Stratigraphy and Paleontology of the Uppermost Pennsylvanian and Lowermost Permian Rocks in Kansas

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By MELVILLE R. MUDGE *and* ELLIS L. YOCHELSON

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With sections on paleontology by
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STRATIGRAPHY AND PALEONTOLOGY OF THE UPPERMOST PENNSYLVANIAN AND LOWERMOST PERMIAN ROCKS IN KANSAS

By MELVILLE R. MUDGE and ELLIS L. YOCHELSON

ABSTRACT

This study of the uppermost part of the Pennsylvanian sequence and the lower part of the Permian sequence of rocks in Kansas has been made to describe the several geologic units and to investigate the placement of the systemic boundary. In describing the stratigraphy of the geologic units from the Dover limestone member of the Stotler limestone (upper Pennsylvanian) up to and including the Beattie limestone (lower Permian) particular attention has been given to the lithologic and paleontologic characteristics of each bed as it is traced southward across the State.

The upper Pennsylvanian and lower Permian rocks differ from upper Permian beds in that sandstone, sandy shale, and sandy channel fillings are relatively common. Thin beds of coal are common in the upper part of many of the shale units except those in the Council Grove group. Within this group, coal is found locally in the Eskridge shale. Most lower Permian shale beds are variegated. These variegated beds are generally more abundant in the central and northern outcrop areas; however, in the Council Grove group they are thicker and more abundant in the southern outcrop area.

The formations and members that change considerably in facies from north to south are the limestones called Aspinwall, Falls City, Five Point, Americus, Red Eagle, Grenola, Cottonwood and Morrill, and the shales called Hughes Creek and Bennett. The most noticeable changes are in the Hughes Creek and the Bennett, which are predominantly shale in the northern outcrop area but are limestone in the southern outcrop area.

The Dover and the Americus are redefined. In the southern part of the State the Dover is a single bed of algal limestone rather than 3 beds of limestone and 2 of shale. The Americus is redefined to include 3 beds of limestone in the southern part of the State and 2 beds in the northern part. The lower shale bed pinches out in Wabaunsee County, and the lower limestone bed coalesces with the next younger bed of limestone.

In general, the geologic units thicken as much as 110 feet toward the south. The upper part of the Wabaunsee group thickens about 55 feet toward the south. The Admire group maintains an equal thickness of about 110 feet in the northern and southern outcrop area, but it thickens in the central outcrop area. The rest of the Permian rocks studied thicken as much as 55 feet to the south. Most of this thickening is in the Foraker, Red Eagle, and Grenola limestones.

Marine fossils were systematically collected from all rock units bearing them. The fusulinids in the Brownville through Americus interval were studied extensively by R. C. Douglass. Eight species of fusulinids are described, of which *Triticites brownvillensis* from the Brownville limestone member of the Wood Siding formation and *Pseudofusulina delicata* from the Five Point limestone member of the Janesville shale are new.

Crinoid calyxes were examined by H. L. Strimple. Seven new species are described: *Delocrinus admirensis, D. densus, D. doveri, Endelocrinus rotundus, Oklahomacrinus cirriferous, Aesicrinus prudentia, Graphiocrinus? kansasensis*. The coral fauna is discussed by Helen Duncan. Cephalopods collected are discussed by Mackenzie Gordon, Jr.; vertebrate remains are listed by D. H. Dunkle.

The remainder of the fauna, except for the bryozoans and ostracodes, are listed or discussed. These are primarily brachiopods, with lesser numbers of pelecypods and gastropods. Several new species are noted, but only *Wellerella cooperi* is named. Distribution data are summarized on one chart. Most of the fossils that are discussed are also illustrated.

In spite of these regional changes, most units are of nearly constant thickness locally. Because of this constancy it has been possible to differentiate types of lithologic and paleontologic assemblages. Three main divisions based on fossils are shale and shaly limestone with brachiopods, argillaceous limestone with pelecypods, and limestone and calcareous shale with fusulinids.

There is little evidence that the sediments were agitated and that the fossils were subjected to much transportation. All organisms are believed to have lived in shallow water, but depth is not considered to be a controlling factor in their distribution. Abrupt faunal changes, coupled with lithologic changes, indicate that southern Kansas may have been covered by slightly deeper water than the northern Kansas area.

In the absence of clear agreement on the position of the systemic boundary in the Permian type area of Russia, any boundary established in Kansas must be considered as tentative. Beds above and below the Five Point limestone member of the Janesville shale are of two slightly different types. Channel-sandstone or sheet-sandstone beds are known from shale beds in the Pennsylvanian rocks and in those of the Admire group of the Permian. The distribution of most larger invertebrates is inconclusive as to placement of a boundary anywhere within the interval studied. The boundary has traditionally been placed locally below the oldest occurrence of *Pseudofusulina*, a genus characteristic of the early part of the *Pseudoschwagerina* zone.

Pseudofusulina first appears in the Five Point limestone member of the Janesville shale. As the next older fusulinid fauna that is found in the Brownville limestone member of the Wood Siding formation indicates Pennsylvanian age, the systemic boundary may lie between these two units. Because of this, and the absence of other conclusive evidence, it is recommended that the boundary be placed at the top of the Brownville limestone member of the Wood Siding formation, the boundary commonly accepted by the Kansas, Nebraska, and Oklahoma Geological Surveys for the last 20 years.

INTRODUCTION

The purpose of this study is twofold: to describe the upper part of the Pennsylvanian sequence and the lower part of the Permian sequence of rocks cropping out in Kansas, and to determine if a consistently recognizable paleontologic boundary exists between the two systems as they are defined in Kansas.

The study was started in 1951 after earlier investigations by Mudge showed that a widespread unconformity did not exist between the two systems as defined by the Kansas Geological Survey and that the rocks of the Admire group are more similar lithologically to those of the Wabaunsee group than to those of the Council Grove group. This study, therefore, includes the beds from the Dover limestone member of the Stotler limestone (upper Pennsylvanian) through the Florena shale member of the Beattie limestone (lower Permian). It covers almost all the different positions that have been proposed for the boundary between the 2 systems in the past 40 years. The information and conclusions contained herein are applicable only to Kansas and southeastern Nebraska, but may apply as well in northern Oklahoma. The north half of the outcrop area in Kansas has been studied in detail; the south half has been covered in reconnaissance only, but with special emphasis on detailed stratigraphic correlation of individual beds, their description, and fossil content.

In an attempt to keep facts separated from inferences, the report is divided into four parts: (1) stratigraphy, (2) paleontology, (3) sedimentation and paleoecology, and (4) placement of the systemic boundary. The senior author is responsible for Part 1, the junior author for Part 2, and both authors for Parts 3 and 4. Contributions by Douglass, Dunkle, Gordon, Strimple, and Duncan bear their names. The compilation of this report was completed in June 1954.

In much of the discussion, particularly in Parts 1 and 3, reference is made to northern, southern, and central outcrop areas in Kansas. Lyon County, mainly the northern part, is used as the arbitrary dividing line between the northern and southern outcrop areas. When reference is made to the central outcrop area, it includes Lyon, Chase, Morris, Wabaunsee, northern Greenwood, southeastern Riley, southern Pottawatomie, southwestern Jackson, western Shawnee, and northwestern Osage Counties. (See fig. 1.)

In this study about 400 sections were measured, and 71 are included in the stratigraphic sections. These sections were selected so that at least one nearly complete section is presented for each county along the outcrop area of the upper Pennsylvanian and lower Permian, with the exception of Wabaunsee, Morris, and Nemaha Counties as many of the sections for these counties have already been published by Mudge and Burton (1959), Mudge, Matthews, and Wells (1958) and Mudge, Walters, and Skoog (1959). These sections are also included to give a more detailed description of each unit and to serve as an aid for future field investigations.

ACKNOWLEDGMENTS

We are particularly grateful to those who contributed sections, bearing their names as authors, to Parts 2 and 4. Members of the U. S. Geological Survey who contributed sections are Raymond C. Douglass, Helen Duncan, and Mackenzie Gordon, Jr. Others who contributed sections are Harrell L. Strimple, Bartlesville, Okla., and David H. Dunkle, of the U. S. National Museum. In addition, the authors wish to acknowledge the assistance of G. A. Cooper and J. Brookes Knight, of the U. S. National Museum, and Thomas Dutro, Jr., of the U. S. Geological Survey, for their aid in identifying certain fossils and their suggestions regarding principles involved in this study.

Dr. R. C. Moore, Kansas Geological Survey, and Dr. Frank G. Stehli, California Institute of Technology, lent specimens of the genus *Omphalotrochus* for examination. Dr. Carl O. Dunbar, Yale Peabody Museum, and Dr. Carl C. Branson, University of Oklahoma, provided stratigraphic information as to the occurrence of certain fusulinids.

We are grateful to the various members of the Kansas Geological Survey, especially Mr. Howard G. O'Connor, and to Dr. J. M. Jewett who provided some of the measured sections used in this report. Mr. O'Connor also spent time showing us part of the stratigraphic section in Lyon County.

Mr. Glenn R. Scott, of the U. S. Geological Survey, furnished descriptions of some of the measured sections of Pottawatomie County, Kans., that are used in this report.

The geologic section of the State Highway Commission of Kansas aided us considerably during the early phases of our fieldwork. We are most grateful to the late Mr. S. E. Horner, formerly the chief geologist, and Mr. Virgil Burgat, chief geologist, for their assistance in the field in southern Kansas.

Dr. E. C. Reed, director of the Nebraska Geological Survey, contributed information on the location of the type sections of some of the formations in the Admire group. This and other data pertaining to these rocks were most helpful in our studies in northern Kansas.

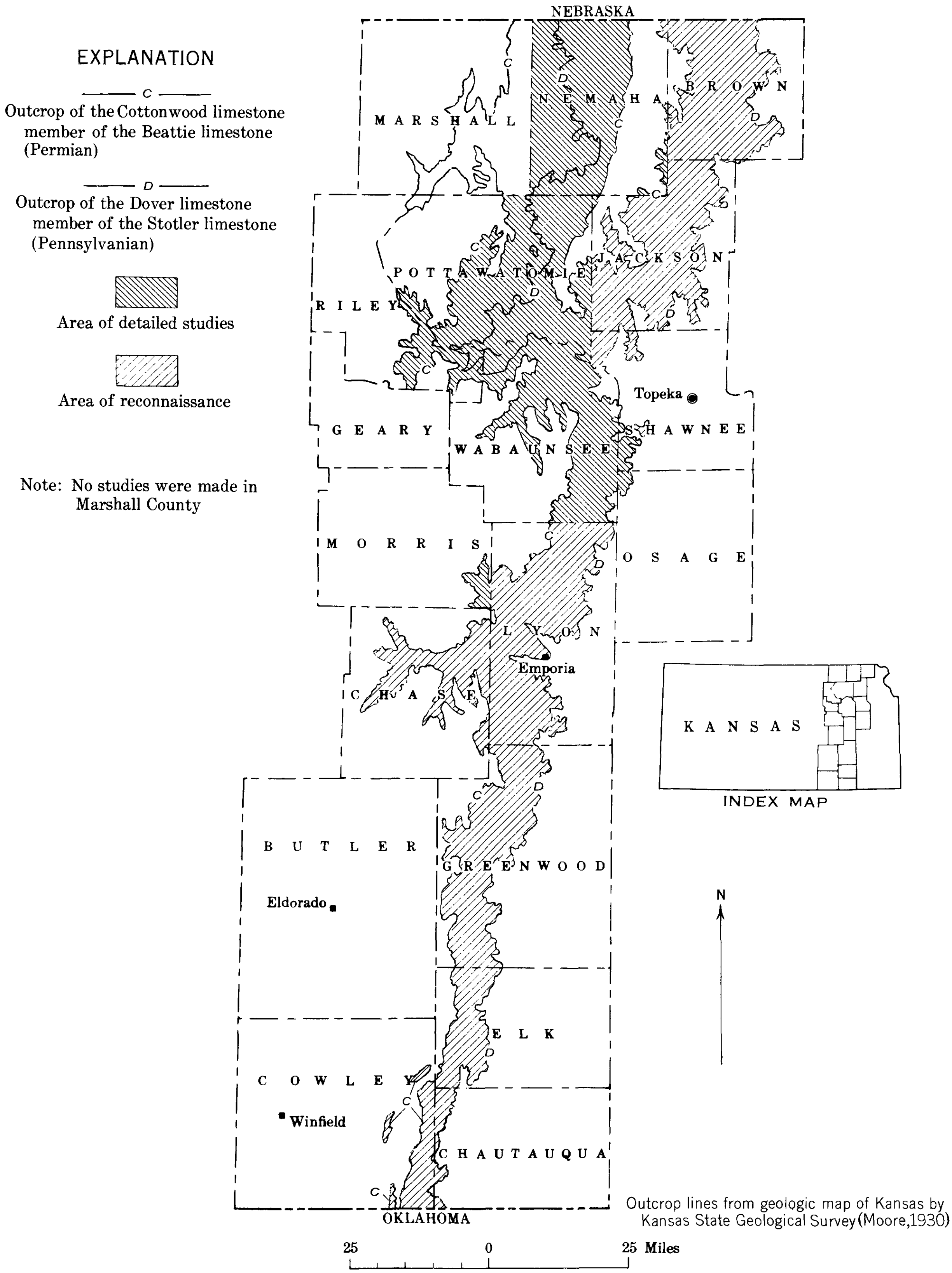

FIGURE 1.—Index map of east half of Kansas showing area studied and the outcrops of the Cottonwood limestone member of the Beattie limestone (Permian) and the Dover limestone member of the Stotler limestone (Pennsylvanian) that essentially mark the upper and lower boundaries of this investigation.

PART 1. STRATIGRAPHY

The rocks of the upper part of the Pennsylvanian system and the lower part of the Permian system are unique in that some units less than a foot thick can be correlated from southeastern Nebraska into Oklahoma (see fig. 2). The upper Pennsylvanian rocks in particular display very little lithologic or paleontologic change along their outcrop in Kansas. The rocks of the Admire group (lower Permian) are the most difficult to correlate from the north, as they change both lithologically and paleontologically. Lack of good exposures presents another difficulty in studying these rocks; much of the outcrop area of the group is covered by colluvium and loess. Also, along most of the outcrop area of the Admire group, the limestone beds do not form prominent hillside benches.

The younger of the lower Permian rocks are well exposed. Many of them form characteristic hillside benches that make them easily identifiable from a distance or on aerial photographs. In the southern outcrop area the most prominent hillside bench is that of the chert-bearing Foraker limestone which forms part of the eastward-facing Flint Hills escarpment (fig. 16). Above the Foraker limestone, other prominent hillside benches are formed by limestone beds of the Red Eagle, Neva, and Morrill. Northward the benches of the Foraker, Red Eagle, and Morrill become less distinctive, and north of Greenwood and Lyon Counties they are not very conspicuous. The limestone units of the Foraker and Red Eagle grade northward into shale facies and do not form prominent benches; the Morrill thins northward and becomes soft limestone. Northward from Greenwood and Lyon Counties the major escarpment is that of the chert-bearing Wreford limestone (about 150 feet above the Morrill). In the northern outcrop area limestone units such as the Dover, Brownville, Five Point, Americus, Neva, and Cottonwood form hillside benches that are distinctive and easily recognized.

North of the Kansas River all the rocks are poorly exposed except in parts of Pottawatomie County. Large quantities of glacial drift and postglacial loess mantle much of the northeastern part of Kansas.

The major geologic structures in the area are the Forest City basin, Bourbon arch, Cherokee basin and Nemaha anticline. These structures are described by Jewett (1951, p. 105–172), and are not discussed in this paper. The Nemaha anticline as well as many of the smaller anticlines are important in that they provide a wider outcrop area of certain units, especially in Pottawatomie County and, locally, in eastern Cowley County (fig. 1).

This section on stratigraphy includes descriptions and correlations of each formation, member, and, where necessary, individual beds. The genera that are characteristic of the formation, member, or bed are included.

Where possible the members and formations have been correlated with their type section. Some of the type sections cannot be precisely located, and certain units were identified by their description and stratigraphic position as given by publications of the Kansas and Nebraska Geological Surveys. Where the correlation of a unit from north to south is problematical, the uncertainty that exists is expressed in the discussion of that unit.

PENNSYLVANIAN SYSTEM

VIRGIL SERIES

WABAUNSEE GROUP

The Wabaunsee group consists of about 500 feet of strata (Moore and others, 1951, p. 58) of which about the upper 90 to 145 feet is discussed in this report. This upper part of the Wabaunsee group differs from the older Pennsylvanian rocks in that most of the limestone units are thinner. The shale formations and members in the upper part of the Wabaunsee group are similar to those below in that they are mostly olive drab or gray and contain local beds of sandstone, sandy shale, coal, or channel deposits.

The limestone units of the upper part of the Wabaunsee group differ from the Permian limestone units in that their lithology and thickness remain almost constant along their outcrop in Kansas, whereas the Permian limestone units show a considerable change (pls. 2–5). In general there is little paleontologic change in the uppermost part of the Wabaunsee group.

The Pennsylvanian rocks, from the Dover limestone up through the Brownville limestone member of the Wood Siding formation, range in thickness from about 90 feet in the northern outcrop area to as much as 145 feet in the southern outcrop area.

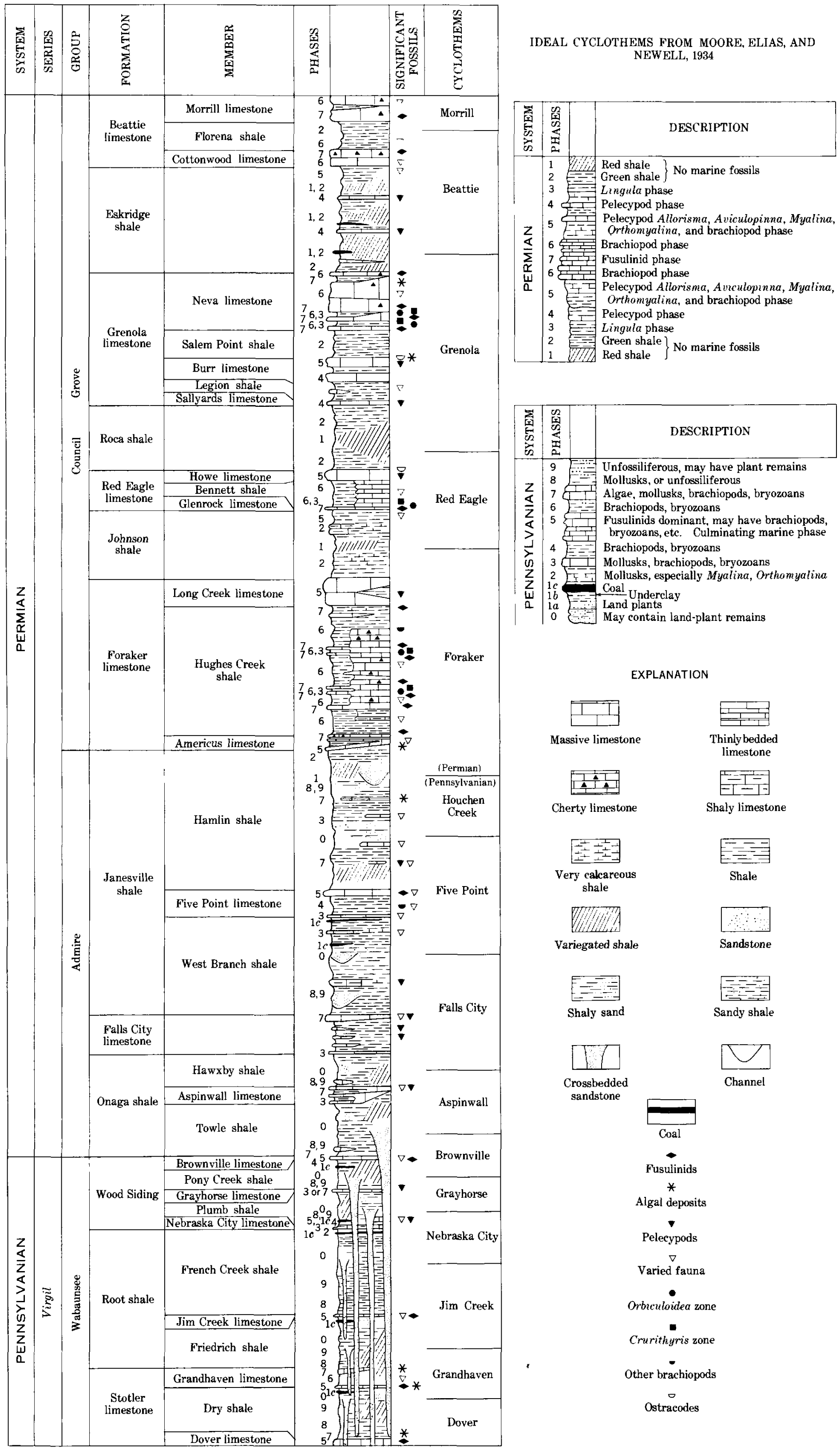

Figure 2.—Generalized diagram of the geologic units studied, and data on cyclic sedimentation.

STOTLER LIMESTONE

The Stotler limestone was named by Moore and Mudge (1956, p. 2275) after the abandoned Stotler post office, which was located in the SW¼ sec. 10, T. 16 S., R. 13 E., Lyon County. The type section is in the SE¼ sec. 13, T. 16 S., R. 12 E., in the spillway along the south side of a pond. Here the Stotler limestone is about 20 feet thick. A maximum thickness of 33 feet was measured in northern Greenwood County. It thins both north and south of this area to about 6 feet in northern Pottawatomie County and to 8 feet in Chautauqua County.

The Stotler limestone consists of three members, which are, in ascending order, the Dover limestone, the Dry shale, and the Grandhaven limestone members. These units were formerly classified as formations (Moore and others, 1951, p. 59).

DOVER LIMESTONE MEMBER

The Dover limestone member is the oldest stratigraphic unit studied in detail. It is considered by many geologists to be a key horizon as it is easily recognized along all its outcrop from Nebraska to Oklahoma. It overlies the Pillsbury shale and underlies the Dry shale member. The Dover limestone member was named by Beede (1898, p. 31) as the limestone unit between his Dover shale and sandstone, below, and his Rossville shales and sandstone, above. Its type locality is in the vicinity of Dover, Shawnee County, Kans. (Moore, 1936, p. 235). Here the Dover limestone member is poorly exposed, but it can be studied in a road-cut exposure on Kansas Highway 10 in the SW¼SW¼ sec. 28, T. 11 S., R. 13 E., Wabaunsee County.

In southern Kansas, a unit ranging from 15 to 20 feet in total thickness and consisting of 3 beds of limestone separated by 2 relatively thick beds of shale has been called the Dover limestone (Moore, 1949, p. 190–191). Moore describes the lowermost bed as fine-grained blue limestone with a varied fauna of bryozoans, brachiopods, and pelecypods. It lies a few feet below a fusulinid-bearing bed considered as the middle limestone bed. The uppermost bed is described as limestone containing algal deposits.

Plate 1 shows the correlation of this fivefold so-called Dover unit northward into Lyon and Wabaunsee Counties. Our studies indicate that only the upper bed (containing algal deposits) is correlative with the Dover limestone member of the northern outcrop area. The middle limestone bed of Moore's fivefold Dover unit is correlative toward the north with the Maple Hill limestone member of the Zeandale limestone. The lowest bed is correlated to the north with a marl bed in the Wamego shale member of the Zeandale limestone that pinches out in northern Lyon County. A fossiliferous shale underlying Moore's fivefold Dover was correlated into southeastern Wabaunsee County; the coal bed beneath the shale persists into central Lyon County. The Stormont limestone of O'Connor (1953, p. 19), which underlies the coal bed in Greenwood and Lyon Counties, crops out in southeastern Wabaunsee County and according to H. G. O'Connor (oral communication, 1954) is also exposed in Osage County. In Elk County, a marl unit is at the stratigraphic position of O'Connor's Stormont limestone and is likely correlative with it. In Elk County the next oldest limestone, about 4 feet beneath the Stormont, was tentatively identified as the Elmont limestone member of the Emporia limestone. Our studies on the problem of the Dover limestone member did not include the beds beneath O'Connor's Stormont limestone. The Tarkio limestone member below the Wamego shale member apparently does not extend further south than northern Lyon County (Moore, 1936, p. 230–231). (See pl. 1.)

Throughout Kansas the Dover limestone member is generally one bed of gray limestone that is massive but that weathers blocky to nodular (pls. 2, 3). Locally in Wabaunsee and northwestern Shawnee Counties the Dover is composed of two beds of limestone separated by a very calcareous shale bed. The lower bed of limestone correlates with the Dover elsewhere in Kansas and is characterized by two particular types of fossils: large fusulinids (*Triticites* sp.) in the lower part, and large and small masses of algal deposits, *Cryptozoon*? and *Osagia*?, in the upper part.

The Dover limestone member is characteristically medium gray and weathers light gray. Locally in Pottawatomie and Nemaha Counties it weathers brown and resembles the Tarkio limestone member of the Zeandale limestone. Comparing these two fusulinid-bearing limestone units, Moore (1949, p. 191) states that the Dover is generally much softer than the Tarkio and that *Cryptozoon*? growths are rare or absent in the Tarkio. The weathered exposures of the two limestone units are also quite different. The Tarkio limestone member generally weathers in large angular blocks, whereas the Dover limestone member weathers into small round blocks, nodules, and irregular plates.

In Wabaunsee, Shawnee, Jackson, and part of Nemaha Counties the Dover limestone member is gray brown to gray. In Lyon (O'Connor, 1953, p. 18) and Riley Counties the freshly broken surface of this limestone generally has a greenish tint. O'Connor stated that in Lyon County, the Dover "occurs as massive limestone, silty and sandy somewhat impure limestone, or as a limy sandstone in various outcrops." Locally in northeastern Lyon County the Dover rests on an erosion surface cut in beds of sandstone in the Pillsbury shale.

A fauna of this limestone is listed in table 1.

In northern and southern Wabaunsee County (pl. 2) and northern Shawnee County the Dover consists of 2 beds of limestone separated by a thin (0.6–1.1 ft) bed of shale. The lower bed of limestone is described on page 6. The bed of shale, in northern Wabaunsee County, is gray, silty, and very calcareous and grades both upward and downward into limestone. In northern Pottawatomie County this bed is nonfossiliferous, gray green, and clayey. The upper limestone bed is medium hard and light gray and generally weathers into small nodules and irregular plates. In southern Wabaunsee County this bed is very thin (0.4 ft), brown, and conglomeratic. It contains rounded limonite and clay balls that are as much as one-eighth inch in diameter. Here, fossil fragments are very abundant and fusulinids are common.

Throughout the State, the Dover forms a small hillside bench that is marked by either a line of light-gray subrounded blocks or small nodules and irregular fragments of light-gray fusulinid-bearing limestone. The stromatolite *Cryptozoon*? weathers lighter in color and almost completely free from its limestone matrix. Where there are two beds of limestone separated by a bed of shale, the lower bed of limestone forms the hillside bench; the upper bed erodes further back on the hillside and is generally covered by talus and soil.

In the northern part of the State the Dover limestone member averages 3.5 feet in thickness, whereas in the southern part it averages 1.6 feet. It ranges from 1.2 feet in thickness in Wabaunsee County to 5.9 feet in Shawnee County. It thins somewhat to the northeast but thickens locally to about 6.0 feet in northern Nemaha County. Where there are two limestone beds separated by a bed of shale, the lower bed of limestone is somewhat thicker than the upper. (See pls. 1–3.) (See measured sections 58, 113, 283, 291, 323, 324, 325, 335, 346, 350, and 370.)

DRY SHALE MEMBER

The Dry shale member was named by Moore, Elias, and Newell (1934) for exposures on Dry Creek, southwest of Emporia, Kans., in sec. 5, T. 20 S., R. 11 E. Moore (1936, p. 236) describes the Dry shale member as

> bluish-gray and clayey for the most part, but sandy beds appear in places. A thin coal bed occurs near the top of the Dry shale in southern Kansas, the coal and sandy beds belong to the Grandhaven cyclothem. The shale between the top of the coal and the base of the Grandhaven limestone is locally rich in marine fossils, calcareous brachiopods and bryozoans being dominant.

The Dry shale member overlies the Dover limestone member and underlies the Grandhaven limestone member. Moore (1949, p. 191) states that

> The Dry shale is a well-defined stratigraphic unit from Shawnee County, Kansas, southward to the Oklahoma line, but northward it coalesces with the Friedrich shale above the Grandhaven limestone, for the Grandhaven disappears.

He designates the resulting thick shale bed as the Dry-Friedrich shale. A thin limestone unit identified as the Grandhaven limestone member was observed by the authors at several places in Pottawatomie County where a thin representative of the Dry shale member separates it from the Dover limestone member (pl. 3). In Nemaha County, this part of the section is generally covered. Inasmuch as the Dry shale member thins northward, it is assumed that it pinches out further northward and that the Grandhaven limestone member directly overlies the Dover limestone member.

The Dry shale member is generally eroded back on hillsides to form a steep slope between the Grandhaven and Dover limestone members. This member is poorly exposed in the southern part of the State and in Nemaha and Brown Counties.

The Dry shale member is silty to clayey but in some places contains beds of sandy shale and sandstone. It is mainly gray thin-bedded shale, but parts of it vary from gray green to gray brown to blue gray. In Lyon County, O'Connor (1953, p. 17) observed beds of dark-red and green shale in some exposures of the Dry shale member. Locally variegated beds are present in Pottawatomie County.

In Wabaunsee, Lyon, Chautauqua, and Elk Counties, beds of sandstone and sandy shale are locally abundant. In northeastern Wabaunsee County, beds of sandstone and sandy shale are present in the upper part of the Dry shale member. Here the sandstone is iron cemented and contains, in addition to grains of quartz and mica, nodules and concretions of limonite. In southern Lyon County, O'Connor (1953, p. 17) found beds of sandstone filling deep channels that originate in the Dry shale member and extend down into the Wamego-Willard shale sequence. In Chautauqua and Elk Counties, beds of sandstone and sandy shale are present in the middle and lower parts of the member. The sand consists of subrounded grains of quartz and minute flakes of mica that are cemented by calcium carbonate and iron. (See pls. 2, 3.)

In the SE¼SW¼ sec. 30, T. 11 S., R. 12 E., Wabaunsee County, the uppermost part of the Dry shale member is silty and calcareous and grades laterally into a limestone bed 1.0 foot thick. The upper part of the limestone contains an intraformational conglomerate composed of angular, somewhat flattened fragments of limestone. These fragments are as much as ¼ inch in diameter, but most are about ⅛ inch.

In Lyon County, O'Connor (1953, p. 17) noted a thin fossiliferous bed of limestone (0.8 ft) in the lower part of the Dry shale member overlying a thin bed of fossiliferous shale. These beds persist southward throughout most of Greenwood County. (See pl. 2.) The limestone is dark gray, somewhat crystalline, and massive, and it weathers into irregular blocks with well-rounded corners.

In southern Kansas, the upper part of the Dry shale member consists of beds of fossiliferous shale (containing mostly brachiopods and bryozoans) underlain by a thin bed of coal (pl. 2). These beds were also seen in parts of Lyon County by O'Connor (1953, p. 17). In Riley County, these fossiliferous shale beds are found in only the extreme southeastern exposures. The bed of coal was not seen north of Lyon County, and the fossiliferous shale is absent elsewhere in the northern outcrop area.

The bed of coal rarely exceeds 0.5 foot in thickness, and it lies 1.5 to 3.0 feet beneath the Grandhaven limestone member. The coal is clayey and black and varies from blocky to fissile.

In southeastern Riley and southern Greenwood Counties a lens of gastropod- and pelecypod-bearing limestone occurs in the middle part of the member. In southern Greenwood County this lens lies about 7 feet beneath the Grandhaven limestone member. O'Connor (1953, p. 17) lists a limestone unit in the upper part of the Dry shale member in Lyon County. He states, "Frequently 5 to 10 feet from the top there is a yellow-brown or gray siltstone or cross-bedded algal and molluscan limestone." He also lists (1953, p. 17) another very fossiliferous limestone bed about 0.8 foot thick that is about 5 feet from the base of the member and that, together with the underlying 1 to 2 feet of shale, contains an abundance of brachiopods, crinoid columnals, and bryozoans.

In the center of the SW¼ sec. 32, T. 10 S., R. 9 E., Riley County, the shale bed above the Dover limestone member contains the same fauna as the limestone. This is very likely a transitional facies of the Dover limestone member into the Dry shale member.

The thickness of the Dry shale member is quite variable and ranges from 0 feet in northern Pottawatomie County to about 26 feet in Lyon County as reported by O'Connor (1953, p. 17) and 31 feet in Greenwood County (pls. 2, 3). In Wabaunsee County it ranges in thickness from 23.1 feet to 5.5 feet. In Pottawatomie County it thickens southward from a featheredge to about 2 feet. This general southward thickening is also apparent in the southeastern part of Riley County where a maximum thickness of 10.4 feet is attained. In northern Jackson County it is about 2 feet thick. In northern Greenwood County the Dry shale member is about 31 feet thick, but it thins southward to about 6 feet in Chautauqua County. (See measured sections 25, 58, 113, 323, 324, 325, 346, 350, and 370.)

GRANDHAVEN LIMESTONE MEMBER

The Grandhaven limestone member was named by Moore, Elias, and Newell (1934) for exposures in sec. 31, T. 13 S., R. 14 E., near Grandhaven, Shawnee County, Kans. (Moore, 1936, p. 237). Moore (1936, p. 237) defines this unit as commonly two beds of limestone separated by a few feet of shale. The lower limestone bed contains fusulinids, whereas the upper limestone contains algal deposits.

The Grandhaven overlies the Dry shale member and underlies the Friedrich shale member of the Root shale. Previously, this limestone was not recognized north of the Kansas River (Moore, 1949, p. 192). In this report, available evidence, although meager, extends the Grandhaven limestone member into northern Pottawatomie County. (See pl. 3.) It is possible that in Nemaha County the Grandhaven lies directly on the Dover limestone member.

In northeastern Jackson County, there is a limestone bed about 2.0 feet above the Dover limestone member. As it is very similar to the Grandhaven lithologically and paleontologically, it is called the Grandhaven(?) limestone member in this report. In Jackson and northern Shawnee Counties detailed investigation will be necessary to determine the areal extent of the Grandhaven limestone member.

The Grandhaven varies from two beds of limestone separated by a thin bed of shale, to a single bed of limestone. The two beds of limestone are in Lyon, northern Greenwood, Riley, and southern Pottawatomie Counties (fig. 3 and pls. 2, 3). The following description of this member is by units as listed in figure 4.

Unit 1 (fig. 3), the lower bed of limestone, persists from northern Pottawatomie and Jackson Counties into Oklahoma. This bed is almost always hard medium- to dark-gray limestone that weathers brown and in irregular blocks. In Riley County it is gray with a greenish tint. The upper surface of the bed is generally covered by a thin crust of limonite, and iron stain has impregnated the upper 1 to 2 inches. This weathering phenomenon was also seen in older lime-

FIGURE 3.—Exposures of the Grandhaven limestone member of the Stotler limestone exposed in a ditch in the SE¼SW¼ sec. 8, T. 23 S., R. 11 E., Greenwood County, Kans.

stone units of similar thickness and lithology, notably in the Maple Hill limestone member of the Zeandale limestone and in the Elmont and Reading limestone members of the Emporia limestone. Locally, within the Grandhaven limestone member, there are small nodules of limonite. In the northern outcrop area, unit 1 contains an abundance of crinoid columnals, some as much as three-fourths of an inch in diameter. They weather white and are readily distinguished from the brown weathered matrix. South of Wabaunsee County the most characteristic fossil is *Aviculopinna;*

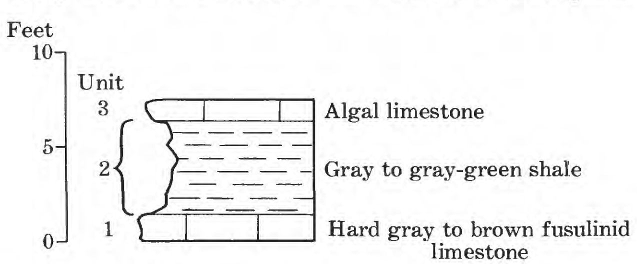

FIGURE 4.—A generalized diagram of the Grandhaven limestone member of the Stotler limestone in an exposure in the central outcrop area. Only unit 1 can be recognized outside this area.

some specimens are as much as 15 inches long. Other common fossils are stromatolites (*Osagia*?), fusulinids, brachiopods, pelecypods, and bryozoans. The abundance of any one of these groups varies considerably from one exposure to another.

Unit 2 is the intervening bed of shale. Where the upper limestone is absent, this shale is regarded as part of the Friedrich shale member of the Root shale. Unit 2 is present in Lyon, northern Greenwood, Riley, and southern Pottawatomie Counties. In southeastern Riley County, unit 2 is gray-green clayey noncalcareous shale. In Pottawatomie County this shale is dark gray, silty, and calcareous and contains fusulinids (Scott, Foster, and Crumpton, 1959). O'Connor (1953, p. 17) states that in Lyon County

> the middle beds are mostly gray, yellow, or green, silty or calcareous shales but locally red shale or brownish-green sandy micaceous shale occurs between the limestones.

The variegated beds have not been seen elsewhere in the State. At the north edge of Emporia, Lyon County, O'Connor (oral communication, 1954) found an assemblage of small gastropods, pelecypods, and brachiopods in the bed of shale overlying the lower bed of limestone.

Unit 3, the upper limestone, is present only locally along the outcrop area of the Grandhaven limestone member. It persists in parts of Lyon, northern Greenwood, southeastern Riley, and southern Pottawatomie Counties. This bed is very lenticular and varies from relatively soft to medium hard. In Riley County, unit 3 is gray to gray green and massive and weathers into small blocks with rounded corners and into small irregular plates and chips. It contains crinoid columnals, fusulinids, and brachiopods, the fossils weathering lighter than the matrix. In Pottawatomie County this bed contains the same fauna as in Lyon County. Moore (1949, p. 192) noted that locally this bed is strongly crossbedded. In Lyon County, O'Connor (1953, p. 17) noted that this bed is light gray, tan, or buff, weathers nearly white in most exposures, and is locally crossbedded. In it he observed stromatolites (*Osagia?*), pelecypods, bryozoans, brachiopods, and crinoid columnals. In northern Greenwood County this bed forms a prominent hillside bench and resembles conglomerate because of the abundance of small, almost symmetrical, nodules of algal deposits.

The Grandhaven limestone member generally forms a small yet distinctive hillside bench about 8 to 31 feet above the Dover limestone member. The bench formed by the Grandhaven limestone member generally is not a protruding rock ledge but is covered by small fragments of limestone. This bench is easily distinguishable from others on the hillside because the limestone fragments weather brown rather than the light gray that is characteristic of the limestone above and below it. Where present, the upper bed of limestone forms a small hillside bench.

The Grandhaven limestone member, where a single bed, averages about 1.5 feet in thickness. Unit 1 ranges from about 3 feet in thickness in Lyon County to 0.8 foot in Wabaunsee County. Unit 2 is reported by Moore (1949, p. 192) to be as much as 10 feet thick. In Riley County this bed is 2.1 feet thick, and it thins to 0.9 foot in central Pottawatomie County. Unit 3 in Lyon County ranges from 1 to more than 8 feet in thickness (O'Connor, 1953, p. 17). In Riley County it is about 1.2 feet thick, whereas in Pottawatomie County it rarely exceeds 0.7 foot. (See pls. 2, 3; measured sections 25, 58, 113, 323, 324, 325, 339, 346, 350, and 370.)

ROOT SHALE

The Root shale was named by Moore and Mudge (1956, p. 2275) after the Root station of the Atchison, Topeka and Santa Fe railway in the SE¼ sec. 23, T. 21 S., R. 11 E., Lyon County. The type section is exposed in a bank along an eastward-flowing stream near the center of the N½SE¼ sec. 20, T. 21 S., R. 11 E. (see section 370 in "Stratigraphic Sections"). Here the French Creek shale member is poorly exposed. It is completely exposed south of this area in road cuts in the NW¼NE¼ sec. 7, T. 22 S., R. 11 E., Greenwood County (see section 71 in "Stratigraphic Sections"). The Root shale varies considerably in thickness and ranges from 86 feet in thickness in Chautauqua County to 35 feet in northern Pottawatomie and Lyon Counties. It is as much as 65 feet thick in Jackson County and 50 feet thick in Wabaunsee County. The variation in thickness is in the shale members.

The Root shale is composed of three members which are, in ascending order, the Friedrich shale, the Jim Creek limestone, and the French Creek shale members. These units were formerly classified as formations by Moore and others (1951, p. 58).

FRIEDRICH SHALE MEMBER

The Friedrich shale member was named by Moore, Elias, and Newell (1934) for exposures on Friedrich Creek, sec. 6, T. 22 S., R. 11 E., Greenwood County, Kans. (Moore, 1936, p. 238. Moore describes this shale as including

> clayey and sandy beds that lie between the Grandhaven and Jim Creek limestones. The unweathered shale is chiefly bluish-gray, but outcrops of weathered shale commonly appear yellowish or brownish. Locally there is sandstone in the upper part of this zone and at least in southern Greenwood County a thin coal bed appears a little below the Jim Creek limestone. *Myalina* and other pelecypods, and some brachiopods, bryozoans and other marine fossils appear near the top of the Friedrich shale, but in some outcrops fossils are rare or absent.

The Friedrich shale member is poorly exposed along most of its outcrop area. This is due in part to the nonresistant character of the overlying Jim Creek limestone member. Between the Grandhaven limestone member of the Stotler limestone and the Grayhorse limestone member of the Wood Siding formation, the hillside slopes are gentle and they are almost invariably mantled with loess and colluvium.

Locally in the north half of the outcrop area the Friedrich shale member contains thin variegated beds, mainly maroon and green, which were not observed in the southern outcrop area. In Wabaunsee County it is silty to clayey, and it grades northward into clay shale. In the southern part of the State the Friedrich shale member is mostly silty calcareous shale.

Many exposures in the southern part of the State contain beds of sandy shale and thick- to thin-bedded sandstone. Locally these beds were seen in the northern part of the State. O'Connor (1953, p. 17) reports a channel sandstone unit in this member in Lyon County. He states that these sandstone-filled channels are 25 feet or more thick and cut nearly to the Dover limestone member of the Stotler limestone. A channel was seen in the upper part of this shale in the SE¼SW¼ sec. 16, T. 26 S., R. 9 E., Greenwood County. In northern Greenwood County the lower part of this shale is very sandy and has many thin beds of dark-brown sandstone. The upper part of this shale contains thick beds of massive to crossbedded sandstone in southwestern Elk County. A sandstone bed in the SW¼SW¼ sec. 22, T. 32 S., R. 8 E., Chautauqua County, contains mostly rounded to subrounded grains of quartz and flakes of muscovite but also secondary calcite, biotite, chlorite, garnet, and opaque minerals in small quantities.

A calcium carbonate cemented bed of sandstone with ripple marks is exposed in a road cut in the NW¼SW¼ sec. 16, T. 10 S., R. 13 E., Shawnee County. A sample of the bed shows that this sandstone is similar to that of Chautauqua County except that it also contains tourmaline and zircon. About 75 percent of the heavy minerals is opaque.

Moore (1949, p. 193) reports a thin coal bed a few feet below the base of the Jim Creek limestone member in Greenwood County. It has been observed in west-central Greenwood County, and Verville[1] reports it in Elk County. This coal was not seen elsewhere in the Friedrich shale member, although carbonaceous shale with wood and leaf fragments is commonly associated with the sandstone.

In many of the exposures in the northern outcrop area there is a thin (1.0±ft) bed of fossiliferous gray shale in the upper part of the member. The fossils are mainly brachiopods and crinoid columnals. In northern Nemaha County perfectly preserved fossils are very abundant in a thin lens in the lower part of this member. Crinoid columnals and a variety of brachiopods, pelecypods, and bryozoans were seen. Crinoid columnals are also common in the shale beneath this lens. Verville[1] lists fossils in the bed of shale that is beneath the Jim Creek limestone member in Elk County, and he also reports thin pelecypod-bearing limestone beds in the lower part of the Friedrich shale member (1951, p. 158).

Locally in northern Wabaunsee County a thin soft light-brown impure bed of limestone is present in the upper part; in the southern part of the county a similar bed of limestone is present in the lower part. Both beds are nonfossiliferous and lenticular.

[1] Verville, G. J., 1951, Pennsylvanian and Permian stratigraphy of Elk County, Kansas: Wisconsin Univ., Ph.D. thesis, p. 158.

In the upper part of this member in Lyon County, O'Connor (1953, p. 16–17) noted a conglomerate unit of shale and limestone pebbles. In the NE¼NE¼ sec. 28, T. 29 S., R. 9 E., Elk County, conglomeratic limestone is present in the middle part of this member; it contains fragments of fossils, coal, and small rounded clay balls in a matrix of sandy limestone.

This member attains a maximum thickness of 47 feet in Chautauqua County. It thins northward to 8 feet in Lyon County; however, in this county the channel facies is at least 25 feet thick (O'Connor, 1953, p. 17). In Nemaha County this member is slightly over 22 feet thick. (See pls. 2, 3; measured sections 25, 33, 58, 104, 113, 114, 323, 324, 325, 338, 339, 350, and 370.)

JIM CREEK LIMESTONE MEMBER

The Jim Creek limestone member was named by Moore, Elias, and Newell (1934) for an exposure on Jim Creek, sec. 29, T. 7 S., R. 11 E., Pottawatomie County, Kans. (Moore, 1936, p. 239). Moore (1936, p. 240) describes this limestone as

> fine-grained, hard and bluish-gray or bluish in fresh exposure. The weathered rock is commonly brown and gray and in most cases there are reddish or purplish tones. The bed appears as a single massive layer that is vertically jointed, but on prolonged weathering there is a tendency for the rock to break down in small shelly chips. A large variety of marine fossils, including especially brachiopods, bryozoans and pelecypods, is found in the Jim Creek limestone in some places.

The Jim Creek is a thin but fairly persistent limestone unit that extends from Nebraska to Oklahoma. It overlies the Friedrich shale member and underlies the French Creek shale member.

The Jim Creek limestone member is massive and hard to medium hard in fresh exposures, but characteristically weathers in small blocks and irregular chips or plates. Locally it is very hard and dense. It is generally medium to dark gray, but locally it is gray brown to brown; it weathers tan to light gray. In Nemaha County it is gray to gray green. Many unweathered surfaces have a purplish tint that was not observed in any of the other beds of limestone in the upper part of the Pennsylvanian system. In many exposures in Pottawatomie and Shawnee Counties this bed is mottled or tinted with green. In most exposures there is a 1- to 2-inch brown weathered zone of limonite encrusted on the top of the bed. In west-central Greenwood County this limestone is absent. It is not known whether it grades into shale, pinches out, or has been eroded in a channel originating in the overlying French Creek shale member.

A diversified fauna is almost invariably present in this unit. Crinoid columnals, brachiopods, pelecypods, and small fusulinids are found in most exposures, and

Chonetes, *Derbyia*, and *Aviculopinna* are the most common. Bryozoans and gastropods are common. Small solitary corals were observed in Wabaunsee County.

The Jim Creek limestone member averages 1.0 foot in thickness. In Pottawatomie County it ranges from 0.3 foot to 2.3 feet in thickness. Here a very calcareous fossiliferous shale unit 1.3 feet thick overlies the 0.3-foot limestone, and it has the same fauna as the limestone. The shale is very likely a facies of the limestone. In Lyon (O'Connor, 1953, p. 16), Wabaunsee, and Jackson Counties this member is as thin as 0.5 foot, but south of Lyon County it ranges from 1.0 to 1.9 feet in thickness. (See measured sections 25, 33, 58, 71, 104, 113, 114, 323, 324, 325, 338, 339, 350, and 370.)

FRENCH CREEK SHALE MEMBER

The French Creek shale member was named by Moore, Elias, and Newell (1934) for exposures on French Creek, Pottawatomie County, Kans. (Moore, 1936, p. 40). Scott, Foster, and Crumpton (1959, p. 114) did not find this member exposed along French Creek. They listed a good exposure in the SE¼NW¼ sec. 28, T. 6 S., R. 12 E., Pottawatomie County. Moore (1936, p. 240) describes this shale as "bluish-gray or yellowish-brown in color, and clayey to sandy in texture. The upper part commonly contains some light brownish or tan sandstone which may be fairly hard, thick and massive." The French Creek shale member is one of the thickest shales of the Upper Pennsylvanian rocks examined in this study. This member overlies the Jim Creek limestone member and underlies the Nebraska City limestone member of the Wood Siding formation.

Generally only the upper part of the French Creek shale member is exposed along the outcrop. The middle and lower parts are exposed only in road cuts, ditches, and in streambanks.

The French Creek shale member is almost invariably bluish gray to gray brown and weathers tan to light brownish gray. It is mainly silty shale with minute flakes of mica on bedding and fracture planes. Limonite nodules and limonite-stained plates are common to very abundant in most exposures and are most noticeable on the weathered surface of the shale.

The upper bed of shale is generally silty, although locally it is clayey or sandy. It varies from brown to gray. This bed of shale ranges from a featheredge in the northern outcrop area to as much as 5 feet in thickness in the southern outcrop area. In many places the overlying Nebraska City limestone member of the Wood Siding formation rests directly on the Lorton coal bed.

A thin persistent bed of coal called the Lorton coal is at or near the top of this member (Moore, 1936, p. 240). In the northern part of the State the coal is apparently absent only where it was eroded by channeling in a younger unit. South of Lyon County the coal bed is lenticular. The coal is of subbituminous grade, is generally blocky to thin bedded, and rarely contains lentils of clay. In some places thin underclay underlies the bed of coal. The coal ranges from 0 to 1 foot in thickness. Schoewe (1946, p. 93) reports an observed thickness of 11 inches in Greenwood County. Here it has been mined locally and he quotes a reported thickness of 37 inches of coal in this bed. In Lyon County, Schoewe (1946, p. 101–102) observed this bed of coal to range from 5 to 12 inches in thickness, and where it has been mined it is reported to be as much as 20 inches thick. Such thicknesses as 20 or 37 inches are either exaggerated or must represent very local thickening, as nowhere was this bed observed to be more than 12 inches thick. This bed of coal is generally thicker than the others in the Upper Pennsylvanian rocks covered in detail in this report.

Another bed of coal occurs in the upper part of the French Creek shale member in Lyon (O'Connor, 1953, p. 16), northern Wabaunsee, central Jackson, northern Pottawatomie, and northern Nemaha Counties. It lies about 2 to 8 feet beneath the Lorton coal.

In northern Pottawatomie and central Jackson Counties a very calcareous shale bed persists between the two beds of coal (pls. 2, 3). In northern Nemaha County a bed of limestone 1.6 feet thick lies between the coal beds. This limestone is medium hard and gray to gray brown and weathers shaly. No other limestone units were observed within this member.

The beds of shale beneath the Lorton coal are generally silty to clayey, calcareous, and gray to gray brown. They weather tan to tan gray. Beds of sandy shale and sandstone are generally present. Locally clay or silt beds grade up into sandy shale and sandstone. Crossbedding and ripple marks are generally in the beds of massive sandstone. Some of these beds appear to represent scour and fill.

Channels of French Creek age are exposed in Jackson, Pottawatomie, Wabaunsee, Lyon, and Elk Counties. A channel filled with sandstone and sandy shale was observed in the NW¼SW¼SW¼ sec. 31, T 6 S., R. 15 S., Jackson County. Here, channel sandstone beds rest disconformably on beds of gray clayey shale. Because the base of this channel is 30.3 feet from the base of the Nebraska City limestone member of the Wood Siding formation, it is assumed that it also cuts into the upper part of the Friedrich shale member. In northeastern Jackson County, massive to thin-bedded sandstone beds, some crossbedded, fill a channel which extends down into the Friedrich shale member to a depth of about 30 feet. In Lyon County, Jewett and O'Connor (1951, p. 11) observed sandstone-filled channels that extend down about 40 feet into the underlying Friedrich shale member. Other small intraformational channels are common in the beds underlying the Lorton coal. These were seen in Lyon, Wabaunsee, Jackson, and Pottawatomie Counties. Verville [2] reports evidence of channeling at the base of sandstone beds in sec. 18, T. 31 S., R. 9 E., and in sec. 3, T. 30 S., R. 9 E., Elk County.

Wood and plant fragments and carbon stains are common in all of the beds of sandstone and most of the beds of sandy shale.

Locally, fossils are present in certain beds in the French Creek shale member. In Nemaha County thin white-shelled pelecypods were seen in a bed of shale that is about 8 feet from the base of the member. Here the bed of limestone, between the coal beds, contains crinoid columnals and gastropods. In south-central Pottawatomie County, brachiopods occur in the bed of shale that underlies the Nebraska City limestone member of the Wood Siding formation. In southeastern Wabaunsee County the bed of shale that overlies the second bed of coal contains crinoid columnals, brachiopods, and pelecypods. In northern Pottawatomie County the shale between the two beds of coal contains brachiopods and bryozoans. In Elk County fossils occur in the beds of shale that lie about 10 feet above the base of the member.[3]

The French Creek shale member averages about 25 feet in thickness. A maximum thickness of 44 feet was observed in Greenwood County and a minimum of 15.3 feet was seen in Pottawatomie County. Along the rest of the outcrop the member ranges from 21 to 30 feet in thickness. In Lyon County a channel facies is 40 feet thick (O'Connor, 1953, p. 16). The channel fill in Jackson County is 30 feet thick. (See pls. 2, 3; measured sections 25, 28, 58, 65, 71, 104, 113, 114, 323, 324, 328, 338, 339, 350, and 353.)

WOOD SIDING FORMATION

The name Wood Siding formation, after the Wood Siding station, Nemaha County, Nebr., was originally proposed by Condra and Reed (1943, p. 41, 43) to include what are now beds from the base of the Brownville limestone member of the Wood Siding formation down to the base of the Nebraska City limestone member of the Wood Siding formation. Moore and Mudge (1956, p. 2273–2275) redefined the formation to include the Brownville limestone member, making the Wood Siding the uppermost formation in the Pennsylvanian system. The type locality is in the Missouri River bluff, south of the Wood Siding station and on the Chicago, Burlington and Quincy Railroad. The Wood Siding formation ranges in thickness from about 50 feet in Chautauqua County to 11 feet in Pottawatomie County. North of Lyon County it averages about 22 feet in thickness; south of that county it averages about 40 feet.

The Wood Siding formation consists of five members, which are, in ascending order, the Nebraska City limestone, the Plumb shale, the Grayhorse limestone, the Pony Creek shale, and the Brownville limestone members. Formerly the upper two units have been considered formations. The other units were members in the Caneyville limestone of Moore (1936), a name rejected by Moore and Mudge (1956, p. 2273–2274).

NEBRASKA CITY LIMESTONE MEMBER

The Nebraska City limestone member was named by Condra (1927, p. 116), probably for exposures in a clay pit southeast of Nebraska City, Nebr.

The Nebraska City limestone member is generally well exposed with the exception of those areas where it is cut by channels filled with the Plumb shale member or younger shale formations.

The Nebraska City varies from massive hard limestone to soft shaly limestone to very calcareous shale. There must have been a very delicate balance in the quantity of calcium carbonate present during the deposition of this bed, as within a lateral distance of about 20 feet it varies from hard limestone to very calcareous shale. In a single exposure, part of it is calcareous shale and the rest is medium-hard limestone —one grading laterally or vertically into the other.

In the north half of the State the Nebraska City is almost invariably dark-gray limestone, and it is readily identified by its brachiopod fauna. In the southern part of the State it is mostly a relatively hard massive tan-brown limestone unit resembling the Grandhaven limestone member of the Stotler limestone. Locally, however, it grades laterally into very calcareous shale. In the southern part of the State it contains crinoid stems, bryozoans, *Derbyia*, *Chonetes*, *Neospirifer*, and *Myalina* (*Orthomyalina*).

The Nebraska City almost invariably weathers into small irregular shaly blocks and chips. Exposures are

[2] Op. cit., p. 161. (See footnote, p. 11.)

[3] Verville, G. J., op. cit., p. 161. (See footnote, p. 11.)

generally restricted to ditches, streambanks, and road cuts.

The Nebraska City limestone member varies considerably in thickness along its outcrop. Where shaly it is as much as 4.4 feet thick, but generally does not exceed 2.5 feet in thickness. It averages about 1 foot in thickness. (See measured sections 28, 58, 65, 71, 104, 113, 114, 323, 324, 328, 339, 350, and 353.)

PLUMB SHALE MEMBER

The Plumb shale member was named by Mudge and Burton (1959, p. 34–35) for exposures in a road cut in the SW¼SE¼SE¼ sec. 30, T. 14 S., R. 13 E., Plumb Township, southeastern Wabaunsee County, Kans. It includes those beds of shale that lie between the Grayhorse and Nebraska City limestone members.

The Plumb shale member is variable lithologically and in thickness. Where the Grayhorse limestone member is absent, this shale cannot easily be distinguished from the overlying Pony Creek shale member.

The Plumb shale member is commonly a clayey shale, but locally it is silty or sandy and contains beds of sandstone. It is mostly gray, but in many exposures in the northern part of Kansas it also contains beds of maroon, green, or gray-green shale.

North of Lyon County the Plumb shale member contains many beds of sandstone, sandy shale, conglomerate, and conglomeratic shale, and some fill deep channels. The beds of sandstone and sandy shale that are not part of a channel fill are lenticular and generally cannot be correlated from one section to another.

The channels of this shale member have been described by Mudge (1956, p. 663–666), but will be briefly mentioned here. These channels were observed in Wabaunsee, western Shawnee, southeastern Riley, western Jackson, and Elk Counties. All the channels except one in western Jackson County extend beneath the member boundary.

Locally the channel fill can arbitrarily be subdivided into three parts: massive beds of sandstone and sandy shale in the lower part; sandy shale, crossbedded sandstone, and some silty to clayey shale in the middle part with thin interfingering beds of sandstone and conglomerate; and silty and clayey shale in the upper part with some interfingering beds of sandy shale, sandstone, and conglomeratic shale.

The best exposure of channel sandstone is in a streambank in the NW¼SW¼ sec. 3, T. 13 S., R. 13 E., Wabaunsee County (fig. 5). Here, the conclusion was reached by Mudge (1956, p. 665) that a channel of the Towle shale member of the Onaga shale, filled with a deposit known as the Indian Cave channel sandstone bed, is incised in a channel deposit of the Plumb shale member. The base of the younger channel is marked by conglomerate. The evidence of channels of two different ages is that (a) a channel of the Plumb shale that trends toward this location is exposed less than one-fourth mile to the west, and (b) the conglomerate in the channel that truncates the underlying beds contains fragments of the Brownville limestone member. As an alternate explanation, the whole exposure may be of Towle age, and a second period of degradation may have eroded part of the channel fill and adjacent areas, thus obtaining additional fragments of the Brownville limestone member. The evidence at hand, although meager, supports the first explanation.

In most of the exposures in the northern part of the State, the thin conglomerate beds in the Plumb shale member appear to be either within the channels or marginal to them. Toward the south very lenticular thin conglomerate beds are present in the upper part of this shale, but they cannot be associated with a channel.

In southern Lyon and northern Greenwood Counties there is a thin bed of limestone in the lower part of this member. It is hard, gray to tan brown, and massive and locally weathers into blocks with conchoidal fractures. It contains fusulinids, crinoid columnals, bryozoans, *Derbyia*, *Marginifera*, *Meekella*, *Chonetes*, *Crurithyris*, *Dictyoclostus*, and *Composita*. The fusulinids vary from rare to common from one outcrop to another. Moore (1949, p. 195) observed this fusulinid-bearing limestone in Chautauqua County. He lists the fusulinids as belonging to the genus *Triticites*.

In southern Wabaunsee County the lower part of the Plumb shale member contains a thin bed of coal.

The thickness of the Plumb shale member is variable. In areas not containing channel facies, this member rarely exceeds 20 feet in thickness and may be as little as 7 feet. It averages 10 feet in thickness in the northern outcrop area but thickens slightly toward the south to an average of about 16 feet. In Elk County, Verville[4] reports this shale as ranging from 17 to 30 feet in thickness. (See measured sections 28, 33, 65, 71, 94, 104, 113, 323, 328, 338, and 353.)

GRAYHORSE LIMESTONE MEMBER

The Grayhorse limestone member was named by Bowen (1918, p. 138) for exposures on the crest of Little Grayhorse anticline, in the NW¼ sec. 11, T. 24 N., R. 6 E., Osage County, Okla. Condra and Reed (1943, p. 41) noted that the Grayhorse limestone member was not persistent in Nebraska and classified all the units from the base of the Brownville to the base of the

[4] Op. cit., p. 163. (See footnote, p. 11.)

FIGURE 5.—Channel sandstone beds in a streambank (Echo Cliff) in the NW¼SW¼ sec. 3, T. 13 S., R. 13 E., Wabaunsee County, Kans. The conglomerate (arrow) in the upper part is probably the basal conglomerate of a channel of Towle age. The beds of sandstone and sandy shale in the lower 40 feet are in a channel of Plumb age.

Nebraska City as their Wood Siding formation. Moore and Mudge (1956, p. 2273–2275) accepted the name Wood Siding formation, but added to the unit the Brownville limestone member. In the northern outcrop area the Grayhorse is present only in the southern part of Pottawatomie and Jackson Counties and in the northern part of Jackson and Nemaha Counties. Elsewhere in the State it appears to be persistent, with the exception of small areas in southern Lyon and northern Greenwood Counties. In these areas there are a few thin pelecypod-bearing limestone beds that are very likely correlative to the Grayhorse.

The Grayhorse limestone member varies lithologically somewhat from north to south. In the northern and central part of the outcrop area it is almost invariably hard grayish-brown conglomeratic limestone. It contains rounded to angular, somewhat flat fragments of limestone, iron (siderite or limonite), and clay balls that commonly do not exceed half an inch in diameter. Locally, however, the particles are as much as 1½ inches in diameter. These were noted in the NW¼SW¼SW¼ sec. 13, T. 16 S., R. 12 E., Lyon County, and in the NW¼NW¼ sec. 16, T. 9 S., R. 9 E., Pottawatomie County.

In the southern part of the State, in Elk and Greenwood Counties, the limestone is locally conglomeratic. It varies from medium-hard light-brown semicrystalline massive limestone to gray platy sandy limestone. Where it is sandy, faint bedding planes and crossbedding are apparent. The conglomerate beds of the Grayhorse appear to be intraformational as they contain mostly limestone fragments that are generally flattened and somewhat angular. Iron nodules and clay balls are also present. The weathered surface of the limestone is light brown. The Grayhorse limestone member generally weathers in small blocks and irregular plates.

In southern Lyon and northern Greenwood Counties there is a group of thin beds of hard, dense gray nodular pelecypodal limestone, one or more of which are very likely correlative with the Grayhorse limestone member. They resemble the pelecypod-bearing limestone beds of the Falls City limestone, but their stratigraphic position, about 10 feet beneath the Brownville limestone member, indicates that they correlate with the Grayhorse limestone member.

In Kansas the most characteristic fossil in this member is the pelecypod *Myalina* (*Orthomyalina*). Although not seen in every exposure, it is distinctive for this bed, as this fossil was rarely observed in the limestone beds immediately above or below this member. Fragments of fossils are abundant in almost every exposure of the limestone. Fusulinids, although quite rare, were observed in the NW¼NW¼ sec. 26, T. 26 S., R. 9 E., Greenwood County.

The Grayhorse limestone member rarely forms a hillside bench except in Greenwood and Wabaunsee Counties. In northern Wabaunsee County it fractures into rectangular blocks as much as 4 feet in maximum dimension.

The Grayhorse limestone member averages about 0.8 foot in thickness. In Wabaunsee County it attains a maximum thickness of 2.8 feet, and in many places it is as thin as 0.2 foot. (See measured sections 65, 71, 94, and 338.)

PONY CREEK SHALE MEMBER

The Pony Creek shale member is the youngest shale unit of the Pennsylvanian system as described by Moore and others (1951, p. 58). It was named by Condra (1927, p. 81) for exposures east of Pony Creek, 2 miles south of Falls City, Nebr., where it overlies the Grayhorse limestone member and underlies the Brownville limestone member. In the northern part of Kansas where the Grayhorse limestone member is absent, the Pony Creek shale member cannot be distinguished from the Plumb shale member, as in this area the two members are similar lithologically.

The Pony Creek shale member varies from silty variegated shale in the northern outcrop area to clayey gray shale in the southern part. Locally it also contains beds of sandstone, sandy shale, conglomerate, channel sandstone and shale, and coal.

In the outcrop area north of Lyon County, the Pony Creek shale member varies considerably lithologically. In Pottawatomie and Nemaha Counties the member generally contains beds of maroon shale in the middle part. The red beds are generally mottled with green and the green beds are commonly mottled with red. East of these areas, maroon shale is locally present in Jackson and Brown Counties. In the southern part of Jackson County the maroon shale beds generally occur in the middle part of the member, but elsewhere in the northern outcrop area and at the type locality in Nebraska they are in the lower part (Condra and Reed, 1943, p. 43). In Wabaunsee County the Pony Creek is mainly clayey noncalcareous gray to gray-brown shale. Beds of maroon, green, and gray-green shale occur locally in the middle part of this unit in the southern part of the county and become more abundant in the northern part. The upper part of the shale normally weathers tan to tan gray, and the middle and lower parts are stained maroon.

South of Wabaunsee County maroon shale was not observed in this member. In the southern part of the State the shale is mostly clayey and gray, gray green, or tan gray. Only locally in this area are there beds of sandstone or sandy and silty shale.

In the northern outcrop area, beds of sandy shale and sandstone are common within this member. They are generally thin lenses, but locally in northwestern Wabaunsee, southeastern Riley, Pottawatomie, and northern Brown Counties they are part of the fill material in a channel.

Channels of Pony Creek age are exposed in Wabaunsee, Riley, Pottawatomie, and Brown Counties. Many of these channels have been described by Mudge (1956, p. 666–668); therefore, they are discussed only briefly here. The channel in the Pony Creek shale member observed in the NE¼NE¼ sec. 6, T. 2 S., R. 17 E., Brown County, originates about 7 feet beneath the Brownville limestone member. It appears to be less than 1.5 miles wide and trends southwest. The fill material is mainly iron-stained beds of micaceous sandstone and sandy shale. Crossbedding, ripple marks, limonite nodules, and concretions are common in the fill material. Other beds of massive sandstone, very likely a part of this channel, are exposed in stream and road cuts both north and southwest of this section.

Many channels of Pony Creek age are present in Pottawatomie County, and it is assumed that most of these are part of one drainage system (Mudge, 1956, p. 676). A part of a channel is well exposed in a streambank in the NW¼NW¼ sec. 16, T. 9 S., R. 9 E., Pottawatomie County. Figure 6, a sketch of the stream cut, shows the upper west bank of the channel.[5] The top of the channel at this exposure was truncated before the deposition of the Brownville limestone member, which lies unconformably on the shale and sandstone that fill the channel (pl. 3). The channel extends down through the upper half of the Plumb shale member, and its exact depth is not known. If much of the channel sandstone in the area west of Wamego is Pony Creek in age and possibly part of the same channel, as postulated by Mudge (1956, p. 668, 669), then

[5] This streambank was first visited in 1950, at which time all the bedrock was completely exposed. It was revisited in 1956 and much of the bedrock was covered by colluvium.

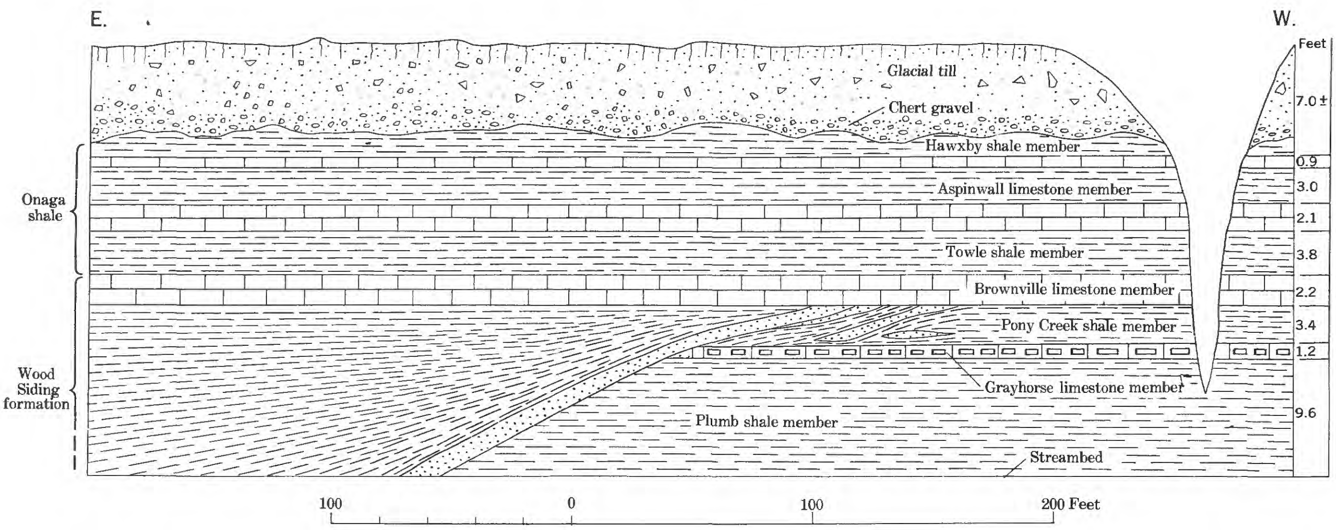

FIGURE 6.—Channel facies of Pony Creek shale member of the Wood Siding formation exposed in a streambank in NW¼NW¼ sec. 16, T. 9 S., R. 9 E., Pottawatomie County, Kans.

this channel is about 140 feet deep and extends down into the Willard shale, which underlies the Zeandale limestone. The channel does not exceed half a mile in width, and it has a southeasterly trend.

Another Pony Creek channel is well exposed in the central part of Pottawatomie County. The upper contact of this channel is 2 to 3 feet beneath the Brownville limestone member. This channel is about 3.5 miles in width, trends southeast, and extends to a depth of about 50 feet, which is to the lower part of the Dry shale member of the Stotler limestone. The fill within the channel is primarily silty to clayey shale that is slightly sandy. Thin lenses of sandstone and sandy shale are present in the upper part of this channel fill along its southwest margin. Thin conglomerate is found at the top and at the contact of the southwestern flank. The upper part of the channel near the northeastern flank is mainly light-brown thin- to thick-bedded sandstone and interbedded sandy shale. Thick beds of prominently crossbedded sandstone are more abundant in the upper part.

Another prominent channel of the Pony Creek age is exposed in the streambanks and road cuts in the SE¼SW¼ sec. 18 and in the NE¼NW¼ sec. 19, T. 7 S., R. 11 E., Pottawatomie County. The position of the top of this channel is not known. The channel extends to the Maple Hill limestone member of the Zeandale limestone on both of the flanks, but in the middle, a smaller channel is cut through the Maple Hill. Many sandstone concretions occur south of the stream in the NW¼NE¼ sec. 19, T. 7 S., R. 11 E. These concretions have weathered from the basal channel sandstone beds of the Pony Creek, and wind erosion has accentuated the crossbedding. The general trend of this channel appears to be southeastward.

The channel in northwestern Wabaunsee County very likely extends west into Riley County, where a similar channel is exposed. In the SE¼NW¼ sec. 7, T. 11 S., R. 10 E., Wabaunsee County, 56.2 feet of shale is exposed beneath the Brownville limestone member. The shale is clayey to sandy with thin lenses of sandstone and many septarian concretions, some as large as 4 feet in diameter. Some of the concretions contain marine fossils in their outer crust. This would indicate that the origin of at least part of the channel fill is marine. The shale beds overlying these concretions are mostly gray to olive-drab and sandy, similar to those found by Lins (1950, p. 24) in the channels of the Tonganoxie sandstone member of the Stranger formation which is the part of the Pennsylvanian system below the Wabaunsee group. West in Riley County, this channel is exposed in the NW¼NE¼ sec. 9, T. 11 S., R. 9 E. Beneath the Brownville limestone member there is 12.6 feet of clayey gray shale that overlies 21.3 feet of sandstone which is thin to massively bedded and, in part, crossbedded. The beds of sandstone are very micaceous and contain asymmetrical ripple marks and carbon and iron stains. This channel trends east and extends down to within about 10 feet of the Grandhaven limestone member of the Stotler limestone. The channel very likely does not exceed 2½ miles in width.

A channel filled with sandstone and sandy shale in the SW¼NW¼NE¼ sec. 18, T. 34 S., R. 8 E., Cowley County, is very likely Pony Creek in age. Although the exposures are not complete, channel sandstone beds crop out about 20 feet beneath the Brownville limestone member. Other massive crossbedded sandstone beds about 60 feet beneath the Brownville limestone member and exposed in road cuts and streambanks may be part of the same channel. Detailed fieldwork in this part of Cowley County and in an adjacent part of Chautauqua County would be necessary to determine the precise age of the channels in this area.

Locally, in Wabaunsee and Pottawatomie Counties, thin conglomerate beds are present in the upper part of the Pony Creek shale member. In most places they can not be definitely associated with channels. The conglomerate consists of small rounded to subangular limonitic, clayey, and siliceous nodules in a lime matrix.

Beds of coal are present locally in the upper part of the Pony Creek shale member in southern Wabaunsee County and in Lyon County (O'Connor, 1953, p. 16). A thin bed of coal lies about 10 feet beneath the Brownville limestone member in southern Elk and northern Chautauqua Counties.

In many places where the Pony Creek is exposed, there is a thin bed of tan-gray shale in the uppermost part of the member that contains a fauna not seen in any of the shale beds in this part of the section. The brachiopod *Chonetes* is generally abundant, and *Marginifera* and other fossils are common. The fauna is similar to that of the overlying Brownville limestone member. Toward the south this bed was seen in only a few places. This bed ranges from 1 inch to as much as 3 feet in thickness.

The Pony Creek shale member averages 8.8 feet in thickness. In the northern part of the outcrop area it rarely exceeds 8 feet, but it thickens gradually toward the south to a maximum thickness of about 25 feet in northern Chautauqua County. In Wabaunsee County this shale exceeds 10 feet in thickness in only a few places. O'Connor (1953, p. 16) noted that in Lyon County it averaged 10 feet in thickness in the northern part and 11 feet in the southern part. From southern Lyon County to Chautauqua County the member averages 14 feet in thickness and is rarely less than 10 feet. A minimum thickness of 3.4 feet was observed in Pottawatomie County.

The discussion of thicknesses given above does not cover the sections of the Pony Creek-Plumb shale sequence in parts of Pottawatomie and Jackson Counties where the Grayhorse limestone member is absent. Here the 2 shale units are combined, and the interval from the base of the Brownville limestone member to the top of the Nebraska City limestone member ranges from about 7 to 23 feet in thickness. (See measured sections 25, 28, 34, 60, 65, 69, 71, 94, 104, 113, 114, 187, 213, 323, 324, 338, and 353.)

BROWNVILLE LIMESTONE MEMBER

The Brownville limestone member was named by Condra and Bengston (1915, p. 17) for exposures in the bluffs along the Missouri River just south of Brownville, Nemaha County, Nebr. Condra and Bengston (1915, p. 17), in describing this limestone, state: "Thickness, 2 feet 6 inches to 6 feet. Color, light bluish green, weathering lighter. The upper part of the stone is somewhat nodular, the lower part massive." An exposure of this limestone, possibly the type section, is in the NW¼SE¼ sec. 19, T. 5 N., R. 16 E., Nemaha County, Nebr.

The Brownville limestone member is a very good marker bed because it is persistent and easily identified. This limestone was selected by Moore (1936, p. 244) as the youngest bed of limestone in the Pennsylvanian system. It overlies the Pony Creek shale member and underlies the Towle shale member of the Onaga shale.

The Brownville generally is medium-hard gray-brown to bluish-gray limestone that weathers distinctively light to dark brown and in 0.3- to 1.0+-foot blocks with rounded corners. Locally, however, this member is two beds of limestone separated by a thin very calcareous shale bed. It is commonly a fine-grained

FIGURE 7.—The Aspinwall limestone member of the Onaga shale down through the Pony Creek shale member of the Wood Siding formation in the SW¼ sec. 26, T. 11 S., R. 12 E., Wabaunsee County, Kans. *a*, Aspinwall limestone; two limestone beds and intervening shale. *b*, Towle shale member of Onaga shale; 10.5 ft thick. *c*, Brownville limestone member of the Wood Siding formation; limestone overlain by red beds of shale; 2.5 ft thick. *d*, Pony Creek shale member of the Wood Siding formation; 7.5 ft thick. *e*, Grayhorse limestone member; base not exposed. (See measured section 80, pl. 2.)

locally dense silty limestone. In the southern part of the State, however, the limestone is somewhat harder and finer grained than toward the north. (See figs. 7, 8.) In many exposures in the northern outcrop area it has a gray-green tint.

The Brownville limestone member forms a small hillside bench in Kansas. It is more apparent in the northern outcrop area than in the southern. In the southern outcrop area this limestone weathers in large light- to medium-brown blocks (fig. 8). Toward the north it generally weathers in small rounded tan-brown blocks and much of it is covered with red stains derived from the overlying red beds of the Towle shale member of the Onaga shale.

The diagnostic fauna of the Brownville is *Chonetes granulifer* Owen and *Marginifera wabashensis* (Norwood and Pratten) in the northern outcrop area, and *Marginifera* and fusulinids in the southern outcrop area. The fusulinids diminish northward and are very rare in Pottawatomie County. A variety of other fossils is also found in this limestone (see table 1, in pocket).

The Brownville limestone member averages 2.2 feet in thickness. Its maximum thickness is 4.5 feet in northwestern Wabaunsee County, whereas a minimum thickness of 1.1 feet was measured in Elk County. In general this limestone unit is somewhat thicker in the northwest than in the south. (See measured sections 25, 28, 34, 52, 60, 65, 69, 71, 73, 94, 104, 113, 114, 187, 213, 323, 324, 328, 338, and 353.)

PERMIAN SYSTEM

ADMIRE GROUP

The Admire group consists of the lowermost part of the Permian system as defined in Kansas by Moore and others (1951, p. 49). Lithologically this group of rocks is more similar to those of the Pennsylvanian system than to the rest of the rocks in the Permian system. The group consists mainly of thick beds of shale with some beds of sandstone, sandy shale, coal, and channel deposits. Most of the beds of limestone resemble those of the upper part of the Pennsylvanian system in that they are thin and in many places are tan brown to brown.

This group of rocks is the most difficult in this study to correlate from the type sections in Nebraska to southern Kansas. The rocks vary considerably lith-

FIGURE 8.—Brownville limestone member of the Wood Siding formation in the NE¼ sec. 14, T. 31 S., R. 8 E., Elk County, Kans. The small white objects protruding from the limestones are crinoid columnals.

ologically and in thickness and somewhat in paleontology. In most areas this group is poorly exposed and is partly or wholly covered with colluvium, loess, or other Quaternary deposits.

This group of rocks ranges from about 100 to 130 feet in thickness and averages about 112 feet. It is thickest in the central outcrop area.

ONAGA SHALE

The Onaga shale was named by Moore and Mudge (1956, p. 2273, 2274) after the city of Onaga, northern Pottawatomie County, Kans. The type section is in an east-west road cut in the SW¼SW¼ sec. 2, T. 8 S., R. 10 E. It includes those strata between the Falls City limestone above, and the Wood Siding formation below. The Onaga shale varies in thickness from one county to another. Its minimum thickness is 16 feet, in southwestern Pottawatomie County; its maximum is 41 feet, in Greenwood County; and its average is 26 feet. The most notable change in thickness is in a westerly direction. For example in eastern Wabaunsee County the Onaga is about 35 feet thick. Westward in southeastern Riley County it is about 17 feet thick. In southern Jackson County the Onaga shale is 28 feet thick, and westward in southwestern Pottawatomie County it is 16 feet thick.

The Onaga shale consists of three members, which are, in ascending order, the Towle shale, the Aspinwall limestone, and the Hawxby shale members. These members were classified as formations by Moore and others (1951, p. 52).

TOWLE SHALE MEMBER

The Towle shale member was named by Moore and Condra (1932). The type section is on the Towle farm, 2 miles south and 3 miles west of Falls City, in the SW¼ sec. 20, T. 1 N., R. 16 E., Richardson County, Nebr. (Wilmarth, 1938, p. 2173). Condra (1935, p. 9) described it in a cross section from Forest City to Dubois, Nebr., as "about 2′ to 2′6″ of gray shale at top; middle 10′–11′ red shale; and basal 1′± gray shale; combined thickness about 14′ or more."

The Towle shale member is regarded by Moore and Mudge (1956, p. 2274) as the lowermost shale unit of the Permian system. Moore and others (1951, p. 52) list one member of their Towle shale, the Indian Cave sandstone member, as channel sandstone. Because other channel sandstone units persist in most of the shale units within 100 feet above or below it, the authors regard the base of the Indian Cave not as a break between systems but as a local unconformity marking the lowermost unit of a cyclothem. The boundary between these two systems is discussed at greater length in another part of this report.

The Towle shale member is commonly gray clayey shale that in some places contains beds of sandy and silty shale and sandstone. North of Wabaunsee County these variegated shale beds are exposed in almost every outcrop of this member. In Jackson, Nemaha, and Brown Counties the lower part of the shale generally consists of beds of red shale that are commonly mottled with green. In many exposures beds of green shale overlie the beds of red shale, which are in turn overlain by beds of gray shale. Locally in Pottawatomie County the upper part of the member contains red shale. Iron leached from the beds of red shale commonly stains the weathered surfaces of the underlying beds of shale and limestone red for a vertical distance of as much as 4 or 5 feet. Variegated beds are not common south of Lyon County.

Thin beds of micaceous sandstone were seen in the middle and upper parts of the Towle shale member in Nemaha, Jackson, Pottawatomie, Wabaunsee, and Greenwood Counties. They appear to be very lenticular and rarely can be correlated with a channel deposit. Thin conglomerate and conglomeratic limestone beds are present in the middle and the upper part of this shale but rarely in the lower part. They were observed locally in Pottawatomie, Jackson, Wabaunsee, Greenwood, and Elk Counties. The conglomerate beds are thin and lenticular and cannot be definitely associated with a channel, and apparently they do not indicate widespread erosion. The conglomerate consists mostly of angular to rounded limestone, limonite, and clay balls that are as much as one-fourth inch in diameter.

The channel of this member has been well known for several years and was selected as the disconformity between the Pennsylvanian and Permian systems in Kansas by Moore and Moss (1934, p. 100). They described it as being exposed near Peru and at Indian Cave, Nebr., and near Dover and Cedar Vale, Kans. The type locality is given as Indian Cave, Nebr. The precise location of this type locality is not recorded, but the present writers examined a channel sandstone very likely of this age at an exposure in a bluff overlooking the Missouri River in the center of sec. 9, T. 3 N., R. 17 E., Richardson County, Nebr. This sandstone bluff is referred to as the Indian Caves by the local inhabitants. Although a massive bed of sandstone 20 to 25 feet thick is well exposed, the upper and lower contacts are poorly exposed. The lack of complete exposures led Mudge (1956, p. 670) to believe that it is possible, but not certain, that this channel is of Towle age. The exposures of the channels of Towle age have been described by Mudge (1956, p. 670–672) and are only briefly mentioned here.

Another exposure of a channel of the Towle shale member in Nebraska is in a railroad cut about 2 miles southeast of Peru. This channel is somewhat better exposed, especially in the upper part. Massive beds of sandstone are overlain by sandy to clayey beds of shale that contain thin beds of limestone in the upper part. These limestone beds are very likely the Aspinwall limestone member.

In Kansas, channels of Towle age are exposed in the NW¼NW¼ sec. 27, T. 9 S., R. 13 E., Jackson County; the NW¼SW¼ sec. 3, T. 13 S., R. 13 E., and NE¼SE¼ sec. 18, T. 14 S., R. 13 E., Wabaunsee County; and in the E½ sec. 15, T. 34 S., R. 8 E., Chautauqua County. They range in depth from about 8 feet to as much as 85 feet. Their width varies from 300 feet to nearly 1 mile. The channel fill consists mainly of thick- to thin-bedded sandstone with some sandy to silty shale. In the deeper channels the beds of sandstone are thicker and more abundant in the lower part of the channels.

An excellent exposure of channel sandstone at "Echo Cliff," a streambank in the NW¼SW¼ sec. 3, T. 13 S., R. 13 E., Wabaunsee County, has been described by Mudge (1956, p. 670, 671). In the past, all of the exposure has been referred to as a channel of the Towle shale member. As suggested on page 14, there is very likely a channel of the Towle shale member within a channel of the Plumb shale member of the Wood Siding formation (fig. 5).

The relation of these two channels is as follows: The Plumb channel trends east to southeast and the Towle channel trends northeast and intersects the Plumb channel in the SE¼ sec. 4, T. 13 S., R. 13 E., and turns and trends east. The width of the upper part of the Towle channel is less than 1 mile; its width in the lower part is unknown. The depth of this channel is about 85 feet.

The basal contact of the channel of the Towle shale member in the Plumb shale member channel is marked by basal conglomerate (fig. 5). This conglomerate is 1 to 2 feet thick and consists of angular to subrounded fragments of local limestone and red shale. The fragments of limestone are from the Brownville and Grayhorse limestone members of the Wood Siding formation. The fragments of red shale are very likely from one of the shale units that was eroded by the stream that cut the channel. This conglomerate has been traced east to Shawnee County, a total distance of about 1.5 miles.

The channel fill of the Towle is mostly sandy shale with some interbedded sandstone. Beds of clay shale and thin beds of impure limestone are present in the upper 20 feet of the channel. The limestone beds resemble those of the Falls City limestone in that they contain many pelecypods.

One or more thin beds of impure, generally fossiliferous limestone are locally present in the Towle shale member. In the southern part of the State these beds of limestone are in the lower part of the shale, whereas toward the north they are generally in the upper part.

In the SE¼SE¼ sec. 6, T. 29 S., R. 9 E., Elk County, there is a thin (0.6 ft) bed of fossiliferous limestone about 4 feet above the Brownville limestone member of the Wood Siding formation. (See collection from USGS loc. 13791, table 1.)

The Towle shale member ranges from less than 6 feet in thickness in Pottawatomie County to as much as 21 feet in Brown County (pl. 4). In northern Wabaunsee County this shale averages about 10 feet in thickness but thickens to as much as 19.5 feet toward the southeast. In Lyon County it ranges from a featheredge to about 20 feet in thickness (O'Connor, 1953, p. 15). From Lyon County southward the Towle shale member thins to about 6.5 feet in Chautauqua County. Verville[6] reports an average thickness of 20 feet for this shale in Elk County, a thickness not observed by the writers. He very likely included in the Towle shale member some of the beds of limestone that are herein included in the Aspinwall limestone member. (See measured sections 34, 52, 60, 65, 69, 73, 94, 104, 113, 114, 187, 213, 324, 328, 338, 353, and 376.)

ASPINWALL LIMESTONE MEMBER

The Aspinwall limestone member was named by Condra and Bengston (1915, p. 17) for exposures at Aspinwall, Nebr. The town of Aspinwall does not exist today and is not recorded on any of the present county or state maps. The exposed section at this former townsite is in the center of the north half of sec. 20, T. 4 N., R. 16 E., Nemaha County, Nebr. Section 353 (pl. 4 and "Stratigraphic Sections") was measured there. This section of the Aspinwall is very thin (0.3 ft) and is not an accurate representation of the limestone as it is found elsewhere in exposures in southeastern Nebraska. The limestone overlies the Towle shale member and underlies the Hawxby shale member.

The Aspinwall limestone member is the lowest limestone unit of the Permian system as defined by Moore and others (1951, p. 52). In Nebraska it is 1 to 3 feet thick and consists of 1 or 2 bluish-gray limestone beds separated by a bed of shale (Condra and Reed, 1943, p. 37). In northern Kansas the member is easily correlated with the type section in Nebraska. From Wa-

[6] Op. cit., p. 174. (See footnote, p. 11.)

baunsee County southward there are many thin limestone beds within a 10-foot interval, of which one or all may be equivalent to the type section. The limestone beds change lithologically and in fossil content from north to south. The correlation made on plate 4 is based mostly on paleontologic and lithologic character, but in many places the correlation of the member is doubtful.

In Nebraska, Condra and Bengston (1915, p. 17) described the Aspinwall as a persistent soft massive light-brown mottled limestone unit 1 to 2 feet thick that is commonly 1 bed with many fossils, especially pelecypods, crinoid stems, and fragments of brachiopods. In northern Brown County the exposures of the Aspinwall fit the general description given above. Southward from Brown County to northern Pottawatomie County the Aspinwall is mainly 1 bed of limestone but locally it is 2 beds of limestone separated by a bed of shale that is comparable in thickness to the combined thickness of the limestone beds. In this general area the Aspinwall is soft to medium-hard light-brown limestone. Locally, it is coarse grained and has a sandy appearance. Although massive, it commonly weathers in thin beds or plates, and thin bedding planes are generally apparent on the weathered surface. Minute specks of iron stains are commonly distributed in thin zones along the bedding planes. Where thick, the upper part of this limestone is mostly hard, dense, and gray. Fossils are sparse, but in some places there are many minute fossil fragments in the thin iron-stained zones.

South of Jackson and Pottawatomie Counties the Aspinwall limestone member consists of one or more beds of limestone (fig. 7). In Wabaunsee County the lowermost bed is very likely correlative with the single bed in Nebraska. It is generally a hard gray-brown massive bed of limestone that in most places contains rounded to angular fragments of limestone and minute specks of iron. In most exposures in this county the limestone contains fossil fragments, but locally it contains complete shells of brachiopods and pelecypods. Here and there the pelecypod *Permophorus* is abundant. Brachiopods increase in abundance southward, whereas pelecypods decrease in abundance.

South of Wabaunsee County the Aspinwall limestone member generally consists of 2 or more beds of limestone, except in southern Greenwood County where there is but 1 bed. In northern Elk County there is a group of thin fossiliferous limestone beds within an interval of 10 to 12 feet. It is very likely that only the lower 1 or 2 beds of limestone are correlative with the Aspinwall to the north, but because of paleontologic and some lithologic similarities, all of these beds are called Aspinwall. Locally in northern Elk and Greenwood Counties there is about 7 feet of impure nonfossiliferous beds of limestone separated by thin beds of shale. These beds of limestone are located stratigraphically in the position of the Aspinwall limestone member and are very likely correlative with it. (See pl. 4.)

In southern Elk County and toward the south, the Aspinwall limestone member is generally two thin beds of medium-hard gray-brown limestone. The lower bed contains pelecypods, the upper bed contains a mixture of bryozoans and crinoid columnals, pelecypods, and brachiopods, and in some exposures algal deposits. The upper bed is locally conglomeratic.

In the SE¼NW¼ sec. 15, T. 34 S., R. 8 E., Chautauqua County, the Aspinwall limestone member is a single bed of medium-hard tan-gray limestone, but it grades laterally into firmly cemented sandstone that overlies a channel of the Towle shale member.

The lowermost bed or group of beds in the southern part of the State and the single bed in the northern part of the State generally form a small hillside bench. Where the other beds are present they are normally covered by grass slopes, and in many areas they have been eroded back even with the slope formed by overlying shale, thus leaving the small bench formed by the lower bed. Only locally are the upper beds resistant enough to form a prominent ledge.

Locally, the thickness of the Aspinwall limestone member is quite variable because beds of limestone of similar lithology and fossil content are combined to form the unit. In these places the member is as much as 10 feet thick. The lowermost bed or group of beds, which are very likely correlative with the type section in Nebraska, range from about 0.5 to 4 feet in thickness. Where there is 1 bed of limestone it is 1 to about 3.5 feet thick. This bed is somewhat thicker in the north half of the State. (See measured sections 34, 52, 60, 65, 69, 73, 94, 104, 113, 187, 213, 244, 246, 324, 328, 338, 353, and 376.)

HAWXBY SHALE MEMBER

The Hawxby shale member was named by Moore and Condra (1932) as the shale unit between what are now the Falls City limestone and Aspinwall limestone member. The type locality is at the Hawxby farm in the SE¼ sec 7, T. 4 N., R. 15 E., Nemaha County, Nebr. (Wilmarth, 1938, p. 927).

The type section of the Hawxby shale member is described by Condra and Reed (1943, p. 37) as

upper 8 [feet] of light gray, calcareous, with thin calcareous blades in joints, weathers crumbly; the middle and lower zones argillaceous, with subzones of blue-gray and dark orange-red; combined thickness 10 to 12 [feet].

The Hawxby shale member is poorly exposed in Kansas. South of Pottawatomie County the overlying Falls City limestone rarely forms a hillside bench; consequently, good exposures of the Hawxby are limited to road cuts and streambanks.

Over most of the outcrop area, the Hawxby shale member is a gray to olive-drab clayey shale. Locally it is silty and contains lenses of thin clayey limestone. Locally in Pottawatomie County variegated beds have been observed in this member (Scott, Foster, and Crumpton, 1959, p. 117, 156). They are beds of red and olive-drab shale that appear to be restricted to the middle and lower parts. These beds were seen locally in northern Nemaha County. O'Connor (1953, p. 15) recorded red, olive, gray, and green beds of shale in this member and noted a zone of mud cracks and limestone pebbles at the top of the red shale. A thin bed of purple shale is present in the middle of this shale member in west-central Elk County.

Beds of sandstone and sandy shale were not seen in this member, although Moore and others (1951, p. 52) report that locally the upper part is sandy. Lee (1949), in a preliminary cross section from Saline to Barber Counties, shows channels and beds of sandstone in this member in the subsurface.

Thin beds of clayey gray to tan nonfossiliferous limestone are locally present in the middle part of the member. In northern Nemaha County fossiliferous shaly limestone in the lower part of this member is overlain by gray-green shale that contains fragments of crinoids and bryozoans. The bed of limestone contains many *Myalina* (*Orthomyalina*).

The Hawxby shale member ranges from about 4 to 19 feet in thickness. It averages about 9.5 feet in thickness. In Pottawatomie County it ranges from 3.5 to 14 feet in thickness. O'Connor (1953, p. 15) noted that in Lyon County it averaged 10 or 12 feet in thickness. The maximum was observed in northern Greenwood County where it is as much as 18.5 feet thick. The unit thins towards the south to about 5 feet. (See measured sections 52, 60, 69, 73, 104, 213, 244, 246, 318, 328, 338, 353, 372, and 376.)

FALLS CITY LIMESTONE

The name Falls City limestone was proposed by Condra and Bengston (1915, p. 17) for a single pelecypod-bearing limestone bed that is 3.5 feet to 4 feet thick. Moore, Elias, and Newell (1934) redefined Condra and Bengston's Falls City to include 2 limestone beds separated by about 4 feet of shale. The upper bed of limestone is the original Falls City limestone. Condra (1935, p. 9) proposed member names for the two beds of limestone and intervening beds of shale, but these were not adopted by the Kansas Geological Survey and they are not used in this report. The type exposure is in Lehmer quarry in sec. 32, 2½ miles south and 1½ miles west of Falls City, Richardson County, Nebr. (Condra, 1927, p. 82).

In Riley County, Mudge (1949, p. 44) erroneously placed in the Hawxby shale member of the Onaga shale the beds herein called the Falls City limestone. He mapped as the Falls City limestone a soft bed of tan earthy limestone that locally overlies the Falls City limestone of this report.

Tentative correlations of the Falls City limestone are presented on figure 9 and plate 4. The discussion to follow is by units as listed in figure 9.

Unit 1, the lower bed of limestone, can tentatively be correlated from the type section in Nebraska into southern Kansas (fig. 9). In southeastern Nebraska,

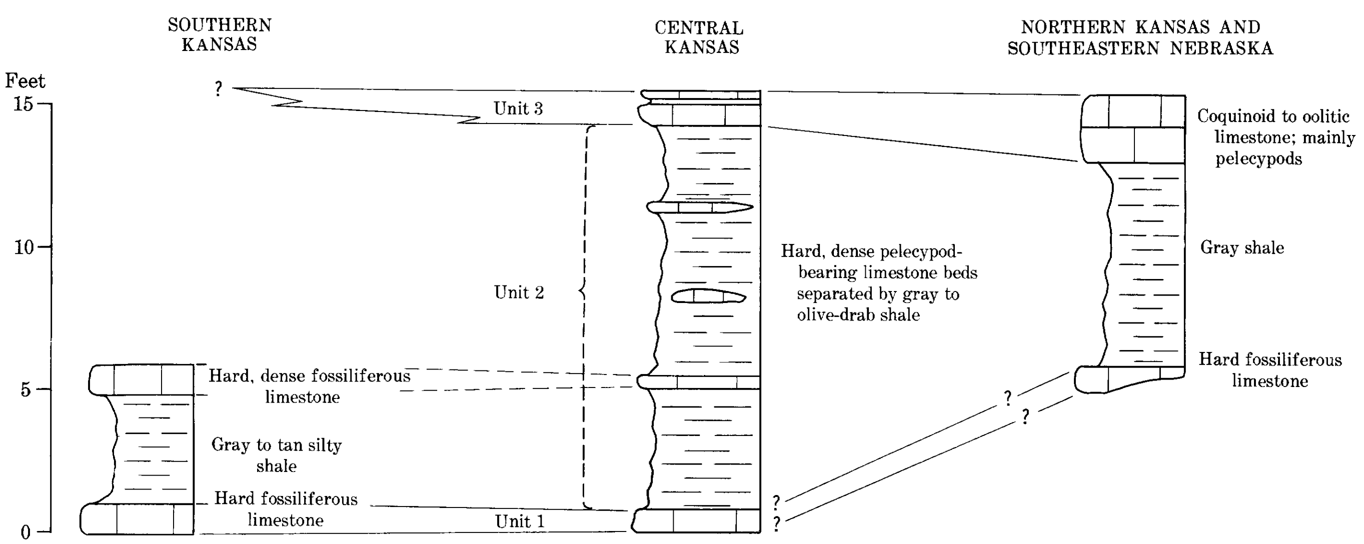

FIGURE 9.—Tentative correlation of the Falls City limestone and its subdivisions in Kansas and southeastern Nebraska.

unit 1 is about 1 foot thick, medium hard, and gray and weathers tan. This limestone is coquina with very abundant fossil fragments in the lower part. The upper part of unit 1 contains thin zones of *Crurithyris*, *Derbyia*, *Chonetes*, some bryozoans, crinoid columnals, and pelecypods. In Brown County, Kans., unit 1 ranges from a featheredge to 0.3 foot in thickness. Fossils are not abundant and those observed are mostly brachiopods. South of Brown County a pelecypod-bearing bed of limestone that rarely exceeds 0.6 foot in thickness has been tentatively chosen as the lower bed (unit 1) of the Falls City limestone. This bed extends southward into southern Elk County where it pinches out (pl. 4). In the central and southern outcrop areas it is hard, generally-dense limestone that locally is a coquinoid of pelecypods.

Unit 2, the intervening bed of shale, is mostly clayey and gray to olive drab (fig. 9). In southeastern Nebraska and northern Kansas, the unit is mostly dark-gray to blue-gray shale. South of central Pottawatomie County, unit 2 has tentatively been correlated with beds of gray clay shale that contain one or more beds of thin hard clayey coquinoid limestone. The fauna is mainly pelecypods with very abundant *Permophorus*. South of central Lyon County there is only one bed of limestone in unit 2 (pl. 4). It is medium hard and gray and ranges in thickness from 0.5 foot in Lyon County to 4 feet in Elk County. It contains a fauna of pelecypods, gastropods, crinoid columnals, and bryozoans. This bed of limestone seems to be the only one in the Falls City limestone that persists into southern Chautauqua County (pl. 4).

Unit 3, the upper bed of limestone, extends from southeastern Nebraska to southern Greenwood County, Kans., where it apparently pinches out (pl. 4 and fig. 9). At the former townsite of the city of Aspinwall at the center of the N½ sec. 20, T. 4 N., R 16 E., Nemaha County, Nebr., the Falls City limestone is exposed in an abandoned quarry high on the hillside. Here unit 3 is relatively hard, massive limestone that consists almost entirely of minute oolites. The oolites are very likely algal deposits. Small fragments of gastropods and pelecypods are abundant. Thin gray clay lentils 1 or 2 inches thick, and parallel to the bedding are common. The oolites and fossil fragments also appear to be parallel to the bedding. Toward the south and at the type section, unit 3 is a coquinoidal limestone that is composed almost entirely of fragments of pelecypods and brachiopods, although some oolites still persist. This lithology persists through Brown and Nemaha Counties and into southern Jackson and southeastern Pottawatomie Counties. South of these counties the upper bed of limestone (unit 3) is hard, dense, gray, and argillaceous and is composed almost entirely of whole shells of pelecypods, gastropods, and rarely brachiopods.

The Falls City limestone forms a prominent hillside bench only in northern Kansas and in southeastern Nebraska. This bench is formed by the upper bed of limestone (unit 3), which makes a recognizable and, in some places, a very prominent bench as far south as southern Jackson and southern Pottawatomie Counties. Further south the Falls City limestone beds do not form hillside benches and they are generally covered by colluvium or loess.

At Falls City, where there are 2 limestone beds, this formation is 11.4 feet thick. A minimum thickness of about 6 feet was observed in the southern part of Kansas, whereas a maximum thickness of over 17 feet was observed in Wabaunsee County. The lower limestone (unit 1) ranges from a featheredge to as much as 1.3 feet in thickness. The shale bed (unit 2) is over 10 feet thick in Pottawatomie County, Kans.; its minimum thickness is 5.3 feet in Nebraska. In northern Kansas and in southern Nebraska the upper limestone (unit 3) has a maximum thickness of over 4 feet and a minimum of 1.8 feet. (See measured sections 52, 60, 69, 73, 212, 213, 244, 246, 318, 328, 338, 353, 372, and 376.)

JANESVILLE SHALE

The Janesville shale was named by Moore and Mudge (1956, p. 2273–2274) after Janesville Township, Greenwood County, Kans. The type section is in an east-west road cut in the SW¼SE¼ sec. 23, T. 23 S., R. 10 E., Greenwood County. Section 69 in "Stratigraphic Sections" is the description of the type section, which is 73 feet thick. The Janesville thickens both southward and northward and attains a maximum thickness of about 90 feet in southeastern Cowley County. The minimum thickness of about 67 feet was measured in southeastern Riley County, which is slightly west of the normal strike of the outcrop.

The Janesville shale as defined by Moore and Mudge (1956, p. 2273–2274) consists of three members, which are, in ascending order, the West Branch shale, the Five Point limestone, and the Hamlin shale members. Moore and others (1951, p. 49) listed these units as formations. They further subdivided their Hamlin into three members, which are, in ascending order, their Stine shale, Houchen Creek limestone, and Oaks shale members. In this report only the name Houchen Creek is retained, and it is given the rank of bed.

WEST BRANCH SHALE MEMBER

The West Branch shale member was named by Condra (1927, p. 82) for exposures in West Branch Township, Pawnee County, Nebr. He described the

FIGURE 10.—A sand body in the West Branch shale member of the Janesville shale in the SE¼SW¼ sec. 22, T. 32 S., R. 8 E., Chautauqua County, Kans. The beds of limestone beneath the sand are the Falls City limestone. (See measured section 52, pl. 4, and "Stratigraphic Sections".)

shale as "composed of greenish-blue, argillaceous, massive and crumbly shale, dark near the top, with calcareous bladed material above the middle, and calcareous lensing material near the base." The type section is about 26 feet thick.

The West Branch shale member consists mainly of clayey shale that is gray to tan gray. Thin beds of red, gray-green, and olive-drab shale are common in the upper parts of this member in the area north of the Kansas River.

A persistent thin bed of coal lies from a few inches to as much as 2 feet beneath the top of the West Branch shale member. This bed of coal crops out in almost all exposures of the shale that were studied south of the Kansas River, and is locally present toward the north (pl. 4). A second bed of coal is present in the middle part of the member in Elk and eastern Wabaunsee Counties, but it was not observed elsewhere (pl. 4).

A persistent calcareous bed that is generally massive tan soft cavernous to porous limestone or, in some places, calcareous shale is present beneath the bed of coal and about 10 feet above the Falls City limestone in all areas except southern Wabaunsee, northern Lyon, and northern Pottawatomie Counties (pl. 4). This bed ranges from a few inches to as much as 4 feet in thickness. Condra (1927, p. 114) noted a yellowish rotten limestone 1.7 feet thick about 6 feet above the top of the Falls City limestone that may correlate with the bed of soft porous limestone noted in Kansas. In Kansas there is a thin limestone or in places a very calcareous shale bed 6 to 8 feet beneath the Five Point limestone member. This limestone almost invariably contains crinoid columnals, bryozoans, pelecypods, and brachiopods. It can be traced southward from northern Pottawatomie County to southern Wabaunsee County and crops out locally in northern Greenwood County (pl. 4).

Thin beds of sandstone, some crossbedded and some filling small shallow channels, were observed in west-central and northeastern Lyon County and eastern Wabaunsee County (Mudge, 1956, p. 673). The channels generally do not exceed 300 feet in width and do not extend below the member boundary. Some have been scoured to depths of 10 to 15 feet. The channels are narrow cigar-shaped bodies that have a length of about 1 to 2 miles. They are filled with massive crossbedded micaceous sandstone and interfingering sandy shale.

A sandstone body in the West Branch shale member is exposed in a road cut in the SE¼SW¼ sec. 22, T. 32 S., R. 8 E., Chautauqua County. It is described by Mudge (1956, p. 673) as being neither a bar nor a channel but very likely a result of scour and fill in beach sands. As is apparent in figure 10, its lower surface is conformable with the underlying beds of shale, whereas on the flanks the beds of sandstone and sandy shale occur as scour fill that truncates the adjacent beds. Other exposures of this sand body were seen in streambanks in the NE¼SE¼SE¼ sec. 30, T. 32 S., R. 8 E., Cowley County, and in the NE¼NE¼ sec. 14, T. 31 S., R. 9 E., Elk County.

The West Branch shale member averages 28.4 feet in thickness. In northern Kansas it is 21 to 26 feet thick, and it thickens southward to as much as 43.1 feet in Chautauqua County. In Cowley County it is 24.9 feet thick. In other sections studied in Lyon and Greenwood Counties, the thickness of this shale is almost constant at 28.3 feet. (See measured sections 11, 52, 60, 69, 212, 213, 244, 246, 247, 286, 292, 318, 328, 338, and 372.)

FIVE POINT LIMESTONE MEMBER

The Five Point limestone member was named by Moore and Condra (1932) for an exposure in Five Point Valley near the Five Point School in sec. 25, T. 1 S., R. 16 E., Richardson County, Nebr. The Five Point limestone member overlies the West Branch shale member and underlies the Hamlin shale member. This limestone is more similar lithologically and paleontologically to the younger limestones (Permian) described by the Kansas Geological Survey than to those of the upper part of the Pennsylvanian system.

Condra (1935, p. 9) describes the Five Point limestone member as "one limestone, or more commonly, two gray limestones separated by gray to dark shale." This definition is applicable to Wabaunsee, Pottawatomie, Riley, and Jackson Counties and in the southern part of the State where there are two or more limestone beds separated by a thin shale bed (pl. 4).

The lower bed of limestone is locally absent in Lyon and Greenwood Counties and in the northern part of Kansas and southern Nebraska (pl. 4). In these counties the intervening bed of shale can be locally differentiated from the West Branch shale member by the presence of brachiopods. The lower bed of limestone is generally soft and tan gray and contains a fauna of fusulinids, crinoid columnals, bryozoans, and brachiopods (table 1). In Cowley County, pelecypods are quite common, particularly *Myalina* (*Orthomyalina*).

The intervening beds of shale are normally gray and silty to clayey and generally contain a brachiopod fauna with *Chonetes* as the diagnostic fossil. In the SW¼ sec. 21, T. 32 S., R. 8 E., Cowley County (measured section 286, pl. 4), the upper part of the shale is carbonaceous, whereas the middle part is clayey and fissile.

The upper bed of limestone is persistent in Kansas (pl. 4). In most of Pottawatomie County and locally in Jackson County and in northern Wabaunsee County this bed is coquinoid limestone that is tan to tan gray and medium hard. The fragments of brachiopods and pelecypods rarely exceed one-half inch in diameter. Locally the texture of the limestone has been referred to as resembling oatmeal in appearance. In the areas of the coquina facies the limestone weathers into large rectangular blocks. The largest block observed is 4 feet thick and as much as 15 feet in diameter.

