and the underlying units is well exposed along the Kansas Turnpike, where, within a very short distance, the bioherm rests on claystone in the lower part of the Soldier Creek, on the eroded and weathered Burlingame, and on the upper part of the Silver Lake Shale Member of the Scranton Shale. Channel deposits tentatively assigned to the Soldier Creek rest on the Scranton Shale in the center of the W½ sec. 17, T. 13 S., R. 15 E., where the Burlingame is absent.

Except for the bioherm, the limestone beds in the Soldier Creek contain fossils only at a few localities near the Wakarusa River and near the Kansas River. Pelecypods are abundant, crinoid stems and brachiopods are fairly numerous, and *Osagia* and fusulinids are sparse. Locally the claystone bed beneath the Wakarusa Limestone Member of the Bern contains a few crinoid stems, and at one locality the basal part of the Soldier Creek contains carbonaceous material. The Soldier Creek bioherm is a profusion of mytiloid pelecypods and high- and low-spired and bellerophontid gastropods. Less abundant forms are fusulinids, crinoid stems, ramose bryozoans, and brachiopods. Nautiloid cephalopods and shark teeth are sparse.

Wakarusa Limestone Member

The Wakarusa Limestone Member (Beede, 1898, p. 30; Condra, 1927, p. 77) is about 1.7–4 feet thick and consists of two limestone beds separated by claystone. The member generally forms a narrow inconspicuous bench on the slope above the Burlingame Limestone Member, and at most places only the upper limestone crops out.

The limestone beds are typically medium light gray to medium gray or light olive gray and generally weather yellowish gray, olive gray, and yellowish brown. They are generally very fine grained, partly argillaceous, thin to thick bedded, hard, and compact. The lower bed is 0.5–1.3 feet thick, locally contains claystone interbeds in its uppermost part, and weathers to a single bed that is platy in its lower part. The upper bed is 1–2.8 feet thick, is commonly vertically jointed, and locally weathers to platy fragments on its upper surface.

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The intervening claystone, 0.1–0.9 foot thick, is generally olive gray or medium gray, slightly to moderately silty, laminated to platy, and calcareous. It weathers light olive gray and pale to moderate yellowish brown and, at many localities, contains very thin beds of fossiliferous argillaceous limestone.

The fauna of the Wakarusa Limestone Member is abundant and varied and is generally more abundant in the upper limestone than in the lower. Typically, the lower limestone contains many *Osagia*, crinoid stems, and brachiopods. Small fusulinids are sparse to abundant in the upper part of the lower limestone. Less abundant are *Cryptozoon*-like algae, ramose and fenestrate bryozoans, and gastropods (fig. 13). Horn corals, pelecypods, and trilobites are sparse. The upper limestone is characterized by many large fusulinids, *Cryptozoon*-like algae, crinoid stems, and brachiopods. Horn corals, and ramose, fenestrate, and encrusting bryozoans are common, and *Osagia*, pelecypods, and gastropods are sparse. Cephalopods and possibly ostracodes are very sparse. E. L. Yochelson (written commun., 1960) reported that fusulinids (USGS colln. f12974), possible algal growths, crinoid stems, and "*Spiriferina*" cf. "*S.*" *kentuckensis*

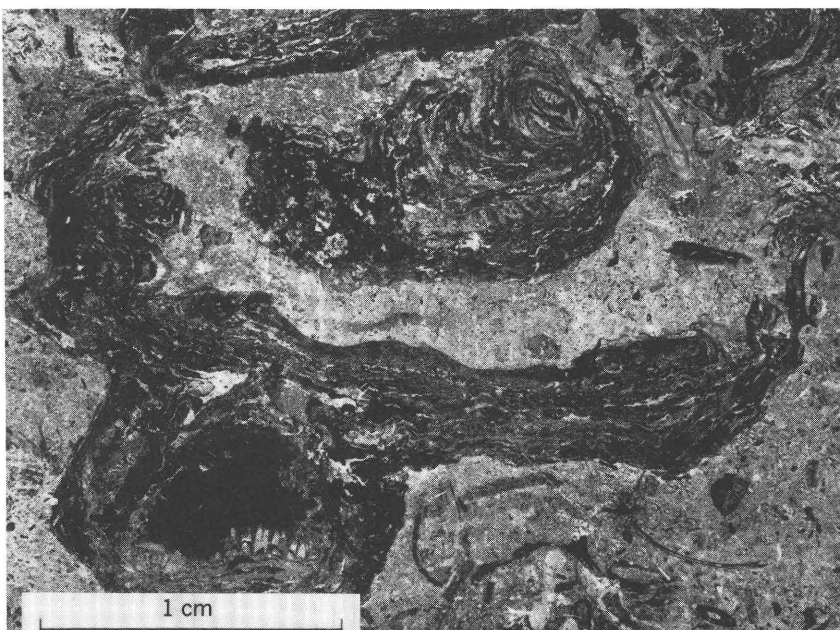

FIGURE 13.—*Cryptozoon*-like algae in lower limestone bed of Wakarusa Limestone Member of Bern Limestone in SW¼NW¼ sec. 23, T. 13 S., R. 14 E. Note algal-encrusted horn coral in lower left corner. Vertical peel print, × 4, courtesy of D. E. Owen.

(Shumard) are present in the Wakarusa in the NW¼ sec. 31, T. 11 S., R. 15 E.

AUBURN SHALE (strat. sections 4, 5)

The Auburn Shale (Beede, 1898, p. 30; Condra, 1927, p. 78) undoubtedly was named for Auburn, Kans., but Beede did not designate a type locality. The formation is well exposed along the Kansas Turnpike in the NE¼SW¼ sec. 35, T. 13 S., R. 14 E., southwest of Auburn. The Auburn is widespread in the east half of the area, where it weathers to a fairly steep slope in which the thicker, more resistant limestone beds form benches.

The Auburn ranges in thickness from about 30 to 70 feet; it is about 60 feet thick at the south edge of the area, 48 feet thick west of Auburn, and 70 feet thick northeast of Auburn near Elevation School. Near the Kansas River the thickness is about 30–45 feet, and north of the river, 30–40 feet. The Auburn rests conformably on the Bern Limestone, and the contact between the two formations is sharp and even.

The Auburn consists mainly of claystone but includes much siltstone, especially in the southern part of the area, and lesser but about equal amounts of limestone and sandstone. The sandstone is also restricted to the southern part. The claystone is light olive gray, olive gray, medium gray, and medium dark gray; it weathers olive gray and yellowish brown. It is silty, laminated to platy, partly calcareous, and micaceous; locally it contains small ironstone concretions and sandstone and limestone nodules. A bed 1–2.2 feet thick of medium-dark-gray to grayish-black silty finely laminated fossiliferous claystone underlain by a 0.1-foot-thick grayish-black claystone that weathers to hard fissile plates occurs 11–13 feet below the top of the Auburn. These dark beds, together with the underlying light-colored claystone, form a conspicuous outcrop along the valley of Little Soldier Creek and along part of Soldier Creek. The dark claystone also crops out at a few localities south of the Kansas River.

Siltstone of the Auburn is mainly olive gray and yellowish gray and weathers light olive gray, yellowish gray, and moderate yellowish brown. Generally the siltstone is clayey to sandy, laminated to platy, micaceous, and partly calcareous. The sandstone is typically yellowish gray, light greenish gray, and yellowish brown, very fine to fine grained, laminated to very thin bedded, and locally micaceous; commonly it is interbedded with siltstone. Some crossbedded layers and limonitic sandstone concretions occur locally.

The limestone is mainly medium gray, brownish gray, olive gray, and yellowish gray. The weathered limestone is generally the same color, but in some places it is yellowish brown and orange. The limestone is generally very fine grained, argillaceous, thin bedded, and very fossiliferous. In many places it has a granular appearance owing to abundant minute fossil fragments.

The limestone is generally restricted to two zones in the Auburn, but locally along Blacksmith Creek (strat. section 4) another zone as much as 10 feet of very argillaceous unfossiliferous limestone occurs near the middle of the Auburn. The lower zone is about 5–15 feet above the base of the formation. Limestone beds in this zone are thicker and more continuous north of the Kansas River than to the south, but some occur as far south as Shunganunga Creek (pl. 3). A massive limestone bed about 5 feet thick forms a prominent ledge or bench along the lower valley of Little Soldier Creek and in adjacent areas along Soldier Creek.

The upper zone of limestone occurs at the top of the Auburn at the south edge of the mapped area and about 10 feet below the top of the Auburn in the northern part of the area, where this zone overlies the grayish-black claystones discussed previously. The upper zone is as much as 9 feet thick and ranges from a single bed of limestone to a very calcareous claystone containing very thin beds of fossiliferous limestone. The limestone forms a prominent bench in the uppermost part of the Auburn Shale along the south side of the Wakarusa River southwest of Auburn. Large blocks of limestone are conspicuous in the east wall of the valley of Little Soldier Creek in the N½ sec. 17, T. 10 S., R. 15 E. Limestone was formerly quarried from this zone along the north side of the Kansas River valley northeast of Silver Lake, in the NW¼NE¼ sec. 10, T. 11 S., R. 14 E., and south of the river in the NW¼SE¼ sec. 35, T. 11 S., R. 14 E. (strat. section 5).

Most limestone of the Auburn Shale contains abundant *Osagia*, crinoid stems, ramose and fenestrate bryozoans, brachiopods, pelecypods (especially myalinid-types), and low-spired and bellerophontid gastropods. Some beds are composed almost entirely of *Osagia*. The claystone, particularly in the upper part, is fossiliferous. The grayish-black claystone contains many *Lingula*. Finely comminuted carbonaceous material and some larger plant remains occur locally in sandstone and at a few places in claystone in the lower part of the Auburn.

EMPORIA LIMESTONE (strat. sections 4, 5)

The Emporia Limestone (Kirk, 1896, p. 80; Condra, 1927, p. 78) contains, in ascending order, the Reading Limestone, Harveyville Shale, and Elmont Limestone Members. It has a narrow dendritic outcrop pattern over the eastern third of the area (pl. 3) and forms a low escarpment or hillside bench. The Emporia is 8–20 feet thick and conformably overlies the Auburn Shale. At most localities the contact is sharp; elsewhere it is slightly gradational. The contacts between the members of the Emporia are sharp and conformable.

Reading Limestone Member

The Reading Limestone Member (Smith, 1905, p. 150), 1.3–4.6 feet thick, is commonly made up of two or three beds of light-olive-gray and medium-light-gray to medium-gray finely crystalline and very fine grained limestone. It is slightly argillaceous in part and is thin to thick bedded, hard, and compact. The Reading has subconchoidal fracture and in places contains small inclusions of light-red celestite. Most of the member weathers mottled light olive gray, moderate yellowish brown, and dark yellowish orange and forms a ledge broken by conspicuous vertical joints. The zone of weathering extends deep into the rock. At some localities the limestone is more argillaceous adjacent to bedding planes, and at one place light-olive-gray slightly calcareous claystone 0.2 foot thick occurs near the middle. The upper limestone is 0.3–0.6 foot thick, is more argillaceous than the underlying beds and characteristically forms an indentation on the outcrop. Its upper surface is commonly pitted and markedly iron stained.

The Reading Limestone Member characteristically has many crinoid columnals that weather white and in relief. Brachiopods, particularly *Chonetes* and productoids, are abundant, and large and small fusulinids are abundant to sparse. *Osagia*, ramose, fenestrate, and encrusting bryozoans, and gastropods are common; pelecypods occur in the basal part at some localities. *Cryptozoon*-like algae, echinoid plates, and horn corals are also present locally. Fusulinids are generally absent in the uppermost bed.

Harveyville Shale Member

The Harveyville Shale Member (Moore, 1963a, p. 226) ranges in thickness from 4.3 to 15 feet and averages about 10 feet. The Harveyville is mainly light-olive-gray laminated to platy partly silty claystone. In places the claystone contains thin siltstone partings that weather moderate yellowish brown. Very small nodules of light-olive-gray fine-grained limestone and of very fine grained sandstone and small concretions of moderate-yellowish-brown ironstone are abundant locally.

Thin beds of medium-light-gray and pale-red very fine grained partly argillaceous limestone are present at many localities. The member contains a few beds of medium-gray and olive-gray clayey to sandy laminated to platy siltstone, mainly in the southern part of the area.

Fossils are sparse in the Harveyville and are confined almost entirely to the limestone beds, although they do occur locally in claystone and siltstone beds near the top. The most common forms are crinoid stems, brachiopods, and pelecypods. Fusulinids and a few *Osagia*?

and *Cryptozoon*-like algae are present locally. *Spirorbis* sp. indet., ostracodes, and the fern *Neuropteris* cf. *N. scheuchzeri* Brongniart were found in the center of the N½ sec. 25, T. 11 S., R. 13 E. (E. L. Yochelson, written commun., 1960).

Elmont Limestone Member

The Elmont Limestone Member (Beede, 1898, p. 30), 2.5–5.2 feet thick, consists of two beds of limestone, which are separated at many localities by a thin unit of claystone. The lower limestone, 0.7–3.2 feet thick, is generally medium light gray, light olive gray, and pale yellowish brown and is very fine grained to very finely crystalline. It is very thin to medium bedded, clayey to sandy in places, and commonly coquinoidal. The limestone weathers light olive gray, yellowish gray, and pale yellowish orange and commonly has a granular texture caused by abundant minute fossil fragments. Light-red to moderate-reddish-orange celestite nodules are sparse to moderately abundant in many outcrops. A claystone parting 0.8–1.2 feet thick locally occurs in the lower limestone along Blacksmith Creek and northwest of Auburn. This parting is light olive gray and calcareous and in places contains nodules of very light gray limestone. In part of the area—especially near the south boundary—the lower limestone is conglomeratic, as previously noted by Moore (1936a, p. 227), and contains subangular to subrounded granules and pebbles of medium-gray to medium-dark-gray limestone. The granules and pebbles are generally less than 0.02 foot in diameter, but a few are as much as 0.1 foot.

The middle unit is 0.4–0.8 foot thick at most places, but locally, it is as much as 2 feet thick. It is medium-light-gray to medium-gray and light-olive-gray partly calcareous claystone and, locally, siltstone. At a few places the claystone contains ironstone concretions, some as much as 0.3 foot thick and 0.8 foot long.

The upper limestone, 0.8–2 feet thick, is the most resistant and most characteristic part of the Elmont. It consists of medium-light-gray to medium-gray and brownish-gray very fine grained hard compact limestone that has subconchoidal fracture and breaks with a sharp ringing sound. It weathers yellowish gray, yellowish orange, and yellowish brown and forms a vertically jointed ledge. Commonly the upper few inches of the limestone is moderately argillaceous and weathers to thin platy fragments. "Cable markings" are conspicuous on some weathered outcrops.

The distinct faunal assemblages in the Elmont Limestone Member aid in its identification. The lower unit is commonly coquinoidal limestone containing abundant *Osagia*, crinoid stems, brachiopods, and pelecypods. Ramose and fenestrate bryozoans are common, and fusulinids, *Cryptozoon*-like algae, and gastropods occur at some localities. The middle claystone unit is generally sparsely fossiliferous, but in places it appears to be unfossiliferous. Fusulinids, crinoid stems, bryozoans, brachiopods, pelecypods, and gastropods are included in the fauna of the middle unit. The upper limestone unit of the Elmont is characterized by abundant, generally small, fusulinids, crinoid stems, and brachiopods. Ramose, fenestrate, and encrusting bryozoans and gastropods are common. *Cryptozoon*-like algae, horn corals, and pelecypods are present at a few localities. The fossil fragments in the upper bed are generally reddish brown, probably owing to a coating of the alga *Osagia*. E. L. Yochelson (written commun., 1960) identified the following forms from the upper limestone unit:

USGS fossil locality 19458–PC (f12972). Along a gully in the SE¼SW¼ sec. 23, T. 10 S., R. 14 E.

- Fusulinids, undet.
- Crinoid stems
- Rhomboporoid bryozoan fragment
- ?*Derbyia* sp. indet.
- *Crurithyris* cf. *C. planoconvexa* (Shumard)
- "*Spiriferina*" *kentuckensis* (Shumard)
- Pelecypod, indet.
- *Bellerophon* cf. *B. singularis* Moore
- *Glabrocingulum* (*Ananias*) *marcouianus* (Geinitz)
- *Paleostylus* (*Pseudozygopleura*) *scitula* (Meek)
- "*Strobeus*" sp. indet.
- *Donaldina* sp. indet.

WILLARD SHALE (strat. sections 4, 6)

The Willard Shale was named by Beede (1898, p. 31) after the village of Willard, south of the Kansas River on the Shawnee County–Wabaunsee County line, and it is well exposed in cutbanks along Post Creek south of the village (pl. 3). The Willard forms a fairly steep partly covered slope between the bench formed by the Emporia Limestone (below) and the ledge or escarpment formed by the Zeandale Limestone (above). The contact between the Willard and the Emporia Limestone is sharp and conformable.

The Willard is about 14–56 feet thick, and locally there is a wide variation in thickness. The formation is about 40 feet thick just south of the mapped area, in the center of the NE¼ sec. 3, T. 14 S., R. 14 E., and 30 feet thick less than 1 mile to the northwest, at the SE cor. sec. 33, T. 13 S., R. 14 E. Along the Wakarusa River valley about 2 miles north of the latter locality, the Willard is approximately 15 feet thick. Maximum thickness, 56 feet, occurs north of the Kansas River in the SW¼ sec. 23, T. 10 S., R. 14 E.

Most of the Willard is composed of claystone and siltstone except south of the Wakarusa River, where the formation is mostly sandstone; elsewhere, thin sandstone beds occur only in the upper part of the formation. The claystone is olive gray to medium gray and weathers light olive gray and yellowish brown. It is commonly silty, is laminated to platy, and in places contains thin beds of ironstone concretions that weather dark yellowish orange to moderate yellowish brown.

The siltstone is typically olive gray and yellowish gray, clayey, laminated to platy, and finely micaceous; it weathers light olive gray to moderate yellowish brown. In many places the siltstone is interbedded with sandstone or claystone. Commonly, hard fragments of siltstone and ironstone concretions are present on the weathered outcrop. The sandstone is light olive gray and light gray, very fine grained, silty, laminated to platy, and micaceous; it weathers mainly light grayish yellow and pale yellowish brown. A very thin coaly streak occurs about 4 feet below the top of the Willard along Haskell Creek in the NE cor. SE¼NW¼ sec. 31, T. 12 S., R. 14 E.

The Willard Shale is generally unfossiliferous, but at a few localities brachiopods are abundant in the basal part, and fusulinids, crinoid stems, brachiopods, and a few pelecypods and gastropods occur in the uppermost part. Coal material and carbonized plant fragments occur locally in the upper part.

ZEANDALE LIMESTONE (strat. section 6)

The Zeandale Limestone (Moore and Mudge, 1956, p. 2276) is composed, in ascending order, of the Tarkio Limestone, Wamego Shale, and Maple Hill Limestone Members. The formation crops out in a broad north-south-trending band, generally through the middle of the the area. The lower limestone member underlies a prominent escarpment, and the two upper members underlie grassy slopes and are poorly exposed. Along the Wakarusa River (pl. 3) the upper half of the Zeandale is absent owing to channeling. The formation is about 18–25 feet thick, but southwest of Auburn it is locally about 40 feet thick. The Zeandale conformably overlies the Willard Shale, and the contact between the two members is sharp and slightly irregular.

Tarkio Limestone Member

Tarkio Limestone Member (Calvin, 1901, p. 420; Condra and Bengston, 1915, p. 8) forms a prominent ledge that is broken by widely spaced vertical joints; large limestone blocks break from the ledge and slump onto the underlying slope. The Tarkio ranges in thickness from 2 feet to 13 feet near Dover. The member is a single limestone unit in most places, but locally it comprises two limestones and a medial claystone.

The Tarkio is composed primarily of one type of limestone, but from the Kansas River south almost to Dover a different type of limestone occurs in the upper part. Light-gray to pale-yellowish-brown very finely crystalline thin-bedded to massive limestone is the dominant lithology; it composes the lower and thicker part of the member, and throughout most of the area it constitutes the entire member. This limestone is generally slightly argillaceous but is locally more argillaceous in its basal part. In the area south of the Wakarusa River, the lower part is moderately sandy. The limestone contains a high percentage of iron oxide and characteristically weathers moderate yellowish brown. In places the lower limestone weathers grayish orange to dark yellowish orange. Where the member is thick bedded or massive, it forms large rectangular blocks; but where it is thin bedded, it weathers to wedge-shaped slabs and has a wavy-bedded appearance. Commonly the upper 1–2 feet of the member is porous, and the upper surface is irregular and pitted. Abundant large fusulinids characteristically stand in relief on the weathered surfaces. Locally, small nodules of light-red to moderate-reddish-orange celestite occur in the upper part.

Medium-light-gray to medium-gray and pale-brown very fine to fine-grained locally argillaceous very thin bedded to massive limestone composes the upper 0.6–5.7 feet of the Tarkio from the Kansas River southward to the vicinity of Dover, especially along Mission Creek valley. In most places the limestone has a pseudo-oolitic texture owing to the presence of finely comminuted algal-coated fossil fragments. Locally along Mission and Haskell Creeks (pl. 3) the basal part of this limestone is sandy. The upper limestone weathers to light-gray, yellowish-gray, and pale-yellowish-brown surfaces that are rough, porous, and deeply pitted. The light-colored porous upper limestone contrasts markedly with the lower dark-colored limestone of the Tarkio.

At most localities the upper limestone rests directly on the lower limestone. At places the contact is sharp and irregular, but elsewhere it is gradational. Locally along Mission and Haskell Creeks, however, a bed 0–3.2 feet thick of light-olive-gray calcareous generally fossiliferous claystone separates the two limestones. Brown limestone nodules less than 0.06 foot in diameter occur in the claystone.

The dominant limestone of the Tarkio is characterized by the large robust fusulinid *Triticites ventricosus* Meek and Hayden (Moore, 1936a, p. 230). Fusulinids from this unit are in USGS foraminiferal collection f12970 from a roadcut in the NW cor. SE¼ sec. 27, T. 10 S., R. 13 E., near Rossville. At some localities brachiopods, especially *Reticulatia*, and crinoid stems are common. Horn corals and ramose bryozoans occur in many places, and gastropods and encrusting and fenestrate bryozoans were noted at several localities. The basal part of the Tarkio contains some pelecypods, and the middle part, some *Cryptozoon*-like algae.

The upper limestone of the Tarkio is characterized by abundant *Osagia*. *Cryptozoon*-like algae, crinoid stems, ramose and fenestrate bryozoans, brachiopods, pelecypods, and gastropods are common. Large fusulinids are present but seldom abundant. Arenaceous foraminifers dominate the coarse fraction of the insoluble residues, according to Wood (1959, p. 76).

Wamego Shale Member

The Wamego Shale Member (Condra and Reed, 1943, p. 42) is about 9–16.5 feet thick throughout most of the area, but locally south of the Wakarusa River (pl. 3) it is 30–35 feet thick. The member is mostly claystone but contains some siltstone, sandstone, and nodules and several thin beds of argillaceous limestone. The claystone is mainly light olive gray to medium gray, slightly to moderately silty, and finely laminated to platy; in places it is also partly micaceous and very calcareous. It weathers very light gray, light olive gray, and yellowish gray. Commonly, light-olive-gray and moderate-yellowish-brown micaceous siltstone is interbedded with the claystone. In places the outcrop is covered with hard fragments of iron-stained siltstone.

A limestone bed generally 0.3–2.2 feet thick but locally as much as 6 feet thick occurs 2–8 feet above the base of the Wamego at many localities. The limestone is light olive gray and shades of brown, cryptocrystalline to very fine grained, moderately to very argillaceous, very thin to medium bedded, and fossiliferous. In Cross Creek in the SW¼NE¼ sec. 15, T. 10 S., R. 13 E., the limestone is about 6 feet thick and is interbedded with claystone. Some of the limestone layers contain small limestone pellets. Thin beds of limestone also occur in the Wamego near the Wakarusa River. Sandy micaceous wavy-bedded limestone 3 feet thick is exposed in roadcuts in the west-central part of sec. 18, T. 10 S., R. 15 E. Fossils in this bed are confined to the upper half.

Dusky-yellow to yellowish-gray very fine grained micaceous sandstone occurs locally in the Wamego near the Wakarusa River. A coaly streak is present in the uppermost part of the member about 1.5 miles south of Willard; at a few other localities the claystone in that part of the member is coaly and carbonaceous.

Near the Wakarusa River, channel deposits of the Onaga (?) Shale rest unconformably on the middle part of the Wamego (pl. 3). Because the two rock types are similar in lithology, the position of the contact between them is questionable.

Limestone beds of the Wamego generally are moderately fossiliferous, and some of the claystone beds are sparsely fossiliferous. Brachiopods, ramose and fenestrate bryozoans, and crinoid stems are common to abundant in the limestone beds; *Osagia*, pelecypods, and gastropods are less numerous. The claystones locally contain abundant crinoid stems and pelocypods and a few gastropods, ostracodes, plant fragments, and worm tracks.

Maple Hill Limestone Member

The Maple Hill Limestone Member (Condra, 1927, p. 80) is present in the outcrop belt of the Zeandale Limestone except near the Wakarusa River (pl. 3), where it has been eroded by a channel. The member is a very uniform and persistent limestone 1.2–2 feet thick. It is light to medium gray, very fine grained, very thin to medium bedded, and hard. Characteristically, it weathers to a single bed that is mottled light olive gray, moderate yellowish brown, and grayish orange and separates along joints into large rectangular blocks. The upper surface is rough, is mottled with grayish-red and dark-brown iron stain, contains small hard limonitic concretions in some places, and weathers to angular chips. At places the lower 0.2 foot is argillaceous and weathers to platy fragments.

The Maple Hill Limestone Member is characterized by abundant slender fusulinids, crinoid stems, and brachiopods. Ramose bryozoans and gastropods are common; and *Osagia*, horn corals, pectenoid pelecypods, possibly ostracodes, and a few trilobites occur at some localities. *Cryptozoon*-like algae are locally abundant in the upper part of the member.

E. L. Yochelson (written commun., 1960) identified the following forms:

USGS fossil locality 19459–PC (f12965). In a gully in the N½SE¼ sec. 2, T. 10 S., R. 14 E.
- Algae (*Cryptozoon*-like)
- Fusulinids, undet.
- Crinoid stems
- *Astartella* sp. indet.
- *Streptacis*? sp. indet.

Fossil locality in stream in the SW cor. sec. 32, T. 13 S., R. 14 E.
- Fusulinids, undet. (abundant) (USGS colln. f12966)
- Crinoid stems
- Fenestrate bryozoan fragment
- *Meekella* cf. *M. striatocostata* (Cox)
- *Lissochonetes*? sp. indet.
- *Amphiscapha* (*Amphiscapha*) sp. indet.
- Trilobite pygidium, indet.

Fusulinids from the Maple Hill also are in USGS foraminiferal collection f12969 from a roadcut in the NW cor. SE¼ sec. 27, T. 10 S., R. 13 E.

PILLSBURY SHALE (strat. section 8)

The Pillsbury Shale (Moore and Mudge, 1956, p. 2275) is rather poorly exposed in a broad outcrop generally along the north edge and in the west half of the area. The Pillsbury is about 33 feet thick at the Shawnee County–Osage County line, about 61 feet thick east of Dover, and about 40 feet thick at the north edge of the area along Dutch Creek.

The Pillsbury conformably overlies the Maple Hill Limestone Member of the Zeandale Limestone, and the contact is sharp and even. Along the Wakarusa River near Dover and locally along the west boundary of the area south of U.S. Highway 40, all or part of the formation was eroded in channels of Late Pennsylvanian and Early Permian age (pl. 3). The upper part of the Pillsbury is cut by channels in a small area around the common corner of secs. 27, 28, 33, and 34, T. 9 S., R. 14 E., and there the Root Shale lies directly on the Pillsbury.

The Pillsbury is primarily interbedded siltstone and claystone but includes some sandstone and, locally, limestone. The siltstone is dominantly yellowish gray and olive gray and laminated to very thin bedded; it weathers yellowish gray and olive gray mottled with yellowish brown and olive brown. The siltstone is clayey to finely sandy and micaceous; where it is ferruginous, it weathers to hard moderate-yellowish-brown layers. The claystone is light olive gray to olive gray and medium gray to medium dark gray, silty, and laminated to platy; in places it contains nodules and lenses of very argillaceous limestone. The weathered claystone typically is light olive gray.

The sandstone, which is generally confined to the upper third of the formation, is light olive gray and yellowish gray, very fine grained, silty, laminated to thin bedded, and micaceous. It weathers to colors similar to those of the fresh rock. Locally the sandstone is slightly crossbedded and ripple marked and contains hard nodules and lenses of pyritic sandstone that weather moderate yellowish brown. At most localities the sandstone is interbedded with siltstone or claystone. Nodules, lenses, and a few hard concretionary beds of light-olive-gray, light-gray, and light-greenish-gray argillaceous partly micaceous limestone occur in the upper part of the Pillsbury. Very thin beds of ironstone concretions that weather dark yellowish orange to reddish brown are common in the lower part.

Fossils are sparse in the Pillsbury Shale and are mainly confined to the uppermost part. Fusulinids, crinoid fragments, and brachiopods are generally the most abundant. Ramose, fenestrate, and encrusting bryozoans, echinoids spines and plates, and pelecypods are also present. Finely comminuted carbonaceous material occurs on bedding planes, particularly in the sandstones and siltstones; and large plant impressions have been found in a sandstone about 10 feet below the top of the formation in the bank of Dutch Creek in the SE¼SW¼ sec. 21, T. 9 S., R. 14 E.

STOTLER LIMESTONE (strat. sections 7, 8, 10)

The Stotler Limestone (Moore and Mudge, 1956, p. 2275) contains, in ascending order, the Dover Limestone, Dry Shale, and Grandhaven Limestone Members. The formation forms a conspicuous bench or low escarpment throughout much of its outcrop area, particularly south of the Kansas River (pl. 3). Its maximum thickness is about 23 feet, on the south side of the Wakarusa River along the line between T. 13 S., R. 13 E., and T. 13 S., R. 14 E.; its minimum thickness is about 5 feet, approximately 2 miles north of Rossville.

Near U.S. Highway 40 in the northeastern part of Wabaunsee County, the Dry Shale Member of the Stotler is very thin; it was mistakenly identified by Mudge and Burton (1959, p. 27–28, 198–199) as the Friedrich Shale Member of the Root Shale. Consequently, in that area they included beds that are properly in the Dry Shale and Grandhaven Limestone Members of the Stotler with the Dover Limestone Member and miscorrelated the Jim Creek Limestone Member of the Root with the Grandhaven.

The Stotler Limestone conformably overlies the Pillsbury Shale. At many localities the contact is gradational through a few inches of very calcareous claystone or very argillaceous limestone; elsewhere the contact is sharp and even. The members of the Stotler are conformable, and at places the contacts between them are slightly gradational. Near Dover and in the upper reaches of the Wakarusa River, younger Pennsylvanian and Early Permian channeling eroded the Stotler (pl. 3). The formation was also channeled out in a small area around the common corner of secs. 27, 28, 33, and 34, T. 9. S., R. 14 E.

Dover Limestone Member

The Dover Limestone Member was named by Beede (1898, p. 31) from unidentified exposures in the vicinity of Dover in the southwestern part of the area. Because no specific locality was stated as the type locality, and because channel-fill sandstone of younger age occupies the stratigraphic position of the Dover near the village, a reference locality in a roadcut in the SW¼NW¼ sec. 31, T. 12 S., R. 14 E., 1.5 miles east of Dover, is hereby designated (strat. section 10). The Dover forms a prominent light-colored bench covered with cobbles and platy fragments of limestone.

The Dover is 1–4.8 feet thick and consists principally of light-olive-gray and light-gray moderately to very argillaceous thin- to thick-bedded partly pyritic hard limestone. In a few exposures it is medium gray and light olive brown. The limestone generally is very fine grained. The basal few inches and roughly the upper half are commonly very argillaceous; at many localities the bedding is irregular and obscure. The weathered limestone is dominantly light olive gray, light gray, and yellowish gray mottled in part by yellowish brown, yellowish orange, and brownish gray.

The lower part of the Dover commonly forms a vertically jointed ledge that weathers to irregularly shaped blocks; the blocks, in turn, may break into platy fragments. At places the lowermost part of the ledge weathers soft and platy. The upper, argillaceous part of the Dover characteristically weathers to nodular rubble owing largely to the presence of resistant algal masses. Many of the cobbles and blocks are pitted. In the center of the E½SW¼ sec. 21, T. 11 S., R. 13 E., a bed 0.5–1.2 feet thick of mottled olive-gray and light-yellowish-brown clayey to finely sandy calcareous siltstone containing many inclusions of sandy limestone occurs in the lower part of the Dover. Very thin partings of siltstone and claystone are present at a few localities.

The Dover is characterized by large fusulinids, biscuit-shaped algal deposits, and brachiopods. The fusulinids are very abundant in the lower half of the member and less abundant to locally sparse in the upper half. Also in the lower half are many brachiopods, especially near the base, and crinoid stems. Less abundant fossils are ramose, rhomboporoid, encrusting, and fenestrate bryozoans, and horn corals. *Osagia*, a few tabulate corals, echinoid fragments, pelecypods, cephalopods, and trilobites are also present. *Cryptozoon*-like algae are the dominant fossils in the upper part; but fusulinids, crinoid columnals, horn corals, and brachiopods are common, and a few *Osagia* and ramose bryozoans are also present. The siltstone in the Dover contains fusulinids, crinoid columnals, brachiopods, and a few pelecypods. E. L. Yochelson (written commun., 1960) reported the following forms from the Dover:

USGS fossil locality 19460–PC (f12964). In a streambank in the NW¼SW¼ SW¼ sec. 30, T. 9 S., R. 14 E.

- Fusulinids, undet. (abundant)
- Trilobite (cf. *Ditomopyge*? sp.)

Fossil locality along U.S. Highway 40 in the SW¼SW¼ sec. 30, T. 11 S., R. 13 E., 1 mile west of mapped area.

- Algae (Cryptozoon)
- Fusulinids, undet. (abundant) (USGS colln. f12963)
- Crinoid stems
- Rhomboporoid bryozoan
- *Meekoporella*? sp. indet.
- *Enteletes hemiplicatus* (Hall)
- *Chonetes granulifer* Owen

Fusulinids from the Dover are included in USGS foraminiferal collection f12962, from the bank of the Wakarusa River at the west line of the SW¼SW¼ sec. 24, T. 13 S., R. 13 E. *Derbyia*? sp. indet. and a trilobite pygidium, indet., from that locality were also identified by Yochelson.

Dry Shale Member

The Dry Shale Member (Moore, Elias, and Newell, 1934) underlies covered slopes in the southern part of the area. In the northern part, where the member is very thin, it forms an inconspicuous reentrant between the underlying Dover Limestone Member and the overlying Grandhaven Limestone Member. The Dry has been eroded near Dover and, to the south, along the Wakarusa River in channels of Late Pennsylvanian and Early Permian age (pl. 3). Near the north border of the area the member is almost 4 feet thick, but it thins to 0.1 foot near the Kansas River (strat. section 8). It is nearly 16 feet thick along the south side of the Wakarusa River.

The Dry is dominantly light-olive-gray to olive-gray silty platy partly calcareous claystone but includes some siltstone. It weathers light olive gray to olive gray mottled by light olive brown and moderate yellowish brown. At most localities the lower and middle parts contain abundant small irregular nodules of light-olive-gray and light-yellowish-gray hard dense argillaceous unfossiliferous limestone. The nodules weather light olive gray to light greenish gray mottled in part by light brownish gray, and they cover the outcrop.

Coquinoidal limestone is present in the Dry Shale Member at several localities. In the SW¼NE¼ sec. 6, T. 13 S., R. 14 E. (strat. section 7), a reeflike body as much as 2.5 feet thick contains beds that have an apparent dip of 3° SE and overlap progressively to the north. Here, the limestone is light olive gray to pale yellowish brown, very finely crystalline, thin bedded, and irregular; it contains many round argillaceous limestone pellets 0.01–0.02 foot in diameter. Coquinoidal limestone, of which 3.5 feet is exposed, occurs on the east side of the road in the SW¼NW¼ sec. 23, T. 12 S., R. 13 E., but it does not contain limestone pellets. Lenses as much as 0.1 foot thick of coquinoidal limestone containing abundant pellets of argillaceous limestone occur in the Dry just west of the mapped area, along U.S. Highway 40 (strat. section 8), and lenses of fossiliferous limestone also crop out along the lower valley of Cross Creek north of Rossville.

Fossils are very sparse or absent in the Dry Shale Member except in the vicinity of the Kansas River and at the few localities where the member contains coquinoidal limestone. Crinoid columnals, ramose and fenestrate bryozoans, brachiopod shells, productoid spines, and pelecypods are abundant near the Kansas River; but elsewhere only a few brachiopod spines and pelecypods occur, and these, locally at the top of the member. The coquinoidal limestone contains very abundant pelecypods and gastropods, many crinoid columnals, and, at places, *Osagia.*

Grandhaven Limestone Member

The Grandhaven Limestone Member was named by Moore, Elias, and Newell (1934), and the type locality was designated by Moore (1936a, p. 237) as sec. 31, T. 13 S., R. 14 E., near the abandoned post office of Grandhaven, in southwestern Shawnee County. The member was defined as a lower fusulinid-bearing limestone unit separated from an algal limestone by 4–10 feet of shale (Moore, 1936a, p. 237). The fusulinid-bearing limestone occurs throughout western Shawnee County and vicinity, but the algal limestone only occurs locally from near Dover southward into Osage County (O'Conner, 1955, p. 9). Consequently, the authors of this report have mapped the algal limestone and the intervening shale with the overlying Friedrich Shale Member of the Root Shale.

In the southern part of the area, where the underlying Dry Shale Member generally is thick, the Grandhaven forms a minor bench on the back slope of the low escarpment formed by the entire Stotler Limestone. Where the Dry is thin, the outcrop of the Grandhaven coalesces with that of the underlying Dover Limestone Member. The Grandhaven is absent owing to channeling in later Pennsylvanian and Early Permian time over parts of the area, primarily near Dover (pl. 3).

The Grandhaven Limestone Member of this report is 1.2–6 feet thick and throughout most of the area consists of two limestones separated by a thin claystone. Near the Kansas River and to the north, however, the member is a single limestone bed and commonly has claystone partings in the basal 1 foot. The lower limestone, 0.5–2.1 feet thick, is mainly light olive gray to medium light gray, very fine grained to very finely crystalline, slightly to very argillaceous, thin to medium bedded, and hard. It commonly weathers light olive gray and yellowish gray mottled with yellowish brown and reddish brown. Locally it has dark-brown rough ferruginous masses on its upper surface. The upper limestone is 0.5–3 feet thick and averages slightly less than 1 foot in thickness. It is mainly light olive gray to olive gray and grayish orange, very fine grained, in part argillaceous, and very thin to thin bedded. Commonly it weathers olive gray and yellowish gray mottled with yellowish brown and orange. The upper limestone generally forms a single bed that is vertically jointed locally.

The intervening claystone of the Grandhaven is 0.2–1.9 feet thick and is light olive gray to olive gray, slightly to moderately silty, laminated, and calcareous. In places it contains thin lenses and small nodules of medium-light-gray, light-olive-gray, or brownish-gray very fine grained and very finely crystalline argillaceous limestone. The claystone weathers light olive gray to light olive brown and forms a reentrant between the limestone beds.

The Grandhaven contains an abundant and varied fauna including small slender fusulinids. Typically, the fusulinids are most abundant in the lower limestone. Generally fossils are abundant in the lower bed, but locally they are sparse. Crinoid stems and brachiopods are abundant, and ramose and rhomboporoid bryozoans and *Osagia* are generally present. Pectenoid and myalinid pelecypods and ostracodes(?) occur in the lower bed at a few localities. The middle claystone unit commonly contains crinoid stems and brachiopods and a few specimens of *Osagia* and ramose bryozoans. The upper limestone unit typically has abundant crinoid columnals, brachiopods, and, at many localities, *Osagia*. Fusulinids are locally abundant but at many places are apparently absent. Ramose bryozoans and productoid spines are common.

ROOT SHALE (strat. sections 7, 8)

The Root Shale (Moore and Mudge, 1956, p. 2275) comprises, in ascending order, the Friedrich Shale, Jim Creek Limestone, and French Creek Shale Members. The Jim Creek Limestone Member was mapped in areas of good exposures. The Root is poorly exposed in the west half and along the north edge of the area. The formation is about 40–60 feet thick, averaging about 48 feet in thickness. The Root rests conformably on the Stotler Limestone, members of the Root are conformable, and locally the contacts between the members are gradational.

Friedrich Shale Member

The Friedrich Shale Member (Moore, Elias, and Newell, 1934) is 12–30 feet thick and averages 22 feet thick. As was discussed previously, the authors of this report mapped the upper algal limestone and intervening shale of the Grandhaven Limestone Member of the Stotler Limestone with the Friedrich in this area. The Friedrich is primarily claystone and siltstone, but it contains some limestone and a little sandstone. The claystone is light olive gray to olive gray, slightly to moderately silty, laminated to platy, and locally micaceous. Colors of weathered surfaces are similar to those of fresh surfaces except that in some places they include yellowish gray, pale yellowish brown, and light olive brown. A bed of mottled grayish-red and greenish-gray claystone commonly occurs in the lower few feet. Nodules and lenses of light-gray argillaceous limestone are abundant in the claystone at several localities. Ironstone concretions that weather pale to dark yellowish orange occur locally.

The siltstone generally is olive gray, clayey, platy, and finely micaceous; locally it is calcareous and pyritic. In many places it is interbedded with claystone. The siltstone weathers mainly moderate yellowish brown and forms hard iron-stained fragments.

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A conspicuous bed 0.7–3.8 feet thick of light-gray to medium-light-gray very fine grained medium- to thick-bedded coquinoidal limestone occurs at various positions within the Friedrich Shale Member at many localities from the vicinity of Dover southward into Osage County; this is the upper limestone of the original Grandhaven Limestone Member of the Stotler Limestone. Locally (strat. section 7) the bed contains abundant limestone(?) pellets less than 0.01 foot in diameter and a few small nodules of light-red barite. The limestone weathers to large light-olive-gray to light-brownish-gray blocks that appear banded, are porous, and show pit and cusp weathering on their upper surfaces. A 1-foot-thick bed of light-yellowish-brown sandy granular very fossiliferous limestone that weathers to nodular porous blocks occurs about 6 feet below the top of the member in the NW¼ sec. 4 and in the E½ sec. 9, T. 12 S., R. 13 E.

Other types of limestone occur at several localities. A bed 0.9 foot thick of olive-gray to moderate-yellowish-brown very argillaceous sparsely fossiliferous limestone crops out in a small area near the south edge of the mapped area. This limestone is a few feet above the conspicuous grayish-red claystone in the basal part of the member. A thin bed of medium-light-gray to pale-yellowish-brown very finely crystalline limestone is present just below the top of the Friedrich along Soldier Creek in Jackson County.

The small amount of sandstone in the Friedrich is grayish yellow and yellowish gray with a brown or purple hue. It is fine grained and laminated to platy and at places is associated with thin beds of sandy limestone. A coal bed 0.2 foot thick occurs about 1 foot below the top of the member in the spillway of the dam at the Girl Scout camp about 2 miles south of Dover. Claystone containing abundant carbonaceous and coaly material occurs at the same stratigraphic position along the road in the SW¼SW¼ sec. 31, T. 9 S., R. 14 E.

Most of the Friedrich Shale Member is unfossiliferous, but the conspicuous limestone bed south of Dover contains very abundant *Osagia* and pelecypods, many crinoid columnals and gastropods, and a few fusulinids. At a few places claystone in the uppermost part of the member contains crinoid stems, productoid brachiopods, and myalinid and pectenoid pelecypods. These fossils, as well as fenestrate bryozoans, also occur locally in sandstone beds. *Lingula* and gastropods are associated with the coaly and carbonaceous material near the top of the member. Very small shell fragments were found in the basal 1 foot at one locality. E. L. Yochelson (written commun., 1960) identified the following forms from the upper 1 foot:

USGS fossil locality 19461–PC. On the west line of the NW¼SW¼ sec. 31, T. 9 S., R. 14 E., Jackson County.

Spirorbis sp. indet. (abundant)
Ostracodes, undet.

Jim Creek Limestone Member

The Jim Creek Limestone Member (Moore, Elias, and Newell, 1934) is seldom exposed because it is very thin, is nonresistant and lies between thick shale units. The best exposure of the limestone is along U.S. Highway 40 near the west edge of the area.

The Jim Creek, 0.4–2.4 feet thick, is light-olive-gray and medium-light-gray to medium-gray very fine grained very thin to medium-bedded hard limestone. The lower part is commonly argillaceous and weathers to a reentrant below the vertically jointed ledge formed by the upper part. Typically, the Jim Creek weathers mottled light olive gray to yellowish gray, pale to moderate yellowish brown, and dark yellowish orange. The upper surface contains hard dark-brown limonitic masses that weather out and leave pits. This upper surface commonly breaks into irregularly shaped chips. In the W½ sec. 31, T. 9 S., R. 14 E., and the E½ sec. 36, T. 9 S., R. 13 E., the Jim Creek is medium-light-gray coquinoidal limestone that weathers to porous tabular blocks and closely resembles the coquinoidal limestone in the Friedrich Shale Member near Dover.

The fauna of the Jim Creek Limestone Member is abundant and very diverse and aids in identification of the member. Brachiopods predominate and weather in relief. At most localities slender fusulinids are abundant, as well as crinoid stems; ramose, fenestrate, encrusting, and rhomboporoid bryozoans; productoid spines; and myalinid, pectenoid, and other types of pelecypods. *Osagia* and gastropods occur in some places, and horn corals are sparse. The following collection from the Jim Creek was reported by E. L. Yochelson (written commun., 1960):

USGS fossil locality 19462–PC f12959). In the NW¼SE¼ sec. 6, T. 13 S., R. 14 E. (strat. section 7).

Fusulinids, undet.
Crinoid stems
Fenestrate bryozoans (worn)
Rhomboporoid bryozoans (worn)
Chonetes granulifer (Owen)
"Spiriferina" kentuckensis (Shumard)
Abundant shell fragments, some of which are pelecypod fragments
A. (*Amphiscapha*) cf. *A.* (*A.*) *muricata* (Knight)
High-spired gastropod, undet.
Dentalium? sp. indet.

At other localities Yochelson identified some of the fossils listed above and these additional forms:

Derbyia crassus (Meek and Hayden)
Marginifera wabashensis (Norwood and Pratten)
Reticulatia cf. *R. huecoensis* (R. E. King)
Crurithyris sp. indet.

Fusulinids from the Jim Creek are also retained in USGS foraminiferal collections f12958, from the SW cor. sec. 18, T. 10 S., R. 13 E.; f12960, from a roadcut on the east line of the SE¼ sec. 17 T. 10 S., R. 13 E.; and f12961, from a roadcut on U.S. Highway 40 in the SW¼ SE¼ sec. 29, T. 11 S., R. 13 E.

French Creek Shale Member

The French Creek Shale Member (Moore, Elias, and Newell, 1934) generally is poorly exposed. All or part of the member is absent from many places near Dover and along the upper reaches of the Wakarusa River owing to channeling in later Pennsylvanian and Early Permian time.

The French Creek is 19–29 feet thick and consists mainly of siltstone and sandstone, which in places are interbedded. The Lorton coal bed occurs in the upper part of the member. The siltstone is light olive gray, yellowish gray, and light to medium gray, clayey to finely sandy, generally laminated to platy, and micaceous. It is partly pyritic and carbonaceous and contains some ironstone concretions. The siltstone weathers olive gray and yellowish gray mottled with moderate yellowish brown and locally forms hard iron-stained chips.

The sandstone is mainly light gray to medium light gray and olive gray, very fine grained, generally laminated to very thin bedded, and micaceous. Some is calcareous and forms hard concretionary partly crossbedded layers. Weathered colors are mainly shades of yellowish brown. The sandstone in the NE¼NW¼ sec. 33, T. 9 S., R. 13 E., is very fine to fine grained and is mainly quartz, but calcite, muscovite, chlorite, feldspar, tourmaline, zircon, garnet, and an opaque mineral are common (Mudge, 1956, table 1).

The Lorton coal bed, 0.2–0.6 foot thick, is present in the upper several feet of the French Creek at most localities and in a few places is underlain by 0.3–0.6 foot of light-gray underclay. In some areas a second and generally thinner coal bed occurs 1.5–6.5 feet below the Lorton. Medium-light-gray to medium-gray silty micaceous carbonaceous iron-stained claystone is commonly associated with the coal beds. Light-olive-gray to medium-gray silty claystone is interbedded with siltstone in the lower part of the member at places. In a few exposures very thin fragments of light-gray argillaceous limestone occur in the basal part of the French Creek.

The French Creek Shale Member is almost barren of fossils. Finely comminuted carbonized plant fragments occur in some beds. At several localities the shales between the coals and mudstone at the top of the member contain abundant megafossils, chiefly brachiopods and pelecypods but also crinoid stems, productoid spines, and ramose and fenestrate bryozoans.

WOOD SIDING FORMATION (strat. section 7)

The Wood Siding Formation (Condra and Reed, 1943, p. 43), the youngest formation of Pennsylvanian age, is composed, in ascending order, of the Nebraska City Limestone, Plumb Shale, Grayhorse Limestone, Pony Creek Shale, and Brownville Limestone Members. It crops out primarily in the west half of the area but is also present in small areas along the north edge (pl. 3). The upper two limestone members form shallow but distinct hillside benches, but the lower limestone has little topographic expression. The formation is uniformly 20–25.5 feet thick, but local channel deposits in the lower part of the formation are as much as 105 feet thick.

Throughout most of western Shawnee County and vicinity, the Wood Siding rests conformably on the Root Shale, but near Dover and along the west edge of the area south of U.S. Highway 40, channel deposits of the formation rest disconformably on rocks as old as the lower part of the Pillsbury Shale (pl. 3). The Nebraska City Limestone Member is absent from many exposures south of the Kansas River. Here, the base of the formation was mapped at the approximate or inferred limits of the channel deposits. At some places south of the Wakarusa River the top of a very thin coal bed, correlated with the Lorton coal bed of the Root Shale, was mapped as the base of the Wood Siding Formation. At many localities, generally south of the latitude of Dover, all or part of the Wood Siding was eroded during Early Permian channeling.

Nebraska City Limestone Member

The Nebraska City Limestone Member (Smith, 1919, p. 526) is poorly exposed as platy fragments of very fossiliferous limestone a few feet above the smut of the Lorton coal bed. Channels originating in the overlying Plumb Shale Member cut through the Nebraska City east, southwest, and, locally, northwest of Dover, and south of the Wakarusa River.

The Nebraska City is 0.3–2.5 feet thick and averages slightly more than 1 foot in thickness. The limestone is light olive gray and light to medium gray, generally very fine grained, moderately to very argillaceous (especially in the lower half), very thin to thick bedded, and partly coquinoidal. It weathers light gray to light olive gray and, in places, olive brown to moderate yellowish brown. Locally the limestone is interbedded with calcareous claystone or is entirely calcareous fossiliferous claystone.

The Nebraska City is very fossiliferous, and the fossils weather in relief. Brachiopods are the most abundant forms, but crinoid columnals and ramose and fenestrate bryozoans are fairly abundant.

The common brachiopods are *Derbyia*, and *Chonetes* and other productoids. Pelecypods and gastropods are less abundant, and *Osagia* occurs at a few localities.

Plumb Shale Member

The Plumb Shale Member (Mudge and Burton, 1959, p. 34) generally is covered, except where it includes thick channel deposits. The Plumb is generally 7–13.3 feet thick and averages about 10.5 feet in thickness; but, where it fills deep channels, it as much as 105 feet thick (Mudge, 1956, p. 665). Typically, the member is made up of thin beds of sandstone, claystone, and some siltstone and coal. The sandstone is commonly yellowish brown to yellowish orange or light gray to yellowish gray. It is generally very fine grained (but is locally fine grained), laminated to very thin bedded, micaceous, and in part calcareous. Weathered colors are similar to the fresh colors. At many places the weathered beds are moderately soft and friable.

The claystone and siltstone are generally olive gray to medium gray and are commonly interbedded. A distinctive grayish-red claystone is present in the upper part of the member in many exposures north of the Kansas River. The claystone is laminated, slightly to moderately silty, and partly micaceous, and it weathers olive gray and olive brown. Small nodules and thin lenses of light-gray, yellowish-brown, grayish-red, and olive-brown argillaceous porous-weathering limestone are abundant in the claystone in places. The siltstone is micaceous and weathers moderate yellowish brown. Limonite stain and finely comminuted carbonaceous material are common on bedding planes of the sandstone and siltstone. Two very thin coal beds, which probably coalesce laterally, crop out in the lower part of the Plumb Shale Member in the SE cor. NW¼ sec. 6, T. 13 S., R. 14 E. (strat. section 7).

The exact boundaries of the channel deposits of the Plumb Shale Member of the Wood Siding Formation and of the channel deposits of the overlying Onaga Shale are generally difficult to determine. They are most accurately established in relation to the confining limestone members. Because exposures are poor and because the lithology of the rocks comprising the channel deposits is very similar to that of the rocks adjacent to the channels, at most places the upper and lower limits and areal extent of the channel deposits within shale units could only be inferred. Channel deposits of the Plumb Shale Member of the Wood Siding are well exposed along the west side of the area south of U.S. Highway 40 and southwest of Dover (Mudge, 1956, p. 664–666). Channel deposits questionably assigned to the Plumb Shale Member occur northeast of Dover.

The channel deposits in the Plumb Shale Member in secs. 5, 8, and 9, T. 12 S., R. 13 E., are part of a channel that extends 3 miles northwestward from sec. 9, is nowhere more than 1.5 miles wide, and narrows to less than 300 feet wide near its base (Mudge, 1956, p. 664). The Stotler Limestone appears to be truncated by the Plumb locally in the W½ sec. 8, T. 12 S., R. 13 E., and has been completely eroded about 1 mile west of the mapped area in a roadcut in the SW¼NW¼ sec. 6, T. 12 S., R. 13 E. (Mudge and Burton, 1959, p. 36). About 45 feet of the channel fill is exposed along the road on the south line of the SW¼ sec. 5, T. 12 S., R. 13 E. The upper contact of the channel is 5 feet below the top of the Plumb Shale Member and is marked by a 2.5-foot-thick light-yellowish-gray conglomeratic claystone containing many ironstone and limestone nodules underlain by a 1.4-foot-thick pale-yellowish-brown to medium-gray conglomerate containing many ironstone concretions and clayballs as much as 0.17 foot in diameter (Mudge and Burton, 1959, p. 189, strat. section 57). About a quarter of a mile to the south, along the west side of sec. 8, T. 12 S., R. 13 E., two additional and similar beds of limestone conglomerate occur in the Plumb Shale Member 21 feet below the upper bed. The rest of the exposed Plumb channel is composed mainly of olive-gray to olive-brown and pale-yellowish-brown sandy micaceous siltstone but includes many thin beds of micaceous sandstone, some of which are crossbedded.

Excellent exposures of channel deposits in the Plumb Shale Member are present along Massasoit Creek in the SW¼SW¼ sec. 4, along Lomis Creek in the SW¼SE¼ sec. 4, and at "Echo Cliff," a cut bank on Mission Creek in the NW¼SW¼ sec. 3, T. 13 S., R. 13 E. These exposures were discussed by Moore (1936b, p. 49), Mudge (1956, p. 664–666), Mudge and Burton (1959, p. 36–37, 189, 193), and Mudge and Yochelson (1962, p. 14, fig. 5). Along Massasoit Creek the top of the channel deposits apparently is just beneath the Grayhorse Limestone Member of the Wood Siding Formation. The deposits are more than 93 feet thick, and the channel base is not exposed. The upper half of the channel fill is olive-gray silty finely laminated claystone interbedded with pale-yellowish-orange platy siltstone and very fine grained platy sandstone. The claystone weathers to very light olive gray very thin fragments and has abundant carbonaceous material on its bedding planes. Near the middle of the channel are lenses of medium-light-gray sandy finely laminated micaceous limestone. The sandstones below the limestone beds are thicker and are crossbedded and contain abundant pyrite or marcasite. Several conspicuous zones 1–2 feet thick of hard crossbedded ripple-marked very fine grained very calcareous concretionary sandstone occur in the lower part of the channel.