FIGURE 11.—The upper bed of the Five Point limestone member of the Janesville shale in the SW¼NW¼NW¼ sec. 29, T. 32 S., R. 8 E., Cowley County, Kans.

In southern Wabaunsee County the upper bed of limestone is very platy and light gray and contains many shale partings. Here it is as much as 8 feet thick. South of Wabaunsee County only locally are there shale partings in this bed of limestone.

South of Lyon County the upper bed of limestone is gray, gray brown, and brown. It is relatively hard, massive, and locally dense. In places it weathers into large slabby blocks. This bed generally contains a varied fauna of fusulinids, crinoid columnals, bryozoans, and pelecypods. Douglass (p. 59, this report) notes that much of the organic debris from Wabaunsee and Greenwood Counties is coated with algae. Fusulinids appear to increase in abundance toward the south. The significance of the fusulinids in this limestone is discussed by Douglass.

In Cowley County the upper limestone bed changes slightly lithologically and in thickness from east to west. In the eastern exposures (stratigraphic section 286) this limestone unit is 2.7 feet thick and contains a thin bed of calcareous shale in the upper part. A zone of fusulinids occurs in the lower part of the bed. About 1¼ miles to the west, this limestone unit is 3½ feet thick (fig. 11) and contains no shale partings. It contains not only the fusulinid zone in the lower part but another fusulinid zone in the upper part. This second fusulinid zone was seen only in Cowley County, whereas the lower fusulinid zone was observed in many places elsewhere.

The Five Point limestone member generally makes a distinguishable, although not prominent, hillside bench. This bench is formed by the upper bed of limestone, and where this bed is thickest or is a coquina facies the bench is prominent.

Where there are 2 beds of limestone separated by a shale bed, the Five Point limestone member averages about 3.1 feet in thickness in the northern part of the State but thickens southward to 13.5 feet in Cowley County. The increase in thickness is mainly in the intervening bed of shale, which thickens from north to south. Of the exposures studied, the upper bed of limestone ranges from 0.8 foot to as much as 4 feet in thickness. The intervening bed of shale ranges from a featheredge to as much as 9.1 feet in thickness. The lower bed of limestone ranges from a featheredge to as much as 2.3 feet in thickness. (See measured sections 11, 52, 69, 212, 244, 247, 286, 292, 300, 318, 328, 355, 372, and 373.)

HAMLIN SHALE MEMBER

The Hamlin shale was named by Moore, Elias, and Newell (1934), but no type locality was listed. This shale, considered a member in this report, overlies the Five Point limestone member and underlies the Americus limestone member of the Foraker limestone. The Hamlin shale member contains a significant stromatolite limestone bed here referred to as the Houchen Creek limestone bed. It occurs in the middle of the member and can be traced only as far south as Jackson and southern Pottawatomie Counties. South of these areas there are thin lenticular beds of limestone that are in about the same stratigraphic position. Although they do not contain stromatolites they may be correlative to the Houchen Creek.

South of the Kansas River, a thin algal limestone bed a few feet beneath the Americus limestone member of the Foraker limestone as formerly used in Chase, Lyon, and Elk Counties has been called the Houchen Creek by Moore, Jewett, and O'Connor (1951, p. 15), O'Connor (1953, p. 14), and Verville.[7] This limestone extends northward into Wabaunsee County where it coalesces with the basal part of the Americus limestone defined by Kirk (1896, p. 80). The limestone that has been called the Houchen Creek in the southern half of Kansas is classified in this report as the lower bed of the Americus limestone member (pl. 5 and fig. 14). In northern Wabaunsee, Riley, Pottawatomie, and southern Jackson Counties this particular limestone unit is at the base of the Americus limestone member and can be identified only by the stromatolite zone. Beneath this limestone there is a thin bed of calcarenite that is present in most of the exposures south of northern Jackson and northern Pottawatomie Counties (pl. 4). The calcarenite was sampled in many places along its outcrop and compared with a sample of the calcarenite that lies about 20 feet above the Houchen Creek limestone bed of the Hamlin shale member in Pottawatomie County. The calcarenite is composed almost entirely of sand-size fragments of calcium carbonate with some fragments of ostracodes.

In the northern outcrop area the Hamlin shale member is mostly maroon and gray green in the lower part and gray to gray green with some maroon in the upper part. In the center of the SW¼ sec. 30, T. 2 S., R. 16 E., Brown County, the upper 1.3 feet of the member is dark gray, fissile, and fossiliferous. The fossils are mostly *Lingula*, *Orbiculoidea*, *Crurithyris*, and crinoid columnals. Locally, there are thin fossiliferous shale beds in the lower part of the member. In the central and southern outcrop areas the Hamlin consists mainly of clayey to silty beds of gray to gray-green shale.

Beds of sandy shale and sandstone are present locally in the Hamlin shale member. Mudge (1956, p. 674) described some as filling small channels that were cut to a depth of as much as 10 feet. The sandstone and sandy shale beds are more abundant in the middle and lower parts of this unit. They are very lenticular and micaceous, and many are crossbedded. Wood and leaf fragments are common in these beds. (See pl. 4.)

Thin beds of limestone are distributed at random throughout the member. The most prominent of these limestone beds, the Houchen Creek, is described on page 28. In northern Greenwood County there are thin beds of limestone in the upper part of the Hamlin shale member, and locally they contain *Orbiculoidea*, *Aviculopecten*, and ostracodes. In southeastern Cowley County there is a medium hard tan-brown to gray-brown massive limestone bed in the lower part of the Hamlin shale member. This limestone has thin shale partings in the middle part and contains pelecypods in the upper part.

In the upper part of the member there is a cellular siltstone bed that is massive, about 2 to as much as 10 feet thick, and distinctively tan. This siltstone grades laterally into beds of silty shale and is present in most exposures from northern Wabaunsee County southward. (See pl. 4.) It lies beneath the persistent calcarenite bed.

In most exposures extending from southern Cowley County into northern Pottawatomie County there is a calcarenite bed (featheredge to 1.0± ft thick) at the very top of this shale (pl. 4). It consists almost entirely of angular calcium carbonate fragments ranging from 0.125 mm to 0.25 mm in size. Fragments of ostracodes are common in this bed. The calcarenite is

[7] Op. cit., p. 184. (See footnote, p. 11.)

locally very thin bedded, in some places contains algal deposits, and is generally impregnated with limonite. Toward the south the bed is transitional into the overlying Americus limestone member. The contact at the base of the calcarenite bed is generally distinct, but locally where it rests directly on massive beds of silt, it appears to be transitional. (See measured sections 244 and 257.)

The Hamlin shale member ranges in thickness from about 34 feet in Elk County to as much as 52 feet in southeastern Cowley County (pl. 4). It averages 41 feet. In the northern outcrop area the Hamlin averages 48 feet in thickness. (See measured sections 11, 69, 212, 229, 235, 244, 247, 257, 270, 286, 292, 300, 318, 327, 328, 330, 352, 355, and 373.)

Houchen Creek limestone bed.—The Houchen Creek limestone bed was named for exposures on Houchen Creek, sec. 29, T. 6 N., R. 13 E., Nemaha County, Nebr., by Condra (1927, p. 84). He describes this limestone as being "massive to irregular, or separated by bluish shale partings; characterized by the presence in most exposures of large masses of an algal growth." Condra has traced this unit as far south as the Kansas River valley, north of Belvue, Pottawatomie County.

The Houchen Creek limestone bed at the type exposure is tan medium-hard stromatolite limestone with distinctive lobate structure. The stromatolites in this limestone are distinctive in that they are finely laminated and generally not more than 4 inches in diameter (fig. 12). They have been identified as *Collenia* Walcott by Richard Rezak (oral communication, 1954).

In the center of the SE¼ sec 33, T. 1 S., R. 11 E., Pottawatomie County, the Houchen Creek limestone bed is about 20 feet beneath the base of the Americus limestone member (pl. 4). Here the Houchen Creek ranges from 0.2 to 0.6 foot in thickness. It is composed entirely of hard gray to gray-brown algal deposits that have a finely laminated lobate structure. Pelecypods are locally common in this member. In cross section, some of the algal colonies extend the full length of the outcrop. The bed is composed of a series

FIGURE 12.—Specimens of the Houchen Creek limestone bed of the Hamlin shale member of the Janesville shale collected from measured section 244 in the center of SE¼ sec. 33, T. 7 S., R. 11 E., Pottawatomie County, Kans. Note the colonies of the stromatolite *Collenia*. The lobate bedding is characteristic of this bed. Enlarged × 1.2

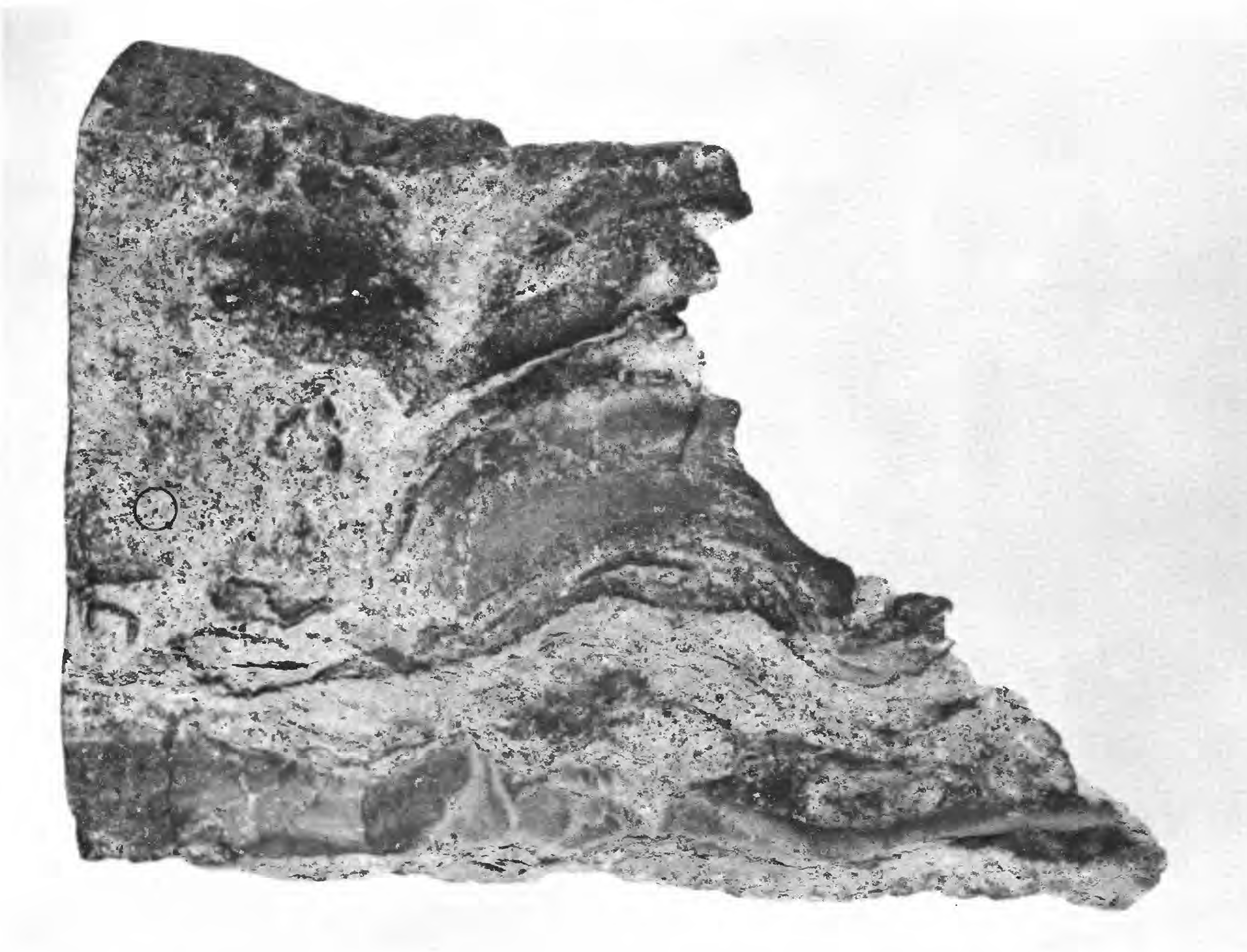

FIGURE 13.—Stromatolite *Collenia* in the lower bed of the Americus limestone member of the Foraker limestone. The dark bands are algal deposits. The white speckled areas are detritus of limestone and ostracode fragments and some complete ostracode shells (see circle). Enlarged × 1.2.

of superimposed colonies. The specimen in figure 12 was collected from the location cited above.

This limestone is different from the basal bed of the Americus limestone member of the Foraker limestone. The Houchen Creek limestone bed consists entirely of *Collenia* (fig. 12). The lower limestone bed of the Americus has a zone of massive algae (*Collenia*) in its lower part; some are lobate bedded. The voids between lobes have been filled with detritus or lime matrix (fig. 13), whereas in the Houchen Creek they have been filled with shale from the overlying and underlying shale units. The Houchen Creek limestone bed was traced as far south as Belvue, Kans. As mentioned previously, south of the Kansas River there are local thin beds of limestone that might be correlative to it, but they do not contain the distinctive lobate algal structure, and correlation is possible only by stratigraphic position.

In Nebraska the Houchen Creek ranges from 1 to 4 feet in thickness (Condra and Reed, 1943, p. 36); in Pottawatomie County it ranges from 0.2 to as much as 0.6 foot. (See measured sections 244, 257, and 355.)

COUNCIL GROVE GROUP

This study includes only the lower 200± feet of the Council Grove group, thus covering those units up to, and including, the Beattie limestone. This part of the Council Grove group ranges in thickness from about 235 feet in the southern outcrop area to about 180 feet in the northern. The rocks in this group are considerably different from those of the Admire group in that the limestone units are thicker and generally lighter in color and some contain chert. Most of the shale units are variegated, and many of the beds of gray shale are fossiliferous. Beds of coal and sandstone are exceedingly rare in comparison with the older groups of rocks. The discussion of this group begins with the oldest formation, the Foraker limestone. (See pl. 5 and fig. 2.)

FORAKER LIMESTONE

The Foraker limestone was named by Heald (1916, p. 21, 25) for the Foraker quadrangle, Osage County, Okla. The Foraker limestone is subdivided into three members, which are, in ascending order, the Americus limestone, the Hughes Creek shale, and the Long Creek limestone members.

The Foraker limestone ranges in thickness from as much as 70 feet in southern Kansas to 30 feet in northern Kansas. As is apparent on plate 5 it thickens southward and changes markedly lithologically.

AMERICUS LIMESTONE MEMBER

The name Americus limestone was proposed by Kirk (1896, p. 80) for exposures near Americus, Lyon County, Kans. He described the Americus as 2 thin beds of limestone separated by about 4 feet of shale. The Kansas Geological Survey has followed this definition of the limits of the Americus (Moore and others, 1951, p. 49). The upper and lower contacts of the Americus limestone member as used by Moore and others (1951) were redefined by Mudge and Burton (1959, p. 53-54). (See fig. 14.) In the original classification the upper bed of limestone, northward from Wabaunsee County, is shaly limestone or in some exposures calcareous shale. Where it is calcareous shale it cannot be distinguished from the shale that lies above and below it. Also, this upper limestone closely resembles, in thickness, color, and fossil content, the beds of limestone 2 to 5 feet above it in the Hughes Creek shale member as used by Moore and others (1951). The shale that underlies this upper limestone closely resembles the shale of the Hughes Creek shale member as used by Moore and others (1951) in color and fossils. (See pl. 5.) Therefore, the top of the Americus limestone member as defined by Mudge and Burton (1959, p. 53–54) and in this report is restricted to the top of the lower bed as described by Kirk (1896, p. 80) and as followed by the Kansas Geological Survey (Moore and others, 1951, p. 49). (See fig. 14.) The base of the Americus limestone member as described by Mudge and Burton (1959, p. 53–54) and herein is at the base of the limestone that normally contains large masses of stromatolites and was previously correlated as the Houchen Creek limestone member in Chase County (Moore, Jewett, and O'Connor, 1951, p. 15) and in Lyon County (O'Connor, 1953, p. 14). In Wabaunsee County (as stated on page 27) this algal limestone does coalesce with the basal part of the Americus limestone as defined by Kirk (1896, p. 80). (See pl. 5 and figs. 14, 15.) In northern Wabaunsee, southern Pottawatomie, and southern Jackson Counties, the algal deposits persist in the lower part of what heretofore has been called the lower bed of the Americus. The algal deposits were not observed in this bed north of these areas.

The following description of the Americus limestone member is by the units that are listed on figure

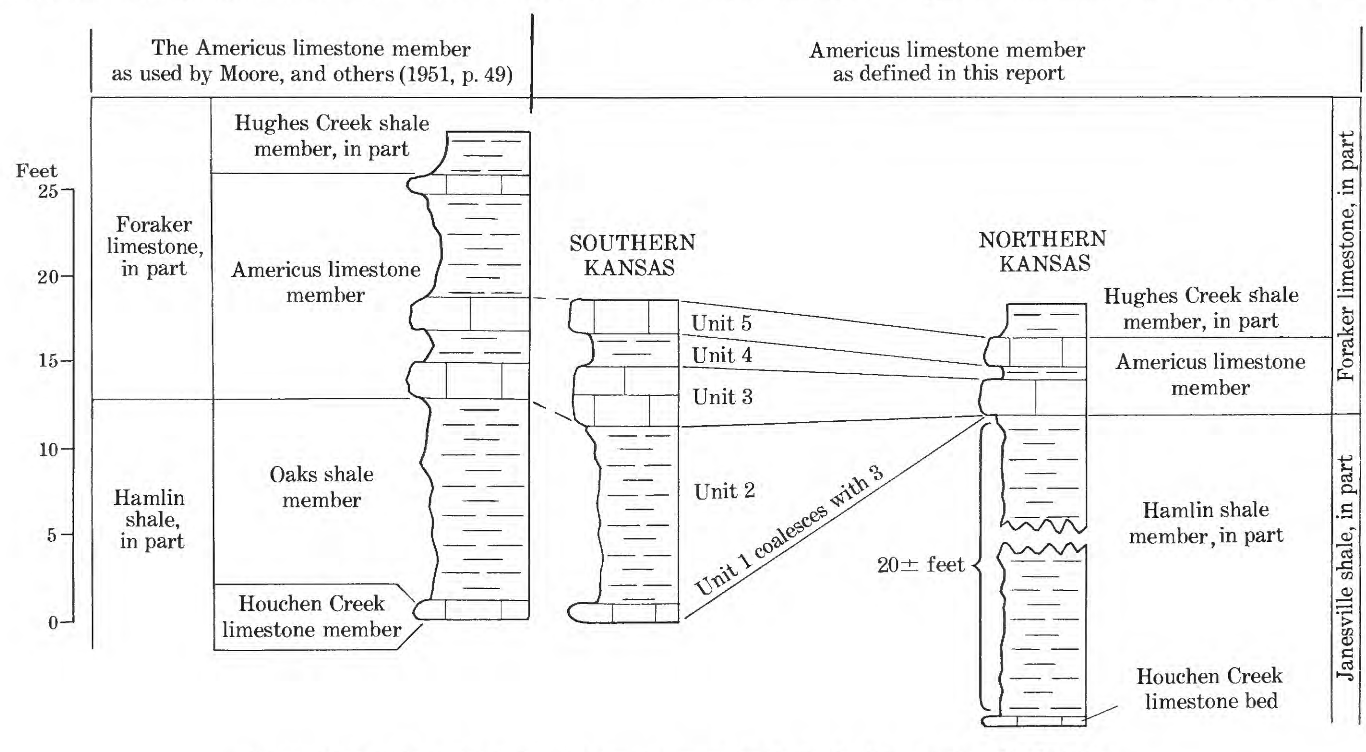

FIGURE 14.—Classification of the Americus limestone member of the Foraker limestone as used in this report.

FIGURE 15.—Americus limestone member of the Foraker limestone in the SW¼SE¼ sec. 12, T. 12 S., R. 11 E., Wabaunsee County, Kans. The bed adjacent to the top part of the pick contains algal deposits (see fig. 13). The calcarenite bed is adjacent to the head of the pick.

14, beginning with unit 1, the oldest. In Kansas the lower bed of Americus limestone member, 1, has been heretofore called the Houchen Creek limestone bed (as mentioned on pages 27 and 30). This bed is hard to medium hard and gray. In the lower part it contains a distinctive fossil stromatolite, *Collenia* (Richard Rezak, oral communication, 1954). It occurs as large convex masses that in thin section show many thin laminae. The laminae in some colonies are connected with those in adjacent colonies. In plane view they are commonly heart-shaped, and each convex mass may be as much as 12 inches in diameter. The depressions between colonies are generally filled with detrital material. The detritus is mainly fragments and some complete shells of ostracodes and possibly other microfossils (fig. 13). The ecology of this stromatolite is described on page 103. These stromatolites differ from those in the Houchen Creek limestone bed because they are enclosed in a lime matrix, are denser and darker, are smaller in diameter, and are always connected. (See figs. 12, 13.) The calcarenite that underlies the Americus limestone member is an aid in the identification of limestone unit 1 (figs. 14, 15). Other fossils in unit 1, all overlying the stromatolite zone, are gastropods, pelecypods, and some brachiopods.

The shale bed, unit 2, beneath the upper two beds of limestone pinches out in east-central Wabaunsee County, but locally it is present in southern Pottawatomie County. (See pl. 5 and fig. 14.) This bed of shale is generally gray and fissile to thin bedded and varies from silty to clayey. Locally in Elk and in southeastern Cowley County it contains thin lenses of limestone. In northern Elk County the upper part of this shale is sandy, and it is overlain by a thin bed of fine-grained sandstone. Also in this area a bed of limestone 1.6 feet thick with a thin conglomerate layer at its base is present in the middle of this shale unit. This limestone contains *Aviculopecten*, *Myalina* (*Orthomyalina*), and *Linoproductus* in its upper part. Toward the south, beds containing the same fossils rest upon the lower limestone unit 1 of the Americus limestone member. The pelecypod-bearing limestone very likely coalesces southward with the lower bed of the Americus limestone member.

Units 3 and 5 are described together for ease of comparison and because locally they form one bed of limestone. In the northern part of the State, these two thin beds of limestone are generally separated by a thin bed of shale. (See pl. 5; units 3, 4, 5, figs. 14, 15.) Each of these limestone beds range from a few inches to as much as 1.5 feet in thickness. They are hard to medium hard and dark gray to blue gray. Locally one or the other is shaly limestone. In a single exposure generally only one of the beds is shaly; rarely, both of them are. Unit 5 is generally harder, more dense, and darker gray than unit 3. Unit 5 characteristically contains many crinoid columnals that are as much as one-half inch in diameter. They weather white and generally protrude from the exposed surface. In addition to the crinoid columnals, fusulinids are generally common to abundant in this bed. Neither of these fossils are common in unit 3. Other fossils in unit 5 are brachiopods, bryozoans, and locally pelecypods and *Osagia?*.

Unit 3 is generally gray to light gray and coarser grained than unit 5 and commonly has a shaly appearance. It almost invariably contains a varied fauna of brachiopods and pelecypods, with fragments of other fossils. From northern Wabaunsee to northern Pottawatomie County, massive banded stromatolites occur in the lower part of unit 3. Here unit 1 has coalesced with unit 3. These stromatolites are generally laminated and are more dense and darker gray than the limestone matrix (fig. 13).

Both limestone units 3 and 5 thin northward, and fusulinids diminish greatly in number toward the north, where they are rare or absent.

South of northern Wabaunsee County the Americus consists of three beds of limestone separated by thin beds of shale (fig. 14). In parts of Lyon and northern Greenwood Counties, units 3 and 5 coalesce to form one bed. (See pl. 5.) In these areas fusulinids and crinoid columnals, which are distinctive of unit 5, are restricted to the upper part of the single bed. South of west-central Greenwood County the upper part of this member contains two beds of limestone, 3 and 5, that are generally separated by shale unit 4. From this point southward the Americus changes considerably in facies.

In the southern outcrop area these upper two limestone beds both thicken and are very hard. They generally contain a lenticular zone of chert nodules in the upper part. The limestone is massive and commonly fractures in large blocks that slump down on the slopes (fig. 16). The contact of the upper limestone, unit 5. with the overlying shale is distinctively sharp. The top of the limestone is a smooth plane with few or no irregularities. The contacts between the two beds of limestone, 3 and 5, and the thin bed of shale, 4, are generally gradational. Locally in southern Kansas worm burrows(?) were observed at the base of unit 3. U-shaped grooves (organic burrows ?) were seen in the top of unit 5 in Chase County. These two beds of limestone form a prominent hillside bench near the top of the east-facing Flint Hills escarpment, which is the main physiographic feature in western Greenwood, Elk and Chautauqua Counties. (See fig. 16.)

In the SW¼ sec. 31, T. 27 S., R. 9 E., Greenwood County, units 3 and 5 resemble, in thickness and zoning of fusulinids and chert, the lower limestone beds of the Hughes Creek shale member. Unit 3 contains a zone of chert nodules about 6 inches from the top, with a few isolated nodules near the top. Fusulinids are abundant in the upper 6 inches of unit 3. Unit 5 contains a lens of chert 5 inches thick. Fusulinids are abundant above the chert, whereas crinoid columnals, bryozoans, and brachiopods are abundant beneath it. The shale between the limestone is silty and tan and contains an abundance of fusulinids.

Shale unit 4, between the two upper limestone beds, is tan to gray and varies from clayey to silty. Locally this unit is very calcareous and contains thin lentils of limestone. In the southern part of the area fusulinids are generally very abundant. Fossils were not seen in this unit north of Greenwood County except in west-central Brown County. Here the shale is very thin (0.1–0.2 ft.) and contains the brachiopod *Composita*.

In southeastern Cowley County and western Elk and Chautauqua Counties unit 1 of the Americus forms the first hillside bench below that of the limestone beds of the Hughes Creek shale member. In these areas large blocks of unit 1 slump onto the underlying shale. In the NE¼ sec. 31, T. 31 S., R. 8 E., Elk County, this limestone 1 is conglomeratic. It contains angular to rounded fragments of limestone that do not exceed one-eighth inch in diameter.

The thickness of the Americus limestone member is variable because of the lenticularity of shale units 2 and 4. North of Lyon County it averages 4 feet in thickness, but south of this area it averages about 12 feet. A maximum thickness of about 20 feet was observed in northwestern Elk County, whereas a minimum thickness of about 1.5 feet was measured in Brown County. Limestone unit 1 ranges from a featheredge to as much as 3.0 feet in thickness. Shale unit 2 ranges from a featheredge to as much as 11 feet in thickness. Unit 3 is generally a few inches thicker than unit 5. The limestone units range from 5 inches to as much as 3.5 feet in thickness. Shale unit 4 between these limestone units ranges from a featheredge to about 2.5 feet in thickness. Limestone unit 5 ranges from 0.5 foot in thickness in Brown County to slightly over 3.5 feet in

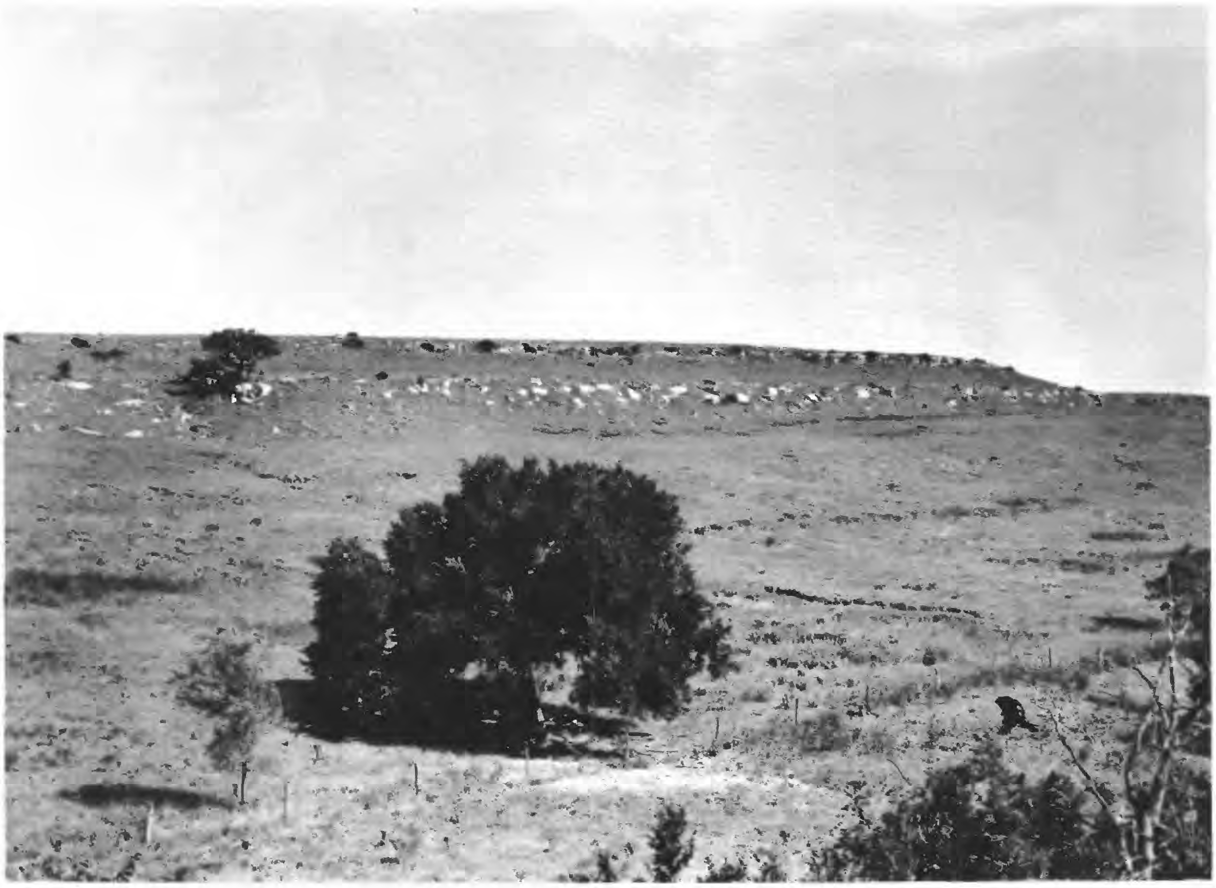

FIGURE 16.—Hillside exposures of the Americus limestone member of the Foraker limestone and lower thick limestones of the Hughes Creek shale member of the Foraker in the SW¼NE¼ sec. 29, T. 32 S., R. 8 E., Cowley County, Kans. The protruding limestone that fractures into large slabs is the upper bed of the Americus limestone member.

western Elk County. In most exposures, unit 1 rarely exceeds 1 foot. (See measured sections 69, 229, 235, 257, 270, 280, 286, 292, 293, 300, 318, 327, 328, 330, 352, and 373.)

HUGHES CREEK SHALE MEMBER

The name Hughes Creek was proposed by Condra (1927, p. 85) for sections along Hughes Creek, Nemaha County, Nebr. The original definition included what are now all the beds of shale and limestone from the base of the Long Creek limestone member down to the top of the Houchen Creek limestone bed. Moore and Condra (1932) revised the classification and restricted their Hughes Creek shale member to those beds between the Long Creek limestone member and their Americus limestone.

The redefinition of the Americus limestone member used in this report affects the Hughes Creek shale in the southern part of the outcrop area but follows the usage in the northern outcrop area of Condra (1935, p. 8), Jewett (1941, p. 44–46), Condra and Reed (1943, p.36), Mudge (1949, p. 50–52), Walters (1953, p. 48; 1954, p. 40), Mudge and Burton (1959, p. 53–56), and Scott, Foster, and Crumpton (1959, p. 119). In the southern part of the State the lower part of the Hughes Creek shale member as defined in this report includes 4 to 8 feet of shale overlain by a bed of limestone about 1 foot thick that has been previously included in the Americus limestone member. (See pl. 5 and fig. 14.)

The Hughes Creek shale member is easily recognized because it is the only thick dark-gray shale in this part of the section. The thin beds of fusulinid limestone and shale are distinctive for this member.

The Hughes Creek shale member in the northern outcrop (Brown County) is about 92 percent shale and 8 percent limestone, whereas in the southernmost outcrop (southeastern Cowley County), it is about 35 percent shale and at least 65 percent limestone (pl. 5). The shale and limestone of the Hughes Creek shale member is divided into the units shown in figure 17. The descriptions below begin with the shale, units 1, 3, and 5, followed by the limestone, units 2 and 4. This method seems feasible because the shale units are lithologically and paleontologically similar, as are the limestone units.

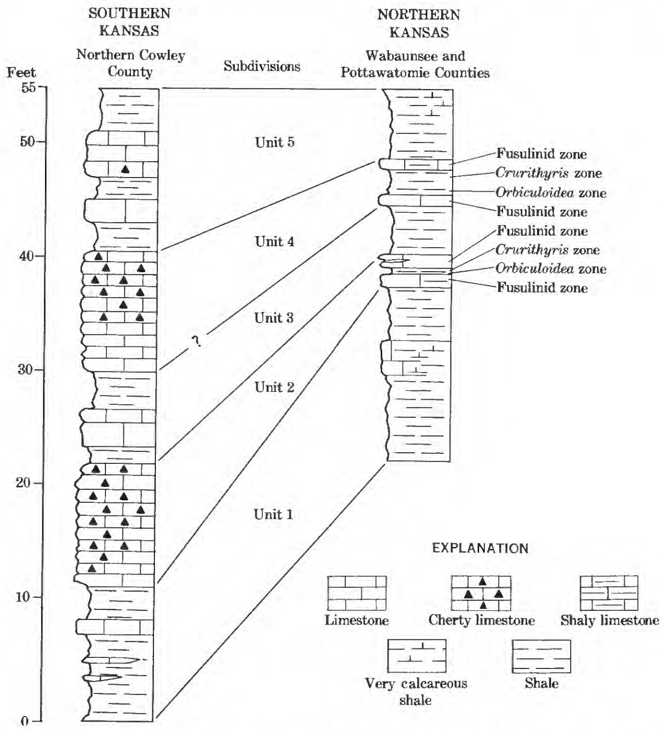

FIGURE 17.—Generalized correlation of the subdivisions of the Hughes Creek shale member of the Foraker limestone in Kansas.

The shale units 1, 3, and 5 vary from silty to clayey and are generally thin bedded. They are light gray to dark gray and occur locally in the northern and southern outcrop areas; units 3 and 5 are gray green to olive drab. In the southern outcrop area, fissile shale is present in the lower part of units 1 and 3. One or more thin beds of limestone are present locally in each of the shale units (pl. 5); these beds are discussed separately below, beginning with the limestone in unit 1.

A thin (1.0 ± ft) bed of gray medium-hard to soft limestone is present in the upper part of unit 1 in Pottawatomie and Wabaunsee Counties and in southern Kansas (pl. 5). Elsewhere this limestone is absent or, as in Wabaunsee County, grades laterally into very calcareous shale. In the southern part of Kansas there are thin, in part dense limestone lentils in the lower part of the unit.

The most prominent limestone bed in unit 3 is in the southern outcrop area, although in Pottawatomie County there is a thin limestone lens in the lower part of this shale. The limestone bed in the southern outcrop area is 3.1 feet thick in east-central Cowley County, and it thins to a featheredge in northern Greenwood County. This limestone is generally hard, gray, and locally dense. In Elk County it is coquinoid in the lower part. In east-central Cowley County it is conglomeratic in the upper part and contains small rounded clay balls. In southeastern Cowley County unit 3 is cherty limestone and cannot be subdivided from units 2 and 4.

The beds of limestone in unit 5 are also generally restricted to the southern outcrop area, although locally in the central outcrop area there is gray shaly limestone in the upper part of this unit that generally is a coquinoid of fusulinids. In the southern outcrop area unit 5 consists of one bed of limestone in some places, and in others, two (pl. 5). The limestone beds are lenticular, hard, gray, and very fossiliferous. As shown in figure 17 and on plate 5, the upper bed of limestone in east-central Cowley County contains chert nodules in its lower part.

Units 2 and 4 are mainly limestone (fig. 17) although in the central and northern outcrop area thin gray shale occurs in the middle of these units. Toward the north the limestone beds are gray to dark gray, medium hard, and locally argillaceous. The lower bed, and in many places the upper bed, of limestone of units 2 and 4 contains fusulinids. North of Lyon County, the shale between the limestones generally contains an *Orbiculoidea* zone in the lower part and a *Crurithyris* zone in the upper part. Locally *Petrocrania* and *Lingula* are associated with the *Orbiculoidea* zone, and *Composita* or *Marginifera* is associated with the *Crurithyris* zone. The areal extent of these zones is from central Wabaunsee County northward to Nebraska. The *Crurithyris* zone is locally present as far south as Greenwood County. The *Orbiculoidea* bed extends into Lyon County but was not observed further south. The significance of this zoning, including the fusulinid limestones, is discussed in Part 3. This sequence of fusulinids, *Orbiculoidea*, and *Crurithyris*, in ascending order, is repeated at least once and locally twice in younger sediments. (See p. 38 and 47.)

South of Lyon County the lithology of the Hughes Creek shale member changes remarkably. Units 2 and 4 each thicken to a total of 10 to 12 feet (pl. 5 and figs. 17, 18) and consist of many beds of limestone that are about 1.0 foot thick. The limestone is hard to medium hard, gray, and massive and weathers into irregular blocks that are locally porous. At least the upper 6 feet of each unit of limestone contains chert lenses and nodules. Most of the chert is in the form of small nodules. The lenses of chert are not widespread even though they are as much as 1 foot thick. The chert is dark blue gray and generally contains an abundance of white fusulinids.

In southeastern Cowley County the lowermost bed of limestone of unit 2 contains an abundance of fusulinids and can be traced for a distance of a few miles. No other individual bed of limestone in either unit 2 or 4 appears to have diagnostic features that could be traced from one section to another.

FIGURE 18.—Foraker limestone; all the beds of limestone in the picture are in the Hughes Creek shale member. The massive beds in the middle and upper left are the thick chert-bearing limestone shown in measured section 286 (pl. 5) and described in "Stratigraphic Sections" Located in the SE¼SE¼ sec. 21, T. 32 S., R. 8 E., Cowley County, Kans.

In the SW¼ sec. 31, T. 27 S., R. 9 E., Greenwood County, unit 2 consists of two beds of cherty limestone separated by shale (measured section 330, pl. 5). Here the beds of limestone are like the upper two beds of limestone (units 3 and 5, fig. 14) in the Americus limestone member (p. 32). The lower limestone of unit 2 has a zone of chert nodules about 6 inches from the top with a few isolated nodules near the top. Fusulinids are abundant above the zone of chert nodules. The upper limestone of unit 2 has a 0.5-foot chert lens in the middle part that is overlain by a fusulinid zone and underlain by a crinoid zone. The shale between the limestones is clayey and tan and contains an abundance of fusulinids.

Unit 4 persists, and is nearly constant in thickness, into southwestern Greenwood County. From this point northward it thins and includes only one or more thin beds of cherty limestone separated by thin beds of shale. It is this unit of cherty limestone beds that Bass (1936, p. 36–37) named the Thrall limestone bed after the Thrall post office in western Greenwood County. Here, he noted it to be 4 feet thick.

Unit 2 forms the uppermost bench of the Flint Hills escarpment in Cowley County (fig. 16). The ledges of limestone are not as conspicuous as those of the Americus limestone member. The shoulders of the bench are smoothly rounded and are mantled with nodules of chert. Unit 4 rarely forms a hillside bench, although in southeastern Cowley County it forms a prominent bench, but only in the upper reaches of small tributaries where unit 2 is buried. Here, large rectangular blocks of limestone from this bench slump down onto the underlying shale.

Most of the beds of the Hughes Creek shale member are very fossiliferous; the fauna is listed in table 1. Many of these have been discussed under the description of the units. The characteristic feature of this shale is the abundance of fusulinids in some of the beds in each of the units. The quantity of fusulinids increases toward the south. Brachiopods are generally abundant in many of the beds, and they are associated with fragments of crinoids, bryozoans, and echinoids. Gastropods and pelecypods are generally present in the fauna but in lesser numbers. Microfossils, such as ostracodes and conodonts, are locally part of the faunas.

Calcareous sinus tubular structures (worm burrows?) are common at the base of many of the limestone beds in the Hughes Creek shale member, especially in the southern outcrop area. These nonbranching tubes are as much as 5 feet long and vary from rounded to somewhat flattened in cross section. The rounded tubes are as much as 2½ inches in diameter, but most of them are not over 1 inch. Many are filled with fine-grained detritus which includes coarse fragments of fossils. Where the tubes are abundant they do not connect, but cross each other at random.

The Hughes Creek shale member averages about 38 feet in thickness. As is apparent on plate 5, it thins northward. The thickest observed section of this member is in southeastern Cowley County, where it is about 56 feet thick. Locally, in Lyon and Chase Counties, it is about 25 feet thick. Walters (1954, p. 45) reports 25 to 30 feet of shale in the Hughes Creek in Marshall County. Eastward in Pottawatomie County, Scott, Foster, and Crumpton (1959, p. 119) report this member to average 35 feet in thickness. North of Lyon County the member averages 38 feet in thickness. (See measured sections 128, 229, 235, 257, 270, 280, 286, 293, 306, 318, 327, 330, and 352.)

LONG CREEK LIMESTONE MEMBER

The name Long Creek limestone was proposed by Condra (1927, p. 85) for exposures on Longs Creek, west of Auburn, Nemaha County, Nebr. He (1927, p. 85–86) describes this limestone as "... usually weathered buff to yellowish, somewhat cavernous and irregular; thickness 2 to 7 feet, averaging about 4 feet. This unit usually carries small geodes and a few fossils representing bryozoa brachiopods, and two or more genera of pelecypods." The Long Creek is herein classed as a member.

The Long Creek limestone member is distinctly tan to gray orange and is generally soft and massive. In the northern outcrop area this member consists of one or more massive beds of limestone that locally contain thin shale lentils (pl. 5 and fig. 19). In the southern outcrop area it is not easily identified because it contains a large amount of shale (pl. 5). These beds of shale vary from clayey to silty, are gray, tan, and olive drab, and are thin bedded and nonfossiliferous. In this area the beds of limestone vary from massive to thin bedded, and locally the bedding is distorted. The limestone is generally slightly dolomitic and granular, and in most exposures it is porous or cavernous and contains secondary calcite, quartz, and celestite. Locally, geodes are common.

FIGURE 19.—The upper two members of the Foraker limestone in a road cut in the SW¼SE¼ sec. 27, T. 11 S., R. 11 E., Wabaunsee County, Kans. *a*, Long Creek limestone member. *b-f*, Hughes Creek shale member. *b*, Unit 5. *c*, Unit 4. *d*, Unit 3. *e*, Unit 2. *f*, Unit 1.

The pelecypod *Permophorus* is locally abundant in the middle or lower parts of this member in the form of molds and casts that are iron stained. This genus is characteristic of this member but is present in other limestone units of similar and different lithologic characteristics (table 1). Locally the Long Creek contains fragments of brachiopods and bryozoans.

The Long Creek limestone member rarely forms a hillside bench. This member is not easily recognized on most grass-covered slopes, but in some places these slopes are covered by calcite-, quartz-, and celestite(?)-lined geodes that weather from the limestone.

The Long Creek limestone member averages 8 feet in thickness and ranges from 2.5 to as much as 12 feet. The maximum thickness is in Elk County. The direction of thickening cannot be ascertained as the thickness varies considerably within a small area. (See measured sections 128, 235, 270, 280, 286, 293, 306, 330, and 352.)

JOHNSON SHALE

The Johnson shale was named by Condra (1927, p. 86) for exposures 1½ miles north of Johnson, Johnson County, Nebr. He describes the unit as "bluish argillaceous shale modified by thin, grayish, sandy layers. calcareous plates, and some gypsiferous material and geodes; thickness 16 to 18 feet." The Johnson shale overlies the Foraker limestone and underlies the Red Eagle limestone.

In Kansas, the Johnson shale generally forms most of the long and gentle slope uphill from the Foraker limestone bench. This shale is rarely exposed on the hillsides.

The Johnson consists of silty to clayey shale that is gray green, olive drab, and gray. Toward the south this formation is composed almost entirely of clay shale. Locally in Pottawatomie County there is a thin bed of maroon shale about 6 to 8 feet from the base of the formation. A bed of purple shale is at about the same position in southern Greenwood and western Cowley Counties. In places there are thin beds of argillaceous to fine-grained limestone and mudstone in this shale. They are generally in the middle but locally occur at other horizons and can be traced for only a short distance. These beds are generally gray to light gray, and they commonly weather to a shaly appearance. Very calcareous shale is common in the upper half of the Johnson shale in the central part of the State. In Pottawatomie, Riley, and Wabaunsee Counties these beds show penecontemporaneous folds that rarely can be traced into the overlying or underlying beds of shale. Locally thin beds of gypsum and gypsum-filled fractures are common. Moore, Jewett, and O'Connor (1951, p. 15) noted that in Chase County the upper part of this shale is dark gray and carbonaceous. These beds were also observed in Lyon County by O'Connor (1953, p. 13). He states that "In southern parts of the county the entire thickness of this part may be black carbonaceous shale."

In southwestern Elk and eastern Cowley Counties there are many thin beds of limestone (0.2 ft thick) in the upper 6 feet of the Johnson shale. The beds in east-central Cowley County are evenly spaced at about 7-inch intervals. The intervening beds of shale are silty and gray and contain calcareous nodules. Well-preserved *Linoproductus*, *Juresania*, and other brachiopods and pelecypods are abundant in the beds of limestone and shale (table 1). The limestone beds pinch out northward, and the fossils decrease in number and are rare to absent north of southwestern Elk County. H. G. O'Connor (oral communication) reports gastropods in the upper part of the Johnson shale in the SW¼NW¼ sec. 35, T. 15 S., R. 11 E., Lyon County. Fossils have not been observed in this formation elsewhere north of Elk County.

The Johnson shale averages 20 feet in thickness. It thins both north and south from Wabaunsee and Riley Counties where it averages about 25 feet in thickness. A minimum thickness of about 13 feet was observed in western Greenwood County. (See measured sections 128, 152, 235, 253, 275, 280, 286, 293, 297, 306, 330, and 374.)

RED EAGLE LIMESTONE

The Red Eagle limestone was named by Heald (1916, p. 24) for exposures near the Red Eagle School, southwest of Foraker, Foraker quadrangle, Osage County, Okla. Condra (1927, p. 86) named the three beds that he later (1935, p. 8) called members of the Red Eagle. These members are, in ascending order, the Glenrock limestone, the Bennett shale, and the Howe limestone members.

The correlation of these members from the type section in Oklahoma to the Cottonwood River in Chase County was made by Bass (1936, p. 41). O'Connor and Jewett (1952, p. 329–362) studied the Red Eagle limestone in detail from southern Nebraska to Oklahoma. Most of the data presented in this report are in agreement with those presented by the early workers. These members can be easily distinguished southward into southern Greenwood County, but further south they are not easily distinguished, as the formation is composed entirely of limestone (fig. 20). North of Elk County the three members are easily identified by lithology and fossil content except in the area along the Lyon-Wabaunsee County line where there is a biostrome in the Bennett shale member (O'Connor and Jewett, 1952, p. 337; and Mudge and Burton, 1959, p. 60). The detailed stratigraphy of the Red Eagle is under the individual members. In the northern outcrop area the Red Eagle limestone averages about 11 feet in thickness. It thickens to as much as 28 feet in northern Lyon County where it contains a biostrome. South of that area it ranges in thickness from 10 to about 25 feet, thickening toward the south where it is entirely limestone. (See pl. 5.)

GLENROCK LIMESTONE MEMBER

Condra (1927, p. 86) proposed the name Glenrock limestone for exposures just northwest of Glenrock, Nemaha County, Nebr. He describes this unit as "Dark gray, dense, weathering light gray or slightly buff; thickness 1 to 2 feet. This forms rectangular blocks. The leading fossils are Fusulina, bryozoa, brachiopods, and Pinna sp." This unit, herein classed as a member, persists along most of its outcrop area except in the area that is east, a few miles north, and northwest of Alma, Wabaunsee County, Kans. This area has a diameter of about 10 miles in which the member is absent. There is no evidence of erosion beneath the clearly identified contact at the base of the Bennett shale member, and therefore it can be assumed that the Glenrock either pinches out or grades laterally into shale. The preferred explanation is that the Glenrock pinches out, because its fossils are also absent in these areas.

The Glenrock limestone member, because of its thinness, rarely makes a hillside bench.

In the northern two-thirds of the State, the Glenrock limestone member is generally a hard massive limestone that is tan to gray and fractures into irregular blocks. Locally, as at Manhattan, Riley County, Kans., this member is conglomeratic. It contains small rounded inclusions of limestone that rarely exceed one-fourth inch in diameter.

Fusulinids are the characteristic fossil in this limestone, and they are generally more abundant in the middle and lower parts of the member. The upper inch or two commonly contains fragments of *Orbiculoidea.* O'Connor and Jewett (1952, p. 343) list a nonfusulinid part beneath the fusulinid-bearing part that contains algal deposits, Foraminifera, and other fossils. Ostracodes, brachiopods, and bryozoans were also observed in this part of the bed. (See table 1.) O'Connor and Jewett (1952, p. 343) describe a conspicuous stromatolite bed at the base of the Glenrock limestone member in Nebraska.

In southwestern Greenwood County this member is about 3 feet thick and contains chert nodules in its upper half. South of this area the Glenrock can locally be distinguished from the rest of the limestone units of the Red Eagle limestone by the abundance of fusulinids.

The Glenrock limestone member ranges from a featheredge to as much as 3 feet in thickness. As mentioned by O'Connor and Jewett (1952, p. 343), it is generally less than 1 foot thick. (See measured section 128, 152, 235, 253, 275, 280, 286, 297, 330, 331, and 374.)

BENNETT SHALE MEMBER

The Bennett shale member was named by Condra (1927, p. 86) for exposures along the Little Nemaha River and its tributaries south of Bennett, Lancaster County, Nebr. He describes it as "formed of bluish gray and nearly black argillaceous shale, with one carbonaceous streak resembling coal and a thin yellowish to brownish limestone; combined thickness 5 to 11 feet." Condra (1927, p. 185) lists carbonaceous shale in a measured section to be 5 inches thick and to lie about 3 feet above the base of the member.

In Kansas the Bennett shale member changes considerably lithologically from north to south (pl. 5). In the outcrop area north of Greenwood County the Bennett is mainly shale, with the exception of a biostrome facies in southern Wabaunsee and northern Lyon Counties. The beds of shale are mainly silty and gray to tan gray, but locally dark-gray fissile shale is present in the lower and upper parts. In places in Pottawatomie and Wabaunsee Counties there is a thin bed of argillaceous limestone in the middle part. In Riley County beds of carbonaceous shale occur about 1.5 feet above the base of the member.

O'Connor and Jewett (1952, p. 340–342) list faunal zones in this member. As shown in figure 31, the upper part of this member, and in many exposures the upper three-fourths, contains a varied fauna of crinoid columnals, echinoid spines, bryozoans, brachiopods, and pelecypods. (Also see table 1.) In many places this shale overlies a thin dark-gray thin-bedded shale unit that contains a *Crurithyris* zone which in turn overlies the lower few inches of the Bennett shale member, a dark-gray fissile shale unit that contains an *Orbiculoidea* zone locally associated with *Lingula.* This lowermost zone rests directly upon the Glenrock limestone member.

In some exposures in Wabaunsee County another *Orbiculoidea* zone overlies the *Crurithyris* zone, or, as in the exposures beneath the biostrome, it is in the uppermost part of the shale. The upper *Orbiculoidea* zone is correlative with the middle part of the shale member further north. This sequence of faunal zones was observed in many of the exposures along the outcrop, but the ascending sequence of *Orbiculoidea*, *Crurithyris*, *Orbiculoidea* zones was seen only in Wabaunsee County. These zones are not easily recognized south of Greenwood County where the Bennett shale member is all limestone, but the lower *Orbiculoidea* zone persists southward into Elk County. The importance of the faunal zones in relation to cyclothems and ecology is discussed on pages 102 under those topics. In Nebraska, Condra (1927, p. 185) recognized these zones, and he recorded a similar sequence as found in Wabaunsee County.

In the area of the Wabaunsee-Lyon County line a biostrome is present in the Bennett shale member (O'Connor, 1953, p. 13; O'Connor and Jewett, 1952, p. 341; and Mudge and Burton, 1959, p. 60). (See pl. 5.) This biostrome originates in the middle of the member. It can best be studied in southern Wabaunsee County where many of its associated components are exposed. This biostrome has a width of about 1½ miles and can be traced for about 8 miles; it trends southwest. The best exposures can be seen in NW¼NE¼ sec. 31, T. 14 S., R. 12 E., Wabaunsee County; NE¼NE¼ sec. 12, T. 15 S., R. 11 E., Wabaunsee County; and in the NE¼NE¼SW¼ sec. 23, T. 15 S., R. 11 E., Lyon County.

In cross section the west slope of the biostrome ends abruptly, whereas the east side has a more gentle slope. The west slope may have faced seaward. The biostrome consists entirely of massive beds of soft to medium-hard dolomitic limestone that locally is hard and crystalline.

In Lyon County the upper part of the biostrome is oolitic, possibly an algal deposit. Beneath the oolitic beds are massive beds of tan to light-gray limestone that in places are brecciated. These beds weather porous to cavernous and contain many solution channels. Many sinkholes are developed in the limestone, and they have been used in tracing the extent of the biostrome. The center of the biostrome contains some nodules of chert. The bedding is irregular and does not, in any single exposure, dip in any prevalent direction. The lower part of the biostrome is locally coquina. Beneath the coquina is a zone of *Crurithyris* and *Orbiculoidea*. Locally above this zone a bed of limestone with fusulinids and fragments of crinoids and echinoids is present. The middle of the biostrome contains small solitary corals, algal deposits, and fragments of crinoids, echinoids, brachiopods, and bryozoans.

The west flank of the biostrome is exposed in the SW¼NE¼ sec. 36, T. 14 S., R. 11 E., Wabaunsee County. Here the limestone in the center of the Bennett shale member contains a 0.3-foot lens of chert, but otherwise this member is normal lithologically and paleontologically. The west flank of the biostrome is also exposed in the SW¼SE¼NE¼ sec. 17, T. 14 S., R. 12 E., Wabaunsee County. Here the lower part of the biostrome contains a conglomeratic lens of well-rounded fragments of claystone and angular fragments of limestone that have a maximum diameter of one-fourth inch. The rest of the bed of limestone is soft, tan, and dolomitic, with interbedded silty tan-gray very calcareous shale. A thin conglomeratic lens is present in the middle part of this limestone.

The east flank is poorly exposed, but the thickness of the limestone of the biostrome indicates a more gradual thinning toward the east.

The limestone beds in the biostrome form a prominent hillside bench with bluffs up to 15 feet high. The biostrome ranges from a few feet to as much as 28 feet in thickness. This thickness is much too great to be compensated entirely by thinning of the Bennett shale member; therefore, the overlying Roca shale apparently thins over the biostrome. The Howe limestone member caps the biostrome.

South of the biostrome O'Connor and Jewett (1952, p. 342) noted "rather massive, light gray to nearly white, porous or cavernous dolomitic limestone in the middle or lower part of the member." These beds are present locally in Lyon, Chase, and Greenwood Counties (pl. 5). Along the outcrop they are very lenticular and apparently are not related to the massive beds of limestone to the south or to the biostrome to the north. Subsurface data west of the outcrop line may establish a direct tie between the beds of limestone of the Bennett shale member and the biostrome. The limestone beds described by O'Connor and Jewett (1952) are medium hard, tan to light gray, and massive. In the SE¼SW¼NW¼ sec. 26, T. 19 S., R. 11 E., Chase County, the lower part of this member contains a massive bed of limestone 5.4 feet thick that is light tan and has a chalky appearance. It is porous in the middle part and contains fragments of fossils. In the SE¼ SE¼ sec. 16, T. 23 S., R. 10 E., Greenwood County, this bed is 6.2 feet thick and is conglomeratic. Here the upper part is coquina.

In Greenwood and Chase Counties the beds of shale in the Bennett are mostly silty, tan gray to gray, and thin bedded. The 3.0 feet of shale overlying the beds of limestone is very fossiliferous and contains well-preserved crinoid columnals, echinoid spines, bryozoans, and brachiopods. The upper part of the member varies from sparsely fossiliferous to nonfossiliferous. In the SW¼SE¼ sec. 12, T. 29 S., R. 8 E., Elk County, the beds of shale in the Bennett are in the upper 4.0 feet (pl. 5). The shale is silty, calcareous, tan gray, thin bedded, and nonfossiliferous, and has calcareous lentils. South of this area only thin lenses of shale are present in this member.

South of Elk County the Bennett shale member is almost all limestone (fig. 20). Its upper and lower boundaries can locally be established, but in many exposures these are not discernible. This member consists of many beds of limestone about 1 foot thick. The beds are medium hard to hard, brittle, locally dense, and gray, and here and there they are separated by thin lentils of gray shale. The limestone is porous to cavernous and weathers into irregular blocks. The bedding planes are generally very irregular, imparting a wavy appearance (fig. 20). Locally the lower beds contain an intraformational conglomerate in which angular flattened fragments of limestone are incorporated in a limestone matrix.

Although fossils are common throughout these beds, they are most abundant in the upper part. The faunal assemblage is given on table 1.

In the southern outcrop area the Bennett forms a prominent hillside bench, but with very little limestone exposed. Bass (1929, p. 54) noted that more shrubs and trees grow on the rock terrace of the Red Eagle limestone than on other limestone benches above and below it.

The limestone facies of the Bennett shale member is about 20 feet thick. North of Elk County, where the shale facies dominate, the Bennett shale member averages 8 feet in thickness. It ranges in thickness from 3 feet in Pottawatomie County to as much as 19 feet in Greenwood. In general, this member thins

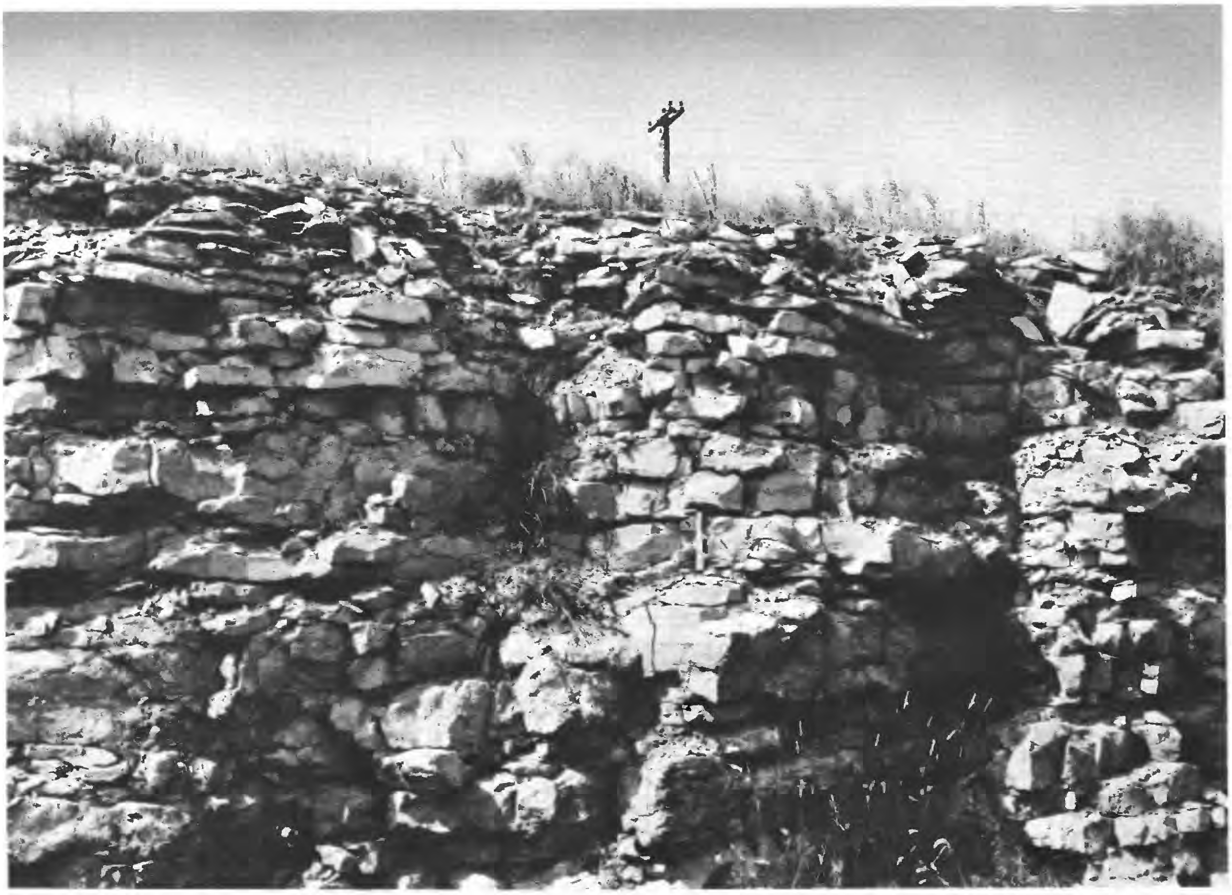

FIGURE 20.—Part of the Bennett shale member of the Red Eagle limestone in a road cut in the SW¼SE¼ sec. 21, T. 32 S., R. 8 E., Cowley County, Kans. (See measured section 286, pl. 5, and "Stratigraphic Sections.")

toward the north (pl. 5). (See measured sections 128, 152, 235, 253, 275, 280, 286, 288, 293, 297, 331, and 374.)

HOWE LIMESTONE MEMBER

The name Howe limestone was proposed by Condra (1927, p. 86) for exposures south of Howe, Nebr. He states that the

> stone in its unweathered condition, dark gray, massive and dense, with considerable free calcite; weathers buff to yellowish, granular, vesicular or cavernous, and very irregular; thickness about 4 feet. This carries geodes at places. It has few fossils.

The unit is classed as a member.

The Howe limestone member is similar in lithology and, in part, paleontology to the Long Creek limestone member of the Foraker limestone and Burr limestone member of the Grenola limestone. It is also similar to some of the younger limestones in the Chase group.

The Howe limestone member is almost invariably one massive bed of limestone that is nearly constant in lithology along its outcrop. It is characteristically tan to yellow on weathered surfaces and tan to gray on fresh surfaces. In the northern outcrop area, O'Connor and Jewett (1952, p. 337) noted that this member was dolomitic. From Wabaunsee County north it is relatively soft, granular, massive limestone that locally contains a thin bed of shale. It generally weathers porous and cavernous; some of the caverns are lined with calcite and celestite(?). Scott, Foster, and Crumpton (1959, p. 121) report two massive beds of limestone in Pottawatomie County; the upper bed is harder and more resistant to erosion than the lower bed.

Locally in Wabaunsee County and toward the south this limestone weathers light gray and in thin irregular beds. In most exposures it is a massive tan to tan-gray bed of medium-hard limestone and in the southern outcrop area is readily distinguishable from the underlying beds of limestone in the Bennett shale member. Bass (1929, p. 54), in reference to the Red Eagle limestone, states that in Cowley County:

> The top 2 to 3 feet is composed of deep buff, rather coarse-grained massive limestone that weathers away easily and so is not exposed in all localities. Where present, this bed crops out as large rounded nodular masses, and because of its deep buff color is unusually conspicuous on the slopes.

This description also fits many of the exposures of this member toward the north. In secs. 31, 32, and 33, T. 23 S., R. 10 E., Greenwood County, Bass observed two benches formed by the Howe limestone member. The lower bench was formed by limestone typical of the Howe and 2 feet above it was a bench formed by white slabby limestone. This thin-bedded facies of the Howe limestone member was also seen in southwestern Greenwood County. Verville [8] reports that the Howe limestone member has a conglomeratic appearance in Elk County that he attributes to a large number of small algal bodies. In east-central and southeastern Cowley County the Howe is hard, dense tan-brown limestone that has a conchoidal fracture. Here it is faintly crossbedded in the middle part. The upper part of the limestone contains stromatolites.

The Howe limestone member overlies the biostrome in the Bennett shale member and is not easily distinguished from it. On the east flank of the biostrome, H. G. O'Connor (written communication, 1954) noted a 0.4-foot bed of cryptozoonlike stromatolites in the upper part of the Howe limestone member in the SW¼NW¼ sec. 35, T. 15 S., R. 11 E., Lyon County. The rest of the limestone contains stromatolites, fusulinids and other Foraminifera, echinoid spines, bryozoan fragments, ostracodes, and small pelecypods and gastropods. On the west of the biostrome the Howe consists of beds of soft dolomitic limestone with thin, silty very calcareous beds of shale.

Fossils are only locally abundant in the Howe limestone member (see table 1). The most persistent fossil zone, 3 or 4 inches thick, consists mostly of ostracode tests and is generally at the top of the member. In some exposures in northern Wabaunsee County this zone is in the middle of the bed, whereas in other exposures it is near the base of the bed. Scott, Foster, and Crumpton (1959, p. 121) note that in the northeast corner of Pottawatomie County the Howe is composed mostly of ostracode tests. This zone of ostracodes is characteristic of this unit and is an aid in identifying it, even though a similar zone occurs in the Burr limestone member of the Grenola limestone.

Other fossils are locally abundant in the member. The fauna commonly present is listed in table 1. Fusulinids were seen only in northern Lyon County.

Only locally does the Howe limestone member form a distinctive and easily recognized hillside bench. On most slopes it forms a small bench with no limestone exposed.

The Howe averages about 3 feet in thickness. The thickness varies considerably within a county, as demonstrated for Lyon County by O'Connor (1953, p. 13), where this member ranges from about 1 to 6 feet in thickness. This same range in thickness was observed by the writers, although O'Connor and Jewett (1952, p. 340) describe it as ranging from about 0.7 to 5 feet. (See measured sections 128, 152, 235, 253, 280, 287, 288, 293, 297, 331, and 374.)

[8] Op. cit., p. 201. (See footnote, p. 11.)

ROCA SHALE

The name Roca shale was proposed by Condra (1927, p. 86, 181) for exposures at Roca, Lancaster County, Nebr. He states that the unit is "Composed of bluish gray, olive green, and reddish argillaceous shale. There are thin fossiliferous limestone seams in the upper portion; thickness of division 18 to 20 feet in Nebraska and somewhat greater in Kansas." The upper part of his Roca, including pelecypod-bearing limestone, was later subdivided into two members and assigned by Condra and Busby (1933, p. 9, 12–13) to their Grenola formation. The Roca shale overlies the Red Eagle limestone and underlies the Grenola limestone (pl. 5).

In Kansas the Roca is composed mainly of beds of gray, gray-green, and green silty to clayey shale that locally contain thin beds of purple and maroon shale. In the northern outcrop area the variegated beds are generally in the upper part of the lower half of the formation. Toward the south the beds of maroon shale thicken, and south of west-central Greenwood County they form one-half to one-third of the unit. Here the maroon beds are generally in the middle or lower part of the formation.

Locally, north of Greenwood County, this formation contains one or more beds of argillaceous limestone in its middle and lower parts. These beds are medium hard to hard, gray, and, in some places, dense. In Lyon County, O'Connor (1953, p. 11) noted a lenticular boxwork type of limestone in the upper part. In Wabaunsee County, there are one or more soft beds of limestone in the upper part of this formation. In the SE¼SE¼ NW¼ sec. 14, T. 12 S., R. 12 E., Wabaunsee County, a thin conglomeratic bed of soft limestone is present in the middle part of this formation. It contains lime and limonite nodules that are as much as one-fourth inch in diameter.

Fossils are present locally in the beds of limestone (see table 1). Fossil leaves have been reported by F. E. Byrne (written communication, 1952) from this shale in exposures southwest of Alma, Wabaunsee County.

The Roca shale averages 18.7 feet in thickness. The maximum thickness of 30.7 feet was observed in Wabaunsee County, the minimum of 8.5 feet was seen in Greenwood County. It is assumed that over the bioherm in the Bennett shale member of the Red Eagle limestone the Roca shale is either absent or very thin, but no exposures of this shale were seen above the bioherm. (See measured sections 128, 151, 152, 235, 253, 280, 287, 288, 293, 297, 322, 331, and 374.)

GRENOLA LIMESTONE [9]

The Grenola limestone was named by Condra and Busby (1933, p. 7, 8) for the beds of limestone overlying the variegated Roca shale, as restricted by Condra and Busby and used herein, and underlying the variegated Eskridge shale. The formation was named for exposures 4 to 5 miles west of Grenola, Elk County, Kans. Measured section 288 of this report is very likely the type section (see "Stratigraphic Sections" and pl. 5). Condra and Busby (1933, p. 9) subdivided this formation into five members, which are, in ascending order, the Sallyards limestone, the Legion shale, the Burr limestone, the Salem Point shale, and the Neva limestone members. Condra and Busby (1933), in their excellent paper on the Grenola limestone, correlated it from southeastern Nebraska, across Kansas, and into northern Oklahoma. This report is mostly in agreement with their correlations and only supplies additional descriptive matter for this unit in Kansas. The Grenola averages about 43 feet in thickness; it ranges from 32 feet to 54 feet and thickens toward the south (pl. 5).

SALLYARDS LIMESTONE MEMBER

The Sallyards limestone member was named by Condra and Busby (1933, p. 9, 10) for exposures 1 mile northeast of Sallyards, Greenwood County, Kans. They described the Sallyards as "bluish-gray, top rough, weathers light gray to yellow with shale reentrant, contains *Myalina*, *Aviculopecten*, gastropods, *Chonetes*, bryozoans, and crinoid joints, 2′6″" (1933, p. 19). Section 341 on plate 5 is in the vicinity of the type section.

In Kansas the Sallyards, although locally quite thin, is a persistent limestone bed. It is hard to medium-hard gray to tan-gray limestone that varies from massive to shaly and in some places weathers platy. Locally, in Chase and Wabaunsee Counties there are thin lenses of shale in this member, and the limestone weathers shaly. In the southern outcrops it is fine grained and is generally light gray. (See fig. 21.) In Oklahoma, Condra and Busby (1933, p. 25) noted this limestone as impure and grading into sandstone.

Pelecypods are the characteristic fossils, and *Aviculopecten* is the most abundant. They are generally found throughout the member, but in the southern outcrop area they are more abundant in the lower part, and toward the north they are more abundant in the upper part. Locally, fossil fragments are abundant in the upper part of the member. Other fossils observed in some exposures are listed in table 1. Stromatolites, including *Cryptozoon?*, are present in many of the exposures. In the southern part of the State the stromatolites are in the middle and lower part of the member.

The Sallyards limestone member generally forms a small and not too prominent grass-covered hillside bench that lies about 10 feet beneath the very prominent bench of the Neva limestone member. Only locally are large blocks of limestone exposed along this bench. This bench is most noticeable in the southern outcrop area where the Sallyards is thicker (fig. 21).

The Sallyards averages 1.3 feet in thickness. Moore, Jewett, and O'Connor (1951, p. 14) stated that this limestone ranges from about 1 to 5 feet in thickness in Chase County. O'Connor (1953, p. 11) observed 5 feet of Sallyards in southern Lyon County, but it thins northward in the county to only 0.3 foot. These thicknesses of the Sallyards are the maximum and minimum. In general this member thickens toward the south. (See measured sections 128, 151, 235, 253, 256, 280, 287, 288, 293, 297, 322, 331, and 374.)

LEGION SHALE MEMBER

The Legion shale member was named by Condra and Busby (1933, p. 9, 10) for exposures on U. S. Highway 40, southwest of the American Legion grounds, 1¾ miles southwest of Manhattan, Riley County, Kans. Stratigraphic section 236 of this report was measured at the type section (see "Stratigraphic Sections" and pl. 5). Condra and Busby (1933, p. 18) described the type section of the Legion shale member as consisting of gray shale in the lower 3.0± feet, overlain by 4 inches of mudstone. The upper 8 to 10 inches is black carbonaceous fissile shale.

In Kansas the Legion shale member is generally gray, but it is tan to gray green in some places. It varies from clayey to silty, with clay shale predominating. Toward the north, dark-gray to almost black fissile shale is common in the upper part. Locally in the southern outcrop area thin pelecypod-bearing limestone beds are common in the middle part. In the NW¼NE¼ sec. 30, T. 32 S., R. 8 E., Cowley County, there are many thin impure beds of limestone in the Legion (fig. 21). Here the beds of shale and limestone are very fossiliferous (see collection from USGS loc. 13769, table 1). The fossils are more abundant in the beds of limestone. Northward, in Elk and Greenwood Counties, limestone is less common and, where present, is nonfossiliferous. In northern Greenwood and east-

[9] The reader's attention is directed also to a paper describing the environment of deposition of the Grenola limestone, by Lane (1958).

FIGURE 21.—The lower part of the Grenola limestone in a road cut in the NW¼NE¼ sec. 30, T. 32 S., R. 8 E., Cowley County, Kans. *a*, Burr limestone member. *b*, Legion shale member. *c*, Sallyards limestone member. *d*, Roca shale member. (See measured section 287, pl. 5, and "Stratigraphic Sections".)

central Wabaunsee Counties, pelecypods occur in the upper part of this shale member.

The Legion shale member averages 5.8 feet in thickness. A maximum thickness of 12.9 feet was seen in northwestern Greenwood County; a minimum thickness of 1.4 feet was observed in Wabaunsee County. In general this member thickens toward the south (pl. 5). (See measured sections 128, 151, 235, 256, 280, 287, 288, 293, 297, 322, and 374.)

BURR LIMESTONE MEMBER

The Burr limestone member was named by Condra and Busby (1933, p. 10) after Burr, Otoe County, Nebr. The type locality is the bluffs and ravines west of the south fork of the Little Nemaha River, 2½ miles northwest of Burr. Condra (1935, p. 8), in a geologic column for Nebraska, lists the Burr as two limestone units, separated by a shale unit. His description of these is as follows:

(3) Burr limestone, 10′–11′.

a. Limestone, gray, massive, weathers buff-brown, upper 6″ pitted, with a crustal ostracodal layer, middle portion weathers yellow and slabby, contains a gastropodal layer, thickness 3′6″–4′.

b. Shale, gray and black, carbonaceous, fissile, with calcareous slabs, contains plant remains, weathers brownish, 3′6″.

c. Limestone, light gray, massive, in one, two or three layers with shale partings, 1′6″–3′6″.

Toward the north the Burr limestone member is easily recognized by its two tan to gray medium-hard *Permophorus*-bearing limestone units that underlie the Neva limestone member. The ostracode zone is an aid in identifying the Burr.

Toward the south the gray medium-hard to hard platy *Aviculopecten*-bearing limestone units beneath the Neva limestone member are easily recognized as the Burr limestone member.

In Kansas the threefold division of the Burr limestone member is easily recognized in the northern outcrop area, but less so in the southern area. The following discussion of the Burr is according to the threefold division, which is (a) the lower bed of limestone, (b) middle bed of shale, and (c) the upper bed of limestone. The Burr averages about 7 feet in thickness. It ranges in thickness from 2.3 feet in Lyon County to over 15 feet in Cowley County. In general it thickens toward the south, even though there may be as much as 8 feet in variation in thickness within a county (pl. 5).

North of Lyon County the lower bed of limestone is generally gray to tan, but locally it is gray orange and resembles the Howe limestone member of the Red Eagle limestone and the Long Creek limestone member of the Foraker limestone. In Nemaha County this bed is dark blue gray. In the north half of Kansas the lower bed of limestone varies from soft to very hard but is mostly medium hard. In most exposures it is massive and weathers into irregular blocks whose upper surface has a shaly appearance. Locally in Wabaunsee and Pottawatomie Counties this bed is dense and argillaceous.

South of Wabaunsee County, the lower limestone is medium hard and gray. It grades southward from shaly limestone to hard, dense crystalline limestone. This is in contrast to the tan to gray softer massive bed seen in the north. Locally in Elk County this limestone contains small subangular clay balls. Toward the south, thin beds of shale, some very calcareous, are common in this bed. Here the lower bed of limestone forms a hillside bench (fig. 22).

The fauna in the lower bed of limestone varies somewhat from north to south, with the most notable change at the Wabaunsee-Lyon County line in the area of the biostrome in the Bennett shale member of the Red Eagle limestone. Across Kansas this bed generally contains a varied fauna of pelecypods, brachiopods, bryozoans, gastropods, and crinoid and echinoid fragments, (for example, col. 14807, table 1). North of Lyon County the pelecypod *Permophorus* is locally very abundant, and rarely are there other pelecypods associated with it. South of Lyon County, *Permophorus* is rare, whereas other pelecypods are generally very abundant. The change in fauna coincides with the changes in the limestone, which varies from soft to medium hard, tan to gray, and massive in the north to hard to medium hard, gray, and platy in the south. Locally stromatolites and microfossils are common in this bed. *Crurithyris* and fusulinids were seen in some exposures in Wabaunsee County.

The lower bed of limestone averages about 2.5 feet in thickness and ranges from 0.4 foot to 7.6 feet. In general it thickens toward the south (pl. 5).

The middle bed of shale is mostly gray and clayey, but in some places, as in Wabaunsee and Cowley Counties, it is silty. Toward the south it is locally very calcareous and contains one or more thin calcareous lenses. In some exposures north of Greenwood County the lower part of the shale contains a bed of dark-gray to black fissile carbonaceous shale.

In the southern outcrop area, fossils occur locally in the calcareous lenses and beds of shale. The fauna is mostly pelecypods, bryozoans, and gastropods, but brachiopods and stromatolites are present. Condra and Busby (1933, p. 26) found plant remains, fern leaves in particular, in an exposure of this shale 7¼ miles south of Dawson, Richardson County, Nebr.

This bed of shale averages about 2.0 feet in thickness. It ranges from a featheredge to as much as 8 feet in thickness (pl. 5).

The upper bed of limestone, like the lower bed, changes somewhat along its outcrop. North of the Lyon County line the upper bed is medium-hard to soft tan to gray massive limestone; whereas south of this line it is hard to medium hard, gray, and platy (fig. 22).

This unit, toward the north, locally resembles the Howe limestone member of the Red Eagle limestone and the Long Creek limestone member of the Foraker limestone. Here and there along the outcrop it is dense and in part crystalline. Toward the south it is shaly and contains one or more thin beds of shale that is generally very calcareous (fig. 22). In east-central Cowley County there is a thin faintly crossbedded siltstone bed in the upper part. In some exposures in Lyon and Greenwood Counties this upper bed of limestone contains rounded to flattened fragments of limestone and limonite that are as much as 1 inch in diameter.

South of the Wabaunsee-Lyon County line the upper bed of limestone contains a fauna that is mostly pelecypods. North of that line *Permophorus* is locally abundant in the middle and lower parts of the upper bed, and occasionally *Aviculopecten* is associated with it. *Permophorus* was rarely seen south of this line. Other fossils common in this bed are bryozoans, brachiopods, and gastropods. These fossils are more common north of the Wabaunsee-Lyon County line than south of it. North of Greenwood County there is a thin (0.3- to 0.5-ft) persistent zone of ostracodes in the upper part of this bed, similar to the Howe limestone member of the Red Eagle limestone. Locally stromatolites occur in this bed, and commonly they are at a horizon equivalent to the ostracode bed. The stromatolite bed is well developed in the SE¼SW¼NW¼ sec. 26, T. 19 S., R. 7 E., Chase County. In the center of sec. 22, T. 8 S., R. 11 E., Pottawatomie County, spinelike objects of undetermined origin are abundant in the lower part of this bed.

FIGURE 22.—The middle part of the Grenola limestone in a road cut in the NW¼NE¼ sec. 30, T. 32 S., R. 8 E., Cowley County, Kans. *a*, Base of Neva limestone member. *b*, Salem Point shale member. *c*, Burr limestone member. *d*, Upper part of the Legion shale.

The upper bed of limestone averages 2.7 feet in thickness. It ranges from 1.0 foot to 5.8 feet in thickness in Cowley County, but rarely exceeds 3.0 feet elsewhere. It thickens somewhat toward the north (pl. 5). (See measured sections 128, 151, 235, 256, 280, 287, 288, 293, 297, 322, 329, 371, and 374.)

SALEM POINT SHALE MEMBER

The Salem Point shale member was named by Condra and Busby (1933, p. 10) for exposures at Salem Point, 1½ miles northwest of Salem, Richardson County, Nebr. They (1933, p. 15) described a section in and near the town of Salem, Nebr., and list the Salem Point as 7 to 8 feet of calcareous shale.

In Kansas this member is mostly silty, calcareous gray to olive-drab to gray-green shale that weathers tan to gray. Locally in the southern outcrop area it is clayey and is very calcareous. In Nebraska, and locally in Kansas, Condra and Busby (1933, p. 27) noted a bed of sandy shale in this member. In parts of Oklahoma they observed that the member consists of red shale. In the central outcrop area in Kansas, very thin calcareous lentils are common, and plates from them are abundant on the exposed surfaces. Although these plates are characteristic of this bed of shale in Riley, Wabaunsee, and parts of Pottawatomie Counties, they were seen elsewhere. The shale is generally thin bedded to blocky, and in some places it contains beds of fissile shale. In west-central Greenwood County a massive bed of siltstone is present in the middle of this member. Locally in Riley, Pottawatomie, Wabaunsee, Chase, and Greenwood Counties there is a bed of argillaceous limestone in the middle of the member. This bed is nonfossiliferous except in southeastern Riley and southern Pottawatomie Counties, where it contains *Aviculopecten* and locally ostracodes. The limestone is very lenticular and can generally be correlated only by stratigraphic position within the member. It was placed in the upper bed of the Burr limestone member by Condra and Busby (1933, p. 29), at the Elmdale and Sallyards sections. (See measured section 280, this report.) In Chase County this thin limestone bed lies above the ostracode zone that is in the upper part of the Burr limestone member toward the north, and is very likely correlative with the thin argillaceous beds of limestone that are in the middle part of the members in southeastern Riley and southern Pottawatomie Counties.

In east-central Cowley County the Salem Point shale member is silty and mostly very calcareous, and it contains many thin lentils of claystone. Gastropods are present in all parts of the bed, pelecypods occur in the middle part, and brachiopods, particularly *Crurithyris*, are found in the upper part. In the NW¼NW¼ sec. 26, T. 10 S., R. 9 E., *Permophorus* is present in the lower part of the member. (See table 1.)

The Salem Point shale member averages about 8 feet in thickness. Its maximum thickness (about 15 feet) is attained in Greenwood County. It thins both north and south of this area and becomes noticeably thinner toward the south (pl. 5). (See measured sections 128, 236, 256, 280, 287, 288, 289, 293, 298, 322, 329, and 371.)

NEVA LIMESTONE MEMBER

The name Neva limestone was proposed by Prosser (1902, p. 709) for exposures near Neva, Chase County, Kans. The Neva limestone member of Condra and Busby (1933, p. 11) consists of the following at the type section:

	Ft.	In.		Ft.	In.
Limestone	4	0	Limestone		8
Shale	1–2	0	Shale		3
Limestone	5–6	0	Limestone		3–4
Limestone	1	6	Shale		10
Shale		5–6	Limestone	2	0

This section contains more beds of limestone and shale in the lower part than were originally described by Prosser (1902, p. 709) who included only the upper two beds of limestone and the intervening bed of shale of the Condra and Busby section (1933, p. 11). The addition of the lower beds has generally been accepted as is done here, because they are recognized to be lithologically and paleontologically similar to the limestones of Prosser's Neva.

Condra and Busby (1933, p. 27) stated that the Neva limestone member was: "Rather uniform in thickness (about 20 feet) from north of the red bed country of Oklahoma to Nebraska." Our investigation did not find this member uniform in thickness. It ranges in thickness from 28 feet in southeastern Cowley County (Bass, 1929, p. 55) to 9 feet in Lyon County (O'Connor 1953, p. 11). The Neva averages about 17 feet in thickness. From the central outcrop area it thickens mostly to the south. (See pl. 5.)

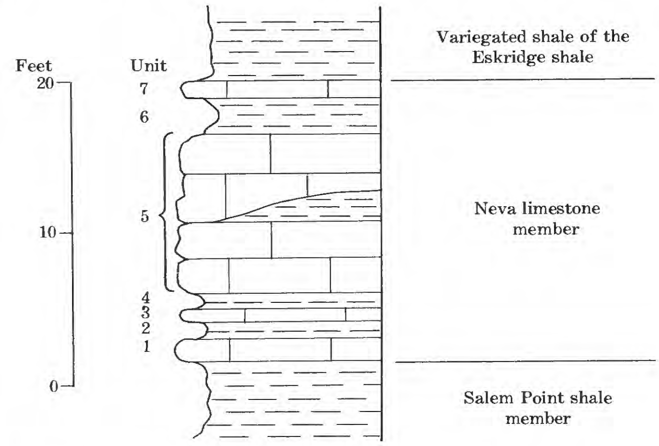

FIGURE 23.—A generalized diagram of the subdivisions of the Neva limestone member of the Grenola limestone.

The member consists of many beds that can be traced for a considerable distance; the following description of this member is by the units listed in figure 23 (also see pl. 5).

Unit 1 is persistent along the outcrop. In most exposures its contact with the underlying beds of shale is relatively sharp, but locally the contact is gradational. This limestone is generally a single bed that is massive, hard to medium hard, and gray. In many exposures the unit is somewhat dense and fractures conchoidally into irregular blocks that further weather into irregular plates. Toward the south it contains thin lentils of shale and has minute wavy bedding that may be algal deposits. In many places the algal growth form *Osagia*? occurs in this unit.

Locally in Lyon County (O'Connor, 1953, p. 11), east-central Cowley, and in southern Wabaunsee Counties, unit 1 contains chert nodules. This unit contains a fauna of bryozoans, brachiopods, (including *Crurithyris*), pelecypods, gastropods, and fragments of echinoids and crinoids (table 1). Fusulinids are not very common, but they were seen in the upper part of unit 1 in Wabaunsee County. Fossil fragments are common to abundant in most exposures; stromatolites are the most characteristic.

Unit 1 ranges in thickness from 0.4 foot to as much as 3.7 feet; it thickens southward. In Kansas it averages about 1.7 feet in thickness (pl. 5).

Unit 2 is easily distinguished in much of the outcrop area even though locally unit 3 or 4 has pinched out or has graded laterally into limestone. In the area where unit 3 pinches out, units 2 and 4 cannot easily be distinguished. Unit 2 is generally silty calcareous dark-gray to tan-gray thin-bedded shale. Locally toward the north it is clayey, fissile, and noncalcareous. Rarely are there thin lenses of limestone in this bed. Locally the lower part of the shale contains a zone of *Orbiculoidea* that is overlain by a zone of *Crurithyris*, which in turn is overlain by a bed with fusulinids and other fossils. Fusulinids are generally very abundant, especially in the upper part. The lower beds are very lenticular and were seen only here and there along the outcrop. The sequence of fossil zones is similar to that in the Bennett shale member of the Red Eagle limestone (p. 38) and parts of the Hughes Creek shale member of the Foraker limestone (p. 34). These zones in unit 2 can be studied in the SE¼SW¼ NW¼ sec. 26, T. 19 S., R. 7 E., Chase County, and in the NE¼SW¼ sec. 7, T. 2 S., R. 13 E., Nemaha County. Condra and Busby (1933, p. 10–28) observed these faunal zones in the shale beds of the Neva limestone member and listed them in their measured sections. Toward the south, pelecypods and gastropods are common in this shale. In the northern and southern outcrop areas there is but one bed of shale in the lower part of the Neva limestone member, very likely unit 2. In the northeastern part of Cowley and northern Pottawatomie Counties, it appears that unit 3 has pinched out, and unit 2 and 4 are both present. Additional data are necessary to determine this fully. Elsewhere, where but one shale bed is present in the lower part of the Neva limestone member, unit 4 and units 3 and 5 have coalesced. This is indicated by the thickness of unit 2, which does not change where unit 4 is missing, although unit 5 thickens considerably.

Unit 2 averages 1.2 feet in thickness. It ranges in thickness from 0.2 foot to as much as 4.0 feet but rarely exceeds 2.0 feet. In general it thickens toward the north (pl. 5).

Unit 3 is fairly persistent in the central part of the outcrop area but is generally absent in the northern and southern parts. This limestone is generally hard to medium hard, gray, locally dense, and massive. It weathers into irregular blocks that are porous to cavernous. Locally in Chase and Greenwood Counties this bed tends to weather with a shaly appearance. In southern Cowley County it contains a lens of dark-gray chert nodules in the middle part.

Fusulinids are almost invariably present in this bed, and they are generally most abundant in the upper and middle parts. The lower part contains brachiopods, bryozoans, gastropods, and fragments of crinoids and echinoids. Locally the brachiopod *Crurithyris* occurs in the upper and middle parts of this bed. (See table 1.)

Unit 3 averages about 1.0 foot in thickness. It ranges from a featheredge to a maximum known thickness of about 3 feet.

Unit 4 is a persistent bed of shale in the central part of the outcrop area, but further north and south it can be distinguished only locally. It is lithologically similar to unit 2 in that it is mainly silty, calcareous, gray to tan gray, and thin bedded. Locally it is dark gray and fissile. In most exposures it contains a zone of *Crurithyris* in the lower part and many fusulinids in the upper part. In northern Nemaha County, *Orbiculoidea* is abundant in a thin zone beneath the *Crurithyris* zone. Other fossils in unit 4 are listed in table 1.

Unit 4 averages about 0.8 foot in thickness. Only in a few exposures in the central part of the outcrop does it exceed 1.0 foot in thickness. Unit 4 ranges from a featheredge to as much as 3.0 feet in thickness (pl. 5).

Unit 5 is the main unit of the Neva limestone. It is persistent along the outcrop, easily recognized, and generally much thicker and more distinctive than the other limestone units. Locally this bed can be further subdivided because parts of it are distinctive and can be correlated for a short distance. The lower part of unit 5 contains a thin stratum of limestone that persists in the central part of the outcrop area. This bed is medium hard, gray to tan, somewhat dense, and massive. This stratum generally forms the prominent hillside bench of the Neva limestone member. South of Wabaunsee County this bed becomes finely laminated and semicrystalline. It contains an abundance of fusulinids in the middle and upper parts, and brachiopods and echinoid fragments in the lower part. The lower contact is generally gradational from unit 4 to unit 5.

The rest of unit 5 is soft to medium-hard massive locally dense tan to tan-gray limestone. It locally contains thin partings of shale in the middle part (pl. 5). In the area from northern Greenwood County to central Pottawatomie County this unit is generally brecciated, with angular fragments of limestone in a lime matrix. Some of the limestone fragments are more than 2 inches in diameter and are more easily seen on a weathered surface. In the same general area and north to the Nebraska State line, this unit weathers porous to cavernous, imparting a rotten appearance to the unit in many exposures. The upper part of the unit, which contains algal deposits, is generally soft and light gray and locally weathers platy.

Scott, Foster, and Crumpton (1959, p. 122) noted that in fresh exposures in Pottawatomie County, unit 5 appears to be a single massive bed, but that it generally weathers into 4 or 5 beds separated by thin silty beds of shale. This characteristic was also seen in the adjacent counties.

In Greenwood County, unit 5 consists of many thin beds of limestone separated by thin beds of very calcareous shale. In the SE¼NE¼ sec. 15, T. 25 S., R. 8 E., Greenwood County, about 3.0 feet above the base of unit 5, there is an oolitic zone that very likely is algal in origin. Here the upper part of unit 5 weathers platy. It is well to note that at this location and further south in the NW¼SW¼ sec. 35, T. 27 S., R. 8 E., Greenwood County, the upper three-fourths of this soft unit grades into a very calcareous shale unit that contains thin beds of limestone. In these areas the hard massive beds in the lower part of 5 are very likely correlative to the lower persistent stratum in unit 5 further north.

South of Greenwood County, unit 5 contains lentils of chert in the middle part and a few nodules of chert scattered throughout. In about the center of the NW¼ sec. 7, T. 18 S., R. 10 E., Lyon County, chert nodules occur in the upper part of this bed.

The most obvious fossil remains in unit 5 are fragments of echinoids. Stromatolites are common to abundant in the upper part of this unit and locally cause a wavy-bedded appearance. Fusulinids are common in the middle part. Locally, horn corals and *Crurithyris* are common. Brachiopod fragments are present throughout unit 5. In the NW¼NW¼ sec. 26, T. 10 S., R 7 E., Riley County, a thin bed of shale in the middle of unit 5 contains *Orbiculoidea*, *Lingula*, and *Composita*. (See table 1.)

Unit 5 ranges in thickness from 14.4 feet in Greenwood County to 1.8 feet in Nemaha County and averages 6.5 feet. In general it thickens toward the south but becomes very thin in northern Greenwood, Chase, Lyon, and Nemaha Counties (pl. 5).

Unit 6, the uppermost unit of shale, is persistent along almost all of the outcrop area but pinches out toward the north. This shale is mostly silty, calcareous, thin bedded, and gray to gray green. Locally in northern Wabaunsee County it is gray green. Toward the south it becomes more clayey and contains thin calcareous lenses.

Unit 6 contains an abundance of fossils in most exposures. The quantity varies considerably from one exposure to another, and locally the unit is barren. The characteristic fossils are listed in table 1. Fusulinids are rare to common toward the north but very abundant toward the south.

Unit 6 averages about 3 feet in thickness. It ranges from a featheredge in the northern outcrop area to as much as 6.0 feet in thickness in Cowley County (pl. 5).

Unit 7 is the uppermost limestone bed of the Neva limestone member. It is readily identified along the outcrop area, except the north where unit 6 is locally absent. Unit 7 is medium hard and gray, and weathers into irregular nodules and blocks. Toward the south it weathers platy and with a shaly appearance. Locally it is granular, dense in part, and crystalline. In southeastern Riley and southern Pottawatomie Counties a thin shale parting is present in this unit. Locally, in the central outcrop area, unit 7 is coquina composed of brachiopods, gastropods, pelecypods, stromatolites, and fragments of echinoids. Moore, Jewett, and O'Connor (1951, p. 14) report this limestone unit, locally coquina, to be as much as 6.0 feet thick.

In most exposures fossil fragments are very abundant, and algal deposits are common to abundant. Other fossils include fusulinids, fragments of echinoids and bryozoans, a variety of brachiopods, and some pelecypods (table 1). Locally, ostracodes and other microfossils are abundant in the upper part. *Crurithyris* was identified in this unit in Cowley County.

Limestone unit 7 averages a little more than 2 feet in thickness. It ranges in thickness from as much as 6 feet in Chase County (Moore, Jewett, O'Connor, 1951, p. 19) to 0.6 foot in Wabaunsee County. In parts of the northern outcrop area, where it is part of unit 5, its thickness was not determined. (See measured sections 128, 236, 252, 256, 280, 287, 288, 289, 298, 329, and 371.)

ESKRIDGE SHALE

The Eskridge shale was named by Prosser (1902, p. 709) for exposures in the vicinity of Eskridge, Wabaunsee County, Kans. He stated:

> Between the Neva and the next higher massive limestone [Cottonwood limestone member of the Beattie limestone] is a mass of shales, with perhaps some thin limestone layers, varying from 30 to 40 feet in thickness. The shales are of greenish, chocolate, and yellowish color, and usually form covered slopes between the two conspicuous limiting limestones.

The Eskridge shale averages about 31 feet in thickness. It ranges in thickness from 22.5 feet in southern Kansas to 41 feet in northern Kansas.

The Eskridge is the uppermost shale formation studied in this investigation and is the thickest and most brightly variegated of the shale formations. The maroon and purple shale beds, although present in minor quantities in the other shale units, are by far more abundant in the Eskridge shale. In the northern outcrop area the Eskridge consists of thin beds of tan, gray, gray-green, green, maroon, purple, and violet shale, with gray green dominating. This variety of color occurs in the lower two-thirds of the formation, whereas the upper third is generally gray or gray green. Only locally, as in west-central Lyon County and east-central Wabaunsee County, are the beds of maroon shale absent. These variegated beds cannot be easily correlated unless many sections are measured in a relatively small area, as was done in Wabaunsee County by Mudge and Burton (1959, pl. 11, p. 70). Here it was noted that certain shale beds pinched out or graded laterally into shale of a different color. For example, beds of maroon shale graded laterally into purple and gray-green shale.

North of central Wabaunsee County as many as 25 different shale beds can be measured according to color changes. Exposures containing many thin beds of colored shale were seen in northern Wabaunsee, southeastern Riley, southwestern Pottawatomie, and northern Nemaha Counties. South of central Wabaunsee County this formation contains thicker beds of variegated shale, which are restricted to the lower two-thirds of the formation. The upper 5 to 12 feet is gray to tan-gray beds of shale. Maroon beds persist in the upper part of the lower half of this shale, and they are overlain by gray, green, and gray-green shale. This maroon zone can be traced southward into Elk and Cowley Counties. In southern Cowley County the upper two-thirds of the Eskridge consists almost entirely of maroon shale.

This formation can be informally subdivided into seven units, as shown in figure 25. With local exceptions these units can be recognized in most of the counties along the outcrop line; therefore the following description of the Eskridge shale is by these units. (See pl. 5 and figs. 24, 25.)

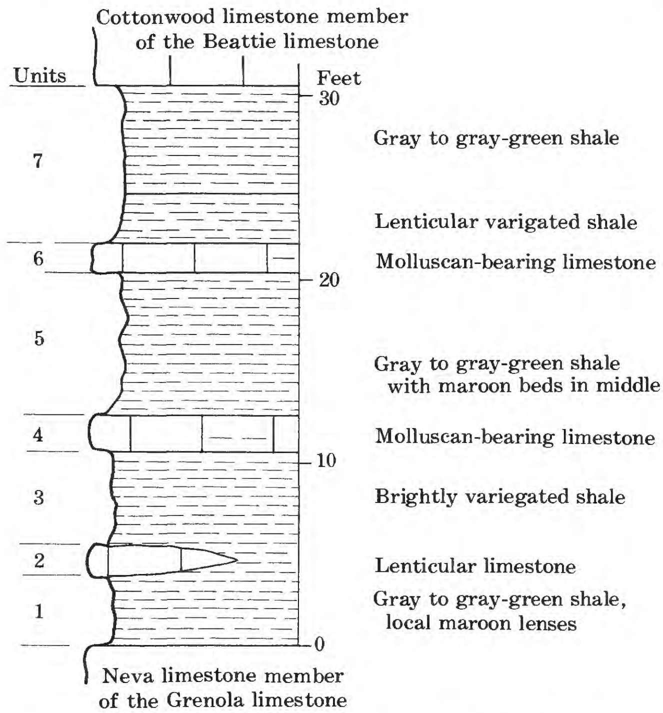

FIGURE 25.—A generalized diagram of the Eskridge shale and its subdivision.

FIGURE 24.—The Eskridge shale overlain by the Cottonwood limestone member of the Beattie limestone in a road cut in the NE¼ sec. 27, T. 11 S., R. 10 E., Wabaunsee County, Kans. *a*, Cottonwood limestone member of the Beattie limestone. *b–f*, Eskridge shale; *b*, Unit 7; *c*, Unit 6; *d*, Unit 5; *e*, Unit 4; *f*, Unit 3.

Unit 1, the lowermost, consists of silty to clayey gray and gray-green shale. Locally in Wabaunsee and Nemaha Counties there are lenses of maroon shale in this unit. In southwestern Greenwood County a thin bed of soft tan-gray limestone is present in the middle part, and it contains microfossils. Along the outcrop this unit can be traced with reasonable accuracy by its color and, where present, by unit 2, which is a thin bed of limestone. In northeastern Elk County this shale and the overlying limestone apparently lens out, and unit 3 rests directly on the Neva limestone member of the Grenola limestone. Unit 1 rarely exceeds 6 feet in thickness, and more generally it is 2 to 4 feet thick.

Unit 2 is a thin lenticular bed of limestone that is present in parts of Wabaunsee, Chase, Morris, and Greenwood Counties. This bed is generally hard, dense clayey to granular limestone that locally contains an abundance of pelecypods, and some gastropods and ostracodes. It is well developed in an exposure in the spillway of Lake Kahola, in the NW¼SE¼ sec. 33, T. 17 S., R. 9 E. Here it is 1.9 feet thick and lies about 4 feet above the Neva limestone member of the Grenola. This bed ranges from a featheredge to slightly more than 2 feet in thickness. In most exposures it is generally less than 1 foot thick.

Unit 3 contains many clayey to silty beds in which maroon and purple colors predominate. It commonly contains a thin bed of gray-green shale in the upper part. South of Wabaunsee County this unit is composed entirely of green to gray-green shale, except in northeastern Cowley County where it is mostly maroon shale. Here this unit can be differentiated from unit 1 by the presence of unit 2, or by the differences in color of the two units. Moore, Jewett, and O'Connor (1951, p. 13) report a bed of lignitic platy material about 5½ feet from the base of the Eskridge shale in Chase County. O'Connor (1953, p. 11) lists a local thin bed of impure coal between the lower bed of molluscan limestone and the top of the Neva limestone member of the Grenola in Lyon County. These beds are in either unit 1 or 3. Unit 3 ranges from 4 to 16 feet in thickness and averages a little more than 8 feet.

Unit 4 is a thin bed of limestone that pinches out locally, but it is present in almost every county along the outcrop (see pl. 5 and figs. 24, 25). It is generally medium-hard gray clayey limestone that grades laterally into shale. It weathers blocky to platy, and locally it is hard and dense, resembling the upper limestone (unit 6). In the NE¼SE¼ sec. 13, T. 7 S., R. 11 E., Pottawatomie County, and SW¼SE¼ sec. 3, T. 11 S., R. 10 E., Wabaunsee County, the upper part of this limestone is conglomeratic. It contains rounded to angular fragments of limestone, and limonite and siliceous nodules that are as much as 1½ inch in diameter. Pelecypods, gastropods, and microfossils, including ostracodes, are common in this bed, and in some places they are found in its shale facies. Locally, brachiopods are also present. This limestone unit ranges from a featheredge to as much as 1.6 feet in thickness; it rarely exceeds 0.8 foot.

Unit 5 consists of beds of gray to gray-green shale with, generally, a thin bed of maroon shale in the middle part. Locally toward the north this unit contains beds of green and purple shale. South of Lyon County it is mostly maroon shale. The shale beds are mainly silty but contain beds of clayey shale in the central and northern outcrop areas. In parts of southern Wabaunsee, southeastern Morris, and northern Lyon Counties, the lower part of this unit contains a thin bed of impure coal that grades laterally into carbonaceous shale. Leaves and wood fragments are common in the carbonaceous shale. Plant fossils are also reported from the middle part of the Eskridge shale in southeastern Riley County.

In Pottawatomie County, Wells (1950, p. 538) shows, near the middle of this unit, a thin bed of limestone grading laterally into two limestone beds containing sharks' teeth. He also lists pelecypods from the beds of shale that overlie the lower molluscan limestone.

Unit 5 averages about 9 feet in thickness. It ranges from about 6 feet to as much as 12 feet in thickness (see pl. 5 and figs. 24, 25).

Unit 6 is a fairly persistent molluscan limestone bed. This limestone is in the upper 12 feet of the Eskridge shale (pl. 5 and figs. 24, 25). Only locally is this bed absent; in some of the exposures where it is absent a shale facies, with pelecypods, is present. Unit 6 is mainly hard, locally dense, gray limestone that generally contains a variety of pelecypods. Laterally this bed grades into soft shaly limestone and calcareous shale. Locally in this unit there are two thin beds of limestone separated by a thin bed of shale. In Riley County where unit 6 is hard and clayey, it contains dark-gray dense clay lentils associated with fine-grained detrital material that is composed in part of ostracodes. In the central outcrop area unit 6 weathers blocky to platy. In southern Wabaunsee, northern Lyon, southeastern Morris and northern Chase Counties it is platy limestone.

Toward the south, unit 6 is a hard to medium-hard, locally dense, impure limestone that weathers into irregular blocks and plates. In southeastern Greenwood County it contains small rounded clay balls. In the southern outcrop area pelecypods and the brachiopod *Juresania* are abundant along with fossil fragments, microfossils, and gastropods. North of Greenwood County no specimens of *Juresania* were found in this unit.

Unit 6 ranges from a featheredge to as much as 4 feet in thickness; the maximum thickness was measured in southeastern Morris County. In most exposures along the outcrop this limestone does not exceed 1 foot in thickness.

Unit 7, the uppermost unit in the Eskridge shale (pl. 5 and figs. 24, 25), is persistent along the outcrop and generally can be easily identified. Locally this unit can be further subdivided. It consists of gray, tan-gray, and gray-green beds of shale that are mostly clayey. In parts of Wabaunsee, Riley, and Nemaha Counties, the lower part (above unit 6) contains beds of variegated shale. In southeastern Cowley County all of this unit is composed of maroon shale that cannot be distinguished from the underlying units of shale. Moore, Jewett, and O'Connor (1951, p. 47) report a thin bed of coal in the upper part of the Eskridge shale in Brown County.

In many exposures of the upper part of this unit, nodules and stains of secondary calcium carbonate are abundant. The carbonate was very likely leached from the overlying Cottonwood limestone member of the Beattie limestone. Beginning in west-central Greenwood County and extending southward, the upper 2 feet of shale is fossiliferous. This fossiliferous bed is present in every section studied as far south as northeastern Cowley County. It contains pelecypods and brachiopods. In southwestern Greenwood County the fossils are thin shelled where this bed of shale is clayey, and careful examination of the bedding planes is necessary to detect the faint impression of the fossils. Further south, where the shale is silty, the fossils are well preserved and easily collected.

Unit 7 ranges from 4 to 12 feet in thickness and averages about 9 feet. (See measured sections 128, 236, 252, 288, 298, 329, and 371.)

BEATTIE LIMESTONE

The Beattie is the uppermost limestone formation studied. It was named by Condra and Busby (1933, p. 13), who followed the classification proposed by the Kansas Geological Survey and grouped three units as members in the Beattie limestone; namely, the Morrill limestone, the Florena shale, and the Cottonwood limestone members. The type locality is at Beattie, Marshall County, Kans.

The Beattie limestone overlies the Eskridge shale and underlies the Stearns shale. It averages about 20 feet in thickness. The following discussion of this unit is by members, beginning with the oldest, the Cottonwood.

COTTONWOOD LIMESTONE MEMBER

The Cottonwood limestone member was named as a formation by Prosser (1895, p. 698), and he stated (1902, p. 712) that this limestone unit and overlying shale units were named for excellent outcrops in the bluffs bordering the Cottonwood River below and above Cottonwood Falls and Strong City, Kans. This limestone, because of its prominence, was called by many names such as Cottonwood Falls limestone, Fusulina limestone, Cottonwood rock, Alma limestone, Manhattan limestone, and Alma massive limestone. The two most likely reasons why this limestone received considerable attention by the early workers in Kansas are that this bed was and still is considered a key horizon for correlation, and it furnishes the principal construction stone for the region encompassing its outcrop area.

The Cottonwood limestone member has been used extensively as a construction stone, particularly trim stone. In Chase, Wabaunsee, and Riley Counties, many civic buildings, schoolhouses, and residential houses have been partly or wholly constructed of limestone from the Cottonwood limestone member. It also has been used for crushed aggregate and agricultural lime.

The original description by Prosser (1895, p. 698) is as follows:

The limestone on a fresh fracture is yellowish-gray in color weathering to a light gray and generally appears along the side of moderately steep bluffs as a series of rectangular blocks that have been separated from the main ledge. The stone is very strongly calcareous containing about 85 percent of calcium carbonate and less than two percent of magnesium carbonate. The amount of flint contained in the rock varies: * * * there are very few fossils, with the exception of *Fusulina cylindrica*, Fisher, which is extremely abundant in the upper part of the stratum.

Prosser (1902, p. 711) states that

Its constant lithologic character, with its line of outcrop frequently marked by a row of massive light gray rectangular blocks filled with *Fusulina*, make it one of the most important stratigraphic horizons in the Upper Paleozoic rocks for at least two-thirds of the distance across Kansas and into Nebraska.

No doubt Prosser recognized that south of Chase County this limestone was not an important stratigraphic horizon. Bass (1936, p. 48) states that

The Cottonwood limestone was identified from Cottonwood River southward to about the northern boundary of Cowley County where it ceases to be a mappable unit. On southward through Cowley County and into Osage County, Oklahoma, the Cottonwood limestone is represented by very limy shale and a few "stringers" of easily soluble limestone beds a few inches thick.

He further states (1936, p. 49) that

I believe it is impossible to segregate the beds that are definitely equivalent to the Cottonwood limestone, and believe also that the beds selected at one locality cannot be identified at other localities not far away.