At "Echo Cliff" and along Lomis Creek, the channel deposits are disconformably overlain by limestone conglomerate composed partly of fragments from the Brownville Limestone Member of the Wood Siding Formation (Mudge, 1956, p. 665; Mudge and Burton, 1959, p. 43 and pl. 6A). The conglomerate is overlain by channel-fill deposits of the Towle Shale Member of the Onaga Shale (Lower Permian). Although the channel fill below the conglomerate could be in the lower part of the channel of Towle age and the conglomerate could represent only a period of erosion before continued Towle deposition, the authors agree with Mudge (1956, p. 665) that because a channel in the Plumb Shale Member is nearby, the deposits at "Echo Cliff" and along Lomis Creek probably represent two separate channels—the younger, of Towle age, eroded into the older, of Plumb age—and the conglomerate marks the base of the younger channel.

Along Lomis Creek in the SW¼SE¼ sec. 4, T. 13 S., R. 13 E., channel deposits in the Plumb Shale Member are in contact with beds from the lower 3 feet of the Root Shale down into the upper part of the Pillsbury Shale (strat. section 9). The channel fill is primarily very fine grained platy to thin-bedded partly crossbedded very micaceous well-sorted sandstone that weathers yellowish brown to light olive gray. Some platy beds of olive-gray sandy micaceous siltstone are also present.

The excellent exposure of the channel in the Plumb Shale Member at "Echo Cliff" shows about 48 feet of the channel fill overlain by conglomerate and other deposits of the channel of Towle age (Mudge and Yochelson, 1962, fig. 5). The channel fill is complexly interbedded yellowish-gray very fine grained laminated to massive micaceous sandstone and olive-gray coarsely micaceous siltstone and claystone. The entire deposit exhibits large-scale crossbedding. Some sandstone crossbeds fill small channels cut into more massive beds. Sandstone from a lower massive bed at "Echo Cliff" is composed mainly of subrounded grains of quartz and flakes of muscovite cemented in part by barite (Mudge, 1956, p. 666). The claystone is commonly brecciated, and blocks as much as 2 feet long occur in the sandstone. Flow casts are common adjacent to bedding planes in the claystone. At places the interlaminated claystone and siltstone show contorted bedding. Carbonized wood fragments are abundant on bedding planes, causing the outcrop to have a streaked or banded appearance. Limonite nodules are abundant, and the entire outcrop is stained with iron oxide. The Plumb channel probably cut rocks as old as the lower part of the Pillsbury Shale; the Maple Hill Limestone Member of the Zeandale Limestone crops out in Mission Creek less than half a mile northeast of and about 10 feet topographically lower than the "Echo Cliff" exposure. Mudge and Burton (1959, p. 37) postulated that the channel may have cut as low as the Tarkio Limestone Member of the Zeandale.

About 41 feet of channel deposits tentatively assigned to the Plumb Shale Member crops out in the SW¼SW¼ sec. 31, T. 12 S., R. 14 E. (strat. section 10), and the E½ sec. 36, T. 12 S., R. 13 E. In sec. 31, T. 12 S., R. 14 E., the deposits overlie rocks in the lower part of the French Creek Shale Member of the Root Shale; a short distance to the northwest, in the S½NE¼ sec. 36, T. 12 S., R. 13 E., these beds appear to rest on the Stotler Limestone. The fairly extensive area of channel deposits northeast of Dover is questionably assigned to the Plumb Shale Member of the Wood Siding Formation. A 0.5-foot-thick sandy conglomeratic fossiliferous limestone, closely resembling the limestone conglomerate at the base of a channel in the Towle Shale Member of the Onaga Shale in the SW¼SW¼ sec. 31, T. 12 S., R. 14 E. (strat. section 10), crops out in a roadcut in the NW¼SW¼ sec. 29, T. 12 S., R. 14 E. To the west this limestone appears to grade into ripple-marked sandstone, some of which contains many small myalinid pelecypods. The channel deposits below the limestone are considered to be part of the Wood Siding Formation, and those above the limestone are assigned to the Onaga Shale.

The mudstones of the Plumb Shale Member are typically unfossiliferous. In a few places limestone beds contain abundant brachiopods, crinoid stems, bryozoans, and pelecypods, and a few *Osagia*. Carbonized plant fragments and, in places, pelecypods are abundant in the channel deposits; finely comminuted plant remains also occur in some siltstone and sandstone in other parts of the member.

Grayhorse Limestone Member

The Grayhorse Limestone Member (Bowen, 1918, p. 138–139) is absent from much of the area near Dover and, to the south, along the Wakarusa River because of local unconformities, and it is possibly missing locally from other parts of the area. This member is 0.5–4 feet thick and averages about 1.8 feet in thickness. The limestone is light to medium gray or pale yellowish brown, very finely to finely crystalline, very thin to thin bedded, hard, and in part argillaceous to sandy. In this area the limestone is typically conglomeratic or brecciated and contains abundant pellets and, in places, angular fragments of pale-yellowish-brown silty limestone, greenish-gray and dark-gray claystone, ironstone, abundant fossil debris, and pyrite. The fragments are 0.01–0.1 foot long but are generally less than 0.05 foot long. The weathered limestone is generally light olive gray, yellowish gray, pale to moderate yellowish brown, and light olive brown. It has a granular appearance and commonly forms rectangular blocks with pitted upper surfaces.

The Grayhorse is generally fossiliferous except at a few places. It is characterized by abundant pelecypods, especially *Orthomyalina*, and many *Osagia*, crinoid stems, and gastropods. Less abundant fossils include brachiopods and ramose bryozoans.

Pony Creek Shale Member

The Pony Creek Shale Member (Condra, 1927, p. 81), 5–11 feet thick, is mainly light-olive-gray to olive-gray laminated to platy claystone. Along the west edge of the area south of the Kansas River and locally north of the river, the member is mottled olive gray and grayish red. The claystone is generally slightly silty and in places is finely sandy and partly calcareous. Locally a few very thin beds of ferruginous siltstone that weather moderate yellowish brown are interbedded with the claystone. In a few outcrops the member contans abundant very small nodules of light-yellowish-gray limestone. The claystone weathers to blocky fragments that are mainly light olive gray to light olive brown. In a few places the member contains beds of very light gray very fine grained platy very micaceous sandstone. Locally a few brachiopods occur in the uppermost part of the Pony Creek Shale Member.

Brownville Limestone Member

The Brownville Limestone Member (Condra and Bengston, 1915, p. 17) is the upper member of the Wood Siding Formation, and the uppermost unit of Pennsylvanian age in the area. It forms a hillside bench or, where partly covered, is indicated by round locally pitted cobbles. The Brownville is absent from much of the area northeast and south of Dover and in the upper reaches of the Wakarusa River (pl. 3), because of channels from the overlying Towle Shale Member of the Onaga Shale. The Brownville is about 1–3 feet thick and is generally very fine grained argillaceous thin- to thick-bedded vertically jointed limestone. It is olive gray, yellowish gray, and light gray mottled with pale to moderate yellowish brown where fresh and weathers mottled light olive gray, light yellowish gray, olive brown, and pale yellowish brown. In places the weathered outcrop is stained grayish red by slope wash from overlying beds.

The Brownville Limestone Member is characterized by an abundance of the brachiopods *Chonetes granulifer* Owen and *Marginifera wabashensis* (Norwood and Pratten) in association with other brachiopods and crinoid columnals. Small fusulinids, and less commonly large ones, are abundant in some localities but are sparse or absent in others. Ramose and fenestrate bryozoans and productoid spines are common, and possible *Osagia* occurs in several exposures. Horn corals, echinoid spines, and gastropods were found at a few localities. E. L. Yochelson (written commun., 1960) identified the following fossils from this member:

Fossil locality along road in the SE¼SE¼ sec. 13, T. 10 S., R. 12 E.
- Fusulinids, undet. (USGS colln. f12957)
- Horn coral, indet.
- Crinoid stems
- *Marginifera wabashensis* (Norwood and Pratten)
- Brachiopods, indet.

In addition to some of the forms listed above, Yochelson identified *Composita subtilita* (Hall) and *Wilkingia* sp. indet. from a roadcut on the west line of the NW¼SW¼ sec. 4, T. 10 S., R. 13 E.

PERMIAN SYSTEM

ADMIRE GROUP

ONAGA SHALE (strat. sections 9, 10, 12, 14)

The Onaga Shale (Moore and Mudge, 1956, p. 2273), the lowermost formation of Permian age, is composed, in ascending order, of the Towle Shale, Aspinwall Limestone, and Hawxby Shale Members. The formation is rather poorly exposed in the western half of the area. Along Massasoit Creek southwest of Dover and along the north edge of the area east of Delia, the Onaga is 27–31 feet thick. South of Dover, where it contains channel deposits, the Onaga may be as much as 155 feet thick. It rests conformably on the Brownville Limestone Member of the Wood Siding Formation, and, except where the channels are present, its members are conformable.

Towle Shale Member

The Towle Shale Member (see chart by R. C. Moore and G. E. Condra, in Moore, 1932, p. 95–97) is 6.5–11.5 feet thick south of the Kansas River and about 15–17 feet thick north of the river. Near Dover, where the member contains channel deposits that are entirely of Towle age, it is as much as 62 feet thick. Along the Wakarusa River the channel deposits are estimated to be about 140 feet thick. South of Dover the Towle could not be differentiated from the channel deposits of the Plumb Shale Member of the Wood Siding Formation; together, the units are probably as much as 125 feet thick.

The Towle is mainly light-olive-gray to olive-gray and light-greenish-gray (and some grayish-red) slightly to very silty laminated to platy partly micaceous claystone. Grayish-red claystone occurs mainly in the upper part, and conspicuous grayish-red to dusky-red siltstone commonly occurs in the lower part, especially north of the Kansas River; at places the two rock types are interbedded. The claystone generally weathers light olive gray, yellowish gray, and olive brown.

The siltstone is clayey to finely sandy, generally platy to very thin bedded, and micaceous. Argillaceous limestone nodules, most of which are very light to light gray but some of which are light grayish red, are common in the upper part of the Towle.

Several limestone beds that are generally less than 1 foot thick are present in the member north of the Kansas River. They are light olive gray to light greenish gray, medium light gray, or light brownish gray; they weather light olive gray to light olive brown or yellowish gray and commonly have a banded and granular appearance. The limestone is very fine grained, moderately to very argillaceous, partly nodular, and sparsely to moderately fossiliferous.

Large channel deposits are common in the Towle Shale Member and are well exposed near Dover. Smaller deposits occur near the north edge of the area east of Delia. A broad channel trends northeastward for about 6.5 miles from Lomis Creek and the upper reaches of Ross Creek southwest of Dover (Mudge, 1956, fig. 3, p. 670–671). The northwest side of this channel is now concealed by the alluvial fill of Mission Creek. Near the head of Ross Creek, the channel apparently intersected a northwest-trending channel that was generally alined along the present Wakarusa River; both channels were part of the same drainage system during Early Permian time.

The channel along Mission Creek is well exposed at "Echo Cliff," in the NW¼SW¼ sec. 3, T. 13 S., R. 13 E., and nearby, along Lomis Creek in the SW¼SE¼ sec. 4 (strat. section 9). Moore (1936b, fig. 30) assigned all deposits at "Echo Cliff" to the Towle channel and correlated them with the Indian Cave Sandstone (the lower, major part of the Towle Shale Member) of southeastern Nebraska. Mudge (1956, p. 665) recognized deposits of two channels at "Echo Cliff" and along Lomis Creek; the lower deposits, probably in the Plumb Shale Member of the Wood Siding Formation, are overlain disconformably by limestone conglomerate marking the base of a channel of Towle age.

The conglomerate, 2.4–3.4 feet thick, is composed of medium-light-gray to light-olive-gray very finely crystalline hard sandy limestone that weathers dark yellowish orange and yellowish brown with a red hue. It contains abundant subangular to subrounded granules and pebbles as much as 0.15 foot long and 0.05 foot wide of dense argillaceous limestone, dark-reddish-brown ironstone, and claystone. The limestone pebbles, some of which are fossiliferous, weather pale yellowish brown to dark grayish red. Fragments of carbonized wood, nodules of pyrite, and reworked fossil remains are also abundant. Many of the limestone fragments are from the Brownville and Grayhorse Limestone Members of the Wood Siding Formation (Mudge, 1956, p. 671). Locally along Lomis Creek the conglomerate is split into two beds by a wedge as much as 0.5 foot thick of olive-gray sandy micaceous siltstone and light-yellowish-brown sandstone. The conglomerate commonly forms a prominent ledge and breaks into large slabs that split into irregular layers and chips. Along Lomis Creek this conglomerate overlies parts of several formations, including channel deposits of the Plumb Shale Member of the Wood Siding Formation, beds in the lower few feet of the Friedrich Shale Member of the Root Shale, and, locally, the Grandhaven Limestone Member of the Stotler Limestone.

The conglomerate was traced southeastward from "Echo Cliff" for about 1 mile to Ross Creek. The lower part of the thick sequence of channel deposits east of Ross Creek and east of Dover (pl. 3) probably includes beds of the channel facies of the Plumb Shale Member of the Wood Siding Formation; however, because the conglomerate between the Plumb and the Towle was recognized in only a small area southeast of Dover, the beds in the Plumb could be differentiated only in that area.

Conglomeratic limestone, probably deposited near the edge of the Towle channel, marks the base of the channel in a small area in the N½ sec. 1, T. 13 S., R. 13 E., in the SE¼ sec. 36, T. 12 S., R. 13 E., in the SW¼ sec. 31, T. 12 S., R. 14 E. (strat. section 10), and also in an area to the north in the NW¼SW¼ sec. 29 and the E½ sec. 30, T. 12 S., R. 14 E. The limestone is medium light gray to medium gray, silty to sandy, pyritic, and hard. Most of the granules and pebbles are subrounded and less than 0.05 foot long, but some are as much as 0.1 foot long. These pebbles and granules are composed of dark claystone, yellowish-brown-weathering limestone, and ironstone. Fragments of crinoid stems, brachiopods, gastropods, and plants are abundant. The uppermost part of the bed is very sandy and at several places is ripple marked. The limestone forms a conspicuous ledge throughout much of its outcrop area. At some places this conglomeratic limestone bed overlies channel deposits tentatively assigned to the Plumb Shale Member of the Wood Siding Formation; at others the limestone rests on beds that occur in the normal sequence of the Plumb. The conglomeratic limestone is at the approximate stratigraphic position of the Grayhorse Limestone Member of the Wood Siding.

At "Echo Cliff" and along Lomis Creek, the basal conglomerate is overlain by as much as 23 feet of light-yellowish-gray to light-olive-gray very fine grained laminated micaceous carbonaceous sandstone that is interbedded in part with sandy siltstone. Locally, fragments of the basal conglomerate are incorporated in the lower few feet of the sandstone. The upper part of the channel fill is composed of light-olive-gray silty claystone containing thin beds of light-olive-gray and brownish-gray generally argillaceous unfossiliferous limestone. Because the rocks in the upper part of the channel fill and those in the regular sequence of the Towle are similar, it is difficult to determine the top of the channel.

The channel exposed along Mission Creek is filled mainly with sandstone and siltstone, but in places, particularly where the channel was shallow, it is filled mostly with greenish-gray silty claystone (see strat. section 10). East of Dover, along the road is sec. 36, T. 12 S., 13 E., lenses of hard very calcareous partly crossbedded sandstone, some of which show oscillation-type ripple marks, are common in the channel. Some sandstone closely resembles sandy limestone. Limestone beds in the shallower parts of the channel are commonly fossiliferous; locally the claystones also contain *Lingula* and ostracodes.

The channel along Mission Creek ranges in depth from about 10 feet to possibly as much as 125 feet. Where it is shallow, only beds as low as the upper part of the Plumb Shale Member of the Wood Siding Formation have been removed; but in its deepest part the channel apparently eroded into the lower part of the Pillsbury Shale. South of Dover, where channel deposits of Plumb and Towle ages are undifferentiated, limestone conglomerate 1.8 feet thick that may mark the base of the channel crops out in a cut bank in the SE¼NE¼NW¼ sec. 2, T. 13 S., R. 13 E., about 10 feet stratigraphically above a nearby outcrop of the Maple Hill Limestone Member of the Zeandale Limestone.

The channel along the Wakarusa River (pl. 3) is more than 4 miles long, about 1–2.5 miles wide, and about 140 feet deep. The sides of the channel are difficult to delineate accurately, except where channeling has removed limestone units; consequently, the boundaries are inferred in many places. The channel fill is well exposed in only a few places, but it appears to be dominantly laminated to platy sandstone and sandy siltstone, particularly in its lower part. In the NW¼ sec. 29, T. 13 S., R. 14 E., the lower part of the channel is interbedded micaceous siltstone and dark-yellowish-orange very fine grained subangular to subrounded platy micaceous sandstone cemented by iron oxide. The upper part of the channel, exposed along a creek in the SE¼NW¼ sec. 26, T. 13 S., R. 13 E., is mainly yellowish-gray partly sandy finely micaceous siltstone but includes some medium-dark-gray platy claystone. The siltstone contains beds of light-gray to olive-gray limestone concretions, some of which are 0.6 foot thick and almost 2 feet long and contain fresh-water pelecypods. Several very thin beds of medium-light-gray unfossiliferous limestone also occur in this part of the channel.

The channel along the Wakarusa River originated in the Towle Shale Member, truncated the Wood Siding Formation (as in the center of the SE¼ sec. 14 and SE¼NW¼ sec. 26, T. 13 S., R. 13 E.), and cut down almost to the top of the Tarkio Limestone Member of the Zeandale Limestone.

A large block of Stotler Limestone and strata in the uppermost part of the Pillsbury Shale occurs in the SE¼SE¼ sec. 24, T. 13 S., R. 13 E., and in the SW¼SW¼ sec. 19, T. 13 S., R. 14 E., in a position much lower topographically than nearby outcrops of Stotler Limestone. This block is apparently enclosed on three sides by channel deposits of Towle age; terrace material in the Wakarusa River valley conceals the other side. The block apparently slumped into the Towle channel, possibly owing to undercutting of the channel side (pl. 3, cross section A–A′). A similar but smaller slump block of Stotler Limestone along a creek in the SW¼SW¼NE¼ sec. 19, T. 13 S., R. 14 E., is surrounded by channel deposits of Towle age; this block is too small to show on the geologic map. The beds in the block dip about 30° N. Mudge (1956, p. 669) also observed slump blocks in channel deposits, in Pottawatomie County.

Two or more channels occur in the Towle Shale Member east of Delia, and a small intraformational channel, previously recognized by Mudge (1956, p. 671), is well exposed in a roadcut in the NW¼NW¼ sec. 27, T. 9 S., R. 13 E. The latter channel is filled with very fine grained micaceous sandstone and sandy siltstone and is truncated by a thin limestone conglomerate. Mudge (1956, p. 671) stated that the channel is not more than 300 feet wide and probably not more than 10 feet deep. A larger channel is present in the SE¼ sec. 23, the W½ sec. 25, and much of sec. 26, T. 9 S., R. 13 E.; but because of poor exposures, its boundaries are poorly defined. In a small exposure in a streambank in the center of the NW¼SW¼ sec. 25, T. 9 S., R. 13 E., the channel fill is light-olive-gray thin-bedded partly clayey sandstone and grayish-black to black slightly sandy very carbonaceous siltstone containing some sandstone concretions. The sandstone has some carbonaceous material, and the siltstone has carbonized wood and coaly streaks at the channel base. A bed 0.3 foot thick of soft coal that may be at the top of the channel is exposed in a road ditch in the NE¼SW¼ sec. 26, T. 9 S., R. 13 E. This channel originates in the Towle Shale Member about 9 feet below the Aspinwall Limestone Member of the Onaga Shale and seems to have cut down into the French Creek Shale Member of the Root Shale. The lowest observed position of the channel base, however, is about 5 feet above the top of the Nebraska City Limestone Member of the Wood Siding Formation.

Fossils are sparse to moderately abundant in the limestone beds of the Towle Shale Member, and locally a few occur in the claystone and the siltstone. Pelecypods are abundant; foraminifers, crinoid stems, ramose and fenestrate bryozoans, brachiopods, and ostracodes are less abundant. Carbonized plant fragments are abundant in the channel deposits; crinoid stems, brachiopods, pelecypods, gastropods, ostracodes, and possible *Osagia* are present locally in the upper part of the deposits, especially in limestone beds.

Aspinwall Limestone Member

The Aspinwall Limestone Member (Condra and Bengston, 1915, p. 17) south of the Kansas River generally consists of two limestones separated by claystone; these beds correspond to the two lower limestones and the intervening shale of the Aspinwall of Mudge and Burton (1959, p. 44–45). North of the river the member is composed of one or, in a few places, two beds of limestone having a total thickness of 2–3 feet. The limestone beds vary widely in number and thickness and, to some extent, in lithology; consequently the upper and lower contacts of the Aspinwall are difficult to identify and map consistently. Near the middle of the overlying Hawxby Shale Member are one or more limestone beds that closely resemble beds in the Aspinwall; locally, where the Hawxby is thin and exposures are poor, part of the Hawxby may have inadvertently been included in the Aspinwall.

The upper limestone commonly forms a relatively inconspicuous hillside bench over much of the area; locally the basal limestone also forms a bench. On grassy slopes, the smooth plates and cobbles and the brecciated appearance of the weathered upper limestone aid in locating the member. The Aspinwall ranges in thickness from 1.5–11.5 feet.

The basal limestone of the Aspinwall south of the Kansas River is commonly very light gray to medium light gray and light olive gray, very finely crystalline, very thin to thin bedded, hard, and compact and at most localities contains abundant pelecypods. Locally the bed contains *Osagia* or foraminifers or is unfossiliferous. At many places the weathered limestone contains many dark-brown or yellowish-brown pyritic specks and shows indistinct banding owing to very small areas of dense limestone dispersed in the granular matrix. A few small nodules of light-red celestite are present locally.

The middle part of the Aspinwall is mainly claystone but contains several lenticular limestones generally less than 0.4 foot thick. The claystone is light olive gray to yellowish gray and light greenish gray and in places is silty. Some grayish-red claystone is present locally in the area northwest of Dover. The individual claystone units are generally 2–3 feet thick but locally are as much as 6 feet thick. The limestone in the middle of the Aspinwall is light gray and yellowish gray, in part argillaceous, hard and generally unfossiliferous. Yellowish-brown iron oxide specks are abundant in some beds. Small nodules and very thin lenses of limestone are common in the claystone.

A distinctive limestone occurs at the top of the Aspinwall Limestone Member throughout most of the area south of the Kansas River. This limestone is commonly light to medium gray, very fine grained, argillaceous, hard, and compact. Characteristically it contains many subangular to subrounded fragments of dense limestone that are generally darker than the matrix; these fragments are all less than 0.1 foot in diameter and most are much smaller. The fragments weather very light gray and stand in relief on weathered surfaces. In places the upper limestone contains minute shell fragments and yellowish-brown limonitic specks. Questionable ostracodes were seen in a few angular fragments at one locality.

North of the Kansas River the Aspinwall is generally a single bed of medium-gray very fine to fine-grained argillaceous thin-bedded fossiliferous limestone that weathers to smooth plates and cobbles, which are commonly porous and contain abundant yellowish-brown limonitic specks. This bed seems to be equivalent to the upper limestone of the Aspinwall south of the river, and thin limestone beds designated as being in the upper part of the underlying Towle Shale Member may actually correlate with beds in the lower part of the Aspinwall to the south. Mudge and Yochelson (1962, p. 22) thought that the lowermost bed of the Aspinwall in Wabaunsee County is probably correlative with the single bed of Aspinwall at the type locality in southeastern Nebraska.

Pelecypods and gastropods occur in most of the limestone beds of the Aspinwall; pelecypods are particularly abundant in the lower limestone. Ostracodes are common in the upper limestone, and *Osagia* is locally present in the lower limestone. A few crinoid stems, fenestrate bryozoans, brachiopods, and foraminifers were noted in places.

Hawxby Shale Member

The Hawxby Shale Member (see chart by R. C. Moore and G. E. Condra, in Moore, 1932, p. 95–97) is poorly exposed in its outcrop area north and south of the Kansas River. Mudge and Burton (1959, p. 183) measured a complete section in the SE¼SE¼ sec. 10, T. 13 S., R. 13 E. The Hawxby is 12–26 feet thick, averaging about 17 feet in thickness, and is dominantly light-olive-gray and light-olive-brown partly silty claystone. The claystone is laminated to platy and commonly calcareous and in many places contains small nodules or lenses of argillaceous limestone. The member includes some yellowish-gray and medium-dark-gray to dark-gray platy to very thin bedded siltstone and one or more beds of limestone.

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South of the Kansas River a limestone 1.5–3 feet thick occurs in the middle or upper part of the Hawxby. The limestone is light gray to light olive gray, very fine grained, thin bedded, hard, and compact. It weathers to smooth light gray, pale yellowish brown, or yellowish orange cobbles. The limestone contains many pale-brown iron oxide specks, and at a few places angular limestone fragments show in relief on its weathered surfaces (strat. section 9). The weathered bed is commonly porous and locally forms a minor bench. At most places this bed is unfossiliferous, but locally it contains a few minute shell fragments. This bed closely resembles the lower limestone of the Aspinwall Limestone Member; but where it contains angular limestone fragments, it resembles the upper limestone of the Aspinwall. North of the Kansas River thin beds of light-olive-gray very finely crystalline moderately fossiliferous limestone occur in the lower part of the member. A coal bed about 0.2 foot thick is present in the upper 3 feet of the Hawxby along the stream in the SW¼SW¼ sec. 26, T. 13 S., R. 13 E.

In the southern part of the area, shell fragments, probably of pelecypods, and some possible specimens of *Osagia* occur in the limestone beds. To the north these beds contain abundant myalinid pelecypods and gastropods and some crinoid stems and possible brachiopods. E. L. Yochelson (written commun., 1960) identified *Permophorus*, *Glabrocingulum?*, and high-spired gastropods from the Hawxby in the NW¼NW¼SE¼ sec. 1, T. 10 S., R. 12 E. At places in the northern part of the area, claystone in the Hawxby contains carbonaceous material.

FALLS CITY LIMESTONE (strat. sections 12, 14)

The Falls City Limestone (Condra and Bengston, 1915, p. 17) is poorly exposed in the southwestern part of western Shawnee County and vicinity; in places in the northwestern part the formation forms a minor hillside bench. On the geologic map (pl. 3) the Falls City is combined with the overlying Janesville Shale. Several thin limestone beds of similar lithologic and paleontologic character compose the Falls City Limestone (Mudge and Burton, 1959, p. 47). Some of these beds may not correlate with the type section of the formation in Richardson County, Nebr. (Condra, 1927, p. 82; Mudge and Yochelson, 1962, fig. 9, p. 23). The Falls City ranges in thickness from 6 to 17 feet (Mudge and Burton, 1959, p. 182) in the vicinity of Dover and is 3.2 feet thick in the northwest corner of the area. The top of the formation is very difficult to determine, which thus accounts for the differences in the reported thickness. The Falls City rests conformably on the Onaga Shale.

South of the Kansas River two or more limestone beds 0.2–1 foot thick are separately by relatively thick units of claystone. The limestone is generally light to medium gray and light olive gray, very fine grained, very thin to medium bedded, hard, compact, and partly coquinoidal. Some beds are slightly to moderately argillaceous and contain small fragments of greenish-gray, grayish-yellow, and light-olive-gray claystone. On weathering the limestone is light olive gray, orange, and brown and forms thin resistant vertically jointed beds, the surfaces of which are covered with fossil debris.

Claystone of the Falls City Limestone is light olive gray and partly silty and in places contains many very small nodules or very thin lenses of light-yellowish-gray argillaceous limestone. South of the Kansas River claystone constitutes most of the formation. North of the river the Falls City is much thinner, has more conspicuous topographic expression, and is composed chiefly of limestone that has the same lithology as that to the south, but it weathers pale yellowish brown and light olive brown. The upper part commonly has very thin light-colored dense argillaceous limestone streaks that give the weathered outcrop a banded appearance. The upper surface of the weathered rock is commonly rough, irregular, and deeply pitted.