The authors believe that in many exposures in Cowley County there are limestone beds that are equivalent to the Cottonwood limestone member, but that a more detailed investigation involving many very detailed sections and zoning of fossils will be necessary to distinguish the beds of the Cottonwood from those of the upper part of the Eskridge shale and the Florena shale member (pl. 5).

The Cottonwood limestone member is easily recognized by its thick massive light-gray beds of limestone that contain some lenses and nodules of chert in the northern two-thirds of the State. In this area, the zone of abundant fusulinids, prominently exposed ledges, and line of bushes also aid in its identification. South of Lyon and Chase Counties this member is more easily identified by its position above the Eskridge shale and Neva limestone member of the Grenola. (See fig. 24.)

In the northern two-thirds of Kansas the Cottonwood limestone member forms prominent benches (fig. 26). The limestone is light gray to gray, medium hard,

FIGURE 26.—Typical hillside exposure of the Cottonwood limestone member of the Beattie limestone; NW¼NE¼ sec. 9, T. 14 S., R. 11 E., Wabaunsee County, Kans.

and massive. Locally toward the north there is a thin shaly parting in the lower 1 foot (fig. 27). The limestone at the base generally weathers nodular and shaly and consists of fragments of fossils and some local algal deposits. Pelecypods, brachiopods, and fragments of bryozoans and echinoids are also common. The rest of the Cottonwood is 1 massive bed that generally weathers into 2 or more beds (fig. 26). The bed can be arbitrarily subdivided into three parts on the basis of fossil content. The lower half of this bed of limestone contains a varied fauna of brachiopods and some fragments of bryozoans and echinoids and stromatolites, but rarely are fossils abundant. In many exposures a thin zone of solitary corals is present in the middle or near the top of this zone, which is arbitrarily selected at about 2 or 3 feet beneath the top of the limestone bed. The upper part is the fusulinid zone recognized by Prosser (1895, p. 698). It is composed almost entirely of fusulinids, but it also contains some brachiopods and fragments of bryozoans, echinoids, and crinoids. On the exposed surfaces of the limestone many of the fusulinids have weathered out, leaving a pitted surface. In many exposures the upper part of this bed is transitional into the overlying Florena shale member.

Chert nodules and lenses are common in the Cottonwood limestone member in the northern two-thirds of the State (pl. 5 and fig. 27). They diminish in number in Lyon County and were not seen south of that county.

In the northern outcrop area the Cottonwood is somewhat softer limestone than in the central part. Nodules of chert are not as abundant and the bed tends to weather as small irregular blocks and to a shaly appearance.

Solution channels as much as 1 foot in diameter were observed in this bed. In Wabaunsee, Riley, and Pottawatomie Counties, this member has a growth of bushes at its base, which aids in its identification.

South of Lyon County the Cottonwood limestone member loses the identity it had toward the north. In Greenwood County the limestone is medium hard and tan gray and locally contains beds of dense limestone. Stromatolites are present in the middle and lower parts, sparse fusulinids in the upper part. In this area the

FIGURE 27.—Cottonwood limestone member of the Beattie limestone in a road cut in the center of sec. 12, T. 12 S., R. 10 E., Wabaunsee County, Kans. The nodules above and below the hammer are chert.

Cottonwood makes a small hillside bench. Further south in eastern Cowley County this member contains thin beds of soft light-colored sparsely fossiliferous limestone with many shale partings (pl. 5). These limestone beds are even more poorly developed in the southeastern part of that county.

In Kansas the Cottonwood limestone member ranges in thickness from about 3 feet to as much as 8.8 feet, and averages a little over 5 feet. Condra and Upp (1931, p. 16) report 12 feet of limestone in the Cottonwood in Nebraska. In Kansas this limestone is generally thicker and better developed in the central outcrop area (pl. 5). (See measured sections 236, 252, 288, 298, 329, and 371.)

FLORENA SHALE MEMBER

The Florena shale member was named by Prosser (1902, p. 712) for exposures in the vicinity of Florena, Marshall County, Kans. He described it as yellowish fossiliferous shale, with the lower part containing an abundance of a few species of fossils. Condra and Upp (1931, p. 17) noted that this shale persists from Nebraska to Oklahoma.

The Florena as observed by Condra and Upp (1931, p. 17) is subdivided into two zones. The lower zone, which is generally the lower 2 or 3 feet of the member, is tan to gray and locally very fossiliferous. This was noted by Imbrie (1955, p. 657) for his locality 1 and 10, but in his locality 11, fossils were most abundant 4 to 8 feet from the base. This zone varies from clayey to silty, and it is apparent that the fossil content varies with the plasticity of the beds. It was noted, particularly in Wabaunsee County, that the more clayey the shale the fewer the fossils, both in genera and quantity. Where the shale is silty and calcareous, fossils are abundant. Locally as in Wabaunsee County, where these beds are clayey, there are no fossils. Imbrie (1955, p. 663–669) found that the abundance of some groups of fossils was statistically related to the strontium-calcium ratio. He advanced the hypothesis that "both the strontium-calcium ratio and the abundance of fossil groups related to that ratio reflect the salinity of the Florena sea" (1955, p. 669).

A famous collecting site of the Florena shale member is the Grand Summit site, located in the SW¼SW¼ SW¼ sec. 4, T. 31 S., R. 8 E., Cowley County, where a variety of genera and species of abundant and well-preserved specimens is found. Greene (1908a, p. 114–127) studied and reported on the fauna. Subsequently it was a favorite collecting locality for many paleontologists. Nowhere else along the outcrop is the Florena shale member as fossiliferous. The most characteristic fossil in this member in Kansas is *Chonetes granulifer* Owen, which is more abundant than any other fossil. The list of fossils collected from this member is given in table 1 for the collection from USGS loc. 13775. In many exposures there are thin lentils of cemented fossils.

Only locally, as toward the south, are there lenses of limestone in this member. The lower part of this zone generally contains an abundance of fusulinids and it very likely is a zone transitional from the Cottonwood limestone member into the Florena shale member.

The upper zone includes as much as two-thirds of the Florena shale member. It is generally gray to olive-drab blocky clay shale that only locally contains a sparse fauna. In most exposures this zone is nonfossiliferous, and it contains secondary calcite filling fractures and geodes.

Condra and Upp (1931, p. 17) note that the Florena shale member ranges from 3 to 13 feet in thickness. It averages a little more than 8 feet. The exact thickness of this shale in southeastern Cowley County is not known, but it very likely exceeds 15 feet. Moore, Jewett, and O'Connor (1951, p. 13) record a thickness of 8 to 15 feet for the Florena in Chase County. In Marshall County, Walters (1954, p. 47) observed as little as 2 feet of shale of the Florena. In general the Florena thins toward the north (pl. 5). (See measured sections 236, 252, 288, 298, and 329.)

MORRILL LIMESTONE MEMBER

The Morrill limestone member was named by Condra (1927, p. 234) for exposures 2 miles northwest of Morrill, Kans. Condra and Upp (1931, p. 18) describe this member as two dark-gray granular limestone beds separated by a thin gray calcareous shale bed.

This member was not studied in detail and no fossil collections were made from it.

In Kansas the Morrill varies from a series of massive beds of limestone to two beds of limestone separated by a bed of shale. Locally in parts of Pottawatomie and Wabaunsee Counties, and in the southern outcrop area, this member consists of a series of beds of limestone that vary from thick to thin bedded. Scott, Foster, and Crumpton (1959, p. 123) observed 10.5 feet of Morrill limestone member, composed of 6 beds of limestone and no shale, in the SW¼NW¼ sec. 10, T. 6 S., R. 8 E., Pottawatomie County. Elsewhere in the northern outcrop area this member consists of two or more beds of limestone separated by thin beds of gray clay shale. The beds of limestone are quite variable in thickness and lithology. Some are locally hard, dense limestone; others are soft, granular tan to gray limestone. The upper beds commonly weather porous to cavernous. In the vicinity of Eskridge, Wabaunsee County, these beds are platy, and the outcrops are covered with many thin plates.

In the northern outcrop area the Morrill limestone member forms a small hillside bench above the prominent one of the Cottonwood limestone member. In the southern outcrop area the bench formed by the Morrill is very distinctive because it is rimmed by a ledge of limestone 2 to 4 feet thick, characteristically resembling the bench of the Cottonwood limestone member as seen further to the north. This resemblance led some of the early workers to map the Morrill limestone member as the Cottonwood limestone member in Cowley County, Kans., and in Kay and Osage Counties, Okla. (Bass, 1936, p. 50). In southern Kansas this member consists of thin beds of limestone separated by thin beds of shale. The lower 5± feet consists of massive beds of medium-hard gray limestone that fractures into large irregular blocks. This part of the member contains nodules of chert in the area south of west-central Greenwood County. In the northern outcrop area chert nodules were seen in this member only in the SE¼NE¼ NW¼ sec. 32, T. 11 S., R. 10 E., Wabaunsee County, Kans. In many of the outcrops in Kansas, the lower bed contains stromatolites. Locally, as in southwestern Greenwood County, fusulinids are also present in the lower bed. In some exposures toward the north this bed contains pelecypods, brachiopods, and fragments of crinoids, bryozoans, and echinoids.

The upper part of the Morrill limestone member consists of medium-hard gray to tan-gray beds of limestone that weather with a porous surface or in irregular plates. Along the outcrop the upper bed is mostly nonfossiliferous, though locally it contains pelecypods and brachiopods.

In the central outcrop area, geodes lined with calcite are common. These were seen in Chase, Morris, Wabaunsee, and Riley Counties.

The Morrill limestone member ranges from 3 feet to about 11 feet in thickness. In most of the counties in the central and northern outcrop areas it rarely exceeds 8 feet in thickness. Locally in Pottawatomie and eastern Cowley Counties it is as much as 10.5 feet thick. (See measured sections 288 and 329.)

PART 2. PALEONTOLOGY

Mudge's finding that there is not one channel sandstone but several channel sandstone units near the Pennsylvanian-Permian boundary presently accepted by the Kansas Geological Survey raised two questions: what the faunas are in the various stratigraphic units in the part of the section that contains these channel sandstones, and how do these faunas differ above and below the presently accepted Pennsylvanian-Permian boundary.

Because most of the early fossil collections of the U.S. Geological Survey could not be precisely placed in regard to the presently used stratigraphic framework, new and accurately located material was needed. In order to have fossils from known small stratigraphic intervals, Mudge and Yochelson made new collections in Kansas during the summer of 1952. Slightly over 400 separate collections from 150 sites were made in the 5-week period spent in the field. Subsequently Mudge collected about 100 additional lots from 60 sites. Marine and nonmarine units were examined, but fossils were found only in the former. Collections from some marine stratigraphic units were made bed by bed, because it has been established that certain thin beds are remarkably widespread in the area.

Except for the fusulinids studied by Douglass, this study is confined to the larger fossils. In general, any fossils requiring a magnification of more than 10 times or thin sections for identification have been excluded from this report. Algae, bryozoans, ostracodes, and conodonts are thus eliminated even though they are known to occur in the strata from which the collections were made. It should be emphasized that study of these and other groups eliminated is needed for the final, complete analysis of the boundary problem.

Existing monographic studies of the commoner larger fossils made the present analysis possible. The basis of this paper is identification of previously described fossils and stratigraphic refinement of their ranges. Particularly useful in identifying the fossils were papers by Dunbar and Condra (1932) and Newell (1937, 1942).

It is not the purpose of the present report to redescribe the fossils in the works of the authors cited above. These earlier descriptions were based on suites of specimens many of which were no doubt more extensive and more perfectly preserved than those available to the present writers. Our main purpose is to consider the distribution and mode of occurrence of the fossils and only to suggest minor modification of descriptions in a few pertinent instances. Emphasis has been placed on illustrating features and fossils that supplement the works of earlier authors.

For the Brachiopoda and part of the Pelecypoda (Pectinacea and Mytilicea), synonymy includes the original reference and those since the date of publication of the papers by Dunbar and Condra (1932) and Newell (1937, 1942) mentioned above. These works should be referred to for fuller synonymy. For other pelecypods, references that have a bearing on occurrences in the midcontinent area studied by Mudge have been given. In so far as it is known, the synonymy for the gastropods, cephalopods, and trilobites is complete.

PHYLUM PROTOZOA

CLASS SARCODINA—ORDER FORAMINIFERA

FUSULINIDAE OF THE BROWNVILLE THROUGH AMERICUS INTERVAL IN KANSAS

By Raymond C. Douglass

A review of the published record indicated that the fusulinids from the Brownville through Americus interval would have the greatest bearing on the Pennsylvanian-Permian boundary problem. The fusulinid-bearing beds older than the Brownville limestone member of the Wood Siding formation have been accepted generally as being of Pennsylvanian age, and the Hughes Creek shale member of the Foraker limestone and younger beds are accepted as being of Permian age. The fusulinids of the intervening beds were little known.

Over 200 collections containing fusulinids were made by Mudge and Yochelson from measured sections along the area of outcrop of upper Pennsylvanian and lower Permian rocks from southern Kansas to Nebraska. These collections, supplemented by others in the U. S. National Museum, form the basis for this study.

I am indebted to Carl O. Dunbar for his help in orienting the stratigraphic terminology used by Dunbar and Condra (1927) with present terminology in Kansas and to Carl C. Branson for supplying new information on Skinner's locality data (Skinner, 1931). M. L. Thompson provided supplemental data on some of his reports.

This study, including the discussion on the Pennsylvanian-Permian boundary, was completed in June 1954 and does not include data more recent than that date.

LOCALITY AND SPECIMEN NUMBERS

The locality numbers referred to in the descriptions of the species are U. S. Geological Survey blue-catalog numbers. The localities represented by these numbers are described in "Register of Localities" (p. 127–138).

All slides containing figured specimens are deposited in the U.S. National Museum and are assigned USNM numbers. The other specimens on which the study is based are in the U. S. Geological Survey collections of Foraminifera.

The correlation between USGS locality (blue-catalog) numbers and USGS foraminiferal-collection numbers for the collections included in this study of the fusulinids follow.

USGS loc. No. (USGS blue catalog No.)	*USGS foraminiferal-collection No.*	*USGS loc. No. (USGS blue catalog No.)*	*USGS foraminiferal-collection No.*
13429	f9901	13703	f9907
13445	f9902	13705	f9935
13494	f9931	13716	f9908
13505	f9903	13726	f9936
13512	f9914	13754	f9923
13527	f9915	13755	f9924
13573	f9916	13757	f9937
13575	f9904	13790	f9910
13588	f9917	13793	f9925
13606	f9918	13796	f9938
13640	f9905	13810	f9911
13641	f9919	13813	f9912
13646	f9932	13815	f9926
13663	f9933	13817	f9939
13667	f9920	13818	f9940
13668	f9921	13836	f9927
13676	f9934	13838	f9941
13690	f9906	13839	f9928
13698	f9922	13840	f9929

PREVIOUS STUDIES

Meek and Hayden (1858a, p. 261) described *Fusulina cylindrica* var. *ventricosa*, now known as *Triticites ventricosus*, from the Hughes Creek shale member of the Foraker limestone of Kansas. Subsequently they published figures of this species (Meek and Hayden, 1865, p. 14, pl. 1, figs. 6d–g). This is one of the first descriptions of *Triticites* from Kansas.

J. W. Beede (1916, p. 11–15) described four species of fusulinids from Kansas and Oklahoma, but he did not illustrate any forms. Three of the forms described by Beede are from the Hughes Creek shale member of the Foraker limestone, the Neva limestone member of the Grenola limestone, and the Florena shale member of the Beattie limestone, all of which are higher in the section than the units under consideration. The other is from the Fort Scott limestone, lower in the Pennsylvanian section.

Beede and Kniker (1924, p. 13–38) described several additional forms and illustrated two of the types of Beede's previously described species. All of the specimens were from the Hughes Creek shale member of the Foraker limestone or younger beds.

Dunbar and Condra (1927, p. 76, 123) described specimens of *Triticites ventricosus* (Meek and Hayden) from the Americus limestone member of the Foraker limestone at Americus, Kans., and several species from younger and older formations. *Triticites acutus* was described from the base of the Brownville limestone member of the Wood Siding formation at Minerville, Nebr.

Skinner (1931, p. 17–22) described five species of fusulinids from the Foraker and younger beds of Oklahoma.

Thompson (1948, pl. 8, figs. 3, 8) illustrated, but did not describe, two specimens in *Triticites* as *Triticites* n. sp. from the Brownville limestone member of the Wood Siding formation of Kansas. Later, Thompson (1954) described 3 new species from the Five Point limestone member of the Janesville shale of Kansas and 2 new species from the Americus limestone member of the Foraker limestone. In addition, several species from younger beds are described.

DISTRIBUTION AND CORRELATION OF THE FUSULINIDS

Fusulinids occur in the Brownville, Five Point, and Americus limestone members at most of their exposures in Kansas. A few localities did not yield fusulinids. These barren localities are rare in central and southern Kansas where specimens are generally abundant and the faunas varied. The variety and abundance of forms declines rapidly north of Wabaunsee County in Kansas. This seems to be true for all the Foraminifera in the beds studied. It was found that some of the beds which have abundant fusulinids in central and southern Kansas yielded very few or no specimens of fusulinids in northern Kansas. Collections from southern Nebraska were also found to be essentially without Foraminifera.

The small Foraminifera were noted wherever they were found, and their occurrence was plotted on the distribution tables. Some of the typical forms found in the thin sections are illustrated (pl. 8, figs. 1–4; pl. 10, figs. 4–6, 8) to give a more complete representation of the foraminiferal faunas.

Figure 28 shows examples of the fusulinids found in the three units described. The geographic distribution of these species and the associated small Foraminifera are shown in tables 2–4.

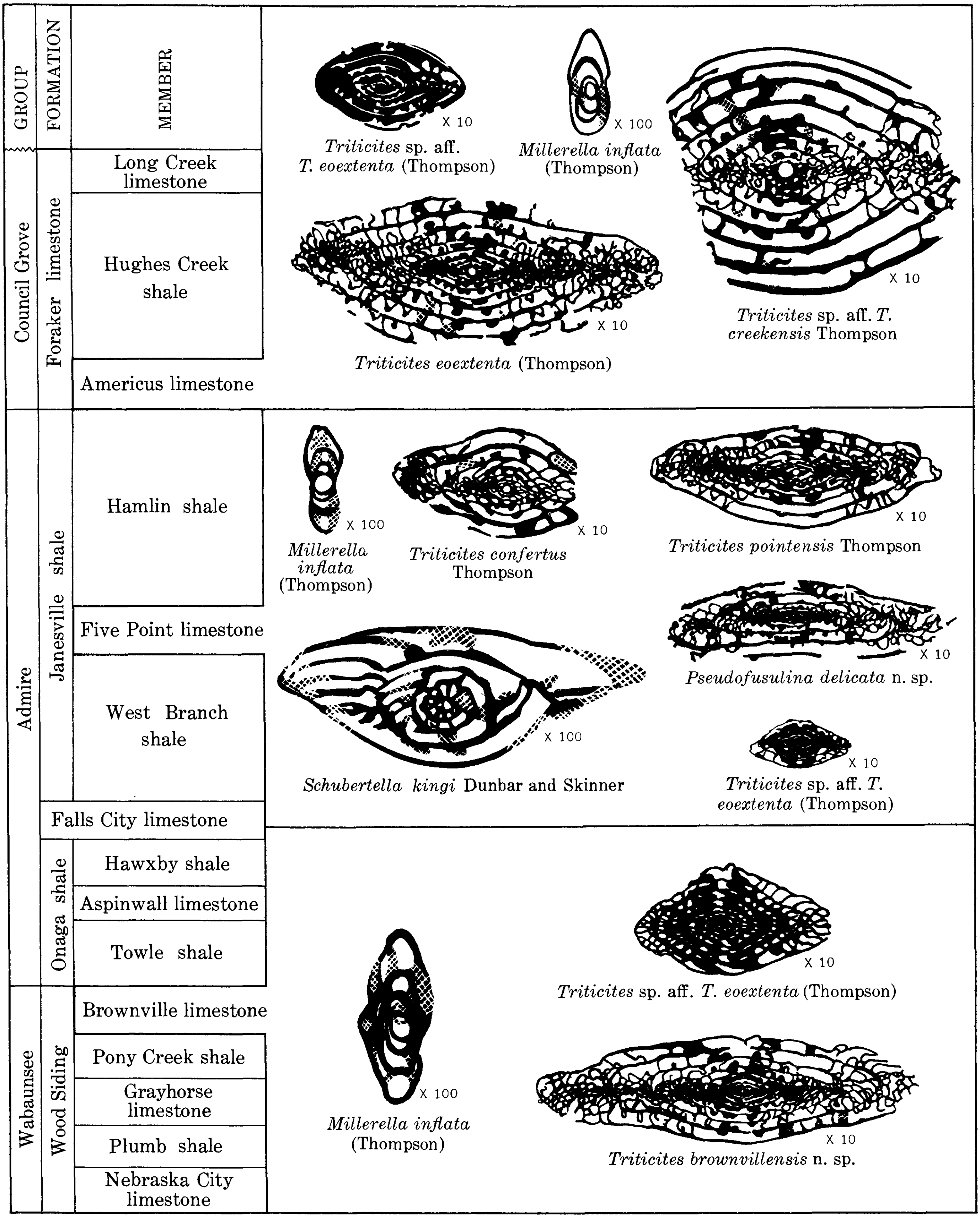

FIGURE 28.—Diagram of the uppermost part of the Wabaunsee group, the Admire group, and the lowermost part of the Council Grove group showing typical fusulinids.

The only fusulinids found in any of the units between the Brownville limestone member of the Wood Siding formation and the Americus limestone member of the Foraker limestone were those in the Five Point limestone member of the Janesville shale. Collections from the intervening units throughout their exposures in Kansas were examined, but no fusulinids were recognized. All the stratigraphic units are described elsewhere in the report, but a few notes on the lithology of the beds bearing fusulinids follow.

BROWNVILLE LIMESTONE MEMBER OF THE WOOD SIDING FORMATION

The Brownville limestone member is generally silty limestone that is gray in fresh exposures but weathers to light rust color. It contains an abundance of echinoderm fragments, bryozoans, and brachiopods associated with Foraminifera. At some localities, such as 13716 in Lyon County, organic material is abundant.

Fusulinids decrease in number to the north as the silt content of the unit increases. In several of the collections in northern Kansas, where the Brownville is nearly siltstone, only one or very few specimens of fusulinids were found, and no fusulinids were found in a collection from the type locality further north in Nebraska.

The dominant fusulinid in the Brownville limestone member is *Triticites brownvillensis* Douglass, n. sp. It is associated with *Millerella inflata* (Thompson), *Triticites* sp. aff. *T. eoextenta* (Thompson), and several smaller Foraminifera (table 2). This association has not been described from any other area, so a close correlation cannot be made. The assemblage suggests late Pennsylvanian age. The Brownville is considered by the Kansas Geological Survey (Moore, Jewett, and O'Connor, 1951, p. 58) to be the youngest Pennsylvanian unit.

TABLE 2.—*Distribution of Foraminifera from north to south in the Brownville limestone member of the Wood Siding formation in Kansas*

	County and locality No.											
	Brown	Jackson	Pottawatomie	Riley	Wabaunsee			Lyon	Greenwood		Elk	Chautauqua
	13429	13640	13575	13505	13703	13690	13445	13716	13810	13813	13790	13748
Fusulinids:												
Millerella inflata (Thompson)	--	--	--	--	×	--	×	×	×	--	×	×
Triticites sp. aff. *T. eoextenta* (Thompson)	--	--	--	--	--	--	--	--	--	--	--	×
brownvillensis Douglass, n. sp.	×	×	×	×	×	×	×	×	×	×	×	×
Small Foraminifera:												
Ammodiscus ? sp.	--	--	--	--	--	--	--	×	--	--	--	--
Bradyina sp	--	--	--	--	--	--	--	×	×	--	--	×
Textularians undifferentiated	--	--	--	--	×	×	--	--	×	--	×	--
Geinitzina sp	--	--	--	--	--	--	--	×	×	--	×	--
Climacammina sp	--	--	--	--	--	--	--	?	--	--	×	×
Tetrataxis sp	--	×	×	--	--	--	--	--	--	--	--	--

FIVE POINT LIMESTONE MEMBER OF THE JANESVILLE SHALE

The Five Point limestone member has a varied lithology and also the most varied fauna of the three units considered. The limestone parts of the Five Point have a high organic content and in some localities the limestone is predominantly organic fragments. The limestone beds grade laterally and vertically into silt-

TABLE 3.—*Distribution of Foraminifera from north to south in the Five Point limestone member of the Janesville shale in Kansas*

	County and locality No.															
	Jackson	Pottawatomie		Wabaunsee						Lyon			Greenwood	Elk	Cowley	
	13641	13527	13588	13698	13668	13667	13512	13606	13573	13839	13840	13836	13815	13793	13755	13754
Fusulinids:																
Millerella inflata (Thompson)	--	--	--	--	×	--	--	--	--	×	--	×	×	×	--	×
Schubertella kingi Dunbar and Skinner	--	--	--	--	×	--	--	--	--	×	--	--	×	--	--	--
Triticites sp. aff. *T. eoextenta* (Thompson)	--	--	--	×	×	--	--	--	--	--	--	--	?	--	--	×
pointensis Thompson	×	×	×	×	×	×	×	×	--	×	--	×	×	?	?	×
confertus Thompson	--	--	--	--	×	--	--	--	--	×	--	--	--	--	--	--
Pseudofusulina delicata Douglass, n. sp	--	--	--	--	×	--	--	--	--	×	--	×	×	--	--	--
Small Foraminifera:																
Ammodiscus ? sp	--	--	--	×	×	--	--	--	--	--	--	×	×	×	--	--
Bradyina sp	--	--	--	×	×	--	--	×	--	×	--	--	×	×	--	×
Textularians undifferentiated	--	--	×	--	--	--	--	--	--	--	--	--	×	--	--	×
Geinitzina sp	--	--	--	--	--	--	--	--	--	×	--	--	×	×	--	--
Climacammina sp	--	--	--	--	--	--	--	--	--	×	--	×	×	×	--	×
Tetrataxis sp	--	--	--	--	--	×	--	--	×	--	×	--	×	--	--	--

stone. In northern Kansas the fusulinids are uncommon and are found only in the shale. Toward the south the fusulinids are more abundant and are associated with a varied fauna of smaller Foraminifera (table 3). In several collections, such as from USGS locs. 13815 in Greenwood County and 13668 in Wabaunsee County, much of the organic debris is coated with algae. The algae occur both in silty limestone and in nearly pure crystalline limestone.

The fusulinids of the Five Point limestone member include *Millerella inflata* (Thompson), *Schubertella kingi* Dunbar and Skinner, *Triticites* sp. aff. *T. eoextenta* (Thompson), *Triticites pointensis* Thompson, *Triticites confertus* Thompson, and *Pseudofusulina delicata* Douglass, n. sp.

This fauna is most important, as is indicated in the discussion of the boundary problems (p. 121). *Triticites pointensis* Thompson and *Triticites confertus* Thompson were both recognized by Thompson in the Five Point limestone member. *Triticites confertus* and *Schubertella kingi* Dunbar and Skinner were recognized by Thompson in north-central Texas in the No. 2 bed of the Waldrip shale member of the Pueblo formation. *Pseudofusulina delicata* Douglass, n. sp. which had not been recognized in either horizon before, appears to be a primitive representative of the genus. As this is the lowest horizon in Kansas at which *Pseudofusulina* is recognized, the Five Point limestone member may be the oldest fusulinid-bearing bed in Kansas assignable to the zone of *Pseudoschwagerina.*

AMERICUS LIMESTONE MEMBER OF THE FORAKER LIMESTONE

The Americus limestone member is bluish-gray, finely bioclastic limestone. Only minor amounts of silt are present in the limestone, which has an abundance of brachiopod, bryozoan, and echinoderm fragments and fusulinids and other Foraminifera. In the Americus limestone member the fusulinids are more abundant in Wabaunsee County and to the south than they are in the northern counties of Kansas (table 4).

The fusulinids of the Americus limestone member include *Millerella inflata* (Thompson), *Triticites* sp. aff. *T. eoextenta* (Thompson), *Triticites eoextenta* (Thompson), and *Triticites* sp. aff. *T. creekensis* Thompson. The most interesting thing about this assemblage is the absence of the genus *Pseudofusulina. Pseudofusulina delicata* Douglass, n. sp. is present in the Five Point limestone member, below the Americus, and *Pseudofusulina longissimoidea* (Beede) is present in the Hughes Creek shale member of the Foraker, above the Americus. It would not be surprising if the genus *Pseudofusulina* were found in the

TABLE 4.—*Distribution of Foraminifera from north to south in the Americus limestone member of the Foraker limestone in Kansas*

	County and locality No.										
	Jackson	Riley	Wabaunsee			Lyon	Chase	Greenwood		Elk	Cowley
	13646	13494	13663	13676	13705	13838	13726	13817	13818	13796	13757
Fusulinids:											
Millerella inflata (Thompson)	--	--	×	?	?	×	--	×	--	?	×
Triticites sp. aff. *T. eoextenta* (Thompson)	--	--	×	×	--	×	×	×	--	×	×
eoextenta (Thompson)	×	×	×	×	×	×	×	×	×	×	×
sp. aff. *T. creekensis* Thompson	--	--	--	--	--	--	--	--	×	--	--
Small Foraminifera:											
Textularians undifferentiated	--	--	--	×	--	--	--	×	--	--	×
Geinitzina sp	--	×	--	×	×	×	×	×	--	--	--
Climacammina sp	×	×	×	×	×	×	×	×	--	--	--
Tetrataxis sp	--	--	--	--	--	--	×	--	--	--	--

Americus limestone member by later workers, but it is also possible that some environmental change may account for its absence.

The assemblage of fusulinids from the Americus limestone member is unlike that so far described from any other region. It appears to be intermediate between that of Waldrip shale member and the Camp Creek shale member of the Pueblo formation in north-central Texas.

DESCRIPTION OF SPECIES

Genus MILLERELLA Thompson, 1942

Millerella inflata (Thompson), 1954

Plate 6, figure 3; plate 8, figures 9–11; plate 10, figure 7

Ozawainella? *inflata* Thompson, 1954, Kansas Univ. Paleont. Contr., Protozoa, art. 5, p. 31, pl. 5, figs. 1–9.

The shell is lenticular, planispiral throughout growth, involute to slightly evolute, and slightly umbilicate to umbilicate. The periphery is rounded in the inner volutions and becomes subrounded to subangular in the exterior volution of some specimens. Adults have 3–4 volutions and are about 0.10 mm in axial length by 0.34 mm in diameter at volution 4. The proloculus is large compared with the size of the specimens. It is 35μ–42μ in outer diameter. The spirotheca is thin, reaching a maximum of about 10μ. The structure of the spirotheca is indistinct. The septa are arched forward but unfluted. The tunnel is narrow and straight. It is bordered by small, asymmetrical chomata. No other epithecal deposits were recognized. The chambers are only slightly arched and generally conform to the spiral of the shell. There are about 9 chambers in the first volution and 15 in the second.

Remarks.—The specimens described here are similar to those from Texas and Arizona described by Thompson (1954, p. 31). According to his description the specimens from Texas and Arizona have a more angular periphery than those from Kansas. He refers the species to *Ozawainella*, with question. Comparison with the illustrations of *Ozawainella angulata* (Colani) (Colani, 1924) and *Millerella marblensis* Thompson, indicates that these specimens have a greater affinity to *Millerella* than to *Ozawainella.* Only in the outer volution of some specimens is there any pronounced angularity. This angularity of the periphery is no greater than in specimens assigned to *Millerella marblensis* by Thompson (1948) from the Mud Springs Mountains in New Mexico.

Occurrence.—The occurrence and association of the specimens studied for this report are given in tables 2–4. The species was described by Thompson (1954, p. 31) from the Waldrip shale member of the Pueblo formation in Texas and from the Swisshelm Mountains in Arizona.

Genus SCHUBERTELLA Staff and Wedekind, 1910

Schubertella kingi Dunbar and Skinner, 1937

Plate 8, figures 5–7

Schubertella kingi Dunbar and Skinner, 1937, Texas Univ. Bull. 3701, p. 610, 611, pl. 45, figs. 10–15.

Thompson and Wheeler, *in* Thompson, Wheeler, and Hazzard, 1946, Geol. Soc. America Mem. 17, p. 24, 25, pl. 8, figs. 6–10.

Thompson and Hazzard, *in* Thompson, Wheeler, and Hazzard, 1946, Geol. Soc. America Mem. 17, p. 40, 41, pl. 10, figs. 1–9.

Thompson, 1954, Kansas Univ. Paleont. Contr., Protozoa, art. 5, p. 33, 34, pl. 5, figs. 11–42; pl. 7, figs. 11–13.

The shell is thickly fusiform to subcylindrical. Adult specimens have about 4½ volutions and attain a half-length up to 0.55 mm and a radius vector of 0.14 mm at volution 4. The proloculus is minute, about 30μ in outer diameter. The structure of the spirotheca is indistinct, generally a thin outer dark line and an inner gray zone. Its thickness is rarely more than 10μ. The shells are coiled in two planes. The juvenarium includes about one and one-half volutions and is at nearly right angles to the adult part of the shell. The septa are unfluted even in the region of the poles. The tunnel is wide and is bordered by low, nearly symmetrical chomata. No other epithecal deposits were recognized. There are about 8 septa in volution 1 and about 13 septa in volution 4. No septal pores were recognized. The chambers show definite arching above the general spiral of the shell.

Remarks.—*Schubertella* generally and *Schubertella kingi* in particular still require a considerable amount of study before they will be well understood. As pointed out by Dunbar and Skinner (1937), the original diagnosis of the genus was inaccurate and inconsistent. Thompson (1937) restudied topotype material of the genotype *S. transitoria* and redescribed the genus. In the same paper Thompson described a new genus *Eoschubertella* to include some of the forms previously assigned to *Schubertella. Eoschubertella* and *Schubertella* differ primarily in their wall structure. *Eoschubertella* is said to have a 4-layer wall and *Schubertella* a 2-layer wall. *Eoschubertella* is said to be a lower Pennsylvanian form and *Schubertella* a Permian form. *Schubertella* is now recognized in the upper Pennsylvanian rocks of Texas.

The important question remaining is the actual position of *Schubertella* biologically. No megalospheric forms of this genus have been recognized. This is perhaps because of the diagnosis of the genus, but possibly because only equally small forms have been considered. The possibility that *Schubertella* and *Pseudofusulina* may be congeneric must be considered.

Two factors suggest this possibility. The first is the wall structure of *Schubertella.* The wall is thin, usually 10μ or less. It appears to be made up of a thin outer layer and a thicker dark-gray layer. On some specimens the wall thickens in the last volution and shows some porosity resembling keriothecal structure. Keriothecal structure is seldom apparent in the Schwagerininae when the wall is less than 20μ thick. It is possible that the wall structure of *Schubertella* is not different from that in the subfamily Schwagerininae.

The second factor is distribution. *Schubertella* from the lower Permian rocks of several areas has been described, and it is known to occur in upper Pennsylvanian rocks. This range coincides generally with that of the primitive schwagerinids or psuedofusulinids.

The evidence on both these factors is, at present, still meager, but it is suggestive and should be studied in more detail. A similar situation should be investigated in connection with *Eoschubertella* of the early Pennsylvanian. The wall structure of this form suggests that it may be closely related to *Fusulina* or *Fusulinella.*

Occurrence.—*Schubertella kingi* was identified only in the Five Point limestone member of the Janesville shale in the collections studied. Its occurrence and associations are shown on table 3. The species was described originally from the basal beds of the Permian in the Hueco Mountains and the Sierra Diablo Plateau and from the Wolfcamp formation of the Glass Mountains. Thompson and Wheeler (Thompson, Wheeler, and Hazzard, 1946) described specimens from the McCloud limestone in northern California; Thompson and Hazzard (Thompson, Wheeler, and Hazzard, 1946) from what they term the Wolfcampian part of the Bird Spring formation in southern California; Thompson (1954) from the Waldrip shale member of the Pueblo formation and the Coleman Junction limestone member of the Putnam formation of north-central Texas, the Cottonwood limestone and Florena shale members of the Beattie limestone of Kansas, and the Oquirrh formation of Utah.

Triticites sp. aff. T. eoextenta (Thompson)

Plate 6, figures 1, 2; plate 7, figures 1, 2; plate 8, figures 12, 13, 26, 27; plate 10, figures 1–3, 16

Several collections from the Brownville, the Five Point, and the Americus contains specimens of short, thick fusulinids that superficially resemble *Fusulinella cadyi* Dunbar and Henbest (1942). The specimens are inflated-fusiform with nearly straight to slightly convex lateral slopes and pointed poles. They have up to 9 volutions but generally have 6–7 with an average axial length of about 3.3 mm and average equatorial diameter of about 1.8 mm. The proloculus is minute, on the order of 15μ–20μ. The spirotheca is composed of a tectum and fine keriotheca. It is generally thin throughout and reaches a maximum thickness of about 40μ in volution 8.

All the forms included in this description appear to be microspheric individuals with 1–2½ volutions coiled at an angle to the remainder of the shell. The shell expands more rapidly in the early volutions than it does in the adult, and the increase in height of volution is only slightly greater toward the poles than it is in the equatorial zone.

The septa are fluted in the poles, and fluting extends toward the equatorial zone but is obscured by the development of epitheca. The tunnel is narrow and nearly straight. The tunnel angle increases gradually but does not exceed 22°–25° even at volution 7. The chomata are massive and asymmetrical; they extend upward to or near the ceiling of the chamber and extend laterally, merging with other epithecal deposits which in some specimens nearly fill the chambers. The septa are closely spaced, and the chambers are only slightly arched in the inner volutions. No septal pores were recognized.

Remarks.—These specimens are highly problematic. The coiling of the juvenarium at a high angle to the adult part of the shell suggests that these are microspheric forms. It is generally believed that microspheric forms are larger than megalospheric specimens of the same species, yet these specimens are one of the smaller elements of the faunas. They are similar in several ways to the fusulinids described as *Triticites brownvillensis* n. sp. in the Brownville limestone member of the Wood Siding formation. *Triticites pointensis* in the Five Point limestone member of the Janesville shale, and *Triticites eoextenta* in the Americus limestone member of the Foraker limestone. In each instance, however, the microspheric forms are smaller than the megalospheric forms.

No forms closely resembling these microspheric forms have been described. The form referred by Thompson (1954, p. 146) to *Dunbarinella* aff. *D. eoextenta* Thompson from the Bursum formation in New Mexico may belong to this group, but the juvenarium is not clearly shown.

Occurrence.—The distribution and association of these forms are shown in tables 2–4.

Triticites eoextenta (Thompson)

Plate 10, figures 9–14, 17–19

Dunbarinella eoextenta Thompson, 1954, Kansas Univ. Paleont. Contr., Protozoa, art. 5, p. 46, pl. 16, fig. 25; pl. 17, figs. 7–20; pl. 18, figs. 1–16.

The shells are fusiform to elongate-fusiform with sharply pointed poles, straight axis of coiling, and irregularly wavy lateral slopes. Specimens attain 7–8 volutions with an axial length of 5–7 mm and a diameter of 2.2–3.2 mm. An equatorial section of 1 specimen has 9 volutions and a diameter of 3.2 mm. The proloculus is generally small but ranges from about 95μ to 200μ in outer diameter. The spirotheca is composed of a tectum and fairly coarse keriotheca. The spirotheca thickens from about 20μ in volution 3 to about 80μ in volution 8.

The shell expands a little more rapidly in the early volutions than in the adult part of the shell, and commonly the last volution has no increase in height. Fluting of the septa is present throughout, forming chamberlets irregularly along the base of the chambers even in the equatorial zone.

The tunnel is generally straight but is irregular in its path in some specimens. It is narrow throughout and increases from about 20° in the early volutions to near 30° in the adult. The chomata are nearly symmetrical and extend ⅓–½ the height of the volution. In some sections the chomata appear to be more massive than they probably are, due to the position of the section with regard to the septa. Extremes of this apparent difference are shown in plate 10 figures 17 and 18.

Some other epitheca is deposited on the floor of the tunnel and occasionally along the lateral slopes. Septa are irregularly spaced and increase in number from about 9 in volution 1 to about 35 in volution 8. Septal pores are uncommon and small, about 10μ in diameter. The chambers are only slightly arched and generally conform to the spiral of the shell.

Remarks.—This species has a high degree of variability both in form and in the development of epitheca. At first it seemed that two species were represented; one resembled Thompson's *Dunbarinella eoextenta*, and the other resembled Thompson's *Dunbarinella americana*. A review of the characteristics, both qualitative and quantitative, indicated that these forms could not be distinguished in the material at hand. The specimens, therefore, have all been considered conspecific. Many of the specimens in the samples studied have proloculi larger than those reported by Thompson (1954) for either *D. eoextenta* or *D. americana*, but the range of sizes in the sample suggests that these specimens cannot be segregated on this basis.

The specimens here described are assigned to the genus *Triticites* Girty, 1904. The character and distribution of the chomata, the lack of tightly coiled juvenarium, and the lack of axial filling prevent assignment of this species to *Dunbarinella*.

Occurrence.—The species described here is from the Americus limestone member of the Foraker limestone of Kansas. Its distribution and associations are shown in table 4. Thompson (1954) described the species from the lower part of the Waldrip shale member of the Pueblo formation in north-central Texas and from the Americus limestone member of the Foraker limestone in Kansas. He also mentions its occurrence in the upper part of the Waldrip shale member of the Pueblo formation in north-central Texas and the Bursum formation in New Mexico.

Triticites pointensis Thompson

Plate 8, figures 21–25; plate 9, figures 1, 2

Triticites pointensis Thompson, 1954, Kansas Univ. Paleont. Contr., Protozoa, art. 5, p. 57, pl. 9, figs. 1–9.

The shells are fusiform—slightly inflated with a straight axis of coiling, pointed poles, and irregular lateral slopes. Mature specimens have 7–8 volutions and are 5 to 5.5 mm in axial length and about 1.5 mm in diameter. The proloculus ranges in size from 60μ to 150μ, with most of the specimens having proloculi less than 100μ in outer diameter. The spirotheca is composed of tectum and keriotheca and is thin throughout. It thickens gradually to about 50μ in volution 7. The shell expands irregularly, with the height of volution increasing from around 50μ in the early volutions to over 200μ in volution 7.

The septa are fluted and form irregular chamberlets even in the equatorial zone. The tunnel is slightly irregular in its path and increases in width gradually from about 15° in volution 1 to about 35° in volution 7. The chomata are distinct and asymmetrical. They reach about two-thirds the height of the volution in the early stages and are steep to overhanging on the tunnel side. In the outer volutions they reach only ⅓–½ the height of the volution and are more symmetrical. Septa are closely and regularly spaced in the inner volutions, but irregularly and more widely spaced in the outer volutions. Septal pores are common but very small in the outer volutions. The chambers are nearly flat, generally conforming to the spiral of the shell.

Remarks.—Most of the specimens referred to this species are small and conform to the description given by Thompson (1954). Several specimens, however, are larger than any assigned by Thompson to this species and resemble those described as *Dunbarinella fivensis* Thompson (1954, p. 44). Since all the smaller specimens in the samples studied seem to be immature specimens of the larger forms, they are described together. It would not be surprising to find that *Triticites pointensis* and *Dunbarinella fivensis* are conspecific. Comparison with the measurements and illustrations provided by Thompson strongly suggests this possibility.

Occurrence.—In this study *Triticites pointensis* was recognized in collections from the Five Point limestone member of the Janesville shale of Kansas. Its distribution and association are shown in table 3. Thompson recognized the species in this limestone in Wabaunsee County, Kans.

Triticites confertus Thompson

Plate 8, figures 19, 20; plate 9, figures 6, 7

Triticites confertus Thompson, 1954, Kansas Univ. Paleont. Contr., Protozoa, art. 5, p. 38, pl. 8, figs. 11–22.

The shell is inflated-fusiform with a straight axis of coiling, pointed poles, and slightly concave lateral slopes. Specimens with about 7 volutions are 3.5 to 4 mm in axial length and 2 to 2.5 mm in diameter. The proloculus is up to 190μ in outer diameter. The spirotheca consists of tectum and rather coarse keriotheca. It is thin in the inner volutions but increases rapidly in thickness to nearly 100μ in volution 5. The shell expands rather rapidly and regularly with only slightly greater height of volution near the poles than in the area of the tunnel. The septa are fluted irregularly, forming chamberlets even in the equatorial area. The tunnel is slightly irregular and widens rapidly from about 26° in the inner volutions to 54° in the outer volutions. The chomata are distinct and asymmetrical and extend ⅓–⅔ the height of the volution. Other epitheca is developed sparingly along the lateral slopes. No septal pores were seen. The ceiling of the chambers is not arched, but conforms to the general spiral of the shell.

Remarks.—The specimens here assigned to *Triticites confertus* Thompson are slightly smaller than the forms described by Thompson, and they have a larger proloculus. In all other features the specimens resemble the described forms closely, and it is likely they are conspecific.

Occurrence.—The distribution and association of this species in the Five Point limestone member of the Janesville shale of Kansas are shown in table 3. Thompson (1954, p. 38) described specimens from the middle part of the Waldrip shale member of the Pueblo formation of north-central Texas and from the Five Point limestone member of the Janesville shale of Kansas.

Triticites brownvillensis Douglass, n. sp.

Plate 6, figures 4–19; plate 7, figures 3–7

Triticites n. sp. Thompson, 1948, Kansas Univ. Paleont. Contr., Protozoa, art. 1, pl. 8, figs. 3, 8.

The most abundant species of *Triticites* in the Brownville limestone member of the Wood Siding formation of Kansas is the elongate-fusiform species here named *Triticites brownvillensis*. Mature specimens have 8–9 volutions and are commonly 7–8 mm in axial length and 2–2.5 mm in diameter. Some specimens are as much as 9.5 mm long and 3 mm wide. The proloculus is small, ranging in size from 90μ to 140μ in outer diameter. The spirotheca is thin in the early volutions and thickens gradually to about 30μ in volution 5 and about 80μ in volution 9. One specimen shows a thickness of over 90μ in volution 8. The keriotheca is well developed, with about 80 alveoli per millimeter in volution 8. The shell expands regularly through the first 4–5 volutions, after which the height of volution increases only slowly and irregularly. In axial sections the walls have an irregular wavy appearance, and irregularity is also shown in equatorial section.

The tunnel is well defined. It is not quite straight as it widens from about 12° in the inner volutions to over 35° in volution 5. In the outermost volutions the tunnel is often indistinct, as the chomata are not as well developed. The chomata in the inner volutions are nearly symmetrical and extend ½–⅔ the height of the volution. In the outermost volutions the chomata are irregularly developed and locally absent. A small amount of epithecal deposit is developed along the axis of the inner volutions. The septa are irregularly fluted and show light fluting and the development of chamberlets along the floor of the chambers even in the equatorial area. Septal pores are abundant in the outer volutions and are as much as 16μ in diameter. The number of chambers per volution increases gradually from about 20 in volution 3 to about 30 in volution 8. The chambers show only slight arching in equatorial section. They tend to conform to the general spiral of the shell.

Remarks.—This species has not been described previously. Two specimens were figured by Thompson (1948, pl. 8, figs. 3, 8) but were not referred to in the text. *Triticites brownvillensis* resembles *Dunbarinella*(?) *americana* Thompson (1954), but has a smaller proloculus and a larger form ratio. They probably belong to the same genetic lineage.

Occurrence.—*Triticites brownvillensis* is described from the Brownville limestone member of the Wood Siding formation of Kansas. Its distribution and association are shown in table 2.

Triticites sp. aff. T. creekensis Thompson, 1954

Plate 10, figure 15

Triticites creekensis Thompson, 1954, Kansas Univ. Paleont. Contr., Protozoa, art. 5, p. 42, pl. 9, figs. 22–26; pl. 10, figs. 1–13.

A single specimen of a highly inflated-fusiform triticitid was found. The specimen has 7½ volutions and is about 8 mm in axial length and 4.6 mm in diameter. The proloculus is large, measuring about 340μ in outer diameter. The spirotheca is composed of a tectum and coarse keriotheca with about 45 alveoli per millimeter. The spirotheca thickens regularly through volution 6, then thins irregularly. The shell expands rapidly through the first six volutions, then increases more slowly. The tunnel is wide and slightly irregular in its path. Measurements, in microns, for each of the seven and one-half volutions are:

	Volution								
	Proloculus	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*7½*
Thickness of spirotheca......μ		20	25	40	65	80	115	90	65
Height of volution..........μ		100	150	250	270	340	420	300	
Angle of tunnel........degrees	28	21	24	26	25	26	35		

The chomata are nearly symmetrical and rise ⅓–½ the height of the volution except in the outermost volution. Other epitheca is developed along the floor of the tunnel and to some extent along the lateral slopes of some of the chambers. Septa are highly fluted in the poles and moderately fluted even in the equatorial zone, especially in the inner volutions. Septal pores are 18μ in diameter and are common even in the inner volutions.

Only one specimen of this large form was found in the collections from the Americus limestone member of the Foraker limestone. Although it resembles *Triticites creekensis* Thompson in many respects, it cannot be excluded from *Triticites meeki* (Meek and Hayden) of Thompson (1954).

The specimen described was collected at USGS loc. 13818 in Greenwood County, Kans., where it is associated with *Triticites eoextenta* (Thompson). Thompson described *Triticites creekensis* from the Camp Creek shale member of the Pueblo formation of Texas and the Bursum formation of New Mexico.

Pseudofusulina delicata Douglass, n. sp.

Plate 8, figures 14–18; plate 9, figures 3–5

The shells are subcylindrical to elongate-fusiform with a straight to slightly arcuate axis of coiling. The poles are sharply pointed in the inner volutions and are blunt in the adult. Shells of 7 volutions are 5.5–6 mm in axial length and about 1.3 mm in diameter. The proloculus is minute, 50μ–60μ in outer diameter. The spirotheca is composed of tectum and fine keriotheca. It is thin, increasing in thickness gradually from about 20μ at volution 3 to 30μ at volution 5 and 60μ at volution 7.

Coiling is in one plane. The shells expand rather rapidly but irregularly. The height of volution increases from 20μ at volution 1 to 120μ at volution 5 and 230μ at volution 7. The septa are strongly but irregularly fluted and form chamberlets along the base of the chambers throughout the shell. The tunnel is not quite straight. It is 35°–45° wide in volution 3 and increases to 55°–75° in volution 5. The chomata are small and symmetrical. They are easily confused with septal loops, and many are nearly confined to a thickening of the base of the septa. No other epithecal deposits were recognized.

The septa are fairly evenly spaced and pitch forward. The number of septa per volution increases gradually from about 7 in volution 1 to 16 or 17 in volution 5. Septal pores are present, but they are small and difficult to see. The chambers are highly arched and do not conform to the general spiral of the shell.

Remarks.—This is one of the earliest forms of *Pseudofusulina* recorded, yet it has all the characteristics typical of the genus. The arching of the chambers, the irregularity of coiling, and the obsolescence of the chomata coupled with the strength of the fluting all place this species in *Pseudofusulina.* The species it most closely resembles is *Schwagerina campa* Thompson, 1954. *Pseudofusulina delicata* strongly resembles *Schwagerina campa* in its rather tight juvenarium and loosely coiled adult, in the nature of the fluting, and in the development of the chomata. The measurable characteristics are consistently smaller, however, in *P. delicata.* These are distinct species, although they are probably of the same genetic stock.

Pseudofusulina delicata has been recognized only in the Five Point limestone member of the Janesville shale of Kansas, where it was found at USGS locs. 13839 in Lyon County and 13668 in Wabaunsee County. Small equatorial sections which may represent this species were also found at USGS locs. 13815 in Greenwood County and 13836 in Lyon County.

Schwagerina campa, the most similar form, is reported only from the Glenrock limestone member of the Red Eagle limestone by Thompson (1954, p. 54)

PHYLUM COELENTERATA

CLASS ANTHOZOA

By Helen Duncan

In a paper titled "The Occurrence of Corals in the Late Paleozoic Rocks of Kansas," Jeffords (1948a) reviewed the general makeup of the Pennsylvanian and Permian faunas and indicated the genera commonly found in various rock units of the area. This helpful summary of data on faunules and the stratigraphic distribution of genera provided a basis for comparison and interpretation of the material examined in connection with the present investigation.

The corals studied were collected only from beds in the upper part of the Virgil series and the lower part of the Permian. The oldest faunule came from the Tarkio limestone member of the Zeandale limestone of the Wabaunsee group; the youngest was obtained from the Florena shale member of the Beattie limestone of the Council Grove group. Corals were collected from some rock units (Tarkio limestone, Wamego shale [Pierson Point shale of Jeffords], and Maple Hill limestone members of the Zeandale limestone; Pillsbury shale [Langdon shale of Jeffords]; Grandhaven limestone member of the Stotler limestone; and Jim Creek limestone member of the Root shale) for which Jeffords (1948a, p. 47–48) cited no occurrences, but corals were not obtained from a few beds (Aspinwall limestone member of the Onaga shale and Falls City limestone) that Jeffords (1948a, p. 48) reported to be coral bearing.

The coral faunules are undiversified. Two general groups are represented: horn corals lacking dissepiments (the lophophyllidid corals), and solitary and semicolonial rugose forms with dissepiments (the dibunophyllid corals and "*Axophyllum*"). No tabulate corals were found in the part of the section under consideration, and none were reported by Jeffords. The distribution of dissepimented and nondissepimented forms appears to have been controlled largely by sedimentary environment. Dissepimented corals are essentially confined to the more calcareous rocks. The lophophyllidids, which are more abundant throughout most of the section, occur in both limestone and shale.

About 150 corals were collected from 43 localities. Many of the collections contained only 1 specimen, few contained as many as 5, and only 3 contained more than 10. Some specimens were too fragmentary, too crushed, or too immature for identification. In certain collections the corals are so crudely silicified that accurate identification is impossible (for example, those from USGS loc. 13712, in the Bennett shale member of the Red Eagle limestone). Because of these circumstances and also because information on the range of specific variation is inadequate, discrimination of species generally was not feasible. Specimens were identified as to genus insofar as the quality of the material warranted. The faunal chart (table 1) shows the distribution of genera and the number of specimens in individual collections.

Actually, only the few species listed below have been described from material collected from the part of the Kansas section considered here.

Species	*Member and formation*
Dibunophyllum exigum Jeffords, 1948b (p. 619–622).	Dover limestone member of the Stotler limestone.
Lophamplexus eliasi Moore and Jeffords, 1941 (p. 91–94).	Foraker and Beattie limestones.
Lophophyllidium dunbari Moore and Jeffords, 1941 (p. 83–85). (Jeffords, 1947, p. 40, referred this species to *Stereostylus*.)	Florena shale member of Beattie limestone.
Malonophyllum kansasense Moore and Jeffords, 1941 (p. 76–77). (Malonophyllum is considered by most students to be a synonym of *Lophophyllidium*; however, Jeffords did not reassign this species in his 1947 paper.)	Florena shale member of Beattie limestone.
Sochkineophyllum mirabile Moore and Jeffords, 1941 (p. 105–108). (Jeffords, 1947, p. 40, referred this species to *Stereostylus*.)	Florena shale member of Beattie limestone.
Stereostylus perversus Jeffords, 1947 (p. 60).	Brownville limestone member of the Wood Siding formation and Dover limestone member of the Stotler limestone.

I do not think, however, that it can be confidently stated that species based on material from somewhat older or somewhat younger rocks may not occur in these upper Virgil and lower Permian strata. A number of lophophyllidid species from the lower part of the Virgil series have been described by Jeffords (1947), and a few other corals from the Virgil and lower Permian rocks of the region have been described or reported (see Bassler, 1950).

The material available for this study is believed to constitute a fairly representative sample of the coral element that occurs in the rocks. Clearly, conditions of sedimentation during the interval were not favorable for the development of an abundant and diversified coral fauna.

Lophophyllidid corals

Plate 11, figures 1–4

In this particular study it was found impractical to recognize different genera of lophophyllidid corals. The genera are based on characteristics affected by the amount of skeletal material secreted. Comparative studies of species belonging to the same genus but occurring in different sedimentary environments have demonstrated that forms living in shaly facies tend to have much more strongly dilated skeletal structures than forms living in facies where limestone was deposited. Fundamentally the coralla of *Lophophyllidium*, *Stereostylus*, and *Lophamplexus* are distinguished from each other by the successive diminution in amount of calcareous material deposited. According to Jeffords (1948a, p. 44), *Lophophyllidium* "is confined chiefly to shales and calcareous shales within a predominantly shaly section," and "*Stereostylus* occurs in formations that range lithologically from shales to pure limestones." Records of the occurrence of *Lophamplexus* suggest that forms referred to the genus came mainly from limestone (see also comments by Jeffords, 1947, p. 79). In my opinion *Lophophyllidium* and *Stereostylus* are slightly different manifestations of a single generic unit. *Lophamplexus* is related but appears to have diverged sufficiently to be considered a separate genus. The many species of *Lophophyllidium* and *Stereostylus* that have been described need to be evaluated with reference to facies occupied and amount of skeletal material deposited before much reliance is placed on them for detailed stratigraphic work.

As morphologic studies of the type needed to reevaluate the characteristics that have been used to distinguish the lophophyllidid genera are beyond the scope of the present study, I have included in *Lophophyl-*

lidium (the oldest name) all specimens having well-defined and persistent columellae. Nearly all the lophophyllidid material belongs to this category. A single specimen from the Florena shale member of the Beattie limestone (USGS loc. 13500) was identified as *Lophamplexus*?. A few fragmentary specimens are more conspicuously tachylasmoid than *Lophophyllidium* and *Stereostylus* are supposed to be. It is entirely possible that a few tachylasmoid forms are present, though Jeffords (1947, p. 40) considered the apparently tachylasmoid *Sochkineophyllum mirabile* Moore and Jeffords to be a *Stereostylus*. In any event, the material I have is inadequate for sure identification and is included with the lophophyllidid corals.

Readily discernible external features suggest that several species of lophophyllidids occur in these collections from the upper Virgil and lower Permian rocks. Some forms have contorted coralla and conspicuous areas of attachment (pl. 11, fig. 4). Others have curved ceratoid coralla and are comparatively symmetrical (pl. 11, fig. 1). Still other forms are spinose. However, because studies bearing on the recognition of proposed generic categories must be accomplished before the species will be soundly established, it did not seem worthwhile to try to identify individual specimens with such species as have been described.

Dibunophyllum and dibunophyllid corals [10]

Plate 11, figures 5, 7, 8

Specimens referable to or related to *Dibunophyllum* were collected at nine localities. Only one lot came from rocks of early Permian age (USGS loc. 13712); these specimens show evidence of asexual increase (pl. 11, fig. 5) and are reported to form a biostromal accumulation. Most of the dibunophyllid corals of Virgil age were found in the Dover limestone member of the Stotler limestone; but 3 were collected from the Tarkio limestone member of the Zeandale limestone, 1 from the Maple Hill limestone member of the Zeandale limestone, 1 from the Pillsbury shale, and 1 from the Grandhaven limestone member of the Stotler limestone.

All of the dibunophyllids are relatively small. Several specimens from the Dover limestone member appear to be identical with *Dibunophyllum exigum* Jeffords (pl. 11, figs. 7, 8). Most of the specimens from rocks in the Wabaunsee group are incomplete or immature. As far as I can tell, they all could be included in *D. exigum.*

Individual specimens of dibunophyllids from the biostrome in the Bennett shale member of the Red Eagle limestone (pl. 11, fig. 5) tend to be considerably larger than the species of *Dibunophyllum* found in the Wabaunsee group. The greater size is probably attributable to rejuvenation or calicular increase. Some coralla show unusually large areas of attachment. All specimens are crudely silicified and inadequate for detailed study. In general, the axial column is less conspicuous and the dissepimentarium is narrower than in *D. exigum.*

"Axophyllum" sp. [11]

Plate 11, figures 6, 9–11

Three formations in the Wabaunsee group yielded a few carcinophyllid corals, which are here referred to "*Axophyllum.*" Most of the specimens are fragmentary. The largest example is embedded in limestone. The calyx of this specimen is illustrated (pl. 11, fig. 10). The smaller broken corallum (pl. 11, fig. 11) came from the Grandhaven limestone member of the Stotler limestone at the same locality (USGS loc. 14861). The transverse section figured (pl. 11, fig. 6) was made from a fragmentary corallum that appears to be turbinate and of comparable size; this specimen came from the Tarkio limestone member of the Zeandale limestone (USGS loc. 13496). Another species (pl. 11, fig. 9) with a smaller and nearly cylindrical corallum, insofar as one can tell from the fragment collected, was found in the Dover limestone member of the Stotler limestone (USGS loc. 13441). As the thin sections indicate, these specimens differ from *Dibunophyllum* in having solid columellae and lonsdaleoid dissepimentaria.

So far as I know, the group of American Pennsylvanian species characterized by strong solid columellae and lonsdaleoid dissepimentaria have not been studied as a unit or definitely assigned to any genus. However,

[10] Fomichev (1953, p. 393) proposed the name *Dibunophylloides* (type species: *Cyathoclisia symmetrica* Dobrolyubova, 1937) for the sort of Pennsylvanian coral Americans have called *Dibunophyllum.* He states that "It may apparently be affirmed rather definitely that the genus *Dibunophyllum* Thom. and Nich. is typically represented only in the upper half of the Lower Carboniferous. It occurs in the Visean stage and attains abundant development in the upper half of the Visean (in the *Dibunophyllum*-zone) and in lower Namurian strata. We do not know it from higher strata, and it is absent there. In the Donets section it is unknown higher than the Lower Carboniferous (Namurian)." [Translation]

Some of the characteristics used to distinguish *Dibunophylloides,* however, are to be observed in specimens of *Dibunophyllum* from the European Lower Carboniferous, and some of the supposed differences listed by Fomichev are not considered to have generic significance. The reported absence of a fossula in *Dibunophylloides* is probably the most important difference cited, but Fomichev's observations were based exclusively on sections and not on the calyxes of free specimens. More detailed study is needed to ascertain whether *Dibunophylloides* should be recogized as the name of a taxon distinct from *Dibunophyllum.*

[11] In a recent monograph on the rugose corals from the Middle and Upper Carboniferous in the Donets Basin, Fomichev (1953, p. 413–417) reviewed the opinions expressed by various students on the status of *Axophyllum* Milne Edwards and Haime as a generic taxon. Lack of information on the skeletal structures of the genotype led Fomichev to erect the genus *Axolithophyllum* (type species: *A. mefferti* Fomichev, 1953). He also referred to this genus the other species from the Russian Middle Carboniferous previously included in *Axophyllum.* The name *Axolithophyllum* could be used for the specimens here called "*Axophyllum,*" but there is a good possibility that *Axophyllum* will prove to have priority as a name for these corals.

comparable species occur in the Moscovian of Russia (approximately the equivalent of the Des Moines) and were assigned to *Axophyllum* (see Dobrolyubova, 1941, p. 57–59, 67, pl. 7, figs. 6–8; Dobrolyubova and Kabakovich, 1948, p. 32–34, pl. 15, figs. 1–5, pl. 16, figs. 1–3). Whether the use of the name *Axophyllum* for this generic unit is legitimate cannot be determined without reference to the European types. As the name has been and possibly should be used for Carboniferous corals with solid columellae and lonsdaleoid dissepimentaria, it seems appropriate to continue using it until the morphology of the type species, *Axophyllum expansum* Milne Edwards and Haime, is properly investigated and the status of the name settled beyond doubt. If *Axophyllum* and *Carcinophyllum* are found to be congeneric, the name *Axophyllum* should supplant *Carcinophyllum* for solitary corals with lonsdaleoid dissepimentaria and compact (but not solid) reticolumns. It would then be necessary to recognize another nomenclatural category for the group of corals possessing solid columellae that are here included in "*Axophyllum*."

Various students have expressed the opinion that *Axophyllum* Milne Edwards and Haime is not definitely recognizable or is a synonym of *Lonsdaleia* McCoy or of *Carcinophyllum* Thomson and Nicholson. As a consequence the name *Axophyllum* has fallen into disrepute and has not been used for American species in the more recent publications. Jeffords (1948b, p. 618) states that most American species referred to *Axophyllum* probably "should be referred to *Dibunophyllum*." In part I agree with Jeffords on this point—at least the corals Girty (1915b, p. 310–314) identified as *Axophyllum cylindricum* Girty, *A. infundibulum* Worthen?, and probably *A. rude* White and St. John appear to be species of *Dibunophyllum*. However, in the same paper Girty (1915b, p. 314–317) referred to *Axophyllum*? and described six unnamed species, which were designated A, B, C, D, E, and F. Girty's *Axophyllum*? spp. A, B, C, E, and F have solid columellae and lonsdaleoid dissepimentaria and obviously belong to the same generic group as the Wabaunsee corals considered here. The species designated "D" appears to be more like *Neokoninckophyllum*.

PHYLUM ECHINODERMATA

CLASS CRINOIDEA

By Harrell L. Strimple

The stratigraphic relations and associations of the crinoid specimens used in this study are described in Part 1 by Mudge and Yochelson. Complete locality data are given in "Register of Localities" (p. 127).

EVIDENCE OF GIGANTISM AMONG SPECIES OF DELOCRINUS

The occurrence of three large forms referable to the genus *Delocrinus* that are obvious derivatives of older species is of considerable interest. *Delocrinus admirensis* Strimple, n. sp. is comparable to *D. brownvillensis* Strimple (1949b); *D. densus* Strimple, n. sp. to *D. extraneous* Strimple (1949a); and *D. doveri* Strimple, n. sp. to *D. stullensis* Strimple (1947).

The oldest known species of *Delocrinus* is *D. matheri* Moore and Plummer (1937). The holotype, a dorsal cup, is reported to have a diameter of 15.0 mm and a height of 4.5 mm, or a ratio of 0.30. The holotype of *D. admirensis*, a dorsal cup, has a width of 33.0 mm and a height of 15.0 mm, or a ratio of 0.46. Thus the Permian species is more than twice as wide as the Morrow species and has a relatively deeper cup. The logical predecessor of *D. admirensis* is the upper Pennsylvanian *D. brownvillensis*, the holotype of which is a dorsal cup with a diameter of 27.2 mm and height of 9.6 mm, or a ratio of 0.36.

The holotype of *D. densus*, a partial crown, has a dorsal cup with a diameter of 30.0 mm, height of 15.0 mm, and ratio of 0.50. The Permian species compares favorably with the Virgil species *D. extraneous*, which has a maximum diameter of 22.9 mm, height of 10.3 mm, and a ratio of 0.45.

The holotype of *D. stullensis*, a dorsal cup, has a maximum diameter of 27.8 mm, height of 8.0 mm, and ratio of 0.28. This species is from the Stull shale member of Moore (1932) of the Kanwaka formation of the Shawnee group, which is considerably below the Dover limestone member of the Stotler limestone. The holotype of *D. doveri*, a dorsal cup, has a maximum diameter of 30.6 mm, height of 9.0 mm, and ratio of 0.29. These two species appear to be closely related.

Delocrinus major Weller (1909), from the Cibolo formation (lower Permian) of Texas, is the largest reported species of the genus. Weller gives the estimated greatest width of the holotype (an incomplete dorsal cup) as 40 mm, and height of 14 mm, which is a ratio of 0.35. Moore and Plummer (1940, p. 254) give an average width of 37.5 mm and height of 13.7 mm for the holotype, or a ratio of 0.36. Either ratio is less than found in *D. admirensis* or *D. densus*. *D. major* is more comparable in general appearance to *D. admirensis* than to *D. densus*.

Teichert (1949) has demonstrated more striking examples of gigantism among species of *Calceolispongia* from the Permian of Australia.

A DIVERGENT TREND IN AESIOCRINUS

The discovery of a new species, *Aesiocrinus prudentia*, from the Dover limestone member of the Stotler limestone, that is comparable with the unique species *A. paucus* Strimple (1951) of the Missouri series is extremely interesting. The older species is characterized by having a very broad anal plate that rests obliquely on the truncated upper surface of posterior basal, does not extend above the edge of the dorsal cup, and is almost indistinguishable from the adjacent radial plates. The dorsal cup is very shallow, the base shallowly concave, and the infrabasals are unusually large for an aesiocrinid. *A. prudentia* has mildly upflared infrabasals, but agrees with the older species in other respects. With the discovery of additional forms having these characteristics, it will probably be necessary to erect a separate genus.

EXTENDED RANGE FOR OKLAHOMACRINUS

A well-preserved dorsal cup, with part of the column and cirri, is described below as *Oklahomacrinus cirriferous* Strimple, n. sp. It is from the Five Point limestone member of the Janesville shale (lower Permian) and thus extends the range of the genus. It is of interest to note that this divergent trend of the aesiocrinids (the genus *Oklahomacrinus*) is in some respects comparable with the forms considered above (*Aesiocrinus paucus* and *A. prudentia*). However, *Oklahomacrinus* has a narrow anal plate and tends toward a deeply invaginated basal area, which is quite different from the trend found in the specialized species of *Aesiocrinus* mentioned above. Normal evolution for late Pennsylvanian and early Permian crinoids is considered by many authors to be toward a deeply invaginated basal area; however, there are numerous examples of trends toward the primitive type of dorsal cup with upflared infrabasals.

A NEW REPRESENTATIVE OF ENDELOCRINUS

The only characteristic of dorsal cups without attached arms that distinguishes *Endelocrinus* from *Delocrinus* is the dimplelike depressions at the angles of the cup plates of *Endelocrinus*. At first glance the form described below as *Endelocrinus rotundus* Strimple, n. sp. would be assigned to *Delocrinus*, but close examination discloses the existence of the diagnostic pits of *Endelocrinus*.

REMARKS ON GRAPHIOCRINUS

The genus *Graphiocrinus* was proposed by de Koninck and Le Hon in 1854, with *Graphiocrinus encrinoides* de Koninck and Le Hon as the type species. Many species have been assigned to the genus and subsequently referred to other genera. Moore and Plummer (1940) redefined the genus, and it is upon their interpretations that the following remarks are based.

The base of the dorsal cup in the type species is invaginated. There is some question as to the exact position of the single anal plate in that species, and it is possible that the problem may be resolved only by the acceptance of evidence afforded by topotypic material. The anal plate was not in contact with the posterior basal plate according to the original description, and the holotype specimen has been lost. Other specimens have been observed and recorded with the anal plate in firm contact with the posterior basal.

Known Pennsylvanian species assigned to the genus have either mildly invaginated or flattened bases, and the anal plate is in firm contact with the posterior basal. The form described below as *Graphiocrinus? kansasensis* Strimple, n. sp. has the infrabasals upflared, readily visible in side view of the dorsal cup. The reservation in assignment is not so much because of the upflared infrabasals as it is for the entire group of Pennsylvanian species currently being considered as representatives of the genus.

OTHER FORMS STUDIED

Two partial dorsal cups recovered in several segments from the Brownville limestone member of the Wood Siding formation are very likely representatives of *Delocrinus brownvillensis*. These specimens are from USGS loc. 13445 and 13690.

A small infrabasal circlet from the Five Point limestone member of the Janesville shale is *Elibatocrinus* sp. indet., from USGS loc. 13495.

A poorly preserved dorsal cup from the Glenrock limestone member of the Red Eagle limestone is considered to be *Plaxocrinus* sp. indet., from USGS loc. 13768.

A partial cup from the Dry shale member of the Stotler limestone is identified as *Delocrinus* sp. indet., from USGS loc. 14867.

DELOCRINUS Miller and Gurley, 1890

Type species: *Poteriocrinus hemisphericus* Shumard.

Delocrinus Miller and Gurley, 1890, Cincinnati Soc. Nat. History, v. 13, p. 9.

Bather, 1899, Geol. Mag., v. 4, no. 6, p. 32; 1900, *in* Lankester, Treatise on zoology: Adam and Charles Black, London, pt. 3, p. 180.

Springer, 1913, *in* Zittel-Eastman, Textbook of paleontology, v. 1, p. 225.

Wanner, 1916, Paläontologie von Timor, pt. 11, no. 11, p. 186.

Moore and Plummer, 1938, Denison Univ. Bull., Jour. Sci. Lab., 32, p. 288; 1940, Texas Univ. Pub. 3945, p. 250–258.

Moore and Strimple, 1941, Denison Univ. Bull., Jour. Sci. Lab., 36, p. 1.

Bassler and Moodey, 1943, Geol. Soc. America Spec. Paper 45, p. 408.

Moore and Laudon, 1943, Geol. Soc. America Spec. Paper 46, p. 60.

Strimple, 1949, Geol. Mag., v. 86, no. 2, p. 123.

Ceriocrinus White, 1880, U.S. Geol. and Geog. Survey Terr., 12th Ann. Rept., p. 127.

Wanner, 1924, Mijnwezen Nederl. Oost-Indië Jaarb, Verh. 1921, Gedeelte 3, p. 237.

[not] *Ceriocrinus* König, 1825, Icones fossilium sectiles, pl. 10 (London).

Agassiz, 1836, Soc. Neuchâteloise Sci. Nat. Mem., v. 1, p. 195.

Desor, 1845, Soc. Neuchâteloise Sci. Nat. Bull., v. 1, p. 215.

Delocrinus admirensis Strimple, n. sp.

Plate 12, figures 9–12; text fig. 29

The dorsal cup is deep, broad, subcircular in outline when viewed from above or below and has a deeply invaginated basal area. Five infrabasals are confined to the proximal part of the funnel-like basal concavity and are mainly covered by the columnar scar. Five basals are very large elements, forming the walls of the basal concavity and recurving to form a large part of the lateral sides of the cup. Distal edge of posterior basal is truncated for the reception of anal X. Five radials are large and pentagonal, with well-defined subhorizontal articulating surfaces. Posterior interradius is mildly concave and is occupied by a single relatively broad anal plate. Anal X has slight curvature to the upper edge of the cup, where it turns sharply inward and narrows very quickly. The outer surface of the cup is devoid of ornamentation but has a slightly frosted appearance.

Arm-articulating facets of the radials are very pronounced and distinctive. Outer ligament pit furrow and pit are deeply impressed but rather narrow. Outer ligament ridge possesses denticles and converges with transverse ridge at the lateral edges. The transverse ridge is sharp and narrow and has pronounced denticles. Lateral furrows are well defined and are backed by strong oblique ridges that have irregular denticles. The facet is deeply impressed about the central pit, which is in fact a pair of pits. A small cluster of elongated pits, generally about five, is present just above the central pits; these pits converge toward the central pits. The intermuscular furrow is shallow. Muscle areas are shallow triangular-shaped depressions. Of most interest are the adsutural areas, which have a group of small nodes and slits, as shown in figure 29, a camera-lucida drawing.

The measurements of the holotype, in millimeters except for the ratio, are as follows:

Height of dorsal cup	15.0
Greatest width of cup	33.0
Ratio of height to width	0.41
Length of right posterior basal[1]	18.8
Width of right posterior basal[1]	15.7
Length of right posterior radial[1]	12.0
Width of right posterior radial[1]	19.7
Length of suture between radials[1]	6.8
Width of anal X	6.8
Length of anal X[1]	9.8
Diameter of columnar cicatrix	3.8
Diameter of basal concavity	16.4
Height of basal concavity (external)	6.6
Diameter of body opening	18.9

[1] Along surface curvature.

Remarks.—Delocrinus admirensis is more similar to *D. brownvillensis* than to other described species. The present form has a deeper dorsal cup, with more erect lateral sides and more pronounced basal invagination than *D. brownvillensis.* The older species also has narrower adsutural areas in the arm-articulating facets of the radials. *D. ponderosus* Strimple (1949a), which is another large Pennsylvanian species, has a dorsal cup with a diameter of 30.0 mm which is close to that of *D. admirensis*, but it has a different height-to-width ratio (0.36). *D. ponderosus* has distinctive, unusually large arm-articulating facets.

Details of articulating facets of radial plates are shown in figure 29.

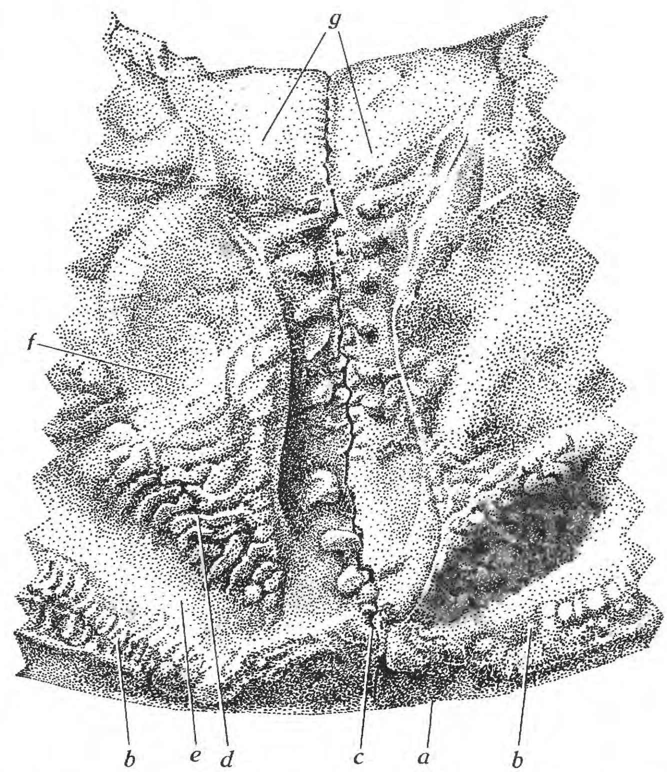

FIGURE 29.—Camera-lucida drawing of *Delocrinus admirensis* Strimple, n. sp. showing the areas adjoining the irregular suture between the arm-articulating facets of two radial plates, × 12. *a*, Outer cup wall. *b*, Transverse ridge with denticles shown. *c*, Suture. *d*, Oblique ridge with denticles shown. *e*, Lateral furrow. *f*, Muscle area. *g*, Adsutural slope.

Delocrinus conicus Boos (1929) is considered here because it is a lower Permian (Cresswell limestone member of the Winfield limestone of the Chase group) form from Kansas. Moore and Plummer (1940, p. 294) state, "Several dorsal cups in the University of Kansas collections show characteristics that suggest identification as *D. major*, and they appear to represent *D. conicus* also." In the same paper (p. 255) those authors give the height-to-width ratio as 0.52 for *D. conicus* which, if correct, certainly demonstrates an entirely different shaped cup than represented by *D. major*, which has a ratio of 0.36. I have been unable to examine the holotype of *D. conicus*, but on the evidence in the literature it appears to be a valid species.

Delocrinus major is a larger Permian form than *D. admirensis* and has a shallower cup, more sloping lateral walls, and a broader basal invagination.

Holotype.—USNM 134648, collected from USGS loc. 13476, Falls City limestone, Admire group.

Delocrinus densus Strimple, n. sp.

Plate 12, figures 21–24

Delocrinus densus is based on a single dorsal cup with brachials in place of some rays. The dorsal cup has a mildly pentagonal outline and depressed posterior interradius when viewed from below. When viewed from the side, adsutural areas between the basal plates are protruberent, or conversely the midsection of the basal plates is concave at the basal plane of the cup. The dorsal cup is full and appears deep. Owing to the nature of the preservation, it is not possible to determine the exact depth of the basal concavity, but it appears to be relatively shallow.

Infrabasal plates have not been observed. Five basals are large, participate in the lateral sides of the cup, curve into the basal concavity, and are concave in midsection at the basal plane. Five radials are pentagonal and prominent. Anal X is of medium size, rests evenly on the truncated upper extremity of the posterior basal, and curves sharply inward in the distal portion. The outer surface of anal X is concave. First primibrachials are axillary, low, and wide and fill the distal face of the radials. They overhang the dorsal cup but are not produced as spines. The anterior first primibrachial is considerably longer than the left anterior first primibrachial. First secundibrachials are very low, wide plates, and second secundibrachials attain twice their height.

The column is round, composed of alternatingly expanded columnals, and has a large pentalobate lumen. The tegmen is unknown. All observed segments of this species have a dense shiny appearance.

The measurements of the holotype, in millimeters except for the ratio, are as follows:

Height of dorsal cup	15.0
Greatest width of dorsal cup	30.0
Ratio of height to width	0.50
Length of left posterior basal	---
Width of left posterior basal	13.2
Length of anterior radial[1]	11.0
Width of anterior radial[1]	19.4
Length of interradial suture[1]	6.6
Diameter of proximal columnals	4.8

[1] Along surface curvature.

Remarks.—*Delocrinus densus* is very close to *D. extraneous* of the Pennsylvanian. Both have extremely smooth, shiny exteriors and have depressions in the midsection of the basals at the basal plane of the cup. *D. densus* is a larger form with a relatively deeper dorsal cup.

Holotype.—USNM 134652, collected from USGS loc. 13528, Five Point limestone member, Janesville shale, Admire group.

Delocrinus doveri Strimple, n. sp.

Plate 12, figures 13–16

The holotype of *Delocrinus doveri* is a dorsal cup that has undergone some weathering and distortion due to pressure. The fundamental outline of the cup has not been affected, and the weathering has not obliterated diagnostic features.

Dorsal cup is low and wide, with deeply invaginated base. Five infrabasals are confined to the basal concavity and are downflared from the columnar-attachment scar. Five large basals curve out of the basal concavity, form the basal plane of the cup, and curve upward to participate in the lateral walls of the cup. Five radials are low, wide, pentagonal elements with arm-articulating facets that slope slightly outward. Posterior interradius is concave and is occupied by the single anal X. Anal X is rather small and curves inward at the summit of the cup.

Outer ligament furrow is narrow. Outer ligament ridge is strongly crenulated and converges with the transverse ridge on each side of the ligament pit so that the denticles continue on the outer slope of the transverse ridge as well as on the inner slope. The ligament pit itself is deep and narrow. Lateral furrows are present but are shallow. Oblique ridges are well defined but do not appear to have denticles. Muscle areas and intermuscular furrow are shallowly depressed. Intermuscular notch is not well defined.

There is no evidence of surface sculpture on the cup. Columnar cicatrix is round, column unknown. Arms and tegmen have not been observed.

The measurements of the holotype, in millimeters except for the ratio, are as follows:

Height of dorsal cup	9.0
Greatest width of cup	30.6
Ratio of height to width	0.29
Length of right posterior basal[1]	13.2
Width of right posterior basal[1]	11.8
Length of suture between basals[1]	8.2
Length of right anterior radial[1]	8.2
Width of right anterior radial	17.0
Length of suture between radials[1]	5.3
Maximum width of anal X	4.8
Length of anal X[1]	8.0
Diameter of columnar scar	3.5
Diameter of basal concavity	12.2
Height of basal concavity (external)	5.4
Diameter of body opening	17.5

[1] Along surface curvature.

Remarks.—This species appears to be closely related to a slightly older Pennsylvanian species, *Delocrinus stullensis*. *D. doveri* is a larger form and the curvature of the basals into the basal concavity is more abrupt. There is no evidence of the surface granulations that are so pronounced on *D. stullensis*.

Holotype.—USNM 134650, collected from USGS loc. 13442, Dover limestone member, Stotler limestone.

Endelocrinus Moore and Plummer, 1940

Type species: *Eupachycrinus fayettensis* Worthen.

Endelocrinus Moore and Plummer, 1940, Texas Univ. Pub. 3945, p. 296–297.

Bassler and Moodey, 1943, Geol. Soc. America Spec. Paper 45, p. 450.

Moore and Laudon, 1943, Geol. Soc. America Spec. Paper 46, p. 60.

Endelocrinus rotundus Strimple, n. sp.

Plate 12, figures 5–8

This species is based on a dorsal cup that would at first glance be assigned to *Delocrinus*. As previously pointed out, the chief difference between *Delocrinus* and *Endelocrinus*, as characterized by the type species, is the presence of dimple-like depressions at the corners of the cup plates in *Endelocrinus* which are absent in *Delocrinus*. Known species having arms preserved also disclose that *Endelocrinus* has cuneiform arms, whereas *Delocrinus* has strongly biserial arms after the first few lower brachials, the latter being cuneiform. The present form has the characteristic dimples of *Endelocrinus*.

Dorsal cup is full and high, with erect lateral sides, and the base is deeply invaginated. When viewed from above or below, the cup has a circular outline broken by the mildly depressed posterior interradius. Five infrabasals are strongly downflared and extend well beyond the columnar scar, though they are restricted to the basal cavity. Five basals curve slightly into the basal concavity but mainly form the basal plane and form part of the lateral sides of the cup. Five radials are pentagonal and curve inward slightly at the summit of the cup. Anal X is a small hexagonal plate, resting evenly on the truncated upper edge of the posterior basal and extending slightly above the summit of the cup.

Arm-articulating facets of the radials slope slightly outward. Outer ligament furrow is prominent. Outer ligament ridge is present but could be easily overlooked. Ligament pit is short and deep. Transverse ridge has denticles and is well defined. Lateral furrows and oblique ridges are well defined. Muscle areas are small. Central pit is round, and intermuscular furrow and intermuscular notch are both poorly defined.

Columnar cicatrix is strongly crenulated and appears to have a round lumen; however, the lumen is definitely pentalobate in the interior of the cup.

The measurements of the holotype, in millimeters except for the ratio, are as follows:

Height of dorsal cup	6.5
Width of cup	14.3
Ratio of height to width	0.45
Length of right posterior basal[1]	7.0
Width of right posterior basal[1]	6.0
Length of suture between basals[1]	3.3
Length of right anterior basal[1]	5.1
Width of right anterior basal[1]	8.5
Length of suture between radials[1]	2.6
Diameter of columnar cicatrix	1.8
Diameter of body opening	8.0
Height of basal concavity (external)	2.3

[1] Along surface curvature.

Remarks.—This species is more comparable to *Endelocrinus fayettensis* than to other described species. That species does not have a sharply impressed base and has more tumid cup elements than found in *E. rotundus*.

Holotype.—USNM 134647, collected from USGS loc. 13792, Falls City limestone, Admire group.

OKLAHOMACRINUS Moore, 1939

Type species: *Oklahomacrinus supinus* Moore

Oklahomacrinus Moore, 1939, Denison Univ. Bull., v. 39, no. 10, p. 255–257.

Bassler and Moodey, 1943, Geol. Soc. America Spec. Paper 45, p. 574.

Moore and Laudon, 1943, Geol. Soc. America Spec. Paper 46, p. 59.

Oklahomacrinus cirriferous Strimple, n. sp.

Plate 12, figures 17–20

This species is based on a single small well-preserved dorsal cup with a small part of the proximal columnal and cirri attached. The cup has a strongly pentagonal outline when viewed from above or below that is only slightly interrupted by the narrow posterior interradius. It is 17.2 mm wide and has a height of 1.5 mm to the transverse ridge of the anterior radial. The base is deeply invaginated and internally the infrabasals cone is much higher than the upper edge of the dorsal cup. The 5 basals and the proximal parts of the 5 large radials participate in the basal concavity. The single anal plate is a slender quadrangular plate with concave midsection and occupies the posterior interradius. It is in contact with the truncate upper edge of the posterior basal. So far as observed, the basals have moderately strong transverse curvature. Articulating facets slope outward and are not too well preserved in the holotype. The ligament area is deeply impressed.

Proximal columnals are mildly pentagonal in outline, with a width of 3.3 mm, and the preserved cirri are circular in outline. Some cirri have a diameter that is half the size of the column. The cirri obviously swirled up around the crown, in life.

Remarks.—On the basis of the extreme internal height of the infrabasal dome, this species is more similar to *Oklahomacrinus stevensi* Moore (1939), *O. bowsheri* Moore (1939), *O. discus* Strimple (1937), and *O. regularis* Strimple (1951) than to other described species. The first three species are Virgil and the last Missouri in age (Pennsylvanian). *O. cirriferous* is devoid of ornamentation and the basals are not tumid. *O. bowsheri* is decorated by minute but coarse granules, and the anal plate has a distinctive appearance in being narrowly constricted at both proximal and distal extremities. The surface of *O. discus* is strongly ornate, the anal plate is entirely eliminated from the outer face of the cup as the distal extremity is reached, and the basal invagination is even more pronounced than in *O. cirriferous*. *O. stevensi* has tumid basal and surface granulations, and the base is not as invaginated as in the present species. *O. regularis* is most similar to *O. cirriferous;* however, it may be distinguished in that the surface curvature of its radials is not so pronounced and its outer ligament furrows are not so well defined in the older species.

Holotype.—USNM 134651, collected from USGS loc. 13606, Five Point limestone member, Janesville shale, Admire group.

AESIOCRINUS Miller and Gurley, 1890

Type species: *Aesiocrinus magnificus* Miller and Gurley.

Aesiocrinus Miller and Gurley, 1890, Cincinnati Soc. Nat. History Jour., v. 13, p. 14.

Moore, 1939, Denison Univ. Bull., v. 39, no. 10, p. 250–252.

Bassler and Moodey, 1943, Geol. Soc. America Spec. Paper 45, p. 283.

Moore and Laudon, 1943, Geol. Soc. America Spec. Paper 46, p. 59.

Phialocrinus Trautschold [not Eichwald], 1879, Soc. Imper. Nat. Moscou Nouv. Mem., v. 14, pt. 1, p. 24.

Pentadelocrinus Strimple, 1939, Bull. Am. Paleontology, v. 24, no. 87, p. 11.

Aesiocrinus prudentia Strimple, n. sp.

Figure 30

The species is based on a single small dorsal cup that has been weathered, though not to the point of obliterating all diagnostic characteristics. The cup is low and bowl shaped, with base widely upflared. Five infrabasals form a pentagonal disk that is horizontal at the large pentagonal columnar cicatrix but thereafter slopes gradually upward. Five basals are of moderate size and are subhorizontal to mildly upflared. Five radials are large irregular pentagonal elements. The single anal plate is a large element that rests obliquely on the truncated upper face of the posterior basal, does not extend above the normal cup height, and has the general appearance of a radial plate. Articulating facets of radials are too weathered to provide much information, but they appear to have been narrow and subhorizontal.

The measurements of the holotype, in millimeters except for the ratio, are as follows:

Height of dorsal cup	2.3
Width of cup	7.4
Ratio of height to width	0.31
Width of infrabasal circlet	2.0
Diameter of body opening	5.4

Remarks.—As previously noted (p. 67), *Aesiocrinus prudentia* is closely related to *A. paucus* and represents a divergent trend that is unique for the aesiocrinids. It is more advanced than *A. paucus*, which has a shallowly depressed basal area as compared to the upflared infrabasals of *A. prudentia*. The term "advanced" as used here means that the forms have passed through the stage where the basal area is depressed, or concave, and has evolved toward the primitive state of having upflared infrabasals.

The specimen cannot be easily photographed. A camera-lucida drawing of the holotype is shown in figure 30.

Holotype.—USNM 134653, collected from USGS loc. 13442, Dover limestone member, Stotler limestone, Wabaunsee group.

GRAPHIOCRINUS de Koninck and Le Hon, 1854

Type species: *Graphiocrinus encrinoides* de Koninck and Le Hon.

Graphiocrinus de Koninck and Le Hon, 1854, Acad. Royale Belgique Mem., v. 28, no. 3, p. 115.

Wachsmuth and Springer, 1879, Revision of Paleocrinoidea: Collins, Philadelphia, pt. 1, p. 121.

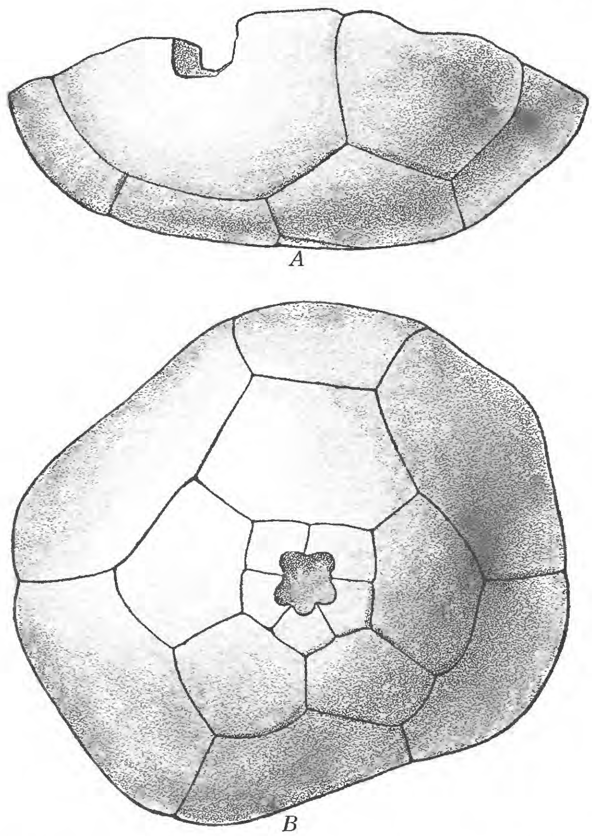

FIGURE 30.—Camera-lucida drawing of *Aesiocrinus prudentia* Strimple, n. sp. Holotype, ×10. *a*, From right-posterior. *b*, From below.

Bather, 1900, *in* Lankester, Treatise on zoology: Adam and Charles Black, London, pt. 3, p. 180.

Springer, 1911, Harvard Mus. Comp. Zoology Mem., v. 25, no. 3, p. 144; 1913 (part), *in* Zittel-Eastman, Textbook of Paleontology, v. 1, p. 225.

Wanner, 1916 (part), Paläontologie von Timor, pt. 6, no. 11, p. 166; 1924 (part), Mijnwezen Nederl. Oost-Indië Jaarb., Verh. 1921, Gedeelte 3, p. 232; 1937 (part), Palaeontographica, Supp. v. 4, sec. 4, pt. 2, p. 172.

Moore, 1939, Denison Univ. Bull., v. 39, no. 10, p. 245.

Moore and Plummer, 1940, Texas Univ. Pub. 3945, p. 312.

Bassler and Moodey, 1943, Geol. Soc. America Spec. Paper 45, p. 495.

Moore and Laudon, 1943, Geol. Soc. America Spec. Paper 46, p. 60.

Wright, 1952, The British Carboniferous Crinoidea, v. 1, pt. 4, p. 103.

Scaphiocrinus Hall, 1858, Iowa Geol. Survey [Rept.], v. 1, pt. 2, p. 549.

Graphyocrinus (*Graphiocrinus* de Koninck and Le Hon), 1926, Tien. Geol. Survey China, Paleont. Sinica, ser. B, v. 5, p. 40.

Graphiocrinus? kansasensis Strimple, n. sp.

Plate 12, figures 1–4

This species is based on a single dorsal cup that is excellently preserved. The entire outer surface of the cup has a frosted or delicately granular appearance. When viewed from below, the impressed sutures give the cup a lobed outline. Five infrabasals are readily visible in side view of the cup. Their proximal areas are confined to the shallow concavity formed by the rather large round columnar cicatrix, the perimeter of which is marked by a sharp rim. The distal parts of the infrabasals are upflared. Five basals are prominent mildly tumid plates that form the greater part of the lateral walls of the cup. Posterior basal is larger and longer than other basals, and the distal tip is truncated for reception of the single anal plate. Five radials are slightly wider than high and have well-developed arm-articulating facets that slope slightly outward. The outer ligament furrow is deeply impressed, and the ligament pit is well defined. Adsutural areas are closed at the point of contact with the outer cup wall and are shallowly depressed between the articulating areas. Muscle areas are shallowly impressed. A very prominent pit is present on each side of the intermuscular furrow to the fore of the intermuscular notch.

The single anal plate is hexagonal and flares strongly upon leaving the restricted area formed by the lateral sides of the adjoining radials. The larger part of the plate extends well above the cup height.

The measurements of the holotype, in millimeters except for the ratio, are as follows:

Height of cup (anterior side)	4.2
Width of dorsal cup	7.7
Ratio of height to width	0.54
Diameter of stem scar	2.0
Diameter of infrabasal circlet	3.3

Remarks.—*Graphiocrinus*? *kansasensis* is the only described American species assigned to the genus in which the infrabasals are readily visible in side view of the dorsal cup. The cup is proportionately higher than is normal for Pennsylvanian species, and the basals are more tumid.

When viewed from below the outline of the dorsal cup is somewhat comparable to that found in *Apographiocrinus* Moore and Plummer. In that genus, the impressed sutures of the radials continue into the arm-articulating region so that the articulating facets do not fill the entire distal face of the radials.

Holotype.—USNM 134647, collected from USGS loc. 14806, Bennett shale member, Red Eagle limestone, Council Grove group.

Comments on the Subphylum Eleutherozoa

Plate 11, figures 12–14

Echinoid remains occur locally in the calcareous shales. At most localities only a few spines are present, but in some beds, particularly the Bennett shale member of the Red Eagle limestone and the Neva limestone member of the Grenola limstone, spines are abundant. Plates are rare at all localities.

Echinoid remains from this part of the section have traditionally been referred to *Archaeocidaris* McCoy, although most workers admit that *Echinocrinus* Agassiz has priority (Mortenson, 1928, p. 59). Insofar as the writer has been able to determine, *Echinocrinus* appears to be the correct biologic reference. Several species have been named from Kansas material, but the types have been lost and there is considerable question as to whether the several species can actually be recognized and differentiated. Until a critical restudy of the upper Paleozoic echinoids is made, it seems best not to attempt to assign specific names to the material.

Most of the echinoid spines are well preserved and do not show signs of wear. In a few localities, many of the spines are incrusted with bryozoa.

Holothurian remains have been reported from the upper Pennsylvanian and lower Permian beds of Kansas (Hanna, 1930, p. 413–414; Kornicker, 1954, p. 117). These occurrences have not been reinvestigated in this present work.

An asteriaform impression has been collected from the West Branch shale member of the Janesville shale (14889) by H. C. Wagner; Dr. G. A. Cooper (oral communication) doubts that it is organic. Similar markings in the Francis formation of Oklahoma have been described and have tentatively been considered to be starfish (Jones, 1935, p. 427).

PHYLUM BRACHIOPODA

CLASS INARTICULATA

Genus LINGULA Bruguliere, 1797

Lingula carbonaria Shumard

Lingula carbonaria Shumard, 1858, Acad. Sci. St. Louis Trans., v. 1, p. 215.
Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 31–33, pl. 1, figs. 1, 2.

Following Dunbar and Condra, this species has been identified by its regular elliptical outline and its fine growth lines. The length is about one and one-half times the width, not only for adults but also for juveniles less than 5 mm long.

In one collection from black shale (USGS loc. 14908) this species is abundant. Two other specimens of this genus, both incomplete, have been identified in the collections studied. One is from black shale, the other from light-gray soft blocky shale. The genus is found with *Orbiculoidea*, but, with the exception of the abundant occurrence noted above, it is rarer. Most inarticulate brachiopods observed in the field are in very thin beds, and the difficulty of collecting them might account for the rarity of *Lingula* in the collections.

Genus ORBICULOIDEA Orbigny, 1847

Orbiculoidea missouriensis (Shumard)

Plate 11, figure 15

Discina missouriensis Shumard, 1858, Acad. Sci., St. Louis Trans., v. 1, p. 221.
Orbiculoidea missouriensis (Shumard). Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 42–45, pl. 1, figs. 12–17.
Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 291, pl. 109, fig. 24.

Specimens from the Kansas collections agree closely with the description of the species given by Dunbar and Condra (1932). Several specimens show the color banding noted by them.

Some of these better preserved specimens show considerable difference in position of the apex on shells from the same collection. The apex of the brachial valve ranges in location from about one quarter of the distance from the front to back margins to nearly central. This is more variation than noted by Dunbar and Condra (1932). In part this is due to ontogenetic change, with the apex not migrating forward with age.

Dunbar and Condra (1932) remark that the species is widespread in black shale, but almost one-third of the Kansas specimens collected are from light-gray argillaceous shale. The collections are not representative of the relative abundance of this species. In the field it was not feasible to collect from all the beds containing *Orbiculoidea* within the interval studied. Mudge has noted that these commonly are above limestone beds, and in many places fragments of *Orbiculoidea* are incorporated into the upper part of the limestone.

Orbiculoidea cf. O. tenuilineata (Meek and Hayden)

Plate 11, figure 16

Discina tenuilineata Meek and Hayden, 1859, Acad. Nat. Sci. Philadelphia Proc., v. 10, p. 25.

This is one of the few species recorded from the midcontinent that was not mentioned by Dunbar and Condra (1932). Description of Meek and Hayden's (1859) holotype and presumably only specimen (USNM 1102) follows: Pedicle valve very slightly elongate in outline, with greatest length being just anterior to center of valve; surface of pedicle valve has distinct sharp concentric lirae, separated by wide, relatively flat, smooth areas between, the lirae being more or less equally spaced except near the center where they are considerably closer together; pedicle slit begins at center of valve, width and extent of slit being unknown; brachial valve unknown.

The specimen is preserved on the surface of a light-gray limestone bed. The shell is eroded away on one side, but, from the imprint left, the following dimensions are estimated: length, 14.5 mm, width, 14.7 mm. The specimen is from bed 16 of Meek and Hayden's sections, which according to Mudge's interpretation may be the Kinney limestone member of the Matfield shale in the Chase group, above the Council Grove group.

Within the collections studied, a single pedicle valve occurring in a light-gray shale bed in the Johnson shale has been tentatively referred to this species. The specimen is slightly distorted, but it is considerably larger than most of the specimens of *Orbiculoidea missouriensis* (Shumard) and is almost the size of the holotype of *O. tenuilineata* (Meek and Worthen). More specimens are needed to show if there is any significant difference between these two species other than gross size, but they are presumed to be distinct forms.

Genus LINDSTROEMELLA Hall and Clarke, 1892

?Lindstroemella sp. indet.

Three specimens from the Falls City limestone have been tentatively referred to this genus, but the specimens are not well preserved. The shape is subtriangular with the apex relatively far anterior. These specimens are twice as large as specimens of *Lindstroemella patula* (Girty) from the Wewoka formation (Pennsylvanian of Oklahoma) and are much less rounded in outline.

Genus PETROCRANIA Raymond, 1911

Petrocrania modesta (White and St. John)

Plate 11, figure 17

Crania modesta White and St. John, 1868, Acad. Sci. Chicago Trans., v. 1, p. 118.
Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 51, pl. 1, figs. 23–26.
Petrocrania modesta (White and St. John). Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 291.

As nearly as can be determined, all specimens of *Petrocrania* in the Kansas collections belong to a single species. Except for variations caused by the structure of the surface to which they are attached, the specimens are remarkably constant in shape, being slightly oval in outline. Smaller specimens do not have a central boss developed, and the outer margin is not distinctly thickened.

Within the collections studied, most specimens occur on shells of *Dictyoclostus*, mostly from the Hughes Creek shale member of the Foraker limestone and the Florena shale member of the Beattie limestone. Two are attached to a *Linoproductus* and several have been seen on shells of *Composita* and *Marginifera*. Another collection from the Florena shale member in the possession of the United States National Museum shows *Petrocrania* attached to *Juresania*. From this distribution it is suggested that *P. modesta* had no host specificity, but simply attached itself to any available shell. Possibly the reason this species is most commonly attached to *Dictyoclostus* is that *Dictyoclostus* is ordinarily the most abundant large shell in the beds that contain *Petrocrania*.

CLASS ARTICULATA [12]

Genus WELLERELLA Dunbar and Condra, 1932

Wellerella osagensis (Swallow)

Plate 11, figures 18–20

Rhynchonella (Camarophoria) osagensis Swallow, 1858, Acad. Sci. St. Louis Trans., v. 1, p. 219.
Wellerella osagensis (Swallow). Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 288–289, pl. 37, figs. 1–4.
Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 315, pl. 120, figs. 27–29.

Specimens in the collections identified as this species agree closely with those described and figured by Dunbar and Condra (1932). All are nearly uniform in gross size, being somewhat smaller than *Wellerella truncata* Dunbar and Condra (1932), but because of distortion, few specimens have their true shape. Of the specimens examined, only 1 shows more than the characteristic 3 plications on the fold and 2 in the sulcus.

Most specimens of *Wellerella* in the Kansas collections occur in calcareous shale. A few were collected from shaly limestone and several were taken from a dark-gray, nearly black shale facies of the Bennett shale member of the Red Eagle limestone. More than three-fourths of the collections contain five or less specimens and many of the specimens are crushed. Many of these have been identified as *Wellerella* sp. indet. Poor preservation prevents positive identification, but the shells appear closer to *W. osagensis* than to the other species of *Wellerella* identified in those beds.

Wellerella truncata Dunbar and Condra

Plate 11, figure 21

Wellerella truncata Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 292–293, pl. 37, figs. 17–21.

Specimens in one small lot from the Hughes Creek shale member of the Foraker limestone have been identified as this species. Specimens in three other small collections from this same member and a single specimen from the Bennett shale member of the Red Eagle limestone, may be representatives of the species. The specimens are about one and one-half times the size of typical *Wellerella osagensis* (Swallow). The larger

[12] Since this section was compiled, the classification of the productoid brachiopods has been revised by Helen Muir-Wood and G. Arthur Cooper, in "Morphology, Classification and Life Habits of the Productoidea (Brachiopoda)," Geological Society of America Memoir 81, 1960.

specimens appear to have the front margin flatly truncated, but all the specimens are distorted and this feature cannot be proved conclusively. The arrangement of plications in the fold and sulcus is the same in both this species and *W. osagensis.*

Wellerella cf. W. delicatula Dunbar and Condra

Plate 11, figures 22, 23

Wellerella delicatula Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 293–294, pl. 37, figs. 5–10.

One specimen of *Wellerella* from the Neva limestone member of the Grenola limestone (USGS loc. 13777) is more oval in outline than are specimens referred to *W. osagensis* (Swallow). Fold and sulcus are much less pronounced than in that species. The shell is subglobular, with greatest thickness near the front. In all these features except the last, the specimen is quite similar to *W. delicatula.*

Wellerella cooperi Yochelson, n. sp.

Plate 11, figures 24–28

A collection from the Florena shale member of the Beattie limestone (USGS loc. 13775) in Cowley County, Kans., contains a dozen specimens of *Wellerella* which differ enough from those described in the literature to warrant a separate name. Description of the species is as follows: Small rhychonelliform brachiopods with 2 plications in shallow pedicle sulcus and 2 or 3 plications on each lateral slope; low brachial fold bearing 3 plications, and 2 plications on each lateral slope of the brachial valve; shell suboval to oval in outline with the anterior very slightly flattened; subglobular in profile, the greatest thickness about midway between center of shell and anterior margin.

	Length (mm)	*Width (mm)*	*Thickness (mm)*
1 (holotype)	6. 0	6. 4	5. 0
2	6. 4	7. 3	4. 9
3	6. 0	6. 6	4. 3
4	5. 6	5. 7	5. 2
5	6. 9	8. 0	6. 0
6	6. 5	7. 0	6. 0

Some of the variation may be due to slight compression by the weight of overlying shale.

Wellerella cooperi seems closest related to *W. osagensis* (Swallow) but differs in being more oval in outline than that species. It is also similar to *W. delicatula* Dunbar and Condra but is more globular and appears to be proportionally wider than that species. There may be internal differences, but attempts to study *W. cooperi* by grinding the beak of a specimen were unsuccessful because of poor differentiation between the shell and a calcite filling.

Genus NEOSPIRIFER Fredricks, 1919

Neospirifer dunbari R. H. King

Plate 11, figures 29–32

Neospirifer triplicatus Hall (not Kutorga), *in* Stansbury, 1852, U. S. 32d Cong., spec. sess., Senate Executive Doc. 3, p. 410.

Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 328–332, pl. 39, fig. 5; pl. 41, figs. 1–6.

Neospirifer dunbari R. H. King, 1933, Jour. Paleontology, v. 7, no. 4, p. 441.

Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 325, pl. 125, figs. 7, 8.

In identifying this species, particular emphasis has been placed upon the occurrence and relatively large size of 9 to 11 plications on the brachial fold. Specimens somewhat more elongate than those figured by Dunbar and Condra (1932) have been included in the species. These few elongate forms approach the variety *alatus* of Dunbar and Condra from the Kansas City and Lansing groups of Pennsylvanian age. Specimens in which the sulcus is slightly shallower than that described by these authors also have been included in the species. These differences in shape are relatively slight, and since specimens exhibiting them intergrade completely with typical specimens, they are believed due to individual variation.

Neospirifer dunbari may have had considerable tolerance in its environmental requirements. It is found in almost all types of beds from which collections were taken except those very argillaceous beds with a fauna of pelecypods. Unlike most of the other brachiopods examined, many of the *Neospirifer* are represented by a single valve. The preponderance of these are pedicle valves. This would seem to imply that there was some sorting of the shells by wave and current action.

Many specimens from the Hughes Creek shale member of the Foraker limestone, and a few from other beds, are worn almost beyond recognition. A few of these are incrusted by bryozoa and, rarely, *Tolypammina*-like tubes. Some shells bear elongate bore holes such as have been ascribed to the action of certain types of bryozoa.

Specimens from Kansas have been compared with the types of *N. dunbari.*

Neospirifer cf. N. kansasensis (Swallow)

Plate 13, figure 1

Spirifer camerata var. *kansasensis* Swallow, 1866, Acad. Sci. St. Louis Trans., v. 2, p. 409.

Several *Neospirifer* from the Hughes Creek shale member of the Foraker limestone and the Neva limestone member of the Grenola limestone differ from *N. dunbari* in having 15 or more plications on the brachial fold and in having more numerous and more uniform plications on the lateral slopes. Bundling of the plications is not pronounced. In these features, the specimens approach *N. kansasensis*, which is characterized by Dunbar and Condra (1932) as bearing 18 to 20 plications on the fold and 80 to 90 on the entire surface. It is possible, but not probable, that poorly preserved specimens of this species have been referred to *N. dunbari*. Also *N. dunbari* may have been interpreted as more variable than considered by Dunbar and Condra (1932). Even if both these factors are considered, it is quite clear that *N. kansasensis* is relatively rare.

Genus CRURITHYRIS George, 1931

Crurithyris expansa (Dunbar and Condra)

Plate 13, figures 2, 3

Ambocoelia expansa Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 348–349, pl. 42, figs. 15–17.

The writer has followed Cloud (1944, p. 62) in referring some American species to *Crurithyris* rather than *Ambocoelia*.

Dunbar and Condra (1932) erected the species *Crurithyris expansa* for those shells which differ from *C. planoconvexa* (Shumard) in being larger, having the ventral beak smaller and more strongly arched downward, and having the umbo less inflated. No differences in the internal characteristics of the two species have been noted.

The writer was fortunate in having available for study topotype specimens of *C. expansa* and specimens that may be from near the type locality of *C. planoconvexa*. Comparison of these collections shows that there seem to be differences in general shape and in size of the beak of the two species. Amount of arching of the beak and inflation of the umbo are variable within each species. Curvature of the brachial valve is a feature subject to much change by subsequent compression of specimens.

If larger size is rejected as a criterion of species, then all specifically identifiable specimens in the Kansas collections are referable to *C. expansa* in that they all have a relatively small beak. There are few collections from the Hughes Creek shale member of the Foraker limestone and several from the Neva limestone member of the Grenola limestone in which the size of the specimens approaches that of the specimens of Dunbar and Condra (1932). There is no consistent geographic or stratigraphic distribution of these larger specimens, but they all come from light- to dark-gray calcareous shale. Their larger size may be a reflection of more favorable environmental conditions.

The differences between *C. expansa* as recognized here and *C. planoconvexa* are small and are differences of degree, not of kind. It is possible that collections from stratigraphically older units would show that there is a continuous series evolving from *C. planoconvexa* which cannot be separated into other species. Tasch (1953, p. 390) has identified specimens of *C. planoconvexa* (Shumard) in the Dry shale member of the Stotler limestone, but study of similar specimens from localities near his suggests that he was dealing with internal molds of *C. expansa*.

Remarks about the distribution of *C. planoconvexa* made by Dunbar and Condra apply equally well to this species. The bulk of specimens is from beds that appear to be argillaceous. They are commonly abundant in thin layers just below or just above unfossiliferous beds. This distribution and other field evidence suggests that it is quite likely that the animals may have been able to live in brackish water. Almost no shells are incrusted with other organisms. Specimens are commonly distorted by pressure of overlying sediments.

Genus COMPOSITA Brown, 1839

Composita subtilita (Hall)

Plate 13, figures 4–7

Terebratula subtilita Hall, in Stansbury, 1852, U. S. 32d Cong., spec. sess., Senate Executive Doc. 3, p. 409, pl. 4, figs. 1a–2c.

Composita subtilita (Hall). Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 363–366, pl. 43, figs. 7–13. Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 335, pl. 128, figs. 9–12.

It has long been known that the genus *Composita* is extremely difficult to separate into species on the basis of external characteristics of the shell. Nevertheless, Dunbar and Condra (1932) have suggested that there are at least two species of the genus present within the stratigraphic interval covered by this study. They characterized *C. ovata* Mather as having an almost circular juvenile shell with a lens-shaped profile, whereas *C. subtilita* (Hall) juveniles were characterized by having an oval outline and early development of a fold and sulcus. Adults of each of the species were believed to intergrade completely and be indistinguishable, although *C. subtilita* adults were commonly thought to be somewhat elongate.

A practical difficulty with this scheme is that it requires both juveniles and adults in the same collection before one can be certain of the identity of the species. Many of the collections from Kansas contain only adults, but most of these specimens are more or less elongate and hence have been referred to *C. subtilita*. A few somewhat more rounded shells have also been referred to this species.

Four collections contain juvenile and adult specimens that fit the description of *C. ovata*. Two of these collections are from the Hughes Creek shale member of the Foraker limestone, 1 from the Bennett shale member of the Red Eagle limestone, and 1 from the Florena shale member of the Beattie limestone. They have a random geographic distribution within Kansas. They all occur in shale, but 1 collection is from light-gray calcareous shale, 1 from nearly black carbonaceous shale, and 2 from tan silty shale.

This small number of specimens which fall within the *C. ovata* category may simply be extremes of variation within *C. subtilita*. Certainly the mean of all specimens examined is toward *C. subtilita*. The youngest Pennsylvanian occurrence of *C. ovata* recorded by Dunbar and Condra (1932) is in the Deer Creek limestone, almost 700 feet stratigraphically below the Hughes Creek shale member of the Foraker limestone. To the writer, it seems illogical to extend the range of this species until better means of identifying it are devised.

Genus DERBYIA Waagen, 1884

Derbyia crassa (Meek and Hayden)

Plate 13, figure 9

Orthisină crassa Meek and Hayden, 1858, Acad. Nat. Sci. Philadelphia proc., v. 10, p. 261.

Derbya crassa (Meek and Hayden). Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 79–83, pl. 3, figs. 1–12.

Derbyia crassa (Meek and Hayden). Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 345, pl. 133, figs. 20–21

As noted by Dunbar and Condra (1932), this is an extremely variable species, and the Kansas collections bear out their statement that rarely are two specimens from the same locality the same in outline. Nevertheless, the small to medium size of the shell and the low beak and small interarea make this a readily identifiable species.

There is slight variation in the ornamentation of the valves. All the lirae of most juvenile specimens are essentially the same size, and small and large lirae alternate in the later stages. Occasional specimens have 2, 3, or very rarely more, small lirae between 2 larger lirae. Only rarely is 1 small lira intercalated at random between 2 larger ones.

The distribution of this species seems to be intimately associated with special facie. The largest specimens and the greatest number are from impure argillaceous beds of the Nebraska City limestone member of the Wood Siding formation. Most of the other specimens also come from argillaceous limestone. Very few specimens are in calcareous shale, and they are generally small.

None of the specimens examined are incrusted by other organisms, and none seem to show wear ascribable to transportation. Specimens from Kansas have been compared with the type specimens.

Derbyia wabaunseensis Dunbar and Condra

Plate 13, figures 10, 11

Derbya wabaunseensis Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 95–98, pl. 7, figs. 1–6.

This species is characterized by its relatively thick shell and its relatively large size. The width of the pedicle valve is much greater than the length in the juvenile stage and less than the length in the late mature and gerontic stages. No brachial valves referable to this species were found. Internally, the pedicle valve has a rimmed callus near the beak on which prominent muscle scars are impressed. Ornamentation commonly consists of fine, evenly spaced, sharp lirae, which may show beading, with an occasional intercalated small lira.

A few specimens of *D. wabaunseensis* have beeen identified in the Hughes Creek shale member of the Foraker limestone. One specimen and several fragments with the same type of ornamentation also have been identified from the Florena shale member of the Beattie limestone.

Derbyia cymbula Hall and Clarke

Plate 13, figures 12–14

Derbya cymbula Hall and Clarke, 1893, New York Geol. Survey, Paleontology, v. 8, pt. 1, p. 348, pl. 11B, figs. 2, 3.
Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 97–101, pl. 8, figs. 1–3, pl. 9, figs. 1a–d.

Derbyia cymbula Hall and Clarke. Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 345, pl. 134, figs. 1–5.

This species is differentiated from *Derbyia crassa* by its strongly convex brachial valve, long interarea, and its ornamentation of many fine lirae. The subelliptical shape of this species distinguishes it from *D. wabaunseensis* and *D. hooserensis*. Most specimens examined have a longer hinge line and are more regular in the vicinity of the beak than those figured by Dunbar and Condra.

Most specimens of *D. cymbula* are from calcareous beds of the Florena shale member of the Beattie limestone. None are incrusted with other organisms. The few specimens that are more or less complete do not appear to be worn. A single incomplete specimen from the Neva limestone member of the Grenola limestone (USGS loc. 14881) is quite similar to this species in shape and ornamentation, but its preservation is too poor to warrant even tentative identification. A single specimen from the Hughes Creek shale member of the Foraker limestone has been referred to this species.

Many of the specimens of *Derbyia* are fragments. Examination of the many identifiable specimens of this genus in the collections suggest that there is more individual variability in ornamentation of the species than was noted by Dunbar and Condra (1932). It is judged that identification based solely on the pattern of lirae is unreliable.

Incomplete specimens associated with an identifiable specimen have been assumed to be the same species. In beds where only fragments are present, identification has been only to genus. Thus a thin-shelled specimen such as *D. cymbula*, which is not very resistant to breaking, may appear to be more restricted geographically than it actually is.

Derbyia cf. D. hooserensis Dunbar and Condra

Plate 13, figure 8

Derbya hooserensis Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 92–94, pl. 5, figs. 6–10.

One specimen in a collection from the Florena shale member of the Beattie limestone (USGS loc. 13609) differs from the others from that unit in being almost one and one-half times greater in width than length. It also has a low cardinal area. In these two features, it resembles *Derbyia hooserensis*. Ornamentation consists of uniform-sized lirae with an occasional finer intercalated lira, the ornamentation being quite similar to that of *D. wabaunseensis*. In this feature, the specimen differs from the description given by Dunbar and Condra (1932) who characterize the species as having lirae separated into groups of three.

The specimen occurs with specimens referred to *D. cymbula* and *D. wabaunseensis*, and many incomplete fragments. The specimen may be an extreme of one of these species, but lack of intermediate forms indicates that this may be a distinct species.

Genus MEEKELLA White and St. John, 1867

Meekella striatocostata (Cox)

Plate 13, figures 15, 16

Plicatula striato-costata Cox, 1857, *in* Owen, Kentucky Geol. Survey Rept. 3, p. 568, pl. 8, fig. 7.

Meekella striatocostata (Cox). Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 125–129, pl. 16, figs. 1–10; pl. 17, figs. 3a–c.

Bridwell, 1939, Kansas Acad. Sci. Trans., v. 42, p. 355, 3 figs.

Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 345, pl. 133, figs. 9–16.

As noted by Dunbar and Condra (1932), this is an extraordinarily variable species. This variation is due in part to irregularity in growth induced by the habit of attachment of the beak, but sharpness of plications, width of hinge line, relative thickness of animal, and other features not directly affected by this habit are also variable. The few specimens available in the Kansas collections indicate that consistent separation of these variants would be impracticable. Specimens at hand are included in a single broadly constituted species. A few specimens from the interval studied seem to duplicate each of the varieties of this species named by Dunbar and Condra (1932).

Most specimens are from more or less calcareous shale beds lithologically like the Nebraska City limestone member of the Wood Siding formation. The largest single collection of *Meekella striatocostata* is from the calcareous Florena shale member of the Beattie limestone in Cowley County. None of the specimens examined are incrusted with other organisms and none of the fine lirae on the shells are worn. Specifically unidentifiable fragments of the genus have been found in most collections from the Florena shale member.

Genus CHONETES Fischer de Waldheim, 1837

Chonetes granulifer Owen

Plate 13, figures 17–19

Chonetes granulifer Owen, 1852, Geol. Rept. Wisc., Iowa, and Minn., Philadelphia, Lippencott, Grambo and Co., table 5, figs. 12a–d.

Dunbar and Condra, 1932, Nebraska Geological Survey Bull. 5, 2d ser., p. 138–143, pl. 18, figs. 1–10.

Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 347, pl. 134, figs. 24–26.

In their "Brachiopds of the Pennsylvanian System in Nebraska" Dunbar and Condra (1932) have described as separate from *Chonetes granulifer* the varieties *meekanus*, *transversalis*, and *armatus*. Girty (1915a, p. 62) earlier named the species *C. meekanus* and the variety *armatus*. The usage of Dunbar and Condra (1932) is certainly that of the varietal category, not subspecific, as they note that generally one or more of these varieties is associated with typical specimens of *C. granulifer*.

The Kansas collections come from a stratigraphic interval which is younger than the type horizon of *C. granulifer* (the Weeping Water limestone member as used by Dunbar and Condra (1932) of the Oread limestone (Dunbar and Condra, 1932, p. 142)), and older than the type horizon of *C. meekanus* (former Garrison shale (Dunbar and Condra, 1932, p. 144), possibly from the Bader limestone). From the oldest to the youngest specimens, *Chonetes* seems to vary from a subquadrate shape similar to *C. granulifer* to a more alate shape similar to *C. meekanus*. This is by no means a simple relation, because specimens similar in shape to *C. granulifer* are in the youngest collections studied, and specimens similar to *C. meekanus* are in some of the oldest. Although one shape commonly predominates in a collection, there is considerable variation.

There also seems to be a general tendency for the average size of adults to be larger in the younger beds. Dunbar and Condra (1932) report that larger specimens occur first in the Americus limestone member of the Foraker limestone, but large specimens are found as low as the Aspinwall limestone member of the Onaga shale. In this feature also, there is considerable variation both between and within populations.

The writer has been unable to find any break in this line of seemingly continuous variation. In this sort of problem, statistical methods are commonly useful in determining whether two or more species are represented. The collections at hand are insufficient for conclusive results, but Greene (1908b), with over 2,000 specimens to study, considered them all to be a single species.

There appear to be no other obvious differences that are of potential value in subdividing the *Chonetes* studied. Dunbar and Condra (1932) remark that the pedicle septum in *C. meekanus* is abbreviated, but this is not so. Examination of the interiors of topotypes of *C. granulifer* and types of *C. meekanus* show that they are both quite similar.

Attempts to divide this continuous series have not been successful, and it seems best to refer all specimens to *Chonetes granulifer* because most specimens seem closest to this form. Future statistical analysis may show significant differences, but until then conservatism in neither synonymizing or recognizing the varieties seems to be the wisest course. Indeed, the question of naming a few extreme shell forms in a population as varieties is a moot point.

R. H. King (1938) has named several species of *Chonetes* from the upper Pensylvanian and lower Permian of north-central Texas. Again, it seems better to wait until large collections are available for study before attempting to comment on the validity of these species.

In addition to the differences mentioned, there seem to be two general shell types among the *Chonetes*. Commonly, shells are thin, light, and relatively fragile, but some are relatively much thicker, heavier, and consequently stronger. The two types are often separate, but a few collections contain both. Most thick shells collected are from calcareous shale. The two shell types do not seem to be stratigraphically distinct. In the Florena shale member of the Beattie limestone thick shells are restricted to the southern part of the State. In the Hughes Creek shale member of the Foraker limestone thin shells predominate, even though there are some thick shells. In the northern part of the State the Five Point limestone member of the Janesville shale contains some thick shells. This seemingly random distribution may indicate that the thickness of the *Chonetes* shell might be only a reflection of the amount of calcium carbonate available to the animal at any one locality.

Many of the *Chonetes* from the Florena shale member of the Beattie limestone and Pony Creek shale member of the Wood Siding formation are incrusted with *Tolypammina*-like foraminifers. In addition, one collection from each of the following stratigraphic units contains a few *Chonetes* with the same type of foraminifers incrusted: Nebraska City and Brownville limestone members of the Wood Siding formation, Hughes Creek shale member of the Foraker limestone, and Neva limestone member of the Grenola limestone. With one exception these incrusted *Chonetes* are all from collections of thinner, lighter shells.

Only 3 or 4 specimens from the Florena shale member of the Beattie limestone have incrusted bryozoans. Two specimens have tiny *Derbyia*-like brachiopods attached. No *Petrocrania* or *Leptalosia* are associated with the *Chonetes*. The fine lirae of some specimens in most populations having shells commonly incrusted by foraminifers are worn. Thick shells commonly do not appear to be worn.

Specimens from Kansas have been identified with topotypes of *C. granulifer*.

Genus LISSOCHONETES Dunbar and Condra, 1932

Lissochonetes geinitzianus (Waagen)

Plate 13, figures 20–25

Chonetes glabra Geinitz [not Hall], 1866, K. Leopoldino-Carolinische Deutsch Akad. Naturf. Verh. 33, p. 60, pl. 4, figs. 15–18.

Lissochonetes geinitzianus (Waagen). Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 170–173, pl. 20, figs. 33–37.

Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 347, pl. 135, figs. 13, 14.

Although no specimens referable to this species were found in the collections under discussion, it seems pertinent to make a few remarks about the species in the hope of clearing up some of the confusion regarding upper Paleozoic chonetids. Through the good office of Dr. H. B. Whittington, Harvard University, what are believed to be the type specimens have been examined.

Unfortunately, there are no brachial interiors in the type collection. Shining light through several specimens with both valves joined shows that the shell is less translucent in the center. The shape and position of the shadow suggests the presence of a median septum. Examination of a large collection of topotype specimens show small but distinct brachial median septum in many specimens. In 1 or 2 specimens, it is so reduced in size as to be nearly nonexistent.

The pedicle interiors also show similar individual differences. All specimens examined have a short median septum, but only a few of the specimens have two short lateral septa diverging from it. This feature does not seem to be significant in the species.

According to Ramsbottom (1952, p. 15), *Tornquistia* Paecklemann, 1930, is characterized by two narrowly diverging septa in the brachial interior and no median septum. *Lissochonetes geinitzianus* clearly is different whether or not it has a median septum, and the two genera are not synonymous as has been suggested by some American workers.

Lissochonetes geronticus (Dunbar and Condra)

Plate 13, figures 26, 27

Lissochonetes geinitzianus var. *geronticus* Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 174–175, pl. 20, figs. 38–45.

Lissochonetes geronticus is characterized by a subquadrate shape and a distinct sulcus in the pedicle valve. It appears to differ enough in shape from *L. geinitzianus* to be considered a distinct species. This view is reinforced by the finding of a few specimens of *L. geronticus* in a large collection of topotype specimens of *L. geinitzianus*. While there is some variation in shape in each of the two species in the collection, there do not appear to be any intermediate forms.

An examination of a suite of topotype specimens of *L. senilis* Dunbar and Condra indicates that there are some specimens that tend toward the shape of *L. geronticus*. In the absence of a large population, these few specimens probably could not certainly be identified. The suite, however, shows that the form is distinct from *L. geronticus*.

More than three-fourths of the Kansas collections contain only 1 or 2 specimens. Most of these are clearly referable to *L. geronticus*. A few specimens are not typical, but even they are more arched and have a deeper sulcus than the extremes seen in the population of *L. senilis*. Because of this, all the Kansas specimens have been classed as a single species.

Most of the specimens of *L. geronticus* are from calcareous shale. A few have been collected from very shaly limestone and several have been found in nearly black shale. The fine lirae of some of the specimens are worn. A *Petrocrania* is attached to one specimen and *Tolypammina*-like organisms are attached to a few others.

Genus LEPTALOSIA Dunbar and Condra, 1932

Leptalosia ovalis Dunbar and Condra

Plate 14, figure 1

Leptalosia ovalis Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 263–264, pl. 32, fig. 12.

As noted by Dunbar and Condra (1932), this is an extremely rare species. Specimens have been found attached to only 9 large productids and 1 *Composita*. These were all collected from calcareous shale units in four localities.

Although some of the shells carry 1 or 2 specimens, several bear colonies of the species. As is normal where attached forms grow under crowded conditions, the shape of the individual shell is distorted. The curvature of the part of the host shell to which *Leptalosia* adheres also seems to affect the shape of the animal. Those growing on the nearly vertical sides of a productid near its ears are more elongate than those located near the middle of the pedicle valve.

There is some variation in the attaching spines. Most commonly there are 10 to 12 spines evenly spaced around the animal, but in some individuals attachment was by only 3 to 5 large spines. The individual spines are quite irregular, as they follow closely the rugosities of the surface to which they are attached.

Genus DICTYOCLOSTUS Muir-Wood, 1930

Dictyoclostus huecoensis (R. E. King)

Plate 14, figures 2–5

Productus huecoensis R. E. King, 1931, Texas Univ. Bull. 3042, p. 68, pl. 11, figs. 7–8.

Dictyoclostus americanus Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 218–220, pl. 34, figs. 3–6. Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 350, pl. 136, figs. 15–19.

The descriptions and illustrations of *Dictyoclostus huecoensis* (R. E. King) from the lower Permian rocks of western Texas, are very similar to those of *D. americanus* Dunbar and Condra. Examination of King's holotype and topotype specimens of Dunbar and Condra's species suggests that they are conspecific, and they are so regarded here. Accordingly, the two names have been synonomized.

In their description of *Dictyoclostus americanus*, Dunbar and Condra (1932) state that the ears of the species bear thick spines arranged in three irregular rows. Examination of the specimens in the collections that retain the auricles show that there are only a few spines on the ears. These are arranged in a single irregular row, at and near the cardinal margin. A small number of spines of the same general size are scattered irregularly over the surface of the ear. There are commonly between 8 and 12 spines on an ear.

Relatively few spines are present on the main surface of the pedicle valve, and these appear to be distributed at random. Preservation of specimens is such that commonly the trail appears to have more spines than the posterior part of the shell. Indeed, loss of a thin outer shell layer gives the impression that no spines are present on a specimen.

Some specimens have a smoothly rounded pedicle valve, and others from the same locality have a relatively broad, shallow sulcus. In part, the sulcus may be a feature of maturity and old age, as there seem to be fewer large specimens without sulci than small ones.

Dictyoclostus newelli R. H. King, from the Upper Pennsylvanian of north-central Texas, differs from *D. huecoensis* in being generally smaller, having a shallow but distinct sulcus in the pedicle valve, and seemingly having many more spines, particularly on the trail. *D. welleri* R. H. King, from the lower Permian rocks of north-central Texas, differs from *D. huecoensis* in having more numerous coarser costae and having more spines on the ears and many more spines on the pedicle valve which are arranged in parallel rows. *D. wolfcampensis* R. E. King, from the lower Permian rocks of western Texas, has numerous fine costae, a distinct sulcus, and much coarser rugosities in the beak area. Because of this difference in ornamentation, none of the sinuate Kansas specimens have been referred to *D. wolfcampensis.*

Most of the Kansas specimens collected from shale are broken. This seems to be due to the action of ground water soaking the shell, as the fragments are all sharp and angular, not rounded. This type of fracture was duplicated by placing specimens in water. Most *Dictyoclostus* collected from limestone beds are whole and unworn.

Some specimens from calcareous shale, particularly the Hughes Creek shale member of the Foraker limestone, are incrusted with *Orbiculoidea*, *Petrocrania*, *Leptalosia*, and bryozoans. Specimens from limestone beds are not incrusted. More animals appear to be attached to shells of *Dictyoclostus* than to all other larger productids combined.

Genus JURESANIA Fredricks, 1928

Juresania nebrascensis (Owen)

Plate 14, figures 6–8

Productus nebrascensis Owen, 1852, Geol. Rept. Wisc., Iowa, and Minn., Philadelphia, Lippencott, Grambo and Co., p. 584, pl. 5, fig. 3.

Juresania nebrascensis (Owen). Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 195–198, pl. 22, figs. 1–9, 13.

Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 350, pl. 137, figs. 1–3.

The detailed description of *Juresania nebrascensis* given by Dunbar and Condra warrants amendation only to the extent of a comment on spine arrangement. All the spines of the ears are larger than the smaller spines on the pedicle valve, and commonly are as large as the larger spines of the two sets on the pedicle valve. In some specimens up to 15 spines are crudely arranged in 3 rows parallel to the cardinal margin. Near the end of the cardinal extremities are thick clusters of spines. These are strikingly different from the single row of large spines of the lateral commissure.

Juresania rectangularia R. H. King, from the Pennsylvanian of north-central Texas, differs from *J. nebrascensis* in being less convex, having coarser spines, and being somewhat more rectangular in outline.

The average specimen from the argillaceous facies of the Nebraska City limestone member of the Wood Siding formation is smaller than the average specimen from the calcareous facies of the Legion shale member of the Grenola limestone and the Florena shale member of the Beattie limestone, but none of these beds contain small specimens. Although the absence of small specimens may be due to current and wave sorting, the relatively well preserved spines on all the specimens suggest little transportation, but rather that this in part may be a biological phenomenon. In other respects than size there appear to be no differences among shells from the various environments.

Few specimens of *Juresania nebrascensis* are broken, although those from argillaceous shale are commonly compressed. The shells seemingly without exception are free from attached organisms.

Juresania sp. 1

Plate 14, figures 9, 10

Six specimens from the Brownville limestone member of the Wood Siding formation are quite similar in size, shape, and outline to *Juresania ovalis* Dunbar and Condra. They seem to differ from that species in having coarser and less numerous spine bases on the pedicle valve. The Brownville specimens are much larger than average specimens of *J. nebrascensis* (Owen). These specimens may represent a new species, but it does not seem feasible to erect one on the basis of so few specimens, particularly in this genus where species are differentiated with difficulty.

Juresania ovalis is reported by Dunbar and Condra (1932) to range from the Kansas City group to the base of the Douglas group. The youngest beds of that group are almost 1000 feet stratigraphically below the Brownville limestone member of the Wood Siding formation.

Juresania? sp. 2

A single large brachial valve that may be a representative of this genus has been found in the Nebraska City limestone member of the Wood Siding formation. The shell has a trifid cardinal process and has an interior similar to that of specimens identified as *J. symmetrica* (McChesney) in the United States National Museum collections. The valve is 45.3 mm long and 63.7 mm wide, but it is somewhat crushed. The specimen itself is rather poorly preserved and does not warrant illustration.

Genus ECHINOCONCHUS Weller, 1914

Echinoconchus moorei Dunbar and Condra

Plate 14, figure 11

Echinoconchus moorei Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 209–211, pl. 24, figs. 1–5.

Four specimens in the collections are referable to this species. The specimens are poorly preserved but have been identified by the distinct sinus in the pedicle valve, the relatively sharp beak, and the growth rugosities near the margin. The species occurs in beds as young as the Dover limestone member of the Stotler limestone; a specifically unidentifiable *Echinoconchus* has been collected from the Friedrich shale member of the Root shale. The highest stratigraphic occurrence reported by Dunbar and Condra (1932) is from the Emporia limestone, 110 feet to 130 feet stratigraphically below the Dover limestone member of the Stotler limestone.

The specimens from Kansas have been compared with topotypes of *E. moorei.*

Genus MARGINIFERA Waagen, 1884

Marginifera wabashensis (Norwood and Pratten)

Plate 14, figures 13–15

Productus wabashensis Norwood and Pratten, 1855, Acad. Nat. Sci. Philadelphia Jour., v. 3, p. 13, pl. 1, figs. 6a–d.

Marginifera wabashensis (Norwood and Pratten). Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 234–236, pl. 35, fig. 23; pl. 36, figs. 18–23, 25, 26.

Marginifera fragilis Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 239, pl. 36, figs. 7–11.

Marginifera wabashensis (Norwood and Pratten). Sutton, 1938, Jour. Paleontology, v. 12, no. 6, pl. 64, fig. 16.

Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 351, pl. 137, figs. 27, 28.

Specimens identified as this species fit the description given by Dunbar and Condra (1932, p. 235) in most respects. However, the statement of these authors that the "ears are typically small and the cardinal extremities at almost right angles" is not verified by their illustrated specimens. Most of the specimens in Kansas collections have distinct, prominent ears, so that the hinge line is commonly the widest part of the shell. In some of the specimens the angle between the cardinal extremities and the lateral margin is as small as 70°.

Marginifera fragilis has beeen differentiated from *M. wabashensis* by the thinness of its shell, the abundance and fineness of its spines, and the luster of its surface. Only three lots of specimens in the collections are similar to *M. fragilis.* They have a lustrous thin shell and about 20 spine bases. It seems to be highly significant that these lots are from black shale and dark-gray shale. These are the only *Marginifera* in the collections from such sediments.

Dunbar and Condra (1932) have noted that there is considerable variation in the number of spines of *M. wabashensis* and that commonly spines may be present but are so small as to be unnoticed on casual inspection. It seems very likely that the differences ascribed to *M. fragilis* are due to unusual preservation of a few specimens of *M. wabashensis* that are somewhat more spinose than average. It is suggested that the two species names be placed in synonymy.

Marginifera wabashensis is locally abundant in dense limestone and shaly weathering limestone. It is less abundant in calcareous shale and is almost never found in other rock types. One interesting association is that one specimen, in a detrital limestone unit, is almost in contact with a specimen of *Orbiculoidea.* Neither specimen shows wear that may be attributed to transportation.

Two or three specimens from calcareous shale bear patches of bryozoa, but most of the shells are free from incrusting organisms.

Marginifera histricula Dunbar and Condra

Plate 14, figures 12, 16

Marginifera histricula Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 238, pl. 36, figs. 1–6.

This species is distinguished from *Marginifera wabashensis* (Norwood and Pratten) in part by the presence of large, irregular costae on the anterior and lateral slopes. The spine bases are larger and more abundant than in many of the specimens of *M. wabashensis*, but there are specimens of the two species that are alike in this characteristic.

All specimens referred to *M. histricula* are from the calcareous Hughes Creek shale member of the Foraker limestone. None of these are associated with specimens of *M. wabashensis.* Several *M. histricula* are incrusted by *Tolypammina*-like organisms.

"Marginifera" lasallensis (Worthen)

Plate 14, figures 18–20

Productus lasallensis Worthen, *in* Meek and Worthen, 1873, Illinois Geol. Survey [Rept.], v. 5, p. 569, pl. 25, figs. 9 a–c.

Marginifera lasallensis (Worthen). Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 225–228, pl. 35, figs. 27–32.

Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 351, pl. 137, figs. 16–18.

This species is somewhat larger than the average specimen of *Marginifera*. It is approximately one-half the size of average specimens of *Dictyoclostus* and superficially resembles this genus in having a reticulated umbonal area. There are relatively few spines on the body surface; no observations have been made on the spine pattern of the ears, as specimens are poorly preserved in this feature. Almost certainly this species represents a new genus of productids.

Most specimens identified in the Kansas collections are poorly preserved. So far as it can be determined, they all seem referable to a single species. Most specimens are from shaly limestone or calcareous shale; several have been collected from dense limestone.

Genus LINOPRODUCTUS Chao, 1927

Linoproductus prattenianus (Norwood and Pratten)

Plate 14, figure 21

Productus prattenianus Norwood and Pratten, 1855, Acad. Nat. Sci. Philadelphia Jour., v. 3, p. 17, pl. 1, figs. 10 a–d.

Linoproductus prattenianus (Norwood and Pratten). Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 241–244, pl. 26, figs. 4, 5b; pl. 27, figs. 1–5, 9.

Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 351, pl. 137, fig. 31.

Linoproductus prattenianus is characterized by abundant small spines on the pedicle valve. Many specimens exhibit a rudely quincunxial arrangement of the spine bases. The spines on the ears, arranged in a double row, have about the same diameter as those on the pedicle valve.

Linoproductus inornatus R. E. King, from the Upper Pennsylvanian of north-central Texas, differs from *L. prattenianus* in having very few spines on the pedicle valve and in having a very much less convex profile.

Most specimens are from argillaceous shale, but a few are found in the more calcareous Hughes Creek shale member of the Foraker limestone. This is the youngest occurrence of *Linoproductus prattenianus* within the collections studied. None of the specimens are incrusted by other organisms.

Linoproductus magnispinus Dunbar and Condra

Plate 14, figures 22–24

Linoproductus magnispinus Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 244–246, pl. 27, figs. 6–8.

In their description of this species, Dunbar and Condra (1932) ascribe a single row of spines to the auricles, with spines rarely forming a second row in some specimens. Examination of the specimens assigned to this species shows that a double row of spines is common on the ears. These spines are normally larger and less abundant than those on the ears of *L. prattenianus*. The shallow sulcus in the pedicle valve that is mentioned by Dunbar and Condra (1932) seems to be a feature that is quite variable among individuals and is more generally absent than present.

Linoproductus magnispinus may be distinguished from *L. prattenianus* by the number and character of the spines on the pedicle valve. In *L. prattenianus* they are relatively few in number, many specimens having less than a dozen, although some of the geologically older specimens studied have a few more. The spine bases are larger than those of *L. prattenianus* and seem to be distributed at random.

The general size of specimens of this species is normally slightly larger than those of *L. prattenianus*. The ribs also appear to be slightly coarser. However, there are so many exceptions that these characteristics cannot be used to differentiate species.

Linoproductus magnispinus is most abundant in limestone and calcareous shale. Contrary to the statement of Dunbar and Condra (1930), *L. prattenianus* and *L. magnispinus* were not found associated. With the exception of half a dozen specimens from the Johnson shale with adherent *Leptalosia* and bryozoans, the shells are free from incrusting organisms.

Genus CANCRINELLA Fredericks, 1928

Cancrinella boonensis (Swallow)

Plate 14, figure 17

Cancrinella boonensis (Swallow). Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 258–260, pl. 32, figs. 1–5.

Less than a dozen specimens of this species have been identified. They are smaller and quite distinct in size from all other productid genera in the collection examined except juveniles of *Juresania*. The fine lirae on the pedicle valve and the arrangement of spines in a single row readily differentiate *Cancrinella boonensis* from *Juresania*. *Cancrinella altissima* R. H. King from the upper Pennsylvanian of north-central Texas differs from *C. boonensis* in having a less convex profile, fewer and finer lirae, and fewer umbonal spines.

All Kansas specimens were collected from beds of limestone. None are incrusted by other organisms and none seem to show wear due to transportation.

Genus RHIPIDOMELLA Oehlert, 1890

Rhipidomella carbonaria (Swallow)

Plate 15, figures 1–3

Orthis carbonaria Swallow, 1858, Acad. Sci. St. Louis Trans., v. 1, p. 218.

Rhipidomella carbonaria (Swallow). Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 52–54, pl. 2, figs. 1–4.

Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 355, pl. 139, figs. 24–26.

Almost all the specimens identified in the Kansas collections are less than half the size of the typical specimen illustrated by Dunbar and Condra (1932). However, individuals as small as 1 mm in width do not differ from the published description of the species. Even in this size the lirae are distinctly coarser than those of *Enteletes*.

Most specimens are from calcareous shale and from the Hughes Creek shale member of the Foraker limestone. None are incrusted by other organisms, and the fine lirae do not appear worn.

Genus ISOGRAMMA Meek and Worthen, 1870

Isogramma sp. indet.

Only two fragments, both specifically unidentifiable, are referable to this genus. As part of this study, all shell fragments in the collections larger than no. 10 size screen (mesh opening 0.0787 in.) were examined. Because of this, these fragments are believed to be an accurate reflection of the scarcity of this genus in the late Pennsylvanian and early Permian seas.

Dunbar and Condra (1932) report *Isogramma millepunctata* (Meek and Worthen) from Nebraska in what they called the Stine shale member of their Elmdale shale. The Stine is now considered a bed in the Hamlin shale member of the Janesville shale. Some of the fossils reported from the Stine shale may actually be from the Hughes Creek shale member of the Foraker limestone (Carl Dunbar, oral communication).

Genus ENTELETES Fischer de Waldheim, 1825

Enteletes cf. E. hemiplicatus (Hall)

Plate 15, figures 4, 5

Spirifer hemiplicata Hall, 1852, *in* Stansbury, U.S. 32d Cong., spec. sess., Senate Executive Doc. 3.

Specimens referred to this species are subglobular in outline and have a prominent fold and sulcus. There appears to be some individual variation as to the size of the shell when plication first becomes prominent, but in the few examples examined all shells smaller than 1.5 cm in length do not have plications. The surface is covered with fine lirae radiating from the beak that are somewhat coarser than those of *Rhipidomella carbonaria* (Swallow).

Most of the *Enteletes* in the Kansas collections are incomplete and poorly preserved specimens. Probably they are referable to this species, but they cannot be certainly identified. The surface sculpture of straight, rather than curved, radiating lirae readily differentiates the shell fragments from those of *Meekella*. Almost all the specimens collected are from shaly limestone or calcareous shale. With one exception, they are not incrusted by other organisms.

Genus HUSTEDIA Hall and Clark, 1893

Hustedia mormoni (Marcou)

Plate 15, figures 6–8

Terebratula mormoni Marcou, 1858, Zurich, Zürcher and Furrer, p. 51, pl. 6, figs. 11–11c.

Hustedia mormoni (Marcou). Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 356–358, pl. 42, figs. 9–11.

Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 363, pl. 141, figs. 43–45.

The specimens in the Kansas collections agree closely with the description and illustrations given by Dunbar and Condra (1932). The plications of a few are slightly narrower than average, but this is a minor difference, very likely due to individual variation and nothing more.

All *Hustedia* were collected from calcareous shale. None are incrusted by other organisms and none seem to show excessive wear. The specimens commonly are somewhat compressed to flattened.

Genus DIELASMA King, 1859

Dielasma bovidens (Morton)

Plate 15, figure 9

Terebratula bovidens Morton, 1836, Am. Jour. Sci., v. 29, p. 156.

Dielasma bovidens (Morton). Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 304–306, pl. 37, figs. 33, 34.

Cooper, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 364, pl. 143, figs. 6–8.

Dunbar and Condra (1932) comment that the pedicle sulcus of this species is somewhat variable in prominence. Examination of a collection from the Florena shale member of the Beattie limestone verifies their conclusion that this is a feature of individual variation. They also suggest that vertical compression may have had some effect on the general outline of the shell. In the collections studied, all extremely wide individuals show cracks running through the shell that may have been caused by compression.

The numerous fine puncta of the surface make this one of the most distinctive of all the brachiopods studied. These puncta distinguish the species from some specimens of *Composita* which superficially resemble it.

With the exception of one collection from the Florena shale member of the Beattie limestone, *Dielasma bovidens* is quite rare. All specimens collected are from calcareous shale; none are incrusted with other organisms.

Genus PUNCTOSPIRIFER North, 1920

Punctospirifer kentuckensis (Shumard)

Plate 15, figures 10–12

Punctospirifer kentuckyensis (Shumard). Dunbar and Condra, 1932, Nebraska Geol. Survey Bull. 5, 2d ser., p. 351–355, p. 38, figs. 1–5.

Punctospirifer kentuckiensis (Shumard). Cooper, 1944 *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 361, pl. 141, figs. 6, 7.

This species is remarkable in the amount of individual variation shown by specimens. To give an example of this variation, measurements were taken of the length and width of a dozen well-preserved mature specimens collected from the Friedrich shale member of the Root shale (USGS loc. 13611). Measurements are as follows:

Length (mm)	*Width (mm)*	*Length: width*
7.0	11. 5	0. 47
7.5	11. 5	. 65
7.0	14. 0	. 50
6.5	12. 0	. 54
7.0	12. 5	. 56
7.5	13. 5	. 56
7.0	13. 0	. 54
7.0	11. 5	. 61
6.5	13. 0	. 50
6.5	11. 5	. 56
6.5	15. 0	. 43
7.5	12. 5	. 60
Mean		. 518
Standard deviation		. 044
Standard error of standard deviation		. 0089

Not only is there variation in overall shape, but also, as noted by Dunbar and Condra (1932), there is some variation in the number of plications. Commonly there are 6 plications on each lateral slope of the pedicle valve, but a few mature individuals have as few as 4 plications or as many as 8.

The largest collection of this species is from a very argillaceous limestone bed in the Friedrich shale member of the Root shale. Most of the other specimens are from other argillaceous shale beds and less commonly from argillaceous limestone.

The original spelling of the name is *Spirifer kentuckensis*, not only as given in the heading of the species description (Shumard, 1855, p. 203) but also in an appended "Catalogues of the Fossils of Missouri" (Swallow, 1855, p. 216). There is no evidence of an error in spelling. At least six subsequent publications used the original spelling until the trivial name was rendered as *kentuckiensis* and later *kentuckyensis*. These variants in spelling appear to be unwarranted emendations with the status of junior synonyms.

PHYLUM MOLLUSCA

CLASS PELECYPODA

Genus EDMONDIA Koninck, 1841

Edmondia nebrascensis (Geinitz)

Plate 15, figure 13

Astarte nebrascensis Geinitz, 1866, K. Leopoldino-Carolinische Deutsch Akad. Naturf. verh. 33, p. 16, pl. 1, fig. 25.

Edmondia? nebrascensis (Geinitz). Meek, 1872, *in* Hayden, U.S. 42d Cong., 1st sess., H. Doc. 19, p. 214, pl. 10, figs. 8, 8b.

This species is identified by its distinctive ornamentation of relatively sharp lirae separated by broad, shallow furrows. The shape is commonly subovate, with the beaks well forward, but, like many of the pelecypods examined, is subject to considerable modification by compaction.

Edmondia aspinwallensis Meek is the species commonly cited in the beds studied. It is supposedly distinguished from *E. nebrascensis* by more undulate and less carinate ridges of ornamentation. The type specimen is not in the collections of the United States National Museum and presumably has been lost. It is impossible at the present time to see how important this difference is. Until further investigations are made with topotype specimens it seems better to use Geinitz' name, which has priority, but not to synonymize the two species.

Edmondia gibbosa Swallow (not McCoy), from Pennsylvanian and (or) Permian strata in Kansas, may be conspecific with *E. nebrascensis*. Unfortunately, Swallow's types have been lost and this possible synonymy cannot be confirmed. It is judged better not to attempt to identify his species on the basis of the description alone, but to consider it an unidentifiable species.

Most of the Kansas specimens were collected from calcareous shale or argillaceous limestone beds. A few come from beds that may be classified as mudstone. Almost all are represented by both valves. None are incrusted or bored by other organisms.

Genus ANTHRACONEILO Girty, 1911

Anthraconeilo sp.

Plate 15, figure 16

Within the collections studied, this genus is represented by a single right valve from the Florena shale member of the Beattie limestone (USGS loc. 13674). The specimen has dentition similar to *Anthraconeilo taffana* Girty, from the Wewoka formation (Pennsylvanian) of Oklahoma. It differs from that species in that the beak is located slightly more anterior and the posterior is somewhat more rounded.

Genus YOLDIA Möller, 1842

Yoldia subscitula Meek and Hayden

Plate 15, figures 14, 15

Leda (*Nucula*) *subscitula* Meek and Hayden, 1858b, Albany Inst. Trans., v. 4, p. 79.

Yoldia? *subscitula* (Meek and Hayden). Meek and Hayden, 1865, Smithsonian Contr. Knowledge, v. 14, p. 60, pl. 2, figs. 4a, b.

Within the collections of the United States National Museum there are two specimens bearing the label *Yoldia subscitula* and a green sticker such as is used to designate a type. The original label and entry in the museum catalog appear to be in Meek's writing. From this it is assumed that these are the type specimens. So far as is known, the types have not been illustrated with photographs.

Kansas specimens from the Florena shale member of the Beattie limestone seem similar in general form to the types, but all except one are considerably smaller. All the Kansas specimens are internal molds composed of relatively soft clay, so that fine details cannot be seen clearly.

The species of Meek and Hayden is reported by them to occur near the mouth of the Smoky Hill Fork of the Kansas River and on Cottonwood Creek. The original label notes "Smoky Hill Fork of Kansas River." From this it is inferred that the type came from beds in the Chase group, or higher than the interval studied here.

Nucula (*Leda*) *subscitula*? of Geinitz (1866, p. 22, table 1, fig. 35) is not a representative of this species. Probably *Yoldia subscitula*? of Meek (1872, p. 205, pl. 10, fig. 10) should also be excluded from the species, as Meek himself suggested.

Genus AVICULOPINNA Meek, 1864

Aviculopinna peracuta (Shumard)

Plate 15, figure 27

Pinna peracuta Shumard, 1858, *in* Shumard and Swallow, Acad. Sci. St. Louis Trans. 1, p. 19.

Meek, 1872, *in* Hayden, U.S. 42d Cong., 1st sess., H. Doc. 19, p. 198, pl. 6, figs. 11a-b.

Aviculopinna peracuta (Shumard). Hyatt, 1892, Boston Soc. Nat. History Proc., v. 25, p. 338.

At several localities in Wabaunsee County, the lower bed of limestone of the Americus limestone member of the Foraker limestone contains *Aviculopinna.* Specimens more than a foot long have been collected, and Mudge has observed some over 2 feet long. Commonly they are crushed, but their original shape may have been subcylindrical. Because of this shape and the general size, they are referred to *A. peracuta. A. nebrascensis* Beede from considerably younger beds is supposed to have been a much larger animal.

Fragments of *Aviculopinna* are found in the Jim Creek limestone member of the Root shale, the Nebraska City and Brownville limestone members of the Wood Siding formation, and the Aspinwall limestone member of the Onaga shale. Most of them are small and so incomplete that they cannot be certainly identified. In addition, several excellently preserved specimens much smaller than those from the Americus limestone member of the Foraker limestone have been referred to this species. They may be representatives of *A. americanus* Meek, but they lack the pronounced biconvex cross section apparently characteristic of the species. Meek's types are not available for study to check other possible differences between these two species. An example of the smaller *Aviculopinna* in the Kansas collections is illustrated on plate 15, figure 25.

With the exception of 1 specimen in the Hughes Creek shale member of the Foraker limestone, 1 in the Johnson shale, and 2 in the Florena shale member of the Beattie limestone, all *Aviculopinna* are from limestone. All are broken, even though the fragments consist of both valves joined.

Genus PTERIA Scopoli, 1777

Pteria cf. P. longa (Geinitz)

Plate 15, figure 17

Gervillia longa Geintz, 1866, K. Leopoldino-Carolinische Deutsch Akad. Naturf., Verh. 33, p. 32, pl. 2, fig. 15.

Avicula longa (Geinitz). Meek, 1872, *in* Hayden, U.S. 42d Cong., 1st sess., H. Doc. 19, p. 199, pl. 9, fig. 8.

Pteria longa (Geintz). Beede, 1900, Kansas Geol. Survey [Rept.], v. 6, pt. 2, p. 125, pl. 16, fig. 4.

A single left valve from the Falls City limestone (USGS loc. 13720) has been tentatively identified as a member of this species. The specimen is incomplete but appears to have the characteristic shape of the species. So far as is known, this is the highest stratigraphic occurrence of this species recorded in the midcontinent.

Genus **PROMYTILUS** Newell, 1942

Promytilus vetulus Newell

Plate 15, figure 19

Promytilus vetulus Newell, 1942, Kansas Geol. Survey [Rept.], v. 10, pt. 2, p. 42, pl. 1, figs. 3, 4.

This species is identified by its elongate shape and its anterior lobe and sinus. Examination of several specimens suggests that there is variation in this lobe and that the lobe of some moderately large specimens may have developed only to a slight degree. All specimens show the prismatic radial structure so characteristic of the genus.

Specimens of this species have been collected from very argillaceous limestone beds in the Falls City limestone (USGS locs. 13508, 13689, 14888). Most specimens are single valves, but none show severe wear.

Genus **VOLSELLINA** Newell, 1942

Volsellina subelliptica (Meek)

Plate 15, figure 18

Volsellina subelliptica (Meek). Newell, 1942, Kansas Geol. Survey [Rept.], v. 10, pt. 3, p. 43, pl. 1, figs. 14–16.

Three specimens of this species have been collected from the Tarkio limestone member and the Wamego shale member of the Zeandale limestone (USGS locs. 13691, 13742). The species is identified by the almost total lack of an anterior lobe, by the relatively sharp umbonal ridge, and by the generally elongate shape of the valve. The Kansas specimens have been compared with the holotype.

Genus **MYALINA** DeKoninck, 1842

Subgenus **ORTHOMYALINA** Newell, 1942

Myalina (Orthomyalina) subquadrata (Shumard)

Plate 15, figure 26

Myalina subquadrata Shumard. 1855, Missouri Geol. Survey Ann. Repts. 1 and 2, p. 207, pl. c, fig. 17.

Myalina (*Orthomyalina*) *subquadrata* (Shumard). Newell, 1942, Kansas Geol. Survey [Rept.], v. 10, pt. 2, p. 58–60, pl. 9, figs. 1–4.

Myalina subquadrata Shumard. Shimer and Shrock, 1944, New York, John Wiley and Sons, Inc., p. 393, pl. 153, fig. 8.

Most of the Kansas specimens agree closely with the description and illustrations given by Newell (1942). As noted by him, however, some specimens resemble *Myalina* (*Orthomyalina*) *slocomi* Sayre in being smaller and having a more quadrate outline. All these small specimens have been referred to this species, however, as they are in collections with typical representatives. The one exception to this is a small collection from the West Branch shale member of the Janesville shale in which the specimens are intermediate in shape between the two species.

Most of the specimens are separate valves. There are too few specimens from any one locality to determine if there has been selective sorting of valves. Specimens are most common in shale which appears to have a high clay content. They are also found in impure limestone, and, in the Americus limestone member of the Foraker limestone, in relatively pure limestone.

The Americus is the youngest unit containing this species. Two incomplete valves from the Florena shale member of the Beattie limestone are representatives of the subgenus but are unidentifiable as to species.

In many collections, the shells have been bored by bryozoans and some have attached foraminifers. Some specimens from the Five Point limestone member of the Janesville shale are coated with an algal growth that commonly is so thick as to obscure all but the general form of the shell. Bryozoan borings are found in this coating. On the basis of field observations, Mudge has suggested that the valves in limestone are thinner than those in shale. The few specimens from limestone in the collections seem to suggest that this may be correct.

Genus **SEPTIMYALINA** Newell, 1942

Septimyalina burmai Newell

Plate 15, figure 21

Septimyalina burmai Newell, 1942, Kansas Geol. Survey [Rept.], v. 10, pt. 2, p. 67–68, pl. 12, figs. 1–6.

Specimens referred to this species have been identified by shape and by the projecting growth laminae. The relatively longer hinge line and the more triangular shape of the valves distinguish this species from *Septimyalina perattenuata* (Meek and Hayden).

All specimens identified are from limestone or from calcareous shale. The valves of most specimens are joined, and none are incrusted by algae or are bored by other organisms.

Septimyalina scitula Newell

Plate 15, figure 20

Septimyalina scitula Newell, 1942, Kansas Geol. Survey [Rept.], v. 10, p. 2, p. 68–69, pl. 11, figs. 4–9, 11–14.

The relatively long hinge line, pronounced triangular shape, and elongated beak make this a very distinctive species. Unfortunately, most of the specimens are internal molds. Enough shell is left on some of the specimens to indicate that it was smooth and relatively thin.

All Kansas specimens are from argillaceous limestone or impure coquinoidal limestone. Most are preserved as single valves on a bedding plane. None are incrusted with algae or bored by other organisms.

Septimyalina cf. S. perattenuata (Meek and Hayden)

Myalina perattenuata Meek and Hayden, 1858, Albany Inst. Trans., v. 4, p. 77.

Specimens tentatively referred to this species are from the Grandhaven limestone member of the Stotler limestone (USGS loc. 13745). The shells are somewhat eroded, and identification of the species is on outline shape only. All the specimens are single valves.

Genus SCHIZODUS King, 1844

Schizodus cf. S. wheeleri (Swallow)

Plate 15, figures 22, 23

Cypricardia? wheeleri Swallow, 1863, Acad. Sci. St. Louis Trans., v. 2, p. 96.

Schizodus obscurus Geinitz, 1866 [not Sowerby, 1823] K. Leopoldino-Carolinische Deutsch Akad. Naturf., Verh. 33, p. 20, tab. 1, figs. 30–31.

Schizodus wheeleri (Swallow). Meek, 1872, *in* Hayden, U. S. 42d Cong., 1st sess., H. Doc. 19, p. 209, pl. 10, figs. 1a-d.

Much of our information about this species is based on a copy of a sketch of Swallow's type specimen figured by Meek (1872), the specimen having been subsequently lost, and additional specimens illustrated on the same plate. Meek suggested that Geinitz' species was a synonym of *Schizodus wheeleri* (Swallow). Subsequently, the specimen figured on plate 10, fig. 1e–f of Meek's work was transferred to *S. meekanus* Girty. There is thus a copy of a sketch of the type and illustrations of a single additional specimen (Meek, 1872, pl. 10, fig. 1c–d) to identify this species. A search of the collections of the United States National Museum failed to reveal Meek's specimen, and it is presumed to be lost.

In addition to the possible inaccuracies that might be in the drawings, there is a further source of uncertainty in identification. All the Kansas specimens that are similar to the description given are internal molds, and these must be compared with sketches of shells. Insofar as these differences can be evaluated, Kansas specimens are referable to this species.

Since there is so much uncertainty as to what this species is, it seems better only to compare them to Swallow's species. When a comprehensive study is made of upper Paleozoic *Schizodus* and its allies, it may be that this species will be treated as unidentifiable.

Schizodus sp.

Plate 15, figure 24

One internal mold of a *Schizodus* from the Johnson shale (USGS loc. 13767) differs from the common type in being more elongate posteriorly. In general shape it seems to be close to *S. ulrichi* Worthen, but the slope of the hinge line is not as pronounced. Specimens of *Schizodus* cf. *S. wheeleri* (Swallow) from the Kansas collections are almost the same size but have a decidedly less elongate shape, so that it is very likely that this specimen represents another species and is not simply a result of allometric growth.

Genus AVICULOPECTEN McCoy, 1851

Aviculopecten arctisulcatus Newell

Plate 16, figure 1

Aviculopecten arctisulcatus Newell, 1937, Kansas Geol. Survey [Rept.], v. 10, pt. 1, p. 50–51, pl. 4, figs. 1–3.

This species is one of the most common of the larger pelecypods in Kansas collections. The abundance of shells at certain horizons indicates that this may have been a very gregarious species. On the other hand, the shells consist almost exclusively of left valves, indicating that sorting may have been a factor in determining their present distribution. Probably the truth is somewhere between the two possibilities. Most of the specimens are from argillaceous limestone; a few have been collected from shale.

Many of the specimens are only moderately well preserved. Identification of the species is based chiefly on the ornamentation of many small to medium-sized costae and on the umbonal angle of about 80°. In one collection from the Burr limestone member of the Grenola limestone several of the specimens approach *A. sumnerensis* Newell in shape, but others in the same collection are typical of *A. arctisulcatus*.

Aviculopecten nodocostata Newell

Plate 16, figure 2

Aviculopecten nodocostata Newell, 1937, Kansas Geol. Survey [Rept.], v. 10, pt. 1, p. 53, pl. 6, figs. 6–10.

In addition to the abundant specimens of *Aviculopecten arctisulcatus*, there are seven specimens referable to *A. nodocostata*. These are characterized by having coarse ribs separated by four or more costae. The ribs commonly bear several spines.

Five specimens are from the Falls City limestone, on the bedding planes of thin argillaceous limestone beds. Two are from the Nebraska City limestone member of the Wood Siding formation. As nearly as can be determined, all are left valves.

Genus CLAVICOSTA Newell, 1938

Clavicosta sp.

Plate 16, figure 3

Four specimens from the Falls City limestone, the Howe limestone member of the Red Eagle limestone, and the Florena shale member of the Beattie limestone have been referred to this genus. All are incomplete but show the characteristic coarse spine-bearing ribs separating finer costae. Newell (1938) has reported *Clavicosta echinata* Newell as the only species of this genus in this interval.

Genus STREBLOCHONDRIA Newell, 1938

Streblochondria sp. indet.

Plate 16, figure 4

One left valve referable to this genus was collected from an argillaceous limestone bed in the Falls City limestone (USGS loc. 13507), but the specimen is specifically unidentifiable. This genus has not been reported in Kansas in strata as young as the Admire group.

Genus PSEUDOMONOTIS Beyrich, 1862

Pseudomonotis cf. P. hawni (Meek and Hayden)

Monotis hawni Meek and Hayden, 1858, Albany Inst. Trans., v. 4, p. 76.

In connection with identification of this species it seems appropriate to quote Newell (1938, p. 95), who, on discussing the difference between *Pseudomonotis hawni* (Meek and Hayden) and *P. beedi* Newell remarks: "Greater difficulty is experienced in dealing with specimens from the lower part of the Big Blue series, because this material consists chiefly of isolated or poorly preserved specimens." Little can be added to this statement except that specimens in the Kansas collections are so poorly preserved that only several are tentatively referred to this species.

Most specimens referred to the genus occur in argillaceous limestone and, rarely, in calcareous shale.

Genus ALLORISMA King, 1844

Allorisma terminale Hall

Plate 16, figures 5, 6

Allorisma terminalis Hall, 1852, *in* Stansbury, U.S. 32d Cong., spec. sess., Senate Executive Doc. 3, p. 413, pl. 4, figs. 4a-b.

Allorisma subcuneata Meek and Hayden, 1858b, Acad. Nat. Sci. Philadelphia Proc., v. 10, p. 263.

Geinitz, 1866, K. Leopoldino-Carolinische Deutsch Akad. Naturf. Verh. 33, p. 14.

Meek, 1872, U.S. 42d Cong., 1st sess., H. Doc. 19, p. 221, pl. 2, figs. 10a-b.

Beede, 1900, Kansas Geol. Survey [Rept.], v. 6, pt. 2, p. 169, pl. 20, figs. 1–16.

All the specimens of *Allorisma* in the Kansas collections seem to be referable to the species *A. terminale* Hall. Girty (1903, p. 437, 438) has given a rather complete synonymy and an excellent discussion of the species. He has shown that Hall's type specimen is deformed by compression. The distortion had led Meek and Hayden (1858b, p. 263) to believe that they were dealing with another species. The Kansas specimens confirm the fact that individuals are subject to considerable distortion by simple compaction.

The Kansas specimens show considerable variation in the development of growth rugosities in the umbonal area. This is considered to be in part a feature of preservation and in part individual variation. There appears to be a complete intergradation between those specimens which are almost smooth and those distinctly rugose.

Most of the *Allorisma* collected are from calcareous shale; a few are from shaly limestone. All specimens have both valves joined.

Kansas specimens have been compared with the type and with Meek and Hayden's specimens.

Genus PERMOPHORUS Chavan, 1954

Permophorus subcostatus (Meek and Worthen)

Plate 16, figures 7, 8

Pleurophorus subcostatus Meek and Worthen, 1865, Philadelphia Acad. Nat. Sci. Proc., p. 246.

Meek and Worthen, 1866, Illinois Geol. Survey [Rept.], v. 2, p. 347, pl. 27, figs. 2-2a.

One internal mold from the Burr limestone member of the Grenola limestone shows structures very similar to those described and figured by Meek and Worthen (1866) for the species. The specimen shows a long hinge line, a long posterior lateral tooth, and a small cardinal tooth below the beak at nearly a right angle to the hinge line. The shell is elongate and slightly swollen and has distinct umbonal ridges. Other specimens have been tentatively identified on the basis of general shape and size, with reference to this specimen.

All the specimens are from tan to light-gray argillaceous limestone or argillaceous shale. Most of them have both valves joined.

Permophorus sp. 1

Plate 16, figure 13

Layers of coquina composed almost exclusively of shells of *Permophorus* are present in the Falls City limestone and the Aspinwall limestone member of the Onaga shale. In the Falls City limestone, shells are found on the bedding planes of argillaceous limestone and are associated with poorly preserved gastropods. The specimens from these two units, and the other scattered specimens of the same general form, are commonly single valves. All specimens collected are poorly preserved, and it is possible that there is more than one species present. These *Permophorus* are noted here simply to call attention to their abundance.

Two species of this genus have been named from beds slightly older than those of the Admire group, where specimens of this genus are so abundant. *P. occidentalis* (Meek and Hayden) was named from "Coal Measures—Nebraska, nearly opposite the northern boundary of Missouri." Meek (1872, p. 102) subsequently remarked that the species occurs in strata of Geinitz' Unit B (Tarkio limestone member of the Zeandale limestone of present nomenclature), but not at his Nebraska City, Nebr., section. This suggests that the type is from somewhere within the Wabaunsee group.

The species itself is based on one specimen. The type specimen is an exterior moderately well preserved but seemingly broken at one edge and shows no distinctive features. Interior details are not available for study. The species is probably not identifiable except for the type.

Permophorus oblongus (Meek) (see pl. 16, figs. 11, 12) is based on three specimens from unit C (probably Pillsbury shale of present nomenclature) of the Nebraska City section. Hinge details are not clear, but the oblong shape is quite distinctive. A few specimens from the Admire group, insofar as they can be identified, show some resemblance to this species.

Permophorus sp. 2

Plate 16, figures 9, 10

Three specimens of *Permophorus* from a thin shale bed just above the Tarkio limestone member of the Zeandale limestone (USGS loc. 13532) are well enough preserved to warrant special note. One excellently preserved interior shows a cardinal tooth. An indistinct short lateral tooth is also present. The specimen seems closest to *P. oblongus* (Meek), but differs from that species in having a well rounded rather than nearly straight posterior.

Very likely this is a new species, but there are not enough specimens to warrant giving a formal name.

Meek's specimens are figured for comparison on plate 16, figures 11, 12.

Genus ANTHRACONEILOPSIS Tasch

Anthraconeilopsis kansana Tasch

Plate 16, figures 14, 15

Anthraconeilopsis kansana Tasch, 1953, Jour. Paleontology, v. 27, no. 3, p. 392, pl. 49, figs. 4, 5.

Three specimens from the Grandhaven limestone member of the Stotler limestone (USGS loc. 14873) have been identified with this species by growth rugosities and hinge-line denticles on steinkerns. The original description leaves considerable doubt as to whether the author is describing a steinkern or an actual shell. It should be noted further that there is question in the writer's mind as to whether *Anthraconeilopsis* is a valid biologic genus.

OTHER PELECYPODS

In addition to the genera and species noted, there are others in the section. *Nuculana*, *Nucula*, *Nuculopsis*, and possibly one other nuculoid genus have been tentatively identified. Specimens are rare, totaling less than a dozen, and most of them are small internal molds with only fair preservation. Literature on the species of the various nuculoid genera is in a chaotic state, and none of the specimens are adequately preserved to identify them provisionally.

CLASS GASTROPODA

Genus EUPHEMITES Warthin, 1930

Euphemites sp.

Plate 16, figures 16–18

Two specimens from the Wamego shale member of the Zeandale limestone (USGS loc. 14874) may represent a new species. The selenizone is depressed and concave. The best preserved specimen shows 6 prominent revolving costae on one side of the selenizone and 8 on the other. Whether this difference in the number of costae is a specific characteristic or only a feature of individual variation cannot be determined until a systematic study of the late Paleozoic genus is undertaken. In any case the relatively few costae distinguish it from other described American Pennsylvanian species.

Genus BELLEROPHON Montfort, 1808

Bellerophon singularis Moore

Plate 16, figures 20, 22

Bellerophon singularis Moore, 1941, Kansas Geol. Survey Bull. 38, pt. 4, p. 128, pl. 1, figs. 1a-c.

Two specimens from a limestone unit in the Wamego shale member of the Zeandale limestone (USGS loc. 14841) have been identified with this species. They are characterized by a smooth whorl profile—the selenizone is level with the general surface and is bordered by narrow lirae. There is some indication that the slit must have been extremely shallow.

This species has previously been known only from its type locality in the Deer Creek limestone, about 500 feet stratigraphically below the Wamego shale member.

Bellerophon cf. B. graphicus Moore

Plate 16, figure 21

Bellerophon graphicus Moore, 1941, Kansas Geol. Survey Bull. 38, pt. 4, p. 127–128, pl. 1, figs. 2–4c; text fig. 6c.

A single juvenile specimen from the Wamego shale member of the Zeandale limestone (USGS loc. 14841) has been tentatively referred to this species. *Bellerophon graphicus* differs from *B. singularis* in that the selenizone is on a rounded crest. As Moore (1941) did not illustrate immature specimens as small as this one, it cannot be definitely referred to the species.

Genus KNIGHTITES Moore, 1941

Subgenus RETISPIRA Knight, 1945

Knightites (Retispira) tenuilineata (Gurley)

Plate 16, figures 23, 24

Bellerophon tenuilineatus Gurley, 1884, Bull. 2, p. 10 [Private pub.]

Bucanopsis tenuilineatus (Gurley). Girty, 1899, U. S. Geol. Survey 19th Ann. Rept., pt. 3, p. 59.

Girty, 1915a, U. S. Geol. Survey Bull. 544, p. 170, pl. 20, figs. 4a-d.

Weller, 1929a, Illinois Acad. Sci Trans., v. 21, p. 320, pl. 1, figs. 4, 5a-b.

Sayre, 1930, Kansas Geol. Survey Bull. 17, p. 129, pl. 13, figs. 6–6a.

Retispira tenuilineata (Gurley). Knight, 1945, Jour. Paleontology, v. 19, no. 4, p. 335.

Three specimens of this species have been identified in collections from the Wamego shale member of the Zeandale limestone and the Dry shale member of the Stotler limestone (USGS locs. 14841, 14872). The species is characterized by a relatively wide, slightly depressed, flattened selenizone. There are many revolving lirae, up to 35 or more, on each side of the selenizone. Transverse growth lines are exceedingly faint.

Except for the reference by Sayre (1930) the synonymy given includes essentially only reprintings of the original description and illustrations of species. Weller (1929a) suggests that this may be a distinct species, but he also notes that it is close to *Bellerophon perlatus* Conrad, *B. meekianus* Swallow, and *B. marcouianus* Geinitz. Until such time as comprehensive studies of Pennsylvanian bellerophontids are undertaken, it seems best not to synonymize any specific names.

Knightites (Retispira) sp.

Plate 16, figure 19

Another species of *Knightites* (*Retispira*) occurs locally in the Dry shale member of the Stotler limestone, Falls City limestone, and the Hawxby shale member of the Onaga shale. This species is characterized by prominent transverse ridges on either side of the depressed selenizone so that the shell is crenulated in profile. Many fine revolving lirae are on each side of the selenizone and cross the transverse ridges without interruption. Insofar as this species can be determined, it appears to be very similar to an undescribed species from the Hueco limestone of western Texas (Yochelson, 1960). Study of the western Texas specimens has shown that this type of bellerophont undergoes considerable ontogenetic change. It seems best not to give a formal name to the Kansas specimens until considerably more specimens of all growth stages are available for study.

Genus AMPHISCAPHA Knight, 1942

Amphiscapha muricata (Knight)

Plate 17, figures 1, 2

Euomphalus muricatus Knight, 1934, Jour. Paleontology, v. 8, no. 2, p. 160–161, pl. 21, figs. 3a–f; pl. 26, fig. 3.

Amphiscapha muricata (Knight). Knight, 1942, Jour. Paleontology, v. 16, no. 4, p. 488.

Straparolus (*Amphiscapha*) *muricatus* (Knight). Knight, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 465, pl. 188, figs. 40–42.

This species has been identified by the characteristic horizontal flange at the juncture of the side and the base. No other species of the genus is known to develop this feature. Because of this, it has been possible to assign incomplete specimens to this species.

Amphiscapha muricata (Knight) was originally described from specimens from the Crouse limestone, about 75 feet stratigraphically above the Florena shale member of the Beattie limestone. In the course of this study, it has been found in beds as old as the Pillsbury shale (USGS loc. 13744).

The largest single collection of specimens is from the Florena shale member of the Beattie limestone in Cowley County (USGS loc. 13755). The specimens are from near the top of the bed where the shale is very calcareous and is argillaceous. Almost all the other specimens are from argillaceous, impure limestone, as for example in parts of the Florena shale member of the Beattie limestone, specimens are rare, and seldom are more than 1 or 2 found at a locality. None of the specimens are incrusted with other organisms.

Genus OMPHALOTROCHUS Meek, 1864

Omphalotrochus obtusispira (Shumard)

Plate 17, figures 3, 4

Pleurotomaria obtusispira Shumard, 1859, Acad. Sci. St. Louis Trans., v. 1, p. 401.

Omphalotrochus obtusispira (Shumard). Girty, 1937, Jour. Paleontology, v. 11, no. 3, p. 203, pl. 33, figs. 1–17.

Knight, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 467; pl. 191, figs. 12–15.

Two specimens from the Florena shale member of the Beattie limestone (USGS loc. 13775) have been identified as this species. Two additional specimens from about the same locality were lent by the Kansas Geological Survey, and another was lent by the California Institute of Technology. These five have been compared with the specimens figured by Girty and are certainly *Omphalotrochus obtusispira.*

Omphalotrochus obtusispira is well known in beds of Wolfcamp age in western Texas and north-central Texas. *Omphalotrochus* species has been listed by Beede and Kniker (1924, p. 43) from the "Zone of *Swagerina*" in Kansas. They did not figure specimens, and it is not certain that they referred to the same species or even to the same genus.

Omphalotrochus wolfcampensis Yochelson, 1956

Plate 17, figures 5, 6

Omphalotrochus wolfcampensis Yochelson, 1956, Am. Mus. Nat. History Bull., v. 110, art. 3, p. 233, 234, pl. 14, figs. 4–10.

Another specimen of *Omphalotrochus* has been collected from the Neva limestone member of the Grenola limestone (USGS loc. 14883). It differs from *O. obtusispira* (Shumard) in having a lower spire, a more subquadrate whorl profile, and a smaller umbilicus with sharper whorls. The species is present in the Wolfcamp formation of western Texas (Yochelson, 1954, p. 233). Study of well-preserved specimens from western Texas shows that this species differs further in having an extremely shallow sinus on the upper surface (Yochelson, 1956, p. 233). Another specimen of this species has been obtained from the Red Eagle limestone near Burbank, Okla.

Genus HYPSELENTOMA Weller, 1929

Hypselentoma perhumerosa (Meek)

Pleurotomaria perhumerosa Meek, 1872, *in* Hayden, U. S. 42d Cong., 1st sess., H. Doc. 19, p. 232, pl. 4, figs. 13a, b.

Questionably *Pleurotomaria perhumerosa* Meek, Barbour, 1903, Nebraska Geol. Survey [Rept.], v. 1, pl. 2, fig. 19.

Woodruff, 1906, Nebraska Geol. Survey Bull., v. 2, p. 284, pl. 15B, fig. 1.

Hypselentoma perhumerosa (Meek). Weller, 1929b, Illinois Geol. Survey Rept. Inv. 18, p. 10.

Knight, 1941, Geol. Soc. America Spec. Paper 32, p. 156, 157, pl. 21, figs. 2a–c.

Baylea perhumerosa (Meek). Knight, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 453, pl. 184, figs. 8, 9.

Eight specimens of this species have been identified from an impure limestone bed in the Friedrich shale member of the Root shale. These specimens show the characteristic relatively high spired form with the flattened ramplike shoulder. Growth lines show a shallow sinus on the ramp, and there is little doubt as to the specific identity of these specimens. This species is known to have a relatively long stratigraphic range. To the best of the writer's knowledge, this is the first time that it has been reported in Kansas.

Poorly preserved specimens referable to this genus have been collected from a bed of impure limestone in the Dry shale member of the Stotler limestone (USGS loc. 13502). Specimens from Kansas have been compared with the lectotype and paratypes.

Genus GLABROCINGULUM Thomas, 1940

Glabrocingulum sp.

Plate 17, figures 8, 9, 15

Glabrocingulum has been collected from several impure argillaceous limestone units in Kansas. The species has a low spire and is very narrowly phaneromphalus or cryptomphalus. A narrow, strongly bordered, concave selenizone forms the periphery. Ornamentation of the upper surface consists of a row of nodes at the suture with two revolving lirae below. Below the periphery, the outer whorl face has revolving rows of nodes which are the same size as four rows of nodes on the basal surface. There are also fine revolving lirae on the base and outer whorl face.

Until the Pennsylvanian pleurotomarians and particularly *Glabrocingulum* and its allies have been studied to determine limits of specific variation, naming of new species will add only confusion to an already complex problem of species differentiation. The Kansas specimens are similar to specimens from the limestone of the Waldrip shale member of the Pueblo formation of north-central Texas and the Bursum formation of New Mexico, both of which are near the local commonly accepted systemic boundary in their representative outcrop areas.

Genus PHYMATOPLEURA Girty, 1939

Phymatopleura aff. P. brazoensis (Shumard)

Plate 17, figures 10–12

Pleurotomania brazoensis Shumard, 1860, Acad. Sci. St. Louis Trans., v. 1, p. 624.

Orestes brazoensis (Shumard). Plummer and Moore, 1922, Texas Univ. Bull. 2132, p. 151, pl. 22, fig. 16.

Phymatopleura brazoensis (Shumard). Girty, 1939, Washington Acad. Sci. Jour., v. 29, no. 1, p. 33–36, figs. 20–21a.

Knight, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 455, pl. 183, figs. 35, 36.

The collections contain a few specimens from shale and impure limestone of Pennsylvanian age that are definitely referable to *Phymatopleura.* Most of the specimens are poorly preserved, but taken all together they appear to be similar to *Phymatopleura brazoensis* (Shumard). The specimens differ from that species in that they lack the prominent, short, nearly straight ridges just below the suture and normal to it. The significance of this feature of ornamentation is not known, but it seems best not to name a new species at this time because of this difference.

Shumard's specimens are lost, and most of our knowledge of the species is based on the description and illustrations supplied by Girty (1939). Unfortunately, the specimens illustrated by him also have been lost. Kansas specimens have been compared with specimens in the collection from which Girty's figured specimens were chosen.

Genus ARAEONEMA Knight, 1933

Araeonema sp.

Plate 17, figure 7

A single specimen referable to this genus is from a calcareous shale unit just above the Tarkio limestone member of the Zeandale limestone (USGS loc. 13532). The specimen differs from *Araeonema virgatum* Knight, the genotype and the only previously reported Pennsylvanian species, in being smooth rather than having revolving ornamentation. The specimen has relatively few whorls and may be a juvenile. It is significant in that it considerably extends the range of this genus, as *A. virgatum* is known only from the Labette shale of Des Moines age.

Araeonema sp. (Knight, 1933a, p. 52–53, pl. 9, fig. 4) is almost certainly not a representative of this genus.

Genus NATICOPSIS M'Coy, 1844

Subgenus NATICOPSIS M'Coy, 1844

Naticopsis subovata Worthen

Plate 17, figure 16

Naticopsis subovata Worthen, 1873, *in* Meek and Worthen, p. 595, pl. 28, fig. 9.

Knight, 1933b, Jour. Paleontology, v. 7, no. 4, p. 379–380, pl. 43, fig. 2a–j.

Knight, 1944, *in* Shimer and Shrock, New York, John Wiley and Sons, Inc., p. 475, pl. 194 figs. 20, 21.

Three specimens of this species were obtained from a calcareous shale unit just above the Tarkio limestone member of the Zeandale limestone (USGS loc. 13532). The three specimens show the low-spired, well-rounded shape characteristic of the species. The parietal inductura of Kansas specimens is almost identical with that of specimens figured by Knight (1933b). So far as is known, this is the youngest reported occurrence of *Naticopsis subovata.*

Other Naticopsis spp.

Plate 17, figures 13, 14, 17–19

In addition to the specimens of *Naticopsis subovata*, there are half a dozen other specimens in the Kansas collections referable to this genus. At least 3 subgenera and 3 species have been recognized. Insofar as one can tell in the absence of growth series, at least two of these species are closely related to, if not conspecific with, forms known from western Texas. For simplicity, they are all grouped under *Naticopsis* spp.

Of the three specimens figured, a specimen showing ornamentation near the suture such as has been described for the subgenus *Jedria* Yochelson (1953) is illustrated on plate 17, figures 13–14. The other two specimens figured are referable to subgenera at present used only for Mesozoic forms.

OTHER GASTROPODS

In addition to those gastropods discussed, there are others, most of them poorly preserved. These give little information of a stratigraphic or biologic nature, but they do provide additional data as to the habitat of some late Paleozoic gastropods.

Locally, bellerophontids are rather common in the argillaceous Aspinwall limestone member of the Onaga shale and the Falls City limestone. Most specimens are unidentifiable but have the same general size as better preserved specimens from these units that are referred to *Knightites* (*Retispira*) spp. There are several specifically indeterminate *Euphemites* with more lirae than the specimens described (p. 91). Two poorly preserved specimens of *Pharkidonotus* were collected at USGS loc. 13674, Florena shale member of the Beattie limestone. *Glabrocingulum* species indeterminate and poorly preserved molds that may be referable to this genus are in argillaceous shale and argillaceous limestone units. This form is abundant in one collection from the Falls City limestone (USGS loc. 13508). Several of these molds bear incrusted *Tolypammina*-like tubes. Rare "*Strobeus*"-like steinkerns have also been collected from these beds.

In contrast to these argillaceous beds, the calcareous shale beds contain a different assemblage. Specimens are very rare, and all are poorly preserved. The most common type is a *Donaldina*-like form. *Worthenia*, 1 or 2 other pleurotomarians, *Paleostylus*, and *Platyceras* have also been identified.

In one collection from the Burr limestone member of the Grenola limestone (USGS loc. 13679) *Donaldina*-like forms make up almost 10 percent of the total rock volume. This is the only exception noted to the fact that small gastropods are rare in the Kansas collection.

CLASS SCAPHOPODA

Genus DENTALIUM Linnaeus, 1758

Dentalium sp. indet.

Plate 17, figure 20

One scaphopod in a collection from the Friedrich shale member of the Root shale (USGS loc. 13842) shows prominent longitudinal ridges and thus appears to be referable to this genus. The specimen is too incomplete to show other significant shell features. Although scaphopods are by no means extremely rare in the upper Paleozoic strata, so far as is known, this is the first report of this genus in the upper Pennsylvanian of Kansas.

Geinitz (1866, p. 13, table 1, fig. 20) has named a scaphopod from the Nebraska City, Nebr., section that is very likely referable to *Plagioglypta* Pilsbury and Sharp.

CLASS CEPHALOPODA

By Mackenzie Gordon, Jr.

Genus PSEUDORTHOCERAS Girty, 1911

Pseudorthoceras knoxense (McChesney)

Plate 17, figure 27

Orthoceras knoxense McChesney, 1860, Extr., Chicago Acad. Sci. Trans., v. 1, Descriptions of New Species of Fossils from the Paleozoic Rocks of the Western States, p. 69.

Pseudorthoceras knoxense (McChesney). Miller and Youngquist, 1949, Geol. Soc. America Mem. 41, p. 18–22, pl. 2, figs. 1–7, pl. 3, figs. 2–8, pl. 55, figs. 15–17. [For complete synonymy]

Three specimens, each from a different locality, are referred to this ubiquitous and long-ranging species. They are from the Wamego member of the Zeandale limestone (USGS loc. 13693), the Hawxby shale member of the Onaga shale (USGS loc. 13672), and the Bennett shale member of the Red Eagle limestone (USGS loc. 14835). All show the characteristic mural deposits within the camerae. A partly sectioned specimen is figured.

Genus MOOREOCERAS Miller, Dunbar, and Condra, 1933

Mooreoceras? sp. indet.

Four poorly preserved specimens of orthoconic nautiloids from as many localities are referred with question to *Mooreoceras*. They are from the Friedrich shale member of the Root shale (USGS loc. 13787), the Falls City limestone (USGS loc. 13689), and the Florena shale member of the Beattie limestone (USGS locs. 13775, 14802).

Three are relatively small, 6 to 14 mm in diameter. One (USGS loc. 13689) is a fragment 55 mm long and more than 28 mm wide. All have rather shallow camerae, roughly 4½ to 5 camerae in the space of 1 diameter on the 3 small specimens. Three exhibit slightly sinuous sutures. The fourth (USGS loc. 14802), the only undistorted specimen, is covered by shell material with a smooth surface. Its orad septum shows the subcentral location of the siphuncle in the slightly depressed cross section of the whorl. In none of the longitudinal sections are connecting rings or cameral deposits present.

Genus TAINOCERAS Hyatt, 1884

Tainoceras sp.

Plate 17, figures 28, 29

A slightly distorted specimen of *Tainoceras* consists of the phragmacone and a quarter of a volution of the body chamber. The shell is about 58 mm in diameter, and at the orad end the subhexagonal whorl is 37 mm wide and 27 mm high, its greatest width at the rounded umbilical shoulder about one-third of the distance ventrad from the umbilical seam. From the umbilical shoulder the sides converge ventrad at an angle of roughly 30°, and the rather straight umbilical walls slope inward toward the umbilical seam.

A row of elongate nodes at each ventrolateral margin and 2 rows of ventral nodes divide the venter into 3 subequal parts. Abrasion of the venter has obscured the shape and distribution of the ventral nodes so that it cannot be determined for certain whether they are staggered or paired.

The shell resembles that of *T. nebrascense* Miller, Dunbar, and Condra in the division of the venter by the rows of nodes into three subequal parts and by the elongation along the ventrolateral margins of the ventrolateral nodes. However, the imperfect condition of the ventral nodes precludes positive identification of this shell.

The specimen is from the Burr limestone member of the Grenola limestone, lower part, in the SW¼ sec. 35, T. 28 N., R. 8 E., Greenwood County, Kan.

Genus METACOCERAS Hyatt, 1884

Metacoceras sp.

A fragment of the body chamber of a coiled nautiloid from the Bennett shale member of the Red Eagle limestone (USGS loc. 14835) is referred to *Metacoceras*. It consists of a third of a volution and includes the final septum of the phragmacone. This fragment of a whorl is 55 mm long and at the better preserved narrow end is 21 mm wide and 15½ mm high; the impressed zone is not quite 3 mm deep.

The venter is broadly rounded, and the strongly rounded ventrolateral zone is marked by a row of subdued rounded nodes that extend weakly down the sides and disappear halfway toward the subangular umbilical shoulder. There are eight nodes on the better preserved side of the specimen. The sides converge very slightly ventrad. The umbilical walls are smooth and convex, and the impressed zone is concave.

The characteristics as preserved do not appear to fit any described species.

Genus NEOAGANIDES Plummer and Scott, 1937

Neoaganides grahamense Plummer and Scott

Plate 17, figures 21–23

Neoaganides grahamense Plummer and Scott, 1937, Texas Univ. Bull. 3701, p. 350, 351, pl. 40, figs. 4–9, text fig. 88.

Imitoceras grahamense (Plummer and Scott). Miller and Unklesbay, 1943, Jour. Paleontology, v. 17, no. 1, p. 11, 12.

Imitoceras grahamense Miller and Furnish [*sic*]. Shimer and Shrock, 1944, New York, John Wiley and Sons, Inc., p. 573, pl. 234, figs. 18, 19.

Imitoceras grahamense (Plummer and Scott). Miller and Downs, 1950, Jour. Paleontology, v. 24, no. 2, p. 193, 194, pl. 32, figs. 1–4, text fig. 2.

Imitoceras grahamense (Plummer and Scott). Tasch, 1953, Jour. Paleontology, v. 27, no. 3, p. 389, pl. 49, figs. 23, 38, probably not fig. 22.

Imitoceras grahamense (Plummer and Scott)? Tasch, 1953, Jour. Paleontology, v. 27, no. 3, p. 447, 448, pl. 50, figs. 3–6, text fig. 1A, B.

Seven specimens, one of which is figured, were collected from shale beds in the Grandhaven limestone member of the Stotler limestone (USGS loc. 14873). They all appear conspecific with typical specimens of this species from the Graham formation of Texas.

The genus *Neoaganides* Plummer and Scott, which includes several small Late Pennsylvanian and Permian species, is here considered to be separate and distinct from the genus *Imitoceras* Schindewolf of the Late Devonian and Early Mississippian. *Neoaganides* differs from *Imitoceras* in having more primitive-looking sutures, with rounded lobes and a subcentral siphuncle (Miller and Unklesbay, 1943, p. 11). No stratigraphically intermediate species are definitely known. The Early Pennsylvanian form "*Imitoceras*" *cherokeense* Miller and Owen, 1939, has an open umbilicus, with the umbilical lobe centered outside of the umbilical seam and an adapically truncate ventral lobe, and therefore belongs neither in *Imitoceras* nor in *Neoaganides*.

Genus GLAPHYRITES Ruzhencev, 1936

Glaphyrites sp.

A specimen from the Jim Creek limestone member of the Root shale (USGS loc. 13832) and another from the Bennett shale member of the Red Eagle limestone (USGS loc. 14835) are referred to this genus. The first is partly crushed and badly eroded but shows the general configuration of the suture. The second is preserved in impure limestone and shows the surface sculpture. Both are subglobose, have rather wide umbilici, and have growth constrictions which bow orad across the venter. The two specimens might represent the same species, but their imperfect preservation precludes their positive identification.

Glaphyrites? sp.

A small pyritized specimen from the Hughes Creek shale member of the Foraker limestone (USGS loc. 13478) is referred with some question to *Glaphyrites*, as the suture is not preserved. The shell, 8 mm in diameter, is narrowly subglobose, the umbilicus equal to nearly two-fifths of the diameter. The surface is ornamented by shallow constrictions and lirae of growth that bow orad over the flanks and are indented by a shallow sinus over the venter. The shell is slightly narrower and has a smaller umbilicus than the specimens from USGS locs. 13832 and 14835 and in general configuration recalls *Glaphyrites modestus* (Böse).

Genus GONIOLOBOCERAS Hyatt, 1900

Gonioloboceras goniolobum (Meek)

Plate 17, figures 24–26

Goniatites goniolobus Meek, 1877, U.S. Geol. Explor. 40th Parallel (King), v. 4, p. 98, 99, pl. 9, figs. 5–5b.

Gonioloboceras goniolobum (Meek). Miller and Downs, 1950, Jour. Paleontology, v. 24, no. 2, p. 196–200, pl. 31, fig. 9, pl. 32, figs. 5–9, text fig. 3A. [For complete synonymy]
Tasch, 1953, Jour. Paleontology, v. 27, no. 3, p. 389, 390, pl. 49, figs. 20, 24, 25.

Ten juvenile specimens, one of which is figured, were collected from shale beds in the Grandhaven limestone member of the Stotler limestone (USGS loc. 14873) and were associated with *Neoaganides grahamense* Plummer and Scott.

PHYLUM ARTHROPODA

CLASS CRUSTACEA

Genus DITOMOPYGE Newell, 1931

Ditomopyge? decurtata (Gheyselinck)

Plate 17, figures 30–33

Phillipsia (*Neophillipsia*) *decurtata* Gheyselinck, 1937, University of Amsterdam, doctorate thesis, p. 56, text fig. 14b.

Ditomopyge decurtata (Gheyselinck). Weller, 1944, Jour. Paleontology, v. 18, no. 4, p. 320–321, pl. 49, fig. 3a–b.
Shimer and Shrock, 1944, New York, John Wiley and Sons, Inc., p. 645, pl. 275, fig. 1–2.

Weller (1944) has suggested that Gheyselinck's type came from the Florena shale member of the Beattie limestone near Grand Summit, Cowley County, Kans. Collections from the various beds from the Pillsbury shale to the Eskridge shale in Chautauqua and Cowley

Counties did not yield any fossils of similar kind or similar preservation. Probably the specimen did not come from those older beds. It seems likely that Weller (1944) is correct in considering the Florena shale member to be the type horizon of this species, but trilobites of similar form and preservation have been collected in Cowley County from beds at least 30 feet stratigraphically above the Florena shale member.

In this species there is a distinct, nearly vertical border in front of the glabella. The pygidium does not have a pronounced trapezoidal axial-lobe profile, and there is not a sharp geniculation of the pleural lobes. In these features, the species differs significantly from the diagnosis of the genus given by Weller (1935, p. 505; 1936, p. 711).

?Ditomopyge sp.

A single crushed, enrolled specimen doubtfully referable to *Ditomopyge* was collected from the Jim Creek limestone member of the Root shale. The general shape of the cephalon, particularly the nearly vertical border, glabellar outline, and shape of free cheeks is much like that of *D.? decurtata* (Gheyselinck). However, the palpebral lobes seem to be somewhat larger, and the axial and pleural parts of the thorax and pygidium lack the transverse rows of granules seen on *D.? decurtata.*

An isolated pygidium and glabella from the Americus limestone member of the Foraker limestone are similar to the specimen described above. The Americus specimens are better preserved and can be referred with certainty to the genus.

OTHER TRILOBITES

In addition to the occurrence of *Ditomopyge?* discussed, there are other trilobite remains scattered throughout the units studied. Pygidia have been found in several shaly limestone beds. Insofar as they can be determined, they may be *Ditomopyge.* Knowledge of late Paleozoic trilobites is such, however, that it seems best not to assign generic names to these isolated pygidia. Free cheeks of unknown trilobites have been found in several localities. They are confined almost exclusively to calcareous shale.

PHYLUM CHORDATA

CLASS VERTEBRATA

By David H. Dunkle

The following vertebrate remains have been identified by me in the collections submitted by Mudge and Yochelson for identification.

USGS loc. 13532 Tarkio limestone member of the Zeandale limestone—cf. *Ctenoptychius occidentalis* (St. John and Worthen).

14810 Grandhaven member of the Stotler limestone—a worn asymmetrical finspine of a chondrichthyian fish tentatively referred to *Physonemus.*

13702 Pony Creek shale member of the Wood Siding formation—*Orodus* sp.

13449 Americus limestone member of the Foraker limestone — *Petalodus* cf. *P. ohioensis* Safford, *Cladodus* sp.

13454 Hughes Creek shale member of the Foraker limestone—*Cladodus* sp.

13487 Hughes Creek shale member of the Foraker limestone—Cochliodontidae: genus and species indeterminate.

13620 Hughes Creek shale member of the Foraker limestone—*Cladodus?* sp.

13759 Hughes Creek shale member of the Foraker limestone — indeterminate paleoniscoid fish tooth

13465 Bennett shale member of the Red Eagle limestone—*Cladodus* sp. and indeterminate paleoniscoid fish scales.

13490 Bennett shale member of the Red Red Eagle limestone—*Cladodus* sp.

13736 Neva limestone member of the Grenola limestone—*Orodus* sp.

PART 3. SEDIMENTATION AND PALEOECOLOGY

Although much of what can be surmised about the sedimentation and paleoecology of the midcontinent area has been presented by Moore (1929, 1936, and 1949), Moore, Jewett, and O'Connor (1951), and Elias (1937a), the present study has provided the opportunity for further field and laboratory observations. From the lithology of the stratigraphic units and the distribution and mode of occurrence of the fossils within these units, it is possible to make certain interpretations of former ecological conditions. Because the writers' interpretations differ somewhat from those of Elias (1937a), his views are presented at appropriate points.

CHANGES IN FACIES AND THICKNESS OF ROCK UNITS

The following discussion is a summary of the changes in facies and thickness of the geologic units covered in Part I and shown on plates 1 to 5. As a detailed discussion would be too lengthy, the principal changes observed along the outcrop of these rocks in Kansas are generalized on table 5 and discussed briefly in the following under headings similar to those in the table. A summary of much of these data has been presented by Mudge (1957a, p. 105-112).

THICKENING

Almost all the rock units show variation in thickness within a small area, but many of them show a more general tendency to thicken in one direction. The rocks studied thicken a total of about 110 feet from north to south over a distance of about 225 miles. The Admire group, although somewhat thicker in the central outcrop area, is of about constant thickness in southern and northern Kansas. The younger Permian rocks (lower half of Council Grove group) thicken as much as 55 feet southward. The younger Pennsylvanian rocks also thicken about 55 feet in the same direction.

The Pennsylvanian shales show a much greater variation in thickness than do those of the lower Permian. The Pillsbury shale, for example, ranges from 0.8 foot to 75 feet in thickness; and the Wamego shale member of the Zeandale limestone in Wabaunsee County thickens from 8 feet to over 50 feet within a distance of 30 miles.

In the Permian rocks the most apparent changes in thickness are in the Americus limestone and Hughes Creek shale members of the Foraker limestone, the Roca shale, the Grenola limestone, and the Eskridge shale. With the exception of the Roca and Eskridge shales, these units thicken toward the south (pl. 5).

SANDSTONE AND SANDY SHALE

Beds of sandstone and sandy shale are present in each of the shale formations of the upper Pennsylvanian rocks and in most shales of the Admire group of early Permian age. These beds of sandstone and sandy shale are local and rarely can be correlated from one section to another a few miles away. Commonly the beds of sandstone or sandy shale are in the middle or upper parts of the shale units and locally fill channels. More persistent beds of sandstone and sandy shale are present in the Pillsbury shale and French Creek shale member of the Root shale.

The beds of sandstone and sandy shale are composed mainly of rounded fragments of quartz and flakes of muscovite. The grain size rarely exceeds 1.0 mm and most are 0.25–0.50 mm in diameter. The flakes of muscovite are generally somewhat larger. Crossbedding, ripple marks, and fragments of leaves and wood are found in many of these beds.

CHANNELS

Deep channels are locally cut into each of the shale formations and members of the upper part of the Pennsylvanian system. In some places shallow channels are also cut into the shale formations of the Admire group. They are not present in the younger Permian strata studied. The deep channels are as much as 100 feet deep and 3 to 4 miles wide. Most channels trend southeast or east. Most of them are in the northern outcrop area, although a few are in the southern area.

Almost all the channels are filled with massive to thin-bedded sandstone and sandy shale; some are crossbedded. Locally in northeastern Wabaunsee and central Pottawatomie Counties there are beds of clayey to silty shale filling the upper parts of the channels. The channels apparently are nonmarine and most of their fill material, except the clayey and silty shale, is very likely nonmarine in origin. The clayey shale is more likely marine (Mudge, 1956, p. 674–675).

VARIEGATED-SHALE BEDS

Variegated-shale beds are present in all the shale formations studied. They are more abundant in the rocks of the Council Grove group, the most notable

TABLE 5.—*Summary of geographic changes in stratigraphic units of Upper Pennsylvanian and Lower Permian rocks*

[N, north of Lyon County; S, south of Wabaunsee County; C, central outcrop area (Lyon, Chase, Wabaunsee, southeastern Riley and southern Pottawatomie Counties); E, east outcrop area; *, significant change]

Geologic unit: Formation	Geologic unit: Member	Direction of thickening	Direction of increase in quantity of sandstone, sandy shale, and conglomerate	Direction of increase in quantity of variegated shale or gray to variegated shale	Area of beds of coal	Area of abundant channels	Direction of change from limestone to shale	Direction of change from algal, oolitic, or coquina limestone to fine-grained gray limestone	Direction of decrease in fusulinids	Direction of increase of detrital material
Beattie limestone	Morrill limestone	S					N	N	N	
	Florena shale	S*							N	
	Cottonwood limestone	N					S*		S*	
Eskridge shale		N*		S	C					
Grenola limestone	Neva limestone	S					N	S	N	
	Salem Point shale	C					N			
	Burr limestone	S								
	Legion shale	S					N			
	Sallyards limestone	S								
Roca shale		C		S*						
Red Eagle limestone	Howe limestone									
	Bennett shale	S*					N*			
	Glenrock limestone	N*							S	
Johnson shale		C		S			N			
Foraker limestone	Long Creek limestone						S			
	Hughes Creek shale	S*					N*		N*	
	Americus limestone	S*							N*	
Janesville shale	Hamlin shale	S	N	N*		N		S		
	Five Point limestone	C						S*	N*	
	West Branch shale	S	N	N*	S–C	N–S				
Falls City limestone		C						S*		
Onaga shale	Hawxby shale			N*						
	Aspinwall limestone	C–N						S		N
	Towle shale	N–E*	N*	N*		N				
Wood Siding formation	Brownville limestone	N							N*	
	Pony Creek shale	S*	N*	N*	C	N*				
	Grayhorse limestone									N*
	Plumb shale	S	N*	N*	C	N*				
	Nebraska City limestone						S			
Root shale	French Creek shale	S*	N		C–N*	C–N				
	Jim Creek limestone	N								
	Friedrich shale	S*–N	C–N	N*	C	C				
Stotler limestone	Grandhaven limestone	C					N?		N	
	Dry shale	C		C	S*	C				
	Dover limestone	N*						N	S*	

being the Eskridge shale, which contains many thin variegated beds of shale in the northern outcrop area but southward is almost all red shale. Red and green shale beds are found locally in the Admire group and the upper part of the Wabaunsee group. In these rocks the variegated shale beds are present only in the central and northern outcrop areas, whereas in the lower part of the Council Grove group they are commonly more abundant and thicker in the southern outcrop area.

Many of the red beds are mottled with green, and the green beds are locally mottled with red. The mottling may be due to more intensive reduction of ferric oxide or oxidation of ferrous oxide in local areas than in the surrounding beds.

STRUCTURE OF SHALE AND LIMESTONE BEDS

The structure of almost all the shale varies considerably, from massive through thin bedded to fissile. The grain size does not greatly influence the type of bedding, although in general the silty shale (not siltstone) is thin bedded, whereas most of the clayey shale is massive but may be fissile. Almost all the fissile beds are dark gray to black and clayey. Massive to thin-bedded shale is commonly lighter gray or variegated and, rarely, very clayey.

The limestone varies from thick to thin bedded; most is massive (over 0.5 ft thick). The more massive limestone units (3–5 ft thick) are generally coarser grained than those that are 1 foot thick. Also, they are generally softer than the others.

Examples of some of the thicker limestone units are the Dover limestone member of the Stotler limestone, Long Creek limestone member of the Foraker limestone, Howe limestone member of the Red Eagle limestone, and unit 5 of the Neva limestone member of the Grenola limestone. The Tarkio limestone member of the Zeandale limestone and Cottonwood limestone member of the Beattie limestone, although thick, do not have the general characteristics of this group. Thin limestone units (1.0 ft thick) include the Maple Hill limestone member of the Zeandale limestone, Grandhaven limestone member of the Stotler limestone, Grayhorse limestone member of the Wood Siding formation, locally the Jim Creek limestone member of the Root shale and Brownville limestone member of the Wood Siding formation, the Americus limestone member of the Foraker limestone, the Glenrock limestone member of the Red Eagle limestone, and the limestone beds of the Neva limestone member of the Grenola limestone. Toward the south the limestone facies of the Hughes Creek shale member of the Foraker limestone and Bennett shale member of the Red Eagle limestone are also in this category.

COAL

Beds of coal are present locally in all the thick beds of shale in the upper part of the Pennsylvanian system and are more common in the central and southern outcrop areas. The upper part of the West Branch shale member of the Janesville shale (lower Permian) contains a persistent coal bed. Generally the coal is subbituminous and varies from fissile to massively bedded. Very few of the beds of coal exceed 1 foot in thickness.

CONGLOMERATE

Conglomerate is present in each of the shale formations of the upper Pennsylvanian and in the Admire group of the lower part of the Permian. It is rare in the Council Grove group of the Permian. The conglomerate is generally associated with channels, either within a channel of peripheral to a channel at its contact with the overlying rocks. Most of the conglomerate consists of limestone and limonite nodules in a shale or lime matrix. Few of the beds exceed 2 feet in thickness. In some places the conglomerate contains fragments of shale and limestone that have been derived from the units eroded during the process of channel cutting.

Intraformational conglomerate units are common in some of the limestones, especially the Grayhorse limestone member of the Wood Siding formation and Aspinwall limestone member of the Onaga shale in northern Wabaunsee, southern Pottawatomie, and southeastern Jackson Counties.

MAJOR CHANGES IN FACIES

Changes have been noted in the lithology of several stratigraphic units from north to south in Kansas. These lithologic changes are reflected by changes in the faunal content, which are summarized below. (See also p. 109. Some of the more striking examples are the following:

1. The Dover limestone member of the Stotler limestone thins southward, and fusulinids become rare or absent.

2. The Brownville limestone member of the Wood Siding formation contains abundant fusulinids in southern Kansas, but they diminish in number northward, where they are rare. The silt content increases northward. *Marginifera* is common in northern and central outcrops, but rare in the south. *Dictyoclostus* becomes more abundant southward.

3. The Falls City limestone is oolitic and coquina limestone in southeastern Nebraska, coquina limestone in northern Kansas, a series of clayey limestone beds containing an abundance of perfectly preserved pelecypods in central Kansas, and two relatively soft impure brachiopod-bearing limestone beds in southern Kansas.

4. The upper bed of the Five Point limestone member of the Janesville shale is a pelecypod coquina in northern Kansas, but from southern Wabaunsee County south to Cowley County it is a typical limestone containing a fauna mostly of brachiopods. In Cowley County it thickens southwestward with the addition of a limestone bed containing the oldest known occurrence of *Pseudofusulina.* The more persistent fusulinid zone is in the middle and lower parts, with the newly added zone in the upper part.

5. The Houchen Creek limestone bed of the Hamlin shale member of the Janesville shale in northern Kansas and southeastern Nebraska is composed entirely of stromatolites. South of Pottawatomie County this unit disappears or grades into a thin bed of impure limestone.

6. In southern and central Kansas algal deposits are abundant in the lower beds of the Americus limestone member of the Foraker limestone, but they cannot be traced north of Pottawatomie County. The upper two limestone beds of the Americus are thick in the south and contain chert and an abundance of fusulinids. Toward the north they thin and do not contain chert, and fusulinids diminish in number whereas brachiopods become more abundant.

7. The Hughes Creek shale member of the Foraker limestone changes markedly from north to south. In the southern part of Kansas this member is mainly limestone that contains chert nodules and lenses. It is considerably thicker and contains a greater number of fusulinids than to the north. In general other larger fossils are more abundant toward the north except for productid brachiopods, which are common in some of the beds of shale in the Hughes Creek shale member to the south. Chert was not seen in this member north of Greenwood County; linguloids were not observed south of northern Greenwood County.

8. South of Lyon County the upper part of the Johnson shale is fossiliferous, containing productid brachiopods and pelecypods.

9. The Bennett shale member of the Red Eagle limestone grades southward into limestone. This shale, in northern Lyon and southern Wabaunsee Counties, contains a bank of organic material. In the north it bears a linguloid fauna; in the central area, an abundant mixed fauna; and in the south, commonly fusulinids.

10. The Roca shale is mostly green, gray-green, and gray shale with local beds of purple and maroon shale in the central outcrop area. Toward the south maroon shale composes one-half to one-third of the formation.

11. North of Lyon County the beds of limestone in the Burr limestone member of the Grenola limestone are commonly soft, tan to gray, and locally gray orange. Locally both beds contain *Permophorus.* A fairly persistent ostracode zone in the upper part of the upper bed disappears south of Lyon County. South of Wabaunsee County the beds of limestone are medium hard, gray, and commonly platy. A variety of pelecypods, other than *Permophorus*, are the common fossils. The area in which the Burr limestone member changes lithologically and faunally coincides with the area containing the biostrome of the Bennett shale member of the Red Eagle. The thickness of the biostrome was greater than the thickness of the Roca shale, and therefore must have had some effect on the deposition of the Burr limestone member.

12. The Neva limestone member of the Grenola limestone varies considerably in thickness along its outcrop, but, in general, it thickens toward the south. The thickening is mainly within the limestone beds. Nodules and lenses of chert, common in the southern outcrop area, were not seen north of west-central Lyon County. Fusulinids appear to be more abundant toward the south, and the fauna is somewhat more varied in southern outcrops.

13. Toward the north the Eskridge shale is thick and contains many thin brightly variegated beds of shale. In the southern outcrop area this shale is thinner and is generally maroon. Locally in the central outcrop area the Eskridge shale contains a thin bed of coal. Fossils are most common in southern outcrops.

14. The Cottonwood limestone member of the Beattie limestone toward the north is a thick, massive medium-hard bed of gray limestone that contains lenses and nodules of chert. Fusulinids are very abundant in the upper part of this bed. Chert occurs as far south as southern Lyon County. Fusulinids diminish in number southward but have been traced into Elk County, where the limestone grades into shale and shaly limestone. Correlation of the Cottowood limestone member south of Elk County is based only on stratigraphic position. At the equivalent position of this member in Cowley County there are thin beds of soft limestone separated by calcareous shale. The beds of limestone and shale contain a brachiopod fauna, but no fusulinids were seen.

15. The Florena shale member of the Beattie limestone thickens southward and becomes more abundantly fossiliferous with a more varied fauna.

16. The Morrill limestone member of the Beattie limestone not only thickens southward but also changes in its fauna. Fusulinids were observed only in the southern outcrop area. Chert nodules are common in the southern outcrop area, but chert was observed in only one place in the central outcrop area.

CYCLIC SEDIMENTATION

Cyclic sedimentation is well exemplified in the upper Pennsylvanian and lower Permian rocks in Kansas. The term "cyclothem" was proposed by Weller (Wanless and Weller, 1932, p. 1003) "to designate a series of beds deposited during the Pennsylvanian period." An early résumé of cyclic sedimentation in the midcontinent region is given in a series of excellent papers published in 1931 by the Illinois Geological Survey. The upper Pennsylvanian cyclothems in Kansas have been discussed previously by Moore (1931, 1934, 1935, 1936, and 1950). Those of the Permian have been discussed by Moore (1934, 1935, and 1950), Jewett (1933), and Elias (1937a). The discussion in this paper is therefore only a summary of what is shown in figures 2 and 31 and does not include data more recent than June 1954.

The cyclothem classification, with phase numbers, listed in figure 2 is that given by Moore, Elias, and Newell (1934) and discussed by Moore (1936, p. 23). The names of individual cyclothems are from Moore, Elias, and Newell (1934), modified slightly by the present authors. These names are derived mainly from the limestone units that they include. The authors consider that cyclothem names are merely a local convenience and have no formal standing in stratigraphic nomenclature. New cyclothems that are here added are the Nebraska City, Grayhorse, and Houchen Creek. The Jim Creek cyclothem is revised. Recent study of the components of a cyclothem indicates that there are actually two cyclothems in the lower part of the Wood Siding formation—the Nebraska City and the Grayhorse. The Houchen Creek cyclothem is not as complete as many of the others, but it does warrant a local name.

The deficiencies of the cyclothem theory as it per tains to the upper Pennsylvanian and lower Permian rocks in Kansas need mention. The more complete cyclothems presented by Moore, Elias, and Newell (1934) are not ideally represented in the rocks studied in this paper. The geologic column shown in figure 2 is a composite compiled from many exposures in Kansas. With the data at hand, certain phases of the ideal cyclothem appear to be consistently absent. Each exposure generally has two or more phases missing, and in several cyclothems the same phase is commonly absent. Two examples of this are the Grandhaven and Jim Creek cyclothems in which phases 2, 3, and 4 have not been observed. The absence of other phases in other cyclothems is apparent in figure 2. Each of the cyclothems does contain enough phases to show that cyclic sedimentation followed the general pattern proposed by Moore, Elias, and Newell (1934).

In some areas a part of one cyclothem is repeated, representing a small reversal within the cyclothem. In the Hughes Creek shale member of the Foraker limestone phase 7 is repeated at least 6 times (fig. 2). Similar examples are shown in some of the other cyclothems in the figure.

The Permian cyclothems, above the Admire group, differ mainly from the Pennsylvanian cyclothems in the lack of sandstone, sandy shale, channel, and coal phases. In place of these the Permian cyclothems contain variegated shales. Moore (1950, p. 9) states that "this red shale definitely corresponds to emergent phases of other cyclic successions."

A typical cyclothem of the Council Grove group of the Permian is illustrated in figure 31. This cycle is applicable to the northern two-thirds of the Kansas outcrop area of the Red Eagle limestone. In interpreting the cyclothem the fusulinid limestone (phase 7) very likely represents the maximum depth of water, if fusulinids indicate deep water. Assuming that they do, then a regression followed. During the regression, shale (phases 6 and 5) and the upper limestone (phase 4) were deposited. Phase 4 is very likely a relatively shallow water deposit. The deposition of the ostracode zone at or near the top of this limestone bed indicates that shoaling conditions existed. After deposition of phase 4 the basin began to subside and fill with shale.

Moore (1936, p. 25) interprets the cyclothem of the Wabaunsee group as:

The sandstone (.0) may rest disconformably on underlying beds and appears definitely to represent the initial deposits of the cyclothem. Locally a thin conglomerate may occur at the base of the sandstone. The succeeding shale and coal (.1) are clearly continental in origin and indicate deposits made on an extremely low, flat coastal plain. The mollusk-bearing shale and limestone (.2 and .3) indicate the submergence of the coal swamps or coastal plain by a very shallow sea, and the overlying shale (.4) marks continued marine transgression that culminates in making the off-shore fusulinid-bearing limestone (.5). The succeeding parts of the cyclothem appear to signify marine regression which leads to shoaling waters inhabited by mollusks and favoring growth of algae (.6, .7 and .8). The terminal unit of the cyclothem (.9) is generally an unfossiliferous shale, but it may contain remains of land plants.