Pelecypods are characteristically abundant in most of the limestone beds. Gastropods are abundant in many beds, and crinoid columnals, ramose and fenestrate bryozoans, and brachiopods are present locally.

JANESVILLE SHALE (strat. sections 11, 12)

The Janesville Shale (Moore and Mudge, 1956, p. 2273) is composed, in ascending order, of the West Branch Shale, Five Point Limestone, and Hamlin Shale Members. It underlies grass-covered slopes south and west of Dover and in the northwestern part of the mapped area. The Five Point Limestone Member forms a prominent bench near the middle of the Janesville along much of the outcrop. The Janesville is 70–75 feet thick near Dover and about 55 feet thick north of the Kansas River. On plate 3 the outcrop of the Janesville is combined with that of the underlying Falls City Limestone, but the Five Point Limestone Member is mapped separately. The contact between the Janesville Shale and the Falls City Limestone is conformable, and the contacts between the members of the Janesville are also conformable.

West Branch Shale Member

The West Branch Shale Member (Condra, 1927, p. 82) is generally 26–33 feet thick, but locally in the SW¼ sec. 26, T. 13 S., R. 13 E., it is 42–47 feet thick. It is mainly claystone but contains some sandstone and thin beds of limestone, siltstone, and coal. The claystone is light olive gray, laminated to platy, in part silty, and, in the upper few feet, locally calcareous. It weathers light olive gray, yellowish gray, and light olive brown. Very thin layers of ironstone concretions occur locally.

Thin beds of sandstone form hard, resistant layers locally in the upper and middle parts of the West Branch Shale Member; but in the SW¼ sec. 26, T. 13 S., R. 13 E., a sandstone unit 33–38 feet thick apparently fills a channel. The sandstone is generally light olive gray and light gray, but in the channel it is grayish orange. Weathering modifies the color to light olive gray or light olive brown. The sandstone is very fine grained, laminated to platy, and micaceous. Carbonaceous material is abundant on bedding planes.

Siltstone of the West Branch is light olive gray and medium to medium dark gray, weathers to shades of olive gray mottled with brown, and generally is clayey to finely sandy, laminated, and micaceous. A bed 1–3 feet thick of very argillaceous limestone that weathers to yellowish-orange boxwork occurs about 5–10 feet above the base of the member. Another bed of limestone 1–3 feet thick occurs 3.5–9.5 feet below the top of the West Branch in most of the southern outcrop area. This bed is medium gray to olive gray, very fine grained, argillaceous, platy to thick bedded, hard, and compact. These limestones were described by Mudge and Burton (1959, p. 48) and by Mudge and Yochelson (1962, p. 25). Very thin lenses of limestone were also noted locally in the claystone and siltstone units.

One or more coal beds 0.1–0.2 foot thick occur in the West Branch in most exposures. The most continuous one is 0.5–5 feet below the top of the member and in places is associated with dark-olive-gray and black very carbonaceous claystone. A coal bed is present locally near the middle of the member, and one occurs in places in the lower 1 foot.

Fossils are common in many of the limestone beds and in the upper few feet of the claystone. Crinoid columnals and brachiopod shells and spines are abundant; pelecypods, gastropods, bryozoans, and questionable ostracodes are less abundant. A few fusulinids were noted at the top of the member at one locality. Very small carbonized plant fragments occur in many of the sandstones and siltstones.

Five Point Limestone Member

The Five Point Limestone Member (see chart by R. C. Moore and G. E. Condra, in Moore, 1932, p. 95–97) forms a prominent hillside bench southwest of Dover. Large rectangular blocks break from the ledge and slide onto the grassy slope below. In the northwestern part of the area the member is generally covered, but locally it forms a narrow bench. The Five Point ranges in thickness from about 4 to 8 feet. Changes in thickness are commonly rather abrupt. The Five

Point apparently is absent from a small area in the S½ sec. 27, NE¼ sec. 34, and NW¼ sec. 35, T. 13 S., R. 13 E., probably owing to erosion of a channel from the Hamlin Shale Member.

Near Dover the Five Point consists of two limestones separated by claystone or very argillaceous limestone. The lower limestone is 0.3–2.2 feet thick, and where thickest, it crops out as a vertically jointed ledge. The limestone is medium gray and light olive gray, very fine grained, thin to medium bedded, hard, and compact. In places it is slightly to moderately argillaceous and very fossiliferous. The member weathers light olive gray and yellowish orange. The lower limestone has several claystone partings 0.2–0.4 foot thick near the south edge of the area.

The intervening claystone is generally about 0.3–1 foot thick but is as much as 3 feet thick locally. It is light olive gray to yellowish gray, laminated, and calcareous and grades laterally into very argillaceous limestone.

The upper limestone, about 0.5–4 feet thick, is light gray to light olive gray, and yellowish gray, very fine grained, argillaceous, and very thin to thin bedded. It generally weathers light olive gray to light yellowish gray, but in some outcrops it weathers a conspicuous white to very light gray. It commonly breaks into small angular fragments but locally weathers to porous dark-yellowish-orange rubble. The upper limestone is commonly unfossiliferous but in a few places contains many fossils.

North of the Kansas River the Five Point Limestone Member, exposed along the road in the NW¼SW¼SW¼ sec. 5, T. 10 S., R. 13 E., consists of a 1.4-foot-thick yellowish-gray to light-olive-gray silty very fossiliferous lower limestone overlain by a 0.9-foot-thick unit of interbedded light-olive-gray silty fossiliferous limestone and platy calcareous siltstone. The upper limestone, 3.5 feet thick, is olive-gray, hard, dense, and coquinoidal; it locally weathers to large blocks and has an "oatmeal" texture.

The lower limestone of the Five Point is very fossiliferous throughout the area. In many outcrops in the southern part, fossils in the upper limestone are either sparse or absent; at other outcrops they are abundant. North of the Kansas River the upper bed contains abundant brachiopods, crinoid stems, and ramose and fenestrate bryozoans. Fusulinids are commonly abundant in the lower bed but are locally sparse or absent, and they are apparently absent from the upper bed. Trilobites are present in the lower limestone, and horn corals locally occur in claystone partings. A few pelecypods, gastropods, and what may be *Osagia* were noted in the upper limestone. The claystone is commonly unfossiliferous, but, where it grades to argillaceous limestone, it generally contains fossils similar to those in the adjacent limestone. E. L. Yochelson (written commun., 1960) identified the following forms from this member:

USGS fossil locality 19463–PC. In the SE cor. SW¼ sec. 33, 13 S., R. 13 E., immediately south of the mapped area.
Crinoid calyx (cf. *Delocrinus*)
Trilobite pygidium (cf. *Ditomopyge*)

Hamlin Shale Member

The Hamlin Shale Member (Moore, Elias, and Newell, 1934) is about 40 feet thick near Dover and is estimated to be about 30 feet thick north of the Kansas River. The Hamlin is primarily light-olive-gray and light-greenish-gray laminated to platy claystone that is commonly very silty. In the southern outcrop area the lower few feet of the member is very calcareous and commonly contains many very small round very argillaceous unfossiliferous limestone nodules, some of which are pyritic and weather moderate yellowish brown. This part of the Hamlin weathers to conspicuous barren light-colored outcrops.

In the northern outcrop area a zone about 8 feet thick of grayish-red and light-greenish-gray claystone occurs locally about 15 feet below the top of the member. The upper part of the zone contains a slightly resistant bed about 3 feet thick of laminated very micaceous siltstone that weathers moderate brown. Locally this bed is very ferruginous and weathers to hard moderate-yellowish-brown fragments. In the northern part of the area the claystone overlying the resistant siltstone bed contains many limestone nodules that weather yellowish gray to very light gray. The claystone at the top of the member is slightly micaceous, contains a few moderate-yellowish-brown calcareous siltstone pellets, and weathers to pale-yellowish-brown blocky fragments. A bed about 2.4 feet thick of hard platy calcareous sandstone is present at the base of the member locally in the northern part of the area.

Thin limestones occur at random throughout the Hamlin Shale Member and are apparently more abundant north of the Kansas River. Several beds, each about 1 foot thick, of light-olive-gray hard silty fossiliferous limestone occurring in the lower 10 feet of the Hamlin are exposed locally north of the river. A thin continuous algal limestone, the Houchen Creek Limestone Bed, occurs near the middle of the Hamlin in Jackson and Pottawatomie Counties (Mudge and Yochelson, 1962, p. 27); because of limited exposures of the Hamlin, the Houchen Creek was not recognized in western Shawnee County and vicinity. A 0.2- to 0.9-foot-thick sandy micaceous limestone, in places containing a breccia of ironstone fragments at the base, is present near the middle of the Hamlin about 4 miles southwest of Dover. A moderately resistant bed about 3 feet thick of light-olive-gray very argillaceous unfossiliferous limestone occurs about 3 feet below the top in both the northern and southern outcrop areas. The bed weathers to a grayish-yellow or pale-yellowish-orange cellular rubble. A few other thin beds of cellular-weathering limestone, as well as several beds of limestone concretions as much as 0.3 foot thick and 0.6 foot long, occur in the upper part of the member near Dover. The concretions are medium gray to olive gray, hard, and dense and break with subconchoidal fracture.

The narrow channel that apparently eroded the underlying Five Point Limestone Member in the S½ sec. 27, NE¼ sec. 34, and NW¼ sec. 35, T. 13 S., R. 13 E., is filled with sandstone and sandy siltstone, possibly of Hamlin age.

Crinoid columnals, bryozoans, brachiopods, pelecypods, and plant fragments occur locally in limestone beds of the Hamlin Shale Member, and plant fragments are abundant in claystone of its uppermost part in outcrops in the northern part of the area.

COUNCIL GROVE GROUP

FORAKER LIMESTONE (strat. sections 13, 14)

The Foraker Limestone (Heald, 1916, p. 21, 25) is composed, in ascending order, of the Americus Limestone, Hughes Creek Shale, and Long Creek Limestone Members. It crops out in the southwest corner of the western Shawnee County and vicinity study area and in very small areas in the northwest corner (pl. 3). The Foraker is about 45 feet thick southwest of Dover and appears to be 30–35 feet thick in the northwest corner. The Foraker rests conformably on the Janesville Shale, and the contacts between Foraker members are also conformable.

Americus Limestone Member

The Americus Limestone Member (Kirk, 1896, p. 80) is about 2.5 feet thick in the northern outcrop area, and 5.7 feet thick in the southern outcrop area; it consists of two limestones separated by claystone. The usage of the Americus in this report follows that of Mudge and Burton (1959, p. 53–54). Their report and the one by Mudge and Yochelson (1962, p. 30–33) discuss in detail the correlation of the Americus in Kansas.

The upper limestone of the Americus, particularly in the southern outcrop area, forms a prominent and very conspicuous hillside bench marked by large limestone blocks that break from the ledge and slump onto the upper part of the steep slope below. The lower limestone forms a minor ledge in streamcuts but is covered elsewhere. As pointed out by Mudge and Burton (1959, p. 54), the sequence in the Americus of two limestones separated by claystone can be mistaken, on casual examination, for a similar sequence of limestone beds in the middle of the overlying Hughes Creek Shale Member. Characteristics, however, such as the distinctive outcrop pattern and the different color, hardness, and fossil content of the Americus Limestone Member make it easily distinguishable from the limestone beds of the Hughes Creek that form only an inconspicuous hillside bench.

In the southern outcrop area the lower limestone is 1.8–2.3 feet thick and consists of one or two beds of light-gray to medium-dark-gray limestone that weathers light gray to light olive gray partly mottled dark yellowish orange. This lower limestone is thin to medium bedded and fine grained and contains abundant foraminifers(?) and many well-preserved pelecypods. Its basal 0.2 foot contains lobate or lens-shaped algal deposits (stromatolites) that are darker, harder and denser than the limestone matrix. When viewed through a microscope the stromatolites appear granular and finely laminated. The stromatolites were described in detail by Mudge and Yochelson (1962, fig. 13, p. 31). The lower limestone is generally moderately argillaceous, but the upper part of the algal zone is very argillaceous. At places the lower limestone occurs as two equally thick beds separated by a 0.1-foot-thick parting of interbedded olive-brown very calcareous claystone and very argillaceous limestone. The lower of the two limestone beds commonly forms a thin ledge, whereas the upper bed weathers to irregular platy fragments.

In the northern outcrop area the lithology of the lower limestone of the Americus is similar to that in the southern outcrop area, but the bed is only about 0.5 foot thick. The stromatolite zone occurs at the base, but the upper part apparently does not contain pelecypods. A quarter of a mile west of the mapped area, in the SW cor. SE¼NE¼ sec. 2, T. 10 S., R. 12 E., nodules about 0.3 foot long and 0.05 foot thick of pale-yellowish-brown to medium-gray dense fossiliferous chert are present at the base of the lower limestone; the chert may also be present but not recognized in this bed within the western Shawnee County area. Along the road on the west line of the NW¼NW¼ sec. 6, T. 10 S., R. 13 E., a 0.1-foot-thick conglomeratic limestone occurs at the top of the lower bed. This conglomerate is composed of subrounded to rounded granules and pebbles of medium-gray dense limestone, very argillaceous limestone, and calcareous claystone in a matrix of light-gray finely crystalline limestone. The fragments are generally less than 0.02 foot in diameter, but a few are as much as 0.05 foot in diameter. The pebbles of argillaceous limestone and calcareous claystone weather dark yellowish orange. The layer weathers with many small pits and is partly stained by iron oxide.

The claystone of the Americus Limestone Member is 2.2–2.5 feet thick in the southern outcrop area but thins to 0.3 foot in the northern area. In both areas the claystone is poorly exposed, but where observed it is slightly silty, calcareous, and finely laminated and weathers yellowish gray or pale yellowish brown. In the northern area it contains many pellets 0.01 foot thick and as much as 0.03 foot long of very argillaceous limestone that weathers white to very light gray. The claystone seems to be unfossiliferous.

The upper limestone of the Americus is 0.9–1.2 feet thick in the southern part of the area and 1.8 feet thick in the northern part. The limestone is medium light gray to medium gray, very fine grained and finely crystalline, and very hard. It weathers light olive gray to medium light gray and breaks into large tabular blocks along strong vertical joints. Some blocks are as much as 6 feet wide and 20 feet long. Locally in the southern part the limestone is sparsely pyritic, and at places in the northern part it contains small nodules of light-red barite. Fossil fragments, especially crinoid stems, weather in relief on the bed.

The fossils of the Americus Limestone Member aid in its identification. The lower limestone is characterized by masses of the stromatolite *Collenia* (Mudge and Yochelson, 1962, p. 29) in the basal part and by a very fine debris of foraminifers(?) and ostracodes in the upper part. Myalinid pelecypods are abundant in the upper part in the southern outcrop area. Less common fossils in the lower limestone include fusulinids, crinoid columnals, bryozoans, and brachiopods. The upper limestone generally contains many fusulinids and white crinoid columnals and less abundant brachiopods and ramose bryozoans. Fusulinids, however, are sparse or absent north of the Kansas River.

Hughes Creek Shale Member

The Hughes Creek Shale Member (Condra, 1927, p. 85) is 35–40 feet thick southwest of Dover and about 25 feet thick north of the Kansas River. The member consists of claystone and several thin limestone beds. The claystone is generally light olive gray to olive gray, but some is grayish yellow, almost white, or black. It is calcareous to very calcareous and partly silty; it weathers light olive gray and light yellowish gray.

Limestone of the Hughes Creek is commonly light olive gray to olive gray but some is medium light gray and medium dark gray. It is very fine grained and generally argillaceous and weathers light olive gray mottled in places with medium dark gray on the upper surfaces. The beds weather either to small tabular blocks with rounded edges or to thin irregular plates. Two fairly resistant limestone beds separated by a 0.6-foot-thick claystone bed occur near the middle of the Hughes Creek southwest of Dover. The limestone are moderately hard, are vertically jointed, and crop out as ledges in streambanks. The resemblance of these beds to the Americus Limestone Member is discussed on p. 188.

The profusion of fossils, particularly fusulinids, is an aid in identification of the Hughes Creek Shale Member. Even where the member is covered, the soil generally contains many fossils. Fusulinids are very abundant in the upper part and are common, particularly in claystone, in the lower part. In the southern part of the area, most limestones also contain abundant fusulinids, which are sparse in these beds north of the Kansas River. Brachiopods, especially *Chonetes* and productoids, are abundant; and crinoid stems, ramose and fenestrate bryozoans, echinoid spines and plates, and foraminifers are common. *Osagia*, gastropods, and ostracodes are sparse to moderately abundant locally. E. L. Yochelson (written commun., 1960) identified the following fossils from the Hughes Creek in a roadcut in the SW cor. NW¼ sec. 6, T. 10 S., R. 13 E.:

Fusulinids, undet. (USGS colln. f12956)
Chonetes granulifer Owen
Linoproductus sp.
Neospirifer cf. *N. kansasensis* (Swallow)

Long Creek Limestone Member

The Long Creek Limestone Member (Condra, 1927, p. 85) crops out only in interstream divides, and its outcrop is marked by abundant limestone cobbles. The member seems to be about 5 feet thick in the southern outcrop area. In the northern outcrop area about 2 feet of the Long Creek is exposed along the road on the west line of the SW¼ sec. 5, T. 10 S., R. 13 E.

The Long Creek is composed of light-olive-gray very fine grained moderately argillaceous very thin to medium-bedded limestone that weathers mainly grayish orange and moderate yellowish brown. The weathered limestone forms rounded cobbles and platy fragments that are deeply pitted and on which fossil fragments commonly weather in relief. Crystals of white and moderate-reddish-orange calcite and celestite partly fill small geodes and partially replace fossils. Chert nodules as much as 0.2 foot long, but generally less than 0.1 foot long, also occur in the Long Creek. The chert is white, moderate reddish orange, or brownish gray to moderate yellowish brown, and in part fossiliferous. Fragments of chert, calcite, and celestite generally mantle the outcrop and aid in identification of this member.

Pelecypods are locally abundant in part of the Long Creek, but most of the member appears to be virtually unfossiliferous. A few brachiopods and gastropods were noted, and in places the chert is fossiliferous.

JOHNSON SHALE

The Johnson Shale (Condra, 1927, p. 86) is the stratigraphically highest bedrock unit in the area. It is poorly exposed near the southwest and northwest corners of the area (pl. 3). The Johnson apparently consists of light-olive-gray claystone containing a few very thin beds of yellowish-gray cryptocrystalline unfossiliferous limestone concretions. Only about 20 feet of the Johnson is exposed in western Shawnee County and vicinity, but the formation averages 25 feet in thickness in Wabaunsee County (Mudge and Burton, 1959, p. 58). The Johnson Shale rests conformably on the Foraker Limestone.

QUATERNARY SYSTEM

Extensive unconsolidated material deposited by glacial ice, streams, wind, and slope wash overlies the Pennsylvanian and Permian bedrock throughout much of the mapped area. Terrace or alluvial deposits occur along all the major streams and their tributaries. Glacial drift, chiefly till and melt-water sediments, covers much of the uplands in the northern two-thirds of the area. Because the till and melt-water sediments (glacial outwash) are poorly exposed, these deposits were not mapped separately. Eolian loess mantles many stream divides, but because the loess is thin and poorly exposed, it was mapped either with the glacial drift or with the underlying bedrock. Mudge and Burton (1959, p. 108) recognized exposures of Peorian Loess (Wisconsin age) in the SW¼SE¼NE¼ sec. 15, T. 11 S., R. 13 E., near Willard, and southwest of Dover in the SE¼ sec. 10, T. 13 S., R. 13 E. This loess consists of brownish-gray to gray blocky clay and silt; locally it is iron stained and leached of calcium carbonate in its upper part. Loess deposits average about 10 feet in thickness (Mudge and Burton, 1959, p. 108). Colluvial deposits—principally of clay, silt, and very fine sand—occur over much of the area but are generally too thin to map separately; hence they were mapped with the underlying bedrock or glacial drift. In many valleys colluvium has been deposited on the back side of stream terraces at the base of valley slopes and has markedly modified the terrace forms. No contact is evident between the colluvial and terrace deposits; thus, the colluvium was mapped as a part of the terrace material.

Chert gravel.—In late Tertiary or early Pleistocene time chert gravel, derived from the west (primarily from the Wreford and Barneston Limestones of Early Permian age), was deposited in the valleys of the Kansas and Wakarusa Rivers and along some of their larger tributaries; subsequent erosion has left remnants of these deposits isolated topographically high above the present flood plains (Todd, 1918b, p. 190; Mudge, 1955, p. 273; Scott and others, 1959, p. 130). During the Pleistocene Glaciation, Kansan ice overrode many of the deposits and incorporated the chert gravel in the till and glacial outwash. Few gravel deposits remain in the area, and none are shown on the geologic map (pl. 3).

Olive-brown to pale-yellowish-brown subangular dense chert granules and pebbles in a clay matrix occur as a thin veneer locally adjacent to the streams in the SE¼ sec. 32 and E½ sec. 34, T. 13 S., R. 13 E., near the southwest corner of the area. These gravels are probably remnants of high-level Pliocene(?) terrace deposits (O'Connor, 1955, p. 7) that formerly lay within the Marais des Cygnes River drainage basin (south of the mapped area).

A deposit of probable pre-Kansan age is exposed in an old gravel pit in the NE¼NW¼NE¼ sec. 31, T. 10 S., R. 14 E. About 99 percent of the deposit consists of light-gray and pale-yellowish-brown subangular to subrounded chert pebbles, and about 1 percent consists of shale and sandstone pebbles in a matrix of clay and silt (Davis, 1951, table 3). A few pebbles of glacially transported materials are also present, but these pebbles were probably added to the deposit from the overlying till by slope wash and by burrowing animals. Another deposit of probable pre-Kansan age, containing pebbles and very small cobbles of gray chert and light-gray, dusky-yellow, and grayish-red limestone, crops out along the road on the north line of the NE¼NE¼ sec. 36, T. 10 S., R. 13 E. The deposit, about 1.6 feet thick, is moderately well cemented with calcium carbonate.

A third deposit of probable pre-Kansan age occurs in the SW¼ NE¼ sec. 13, T. 10 S., R. 13 E. This deposit appears to be composed dominantly of chert gravel overlain by till. Because of poor exposures however, it was not possible to determine with certainty that erratics are not incorporated. A deposit, possibly also of pre-Kansan age, composed of chert gravel embedded in light-yellowish-brown medium to coarse sand underlies valley fill of Kansan age in an exposure in the SW¼SE¼NE¼ sec. 6, T. 11 S., R. 14 E.

GLACIAL DRIFT

Principal drainage in western Shawnee County and vicinity has been to the east—at least since early Pleistocene time. During Kansan Glaciation the northern two-thirds of the area was occupied by glacial ice that caused major but only temporary changes in the drainage pattern. The Kansas River was dammed at St. George, Pottawatomie County (Smyth, 1898, pl. 1; Mudge, 1955, p. 271–274), and was diverted eastward through a series of channels across northern Wabaunsee County to the present confluence of Dry Creek with Mill

Creek, near Maple Hill, just west of the western Shawnee County area (Mudge, 1955, p. 274, 277–279).

The water was ponded in Dry and Mill Creeks and as the lake deepened the water rose to an altitude of about 1,115 feet and spilled southeastward across the divide between Dry and Mission Creeks (Mudge, 1955, p. 279) at the west side of the mapped area, about 3 miles northwest of Dover (fig. 14). The valley of Mission Creek also was blocked by ice below the present mouth of Haskell Creek, about 2 miles northeast of Dover. Again the water ponded, reached an altitude of about 1,150 feet, and spilled over the divide southeastward into North Branch Wakarusa River west of Auburn (Todd, 1911, p. 213), from whence it reentered the Kansas River valley east of Lawrence by way of the Wakarusa River.

The southernmost extent of the ice sheet in the mapped area was at the approximate position of the diversion channel that extended from the west side of the area about 3 miles northwest of Dover to the mouth of Haskell Creek, northeast of Dover (fig. 14). East of Haskell Creek the southward movement of the ice was restricted by the divide between the Kansas and the Wakarusa Rivers; the ice advanced to a line that extended from Mission Creek eastward to Shunganunga Creek in the east-central part of the area. The drift border in the western part of the area north of Dover is marked by many boulders that probably are the residue of the terminal moraine. The terminal moraine in the east half of the area is partly buried in the valley of Shunganunga Creek (Smyth, 1898, p. 97–98). The presence of glacial ice over the part of the mapped area south of the Kansas River valley probably was of fairly short duration, for the diversion channels are not as deeply incised as some channels in Wabaunsee County that were utilized by the diverted river for a longer period.

As the ice gradually retreated to north of the Kansas River valley the river resumed, in general, its previous course, and its major tributaries reoccupied their old valleys. Not all the river valley within the mapped area was free of ice at the same time, for the river was diverted southward temporarily through a channel that extended from the river valley in sec. 29, T. 11 S., R. 15 E., to Shunganunga Creek in sec. 16, T. 12 S., R. 15 E., on the east side of the area (fig. 14). From there the waters probably flowed southeastward beyond the mapped area into the Wakarusa River. During the retreat, the front of the ice sheet was probably stationary just north of the Kansas River valley for a long period of time; this stability allowed a considerable thickness of glacial outwash to fill the valley.

Diversion channels are evident at several places where melt water from the glacier spilled over stream divides and interfluves as the

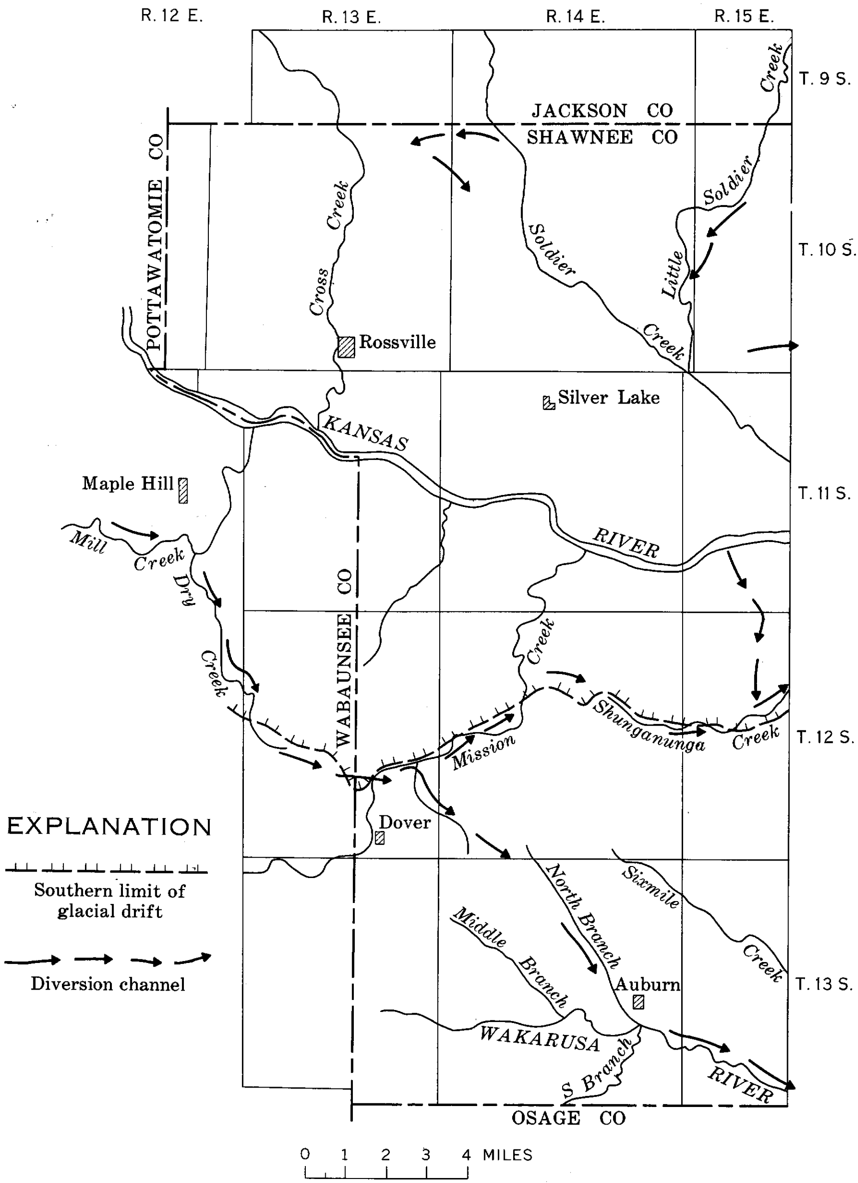

FIGURE 14.—Position of glacial diversion channels during Kansan Glaciation.

glacier retreated northward from the mapped area. Melt water probably flowed across the divide between Cross and Soldier Creeks northeast of Rossville through a short diversion channel in the N½ sec. 1, T. 10 S., R. 13 E., and the N½ sec. 6, T. 10 S., R. 14 E., and through a channel centered near the common corner of secs. 1 and 12, T. 10 S.,

R. 13 E., and secs. 6 and 7, T. 10 S., R. 14 E. (fig. 14). On the east side of the area, melt water may have spilled eastward in a temporary channel in the NW¼ sec. 33, T. 10 S., R. 15 E. Little Soldier Creek formerly flowed across the E½ sec. 18 and the NW¼ sec. 19, T. 10 S., R. 15 E., but was diverted a short distance to the northwest into a tributary valley and did not resume its former course after retreat of the glacier. Other diversion channels undoubtedly existed but have since been destroyed or so modified by erosion as to be unrecognizable.