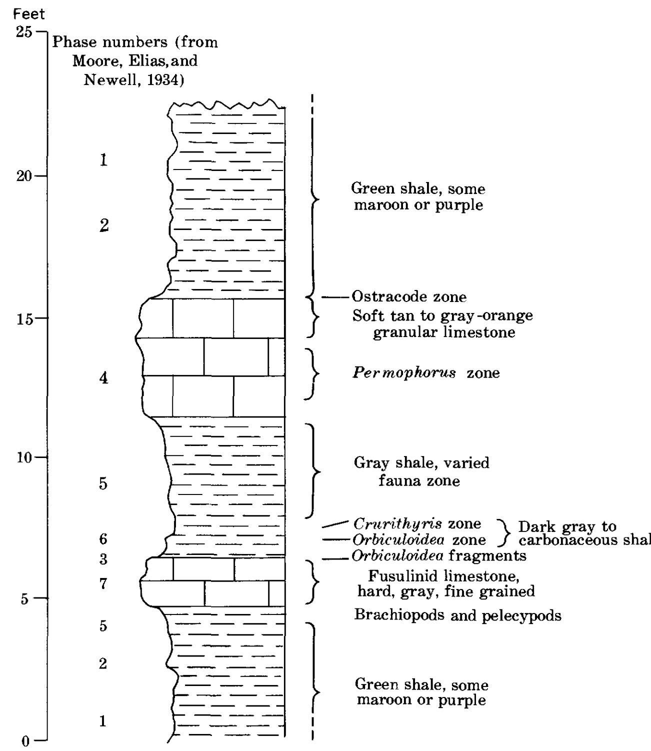

FIGURE 31.—The Red Eagle cyclothem (Permian) showing zoning of fossils.

FOSSIL BIOTA

Observations on the occurrence of individual genera are discussed below according to biological grouping. All fossil occurrences are plotted on an occurrence chart (table 1), but summary statements appear in order. This treatment emphasizes the observation that phylogenetically close forms may have pronounced differences in ecological requirements, and conversely, that genera belonging to different phyla may be ecological vicars. Opinions of earlier workers on the life habits of some of the animals studied are included.

STROMATOLITES

The algal deposits in the rocks represent three different types. Most conspicuous is the lobate massive *Collenia* type in the Houchen Creek limestone bed of the Hamlin shale member of the Janesville shale and in the lower part of the Americus limestone member of the Foraker limestone. *Cryptozoon*(?) and *Osagia* (?), an algal growth form (Johnson, 1946, p. 1105), are present in many of the Pennsylvanian and Permian limestones.

Richard Rezak (oral communication, 1954) has observed structures formed by blue-green algae in the Florida Keys that resemble the structure on Andros Island in the Bahamas described by Black (1933). Rezak states that the structures on the Florida Keys are similar to *Cryptozoon*(?) and *Collenia*, and that most of them occur above low tide. However, a few were 1 to 5 feet below low tide. Their depth distribution differs somewhat from that given by Black (1933, p. 169), who states:

> It was only above low-water mark, where the Cyanophyceae (blue-green algae) are the prevalent algae, that alga-controlled lamination and algal heads with characteristic internal structure were found.

Several limestone beds examined (in the Dover limestone member of the Stotler limestone) have a zone of fusulinids near the base and a zone of *Cryptozoon*(?) algal deposits near the top.

FORAMINIFERA

Several kinds of foraminifers are known to occur in the interval studied, but field observations were limited to the fusulinids. Elias (1937a, p. 418) has suggested, in part by analogy with living large foraminifers, that fusulinids lived in the deepest part of the epicontinental sea. However, the occurrence of abundant fusulinids both in limestone and in several types of calcareous shale—which probably indicates several kinds of sedimentary environments—suggests that the fusulinids may have had rather wide limits of tolerance.

Fusulinids are so abundant in the Tarkio limestone member of the Zeandale limestone and Cottonwood limestone member of the Beattie limestone that their volume may equal that of the matrix which binds them together. They are as abundant or perhaps even more abundant in calcareous parts of the Hughes Creek shale member of the Foraker limestone. Several of the other rock units contain abundant fusulinids locally (the Dover limestone member of the Stotler limestone, Jim Creek limestone member of the Root shale, and Neva limestone member of the Grenola limestone), but not everywhere in such large numbers. In some localities, but not all, the fusulinids in the Tarkio limestone member of the Zeandale limestone and Cottonwood limestone member of the Beattie limestone are oriented, probably as a result of current action. In many sections fusulinids are restricted to a definite zone within a limestone stratum.

COELENTERATA

All the corals collected from Kansas for this study are solitary forms and are most common in calcareous shale and shaly-weathering limestone. Duncan (this paper, p. 64) has noted that dissepimented forms are more common in the more calcareous rocks. Corals are absent from the more argillaceous beds, which carry a pelecypod fauna.

A zone of corals in the lower part of fusulinid limestone (the Tarkio limestone member of the Zeandale limestone and Cottonwood limestone member of the Beattie limestone) has been observed in many localities. In the Dover limestone member of the Stotler limestone, corals are commonly associated with algae. Many specimens show talons and radiciform processes in the apical region; these forms were attached to other objects and possibly are indicative of more turbulent environment than at those localities at which the corals lack talons. Rarely are there more than 2 or 3 specimens in collections from any 1 locality, and nowhere are they a significant part of the fauna.

BRYOZOA

The bryozoans are widely distributed in the upper Paleozoic rocks of Kansas. They are most common in calcareous shale and shaly-weathering limestone, and less common, with local exceptions, in more calcareous and more argillaceous beds. Five general growth forms—bilamellar, fenestrate, ramose, incrusting, and boring—can be distinguished. Certain growth forms appear to be limited to certain types of sediments.

Bilamellar forms are confined almost exclusively to the calcareous Hughes Creek shale member of the Foraker limestone, where they are more abundant than other forms. Fenestrate forms are rare and commonly are only small fragments. In the few collections where fenestrate forms are relatively large and complete, they are from argillaceous sediments and are associated with *Myalina* (*Orthomyalina*), or they are from argillaceous limestone and associated with pectinoids.

Small ramose bryozoa are most common in shaly to massive limestones (the Five Point limestone member of the Janesville shale and Brownville limestone member of the Wood Siding formation). Large ramose forms are confined almost exclusively to the Hughes Creek shale member of the Foraker limestone. These and the bifoliate forms are judged by Helen Duncan to indicate relatively quiet water.

Incrusting forms are most common in the Hughes Creek shale member of the Foraker limestone and Neva limestone member of the Grenola limestone. In the former unit they cover chiefly brachiopods, and in the latter, echinoid spines. Boring forms are most common in the Hughes Creek shale member, although they are found in other beds with large shells. Borings occur in shells of genera of several different phyla.

ECHINODERMATA

The echinoderms are represented in the collections of larger fossils by crinoid and echinoid remains. Holothurian plates have been reported from several units of the section studied (Hanna, 1930, p. 413). So far as is known, no asteroids or ophiuroids have been reported.

Next to fusulinids, crinoids probably furnished the most organic detritus to the formation of sediments. Crinoid stems or plates occur in almost every fossiliferous unit except those with abundant inarticulate brachiopods. Many of the limestone units contain a large amount of crinoid debris. Crinoid fragments are less common in the more argillaceous beds that carry abundant pelecypods. The few more or less complete calyxes found were collected chiefly from limestone and calcareous shale.

Disarticulated pieces of echinoids are found in many of the calcareous shale and limestone units. Almost without exception, where there are echinoids there are also remains of crinoids and bryozans; the reverse is not true. The significance of this observation is not known, but it may indicate that the echinoids required more favorable conditions for survival than did the other two groups. Echinoids are generally represented by only a few small spines, but in a few units (Bennett shale member of the Red Eagle limestone, Neva limestone member of the Grenola limestone) large echinoid spines are extremely abundant; they are most characteristic of the central and southern Kansas outcrops. In these two members, echinoid remains are more common than crinoid remains.

BRACHIOPODA

The brachiopods are the most varied of all the phyla and are the most abundant of the larger fossils. None of the genera seem to be ubiquitous in distribution, but rather each is closely related to the enclosing matrix. In general, where pelecypods are abundant, brachiopods are absent to rare, and vice versa. Only in a few localities are very abundant brachiopods and some pelecypods found together; most of the pelecypods are those noted below as possible burrowing forms.

Inarticulate brachiopods, chiefly *Orbiculoidea*, are confined to black shale units (the Bennett shale member of the Red Eagle limestone) and to the dark parts of more lime-rich units (certain zones in the Neva limestone member of the Grenola limestone). The inarticulate brachiopods are common as small fragments in the upper part of fusulinid-bearing limestone units (the Hughes Creek shale member of the Foraker limestone, Glenrock limestone member of the Red Eagle limestone, and Neva limestone member of the Grenola limestone). *Lingula* is much less abundant than *Orbiculoidea.* These occurrences of inarticulate brachiopods are quite important for correlation of smaller divisions of some of the members, and they are discussed in Part 1.

Schuchert (1911) and Cooper (1937) have summarized what is known about the depth ranges of Recent brachiopods. They have suggested that the fossil inarticulate brachiopods may have been limited to shallow water, some possibly estuarine. From a summary of the literature, Craig (1952, p. 115) has concluded that Recent *Lingula* is most common in argillaceous sediments less than 60 feet deep.

Commonly a thin shale bed crowded with *Crurithyris* lies directly above a bed of inarticulate brachiopods, and, rarely a similar bed occurs below. Ekman (1953, p. 183) and others have noted that where environmental conditions are extreme, few species are found but many specimens are present. This is the situation in the *Crurithyris* beds, and the occurrence of these beds between beds of inarticulate brachiopods and those which contain a more normal marine fauna suggests that specimens may have lived under environmental conditions intermediate between brackish and marine. *Crurithyris* also occurs with other brachiopod genera in the more typically marine beds.

Most of the other articulate brachiopods are found in calcareous shale and limestone beds. The productoid genera, which comprise the largest single group of brachiopods in number, may all be found together in some localities, but this is most exceptional. The distribution of the productoids suggests that there was considerable difference in the ecological tolerances of the various genera.

In some beds, as in southern exposures of the Johnson shale, *Linoproductus* may comprise over 90 percent of the fossils. *Dictyoclostus* is common in the Brownville limestone member of the Wood Siding formation, but it is rare in the same beds with pelecypods. Neither of these two genera has been collected from highly argillaceous limestone. Field evidence suggests that *Dictyoclostus* preferred a more calcareous environment and *Linoproductus* a more argillaceous environment. *Juresania* and *Marginifera* rarely occur together.

Chonetes, *Wellerella*, *Hustedia*, *Neospirifer*, and *Composita* are most common in calcareous shale beds, though *Chonetes* is nearly as abundant in limestone. In the southern part of Kansas, *Composita* and *Neospirifer* commonly occur in limestone. These forms are rare in pelecypod-bearing argillaceous beds. *Punctospirifer* is occasionally found associated with pelecypods. The two spiriferoid-shaped forms are found together in almost equal numbers in a few localities. From this occurrence, it is thought that they were not in direct competition for food or for living space.

Derbyia is relatively abundant where associated with other brachiopods and bryozoans in calcareous shale and limestone beds (the Florena shale member of the Beattie limestone) and also occurs in somewhat more argillaceous beds containing *Juresania* and pelecypods (the Nebraska City limestone member of the Wood Siding formation). *Meekella* has essentially the same type of distribution, except that it is more common in limestone.

MOLLUSCA

Mollusks form the second most abundant group of larger fossils collected. Four of the six known classes of Mollusca were collected from the units studied; the Amphineura (chitons) and Monoplacophora were not represented. A single scaphopod was collected from the Friedrich shale member of the Root shale.

Cephalopods are represented in the collection by 7 specimens of straight nautiloids, 2 coiled nautiloids, and 23 ammonites; most of the ammonites are from a single locality (14873). The ammonites *Properrinites* and *Artinskia*, each represented by a single specimen, had been described previously from the Neva limestone member of the Grenola limestone and the Florena shale member of the Beattie limestone, respectively (Elias, 1938, p. 101; Miller, 1936, p. 490). So few cephalopods are known from Kansas that little can be learned of their distribution except that specimens have been collected from beds of almost all lithologic types. They are most abundant in the Grandhaven limestone member of the Stotler limestone of "Dry shale" type (Tasch, 1953).

More than a dozen species of gastropods have been identified in the collections, but most of these are represented by only 1 or 2 specimens at a locality. Bellerophontoid gastropods and *Glabrocingulum* are locally abundant in argillaceous limestone and siltstone associated with pelecypods. *Amphiscapha* is widely distributed in calcareous shale and limestone.

Certain argillaceous limestone units in Kansas are noteworthy for their abundance of pectinoids (Falls City limestone, and the Burr and Sallyards limestone members of the Grenola limestone), particularly *Aviculopecten*, although some specimens are occasionally found in less argillaceous beds. This pelecypod is believed to have been an active form, possibly with a swimming habit like the living *Pecten* (Newell, 1937, p. 20). *Pseudomonotis*, a closely related genus, is found almost exclusively in silty and argillaceous sediments; it is believed to have lived attached (Nicol, 1944, p. 90). Almost without exception, where *Pseudomonotis* is present, *Aviculopecten* is present also, but the reverse is not true.

Schizodus and *Edmondia* are most common in the more argillaceous sediments, along with *Pseudomonotis* and *Aviculopecten*. Either genus or both may be present at a locality, but never in more than small numbers. Because of their shell form these genera are judged to have been free-living forms, possibly burrowing a short distance into the bottom.

Myalinids are found in several rock types but are most common in somewhat calcareous silty shale units such as the Friedrich shale member of the Root shale and Nebraska City limestone member of the Wood Siding formation. It was observed in the field that myalinid shells in limestone appear to be thinner than those in shale and that commonly shells in shale are bored by other organisms. Myalinids and particularly *Myalina* (*Orthomyalina*) are believed to have been sedentary forms, but they were not necessarily attached by a byssus. They are commonly gregarious and often are the only type of invertebrate present at a locality. Newell (1942, p. 19) has suggested that these myalinids lived in "the shallow, turbid waters of the shore zone, tolerating an unusually great amount of variation in the salinity of the water."

Aviculopinna is most common in limestone, often being found in fusulinid-bearing limestone. Specimens up to 15 inches in length have been observed in the Grandhaven limestone member of the Stotler limestone and Americus limestone member of the Foraker limestone. The genus may have been an attached form or a burrowing form, more likely the latter. *Allorisma* is found in a variety of units but is most common in calcareous shale. This genus is rarely represented by more than 1 or 2 specimens at a locality, except in outcrops of the Florena shale member of the Beattie limestone in southern Kansas. Because of its shell form, *Allorisma* is also believed to have been a burrowing form (Elias, 1937a, p. 409).

Locally in the Admire group in northern and central Kansas thin coquina beds are composed almost entirely of molds of *Permophorus*. Most commonly these are impressions of single disarticulated valves. All shells have been dissolved, and it is impossible to tell if the specimens have been worn.

ARTHROPODA

The arthropods are represented by at least two classes or subclasses. The distribution of trilobites is similar to that of the corals in that they occur chiefly in calcareous shale and shaly-weathering limestone. The trilobites are similar further in being rare at almost all localities from which they have been collected and in always being an insignificant part of the fauna.

They are relatively abundant locally in the Brownville limestone member of the Wood Siding formation and the Florena shale member of the Beattie formation.

Ostracodes are present in many of the fossiliferous shale units and have been collected from some of the limestone units. In many sections, the upper parts of the Howe limestone member of the Red Eagle limestone and Burr limestone member of the Grenola limestone contain an appreciable number of tests. The ostracodes were not studied in detail, and any discussion of the distribution of the various genera beyond that already given by Kellett (1933, 1934, 1935) is precluded.

VERTEBRATA

Scattered fish teeth, plates, and bone fragments have been found in some of the units studied. These vertebrate remains are rare and appear to have a random distribution, except that no remains were found in the pectenoid-bearing argillaceous limestone units. Rarely were more than 1 or 2 teeth, plates, or bone fragments found at any 1 locality.

MASS ASPECTS OF THE FAUNA

Besides knowledge of the genera and species that are present, and observations as to their individual occurrences, other information can be derived by examining collections in their entirety.

CONDITION OF SPECIMENS

Parts of animals suitable for fossilization are subject to at least four periods of possible wear or destruction: (a) while living, (b) before enclosure in sediments, (c) while entombed in rocks, and (d) following release from the enclosing sediments.

In reverse order, effects since their release from the enclosing rock appear to be negligible. Ground water and rain saturating the exposed shells may cause them to break, but such effects generally can be easily distinguished and accounted for.

Within the midcontinent area, events occurring while fossils were preserved in the rock are not as important as in other regions because the sediments are not strongly deformed or mineralized. However, some specimens are subject to considerable deformation by compaction, a case in point being the thin-shelled pelecypod *Allorisma*. Another major problem is the solution of the shell in mollusks, particularly gastropods and, to a lesser extent, the pelecypods.

If we take into account effects that may be ascribed to events before and during enclosure in the rocks, there remain those observations which may reveal additional information as to the habitat of the animals. Three of the observations that can be made are on the disarticulation of valves and other attached hard parts, the amount of abrasion and breaking of the fossils, and the presence of incrusting and boring organisms. Notation of such information must be on a purely qualitative basis at the present time. Some abrasion and incrustration could have occurred while the animals were living. The valves of most brachiopods are articulated, although some genera, particularly the thin-shelled *Derbyia*, are represented mostly by fragments. Most specimens of *Neospirifer* and some *Chonetes* are commonly disarticulated in certain zones. Articulation of most brachiopods appears to be the normal condition for most collections of post-Mississippian brachiopods from the midcontinent area.

The pelecypods *Myalina* (*Orthomyalina*) and *Aviculopecten* are commonly disarticulated and are represented in the collections by a preponderance of one valve. Most other pelecypods have both valves joined.

All echinoids are disarticulated, as they are in most occurrences within the upper Paleozoic. The preponderance of spines over unbroken plates is on the order of 40 to 50 to 1. Some of the plates may be present as part of the echinoderm debris in the limestone units.

Crinoid stems are commonly preserved as single ossicles or short pieces. The longer pieces of stem are most common in shaly-weathering limestone (the Brownville limestone member of the Wood Siding formation and the Five Point limestone member of the Janesville shale). Most calyxes are represented by scattered, separated plates, rather than heaps of plates at any one spot.

Relatively few of the fossils appear to be abraded. *Neospirifer* stands out among the brachiopods as having proportionally more worn specimens than all other genera of brachiopods.[13] Specimens of *Linoproductus* and *Juresania* are rarely worn, *Dictyoclostus* still more rarely. The fine lirae on a few specimens of *Chonetes* show abrasion. There appear to be more worn brachiopods in the Hughes Creek shale member of the Foraker limestone than in the other units studied.

Examination of mollusks for abrasion is hampered because the shell of many of the forms has been dissolved. Most myalinids and pectinoids, whose shells are commonly preserved, do not appear to be worn.

Generally only small fragments of fenestellate bryozoans are found in the limestone and calcareous shale beds, but more complete specimens have been collected from more argillaceous beds. Small ramose forms in the argillaceous beds are incomplete but are commonly

[13] An alternative possibility not considered when the fossils were studied is that some shells may have undergone partial solution, which indicates chemical rather than mechanical activity.

in lengths of more than one-quarter inch. Most bryozoans examined are well preserved and could not have undergone much transportation.

In examining collections for incrusting organisms, one is impressed with the number of specimens adhering to shells from the Hughes Creek shale member of the Foraker limestone. Indeed, there seems to be more incrustation of fossils in that unit than in all others studied. *Petrocrania* is particularly noteworthy for its abundance, and is found most commonly on *Dictyoclostus*. Bryozoans also incrust many shells in both this unit and the Neva limestone member of the Grenola limestone. *Tolypammina*-like foraminifers are more abundant in the Florena shale member of the Beattie limestone and Pony Creek shale member of the Wood Siding formation. Other occurrences have been noted under the discussion of *Chonetes*. The algal colony *Osagia*(?) incrusts many shell fragments in the upper Pennsylvanian and younger beds.

Borings and etchings such as have been ascribed to the action of ctenostomatous bryozoans are found in some of the shells. There is no obvious distribution of these borings except that they are most common in large shells, whether they be brachiopods, pelecypods, or gastropods. Many borings begin on the inside of shells, indicating that the shells were bored after the animal had died.

FAUNAL ASSOCIATIONS

Accumulations of fossils, like those of modern organisms, may be divided in two categories: the biocoenose, or community of life, and the thanatocoenose, or assemblage of remains brought together after death. A continuous spectrum of associations may be found between wholly local and wholly transported. It is important that the student of former ecologies understand whether his conclusions are based on assemblages that represent a biocoenose or a thanatocoenose.

Boucot (1953, p. 27–35) has given several criteria for identifying a fossil biocoenose. These are that the population is not sorted according to size, but that individuals of all ages are present; that shells which are readily disarticulated are joined; and that separated opposing valves are present in approximately equal numbers.

Specimens of the brachiopod *Chonetes* were examined to test these criteria. The collection from USGS loc. 13775, from the Florena shale member of the Beattie limestone, contains some of the best preserved fossils. All pelecypods have both valves articulated, and the delicate protruding genal spines of enrolled trilobites are unbroken. From these indications it is suggested that this collection represents a biocoenose.

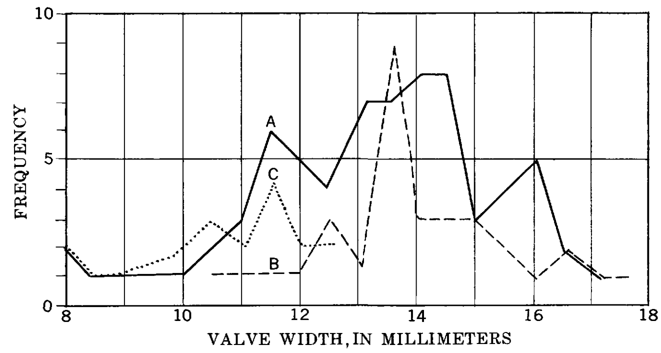

FIGURE 32.—Size-frequency distribution of three collections of *Chonetes granulifer* Owen. *A*, Collection from USGS loc. 13775, Florena shale member of the Beattie limestone, 70 specimens with both valves articulated, treated as 70 individuals; *B*, Collection from USGS loc. 13594, Hughes Creek shale member of the Foraker limestone, 9 specimens with both valves articulated, 12 specimens with pedicle valve only, 13 specimens with brachial valve only, treated as 30 individuals; *C*, Collection from USGS loc. 13445, Brownville limestone member of the Wood Siding formation, 12 specimens with both valves articulated, 6 specimens with pedicle valve only, 1 specimen with brachial valve only, treated as 18 individuals.

The widths of 70 *Chonetes* from this locality that had both valves articulated were measured and plotted (*A*, fig. 32). The plot does not follow an asymptotic curve as should be expected from a representative sample of a living population (Boucot, 1953) but rather approaches a bell shape. Two smaller samples of *Chonetes*, each containing several disarticulated valves, from localities that do not as clearly indicate a biocoenose were also measured and plotted (*B* and *C*, fig. 32). The plot from these data also is not an asymptotic curve but approaches a bell-shaped curve.

The comparison of curves B and C with A, and the form of curve A, suggest that Boucot's first criterion is not applicable to *Chonetes*, at least in the midcontinent area. This genus was chosen because it is one of the most common of all the fossils.

Probably pelecypods would be a better group of animals to test the second and third criteria because their valves commonly disarticulate readily after death of the animal. Unfortunately, there are not enough pelecypods at any one locality to count for possible sorting of right and left valves with any degree of significance.

In the absence of quantitative data, one is forced to use qualitative data for deciding just what the assemblages imply. The writers are of the opinion that most of the animal accumulations of the midcontinent area more nearly represent a biocoenose than they do a thanatocoenose. The absence of clear indications of current or wave action in the sediments and the relatively small amount of abrasion which the fossils have undergone suggest that there was little or no strong agitation of the water which would have resulted in the mixing of life assemblages. Some of the small delicate bryozoans could not have undergone much transportation, and large *Aviculopinna* presumably would have broken with much transit.

To the writers, the most compelling indication of a biocoenosis is the persistent association of certain fossil groups with certain types of sediments. In many horizons this association has been observed throughout the width of Kansas. It is rather difficult to visualize currents that would sort so that *Hustedia* and *Dictyoclostus*, for example, would be associated in calcareous shale beds for a distance of more than 200 miles.

It should be emphasized that this does not imply total lack of sorting. Rather, it is suggested that there was little sorting and that the forms that are present very likely lived near one another. One obvious indication of a certain degree of sorting is the absence of small specimens of productoids.

Moore (1929) and Elias (1937a) imply that the assemblages of animals in the midcontinent area represent biocoenoses, even though they do not discuss this problem specifically.

ABUNDANCE OF FOSSILS

Distribution of the fossils has been plotted on the accompanying occurrence chart (table 1). Localities have been arranged following a north to south distribution, and up the section through any one member or formation. Unfortunately, faunal continuity of certain beds has been masked by this procedure. For example, the Five Point limestone member of the Janesville shale characteristically is a limestone, shale, limestone sequence, but collection of specimens from each of these beds, and the individual beds of all the stratigraphic units studied, would have increased the collections to an almost unworkable number. Distinct lithologic and faunal units have been differentiated in the Hughes Creek shale member of the Foraker limestone and Neva limestone member of the Grenola limestone.

The total number of individuals of each sort at each locality has been reported, rather than the conventional "abundant," "common," and "rare." In counting the specimens an attempt has been made to evaluate the individual fragments and single valves so that the minimum number of specimens has been recorded. Thus, 3 pedicle valves and 5 brachial valves all about the same size have been considered to represent 5 specimens of a species, while 3 small pedicle valves and 1 large brachial valve are indicative of 4 specimens. Although there is no present need for this sort of data, it may possibly be useful to some future worker. Because of obvious difficulties, fusulinids, bryozoans, crinoids, and echinoids have not been counted.

The number of specimens listed may be considered as semiquantitative data, since about the same time was spent collecting at each locality, with the exception of samples of limestone with fusulinids and at the unusually fossiliferous USGS loc. 13775. At all localities, specimens were collected with as little personal bias as possible as to their preservation. Objections may be raised that this method is most inaccurate, but samples were collected from many outcrops in a short field season, and the samples are as accurate as could be taken without interfering with other, more pressing, aspects of this study.

In the entire fauna, brachiopods are estimated to comprise just under 50 percent of the total bulk of specimens, pelecypods probably 30 to 35 percent of the bulk, and all other fossil groups the remainder. Fusulinids and crinoid debris in limestone have been excluded from the above estimates.

Over half the brachiopods collected are productoids; *Linoproductus* and *Dictyoclostus* are the most abundant genera. More collecting from several selected localities would have greatly increased the number of specimens of these two genera. *Juresania* is less abundant but is much more abundant than *Cancrinella* and *Echinoconchus*, which are present in insignificant numbers. Among the other brachiopods, *Crurithyris*, *Derbyia*, *Composita*, and *Neospirifer* are the most abundant, in that order; most of the other genera do not form an appreciable bulk of the collections.

Pectinoids and myalinids comprise two-thirds of the bulk of the pelecypods. *Myalina* (*Orthomyalina*), *Aviculopecten*, and *Septimyalina* are the most abundant genera of these two groups, in the order arranged. *Permophorus* and *Aviculopinna* make up most of the bulk of the other pelecypods.

Of the remainder of the fauna, bryozoans are certainly the single most abundant group. Gastropods are probably the next most common class of organisms. Echinoids, corals, trilobites, and cephalopods, in that order, are increasingly rare and constitute a negligible part of the collections. It is impossible to state the volume of fusulinids and crinoid debris, but these two groups probably contribute more to the sediment than all other fossil groups combined.

FOSSIL BIOTOPES

The remarkable continuity of fossil assemblages in outcrops throughout most of Kansas results in characteristic faunal assemblages. These assemblages have been identified on the occurrence table (table 1) as noted below.

Close correlation appears between the lithologic characteristics of the various units studied and their plant and animal content. The abundance and kind of animals, coupled with the lithology, show several distinct groups. These categories have been designated by number, and on the occurrence chart a group number is given for each collection directly above the locality number. The groups recognized are as follows:

1. Limestone composed almost exclusively of fusulinid tests, though an occasional coral may be present. This group contains the Tarkio limestone member of the Zeandale limestone and Cottonwood limestone member of the Beattie limestone, and locally some of the limestone beds of the Hughes Creek shale member of the Foraker limestone and Neva limestone member of the Grenola limestone. In the Tarkio and Cottonwood limestone members, fusulinids are exceedingly abundant only in the upper ⅓ or ½ of the bed. Some limestone beds of the Hughes Creek shale member are composed almost entirely of fusulinids.

2. Limestone with more or less abundant fusulinids and crinoidal debris, locally with pelecypods and brachiopods, and sometimes with evidence of algae. This group contains the Maple Hill limestone member of the Zeandale limestone, the Dover and Grandhaven limestone members of the Stotler limestone, the Jim Creek limestone member of the Root shale, the limestone beds of the Five Point limestone member of the Janesville shale, the Americus limestone and Hughes Creek shale members of the Foraker limestone, the Glenrock limestone member of the Red Eagle limestone, and some of the limestone beds of the Neva limestone member of the Grenola limestone. Both the Dover and Grandhaven limestone members of the Stotler limestone contain fusulinids and algae. The Maple Hill limestone member of the Zeandale limestone and Jim Creek limestone member of the Root shale, although containing some fusulinids, locally contain a variety of other fossils, mainly brachiopods. The limestone beds of the Five Point limestone member of the Janesville shale locally contain an abundance of fusulinids in the southern outcrop area, but contain mainly brachiopods toward the north.

3. Calcareous shale with fusulinids as abundant as in group 1, and commonly with some crinoid stems and bryozoa and occasionally with echinoid spines. Commonly less than four genera of brachiopods are present. The representatives of this group are the upper part of the Pillsbury shale in northern Kansas, locally one of the shale beds in the Five Point limestone member of the Janesville shale, part of the Hughes Creek shale member of the Foraker limestone, part of the Neva limestone member of the Grenola limestone, and locally the lowermost part of the Florena shale member of the Beattie limestone. In the central and northern outcrop areas, certain beds of shale in the Hughes Creek shale member of the Foraker limestone and Neva limestone member of the Grenola limestone are composed almost entirely of fusulinids.

4. Shaly-weathering limestone or calcareous shale with abundant brachiopods, some fusulinids, crinoid stems, bryozoa (most of the specimens are ramose), a few echinoid spines, and rarely corals. This group includes beds of the Friedrich shale member of the Root shale, Brownville limestone member of the Wood Siding formation, one shale bed of the Five Point limestone member of the Janesville shale, certain beds of the Hughes Creek shale member of the Foraker limestone and Neva limestone member of the Grenola limestone and the Florena shale member of the Beattie limestone. The typical example of this group is the Brownville limestone member of the Wood Siding formation in the northern and central areas.

5. Black shale with inarticulate brachiopods. This group is represented by parts of the Hughes Creek shale member of the Foraker limestone and Bennett shale member of the Red Eagle limestone in northern Kansas and parts of the Neva limestone member of the Grenola limestone. The black fissile shale beds are more common in the Hughes Creek shale member and the Bennett shale member, almost invariably overlying fusulinid limestone, and where black shale is present in the Neva limestone member the stratigraphic relation is the same.

6. Thin-bedded to fissile black shale or dark calcareous shale with abundant *Crurithyris* and few other fossils. This group contains parts of the Hughes Creek shale member and the Bennett shale member, and parts of the Neva limestone member. It is most commonly associated with group 5 and always overlies it.

7. Siltstone or argillaceous limestone with *Aviculopecten*, *Pseudomonotis* and other pelecypods, locally abundant gastropods, and, rarely, fenestrate bryozoa. Representatives of this group are the Aspinwall limestone member of the Onaga shale, Falls City limestone, and Sallyards limestone member of the Grenola limestone, and the lower part of the Burr limestone member of the Grenola limestone, all in the northern outcrop area.

8. Silty shale or impure limestone with myalinids and rarely other pelecypods. This group includes the upper part of the Wamego shale member of the Zeandale limestone in southern Kansas, the Grayhorse lime-

stone member of the Wood Siding formation, and part of the Five Point limestone member of the Janesville shale in southern Kansas.

9. Limestone coquina commonly composed almost exclusively of *Permophorus* and rarely with few other pelecypods. This group is represented best by the upper beds of the Falls City limestone, Aspinwall limestone member of the Onaga shale, and Five Point limestone member of the Janesville shale in northern Kansas. Coarse-grained limestone units with a similar fauna are included. These are the Long Creek limestone member of the Foraker limestone, Howe limestone member of the Red Eagle limestone, and the lower bed of the Burr limestone member of the Grenola limestone north of Lyon County.

10. Calcareous sandstone with some small detrital fossil fragments, locally with abundant ostracode tests. This group is represented mainly by zones within a limestone bed, as in the Howe limestone member of the Red Eagle limestone, the upper part of the Burr limestone member of the Grenola limestone in northern Kansas, and locally in the Neva limestone member of the Grenola limestone. It is also represented by the calcarenite in the upper part of the Hamlin shale member of the Janesville shale.

11. Limestone composed chiefly of stromatolites. The Houchen Creek limestone bed of the Hamlin shale member of the Janesville shale in northern Kansas and southeastern Nebraska is composed entirely of stromatolites. This group is generally restricted to zones within a limestone bed, as in the Dover limestone member of the Stotler limestone, the upper bed of the Grandhaven limestone member of the Stotler limestone in Lyon County, the lowermost bed of the Americus limestone member of the Foraker limestone in the southern two-thirds of Kansas, and locally the Burr and Neva limestone members of the Grenola limestone.

12. Nonfossiliferous shale, sandy shale, and sandstone with coal beds and channel deposits. All the shale formations of the upper part of the Wabaunsee group (Pennsylvanian) and of the Admire group (lower Permian) are in this category.

13. Nonfossiliferous variegated shale with or without beds of impure clayey nonfossiliferous limestone. All the shaly formations of the lower part of the Council Grove group (Permian) and locally some of the other shale formations included in group 12 are in this group.

In addition to the formations and members listed above, there are some units which are commonly unfossiliferous. Where fossils do occur the beds may be classed with the types above. The Johnson shale and Salem Point shale members of Grenola limestone seem closely related to group 4.

Finally, there are some units that contain so few fossils that they cannot be fitted into the above classification (beds in the Hamlin shale member of the Janesville shale). Scattered collections from other units also do not fit readily into this scheme and all these have been classified as group 0.

While these groups are by no means invariable, the classification is believed to represent the best compromise at this time between treating almost every assemblage as different and considering the units only as brachiopod, pelecypod, and fusulinid beds. Groups 1 and 3, with abundant fusulinids, probably are only slightly different manifestations of the same general environment; group 2 might be considered in part as belonging to group 1, but with fewer fusulinids.

The change from fusulinid beds to group 4, with abundant brachiopods, is abrupt, but part of this abruptness may be a reflection of collecting, as an outcrop of shaly-weathering limestone would yield more megafossils compared to fusulinids than would more massive limestone with a similar fauna. Group 4 is what is commonly thought of when "collections of the midcontinent type" are mentioned. Undoubtedly many minor subdivisions of this group can be made according to the number of various fossils present. Detailed chemical analyses and microstratigraphic studies such as have been made of the Florena shale member of the Beattie limestone (Imbrie, 1955) may show close correlation of changes in faunules and certain changes in the lithology of the enclosing matrix.

Group 5, inarticulate brachiopods, and group 6, *Crurithyris* beds, probably are related. In the north half of the State, a common sequence in the Hughes Creek shale member of the Foraker limestone, Red Eagle limestone, and Neva limestone member of the Grenola limestone is, in ascending order, fusulinid limestone commonly with inarticulate-brachiopod fragments in the upper part, a thin bed of inarticulate brachiopods, a thin bed of *Crurithyris*, and a shale bed with a predominant brachiopod fauna (fig. 31). A change from marine to brackish conditions and back to more marine conditions through the *Crurithyris* beds is a plausible interpretation, although other interpretations are possible.

Myalinid-bearing beds, group 8, are rather abruptly separated from those of group 4, but certain collections from the Nebraska City limestone member of the Wood Siding formation present a real problem in deciding in which group they should be placed. The collections of group 8 are in turn rather sharply separated from the pectinoid beds of group 7, but again there are a few collections that are hard to assign to either group.

Ostracode coquina zones, group 10, and stromatolite-bearing limestone beds, group 11, are common. Since they do have considerable importance in certain intramember correlations, and since they are not readily included in the other groups, the rock types of groups 10 and 11 have been placed in separate categories. When more detailed faunal studies are made, it might be feasible to designate some limestone units (Dover and Grandhaven limestone members of the Stotler limestone) as group 2 at the base and group 11 at the top. Groups 12 and 13 although dissimilar lithologically may in part represent a somewhat similar environment.

In a general way, the groupings outlined correspond with those proposed by Elias (1937a). He did not study beds from the Tarkio limestone member of the Zeandale limestone to the Brownville limestone member of the Wood Siding formation, but did investigate up into the lower part of the Permian (Sumner group), which is stratigraphically considerably above the highest unit studied here. The two classifications are believed to correlate as follows: Groups 1, 2, and 3 probably correspond with Elias' group 7, fusulinid phase; group 4 with his 6, brachiopod phase, and his 5, mixed phase; groups 7 and 8, with his 4, molluscan phase; and group 5 with his 3, *Lingula* phase. Elias apparently did not recognize groups 6, 10, and 11 of the present classification. The beds listed as groups 12 and 13 correspond in part to Elias' 2, green shale phase, and 1, red shale phase.

PALEOGEOGRAPHIC CONSIDERATIONS

The number of fossils in the southern part of Kansas seems to increase greatly as compared to the more northern outcrops. This increase is chiefly in the number of brachiopods, although in some units (Five Point limestone member of the Janesville shale, for example) there is an increase in the number of pelecypods. In certain units fusulinids appear to be more abundant toward the south. Most productoids in particular increase markedly in number in the southern area, as in the upper part of the Johnson shale. On the other hand, *Marginifera* decreases in abundance southward. Most of the post-Pennsylvanian pelecypod-bearing beds, for example the Sallyards and Burr limestone members of the Grenola limestone, are more calcareous and contain more brachiopods. Other trends have been observed, but more collections are needed to test them.

The reasons for the increase in the number of brachiopods in the calcareous shaly units of southern Kansas are not known. Beds thin both north and south of this area. Several thick limestone beds pinch out just north of this area, and chert is abundant in the southern area and rare elsewhere. These facts suggest to the writers that the outcrop in southern Kansas turns markedly away from the former shoreline. Better circulation of water, more normal salinity, slightly greater depth, colder water with an increased food supply, and other intrinsic factors of the environment may provide a partial explanation.

It has long been known that many Recent benthonic animals vary in number from place to place. Moore (1936, p. 244) has noted the occurrence of fossils in clusters or "nests" in the Brownville limestone member of the Wood Siding formation. Differences between collections from the same unit may be only local, but some variations in collections from northern and central Kansas may be a reflection of regional differences in the former environment. Definite trends or patterns could have been developed and might still be reflected in slight changes in the faunal composition from locality to locality.

To test this hypothesis, collections from the Brownville limestone member of the Wood Siding formation were analyzed from the data on the occurrence chart. Articulate brachiopods comprise 75 percent or more of the faunule at each locality. As a graphic aid the articulate brachiopods in each collection were next plotted on bar graphs, with all those in each collection equal to 100 percent (fig. 33). The collecting localities were then marked on a map with percentages of certain brachiopods at each locality. Points of similar percentage were then contoured (fig. 34). An alternative, more generalized method of plotting similar data is shown for the Nebraska City limestone member of the Wood Siding formation (fig. 35).

Contours show a distinct prong extending southwestward across southern Pottawatomie and northern Wabaunsee Counties, even though the outcrop belt is relatively narrow. Lithologic data concerning the Grayhorse limestone member of the Wood Siding formation and, in part, the Aspinwall limestone member of the Onaga shale indicate that the area within the prong was an area of deeper water, a small trough trending eastward. In southern Jackson and Pottawatomie Counties the Grayhorse limestone member is present, but it is absent for a few miles south of the area and for at least 30 miles north of it.

If these lines circumscribe areas of similar faunal and lithologic environment, there may be significant economic implications in this technique. Contouring of several other units, unfortunately with fewer points, has shown that the same general trends persisted for longer than the time of deposition of the Brownville limestone member of the Wood Siding formation. Irregularities in the shoreline which these trends might

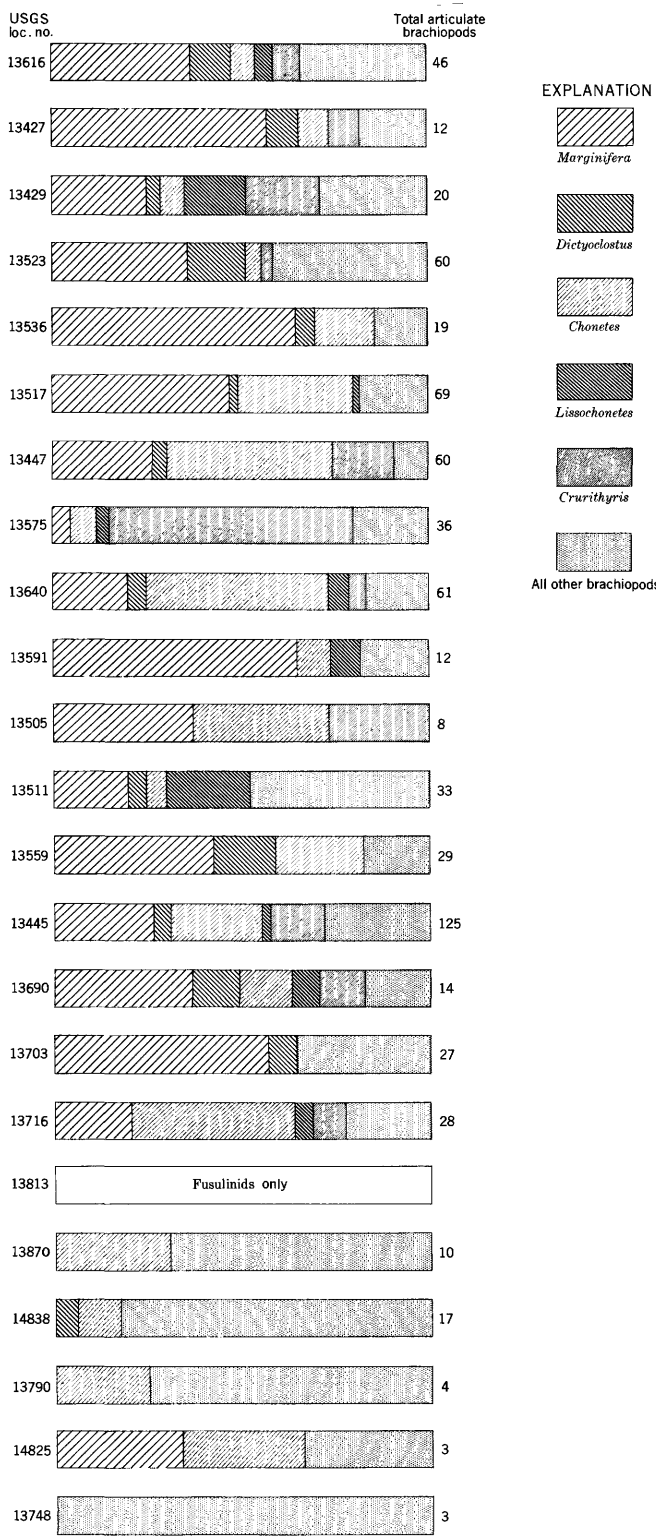

FIGURE 33.—Bar graphs showing percentage of brachiopods in collections from the Brownville limestone member of the Wood Siding formation.

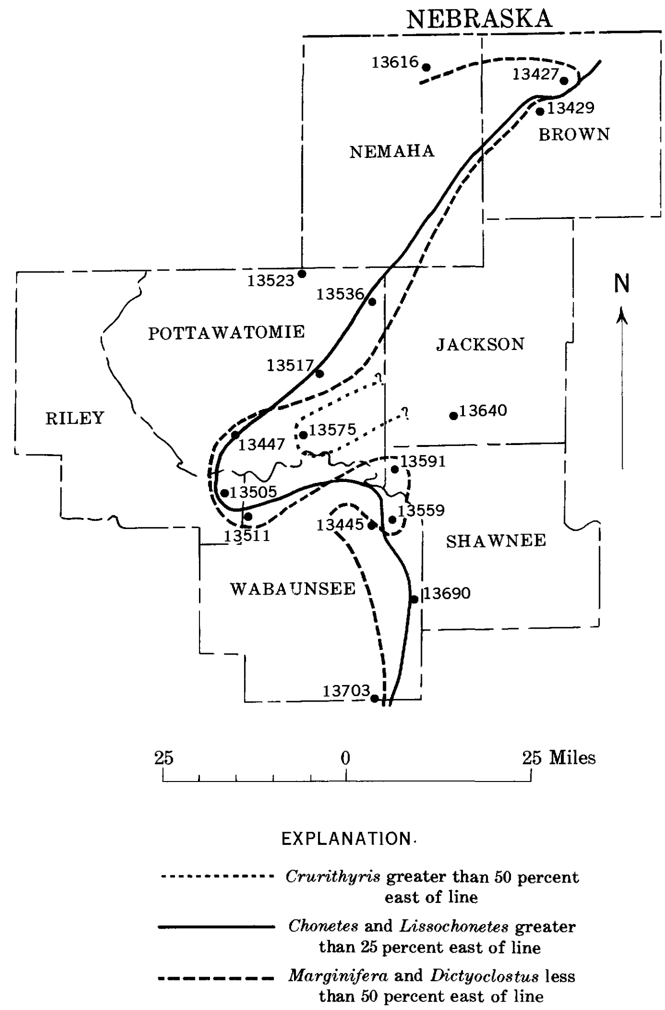

FIGURE 34.—Isograms showing proportions of brachiopods in collections from the Brownville limestone member of the Wood Siding formation in northeastern Kansas.

represent may very well have caused the formation of offshore bars. Oil production from buried offshore bars is known in southern Kansas (Bass, 1936), and there is no reason to assume that the same physiographic features would not have been formed in northern Kansas. Thus, this might be a relatively inexpensive method of outlining areas that warrant more detailed study. Further, so far as is known to the authors, no one has seriously investigated drilling shallow oil wells in Kansas directed at stratigraphic traps controlled by porosity and permeability changes, which might also be determined by this method.

This experiment is helpful in establishing some of the requirements needed for this type of mapping: Collections must be from a distinctive bed which cannot be readily confused with others in the stratigraphic section; the unit must be relatively fossiliferous; and the unit should contain few genera, which should be distinctive and easy to identify.

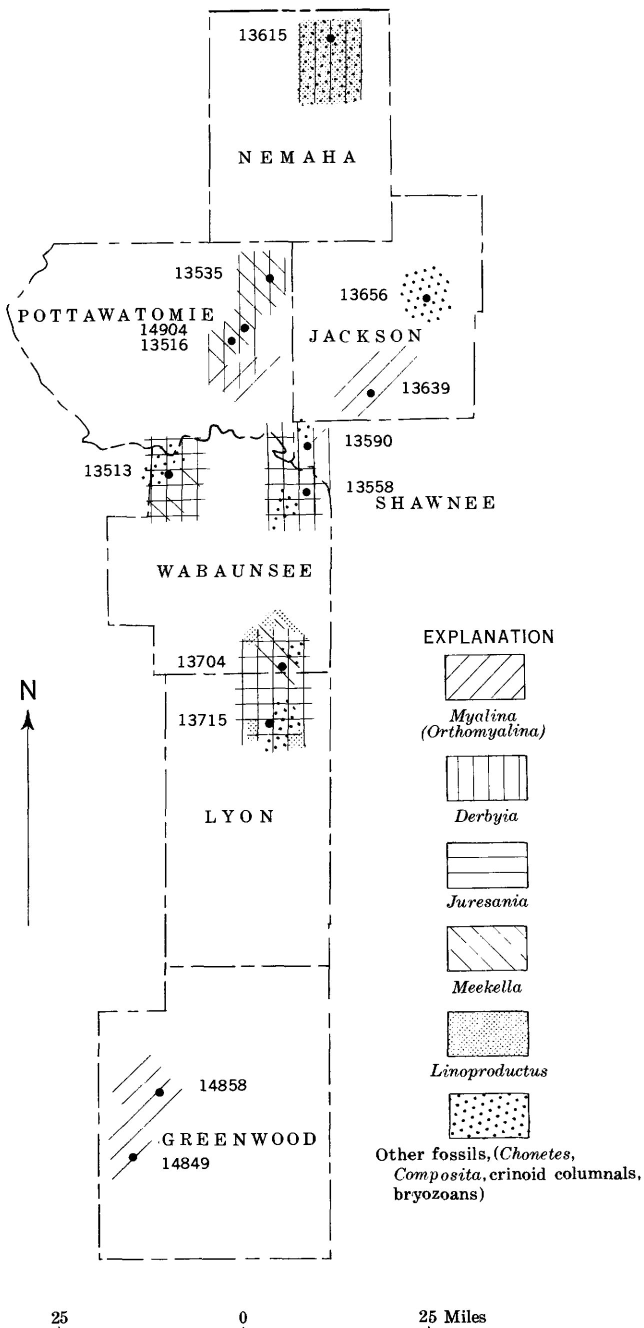

FIGURE 35.—Distribution of kinds of megafossils in the Nebraska City limestone member of the Wood Siding formation.

PHYSICAL ENVIRONMENT

Considerable petrographical and geochemical study ought to be done before even tentative conclusions regarding part of the environment are given. The comments below are general statements of our knowledge or opinions based on study of the fossils and observation in the field of the lithologic nature of the formations.

COMPOSITION OF SEA WATER

Rubey's (1951) investigation of the geologic history of sea water suggests that the carbon dioxide content and pH of the open sea throughout most of geologic time were essentially as they are today. So far as is known, nothing has been published on the salinity and other chemical features of the upper Paleozoic midcontinent seas. Miller and Youngquist (1949, p. 4) suggest that abnormal salinity of the former seas is the reason for scarcity of cephalopods in the area, but give no evidence.

TEMPERATURE

To date there is no generally accepted method for determining the average temperature of Paleozoic epicontinental seas[14] or even the temperature range, and for the present the importance of this factor cannot be analyzed with any satisfaction. In warm shallow water this may have been a factor of secondary importance.

BOTTOM

Hesse, Allee, and Schmidt (1951, p. 219) have divided marine bottoms into two general end types without naming or defining the transitional phases. These end members are rocky bottoms and soft bottoms or solid and loose substrata, respectively. There is nothing preserved in the sedimentary record of the interval studied to suggest a rocky bottom. Indeed, bottoms with a high percentage of sand must have been rare, as sediments of sand size are very rare in the outcrop. Undoubtedly most of the sediments, except bioclastic particles, were either clay-rich or calcium carbonate-rich mud, and as such presumably constituted a relatively soft bottom.

To estimate how soft this bottom was would require study of particle size, degree of sorting, mineralogic composition, and probable amount of interstitial water in the original sediments, which are factors outside the scope of this study.

The animals supply little evidence. Pelecypods that could have been burrowing forms are much more abundant in the calcareous shale than in the argillaceous beds. If *Pseudomonotis* cemented its right valve directly to the substratum rather than to harder particles in the bottom, this would suggest a firm bottom; more and better specimens than those collected should be studied from this point of view. By and large, however, the observation that many small brachiopods which must have been near or on the bottom (*Hustedia*,

[14] Since this was written the oxygen isotope method of temperature determination has been used for a few specimens of Paleozoic age (Lowenstam, H. A., 1959, O^{18}/O^{16} ratios and Sr and Mg contents of calcareous skeletons of recent and fossil brachiopods and their bearing on the history of the oceans: Internat. Oceanog. Cong. Preprints of abstracts of papers edited by Mary Sears, p. 71, 72, Am. Assoc. Adv. Sci.

Lissochonetes, *Wellerella*, and others) grew to maturity suggests that the bottom of the Kansas sea was firm insofar as required by the living habits of these small animals.

RATE OF SEDIMENTATION

Elias (1937a, p. 422–426) has noted that in the four most complete cycles he studied, the brachiopod and mixed phases combined averaged three and one-half times the thickness of the fusulinid phase. The brachiopod phases of the Hughes Creek shale member of the Foraker limestone which have many bored and incrusted shells must have been deposited slowly enough not to interfere with the incrusting and boring organisms.

AGITATION

In northern and central Kansas the Grayhorse limestone member of the Wood Siding formation and the Aspinwall limestone member of the Onaga shale are conglomeratic and contain pebbles of small size. Locally there are also conglomerate beds in the Glenrock limestone member of the Red Eagle limestone, the Neva limestone member of the Grenola limestone, and the Cottonwood limestone member of the Beattie limestone. Pelecypod coquina beds, in part associated with pebble conglomerate, have been found in the Aspinwall limestone member of the Onaga shale, Falls City limestone, and, locally, in the Five Point limestone member of the Janesville shale. Oriented fusulinids, which suggest wave or current action, were observed in some localities of the Tarkio limestone member of the Zeandale limestone and the Cottonwood limestone member of the Beattie limestone. These indications of agitated water are most common in northern Kansas. Graded bedding was not observed at any of the outcrops visited.

DEPTH

Elias (1937a) emphasized the view that depth was the single most important factor controlling distribution of organisms in the Pennsylvanian and Permian seas of Kansas. The writers agree that depth was a factor but suggest that it may have been relatively unimportant compared with other factors of the environment. Cyclic sedimentation is accepted as a prevailing pattern, but the assigning of depths to various phases of the cycle is viewed with misgiving.

Red shale units within the interval studied could have formed subaerially (Elias, 1937a, p. 426) or could have formed from red sediments deposited in the sea. Elias' comments regarding the formation of green shale in a zone of reduction below high tide are plausible. It is his remarks about depth of deposition of fossiliferous beds to which exception is taken.

Fusulinid limestone beds are in the center of the cyclothem as it is currently interpreted, and they necessarily form the keystone for any interpretation of depth. Elias gives the life zone of the fusulinids as from 150 to 180 feet because "it seems probable that the fusulinids lived at depths comparable to those inhabited by modern large benthonic Foraminifera" (Elias, 1937a, p. 418).

Since 1937, considerable information has been gathered about the life habits of the larger foraminifers. For example, Grimsdale (1952, p. 3) has noted that off Funafuti atoll, the genus *Cycloclypeus* occurs at depths of 180 to 1,200 feet and is most common from 240 to 600 feet. In the Marshall and Mariana Islands abundant *Heterostegina* and *Operculina*, probably life assemblages, live from near low-tide lines to at least 240 feet (Ruth Todd, oral communication). Other examples of wide bathymetric distribution of living genera are known.

If living genera of the Camerinidae cited above have such a wide bathymetric distribution, they cannot be used to infer the narrow depth range which Elias ascribed to the fusulinids. Evidence that the fusulinid limestone was deposited at shallow depth may be indicated by the occurrence of inarticulate-brachiopod fragments in the upper part of the limestone beds. Thompson (1927, p. 126) suggests that living linguloids are most common at depths of less than 100 feet. A ninety-foot depth, "below which most modern articulate or calcareous brachiopods live," was used by Elias (1937a, p. 425) to mark the upper limit of the brachiopod fauna in the early Permian seas. It seems pertinent to remark that the extant articulate brachiopods bear little more resemblance to the Paleozoic brachiopods than do the camerinids to the fusulinids.

Should the stromatolites found in many of the beds of limestone have lived in an environment similar to those observed by Rezak (p. 103) and recorded by Black (1933), then a relatively shallow depth may be inferred for fusulinids, since fusulinids and *Cryptozoon*(?) do occur in the same limestone bed (the Dover limestone member of the Stotler limestone). The occurrence of inarticulate-brachiopod fragments in the upper part of fusulinid limestone beds, noted previously, also suggests a shallow-water environment for these fusulinids.

Three biostromes have been discovered recently in the Permian of Kansas. The oldest of these is in the Bennett shale member of the Red Eagle limestone (O'Connor and Jewett, 1952, p. 341; O'Connor, 1953, p. 13; Mudge and Burton, 1959; this paper, p. 38). The other two biostromes are in the Funston limestone and the Threemile limestone member of the Wreford limestone (Mudge, Matthews, and Wells, 1958; Mudge and Burton, 1959). The maximum known thickness of each of these structures is 28 feet for the Bennett, 26 feet for the Funston, and 36 feet for the Threemile. Evidence does not indicate that any of these extended above low tide. If these banks were near the surface, this gives approximately 30 to 40 feet as an order of magnitude for the depth of the shallow sea in that area. The biostrome in the Funston does contain thin beds of conglomeratic material on its flanks, which may indicate erosion either by wave or strong current action.

Assuming that the seas were no deeper than 100 feet, there is no evidence available to show that any animal assemblage recognized was restricted to any particular depth below the littoral zone. The writers are convinced that, in this area, depth was not a significant factor in controlling distribution of the animals studied, and that Elias' (1937a) conclusions can not be confirmed by the available evidence.

CONCLUSIONS

From the foregoing discussion the following conclusions are drawn:

1. The upper Pennsylvanian and the lowermost Permian rocks (Admire group) differ from the rest of the Permian rocks studied in that the shale units contain sandstone beds, channel deposits, and coal and are generally gray to olive drab and more variable in thickness; and that the limestone beds are generally thinner and darker.
2. Deposits such as sandstone, sandy shale, variegated beds, and channel deposits are more noticeable and possibly more abundant in the central and northern outcrop areas. Beds of coal, however, are more abundant in the central and southern outcrop area.
3. The limestone units almost invariably thicken toward the south. Along with this thickening, fusulinids increase in quantity, and nodules and lenses of chert are generally present.
4. Some units change in facies from north to south. These four conclusions suggest that the ancient seas, at least part of the time, were deeper in the southern outcrop area.
5. Three principal associations of marine animals and sediments are found within the interval studied: abundant fusulinids in limestone and calcareous shale; rich, varied fauna abounding in brachiopods in calcareous shale and shaly-weathering limestone; and pelecypods in silty shale, argillaceous limestone, and siltstone.
6. Most of the individual faunules gave no evidence of transportation and may approximate biocoenoses.
7. With the possible exception of inarticulate brachiopods and certain assemblages of *Crurithyris*, the animals in the strata studied lived under essentially normal marine conditions for the geologic province.
8. All animals, except incrusting and boring forms, lived on a more or less firm mud bottom. The calcareous shale beds may represent an originally slightly looser bottom than the argillaceous limestone beds, as indicated by more burrowing pelecypods in the shale.
9. For the most part, the water was relatively quiet, and sediment was deposited slowly. Certain myalinid and pectenoid pelecypod assemblages, however, may have been overwhelmed by a rapid influx of mud.
10. None of the genera or species can be taken as indicating a precise depth, although inarticulate brachiopods may indicate water less than 30 feet deep. Depth may not have been an important factor in determining distribution of the various animals beyond the littoral zone.
11. Other intrinsic factors of the environment were important in determining distribution of the various animals. Attempts to formulate estimates of such factors as pH, salinity, and amount of organic matter are major omissions of this study. The marine conditions prevailing in Kansas may very well not have been those of an open sea.
12. When more is known about the environment of deposition and the paleoecology of the midcontinent area, a close relation between the relief of nearby land masses and the amount of sediment carried to the seas will probably be shown. The relation between the rock types and faunal assemblages of the midcontinent area, attributed by some individuals to rapid fluctuations of sea level, might be explained equally well by combinations of other physical and chemical factors. Cyclic sedimentation may be as much a reflection of changes on the land as of changes in sea level.

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PART 4. PLACEMENT OF THE PENNSYLVANIAN-PERMIAN BOUNDARY IN KANSAS

It is virtually impossible to discuss the Pennsylvanian-Permian boundary question without some repetition of the work of others. Discussion of the Permian strata in one area inevitably involves discussion of other areas. Rather than include innumerable references and quotations from the works of others, the writers have been brief in their presentation of the problem. Interested readers will find references to most of the voluminous literature treating of the Permian in North America in the references cited. The points noted below are not meant to be pedantic, but rather represent an effort to find logical, common ground and to show what has and has not been done by earlier workers.

Geologic periods.—A geologic period has been defined as "the fundamental unit of the standard geologic time scale, the time during which a standard system of rocks was formed" (Ashley and others, 1933, p. 429). Similarly a geologic system "contains the rocks formed during * * * a period" (Ashley and others, 1933, p. 445). Some of the implications of these mutually inclusive definitions have been discussed by Tomlinson and others (1940, p. 343–344) and will not be elaborated on here.

At present there appear to be at least two schools of thought among geologists regarding the nature of periods: that they are arbitrary divisions of time, and that they are natural divisions representing fundamental events in the earth's history. Exponents of the latter school suggest that systems are commonly separated by evidence of nearly worldwide, or at least widespread, diastrophism. Exponents of the former school hold that this periodicity of orogeny is unproved and probably is not so (Gilluly, 1949). Many geologists of both schools, however, agree that there are some places in the world where there is no pronounced orogenic disturbance between geologic systems. Most of the students of midcontinent geology, no matter what their personal beliefs regarding geologic periods, agree that the outcrop region of the Pennsylvanian and Permian rocks in Kansas is one area where there is no pronounced diastrophic break between rocks referred to these two systems.

Correlation of systems.—Almost all geologists have agreed in the last century that rocks in themselves are not diagnostic of their age. It is only the rare radioactive minerals or accumulations of fossils in the rocks that give some idea of absolute or relative age, respectively.

In spite of many earlier statements as to the value of diastrophism in correlation, it is our impression that most geologists who have expressed opinions on this subject in the last 25 years agree that at least in those areas of Paleozoic sedimentary rocks where there are no prominent diastrophic breaks in the geologic sequence, study of contained fossils gives the only presently workable method known for correlating these sediments with those of other distant areas.

PERMIAN SYSTEM

Most students of upper Paleozoic stratigraphy have some familiarity with the problem of what constitutes the base of the type Permian. Until at least 1937, there was no common agreement among Russian geologists as to where the base of the Permian system should be placed in Russia (Williams, 1938). There appears to have been considerable differences of opinion as to whether certain units contain important unconformities, and even disagreements as to which fossils are contained in each bed.

The Permian system in North America.—The U.S. Geological Survey currently divides the Permian into four provincial series: the Wolfcamp, at the base, followed by the Leonard, Guadalupe, and Ochoa. The provincial series are recognized only in western Texas and eastern New Mexico, but Wolfcamp equivalents in other States are considered to be of Permian age.

The base of the Permian system.—In 1939, the Central Geological and Prospecting Institute, the official geological agency in Russia, recommended that the Carboniferous-Permian boundary be placed at the top of the "*Schwagerina*" zone (Gorsky and others, 1939, p. 26). A subsequent conference on the Permian by Russian geologists has resulted in a downward revision of this boundary so that the Sakmarian stage, which includes the "*Schwagerina*" zone, is now considered lower Permian (Likharew, 1956, p. 804).

The American Association of Petroleum Geologists Subcommittee on the Permian (Tomlinson and others, 1940, p. 340) has made the following recommendation: "The zone of *Pseudoschwagerina* and *Properrinites* should be recognized as comprising the lowest part of the Permian System." Necessarily, one must then refer to presumed earlier published statements defining these two zones. Because of the language difficulty, Russian literature was not searched during the present study for definitions of this zone.

The zone of *Schwagerina* (=*Pseudoschwagerina*) has been discussed by Beede and Kniker (1924) in great detail. In faunal lists they mention the occurrence of other organisms in addition to the fusulinids. Although it was of great importance in influencing thinking about the Permian in the United States, this work now has only limited value, except for the part concerning fusulinids, because the authors could not illustrate the larger fossils listed. This paper and others devoted principally to fusulinids are discussed by Douglass (this paper, p. 55).

The American Association of Petroleum Geologists (Tomlinson and others, 1940, p. 340) states:

> Although the Wolfcamp fauna includes many genera that range up from the Pennsylvanian, it is characterized by the abrupt incursion of the fusuline genera *Schwagerina* s. s., *Pseudoschwagerina*, and *Paraschwagerina*, and by the presence of the ammonoid genus *Properrinites*, the brachiopod genus *Parakeyserlingina*, and other distinctive Permian genera.

The "other distinctive Permian genera" are not named.

Miller and Furnish (1940, p. 26) have discussed the zone of *Properrinites*, noting the occurrence of other associated ammonoids in various localities throughout the world. They do not mention other fossils, except to note that "the stratigraphic range of *Properrinites* is essentially the same as the fusulinid genera *Paraschwagerina*, *Pseudoschwagerina*, and *Schubertella*."

The definition of a zone should include, ideally, the mention of all the members of the fauna represented in the zone, together with their ranges. Generally, papers dealing with megafossils do not mention the Foraminifera, and vice versa. In addition to the 3 papers quoted above, only 2 others note several fossil groups as marking Permian age. Elias (1936, p. 694) compares the range of certain plants, fusulinids, and ammonoids in the northern midcontinent area. C. L. Cooper (1947, p. 267), in a chart showing Pennsylvanian and lower Permian faunal zones, shows correlation between the zones of *Callipteris* (a plant), *Perrinites* (a cephalopod), *Kellettina robusta* (an ostracode), and *Schwagerina* (a fusulinid).

Stratigraphic units considered to be of latest Pennsylvanian age have been assembled by Moore and others (1944). This correlation chart of the Pennsylvanian is of assistance in suggesting by inference what formations many geologists consider to be basal Permian.

PENNSYLVANIAN-PERMIAN BOUNDARY IN KANSAS

Two excellent summaries of the history of the placement of the Pennsylvanian-Permian boundary in Kansas have been given by Moore (1940, p. 298–305; 1949, p. 19–22), and it seems unnecessary to repeat this history in detail.

In both publications noted above, Moore has included a diagram showing the position of the boundary as given by each of the numerous writers on Kansas stratigraphy and Permian correlations. His 1940 diagram, redrawn, is reproduced here as figure 36. With the exception of Romer (1935), writers have tended to place the systemic boundary stratigraphically lower and lower since Beede and Kniker (1924) started the trend by placing the boundary at the base of the Neva limestone member of the Grenola limestone. Since 1940, all papers concerned with the subject have placed the systemic boundary just above the Brownville limestone member of the Wood Siding formation. Romer's comments have to do more with the placement of the boundary of the type Permian, and he reaches essentially the same correlations within the Upper Pennsylvanian and Wolfcamp equivalents as are commonly accepted by most workers today.

The majority of the papers on Kansas geology do not discuss the boundary, but simply accept the current literature as a basis for local work. The few more recent significant papers not noted previously are annotated below.

Schuchert (1928, p. 827), in accepting the base of the Neva as the systemic boundary, follows Beede and Kniker (1924) and White (1926). Schuchert comments that "As there *appears* to be no break in deposition with the Pennsylvanian below, the boundary with the Permian is an arbitrary one."

R. E. King (1931, p. 22), on the basis of his observations in west Texas and the published data on midcontinent fossils, suggests that "the *Uddenites* zone is of the age of the beds immediately below the Neva limestone." He further states that the Pennsylvanian-Permian "contact should actually be placed approximately at the Americus, with the first appearance of the Permian type of fusulinids."

Moore (1932, p. 89) suggested placement of the Pennsylvanian-Permian boundary in Kansas below the Americus limestone member of the Foraker limestone because:

> the most sharply defined changes from lithologic and paleontologic characters of the upper Pennsylvanian rocks to those distinctive of the lower Elmdale contain a profusion of fusulinids which differ from those of the upper Pennsylvanian horizons, and include the first appearance of *Pseudofusulina*.

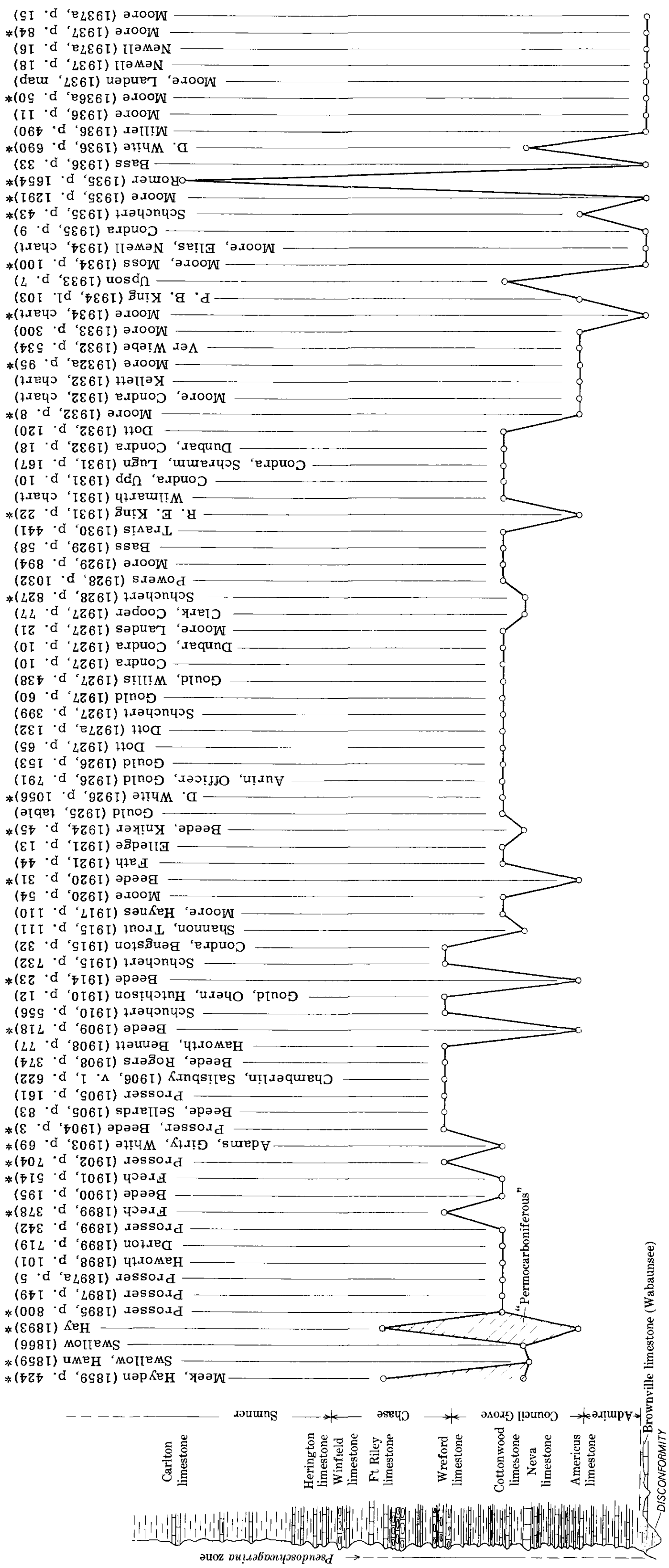

FIGURE 36.—Diagram showing placement of Carboniferous-Permian boundary in northern midcontinent region. This is only a representative indication, not an exhaustive survey of published usage. Citations marked by asterisk (*) are important because special consideration was given to the problem of stratigraphic classification. From Moore (1940, fig. 3, p. 300).

Schuchert (1935, p. 42–44), in a general summary of the Permian beds of the world, places the systemic boundary below the Americus limestone member of the Foraker limestone. He comments:

In view of this gradual faunal transition from the Pennsylvanian into the Permian of Kansas, unmarked by evidence of physical change, the line of division will have to be decided by a commission.

* * * * * * * * * *

A marked faunal change occurs at the base of the Elmdale member of the Wabaunsee group [essentially lower-half of Council Grove group] and here is found an abundance of *Triticites ventricosus* (a high Pennsylvania fusuline) and *Pseudofusulina longissimoidea.*

DIASTROPHIC EVIDENCE FOR PLACEMENT OF THE PERIOD BOUNDARY

The geology of Kansas has been studied for more than 100 years, and in that time there has been no report of a pronounced angular unconformity between beds presently classified as Pennsylvanian and those classified as Permian by the Kansas Geological Survey. Field study on which this report is based gave no evidence of anything but an essentially conformable relation between the strata.

Possible disconformity in this seemingly complete sequence at the base of the Admire group was noted by Moore and Moss (1934, p. 100) as "manifested by channel sandstones which cut out at least 100 feet of underlying formations." They state further that:

Since this disconformity is the only discovered evidence of interruption of sedimentation in this part of the geologic section, since it coincides in position with the line of separation of rather strikingly different lithologies that broadly characterize typical Wabaunsee (Upper Pennsylvanian) and Big Blue (Lower Permian) strata, and since there are distinctions in the fossils below and above the break, the disconformity is regarded as marking the most logical boundary in the northern mid-continent of rocks respectively classed as Pennsylvanian and as Permian.

Further discussion of this disconformity was not given by Moore and Moss, and the lack of elaboration on this point was one of the reasons that Mudge undertook the field investigations. His investigations have shown that there is not a single disconformity, but rather that during the time of deposition of the upper part of the Wabaunsee group and the lower part of the Admire group there were periods of channel erosion, deposition of sand sheets, and other abnormalities in the otherwise generally quiet sedimentation pattern (Mudge, 1956, p. 654-678; Mudge, 1957b; this paper, p. 19–21).

LITHOLOGIC EVIDENCE FOR PLACEMENT OF THE PERIOD BOUNDARY

Although the actual lithology of a formation or formations should have no bearing on its age, many geologists attempt to divide essentially homogeneous rock masses which contain fossils of several different ages. It should be noted also that unless one can prove worldwide diastrophism, or epeirogeny, changes in sedimentation are the reflection of changes in local conditions of deposition and not necessarily anything more. Nevertheless, it seems pertinent to include this information, particularly in view of the cyclic nature of the Kansas sediments.

Slight but consistent lithologic differences in the beds called Pennsylvanian and those called Permian have been noted for more than 50 years. Adams (Adams, Girty, and White, 1903, p. 70) remarked:

At the western border of this bed of shales the first limestone of the section appears. In traveling westward, and consequently in crossing the higher formations, which are exposed as a result of the westward dip, other limestone beds are found interstratified with the shales and sandstones at varying intervals. The texture of the limestones and their general appearance is far from being uniform, but they are all alike in becoming, on exposure to atmospheric agencies, more or less yellowish by reason of the oxidation of the iron contained in them. The limestones which are valuable for building purposes are largely marred in beauty by the yellowish tinge which they gradually assume, and occasionally beds which have been long exposed are even brown.

Higher in the section, in the country to the west along a line passing approximately through Grenola, Eureka, Emporia, and Manhattan, the limestones, which are interstratified with shales, are seen to be much whiter. The line of transition from the yellowish to the whiter rocks is approximately at the Americus limestone. The occurrence of limestones in hillsides and terraces is conspicuous because of their glaring color, which is in strong contrast with the vegetation at all times of the year. Along with this change in color there is a certain change in texture, which is not easy to define but which is so marked a feature that anyone familiar with the building stones of eastern Kansas would have little hesitancy in stating whether a building was constructed of limestone from this belt or the one to the east. The higher rocks are less crystalline and have a rougher fracture. Their jointing is also less pronounced, and the individual blocks are usually right-angled, while those of the lower limestones are more acute. The difference in texture has given rise to the term 'magnesian,' although they are not properly so called.

Further study has shown that the thin units of the Kansas section repeat themselves in definite cycles. Moore (1936) defined and discussed the cycles of the Kansas Pennsylvanian beds and has recently published an excellent summary of his opinions (Moore and others, 1951). Elias (1937a) has discussed, in somewhat less detail, cycles in the beds classified as Permian by the Kansas Geological Survey.

The Permian-type of cycle is described briefly on page 102 and is shown to differ from that of the Pennsylvanian. The Permian type of cycle begins locally at the Five Point limestone member of the Janesville shale, but it is first clearly developed at the level of the Americus limestone member of the Foraker limestone.

Moore (1932, p. 89) proposed moving the systemic boundary in Kansas downward from the Neva limestone member of the Grenola limestone to the base of the Americus limestone member of the Foraker limestone in part on the basis of lithologic criteria as quoted above. He states:

The Wabaunsee beds below the Americus (including Admire group of present nomenclature) consist of gray and brownish, clayey and sandy shales, thin blue and brown limestones, and at certain horizons, thin coal beds. Beginning with the Americus, the limestones of the Elmdale, Foraker, and higher formations are characteristically light bluish gray, weather to a so-called 'dry bone' color; shales are typically variegated blues, purples, reds and greens. Sandy beds are very inconspicuous and coals are absent.

PALEONTOLOGIC EVIDENCE FOR PLACEMENT OF THE PERIOD BOUNDARY

Available information on the stratigraphic distribution of the fossil groups in the upper Pennsylvanian and lower Permian beds is summarized in the following discussion. In addition to those fossils described in Part 2, brief notes are included on others. Because more emphasis has been placed on the fusulinids as indicators of time than on any of the other groups, they are treated more fully.

FUSULINIDAE

By RAYMOND C. DOUGLASS

ZONE OF PSEUDOSCHWAGERINA

Consideration of the Pennsylvanian-Permian boundary in Kansas must include an appraisal of the boundary in related areas. Where evidence for the boundary is based on fusulinids, it is common to refer to the zone of *Pseudoschwagerina*. The zone of *Pseudoschwagerina* has been commonly considered as representing the earliest Permian deposits in North America.

In order to understand what is meant by the zone of *Pseudoschwagerina* it might be well to restate the concept of the term "zone." A zone (faunizone) is a bed or group of beds characterized by an assemblage of organisms, one of which is chosen as an index (or name bearer) but which need not necessarily be either confined to its zone or found throughout every part of the zone (Muller and Schenck, 1943, p. 271). The zone of *Pseudoschwagerina* fits well within this concept but has never been clearly defined in the literature. The revisions of the nomenclature of the fusulinids involved in the zone have compounded the confusion.

Beede and Kniker (1924, p. 38, 39, and 52) were the first to discuss the stratigraphic relations of the zone of *Pseudoschwagerina* (*Schwagerina* of their terminology) in this country. They did not define the zone, but it is evident from the discussion that they considered it as being the zone in which *Pseudofusulina*[15] and *Paraschwagerina* and, in stratigraphically slightly higher beds, *Pseudoschwagerina* are associated. They point out that *Pseudofusulina* (*Fusulina* of Beede and Kniker) occurs in the Foraker limestone about 150 feet below the horizon of its first association with *Paraschwagerina* in the Neva limestone member of the Grenola limestone and about 300 feet below the horizon of *Pseudoschwagerina* in the Florence limestone member of the Barneston limestone. In drawing the lower boundary of the Permian, they choose the lowest occurrence of *Paraschwagerina* (*Schwagerina* of Beede and Kniker) and regard the top Elmdale shale of former usage (the base of the Neva limestone member of the Grenola limestone) as the base of the Permian.

Dunbar and Condra (1927, p. 125) in referring to the *Pseudoschwagerina* zone state:

It is characterized by the appearance of subcylindrical species with highly fluted septa referable to the genus *Fusulina* [now *Pseudofusulina*] which are shortly joined by gibbous shells of the genus *Schwagerina* [now *Paraschwagerina* and *Pseudoschwagerina*]. The zone is introduced by the appearance in Oklahoma and southern Kansas of the elongate species *F. longissimoidea* [now *Pseudofusulina longissimoidea*] ***."

It should be noted that use of this concept would include beds as low as the Foraker limestone within the zone.

Dunbar and Skinner (1937, p. 581) state:

The zone of *Pseudoschwagerina* has the most diversified fusuline faunas, including numerous species of *Triticites*, *Schwagerina* (sensu novo), [now *Pseudofusulina* and *Schwagerina* s.s.], *Paraschwagerina*, and *Pseudoschwagerina*. It is readily distinguished from the underlying Pennsylvanian beds, which include none of the above genera except *Triticites*, and from the overlying zone of *Parafusulina* where all the genera mentioned above disappear and diverse species of *Parafusulina* dominate the fauna.

At the time this definition was written it was intended that the Wolfcamp formation of western Texas and the zone of *Pseudoschwagerina* should be coincident. Now *Pseudofusulina* has been recognized in the *Uddenites* zone which underlies the type of Wolfcamp. *Pseudoschwagerina* is represented in the Leon-

[15] The genus *Pseudofusulina* is used in a restricted sense throughout this discussion. Its use is illustrated in the section describing the fusuline faunas.

ard formation of western Texas, which overlies the Wolfcamp (Dunbar, 1953).

Thompson (*in* Thompson, Wheeler, and Hazzard, 1946, p. 5–9) discusses the zone of *Pseudoschwagerina* and lists the characteristic fusulinids represented in many of the American localities. He notes that *Pseudoschwagerina* does not occur at the base of the Wolfcamp series of western Texas and southeastern New Mexico, and that:

the lowest fusulinid faunas known from the Wolfcampian rocks in Kansas, in north-central Texas, and in the type section of the Glass Mountains contain only forms of the fusulinid genus *Triticites*.

SUMMARY OF FUSULINID SUCCESSION IN KANSAS

The fusulinids of the Brownville through Americus interval in Kansas are described elsewhere in this paper (p. 55). A summary of the succession of fusulinid faunas of this report and from the literature will help in clarifying the Pennsylvanian-Permian boundary problem.

The succession of fusulinids in beds up to and including the Brownville limestone member of the Wood Siding formation in Kansas is accepted by specialists on the fusulinids as representative of the Pennsylvanian age. The Brownville limestone member contains species of *Triticites* associated with *Millerella* and smaller Foraminifera.

Though the beds in the middle and lower parts of the Admire group were examined and fossils were collected in detail, the first stratigraphic unit above the Brownville limestone member found to yield fusulinids is the Five Point limestone member of the Janesville shale. This unit bears an abundant fauna of fusulinids and small Foraminifera. In the basal beds of this unit the first representatives of *Pseudofusulina* were found. These are associated with species of *Millerella*, *Schubertella*, and *Triticites*.

The Americus limestone member of the Foraker limestone in Kansas contains species of *Triticites* associated with *Millerella* and small Foraminifera. No representatives of *Pseudofusulina* were found in the Kansas collections. King (1934, p. 696) indicates on a chart the occurrence in Kansas of *Pseudofusulina longissimoidea* in the Americus limestone member of the Foraker limestone. Dunbar (written communication, 1953) assures me that the occurrence mentioned by Dunbar and Condra (1927, p. 128), the probable source of King's information, is from the Hughes Creek shale member of the Foraker limestone and its equivalent in the Foraker limestone in Oklahoma, not the Americus limestone member.

Fusulina [now *Pseudofusulina*] *longissimoidea* Beede is reported by Beede (1916, p. 15), Beede and Kniker (1924, p. 39), and Dunbar and Condra (1927, p. 116) from what is now known as the Hughes Creek shale member of the Foraker limestone in Kansas and its equivalent in the Foraker limestone in Oklahoma. Similar forms are reported by Skinner (1931, p. 17, 18) from the Foraker limestone of Oklahoma. These are associated, in each case, with species of *Triticites*.

The stratigraphically earliest occurrence of *Paraschwagerina* in Kansas is in the Neva limestone member of the Grenola limestone at Hooser, Kans., and is described by Beede and Kniker (1924, p. 30). This is the only unit in Kansas from which the genus has been described. Beede and Kniker (1924, p. 39) mention another species of *Schwagerina* occurring in the Florence limestone member of the Barneston limestone, but this form is of the genus now called *Pseudoschwagerina*.

The form mentioned by Beede and Kniker, or similar forms, are described as *Pseudoschwagerina uddeni* (Beede and Kniker) and *P. texana* Dunbar and Skinner (1937, p. 658, 662) from the Florence limestone member northeast of Silverdale, Kans. Except for the occurrence mentioned by Thompson (1948, p. 24) and later questioned by him (Thompson, 1954, p. 15) this is the oldest described occurrence of *Pseudoschwagerina* in Kansas.

CONCLUSIONS

The zone of *Pseudoschwagerina*, which is a loosely defined zone, is commonly considered the basal unit of the Permian. The difference in opinion as to what constitutes the base of the zone has been partly responsible for the difference of opinion on the position of the lower Permian boundary.

Beede and Kniker (1924, p. 52) considered that the introduction of the "*Schwagerina*" fauna in the Neva limestone member of the Grenola limestone, with *Paraschwagerina kansasensis* (Beede and Kniker), marked the base of the Permian beds of Kansas. Dunbar and Condra (1927, p. 125) considered the zone introduced by the appearance in Oklahoma and southern Kansas of *Pseudofusulina longissimoidea* (Beede). Evidence presented elsewhere in this report (p. 59) indicates that the first occurrence of *Pseudofusulina* is in the Five Point limestone member of the Janesville shale of Kansas.

Examination of faunas from the type Wolfcamp of western Texas indicates that if the first occurrence of *Pseudofusulina* were considered as introducing the zone of *Pseudoschwagerina*, the lower boundary in western Texas would be placed below the *Uddenites* zone. If the first appearance of *Paraschwagerina* were used, the zone boundary would be raised to the base of bed 4 of King's type section (King, 1930, p. 54), and if the first appearance of *Pseudoschwagerina* were used, the base of the zone would be raised to bed 12 of the type section.

Available evidence does not indicate that a completely transitional sequence of fusulinid faunas is present in Kansas, but no major breaks in the evolutionary succession are indicated. This type of succession is not as easily split into periods of geologic time as one showing such breaks, but it is the kind on which the divisions will ultimately have to be based.

COELENTERATA

By Helen Duncan

With the exception of the dibunophyllids found in the Red Eagle limestone in the Permian part of the sequence, all the dissepimented corals identified in connection with this study came from rocks of Pennsylvanian age. Jeffords reported, however, that dibunophyllids occur in other limestone units of Permian age in the Kansas section (Jeffords, 1948a, p. 48). Consequently these corals furnish no reliable evidence for differentiating Pennsylvanian from Permian or for placing a systemic boundary.

No significant change occurred in the composition of the coral faunules during the time intervening between deposition of the Tarkio limestone member of the Zeandale limestone (Wabaunsee group) and the Florena shale member of the Beattie limestone (Council Grove group). Critical study would very likely show that some species in this sequence have fairly restricted ranges, but it seems unlikely that slight specific changes would furnish independent evidence for determining the Pennsylvanian-Permian boundary in this region. The coral fauna typical of the late part of the Pennsylvanian continues essentially unchanged into the early part of the Permian. Lophophyllid corals persist throughout the Permian in suitable facies. Clisiophyllids (including the dibunophyllids), as I interpret the family, seem to have disappeared at about the end of Sakmarian time of the European classification. In many parts of the world, rocks of Permian age are characterized by the appearance of *Waagenophyllum*, *Wentzelella*, and related lonsdaleoids. The Florence limestone member of the Barneston limestone (Chase group), about 200 feet stratigraphically above the Florena shale member of the Beattie limestone, is the oldest unit in the Kansas section that contains corals having affinities with strictly Permian genera. *Heritschia*, the genus that occurs in the Florence limestone member, is a primitive waagenophyllid. It might be possible to attribute some significance to the first occurrence of *Heritschia* because it is the forerunner of typical Permian corals. Even if this coral was assumed to be diagnostic of the Permian, however, it first appeared so late in Wolfcamp time that it would have little bearing on the discrimination of the Pennsylvanian-Permian boundary in Kansas unless that boundary was shifted to a high horizon in the Wolfcamp.

ECHINODERMATA

Of the five classes of echinoderms, the holothurians, asteroids, and ophiuroids are so rare in the Pennsylvanian and Permian of the United States that they will probably never be of much use in correlation. Of the remaining two classes, the echinoids are abundant in the Kansas section. They are represented, however, only by scattered spines and rare plates. A cursory examination of the specimens collected by Mudge and Yochelson suggests that all are of one general type. Several species of echinoids from Kansas have been named on the basis of isolated spines or plates (Jackson, 1912), but most of the types have been lost, and the type horizon cannot be located with any degree of certainty.

Crinoids, on the other hand, are quite diversified. In the last 15 years, quite a few new species from the upper Pennsylvanian and lower Permian beds of Kansas have been named. However, reasonably complete calyxes are uncommon; and this rarity limits their usefulness in correlation.

BRACHIOPODA

The brachiopods are the most abundant of the larger fossils collected in Kansas. Most collections consist of many representatives of few species and rare occurrences of other species. In proportion to the number of specimens collected, the brachiopods show less variety than the pelecypods.

So far as is known, none of the genera or species identified in the Kansas collections are considered by authors to be diagnostic of either Pennsylvanian or Permian age. The fauna appears to be more closely related to the Pennsylvanian, because specialized cemented brachiopods that characterize the Permian are absent. Reef environments which occur in the western Texas Permian appear to be missing from the Kansas section.

Examination of the determined ranges of brachiopods within the interval studied (table 6) show that 11 "new species" first occur in the Wamego shale member of the Zeandale limestone, 5 in the Dover limestone member of the Stotler limestone, 4 in the Brownville limestone member of the Wood Siding formation, and 7 in the Hughes Creek shale member of the Foraker limestone, the others being scattered throughout the other units. Seven species do not range above the Neva limestone member of the Grenola limestone, and 11 do not range above the Florena shale member of the Beattie limestone, the youngest stratigraphic unit studied. Nine species are confined to 1 member or formation, with 3 occurring in the Hughes Creek shale member of the Foraker limestone and 3 occurring in the Florena shale member of the Beattie limestone.

Extension of ranges downward to occurrences reported by Dunbar and Condra (1932, p. 28) shows that all except 12 species occur below the Tarkio limestone member of the Zeandale limestone; 6 of these were found at only 1 locality apiece. Only 4 of the brachiopods identified here were reported above the Florena shale member of the Beattie limestone by Dunbar and Condra (1932). Dunbar notes (oral communication) that relatively few specimens from beds above the Florena shale member were available for study in 1932. Field observations of some species strongly suggest that further collecting would extend the range of most species upward.

MOLLUSCA

Three of the classes of mollusks have some use as more or less detailed indicators of age in study of the Paleozoic. Chitons and scaphopods are so rare that they are of little use for correlation or for age determination, except within broad limits.

PELECYPODA

Twenty-two species of pelecypods have been identified in the Kansas collections. The most conspicuous feature of their ranges (table 6) in the interval studied is the first occurrence of 2 species in the Falls City limestone, and the unique occurrence of 2 other species in the same unit. Three other species do not range above the Falls City limestone. Occurrences in older beds are reported for one of the species "confined" to the Falls City limestone, and the other is reported from younger beds (Newell, 1942). Several other younger or older occurrences of the pelecypods have been recorded which serve to further confuse what little pattern there is to their ranges. The literature on late Paleozoic pelecypods is in a chaotic state, except for that of Mytilacea and Pectinacea, and reported identifications of species must be treated with some skepticism at the present time. It is very likely that most species range both above and below the stratigraphic units shown in the table.

GASTROPODA

Thirteen species of gastropods have been identified. *Omphalotrochus* might be a guide to the Permian if the *Uddenites* zone of western Texas is considered Permian (Yochelson, 1954, p. 234). The *Glabrocingulum* species is similar to those occurring near the supposed period boundary in New Mexico and north-central Texas. *Hypselentoma*, a poorly known genus, has not been reported from the Permian nor have *Bellerophon singularis* or *B. graphicus*. The ranges of the gastropods do not form a clear pattern.

CEPHALOPODA

By MACKENZIE GORDON, JR.

The specimens identified are assigned to 7 genera, 2 of them straight nautiloids, 2 of them coiled nautiloids, and the remaining 3 ammonoids. With the possible exception of *Gonioloboceras*, all are long-ranging genera, of little or no help with a boundary problem. *Pseudorthoceras knoxense* (McChesney), for example, is said to range from the lower part of the Pennsylvanian to the middle part of the Permian. *Tainoceras nebrascense* Miller, Dunbar, and Condra is reported to characterize the Wabaunsee group and lower units of the Council Grove group. It is fairly common in the Hughes Creek shale member of the Foraker limestone, and the type came from the Fort Riley limestone member of the Barneston limestone (Miller, Dunbar, and Condra, 1933, p. 151–154).

Perhaps the best correlated faunule is that of the collection from USGS loc. 14783 from the Grandhaven limestone member of the Stotler limestone. The species *Gonioloboceras goniolobum* (Meek) and *Imitoceras grahamense* (Plummer and Scott) occur together also in Plummer and Moore's (1921) Finis shale member of the Graham formation of north-central Texas, where they are associated with *Uddenites*. The *Uddenites* zone is currently included in the Pennsylvanian, although there are some paleontologists who would like to see it put in the Permian.

Gonioloboceras goniolobum occurs also in the Graford formation, 850 feet stratigraphically below the Finis shale, according to Miller and Downs (1950, p. 188). *Gonioloboceras goniolobum* was collected also in Westerville and Rayton (?) limestone of the Kansas City group at Kansas City, Mo., and at Kansas City, Kans., and at the top of the Raytown of the Iola limestone at Iola, Kans., according to Elias (1938, p. 98, 99). It has been reported also from the Drum limestone of Kansas and Missouri by Sayre (1930, p. 157). The presence of *Gonioloboceras*, identified in the Grandhaven limestone member of the Stotler limestone only on the basis of young specimens and hence subject to confirmation by the discovery of adult specimens, is generally taken to indicate Pennsylvanian age.

TABLE 6.—*Range of brachiopods, pelecypods, and gastropods identified in collections from units from the Tarkio limestone member of the Zeandale limestone to the Florena shale member of the Beattie limestone*

[X, range established in stratigraphic interval studied; O, probable extension of range into younger or older beds]

Formation	Reported or observed in older beds	Zeandale limestone			Pillsbury shale	Stotler limestone			Root shale			Wood Siding formation					Onaga shale			Falls City limestone	Janesville shale			Foraker limestone			Johnson shale	Red Eagle limestone			Roca shale	Grenola limestone					Eskridge shale	Beattie limestone		Reported or observed in younger beds
Member		Tarkio Limestone	Wamego shale	Maple Hill limestone		Dover limestone	Dry shale	Grandhaven limestone	Friedrich shale	Jim Creek limestone	French Creek shale	Nebraska City limestone	Plumb shale	Grayhorse limestone	Pony Creek limestone	Brownville limestone	Towle shale	Aspinwall limestone	Hawxby shale		West Branch shale	Five Point limestone	Hamlin shale	Americus limestone	Hughes Creek shale	Long Creek limestone		Glenrock limestone	Bennett shale	Howe limestone		Sallyards limestone	Legion shale	Burr limestone	Salem Point shale	Neva limestone		Cottonwood limestone	Florena shale	
Naticopsis subovata Worthen	O	X																																						
Araeonema sp.	O	X																																						
Permophorus sp. 2		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																		
Composita subtilita (Hall)	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O
Allorisma terminale Hall	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Euphemites sp.			X																																					
Bellerophon singularis Moore	O	O	X																																					
Bellerophon cf. *B. graphicus* Moore	O	O	X																																					
Knightites (*Retispira*) *tenuilineata* (Gurley)	O	O	X	X	X	X	X																																	
Volsellina subelliptica (Meek)	O	O	X	X	X	X	X																																	
Echinoconchus moorei Dunbar and Condra	O	O	X	X	X	X	X	X	X																															
Knightites (*Retispira*) sp.			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																				
Glabrocingulum sp.			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																				
Punctospirifer kentuckensis (Shumard)	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																		
Enteletes hemiplicatus (Hall)	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																		
Myalina (*Orthomyalina*) *subquadrata* (Shumard)	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																
Linoproductus prattenianus (Norwood and Pratten)	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X															
Wellerella osagensis (Swallow)	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X											
Neospirifer dunbari R. H. King	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Marginifera wabashensis (Norwood and Pratten)	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Derbyia crassa (Meek and Hayden)	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Schizodus cf. *S. wheeleri* (Swallow)	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Chonetes granulifer Owen	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O
Dictyoclostus huecoensis (R. E. King)	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O
Amphiscapha muricata (Knight)			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Phymatopleura aff. *P. brazoensis* (Shumard)					X	X	X	X	X	X	X	X																												
Lissochonetes geronticus Dunbar and Condra	O	O	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
"*Marginifera*" *lasallensis* (Worthen)	O	O	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Hustedia mormoni (Marcou)	O	O	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Meekella striatocostata (Cox)	O	O	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O
Crurithyris expansa (Dunbar and Condra)					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Aviculopecten arctisulcatus Newell	O	O	O	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Septimyalina cf. *S. perattenuata* (Meek and Hayden)	O	O	O	O	O	O		X																																
Anthraconeilopsis kansana Tasch								X																																
Juresania nebrascensis (Owen)	O	O	O	O	O	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O
Hypselentoma perhumerosa (Meek)	O	O	O	O	O	O	O	O	X																															
Edmondia nebrascensis (Geinitz)									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Septimyalina burmai Newell									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O
?*Juresania* sp. 2												X																												
Aviculopecten nodocostata Newell												X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Cancrinella boonensis (Swallow)	O	O	O	O	O	O	O	O	O	O	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Septimyalina scitula Newell	O	O	O	O	O	O	O	O	O	O	O	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
Juresania sp. 1																X																								
Rhipidomella carbonaria (Swallow)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X											
Linoproductus magnispinus Dunbar and Condra																X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			

Dielasma bovidens (Morton)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	--
Clavicosta sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Permophorus sp. 1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
?*Lindstroemella* sp. indet.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pteria cf. *P. longa* (Geinitz)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Promytilus vetulus Newell	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Pseudomonotis cf. *P. hawni* (Meek and Hayden	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	O	O
Permophorus subcostatus (Meek and Worthen	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	--	--	--	--	--
Orbiculoidea missouriensis (Shumard)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	--	--	--
Lingula carbonaria Shumard	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Yoldia subscitula (Meek and Hayden)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	--
Aviculopinna peracuta (Shumard)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Petrocrania modesta (White and St. John)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	--
Leptalosia ovalis Dunbar and Condra	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	--
Neospirifer cf. *N. kansasensis* (Shumard)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	X	X	X	X	X	X	X	X	X	X	X	X	O	O	O	O
Derbyia wabaunseensis Dunbar and Condra	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	--
Wellerella truncata Dunbar and Condra	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Wellerella cf. *W. delicatula* Dunbar and Condra	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Marginifera histricula Dunbar and Condra	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Schizodus sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--
Orbiculoidea cf. *O. tenuilineata* (Meek and Hayden)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	O	O	O	O	O	O	O	O	O	O	O	O	O
Omphalotrochus sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	X	X	X	X	X	X	X	--	--	--	--
Derbyia cymbula Hall and Clarke	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	O
Wellerella cooperi Yochelson, n. sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--
Derbyia cf. *D. hooserensis* Dunbar and Condra	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--
Omphalotrochus obtusispira (Shumard)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--
Anthraconeilo sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	X	--

The only diagnostic Permian forms that have as yet been reported from Kansas are *Artinskia whortani* Miller (1936, p. 490–496) from the Florena shale member of the Beattie limestone, 300 feet east of the Cowley County line and *Properrinites plummeri* Elias (1938, p. 101–105) from the uppermost layer of the Neva limestone member of the Grenola limestone, east of Beaumont, Kans.

On the basis of the known cephalopods, one would expect to see the Pennsylvanian-Permian boundary placed somewhere between the Grandhaven limestone member of the Stotler limestone below and the Florena shale member of the Beattie limestone above. Actually, however, the scarcity of cephalopods and particularly of diagnostic genera and species precludes their use in any more than a general way for placing a hypothetical Pennsylvanian-Permian boundary.

OTHER FOSSIL GROUPS

In addition to those forms mentioned, other groups of fossils occur in Kansas. For reasons previously noted, these groups were not studied. A brief summary of the importance of these groups in relation to the boundary problem is given below.

Bryozoans might be one of the more significant groups in regard to stratigraphic studies in Kansas because they are varied and in some places are abundant. However, the group has been neglected by most workers, and literature on the upper Paleozoic, with few exceptions, is scattered. The only papers treating of this group in the stratigraphic interval studied in Kansas are those of Elias (1937a) and Moore and Dudley (1944), and neither paper gives statements on the placement of the boundary that are applicable to this study.

The arthropods, particularly the ostracodes, are an abundant group. Due to the work of Kellett (1933, 1934, 1935), the late Pennsylvanian and early Permian ostracode faunas of Kansas are some of the best known in the Paleozoic. Kellett (1933, p. 61) remarked:

> The ostracodes show practically no evidence of a faunal break between the Americus limestone and the higher Neva or Cottonwood limestones.*** There is perhaps a little more evidence for a change in the ostracode fauna coming at the base of the Americus limestone, but the transition from the forms of the Shawnee group to the typical Permian fauna is gradual.

Kellett (1943, p. 620) listed the Admire group as the base of the Permian in a chart of Permian ostracode occurrences. She also stated:

> The lower Permian beds of Kansas and Nebraska carry many diagnostic ostracodes, 38 of the 62 species being known only in the Permian. The basal Permian is marked by 15 species which appear below the Grenola formation, many of which also occur above the Grenola.

Mrs. Nadeau (Miss Kellett) has clarified her position with the following statement (written communication, 1954):

> When I started writing on the ostracodes, the top of the Permian was taken as the Neva limestone (or now called Grenola) and the idea that it should be placed lower was just being discussed seriously for the first time, so I was more interested in showing that the Americus-Neva ostracodes were probably little different from those above, and that the base of the Permian should be dropped as low as the base of the Americus, rather than just where it should be dropped. Also at the time it was fashionable to place major divisions at the base of limestones where they could (at least locally) be easily followed.

Conodonts have been reported from some of the beds in the interval examined (Ellison, 1941). Relatively few occurrences are recorded, and unfortunately no systematic study has been undertaken. As with other groups, until such study is made it is impossible to guess what importance the group has in the placement of the boundary. Vertebrate remains are also known, but they are exceedingly rare compared to all other groups of fossil animals.

Johnson (1946) has recently published a comprehensive survey of the late Pennsylvanian and early Permian algae of Kansas. *Ottonsia* Twenhofel from the Crouse limestone, which is approximately 75 feet stratigraphically above the Florena shale member of the Beattie limestone, is the only genus reported by him as restricted to beds now classified as Permian by the Kansas Geological Survey. Johnson (oral communication, 1954) remarks that study of upper Carboniferous algae has not progressed to the point of assigning them as index fossils for systems.

Much of the stratigraphic information derived from study of higher plants in the midcontinent area is the work of the late David White. Moore (1940, p. 302) quotes White as suggesting that beds as old as the Elmdale shale of former usage in Oklahoma might be Permian in age. White's last published opinion (1936) notes the Americus limestone member of the Foraker limestone as Permian in age but suggests a somewhat lower boundary based on diastrophism. Discovery of a flora with some Permian affinities low in the upper Pennsylvanian rocks of Kansas (Moore, Elias, and Newell, 1936) demonstrates the difficulty in using only plant remains to draw precise systemic boundaries.

Elias (1936, p. 693) states that Moore's (1936b) Carlton limestone member of the Wellington formation of the Sumner group contains abundant *Callip-*

teris, typically *C. conferta*, but that that genus is not found below the Americus limestone member. *Callipteris* has been considered as typically Permian (Jongmans, 1928, p. XXVII).

CONCLUSIONS

1. As there is no clear agreement as to what constitutes the Permian, especially in regard to definition on the basis of fossils, any boundary established in Kansas must be regarded as tentative and subject to change when more is known of the type area in Russia or of the standard sequence for North America.

2. During the last century, the position of the Pennsylvanian-Permian boundary in Kansas has been changed several times, and most authors suggested placing it lower and lower in the stratigraphic column.

3. The placement of the boundary in the earlier work was based on fossils. The more recent placement of the boundary has been based on lithology and on suggested disconformity in the record.

4. There is a characteristic lithology and cycle of sedimentation in beds up through the Brownville limestone member of the Wood Siding formation; there is a different lithologic cycle starting at the Americus limestone member of the Foraker limestone. Disconformity between the two types of deposits indicates that beds at least as old as the Dover limestone member of the Stotler limestone and as young as the Five Point limestone member of the Janesville shale were deposited when local conditions favored channeling or sheet-sand deposition.

5. Certain rare fossils occurring near the top and base of the sequence can be correlated readily to the standard sequence of the western Texas area. Most fossil groups continue through the interval with little change. Further studies of fossils from other areas may result in refinement in species concept and may show the Kansas fossils to be more diagnostic than currently considered.

There is apparently no faunal evidence for placing the systemic boundary at the top of the Brownville limestone member of the Wood Siding formation, but since this boundary is commonly accepted by workers in the midcontinent, is used on the geologic maps of Kansas and Oklahoma and the Pennsylvanian correlation chart, and is used by the State surveys of Iowa, Kansas, Missouri, Nebraska, and Oklahoma, it may as well be continued as the boundary. The writers of this report wish to emphasize what little actual evidence there is, however, for placing the boundary at any one place in this general conformable sequence.

REGISTER OF LOCALITIES

The numbers assigned below to the collections are permanent localities listed in the "blue" catalog of the Upper Paleozoic section, Paleontology and Stratigraphy Branch, U. S. Geological Survey.

[All localities are in Kansas except 14929 through 14937, which are in Nebraska. See p. 138–139 for sections described herein.]

USGS loc. no.	*Description*
13427	Streambank, NE¼NE¼ sec. 6, T. 2 S., R. 17 E., Brown County; strat. sec. 7; Wood Siding formation, Brownville limestone member.
13428	Streambank and road cut, SW¼NW¼ sec. 23, T. 2 S., R. 16 E., Brown County; strat. sec. 73; Falls City limestone, lower part.
13429	Streambank and road cut, SW¼NW¼ sec. 23, T. 2 S., R. 16 E., Brown County; strat. sec. 73; Wood Siding formation, Brownville limestone member.
13430	Road cut, SW¼NW¼NW¼ sec. 23, T. 2 S., R. 16 E., Brown County; Falls City limestone, upper part.
13432	Streambank, NE¼NW¼ sec. 31, T. 1 S., R. 16 E., Brown County; strat. sec. 306; Foraker limestone, Hughes Creek shale member, lower part of unit 1.
13433	Same locality and section as 13432; Foraker limestone, Hughes Creek shale member, upper part of unit 1.
13434	Same locality and section as 13432; Foraker limestone, Hughes Creek shale member, lower part of unit 3.
13435	Same locality and section as 13432; Foraker limestone, Hughes Creek shale member, middle of unit 3.
13436	Same locality and section as 13432; Foraker limestone, Hughes Creek shale member, upper part of unit 3.
13437	Same locality and section as 13432; Foraker limestone, Hughes Creek shale member, units 5 and 6.
13438	Road cut, NE¼NE¼ sec. 27, T. 11 S., R. 13 E., Wabaunsee County; strat. sec. 228; Zeandale limestone, Tarkio limestone member.
13439	Road cut, Kansas Highway 10, SW¼SE¼ sec. 27, T. 11 S., R. 13 E., Wabaunsee County; Zeandale limestone, Maple Hill limestone member.
13440	Road cut, Kansas Highway 10, SW¼SW¼ sec. 28, T. 11 S., R. 13 E., Wabaunsee County; strat. sec. 1; Pillsbury shale.
13441	Same locality and section as 13440; Stotler limestone, Dover limestone member, lower limestone.
13442	Same locality and section as 13440; Stotler limestone, Dover limestone member, upper limestone.
13443	Road cut, Kansas Highway 10, SE¼SW¼ sec. 30, T. 11 S., R. 13 E., Wabaunsee County; strat. sec. 77; Stotler limestone, Grandhaven limestone member. (Section given in Mudge and Burton, 1959, section 69, p. 198.)
13444	Road cut, Kansas Highway 10, SW¼SW¼ sec. 28, T. 11 S., R. 12 E., Wabaunsee County; strat. sec. 169; Wood Siding formation, Pony Creek shale member. (Section given in Mudge and Burton, 1959, section 55, p. 185.)
13445	Same locality and section as 13444; Wood Siding formation, Brownville limestone member.
13446	Streambank, NW¼NW¼ sec. 16, T. 9 S., R. 9 E., Pottawatomie County; strat. sec. 94; Wood Siding formation, Grayhorse limestone member.
13447	Same locality and section as 13446; Wood Siding formation, Brownville limestone member.

USGS loc. no.	*Description*
13448	Streambank, NW¼NW¼ sec. 17, T. 9 S., R. 9 E., Pottawatomie County; strat. sec. 229; Foraker limestone, Americus limestone member, shale between upper and lower limestone beds.
13449	Same locality and section as 13448; Foraker limestone, Americus limestone member, upper limestone.
13450	Same locality and section as 13448; Foraker limestone, Hughes Creek shale member, unit 1.
13451	Streambank, NE¼NW¼ sec. 3, T. 8 S., R. 9 E., Pottawatomie County; strat. sec. 128, Foraker limestone, Hughes Creek shale member, lower shale of unit 1.
13452	Same locality and section as 13451; Foraker limestone, Hughes Creek shale member, limestone of unit 1.
13453	Same locality and section as 13451; Foraker limestone, Hughes Creek shale member, upper shale of unit 1.
13454	Same locality and section as 13451; Foraker limestone, Hughes Creek shale member, unit 2.
13455	Same locality and section as 13451; Foraker limestone, Hughes Creek shale member, unit 2.
13456	Same locality and section as 13451; Foraker limestone, Hughes Creek shale member, unit 2.
13457	Same locality and section as 13451; Foraker limestone, Hughes Creek shale member, unit 3.
13458	Same locality and section as 13451; Foraker limestone, Hughes Creek shale member, unit 4.
13459	Same locality and section as 13451; Foraker limestone, Hughes Creek shale member, unit 4.
13460	Same locality and section as 13451; Foraker limestone, Hughes Creek shale member, unit 4.
13461	Same locality and section as 13451; Foraker limestone, Hughes Creek shale member, lower zone of unit 5.
13462	Same locality and section as 13451; Foraker limestone, Hughes Creek shale member, upper zone of unit 5.
13463	Same locality and section as 13451; Foraker limestone, Hughes Creek shale member, unit 5.
13464	Same locality and section as 13451; Red Eagle limestone, Glenrock limestone member.
13465	Same locality and section as 13451; Red Eagle limestone, Bennett shale member.
13466	Same locality and section as 13451; Red Eagle limestone, Howe limestone member.
13467	Same locality and section as 13451; Grenola limestone, Burr limestone member.
13468	Same locality and section as 13451; Grenola limestone, Neva limestone member, unit 2.
13469	Same locality and section as 13451; Grenola limestone, Neva limestone member, unit 5.
13470	Roadside ditch, NW¼NW¼ sec. 9, T. 8 S., R. 10 E., Pottawatomie County; strat. sec. 231; Janesville shale, Hamlin shale member.
13471	Road cut, NW¼NW¼ sec. 9, T. 8 S., R. 10 E., Pottawatomie County; strat. sec. 231; Foraker limestone, Americus limestone member, shale between upper and lower limestone.
13472	Roadside, NE¼NW¼ sec. 10, T. 8 S., R. 10 E., Pottawatomie County; strat. sec. 232; Janesville shale, West Branch shale member.
13473	Same locality and section as 13472; Janesville shale, Five Point limestone member, shale below massive 1.8-ft limestone bed.
13474	Same locality and section as 13472; Janesville shale, Five Point limestone member, massive 1.8-ft limestone bed.
13475	Road cut, SW¼SW¼ sec. 2, T. 8 S., R. 10 E., Pottawatomie County; strat. sec. 233; Falls City limestone, middle limestone.
13476	Same locality and section as 13475; Falls City limestone, shale below upper limestone.
13478	Railroad cut, SW¼SE¼SE¼ sec. 7, T. 10 S., R. 8 E., Riley County; strat. sec. 235; Foraker limestone, Hughes Creek shale member, unit 1.
13480	Same locality and section as 13478; Foraker limestone, Hughes Creek shale member, unit 2.
13481	Same locality and section as 13478; Foraker limestone, Hughes Creek shale member, unit 2.
13482	Same locality and section as 13478; Foraker limestone, Hughes Creek shale member, unit 2.
13483	Road cut, SW¼SE¼SE¼ sec. 7, T. 10 S., R. 8 E., Riley County; strat. sec. 235; Foraker limestone, Hughes Creek shale member, unit 2.
13484	Same locality and section as 13483; Foraker limestone, Hughes Creek shale member, unit 3.
13485	Same locality and section as 13483; Foraker limestone, Hughes Creek shale member, unit 4.
13486	Same locality and section as 13483; Foraker limestone, Hughes Creek shale member, lower part of unit 6.
13487	Same locality and section as 13483; Foraker limestone, Hughes Creek shale member, middle part of unit 6.
13488	Same locality and section as 13483; Red Eagle limestone, Glenrock limestone member.
13489	Same locality and section as 13483; Red Eagle limestone, Bennett shale member, lower shale.
13490	Same locality and section as 13483; Red Eagle limestone, Bennett shale member, middle limestone.
13491	Same locality and section as 13483; Red Eagle limestone, Howe limestone member.
13492	Streambank, NE¼NW¼ sec. 20, T. 10 S., R. 8 E., Riley County; strat. sec. 225; Foraker limestone, Americus limestone member, lower limestone.
13494	Same locality and section as 13492; Foraker limestone, Americus limestone member, upper limestone.
13495	Old quarry on hilltop, center SW¼ sec. 30, T. 10 S., R. 9 E., Riley County; strat. sec. 212; Janesville shale, Five Point limestone member.
13496	Pillsbury's Crossing, NE¼NW¼ sec. 5, T. 11 S., R. 9 E., Riley County; strat. sec. 237; Zeandale limestone, Tarkio limestone member, lower limestone.
13497	Same locality and section as 13496; Zeandale limestone, Tarkio limestone member, shale between upper and lower limestone.
13498	Same locality and section as 13496; Zeandale limestone, Tarkio limestone member, upper limestone.
13499	Quarry, SW¼SE¼ sec. 33, T. 13 S., R. 11 E., Wabaunsee County; Beattie limestone, Cottonwood limestone member.
13500	Same locality as 13499; Beattie limestone, Florena shale member.
13501	Pasture gully, SW¼SE¼ sec. 28, T. 10 S., R. 9 E., Riley County; strat. sec. 216; Stotler limestone, Dover limestone member.
13502	Same locality and section as 13501; Stotler limestone, Dry shale member, limestone lens in shale.

USGS loc. no.	Description
13503	Same locality and section as 13501; Stotler limestone, Grandhaven limestone member.
13504	Roadside, SW¼NW¼NW¼ sec. 27, T. 10 S., R. 9 E., Riley County; strat. sec. 211; Zeandale limestone, Maple Hill limestone member.
13505	Pasture gully, NW¼NE¼ sec. 31, T. 10 S., R. 9 E., Riley County; strat. sec. 222; Wood Siding formation, Brownville limestone member.
13506	Same locality and section as 13505; Onaga shale, Aspinwall limestone member.
13507	SW¼SE¼NW¼ sec. 9, T. 11 S., R. 9 E., Riley County; strat. sec. 215; Falls City limestone.
13508	Road cut, NE¼SW¼ sec. 10, T. 11 S., R. 9 E., Riley County; Falls City limestone.
13509	NE¼SE¼ sec. 7, T. 11 S., R. 9 E., Riley County; strat. sec. 213; Janesville shale, Five Point limestone member.
13510	Streambank, NE¼SE¼ sec. 11, T. 11 S., R. 9 E., Wabaunsee County; strat. sec. 46; Wood Siding formation, Pony Creek shale member.
13511	Same locality and section as 13510; Wood Siding formation, Brownville limestone member.
13512	Roadside ditch, SW¼SW¼ sec. 12, T. 11 S., R. 9 E., Wabaunsee County; strat. sec. 164; Janesville shale, Five Point limestone member, limestone-shale-limestone sequence.
13513	Streambank, NE¼SW¼NW¼ sec. 33, T. 10 S., R. 10 E., Wabaunsee County; strat. sec. 242; Wood Siding formation, Nebraska City limestone member. (Section given in Mudge and Burton, 1959, section 59, p. 190.)
13514	Road ditch, SW¼SW¼ sec. 33, T. 10 S., R. 10 E., Wabaunsee County; strat. sec. 243; Onaga shale, Towle shale member.
13515	Streambank, NW¼NE¼NE¼ sec. 7, T. 8 S., R. 11 E., Pottawatomie County; strat. sec. 104; Root shale, Jim Creek limestone member.
13516	Same locality and section as 13515; Wood Siding formation, Nebraska City limestone member.
13517	Same locality and section as 13515; Wood Siding formation, Brownville limestone member.
13518	Same locality and section as 13515; Onaga shale, Aspinwall limestone member.
13519	Center of SE¼ sec. 33, T. 7 S., R. 11 E., Pottawatomie County; strat. sec. 244; Falls City limestone.
13520	Same locality and section as 13519; Janesville shale; Five Point limestone member.
13521	Same locality and section as 13519; Janesville shale, Hamlin shale member, limestone in shale.
13522	Same locality and section as 13519; Janesville shale, Hamlin shale member, limestone bed.
13523	Streambank, SE¼SW¼SW¼ sec. 1, T. 6 S., R. 10 E., Pottawatomie County; strat. sec. 245; Wood Siding formation, Brownville limestone member.
13524	Same locality and section as 13523; Onaga shale, Aspinwall limestone member.
13526	Streambank, SW¼SE¼ sec. 8, T. 9 S., R. 9 E., Pottawatomie County; strat. sec. 246; Onaga shale, Aspinwall limestone member, upper limestone.
13527	Streambank, SE¼SW¼ sec. 8, T. 9 S., R. 9 E., Pottawatomie County; strat. sec. 247; Janesville shale, Five Point limestone member, shale between lower and middle limestone.
13528	Same locality and section as 13527; Janesville shale, Five Point limestone member, middle limestone.
13529	Same locality and section as 13527; Janesville shale, Hamlin shale member.
13530	Roadside, SE¼SW¼SW¼ sec. 2, T. 8 S., R. 9 E., Pottawatomie County; strat. sec. 248; Beattie limestone, Cottonwood limestone member.
13531	Same locality and section as 13530; Beattie limestone, Florena shale member.
13532	Road cut, SE¼SE¼ sec. 35, T. 6 S., R. 11 E., Pottawatomie County; strat. sec. 249; Zeandale limestone, Tarkio limestone member.
13533	Road cut, SE¼SW¼NW¼ sec. 28, T. 6 S., R. 12 E., Pottawatomie County; strat. sec. 250; Stotler limestone, Grandhaven limestone member.
13534	Roadside ditch, NE¼SW¼ sec. 28, T. 6 S., R. 12 E., Pottawatomie County; strat. sec. 113; Root shale, Jim Creek limestone member.
13535	Same locality and section as 13534; Wood Siding formation, Nebraska City limestone member.
13536	Same locality and section as 13534; Wood Siding formation, Brownville limestone member.
13537	NE¼SE¼ sec. 13, T. 7 S., R. 11 E., Pottawatomie County; strat. sec. 252; Eskridge shale, limestone lens in shale.
13538	Same locality and section as 13537; Beattie limestone, Cottonwood limestone member.
13539	Same locality and section as 13537; Beattie limestone, Florena shale member.
13540	Streambank, NW¼SW¼SE¼ sec. 10, T. 8 S., R. 12 E., Pottawatomie County; strat. sec. 253; Red Eagle limestone, Glenrock limestone member.
13541	Same locality and section as 13540; Red Eagle limestone, Bennett shale member.
13542	Same locality and section as 13540; Red Eagle limestone, Howe limestone member.
13544	Roadside ditch, SE¼NE¼ sec. 6, T. 10 S., R. 10 E., Pottawatomie County; Zeandale limestone, Maple Hill limestone member.
13545	Same locality as 13544, Stotler limestone, Dover limestone member.
13546	Roadside ditch, SW¼NE¼ sec. 7, T. 9 S., R. 10 E., Pottawatomie County; Zeandale limestone, Tarkio limestone member.
13547	Quarry, center sec. 7, T. 10 S., R. 8 E., Riley County; Beattie limestone, Cottonwood limestone member.
13548	Same locality as 13547; Beattie limestone, Florena shale member.
13549	Road cut and quarry, NW¼NW¼ sec. 26, T. 10 S., R. 7 E., Riley County; strat. sec. 236; Grenola limestone, Burr limestone member, top of limestone.
13550	Same locality and section as 13549; Grenola limestone, Neva limestone member, unit 2.
13551	Same locality and section as 13549; Grenola limestone, Neva limestone member, shale in unit 5.
13552	Same locality and section as 13549; Eskridge shale, two limestone beds in shale.
13553	Road cut, SW¼SE¼SE¼ sec. 7, T. 10 S., R. 8 E., Riley County; strat. sec. 235; Grenola limestone, Sallyards limestone member.

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13554	Same locality and section as 13553; Grenola limestone, Burr limestone member, shale between upper and lower limestone.
13555	Same locality and section as 13553; Grenola limestone, Burr limestone member, upper limestone.
13556	Same locality and section as 13427; Grenola limestone, Neva limestone member, unit 2.
13557	Pasture gully, NE¼SW¼ sec. 29, T. 11 S., R. 13 E., Wabaunsee County; strat. sec. 81; Root shale, Jim Creek limestone member. (Section given in Mudge and Burton, 1959, section 63, p. 193.)
13558	Same locality and section as 13557; Wood Siding formation, Nebraska City limestone member.
13559	Same locality and section as 13557; Wood Siding formation, Brownville limestone member.
13562	Road cut, south side Kansas Highway 10, SW¼SW¼ sec. 30, T. 11 S., R. 12 E., Wabaunsee County; strat. sec. 76; Foraker limestone, Hughes Creek shale member, unit 1. (Section given in Mudge and Burton, 1959, section 42, p. 170.)
13563	Same locality and section as 13562; Foraker limestone, Hughes Creek shale member, unit 2.
13564	Same locality and section as 13562; Foraker limestone, Hughes Creek shale member, unit 3.
13565	Same locality and section as 13562; Foraker limestone, Hughes Creek, shale member, unit 4.
13566	Same locality and section as 13562; Foraker limestone, Hughes Creek shale member, unit 5.
13567	Road cut, north side Kansas Highway 10, SW¼SW¼ sec. 30, T. 11 S., R. 12 E., Wabaunsee County; strat. sec. 76; Foraker limestone, Long Creek limestone member, clay lens near middle.
13568	Same locality and section as 13567; Red Eagle limestone, Glenrock limestone member.
13570	Same locality and section as 13567; Red Eagle limestone, Howe limestone member.
13571	Roadside ditch, SE¼SW¼SW¼ sec. 19, T. 11 S., R. 12 E., Wabaunsee County; strat. sec. 41; Falls City limestone. (Section given in Mudge and Burton, 1959, section 49, p. 179.)
13572	Same locality and section as 13571; Janesville shale, West Branch shale member, limestone in shale.
13573	Same locality and section as 13571; Janesville shale, Five Point limestone member; shale between limestone.
13574	Streambank, SW¼NE¼ sec. 24, T. 9 S., R. 10 E., Pottawatomie County, Kans.; strat. sec. 254; Root shale, Jim Creek limestone member.
13575	Roadside ditch, SW¼NE¼ sec. 24, T. 9 S., R. 10 E., Pottawatomie County; strat. sec. 254; Wood Siding formation, Brownville limestone member.
13576	Farmyard, SW¼SE¼ sec. 5, T. 9 S., R. 11 E., Pottawatomie County; strat. sec. 255; Onaga shale, Aspinwall limestone member.
13577	Road cut and ditch, center sec. 22, T. 8 S., R. 11 E., Pottawatomie County; strat. sec. 256; Grenola limestone, Sallyards limestone member.
13578	Road cut and ditch, center sec. 22, T. 8 S., R. 11 E., Pottawatomie County; strat. sec. 256; Grenola limestone, Burr limestone member, lower limestone and shale.
13580	Same locality and section as 13577; Grenola limestone, Neva limestone member, unit 2.
13581	Road ditch, NW¼SW¼ sec. 21, T. 9 S., R. 11 E., Pottawatomie County; strat. sec. 257; Foraker limestone, Americus limestone member, middle limestone.
13582	Same locality and section as 13581; Foraker limestone, Americus limestone member, upper limestone.
13583	Same locality and section as 13581; Foraker limestone, Hughes Creek shale member, unit 1.
13584	Same locality and section as 13581; Foraker limestone, Hughes Creek shale member, unit 1.
13585	Same locality and section as 13581; Foraker limestone, Hughes Creek shale member, unit 3.
13586	Same locality and section as 13581; Foraker limestone, Hughes Creek shale member, unit 4.
13587	Same locality and section as 13581; Foraker limestone, Hughes Creek shale member, unit 6.
13588	Roadside, SE¼NE¼NW¼ sec. 27, T. 9 S., R. 11 E., Pottawatomie County; strat. sec. 258; Janesville shale, Five Point limestone member, shale between limestone.
13589	Roadside ditch, NW¼SW¼SW¼ sec. 18, T. 10 S., R. 12 E., Shawnee County; strat. sec. 114; Root shale, Jim Creek limestone member.
13590	Same locality and section as 13589; Wood Siding formation, Nebraska City limestone member.
13591	Same locality and section as 13589; Wood Siding formation, Brownville limestone member.
13593	Quarry along Kansas Highway 99, center sec. 33, T. 10 S., R. 10 E., Wabaunsee County; strat. sec. 261; Foraker limestone, Hughes Creek shale member, lower shale of unit 2. (Section given in Mudge and Burton, 1959, section 45, p. 175.)
13594	Same locality and section as 13593; Foraker limestone, Hughes Creek shale member, unit 2.
13595	Same locality and section as 13593; Foraker limestone, Hughes Creek shale member, unit 2.
13596	Same locality and section as 13593; Foraker limestone, Hughes Creek shale member, unit 4.
13597	Same locality and section as 13593; Foraker limestone, Hughes Creek shale member, unit 5.
13598	Road cut, NE¼SE¼ sec. 27, T. 11 S., R. 10 E., Wabaunsee County; strat. sec. 75; Grenola limestone, Burr limestone member, lower limestone. (Section given in Mudge and Burton, 1959, section 33, p. 158.)
13599	Same locality and section as 13598; Grenola limestone, Burr limestone member, upper limestone.
13600	Same locality and section as 13598; Grenola limestone, Neva limestone member, unit 2.
13601	Same locality and section as 13598; Grenola limestone, Neva limestone member, unit 6.
13602	NE¼NW¼SW¼ sec. 26, T. 11 S., R. 10 E., Wabaunsee County; strat. sec. 147; Red Eagle limestone, Bennett shale member.
13603	Same locality and section as 13602; Red Eagle limestone, Howe limestone member.
13604	Road cut, Kansas Highway 99, NW¼NW¼ sec. 3, T. 11 S., R. 10 E., Wabaunsee County; strat. sec. 45; Red Eagle limestone, Glenrock limestone member.
13605	Streambank, NE¼SW¼ sec. 32, T. 11 S., R. 11 E., Wabaunsee County; strat. sec. 262; Janesville shale, West Branch shale member, limestone in shale.

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13606	Same locality and section as 13605; Janesville shale, Five Point limestone member, lower shale.
13607	Roadside ditch, NE¼SE¼ sec. 36, T. 6 S., R. 11 E., Pottawatomie County; Zeandale limestone, Maple Hill limestone member.
13608	Road cut, NE¼NE¼ sec. 1, T. 6 S., R. 12 E., Jackson County; strat. sec. 264; Beattie limestone, Cottonwood limestone member. (Mudge, Walters, and Skoog, 1959, bed 1, p. 230.)
13609	Same locality and section as 13608; Beattie limestone, Florena shale member. (Mudge, Walters, and Skoog, 1959, bed 2, p. 230.)
13610	Road cut, SE¼SW¼ sec. 36, T. 5 S., R. 12 E., Nemaha County, Kans., Eskridge shale. (Mudge, Walters, and Skoog, 1959, bed 10, p. 232.)
13611	Streambank, SE¼SW¼ sec. 23, T. 1 S., R. 13 E., Nemaha County; strat. sec. 124; Root shale, Friedrich shale member, calcareous zone near top.
13612	Same locality as 13611; strat. sec. 125; Root shale, Friedrich shale member, uppermost bed.
13613	Same locality as 13611; strat. sec. 125; Root shale, Jim Creek limestone member.
13614	Same locality as 13611; strat. sec. 125; Root shale, French Creek shale member, limestone in shale.
13615	Same locality as 13611; strat. sec. 125; Wood Siding formation, Nebraska City limestone member. (Mudge, Walters, and Skoog, 1959, bed 11, p. 239.)
13616	Same locality as 13611; strat. sec. 126; Wood Siding formation, Brownville limestone member.
13617	Streambank, SW¼NW¼ sec. 1, T. 2 S., R. 13 E., Nemaha County; strat. sec. 135; Falls City limestone, upper limestone. (Mudge, Walters, and Skoog, 1959, bed 4, p. 237.)
13619	Streambank, NE¼SW¼ sec. 1, T. 2 S., R. 13 E., Nemaha County; strat. sec. 132; Foraker limestone, Hughes Creek shale member, probably unit 4. (Mudge, Walters, and Skoog, 1959, bed 2, p. 235.)
13620	Same locality and section as 13619; Foraker limestone, Hughes Creek shale member, probably unit 4. (Mudge, Walters, and Skoog, 1959, bed 1, p. 235.)
13621	Same locality and section as 13619; Foraker limestone, Hughes Creek shale member, units 5 and 6. (Mudge, Walters, and Skoog, 1959, bed 4, p. 235.)
13622	Same locality and section as 13619; Red Eagle limestone, Glenrock limestone member. (Mudge, Walters, and Skoog, 1959, bed 13, p. 235.)
13623	Same locality and section as 13619; Red Eagle limestone, Bennett shale member. (Mudge, Walters, and Skoog, 1959, bed 14, p. 234.)
13624	Same locality and section as 13619; Red Eagle limestone, Howe limestone member. (Mudge, Walters, and Skoog, 1959, bed 16, p. 234.)
13625	Streambank, NW¼SE¼ sec. 1, T. 2 S., R. 13 E., Nemaha County; strat. sec. 131, Grenola limestone, Sallyards limestone member. (Mudge, Walters, and Skoog, 1959, bed 5, p. 234.)
13626	Same locality and section as 13625; Grenola limestone, Burr limestone member, upper limestone.
13627	Same locality and section as 13625; Grenola limestone, Burr limestone member, upper limestone.
13628	Streambank, NE¼SW¼ sec. 7, T. 2 S., R. 13 E., Nemaha County; strat. sec. 130; Grenola limestone, Neva limestone member, unit 1.
13629	Same locality and section as 13628; Grenola limestone, Neva limestone member, unit 4. (Mudge, Walters, and Skoog, 1959, bed 3, p. 233.)
13630	Same locality and section as 13628; Grenola limestone, Neva limestone member, unit 5. (Mudge, Walters, and Skoog, 1959, bed 4, p. 233.)
13631	Same locality and section as 13628; Grenola limestone, Neva limestone member, shale in lower part of unit 5. (Mudge, Walters, and Skoog, 1959, bed 5, p. 233.)
13632	Spillway at Sabetha City Lake, NW¼SE¼NE¼ sec. 1, T. 2 S., R. 13 E., Nemaha County; strat. sec. 137; Beattie limestone, Cottonwood limestone member.
13633	Same locality and section as 13632; Beattie limestone, Florena shale member.
13634	Road cut, U. S. Highway 36, NE¼NW¼ sec. 35, T. 2 S., R. 15 E., Brown County; strat. sec. 263; Grenola limestone, Burr limestone member, upper limestone.
13635	Road cut, NW¼NE¼ sec. 22, T. 10 S., R. 13 E., Shawnee County; strat. sec. 265; Pillsbury shale, upper 2.2 ft.
13636	Same locality and section as 13635; Stotler limestone, Dover limestone member.
13637	Road cut, NW¼SE¼ sec. 27, T. 10 S., R. 13 E., Shawnee County; strat. sec. 266; Zeandale limestone, Tarkio limestone member.
13638	Same locality and section as 13637; Zeandale limestone, Maple Hill limestone member.
13639	Roadside ditch, SW¼NW¼ sec. 19, T. 9 S., R. 14 E., Jackson County; strat. sec. 33; Wood Siding formation, Nebraska City limestone member.
13640	Same locality and section as 13639; Wood Siding formation, Brownville limestone member.
13641	Roadside ditch, NW¼SW¼SW¼ sec. 15, T. 9 S., R. 13 E., Jackson County; strat. sec. 268; Janesville shale, Five Point limestone member, shale between upper and lower limestone.
13642	Road cut, west side Kansas Highway 63, NE¼SW¼ sec. 34, T. 9 S., R. 12 E., Pottawatomie County; Grenola limestone, Sallyards limestone member.
13643	Road cut, east side Kansas Highway 63, NE¼SE¼SW¼ sec. 34, T. 9 S., R. 12 E., Pottawatomie County; Grenola limestone, Burr limestone member, upper surface.
13644	Roadside ditch, SW¼SE¼SE¼ sec. 23, T. 8 S., R. 12 E., Pottawatomie County; strat. sec. 269; Foraker limestone, Hughes Creek shale member, unit 1.
13645	Same locality and section as 13644; Foraker limestone, Hughes Creek shale member, unit 3.
13646	Roadside ditch, SW¼NW¼ sec. 8, T. 8 S., R. 14 E., Jackson County; strat. sec. 270; Foraker limestone, Americus limestone member, upper limestone.
13648	Same locality and section as 13646; Foraker limestone, Hughes Creek shale member, lower limestone bed of unit 1.
13649	Same locality and section as 13646; Foraker limestone, Hughes Creek shale member, upper limestone bed of unit 1.
13650	Same locality and section as 13646; Foraker limestone, Hughes Creek shale member, unit 2.

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13651	Same locality and section as 13646; Foraker limestone, Hughes Creek shale member, unit 3.
13652	Same locality and section as 13646; Foraker limestone, Hughes Creek shale member, unit 5.
13653	Same locality and section as 13646; Foraker limestone, Hughes Creek shale member, unit 6.
13654	Small quarry, SE¼SW¼ sec. 35, T. 6 S., R. 15 E., Jackson County; Stotler limestone, Dover limestone member.
13655	Streambank, NW¼SW¼ sec. 9, T. 7 S., R. 15 E., Jackson County; strat. sec. 271; Root shale, Jim Creek limestone member.
13656	Same locality and section as 13655; Wood Siding formation, Nebraska City limestone member.
13657	Roadside ditch, NW¼NE¼ sec. 33, T. 7 S., R. 14 E., Jackson County; strat. sec. 272; Grenola limestone, Burr limestone member, upper limestone.
13658	Road cut, Kansas Highway 62, NW¼SW¼SW¼ sec. 3, T. 7 S., R. 13 E., Jackson County; strat. sec. 273; Grenola limestone, Neva limestone member, unit 2.
13659	Same locality and section as 13658; Grenola limestone, Neva limestone member, unit 3.
13660	Roadside ditch, SE¼SE¼ sec. 21, T. 7 S., R. 13 E., Jackson County; Beattie limestone, Cottonwood limestone member.
13661	Same locality as 13660; Beattie limestone, Florena shale member.
13662	Roadside ditch, SW¼NE¼NE¼ sec. 21, T. 13 S., R. 12 E., Wabaunsee County; strat. sec. 186; Foraker limestone, Americus limestone member, lower limestone.
13663	Same locality and section as 13662; Foraker limestone, Americus limestone member, upper limestone.
13664	Roadside ditch, SW¼NW¼NW¼ sec. 22, T. 13 S., R. 12 E., Wabaunsee County; strat. sec. 185; Foraker limestone, Hughes Creek shale member, unit 1.
13665	Same locality and section as 13664; Foraker limestone, Hughes Creek shale member, unit 3.
13666	Same locality and section as 13664; Foraker limestone, Hughes Creek shale member, units 5 and 6.
13667	Road cut, NW¼NW¼ sec. 14, T. 13 S., R. 12 E., Wabaunsee County; strat. sec. 83; Janesville shale, Five Point limestone member, lower shale. (Section given in Mudge and Burton, 1959, section 50, p. 180.)
13668	Same locality and section as 13667; Janesville shale; Five Point limestone member, middle limestone.
13669	Same locality and section as 13667; Janesville shale, Five Point limestone member, upper limestone.
13670	Road cut, SW¼SE¼ sec. 12, T. 12 S., R. 11 E., Wabaunsee County; strat. sec. 116; Foraker limestone, Americus limestone member, lower part. (Section given in Mudge and Burton, 1959, section 47, p. 177.)
13672	Streambank, SW¼NW¼NW¼ sec. 36, T. 11 S., R. 11 E., Wabaunsee County; strat. sec. 143; Onaga shale, Hawxby shale member, lowest limestone.
13673	Roadside ditch, NE¼SE¼ sec. 27, T. 11 S., R. 10 E., Wabaunsee County; strat. sec. 75; Beattie limestone, Cottonwood limestone member.
13674	Same locality and section as 13673; Beattie limestone, Florena shale member.
13675	Streambank, SW¼NE¼ sec. 11, T. 12 S., R. 10 E., Wabaunsee County; strat. sec. 274; Foraker limestone, Americus limestone member, lower limestone.

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13676	Same locality and section as 13675; Foraker limestone, Americus limestone member, upper limestone.
13677	Roadside ditch, SW¼SE¼ sec. 31, T. 12 S., R. 12 E., Wabaunsee County; strat. sec. 200; Beattie limestone, Cottonwood limestone member.
13678	Same locality and section as 13677; Beattie limestone, Florena shale member.
13679	Road cut, NW¼SE¼ sec. 30, T. 12 S., R. 12 E., Wabaunsee County; strat. sec. 199; Grenola limestone, Burr limestone member, lower limestone. (Section given in Mudge and Burton, 1959, section 35, p. 162.)
13680	Same locality and section as 13679; Grenola limestone, Burr limestone member, upper limestone.
13681	Same locality and section as 13679; Grenola limestone, Neva limestone member, unit 1.
13682	Same locality and section as 13679; Grenola limestone, Neva limestone member, unit 2.
13683	Same locality and section as 13679; Grenola limestone, Neva limestone member, unit 4.
13684	Roadside ditch, NW¼SW¼ sec. 34, T. 12 S., R. 13 E., Wabaunsee County; strat. sec. 175; Stotler limestone, Grandhaven limestone member. (Section given in Mudge and Burton, 1959, section 71, p. 200.)
13685	Same locality and section as 13684; Root shale, Friedrich shale member, near base.
13686	Streambank, SW¼NW¼ sec. 33, T. 12 S., R. 13 E., Wabaunsee County; strat. sec. 190; Root shale, Jim Creek limestone member. (Section given in Mudge and Burton, 1959, section 65, p. 195.)
13687	Road cut, SE¼SE¼ sec. 23, T. 12 S., R. 13 E., Shawnee County; Zeandale limestone, Tarkio limestone member.
13688	Roadside ditch, SE¼SE¼ sec. 10, T. 13 S., R. 13 E., Wabaunsee County; strat. sec. 84; Onaga shale, Aspinwall limestone member. (Section given in Mudge and Burton, 1959, section 52, p. 182.)
13689	Same locality and section as 13688; Falls City limestone.
13690	Road cut, SE¼SW¼NW¼ sec. 32, T. 12 S., R. 13 E., Wabaunsee County; Wood Siding formation, Brownville limestone member.
13691	Streambank, SW¼NW¼ sec. 3, T. 15 S., R. 13 E., Wabaunsee County; strat. sec. 85; Stotler limestone, Dover limestone member. (Section given in Mudge and Burton, 1959, section 72, p. 200.)
13692	Roadside ditch, SE¼SE¼ sec. 11, T. 15 S., R. 13 E., Osage County; Zeandale limestone, Tarkio limestone member.
13693	Streambank, SE¼NW¼ sec. 15, T. 15 S., R. 13 E., Wabaunsee County; strat. sec. 90; Zeandale limestone; Wamego shale member, fossiliferous zone. (Section given in Mudge and Burton, 1959, section 74, p. 202.)
13694	Same locality and section as 13693; Zeandale limestone, Maple Hill limestone member.
13695	Spillway of Lake Wabaunsee, NE¼NW¼ sec. 4, T. 14 S., R. 11 E., Wabaunsee County; strat. sec. 209; Grenola limestone, Neva limestone member, unit 2. (Section given in Mudge and Burton, 1959, section 32, p. 157.)
13696	Same locality and section as 13695; Grenola limestone, Neva limestone member, unit 6.

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13697	Streambank, SW¼SE¼SE¼ sec. 16, T. 14 S., R. 12 E., Wabaunsee County; Foraker limestone, Hughes Creek shale member, units 5 and 6.
13698	Road cut, NE¼SE¼ sec. 23, T. 14 S., R. 12 E., Wabaunsee County; strat. sec. 87; Janesville shale, Five Point limestone member, lower limestone. (Section given in Mudge and Burton, 1959, section 51, p. 181.)
13699	Road cut, NW¼SW¼SW¼ sec. 9, T. 15 S., R. 13 E., Wabaunsee County; strat. sec. 189; Stotler limestone, Grandhaven limestone member. (Section given in Mudge and Burton, 1959, section 70, p. 199.)
13700	Streambank, SE¼NE¼ sec. 17, T. 15 S., R. 13 E., Wabaunsee County; strat. sec. 86; Root shale, Friedrich shale member, upper part. (Section given in Mudge and Burton, 1959, section 67, p. 197.)
13701	Same locality and section as 13700; Root shale, Jim Creek limestone member.
13702	Roadside ditch, SE¼SW¼ sec. 17, T. 15 S., R. 13 E., Wabaunsee County; strat. sec. 187; Wood Siding formation, Pony Creek shale member.
13703	Same locality and section as 13702; Wood Siding formation, Brownville limestone member.
13704	Roadside ditch SW¼NE¼ sec. 16, T. 15 S., R. 13 E., Wabaunsee County; Wood Siding formation, Nebraska City limestone member.
13705	Roadside ditch, SW¼NW¼ sec. 1, T. 15 S., R. 12 E., Wabaunsee County; strat. sec. 118; Foraker limestone, Americus limestone member, upper limestone. (Section given in Mudge and Burton, 1959, section 46, p. 176.)
13706	Streambank, SW¼SE¼NE¼ sec. 17, T. 14 S., R. 12 E., Wabaunsee County; strat. sec. 152; Red Eagle limestone, Glenrock limestone member.
13707	Same locality and section as 13706; Red Eagle limestone, Bennett shale member.
13708	Same locality and section as 13706; Red Eagle limestone, Howe limestone member, lower part.
13709	Same locality and section as 13706; Red Eagle limestone, Howe limestone member, brachiopod zone.
13710	Road cut, SE¼NE¼ sec. 17, T. 14 S., R. 12 E., Wabaunsee County; strat. sec. 151; Grenola limestone, Sallyards limestone member.
13711	Same locality and section as 13710; Grenola limestone, Burr limestone member, lower limestone.
13712	Quarry, NW¼NE¼ sec. 31, T. 14 S., R. 12 E., Wabaunsee County; strat. sec. 88; Red Eagle limestone, Bennett shale member, biostrome.
13713	Pasture gully, SE¼NE¼ sec. 23, T. 15 S., R. 11 E., Lyon County; strat. sec. 275; Red Eagle limestone, Bennett shale member, upper 10 ft of biostrome.
13714	Roadside ditch, SW¼NW¼NW¼ sec. 36, T. 14 S., R. 11 E., Wabaunsee County; strat. sec. 206; Eskridge shale, upper limestone. (Section given in Mudge and Burton, 1959, section 31, p. 156.)
13715	Pasture gully, NW¼SW¼SW¼ sec. 13, T. 16 S., R. 12 E., Lyon County; strat. sec. 65; Wood Siding formation, Nebraska City limestone member.
13716	Same locality and section as 13715; Wood Siding formation, Brownville limestone member.
13717	Pond spillway, SE¼SE¼ sec. 13, T. 16 S., R. 12 E., Lyon County; strat. sec. 276; Stotler limestone, Dover limestone member.
13718	Same locality and section as 13717; Stotler limestone, Grandhaven limestone member.
13719	Roadside ditch, SE¼SE¼ sec. 16, T. 16 S., R. 12 E., Lyon County; strat. sec. 277; Onaga shale, Aspinwall limestone member.
13720	Same locality and section as 13719; Falls City limestone.
13721	Road cut, NW¼SW¼SW¼ sec. 24, T. 17 S., R. 9 E., Morris County; strat. sec. 278; Grenola limestone, Sallyards limestone member.
13722	Same locality and section as 13721; Grenola limestone, Burr limestone member.
13723	Same locality and section as 13721; Grenola limestone, Burr limestone member, upper limestone.
13724	Lake Kahola spillway, SW¼NE¼ sec. 33, T. 17 S., R. 9 E., Morris County; strat. sec. 279; Beattie limestone, Cottonwood limestone member. (Section given in Mudge, Matthews, and Wells, 1958, section 33, p. 54.)
13725	Same locality and section as 13724; Beattie limestone, Florena shale member.
13726	Streambank, SE¼SW¼NW¼ sec. 26, T. 19 S., R. 7 E., Chase County; strat. sec. 280; Foraker limestone, Americus limestone member, upper limestone.
13727	Same locality and section as 13726; Foraker limestone, Hughes Creek shale member, unit 1.
13728	Same locality and section as 13726; Foraker limestone, Hughes Creek shale member, unit 2.
13729	Same locality and section as 13726; Foraker limestone, Hughes Creek shale member, unit 3.
13730	Road cut, SE¼SW¼NW¼ sec. 26, T. 19 S., R. 7 E., Chase County; strat. sec. 280; Red Eagle limestone, Glenrock limestone member.
13731	Same locality and section as 13730; Red Eagle limestone, Bennett shale member.
13732	Same locality and section as 13730; Red Eagle limestone, Howe limestone member.
13733	Same locality and section as 13730; Grenola limestone, Sallyards limestone member.
13734	Same locality and section as 13730; Grenola limestone, Burr limestone member, lower limestone.
13735	Same locality and section as 13730; Grenola limestone, Burr limestone member, limestone and shale near middle.
13736	Same locality and section as 13730; Grenola limestone, Neva limestone member, unit 2.
13737	Same locality and section as 13730; Grenola limestone, Neva limestone member, unit 3.
13738	Same locality and section as 13730; Grenola limestone, Neva limestone member, unit 4.
13739	Same locality and section as 13730; Grenola limestone, Neva limestone member, unit 5.
13740	Roadside ditch, SE¼NE¼ sec. 24, T. 19 S., R. 9 E., Chase County; strat. sec. 281; Foraker limestone, Americus limestone member lower limestone.
13742	Stream gully, NE¼NE¼ sec. 1, T. 32 S., R. 8 E., Chautauqua County; strat. sec. 283; Zeandale limestone, Wamego shale member, limestone in shale.
13743	Same locality and section as 13742; Zeandale limestone, Maple Hill limestone member.
13744	Same locality and section as 13742; Pillsbury shale.

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13745	Road cut, SW¼SW¼ sec. 22, T. 32 S., R. 8 E., Chautauqua County; strat. sec. 284; Stotler limestone, Grandhaven limestone member.
13746	Roadside ditch, SW¼SW¼ sec. 22, T. 32 S., R. 8 E., Chautauqua County; strat. sec. 285; Root shale, Friedrich shale member, upper part.
13747	Same locality and section as 13746; Root shale, Jim Creek limestone member.
13748	Road cut, SW¼SW¼ sec. 22, T. 32 S., R. 8 E., Chautauqua County; strat. sec. 52; Wood Siding formation, Brownville limestone member.
13749	Same locality and section as 13748; Onaga shale, Aspinwall limestone member, shale between limestone.
13751	Same locality and section as 13748; Falls City limestone, upper limestone.
13752	Same locality and section as 13748; Janesville shale, Five Point limestone member, shale between limestone.
13753	Road cut, SE¼ sec. 21, T. 32 S., R. 8 E., Cowley County; strat. sec. 286; Janesville shale, West Branch shale member, upper part.
13754	Same locality and section as 13753; Janesville shale, Five Point limestone member, lower part of upper limestone.
13755	Same locality and section as 13753; Janesville shale, Five Point limestone member, upper part of upper limestone.
13756	Same locality and section as 13753; Foraker limestone, Americus limestone member, lower limestone.
13757	Same locality and section as 13753; Foraker limestone, Americus limestone member, upper and middle limestone.
13758	Same locality and section as 13753; Foraker limestone, Hughes Creek shale member, unit 1.
13759	Same locality and section as 13753; Foraker limestone, Hughes Creek shale member, unit 1.
13760	Same locality and section as 13753; Foraker limestone, Hughes Creek shale member, unit 2.
13761	Same locality and section as 13753; Foraker limestone, Hughes Creek shale member, unit 2.
13762	Same locality and section as 13753; Foraker limestone, Hughes Creek shale member, unit 3.
13763	Same locality and section as 13753; Foraker limestone, Hughes Creek shale member, unit 4.
13764	Same locality and section as 13753; Foraker limestone, Hughes Creek shale member, unit 4.
13765	Same locality and section as 13753; Foraker limestone, Hughes Creek shale member, unit 5.
13766	Same locality and section as 13753; Foraker limestone, Hughes Creek shale member, unit 5.
13767	Road cut, SE¼ sec. 21, T. 32 S., R. 8 E., Cowley County; strat. sec. 286; Johnson shale, upper part.
13768	Same locality and section as 13767; Red Eagle limestone.
13769	Road cut, NW¼NE¼ sec. 30, T. 32 S., R. 8 E., Cowley County; strat. sec. 287; Grenola limestone, Legion shale member.
13770	Same locality and section as 13769; Grenola limestone, Burr limestone member.
13771	Same locality and section as 13769; Grenola limestone, Salem Point shale member.
13772	Same locality and section as 13769; Grenola limestone, Salem Point shale member.
13773	Hillside exposure, SE¼SW¼SW¼ sec. 4, T. 31 S., R. 8 E., Cowley County; strat. sec. 288; Grenola limestone, Neva limestone member, unit 6.
13774	Same locality and section as 13773; Eskridge shale, limestone in shale.
13775	Same locality and section as 13773; Beattie limestone, Florena shale member.
13776	Railroad cut, SE¼NW¼ sec. 12, T. 34 S., R. 7 E., Cowley County; strat. sec. 289; Grenola limestone, Salem Point shale member.
13777	Same locality and section as 13776; Grenola limestone, Neva limestone member, unit 2.
13778	Same locality and section as 13776; Grenola limestone, Neva limestone member, unit 3.
13779	Same locality and section as 13776; Grenola limestone, Neva limestone member, unit 4.
13780	Same locality and section as 13776; Grenola limestone, Neva limestone member, upper part of unit 5.
13781	Road cut, NW¼NE¼ sec. 30, T. 32 S., R. 8 E., Cowley County; strat. sec. 287; Red Eagle limestone, Howe limestone member.
13783	Roadside ditch, SE¼SE¼ sec. 36, T. 29 S., R. 9 E., Elk County; strat. sec. 291; Zeandale limestone, Wamego shale member, middle part.
13784	Same locality and section as 13783; Zeandale limestone, Wamego shale member, limestone in shale.
13785	Same locality and section as 13783; Zeandale limestone, Maple Hill limestone member.
13787	Roadside ditch, NE¼NE¼ sec. 28, T. 29 S., R. 9 E., Elk County; strat. sec. 58; Root shale, Friedrich shale member, limestone in shale.
13788	Same locality and section as 13787; Root shale, Jim Creek limestone member.
13789	Roadside ditch, SE¼NW¼NW¼ sec. 8, T. 29 S., R. 9 E., Elk County; strat. sec. 59; Wood Siding formation, Grayhorse limestone member.
13790	Same locality and section as 13789; Wood Siding formation, Brownville limestone member.
13791	Roadside ditch, SE¼SE¼ sec. 6, T. 29 S., R. 9 E., Elk County; strat. sec. 60; Onaga shale, Towle shale member, limestone in shale.
13792	Same locality and section as 13791; Falls City limestone.
13793	Roadside ditch, SE¼ sec. 31, T. 28 S., R. 8 E., Elk County; strat. sec. 292; Janesville shale, Five Point limestone member, upper limestone.
13794	Same locality and section as 13793; Foraker limestone, Americus limestone member, lower limestone.
13795	Streambank, SE¼ sec. 31, T. 28 S., R. 8 E., Elk County; strat. sec. 292; Foraker limestone, Americus limestone member, middle limestone.
13796	SW¼SE¼ sec. 12, T. 29 S., R. 8 E., Elk County, Kans.; strat. sec. 293; Foraker limestone, Americus limestone member, middle limestone.
13797	Same locality and section as 13796; Foraker limestone, Americus limestone member, upper limestone.
13798	Same locality and section as 13796; Foraker limestone, Hughes Creek shale member, unit 2.
13799	Same locality and section as 13796; Foraker limestone, Hughes Creek shale member, unit 2.

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13800	Same locality and section as 13796; Foraker limestone, Hughes Creek shale member, unit 2.
13801	Same locality and section as 13796; Foraker limestone, Hughes Creek shale member, unit 4.
13802	Same locality and section as 13796; Foraker limestone, Hughes Creek shale member, unit 4.
13803	Same locality and section as 13796; Foraker limestone, Hughes Creek shale member, units 5 and 6.
13804	Streambank, SW¼SE¼ sec. 12, T. 29 S., R. 8 E., Elk County; strat. sec. 293; Red Eagle limestone.
13805	Same locality and section as 13804; Grenola limestone, Burr limestone member, upper limestone.
13806	Stream gully, NW¼ sec. 13, T. 29 S., R. 8 E., Elk County; strat. sec. 293; Eskridge shale, upper part.
13807	Same locality and section as 13806; Beattie limestone, Cottonwood limestone member.
13808	Same locality and section as 13806; Beattie limestone, Florena shale member.
13809	Roadside ditch, NW¼NW¼ sec. 26, T. 26 S., R. 9 E., Greenwood County; strat. sec. 62; Wood Siding formation, Pony Creek shale member.
13810	Same locality and section as 13809; Wood Siding formation; Brownville limestone member.
13811	Quarry near spillway of lake, NW¼SE¼SE¼ sec. 10, T. 25 S., R. 10 E., Greenwood County; strat. sec. 294; Stotler limestone, Dover limestone member, lower limestone.
13812	Roadside ditch, SW¼SE¼ sec. 23, T. 23 S., R. 10 E., Greenwood County; strat. sec. 69; Wood Siding formation, Pony Creek shale member.
13813	Same locality and section as 13812; Wood Siding formation, Brownville limestone member.
13814	Same locality and section as 13812; Falls City limestone.
13815	Same locality and section as 13812; Janesville shale, Five Point limestone member, shale and upper limestone.
13816	Same locality and section as 13812; Foraker limestone, Americus limestone member, lower limestone.
13817	Stream gully, NE¼NW¼ sec. 26, T. 23 S., R. 10 E., Greenwood County; strat. sec. 295; Foraker limestone, Americus limestone member, middle limestone.
13818	Same locality and section as 13817; Foraker limestone, Hughes Creek shale member, unit 2.
13819	Same locality and section as 13817; Foraker limestone, Hughes Creek shale member, lower part of unit 4.
13820	Same locality and section as 13817; Foraker limestone, Hughes Creek shale member, upper part of unit 4.
13821	Same locality and section as 13817; Foraker limestone, Hughes Creek shale member, unit 5.
13822	Same locality and section as 13817; Foraker limestone, Hughes Creek shale member, float on upper bed of unit 4.
13823	Roadside ditch, NE¼NW¼ sec. 5, T. 24 S., R. 10 E., Greenwood County; strat. sec. 296; Foraker limestone, Hughes Creek shale member, units 5 and 6.
13824	Roadside ditch, SE¼SE¼ sec. 16, T. 23 S., R. 10 E., Greenwood County; strat. sec. 297; Red Eagle limestone, Glenrock limestone member.
13825	Same locality and section as 13824; Red Eagle limestone, Bennett shale member.
13826	Same locality and section as 13824; Roca shale, thin lime in shale.
13827	Same locality and section as 13824; Grenola limestone, Sallyards limestone member.
13828	Same locality and section as 13824; Grenola limestone, Burr limestone member.
13829	Road ditch, SE¼NE¼NW¼ sec. 15, T. 23 S., R. 9 E., Greenwood County; strat. sec. 298; Grenola limestone, Neva limestone member, unit 2.
13830	Same locality and section as 13829; Grenola limestone, Neva limestone member, unit 6.
13831	Same locality and section as 13829; Beattie limestone, Florena shale member.
13832	Roadside ditch, NW¼NE¼ sec. 7, T. 22 S., R. 11 E., Greenwood County; strat. sec. 71; Root shale, Jim Creek limestone member.
13833	Roadside ditch, SE¼NE¼NW¼ sec. 6, T. 22 S., R. 11 E., Greenwood County; strat. sec. 299; Stotler limestone, Dover limestone member, lower limestone.
13834	Roadside ditch, NW¼SW¼SW¼ sec. 23, T. 21 S., R. 10 E., Lyon County; strat. sec. 72; Wood Siding formation, Grayhorse limestone member.
13835	Roadside ditch, NW¼SW¼ sec. 14, T. 18 S., R. 10 E., Lyon County; strat. sec. 300; Janesville shale, Five Point limestone member, shale between upper and lower limestone.
13836	Same locality and section as 13835; Janesville shale, Five Point limestone member, upper limestone.
13838	Same locality and section as 13835; Foraker limestone, Americus limestone member, middle limestone.
13839	Road cut, center NW¼ sec. 29, T. 19 S., R. 10 E., Lyon County; strat. sec. 301; Janesville shale, Five Point limestone member, lower limestone.
13840	Same locality and section as 13839; Janesville shale, Five Point limestone member, shale between upper and lower limestone.
13841	Streambank, NE¼SW¼ sec. 35, T. 17 S., R. 12 E., Lyon County; strat. sec. 302; Zeandale limestone, Maple Hill limestone member.
13842	Streambank, NE¼SW¼ sec. 13, T. 16 S., R. 13 E., Lyon County; strat. sec. 304; Root shale, Friedrich shale member, upper part.
13843	Same locality and section as 13842; Root shale, Jim Creek limestone member.
14795	NE¼SW¼ sec. 18, T. 34 S., R 8 E., Cowley County; strat. sec. 318; Janesville shale, Five Point limestone member, lower limestone.
14796	Same locality and section as 14795; Janesville shale, Five Point limestone member, upper limestone.
14798	Same locality and section as 14795; Foraker limestone, Americus limestone member, middle limestone.
14799	Same locality and section as 14795; Foraker limestone, Americus limestone member, shale bed in upper limestone.
14800	Same locality and section as 14795; Foraker limestone, Hughes Creek shale member, unit 1.
14801	Same locality and section as 14795; Foraker limestone, Hughes Creek shale member, unit 2 (Thrall limestone bed of Bass, 1936).
14802	SW¼SW¼ sec. 12, T. 34 S., R. 8 E., Cowley County; strat. sec. 319; Beattie limestone, Florena shale member.

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14803	NW¼SE¼ sec. 11, T. 34 S., R. 7 E., Cowley County; strat. sec. 320; Grenola limestone, Neva limestone member, unit 6.
14804	Same locality and section as 14803; Grenola limestone, Neva limestone member, unit 7.
14805	NW¼SW¼ sec. 7, T. 34 S., R. 8 E., Cowley County; strat. sec. 321; Red Eagle limestone, Bennett shale member, limestone in shale.
14806	Same locality and section as 14805; Red Eagle limestone, Bennett shale member.
14807	Railroad cuts, SE¼ sec. 12, T. 34 S., R. 7 E., Cowley County; strat. sec. 322; Grenola limestone, Burr limestone member, lower limestone.
14808	Same locality and section as 14807; Grenola limestone, Burr limestone member, thick limestone.
14810	NE¼SE¼ sec. 16, T. 33 S., R. 8 E., Cowley County; strat. sec. 324; Stotler(?) limestone, Grandhaven(?) limestone member.
14815	Cattle tank near railroad, SE¼SW¼SW¼ sec. 4, T. 31 S., R. 8 E., Cowley County, Kans.; strat. sec. 288; Red Eagle limestone, Howe limestone member.
14816	Same locality and section as 14815; Grenola limestone, Sallyards limestone member.
14817	Same locality and section as 14815; Grenola limestone, Burr limestone member, upper limestone.
14818	Same locality and section as 14815; Grenola limestone, Neva limestone member, unit 5.
14819	SW¼SE¼ sec. 3, T. 31 S., R. 8 E., Elk County; strat. sec. 326; Johnson shale, upper part.
14820	NE¼ sec. 13, T. 31 S., R. 8 E., Elk County; strat. sec. 327; Foraker limestone, Americus limestone member.
14821	Same locality and section as 14820; Foraker limestone, Hughes Creek shale member, unit 1.
14822	Same locality and section as 14820; Foraker limestone, Hughes Creek shale member, unit 1.
14823	Same locality and section as 14820; Foraker limestone, Hughes Creek shale member, unit 3.
14824	NW¼NW¼ sec. 10, T. 30 S., R. 9 E., Elk County; strat. sec. 328, Wood Siding formation, Nebraska City limestone member, shale beneath limestone.
14825	Same locality and section as 14824; Wood Siding formation, Brownville limestone member.
14826	Same locality and section as 14824; Onaga shale, Aspinwall limestone member.
14827	Same locality and section as 14824; Janesville shale, Five Point limestone member.
14828	NW¼SW¼ sec. 35, T. 27 S., R. 8 E., Greenwood County; strat. sec. 329; Grenola limestone, Burr limestone member.
14829	Same locality and section as 14828; Eskridge shale, limestone in lower part.
14830	Same locality and section as 14828; Eskridge shale, shale in upper part.
14831	Same locality and section as 14828; Beattie limestone, Florena shale member.
14832	SW¼ sec. 31, T. 27 S., R. 9 E., Greenwood County; strat. sec. 330; Foraker limestone, Hughes Creek shale member, unit 3.
14833	Same locality and section as 14832; Foraker limestone, Hughes Creek Shale member, unit 4.
14834	Same locality and section as 14832; Foraker limestone, Hughes Creek shale member, units 5 and 6.
14835	NE¼ sec. 2, T. 28 S., R. 8 E., Greenwood County; strat. sec. 331; Red Eagle limestone, Bennett shale member.
14836	Same locality and section as 14835; Grenola limestone, Sallyards limestone member.
14837	NW¼SW¼SW¼ sec. 12, T. 28 S., R. 9 E., Greenwood County; strat. sec. 332; Onaga shale, Aspinwall limestone member.
14838	NW¼NE¼ sec. 24, T. 28 S., R. 9 E., Elk County; strat. sec. 333; Wood Siding formation, Brownville limestone member.
14839	Same locality and section as 14838; Onaga shale, Towle shale member, limestone in lower part of shale.
14840	Same locality and section as 14838; Wood Siding formation, Nebraska City limestone member.
14841	NE¼SE¼ sec. 12, T. 28 S., R. 9 E., Greenwood County; strat. sec. 335; Zeandale limestone, Wamego shale member, limestone in shale.
14842	Same locality and section as 14841; Zeandale limestone, Wamego shale member, shale beneath limestone.
14843	Same locality and section as 14841; Stotler limestone, Dover limestone member, shale between limestone.
14844	NW¼SW¼ sec. 30, T. 26 S., R. 10 E., Greenwood County; strat. sec. 337; Zeandale limestone, Wamego shale member, limestone in shale.
14845	NW¼NW¼ sec. 27, T. 26 S., R. 9 E., Greenwood County; strat. sec. 338, Onaga shale, Aspinwall limestone member, lower limestone.
14846	Same locality and section as 14845; Onaga shale, Aspinwall limestone member.
14847	Same locality and section as 14845; Falls City limestone, lower part.
14848	Same locality and section as 14845; Falls City limestone, upper part.
14849	SE¼SW¼ sec. 16, T. 26 S., R. 9 E., Greenwood County; strat, sec. 339; Wood Siding formation, Nebraska City limestone member.
14850	NW¼SW¼ sec. 11, T. 26 S., R. 9 E., Greenwood County; strat. sec. 341; Grenola limestone, Sallyards limestone member.
14851	Same locality and section as 14850; Grenola limestone, Burr limestone member, lower limestone.
14852	Same locality and section as 14850; Grenola limestone, Burr limestone member, shale in limestone.
14853	NW¼SW¼SW¼ sec. 6, T. 26 S., R. 9 E., Greenwood County; strat. sec. 342; Foraker limestone, Hughes Creek shale member, unit 2.
14854	Same locality and section as 14853; Foraker limestone, Hughes Creek shale member, unit 3.
14855	Same locality and section as 14853; Foraker limestone, Hughes Creek shale member, lower part of unit 4.
14856	Same locality and section as 14853; Foraker limestone, Hughes Creek shale member, lower part of unit 5.
14857	Same locality and section as 14853; Foraker limestone, Hughes Creek shale member, units 5 and 6.
14858	SE¼ sec. 1, T. 25 S., R. 9 E., Greenwood County; strat. sec. 343; Wood Siding formation, Nebraska City limestone member.
14859	Same locality and section as 14858; Wood Siding formation, Plumb shale member, limestone in shale.
14860	SE¼NE¼ sec. 15, T. 25 S., R. 8 E., Greenwood County; strat. sec. 344; Eskridge shale, limestone in upper part.

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14861	SW¼NW¼ sec. 7, T. 24 S., R. 11 E., Greenwood County; strat. sec. 345; Stotler limestone, Grandhaven limestone member.
14862	SE¼SE¼ sec. 8, T. 23 S., R. 11 E., Greenwood County; strat. sec. 346; Stotler limestone, Grandhaven limestone member.
14863	Same locality and section as 14862; Stotler limestone, Dry shale member.
14864	Same locality and section as 14862; Zeandale limestone, Maple Hill limestone member.
14865	N½SE¼ sec. 20, T. 21 S., R. 11 E., Lyon County; Root shale, Jim Creek limestone member.
14866	Same locality and section as 14865; Stotler limestone, Grandhaven limestone member.
14867	Same locality and section as 14865; Stotler limestone, Dry shale member, "stray" limestone.
14868	Same locality and section as 14865; Stotler limestone, Dover limestone member.
14869	SW¼NW¼ sec. 6, T. 22 S., R. 11 E., Greenwood County; Stotler limestone, Grandhaven limestone member, upper limestone.
14870	Same locality as 14869; Stotler limestone, Dry shale member, lower part.
14871	Same locality as 14869; Zeandale limestone, Maple Hill limestone member.
14872	SE¼SW¼ sec. 8, T. 23 S., R. 11 E., Greenwood County; Stotler limestone, Dry shale member, thin limestone beneath Grandhaven limestone member.
14873	SE¼SW¼ sec. 3, T. 19 S., R. 11 E., Lyon County; Stotler limestone, Grandhaven limestone member, shale in limestone.
14874	Center north side, sec. 23, T. 20 S., R. 11 E., Lyon County; strat. sec. 349; Zeandale limestone, Wamego shale member, shale above coal.
14875	Same locality and section as 14873; Zeandale limestone, Wamego shale member, concretionary zone above coal.
14876	Same locality and section as 14873; Zeandale limestone, Wamego shale member, marl zone above concretionary zone.
14877	Same locality and section as 14873; Zeandale limestone, Wamego shale member, "Stormont" limestone in shale.
14878	SW¼SW¼ sec. 24, T. 20 S., R. 11 E., Lyon County; Zeandale limestone, Wamego shale member, "Stormont" limestone of O'Connor (1953) in shale.
14879	SE¼ sec. 34, T. 21 S., R. 11 E., Lyon County; Zeandale limestone, Wamego shale member, shale above coal.
14880	Same locality as 14879; Zeandale limestone, Wamego shale member, marl zone above shale.
14881	Center NW¼ sec. 7, T. 18 S., R. 10 E., Lyon County; strat. sec. 11; Grenola limestone, Neva limestone member, unit 7.
14882	Same locality and section as 14881; Grenola limestone, Neva limestone member, unit 6.
14883	Same locality and section as 14881; Grenola limestone, Neva limestone member, unit 4.
14884	Same locality and section as 14881; Grenola limestone, Neva limestone member, unit 3.
14885	Center NW¼ sec. 7, T. 18 S., R. 10 E., Lyon County; strat. sec. 10; Grenola limestone, Burr limestone member, upper limestone.
14886	Same locality and section as 14885; Grenola limestone, Burr limestone member, shale in limestone.
14887	Center SE¼ sec. 7, T. 16 S., R. 12 E., Lyon County; strat. sec. 4; Janesville shale, Five Point limestone member.
14888	Same locality and section as 14887; Falls City limestone, upper part.
14889	Same locality and section as 14887; Janesville shale, West Branch shale member, lower part.
14890	Same locality and section as 14887; Falls City limestone, lower part.
14891	SE¼SE¼ sec. 26, T. 15 S., R. 11 E., Lyon County; strat. sec. 305; Foraker limestone, Hughes Creek shale member, lower part of unit 5.
14892	Same locality and section as 14891; Foraker limestone, Hughes Creek shale member, upper shale of unit 4.
14893	Same locality and section as 14891; Foraker limestone, Hughes Creek shale member, limestone in middle of unit 4.
14894	Same locality and section as 14891; Foraker limestone, Hughes Creek shale member, unit 3.
14895	Same locality and section as 14891; Foraker limestone, Hughes Creek shale member, unit 6.
14896	Streambank, SE¼NW¼ sec. 15, T. 15 S., R. 13 E., Wabaunsee County; strat. sec. 90; Zeandale limestone, Wamego shale member. (Section given in Mudge and Burton, 1959, section 74, p. 202.)
14897	NW¼NW¼ sec. 6, T. 9 S., R. 10 E., Pottawatomie County; strat. sec. 325; Stotler limestone, Dry shale member.
14898	Same locality and section as 14897; Stotler limestone, Grandhaven limestone member, lower limestone.
14899	Same locality and section as 14897; Stotler limestone, Grandhaven limestone member, upper limestone.
14903	SE¼SE¼ sec. 29, T. 7 S., R. 11 E., Pottawatomie County; strat. sec. 350; Root shale, Jim Creek limestone member.
14904	Same locality and section as 14903; Wood Siding formation, Nebraska City limestone member.
14905	SW¼SW¼ sec. 4, T. 3 S., R. 11 E., Brown County; strat. sec. 351; Beattie limestone, Florena shale member.
14906	Center, SW¼ sec. 30, T. 2 S., R. 16 E., Brown County; strat. sec. 352; Foraker limestone, Americus limestone member, lower limestone.
14907	Same locality and section as 14906; Foraker limestone, Americus limestone member, upper limestone.
14908	Same locality and section as 14906; Janesville shale, Hamlin shale member, just below Americus limestone member of the Foraker.
14909	Same locality and section as 14906; Foraker limestone, Hughes Creek shale member, lower two-thirds of unit 1.
14910	Same locality and section as 14906; Foraker limestone, Hughes Creek shale member, unit 2.
14911	Same locality and section as 14906; Foraker limestone, Hughes Creek shale member, upper part of unit 3.
14912	Same locality and section as 14906; Foraker limestone, Hughes Creek shale member, units 5 and 6.
14913	SW¼SE¼ sec. 10, T. 5 S., R. 16 E., Jackson County; strat. sec. 324; measured by R. G. Moss, Kansas Geological Survey; Stotler limestone, Grandhaven limestone member.

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14914	Roadside ditch, SE¼SE¼ sec. 36, T. 29 S., R. 9 E., Elk County; strat. sec. 291; Zeandale limestone, Wamego shale member, ostracode(?) zone above coal.
14915	Stream gully, NE¼NE¼ sec. 1, T. 32 S., R. 8 E., Chautauqua County; strat. sec. 283; Zeandale limestone, Wamego shale member, ostracode zone above coal.
14924	NW¼SE¼ sec. 12, T. 28 S., R. 9 E., Greenwood County; strat. sec. 336; Stotler limestone, Dry shale member, 7 ft beneath Grandhaven limestone member, limestone in shale.
14928	Road cut, Kansas Highway 36, NW¼SE¼ sec. 28, T. 2 S., R. 16 E., Brown County; strat. sec. 356; Falls City limestone, lower limestone.
14929	Center N½ sec. 20, T. 4 N., R. 16 E., Nemaha County, Nebr.; strat. sec. 353; Wood Siding formation, Nebraska City limestone member.
14930	Same locality and section as 14929; Wood Siding formation, Brownville limestone member.
14932	Same locality and section as 14929; Falls City limestone, lower limestone.
14933	Same locality and section as 14929; Falls City limestone, upper limestone.
14934	NW¼SE¼ sec. 19, T. 5 N., R. 16 E., Nemaha County, Nebr.; strat. sec. 354; Wood Siding formation, Brownville limestone member.
14935	Same locality and section as 14934; Wood Siding formation, Brownville limestone member, upper limestone.
14936	Same locality and section as 14934; Onaga shale, Aspinwall limestone member.
14937	SW¼SE¼ sec. 29, T. 6 N., R. 13 E., Nemaha County, Nebr.; strat. sec. 355; Janesville shale, Hamlin shale member.
14938	SW¼SW¼ sec. 24, T. 8 S., R. 13 E., Jackson County; strat. sec. 356; Janesville shale, Hamlin shale member, limestone bed.
14939	SE¼ sec. 21, T. 32 S., R. 8 E., Cowley County; strat. sec. 286; Janesville shale, Five Point limestone member, shale just below dense limestone.
14940	SW¼NW¼ sec. 29, T. 32 S., R. 8 E., Cowley County; Janesville shale, Five Point limestone member, lower fusulinid zone.
14941	Same locality as 14940; Janesville shale, Five Point limestone member, upper fusulinid zone.
15051	NE¼SE¼ sec. 12, T. 28 S., R. 9 E., Greenwood County; strat. sec. 335; Zeandale limestone, Wamego shale member, ostracode zone above coal.

STRATIGRAPHIC SECTIONS

The following stratigraphic sections include some of those illustrated on plates 1 to 5 and referred to in Part 1. The section numbers are those assigned in the field, and since many of the sections measured are not included herein, the numbers are not consecutive although the descriptions begin with the lowest field number and progress to the highest. The finding list below is included for ease in locating the sections in the following pages and on the correlation charts.

Most of the measured sections from Wabaunsee, Morris, Nemaha, and Pottawatomie Counties are omitted from this text, as many of them have been published previously (Mudge and Burton, 1959, p. 125–203); Mudge, Walters, and Skoog, 1959, p. 224–254; Mudge, Matthews, and Wells, 1958, p. 35–59; and Scott, Foster, and Crumpton, 1959, p. 148–176).

The number in parentheses after the description of a bed, for example (13640), is the fossil-collection number of that bed. These numbers also appear in Part 2 and in table 1.

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11. *Section from middle part of Hamlin shale member down into middle part of West Branch shale member of Janesville shale in a road cut in NW¼NW¼ sec. 21, T. 13 S., R. 13 E., Wabaunsee County, Kans.*

Permian system:
Janesville shale:
Hamlin shale member: Feet
14. Shale, silty, calcareous, tan, very cavernous ---- 5.6
13. Shale, clayey, calcareous, tan-gray to gray-green, thin-bedded; some iron-stained calcareous plates ---- 11.3
12. Sandstone and sandy shale, very micaceous, tan to brown, thin-bedded; well cemented and clayey in upper part; iron stains abundant ---- 4.1
11. Shale, clayey, noncalcareous, gray, thin-bedded; iron stains abundant ---- 16.9

Thickness exposed ---- 37.9

Five Point limestone member:
10. Limestone, clayey, light-gray, weathers blocky and platy; iron specks abundant; some fossil fragments ---- 3.2
9. Shale, silty, calcareous, tan, thin-bedded ---- 1.2
8. Limestone, hard, gray, weathers blocky; brachiopods abundant; pelecypods and crinoid columnals common ---- .6

Total thickness ---- 5.0

West Branch shale member:
7. Shale, silty, calcareous, tan-gray, thin-bedded ---- 1.3
6. Shale, very calcareous, gray, weathers to small irregular plates ---- .3
5. Shale, silty, calcareous, gray, thin-bedded ---- .6
4. Coal, impure, black, thin-bedded ---- .2
3. Shale, clayey, noncalcareous, gray, thin-bedded; iron stains abundant ---- 3.7
2. Shale, very calcareous, gray, weathers to small plates ---- 1.1
1. Shale, clayey, gray to tan-gray, thin-bedded; grades into sandy shale in upper part; thin calcareous plates abundant in upper part ---- 10.2

Thickness exposed ---- 17.4

Total thickness of exposed Janesville shale ---- 60.3

Base Covered.

25. *Section from Brownville limestone member of Wood Siding formation down into Dry shale member of Stotler limestone in a streambank in NW¼NE¼ sec. 9, T. 11 S., R. 9 E., Riley County, Kans.*

Pennsylvanian system:
Wood Siding formation:
Brownville limestone member: Feet
11. Limestone, hard, somewhat crystalline, gray-brown, massive, weathers to light brown and to irregular blocks; crinoid columnals, brachiopods, and bryozoans. Thickness exposed ---- 0.6
Pony Creek shale member:
10. Shale, clayey, noncalcareous, gray to blue-gray, thin-bedded; thin coal lens near base, many carbon stains on bedding planes in lower part; iron and limonite stains ---- 11.2
9. Channel sandstone, fine-grained, light-brown, thin-bedded; shaly in upper part; some crossbedding; well-sorted quartz grains, abundant mica flakes; limonite stains and concretions, some carbon stains ---- 21.3

Total thickness ---- 32.5

Total thickness of exposed Wood Siding formation ---- 33.1

Covered interval ---- 11.0
Root shale:
French Creek shale member:
8. Shale, clayey, noncalcareous, gray-brown, weathers tan; thin bedded to blocky; many limonite stains. Thickness ---- 5.5

Jim Creek limestone member:
7. Limestone, hard, dense, gray with purple tint, massive, weathers to gray with a brown zone near the top and to blocks which weather to small chips; iron stains in upper part; crinoid columnals, brachiopods, bryozoans, and pelecypods. Thickness ---- 1.1
Friedrich shale member:
6. Shale, clayey, noncalcareous, gray-green at base, grades to tan gray in upper part, weathers yellowish tan, thin-bedded; limonite stains ---- 8.2
5. Covered interval ---- 4.1

Thickness ---- 12.3

Total thickness of Root shale ---- 18.9

Stotler limestone:
Grandhaven limestone member:
4. Limestone, hard, gray with a green tint, massive, weathers tan gray and to irregular blocks or small chips; iron stains; small and large fusulinids, echinoid spines, pelecypods, and abundant crinoid columnals. Thickness ---- 1.6

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25. *Section from Brownville limestone member of Wood Siding formation down into Dry shale member of Stotler limestone in a streambank in NW¼NE¼ sec. 9, T. 11 S., R. 9 E., Riley County, Kans.*—Continued

Pennsylvanian system—Continued
Stotler limestone—Continued
Dry shale member: Feet

3. Shale, silty, very calcareous, gray-green, weathers tan, thin-bedded; thin limestone lens near base; brachiopods, bryozoans, crinoid columnals, and pelecypods. Possibly a transitional phase between the Dry shale member and the Grandhaven limestone member 2.1
2. Shale, clayey, noncalcareous, medium-gray-green, weathers light gray green, thin-bedded; many calcareous nodules at base; some limonite stains 3.6
1. Shale, silty, calcareous, light-brown, weathers yellow brown, thin-bedded; iron stains and calcareous nodules 4.3

Thickness exposed 10.0

Total thickness of exposed Stotler limestone 11.6

Base covered.

28. *Section of Brownville limestone member of Wood Siding formation down into a channel sandstone facies of French Creek shale member of Root shale in a stream and road cut in NW¼SW¼SW¼ sec. 31, T. 6 S., R. 15 E., Jackson County, Kans.*

Pennsylvanian system:
Wood Siding formation:
Brownville limestone member:

9. Limestone, medium-hard, tan to brown, weathers blocky to nodular; brown specks abundant; brachiopods and crinoid columnals 1.9
8. Shale, silty, calcareous, tan to tan-gray, thin-bedded .2
7. Limestone, medium-hard, light-brown, weathers blocky; brachiopods and crinoid columnals .7

Total thickness 2.8

Plumb and Pony Creek shale members, undifferentiated:

6. Shale, clayey, noncalcareous, gray, mottled with maroon in upper part, thin-bedded; some micaceous sandstone lentils 5.6
5. Shale and sandstone, micaceous, light-brown, thin- to thick-bedded 5.3
4. Shale, clayey, noncalcareous, gray, thin-bedded; limonite stains abundant 5.6

Total thickness 16.5

28. *Section of Brownville limestone member of Wood Siding formation down into a channel sandstone facies of French Creek shale member of Root shale in a stream and road cut in NW¼SW¼SW¼ sec. 31, T. 6 S., R. 15 E., Jackson County, Kans.*—Continued

Pennsylvanian system—Continued
Wood Siding formation—Continued Feet
Nebraska City limestone member:

3. Limestone, medium-hard, gray to tan, weathers blocky and to irregular chips; fossil fragments abundant, including brachiopods and bryozoans. Total thickness 1.2

Total thickness of Wood Siding formation 20.5

Root shale:
French Creek shale member:

2. Shale, sandy to clayey, tan to gray, thin-bedded; iron and carbon stains; many wood fragments, thin coal bed in upper part; upper part poorly exposd, basal contact disconformable on lower shale 30.3
1. Shale, clayey, noncalcareous, gray, thin-bedded to blocky; limonite-filled fractures 2.0

Thickness exposed 32.2

Total thickness of exposed Root shale 32.2

Base covered.

33. *Section of Brownville limestone member of Wood Siding formation down into the Friedrich shale member of Root shale in a road cut in the SW¼NW¼ sec. 19, T. 9 S., R. 14 E., Jackson County, Kans.*

Pennsylvanian system:
Wood Siding formation:
Brownville limestone member:

11. Limestone, medium-hard, gray to light-brown, weathers blocky and to irregular plates; crinoid columnals, brachiopods, and bryozoans (13640). Thickness 1.9

Plumb and Pony Creek shale members, undifferentiated:

10. Shale, clayey, some sand; calcareous, gray; mottled with some maroon, thin-bedded; very calcareous in lower part 7.2
9. Shale, silty, calcareous, maroon, blocky, weathers platy; cavernous 1.6
8. Shale, clayey, some silt, noncalcareous, gray-green to purple, blocky 5.6
7. Shale, silty, calcareous, maroon, weathers cavernous and porous 8.3

Total thickness 22.7

33. *Section of Brownville limestone member of Wood Siding formation down into the Friedrich shale member of Root shale in a road cut in the SW¼NW¼ sec. 19, T. 9 S., R. 14 E., Jackson County, Kans.*—Continued

	Feet
Pennsylvanian system—Continued	
Wood Siding formation—Continued	
Nebraska City limestone member:	
6. Limestone, medium-hard, gray, weathers platy; fossil fragments abundant, including crinoid columnals, brachiopods, and bryozoans (13639). Thickness	.6
Total thickness of Wood Siding formation	25.2
Root shale:	
French Creek shale member:	
5. Shale, clayey, calcareous, gray, thin-bedded; some iron stains	.6
4. Coal, impure, black, granular	.3
3. Shale, clayey, some sand, gray to light-brown, thin bedded in lower part, thick bedded in upper part; carbon stains, iron-stained plates abundant	23.7
Total thickness	24.6
Jim Creek limestone member:	
2. Limestone, medium-hard, gray to light-brown, weathers blocky and platy; fossil fragments abundant, including brachiopods. Thickness	.6
Friedrich shale member:	
1. Shale, clayey, calcareous, tan, thin-bedded; some sandstone lentils. Thickness exposed	4.8
Total thickness of exposed Root shale	30.3

Base covered.

34. *Section from Aspinwall limestone member of Onaga shale down into the Pony Creek shale member of Wood Siding formation in a road cut in the NW¼NW¼ sec. 27, T. 9 S., R. 13 E., Jackson County, Kans.*

	Feet
Permian system:	
Onaga shale:	
Aspinwall limestone member:	
8. Limestone, medium-hard, gray to light-brown, massive, weathers blocky; some brown specks and limonite nodules; porous. Thickness exposed	2.8
Towle shale member:	
7. Shale, clayey, calcareous, gray, mottled with purple and maroon, weathers blocky; sandy and conglomeratic in lower part; many calcium carbonate nodules, some limonite nodules	7.1
6. Limestone, impure, hard, light-gray, weathers shaly	.5

34. *Section from Aspinwall limestone member of Onaga shale down into the Pony Creek shale member of Wood Siding formation in a road cut in the NW¼NW¼ sec. 27, T. 9 S., R. 13 E., Jackson County, Kans.*—Continued

	Feet
Permian system—Continued	
Onaga shale—Continued	
Towle shale member—Continued	
5. Sandstone, very micaceous, tan gray in north part of cut, maroon in south part, thin- to thick-bedded; limonite nodules abundant; a channel sandstone facies is in south part of cut	2.1+
4. Shale, clayey, calcareous, tan to gray, blocky; many limonite plates; conglomeratic in basal part	3.9
3. Shale, clayey, noncalcareous, maroon, mottled with gray green, grades into gray in lowermost part, blocky	5.7
Thickness exposed	19.3
Total thickness of exposed Onaga shale	22.1
Pennsylvanian system:	
Wood Siding formation:	
Brownville limestone member:	
2. Limestone, medium-hard, light-brown, weathers blocky to nodular; thin shale parting; brachiopods, crinoid columnals, and bryozoans. Thickness	1.9
Pony Creek shale member:	
1. Shale, sandy, clayey, micaceous, gray, thin-bedded to massive; very sandy in upper part. Thickness exposed	7.7
Total thickness of exposed Wood Siding formation	9.6

Base covered.

52. *Section from Five Point limestone member of Janesville shale down into Wood Siding formation in a road cut in the SW¼SW¼ sec. 22, T. 32 S., R. 8 E., Chautauqua County, Kans.*

	Feet
Permian system:	
Janesville shale:	
Five Point limestone member:	
18. Shale, clayey, calcareous, gray-brown, thin-bedded; brachiopods, bryozoans, and pelecypods (13752)	5.6
17. Limestone, medium-hard, tan-gray, weathers blocky; fossil fragments abundant	.4
Total thickness exposed	6.0
West Branch shale member:	
16. Coal, impure, black, thin-bedded	.3
15. Shale, silty, calcareous, carbonaceous, tan-gray, thin-bedded; many iron-stained plates	23.3

52. *Section from Five Point limestone member of Janesville shale down into Wood Siding formation in a road cut in the SW¼SW¼ sec. 22, T. 32 S., R. 8 E., Chautauqua County, Kans.*—Continued

Permian system—Continued
Janesville shale—Continued
West Branch shale member—Continued (Feet)

14. Limestone, soft, gray to brown, weathers blocky; porous ---- 4.4
13. Shale, clayey, calcareous, gray, blocky ---- 3.8
12. Shale, sandy, micaceous, very carbonaceous, noncalcareous, dark-gray, thin-bedded; some massive sandstone beds show small scour and fill structures; some crossbedding and sand nodules and calcareous plates in upper part; west end of cut shows prominent sandstone-filled scour that does not cut into the underlying limestone ---- 11.3
11. Shale, very calcareous, tan-gray, thin-bedded; upper part more resistant to erosion ---- .6

Total thickness ---- 43.7

Total thickness of exposed Janesville shale ---- 49.7

Falls City limestone:

10. Limestone, hard, dense, dark-gray, weathers blocky; brown stains on weathered zone; shaly in upper part; fossil fragments including crinoid columnals (13751) ---- 1.5
9. Shale, clayey, calcareous, gray, thin-bedded ---- 1.2
8. Limestone, soft, tan to gray, shaly to blocky; impure in lower part, many thin shale partings ---- 3.3

Total thickness ---- 6.0

Onaga shale:
Hawxby shale member:

7. Shale, clayey, calcareous, gray, blocky. Thickness ---- 8.2

Aspinwall limestone member:

6. Limestone, medium-hard, light-brown, weathers blocky; crinoid columnals, bryozoans, brachiopods, pelecypods, and ostracodes(?) (13750) ---- .5
5. Shale, clayey, calcareous, gray, thin-bedded; calcium carbonate nodules; crinoid columnals, brachiopods, and bryozoans (13749) ---- .8
4. Limestone, medium-hard, tan-gray, weathers blocky; pelecypods abundant .6

Total thickness ---- 1.9

52. *Section from Five Point limestone member of Janesville shale down into Wood Siding formation in a road cut in the SW¼SW¼ sec. 22, T. 32 S., R. 8 E., Chautauqua County, Kans.*—Continued

Permian system—Continued
Onaga shale—Continued
Towle shale member: (Feet)

3. Shale, clayey, calcareous, gray-green, blocky ---- 3.3
2. Shale, silty, calcareous, light-brown, thin-bedded to blocky ---- 3.2

Total thickness ---- 6.5

Total thickness of Onaga shale ---- 16.6

Pennsylvanian system:
Wood Siding formation:
Brownville limestone member:

1. Limestone, hard, gray-brown, weathers brown and blocky; crinoid columnals and brachiopods (13748). Thickness ---- 1.5

Total thickness of exposed Wood Siding formation ---- 1.5

Base covered.

58. *Section of Nebraska City limestone member of Wood Siding formation down into Pillsbury shale in a road cut in the NE¼NE¼ sec. 28, T. 29 S., R. 9 E., Elk County, Kans.*

Pennsylvanian system:
Wood Siding formation:
Nebraska City limestone member:

15. Limestone, gray to tan-gray, weathers shaly; brachiopod fragments and pelecypods. Thickness exposed ---- 0.6

Total thickness of exposed Wood Siding formation ---- 0.6

Root shale:
French Creek shale member:

14. Shale, sandy, and sandstone, very micaceous, gray to light-brown, thin-bedded to massive; carbon and limonite stains; crossbedded; ripple marks; wood fragments; thin carbonaceous zones; limonite plates very abundant, especially in upper part. Thickness ---- 42.7

Jim Creek limestone member:

13. Limestone, hard, gray, weathers blocky; iron stains; crinoid columnals, fusulinids, shark teeth, and brachiopod fragments (13788). Thickness ---- 1.0

Friedrich shale member:

12. Shale, sandy, micaceous, tan-gray, thin-bedded; carbon and iron stains abundant; many sandstone lentils ---- 16.9

58. *Section of Nebraska City limestone member of Wood Siding formation down into Pillsbury shale in a road cut in the NE¼NE¼ sec. 28, T. 29 S., R. 9 E., Elk County, Kans.*—Continued

Pennsylvanian system—Continued
Root shale—Continued
Friedrich shale member—Continued — Feet

11. Limestone, medium-hard, gray, weathers tan and to irregular chips; some coal fragments; conglomeratic with subrounded clay balls; fossil fragments very abundant (13787) — .8
10. Shale, clayey, noncalcareous, gray, thin-bedded; covered in lower part — 6.7
9. Covered interval — 6.7

Total thickness — 31.1

Total thickness of Root shale — 74.8

Stotler limestone:
Grandhaven limestone member:

8. Limestone, medium-hard, gray with a purple tint, weathers tan, blocky, and to irregular fragments; crinoid columnals, fusulinids, brachiopods, bryozoans, and pelecypods. Thickness — .4

Dry shale member:

7. Shale, tan-gray, thin-bedded; crinoids and brachiopods in upper part — 3.5
6. Coal, black — .4
5. Covered interval; massive fine-grained sandstone beds 1.0 ft thick about 4.5 ft above Dover limestone — 5.2

Total thickness — 9.1

Dover limestone member:

4. Limestone, hard, fine-grained, light-brown, weathers tan, blocky; conchoidal fracture; algal deposits, brachiopods, and bryozoans, with rare fusulinids. Thickness — 2.0

Total thickness of Stotler limestone — 11.5

Pillsbury shale:

3. Shale, clayey, light-tan, mottled with gray; thin nodular limestone beds — 4.3
2. Limestone, hard, crystalline, light-brown — .3
1. Shale, silty, light-brown, thin-bedded — 8.9

Total thickness of exposed Pillsbury shale — 13.5

Base covered.

60. *Section from West Branch shale member of Janesville shale down into Pony Creek shale member of Wood Siding formation in a road cut in the SE¼SE¼ sec. 6, T. 29 S., R. 9 E., Elk County, Kans.*

Permian system:
Janesville shale:
West Branch shale member: — Feet

14. Limestone, impure, soft, light-brown, weathers tan and blocky; porous; columnar structure — 5.6
13. Shale, clayey, noncalcareous, gray, thin-bedded; some iron stains — 14.2

Total thickness exposed — 19.8

Total thickness of exposed Janesville shale — 19.8

Falls City limestone:

12. Limestone, hard, gray-brown to brown, weathers blocky; some iron stains; porous in lower part; thin shale parting; sandy in upper part; fossil fragments with crinoid columnals and pelecypod fragments abundant in lower part (13792) — 2.4
11. Shale, silty, calcareous, gray, thin-bedded; many calcium carbonate nodules — 3.9
10. Limestone, impure, dense, gray-brown, with brown lenses, weathers blocky — .3

Total thickness — 6.6

Onaga shale:
Hawxby shale member:

9. Shale, clayey, calcareous, gray to gray-brown; many calcium carbonate nodules and limonite-stained plates. Thickness — 3.5

Aspinwall limestone member(?):

8. Shale, clayey, calcareous, gray, thin-bedded; many impure gray and crystalline limestone lenses. Thickness — 7.3

Towle shale member:

7. Shale, clayey, calcareous, gray, thin bedded in upper part, blocky in lower part; separated by limonitic concretionary zone — 5.5
6. Limestone, sandy, micaceous, tan-gray, weathers blocky; lenticular — .4
5. Shale, clayey, calcareous, gray, thin-bedded; iron stains; many calcium carbonate and limonite nodules — 2.5

60. *Section from West Branch shale member of Janesville shale down into Pony Creek shale member of Wood Siding formation in a road cut in SE¼SE¼ sec. 6, T. 29 S., R. 9 E., Elk County, Kans.*—Continued

Permian system—Continued
  Onaga shale—Continued
    Towle shale member—Continued — Feet

4. Limestone, medium-hard, gray, weathers platy; fossil fragments, including abundant crinoid columnals; corals, fusulinids, bryozoans, pelecypods, and brachiopods (13791) — .6
3. Shale, clayey, calcareous, gray, thin-bedded; iron stains especially abundant in upper part — 4.0

Total thickness — 13.0

Total thickness of Onaga shale — 23.8

Pennsylvanian system:
  Wood Siding formation:
    Brownville limestone member:

2. Limestone, hard, gray-brown, weathers blocky; crinoid columnals and brachiopods abundant, bryozoans and fusulinids common. Thickness — 1.1

    Pony Creek shale member:

1. Shale, clayey, calcareous, gray, blocky to thin-bedded. Thickness exposed — 8.7

Total thickness of exposed Wood Siding formation — 9.8

Base covered.

65. *Section from Aspinwall limestone member of Onaga shale down into French Creek shale member of Root shale in a streambank and road cut in the NW¼SW¼SW¼ sec. 13, T. 16 S., R. 12 E., Lyon County, Kans.*

[See note at end of this section]

Permian system:
  Onaga shale:
    Aspinwall limestone member:

12. Limestone, medium-hard, crystalline, tan-gray, weathers gray and platy; porous; fossil fragments, especially pelecypods. Thickness exposed — 1.8±

    Towle shale member:

11. Covered. Thickness — 9.8

Total thickness of exposed Onaga shale — 11.6

Pennsylvanian system:
  Wood Siding formation:
    Brownville limestone member:

10. Limestone, medium-hard, gray to gray-brown, blocky to nodular; limonite-stained surface; brachiopods, crinoid columnals, and fusulinids. Thickness — 2.1

65. *Section from Aspinwall limestone member of Onaga shale down into French Creek shale member of Root shale in a streambank and road cut in the NW¼SW¼SW¼ sec. 13, T. 16 S., R. 12 E., Lyon County, Kans.*—Continued

Pennsylvanian system—Continued
  Wood Siding formation—Continued
    Pony Creek shale member: — Feet

9. Shale, silty, calcareous, tan gray in upper part; brachiopods in upper part; mostly covered. Thickness — 5.5

    Grayhorse limestone member:

8. Limestone, medium-hard, weathers tan, and to irregular plates; limonite nodules and clay balls, angular to rounded and as much as 1½ inches in diameter; crinoids, bryozoans, brachiopods, and pelecypods. Thickness — 1.3

    Plumb shale member:

7. Shale, clayey, some silt; calcareous, gray-green, blocky; iron stains on fracture planes — 5.4
6. Shale, silty, very calcareous, gray, thin-bedded; calcareous lentils; limonite stains — 2.3
5. Shale, clayey, noncalcareous, gray, thin-bedded; limonite stains and nodules abundant — 10.9

Total thickness — 18.6

    Nebraska City limestone member:

4. Limestone, hard, dark-gray, weathers shaly; fossil fragments abundant, including brachiopods — .5
3. Shale, silty, calcareous, gray, thin-bedded; brachiopods abundant, some crinoid columnals (13715) — 1.8

Total thickness — 2.3

Total thickness of Wood Siding formation — 29.8

  Root shale:
    French Creek shale member:

2. Coal, impure, black — .2
1. Shale, sandy, and sandstone, very micaceous, calcareous, light-brown, thin-bedded to massive; crossbedded; some ripple marks; carbon and iron stains abundant; plant fragments — 12.3

Total thickness exposed — 12.5

Total thickness of exposed Root shale — 12.5

Base covered.

(Section on plate 2 from French Creek shale member down to and including the Dover limestone member of the Stotler limestone obtained from the Kansas Geological Survey.)

69. *Section from the Americus limestone member of the Foraker limestone down into the Towle shale member of the Onaga shale in a road cut in the SW¼SE¼ sec. 23, T. 23 S., R. 10 E., Greenwood County, Kans.*

Permian system:

Foraker limestone:

Americus limestone member:

		Feet
38.	Shale	3.7
37.	Shale, clayey, grades to silty to sandy in upper part; calcareous, tan, in upper part, gray in lower part	5.8
36.	Limestone, crystalline to sandy, gray, medium-hard; thin clay seams; ostracodes (13816)	.2
	Thickness exposed	9.7
	Total thickness of exposed Foraker limestone	9.7

Janesville shale, type section:

Hamlin shale member:

		Feet
35.	Sandstone (calcarenite), calcareous fragments, tan, weathers platy; ostracode fragments	2.1
34.	Shale, silty, calcareous, tan, massive	6.4
33.	Limestone, clayey, dense in part, gray, weathers blocky; conchoidal fracture	.4
32.	Shale, covered	7.6
31.	Shale, clayey to silty, well-cemented, light-brown, cavernous	1.0
30.	Shale, silty, noncalcareous, gray to tan, blocky; sandy in lower part	8.0
29.	Sandstone, medium-hard, calcareous, fine-grained, light-brown, weathers thin bedded to blocky; iron stains in upper part	.3
28.	Shale, sandy to clayey, calcareous, tan to tan-gray, thin-bedded	13.5
27.	Conglomerate, hard, gray, weathers blocky; well-rounded clay and limonite balls that are not more than one-fourth inch in diameter; fossil fragments	.7
26.	Shale, covered	2.7
	Total thickness	42.7

Five Point limestone member:

		Feet
25.	Limestone, hard, gray, weathers gray and blocky; crinoid columnals, brachiopods, and fusulinids (13815)	.9
24.	Shale, silty, calcareous, gray, thin-bedded (13815)	.1
23.	Limestone, hard, brown, weathers tan, blocky; fractures at right angles; fossil fragments abundant, including crinoid columnals, pelecypods, bryozoans, and brachiopods (13815)	1.0
	Total thickness	2.0

69. *Section from the Americus limestone member of the Foraker limestone down into the Towle shale member of the Onaga shale in a road cut in the SW¼SE¼ sec. 23, T. 23 S., R. 10 E., Greenwood County, Kans.*—Con.

Permian system—Continued

Janesville shale, type section—Continued

West Branch shale member:

		Feet
22.	Shale, silty, calcareous, gray-brown, weathers tan, thin-bedded; iron stains	.7
21.	Coal, impure, black, thin-bedded	.2
20.	Shale, silty, calcareous, gray, weathers tan, thin-bedded; limonite stains	2.3
19.	Shale, sandy, and sandstone, calcareous, micaceous, light-brown, massive in upper part, thin bedded in lower part; carbon and iron stains abundant	5.8
18.	Limestone, hard, clayey, medium-gray, weathers light gray and blocky; pelecypods	.5
17.	Shale, silty, calcareous, tan-gray, blocky	3.5
16.	Limestone, soft, tan, massive; porous to cavernous	1.6
15.	Shale, clayey, calcareous, gray, thin-bedded; many limonite stains; some plates	9.2
14.	Shale, clayey to sandy, calcareous, micaceous, conglomeratic, gray to tan, clayey and thin bedded in lower part; clay balls and limestone nodules as much as 1 inch in diameter	4.5
	Total thickness	28.3
	Total thickness of Janesville shale	73.0

Falls City limestone:

		Feet
13.	Limestone, medium-hard, gray, weathers tan, platy; pelecypods, crinoid columnals, bryozoans, and brachiopods (13814)	.2
12.	Shale, clayey, calcareous, gray, thin-bedded; some iron stains	5.9
11.	Limestone, hard, dense in part, gray, blocky; fossil fragments abundant, including crinoid columnals (13814)	.8
10.	Limestone, hard, dense in part, gray, blocky; very irregular surface; pelecypods (13814)	.3
9.	Shale, silty, calcareous, gray-brown, blocky; calcareous lentils and nodules abundant	4.5
8.	Limestone, hard, clayey, gray, weathers blocky; pelecypods abundant (13814)	.4
	Total thickness	12.1

Onaga shale:

Hawxby(?) shale member:

		Feet
7.	Shale, clayey, calcareous, gray, blocky; heavily iron stained in part. Thickness	18.4

69. *Section from the Americus limestone member of the Foraker limestone down into the Towle shale member on the Onaga shale in a road cut in the SW¼SE¼ sec. 23, T. 23 S., R 10 E., Greenwood County, Kans.*—Con.

	Feet
Permian system—Continued	
Onaga shale—Continued	
Aspinwall limestone member:	
6. Shale, silty, calcareous, light-brown; many thin beds of clayey limestone, thicker beds of limestone in upper part. Thickness	7.6
Towle shale member:	
5. Shale, silty, calcareous, gray to gray-brown, thin-bedded; iron stains	.3
4. Shale, clayey, calcareous, gray to gray-brown, thin-bedded	10.6
3. Shale, covered	4.4
Total thickness	15.3
Total thickness of Onaga shale	41.3
Pennsylvanian system:	
Wood Siding formation:	
Brownville limestone member:	
2. Limestone, hard, brown to gray-brown, weathers brown and blocky and to irregular plates; crinoid columnals, brachiopods, fusulinids, and bryozoans (13813). Thickness	1.5
Pony Creek shale member:	
1. Shale, clayey, noncalcareous, gray, thin-bedded; some fossils in upper part (13812). Thickness exposed	7.6
Total thickness of exposed Wood Siding formation	9.1

Base covered.

71. *Section from Brownville limestone member of Wood Siding formation down into Jim Creek limestone member of Root shale in a road cut in the NW¼NE¼ sec. 7, T. 22 S., R. 11 E., Greenwood County, Kans.*

	Feet
Pennsylvanian system:	
Wood Siding formation:	
Brownville limestone member:	
15. Limestone, medium-hard, gray to gray-brown, weathers brown; crinoid columnals, brachiopods, fusulinids, bryozoans, and corals. Thickness	2.1
Pony Creek shale member:	
14. Shale, clayey, noncalcareous, gray, thin-bedded; some iron stains. Thickness	7.1
Grayhorse limestone member:	
13. Limestone, medium-hard, gray-brown, thin-bedded; pelecypods	.1

71. *Section from Brownville limestone member of Wood Siding formation down into Jim Creek limestone member of Root shale in a road cut in the NW¼NE¼ sec. 7, T. 22 S., R. 11 E., Greenwood County, Kans.*—Continued

	Feet
Pennsylvanian system—Continued	
Wood Siding formation—Continued	
Grayhorse limestone member—Continued	
12. Shale, silty, some sand, light-brown, massive to thin-bedded; many limestone lentils; pelecypods and bryozoans	6.8
Total thickness	6.9
Plumb shale member:	
11. Shale, clayey, noncalcareous, gray, thin-bedded; limonite stains	11.6
10. Limestone, hard, gray-brown, weathers tan, blocky; iron stains; fossil fragments very abundant, including brachiopods	1.1
9. Shale, clayey, noncalcareous, gray, thin-bedded; iron-stained zones	6.3
Total thickness	19.0
Nebraska City limestone member:	
8. Shale, silty, calcareous, gray-brown, thin-bedded; brachiopods and pelecypods. Thickness	.6
Total thickness of Wood Siding formation	35.7
Root shale:	
French Creek shale member:	
7. Shale, clayey, noncalcareous, gray	2.9
6. Shale, sandy, micaceous, noncalcareous, tan-gray, thin-bedded; limonite and carbon stains	2.2
5. Sandstone, medium-hard, micaceous, gray-brown; iron stains in upper part	.3
4. Shale, sandy, micaceous, tan to gray-brown, thin-bedded	1.6
3. Sandstone, medium-hard, micaceous, gray-brown, thin-bedded	.3
2. Shale, clayey, noncalcareous, gray to gray-brown, thin-bedded to blocky; iron-stained plates; iron stains abundant on fracture planes	26.0
Total thickness	33.3
Jim Creek limestone member:	
1. Limestone, medium-hard, gray with purple tint, weathers to irregular chips; very fossiliferous (13832). Thickness	1.1
Total thickness of exposed Root shale	34.4

Covered interval of 53.6 ft to top of Dover limestone member of Stotler limestone. About 1.5 ft of Dover limestone member is exposed.

Base covered.

73. *Section from lower part of Falls City limestone down into Brownville limestone member of Wood Siding formation in a stream bank and road cut in the SW¼NW¼ sec. 23, T. 2 S., R. 16 E., Brown County, Kans.*

Permian system:

Falls City limestone: Feet

7. Limestone, medium-hard, gray; thin clay lentils, dense and cherty in appearance; many limonite stains in minute nodules; coquina ---- 1.8
6. Shale, clayey, calcareous, medium-gray, mottled with dark gray, thin-bedded; iron stains abundant ---- 9.6
5. Limestone, medium-hard, gray, weathers blocky to shaly; crinoid columnals, bryozoans, and pelecypods (13428) ---- 1.3

Thickness exposed ---- 12.7

Onaga shale, undifferentiated:

4. Shale, clayey, calcareous, gray, thin-bedded ---- 14.1
3. Sandstone and sandy shale, micaceous, fine-grained, maroon, massive to thin-bedded ---- 3.4
2. Shale, clayey, noncalcareous, gray, thin-bedded ---- 3.1

Total thickness ---- 20.6

Pennsylvanian system:

Wood Siding formation:

Brownville limestone member:

1. Limestone, medium-hard, gray to tan-gray, weathers blocky to shaly; brachiopods, crinoid columnals, and minute fossil fragments (13429). Thickness ---- 1.9

Total thickness of exposed Wood Siding formation ---- 1.9

Base covered.

94. *Section from Aspinwall limestone member of Onaga shale down into Plumb shale member of Wood Siding formation in a stream bank in the NW¼NW¼ sec. 16, T. 9 S., R. 9 E., Pottawatomie County, Kans.*

Permian system:

Onaga shale:

Aspinwall limestone member:

8. Limestone, medium-hard, tan, weathers blocky to platy; fossil fragments abundant in zones ---- 0.9
7. Shale, silty, calcareous, tan to tan-gray; many thin clayey limestone beds; siltstone bed 0.4 ft thick in lower part ---- 3.0
6. Limestone, medium-hard, clayey, light-brown, weathers nodular and blocky; some brachiopod fragments, crinoid columnals, and pelecypods ---- 2.1

Total thickness ---- 6.0

94. *Section from Aspinwall limestone member of Onaga shale down into Plumb shale member of Wood Siding formation in a stream bank in the NW¼NW¼ sec. 16, T. 9 S., R. 9 E., Pottawatomie County, Kans.*—Continued

Permian system—Continued

Onaga shale—Continued Feet

Towle shale member:

5. Shale, silty, noncalcareous, gray, blocky. Thickness ---- 3.8

Total thickness of exposed Onaga shale ---- 9.8

Pennsylvanian system:

Wood Siding formation:

Brownville limestone member:

4. Limestone, medium-hard, gray to light-brown, weathers blocky to nodular; brachiopods abundant, crinoid columnals, bryozoans, and gastropods common (13447). Thickness ---- 2.2

Pony Creek shale member:

3. Shale, clayey to silty, noncalcareous, gray to tan-gray, thin-bedded; iron stains, especially in upper part; channel facies in east end of exposure, that cuts through Grayhorse limestone member and Plumb shale member. Thickness ---- 3.4

Grayhorse limestone member:

2. Limestone, hard, conglomeratic, light-gray to tan-gray, weathers blocky; mud balls, angular, some rounded and elongated, range from microsize to 2½ inches in diameter; limestone fragments of various sizes and shapes; pyrite nodules abundant on upper surface; pelecypods abundant; crinoid columnals, bryozoans, and brachiopods; fossils, especially pelecypods, are well preserved; all are thin shelled. Thickness ---- 1.2

Plumb shale member:

1. Shale, clayey, some silt, noncalcareous, gray, blocky to thin-bedded; many iron stains on fracture planes. Thickness exposed ---- 9.6

Total thickness of exposed Wood Siding formation ---- 16.4

Base covered.

104. *Section from Hawxby shale member of Onaga shale down into Friedrich shale member of Root shale in a road cut and stream bank in the NW¼NE¼NE¼ sec. 7, T. 8 S., R. 11 E., Pottawatomie County, Kans.*

	Feet
Permian system:	
Onaga shale:	
Hawxby shale member:	
15. Shale, maroon in lower part, grades into purple. Thickness exposed	5.7
Aspinwall limestone member:	
14. Limestone, medium-hard, tan, with brown streaks, weathers platy to blocky; streaks contain minute fossil fragments and microfossils (13518), also iron stains; porous	1.2
13. Shale, calcareous, gray-green, thin-bedded	.8
12. Limestone, soft, gray, blocky, porous	.3
Total thickness	2.3
Towle shale member:	
11. Shale, silty, some sand and mica, calcareous, maroon, mottled with gray green, blocky. Thickness	9.3
Total thickness of exposed Onaga shale	17.3
Pennsylvanian system:	
Wood Siding formation:	
Brownville limestone member:	
10. Limestone, medium-hard, brown to tan, weathers blocky; crinoid columnals and brachiopods	.4
9. Shale, silty, calcareous, tan, thin-bedded; brachiopod fragments	.8
8. Limestone, medium-hard, medium- to light-brown, weathers blocky and nodular; brachiopods abundant; crinoid columnals and brachiopod fragments (13517)	1.2
Total thickness	2.4
Plumb and Pony Creek shale members, undifferentiated:	
7. Shale, clayey, some silt, noncalcareous, gray, with dark-gray lens, thin-bedded; iron stains abundant on fracture planes; sandy in lower part; upper foot is silty and contains brachiopods. Thickness	9.6
Nebraska City limestone member:	
6. Limestone, shaly, soft to medium-hard, gray, weathers to small chips; brachiopods (13516). Thickness	1.3
Total thickness of Wood Siding formation	13.3

104. *Section from Hawxby shale member of Onaga shale down into Friedrich shale member of Root shale in a road cut and stream bank in the NW¼NE¼NE¼ sec. 7, T. 8 S., R. 11 E., Pottawatomie County, Kans.*—Continued

	Feet
Pennsylvanian system—Continued	
Root shale:	
French Creek shale member:	
5. Shale, silty, calcareous, tan, thin-bedded; many iron stains	.4
4. Coal, black, impure, thin-bedded	.4
3. Shale, clayey and sandy in lower part, grades up into beds of gray sandstone and sandy shale; sandstone beds are massive to thin bedded, micaceous, and calcareous; some beds are firmly cemented; sandy shale is thin bedded and gray with many limonite stains, nodules, and plates	29.2
Total thickness	30.0
Jim Creek limestone member:	
2. Limestone, medium-hard, gray, mottled with dark gray, weathers to small chips; small fusulinids abundant; brachiopods (13515). Thickness	1.0
Friedrich shale member:	
1. Shale, sandy, tan, thin-bedded; ripple marked; many iron stains and brown specks. Thickness	2.0
Total thickness of exposed Root shale	33.0

Base covered.

113. *Section from Aspinwall limestone member of Onaga shale down into Pillsbury shale in a road cut in the NE¼SW¼ sec. 28, T. 6 S., R. 12 E., Pottawatomie County, Kans.*

Permian system:	
Onaga shale:	
Aspinwall limestone member:	
29. Limestone, medium-hard, gray, weathers blocky; some clay balls as much as 1 inch in diameter, limonite nodules, partly conglomeratic. Thickness exposed	0.7
Towle shale member:	
28. Shale, silty, calcareous, gray to tan-gray, mottled with maroon, blocky; many calcareous nodules, and limonite-stained areas	4.4
27. Shale, sandy, micaceous, gray-green, thin-bedded; thin sandstone beds in lower part; many iron stains	1.4
26. Shale, clayey, some mica, slightly calcareous, maroon, mottled with gray green, thin-bedded; some iron stains	4.1
Total thickness	9.9
Total thickness of exposed Onaga shale	10.6

113. *Section from Aspinwall limestone member of Onaga shale down into Pillsbury shale in a road cut in the NE¼SW¼ sec. 28, T. 6 S., R. 12 E., Pottawatomie County, Kans.*—Continued

Pennsylvanian system:
Wood Siding formation:
Brownville limestone member: Feet
25. Limestone, soft to medium-hard, light-brown, weathers blocky to nodular; shaly in part; brown specks abundant; brachiopods common (13536). Thickness 2.3

Plumb and Pony Creek shale members, undifferentiated:
24. Shale, sandy, micaceous, calcareous, gray-green, massive; many iron stains 1.1
23. Conglomerate, composed of sandstone, clay balls, mica, limonite nodules and plates, and sandstone lentils 1
22. Shale, silty, some mica, noncalcareous, maroon, mottled with gray green, thin-bedded; some iron stains 2.5
21. Shale, silty to sandy, micaceous, calcareous, gray-green, thin-bedded; sandstone lentils in lower part; iron stains and nodules common 3.9
20. Shale, clayey, noncalcareous, maroon, mottled with gray, thin-bedded 1.9
19. Shale, clayey, noncalcareous, tan-gray to gray, thin-bedded; limonite stains abundant 3.9

Total thickness 13.4

Nebraska City limestone member:
18. Limestone, hard in upper part, soft and shaly in lower part, tan to gray, weathers blocky and to small plates; brachiopods abundant (13535). Thickness 1.6

Total thickness of Wood Siding formation 17.3

Root shale:
French Creek shale member:
17. Shale, silty, some clay, noncalcareous, tan, thin-bedded; brachiopods 1.1
16. Coal, impure, black, thin-bedded; clay lentils 2
15. Shale, clayey, noncalcareous, light-gray, thin-bedded; iron plates, nodules, and stains abundant 3.8
14. Shale, clayey, noncalcareous, thin-bedded; many calcareous lenses consisting entirely of fossil fragments with many wood and coal fragments; upper lenses contain brachiopods and bryozoans 9
13. Shale, clayey, noncalcareous, slightly micaceous, tan-gray, thin-bedded; some iron stains; some thin beds of limestone 3.2

113. *Section from Aspinwall limestone member of Onaga shale down into Pillsbury shale in a road cut in the NE¼SW¼ sec. 28, T. 6 S., R. 12 E., Pottawatomie County, Kans.*—Continued

Pennsylvanian system—Continued
Root shale—Continued
French Creek shale member—Continued Feet
12. Coal, black, blocky; many iron stains 5
11. Shale, silty to sandy, micaceous, tan to tan-gray, thin-bedded; some sandstone lentils; iron-stained plates and nodules abundant; some carbon stains 5.6

Total thickness 15.3

Jim Creek limestone member:
10. Limestone, medium-hard, gray, with green tint, weathers blocky and to chips; iron stains; brachiopod fragments abundant, crinoid columnals and fusulinids common (13534). Thickness 1.1

Friedrich shale member:
9. Sandstone, fine-grained, micaceous, light-brown, weathers medium brown, thin-bedded to platy; iron stains abundant; some sandy shale lenses 3.3
8. Shale, clayey, gray-green, with some maroon in upper part; sandy in lower part; mostly covered 14.8

Total thickness 18.1

Total thickness of Root shale 34.5

Stotler limestone:
Grandhaven limestone member:
7. Limestone, medium-hard, gray to light-brown, weathers brown and to irregular plates; iron stains on upper surface; fossil fragments and crinoid columnals (13533). Thickness 9

Dry shale member:
6. Shale, silty, calcareous, tan-gray, thin-bedded; calcareous plates. Thickness 3

Dover limestone member:
5. Limestone, medium-hard, gray to tan-gray, weathers to irregular plates; fusulinids abundant 1.6
4. Shale, clayey, calcareous, gray-green, blocky 6
3. Limestone, medium-hard, dense in upper part, light-brown, massive, weathers blocky; fusulinids 1.9

Total thickness 4.1

Total thickness of Stotler limestone 5.3

113. *Section from Aspinwall limestone member of Onaga shale down into Pillsbury shale in a road cut in the NE¼SW¼ sec. 28, T. 6 S., R. 12 E., Pottawatomie County, Kans.*—Continued

Pennsylvanian system—Continued

Pillsbury shale: (Feet)

2. Shale, silty, noncalcareous, gray-green, mottled with maroon in lower part, thin-bedded; limonite nodules in upper part ---- 2.2
1. Shale, silty, slightly sandy and calcareous, purple and maroon, thin-bedded to blocky ---- 2.5

Total thickness of exposed Pillsbury shale ---- 4.7

Base covered.