The glacial drift ranges in thickness from a very thin veneer at places south of the Kansas River to about 85 feet locally along the north side of the Kansas River valley. Test holes in the NW¼ and N½SW¼ sec. 12, T. 11 S., R. 14 E., just north of the valley, penetrated 70–80 feet of drift (Davis and Carlson, 1952, pl. 3), and a driller reported presence of glacial drift about 45 feet thick just to the north in a water well near the SW cor. sec. 1. On the north side of the valley east of Rossville, the drift is 60–84 feet thick in test holes along the west line of sec. 32, T. 10 S., R. 14 E., and in the SW¼NW¼ sec. 5, T. 11 S., R. 14 E. (Beck, 1959, p. 79–81). In general, the drift thins northward away from the river valley, but locally it is more than 20 feet thick. South of the Kansas River the outwash deposits are as much as 30 feet thick locally, but the drift apparently averages less than 5 feet in thickness.

The glacial drift is predominantly unstratified unsorted till but includes, particularly near both the terminal area and the Kansas River valley, deposits of stratified glacial outwash. Because the till and the outwash are poorly exposed, these deposits were not differentiated; over much of the glaciated area it was difficult to identify the glacial drift beneath the mantle of soil and loess. The identification and, consequently, the mapping of drift depended largely on the presence of erratics and on topographic position. The distribution of glacial drift shown on the geologic map (pl. 3) represents the minimum rather than the maximum extent. Many small areas with only a thin veneer of drift were not mapped.

Till

The till ranges from 0 to slightly more than 10 feet in thickness in quarry and roadcut exposures. Clay is the principal constituent of the till, but a large percentage of rock particles of silt, sand, granule, pebble, cobble, and boulder size are also included. Most of the till was derived from rocks that crop out in this part of Kansas, and only a small percentage consists of rock fragments from the northern part of the United States. Most fragments of pebble size or larger are limestone; smaller sized fragments are mainly sandstone and shale. In places, pale-yellowish-brown chert, incorporated in the till from the local gravel deposits of pre-Kansan age, is most abundant. Igneous and metamorphic rocks, ironstone, and quartz are also common. Cobbles and boulders of pale-red and pale-reddish-purple quartzite and quartzite conglomerate are most conspicuous, although these constituents actually compose only a small percentage of the total coarse fraction of the till (Davis, 1951, p. 191). Most boulders are less than 2 feet long, but locally some as much as 5 feet long are fairly common. The till is gray and weathers light brown or pale reddish brown. Where it is deeply weathered, much of the clay, silt, and sand fraction has been removed, and a concentrate of pebbles, cobbles, and boulders now remains. The concentrate contains a higher percentage of glacial erratics than fresh till. The largest concentration of boulders occurs in the area formerly occupied by the terminal moraine of the ice sheet. Boulders are particularly abundant northwest of Dover in sec. 22, the W½ sec. 23, and near the common corner of secs. 8, 9, 16, and 17, T. 12 S., R. 13 E.

Glacial outwash

The glacial outwash consists of stratified clay, silt, sand, gravel, and many random cobbles and boulders, deposited by melt water from the Kansan ice sheet during its advance and retreat. The outwash deposited during the ice advance is classified as the Atchison Formation (Moore and others, 1951, p. 15) by the State Geological Survey of Kansas; the deposits of the retreatal phase are classified as the Grand Island and Sappa Formations. The composition of the outwash is complex and varied, and seldom can the Atchison and Grand Island Formations in this part of Kansas be definitely separated on the basis of lithology. In fact, the Atchison is recognized with reasonable certainty only where it is overlain by Kansan Till. The Sappa Formation overlies the Grand Island and is made up chiefly of silt of glaciofluvial and glaciolacustrine origin. In the mapping of the area, the glacial outwash was not differentiated into the three formations. Deposits of the Grand Island and Sappa Formations were included in the Menoken Terrace deposits by Beck (1959), and in the Meade Formation by Davis and Carlson (1952).

The proglacial outwash—the Atchison Formation—commonly consists of indistinctly crossbedded gravel interstratified with medium to coarse sand. Some gravel lenses are moderately well cemented by calcium carbonate. In some places the pebble-sized rock fragments are chiefly chert and limestone but some are shale and sandstone and a few are glacial erratics (Davis and Carlson, 1952, p. 222). At other localities the Atchison contains a large percentage of glacial erratics and is indistinguishable from the Grand Island Formation.

Pebbles 4–8 millimeters long, examined by Davis (1951, table 3), from the Atchison in a gravel pit in the center of the SW¼ sec. 9, T. 11 S., R. 15 E., were about 55 percent limestone, 36 percent chert, 9 percent shale and sandstone, and less than 1 percent quartzite and granitic erratics. In a small pit in the center of the N½SW¼ sec. 7, T. 11 S., R. 15 E., chert is the dominant rock among the gravel-sized fragments, particularly those fragments more than 8 millimeters long (Davis, 1951, table 3). The Atchison Formation in a large pit in the SW cor. sec. 26, T. 10 S., R. 13 E., is composed of 4 feet of stratified coarse sand containing sorted gravels overlain by 8 feet of sorted gravels and cobbles mainly of limestone. Overlying this unit is about 17 feet of light-gray silt that shows well-formed deltaic bedding with apparent dip to the southeast; about 5 feet of clay till and soil cap the deposit. About 10 feet of well-sorted subrounded gravel of the Atchison is exposed below till in a gravel pit in SE¼SE¼ sec. 9, T. 10 S., R. 14 E., northeast of Grove. The possible varved sediments in the SE¼SE¼ sec. 28 and the SE¼ sec. 29, T. 11 S., R. 13 E., described by Mudge and Burton (1959, p. 102), may belong to the Atchison. They consist of very fine sand, silt, and clay in alternating bands of light and dark gray brown and contain granule-sized erratics.

A deposit, possibly in the Atchison Formation, composed of poorly stratified sand, granules, pebbles, cobbles, and boulders, as well as large masses of till, fills part of a preglacial valley in the E½ sec. 10 and the west-central part of sec. 11, T. 12 S., R. 13 E. This deposit was classified by Mudge and Burton (1959, p. 103) as an ice-contact deposit. The matrix material of the deposit ranges in size from coarse sand to granules and is composed dominantly of subangular to subrounded limestone fragments; but it also includes a large amount quartz and smaller amounts of chert, ironstone, and igneous and metamorphic rock. The material contains abundant pebbles, most of which are less than 0.17 feet long, mainly of limestone but partly of pale-yellowish-brown chert. Cobble-sized fragments are common and some boulders are present. The larger fragments of granitic rock are deeply weathered and crumble when struck. The deposit shows deltaic bedding with apparent dip to the southeast, and much of the deposit is moderately well cemented by calcium carbonate and is deeply stained by limonite. The deposit is more than 30 feet thick and rests on bedrock. Mudge and Burton (1959, pl. 2) also recognized small ice-contact deposits in the center and NE cor. sec. 9 and in the adjacent part of sec. 10, T. 12 S., R. 13 E.

Gravel of the Grand Island Formation, described by Lugn (1935, p. 103–104) as "the inwash-outwash equivalent of the Kansan till and the early Kansan inter-till sands and gravels of eastern Nebraska," composes most of the glacial outwash in the area; this gravel is thickest and most extensive along the north side of the Kansas River valley. The Grand Island is well exposed in a large pit in the center of the SW¼ sec. 9, T. 11 S., R. 15 E., where it is about 18 feet thick and contains 14 feet of coarse gravel overlain by 4 feet of coarse sand. The gravel is interbedded with lenses of yellowish-gray very fine to fine sand containing limestone and quartzite boulders as much as 2 feet in diameter. Some of the gravel is cemented by calcium carbonate. The deposit shows deltaic bedding. The sand is pale reddish brown and medium to coarse and contains scattered pebbles. Davis (1951, table 3) found that of the gravel 4–8 millimeters in length, about 49 percent was limestone, 23 percent was chert, 10 percent was shale and sandstone, and the remaining 18 percent was glacial erratics—mainly quartz and metamorphic and granitic rocks.

The Grand Island, which consists of 9 feet of very coarse sand and very small pebbles overlain by 2 feet of dark-reddish-brown silt, is well exposed in a gravel pit on the south side of the Kansas River in the S½SE¼ sec. 24, T. 11 S., R. 13 E. The pebbles in the lower part are primarily dark-yellowish-gray to dark-yellowish-brown and moderate-reddish-brown limestone, but quartz, chert, and sandstone are also common. The basal 4 feet has indefinite bedding, some moderately well cemented gravel lenses, and very thin streaks of gravel coated with brownish-black manganese oxide; it weathers light yellowish gray. The upper 5 feet of the very coarse sand contains some subangular to subrounded boulders as much as 1.2 feet long and irregular lenses of olive-gray pebbly clayey silt; it weathers dark brown and is also streaked with manganese oxide. The silt at the top of the deposit contains pebbles of limestone and glacial erratics. Some large cobbles of light-red quartzite are also present. The poorly defined bedding of the deposit dips eastward.

About 17 feet of partly to moderately well cemented gravel, probably of the Grand Island, is exposed in an abandoned pit in the SW¼ NE¼ sec. 18, T. 10 S., R. 15 E., on the south side of Little Soldier Creek. The deposit overlies the Wakarusa Limestone Member of the Bern Limestone, and its bedding seems to dip to the southwest. The gravel exposed in the basal 6 feet of an old pit in the NW¼SE¼ sec. 12, T. 11 S., R. 14 E., is also correlated with the Grand Island. At many localities the poorly sorted and stratified glacial outwash of the Grand Island closely resembles gravel and boulder till, or till from which much of the original clay and silt has been removed.

A lag concentrate of pebbles, cobbles, and boulders of limestone and glacial erratics is the remnant of glacial outwash along the diversion channel in the valley of the North Branch Wakarusa River. In a few places along that stream small deposits of sand and gravel are also present. In the stream gully in the SW¼NW¼ sec. 3, T. 13 S., R. 14 E., blocks of limestone, pink quartzite, and greenstone are imbedded in sand. Most of the erratics are scattered along the east side of the valley at levels ranging from 5 feet above the stream near its headwaters to as much as 60 feet above the stream near its mouth. Near the southeast corner of the mapped area, a deposit of glacial outwash containing pebbles and cobbles of limestone and pink quartzite caps a small hill on the north side of the Wakarusa River in the NE¼SE¼ sec. 29, T. 13 S., R. 15 E. This deposit is about 80 feet above the river.

Thick deposits of pale-yellowish-brown to pale-red clayey to finely sandy silt and fine sand, assigned to the Sappa Formation (Condra and others, 1947, p. 12, 22), are present on the north side of the Kansas River valley but are concealed by loess and soil. About 14 feet of sediments, probably in the Sappa, consisting of well-sorted medium to coarse arkosic sand that grades upward into fine dark-stained sand, silt, and clay overlies gravel of the Grand Island Formation in a pit in the NW¼SE¼ sec. 12, T. 11 S., R. 14 E. (Beck, 1959, p. 31). Good exposures of the Sappa are present in the north bank of Soldier Creek about 2.5 miles east of the report area, in the SW¼ sec. 12, T. 11 S., R. 15 E., where the formation is more than 40 feet thick.

TERRACE DEPOSITS OF KANSAN GLACIATION

South of the glaciated area along Mission Creek, deposits of gravel, probably contemporaneous with the glacial outwash, occur as terraces mainly along the north side of the creek (Mudge and Burton, 1959, p. 105). About 9 feet of Kansan terrace gravel is exposed in a pit in the NW¼NW¼ sec. 3, T. 13 S., R. 13 E. The lower half of the deposit consists mainly of subangular to subrounded granules and pebbles dominantly of limestone but also of chert, quartz, and ironstone. The upper half is mainly very fine to very coarse sand composed of fragments of limestone, sandstone, chert, quartz, ironstone, and fossils. Some moderately well cemented lenses of sand and gravel occur in the sand. Bedding in the sand dips to the east-southeast. The toe of the terrace of Kansan age is about 10 feet above a lower terrace in Mission Creek valley and about 40 feet above the present stream channel. The back side of the terrace deposit is concealed by loess and colluvium of younger age that mantle the north slope of this part of Mission Creek valley; because the contact between the two deposits is difficult to determine, they were not mapped separately. Mudge and Burton (1959, p. 104, pl. 2) included the Kansan terrace deposits in the Grand Island Formation and the colluvium in the Sanborn Formation (now considered the Sanborn Group).

BUCK CREEK TERRACE DEPOSITS

Terrace deposits correlated with the Buck Creek terrace of Illinoian age, as defined by Davis and Carlson (1952, p. 213) farther downstream in the Kansas River valley, occur on the south side of the Kansas River west of Willard, on the north side west of Rossville, and along its major tributaries. Terrace remnants questionably correlated with the Buck Creek terrace deposit are also present along the Wakarusa River. A test hole in a narrow unmapped Buck Creek deposit along the north side of the Kansas River valley in the NE¼ NE¼ sec. 19, T. 11 S., R. 13 E., penetrated 49 feet of sediments consisting, in ascending order, of 15 feet of yellow silty friable clay; 14 feet of clayey sand and gravel composed of quartz, limestone, quartzite, and some igneous rock; 2 feet of clay containing quartz, quartzite, and limestone pebbles; 12 feet of light-brown silty calcareous clay; 2 feet of slightly sandy calcareous silt containing a few subangular pebbles; and 4 feet of black silt and clay (Beck, 1959, p. 78). The upper 15 feet of clay in the test hole is probably colluvium of more recent age. Generally only the upper few feet of the Buck Creek deposits is exposed; it is reddish-brown and pale-yellowish-brown to light-brown clayey coarse silt containing scattered granules and pebbles.

In the Kansas River valley the Buck Creek deposits are about 30–80 feet above the river. The extensive remnant of the Buck Creek terrace along the west side of Cross Creek north of Rossville ranges in height from about 20 feet to as much as 90 feet above the creek locally in the NW¼NW¼ sec. 10, T. 10 S., R. 13 E. The higher part of the deposit overlies bedrock. Remnants of the Buck Creek terrace along Mission Creek range in height from as much as 45 feet above the creek near its mouth to as little as 15 feet above the creek at the west edge of the area, near Dover. The few exposures of the Buck Creek(?) terrace deposits along the Wakarusa River show light-reddish-brown silt, locally containing gravel of yellowish-brown chert and light-pink quartzite. Because they are partly covered by colluvium and loess, the Buck Creek terrace deposits in the area can be delineated only generally.

NEWMAN TERRACE DEPOSITS

Alluvial deposits of Wisconsin age occupy much of the bottom land of the Kansas River valley and almost entirely cover the bottom of the valleys of the Wakarusa River and major creeks (pl. 3). In the Kansas River valley the deposits underlie a nearly flat poorly drained terrace surface—the Newman—which is 20–45 feet above the river. The Newman is best preserved on the north side of the river, where it ranges in width from about 700 feet to almost 2 miles and averages slightly more than 1 mile in width. Together, the Newman and the alluvium form the flood plain of the Kansas River; however, only severe floods inundate the terrace, and the high points remain above flood level.

Test holes drilled in the Newman east and west of Silver Lake and near the west edge of the mapped area showed that the deposit is 50–75 feet thick (Beck, 1959, p. 78, 81, 82; Davis and Carlson, 1952, pl. 3). According to Beck, the lower ⅔–¾ of the deposit is sand that, near its base, contains a considerable amount of gravel. The sand is coarse in its lower part and grades upward into medium to very fine sand. A few lenses of clay also occur in the gravelly sand. The upper part of the Newman terrace deposit is mainly sandy clay capped by a layer of clayey silt. Colluvial material derived by slope wash from the valley sides mantles the Newman deposits at most places adjacent to the valley slopes.

Newman terrace deposits form most of the flood plain of the Wakarusa River and most of those of major creeks in the area; in ordinary floods these deposits are covered. The Wakarusa River and the creeks have cut channels 10–15 feet below the level of the flood plains on the Newman deposits. The thickness and composition of the Newman deposits outside the Kansas River valley are not known, but a test hole drilled near Soldier Creek in the NE¼NE¼NW¼ sec. 8, T. 11 S., R. 15 E., near the mouth of the valley reportedly penetrated 35 feet of mud (probably clay and silt) underlain by 12 feet of gravel.

ALLUVIUM

The alluvium along the Kansas River ranges in width from about 1 mile near the east edge of the area to 3.5 miles near the west edge. Together with the Newman terrace it forms the flood plain of the river. A scarp commonly marks the contact between the alluvium and the Newman terrace. Along creeks this scarp is generally less than 5 feet high, and in many places it is obscure. Locally between Rossville and Silver Lake, alluvium occupies most of the valley bottom. The alluvial surface is irregular and is marked by meander scars that in places contain small lakes; of these, Silver Lake is the largest. The upper 6–10 feet of alluvium is silt and silty clay that grades downward into very fine to coarse sand containing gravel, some boulders, and some clay lenses in its lower part (Beck, 1959, p. 82, 83).

Along some of the larger tributaries of the Kansas River, alluvium borders the streams in the upper reaches of the valleys, but downstream, where the channels are more deeply incised, it is too narrow to be shown on the geologic map. Along the narrow channel of the Wakarusa River, the alluvium was included with the Newman deposits. Near the mouths of the creeks, the channel bottoms are broader, and, therefore, the alluvium is wider.

STRUCTURE

Western Shawnee County and vicinity is in the western part of the Forest City basin—a structural basin in the northeastern part of Kansas and in neighboring parts of Missouri, Nebraska, and Iowa—that formed mainly after Mississippian time (Lee, 1943, p. 13). The west edge of the basin is delineated by the Nemaha uplift, which lies 12–20 miles west of the mapped area. The axis of the Forest City basin is adjacent to the uplift; the mapped area lies east of the axis. Here, the outcropping rocks strike mainly N. 15°–30° E. and dip to the northwest about 15–30 feet per mile. In several places there are small folds trending northeastward and having less than 20 feet of closure. The structural relief in the area is about 380 feet. The structural pattern is shown on plate 3 by contours drawn at 20-foot intervals on the base of the Zeandale Limestone.

Two major sets of vertical joints are apparent in many of the limestone units. The primary system trends generally N. 60°–70° E., and the secondary system about N. 20°–30° W. In some places another, less pronounced system of joints of varied trend occurs with the two major sets.

ECONOMIC GEOLOGY

OIL AND GAS

To date (1963), 16 wells have been drilled for oil and gas in the western Shawnee County area (pl. 3), but no oil or gas in commercial quantities has been found. Shows of oil were reported in drillers' logs from sandstone, probably in the Cherokee Group (Middle Pennsylvanian), in the St. Marys Coal, Oil and Gas Co. St. Marys College 1 well in the SE cor. NW¼NW¼ sec. 12, T. 10 S., R. 12 E., and from dolomite in the Simpson Group (Middle Ordovician) in the McKnab Fritz 1 well in the center of the SW¼SE¼NW¼ sec. 4, T. 12 S., R. 14 E. Oil stains were noted in samples of dolomite from the Devonian part of the Hunton Formation in the Kaiser–Francis and Shawver–Armour Adams "A" 1 well in the center of the SE¼NW¼ sec. 20, T. 11 S., R. 13 E., and in samples of the Viola Limestone (Middle and Upper Ordovician) from the Skelly Oil Co. Wallace 1 well in the NW¼SE¼SW¼ sec. 13, T. 10 S., R. 13 E., and from the Musgrove Petroleum Co. Heiland 1 well in the NW¼NW¼NW¼ sec. 6, T. 10 S., R. 13 E. Oil stains are present in sandstone of the Simpson Group (Middle Ordovician) in the Musgrove Heiland 1 well and in dolomite of the Simpson in the Kaiser-Francis and Shawver–Armour Adams "A" 1 well.

Shows of gas have been reported in drillers' logs of sandstone in the Scranton Shale in the St. Marys Coal, Oil and Gas Co. St. Marys College 1 well, and in the Holl et al Warner 1 well in the SE cor. NW¼ sec. 36, T. 11 S., R. 13 E., and of sandstone in the Douglas and Pleasanton Groups (Upper Pennsylvanian) and the Cherokee Group (Middle Pennsylvanian) in the Jenkins and Scott Hayden 1 well in the NW¼NE¼SE¼ sec. 8, T. 12 S., R. 14 E. Gas was also reported from rocks in the Kansas City Group (Upper Pennsylvanian) in the Jones–Davidson Omar Allen 1 well in the SE cor. NE¼NW¼ sec. 2, T. 11 S., R. 14 E., and in the T. M. Barnsdall Staley 1 well in the SW¼NW¼SW¼ sec. 23, T. 11 S., R. 13 E.

Rocks in the Kansas City Group, Hunton Formation, Viola Limestone, and Simpson Group yield oil on small anticlinal structures in the north-central, south-central, and southwestern parts of Wabaunsee County (Smith and Anders, 1951; Hilpman, 1958; Goebel and others, 1962). Carbonate rocks in the Hunton Formation and Viola Limestone yield most of the oil, primarily from local porous zones. Several small folds or noses with slight closure at the surface in western Shawnee County and vicinity were drilled (pl. 3) but did not yield oil or gas. The occurrence of good vuggy porosity in parts of both the Hunton and the Viola in several wells and the presence of oil stains indicate, however, that continued exploration might be successful.

COAL

Four coal beds have been mined in western Shawnee County and vicinity for domestic and commercial use. Schoewe (1946) described the coal resources of the Wabaunsee Group in detail, and most of the data presented herein are from his publication. Whitla (1940) described the coal resources of all post-Cherokee rocks in Kansas.

The Nodaway coal bed (at the base of the Howard Limestone), which was formerly mined fairly extensively around Topeka, crops out just above the flood plain on the south side of the Kansas River at the east edge of the area. The Nodaway has not been exploited in its outcrop area, but Schoewe (1946, table 35) reported that it was mined in a shaft in the SE¼ sec. 32, T. 11 S., R. 15 E. The Elmo coal bed in the uppermost part of the Cedar Vale Shale Member of the Scranton Shale was formerly mined by shaft, drift, and strip operations south of U.S. Highway 40 near Wanaker School. The coal is 1–1.4 feet thick in the SW¼ sec. 29 and the NW¼SE¼ sec. 31, T. 11 S., R. 15 E., and in sec. 36, T. 11 S., R. 14 E. (Schoewe, 1946, table 35); the reported mine in sec. 29 may have properly been in the SE¼, rather than the SW¼. A 1- to 1.6-foot-thick seam of Elmo coal was formerly drift mined along Blacksmith Creek in the N½ sec. 10, T. 12 S., R. 14 E. (Schoewe, 1946, table 35). This bed was also mined in drift and shaft openings in the NW¼NE¼ sec. 1, T. 11 S., R. 14 E., until 1927, when excessive water caused the mine to be abandoned (Schoewe, 1946, p. 132). A landowner reported that a small amount of coal was taken from the Elmo along a stream in the W½NE¼ sec. 35, T. 11 S., R. 14 E.

Schoewe (1946, p. 132) reported that a coal bed 1.2–1.6 feet thick in the basal part of the Wamego Shale Member of the Zeandale Limestone was strip mined near the south line of the NE¼ sec. 27, T. 12 S., R. 14 E., until 1920. The bed may have been subsequently obscured by slope wash and cultivation, for the authors found no evidence of it. The Lorton coal bed, in the uppermost part of the French Creek Shale Member of the Root Shale, was mined as recently as 1939, for domestic use, in a small cut along a tributary of Gladden Ravine in the SW¼ sec. 28, T. 12 S., R. 13 E., west of Dover. There, the coal is about 0.5 foot thick but is shaly in its basal part.

The Elmo coal, the most important bed in the mapped area, is bituminous in rank and contains proved reserves of 3,950,000 tons and potential reserves of 256 million tons (Schoewe, 1946, p. 134). The unnamed coal bed in the Wamego Shale contains proved reserves of 1,280,000 tons and potential reserves of 64 million tons (Schoewe, 1946, p. 134). Most reserves in the Nodaway coal bed occur at localities east of the report area; the potential reserves of the Nodaway in the mapped area are very small. Reserves in the Lorton coal bed have not been calculated.

LIMESTONE

Limestone quarried in western Shawnee County and vicinity is used primarily as road metal and concrete aggregate. The Burlingame and Wakarusa Limestone Members of the Bern Limestone and the Tarkio Limestone Member of the Zeandale Limestone are the principal units quarried. A limestone in the upper part of the Auburn Shale was formerly quarried in a pit, now bisected by U.S. Highway 40, in sec. 35, T. 11 S., R. 14 E. In 1962, quarrying of the Bern Limestone was concentrated along Blacksmith Creek; but formerly, the Bern was quarried farther east, in the SW¼ sec. 31, T. 11 S., R. 15 E., and north of the Kansas River, in the SE¼NE¼ sec. 29, T. 10 S., R. 15 E. The principal rock quarried is the Burlingame Limestone Member of the Bern, but the Wakarusa is also used where it is not intensely weathered. A thick limestone lens in the Soldier Creek Shale Member of the Bern Limestone was quarried along both sides of the Kansas Turnpike south of Auburn in the NW¼SW¼ sec. 25, T. 13 S., R. 14 E., for use in construction of the highway.

The Tarkio Limestone Member of the Zeandale is quarried north of U.S. Highway 40 near West Union School southeast of Willard, 1.75

miles north-northwest of Dover, and 3.2 miles west-northwest of Auburn.

Where quarried, the Burlingame and Wakarusa Limestone Members of the Bern are 5.7–7 feet and 3.2–4 feet thick, respectively. The limestone lens in the Soldier Creek Shale Member of the Bern is 10.5 feet thick, and the Tarkio Limestone Member of the Zeandale Limestone ranges from 5 to 10.5 feet in thickness. The limestone in the upper part of the Auburn Shale is about 4 feet thick. Chemical analyses of limestone from three of these beds are given in table 1. Test data on the structural quality of the Tarkio and Maple Hill Limestone Members of the Zeandale Limestone, the Dover Limestone Member of the Stotler Limestone, and the Grayhorse Limestone Member of the Wood Siding Formation from that part of Wabaunsee County which is within western Shawnee County and vicinity study area are included in the report by Mudge and Burton (1959, table 1).

No dimension stone is produced commercially in the area, but the Reading Limestone Member of the Emporia Limestone and the Tarkio Limestone Member of the Zeandale have been quarried along their outcrops for local use in construction of houses, barns, and small bridges. Limestone of the Tarkio is difficult to saw because of its hardness but can be hand dressed satisfactorily (Risser, 1960, p. 110).

SAND AND GRAVEL

Sand and gravel is produced commercially in Shawnee County from the alluvium along the Kansas River. Most of the pits are east of the mapped area, but in 1962 one was being operated in the northern part of sec. 29, T. 11 S., R. 15 E. Most of the sand is used as building, paving, and fill material, but small amounts are used as engine blast sand. Most of the gravel is utilized by the building industry, but some is used for paving or for fill.