114. *Section from Towle shale member of Onaga shale down into Friedrich shale member of Root shale in the NW¼SW¼SW¼ sec. 18, T. 10 S., R. 12 E., Shawnee County, Kans.*

Permian system:

Onaga shale:

Towle shale member:

12. Shale, clayey, noncalcareous, gray to gray-green, thin-bedded; some sandstone lentils in upper part ---- 5.5
11. Shale, silty, slightly micaceous, noncalcareous, tan gray in lower part, maroon in upper part, thin-bedded; some limonite-stained zones ---- 5.6

Total thickness exposed ---- 11.1

Total thickness of exposed Onaga shale ---- 11.1

Pennsylvanian system:

Wood Siding formation:

Brownville limestone member:

10. Limestone, medium-hard to hard, tan to brown, massive, weathers blocky; minute brown specks; zones of minute fossil fragments common, crinoid columnals and brachiopods abundant, corals and gastropods common. Thickness ---- 2.3

Plumb and Pony Creek shale members, undifferentiated:

9. Shale, noncalcareous, clayey in upper part, sandy and micaceous in lower part, tan to gray-green, thin bedded in lower part; sandy beds above maroon zone; some iron-stained zones; thin carbon-stained zones 2.8 ft beneath the Brownville; brachiopods in uppermost part ---- 8.4
8. Shale, sandy, calcareous, micaceous, maroon, with many gray-green or tan-gray lenses, thin-bedded; micaceous sand lentils ---- 3.3

114. *Section from Towle shale member of Onaga shale down into Friedrich shale member of Root shale in the NW¼SW¼SW¼ sec. 18, T. 10 S., R. 12 E., Shawnee County, Kans.*—Continued

Pennsylvanian system—Continued

Wood Siding formation—Continued (Feet)

Plumb and Pony Creek shale members, undifferentiated—Continued

7. Shale, clayey, some silt, gray to tan, with some purple stains in upper part, thin-bedded; many iron-stained beds and plates; sandy and micaceous in upper part ---- 6.3

Total thickness ---- 18.0

Nebraska City limestone member:

6. Limestone, soft, gray, weathers shaly and to small plates; brachiopods and pelecypods abundant. Thickness ---- 1.3

Total thickness of Wood Siding formation ---- 19.3

Root shale:

French Creek shale member:

5. Shale, silty, calcareous, tan, thin-bedded; fossil fragments ---- .6
4. Coal, impure, black, thin-bedded; clay lentils ---- .3
3. Shale, silty to clayey in lower part, sandy shale and sandstone in upper part, micaceous, tan to tan-gray, thin- to thick-bedded; firmly cemented sandstone in upper part; some crossbedding in sandy shale beneath cemented sandstone; many iron stains in nodules and plates; carbon stains; secondary calcite fills fractures; wood fragments ---- 23.9

Total thickness ---- 24.8

Jim Creek limestone member:

2. Limestone, hard, gray, with purple and green tint, weathers blocky to platy; 1- to 2-inch limonite-weathered zone; crinoid columnals, small fusulinids, and brachiopod fragments. Thickness 1.2

Friedrich shale member:

1. Shale, sandy to silty, gray to gray-green, with some thin maroon shale lenses in middle part, gray-green and tan sandy shale in upper part, noncalcareous; thin micaceous sandstone lenses in upper part; iron stains and plates abundant. Thickness exposed ---- 17.3

Total thickness of exposed Root shale ---- 43.3

Base covered.

128. *Section from Eskridge shale into lower part of Hughes Creek shale member of Foraker limestone in a streambank in the NE¼NW¼ sec 3, T. 8 S., R. 9 E., in Pottawatomie County, Kans.*

Permian system:

	Feet
Colluvium and gray silty soil covering the upper part of the Eskridge shale	15+
Eskridge shale:	
65. Shale, silty, calcareous, gray-green, mottled with purple in lower part, maroon in upper part, blocky. Thickness exposed	6.6
Grenola limestone:	
Neva limestone member:	
64. Limestone, medium-hard, light-gray, massive, weathers blocky; algal deposits, some microfossils, crinoid columnals, pelecypods, and abundant minute fossil fragments	4.9
63. Shale, silty, calcareous, gray-green, weathers light gray, thin-bedded (13469)	.2
62. Limestone, hard, argillaceous, dense, gray, massive, weathers tan gray and blocky	.8
61. Shale, silty, calcareous, tan-gray, thin-bedded	1.0
60. Limestone, medium-hard, argillaceous, gray, massive, weathers tan gray, and shaly; some microfossils	.5
59. Shale, silty, very calcareous, gray-green, thin-bedded	.3
58. Limestone, soft, argillaceous, tan-gray, with some gray-green stains, massive, weathers porous; conglomeratic appearance	7.1
57. Shale, silty, calcareous, tan-gray, mottled with gray, blocky; fusulinids, crinoid columnals, and brachiopods (13468)	.9
56. Shale, clayey, calcareous, very dark gray, fissile; iron stains on fracture planes	1.6
55. Limestone, medium-hard, slightly argillaceous, tan-gray, massive, weathers blocky; pelecypods and some fossil fragments	1.7
Total thickness	19.0
Salem Point shale member:	
54. Shale, silty, calcareous, tan-gray, mottled with some gray, thin-bedded; some limonite stains	1.9
53. Limestone, medium-hard, argillaceous, light-gray, massive, weathers tan gray, and blocky to shaly; many limonite-stained areas; pelecypods and ostracodes	1.9

128. *Section from Eskridge shale into lower part of Hughes Creek shale member of Foraker limestone in a streambank in the NE¼NW¼ sec. 3, T. 8 S., R. 9 E., in Pottawatomie County, Kans.*—Continued

Permian system—Continued

	Feet
Grenola limestone—Continued	
Salem Point shale member—Continued	
52. Shale, silty, calcareous, light-gray-green, thin-bedded to blocky; some iron stains	2.9
Total thickness	6.7
Burr limestone member:	
51. Limestone, soft, tan, massive; weathers tan gray, blocky, and porous; pelecypods and ostracodes very abundant in top part	3.8
50. Shale, clayey, noncalcareous, very-dark-gray, mottled with some tan gray, thin-bedded to fissile; some limonite-stained zones containing microfossils	1.4
49. Limestone, hard, argillaceous in part, tan-gray, massive, weathers blocky; some fossil fragments (13467)	2.3
Total thickness	7.5
Legion shale member:	
48. Shale, silty, some clay, calcareous, tan-gray, blocky; some iron stains	.7
47. Shale, silty, calcareous, light-gray to gray, blocky	4.1
Total thickness	4.8
Sallyards limestone member:	
46. Limestone, hard, argillaceous, dense, tan-gray, massive, weathers blocky; brachiopods, pelecypods, algal deposits, crinoid columnals, echinoid spines, and many minute fossil fragments; all fossils at very top. Thickness	.9
Total thickness of Grenola limestone	38.9
Roca shale:	
45. Shale, silty, calcareous, dark-gray-green, weathers light gray green, blocky; very abundant rounded to angular limestone granules; possibly denotes intraformational conglomerate	.7
44. Limestone, hard, argillaceous, dense, tan-gray, with gray-green tint, massive, weathers light gray and blocky to nodular; some iron stains	1.4
43. Shale, silty, calcareous, gray-green, mottled some gray brown, blocky; many iron stains	4.3

128. *Section from Eskridge shale into lower part of Hughes Creek shale member of Foraker limestone in a streambank in the NE¼NW¼ sec. 3, T. 8 S., R. 9 E., in Pottawatomie County, Kans.*—Continued

	Feet
Permian system—Continued	
Roca shale—Continued	
42. Shale, silty, calcareous, very-light-gray, blocky; some iron stains	.9
41. Shale, clayey, some silt, calcareous, dark-gray-green, weathers gray to gray green, blocky	2.4
40. Limestone, hard, argillaceous, dense in part, tan-gray, with gray-green tint, massive; weathers light gray and blocky; some iron stains	1.8
39. Shale, silty, calcareous, gray-green, blocky	.2
38. Limestone, hard, argillaceous, dense, light-gray, massive, weathers blocky to shaly	1.2
37. Shale, silty, calcareous, green, mottled with maroon in middle part, blocky	4.4
Total thickness	17.3
Red Eagle limestone:	
Howe limestone member:	
36. Limestone, medium-hard, tan-gray, massive; weathers tan and blocky; porous, with some pore spaces filled with calcite; some limonite stains; ostracodes very abundant, some gastropods; all fossils in zone near middle part of limestone	1.4
35. Shale, silty, calcareous, tan-gray, weathers gray, thin-bedded; some limonite stains	.4
34. Limestone, soft, dolomitic, tan-gray, massive; weathers tan and blocky and to thin chips; many limonite stains. (13466)	2.5
Total thickness	4.3
Bennett shale member:	
33. Shale, silty, calcareous, dark-gray, weathers light gray, thin-bedded; some iron stains; *Crurithyris*, bryozoans, some microfossils in lower part, brachiopod fragments abundant in upper part (13465). Thickness	3.2
Glenrock limestone member:	
32. Limestone, hard, argillaceous in part, crystalline in part, gray, massive; weathers brown and blocky; *Orbiculoidea;* fossil fragments very abundant on surface (13464)	.5

128. *Section from Eskridge shale into lower part of Hughes Creek shale member of Foraker limestone in a streambank in the NE¼NW¼ sec. 3, T. 8 S., R. 9 E., in Pottawatomie County, Kans.*—Continued

	Feet
Permian system—Continued	
Red Eagle limestone—Continued	
Glenrock limestone member—Continued	
31. Shale, silty, calcareous, dark-gray-brown, weathers gray, thin-bedded; dark-gray specks abundant in lower part; limonite stains in upper part; microfossils abundant in top part	.6
Total thickness	1.1
Total thickness of Red Eagle limestone	8.6
Johnson shale:	
30. Shale, clayey, very calcareous, medium-gray, mottled with light gray, weathers light gray; blocky; dark-gray intraformational conglomerate, abundant clay balls that are flat and angular; some have a maximum diameter of ¾ inches; some iron stains on fracture planes	1.5
29. Shale, clayey, calcareous, dark-gray, blocky; some iron stains on fracture planes	4.7
28. Limestone, hard, dense, gray, massive, weathers tan gray and blocky to platy; penecontemporaneous folding	1.0
27. Shale, silty, calcareous, tan-gray, blocky; some limestone nodules	.2
26. Limestone, medium-hard, argillaceous, dark-gray-brown, weathers tan gray, blocky; some iron stains	.1
25. Shale, clayey, noncalcareous, dark-gray, mottled with gray green, weathers light gray green, blocky; fractures 60° from horizontal; iron stains on fracture planes	.4
24. Limestone, soft, dolomitic in part, light-gray to tan-gray, massive, weathers light gray and blocky to shaly	1.3
23. Limestone, hard, argillaceous, gray-brown, massive, weathers light gray and blocky to shaly; some iron stains	.4
22. Shale, silty, calcareous, gray-green, weathers light gray green, blocky; limestone lenses in middle; limonite and iron stains on fracture planes	4.6
21. Shale, clayey, very calcareous, gray, weathers light gray, blocky to thin-bedded; fractures at 45° from horizontal; basal part weathers nodular	5.7
20. Shale, clayey, noncalcareous, gray-green, weathers light gray green, blocky; limonite stains on fracture planes	1.0

128. *Section from Eskridge shale into lower part of Hughes Creek shale member of Foraker limestone in a streambank in the NE¼NW¼ sec. 3, T. 8 S., R. 9 E., in Pottawatomie County, Kans.*—Continued

	Feet
Permian system—Continued	
Johnson shale—Continued	
19. Shale, silty, calcareous, maroon, mottled with gray green, blocky	.9
18. Shale, silty, calcareous, gray-green, blocky; fine-grained limestone lenses near top	3.8
Total thickness	25.6
Foraker limestone:	
Long Creek limestone member:	
17. Limestone, soft, dolomitic, tan, massive, weathers to irregular blocks and plates; porous; celestite(?)-lined cavities abundant	4.1
16. Shale, silty, calcareous, tan-gray, thin-bedded	.3
15. Limestone, medium-hard, tan, massive, weathers blocky; fossil fragments abundant, including crinoid columnals, algal deposits, and shark teeth	.5
Total thickness	4.9
Hughes Creek shale member:	
14. Shale, silty, calcareous, dark-gray, weathers light gray, thin-bedded; crinoid columnals	.3
13. Limestone, medium-hard, argillaceous, gray-brown, massive, weathers tan gray and blocky to shaly; iron stains abundant near base; composed almost entirely of fusulinids; some brachiopods (13463)	2.1
12. Shale, clayey, noncalcareous, dark-gray, weathers medium gray, thin-bedded to blocky; pelecypods, brachiopods, and ostracodes; some fossil fragments including crinoid columnals and bryozoans (13462)	3.8
11. Shale, silty, calcareous, dark-gray, weathers medium gray, blocky; very calcareous in top part; large and small fusulinids abundant; brachiopods and bryozoans common (13461)	1.8
10. Limestone, soft, argillaceous; dark gray, massive, weathers gray and shaly and to irregular fragments; brachiopods, fusulinids, crinoid columnals, and other fossil fragments (13460)	.9
9. Shale, silty, calcareous, dark-gray, weathers gray, thin-bedded to blocky; some iron-stained areas; microfossils at base; brachiopods abundant (13459)	2.1

128. *Section from Eskridge shale into lower part of Hughes Creek shale member of Foraker limestone in a streambank in the NE¼NW¼ sec. 3, T. 8 S., R. 9 E., in Pottawatomie County, Kans.*—Continued

	Feet
Permian system—Continued	
Foraker limestone—Continued	
Hughes Creek shale member—Continued	
8. Limestone, medium-hard, light-brown, massive, weathers blocky; some limonite stains on surface; minute fossil fragments abundant; brachiopods (13458)	1.2
7. Shale, silty, calcareous, dark-gray, weathers gray, thin-bedded; more calcareous in lower part; brachiopods, pelecypods, bryozoans, crinoid columnals, fusulinids, and microfossils abundant; fossils more abundant in lower half (13457)	5.8
6. Limestone, medium-hard, argillaceous, dark-gray, massive, weathers tan gray and blocky to shaly; fusulinids, echinoid spines, brachiopods, and crinoid columnals (13456)	1.1
5. Shale, clayey, slightly calcareous, dark-gray, weathers gray, thin-bedded; pelecypods and brachiopods abundant (13455)	.6
4. Limestone, medium-hard, somewhat argillaceous, tan-gray, massive, weathers blocky; some carbon specks; brachiopods (13454)	.9
3. Shale, silty, slightly calcareous, dark-gray, weathers light gray, blocky. (13453)	2.8
2. Limestone, soft, argillaceous, light-brown, massive, weathers tan and blocky and to irregular nodules; limonite stains abundant; many clay balls; algal deposits, gastropods, fusulinids, bryozoans, brachiopods, echinoid spines, and crinoid columnals abundant (13452)	1.5
1. Shale, clayey, some silt, noncalcareous, dark-gray, with some light-gray lenses, weathers medium gray, blocky at top to thin bedded toward base; some iron stains on fracture planes; many large fractures at an angle of 30° from horizontal; brachiopods; fossils rare (13451)	8.1
Total thickness exposed	33.0
Total thickness of exposed Foraker limestone	37.9

Base covered.

(Note: The Americus limestone member is exposed, as a result of a local structural feature, 225 ft to the east.)

151. *Section from Burr limestone member of Grenola limestone down into lower part of Roca shale in a road cut in the SE¼NE¼ sec. 17, T. 14 S., R. 12 E., Wabaunsee County, Kans.*

	Feet
Permian system:	
Grenola limestone:	
Burr limestone member:	
12. Shale, silty, very calcareous, gray, thin-bedded; thin platy limestone in upper part	1.3
11. Limestone, soft, light-brown, weathers blocky; shale parting in middle part; fossil fragments	.6
10. Shale, silty, calcareous, tan-gray, thin-bedded	.9
9. Limestone, soft, gray, weathers blocky to shaly; crinoid columnals, bryozoans, brachiopods, and gastropods	2.5
Total thickness exposed	5.3
Legion shale member:	
8. Shale, clayey, some silt, calcareous, gray, thin-bedded. Thickness	7.0
Sallyards limestone member:	
7. Limestone, hard, gray-brown, weathers blocky; pelecypods and minute fossil fragments abundant; some microfossils and ostracodes. Thickness	.8
Total thickness of exposed Grenola limestone	13.1
Roca shale:	
6. Shale, silty, calcareous, gray to tan-gray, thin-bedded	10.5
5. Limestone, medium-hard, gray, with gray-green tint, weathers blocky to nodular	.7
4. Shale, clayey, calcareous, gray-green, blocky	2.9
3. Limestone, hard, dense, gray, weathers nodular	.2
2. Shale, clayey, calcareous, gray to gray-green, blocky	4.6
1. Limestone, medium-hard, dense, gray, weathers blocky	.3
Total thickness exposed	19.2

Base covered.

152. *Section from lower part of Roca shale down into the upper part of Johnson shale in a streambank in the SW¼SE¼NE¼ sec. 17, T. 14 S., R. 12 E., Wabaunsee County, Kans.*

	Feet
Permian system:	
Roca shale:	
11. Shale, clayey, calcareous, gray-green and purple, blocky. Thickness exposed	3.0±
Red Eagle limestone:	
Howe limestone member:	
10. Shale, very calcareous, tan-gray, thin-bedded; lenticular limestone in upper part	1.0
9. Limestone, soft, dolomitic, tan-gray; blocky	.7
8. Shale, silty, very calcareous, tan-gray, thin-bedded	.6
7. Limestone, soft, dolomitic, tan-gray, weathers shaly	.4
6. Shale, silty, very calcareous, tan-gray, thin-bedded	.9
Total thickness	3.6
Bennett shale member:	
5. Limestone, soft, dolomitic, tan-gray, weathers blocky to shaly; thin conglomerate lens in middle part with minute clay balls; poorly preserved fossils in upper part; ostracodes abundant in middle part and in thin zone in middle of upper half; brachiopods common (13709)	4.2
4. Limestone, soft, tan-gray, weathers to irregular blocks; conglomeratic in lower part with well-rounded claystone and angular limestone fragments as much as ¼ inch in diameter (13708)	1.9
3. Shale, clayey, noncalcareous, gray, blocky; thin conglomeratic zone 0.7 ft from base of overlying limestone; well-rounded claystone fragments as much as ¼ inch in diameter; conglomerate only in west side of cut; fragments of *Orbiculoidea* are abundant in upper and lower parts (13707)	2.3
Total thickness	8.4
Glenrock limestone member:	
2. Limestone, hard, gray, weathers blocky; fusulinids abundant; *Orbiculoidea* abundant in upper part (13706). Thickness	1.2
Total thickness of Red Eagle limestone	13.2
Johnson shale:	
1. Shale, silty, calcareous, dark-gray, thin-bedded; microfossils(?) in upper part. Thickness exposed	2.5

Base covered.

187. *Section from Aspinwall limestone member of Onaga shale down into Pony Creek shale member of Wood Siding formation exposed in a road cut in the SE¼SW¼ sec. 17, T. 15 S., R. 13 E., Wabaunsee County, Kans.*

Permian system:
Onaga shale:

	Feet
Aspinwall limestone member:	
10. Limestone, hard, conglomeratic, gray-brown, weathers tan	0.3
9. Shale, silty, calcareous, conglomeratic, tan-gray, thin-bedded	.1
8. Limestone, hard, conglomeratic, gray-brown, weathers tan and blocky to platy; clay balls and limonite nodules as much as ¼ inch in diameter; fossil fragments abundant	1.1
Total thickness exposed	1.5
Towle shale member:	
7. Shale, clayey, noncalcareous, gray, mottled with maroon in upper part, thin-bedded to blocky; some iron stains	18.2
6. Limestone, hard, gray-brown, blocky; fossil fragments abundant	.2
5. Shale, clayey, noncalcareous, gray, thin-bedded	.8
Total thickness	19.2
Total thickness of exposed Onaga shale	20.7

Pennsylvanian system:
Wood Siding formation:

	Feet
Brownville limestone member:	
4. Limestone, hard, gray-brown, weathers light brown and blocky; crinoid columnals, fusulinids, corals, bryozoans, and brachiopods (13703). Thickness	2.0
Pony Creek shale member:	
3. Shale, clayey, calcareous, gray to tan-gray, thin-bedded; cemented zone in upper part; brachiopods in upper part (13702)	1.8
2. Coal, impure, black, thin-bedded; thin clay lentils; iron stains common	.3
1. Shale, clayey, noncalcareous, gray, thin-bedded; limonite-stained plates abundant; carbonaceous in upper part	8.1
Total thickness exposed	10.2
Total thickness of exposed Wood Siding formation	12.2

Base covered.

212. *Section from base of Americus limestone member of Foraker limestone down into Falls City limestone in a trail on south side of a hill in center of SW¼ sec. 30, T. 10 S., R. 9 E., Riley County, Kans.*

Permian system:
Foraker limestone:

	Feet
Americus limestone member, only basal part exposed.	

Janesville shale:

	Feet
Hamlin shale member:	
13. Covered interval	31.5
12. Shale, clayey, calcareous, gray-green, weathers light gray green, thin-bedded; many limonite nodules	5.5
Total thickness	37.0
Five Point limestone member:	
11. Limestone, hard, argillaceous, medium-gray, thin-bedded; weathers light gray and blocky; some limonite stains	2.2
10. Limestone, hard, medium-gray, massive, weathers light gray and blocky; some limonite stains; forms hillside bench; brachiopods, pelecypods, echinoid spines, crinoid columnals, corals, and bryozoans (13495)	1.6
Total thickness	3.8
West Branch shale member:	
9. Shale, silty, some clay, calcareous, gray-brown to blue-gray, weathers tan gray, thin-bedded; covered in much of upper part, fine-grained thin-bedded sandstone lens containing limonite stains and mica flakes in middle part; limonite stains and plates common; wood and leaf fragments in upper exposed part	11.1
8. Covered interval	6.5
7. Limestone, soft, light-brown, blocky; shows bedding planes on weathered surface, porous; lenticular; heavily limonite stained	.3
6. Shale, clayey, noncalcareous, gray-green, thin-bedded to blocky	8.5
Total thickness	26.4
Total thickness of Janesville shale	67.2

Falls City limestone:

	Feet
5. Limestone, soft, gray-brown, massive, weathers brown and to small chips; limonite stains abundant; bryozoans and pelecypods abundant; gastropods common	.3

212. *Section from base of Americus limestone member of Foraker limestone down into Falls City limestone in a trail on south side of a hill in center of SW¼ sec. 30, T. 10 S., R. 9 E., Riley County, Kans.*—Continued

	Feet
Permian system—Continued	
Falls City limestone—Continued	
4. Shale, clayey, calcareous, gray-green, thin-bedded; limonite stains	.9
3. Limestone, soft, argillaceous, gray-brown, massive, weathers light brown and nodular and blocky; limonite stains abundant; pelecypods abundant; bryozoans and gastropods common	.2
2. Shale, clayey, some silt, calcareous, gray-green, weathers light brown, thin-bedded; limonite stains common	.3
1. Limestone, soft, gray-brown, massive, weathers brown and blocky and to irregular plates; limonite stains common; pelecypods	.6
Total thickness exposed	2.3

Base covered.

213. *Section from Five Point limestone member of Janesville shale down into the Pony Creek shale member of Wood Siding formation in a ditch along a road in the NE¼SE¼ sec. 7, T. 11 S., R. 9 E., Riley County, Kans.*

	Feet
Permian system:	
Janesville shale:	
Upper bed of Five Point limestone member (13509).	
Five Point limestone member:	
27. Shale, clayey, calcareous, gray, weathers tan gray, thin-bedded; many limonite plates, limonite stains on bedding planes	5.5
26. Limestone, hard, gray-brown, massive, weathers tan and to small blocks, lenticular; fossil fragments of brachiopods, bryozoans, echinoid spines, and crinoid columnals very abundant	.1
Total thickness exposed	5.6
West Branch shale member:	
25. Shale, clayey, some silt, slightly arenaceous, calcareous, gray, thin-bedded; limonite stains	7.1
24. Shale, arenaceous, light-brown, thin-bedded; mica flakes; heavily limonite stained; two thin limestone lenses; leaf and wood fragments	.9
23. Shale, clayey, calcareous, arenaceous, blue-gray, weathers blue gray to tan, thin-bedded; iron stains on fracture planes	.8
22. Shale, silty, calcareous, arenaceous, light-brown, thin-bedded; many limonite-stained plates; leaf and wood fragments	1.6

213. *Section from Five Point limestone member of Janesville shale down into the Pony Creek shale member of Wood Siding formation in a ditch along a road in the NE¼SE¼ sec. 7, T. 11 S., R. 9 E., Riley County, Kans.*—Continued

	Feet
Permian system—Continued	
Janesville shale—Continued	
West Branch shale member—Continued	
21. Shale, clayey, calcareous, blue-gray, thin-bedded	3.5
20. Limestone, hard, gray-brown, massive, weathers light brown and to thin blocks; weathering exposes thin bedding planes; limonite stains; bryozoans	.2
19. Limestone, soft, gray-brown, weathers tan, porous with fibrous appearance, cavernous; limonite stains	2.6
18. Shale, clayey, slightly calcareous, gray-green, thin-bedded; limonite stains on bedding planes	4.9
Total thickness	21.6
Total thickness of exposed Janesville shale	27.2
Falls City limestone:	
17. Limestone, hard, argillaceous, gray to gray-brown, massive, weathers tan gray and blocky; limonite stains; pelecypods abundant; some brachiopods and bryozoans	.3
16. Shale, clayey, slightly calcareous, gray-green, thin-bedded; iron stains on bedding planes, some calcareous nodules	2.4
15. Limestone, hard, dense, somewhat argillaceous, blue-gray to tan, massive, weathers tan, and to irregular blocks; iron stains on fracture planes; pelecypods and gastropods abundant	.4
14. Shale, clayey, some silt, noncalcareous, gray, weathers tan gray, thin-bedded; limonite stains	5.5
13. Limestone, hard, argillaceous, tan, massive, weathers nodular; iron stains; pelecypods, gastropods, and some fossil fragments	.4
12. Shale, clayey, noncalcareous, tan-gray, weathers tan, thin-bedded; iron stains	1.4
11. Limestone, hard, gray-brown, massive, weathers to small blocks; iron stains; pelecypods and gastropods	.1
10. Shale, clayey, noncalcareous, blue-gray, weathers tan, thin-bedded; limonite stains	1.4
9. Limestone, hard, dense, gray-brown, weathers tan, massive; iron stains on fracture planes; pelecypods and gastropods	.1

213. *Section from Five Point limestone member of Janesville shale down into the Pony Creek shale member of Wood Siding formation in a ditch along a road in the NE¼SE¼ sec. 7, T. 11 S., R. 9 E., Riley County, Kans.*—Continued

Permian system—Continued

Falls City limestone—Continued — Feet

8. Limestone, hard, crystalline, gray to brown, massive, weathers tan and blocky; limonite nodules and clay balls in upper part; pelecypods and gastropods 3

Total thickness 12.3

Onaga shale:

Hawxby shale member:

7. Shale, clayey, noncalcareous, tan to tan-gray, weathers tan, thin-bedded; limonite stains. Thickness 6.5

Aspinwall limestone member:

6. Limestone, soft, tan, porous, cavernous, fibrous appearance; heavily limonite stained 2.1
5. Shale, clayey, noncalcareous, tan, thin-bedded; limonite stains on bedding planes 1.7
4. Limestone, hard, gray-brown, with green tint, massive, weathers tan and blocky; septarianlike appearance on top; limonite stains and iron specks 3

Total thickness 4.1

Towle shale member:

3. Shale, silty, some clay, calcareous, gray-green, weathers tan; some calcareous nodules and limonite stains. Thickness 7.1

Total thickness of Onaga shale 17.7

Pennsylvanian system:

Wood Siding formation:

Brownville limestone member:

2. Limestone, hard, argillaceous, crystalline in part; gray-brown, with green tint in places, massive, weathers light gray and blocky; lenticular; some limonite specks; fossil fragments abundant, including crinoid columnals and brachiopods. Thickness 7

Pony Creek shale member:

1. Shale, clayey, somewhat silty; calcareous, blue-gray, weathers tan, thin-bedded; iron stains. Thickness exposed 5.5

Total thickness of exposed Wood Siding formation 6.2

Base covered.

229. *Section from lower part of Hughes Creek shale member of Foraker limestone down into the lower part of Hamlin shale member of Janesville shale in a streambank in the NW¼NW¼ sec. 17, T. 9 S., R. 9 E., Pottawatomie County, Kans.*

Permian system:

Foraker limestone:

Hughes Creek shale member: — Feet

11. Shale, silty, tan-gray, thin-bedded (13450). Thickness exposed .... 4.0±

Americus limestone member:

10. Limestone, hard, blue-gray, massive, weathers blocky; large white crinoid columnals; brachiopods (13449) 9
9. Shale, clayey, calcareous, gray, weathers tan, very thin bedded (13448) 1.1
8. Limestone, medium-hard, light-gray, massive, weathers tan, blocky, and to irregular plates; pelecypods 1.7

Total thickness 3.7

Total thickness of exposed Foraker limestone .... 7.7±

Janesville shale:

Hamlin shale member:

7. Shale, silty, calcareous, gray green in lower part, becomes tan gray in upper part, thin-bedded to blocky 12.8
6. Shale, very calcareous, slightly sandy, micaceous, gray-green, with lens of light gray mottled with purple in lower part, massive to thin-bedded; some iron stains 3.1
5. Shale, silty, calcareous, gray to tan-gray, thin-bedded to blocky; thin lenticular calcareous zone in middle part 3.6
4. Sandstone, in part siltstone, micaceous, light-brown, massive in part and thin bedded in part, weathers platy; some irregular bedding 2.1
3. Shale, clayey, some silt, noncalcareous, gray, thin-bedded; tan platy bed in lower part 11.2
2. Limestone, medium-hard, medium-gray, massive, weathers light gray and platy; minute fossil fragments; limestone forms a waterfall in stream 9
1. Shale 2.8

Total thickness exposed 36.5

Total thickness of exposed Janesville shale 36.5

Base covered.

235. *Section from Burr limestone member of Grenola limestone down into Hamlin shale member of Janesville shale in a road cut in SW¼SE¼ sec. 7, T. 10 S., R. 8 E., and in a railroad and road cut in SW¼SE¼SE¼ sec. 7, T. 10 S., R. 8 E., Riley County, Kans.*

Silt, gray-brown ... 2—

Permian system: (Feet)

Grenola limestone:

Burr limestone member:

108. Limestone, soft, gray-orange, weathers tan, platy; lenticular 2
107. Limestone, soft, gray, weathers tan, massive; cavernous at base; lenticular 3
106. Limestone, dense, gray-orange, massive, weathers tan, and platy at base 8
105. Shale, clayey, slightly calcareous, olive-drab, weathers tan, thin-bedded to blocky; iron stains ... 3.2
104. Limestone, soft, red-brown, weathers tan, massive, porous and lenticular; ostracodes very abundant (13555) 2
103. Limestone, hard, dense, gray-orange, weathers tan, massive; some brachiopod fragments ... 1.8
102. Limestone, hard, dense, light-gray, weathers tan, massive; echinoid spines ... 2.1
101. Limestone, slightly crystalline, gray, weathers tan, massive; brachiopod fragments and some algal deposits 2
100. Shale, clayey, noncalcareous; gray, grades downward to black, weathers gray; fissile; some carbon stains. (13554) ... 1.2
99. Limestone, hard, dense, tan, massive, weathers blocky; crinoid columnals, pelecypods, and brachiopods ... 2.4

Total thickness exposed ... 12.4

Legion shale member:

98. Shale, silty, calcareous, dark-gray, with light-gray bands, weathers light gray, thin-bedded; worm burrows(?) abundant 2
97. Limestone, hard, dense, gray-brown, weathers tan, massive, lenticular; worm burrows(?) 1
96. Shale, silty, calcareous, dark-gray, weathers light gray, thin-bedded; lenticular 5
95. Limestone, argillaceous, gray, weathers light gray, blocky; lenticular 3
94. Shale, silty, calcareous, dark-gray, weathers light gray, blocky to fissile 8
93. Shale, clayey, some silt, calcareous, white, mottled with dark gray green, weathers tan, blocky 6
92. Shale, clayey, some silt, calcareous, dark-gray, weathers gray with light gray bands, blocky ... 1.0

235. *Section from Burr limestone member of Grenola limestone down into Hamlin shale member of Janesville shale in a road cut in SW¼SE¼ sec. 7, T. 10 S., R. 8 E., and in a railroad and road cut in SW¼SE¼SE¼ sec. 7, T. 10 S., R. 8 E., Riley County, Kans.*—Continued

Permian system—Continued

Grenola limestone—Continued

Legion shale member—Continued (Feet)

91. Shale, clayey, noncalcareous, tan, banded with gray, weathers tan, thin-bedded to blocky 7

Total thickness ... 4.2

Sallyards limestone member:

90. Limestone, hard, tan, massive; fragments tentatively identified as fossil plants (13553). Thickness ... 1.0

Total thickness of exposed Grenola limestone ... 17.6

Roca shale:

89. Shale, clayey, some silt, noncalcareous, light-green in upper part, grades downward to dark green, weathers light green, blocky; iron stains ... 3.2
88. Shale, silty, very calcareous, light-green, blocky; heavily iron stained 9
87. Shale, clayey, some silt, calcareous, gray-green, weathers light green, blocky; iron stains and clay nodules ... 1.9
86. Shale, silty, noncalcareous, purple in upper part, grades downward to maroon to gray, blocky; iron stains on fracture planes ... 2.6
85. Shale, silty, noncalcareous, dark-gray, weathers gray, blocky; lenticular; limonite stains on bedding planes 4
84. Shale, silty, very calcareous, maroon, mottled with light gray, blocky ... 1.0
83. Shale, silty, calcareous, maroon, mottled with green, blocky 9
82. Shale, clayey, noncalcareous, gray-green, weathers light gray, blocky 5
81. Limestone, argillaceous, light-gray, massive; lenticular 5
80. Shale, silty, calcareous, light-green, banded with various shades of green, thin-bedded 4
79. Shale, clayey, some silt, slightly calcareous, maroon, thin-bedded to blocky; some penecontemporaneous folding ... 1.6
78. Shale, silty, noncalcareous, light-green, blocky ... 1.0
77. Shale, clayey, slightly calcareous, light-gray, thin-bedded to blocky; limonite stains on bedding planes 1
76. Shale, silty, calcareous, dark-gray, weathers gray, thin-bedded; lenticular 1

235. *Section from Burr limestone member of Grenola limestone down into Hamlin shale member of Janesville shale in a road cut in SW¼SE¼ sec. 7, T. 10 S., R. 8 E., and in a railroad and road cut in SW¼SE¼SE¼ sec. 7, T. 10 S., R. 8 E., Riley County, Kans.*—Continued

Permian system—Continued

Roca shale—Continued

	Feet
75. Shale, silty, slightly calcareous, light-gray, banded with various shades of gray, thin-bedded; limonite stains on fracture planes	.3
74. Shale, clayey, some silt, noncalcareous, gray, weathers light gray, blocky	.2
73. Shale, clayey, some silt, noncalcareous, gray-green, banded with various shades of gray, weathers gray; iron stains	.3
72. Shale, clayey, noncalcareous, gray-green, weathers light gray green, blocky	.3
71. Shale, silty, calcareous, gray, blocky, lenticular	.3
70. Shale, clayey, some silt, slightly calcareous, gray to gray-green, weathers gray, blocky; lenticular	.4
69. Shale, silty, calcareous, gray-green, weathers gray, blocky; lenticular; limonite stains in basal part	.7
Total thickness	17.6

Red Eagle limestone:

Howe limestone member:

68. Limestone, soft, tan, weathers tan gray, massive; lenticular	.8
67. Limestone, soft, gray-orange, weathers tan, massive; limonite and maroon stains. (13491)	3.6
Total thickness	4.4

Bennett shale member:

66. Shale, clayey, slightly silty, slightly calcareous, olive-drab, weathers tan, thin-bedded; brachiopod fragments	2.0
65. Shale, silty, carbonaceous, calcareous, black, weathers gray, thin-bedded to blocky; brachiopods and pelecypods (13490)	.9
64. Shale, silty, calcareous, carbonaceous, black, weathers blue gray, thin-bedded	1.2
63. Shale, silty, calcareous, dark-gray, weathers gray, thin-bedded; brachiopods (13489)	1.0
Total thickness	4.7

235. *Section from Burr limestone member of Grenola limestone down into Hamlin shale member of Janesville shale in a road cut in SW¼SE¼ sec. 7, T. 10 S., R. 8 E., and in a railroad and road cut in SW¼SE¼SE¼ sec. 7, T. 10 S., R. 8 E., Riley County, Kans.*—Continued

Permian system—Continued

Red Eagle limestone—Continued

Glenrock limestone member:

	Feet
62. Limestone, hard, dense, gray-brown, massive, weathers tan and blocky; some small clay nodules; fusulinids, few brachiopod fragments (13488). Thickness	1.4
Total thickness of Red Eagle limestone	10.5

Johnson shale:

61. Shale, clayey, some silt, slightly calcareous, carbonaceous in lower part, olive-drab, grades downward to black, thin bedded to blocky in upper part, thin bedded in lower part	3.2
60. Shale, silty, calcareous, olive drab, weathers tan, thin-bedded	.8
59. Shale, clayey, some silt, slightly calcareous, olive-drab, weathers tan, thin-bedded; carbon stains	1.7
58. Limestone, medium-hard, argillaceous, tan-gray, weathers tan, massive to platy in lower part, platy in upper part; lenticular	1.0
57. Shale, silty, calcareous, olive-drab, weathers light gray, thin-bedded, two thin calcareous lenses in middle part; limonite stains	1.9
56. Limestone, argillaceous, tan-gray, massive to platy; lenticular	.9
55. Shale, clayey, some silt, calcareous, olive-drab, weathers tan, thin-bedded to blocky; limonite stains	.6
54. Shale, silty, slightly calcareous, yellow-green, weathers tan, thin-bedded; lenticular	.1
53. Shale, silty, calcareous, olive drab in upper part, grades downward to gray green, weathers gray, thin-bedded to blocky	2.0
52. Shale, silty, calcareous, gray, weathers light gray, blocky, massive in upper part; lenticular	3.6
51. Limestone, medium-hard, argillaceous, gray, massive, weathers blocky to platy; thin shale parting near top; limonite stains	2.8
50. Shale, clayey, calcareous, gray-green, weathers light gray, thin-bedded	5.3
Total thickness	23.0

235. *Section from Burr limestone member of Grenola limestone down into Hamlin shale member of Janesville shale in a road cut in SW¼SE¼ sec. 7, T. 10 S., R. 8 E., and in a railroad and road cut in SW¼SE¼SE¼ sec. 7, T. 10 S., R. 8 E., Riley County, Kans.*—Continued

Permian system—Continued

Foraker limestone:

Long Creek limestone member: Feet

49. Limestone, soft, fine-grained, gray-orange, massive, weathers tan and platy; calcite nodules along bedding planes .5
48. Limestone, soft, fine-grained, gray-orange, massive, weathers tan; porous; celestite(?) nodules .7
47. Limestone, soft, dolomitic, tan-gray, massive, weathers light tan; some celestite(?) nodules .8
46. Shale silty, slightly calcareous, olive-drab, weathers gray, blocky; carbon stains on bedding planes .5
45. Shale, clayey, some silt, slightly calcareous, gray-orange, weathers tan, blocky .3
44. Shale, silty, calcareous, dark-gray, weathers gray, thin-bedded .1
43. Limestone, soft, gray-orange, massive, weathers tan in lower part, platy in upper part 2.6
42. Limestone, soft, argillaceous, dolomitic, brown, weathers light tan, massive; some small celestite(?) nodules 2.4
41. Limestone, soft, dolomitic, light-brown, blocky, lenticular; limonite stains .1

Total thickness 8.0

Hughes Creek shale member:

40. Shale, silty, noncalcareous, olive-drab, with tan streaks, weathers tan, blocky .5
39. Shale, silty, calcareous, dark-gray, weathers gray, thin-bedded to blocky .8
38. Shale, silty, very calcareous, gray, weathers tan, thin-bedded; lenticular; *Orbiculoidea* and organic material (13487) .2
37. Shale, silty, calcareous, blue-gray to olive-drab, weathers tan, thin-bedded to blocky; lenticular .8
36. Limestone, argillaceous; gray-orange, weathers tan, massive; lenticular; fusulinids very abundant (13486) 1.3
35. Shale, silty, very calcareous, gray, weathers light gray, thin-bedded; fusulinids very abundant, crinoid columnals common 1.9

235. *Section from Burr limestone member of Grenola limestone down into Hamlin shale member of Janesville shale in a road cut in SW¼SE¼ sec. 7, T. 10 S., R. 8 E., and in a railroad and road cut in SW¼SE¼SE¼ sec. 7, T. 10 S., R. 8 E., Riley County, Kans.*—Continued

Permian system—Continued

Foraker limestone—Continued

Hughes Creek shale member—Continued Feet

34. Shale, clayey, noncalcareous, dark-gray to black, weathers gray, fissile; fusulinids and crinoid columnals at very base 4.2
33. Shale, silty, very calcareous, gray, thin-bedded to blocky; more resistant to weathering than shale above and below; fusulinids, crinoid columnals, brachiopods, and *Crurithyris* .8
32. Shale, clayey, some silt, calcareous, gray-green, weathers gray, thin-bedded .2
31. Shale, silty, calcareous, gray-brown, weathers gray orange, thin-bedded; lenticular; limonite stains .1
30. Shale, silty, calcareous, gray, weathers tan gray, thin-bedded to blocky; pelecypods, *Crurithyris*, brachiopods, echinoid spines, crinoid columnals, and fusulinids (13485) 1.3
29. Shale, carbonaceous, noncalcareous, black, weathers blue gray, thin-bedded; few clay inclusions, some limonite-stained zones; *Orbiculoidea*, *Crurithyris*, and *Chonetes* (13485) 1.4
28. Shale, silty, calcareous, gray-orange to gray, weathers gray orange, thin-bedded; some limonite stains; *Orbiculoidea* abundant (13485) .1
27. Limestone, hard, tan, weathers tan gray, massive; algal deposits, brachiopod fragments and fusulinids (13485) 1.2
26. Shale, clay in upper part, grades downward to silt, calcareous, dark-gray, grades downward to gray orange, weathers tan to gray, thin-bedded to fissile; brachiopods (13484) 5.3
25. Shale, silty, calcareous, dark-gray, weathers gray, thin-bedded to blocky; calcareous nodules in upper part; large crinoid columnals, and brachiopods (13484) 2.2
24. Shale, silty, calcareous, olive-drab, weathers tan, thin-bedded; *Crurithyris* and other brachiopods, crinoid columnals, and fusulinids (13484) .8
23. Limestone, argillaceous, gray, massive, weathers shaly; lenticular; *Crurithyris* and *Lissochonetes* (13483) .3

235. *Section from Burr limestone member of Grenola limestone down into Hamlin shale member of Janesville shale in a road cut in SW¼SE¼ sec. 7, T. 10 S., R. 8 E., and in a railroad and road cut in SW¼SE¼SE¼ sec. 7, T. 10 S., R. 8 E., Riley County, Kans.*—Continued

Permian system—Continued
Foraker limestone—Continued
Hughes Creek shale member—Continued — Feet

22. Shale, silty, calcareous, dark-gray, weathers gray, thin-bedded; *Crurithyris* (13483) — .2
21. Limestone, argillaceous, gray, massive, weathers shaly; lenticular; brachiopods and crinoid columnals (13483) — .5
20. Shale, silty, slightly calcareous, olive-drab, weathers gray, thin-bedded; brachiopods, bryozoans, crinoid columnals, and *Crurithyris* (13482) — .6
19. Limestone, argillaceous, dark-gray, weathers gray orange, thin-bedded — .1
18. Shale, silty, calcareous, gray, weathers light gray, thin-bedded; *Crurithyris* and *Marginifera* — .1
17. Limestone, hard, tan-gray, massive; some brachiopod fragments — .8
16. Shale, silty, calcareous, gray, blocky; limonite stains in lower part; brachiopods, including *Derbyia*, and *Crurithyris* (13481) — .5
15. Shale, clayey, slightly calcareous, dark-gray to black, weathers gray, blocky to thin-bedded; brachiopods (13480) — 1.5
14. Limestone, argillaceous, gray-orange, blocky; brachiopods, *Crurithyris* — 1.3
13. Shale, silty, gray, grades downward to black, weathers gray, thin-bedded to fissile; calcareous in upper part; brachiopods, fusulinids, and pelecypods (13479) — 9.2
12. Shale, silty, very calcareous, gray-brown, weathers gray, thin-bedded; lenticular; limonite stains (13479) — .3
11. Shale, silty, calcareous, dark-gray, weathers gray with orange spots, thin-bedded; crinoid columnals and brachiopods (13478) — .3

Total thickness — 38.8

Americus limestone member:

10. Limestone, hard, slightly crystalline, blue-gray, weathers tan, massive; fragments of large crinoid columnals, echinoids, brachiopods, and bryozoans; fusulinids — 1.0
9. Shale, slightly silty, calcareous, black, weathers gray, thin-bedded — .2
8. Shale, silty, calcareous, gray, weathers light gray, thin-bedded — .5

235. *Section from Burr limestone member of Grenola limestone down into Hamlin shale member of Janesville shale in a road cut in SW¼SE¼ sec. 7, T. 10 S., R. 8 E., and in a railroad and road cut in SW¼SE¼SE¼ sec. 7, T. 10 S., R. 8 E., Riley County, Kans.*—Continued

Permian system—Continued
Foraker limestone—Continued
Americus limestone member—Continued — Feet

7. Shale, silty, noncalcareous, dark-gray, weathers light gray, thin-bedded to fissile; carbon stains on bedding planes — 1.0
6. Limestone, hard, dense, argillaceous in lower part, dark-gray, weathers tan gray, massive; stromatolites abundant in lower part; crinoid columnals and brachiopod fragments — .8

Total thickness — 3.5

Total thickness of Foraker limestone — 50.3

Janesville shale:
Hamlin shale member:

5. Shale, silty, calcareous, red-brown, weathers tan gray, thin-bedded; some algal deposits — .1
4. Limestone, arenaceous, gray-orange, weathers tan, massive; lenticular — .3
3. Shale, clayey, calcareous, gray-orange, weathers tan, thin-bedded to blocky — .3
2. Shale, silty, calcareous, dark-gray, weathers light gray, blocky; limonite stains in upper part — 1.5
1. Shale, clayey, some silt, calcareous, dark-gray, weathers light gray, thin-bedded — 2.9

Total thickness exposed — 5.1

Total thickness of exposed Janesville shale — 5.1

Base covered.

236. *Section from Florena shale member of Beattie limestone down to the top of Burr limestone member of Grenola limestone in an old road cut in the NW¼NW¼ sec. 26, T. 10 S., R. 7 E., Riley County, Kans.*

Permian system:
Beattie limestone:
Florena shale member: — Feet

43. Shale, silty, calcareous, tan to gray, weathers tan gray, thin-bedded; some calcareous plates in lower part; *Chonetes* very abundant; brachiopods, bryozoans, crinoid columnals, echinoid spines, and trilobites common. Thickness — 8.0

236. *Section from Florena shale member of Beattie limestone down to the top of Burr limestone member of Grenola limestone in an old road cut in the NW¼NW¼ sec. 26, T. 10 S., R. 7 E., Riley County, Kans.*—Continued

	Feet
Permian system—Continued	
Beattie limestone—Continued	
Cottonwood limestone member:	
42. Limestone, hard, dense, gray, massive, weathers tan gray and blocky; lens of chert nodules in middle part, chert nodules scattered throughout; fractures irregularly; fusulinids very abundant in upper half; crinoid columnals, echinoid spines, bryozoans, brachiopod fragments, and corals common near base; where exposed, large blocks are slumped on face of underlying shale; growth of bushes at base characteristic; forms prominent hillside bench	5.9
41. Limestone, soft, light-gray, massive, weathers tan and shaly; lenticular; crinoid columnals	.1
40. Limestone, hard, gray-orange, weathers gray, massive, lenticular; brachiopod fragments	.4
Total thickness	6.4
Total thickness of exposed Beattie limestone	14.5
Eskridge shale:	
39. Shale, clayey, noncalcareous, light-green, thin-bedded; calcium carbonate stains and nodules	2.3
38. Shale, silty, some clay, very calcareous, light-gray, thin-bedded to blocky; small clay nodules; lenticular	.7
37. Shale, clayey, noncalcareous, gray, weathers light gray, blocky; lenticular	.6
36. Shale, clayey, some silt, very calcareous, light-gray to light-violet, blocky to thin-bedded	2.0
35. Limestone, argillaceous, light-gray, weathers tan, massive, oolitic in part; pelecypods (13552)	.5
34. Shale, clayey, some silt, calcareous, light-green, weathers light gray, blocky	.3
33. Shale, silty, calcareous, maroon, blocky	.1
32. Shale, clayey, calcareous, gray-brown, blocky	.3
31. Shale, clayey, calcareous, maroon, blocky	.4
30. Shale, clayey, some silt, calcareous, olive-drab, weathers tan, blocky	1.5
29. Shale, silty, calcareous, gray, mottled with maroon, thin-bedded to blocky	1.1
28. Shale, clayey, slightly calcareous, dark-gray, weathers light gray, thin-bedded	.5

236. *Section from Florena shale member of Beattie limestone down to the top of Burr limestone member of Grenola limestone in an old road cut in the NW¼NW¼ sec. 26, T. 10 S., R. 7 E., Riley County, Kans.*—Continued

	Feet
Permian system—Continued	
Eskridge shale—Continued	
27. Shale, silty, calcareous, maroon, blocky to thin-bedded	2.1
26. Shale, clayey, calcareous, dark gray in upper part, grades downward to tan gray, weathers tan, thin-bedded; pelecypods (13552)	3.4
25. Shale, clayey, some silt, calcareous, dark-gray-green, weathers light gray green, blocky	1.1
24. Shale, silty, calcareous, maroon, mottled with gray and green, thin-bedded to blocky	2.6
23. Shale, silty, calcareous, dark-violet, weathers light purple, blocky; lenticular	2.8
22. Shale, clayey, some silt, calcareous, maroon, blocky; lenticular	.9
21. Shale, silty, noncalcareous, violet, blocky; lenticular	1.2
20. Shale, clayey, slightly silty, calcareous, light-gray-green, weathers gray green, thin-bedded	.5
19. Shale, clayey, some silt, calcareous, maroon; lenticular	.2
18. Shale, silty, calcareous, gray-green, weathers light gray, thin-bedded	.6
17. Shale, clayey, some silt, calcareous, maroon and gray-green, thin-bedded; lenticular	.8
16. Shale, clayey, some silt, calcareous, gray-green, weathers light gray green, thin-bedded	.6
Total thickness	27.1
Grenola limestone:	
Neva limestone member:	
15. Limestone, hard, light-gray, massive, weathers platy; shale parting in upper part; fragments of echinoids, bryozoans, and brachiopods	2.5
14. Limestone, hard, dense, light-gray, massive, weathers tan, and blocky; fragments of crinoids, echinoids, and brachiopods; forms hillside bench	5.5
13. Shale, silty, very calcareous, light-gray, thin-bedded to blocky; lenticular; *Lingula*, *Composita*, and *Orbiculoidea* (13551)	.8
12. Limestone, hard, dense, gray-orange, massive, weathers tan and blocky; cavernous in lower part; brachiopod fragments	5.0
11. Limestone, soft, tan, massive, weathers blocky; lenticular	.9
10. Limestone, soft, light-gray, weathers tan, massive; lenticular	.6

236. *Section from Florena shale member of Beattie limestone down to the top of Burr limestone member of Grenola limestone in an old road cut in the NW¼NW¼ sec. 26, T. 10 S., R. 7 E., Riley County, Kans.*—Continued

Permian system—Continued
Grenola limestone—Continued

Neva limestone member—Continued	Feet
9. Shale, clayey, slightly calcareous, dark-gray, weathers blue gray, thin-bedded; crinoid columnals (13550)	1.5
8. Limestone, hard, gray-orange, massive, weathers tan and blocky; echinoid spines and brachiopod fragments	1.4
Total thickness	18.2

Salem Point shale member:	
7. Shale, silty, calcareous, tan, with gray stains, weathers light tan, blocky	.6
6. Shale, silty, calcareous, olive-drab, weathers light gray, blocky to thin-bedded; pelecypods	2.4
5. Shale, clayey, slightly calcareous, black and gray, weathers gray, thin-bedded	.5
4. Limestone, argillaceous, light-gray, weathers tan; platy at top, becomes massive at base	.6
3. Shale, silty, calcareous, light-tan, blocky; lenticular	.2
2. Shale, silty, calcareous, gray, weathers light gray, thin-bedded	.8
1. Shale, silty, calcareous, olive-drab, weathers light gray, blocky to thin-bedded	2.3
Total thickness	7.4
Total thickness of measured Grenola limestone	25.6

Top of Burr limestone member.

244. *Section from base of Americus limestone member of Foraker limestone down to base of Aspinwall limestone member of Onaga shale in center of SE¼ sec. 33, T. 7 S., R. 11 E., Pottawatomie County, Kans.*

Permian system:
Base of Americus limestone member of Foraker limestone.
Janesville shale:

Hamlin shale member:	Feet
25. Covered interval	5.7
24. Limestone and cavernous shale, medium-hard to soft, gray-brown	1.2
23. Covered interval, mostly shale	16.8
22. Limestone, hard, gray to gray-brown, upper surface very nodular, dense and finely laminated; composed almost entirely of stromatolites, fossil fragments, including pelecypods (13522)	.2–.6
21. Shale, clayey, noncalcareous, gray, thin-bedded, middle and upper parts sandy and calcareous, carbonaceous zone in middle part; iron nodules abundant in middle part	16.8

244. *Section from base of Americus limestone member of Foraker limestone down to base of Aspinwall limestone member of Onaga shale in center of SE¼ sec. 33, T. 7 S., R. 11 E., Pottawatomie County, Kans.*—Continued

Permian system—Continued
Janesville shale—Continued

Hamlin shale member—Continued	Feet
20. Limestone, medium-hard, gray, weathers blocky (13521)	.4
19. Shale, medium-soft, clayey, calcareous, dark-gray, blocky	1.9
18. Limestone, tan-brown, nodular; iron stains	1.5
17. Shale, silty, calcareous, maroon, grades to gray green in upper part, blocky	3.3
16. Covered interval	4.6
Total thickness	52.4–52.8

Five Point limestone member:	
15. Limestone, medium-hard, light-gray, platy	.3
14. Shale, clayey, calcareous, gray, thin-bedded	1.2
13. Shale, very calcareous, gray, weathers nodular and to irregular plates; brachiopods (13520)	1.6
Total thickness	3.1

West Branch shale member:	
12. Shale, clayey, calcareous, gray, thin-bedded; many iron stains and nodules near base	3.6
11. Carbonaceous zone, thin-bedded	.2
10. Shale, clayey, noncalcareous, dark-gray-green, blocky	.9
9. Shale, clayey, calcareous, gray to gray-green, light gray to tan in upper part, thin-bedded; thin mudstone lenses in lower part; many iron stains; calcareous nodules in upper part	16.3
Total thickness	21.0
Total thickness of Janesville shale	76.5–76.9

Falls City limestone:	
8. Limestone, very soft in lower part, nodular, porous, platy, dense in upper part, gray-brown shale in middle part; pelecypods in upper 0.4 ft	1.7
7. Shale, clayey, calcareous, gray, thin-bedded; thin limestone beds in upper part	9.5
6. Shale, very calcareous, gray, grades laterally into limestone, weathers into thin irregular plates	1.2
Total thickness	12.4

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244. *Section from base of Americus limestone member of Foraker limestone down to base of Aspinwall limestone member of Onaga shale in center of SE¼ sec. 33, T. 7 S., R. 11 E., Pottawatomie County, Kans.*—Continued

Permian system—Continued

Onaga shale: Feet

Hawxby shale member:

5. Shale, silty, clayey in lower part, calcareous, gray-brown, thin-bedded; limonite stains in upper part; many thin calcareous plates .2
4. Shale, very calcareous, gray, blocky to nodular .6
3. Shale, clayey, calcareous, tan gray with some gray green in lower part, tan gray in upper part, thin maroon and purple lentils about 1.5 ft from base; blocky; pelecypods (13519) 4.2
2. Shale, clayey, some silt, calcareous, maroon in lower 1.0 ft, grades up into gray green, blocky 3.2

Total thickness 8.2

Aspinwall limestone member:

1. Limestone, medium-hard, gray-brown, with clay balls and lenses, brown specks abundant but restricted to zones; upper part gray green. Thickness 1.9

Total thickness of exposed Onaga shale 10.1

Base covered.

246. *Section of West Branch shale member of Janesville shale down to the base of Aspinwall limestone member of Onaga shale in a streambank in the SW¼SE¼ sec. 8, T. 9 S., R. 9 E., Pottawatomie County, Kans.*

Permian system:

Janesville shale:

West Branch shale member:

12. Limestone, somewhat sandy, tan, platy 1.4
11. Limestone, soft, tan, massive, weathers shaly 3.6
10. Shale, clayey, calcareous, dark-gray, blocky 6.1
9. Shale, silty, calcareous, gray; many calcareous lenses 5.6

Total thickness exposed 16.7

Total thickness of exposed Janesville shale 16.7

Falls City limestone:

8. Limestone, medium-hard, gray-brown, weathers blocky, semiconchoidal fracture 1.1

246. *Section of West Branch shale member of Janesville shale down to the base of Aspinwall limestone member of Onaga shale in a streambank in the SW¼SE¼ sec. 8, T. 9 S., R. 9 E., Pottawatomie County, Kans.*—Continued

Permian system—Continued

Falls City limestone—Continued Feet

7. Shale, silty, calcareous, gray, many lenses of thin shale and platy limestone, weathers to thin beds 6.8

Total thickness 7.9

Onaga shale:

Hawxby shale member:

6. Shale, clayey, calcareous, gray, thin-bedded; calcareous lens and claystone lens; mostly covered. Thickness 11.2

Aspinwall limestone member:

5. Limestone, clayey, light-gray, weathers nodular; pelecypods and gastropods (13526) .9
4. Shale, clayey, calcareous, gray, thin-bedded; pelecypod lens 0.1 ft thick in middle part .4
3. Limestone, medium-hard, gray, weathers blocky; minute clay balls; conglomeratic in upper part 1.4
2. Shale, silty, calcareous, gray, thin-bedded; calcareous nodules in upper part .7
1. Limestone, hard, gray, massive, weathers blocky; ostracodes (13525) 1.9

Total thickness exposed 5.3

Total thickness of exposed Onaga shale 16.5

Base covered.

247. *Section of Hamlin shale member down into West Branch shale member of Janesville shale in a streambank in the SE¼SW¼ sec. 8, T. 9 S., R. 9 E., Pottawatomie County, Kans.*

Permian system:

Janesville shale:

Hamlin shale member:

13. Limestone, medium-hard, gray to gray-brown, massive, weathers platy to shaly; many fossil fragments (13529) 0.9
12. Shale, silty, calcareous, maroon in upper part, gray in lower part; many calcium carbonate nodules in lower part 4.2

Total thickness exposed 5.1

Five Point limestone member:

11. Limestone, medium-hard, tan-gray, weathers blocky; many iron specks .4
10. Limestone, clayey, gray, nodular 1.4
9. Shale, silty, calcareous, gray-green, thin-bedded; calcareous nodules in upper part .3

247. *Section of Hamlin shale member down into West Branch shale member of Janesville shale in a streambank in the SE¼SW¼ sec. 8, T. 9 S., R. 9 E., Pottawatomie County, Kans.*—Continued

Permian system—Continued
Janesville shale—Continued

	Feet
Five Point limestone member—Continued	
8. Limestone, medium-hard, tan-brown, weathers blocky; coquina (13528)	.5
7. Shale, silty, calcareous, gray, thin-bedded	.2
6. Limestone, medium-hard, gray to tan-gray, weathers blocky, fossiliferous (13528)	.6
5. Shale, silty, calcareous, gray, thin-bedded; brachiopods (13527)	1.2
4. Limestone, medium-hard, gray, weathers blocky to shaly; fossil fragments	.6
Total thickness	5.2
West Branch shale member:	
3. Shale, silty, calcareous; clayey and slightly calcareous in upper part; gray to olive drab, thin maroon bed in middle part, gray lens in upper part; blocky to thin-bedded	5.7
2. Limestone, clayey, gray, weathers shaly to irregular plates; fossil fragments	1.0
1. Shale, silty, noncalcareous, gray green in lower part, gray brown in middle part, gray in upper part, thin-bedded	5.7
Total thickness exposed	12.4
Total thickness of exposed Janesville shale	22.7

Base covered.

252. *Section from Florena shale member of Beattie limestone down into Neva limestone member of Grenola limestone in a road cut in the NE¼SE¼ sec. 13, T. 7 S., R. 11 E., Pottawatomie County, Kans.*

Permian system:
Beattie limestone:

	Feet
Florena shale member:	
11. Shale, silty, calcareous, gray to light-gray, calcareous lens in middle part; fragments of celestite(?) cover upper surface; brachiopods abundant in lower part (13539). Thickness exposed	5.8
Cottonwood limestone member:	
10. Limestone, medium-hard, light-tan-gray, massive, weathers blocky and to irregular plates; chert nodules; corals and fusulinids in upper part; coral zone near middle part (13538). Thickness	5.1
Total thickness of exposed Beattie limestone	10.9

252. *Section from Florena shale member of Beattie limestone down into Neva limestone member of Grenola limestone in a road cut in the NE¼SE¼ sec. 13, T. 7 S., R. 11 E., Pottawatomie County, Kans.*—Continued

Permian system—Continued

	Feet
Eskridge shale:	
9. Shale, silty, noncalcareous, gray-green, becomes tan in upper part, purple tint in middle part; calcareous lens in upper part	5.8
8. Shale, silty, calcareous, gray green in lower part, tan gray tinted with purple in upper part; calcareous lenses, calcium carbonate stains abundant in upper part; partly covered	14.5
7. Limestone, hard, dense, clayey, gray, weathers platy; clay balls in upper part; pelecypods and gastropods (13537)	.5
6. Shale, clayey, some silt, calcareous, gray-green, blocky	5.1
5. Shale, silty, calcareous, maroon in lower part, light maroon in middle part, purple and maroon in upper part, massive, blocky in upper part	7.0
4. Shale, silty, calcareous, gray-green, thin-bedded	1.1
Total thickness	34.0

Grenola limestone:

	Feet
Neva limestone member:	
3. Limestone, medium-hard, tan, massive, weathers blocky; fossil fragments	1.2
2. Shale, silty, calcareous, gray thin-bedded	.5
1. Limestone, medium-hard, tan-gray, massive, weathers porous and blocky	5.6
Total thickness exposed	7.3
Total thickness of exposed Grenola limestone	7.3

Base covered.

253. *Section from Sallyards limestone member of Grenola limestone down into Johnson shale in a streambank and road cut in the NW¼SW¼SE¼ sec. 10, T. 8 S., R. 12 E., Pottawatomie County, Kans.*

Permian system:
Grenola limestone:

	Feet
Sallyards limestone member:	
10. Limestone, hard, gray to tan-gray, massive, weathers blocky; minute fossil fragments; some microfossils (13543). Thickness	0.7
Total thickness of exposed Grenola limestone	0.7

253. *Section from Sallyards limestone member of Grenola limestone down into Johnson shale in a streambank and road cut in the NW¼SW¼SE¼ sec. 10, T. 8 S., R. 12 E., Pottawatomie County, Kans.*—Continued

	Feet
Permian system—Continued	
Roca shale:	
9. Shale, clayey, some silt, very calcareous, green grades up into gray-green; blocky in upper part, cavernous zone in middle part	9.7
8. Shale, silty, calcareous, purple, gray-green and maroon, thin-bedded to blocky; many thin calcareous lenses in upper part	7.3
7. Shale, clayey, noncalcareous, gray green with a 0.5-ft maroon lens in upper part, nodular; many calcareous lentils; somewhat cavernous; secondary calcium carbonate in upper part	12.0
Total thickness	29.0
Red Eagle limestone:	
Howe limestone member:	
6. Limestone, soft, tan, weathers blocky to shaly; ostracode zone in upper part; fossil fragments in lower part (13542). Thickness	3.2
Bennett shale member:	
5. Shale, silty, calcareous, very-dark-gray, thin-bedded; calcareous zone in middle part; brachiopod zone in upper part (13541). Thickness	6.3
Glenrock limestone member:	
4. Limestone, hard, gray, massive, weathers blocky; *Orbiculoidea* in top surface; some ostracodes (13540). Thickness	.9
Total thickness of Red Eagle limestone	10.4
Johnson shale:	
3. Shale, silty, calcareous, dark-gray, thin-bedded	4.7
2. Shale, very calcareous, gray, platy; grades down into argillaceous limestone	1.5
1. Shale, silty, calcareous, gray to gray-green, blocky to thin-bedded; nodular in upper part	5.9
Total thickness of exposed Johnson shale	12.1

Base covered.

256. *Section of Grenola limestone in a road cut in the center of sec. 22, T. 8 S., R. 11 E., Pottawatomie County, Kans.*

	Feet
Permian system:	
Grenola limestone:	
Neva limestone member:	
12. Limestone, hard, light-gray, weathers blocky, porous; coquina in upper part	.9
11. Shale, silty, very calcareous, tan-gray, thin-bedded to platy	.7
10. Limestone, medium-hard, gray, weathers shaly in upper part; *Crurithyris*, fossil fragments, including bryozoans	4.2
9. Limestone, medium-hard, light-gray, weathers tan and blocky, porous; *Composita;* fossils not common	3.6
8. Shale, silty, calcareous, tan-gray, thin-bedded; calcareous lens in upper part, middle, and lower parts; *Crurithyris* and fusulinids in lower lens	6.2
7. Limestone, medium-hard, light-gray, massive; weathers to irregular plates	1.4
Total thickness	17.0
Salem Point shale member:	
6. Shale, silty, calcareous, gray to olive-drab, thin-bedded to blocky; some iron stains; limestone bed 0.4 ft thick and 4 ft from base of Neva; many calcareous plates. Thickness	7.1
Burr limestone member:	
5. Limestone, medium-hard, dense, clayey, gray, massive, weathers platy; chitinous spines abundant in lower part; ostracodes in upper 0.5 ft	3.6
4. Shale, clayey, noncalcareous, gray, blocky to thin-bedded; iron stains on bedding planes	1.6
3. Limestone, medium-hard, gray, massive, weathers blocky in lower part, irregular plates in upper part; fossil fragments, including bryozoans	2.7
Total thickness	7.9
Legion shale member:	
2. Shale, clayey, calcareous, gray-green to gray, blocky; calcareous nodules in middle part. Thickness	6.3
Sallyards limestone member:	
1. Limestone, hard, gray, weathers light gray and blocky; pelecypods common on upper surface. Thickness	1.1
Total thickness of Grenola limestone	39.4

Base covered.

257. *Section from Hughes Creek shale member of Foraker limestone down into Hamlin shale member of Janesville shale in the NW¼SW¼ sec. 21, T. 9 S., R. 11 E., Pottawatomie County, Kans.*

Permian system:

Foraker limestone:

Hughes Creek shale member: Feet

25. Shale, clayey to silty, calcareous, gray, thin-bedded; fossils in lower part (13587) ---- 5.6
24. Shale, very calcareous, gray, weathers to irregular chips; fossil fragments (13586) ---- 3.1
23. Shale, covered ---- 2.4
22. Limestone, hard, gray, weathers tan and blocky; fossil fragments (13586) ---- 1.2
21. Shale, silty, calcareous, gray, grades to dark gray in lower part, weathers tan, thin-bedded; very calcareous in middle part (13585) ---- 8.4
20. Limestone, medium-hard, gray, weathers blocky; fossil fragments ---- .5
19. Shale, covered ---- 1.3
18. Limestone, medium-hard, locally dense, gray, weathers blocky; fossil fragments ---- .6
17. Shale, covered ---- 2.9
16. Limestone, medium-hard, tan-gray, with gray-green tint, weathers nodular; some clay balls as much as ⅛ inch in diameter (13584) ---- 1.7
15. Shale, silty, calcareous, tan-gray, thin-bedded; calcareous lentils in upper part; fossils (13584) ---- 2.6
14. Limestone, medium-hard, sandy, tan, weathers blocky; brachiopods (13584) ---- .3
13. Shale, clayey, some silt, calcareous, gray, thin-bedded; calcareous plates (13583) ---- 8.8

Total thickness exposed ---- 39.4

Americus limestone member:

12. Limestone, hard, dark-gray, massive, weathers blocky; crinoid columnals abundant; other fossil fragments common (13582) ---- 1.0
11. Shale, silty, calcareous, gray, thin-bedded; fossil fragments ---- .4
10. Limestone, hard, tan, massive, weathers light gray to tan and blocky to irregular plates; minute fossil fragments abundant (13581) ---- 1.7

Total thickness ---- 3.1

Total thickness of exposed Foraker limestone ---- 42.5

257. *Section from Hughes Creek shale member of Foraker limestone down into Hamlin shale member of Janesville shale in the NW¼SW¼ sec. 21, T. 9 S., R. 11 E., Pottawatomie County, Kans.*—Continued

Permian system—Continued

Janesville shale:

Hamlin shale member: Feet

9. Sandstone, calcareous, conglomeratic, tan ---- .2–.6
8. Shale, clayey, calcareous, gray, blocky ---- .5
7. Limestone, soft, gray, weathers shaly and nodular ---- .6
6. Shale, silty to clayey, calcareous, gray to gray-green, thin-bedded; cavernous in lower part; calcareous nodules and plates abundant ---- 14.1
5. Shale, sandy, micaceous, noncalcareous, fine-grained, tan-gray; sandstone lentils ---- 4.3
4. Shale, silty, calcareous, tan, with maroon stains ---- .9
3. Shale, clayey, calcareous, maroon, mottled with gray green, thin-bedded ---- 3.2
2. Limestone, wavy to nodular, brittle, tan, nodular part may be interbedded silt; stromatolites ---- .5
1. Sandstone and sandy shale, noncalcareous, micaceous, tan-brown, grades to gray in upper part, thin- to thick-bedded ---- 5.6

Total thickness exposed ---- 29.9–30.3

Total thickness of exposed Janesville shale ---- 29.9–30.3

Base covered.

270. *Section from Foraker limestone down into Hamlin shale member of Janesville shale in a road cut in the SW¼NW¼ sec. 8, T. 8 S., R. 14 E., Jackson County, Kans.*

Permian system:

Foraker limestone:

Long Creek limestone member:

19. Limestone, soft, tan, massive, weathers shaly. Thickness exposed ---- 5.0±

Hughes Creek shale member:

18. Shale, silty, calcareous, tan-gray to tan, thin-bedded; fusulinids and brachiopods ---- 3.4
17. Shale, clayey, noncalcareous, gray, grades to dark gray in middle part, blocky to thin-bedded; middle part contains fragments of brachiopods. A mixed *Composita* and *Marginifera* zone overlies a *Crurithyris* zone, which, in turn, overlies *Orbiculoidea* and *Lingula* zone ---- 2.2

270. *Section from Foraker limestone down into Hamlin shale member of Janesville shale in a road cut in the SW¼NW¼ sec. 8, T. 8 S., R. 14 E., Jackson County, Kans.*—Continued

Permian system—Continued
Foraker limestone—Continued
Hughes Creek shale member—Continued

	Feet
16. Limestone, medium-hard, tan-gray, weathers blocky and to irregular chips and blocks; fossil fragments with encrusted stromatolites(?)	1.5
15. Shale, silty, calcareous, gray-brown to gray, thin-bedded to blocky; very calcareous and fossiliferous in middle and lower part; thin lens in upper part contains gastropods, *Dictyoclostus*, *Crurithyris*, and *Hustedia;* fusulinids abundant in lower part, brachiopods abundant in middle part	6.6
14. Limestone, medium-hard, gray-brown, blocky; fossil fragments	.3
13. Shale, silty, calcareous, tan-gray, thin-bedded; brachiopods and bryozoans	1.4
12. Limestone, medium-hard, gray, weathers shaly to blocky; fossil fragments	.6
11. Shale, clayey, noncalcareous, gray, thin-bedded to blocky	5.0
10. Limestone, medium-hard, gray-brown, weathers blocky to shaly in middle part; fossil fragments abundant	1.6
9. Shale, silty to sandy, calcareous, tan, thin-bedded	.6
8. Limestone, medium-hard, sandy, tan-gray, platy; thin shale partings; brachiopods	.8
7. Shale, clayey, some silt, noncalcareous, gray to olive-drab, blocky; iron stains common on fracture planes; fossiliferous lentils in lower part	10.4
Total thickness	34.4

Americus limestone member:

	Feet
6. Limestone, hard, gray to tan-gray, weathers blocky; crinoid columnals abundant; fusulinids common	.8
5. Shale, silty, some clay, calcareous, gray, thin-bedded	2.5
4. Limestone, hard, crystalline, gray, weathers blocky; few clay balls and lentils, clay zone in lower and upper parts	.6
Total thickness	3.9
Total thickness of Foraker limestone	43.3±

Janesville shale:
Hamlin shale member:

	Feet
3. Shale, silty to clayey, calcareous, gray-green, blocky; cavernous zone in upper part; iron stains abundant on fracture planes and in cavernous zone	5.0

270. *Section from Foraker limestone down into Hamlin shale member of Janesville shale in a road cut in the SW¼NW¼ sec. 8, T. 8 S., R. 14 E., Jackson County, Kans.*—Continued

Permian system—Continued
Janesville shale—Continued
Hamlin shale member—Continued

	Feet
2. Shale, cavernous, gray-brown, irregular bedding; some calcium carbonate	2.3
1. Shale, clayey, calcareous, gray-green, blocky	10.0±
Total thickness exposed	17.3±
Total thickness of exposed Janesville shale	17.3±

Base covered.

275. *Section from Red Eagle limestone down into Johnson shale is in a stream cut in the SE¼NE¼ sec. 23, T. 15 S., R. 11 E., Lyon County, Kans.*

Permian system:
Red Eagle limestone:
Bennett shale member:

	Feet
5. Limestone (biostrome), medium-hard, soft on weathered surface in lower part, tan, weathers light gray; chert nodules common; porous to cavernous with some caverns filled with oxidized soil; fossils very abundant in upper part; crinoid columnals, echinoid spines, and bryozoans; lower 16 ft is a hard dense limestone with many fossil fragments; altered to calcite, weathers blocky, fragmental appearance; locally in upper part, the limestone is coquina; fossils not abundant in lower part; ostracodes very abundant in upper part (13713)	34.9
4. Shale, clayey, dark-gray, grades to lighter gray in upper part; blocky, becomes fissile in upper part; brachiopods in lower part	2.4
Total thickness exposed	37.3

Glenrock limestone member:

	Feet
3. Limestone, hard, gray, weathers blocky; iron stains; fusulinids abundant, brachiopod fragments abundant on upper surface. Thickness	.4–.5
Total thickness of exposed Red Eagle limestone	37.7–37.8

Johnson shale:

	Feet
2. Shale, clayey, some silt, olive-drab, mottled with gray, blocky	3.3
1. Shale, very calcareous, tan-gray, massive, weathers platy	7.6
Total thickness exposed	10.9

Base covered.

280. *Section from upper part of Neva limestone member of Grenola limestone down into Americus limestone member of the Foraker limestone in a streambank and road cut in the SE¼SW¼NW¼ sec. 26, T. 19 S., R. 7 E., Chase County, Kans.*

Permian system:

Grenola limestone:

Neva limestone member: Feet

47. Limestone, hard, locally dense, light-gray to tan-gray, massive, weathers blocky; cavernous in middle part; dense limestone fragments as much as 2 inches or more in diameter in limestone matrix; angular to subrounded — 4.4
46. Limestone, medium-hard, light-gray, weathers tan and blocky; echinoid spines; fusulinids abundant in lower part — 1.7
45. Shale, silty, calcareous, tan-gray, thin-bedded; *Crurithyris* abundant in lower part; fusulinids abundant in upper part — .4
44. Limestone, medium-hard, light-gray, blocky, weathers shaly in middle and lower parts; fusulinids abundant; especially in upper part — 1.2
43. Shale, silty, calcareous, gray-brown, thin-bedded; *Crurithyris* zone in upper part; *Orbiculoidea* zone in lower part — .8
42. Limestone, hard, brittle, light-gray, semiconchoidal fracture; fossil fragments each with weathered zone that is lighter than the matrix, some limonite filled — 1.7

Total thickness exposed — 10.2

Salem Point shale member:

41. Shale, silty, calcareous, tan-gray, thin-bedded; mostly covered — 7.4
40. Limestone, medium-hard, tan in upper part, gray in lower part; weathers cavernous to porous — 1.2
39. Shale, clayey, calcareous, gray-green, blocky; limonite stains on fracture planes — 3.7

Total thickness — 12.3

Burr limestone member:

38. Limestone, hard, brittle, dense, tan-gray to gray, irregular bedding in upper part, massive, weathers platy, becomes massive and blocky in upper part; upper part contains a 0.5-ft zone of stromatolite limestone — 4.3
37. Shale, silty, calcareous, tan-gray, thin-bedded to fissile; small algal deposits(?) — .4
36. Limestone, hard, tan-gray, blocky; fragments of pelecypods — .6

280. *Section from upper part of Neva limestone member of Grenola limestone down into Americus limestone member of the Foraker limestone in a streambank and road cut in the SE¼SW¼NW¼ sec. 26, T. 19 S., R. 7 E., Chase County, Kans.*—Continued

Permian system—Continued

Grenola limestone—Continued

Burr limestone member—Continued Feet

35. Shale, silty, calcareous, gray to tan-gray, thin-bedded; 2 limestone lenses with pelecypods in lower part, 1 limestone lens in upper part — .9
34. Limestone, hard, dark-gray, weathers blocky; pelecypods abundant — .3
33. Shale, fissile, dark-gray — .2
32. Limestone, shaly, clayey, soft, gray, weathers shaly and to irregular chips; more massive in upper part; fossil fragments — 2.5

Total thickness — 9.2

Legion shale member:

31. Shale, silty, calcareous, gray, thin-bedded, weathers to irregular chips; very calcareous in upper and lower parts — 1.8
30. Shale, clayey, calcareous, gray, thin-bedded to blocky — 5.2

Total thickness — 7.0

Sallyards limestone member:

29. Limestone, hard, gray, blocky; pelecypods and gastropods — .2
28. Shale, silty, calcareous, tan-gray, thin-bedded — .5
27. Limestone, hard, gray, semiconchoidal fracture, blocky; pelecypods — .9
26. Shale, clayey, calcareous, tan-gray, thin-bedded — .4
25. Limestone, impure, gray, weathers shaly; pelecypods — 1.0

Total thickness — 3.0

Total thickness of exposed Grenola limestone — 41.7

Roca shale:

24. Shale, clayey, calcareous, gray, thin-bedded — 2.5
23. Shale, covered — 5.6
22. Shale, clayey, calcareous, gray-green, with purple and maroon tint in lower part, blocky — .6
21. Shale, clayey, calcareous, tan, becoming tan-gray in upper part, blocky; nodular in lower part — 1.8
20. Shale, clayey, calcareous, gray-green, with purple tint in upper part, blocky — 2.8

280. *Section from upper part of Neva limestone member of Grenola limestone down into Americus limestone member of the Foraker limestone in a streambank and road cut in the SE¼SW¼NW¼ sec. 26, T. 19 S., R. 7 E., Chase County, Kans.*—Continued

Permian system—Continued

Roca shale—Continued — Feet

19. Shale, covered — 4.6

Total thickness — 17.9

Red Eagle limestone:

Howe limestone member:

18. Limestone, soft, tan-brown, weathers blocky; lower two-thirds porous to cavernous; ostracode zone 0.3 ft thick and 0.3 ft from top. Thickness — 1.6

Bennett shale member:

17. Shale, silty, calcareous, tan-gray, dark gray in lower part, thin-bedded; calcareous lentils in middle part; fossils abundant in lower two-thirds; brachiopods and echinoids — 3.9

16. Limestone, medium-hard, brittle, light-tan, massive, weathers blocky; porous in middle part; fossil fragments — 5.4

15. Shale, very calcareous, tan-gray, thin-bedded; fusulinids and crinoid columnals — .4

Total thickness — 9.7

Glenrock limestone member:

14. Limestone, medium-hard, gray-brown, weathers blocky; minute fossil fragments abundant. Thickness — .4

Total thickness of Red Eagle limestone — 11.7

Johnson shale:

13. Shale, clayey, noncalcareous, gray-green to tan to gray, blocky; thin nodular calcareous lentils in upper and middle parts; lower part covered. Thickness — 21.1

Foraker limestone:

Long Creek limestone member:

12. Limestone, medium, tan-gray, semicrystalline, weathers platy; many fossil fragments — 1.0

11. Limestone, medium-hard, tan, massive, weathers blocky to shaly in upper part — 4.9

10. Limestone, soft to medium-hard, tan, shaly; some fossil fragments — .3

9. Limestone, medium-hard, tan, massive, weathers blocky; coquina — 1.5

Total thickness — 7.7

280. *Section from upper part of Neva limestone member of Grenola limestone down into Americus limestone member of the Foraker limestone in a streambank and road cut in the SE¼SW¼NW¼ sec. 26, T. 19 S., R. 7 E., Chase County, Kans.*—Continued

Permian system—Continued

Foraker limestone—Continued — Feet

Hughes Creek shale member:

8. Shale and limestone covered — 14.3

7. Shale, silty, very calcareous, gray to tan-gray, thin-bedded to irregular chips; fusulinids very abundant; brachiopods — 5.6

6. Limestone, medium-hard, gray, weathers tan and blocky; fusulinids abundant — .6

5. Shale, silty, very calcareous, gray, thin-bedded; fusulinids abundant — .2

4. Limestone, hard, dark-gray, massive, weathers blocky; fusulinids abundant; *Crurithyris* abundant in upper part — .3

3. Shale, silty, calcareous, becomes very calcareous in lower part, gray, thin-bedded; brachiopods; mostly covered — 7.2

Total thickness — 28.2

Americus limestone member:

2. Limestone, hard, dark-gray, weathers platy and to irregular chips; worm burrows(?) and fusulinids abundant in upper part; crinoid columnals; brachiopods beneath fusulinid zone — 1.2

1. Shale, silty, calcareous, gray, thin-bedded to fissile — 1.0

Total thickness exposed — 2.2

Total thickness of exposed Foraker limestone — 38.1

Base covered.

283. *Section from Dover limestone member of Stotler limestone down into Wamego shale member of Zeandale limestone in a streambank in the NE¼NE¼ sec. 1, T. 32 S., R. 8 E., Chautauqua County, Kans.*

Pennsylvanian system:

Stotler limestone:

Dover limestone member:

9. Limestone, medium-hard, gray to light-gray, blocky to nodular; iron stains; crinoid columnals, stromatolites and fossil fragments. Thickness exposed — 0.8

Total thickness of exposed Stotler limestone — 0.8

Pillsbury shale:

8. Shale, clayey, some silt, calcareous, gray to tan-gray, thin-bedded to fissile; fossils in lower 1.5 ft, consisting of crinoid columnals, brachiopods, corals, and gastropods — 11.2

283. *Section from Dover limestone member of Stotler limestone down into Wamego shale member of Zeandale limestone in a streambank in the NE¼NE¼ sec. 1, T. 32 S., R. 8 E., Chautauqua County, Kans.*—Continued

Pennsylvanian system—Continued
Pillsbury shale—Continued

	Feet
7. Shale, clayey, noncalcareous, dark-gray, fissile	.8
6. Shale, silty, calcareous, gray-brown, grades to gray in the lower part, thin-bedded	2.1
Total thickness	14.1

Zeandale limestone:
Maple Hill limestone member:

5. Limestone, medium-hard, gray, weathers blocky and shaly in upper part; fusulinids common; gastropods and brachiopods. Thickness	.4

Wamego shale member:

4. Shale, clayey, noncalcareous, gray, thin-bedded to fissile; iron stains	2.9
3. Limestone, hard, dense, dark-blue-gray, thin tan weathered crust, blocky; conchoidal fracture; echinoid spines; crinoid columnals, brachiopods, and gastropods	1.0
2. Shale, very calcareous, gray; heavily iron stained in upper part; pelecypods and brachiopods	2.9
1. Coal, black, blocky	.6
Total thickness exposed	7.4
Total thickness of exposed Zeandale limestone	7.8

Base covered.

286. *Section from Red Eagle limestone down into the West Branch shale member of the Janesville shale in a road cut in SE¼ sec. 21, T. 32 S., R. 8 E., Cowley County, Kans.*

Permian system:
Red Eagle limestone:
Bennett shale member:

	Feet
52. Limestone, hard, brittle, dense, gray, weathers blocky; weathers shaly in upper part; iron stains on surface; bedding irregular and wavy; conchoidal fracture; locally porous; thin shale partings in middle part; brachiopods, echinoid spines, and other fossil fragments abundant; secondary calcium carbonate replacement	15.1
51. Limestone, hard, dense, brittle, gray, bedding wavy and irregular; semiconchoidal fracture; secondary calcite common; thin gray shale parting in lower part; fossil fragments abundant, including brachiopods, fusulinids, stromatolites(?), and bryozoans. Fusulinids common in lowest bed (0.6 ft) which is very likely the Glenrock limestone member (13768)	5.6
Total thickness exposed	20.7
Total thickness of exposed Red Eagle limestone	20.7

286. Section from Red Eagle limestone down into the West Branch shale member of the Janesville shale in a road cut in SE¼ sec. 21, T. 32 S., R. 8 E., Cowley County, Kans.—Continued

Johnson shale:

50. Shale, silty, calcareous, gray to tan-gray, weathers tan, 8 thin evenly spaced 0.0- to 0.2-ft calcareous lentils; calcareous nodules in upper part; perfectly preserved fossils, which include brachiopods and pelecypods (13767)	5.6
49. Limestone, hard, dense, clayey, gray, weathers blocky; small calcite-filled pores	1.3
48. Shale, silty, some clay in lower part, calcareous, gray to tan-gray, thin-bedded in upper part, blocky in lower part	7.4
47. Shale, silty, calcareous, purple, with maroon tint, thin-bedded to blocky	1.0
46. Shale, silty, calcareous, gray-green, thin-bedded to blocky; nodular in lower part	1.6
Total thickness	16.9

Foraker limestone:
Long Creek limestone member:

45. Limestone, algal-like, hard, dense, gray, weathers nodular to blocky; iron-stained streaks	.8
44. Shale, clayey, noncalcareous, gray to gray-green, blocky; calcareous lentils in upper part; iron-stained zone in middle part	2.8
43. Limestone, hard, dense, tan, weathers blocky; thin shale parting in lower part; abundant iron stains on irregular upper surface	1.1
42. Shale, silty, calcareous, tan, thin-bedded; thin impure limestone in lower part	1.6
41. Limestone, hard, dense, gray, thin bedding planes apparent in upper three-fourths of bed; conchoidal fracture	1.9
Total thickness	8.2

286. *Section from Red Eagle limestone down into the West Branch shale member of the Janesville shale in a road cut in SE¼ sec. 21, T. 32 S., R. 8 E., Cowley County, Kans.*—Continued

Permian system—Continued

Foraker limestone—Continued

Hughes Creek shale member: Feet

40. Shale, silty, calcareous, tan, thin-bedded 4.0
39. Limestone, medium-hard, tan-gray to gray, conchoidal fracture; chert nodules in lower part; sugary texture 3.9
38. Shale, silty, calcareous, gray to tan-gray, thin-bedded; calcareous lens in lower part; crinoid columnals, worm burrows(?), and brachiopods 2.0
37. Limestone, hard, gray, weathers blocky; iron stains in upper part; microfossils and fusulinids in middle part (13766) 2.1
36. Shale, very calcareous, some soft limestone, gray-brown, thin-bedded to massive; fusulinids very abundant (13765) 2.6
35. Limestone, medium-hard to hard, gray, weathers blocky; 2 chert lenses in upper 3 ft; chert nodules in upper 5 ft; fusulinids abundant; brachiopod zone about 3 ft from base (13764) 10.6
34. Shale, silty, calcareous, gray-brown, thin-bedded; fusulinids abundant; brachiopods common (13763) 3.7
33. Limestone, medium-hard, gray; shale parting; conglomeratic in upper part; small rounded clay balls; shale, clayey, fissile, dark-gray; brachiopods .9
32. Limestone, hard, dense, gray, weathers blocky; conchoidal fracture; fossil fragments abundant, especially in middle part; stromatolites 2.2
31. Shale, silty, calcareous, tan-gray, thin-bedded; brachiopods, echinoid spines, and bryozoans (13762) 1.5
30. Limestone, hard, dense in part, brittle; light- to dark-gray, weathers blocky; chert lens in lower and upper parts; chert nodules scattered throughout, white long, slender fusulinids abundant (13761) 7.5
29. Limestone, medium-hard, gray, weathers blocky in lower part, cavernous in upper part; fusulinids abundant in lowermost 1.0 ft, diminish in abundance upwards, become abundant in topmost 0.6 ft; brachiopods in upper 1.0 ft; limestone becomes shaly in west end of cut (13760) 3.2
28. Shale, silty, calcareous, gray-brown to gray; fissile in lower part, thin-bedded; brachiopods in lower half (13759) 3.3

286. *Section from Red Eagle limestone down into the West Branch shale member of the Janesville shale in a road cut in SE¼ sec. 21, T. 32 S., R. 8 E., Cowley County, Kans.*—Continued

Permian system—Continued

Foraker limestone—Continued

Hughes Creek shale member—Continued Feet

27. Limestone, hard, brittle, gray, weathers blocky, conchoidal fracture; fossil fragments including crinoid columnals 1.3
26. Shale, silty, calcareous, gray-brown, thin-bedded to blocky; calcareous lentils in lower part; brachiopods throughout shale and in lower calcareous lentil; worm burrows(?) in upper part that contain fossil fragments; brachiopods and gastropods in lower part (13758) 2.2
25. Limestone, medium-hard, clayey, dark-gray, blocky; brachiopods (13758) .2
24. Shale, silty, calcareous, tan-gray, thin-bedded; calcareous lentils in middle part. (13758) 1.3
23. Limestone, clayey, medium-hard, dark-gray; weathers blocky. (13758) .2
22. Shale, silty, calcareous, tan-gray, thin-bedded; thin calcareous lentils in upper part; brachiopods (13758) 3.4

Total thickness 56.1

Americus limestone member:

21. Limestone, hard, dense, dark-gray, weathers blocky; cherty in upper part; fusulinids abundant; crinoid columnals and brachiopods common (13757) 2.1
20. Shale, very calcareous, tan (13757) .2
19. Limestone, hard, dense, dark-gray, weathers blocky; fusulinids abundant; crinoid columnals common (13757) 2.5
18. Shale, clayey, noncalcareous, dark-gray, fissile 3.7
17. Limestone, clayey, dense in part, dark gray, weathers nodular to blocky; dense algal zones; brachiopods; some microfossils replaced by limonite (13756) .8

Total thickness 9.3

Total thickness of Foraker limestone 73.6

Janesville shale:

Hamlin shale member:

16. Shale, (calcarenite), sandy, fine-grained, tan; calcareous fragments 1.0
15. Limestone, dense, hard, dark-gray, weathers blocky; conchoidal fracture .3

286. *Section from Red Eagle limestone down into the West Branch shale member of the Janesville shale in a road cut in SE¼ sec. 21, T. 32 S., R. 8 E., Cowley County, Kans.*—Continued

Permian system—Continued
Janesville shale—Continued

	Feet
Hamlin shale member—Continued	
14. Shale, silty, calcareous, dark-gray, massive in part; cavernous where not cemented; grades up into a massive siltstone and fissile shale in upper 1.0 ft	8.0
13. Shale, silty, calcareous, tan-gray to gray, thin-bedded; calcareous lentils common	9.0
12. Shale, noncalcareous, clayey, dark-gray; mostly covered; fissile shale in lower 4.0 ft	11.2
11. Shale, silty, calcareous, light-brown; many siltstone and fine-grained sandstone lentils	5.6
10. Sandstone, very fine-grained, dark-brown, crossbedded; calcium carbonate cemented	.9
9. Shale, silty, calcareous, thin-bedded; some very fine-grained micaceous sandstone lentils	1.1
8. Shale, silty, calcareous, dark-gray, thin-bedded	4.4
Total thickness	41.5
Five Point limestone member:	
7. Limestone, medium-hard, gray to tan-gray; weathers blocky to shaly; fossil fragments abundant, including large crinoid columnals (13755)	.8
6. Shale, silty, calcareous, tan-gray, thin-bedded, crinoid columnals and brachiopods (13755)	.4
5. Limestone, hard, dense, brittle, dark-gray, blocky, conchoidal fracture; iron stains on weathered zone that is 2 or more inches thick; fusulinids abundant; crinoid columnals common (13754)	1.5
4. Shale, silty, calcareous, gray to tan-gray, thin-bedded, fissile in middle part, calcareous lentils and plates; thin carbonate zone in upper part below a silty zone of white brachiopod fragments; pelecypods, gastropods, and brachiopods abundant in lower 5 ft	9.1
3. Limestone, medium-hard, gray-brown, blocky; iron stains on fracture planes	.2
Total thickness	12.0

286. *Section from Red Eagle limestone down into the West Branch shale member of the Janesville shale in a road cut in SE¼ sec. 21, T. 32 S., R. 8 E., Cowley County, Kans.*—Continued

Permian system—Continued

	Feet
West Branch shale member:	
2. Shale, silty, calcareous, gray, thin-bedded to fissile; pelecypods (13753)	1.1
1. Coal, black, blocky	.3
Total thickness exposed	1.4
Total thickness of exposed Janesville shale	54.9

Base covered

287. *Section from Neva limestone member of Grenola limestone down to base of Howe limestone member of Red Eagle limestone in a road cut in the NW¼NE¼ sec. 30, T. 32 S., R. 8 E., Cowley County, Kans.*

Permian system:
Grenola limestone:

	Feet
Neva limestone member:	
15. Limestone, hard, somewhat dense, gray, thin shale parting in the lower part; local chert lenses and nodules in upper and lower parts; fossil fragments abundant, including crinoid columnals, echinoid spines, and bryozoans; brachiopods. Thickness exposed	2.8
Salem Point shale member:	
14. Shale, silty, calcareous, tan-gray, thin-bedded; brachiopods and gastropods (13772)	1.2
13. Shale, clayey, very calcareous, gray, platy to blocky; many irregular claystone beds; pelecypods and gastropods in lower part (13771)	3.3
12. Shale, silty, calcareous, tan-gray, thin-bedded to blocky; thin limestone in middle part; gastropods (13771)	1.6
Total thickness	6.1
Burr limestone member:	
11. Limestone, silty, fine-grained, tan, faint crossbedding	.8
10. Limestone, medium-hard, clayey to silty, tan, crossbedded; shale parting in lower part; gastropods in shaly part (13770)	2.4
9. Limestone, medium-hard, dense in part, clayey, gray, thin shale partings; weathers shaly; pelecypods (13770)	2.6
8. Shale, very calcareous, gray, platy; 0.5-ft limestone unit in middle part; fossil fragments (13770)	1.7

287. *Section from Neva limestone member of Grenola limestone down to base of Howe limestone member of Red Eagle limestone in a road cut in the NW¼NE¼ sec. 30, T. 32 S., R. 8 E., Cowley County, Kans.*—Continued

Permian system—Continued
Grenola limestone—Continued
Burr limestone member—Continued — Feet

7. Limestone, hard, dense to crystalline, gray-brown; weathers blocky; minute fossil fragments abundant; small gastropods ---- 4.0

Total thickness ---- 11.5

Legion shale member:

6. Shale, silty, calcareous, tan gray in lower part, gray in upper part; thin limestone lenses scattered throughout; brachiopods, pelecypods, and bryozoans in middle part; fossils most abundant in limestone lenses (13769). Thickness -- 7.4

Sallyards limestone member:

5. Limestone, hard, dense, gray, weathers blocky; stromatolites in middle part; fossil fragments abundant. Thickness - 2.2

Total thickness of Grenola limestone ---- 30.0

Roca shale:

4. Shale, silty, calcareous, tan, thin-bedded to blocky; dense tan-gray claystone lentils in upper part ---- 6.7
3. Shale, clayey, calcareous, maroon, with purple in lower part, blocky; calcium carbonate nodules in local areas ---- 4.5
2. Shale, clayey, some silt, tan-gray to gray; blocky; thin limestone lentils in lower part ---- 7.3

Total thickness ---- 18.5

Red Eagle limestone:
Howe limestone member:

1. Limestone, hard, dense, tan-brown, massive, weathers blocky, porous; possible crossbedding; semiconchoidal fracture; fossil fragments abundant; stromatolites in upper part; ostracodes(?) in middle part (13781). Overlies limestone units of the Bennett shale (20.7 ft exposed). Thickness ---- 4.3

Total thickness of exposed Red Eagle limestone ---- 25.0

288. *Section from Beattie limestone down into Red Eagle limestone on a hillside in the SE¼SW¼SW¼ sec. 4, T. 31 S., R. 8 E., and northeast and east along railroad and north side of stream in Cowley County, Kans.*

Permian system:
Beattie limestone:
Morrill limestone member: — Feet

33. Limestone, medium-hard, tan-gray, weathers blocky and to irregular chips; brachiopods and pelecypods ---- 5.7
32. Limestone, medium-hard, light-gray to gray, weathers blocky; some chert nodules; porous; stromatolites abundant; upper part more resistant to erosion, forms hillside bench ---- 4.3

Total thickness exposed ---- 10.0

Florena shale member:

31. Shale, silty, calcareous, tan-gray; many limestone lentils; chert nodules in lower part; pelecypods, brachiopods, and gastropods very abundant and perfectly preserved (13775); mostly covered. Thickness ---- 14.3

Cottonwood(?) limestone member:

30. Limestone and shale, thin alternating beds; limestone is medium hard, clayey, gray, and weathers nodular. Thickness ---- 3.0

Total thickness of exposed Beattie limestone ---- 27.3

Eskridge shale:

29. Shale, silty, calcareous, gray to tan, thin-bedded to fissile; thin calcareous limestone in upper part; brachiopods and pelecypods ---- 6.2
28. Shale, silty, maroon, with purple tint, tan gray in lower part ---- 5.6
27. Limestone, hard, clayey, gray, weathers blocky; pelecypods and brachiopods (13774) ---- 1.0
26. Shale, silty, calcareous, mostly maroon -- 6.2
25. Limestone, medium-hard, tan-gray, weathers blocky ---- .4
24. Shale, silty, calcareous, maroon, becomes gray green in upper part ---- 3.0

Total thickness ---- 22.4

Grenola limestone:
Neva limestone member:

23. Limestone, medium-hard, gray, weathers platy; fossil fragments ---- 2.3

288. *Section from Beattie limestone down into Red Eagle limestone on a hillside in the SE¼SW¼SW¼ sec. 4, T. 31 S., R. 8 E., and northeast and east along railroad and north side of stream in Cowley County, Kans.*—Continued

Permian system—Continued
Grenola limestone—Continued
Neva limestone member—Continued

	Feet
22. Shale, silty, calcareous, gray to tan-gray, thin-bedded; fusulinids, echinoid spines, and plates (13773)	3.3
21. Limestone, medium-hard, light-gray, blocky, weathers to thin beds; brachiopods	1.7
20. Shale, silty, calcareous, tan-gray, thin-bedded; fusulinids	.8
19. Limestone, hard, tan to tan-gray, massive, weathers blocky; lower part weathers to beds about 1.5 ft thick, middle part is thin bedded, upper part has 1.5 ft bed which weathers to irregular plates, forms hillside bench; chert lentils about 2 inches thick in the middle part; fusulinids abundant, echinoid spines and brachiopods common (14818)	6.9
18. Shale, silty, tan, thin-bedded; fusulinids abundant in upper part; brachiopods common	2.2
17. Limestone, medium-hard, gray, weathers to irregular plates and nodules; irregular bedding; thin shale partings in middle and lower part somewhat porous; minute fossil fragments including echinoids, crinoids, and brachiopods	3.5
Total thickness	20.7

Salem Point shale member:

16. Shale, very calcareous, tan, boxwork zone in upper 5.0 ft. Thickness	7.7

Burr limestone member:

15. Limestone, hard, clayey in part, gray, weathers blocky; pelecypods	.3
14. Shale, silty, tan, thin-bedded	.2
13. Limestone, hard, gray, weathers blocky and tan; pelecypods abundant (14817)	.5
12. Shale, calcareous, silty, very calcareous in part, tan, thin-bedded; thin limestone lentils	1.9
11. Limestone, hard, gray, massive, weathers blocky, upper part weathers to thin irregular plates; ostracodes abundant in upper part, restricted to very thin lenticular zones; fossil fragments and minute fossils abundant. Forms a hillside bench	2.4

288. *Section from Beattie limestone down into Red Eagle limestone on a hillside in the SE¼SW¼SW¼ sec. 4, T. 31 S., R. 8 E., and northeast and east along railroad and north side of stream in Cowley County, Kans.*—Continued

Permian system—Continued
Grenola limestone—Continued
Burr limestone member—Continued

	Feet
10. Shale, silty, very calcareous, tan, thin-bedded	.2
9. Limestone, hard, grades up to very calcareous shale, gray, weathers blocky; some pelecypod fragments	1.4
Total thickness	6.9

Legion shale member:

8. Shale, silty, tan, blocky, thin impure limestone beds; iron stains on fracture planes; no fossils. Thickness	9.1

Sallyards limestone member:

7. Limestone, hard, gray, weathers blocky and to thin irregular beds that slump down slope; upper part is porous and weathers to small irregular blocks; some secondary calcite; upper surface pitted; pelecypods abundant in thin beds; fossil fragments abundant in upper beds; gastropods and pelecypods common (14816). Forms hillside bench. Thickness	3.8
Total thickness of Grenola limestone	48.2

Roca shale:

6. Shale, lower 13.0 ft mostly maroon, upper 2.5 ft tan to tan-gray; mostly covered. Thickness	15.5

Red Eagle limestone:
Howe limestone member:

5. Limestone, medium-hard, tan, weathers blocky with rounded edges; oolitic; ostracodes abundant especially in upper part; this bed appears to be all ostracodes although some of the fragments are nonsymmetrical (14815). Thickness	2.1

Bennett shale member:

4. Shale, very calcareous, tan, thin-bedded	.5
3. Limestone, hard, semicrystalline, tan-gray, massive, with thin beds, weathers blocky; forms hillside bench; brachiopods and bryozoans	11.2
2. Limestone, hard, crystalline, tan-gray, massive, weathers blocky; fossil fragments abundant	1.5

288. *Section from Beattie limestone down into Red Eagle limestone on a hillside in the SE¼SW¼SW¼ sec. 4, T. 31 S., R. 8 E., and northeast and east along railroad and north side of stream in Cowley County, Kans.*—Continued

	Feet
Permian system—Continued	
Red Eagle limestone—Continued	
Bennett shale member—Continued	
1. Limestone, medium-hard, tan-gray, weathers blocky to platy; many thin beds with some thin shale partings; fossil fragments	4.3
Total thickness exposed	17.5
Total thickness of exposed Red Eagle limestone	19.6

Base covered.

289. *Section of Neva limestone member and upper part of Salem Point shale member of Grenola limestone in a railroad cut in the SE¼NW¼ sec. 12, T. 34 S., R. 7 E., Cowley County, Kans.*

	Feet
Permian system:	
Grenola limestone:	
Neva limestone member:	
12. Limestone, hard, semicrystalline, light-gray, blocky, weathers into many thin beds, porous; semiconchoidal fracture; chert nodules in upper two-thirds; angular fragments of limestone in middle part; many thin shale partings 0.2 ft in lower part about 1.5 ft from base; fusulinids throughout, brachiopods in lower part; corals and stromatolites(?) (13780)	7.0
11. Shale, silty, calcareous, gray, thin-bedded	1.0
10. Limestone, medium-hard, tan, weathers to irregular plates; fossil fragments	.4
9. Shale, silty, calcareous, gray, thin-bedded	.5
8. Limestone, hard, dense in part, light-gray, weathers blocky; many chert nodules in upper part; upper half is porous and has limestone fragments in lime matrix; fossil fragments	3.7
7. Shale, silty, calcareous, gray, thin-bedded; calcareous plates; fusulinids (13779)	.7
6. Limestone, hard, dense in part, gray to tan-gray, weathers blocky to shaly; chert nodules in upper part of lower half; crinoid columnals, fusulinids, and brachiopods (13778)	2.9
5. Shale, silty, calcareous, tan-gray, thin-bedded; lenticular limestone bed in upper part with many minute fossil fragments; brachiopods (13777)	.3
4. Limestone, hard, dense, gray, weathers blocky, and to thin irregular beds; porous; fossil fragments abundant	2.2

289. *Section of Neva limestone member and upper part of Salem Point shale member of Grenola limestone in a railroad cut in the SE¼NW¼ sec. 12, T. 34 S., R. 7 E., Cowley County, Kans.*—Continued

	Feet
Permian system—Continued	
Grenola limestone—Continued	
Neva limestone member—Continued	
3. Shale, silty, calcareous, tan-gray, thin-bedded	.3
2. Limestone, hard, slightly dense, gray, weathers nodular; crinoid columnals and pelecypods	1.2
Total thickness exposed	20.2
Salem Point shale member:	
1. Shale, thin limestone; brachiopods in upper part. (13776). Thickness exposed	4.0±
Total thickness of exposed Grenola limestone	24.2±

Base covered.

291. *Section from Dover limestone member of Stotler limestone down to Elmont(?) limestone member of Emporia(?) limestone in NW¼SW¼SW¼ sec. 36, T. 29 S., R. 9 E., Elk County, Kans.*

Pennsylvanian system:	
Stotler limestone:	
Dover limestone member:	
7. Limestone, medium-hard, gray-brown, weathers to irregular plates; fossil fragments, including bryozoans, abundant; stromatolites common. Thickness exposed	0.6
Total thickness of exposed Stotler limestone	0.6
Pillsbury shale:	
6. Shale, silty, calcareous, gray, thin-bedded to fissile; lower part covered. Thickness	13.9
Zeandale limestone:	
Maple Hill limestone member:	
5. Limestone, hard, dark-gray, weathers blocky and to irregular chips; stromatolites(?) abundant; trilobites, brachiopods, and fusulinids (13785). Thickness	.8
Wamego shale member:	
4. Shale, clayey, gray, fissile	7.8
3. Limestone, hard, gray, weathers to irregular blocks; brachiopods and crinoid columnals (13784)	1.2
2. Shale, clayey to silty, calcareous; calcareous shale in upper part contains pelecypods; carbonaceous zone below pelecypods 2.8 ft from top; minute fossil fragments that are very likely	

291. *Section from Dover limestone member of Stotler limestone down to Elmont(?) limestone member of Emporia(?) limestone in NW¼SW¼SW¼ sec. 36, T. 29 S., R. 9 E., Elk County, Kans.*—Continued

Pennsylvanian system—Continued
Zeandale limestone—Continued
Wamego shale member—Continued — Feet
ostracodes; very calcareous zone in the uppermost part overlies 0.4 ft bed of coal; a marl zone 1.0 ft thick is present 5.3 ft beneath coal bed (13783) — 13.4

Total thickness — 22.4

Total thickness of Zeandale limestone — 25.6

Emporia (?) limestone:
Elmont(?) limestone member:
1. Limestone, hard, gray-brown, massive, weathers to brown crust and blocky; fusulinids abundant; crinoid columnals common (13782). Thickness — 2.4

Base covered.