Deposits of glacial sand and gravel of Kansan age are quarried at many places for use as road metal. Much material has been removed from the thick deposit just east of Rossville in the SW cor. sec. 36, T. 10 S., R. 13 E., and from the glacial outwash deposit in the NE¼SE¼ sec. 10, T. 12 S., R. 13 E., along the Wabaunsee County–Shawnee County line. The glacial-outwash deposit contains hard lenses cemented by calcium carbonate. These lenses and the large cobbles and small boulders must be removed by screening. Gravel for use on the roads near Grove has been obtained from a pit in the SE¼SE¼ sec. 9, T. 10 S., R. 14 E. Glacial sand and gravel have also been dug in the center of the S½SE¼ sec. 24, T. 11 S., R. 13 E. Gravel from several small pits in Kansan terrace deposits on the north side of Mission Creek southwest of Dover has been used locally,

TABLE 1.—*Chemical analyses of selected limestones in western Shawnee County, Kans., and vicinity*

[In percent by weight. Adapted from Runnels and Schleicher, 1956]

Formation	Unit	Sample Locality			Thickness (ft)	Lab. No.	$CaCO_3$ [a]	$MgCO_3$ [a]	$CaCO_3$ [a]	CaO	MgO	L.O.I. [b]	SiO_2	Al_2O_3 [c]	Fe_2O_3 [d]	K_2O	Na_2O	SO_3	S [e]	P_2O_5	Total [f]
		Section	Range	Township																	
Zeandale Limestone	Tarkio Limestone Member.	SW¼SW¼ 29	11 S	14 E.	3.0	49444	86.94	1.90	89.34	48.71	0.91	39.31	3.36	1.16	6.72	----	----	0	----	0	100.17
Auburn Shale	Limestone bed	SE¼NE¼ 35	11 S.	14 E.	4.1	53209	88.31	4.56	92.75	49.75	2.18	40.81	3.85	.86	1.86	----	----	0.12	0.01	0.15	99.58
Bern Limestone	Burlingame Limestone Member.	SW¼ 31	11 S.	15 E.	4.0	49453	86.10	7.01	95.55	48.41	3.25	42.04	2.19	.51	3.23	----	----	.05	----	.10	99.88

[a] Calculated.
[b] Net loss of weight on ignition from 105° to 1000° C.
[c] Includes MnO, ZrO_2, V_2O_5, and TiO_2 when present.
[d] Total iron expressed as Fe_2O_3.
[e] Omitted in computing total, because included in loss on ignition (L.O.I.).
[f] Does not include amounts shown for $CaCO_3$, $MgCO_3$, and $CaCO_3$ equivalent.

probably as road metal. These pits are in the NW¼NW¼ sec. 3 and NE¼NW¼ and NW¼NE¼ sec. 5, T. 13 S., R. 13 E.

STRATIGRAPHIC SECTIONS

Each geologic formation or member that crops out in western Shawnee County and vicinity, except the Johnson Shale, is represented, at least in part, starting with the oldest, in one or more of the measured sections that follow. Many additional sections were measured for this study. Only partial sections of the Severy, Scranton, and Pillsbury Shales are included. H. D. Wagner measured sections in the Dover quadrangle. Some of these sections were later slightly modified by W. D. Johnson, Jr. The rest of the sections were measured by Johnson, usually assisted by W. L. Adkison. Lists of fossils in the U.S. Geological Survey Permian and Carboniferous fossil collection (for example, 19465–PC), noted in the measured sections, are shown in the text under the proper stratigraphic unit. Fusulinids retained in the U.S. Geological Survey foraminiferal collection are noted also (for example, f12962); however, these fossils had not been identified at the time of preparation of this report. Fossil identifications that are not credited are those made by the authors in the field.

1. *Howard Limestone and the uppermost part of the Severy Shale*

[In streambank and bed of Sixmile Creek in the NE¼SW¼ and SE¼NW¼ sec. 16, T. 13 S., R. 15 E., Shawnee County]

Howard Limestone:

Utopia Limestone Member: *Feet*

Limestone, light-olive-gray, very finely crystalline, silty, thin-bedded; weathers dark yellowish orange to light grayish yellow and forms prominent ledge in stream bottom; upper 0.9 ft weathers to conspicuous oval concretionary masses, some as much as 2–3 ft long and 0.3 ft thick; abundant fusulinids; many fenestrate and ramose bryozoans, and *Composita*, *Reticulatia*, and other brachiopods, particularly in lower 0.7 ft; varied thickness along stream ___ 1.0–2.8

Limestone, light-gray (with brown hue), silty, very thin to thin-bedded; weathers to light-gray rubbly wavy beds and forms ledge; abundant fossil fragments, including small high-spired gastropods and ostracodes; thickness varies along stream ___ 0.6–1.3

Thickness of Utopia Limestone Member ___ 2.3–3.4

1. *Howard Limestone and the uppermost part of the Severy Shale*—Continued

Howard Limestone—Continued

	Feet
Winzeler Shale Member:	
Siltstone, dark-gray, finely laminated; weathers to medium-dark-gray very fissile pieces; abundant ostracodes; varied thickness along stream	0.6–1.4
Total combined thickness of Utopia Limestone and Winzeler Shale Members	3.7–4.0
Church Limestone Member:	
Limestone, medium-light-gray to medium-gray, very fine grained, slightly silty, thin- to thick-bedded, very hard; weathers light olive gray, in places mottled by pale yellowish orange; forms minor ledge that in part shows thin wavy bedding; locally contains hard algal(?) nodules as much as 0.15 ft long; abundant *Cryptozoon*-like algae, crinoid stems, horn corals, brachiopods, including specimens of *Reticulatia*, and productoid spines; fusulinids abundant in places, sparse or absent elsewhere; abrupt changes in thickness largely compensated for by changes in underlying Aarde Shale Member	0.3–1.3
Aarde Shale Member:	
Siltstone, light-olive-gray, laminated, carbonaceous; interbedded with medium-dark-gray to grayish-black carbonaceous siltstone that weathers to fissile plates; lenses, generally 0.1 ft thick and 0.2 ft long (some as much as 0.5 ft long), of light-brownish-gray very calcareous fossiliferous siltstone; siltstone grades laterally into medium-light-gray to light-olive-gray very silty laminated to platy fossilliferous limestone containing medium-dark-gray siltstone laminae. A siltstone 0.2 ft thick separates this limestone from overlying limestone unit, and in places this siltstone grades into olive-gray argillaceous platy calcareous sparsely carbonaceous sandstone. Weathered outcrop is streaked light olive gray and grayish black. Abundant crinoid stems and brachiopod fragments	0.3–1.0
Claystone and coal (Nodaway coal); grayish-black to black finely laminated very carbonaceous claystone containing partings as much as 0.03 ft thick of black hard brittle vitreous coal in upper half; claystone weathers grayish black, has much brownish-black iron stain and contains abundant secondary gypsum; lenses as much as 0.1 to 0.2 ft thick and 1 ft long of medium-gray to brownish-gray very argillaceous limestone in middle part; limestone lenses weather brownish gray, are iron stained, and contain very abundant crinoid stems, bryozoans, and brachiopods	.4
Thickness of Aarde Shale Member	0.7–1.4
Thickness of Howard Limestone	5.4–6.0

1. *Howard Limestone and the uppermost part of the Severy Shale*—Continued

	Feet
Severy Shale:	
Claystone, medium-dark-gray to grayish-black, silty, laminated; weathers medium dark gray to brownish gray; much dark-brown iron stain. Lenses as much as 0.25 ft thick and 1 ft long of medium-dark-gray very silty laminated very fossiliferous limestone form discontinuous bed at top of unit. Upper contact gradational; abundant crinoid stems, bryozoans, and brachiopod fragments	0.9
Claystone, light-olive-gray, very silty, laminated to platy; weathers light olive gray to light yellowish gray; much light-yellowish-brown iron stain; some plant fragments; basal contact below creek level	4.7
Thickness of exposed Severy Shale	5.6

2. *Howard Limestone*

[Along tributary of the Wakarusa River in the NW¼SW¼ sec. 33 and on the east line of the SE¼ sec. 32, T. 13 S., R. 15 E., Shawnee County]

	Feet
Howard Limestone:	
Utopia Limestone Member:	
Limestone, medium-light-gray to medium-gray, finely crystalline, very thin bedded; weathers light gray; upper 1.7 ft contains abundant fusulinids; next lower 0.1 ft is coquinoidal limestone of *Osagia*, ramose and fenestrate bryozoans, *Composita*, *Meekella*, and other brachiopods, pelecypods, and gastropods; limestone in lower 0.3 ft composed mainly of *Osagia;* basal 0.1 ft gradational into underlying unit	2.5
Siltstone, dark-gray, finely laminated; weathers to light-gray hard fissile fragments; abundant ostracodes	2.0
Limestone; medium gray with brown hue, generally finely to medium crystalline; parts coarsely crystalline; very thin bedded, partly coquinoidal; very thin beds of light-olive-gray to olive-gray slightly sandy finely laminated claystone, particularly in lower 2.5 ft; limestone weathers to irregular yellowish-gray to light-olive-gray beds; large dark-yellowish-orange patches on upper surfaces; large fragments of cone-in-cone calcite; very abundant fenestrate and ramose bryozoans; abundant *Osagia*, crinoid stems, echinoid spines, *Neospirifer*, *Juresania*, and other brachiopods, *Myalina*, *Orthomyalina*, and other pelecypods, gastropods; conspicuous amphibian tracks locally	7.3
Thickness of Utopia Limestone Member	11.8

2. *Howard Limestone*—Continued

	Feet
Howard Limestone—Continued	
Winzeler Shale Member:	
Claystone, light-olive-gray to light-olive-brown, silty	0.6
Siltstone, sandy; weathers moderate yellowish brown	.4
Sandstone, very fine grained, calcareous; weathers moderate yellowish brown; nodules less than 0.3 ft thick of medium-gray medium-crystalline limestone	.9
Limestone, medium gray with brown hue, finely crystalline, hard, hackly; lenticular nodular beds; weathers yellowish gray to light gray; upper contact irregular, basal contact gradational; sparse crinoids, *Juresania*, *Composita*, and other brachiopods; forms ledge	1.8–2.2
Limestone, yellowish-gray to light-olive-gray, finely crystalline, silty, very thin bedded; weathers yellowish gray; irregular beds of hard nodules generally less than 0.4 ft thick and as much as 1.5 ft long of finely to medium-crystalline limestone that is medium gray with brown hue; nodules are more resistant than matrix; a few crinoids, *Composita*, and other brachiopods; forms reentrant in outcrop	2.1
Thickness of Winzeler Shale Member	5.8–6.2
Church Limestone Member:	
Limestone, light-olive-gray to light-brownish-gray, medium-crystalline, partly silty, hard; generally weathers to single moderate-yellowish-brown ledge; abundant *Juresania*, *Composita*, *Hustedia*, and other spiriferoid brachiopods; also *Chonetes* and *Marginifera;* many *Osagia* and crinoid stems; a few gastropods and horn corals	2.2
Aarde Shale Member:	
Siltstone, light-olive-gray, sandy, finely laminated; shell fragments and crinoid stems	2.5
Coal (Nodaway); base concealed	.7+
Thickness of exposed Aarde Shale Member	3.2
Thickness of exposed Howard Limestone	23.0–23.4

3. *Soldier Creek Shale Member of the Bern Limestone down into the upper part of the White Cloud Shale Member of the Scranton Shale*

[In streambank and along farm road in the NW¼NE¼ sec. 1, T. 14 S., R. 14 E., Osage County (south of mapped area)]

	Feet
Bern Limestone:	
Soldier Creek Shale Member:	
Limestone, light-gray to medium-light-gray streaked with brownish-gray, finely crystalline, hard; weathers light yellowish brown; abundant pelecypods; upper contact concealed	3.7+

3. *Soldier Creek Shale Member of the Bern Limestone down into the upper part of the White Cloud Shale Member of the Scranton Shale*—Continued

	Feet
Bern Limestone—Continued	
Burlingame Limestone Member:	
Limestone, very light brownish gray, finely crystalline, very thin bedded; weathers to thin rounded moderate-yellowish-brown plates; dark-yellowish-orange patches on upper surface of some plates; many dark-yellowish-orange ferruginous spots; fusulinids, *Cryptozoon*-like algae, *Osagia*, crinoids, ramose bryozoans, and brachiopods	3.1
Thickness of exposed Bern Limestone	6.8
Scranton Shale:	
Silver Lake Shale Member:	
Partly covered interval; grayish-olive slightly sandy claystone; scattered nodules less than 0.1 ft thick just below top	5.0
Claystone, light-olive-gray to light-olive-brown, slightly silty; weathers yellowish gray mottled with pale grayish orange; many thin beds of medium-light-gray, and some brownish-gray finely crystalline sandy micaceous limestone in upper 10 ft; limestone weathers mottled yellowish gray and light brown; many ramose bryozoans, brachiopods, and pelecypods (mainly *Myalina*)	23.4
Thickness of Silver Lake Shale Member	28.4
Rulo Limestone Member:	
Limestone, medium-light-gray, finely crystalline; weathers light gray to yellowish gray; crinoid stems, bryozoans, and brachiopods; partly covered	1.2
Cedar Vale Shale Member:	
Coal (Elmo), intensely weathered	0.3
Clay, pale-olive to light-olive-gray, slightly sandy; carbonaceous streaks	.5
Sandstone, yellowish-gray (with brown hue), fine-grained, soft; silty in basal 1 ft; weathers yellow gray; some hard crossbedded lenses at top	12.5
Limestone, silty; weathers pale yellowish orange	1.4
Claystone, dusky-yellow, silty; weathers pale olive	7.8
Sandstone, pale-olive, silty, soft; weathers yellowish gray; hard yellowish-gray calcareous thin-bedded sandstone interbeds containing some crossbedded lenses as much as 0.7 ft thick; some ferruginous micaceous sandstone nodules that weather dark yellowish orange to light brown; forms resistant bed	3.0
Thickness of Cedar Vale Shale Member	25.5

3. *Soldier Creek Shale Member of the Bern Limestone down into the upper part of the White Cloud Shale Member of the Scranton Shale*—Continued

	Feet
Scranton Shale—Continued	
Happy Hollow Limestone Member:	
Limestone, greenish-gray, finely crystalline, thin-bedded, sandy, ferruginous, hard, compact; weathers to mottled dark-yellowish-orange, moderate-yellowish-brown, and light-brown knobby beds; abundant fenestrate and ramose bryozoans, brachiopods (*Meekella*?, *Derbyia*, *Reticulatia*), and low-spired gastropods	1.4
White Cloud Shale Member:	
Siltstone, medium-dark-gray, slightly sandy, laminated; weathers pale olive, grayish olive and medium light gray; brown iron stains on bedding planes; carbonaceous material; upper contact irregular	6.7
Coal, black, hard, brittle	.4
Thickness of exposed White Cloud Shale Member	7.1
Thickness of exposed Scranton Shale	63.6

4. *Tarkio Limestone Member of the Zeandale Limestone down to the base of the Bern Limestone*

[In quarry in the SE¼SW¼ sec. 3, and along adjacent road on the south line of the SW¼ sec. 3, T. 12 S., R. 14 E., Shawnee County]

	Feet
Zeandale Limestone:	
Tarkio Limestone Member:	
Limestone, brownish-gray, very fine grained, slightly argillaceous, medium-bedded; weathers to moderate-yellowish-brown trapezoidal blocks; abundant large fusulinids, crinoid stems, and bryozoans; a few brachiopods; only lower part exposed	2.8+
Willard Shale:	
Claystone (deeply weathered), olive-gray to moderate-yellowish-brown	0.4
Sandstone, medium-gray to olive-gray, very fine grained, very silty, platy, micaceous; weathers light olive gray to pale yellowish brown	.9
Siltstone, clayey, micaceous; weathers olive gray; many hard ferruginous siltstone layers less than 0.02 ft thick that weather moderate yellowish brown and form small hard fragments	26.0
Claystone (deeply weathered), olive-gray; olive-gray limestone pellets less than 0.05 ft in diameter; upper contact gradational; poorly exposed	10.2
Covered interval	1.4
Thickness of Willard Shale	38.9

4. *Tarkio Limestone Member of the Zeandale Limestone down to the base of the Bern Limestone*—Continued

	Feet
Emporia Limestone:	
Elmont Limestone Member:	
Limestone, medium-dark-gray, very fine grained; weathers to pale-yellowish-brown and olive-gray cobbles; brown fossil fragments; many fusulinids, crinoid stems, and bryozoans; partly exposed; basal contact covered	0.6+
Lower part of Elmont Limestone Member and upper part of Harveyville Shale Member:	
Covered interval	5.8
Harveyville Shale Member:	
Siltstone, olive-gray, clayey, laminated to platy; irregular plates about 0.05 ft thick and as much as 0.4 ft long of medium-light-gray very fine grained argillaceous limestone in upper 3.8 ft; moderate-yellowish-brown iron stain on bedding planes in lower 3.2 ft; lower contact sharp, even	8.6
Reading Limestone Member:	
Limestone, medium-gray, very fine grained; moderately argillaceous in upper 0.45 ft and lower 0.2 ft; thin to medium bedded; weathers mottled pale to moderate yellowish brown and olive gray; darker bed in upper 0.45 ft forms step back into outcrop face; some light-red barite inclusions; basal contact irregular, slightly gradational; abundant fusulinids, crinoid stems, bryozoans, and brachiopods; some small gastropods	2.7
Thickness of exposed Emporia Limestone	17.7
Auburn Shale:	
Siltstone, medium-dark-gray, clayey, laminated; weathers olive gray; sparse brachiopods and pelecypods	5.8
Limestone, medium-gray, very fine grained, argillaceous; weathers olive gray; crinoid stems, brachiopod-shell fragments, productoid spines, bryozoans	.5
Claystone, olive-gray, silty, calcareous; abundant crinoid stems, bryozoans, *Reticulatia, Neospirifer, Chonetes, Derbyia, Composita,* and productoid spines	.5
Limestone, medium-gray, very fine grained, very argillaceous; bedding indistinct; weathers olive gray; crinoid stems, bryozoans, *Chonetes* and other brachiopods, and productoid spines	.5
Claystone, olive-gray, silty, calcareous, platy	.2
Claystone, olive-gray, silty, calcareous, platy; a few fossiliferous limestone beds less than 0.02 ft thick; abundant small fossil fragments	.5
Limestone, medium-gray to olive-gray, very fine grained, argillaceous; abundant crinoid stems, bryozoans, and shell fragments	.1

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4. *Tarkio Limestone Member of the Zeandale Limestone down to the base of the Bern Limestone*—Continued

	Feet
Auburn Shale—Continued	
Claystone, olive-gray, silty, calcareous, platy; shell fragments	0.2
Limestone, medium-gray to olive-gray, very fine grained, argillaceous, thin-bedded; abundant crinoid stems, bryozoans, shell fragments (including *Chonetes* and *Derbyia*), productoid spines, and pelecypods	.6
Limestone and claystone, interbedded; limestone, in beds 0.02–0.05 ft thick, is medium gray, very fine grained, and argillaceous, and weathers olive gray to moderate yellowish brown. Claystone, in beds as much as 0.02 ft thick is medium gray to olive gray and calcareous; abundant very fine shell hash in all beds	.8
Claystone, dark-gray, silty, calcareous, platy to very thin bedded; weathers medium dark gray; a few pyrite crystals	2.3
Limestone, light-gray, very fine grained, very argillaceous, thin- to medium-bedded; many light-brownish-gray and greenish-gray claystone partings; subconchoidal fracturing, mud cracks, and scattered clusters of pyrite in upper two-thirds; lower one-third contains some less resistant beds as much as 0.15 ft thick of mottled light-olive-gray and medium-dark-gray very argillaceous limestone	6.7
Limestone, medium-gray, very clayey to silty; weathers medium light gray; scattered small dark inclusions	.2
Limestone, light-olive-gray to light-olive-brown, very fine grained, very argillaceous, thin- to medium-bedded; some greenish-gray clayey siltstone pellets as much as 0.04 ft thick and pale-yellowish-brown argillaceous limestone pellets as much as 0.02 ft in diameter; unit weathers pale yellowish brown; upper 0.6 ft forms separate ledge in places	3.3
Claystone; medium dark gray in lower part to olive gray in upper part; silty, slightly calcareous; light-olive-gray very argillaceous nodular limestone beds as much as 0.13 ft thick in upper 10.5 ft; some light-red calcite crystals in limestone; basal contact sharp; sparse small fossil fragments in claystone	13.8
Thickness of Auburn Shale	36.0
Bern Limestone:	
Wakarusa Limestone Member:	
Limestone, grayish-brown, very fine grained, slightly silty, hard; weathers light olive gray to light gray; abundant fusulinids (especially in upper part) *Cryptozoon*-like algae, and crinoid stems	2.8
Claystone, dark-olive-gray to medium-dark-gray, silty, laminated; small brachiopods	.3
Limestone, dark-olive-gray, very argillaceous; abundant small shell fragments and crinoid stems	.1

4. *Tarkio Limestone Member of the Zeandale Limestone down to the base of the Bern Limestone*—Continued

	Feet
Bern Limestone—Continued	
Wakarusa Limestone—Continued	
Claystone; dark gray to grayish black and very calcareous in lower half; dark olive gray in upper half; abundant shell hash	0.1
Limestone, medium-gray, very fine grained; very argillaceous in lower 0.2 ft; single bed; abundant shell hash, crinoid stems, and small gastropods	.7
Thickness of Wakarusa Limestone Member	4.0
Soldier Creek Shale Member:	
Claystone, dark-greenish-gray, silty, slightly calcareous; platy in upper 0.2 ft; weathers light greenish gray	1.5–1.8
Limestone, light-gray, very fine grained; particularly argillaceous in upper part; irregular laminae and patches of light-greenish-gray calcareous claystone; upper contact gradational	1.4–1.6
Limestone and claystone, interbedded; limestone, generally in beds 0.2–0.32 ft thick, is light gray to light olive gray, very fine grained, and very argillaceous and weathers light yellowish gray to light yellowish brown and has subconchoidal fracture; claystone, in beds 0.01–0.05 ft thick, is greenish gray, very silty, and calcareous	3.0
Claystone, light-greenish-gray, silty, laminated; weathers to small smooth rounded blocks	.7
Thickness of Soldier Creek Shale Member	6.6–7.1
Burlingame Limestone Member:	
Limestone, medium-light-gray, very fine grained, argillaceous, medium- to thick-bedded; brecciated in upper 4 ft; pyritic; upper contact irregular; sparse crinoid stems, brachiopods (including *Neospirifer*), and small gastropods in upper 4 ft; abundant fusulinids, *Osagia*, crinoid stems, brachiopods, and gastropods in lower 0.8 ft	4.8
Claystone, yellowish-gray, silty, calcareous; weathers grayish orange	.2
Limestone, pale-yellowish-brown, very fine grained, hard, conglomeratic; weathers to single pale-yellowish-brown bed; lower contact sharp, uneven; abundant *Osagia*, pelecypods, and gastropods, especially in the upper part	1.9
Thickness of Burlingame Limestone Member	6.9
Thickness of Bern Limestone	17.5–18.0

5. *Basal part of the Willard Shale down to the top of the Bern Limestone*

[Along farm-access road and along U.S. Highway 40 in the SW¼NE¼ sec. 35, T. 11 S., R. 14 E., Shawnee County]

	Feet
Willard Shale:	
Claystone, calcareous, partly very fossiliferous; weathers olive gray; abundant *Composita*, *Hustedia*, *Chonetes*, and other brachiopods in lower 0.6 ft; upper part not exposed	2.0+
Emporia Limestone:	
Elmont Limestone Member:	
Limestone, brownish-gray, very fine grained; argillaceous in upper 0.2 ft; weathers to single olive-gray to moderate-yellowish-brown bed; platy fragments in upper 0.2 ft; brownish-gray fossil fragments; abundant fusulinids and brachiopod fragments	0.9
Claystone, medium-gray, calcareous; weathers olive gray; abundant fossil fragments	.4
Limestone, brownish-gray, very fine grained, thin- to thick-bedded; weathers olive gray to moderate yellowish brown; some small vugs filled with moderate-pink barite; abundant brachiopods, including *Composita*	2.8
Thickness of Elmont Limestone Member	4.1
Harveyville Shale Member:	
Claystone, medium-dark-gray, silty; interbedded with medium-dark-gray siltstone laminae; unit weathers olive gray	12.5
Reading Limestone Member:	
Limestone, medium-gray, moderately argillaceous; weathers to moderate-yellowish-brown bed; forms step back into outcrop face; crinoid stems and braciopods	0.5
Limestone, medium-gray, very fine grained, hard; weathers moderate yellowish brown; forms ledge; some vugs filled with moderate-pink barite; abundant fusulinids, crinoid stems, and brachiopods	1.7
Limestone, very argillaceous; weathers moderate yellowish brown; forms reentrant between limestone layers	.1
Limestone, medium-gray, very fine grained; weathers moderate yellowish brown; small fossil fragments	.6
Thickness of Reading Limestone Member	2.9
Thickness of Emporia Limestone	19.5
Auburn Shale:	
Claystone, medium-dark-gray, platy; weathers light olive gray; argillaceous limestone bed 0.5 ft thick that weathers light olive brown to grayish yellow about 1 ft below top; abundant *Chonetes*, *Neospirifer*, and other brachiopods in upper 1 ft; some gastropods and fenestrate bryozoans	6.0

5. *Basal part of the Willard Shale down to the top of the Bern Limestone*—Con.

Auburn Shale—Continued	*Feet*
Limestone, medium-dark-gray, very fine grained, hard, compact; some thin calcareous claystone partings; upper contact irregular; crinoid stems and *Chonetes*, *Neospirifer*, and other brachiopods; some pelecypods and gastropods	1.3
Claystone, very calcareous; weathers olive gray to yellowish brown; abundant crinoid stems, brachiopods (including *Chonetes*), and pelecypods	.1
Limestone, medium-dark-gray, medium-grained, coquinoidal; weathers brownish gray; abundant small claystone pellets; upper surface wavy; abundant pelecypods (mainly *Myalina*)	3.9
Claystone, dark-gray, laminated to platy; weathers olive gray to olive brown; upper contact sharp; abundant *Lingula*	1.0
Claystone, dark-gray to grayish-black; weathers light olive brown; very carbonaceous in lower 0.2 ft; abundant *Lingula*	1.2
Claystone, light-olive-gray	.4
Claystone, very silty, very calcareous; weathers grayish yellow; scattered concretions as much as 0.6 ft thick and 0.8 ft long of dark-gray very fine grained argillaceous hard compact limestone at base	3.3
Claystone, medium-gray; weathers olive gray; outcrop crossed by joints as much as 0.2 ft wide filled with medium-gray very argillaceous limestone	2.2
Claystone, medium-gray, slightly silty; weathers mottled light olive gray and light olive brown; abundant light-yellowish-gray limestone pellets less than 0.02 ft in diameter	2.2
Covered interval; probably claystone	6.8
Claystone, medium-gray, slightly silty; weathers mottled light olive gray and light olive brown; abundant light-yellowish-gray limestone pellets less than 0.02 ft in diameter	17.0
Thickness of Auburn Shale	45.2
Bern Limestone:	
Wakarusa Limestone Member: not described)	2.4+

6. *Basal part of the Pillsbury Shale down into the upper part of the Willard Shale*

[Along U.S. Highway 40 in the NW¼NW¼ sec. 32, T. 11 S., R. 14 E., Shawnee County]

Pillsbury Shale:	*Feet*
Claystone; weathers light olive gray; abundant irregular light-gray argillaceous limestone nodules less than 0.04 ft thick and 0.07 ft long; upper contact not exposed	2.0+

6. *Basal part of the Pillsbury Shale down into the upper part of the Willard Shale*—Continued

	Feet
Zeandale Limestone:	
Maple Hill Limestone Member:	
Limestone, medium-gray to medium-dark-gray, very finely crystalline, argillaceous in lower 0.13 ft; weathers moderate yellowish brown; weathered deep into rock; upper surface irregular, much mottled by iron stain; forms single bed; very thin bedded in basal part; abundant small fusulinids, crinoid stems, bryozoans, and brachiopods	2.0
Wamego Shale Member:	
Claystone, olive-gray to medium-gray, platy; many moderate yellowish-brown laminated to platy ferruginous siltstone beds less than 0.02 ft thick; *Lingula*, and pectinoid pelecypods	6.2
Claystone, very calcareous, moderately hard; weathers moderate yellowish brown; abnudant crinoid stems and pelecypods	.4
Claystone, olive-gray, silty; shell fragments	.2
Limestone, brownish-gray, very fine grained, very argillaceous, very thin bedded; very small argillaceous limestone pellets; abundant crinoid stems, productoid(?) spines, and pelecypods	.4
Claystone, olive-gray, silty, fossiliferous; light-olive-gray micaceous siltstone laminae; moderate-yellowish-brown argillaceous fossiliferous limestone nodules and lenses	1.8
Thickness of Wamego Shale Member	9.0
Tarkio Limestone Member:	
Limestone, light-olive-gray, very fine grained; weathers pale yellowish brown; weathers to small rubbly fragments in upper 0.4 ft; forms ledge in lower 1 ft; lower contact sharp; abundant foraminifers (including some fusulinids) and *Osagia;* fragments of brachiopods, pelecypods, and gastropods	1.5
Limestone, very fine grained; single bed; weathers to moderate-yellowish-brown irregular elongate blocks; many large vugs in upper 0.4 ft; light-red barite in some vugs; abundant large fusulinds and crinoid stems	5.9
Thickness of Tarkio Limestone Member	7.4
Thickness of Zeandale Limestone	18.4
Willard Shale:	
Siltstone, olive-gray, clayey to very finely sandy, micaceous; weathers light olive gray mottled with moderate yellowish brown and grayish red	1.3
Sandstone, light-olive-gray, very fine grained, silty, platy, micaceous; weathers light yellowish gray; upper contact gradational	.7
Siltstone, claystone, and sandstone, interbedded; siltstone very finely sandy; claystone silty; sandstone silty and very fine grained. Entire unit is olive gray, laminated to platy, and micaceous and weathers light olive gray, except for a few siltstone beds that weather moderate yellowish brown	2.8

6. *Basal part of the Pillsbury Shale down into the upper part of the Willard Shale*—Continued

	Feet
Willard Shale—Continued	
Sandstone, light-olive-gray, very fine grained, silty, laminated to platy, very micaceous; weathers light yellowish gray to pale yellowish brown; lower contact gradational	1.3
Siltstone and sandstone, interbedded; siltstone light-olive-gray and clayey; sandstone very fine grained; some siltstone layers weather moderate yellowish brown	.7
Sandstone, light-olive-gray, very fine grained, silty, laminated to platy, very micaceous; weathers light yellowish gray to pale yellowish brown	.7
Claystone, medium-gray, silty; weathers light olive gray; many moderate-yellowish-brown ferruginous micaceous siltstone beds less than 0.04 ft thick that weather to hard chips; upper contact gradational; basal contact not exposed	6.0+
Thickness of exposed Willard Shale	13.5+

7. *Aspinwall(?) Limestone Member of the Onaga Shale down into the upper part of the Pillsbury Shale*

[Along streams and in the hillside in the SE¼NW¼, NW¼SE¼, and SW¼NE¼ sec. 6, T. 13 S., R. 14 E., Shawnee County]

	Feet
Onaga Shale:	
Aspinwall(?) Limestone Member:	
Limestone, silty; weathers to large mottled light-yellowish-gray to light-brownish-gray blocks having irregular upper surfaces; many clayey limestone inclusions as much as 0.07 ft long that weather light yellowish gray to light yellowish brown; scattered barite inclusions; shell fragments (mainly pelecypods); poorly exposed	0.5
Towle Shale Member:	
Covered interval	7.5
Thickness of exposed Onaga Shale	8.0
Wood Siding Formation:	
Brownville Limestone Member:	
Limestone, very fine grained, argillaceous; weathers mottled light olive gray and olive brown; abundant fusulinids and *Marginifera*	1.0
Pony Creek Shale Member:	
Covered interval	5.0
Grayhorse Limestone Member:	
Limestone, very fine grained, argillaceous, thin-bedded; weathers to large light-olive-gray to light-olive-brown rectangular pitted blocks having irregular upper surfaces; abundant subrounded argillaceous limestone inclusions 0.01–0.1 ft long; abundant crinoid stems and minute fragments of shells (including those of pelecypods)	1.9

7. *Aspinwall(?) Limestone Member of the Onaga Shale down into the upper part of the Pillsbury Shale*—Continued

	Feet
Wood Siding Formation—Continued	
Plumb Shale Member:	
Covered interval; probably siltstone	6.2
Siltstone, olive-gray, silty, laminated to platy; abundant hard micaceous siltstone layers that weather yellowish brown; medium-dark-gray very argillaceous platy limestone lens as much as 0.4 ft thick locally at base; moderate-brown claystone bed 0.07 ft thick locally overlies limestone; coal bed 0.02 ft thick overlies claystone. The coal apparently merges laterally with underlying coal bed. Crinoid stems, bryozoans, *Derbyia*, *Chonetes*, *Composita*, *Orthomyalina*, and *Myalina* present in limestone bed	6.0
Coal; deeply weathered	.7
Claystone, olive-gray to medium-gray, silty, laminated, micaceous, carbonaceous	1.0
Siltstone, medium-gray, clayey, laminated, micaceous; much iron stain on bedding planes; some hard layers weather pale yellowish brown	2.9
Thickness of Plumb Shale Member	16.8
Nebraska City Limestone Member:	
Limestone, olive-gray, very fine grained, very argillaceous, very thin bedded; olive-gray claystone interbeds; abundant crinoid stems, *Derbyia*, *Juresania*, and *Orthomyalina*	0.9
Thickness of Wood Siding Formation	25.6
Root Shale:	
French Creek Shale Member:	
Claystone (intensely weathered), olive-gray; upper contact gradational; shell fragments	0.3
Claystone, medium-dark-gray, silty; much iron stain and carbonaceous material on bedding planes	.3
Coal (Lorton) (intensely weathered)	.3
Claystone, medium-gray, silty; platy in lower part to poorly bedded in upper part; weathers light olive gray; much carbonaceous material and iron stain on bedding planes	1.4
Siltstone, laminated, micaceous; weathers light olive brown; disseminated carbonaceous material	1.5
Sandstone, olive-gray, very fine grained, laminated to platy; clayey siltstone interbeds; weathers olive brown	1.0
Sandstone, light-gray, very fine grained, very thin bedded, calcareous, micaceous, hard; weathers to hard light-olive-gray concretionlike masses; disseminated carbonaceous material	1.9

7. *Aspinwall(?) Limestone Member of the Onaga Shale down into the upper part of the Pillsbury Shale*—Continued

Root Shale—Continued	
French Creek Shale Member—Continued	*Feet*
Sandstone, olive-gray, very fine grained, laminated to platy; clayey siltstone interbeds; weathers olive brown	1.8
Covered interval; probably sandstone	3.3
Sandstone, olive-gray, very fine grained, laminated to platy; clayey siltstone interbeds in lower 0.6 ft; weathers olive brown	2.0
Siltstone, olive-gray, clayey, laminated, micaceous; many hard pale- to moderate-yellowish-brown ferruginous micaceous siltstone interbeds; upper contact gradational; finely disseminated carbonaceous material	7.8
Covered interval	5.3
Thickness of French Creek Shale Member	26.9
Jim Creek Limestone Member:	
Limestone, olive-gray, very fine grained, argillaceous, very thin to thin-bedded; weathers to pale-yellowish-brown to brownish-gray platy beds; many very ferruginous masses; much shell hash in relief; abundant fusulinids, crinoid stems, *Reticulatia*, *Derbyia*, and productoid spines; *Orthomyalina* and gastropods; poorly exposed; USGS fossil locality 19462–PC(f12959)	0.4
Friedrich Shale Member:	
Claystone, olive-gray, silty, laminated, micaceous; weathers light olive gray; many moderate-yellowish-brown silty limestone lenses as much as 0.1 ft thick; limestone weathers to brown fragments	8.1
Claystone, mottled grayish-red, light-brown, and light-olive-gray; poorly exposed	.6
Claystone; weathers light olive gray	.2
Limestone, light-olive-gray, medium-light-gray, and pale-yellowish-brown, slightly argillaceous, medium- to thick-bedded; abundant limestone(?) pellets less than 0.01 ft thick; weathers to large tabular pitted blocks with rough, irregular upper surfaces; scattered nodules of light-red barite; abundant *Osagia*, crinoids, pelecypods, and gastropods; a few fusulinids; forms prominent ledge	2.0–3.8
Covered interval	.8
Limestone, olive-gray; weathers to mottled light-olive-gray and yellowish-brown pitted rubbly blocks	.4
Claystone, light-olive-gray, slightly silty, laminated to platy; many very thin layers of moderate-yellowish-brown ferruginous calcareous siltstone	4.5
Claystone, light-olive-gray; partly mottled with grayish red and light brown; slightly silty; platy	2.6
Claystone, grayish-red to light-brown, slightly silty, platy	1.6
Claystone, light-olive-gray	.5

7. *Aspinwall(?) Limestone Member of the Onaga Shale down into the upper part of the Pillsbury Shale*—Continued

	Feet
Root Shale—Continued	
Friedrich Shale Member—Continued	
Covered interval; probably claystone	0.6
Claystone (deeply weathered), grayish-red to reddish brown and olive-gray; forms light-grayish-red outcrop; poorly exposed	.9
Claystone, olive-gray, laminated; weathers light olive gray	2.8
Thickness of Friedrich Shale Member	25.6–27.4
Thickness of Root Shale	52.9–54.7
Stotler Limestone:	
Grandhaven Limestone Member:	
Limestone, light-olive-gray, very fine grained, slightly argillaceous; weathers to prominent light-olive-gray ledge; many ferruginous masses on upper surface; abundant crinoid stems, *Reticulatia*, and *Meekella*	0.7
Claystone, olive-gray, slightly silty; weathers light olive gray to light olive brown; irregular light-olive-gray very finely crystalline limestone bed near middle; fine shell hash throughout; *Osagia* in limestone bed	.5
Limestone, light-olive-gray, very fine grained, slightly argillaceous; weathers light olive gray mottled with moderate yellowish brown; an upper bed 0.3 ft thick and a lower bed 1 ft thick; forms ledge that has rough very ferruginous masses on upper surface; abundant fusulinids, *Osagia*, crinoid stems, ramose bryozoans, *Chonetes*, and *Derbyia*	1.3
Thickness of Grandhaven Limestone Member	2.5
Dry Shale Member:	
Limestone (reef), light-olive-gray to pale-yellowish-brown, very finely crystalline, thin-bedded, coquinoidal; many round argillaceous limestone pellets as much as 0.02 ft in diameter (but most pellets are less than 0.01 ft in diameter); beds overlap progressively to the north; apparent dip is 3° SE; upper and lower contacts sharp, irregular; scattered small spots of green stain; abundant shell fragments (primarily pelecypods); some crinoid stems; exposed part of reef is about 100 yds long	0–2.4
Claystone, intensely weathered; light-olive-gray, silty, calcareous; abundant light-olive-gray very fine grained limestone pellets as much as 0.15 ft long and 0.5 ft thick in lower 0.2 ft; where reef is present, this unit is locally only 0.03 ft thick; poorly exposed	0.1–3.3
Thickness of Dry Shale Member	2.5–3.3

7. *Aspinwall(?) Limestone Member of the Onaga Shale down into the upper part of the Pillsbury Shale*—Continued

	Feet
Stotler Limestone—Continued	
Dover Limestone Member:	
Limestone, deeply weathered; light-olive-gray, very fine grained, very argillaceous; probably thin bedded; lower 1.3 ft is olive gray mottled with olive brown, very clayey, and has hard layers; elsewhere lower part may grade laterally into underlying unit; abundant large fusulinids, algae (*Cryptozoon*), crinoid stems, horn corals, *Chonetes*, and *Hustedia*	3.0
Thickness of Stotler Limestone	8.0–8.8
Pillsbury Shale:	
Siltstone, olive-gray, platy to very thin bedded, finely micaceous; weathers light olive gray mottled by light olive brown; scattered pyrite; upper contact gradational; base not exposed	6.7+

8. *Upper part of the French Creek Shale Member of the Root Shale down into the Pillsbury Shale*

[Along U.S. Highway 40 in the SW¼SW¼ sec. 30, T. 11 S., R. 13 E., Wabaunsee County (1 mile west of area)]

	Feet
Root Shale:	
French Creek Shale Member:	
Claystone, medium-gray, silty, platy; abundant chips of pale- to moderate-yellowish-brown iron-stained siltstone in upper 10 ft; weathers light olive gray; upper part not exposed	16.0+
Jim Creek Limestone Member:	
Limestone, light-olive-gray, very fine grained; argillaceous, especially in lower 0.7 ft; thin to medium bedded; weathers moderate yellowish brown; upper surface irregular, pitted, and greatly mottled with iron oxide; abundant small fragments of brachiopods and pelecypods (including *Aviculopecten* and *Myalina*?); fusulinids, crinoid stems, bryozoans	1.7
Friedrich Shale Member:	
Claystone, olive-gray, platy, micaceous; weathers light olive gray; many very small pyritic inclusions that weather dark yellowish brown	0.9
Siltstone, light-olive-gray, coarse, probably calcerous, finely micaceous; abundant very small pyritic(?) inclusions; weathers pale to moderate yellowish brown; forms ledge	3.4
Claystone, light-gray; upper contact sharp, slightly irregular	2.0
Claystone, medium-dark-gray, silty; many beds 0.05–0.3 ft thick of hard light-gray silty limestone that weathers pale yellowish brown; limestone contains many very small pyrite inclusions	2.8

8. *Upper part of the French Creek Shale Member of the Root Shale down into the Pillsbury Shale*—Continued

	Feet
Root Shale—Continued	
Friedrich Shale Member—Continued	
Claystone, medium-dark-gray, silty, micaceous; many oval to kidney-shaped olive-gray to medium-gray dense argillaceous limestone concretions that weather moderate yellowish brown. Concretions are generally 0.07–0.25 ft thick and 0.1–0.6 ft long and contain narrow joints filled with white calcite, pyrite, and light-red barite	3.0
Claystone, dark-gray, silty, laminated, micaceous; very small pyrite inclusions that weather dark brown; several yellowish-gray siltstone beds as much as 0.15 ft thick in upper 2 ft; many clayey micaceous siltstone beds less than 0.05 ft thick that weather moderate yellowish brown 1.8 ft above base; siltstone weathers to hard iron-stained plates that contain finely disseminated carbonaceous material; claystone weathers olive brown in basal part and mainly pale yellowish brown in rest of unit; many very small shell fragments in basal 0.2 ft	12.7
Thickness of Friedrich Shale Member	24.8
Thickness of exposed Root Shale	42.5
Stotler Limestone:	
Grandhaven Limestone Member:	
Limestone, medium-gray, very fine grained; very argillaceous in upper 1 ft; very thin to medium bedded; some parts slightly pyritic; weathers light olive gray to moderate yellowish brown; weathers to thin rubbly plates in upper 1.2 ft; capped by very porous iron-rich layer 0.25 ft thick that contains large gypsum crystals; abundant fusulinids, bryozoans, and *Composita*, *Juresania*, and other brachiopod shells; abundant productoid spines; many fossil casts in upper 0.25 ft	3.3
Dry Shale Member:	
Claystone, olive-gray, silty, laminated, calcareous, slightly micaceous; many lenses as much as 0.1 ft thick of light-olive-gray to light-olive-brown very fine grained very argillaceous very fossiliferous limestone that contains many pellets as much as 0.02 ft in diameter of argillaceous limestone; abundant crinoid stems, bryozoans, *Derbyia* and other brachiopods, productoid spines, and *Myalina* and other pelecypods; forms inconspicuous reentrant	0.1–0.6

8. *Upper part of the French Creek Shale Member of the Root Shale down into the Pillsbury Shale*—Continued

Stotler Limestone—Continued	
Dover Limestone Member:	*Feet*
Limestone, light-olive-gray to light-brownish-gray, very fine grained, thin- to medium-bedded; argillaceous, particularly in lower 1.1 ft; weathers light brownish gray to pale yellowish brown; nodular rubble or platy fragments in upper 1 ft and lower 1 ft; upper contact uneven; abundant large fusulinids (USGS colln. f12963), algae (*Cryptozoon*), crinoid stems, and brachiopods; in addition, E. L. Yochelson (written commun., 1960) reported a rhomboporoid bryozoan, *Meekoporella?* sp. indet., *Enteletes hemiplicatus* (Hall), and *Chonetes granulifer* Owen	3.5
Thickness of Stotler Limestone	6.9–7.4
Pillsbury Shale:	
Claystone, olive-gray, very silty, platy; weathers light olive gray; abundant nodules 0.15 ft thick of medium-gray argillaceous pyritic limestone that weathers moderate yellowish brown; upper contact gradational; some fusulinids in upper 0.2 ft	3.4
Sandstone, light-olive-gray, very fine grained, silty, laminated, slightly crossbedded, very micaceous; weathers light olive gray to light olive brown; many very thin lenses and stringers of hard pyritic sandstone that weathers moderate brown; very carbonaceous on bedding planes; fairly resistant	3.7
Siltstone, medium-dark-gray to olive-gray, laminated, micaceous	.6
Sandstone, light-olive-gray, very fine grained, silty, laminated, very micaceous; weathers moderate yellowish brown; at base is lenticular bed as much as 0.1 ft thick of finely crossbedded very pyritic sandstone that weathers moderate brown; basal contact gradational, uneven; carbonaceous fragments on bedding planes	1.2
Siltstone, medium-dark-gray to olive-gray, laminated, micaceous; basal contact gradational	.3
Sandstone, light-olive-gray, very fine grained, silty, laminated, very micaceous; carbonaceous material on bedding planes; basal contact gradational	.4
Siltstone, medium-dark-gray to olive-gray, laminated, micaceous	1.7
Sandstone, light-olive-gray, very fine grained, laminated; slightly crossbedded in lower half; very micaceous; weathers light olive to light olive brown; channel deposit; thins laterally	3.8

8. *Upper part of the French Creek Shale Member of the Root Shale down into the Pillsbury Shale*—Continued

	Feet
Pillsbury Shale—Continued	
Claystone, and siltstone, medium-dark-gray, laminated to platy, very finely micaceous, slightly carbonaceous; weathers olive brown; clayey siltstone in upper 12.4 ft; very silty claystone in lower 10 ft; upper 2.4 ft contains very thin beds of very micaceous very carbonaceous very coarse siltstone that weathers light olive gray to light yellowish gray; entire unit contains nodules as much as 0.05 ft in in diameter of pyritic siltstone and is broken by vertical joints as much as 0.2 ft wide filled with siltstone that weathers pale yellowish brown; basal contact not exposed	22.4+
Thickness of exposed Pillsbury Shale	37.5+

9. *Hawxby Shale Member of the Onaga Shale down into the uppermost part of the Pillsbury Shale*

[In bank of Lomis Creek and eastward along road on the south line of the SE¼ sec. 4, T. 13 S., R. 13 E., Wabaunsee County]

	Feet
Onaga Shale:	
Hawxby Shale Member:	
Limestone, white	1.0
Covered interval	6.0
Limestone, olive-gray to very pale yellowish brown; argillaceous; hard and dense in lower 1 ft; softer and slightly porous in rest of unit; many angular areas, mostly less than 0.02 ft thick but some as much as 0.2 ft long, possibly of algal origin; some angular areas striated; many pale-brown limonitic spots and streaks; weathers pale yellowish orange to yellowish gray; large and small holes in blocks	3.0
Covered interval; several platy beds of yellowish-gray silty micaceous limestone in lower 2 ft	13.6
Thickness of Hawxby Shale Member	23.6
Aspinwall Limestone Member:	
Limestone, yellowish-gray, laminated, hard, vertically jointed; weathers yellowish gray	0.5
Covered interval	3.0
Limestone, very light gray, platy; weathers mottled yellowish gray and pale yellowish orange; a few *Aviculopecten*?; many other shells (apparently pelecypods) in basal part	.6
Thickness of Aspinwall Limestone Member	4.1

9. *Hawxby Shale Member of the Onaga Shale down into the uppermost part of the Pillsbury Shale*—Continued

Onaga Shale—Continued	
Towle Shale Member (channel):	*Feet*
Mostly covered interval; some light-olive-gray claystone; a few limestone concretions and platy beds of limestone	13.0
Claystone, light-olive-gray	5.0
Limestone, light-olive-gray; brown cone-in-cone structures at top	.3
Covered interval	10.0
Claystone, light-olive-gray	3.0
Covered interval	15.0
Sandstone and siltstone, yellowish-gray, very finely micaceous; weathers yellowish gray	5.0
Sandstone, light-yellowish-gray to light-olive-gray, very fine grained; laminated, micaceous, carbonaceous; contains lenses generally 0.1–0.25 ft thick (some as much as 0.8 ft thick) of conglomeratic limestone. The limestone is medium light gray, very finely crystalline, sandy, micaceous, and hard and contains weathered subangular to subrounded granules and pebbles of light-yellowish-brown to dark-grayish-red dense argillaceous limestone, ironstone, and claystone. In places this unit forms the upper part of the ledge formed by the underlying limestone, but elsewhere it weathers to a slope	2.8
Limestone conglomerate; medium-light-gray, very finely crystalline, sandy, very thin to thin-bedded, hard; abundant subangular to subrounded granules and pebbles as much as 0.15 ft long and 0.05 ft thick of weathered light-yellowish-brown to dark-grayish-red dense argillaceous unfossiliferous limestone, ironstone, and claystone; much pyrite; many wood fragments and fossils; fossils include crinoid stems, bryozoans, and brachiopods (*Marginifera*, *Chonetes*, *Reticulatia*?, *Derbyia*, *Chonetina*); breaks into large slabs that split into irregular layers; forms prominent ledge	2.3
Siltstone, olive-gray, sandy, laminated to platy, micaceous; upper half contains some platy beds of very fine grained sandstone that weathers light yellowish brown; carbonaceous material on bedding planes	.5
Limestone conglomerate; medium-light-gray to light-olive-gray very finely crystalline sandy limestone in irregular beds as much as 0.15 ft thick and containing pellets and nodules as much as 0.05 ft long of light-yellowish-brown argillaceous limestone, limonite, claystone, and ironstone; many shell fragments; some wood fragments; weathers dark grayish red to dark reddish brown	.6
Thickness of Towle Shale Member (channel)	57.5
Thickness of exposed Onaga Shale	85.2

9. *Hawxby Shale Member of the Onaga Shale down into the uppermost part of the Pillsbury Shale*—Continued

Disconformity.

Wood Siding Formation:

Plumb(?) Shale Member:

	Feet
Sandstone, very fine grained, well-sorted, platy to very thin bedded, partly crossbedded, very micaceous; weathers light yellowish brown to light olive gray; platy beds of olive-gray sandy micaceous siltstone; upper contact moderately sharp, slightly irregular; lower contact poorly exposed; black carbonaceous material on bedding planes. Unit is 2 ft thick near south end of exposure; to the north, where underlying beds have been channeled out, it is more than 20 ft thick	2.0–20.0+

Unconformity.

Root Shale:

Friedrich Shale Member:

Claystone, laminated to platy; weathers light olive gray to light olive brown; poorly exposed	0–2.7

Stotler Limestone:

Grandhaven Limestone Member:

Limestone, medium-light-gray to light-olive-gray, very fine grained, moderately argillaceous, thin-bedded; very fine light-olive-gray claystone laminae in zone 0.4 ft thick 1.1 ft above base; weathers light olive gray; upper weathered surface mottled moderate yellowish brown, dark reddish brown, and dark grayish red; forms ledge that splits into thin irregular plates; some medium-dark-gray mottling on bedding planes; abundant small fusulinids, crinoid stems, ramose bryozoans, brachiopods (including *Chonetes*, *Marginifera*?, *Hustedia*, and *Derbyia*), and productoid spines; outcrop partly slumped; lower contact concealed; channeled out laterally	0–2.2+

Dry Shale Member:

Covered interval	0–6.8
Claystone, light-olive-gray, very slightly silty; round white limestone nodules 0.04–0.08 ft in diameter in upper 1 ft; upper contact not exposed; claystone and overlying unit channeled out laterally	0–5.0
Thickness of Dry Shale Member	0–11.8

9. *Hawxby Shale Member of the Onaga Shale down into the uppermost part of the Pillsbury Shale*—Continued

	Feet
Stotler Limestone—Continued	
Dover Limestone Member:	
Limestone, light-gray to light-olive-gray, very fine grained, argillaceous; bedding irregular, obscure; sparsely pyritic; weathers light olive gray; pale to moderate-yellowish-brown and pale-red stain on weathered surfaces; breaks into large blocks that have irregular upper surface; abundant large fusulinids; many round masses of *Cryptozoon*-like algae; many crinoid stems, ramose bryozoans, horn corals, and brachiopods (including *Composita*, *Crurithyris*, and *Hustedia*); lower contact gradational; channeled out laterally	0–1.7
Thickness of Stotler Limestone	0–15.7
Pillsbury Shale:	
Claystone, greenish-gray, calcareous platy; greenish-gray very argillaceous very fossiliferous limestone lenses as much as 0.05 ft thick and 0.15 ft long; abundant large fusulinids; many crinoid stems; some shell fragments; basal contact not exposed; channeled out laterally	0–2.0+

10. *Aspinwall Limestone Member of the Onaga Shale Down into the Tarkio Limestone Member of the Zeandale Limestone*

[Along stream gullies and in roadcuts in the W½NW¼ and W½SW¼ sec. 31, T. 12 S., R. 14 E., Shawnee County]

	Feet
Onaga Shale:	
Aspinwall Limestone Member:	
Limestone, pale-yellowish-brown to grayish-orange, hard, brittle, porous; weathers pale yellowish orange; angular fragments as much as 0.05 ft long of medium-dark-gray algal(?) limestone that weathers very light gray; very small shell fragments	0.6
Claystone, light-olive-gray, slightly silty; weathers yellowish gray; forms angular rhombic fragments; several thin beds of yellowish-gray siltstone 1.5–3 ft below top	5.0
Limestone; very light gray with pink hue; cryptocrystalline, very thin to thin bedded; massive at top; well stratified in middle; weathers yellowish gray; much dark-brown iron stain in cracks; abundant *Promytilus*-type pelecypods in lower 0.7 ft	4.2
Thickness of Aspinwall Limestone Member	9.8
Towle Shale Member (channel):	
Claystone, greenish-gray; slightly silty in upper 3.5 ft; finely laminated, very micaceous; very carbonaceous on bedding planes; several beds of light-olive-gray platy micaceous siltstone and several very thin beds of ironstone near middle; many *Lingula* and ostracodes 8.3 ft above base	13.5

10. *Aspinwall Limestone Member of the Onaga Shale down into the Tarkio Limestone Member of the Zeandale Limestone*—Continued

	Feet
Onaga Shale—Continued	
Towle Shale Member (channel)—Continued	
Limestone, light-brownish-gray, finely crystalline, very thin bedded; some angular areas as much as 0.04 ft long of yellowish-gray clayey limestone that weathers very pale orange; few *Osagia*?, crinoid stems, *Derbyia*, and *Chonetes;* caps underlying bed	0.2
Limestone, medium-gray, hard, dense, concretionary; weathers dark yellowish orange; abundant molluscan fragments; probably some *Osagia*	.8
Claystone, light-grayish-olive, slightly silty	3.6
Sandstone, medium-gray, very fine grained, very calcareous, micaceous, hard, ripple-marked; much carbonaceous material; rests directly on underlying bed	.9
Limestone conglomerate (base of channel); medium-light-gray hard sandy pyritic limestone containing abundant fragments less than 0.1 ft long (most less than 0.05 ft long) of dark claystone, ironstone, yellowish-brown limestone, and shells; weathers light olive gray; many crinoid stems, *Derbyia, Reticulatia, Chonetes*, bellerophontid gastropods, and carbonized plant fragments. This bed is at the approximate stratigraphic position of the Grayhorse Limestone Member of the Wood Siding Formation that crops out to the southeast	.7
Thickness of Towle Shale Member (channel)	19.7
Thickness of exposed Onaga Shale	29.5
Disconformity.	
Wood Siding(?) Formation:	
Plumb(?) Shale Member (channel):	
Siltstone, yellowish-gray, platy, very micaceous, carbonaceous; limestone conglomerate lens 2.2 ft long and 0.5 ft thick interbedded in uppermost part; weathers yellowish gray	1.3
Siltstone and sandstone, light-olive-gray and yellowish-gray, platy, micaceous, carbonaceous; sandstone is very fine grained	5.0
Covered interval	14.0
Sandstone, light-olive-gray, micaceous; locally very calcareous; forms large hard crossbedded lenses that resemble limestone	10.0
Sandstone, light-olive-gray, micaceous, friable	10.0

10. *Aspinwall Limestone Member of the Onaga Shale down into the Tarkio Limestone Member of the Zeandale Limestone*—Continued

Wood Siding(?) Formation—Continued	
Plumb(?) Shale Member (channel)—Continued	*Feet*
Limestone (base of channel), light-gray, sandy, micaceous, concretionary; many large black carbonaceous fragments on bedding planes; forms series of elongate concretions; float indicates a possible conglomerate at base	1.0
Thickness of Plumb(?) Shale Member (channel)	41.3
Thickness of Wood Siding(?) Formation	41.3
Disconformity.	
Root Shale:	
French Creek Shale Member:	
Claystone, light-olive-gray with blue hue	5.5–8.0
Jim Creek Limestone Member:	
Limestone, light-gray, clayey, hard, vertically jointed; weathers to yellowish-gray angular fragments; scattered small fusulinids; abundant crinoid stems and brachiopods (including *Chonetes* and productoid spines)	0.6
Friedrich Shale Member:	
Claystone, light-olive-gray, very slightly silty, poorly bedded; weathers yellowish gray	9.8
Limestone, light-gray, very finely crystalline, hard, conglomeratic; abundant angular pieces as much as 0.02 ft long of ironstone and green shale; weathers to single yellowish-gray bed	.4
Claystone, grayish-red, mottled with grayish-olive, slightly silty; poorly exposed	2.3
Thickness of Friedrich Shale Member	12.5
Thickness of Root Shale	18.6–21.1
Stotler Limestone:	
Grandhaven Limestone Member:	
Limestone, light-gray; clayey, particularly in lower part; hard; weathers grayish orange; possible claystone parting 0.3 ft thick 0.5 ft below top; upper and lower parts form ledges in stream; middle part rubbly; *Osagia*, scattered fusulinids, crinoid stems, and *Reticulatia*, *Meekella*, *Chonetes*, and *Punctospirifer* in upper part; ramose bryozoans, *Derbyia*, *Orthomyalina*, and *Aviculopecten* in lower part	2.5
Dry Shale Member:	
Claystone, light-olive-gray, slightly to moderately silty; weathers yellowish gray; a few pelecypods 0.5 ft below top; lower half not exposed	4.0

10. *Aspinwall Limestone Member of the Onaga Shale down into the Tarkio Limestone Member of the Zeandale Limestone*—Continued

	Feet
Stotler Limestone—Continued	
Dover Limestone Member:	
Limestone; very light gray with green hue, very argillaceous; weathers to rounded pale-yellowish-orange cobbles; abundant fusulinids; many algal deposits (*Cryptozoon*), crinoid stems, horn corals, *Neospirifer*, and *Meekella*	2.7
Thickness of Stotler Limestone	9.2
Pillsbury Shale:	
Siltstone, greenish-gray, massive, micaceous; a few brachiopods about 2.5 ft below top	8.0
Siltstone and claystone, yellowish-gray, interbedded	4.0
Limestone, yellowish-gray, silty or sandy, hard, concretionary	.9
Claystone, siltstone, and sandstone, yellowish-gray, micaceous; claystone is silty	33.2
Covered interval	15.0
Thickness of Pillsbury Shale	61.1
Zeandale Limestone:	
Maple Hill Limestone Member:	
Limestone, pale-yellowish-brown with green areas, clayey, hard, vertically jointed; weathers to single grayish-orange bed; red splotches on upper surface; abundant small fusulinids; many *Osagia*? *Cryptozoon*-like algae, crinoid stems, ramose bryozoans, *Crurithyris*, *Chonetes*, and low- and high-spired gastropods	1.2
Wamego Shale Member:	
Claystone, medium-gray, very slightly silty, finely laminated; weathers very light gray	3.0
Covered interval	11.5
Thickness of Wamego Shale Member	14.5
Tarkio Limestone Member:	
Limestone, hard, vertically jointed; weathers to orange-brown beds about 0.7 ft thick; abundant large fusulinids in relief; many *Cryptozoon*-like algae, crinoid stems, horn corals, *Meekella*, and *Reticulatia;* base not exposed	4.0+
Thickness of exposed Zeandale Limestone	19.7+

11. *Base of the Foraker Limestone down into the West Branch Shale Member of the Janesville Shale*

[In streambank and up hillside immediately west in the center of the N½ sec. 29, T. 13 S., R. 13 E., Wabaunsee County]

	Feet
Foraker Limestone:	
Americus Limestone Member: not measured.	
Janesville Shale:	
Hamlin Shale Member:	
Covered interval; upper contact arbitrarily chosen	32.5
Claystone, olive-gray; weathers light olive gray; abundant round nodules less than 0.04 ft in diameter of argillaceous pyritic limestone that weathers moderate yellowish brown; upper contact not exposed	3.1
Claystone, light-olive-gray, very calcareous; very argillaceous limestone lens locally in upper 2.4 ft; weathers to light-olive-gray outcrop covered with abundant round argillaceous limestone nodules	3.6
Thickness of Hamlin Shale Member	39.2
Five Point Limestone Member:	
Limestone, light-olive-gray, very fine grained, argillaceous, very thin to thin-bedded; a few moderate-brown-weathering pyritic inclusions; weathers light olive gray to light yellowish gray; forms ledge	2.5
Claystone, calcareous; weathers light olive gray; poorly exposed	3.1
Limestone, medium-light-gray to light-olive-gray, very fine grained, moderately argillaceous, thin- to medium-bedded, hard, vertically jointed; weathers light olive gray to light yellowish gray; forms ledge that breaks into large blocks; abundant crinoid stems, ramose bryozoans, *Chonetes*, *Derbyia*, *Reticulatia*, and *Marginifera*; a few trilobites	2.2
Thickness of Five Point Limestone Member	7.8
West Branch Shale Member:	
Claystone (intensely weathered), dark-olive-gray to olive-brown, platy, calcareous; light-olive-gray argillaceous fossiliferous limestone lens as much as 0.25 ft thick and 3 ft long in upper 0.6 ft; shell fragments in upper half	1.3
Claystone, black, very finely laminated; coaly in lower half; much iron enrichment; weathers to medium-dark-gray fissile pieces	.5
Sandstone, light-gray, very fine grained; weathers light olive gray to light olive brown; moderately resistant	.5
Siltstone, light-olive-gray, laminated, micaceous; intercalated with thinner beds of medium-gray silty micaceous claystone; outcrop weathers light olive gray and is stained reddish brown by iron; upper contact gradational; much carbonaceous material on bedding planes	3.4

11. *Base of the Foraker Limestone down into the West Branch Shale Member of the Janesville Shale*—Continued

Janesville Shale —Continued	
West Branch Shale Member—Continued	*Feet*
Limestone, medium-gray, very fine grained to very finely crystalline, slightly argillaceous, hard, dense; platy to very thin bedded in lower 0.6 ft and upper 0.3 ft; rest of unit forms single bed; weathers light olive gray to light olive brown; upper contact gradational; abundant small fragments of brachiopods, pelecypods, and gastropods	3.3
Siltstone, medium-dark-gray, clayey, laminated, micaceous; weathers olive gray to olive brown; olive-gray platy silty fossiliferous limestone layers in upper 0.2 ft; upper contact gradational; abundant brachiopod shells and spines and pelecypods; base not exposed in stream	1.5+
Thickness of exposed West Branch Shale Member	10.5+
Thickness of exposed Janesville Shale	57.5+

12. *Five Point Limestone Member of the Janesville Shale down into the upper part of the Pillsbury Shale*

[Along road from the center of the S½ sec. 2 southward to top of hill in the SW¼NE¼ sec. 11, T. 13 S., R. 13 E., Shawnee County]

Janesville Shale:	
Five Point Limestone Member:	*Feet*
Limestone, olive-gray, argillaceous; abundant shell fragments; poorly exposed; upper contact not exposed	0.2+
Limestone (intensely weathered), dark-yellowish-orange, argillaceous, porous; shell fragments; poorly exposed	.3
Limestone, light-gray, very argillaceous; weathers similar to claystone; very poorly exposed	1.0
Limestone, medium-gray, very fine grained, hard, compact; weathers to light-yellowish-gray granular-appearing plates that contain many holes; upper contact gradational; abundant fusulinids, crinoid stems, ramose, fenestrate, and encrusting bryozoans, and brachiopods (including *Punctospirifer*); some *Osagia*; forms ledge	1.4
Thickness of exposed Five Point Limestone Member	2.9+
West Branch Shale Member:	
Claystone; calcareous in upper 2.3 ft; weathers light olive gray; contains argillaceous limestone beds less than 0.1 ft thick that weather light yellowish gray, and a middle bed 0.5 ft thick of very argillaceous limestone that weathers dark yellowish orange; weathers light olive brown in lower 2.2 ft; abundant very small shell fragments in the limestone beds; poorly exposed	5.0
Coal, black	.1

12. *Five Point Limestone Member of the Janesville Shale down into the upper part of the Pillsbury Shale*—Continued

	Feet
Janesville Shale —Continued	
West Branch Shale Member—Continued	
Sandstone, light-olive-gray, very fine grained, laminated to platy, very micaceous; weathers light olive gray to light olive brown; much iron stain; much carbonaceous material on bedding planes	4.5
Limestone, olive-gray, very silty to finely sandy; very small brachiopod shells and spines	.2
Siltstone, medium-gray, slightly sandy, laminated, micaceous; weathers medium light gray to moderate olive brown	1.4
Sandstone, light-olive-gray, very fine grained, laminated to platy, very micaceous; weathers light olive gray to light olive brown; much iron stain; much carbonaceous material on bedding planes	7.2
Coal (intensely weathered), brownish-black, very clayey	.2
Claystone, light-olive-gray; calcareous except in lower 0.5 ft; very calcareous in upper part; laminated to platy; some thin light-olive-gray argillaceous limestone beds; weathers to a light-olive-gray to light-yellowish-gray outcrop that has a honeycomb appearance owing to vertical joints filled with more resistant claystone	3.7
Limestone, light-olive-gray, very fine grained, very argillaceous; olive-gray platy calcareous claystone partings less than 0.1 ft thick in upper 1.9 ft; partings weather to light-yellowish-orange to light-yellowish-brown platy beds, some of which have honeycomb appearance; weathers to light-yellowish-orange boxwork in lower 1 ft	2.9
Claystone, platy; weathers light olive gray to light olive brown mottled with some medium dark gray and olive gray	1.5
Limestone, very argillaceous; weathers to hard light-yellowish-orange rubble	1.1
Claystone, platy, weathers light olive gray to light olive brown mottled with some medium dark gray and olive gray	2.5
Thickness of West Branch Shale Member	30.3
Thickness of exposed Janesville Shale	33.2
Falls City Limestone:	
Limestone, light-olive-gray, slightly argillaceous, hard, compact; some very thin light-olive-gray claystone partings; weathers to light-olive-gray, dark-yellowish-brown, and olive-brown nodular beds as much as 0.3 ft thick; bryozoans, brachiopods, pelecypods, gastropods; less resistant than underlying bed	1.1
Limestone, light-olive-gray, slightly argillaceous, hard, compact; weathers to single bed that is light olive gray, dark yellowish brown, and olive brown; many gastropods and pelecypods; some fenestrate bryozoans and brachiopods	.6

12. *Five Point Limestone Member of the Janesville Shale down into the upper part of the Pillsbury Shale*—Continued

	Feet
Falls City Limestone—Continued	
Claystone, calcareous; weathers light olive gray; many very small light-yellowish-gray argillaceous limestone nodules; basal contact not exposed	2.0
Thickness of exposed Falls City Limestone	3.7
Lower part of Falls City Limestone, and the Hawxby Shale Member and upper part of Aspinwall Limestone Member of the Onaga Shale:	
Covered interval	23.5
Onaga Shale:	
Aspinwall Limestone Member:	
Claystone, calcareous; weathers light olive gray to light olive brown; contains 5 beds 0.1 to 0.2 ft thick of light-olive-gray argillaceous platy limestone that weathers to light-olive-gray to light-yellowish-gray nodular to platy fragments; some shell fragments in limestone beds	2.7
Limestone, light-olive-gray to light-gray, very finely crystalline, hard, compact; weathers to light-olive-gray to light-yellowish-brown granular blocks that contain small areas of compact very fine grained limestone and many pyritic spots that weather dark brown; abundant very small fossil debris, including many very small white foraminifers(?) or algae	.4
Thickness of exposed Aspinwall Limestone Member	3.1
Towle Shale Member (channel):	
Siltstone and sandstone, interbedded; sandy laminated to platy siltstone interbedded with a lesser amount of very fine grained sandstone; both weather light olive gray to light olive brown; some olive-gray silty platy claystone in lower 5 ft	16.0
Sandstone, medium-light-gray, very calcareous, platy to medium-bedded; crossbedded in lower half; hard; weathers pale yellowish brown; oscillation ripple marks common; carbonaceous fragments on bedding planes; forms ledge	2.2
Partly covered interval; interbedded light-olive-gray micaceous sandstone, claystone, and siltstone; all weather yellowish gray	14.5
Sandstone, medium-light-gray, silty, very calcareous platy to very thin bedded, micaceous; platy interbeds of claystone; weathers pale yellowish brown; closely resembles limestone; oscillation ripple marks; plant fragments	1.4
Sandstone and siltstone, interbedded; light olive gray, platy, micaceous; weather yellowish gray; sandstone is very fine grained; some carbonaceous layers	4.0
Covered interval	7.0

12. *Five Point Limestone Member of the Janesville Shale down into the upper part of the Pillsbury Shale*—Continued

	Feet
Onaga Shale—Continued	
Towle Shale Member (channel)—Continued	
Limestone, very light gray to light-brownish-gray, very finely sandy, partly crossbedded, hard, brittle; conglomerate of ironstone concretions and claystone fragments in limestone matrix in lower 0.5 ft; few interbeds of noncalcareous sandstone; weathers light olive gray; carbonaceous fragments in conglomerate	4.5
Sandstone, dark-yellowish-brown, very fine grained, micaceous, friable; weathers yellowish gray	4.0
Covered interval	7.5
Limestone, very light gray with pink hue, sandy, hard; weathers pale yellowish brown; many round ironstone concretions; a few fragments of gray claystone; poorly exposed	.7
Thickness of exposed Towle Shale Member (channel)	61.8
Thickness of exposed Onaga Shale	64.9
Basal part of Onaga Shale, and possible lower part of Root Shale and upper part of Stotler Limestone:	
Covered interval	27.0
Stotler Limestone:	
Dover Limestone Member:	
Limestone, pale-grayish-orange, interbedded with calcareous claystone; weathers to irregular nodular blocks; varies laterally from very argillaceous to almost pure limestone; crinoid stems and *Reticulatia*	1.5
Limestone, grayish-yellow; some green areas; argillaceous, hard; weathers to a single irregular pale-grayish-orange bed; scattered large fusulinids; many *Cryptozoon*-like algae, crinoid stems, and horn corals	1.7
Thickness of Dover Limestone Member	3.2
Thickness of exposed Stotler Limestone	3.2
Pillsbury Shale:	
Claystone, light-olive-gray, slightly silty; calcareous in upper 0.9 ft; weathers grayish yellow; very fossiliferous in upper 1 ft; a few brachiopods about 3 ft below top; abundant fusulinids; some crinoid stems; a few *Meekella* and *Juresania*; base not exposed	10.0+

13. *Long Creek Limestone Member of the Foraker Limestone down into the upper part of the Hamlin Shale Member of the Janesville Shale*

[Along stream and up hillside immediately west in the NE¼SW¼ sec. 29, T. 13 S., R. 13 E. Wabaunsee County]

Foraker Limestone:	
Long Creek Limestone Member:	*Feet*
Mostly covered interval; light- to moderate-yellowish-brown very fine grained to very finely crystalline argillaceous porous limestone cobbles; scattered fragments of white to moderate-reddish-orange chert, barite, and calcite that probably weathered from the limestone; underlies crest of ridge	5.0+
Hughes Creek Shale Member:	
Mostly covered interval; lower 6 ft is calcareous claystone that weathers light olive gray and contains beds as much as 0.22 ft thick of light-olive-gray argillaceous limestone; many fusulinids and brachiopod fragments in claystone and limestone beds	17.7
Claystone, laminated, calcareous; weathers light olive gray; abundant fusulinids and brachiopods	1.0
Limestone, olive-gray, very fine grained, argillaceous; weathers light olive gray; abundant fusulinids and brachiopods	.6
Claystone, calcareous; weathers olive gray to moderate olive brown; very thin black claystone laminae at base; abundant brachiopod fragments	.2
Limestone, medium-dark-gray, very fine grained; slightly argillaceous, especially in upper 0.2 ft; hard; vertically jointed; weathers to fairly large blocks that are light olive gray mottled with medium dark gray on upper surface; in two beds, the upper of which is 0.6 ft thick; abundant large fusulinids and brachiopods	1.1
Covered interval; probably claystone	9.3
Claystone, very calcareous; weathers light yellowish gray to light olive gray; many beds generally less than 0.1 ft thick (some as much as 0.25 ft thick) of light-olive-gray very fine grained argillaceous limestone; limestone weathers as hard plates mottled light olive gray, olive brown, and dark yellowish orange; abundant fusulinids, crinoid stems, ramose and fenestrate bryozoans, and brachiopods (including *Chonetes, Hustedia, Juresania, Composita, Reticulatia,* and *Meekella*) in claystone and limestone; upper contact not exposed	5.3
Thickness of Hughes Creek Shale Member	35.2
Americus Limestone Member:	
Limestone, medium-light-gray, very fine grained, sparsely pyritic, vertically jointed; weathers to single light-olive-gray to light-gray bed that breaks into blocks as much as 6 ft wide and 20 ft long; blocks slump onto underlying beds; abundant fusulinids and crinoid stems; many very small fragments of brachiopods and fenestrate bryozoans	1.1
Covered interval; probably claystone	2.5

13. *Long Creek Limestone Member of the Foraker Limestone down into the upper part of the Hamlin Shale Member of the Janesville Shale*—Continued

	Feet
Foraker Limestone—Continued	
Americus Limestone Member—Continued	
Limestone, medium-dark-gray, fine-grained, slightly argillaceous; weathers to thin irregular platy granular-appearing fragments that are mottled medium dark gray, light olive gray, and dark yellowish orange; many very small fragments of brachiopods, pelecypods, and very small gastropods(?)	1.0
Claystone, olive-brown, very calcareous, interbedded with very argillaceous limestone of same color; weathered; forms slight reentrant	.1
Limestone, medium-light-gray, very fine grained, moderately argillaceous, thin- to medium-bedded; forms two granular-appearing units that weather light gray; top of lower unit is very argillaceous and weathers yellowish gray to dark yellowish orange; abundant foraminifers(?) and ostracodes in both units; upper 0.8 ft contains well-preserved myalinid pelecypods; lower 0.2 ft contains lobate masses of stromatolites that are olive gray, hard, and dense	1.0
Thickness of Americus Limestone Member	5.7
Thickness of exposed Foraker Limestone	45.9+
Janesville Shale:	
Hamlin Shale Member:	
Mostly covered interval; calcareous silty claystone that weathers dark yellowish orange exposed at base and top	3.3
Limestone, olive-gray, very fine grained, very argillaceous; weathers to light-olive-gray nodular to rubbly bed; forms ledge in gully	2.0
Claystone, greenish-gray to olive-gray, laminated to platy, slightly micaceous; nodules and lenses of light-olive-gray clayey limestone that weathers olive gray to olive brown and porous	2.3
Limestone, very fine grained, very argillaceous; weathers light olive gray and porous; grades laterally to claystone	.5
Claystone, greenish-gray to olive-gray, laminated to platy, slightly micaceous; nodules and lenses generally less than 0.2 ft long of light-olive-gray clayey limestone that weathers olive gray to olive brown and porous	3.3
Siltstone, greenish-gray, laminated, very micaceous; weathers olive gray to light greenish gray; upper contact gradational	.5
Claystone, greenish-gray, very calcareous, laminated; weathers olive gray mottled with moderate yellowish orange; silty platy limestone lenses less than 0.2 ft long; basal contact not exposed in stream	.8+
Thickness of exposed Hamlin Shale Member	12.7
Thickness of exposed Janesville Shale	12.7

14. *Hughes Creek Shale Member of the Foraker Limestone down to the base of the Aspinwall Limestone Member of the Onaga Shale*

[In streambank in the NW¼SE¼ sec. 1, and along adjacent road on the north line of the SE¼ sec. 1, T. 10 S., R. 12 E., and in roadcuts in the SW cor. NW¼ sec. 6, T. 10 S., R. 13 E., Shawnee County]

	Feet
Foraker Limestone:	
Hughes Creek Shale Member:	
Claystone, light-olive-gray; beds less than 0.05 ft thick of clayey limestone that weathers light olive brown; crinoid stems, bryozoans, very small shell fragments; upper contact not exposed	4.5
Limestone, light-olive-gray, very fine grained, silty, very thin to thin-bedded; many crinoid stems, bryozoans, and minute shell fragments; some ostracodes	.7
Claystone, light-olive-gray, calcareous; weathers light grayish yellow to light olive gray; many beds less than 0.05 ft thick of clayey limestone that weathers light olive brown; outcrop has banded appearance on weathering; many crinoid stems, ramose bryozoans, and minute shell fragments	5.3
Limestone, light-olive-gray, very fine grained, silty, very thin to thin-bedded; abundant minute shell fragments	.5
Claystone, light-olive-gray, calcareous; weathers light grayish yellow to light olive gray; abundant oval pellets as much as 0.02 ft long of light-olive-gray limestone; minute fossil fragments	1.0
Limestone, light-olive-gray, very fine grained, silty, very thin to thin-bedded; abundant shell fragments	.7
Claystone, light-olive-gray; weathers light olive gray to light grayish yellow; partly covered	3.8
Limestone, light-olive-gray, very fine grained, silty, very thin bedded, very finely pyritic; beds as much as 0.12 ft thick; abundant minute fossil fragments, foraminifers, crinoid stems, echinoid spines, bryozoans, *Chonetes* and other brachiopods, and productoid spines	1.3
Claystone, light-olive-gray, calcareous; weathers light grayish yellow; many oval pellets as much as 0.02 ft long of light-olive-gray limestone; fusulinids, crinoid stems, ramose bryozoans, and minute shell fragments; partly covered	4.0

E. L. Yochelson (written commun., 1960) identified these following forms from the Hughes Creek Shale Member:

Fusulinids, undet. (USGS colln. f12956)
Chonetes granulifer Owen
Linoproductus sp.
Neospirifer cf. *N. kansasensis* (Swallow)

Thickness of exposed Hughes Creek Shale Member	21.8

14. *Hughes Creek Shale Member of the Foraker Limestone down to the base of the Aspinwall Limestone Member of the Onaga Shale*—Continued

	Feet
Foraker Limestone—Continued	
Americus Limestone Member:	
Limestone, medium-gray, finely crystalline; weathers medium light gray to light olive gray; forms single vertically jointed bed, the upper part of which breaks into thin platy fragments; small light-red barite nodules; abundant crinoid stems, ramose bryozoans, and brachiopods (including *Chonetes*, *Reticulatia*, *Marginifera*?, and *Crurithyris*); fossils weather in relief; forms prominent bench	1.8
Claystone (intensely weathered), pale-yellowish-brown, calcareous; many white to very light gray very argillaceous limestone nodules as much as 0.03 ft long and 0.01 ft thick	.3
Limestone, light-olive-gray to medium-light-gray, very fine grained to very finely crystalline, moderately argillaceous; weathers light gray to light brownish gray; moderately resistant; a few very thin lenses of light-olive-gray calcareous claystone in lower part; upper part appears to be mainly matrix of foraminifers containing many ostracodes; basal 0.1 ft contains lobate masses of medium-gray dense algal deposits (stromatolites) that weather pale yellowish brown and commonly appear striated	.5
Thickness of Americus Limestone Member	2.6
Thickness of exposed Foraker Limestone	24.4
Janesville Shale:	
Hamlin Shale Member:	
Claystone, slightly silty and micaceous, laminated; weathers pale yellowish brown; forms blocky fragments; a few small calcareous siltstone pellets that weather moderate yellowish brown; many plant fragments; partly covered	1.0
Claystone, light-olive-gray, slightly silty; nodules and lenses as much as 0.05 ft thick of light-olive-gray very argillaceous limestone that weathers to hard yellowish-gray to very light gray fragments; partly covered	12.7
Claystone, light-olive-gray, slightly silty	1.9
Thickness of exposed Hamlin Shale Member	15.6
Lower part of Hamlin Shale Member, Five Point Limestone Member, and West Branch Shale Member:	
Covered interval	40.6
Thickness of Janesville Shale	56.2

14. *Hughes Creek Shale Member of the Foraker Limestone down to the base of the Aspinwall Limestone Member of the Onaga Shale*—Continued

	Feet
Falls City Limestone:	
Limestone, light-gray to very light olive gray, fine-grained, slightly micaceous, coquinoidal; lenses less than 0.01 ft thick and 0.1 ft long of very light greenish gray dense limestone; weathers to single light-yellowish-brown bed that has a banded and granular appearance; upper surface weathers irregular, castellated; very small fossil fragments, some recrystallized, including some *Osagia*, crinoid stems, and gastropods	1.7
Claystone, light-olive-gray, calcareous	.2
Limestone, light-olive-gray, very fine grained, silty, slightly micaceous, coquinoidal; weathers to single light-yellowish-brown bed that has indistinct banding and a granular appearance; minute shell fragments, and a few *Osagia* and crinoid stems	1.3
Thickness of Falls City Limestone	3.2
Onaga Shale:	
Hawxby Shale Member:	
Covered interval	1.6
Limestone, dense to very fine grained, argillaceous; weathers to sharp-edged fragments that are moderate yellowish brown to dark yellowish orange; some brachiopod shells and spines	2.1
Covered interval; siliceous sandstone fragments as much as 0.7 ft long; vugs filled with quartz crystals	3.5
Sandstone, very fine grained, very thin bedded, weathers light brown; greenish-gray claystone inclusions as much as 0.01 ft long; upper contact not exposed	.8
Claystone, light-olive-brown, slightly silty, laminated; some brownish-black stain on bedding planes and joints; scattered carbonaceous material	1.9
Limestone, light-olive-gray, very finely crystalline, argillaceous; weathers moderate yellowish brown; abundant gastropods and myalinid pelecypods	.5
Claystone, light-olive-brown, slightly silty, laminated; some brownish-black stain on bedding planes; sparse carbonaceous material	.3
Limestone, light-olive-gray, very fine crystalline, argillaceous; weathers moderate yellowish brown; abundant myalinid pelecypods and gastropods	.1
Claystone, light-olive-brown, slightly silty, laminated; some brownish-black stain on bedding planes	.1
Limestone, light-olive-gray, very fine crystalline, argillaceous; weathers pale yellowish brown; pelecypods and gastropods	.1
Claystone, light-olive-brown, slightly silty, laminated; some brownish-black stain on bedding planes and joints; two light-olive-gray very finely crystalline argillaceous limestone beds less than 0.04 ft thick that weather moderate yellowish brown in upper 0.3 ft; abundant myalinid pelecypods and gastropods in limestone beds; sparse carbonaceous material in claystone	5.7

14. *Hughes Creek Shale Member of the Foraker Limestone down to the base of the Aspinwall Limestone Member of the Onaga Shale*—Continued

	Feet
Onaga Shale—Continued	
E. L. Yochelson (written commun., 1960) identified the following forms from the limestone beds:	
Abundant *Permophorus* sp. indet.	
Glabrocingulum? sp. indet.	
High-spired gastropods	
Thickness of Hawxby Shale Member	16.7
Aspinwall Limestone Member:	
Limestone, light-gray, very fine grained, slightly argillaceous, moderately pyritic; single bed that weathers to smooth plates mottled light gray and light yellowish gray and containing many very small vugs partly filled with pyrite that weathers dark yellowish orange; many minute shell fragments, especially in upper part; some gastropods and ostracodes	2.3
Thickness of exposed Onaga Shale	19.0

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