292. *Section from Americus limestone member of Foraker limestone down to the top of Falls City limestone in the SE¼ sec. 31, T. 28 S., R. 8 E., Elk County, Kans.*

Permian system:
Foraker limestone:
Americus limestone member:
13. Limestone, hard, dark-gray, weathers to large blocks; crinoid columnals abundant, brachiopods and fusulinids common — 1.3
12. Shale, silty, calcareous, gray; mostly covered — 4.6
11. Limestone, hard, gray, weathers to irregular blocks; fossil fragments abundant, including pelecypods and brachiopods in upper part (13795) — 1.6
10. Conglomerate, pebbles angular to rounded; flat limestone and clay fragments as much as 2×1×½ inches with slightly rounded corners, in a limestone matrix. Conglomerate grades up into lower part of overlying limestone — .5
9. Shale, calcareous, silty, tan-gray, thin-bedded to massive; siltstone in upper part — 4.3
8. Limestone, hard, dark-gray, massive, weathers blocky; stromatolites abundant (13794) — .5

Total thickness exposed — 12.8

Total thickness of exposed Foraker limestone — 12.8

292. *Section from Americus limestone member of Foraker limestone down to the top of Falls City limestone in the SE¼ sec. 31, T. 28 S., R. 8 E., Elk County, Kans.*—Continued

Permian system—Continued
Janesville shale:
Hamlin shale member: — Feet
7. Sandstone, tan, thin-bedded — .3
6. Siltstone, tan, massive, cavernous — 5.6
5. Shale, clayey, gray to gray-green; mostly covered — 28.0

Total thickness — 33.9

Five Point limestone member:
4. Limestone, medium-hard, dark-gray, weathers to large blocks; small fusulinids very abundant, brachiopods and crinoid columnals common (13793) — 1.1
3. Shale, covered — 5.6
2. Limestone, somewhat crystalline, dark-gray, weathers blocky; crinoid columnals abundant; brachiopods common — .5

Total thickness — 7.2

West Branch shale member:
1. Shale, clayey, noncalcareous, thin-bedded, fissile in lower part; thin coal seam 8.7 ft above the Falls City limestone; another thin coal seam 14.6 ft above base of member. Thickness — 16.0

Total thickness of Janesville shale — 57.1

Top of the Falls City limestone.
Base covered.

293. *Section from Salem Point shale member of Grenola limestone down into the upper limestone of Americus limestone member of Foraker limestone in a streambank in the SW¼SE¼ sec. 12, T. 29 S., R. 8 E., Elk County, Kans.*

Permian system:
Grenola limestone:
Salem Point shale member:
30. Shale. Thickness — 2.0

Burr limestone member:
29. Limestone, shale partings, siltstone bed in upper part; pelecypods — 3.4
28. Limestone, hard, gray, weathers blocky; coquina in upper part clayey in part; small subangular clay balls. Forms a small hillside bench (13805) — 4.5

Total thickness — 7.9

Legion shale member:
27. Shale, clayey, calcareous, gray, blocky — 3.8
26. Limestone, medium-hard, gray, weathers blocky; fossil fragments abundant — 1.5

293. *Section from Salem Point shale member of Grenola limestone down into the upper limestone of Americus limestone member of Foraker limestone in a streambank in the SW¼SE¼ sec. 12, T. 29 S., R. 8 E., Elk County, Kans.*—Continued

Permian system—Continued
Grenola limestone—Continued
Legion shale member—Continued

	Feet
25. Shale, silty, calcareous, gray, thin-bedded; pelecypods rare	2.8
Total thickness	8.1

Sallyards limestone member:

24. Limestone, hard, gray, blocky, weathers to irregular chips; pelecypods abundant; some gastropods. Thickness	2.1
Total thickness of exposed Grenola limestone	20.1

Roca shale:

23. Shale, silty, maroon in lower part, gray green in upper part, thin-bedded	10.9
22. Shale, tan, cavernous zone in lower part; covered	11.2
Total thickness	22.1

Red Eagle limestone undifferentiated:

21. Limestone, medium-hard, semicrystalline, gray, weathers blocky, porous; coquina with minute fossil fragments and microfossils(?) very abundant	1.8
20. Shale, calcareous, tan-gray, thin-bedded, upper part silty; calcareous lentils; mostly covered	3.8
19. Limestone, hard, gray, weathers porous to cavernous to many thin beds 1.0 ft thick; lower part weathers to blocks about 5 ft thick; some angular limestone fragments in lower part; blue-gray shale parting in thin pelecypod-bearing limestone; iron stains abundant in some porous zones; fossil fragments are common throughout; stylolites common (13804)	16.7
18. Lower part of Red Eagle limestone, not exposed, but there is soft light-brown limestone that contains celestite(?) and weathers cavernous	3.3
Total thickness	25.6

Johnson shale:

17. Shale, mostly covered	2.2
16. Shale, clayey, calcareous, gray-green, with maroon tint in middle part, blocky; calcareous lentils in lower and upper part	11.2
Total thickness	13.4

293. *Section from Salem Point shale member of Grenola limestone down into the upper limestone of Americus limestone member of Foraker limestone in a streambank in the SW¼SE¼ sec. 12, T. 29 S., R. 8 E., Elk County, Kans.*—Continued

Permian system—Continued
Foraker limestone:
Long Creek limestone member:

	Feet
15. Limestone, clayey, medium-hard, dense, gray, weathers shaly to blocky, algal-like appearance	1.7
14. Shale, clayey, calcareous, gray, blocky	1.4
13. Limestone, soft, tan, massive, thin bedded in upper part with shale zone in middle part	2.8±
Total thickness	5.9±

Hughes Creek shale member:

12. Shale, very calcareous, silty, dark-gray, thin-bedded to massive; brachiopods and fusulinids. Many thin fossiliferous mudstone and limestone lenses in upper part. Includes the lower part of Long Creek limestone, which is covered (13803)	15.6
11. Limestone, medium-hard, tan-gray, massive, weathers in 4 layers in lower part; forms prominent hillside bench about 4 ft thick; iron specks abundant; chert lens in lower and upper parts; gastropods and fusulinids abundant in lower and upper parts; fusulinids weather white (13802)	10.3
10. Shale, tan-gray to blue-gray, thick- and thin-bedded, calcareous; thin limestone lens in middle part; brachiopods abundant; fusulinids common (13801); mostly covered	5.5
9. Limestone, hard, brittle, gray, weathers blocky; three poorly exposed shale partings; subconchoidal fracture	3.9
8. Shale, silty, calcareous, gray, thin-bedded; fusulinids abundant	2.7
7. Limestone, hard, tan-gray, coquina, weathers to large blocks; chert nodules in upper part; fusulinids abundant in chert, and very abundant in the upper surface; fossil fragments very abundant. Forms small hillside bench (13800)	2.0
6. Shale, silty, calcareous, gray, thin-bedded; fusulinids very abundant (13799)	1.6
5. Limestone, hard, tan-brown, weathers blocky; semiconchoidal fracture; fusulinids and gastropods (13798)	1.5
4. Shale, silty, calcareous, tan-gray, thin-bedded to blocky; some calcareous nodules	6.8
Total thickness	49.9

293. *Section from Salem Point shale member of Grenola limestone down into the upper limestone of Americus limestone member of Foraker limestone in a streambank in the SW¼SE¼ sec. 12, T. 29 S., R. 8 E., Elk County, Kans.*—Continued

Permian system—Continued
Foraker limestone—Continued
Americus limestone member: Feet
3. Limestone, hard, dark-gray, weathers blocky to nodular; upper surface irregular; chert nodules (13797) 2.0
2. Shale, covered 1.7
1. Limestone, hard, somewhat dense, dark-gray, weathers to large rectangular blocks; chert nodules in upper part are darker than the matrix, contain fusulinids; chert weathers to protruding lenses or knobs on the surface of limestone (13796) 3.5

Total thickness exposed 7.2

Total thickness of exposed Foraker limestone 63.0

Base covered.

297. *Section from Salem Point shale member of Grenola limestone down to the top of Long Creek limestone member of the Foraker limestone in a road cut in the SE¼SE¼ sec. 16, T. 23 S., R. 10 E., Greenwood County, Kans.*

Permian system:
Grenola limestone:
Salem Point shale member: Thickness exposed 8.0±

Burr limestone member:
14. Limestone, medium-hard, tan, weathers blocky; thin shale parting in lower part; upper bed dense, contains rounded fragments of limestone as much as ½ inch in diameter; limestone above the shale parting contains flattened limestone fragments as much as 1 inch in diameter; pelecypods abundant; many are iron-stained molds and casts. A shale bed (0.7 ft thick) is present 1.0 ft from base (13828). Thickness 4.9

Legion shale member:
13. Shale, silty, calcareous, tan, thin-bedded; many calcareous plates on weathered surface; pelecypods in very uppermost part 7.6
12. Limestone, medium-hard, dark-gray, blocky to shaly; pelecypods abundant (13827) .7
11. Shale, silty, calcareous, tan-gray, thin-bedded, weathers platy 4.6

Total thickness 12.9

297. *Section from Salem Point shale member of Grenola limestone down to the top of Long Creek limestone member of the Foraker limestone in a road cut in the SE¼SE¼ sec. 16, T. 23 S., R. 10 E., Greenwood County, Kans.*—Continued

Permian system—Continued
Grenola limestone—Continued Feet
Sallyards limestone member:
10. Limestone, impure, soft, tan-gray; shale in middle part; pelecypods (13826). Thickness .8

Total thickness of exposed Grenola limestone 26.6±

Roca shale:
9. Shale, mostly covered. Thickness 15.9

Red Eagle limestone:
Howe limestone member:
8. Limestone, hard, tan-gray, weathers blocky; limonite-filled pore spaces; fossil fragments, ostracodes in upper part. Thickness 2.0

Bennett shale member:
7. Shale, silty, calcareous, tan-gray to gray, blocky 5.6
6. Limestone, medium-hard, tan-gray, blocky, weathers shaly .6
5. Shale, silty, calcareous, tan-gray, thin-bedded; crinoid columnals, bryozoans, and brachiopods (13825) 4.5

Total thickness 10.7

Glenrock limestone member:
4. Limestone, medium-hard, tan-gray, semiconchoidal fracture; conglomeratic in lower part; coquina; fossil fragments abundant in upper part, including crinoid columnals (13824). Thickness 6.2

Total thickness of Red Eagle limestone 18.9

Johnson shale:
3. Shale, covered 1.6
2. Limestone, hard, brittle, gray to gray-brown, weathers platy .6
1. Shale, clayey, noncalcareous, gray-green to gray, blocky; mudstone lens in middle part 10.8

Total thickness 13.0

Top of Long Creek limestone member of the Foraker limestone.

Base covered.

298. *Section from Florena shale member of Beattie limestone down to top of Burr limestone member of Grenola limestone in a road cut in the SE¼NE¼NW¼ sec. 15, T. 23 S., R. 9 E., Greenwood County, Kans.*

	Feet
Permian system:	
Beattie limestone:	
Florena shale member:	
14. Shale, silty, calcareous, tan-gray, thin-bedded, becomes blocky in upper part; brachiopods abundant; fusulinids in lower part (13831). Thickness exposed	10.0
Cottonwood limestone member:	
13. Limestone, medium-hard, gray, weathers blocky and to irregular plates; fragments of limestone in limestone matrix in middle part; fossil fragments, including crinoid columnals; fusulinids rare; brachiopod zone about 0.8 ft from base. Thickness	3.7
Total thickness of exposed Beattie limestone	13.7
Eskridge shale:	
12. Shale, clayey, calcareous, gray green in lower part, grades up to tan gray in upper part, blocky; more resistant zone in basal part; iron stains on fracture planes; calcareous plates and lentils in upper two-thirds	6.8
11. Shale, silty, calcareous, tan, thin-bedded to blocky	2.2
10. Shale, clayey, calcareous, maroon, blocky; thin calcareous claystone in lower part	5.5
9. Shale, clayey, calcareous, gray-green, blocky	5.6
Total thickness	20.1
Grenola limestone:	
Neva limestone member:	
8. Limestone, medium-hard, semicrystalline, gray, weathers blocky to platy, porous; iron stains in pores; fossil fragments of echinoid spines and brachiopods	3.0
7. Shale, in upper part, silty, calcareous, tan, thin-bedded; brachiopods (13830); mostly covered	5.7
6. Limestone, medium-hard, tan to gray, weathers tan and blocky; many iron stains in pore spaces; echinoid spines	3.9
5. Shale, silty, calcareous, tan-gray, thin-bedded; brachiopods in lower part	.9
4. Limestone, shaly, tan-gray, weathers blocky; fossil fragments; brachiopods in upper part	.3
3. Shale, silty, calcareous, tan-gray, thin-bedded; fusulinids abundant (13829)	1.0

298. *Section from Florena shale member of Beattie limestone down to top of Burr limestone member of Grenola limestone in a road cut in the SE¼NE¼NW¼ sec. 15, T. 23 S., R. 9 E., Greenwood County, Kans.*—Continued

	Feet
Permian system—Continued	
Grenola limestone—Continued	
Neva limestone member—Continued	
2. Limestone, hard, gray, weathers blocky; crinoid columnals and other fossil fragments	.6
Total thickness	15.4
Salem Point shale member:	
1. Shale, silty, calcareous, tan-gray, thin-bedded; many calcareous plates on surface. Thickness exposed	10.6
Total thickness of exposed Grenola limestone	26.0
Top of Burr limestone member.	
Base covered.	

300. *Section from lower part of Americus limestone member of Foraker limestone down into West Branch shale member of Janesville shale in the NW¼SW¼ sec. 14, T. 18 S., R. 10 E., Lyon County, Kans.*

	Feet
Permian system:	
Foraker limestone:	
Top of middle bed of Americus limestone member of Foraker limestone (13838).	
Americus limestone member:	
13. Covered	6.0
12. Limestone, medium-hard, gray with dark-gray banded stromatolites	.2–.4
Total thickness exposed	6.3±
Total thickness of exposed Foraker limestone	6.3±
Janesville shale:	
Hamlin shale member:	
11. Shale, silty to clayey, gray green in lower two-thirds; thin-bedded to massive; siltstone in upper one-third; conglomeratic in upper part; calcarenite in upper 0.3 ft	9.5
10. Claystone, gray with green tint, blocky to shaly; ostracodes (13837)	.3–.6
9. Shale, clayey, calcareous, purple in lower part, gray green and some maroon in upper part; blocky; siltstone plates in middle part	9.3
8. Sandstone, tan-brown; heavily iron stained	.2
7. Shale, silty, some clay, noncalcareous, gray-green, thin-bedded	2.1
6. Shale, silty, calcareous, maroon, thin-bedded	2.9

300. *Section from lower part of Americus limestone member of Foraker limestone down into West Branch shale member of Janesville shale in the NW¼SW¼ sec. 14, T. 18 S., R. 10 E., Lyon County, Kans.*—Continued

Permian system—Continued
Janesville shale—Continued
Hamlin shale member—Continued — Feet

5. Shale, clayey, noncalcareous, gray-green, with 1.5-ft maroon bed in lower part, silty in upper part; many limonite-stained plates; some calcareous lentils — 13.9
4. Shale, covered — 9.3

Total thickness — 47.5–47.8

Five Point limestone member:

3. Limestone, hard, dark-blue-gray, weathers blocky and to irregular chips. (13836) — 1.8
2. Shale, silty, calcareous, tan-gray, thin-bedded; brachiopods (13835) — 1.2

Total thickness — 3.0

West Branch shale member:

1. Sandstone and sandy shale. Thickness exposed — 6.0

Total thickness of exposed Janesville shale — 56.5–56.8

Base covered.

306. *Section from lower part of Johnson shale down into lower part of Hughes Creek shale member of Foraker limestone in a streambank in the NE¼NW¼ sec. 31, T. 1 S., R. 16 E., Brown County, Kans.*

Permian system:
Johnson shale:

11. Shale, silty to clayey, calcareous, gray to gray-green; many thin calcareous lentils. Thickness exposed — 10.0±

Foraker limestone:
Long Creek limestone member:

10. Limestone, soft, dolomitic, tan, weathers blocky, clayey and shaly in lower part; many minute brown specks; celestite(?)-filled cavities; thin coquina zone about 3 ft below top; pelecypods. Thickness — 11.2

Hughes Creek shale member:

9. Shale, silty, calcareous, dark gray in lower part, light gray in upper part, thin-bedded to blocky (13437) — 7.5
8. Limestone, hard, light-gray, weathers blocky — 1.3
7. Shale, silty, calcareous, gray, thin-bedded with calcareous zones; brachiopods and bryozoans (13436) — 6.7

306. *Section from lower part of Johnson shale down into lower part of Hughes Creek shale member of Foraker limestone in a streambank in the NE¼NW¼ sec. 31, T. 1 S., R. 16 E., Brown County, Kans.*—Continued

Permian system—Continued
Foraker limestone—Continued
Hughes Creek shale member—Continued — Feet

6. Claystone, sandy, micaceous, gray, blocky; shale parting in upper and middle parts; brachiopod zone (13434) 1.6 ft beneath top and at the base of the shaly zone, another brachiopod zone (13435) at very top; pelecypods, and brachiopods common throughout — 3.1
5. Shale, clayey, some silt, calcareous, gray, blocky — 1.6
4. Limestone, shaly, sandy, micaceous, lenticular, gray, weathers shaly; microfossils and pelecypods (13433) — .9
3. Shale, silty, calcareous, gray, thin-bedded — 4.3
2. Limestone, clayey, gray, weathers blocky; small clay balls common; shaly in upper part; some fossils (13432) — .9
1. Shale, silty, calcareous, gray, thin-bedded, with calcareous lentils — 1.0

Total thickness exposed — 27.3

Total thickness of exposed Foraker limestone — 38.5

Base covered.

318. *Section from Hughes Creek shale member of Foraker limestone down into Hawxby shale member of Onaga shale in a road cut in the NE¼NW¼ sec. 18, T. 34 S., R. 8 E., Cowley County, Kans.*

Permian system:
Foraker limestone:
Hughes Creek shale member:

27. Shale, tan-gray — 2.0
26. Limestone, hard to medium-hard, gray, massive, weathers blocky; locally porous; chert lenses 4.5 ft from base, weathers to thin irregular beds; fusulinids abundant in chert; brachiopod, echinoid and crinoid fragments (14801) — 10.8
25. Shale, silty, calcareous, tan to tan-gray; calcareous plates and nodules; fusulinids abundant; some corals and brachiopods — .8
24. Limestone, hard, tan-gray, weathers blocky; porous in upper part; fusulinids abundant, especially in lower half; pelecypods in upper part; echinoid spines; crinoid columnals; *Crurithyris* zone above fusulinids — 1.6
23. Shale, silty, calcareous, tan-gray, thin-bedded to blocky; limestone lenses in lower part; fusulinids abundant; *Neospirifer* and *Linoproductus* zones in lower part (14800) — 3.8

318. *Section from Hughes Creek shale member of Foraker limestone down into Hawxby shale member of Onaga shale in a road cut in the NE¼NW¼ sec. 18, T. 34 S., R. 8 E., Cowley County, Kans.*—Continued

Permian system—Continued

Foraker limestone—Continued

Hughes Creek shale member—Continued

	Feet
22. Limestone, hard, somewhat dense, dark-gray, weathers blocky and to fragments; fossil fragments abundant; pelecypods on upper surface	.6
21. Shale, covered	9.5
Total thickness exposed	29.1

Americus limestone member:

	Feet
20. Limestone, hard, dense, blue-gray, weathers blocky; fusulinids abundant (14799)	1.8
19. Shale, silty, tan, thin-bedded, with limestone plates	.2
18. Limestone, hard, gray-brown, massive, weathers blocky; crinoid columnals abundant; fusulinids abundant in upper half; stromatolites in thin zone about 1.3 ft from top (14798)	2.2
17. Shale, clayey, dark-gray, fissile in upper part; one or more thin lenses of concretionary gray limestone in lower part; fossil fragments; pelecypods in limestone	3.6
16. Limestone, hard, somewhat dense, gray, weathers blocky; fossil fragments and pelecypods	1.1
Total thickness	8.9
Total thickness of exposed Foraker limestone	38.0

Janesville shale:

Hamlin shale member:

	Feet
15. Covered interval	20.8
14. Limestone, tan, thin-bedded, cavernous	.9
13. Shale, clayey, gray, grades to tan in upper part, fissile; silty and micaceous in upper part; iron stains abundant on bedding planes	15.7
12. Shale, calcareous, tan to gray; upper three-fourths cavernous to nodular; lower part covered	5.6
11. Limestone, medium-hard, light-brown to gray-brown; massive in upper and lower parts; shale partings in middle part; very fine laminae on weathered surface of massive limestone; pelecypods in uppermost beds	1.6
10. Shale, covered	6.4
Total thickness	51.0

318. *Section from Hughes Creek shale member of Foraker limestone down into Hawxby shale member of Onaga shale in a road cut in the NE¼NW¼ sec. 18, T. 34 S., R. 8 E., Cowley County, Kans.*—Continued

Permian system—Continued

Janesville shale—Continued

Five Point limestone member:

	Feet
9. Limestone, hard, brown, massive, weathers light brown and blocky; in part fractures conchoidally; some limonite specks; small masses of stromatolites in nests; fusulinids more abundant in upper part; crinoid columnals, corals, echinoid fragments, and brachiopods (14796)	2.6
8. Shale, clayey, gray, thin-bedded; mostly covered	8.6
7. Shale, very calcareous, gray, weathers tan and shaly to platy; grades to limestone in upper part; limestone concretion in lower part; brachiopods; fossil fragments very abundant, including bryozoans; variety of pelecypods (14795)	2.3
Total thickness	13.5

West Branch shale member:

	Feet
6. Shale, silty, light-brown, thin-bedded to fissile	.6
5. Coal, clayey, black, thin-bedded	.6
4. Shale, sandy, micaceous, light-brown, thin-bedded to fissile, becomes clayey in upper part; wood and leaf fragments abundant	12.5
3. Shale, clayey, gray, thin-bedded; mostly covered	11.2
Total thickness	24.9
Total thickness of Janesville shale	89.4

Falls City limestone:

	Feet
2. Limestone, hard, gray, massive, weathers tan and blocky and in small chips; locally fractures conchoidally; some iron stains; upper part iron-stained crust and weathers platy; bryozoans, pelecypods, brachiopods, and minute fossil fragments. Thickness	1.8

Onaga shale:

Hawxby shale member:

	Feet
1. Shale, clayey, gray, thin-bedded to blocky. Thickness exposed	4.5
Total thickness of exposed Onaga shale	4.5

Base covered.

322. *Section from Salem Point shale member of Grenola limestone down to the top of Howe limestone member of Red Eagle limestone in two road cuts in SE¼ sec. 12, T. 34 S., R. 7 E., Cowley County, Kans.*

Permian system:
Grenola limestone:
Base of Neva limestone member.
Salem Point shale member: Feet
13. Shale, mostly covered. Thickness ------ 5.6

Burr limestone member:
12. Limestone, medium-hard, dense in part, tan-gray, weathers to thin beds about 3 or 4 inches thick; pelecypods and fossil fragments ---------- 2.3
11. Shale, silty, gray, thin-bedded to nodular; a thin 0.4-ft bed of limestone is about 2.7 ft from base; limestone is medium hard, gray, weathers blocky; contains stromatolites and fossil fragments. Another thin platy limestone is in middle part, contains pelecypods (14808) ---------- 5.1
10. Limestone, medium-hard, gray, weathers to two beds that weather blocky; thin bedded in lower part, some clay nodules in upper part; stromatolites---- 1.5
9. Shale, very calcareous, and limestone, tan-gray, thin-bedded ---------- 1.7
8. Limestone, hard, semicrystalline, gray, weathers to two beds; fossil fragments, stromatolites in lower part--- 1.4
7. Shale, very calcareous, and limestone, silty, tan-gray, nodular---------- 1.5
6. Limestone, medium-hard, gray, weathers blocky to shaly; very fossiliferous zone of pelecypods and bryozoans in lower part (14807) ---------- 1.5

Total thickness ---------- 15.0

Legion shale member:
5. Shale, silty, tan-gray, thin-bedded. Thickness ---------- 4.2

Sallyards limestone member:
4. Limestone, hard, somewhat dense, gray, massive; zones of clay nodules------ 1.3
3. Limestone, gray, massive, shale partings ---------- .4
2. Limestone, hard, somewhat dense, gray, massive; fossil fragments very abundant; pelecypods ---------- .8

Total thickness ---------- 2.5

Total thickness of exposed Grenola limestone ---------- 27.3

Roca shale:
1. Covered. Thickness ---------- 9.9
Top of Howe limestone member of Red Eagle limestone.
Base covered.

323. *Composite section from Brownville limestone member of Wood Siding formation down into Pillsbury shale in the SW¼NW¼ sec. 9, and center S½ sec. 10, T. 5 S., R. 16 E., Jackson County, Kans.; by R. G. Moss, Kansas Geological Survey, modified slightly by the authors.*

Pennsylvanian system:
Wood Siding formation: Feet
Brownville limestone member:
23. Limestone, impure, brown; brachiopods, bryozoans, and crinoids. Thickness-- 2.0

Plumb and Pony Creek shale members, undifferentiated:
22. Shale, gray ---------- 6.0
21. Limestone, impure, gray-brown, fossiliferous ---------- .3
20. Shale, yellow-gray ---------- 1.0
19. Shale, sandy, micaceous, red---------- 7.0

Total thickness ---------- 14.3

Nebraska City limestone member:
18. Limestone, impure, brown-yellow, massive; lenticular; brachiopods. Thickness ---------- 1.2

Total thickness of Wood Siding formation ---------- 17.5

Root shale:
French Creek shale member:
17. Shale, gray; brachiopods and other fossils ---------- 1.0
16. Coaly zone ---------- .2
15. Shale, gray ---------- 3.7
14. Coal ---------- .2
13. Shale, sandy, gray to brown-yellow---- 15.4

Total thickness ---------- 20.5

Jim Creek limestone member:
12. Limestone, granular, impure, gray; brachiopods. Thickness ---------- .5
Friedrich shale member:
11. Shale and sandstone, top 3.0 ft is gray shale ---------- 5.2
10. Sandstone, calcareous ---------- 1.0
9. Sandstone, soft, gray---------- 3.0
8. Sandstone, hard, tan-brown---------- 2.0
7. Sandstone, gray, crossbedded---------- 5.0
6. Sandstone, soft, gray---------- 5.0
5. Shale, sandy, gray to yellow-brown, platy ---------- 20.8

Total thickness ---------- 42.0

Total thickness of Root shale-- 63.0

323. *Composite section from Brownville limestone member of Wood Siding formation down into Pillsbury shale in the SW¼NW¼ sec. 9, and center S½ sec. 10, T. 5 S., R. 16 E., Jackson County, Kans.; by R. G. Moss, Kansas Geological Survey, modified slightly by the authors*—Continued

Pennsylvanian system—Continued — Feet

Stotler limestone:

Grandhaven(?) limestone member:

4. Limestone, gray, weathers tan and to irregular plates; upper 0.6 ft slabby fossiliferous limestone; many crinoid fragments in basal 0.9 ft; fossil fragments very abundant, including crinoids, brachiopods, small fusulinids, and stromatolites(?) (14913). Thickness — 1.5

Dry(?) shale member:

3. Shale, gray, nodular. Thickness — 2.0

Dover limestone member:

2. Limestone, impure, brown to gray, mottled with gray green; some clay inclusions; weathers nodular and granular; brachiopod fragments; lower 1.0 ft is brown, contains fusulinids and large white crinoid columnals; fusulinids common; upper 2.0 ft is stromatolite limestone. Thickness — 3.0

Total thickness of Stotler limestone — 6.5

Pillsbury shale:

1. Shale, sandy, gray; brown sandstone streaks. Thickness exposed — 6.0±

Base covered.

324. *Section from Aspinwall limestone member of Onaga shale down in to Dover limestone member of the Stotler limestone in a streambank in the NE¼SE¼ sec. 16, T. 33 S., R. 8 E., Cowley County, Kans.*

Permian system:

Onaga shale:

Aspinwall limestone member:

13. Limestone, medium-hard, light-brown, weathers blocky and to two distinct beds; minute limonite specks and nodules; some clay balls; pelecypods. Thickness exposed — 1.2

Towle shale member:

12. Shale, partly covered; a 0.5± ft thick hard conglomeratic limestone lens about 4.0 ft below base of Aspinwall limestone; angular fragments of limestone as much as 1 inch in diameter. Thickness — 24.9

Total thickness of exposed Onaga shale — 26.1

324. *Section from Aspinwall limestone member of Onaga shale down in to Dover limestone member of the Stotler limestone in a streambank in the NE¼SE¼ sec. 16, T. 33 S., R. 8 E., Cowley County, Kans.*—Continued

Pennsylvanian system:

Wood Siding formation:

Brownville limestone member: — Feet

11. Limestone, medium-hard, tan, weathers blocky; upper part iron stained and weathers porous; minute fossil fragments are abundant; microfossils(?), bryozoans, crinoid columnals, fusulinids. Thickness — 1.3

Pony Creek shale member:

10. Shale and sandy shale, slightly micaceous, tan-gray, thin-bedded; limonite concretions and stained plates; wood fragments — 22.1

9. Shale; covered (contains lower part of Pony Creek shale member and possibly the Grayhorse limestone and Plumb shale members) — 22.6

Total thickness of interval from base of Brownville limestone member to top of Nebraska City limestone member — 44.7

Nebraska City limestone member:

8. Limestone, hard, light-brown, with minute specks; weathers blocky; has iron-stained zone on top; fragments of brachiopods, bryozoans; crinoids are very abundant; some bone fragments. Thickness — 1.6

Total thickness of Wood Siding formation — 47.6

Root shale:

French Creek shale member:

7. Shale, silty, tan, thin-bedded, sandy in upper part, slightly sandy in lower part. Thickness — 33.9

Jim Creek limestone member:

6. Limestone, hard, brown to gray, massive, weathers tan and blocky; iron-stained weathered crust in upper part; brachiopods, stromatolites, fusulinids, corals, and other fossil fragments. Thickness — 1.2

Friedrich shale member:

5. Shale, dark-gray, thin-bedded, sandy in upper part, clayey in lower part; tan beds of sandy shale and sandstone in upper part — 47.2

324. *Section from Aspinwall limestone member of Onaga shale down in to Dover limestone member of the Stotler limestone in a streambank in the NE¼SE¼ sec. 16, T. 33 S., R. 8 E., Cowley County, Kans.*—Continued

Pennsylvanian system—Continued
Root shale formation—Continued
Friedrich shale member—Continued — Feet

4. Shale, very calcareous, dark-gray, weathers platy; brachiopods, fish spines, crinoid columnals, and trilobites (14810) — 4.1

Total thickness — 51.3

Total thickness of Root shale — 86.4

Stotler limestone:
Grandhaven limestone member:

3. Limestone, soft to medium-hard, gray, weathers shaly; brachiopods, fish spines, and crinoid columnals (14810). Thickness — .7±

Dry shale member:

2. Shale, clayey, dark-gray, thin-bedded, silty in upper part. Thickness — 6.2

Dover limestone member:

1. Limestone, hard, fine-grained, gray, weathers light brown, blocky; iron stains; stromatolites that weather lighter than matrix are abundant in upper surface, *Aviculopinna* 14 inches or more long, corals (14811). Thickness exposed — 1.4

Total thickness of exposed Stotler limestone — 8.3±

Base covered.

325. *Section from Jim Creek limestone member of Root shale down into Pillsbury shale in a stream bank in the NW¼NW¼ sec. 6, T. 9 S., R. 10 E., Pottawatomie County, Kans. Measured by G. R. Scott, U.S. Geological Survey, modified by the authors.*

Pennsylvanian system:
Root shale:
Jim Creek limestone member:

10. Limestone, tan, mottled with light green, weathers tan gray, massive, nodular; fossiliferous. Thickness — 2.3

Friedrich shale member:

9. Shale, clayey, variegated olive drab and maroon — 14.6
8. Shale, silty, black, weathers dark gray — .8

Total thickness — 15.4

Total thickness of exposed Root shale — 17.7

325. *Section from Jim Creek limestone member of Root shale down into Pillsbury shale in a streambank in the NW¼NW¼ sec. 6, T. 9 S., R. 10 E., Pottawatomie County, Kans. Measured by G. R. Scott, U.S. Geological Survey, modified by the authors*—Continued

Pennsylvanian system—Continued
Stotler limestone: — Feet
Grandhaven limestone member:

7. Limestone, dark-gray, massive, weathers tan and shaly; fossil fragments, very abundant, including crinoid columnals, *Chonetes*, *Derbyia*, small fusulinids, and *Osagia*(?) (14899) — .7
6. Shale, silty, calcareous, dark-gray, weathers tan gray; fusulinids (14899) — .9
5. Limestone, gray-orange, massive, weathers tan gray and blocky; conglomeratic with rounded nodules and fragments of dark-green limestone; brachiopods, pelecypods, crinoid columnals. Stromatolites abundant in upper part; shells are orange (14899) — 1.0

Total thickness — 2.6

Dry shale member:

4. Shale, silty, gray, thin-bedded; grades eastward into conglomerate with limonite nodules, nodular clay balls, and shale, as much as one-half inch in diameter; most are one-eighth inch in diameter (14898) — .5
3. Shale, silty, calcareous, light green mottled with tan gray; nodular; fossil fragments, including crinoid columnals, and bryozoans; brachiopods (14897) — 1.3

Total thickness — 1.8

Dover limestone member:

2. Limestone, dense, light-gray, weathers tan gray, massive, nodular, fossiliferous; large fusulinids in lower 2.5 ft; stromatolites in upper part; brachiopods. Thickness — 3.5

Total thickness of Stotler limestone — 7.9

Pillsbury shale:

1. Claystone, olive-drab, weathers light gray, blocky. Thickness exposed — 2.8

Base covered.

327. *Section from Hughes Creek shale member of Foraker limestone down into Hamlin shale member of Janesville shale along Highway 160 in a road cut in the NE¼ sec. 13, T. 31 S., R. 8 E., Elk County, Kans.*

Permian system:
Foraker limestone:
Hughes Creek shale member:

26. Limestone, hard, tan to tan-gray, weathers blocky, porous; forms hillside bench; fusulinids very abundant, stromatolites in middle part; brachiopods — 3.0

327. *Section from Hughes Creek shale member of Foraker limestone down into Hamlin shale member of Janesville shale along Highway 160 in a road cut in the NE¼ sec. 13, T. 31 S., R. 8 E., Elk County, Kans.*—Continued

Permian system—Continued
Foraker limestone—Continued
Hughes Creek shale member—Continued | Feet

25. Shale, clayey, tan-gray, thin-bedded; fusulinids very abundant in upper part; brachiopods ---------- 3.0
24. Limestone, hard, dense, fine-grained, light-gray, weathers blocky; conchoidal fracture; some fossils---------- 1.5
23. Limestone, medium-hard, tan, thin-bedded; coquina in lower part; fragments of crinoids, bryozoans, brachiopods, and echinoids---------- 2.1
22. Shale, silty, calcareous, tan, thin-bedded .7
21. Limestone, medium-hard, gray, blocky; crinoid columnals and plates, bryozoans, brachiopods, and pelecypods-- .1
20. Shale, silty, calcareous, tan, thin-bedded; brachiopods, bryozoans, fusulinids, and crinoid columnals and plates (14823) ---------- 4.5
19. Limestone, hard, light-gray, weathers blocky; many dark-gray chert nodules and lentils; chert lenses locally 0.6 ft thick; abundant fusulinids that weather white ---------- 2.4
18. Limestone, hard, gray-brown, weathers tan and blocky with rounded corners, weathers porous in hard dense upper part; chert nodules in upper part; abundant crinoid fragments protrude on weathered surface; fusulinids very abundant in lower part and common to abundant in upper part---------- 2.2
17. Shale, calcareous, silty, tan; fusulinids abundant ---------- 1.0
16. Limestone, medium-hard, tan, weathers blocky; iron stains on weathered surface give yellow appearance; some chert nodules; composed mostly of fusulinids ---------- 1.6
15. Shale, silty, calcareous, tan-gray, thin-bedded to fissile; 1.2 ft above base is thin bed of limestone that contains brachiopods; shale, in lower 1.2 ft, slightly micaceous, wood fragments, and carbon stains; fusulinids abundant in upper part (14822)---------- 2.8
14. Limestone, hard, sugary texture, light-gray; weathers blocky, thin-bedded appearance in upper part; brachiopods in upper part---------- .6
13. Shale, silty, calcareous, tan, thin-bedded ---------- .5
12. Limestone, hard, dark-gray, weathers tan and blocky; crinoid fragments,

327. *Section from Hughes Creek shale member of Foraker limestone down into Hamlin shale member of Janesville shale along Highway 160 in a road cut in the NE¼ sec. 13, T. 31 S., R. 8 E., Elk County, Kans.*—Continued

Permian system—Continued
Foraker limestone—Continued
Hughes Creek shale member—Continued | Feet

fusulinids, brachiopods, stromatolites, bryozoans, and pelecypods---------- .6
11. Shale, silty, very calcareous, tan, thin-bedded; grades up into limestone; fusulinids, worm burrows(?), brachiopods, and crinoid columnals---------- .4
10. Limestone, hard, granular, gray, weathers blocky in lower part; grades up into shale; worm burrows(?) bryozoans, crinoid columnals, and other fossil fragments ---------- .7
9. Shale, silty, dark-gray, fissile; many thin limestone lentils; brachiopods, bryozoans, fusulinids and worm burrows(?) at upper surface; *Neospirifer* zone about 0.4 ft from top (14821)-- 5.8

Total thickness ---------- 33.5

Americus limestone member:

8. Limestone, hard, gray, weathers tan and blocky; semiconchoidal fracture; crinoid fragments and fusulinids abundant, stromatolites in upper part---- 2.7
7. Limestone, hard, gray, weathers tan and blocky; porous in middle part; some hard dense zones; fossil fragments abundant, including crinoid columnals; fusulinids ---------- 1.1
6. Sandstone, fine-grained, tan, weathers platy; minute fossils and ostracodes(?) ---------- .7
5. Shale, carbonaceous, clayey, dark-gray to black, fissile; silty to sandy in upper part; a thin impure 0.2 ft limestone layer is 1.2 ft from base---------- 5.3
4. Limestone, medium-hard, gray, weathers shaly; shale partings; brachiopods and pelecypods ---------- 1.1
3. Limestone, hard, gray, weathers blocky; conglomeratic, with small rounded to angular fragments of limestone that are not over one-eighth inch in diameter; stromatolites abundant in upper part, upper 0.3 ft contains fragments of gastropods and pelecypods (14820)- 1.3

Total thickness ---------- 12.2

Total thickness of exposed Foraker limestone ---------- 45.7

327. *Section from Hughes Creek shale member of Foraker limestone down into Hamlin shale member of Janesville shale along Highway 160 in a road cut in the NE¼ sec. 13, T. 31 S., R. 8 E., Elk County, Kans.*—Continued

Permian system—Continued
Janesville shale:
Hamlin shale member: Feet

2. Sandstone (calcarenite), calcareous, tan, thin-bedded; fragments of ostracodes .6
1. Shale, very calcareous boxworklike structure 5.0±

Total thickness exposed 5.6±

Total thickness of exposed Janesville shale 5.6±

Base covered.

328. *Section from the lower part of Americus limestone member of Foraker limestone down into French Creek shale member of Root shale in a road cut along the south side of the NW¼NW¼ sec. 10, T. 30 S., R. 9 E., Elk County, Kans.*

Permian system:
Foraker limestone:
Americus limestone member:

30. Limestone, hard, gray, small dense areas; conglomeratic with zones of minute fragments of clay and limestone nodules; weathers blocky; pelecypods and fossil fragments abundant; lowermost part sandy, possibly ostracodes 2.0
29. Shale, clayey, tan-gray to olive-drab, thin-bedded; cavernous tan zone in upper part 5.7
28. Limestone, dense, hard, dark-gray, weathers platy; carbon stains; minute fossil fragments .2

Total thickness exposed 7.9

Total thickness of exposed Foraker limestone 7.9

Janesville shale:
Hamlin shale member:

27. Siltstone, sugary texture, tan, thin-bedded; forms small ledge beneath limestone .5
26. Shale, silty, tan, thin-bedded in lower part; many small silty plates; grades up into a 0.8 ft massive siltstone bed; thin veinlets of secondary calcium carbonate in upper part 12.8
25. Shale, dark-gray, weathers gray green with purple tint in upper part, blocky to thin-bedded; many platy brown sandstone lenses in lower 8 ft; mostly covered 25.1

Total thickness 38.4

328. *Section from the lower part of Americus limestone member of Foraker limestone down into French Creek shale member of Root shale in a road cut along the south side of the NW¼NW¼ sec. 10, T. 30 S., R. 9 E., Elk County, Kans.*—Continued

Permian system—Continued
Janesville shale—Continued Feet
Five Point limestone member:

24. Limestone, hard, dark-gray, weathers brown and blocky; bryozoans, crinoid columnals, brachiopods, and fusulinids abundant in lower part; fossils protrude on weathered surface (14827) 2.5
23. Shale, silty, gray, thin-bedded 4.0
22. Limestone, medium-hard, crystalline, gray, platy; shale partings .6

Total thickness 7.1

West Branch shale member:

21. Shale, silty to sandy, gray, thin-bedded; coal lentils in middle part 19.9
20. Limestone, soft, tan, blocky, weathers porous and with a cellular structure; thin shale lentils; iron stains 2.4
19. Shale, silty to slightly sandy, micaceous, gray-brown, thin-bedded 12.5

Total thickness 34.8

Total thickness of Janesville shale 80.3

Falls City limestone:

18. Limestone, hard, fine-grained, sugary texture, gray-brown, massive, weathers blocky; iron-stained zones; crinoid columnals and other fossil fragments 1.4
17. Shale, silty to sandy, slightly micaceous, light-brown, thin-bedded 3.7
16. Limestone, medium-hard, gray-brown, weathers blocky and nodular; iron stains; porous; brachiopods, pelecypods, and crinoid columnals .7

Total thickness 5.8

Onaga shale:
Hawxby shale member:

15. Shale, clayey, purple in middle part, gray green in upper and lower parts 5.0
14. Limestone, hard, fine-grained, brown; many iron specks .3
13. Shale, silty, calcareous, tan, thin-bedded .8
12. Limestone, hard, gray-brown, blocky; crinoid columnals that weather white; bryozoans and other fossil fragments abundant .2

328. *Section from the lower part of Americus limestone member of Foraker limestone down into French Creek shale member of Root shale in a road cut along the south side of the NW¼NW¼ sec. 10, T. 30 S., R. 9 E., Elk County, Kans.*—Continued

Permian system—Continued
Onaga shale—Continued
Hawxby shale member—Continued — Feet

11. Shale, silty, very calcareous, tan-gray; sandstone nodules abundant — 3.6

Total thickness — 9.9

Aspinwall limestone member:

10. Limestone, medium-hard, crystalline, light-brown, weathers to irregular plates; limonite stains and some specks; upper part contains many limonite specks; pelecypods and fossil fragments — .5
9. Shale, silty, tan-gray, thin-bedded; 4 thin limestone lentils in lower 2.5 ft; hard, dense, clayey, gray — 3.8
8. Limestone, medium-hard, tan-gray, weathers blocky and to irregular plates; bryozoans very abundant, pelecypods and brachiopods common (14826) — .5

Total thickness — 4.8

Towle shale member:

7. Shale, clayey to silty, gray, thin-bedded to blocky. Thickness — 11.2

Total thickness of Onaga shale — 25.9

Pennsylvanian system:
Wood Siding formation:
Brownville limestone member:

6. Limestone, hard, dense, fine-grained, dark-brown, massive, weathers blocky; weathers nodular in upper part; crinoid columnals very abundant, some as much as one-half inch in diameter; brachiopods, fusulinids, and bryozoans (14825). Thickness — 1.7

Plumb and Pony Creek shale members, undifferentiated:

5. Shale, clayey, gray, with green tint, gray green in upper part; thin-bedded to blocky; nodular in uppermost part. Thickness — 16.6

Nebraska City limestone member:

4. Limestone, medium-hard, fine-grained, sugary texture, gray, weathers light brown, massive in lower part, platy in middle and upper parts, crossbedded; has appearance of sandstone; fine laminae on weathered surface; fossil fragments abundant in upper part; pelecypods and brachiopods. Thickness — 2.5

328. *Section from the lower part of Americus limestone member of Foraker limestone down into French Creek shale member of Root shale in a road cut along the south side of the NW¼NW¼ sec. 10, T. 30 S., R. 9 E., Elk County, Kans.*—Continued

Pennsylvanian system—Continued
Wood Siding formation—Continued
Nebraska City limestone member—Continued — Feet

Total thickness of Wood Siding formation — 20.8

Root shale:
French Creek shale member:

3. Shale, silty, calcareous, light-brown, thin-bedded; pelecypods (14824) — .7
2. Shale and sandstone, mostly covered, especially in middle part; sandstone, fine-grained, loosely cemented, micaceous, light-brown; shale, clayey to silty, tan-gray, near the top of unit — 36.1
1. Shale, silty, somewhat sandy, micaceous, gray-brown, weathers tan, blocky; some sandstone plates on surface; clayey and darker gray in lower parts; some wood fragments — 16.9

Total thickness exposed — 53.7

Total thickness of exposed Root shale — 53.7

Base covered.

329. *Section from Morrill limestone member of Beattie limestone down into Burr limestone member of Grenola limestone along Highway 96 in the NW¼SW¼ sec. 35, T. 27 S., R. 8 E., Greenwood County, Kans.*

Permian system:
Beattie limestone:
Morrill limestone member:

35. Limestone, medium-hard, tan, many thin beds with nodules of chert, weathers blocky; echinoid spines and brachiopods; some fusulinids in lower part. Thickness — 5.7

Florena shale member:

34. Shale, clayey, gray to tan, thin-bedded; fusulinids abundant in the lowermost part; brachiopods and crinoid fragments common (14831). Thickness — 6.7

Cottonwood limestone member:

33. Limestone, medium-hard, tan to tan-gray; many dense zones in middle part; fusulinids common in upper part; dense zone may have stromatolites in weathered surface; has many

329. *Section from Morrill limestone member of Beattie limestone down into Burr limestone member of Grenola limestone along Highway 96 in the NW¼SW¼ sec. 35, T. 27 S., R. 8 E., Greenwood County, Kans.*—Continued

Permian system—Continued

Beattie limestone—Continued

Cottonwood limestone member—Continued — Feet

thin wavy bands; fossil fragments in upper and lower beds which weather blocky; upper bed forms hillside bench with blocks about 1 foot in diameter; middle part weathers shaly and porous; lower bed is locally very dense and porous. Thickness ______ 5.1

Total thickness of Beattie limestone ______ 17.5

Eskridge shale:

32. Shale, silty, some clay, tan, weathers light tan, thin-bedded and blocky; varied fauna in upper 2± ft (14830) ______ 8.8
31. Limestone, hard, somewhat crystalline, gray, weathers tan and blocky; thin shale partings in upper part; upper part weathers to irregular chips; clay nodules; pelecypods abundant in upper part; gastropods, ostracodes, and fossil fragments in lower part ______ .5
30. Shale, silty, tan, blocky ______ 1.4
29. Shale, silty, maroon, weathers violet, blocky ______ 1.9
28. Shale, silty, tan, blocky ______ .3
27. Shale, silty, maroon, thin-bedded ______ 5.0
26. Shale, clayey, tan-gray, thin-bedded ______ 1.6
25. Limestone, medium-hard, gray, with light greenish tint, weathers blocky with thin plates on upper surface; fossil fragments very abundant; coquina, gastropods, and ostracodes ______ .4
24. Shale, clayey, tan, thin-bedded ______ 3.5
23. Limestone, hard, crystalline, gray, weathers blocky; pelecypod fragments, small gastropods, and other minute fossils (14829) ______ .2
22. Shale, clayey, gray-green, blocky ______ 3.8
21. Limestone, soft, tan-gray, weathers blocky; minute fossils ______ .3
20. Shale, clayey, green, blocky ______ 1.7

Total thickness ______ 29.4

Grenola limestone:

Neva limestone member:

19. Limestone, hard, tan in lower part, grading up into gray; massive; weathers blocky; conchoidal fracture; upper few inches very dense and hard; limonite nodules; brachiopod fragments; ostracodes in upper part;

329. *Section from Morrill limestone member of Beattie limestone down into Burr limestone member of Grenola limestone along Highway 96 in the NW¼SW¼ sec. 35, T. 27 S., R. 8 E., Greenwood County, Kans.*—Continued

Permian system—Continued

Grenola limestone—Continued

Neva limestone member—Continued — Feet

echinoid spines; microfossils on top surface impart a sugary texture; pelecypods. Forms hillside bench with a line of small square blocks about 1.0 to 1.5 ft in diameter that weather porous ______ 2.5

18. Limestone, hard, fine-grained, light-brown, massive, weathers tan, mottled with gray and blocky; brachiopods, minute fossil fragments including echinoids ______ 1.8
17. Shale lens, clayey, tan ______ 0–.2
16. Limestone, medium-hard, locally dense, gray, mottled with tan, massive, weathers to irregular fragments; echinoid spines, crinoid columnals, and brachiopods ______ 2.0
15. Shale, silty, dark-gray, thin-bedded, crinoid columnals ______ 2.2
14. Limestone, shaly, gray, weathers light gray and shaly; fusulinids ______ .6
13. Shale, very calcareous, silty, dark-gray, thin-bedded; grades up into the overlying limestone; fusulinids ______ 1.2
12. Shale, silty, tan, thin-bedded ______ .7
11. Limestone, tan, weathers tan gray and platy; thin shale partings at base; fusulinids, brachiopod fragments, and echinoid spines ______ 1.9
10. Limestone, medium-hard, tan-gray, weathers blocky; fractures to irregular plates in upper part ______ 1.1
9. Shale, silty, tan, thin-bedded, fusulinids and echinoid spines ______ .3
8. Limestone, medium-hard, tan-gray, weathers tan and blocky; fusulinids, crinoid columnals, and brachiopods ______ .9
7. Shale, silty, tan-gray; fusulinids abundant ______ .6
6. Limestone, nodular, medium-hard, tan to gray; fossil fragments ______ 2.2

Total thickness ______ 18.2

Salem Point shale member:

5. Shale, covered ______ 1.8
4. Limestone, boxwork, medium-hard, tan, very porous, weathers with rounded corners ______ 1.1
3. Shale, covered ______ 2.1

Total thickness ______ 5.0

329. *Section from Morrill limestone member of Beattie limestone down into Burr limestone member of Grenola limestone along Highway 96 in the NW¼SW¼ sec. 35, T. 27 S., R. 8 E., Greenwood County, Kans.*—Continued

Permian system—Continued
Grenola limestone—Continued
Burr limestone member: Feet

2. Limestone, hard, gray, weathers blocky and to a thin 0.2-ft plate; fractures semiconchoidally; thin lentils of clay common; coquina with bryozoans, crinoid columnals and other fossil fragments very abundant; pelecypods (14828) ---- 3.4
1. Shale, clayey to silty, gray to olive-drab, weathers tan and blocky ---- 6.5

Total thickness exposed ---- 9.9

Total thickness of exposed Grenola limestone ---- 33.1

Base covered.

330. *Section from Glenrock limestone member of Red Eagle limestone down into Hamlin shale member of Janesville shale along Highway 96 in the SW¼ sec. 31, T. 27 S., R. 9 E., Greenwood County, Kans.*

Permian system:
Red Eagle limestone:
Glenrock limestone member:

33. Limestone, medium-hard, light-tan-gray, blocky, porous; fusulinids and crinoid columnals ---- 1.0
32. Limestone, medium-hard, light-gray, weathers blocky, porous; fusulinids very abundant; crinoid columnals and brachiopods common ---- 1.3

Total thickness ---- 2.3

Total thickness of exposed Red Eagle limestone ---- 2.3

Johnson shale:

31. Shale, very calcareous, tan-gray thin-bedded; limestone nodules ---- .4
30. Limestone, medium-hard, tan, weathers blocky ---- .2
29. Shale, silty, very calcareous, tan ---- .1
28. Limestone, medium-hard, tan, with minute black specks, weathers tan and blocky ---- .4
27. Shale, clayey, gray-green to green, with purple in lower 5 ft, thin-bedded ---- 11.3

Total thickness ---- 12.4

330. *Section from Glenrock limestone member of Red Eagle limestone down into Hamlin shale member of Janesville shale along Highway 96 in the SW¼ sec. 31, T. 27 S., R. 9 E., Greenwood County, Kans.*—Continued

Permian system—Continued
Foraker limestone:
Long Creek (?) limestone member: Feet

26. Limestone, hard, gray, massive in upper part, very thin-bedded in lower part, dense in upper part, wavy bedding in the lower part ---- 1.1
25. Shale, clayey, olive-drab, thin-bedded ---- 7.5
24. Limestone, fine-grained, tan, massive, distorted bedding, wavy and folded, porous especially in upper part ---- 1.8

Total thickness ---- 10.4

Hughes Creek shale member:

23. Shale, clayey, some silt, calcareous, gray, thin-bedded ---- 1.4
22. Limestone, medium-hard, tan-gray, weathers tan and blocky; fossil fragments very abundant; fusulinids, bryozoans, and stromatolites ---- 1.2
21. Shale, silty, calcareous, tan-gray, thin-bedded; thin dark-gray fissile pelecypod-bearing limestone beds in lower part; brachiopods and fusulinids (14834) ---- 4.5
20. Limestone, medium-hard, locally dense, light-gray, weathers blocky, porous; some chert nodules; thin irregular chert lenses near top, many beds of limestone with thin shale partings in lower part; fusulinids abundant throughout, echinoids. Forms a prominent hillside bench with bush line ---- 13.0
19. Shale, silty, calcareous, tan, thin-bedded; 1-ft thick dense pelecypod-bearing limestone 1.7 ft from top; weathers thin bedded gray and tan; varied fauna, with fusulinids (14833) ---- 7.2
18. Limestone, hard, gray, massive, weathers blocky; fossil fragments, including crinoid columnals ---- 1.1
17. Shale, silty, tan, thin-bedded; varied fauna, with fusulinids abundant (14832) ---- 4.8
16. Limestone, hard, gray, massive, weathers tan and blocky; chert lens 0.4 to 0.5 ft thick in middle part; crinoid columnals especially abundant in lower part; fusulinids abundant in upper part ---- 2.1
15. Shale, clayey, calcareous, tan, thin-bedded; fusulinids very abundant ---- 1.3

330. *Section from Glenrock limestone member of Red Eagle limestone down into Hamlin shale member of Janesville shale along Highway 96 in the SW¼ sec. 31, T. 27 S., R. 9 E., Greenwood County, Kans.*—Continued

Permian system—Continued
Foraker limestone—Continued

Hughes Creek shale member—Continued	Feet
14. Limestone, silty, hard, fine-grained, light-brown, weathers blocky; fossil fragments including bryozoans, brachiopods	.4
13. Limestone, hard, gray, massive, weathers blocky; chert nodules in a line about 6 inches from top and also on top; fusulinids abundant	2.1
12. Shale, clayey, dark-gray, weathers tan, fissile; fusulinids very abundant in upper part; brachiopods common	5.1
Total thickness	44.2
Americus limestone member:	
11. Limestone, hard, gray, massive, weathers blocky; thick 0.5-ft lens in middle part; fusulinids very abundant; brachiopods, bryozoans, and crinoid fragments common	1.8
10. Shale, silty, tan, thin-bedded; fusulinids very abundant	.4
9. Limestone, hard, semicrystalline, gray, massive, weathers blocky; line of chert nodules about 6 inches from top; crinoid columnals and brachiopods; fusulinids in upper part	2.1
8. Shale, silty, tan, fissile	1.8
7. Shale, clayey, dark-gray, fissile	3.1
6. Limestone, hard, slightly crystalline, gray, massive, weathers blocky; gastropods, crinoid columnals, bryozoans, brachiopods; bands of stromatolites overlie an ostracode zone; space between the colonies of stromatolites filled with detrital material	1.7
Total thickness	10.9
Total thickness of Foraker limestone	65.5

Janesville shale:

Hamlin shale member:	Feet
5. Shale, silty, tan, thin-bedded to fissile; local channel fillings of blocky siltstone	1.4
4. Shale, silty, carbonaceous, dark-gray, blocky	.7
3. Shale, very silty, tan, thin-bedded; nodular in upper part	1.8
2. Shale, clayey, olive-drab to gray, thin-bedded	3.2
1. Limestone, fine-grained, tan; many thin beds; iron stained	.8
Total thickness exposed	7.9
Total thickness of exposed Janesville shale	7.9

Base covered.

331. *Section from Sallyards limestone member of Grenola limestone down into Glenrock limestone member of Red Eagle limestone in a streambank in the NE¼ sec. 2, T. 28 S., R. 8 E., Greenwood County, Kans.*

Permian system:
Grenola limestone:

Sallyards limestone member:	Feet
9. Limestone, medium-hard, locally dense, tan, weathers blocky; silty shale lens near base	1.5
8. Limestone, hard, locally dense, weathers blocky; pelecypods and bryozoans abundant; stromatolites in upper part (14836)	.6
Total thickness	2.1
Total thickness of exposed Grenola limestone	2.1
Roca shale:	
7. Shale, silty, green, mottled with maroon, blocky and thin-bedded	6.8
6. Shale, silty, maroon, mottled with green, blocky	4.2
Total thickness	11.0
Red Eagle limestone:	
Howe limestone member:	
5. Limestone, hard, dense, tan, mottled with light gray, weathers gray; weathers to thin plates 0.2 ft thick; porous. Thickness	2.0±
Bennett shale member:	
4. Shale, clayey, dark-gray, thin-bedded	2.1
3. Limestone, clayey, medium-hard, gray, nodular; many fossils on upper surface; crinoid columnals throughout (14835)	1.0

331. *Section from Sallyards limestone member of Grenola limestone down into Glenrock limestone member of Red Eagle limestone in a streambank in the NE¼, sec. 2, T. 28 S., R. 8 E., Greenwood County, Kans.*—Continued

Permian system—Continued
Red Eagle limestone—Continued
Bennett shale member—Continued

	Feet
2. Shale, silty, tan in upper part, dark gray in lower part, blocky; varied fauna (14835)	8.1
Total thickness	11.2

Glenrock limestone member:

1. Limestone, medium-hard, tan to light-gray, weathers light gray, massive and blocky; chert nodules in upper half; fusulinids and crinoid columnals. Thickness	3.1
Total thickness of Red Eagle limestone	16.3±

Base covered.

335. *Section from Dover limestone member of Stotler limestone down into Wamego shale member of Zeandale limestone in a streambank and a road ditch in the NE¼SE¼ sec. 12, T. 28 S., R. 9 E., Greenwood County, Kans.*

Pennsylvanian system:
Stotler limestone:
Dover limestone member:

8. Limestone, hard, brown, mottled with tan, massive, weathers blocky; lower bed more massive; crinoid columnals, brachiopods, corals, and bryozoans. Thickness exposed	2.6
Total thickness of exposed Stotler limestone	2.6

Pillsbury shale:

7. Shale, clayey, gray, thin-bedded; bryozoans and brachiopods in upper part (14843). Thickness	8.7

Zeandale limestone:
Maple Hill limestone member:

6. Limestone, hard, slightly crystalline, gray, massive, weathers to irregular plates and blocks; fossil fragments, including crinoid columnals, stromatolites(?), and bryozoans; gastropods. Thickness	1.2

Wamego shale member:

5. Shale, upper part clayey, gray, weathers tan, thin-bedded; mostly covered	7.9
4. Limestone, medium-hard, tan, massive, weathers to irregular plates and blocks; gastropods, crinoid columnals, and brachiopods (14841)	.9

335. *Section from Dover limestone member of Stotler limestone down into Wamego shale member of Zeandale limestone in a streambank and a road ditch in the NE¼SE¼ sec. 12, T. 28 S., R. 9 E., Greenwood County, Kans.*—Continued

Pennsylvanian system—Continued
Zeandale limestone—Continued
Wamego shale member—Continued

	Feet
3. Shale, silty, calcareous, dark-gray, thin-bedded; upper 2.6 ft light-gray; contains brachiopods (14842)	6.8
2. Limestone, hard, dark-gray, massive, weathers platy and thin bedded; carbon stains; ostracodes very abundant in upper part	.8
1. Coal, black, blocky to thin-bedded	.4–.6
Total thickness exposed	16.9±
Total thickness of exposed Zeandale limestone	18.1±

Base covered.

338. *Section from West Branch shale member of Janesville shale down into Friedrich shale member of Root shale along the west side of SE¼SE¼ sec. 21, and in the NW¼NW¼ sec. 27, T. 26 S., R. 9 E., Greenwood County, Kans.*

Permian system:
Janesville shale:
West Branch shale member:

27. Shale, clayey in lower part, grades up into silt, gray-green, thin-bedded; thin crystalline impure limestone in upper part. Thickness exposed	7.5
Total thickness of exposed Janesville shale	7.5

Falls City limestone:

26. Limestone, hard, gray-green; very fossiliferous, with pelecypods (14848)	.2–.3
25. Shale, covered	3.1
24. Limestone, medium-hard, gray, mottled with tan, massive, weathers blocky; shale partings in upper part; some iron stains; pelecypods, gastropods, crinoid columnals, and bryozoans in upper part	2.1
23. Shale, clayey, tan-gray, thin-bedded	3.8
22. Limestone, hard, fine-grained, somewhat clayey, gray, weathers blocky and to two beds; pelecypod fragments very abundant; gastropods (14847)	.8
Total thickness	10.0±

Onaga shale:
Hawxby shale member:

21. Shale, clayey, gray-green, blocky. Thickness	8.9

338. *Section from West Branch shale member of Janesville shale down into Friedrich shale member of Root shale along the west side of SE¼SE¼ sec. 21, and in the NW¼NW¼ sec. 27, T. 26 S., R. 9 E., Greenwood County, Kans.*—Continued

	Feet
Permian system—Continued	
Onaga shale—Continued	
Aspinwall limestone member:	
20. Limestone, gray, with green tint, weathers blocky; pelecypods abundant; bryozoans and brachiopods (14846)	.2
19. Shale, silty, tan; many thin lentils of siltstone	3.0
18. Limestone, medium-hard, crystalline, tan, weathers porous and to 3 or 4 beds; mottled with iron stains; bryozoans especially abundant; crinoid columnals, pelecypods, and brachiopods common (14845)	.4
Total thickness	3.6
Towle shale member:	
17. Shale, silty, some clay, gray, weathers tan, thin-bedded to fissile; calcareous plates common; lower part covered	7.3
16. Limestone, sandy, somewhat crystalline, brown, weathers tan and platy; fossil fragments and crinoid columnals	.3
15. Shale, clayey, gray-green, thin-bedded; calcareous plates; partly covered	3.5
14. Shale, clayey, gray-green, blocky; thin lenses of limestone in upper part	4.6
13. Shale, covered	3.3
Total thickness	19.0
Total thickness of Onaga shale	31.5
Pennsylvanian system:	
Wood Siding formation:	
Brownville limestone member:	
12. Limestone, hard, brown, massive, weathers tan and blocky; large solution channels in lower part; crinoid columnals weather white, are very conspicuous, and are very abundant in upper 0.7 foot; fusulinids abundant in middle part. Thickness	2.1
Pony Creek shale member:	
11. Shale, clayey, gray, thin-bedded; tan and fossiliferous in upper part; brachiopods and worm burrows(?). Thickness	10.6
Grayhorse limestone member:	
10. Limestone, tan, weathers nodular; coquina; bryozoans, brachiopods, crinoid columnals; pelecypods, and gastropods. Thickness	.2–.6

338. *Section from West Branch shale member of Janesville shale down into Friedrich shale member of Root shale along the west side of SE¼SE¼ sec. 21, and in the NW¼NW¼ sec. 27, T. 26 S., R. 9 E., Greenwood County, Kans.*—Continued

	Feet
Pennsylvanian system—Continued	
Wood Siding formation—Continued	
Plumb shale member of Wood Siding formation and French Creek(?) shale member of Root shale:	
9. Shale, clayey, gray-green, blocky, grades to thin beds	9.0
8. Sandstone, micaceous, hard, fine-grained, tan, massive; fills small channel	1.8
7. Shale, silty, micaceous, tan-gray, weathers tan, thin-bedded; some iron stains; grades up into a sandy shale; some sandstone lenses contain ripple marks	24.0
(Note: The Nebraska City limestone member of the Wood Siding formation is absent. It could not be determined whether it pinched out or it was cut out by a channel.)	
6. Coal, black, thin-bedded	.2
5. Shale, clayey, gray to light-brown, thin-bedded; sandstone lentils and sandy shale in upper part; clayey in uppermost part; thin calcareous lentils and iron stains on surface	30.1
4. Shale, covered	4.6
Total thickness	69.7
Total thickness of Wood Siding formation (thickness includes underlying French Creek shale member of the Root shale)	82.6–83.0
Root shale (see note and discussion of Wood Siding formation above):	
Jim Creek limestone member:	
3. Limestone, hard, gray to tan, weathers tan and blocky; lower surface very irregular; fossil fragments very abundant, including crinoid columnals, brachiopods, fusulinids, and echinoids. Thickness	.6
Friedrich shale member:	
2. Shale, clayey, gray, weathers tan, thin-bedded; calcareous in upper part; iron stains	2.6
1. Coal, impure, black	.4
Total thickness exposed	3.0
Total thickness of exposed Root shale	3.6

Base covered.

339. *Section from Nebraska City limestone member of Wood Siding formation down into Grandhaven limestone member of Stotler limestone in a streambank and road cut along the east side of the SE¼SW¼ sec. 16, T. 26 S., R. 9 E., Greenwood County, Kans.*

Pennsylvanian system:
Wood Siding formation: Feet
Nebraska City limestone member:
7. Limestone, shaly, gray, platy; pelecypods, crinoid columnals, brachiopods (14849). Thickness exposed 1.8

Total thickness of exposed Wood Siding formation 1.8

Root shale:
French Creek shale member:
6. Shale and sandy shale, micaceous, tan, massive sandstone bed 33.1 ft above underlying limestone; upper 4 ft contains brachiopods, crinoid columnals, and pelecypods (14849); lower part covered. Thickness 49.0

Jim Creek limestone member:
5. Limestone, medium-hard, crystalline, gray, massive, weathers blocky and to irregular plates; fusulinids, fossil fragments, bryozoans, brachiopods, and stromatolites; fossils weather white. Thickness 1.9

Friedrich shale member:
4. Shale, clayey, tan, thin-bedded .6
3. Coal, black .4
2. Shale, sandy in upper part, with small local channels filled with tan micaceous massive beds of sandstone speckled with limonite. Lower part covered, but sandy shale lenses with thin sandstone lentils are beneath channels 22.7

Total thickness 23.7

Total thickness of Root shale 74.6

Stotler limestone:
Grandhaven limestone member:
1. Limestone, medium-hard, crystalline, gray; pelecypods, fusulinids, and fragments of other fossils. Thickness exposed .4

Total thickness of exposed Stotler limestone .4

Base of stream.
Base covered.

346. *Section from Grandhaven limestone member of Stotler limestone down into Wamego shale member of Zeandale limestone in a road cut in the SE¼SE¼ sec. 8, T. 23 S., R. 11 E., Greenwood County, Kans.*

Pennsylvanian system:
Stotler limestone:
Grandhaven limestone member: Feet
8. Limestone, medium-hard, dark-gray, with green tint, weathers tan and to irregular plates; pelecypods, bryozoans, and brachiopods (14862). Thickness 0.7

Dry shale member:
7. Shale, clayey, gray to gray-green, weathers tan; mostly covered; contains a thin nodular limestone bed; some carbon stains in upper part; fossil fragments in upper part 27.3
6. Limestone, hard, crystalline, light-gray, massive, weathers blocky with well-rounded corners; contains fragments of angular siltstone; fossil fragments very abundant; fusulinids, stromatolites, and brachiopods (14863) .9
5. Shale, clayey, gray, thin-bedded; crinoid columnals and brachiopods (14864) 6.2

Total thickness 34.4

Dover limestone member:
4. Limestone, hard, dense in part, gray, weathers tan; massive in upper part, blocky to platy in lower part; stromatolites(?) abundant; corals, crinoid columnals, and fusulinids. Thickness 1.4

Total thickness of Stotler limestone 26.5

Pillsbury shale:
3. Shale, clayey, gray, thin-bedded. Thickness 6.2

Zeandale limestone:
Maple Hill limestone member:
2. Limestone, hard, crystalline, gray, massive, weathers tan to light gray and blocky; fusulinids, brachiopods, bryozoans, and stromatolites(?). Thickness 2.5

Wamego shale member:
1. Shale, clayey, gray to tan. Thickness exposed 15.2

Total thickness of exposed Zeandale limestone 17.7

Base covered.

350. *Section from the Nebraska City limestone member of Wood Siding formation down into Pillsbury shale in a road cut in the SE¼SE¼ sec. 29, T. 7 S., R. 11 E., Pottawatomie County, Kans.*

Pennsylvanian system:
Wood Siding formation:
Nebraska City limestone member: Feet
15. Shale, very calcareous, gray; limestone lentils; brachiopods, bryozoans, crinoid columnals, and other fossil fragments (19904) ---- 1.0±
14. Limestone, medium-hard, gray, mottled with gray green, massive, weathers blocky and to irregular plates; stromatolites, brachiopods; fossil fragments very abundant, including bryozoans and crinoid columnals (14904) ---- 1.0

Total thickness ---- 2.0±

Total thickness of exposed Wood Siding formation ---- 2.0±

Root shale:
French Creek shale member:
13. Shale, very calcareous, tan-gray, thin-bedded to nodular ---- 1.3
12. Coal, with clay lentils, black ---- .3
11. Shale, silty, gray, thin bedded in upper part underlain by tan-gray sandy shale with lentils of sandstone; sandstone concretions and plates abundant; iron stains ---- 19.3

Total thickness ---- 20.9

Jim Creek limestone member:
10. Limestone, medium-hard, light-gray, mottled with tan, massive, weathers tan and blocky and to irregular plates; coquina with fossil fragments, brachiopods, fusulinids, *Osagia*? and bryozoans (14903) ---- .7
9. Shale, calcareous, gray, conglomeratic; limestone and limonite nodules; brachiopods, including *Derbyia* ---- .3
8. Limestone, sandy, hard, conglomeratic, gray, mottled with tan, weathers tan; ostracodes(?) and fossil fragments ---- .3

Total thickness ---- 1.3

Friedrich shale member:
7. Shale, clayey, gray-green, blocky ---- 1.0
6. Sandstone, fine-grained, micaceous, tan, blocky, weathers shaly ---- 1.5
5. Shale, micaceous, gray-green, lower 1±ft is maroon; sandstone plates; upper 4 ft is sandy; mostly covered ---- 15.8

Total thickness ---- 18.3

Total thickness of Root shale ---- 40.5

350. *Section from the Nebraska City limestone member of Wood Siding formation down into Pillsbury shale in a road cut in the SE¼SE¼ sec. 29, T. 7 S., R. 11 E., Pottawatomie County, Kans.*—Continued

Pennsylvanian system—Continued
Stotler limestone:
Grandhaven limestone member: Feet
4. Limestone, medium-hard, gray to tan-gray, with green tint, weathers blocky to shaly; varied fauna with fossil fragments very abundant, including brachiopods, bryozoans, pelecypods, and crinoid columnals; fusulinids and stromatolites. Thickness ---- 1.2

Dry shale member:
3. Shale, clayey, gray-green, thin-bedded. Thickness ---- 1.0

Dover limestone member:
2. Limestone, medium-hard, gray, with green tint, massive, weathers nodular; many iron specks; fusulinids very abundant in lower part, also common throughout; fossil fragments and stromatolites abundant in upper part. Thickness ---- 3.4

Total thickness of Stotler limestone ---- 5.6

Pillsbury shale:
1. Shale, silty, calcareous, gray-green; grades up into Dover limestone; fusulinids abundant in upper part. Thickness exposed ---- 3.2

Base covered.

352. *Section from Foraker limestone down into Hamlin shale member of Janesville shale in a streambank in the center of SW¼ sec. 30, T. 2 S., R. 16 E., Brown County, Kans.*

Permian system:
Foraker limestone:
Long Creek limestone member: Feet
20. Limestone, soft, tan, blocky. Thickness exposed ---- 4.0±

Hughes Creek shale member:
19. Shale, clayey, dark gray in lower part, gray silty shale in upper part, fissile; mostly covered; brachiopods ---- 11.6
18. Limestone, medium-hard, gray, weathers blocky, becomes shaly in upper part; brachiopods and fossil fragments ---- .7
17. Shale, clayey, dark-gray, fissile to platy; brachiopods ---- 2.4
16. Shale, silty, tan-gray, thin-bedded; fossiliferous ---- 3.0
15. Limestone, hard, gray, blocky; brachiopods (14910) ---- .6

352. *Section from Foraker limestone down into Hamlin shale member of Janesville shale in a streambank in the center of SW¼ sec. 30, T. 2 S., R. 16 E., Brown County, Kans.*—Continued

Permian system—Continued

Foraker limestone—Continued — Feet

Hughes Creek shale member—Continued

14. Shale, silty, gray, thin-bedded (14910) .1
13. Limestone, gray, blocky; fusulinids very abundant (14910) .4
12. Shale, clayey, dark-gray, blocky (14910) .6
11. Limestone, clayey, medium-hard, gray, weathers blocky; shale partings in middle part; fossil fragments and brachiopods (14910) .7
10. Shale, clayey to silty, calcareous, gray, thin-bedded; thin calcareous lentils 5.3
9. Shale, gray; very calcareous nodular zone in upper part. (14909) 12.5

Total thickness 37.9

Americus limestone member:

8. Limestone, silty, soft, gray, weathers shaly; brachiopods (14907) .5
7. Shale, silty, gray, thin-bedded; brachiopods .1–.2
6. Limestone, hard, dark-gray, weathers tan gray and blocky; brachiopods and crinoid columnals (14906) .7

Total thickness 1.3–1.4

Total thickness of exposed Foraker limestone 43.2±

Janesville shale:

Hamlin shale member:

5. Shale, clayey, dark-gray, thin-bedded to fissile; *Lingula* and *Orbiculoidea* (14908) 1.1
4. Siltstone, micaceous, gray, weathers shaly; crinoid columnals .2
3. Shale, clayey, dark-gray, fissile; gypsum fills fracture in middle part, a 0.2 ft layer of sandy conglomerate with clay and limonite nodules as much as 14 inches in diameter; grades up into limestone 1.0
2. Siltstone, shaly, light-gray, massive, weathers tan and blocky 3.1
1. Shale, clayey, gray-green, blocky 18.9

Total thickness exposed 24.3

Total thickness of exposed Janesville shale 24.3

Base covered.

353. *Section from Falls City limestone down into French Creek shale member of Root shale at the old town site of Aspinwall in the center N½ sec. 20, T. 4 N., R. 16 E., Nemaha County, Nebr.*

Permian system:

Falls City limestone: — Feet

15. Limestone, soft, gray, massive, weathers blocky; oolitic; porous; bedding planes apparent on weathered surface; thin gray clay lentils 1 or 2 inches long parallel with bedding; pelecypod fragments very abundant; stromatolite nodules (14933) 2.4
14. Shale, covered 5.3
13. Limestone, medium-hard, gray, weathers tan, blocky, and to irregular plates; coquina, especially in lower 0.7 ft; top part contains thin zone of *Crurithyris* and other brachiopods, bryozoans, crinoid columnals, and pelecypods (14932) 1.0

Total thickness 8.7

Onaga shale:

Hawxby shale member:

12. Shale, clayey, gray-green, thin-bedded; limonite nodules abundant in upper part 1.5
11. Siltstone, tan, massive to thin-bedded .8
10. Shale, clayey, gray to gray-green, blocky; purple tint on weathered surface; tan zone in upper part; fractures filled with calcite 12.1

Total thickness 14.4

Aspinwall limestone member:

9. Limestone, medium-hard, light-gray, with green tint; coquina of fossil fragments (14931). Thickness .3

Towle shale member:

8. Shale, silty, tan, maroon, and gray in lower part; poorly exposed. Thickness 7.6

Total thickness of Onaga shale 22.3

Pennsylvanian system:

Wood Siding formation:

Brownville limestone member:

7. Limestone and calcareous shale, medium-hard, light-brown, fine-grained. *Marginifera* and other brachiopods (14930) 1.4
6. Limestone, hard, light-brown, massive, weathers tan and blocky; *Marginifera* abundant; *Crurithyris* and other brachiopods and crinoid columnals common (14930) 2.7

Total thickness 4.1

353. *Section from Falls City limestone down into French Creek shale member of Root shale at the old town site of Aspinwall in the center N½ sec. 20, T. 4 N., R. 16 E., Nemaha County, Nebr.*—Continued

	Feet
Pennsylvanian system—Continued	
Wood Siding formation—Continued	
Plumb and Pony Creek shale members, undifferentiated:	
5. Shale, gray-green, mostly covered	10.3
4. Shale, sandy, gray-green, grades to maroon in upper part, thin-bedded; iron stains and plates common	5.7
Total thickness	16.0
Nebraska City limestone member:	
3. Limestone, hard, gray, weathers tan, massive; weathers blocky to shaly in upper part; fossil fragments abundant; brachiopods and bryozoans (14929). Thickness	1.2
Total thickness of Wood Siding formation	21.3
Root shale:	
French Creek shale member:	
2. Shale, calcareous, gray, weathers tan, thin-bedded; brachiopod fragments	.5
1. Coal, black, thin-bedded	.3
Total thickness exposed	.8
Total thickness of exposed Root shale	.8

Base covered.

355. *Section from Hamlin shale member down into Five Point limestone member of Janesville shale along the west side of the SW¼SE¼ sec. 29, T. 6 N., R. 13 E., Nemaha County, Nebr.*

	Feet
Permian system:	
Janesville shale:	
Hamlin shale member:	
8. Limestone, medium-hard, tan, platy; lobate bedding; composed entirely of stromatolites (14938)	0.3±
7. Shale, mostly green and maroon	3.5
6. Shale, silty, tan-gray, blocky, calcareous lens in middle part; iron stains in upper part; fossiliferous (14937)	3.1
5. Siltstone, tan, nodular	.6
4. Shale, gray to gray green with maroon beds in lower and upper parts; mostly covered; 2± ft gray shale at base contains brachiopods, bryozoans, and crinoid columnals	14.9
Total thickness exposed	22.4±

355. *Section from Hamlin shale member down into Five Point limestone member of Janesville shale along the west side of the SW¼SE¼ sec. 29, T. 6 N., R. 13 E., Nemaha County, Nebr.*—Continued

	Feet
Permian system—Continued	
Janesville shale—Continued	
Five Point limestone member:	
3. Limestone, hard, tan, massive, weathers blocky; coquina	1.1
2. Shale, covered	3.4
1. Mudstone, gray to gray-green, blocky	1.1
Total thickness exposed	5.6±
Total thickness of exposed Janesville shale	28.0±

Base covered.

370. *Section from Jim Creek limestone member of Root shale down into Maple Hill limestone member of Zeandale limestone along east-flowing creeks in N½SE¼ sec. 20, T. 21 S., R. 11 E., Lyon County, Kans. Measured by H. G. O'Connor, Kansas Geological Survey, modified by authors.*

	Feet
Pennsylvanian system:	
Root shale:	
Jim Creek limestone member:	
18. Limestone, sandy, fine-grained, gray, weathers drab gray with purple at top; fusulinids, crinoid columnals, bryozoans, and brachiopods (14865)	0.7
17. Shale, gray and tan; crinoid fragments and brachiopods	.3±
16. Limestone, very sandy, gray; pelecypods, brachiopods, and bryozoans	.9±
Total thickness	1.9±
Friedrich shale member:	
15. Shale, sandy, micaceous to silty in part, gray; shaly sandstone, upper 3± ft contains siltstone nodules	14.9
14. Shale, sandy and micaceous in part, gray, thin-bedded, blocky; limonite stains on joints	13.0
Total thickness	27.9
Total thickness of exposed Root shale	29.8±
Stotler limestone:	
Grandhaven limestone member:	
13. Limestone, silty, medium to dark-gray, weathers light gray to light brown; pelecypods, bryozoans, and crinoid fragments (14866). Thickness	.7

370. *Section from Jim Creek limestone member of Root shale down into Maple Hill limestone member of Zeandale limestone along east-flowing creeks in N½SE¼ sec. 20, T. 21 S., R. 11 E., Lyon County, Kans. Measured by H. G. O'Connor, Kansas Geological Survey, modified by authors*—Continued

Pennsylvanian system—Continued
Stotler limestone—Continued
Dry shale member:

	Feet
12. Shale, argillaceous in lower part, gray and tan; pelecypods, brachiopods, and crinoid fragments. Bryozoans in upper part	1.0
11. Coal	.2±
10. Shale, green to olive, brown in upper part, blocky; calcareous siltstone nodules	8.1
9. Siltstone, soft, impure, brown to yellow with tinge of green; nodular, slabby	3.2±
8. Shale, silty, calcareous, micaceous, blue-green to light-gray; some brown impure calcareous nodules	3.0±
7. Covered	4.0±
6. Limestone, shaly in lower part, fine grained to medium crystalline in upper part, light- to very-dark-gray, has purplish cast on top locally; very fossiliferous; crinoids, bryozoans, brachiopods, *Chonetes* only in lower part (14867)	.9
5. Shale, very calcareous, gray; brachiopods, crinoids, bryozoans; grades into underlying bed	1.2±
4. Shale and sandstone, sandy and micaceous, upper part very sandy, gray, thin-bedded, some crossbedding in lower part; coaly zone in upper part; much plant material	3.7±
Total thickness	25.3±

Dover limestone member:

3. Limestone, upper part brown to greenish, silty, variable thickness up to 0.3 ft, thin limestone, lower part light gray to light tan, weathers same with many stromatolites, also crinoids, horn corals, and brachiopods. Massive ledge weathers to slabs; lower 0.5 to 0.7 ft contains fusulinid and fossil fragments; upper part contains mostly nodules of stromatolites with varied fauna (14868). Thickness	2.4±
Total thickness of Stotler limestone	28.4±

Pillsbury shale:

2. Shale, argillaceous, green, probably blocky when dry. Thickness	.8±

370. *Section from Jim Creek limestone member of Root shale down into Maple Hill limestone member of Zeandale limestone along east-flowing creeks in N½SE¼ sec. 20, T. 21 S., R. 11 E., Lyon County, Kans. Measured by H. G. O'Connor, Kansas Geological Survey, modified by authors*—Continued

Pennsylvanian system—Continued
Zeandale limestone:
Maple Hill limestone member:

	Feet
1. Limestone, hard, gray to brown, massive; some widely spaced joints; fusulinids, stromatolites, crinoids, and brachiopods. Thickness	.4±
Total thickness of exposed Zeandale limestone	.4±

Base covered.

371. *Section from Cottonwood limestone member of Beattie limestone down into Burr limestone member of Grenola limestone along pasture ditch in the center of NW¼ sec. 7, T. 18 S., R. 10 E., Lyon County, Kans. Measured by D. M. Jewett and H. G. O'Connor, Kansas Geological Survey, modified slightly by authors.*

Permian system:
Beattie limestone:
Cottonwood limestone member:

21. Limestone, upper part light gray, weathers porous; chert nodules rare; fusulinids forms hillside bench	1.3
20. Limestone, algal	.3
19. Limestone, light-gray; coal zone at top; fossil fragments very abundant; brachiopods and pelecypods	2.0
Total thickness exposed	3.6
Total thickness of exposed Beattie limestone	3.6

Eskridge shale:

18. Shale, upper part light tan; mostly covered	1.6
17. Shale, gray	1.0
16. Covered	2.6
15. Shale, greenish-gray, blocky; lower part contains an impure dark-gray to tan nodular limestone bed 0.6 ft. thick	6.0
14. Shale, mostly covered; coal streak 0.5± ft thick overlies detrital limestone with ostracodes and fossil fragments; rest of shale mostly green near middle; marly zone near base	14.3
13. Shale, greenish-gray; stringers of impure limestone	3.0
Total thickness	28.5

371. *Section from Cottonwood limestone member of Beattie limestone down into Burr limestone member of Grenola limestone along pasture ditch in the center of NW¼ sec. 7, T. 18 S., R. 10 E., Lyon County, Kans. Measured by D. M. Jewett and H. G. O'Connor, Kansas Geological Survey, modified slightly by authors*—Continued

	Feet
Permian system—Continued	
Grenola limestone:	
Neva limestone member:	
12. Limestone, granular, crystalline, gray, dense and porous layers; echinoid spines, pelecypods, and brachiopods (14881)	1.2
11. Shale, light-gray; abundant brachiopods (14882)	3.9
10. Limestone, gray in upper part; chert nodules; fusulinids in basal part	2.1
9. Shale, calcareous, yellow; fusulinids (14883)	1.0
8. Covered	1.1
7. Limestone, white, weathers brown; fusulinids (14884)	.8
6. Shale, yellow	.9
5. Limestone, gray, weathers yellow and brown, pitted; worm burrows(?) on upper surface; stromatolites abundant	.6
Total thickness	11.6
Salem Point shale member:	
4. Shale, yellow	.3
3. Covered	9.0
2. Shale, black	1.8
Total thickness	11.1
Burr limestone member:	
1. Shale, calcareous, platy. Thickness exposed	.5
Total thickness of exposed Grenola limestone	23.2

Base covered.

372. *Section from Five Point limestone member of Janesville shale down into Hawxby shale member of Onaga shale in a streambank in the center of the SE¼ sec. 7, T. 16 S., R. 12 E., Lyon County, Kans. Measured by H. G. O'Connor, Kansas Geological Survey.*

	Feet
Permian system:	
Janesville shale:	
Five Point limestone member:	
25. Limestone, hard, gray, weathers drab gray brown, massive; 0.5-ft gray shale lens, 1.3 ft below top; abundant fossils; brachiopods, pelecypods (14887). Thickness	2.1
West Branch shale member:	
24. Shale, gray to olive	.5
23. Carbon smut, impure coal	.1±
22. Shale, clayey, gray and buff	1.1
21. Sandstone and sandy shale, micaceous, brown	2.9

372. *Section from Five Point limestone member of Janesville shale down into Hawxby shale member of Onaga shale in a streambank in the center of the SE¼ sec. 7, T. 16 S., R. 12 E., Lyon County, Kans. Measured by H. G. O'Connor, Kansas Geological Survey*—Continued

	Feet
Permian system—Continued	
Janesville shale—Continued	
West Branch shale member—Continued	
20. Shale, sandy, gray, limonitic; gypsiferous	2.7
19. Shale, calcareous, gray to olive, blocky	.4
18. Mudstone, olive gray, weathers nodular	.3
17. Shale, gray; gypsiferous; *Lingula*	6.1
16. Shale, silty, gray to green	2.5
15. Shale, blue-green, blocky, earthy; grades into dark-gray shale with calcareous concretions in lower part	7.9
14. Limestone, hard, dense, gray, concretionary	.2±
13. Shale, dark-gray	2.1
12. Limestone, hard, dense, gray	.5±
11. Shale, silty, dark-gray (14889)	1.0
Total thickness	28.3±
Total thickness of exposed Janesville shale	30.4±
Falls City limestone:	
10. Limestone, fine-grained, gray, concretionary; upper part contains large *Orbiculoidea;* pelecypods, bryozoans, crinoids, and cone-in-cone zones (14888)	1.3
9. Shale, gray, blocky	2.3
8. Limestone, fine-grained, gray; same fossils as bed 10 above, cone-in-cone zone at top (14888)	.3
7. Shale, olive-tan, thin-bedded; thin calcareous sandy platelets	2.4
6. Limestone, hard, silty, fine-grained to partly crystalline, dark-gray; bryozoans and pelecypods	.1±
5. Shale, calcareous, dark-gray, blocky	4.6
4. Limestone, gray, weathers tan; grades laterally into calcareous shale with calcareous nodules or interbedded limestone and shale; upper 0.5 ft most resistant and fossiliferous; pelecypods abundant; brachiopods, bryozoans, crinoids, and gastropods (14890)	1.8
3. Shale, silty, calcareous, gray	2.0
2. Limestone, silty, gray to tan, weathers tan and brown; a coquina of pelecypods and gastropods	1.0
Total thickness	15.8±
Onaga shale:	
Hawxby shale member:	
1. Shale, calcareous, light-gray to tan. Thickness exposed	1.1
Total thickness of exposed Onaga shale	1.1

Base covered.

373. *Section from Americus limestone member of Foraker limestone down into West Branch shale member of Janesville shale in a road ditch and pasture ditch in the NW¼ sec. 3, T. 20 S., R. 10 E., Lyon County, Kans. Measured by H. G. O'Connor, Kansas Geological Survey, modified by authors.*

Permian system:
 Foraker limestone:
  Americus limestone member: Feet
   19. Limestone, "salt and pepper" texture, light-gray-buff, weathers to massive diamond-shaped blocks; fusulinids, crinoids, cephalopods, and brachiopods ---- 1.8
   18. Covered ---- 2.2
   17. Limestone, hard, gray, sandy to conglomeratic; algal in top 0.1 ft ---- .8
   16. Limestone, marly, dark-brown ---- 1.0
    Total thickness ---- 5.8
    Total thickness of exposed Foraker limestone ---- 5.8

 Janesville shale:
  Hamlin shale member:
   15. Covered ---- 3.9
   14. Shale, clayey, green, with slight tinge of red; light-colored calcareous nodules ---- 2.2
   13. Covered, mostly variegated shale with calcareous nodules ---- 22.6
   12. Shale, sandy, micaceous, green, thin-bedded; pyrite nodules weather to limonite and stain the surface; plant fossils ---- 8.3
   11. Limestone, dark-brown ---- .1
   10. Limestone, hard, gray and gray-brown; abundant small pelecypods ---- .4
   9. Aragonite, crystalline, green; variable thickness ---- .2
   8. Shale, olive and green, mottled, blocky; calcareous nodular lentils ---- 6.7
   7. Shale, olive; fauna of brown snails ---- .3
   6. Shale, calcareous in part, micaceous, hard, buff-gray, blocky; thick-bedded; possibly small faults ---- .8
   5. Shale, calcareous in part, gray, blocky, massive ---- 4.2
    Total thickness ---- 49.7

  Five Point limestone member:
   4. Limestone, crystalline, gray, weathers gray; limonite nodules; crinoids, echinoids, bryozoans, and brachiopods ---- 1.7
   3. Shale parting not well exposed ---- .1±
   2. Limestone, gray and brown, weathers brown, slabby in upper part, lower 0.9 ft massive; abundant crinoids; also *Marginifera*, fusulinids (*Triticites*); upper part has gastropods, brachiopods, and bryozoans ---- .9
    Total thickness ---- 2.7±

  West Branch shale member:
   1. Shale, gray and brown. Thickness exposed ---- .9
    Total thickness of exposed Janesville shale ---- 53.3±

Base covered.

374. *Section from Burr limestone member of Grenola limestone down into Johnson shale along road ditch in the SW¼NW¼ sec. 35, T. 15 S., R. 11 E., Lyon County, Kans. Measured by H. G. O'Connor, Kansas Geological Survey, modified by authors.*

Permian system:
 Grenola limestone:
  Burr limestone member:
   25. Limestone, brown, speckled with light gray; pebbles or inclusions of light-tan and gray limestone; pelecypods, fenestellid bryozoans ---- 1.1
   24. Shale, silty, calcareous, gray; pelecypods and bryozoans; grades into underlying bed ---- .7
   23. Limestone, silty to shaly, gray; pelecypods, brachiopods, and bryozoans ---- .5±
    Total thickness ---- 2.3±

  Legion shale member:
   22. Shale, tan, calcareous nodules in upper part; vertical veins of porous chert and fine-grained quartz ---- 8.3±
   21. Shale, dark-gray to black, fissile, calcareous at top ---- .5±
    Total thickness ---- 8.7±

  Sallyards limestone member:
   20. Limestone, shaly, gray, mottled; pelecypods. Thickness ---- .3±
    Total thickness of exposed Grenola limestone ---- 11.3±

 Roca shale:
   19. Shale, light-green to dark-green and tan, blocky, nodular ---- 9.5

374. *Section from Burr limestone member of Grenola limestone down into Johnson shale along road ditch in the SW¼NW¼ sec. 35, T. 15 S., R. 11 E., Lyon County, Kans. Measured by H. G. O'Connor, Kansas Geological Survey, modified by authors*—Continued

Permian system—Continued

Roca shale—Continued

	Feet
18. Shale, calcareous, dark-green, blocky; grades into underlying bed	1.2±
17. Limestone or marl, dense, green, clay veinlets	2.1±
16. Shale, calcareous, red, purple, green; calcareous nodules; blocky	3.5
15. Limestone, light-gray to green, secondary calcite; algal-like structures	2.6
14. Shale, calcareous, silty, green, weathers platy	2.2
Total thickness	21.1±

Red Eagle limestone:

Howe limestone member:

	Feet
13. Limestone, gray and green, mostly large *Cryptozoon*-like algae	.4
12. Limestone, light-gray; spergenite of minute snails, pelecypods, clams, oolites, stromatolites, ostracodes, fusulinids and other Foraminifera; echinoderm and bryozoan fragments	2.8
11. Limestone, light-gray, fragmental and crystalline; locally dense; crinoid fragments, microsnails and clams, stromatolites	.9
10. Limestone, gray and green; echinoderms, stromatolites	.3
Total thickness	4.4

Bennett shale member:

	Feet
9. Shale, tan and gray; abundant echinoderms, brachiopods; grades into underlying bed	5.8
8. Limestone, silty, shaly, light- to dark-gray; sparse crinoid, bryozoan, and brachiopod fragments	1.2
7. Limestone, mottled light and dark gray; chert in upper part; fusulinids, *Orbiculoidea*, *Hustedia*, and shark teeth	1.3
6. Shale, upper part gray, lower part brown; basal part coquina of *Orbiculoidea;* fossils abundant in upper part	.5
Total thickness	8.8

374. *Section from Burr limestone member of Grenola limestone down into Johnson shale along road ditch in the SW¼NW¼ sec. 35, T. 15 S., R. 11 E., Lyon County, Kans. Measured by H. G. O'Connor, Kansas Geological Survey, modified by authors*—Continued

Permian system—Continued

Red Eagle limestone—Continued

Glenrock limestone member:

	Feet
5. Limestone, hard, brown to gray, massive; small pebblelike masses of gray-brown limestone; abundant fusulinids; *Marginifera* and *Orbiculoidea* in top crust. Thickness	.9
Total thickness of Red Eagle limestone	14.1

Johnson shale:

	Feet
4. Shale, argillaceous, gray to tan, blocky	.7
3. Shale, calcareous, gray to gray-green and olive	2.0
2. Shale, dark-gray to black, fissile; carbonized plant fragments; minute white snails	1.2
1. Siltstone or impure slabby limestone, gray to tan	2.9
Total thickness exposed	6.8

Base covered.

376. *Section from Falls City limestone down to top of Brownville limestone member of Wood Siding formation in a road ditch along U. S. 50–N and along creek in the NW¼NW¼ sec. 22, T. 16 S., R. 12 E., Lyon County, Kans. Measured by H. G. O'Connor, Kansas Geological Survey, modified by authors.*

Permian system:

Falls City limestone:

	Feet
16. Limestone, impure, gray, weathers tan, argillaceous; weathers nodular; bryozoans, pelecypods, and gastropods	0.8
15. Shale, calcareous, gray and olive, earthy; partly covered	6.3
14. Limestone, silty to shaly, light-gray; pelecypods and gastropods	.7
13. Covered	2.7
12. Limestone, partly hard, dense, and crystalline, gray; coquina of small pelecypods	1.1
Total thickness	11.6

376. *Section from Falls City limestone down to top of Brownville limestone member of Wood Siding formation in a road ditch along U. S. 50–N and along creek in the NW¼NW¼ sec. 22, T. 16 S., R. 12 E., Lyon County, Kans. Measured by H. G. O'Connor, Kansas Geological Survey, modified by authors*—Continued

Permian system—Continued
Onaga shale:

	Feet
Hawxby shale member:	
11. Shale, gray to buff; thin small calcareous sandy platelets; some pelecypods	5.4
10. Covered	.5
9. Shale, calcareous, gray to buff; small calcareous concretions	4.5
8. Covered	3.1
Total thickness	13.5
Aspinwall limestone member:	
7. Limestone, sandy, hard, gray; fossils chiefly pelecypods	.5
6. Shale, argillaceous, green	.7
5. Covered	.6
4. Limestone, silty to slightly sandy, gray to brown, thin-bedded	.5

376. *Section from Falls City limestone down to top of Brownville limestone member of Wood Siding formation in a road ditch along U. S. 50–N and along creek in the NW¼NW¼ sec. 22, T. 16 S., R. 12 E., Lyon County, Kans. Measured by H. G. O'Connor, Kansas Geological Survey, modified by authors*—Continued

Permian system—Continued
Onaga shale—Continued

	Feet
Aspinwall limestone member—Continued	
3. Shale, slightly sandy, micaceous, gray to green	5.0
2. Limestone, silty or sandy, greenish-gray; brachiopods	.2±
Total thickness	7.5±
Towle shale member:	
1. Covered. Total thickness	16.3
Total thickness of Onaga shale	37.3±

Pennsylvanian system:
Top of Brownville limestone member of Wood Siding formation.

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PLATES 6–17

PLATE 6

FIGURES 1, 2. *Triticites* sp. aff. *T. eoextenta* (Thompson) (p. 61).

1. Part of a thin section; slightly oblique equatorial section. × 10. USNM 134654. From USGS loc. 13748.
2. Deep tangential section, showing the development of epitheca. × 10. USNM 134655. From USGS loc. 13748.
3. *Millerella inflata* (Thompson) (p. 59). Axial section of a slightly compressed specimen. × 100. USNM 134656. From USGS loc. 13716.

4–19. *Triticites brownvillensis* Douglass n. sp. (p. 63).

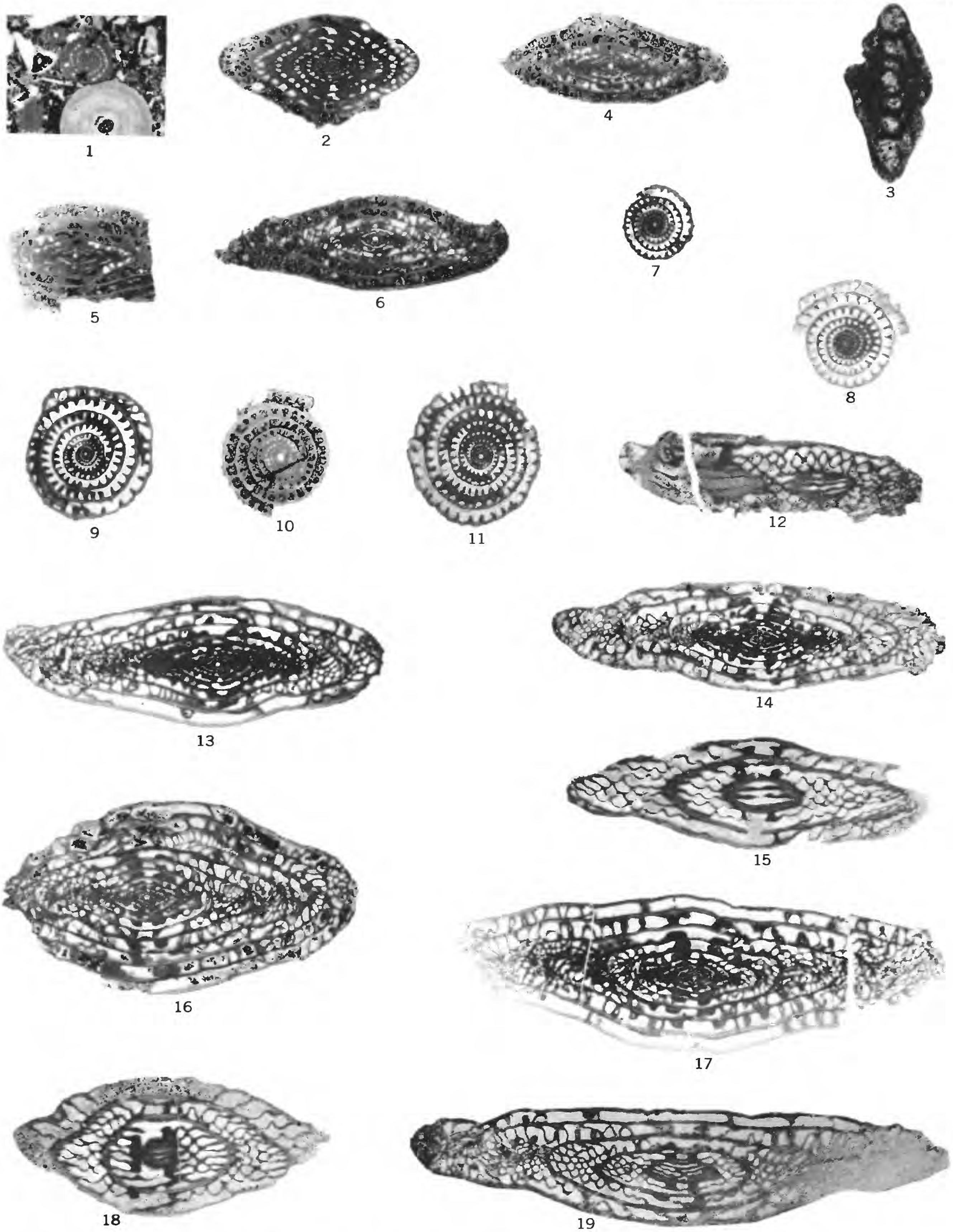
4–6. Axial sections of three immature specimens showing variation in the development of epitheca. × 10. USNM 134657, 134658, and 134659. From USGS loc. 13748.

7–11. Equatorial sections showing variation in size of proloculus and development of septa. × 10.

7. USNM 134660. From USGS loc. 13703.
8. USNM 134661. From USGS loc. 13810.
9. USNM 134662. From USGS loc. 13790.
10. UNSM 134663. From USGS loc. 13748.
11. USNM 134664. From USGS loc. 13716.
12. Tangential section paralleling lateral slope, showing development of chamberlets. × 10. USNM 134665. From USGS loc. 13703.
13. Axial section, slightly oblique. × 10. Same specimen as plate 6, figure 12.
14. Axial section of elongate specimen. × 10. USNM 134666. From USGS loc. 13703.
15. Tangential section. × 10. USNM 134667. From USGS loc. 13716.
16. Axial section of an abnormal specimen showing damage and repair in volution 8 and the development of an unusually short, thick shape for the species. × 10. USNM 134668. From USGS loc. 13810.
17. Axial section of holotype. × 10. USNM 134669. From USGS loc. 13703.

18, 19. Tangential sections showing extremes of variation in form. × 10.

18. USNM 134670. From USGS loc. 13703.
19. USNM 134671. From USGS loc. 13813.



FUSULINIDS IN THE BROWNVILLE LIMESTONE MEMBER OF THE WOOD SIDING FORMATION

PLATE 7

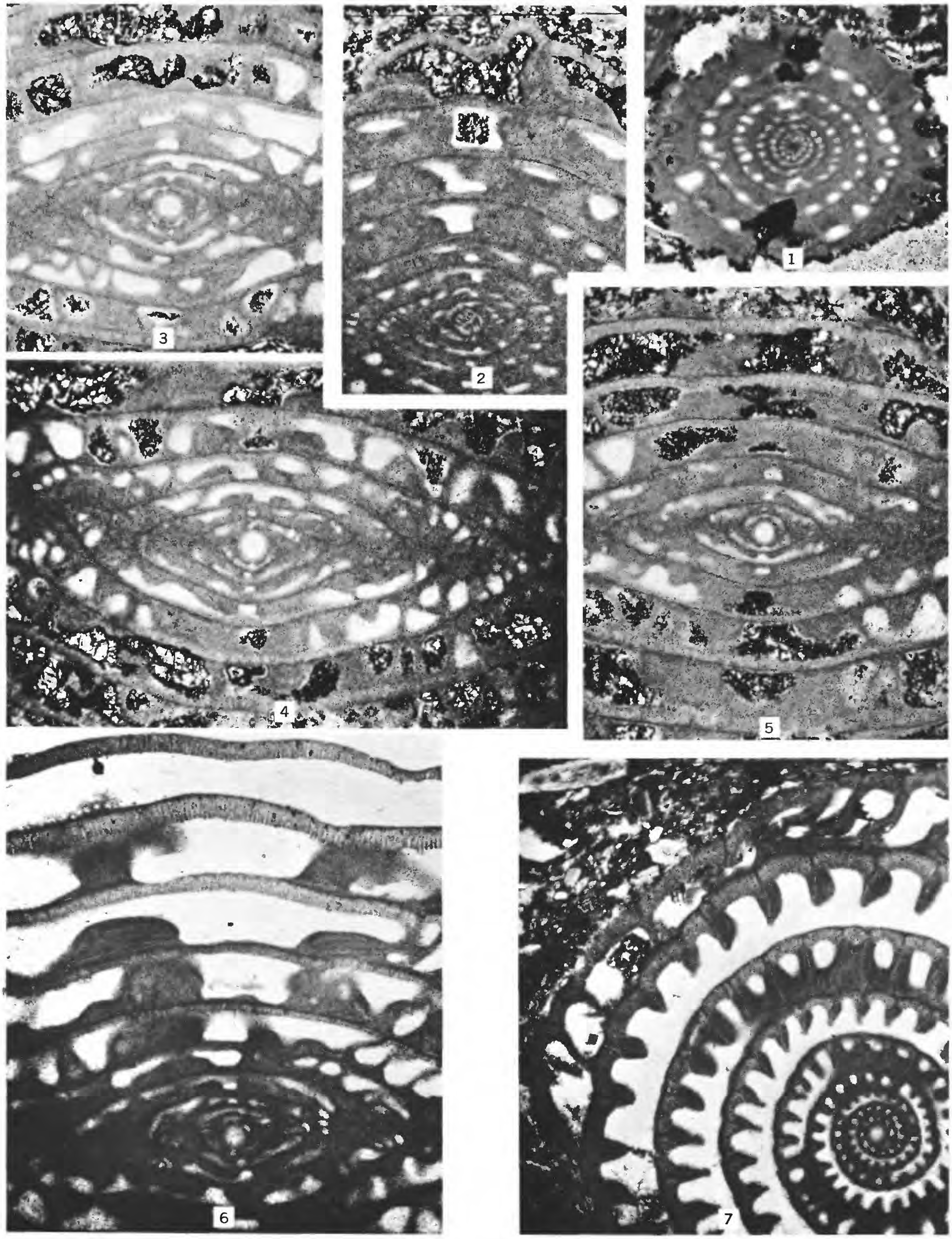
FIGURES 1, 2. *Triticites* sp. aff. *T. eoextenta* (Thompson) (p. 61).

1. Slightly oblique equatorial section showing the endothyroid juvenarium. × 50. Same specimen as plate 6, figure 1.
2. Deep tangential section that grazes the juvenarium. × 50. Same specimen as plate 6, figure 2.

3–7. *Triticites brownvillensis* Douglass, n. sp. (p. 63).

3–5. Axial sections showing variation in the development of epitheca.

3. Part of axial section shown in plate 6, figure 6. × 50.
4. Part of axial section shown in plate 6, figure 4. × 50.
5. Part of axial section shown in plate 6, figure 5. × 50.
6. Part of axial section of the holotype. Note the pores in volution 9. Same specimen as plate 6, figure 17. × 50.
7. Part of equatorial section. Same specimen as plate 6, figure 9. × 50.



FUSULINIDS IN THE BROWNVILLE LIMESTONE MEMBER OF THE WOOD SIDING FORMATION

PLATE 8

FIGURE 1. *Bradyina* sp. (p. 58). × 50. USNM 134672. From USGS loc. 13839.
2. *Geinitzina* sp. (p. 58). × 50. USNM 134673. From USGS loc. 13668.
3. *Tetrataxis* sp. (p. 58). × 50. USNM 134674. From USGS loc. 13815.
4. *Ammodiscus*? sp. (p. 58). × 100. USNM 134675. From USGS loc. 13836.

5–7. *Schubertella kingi* Dunbar and Skinner (p. 60).
- 5. Axial section, slightly oblique. × 100. USNM 134676. From USGS loc. 13839.
- 6. Equatorial section. × 50. USNM 134677. From USGS loc., 13815.
- 7. Axial section. × 100. On same slide as figure 5.

8. *Climacammina* sp. × 50. USNM 134678. From USGS loc. 13836.

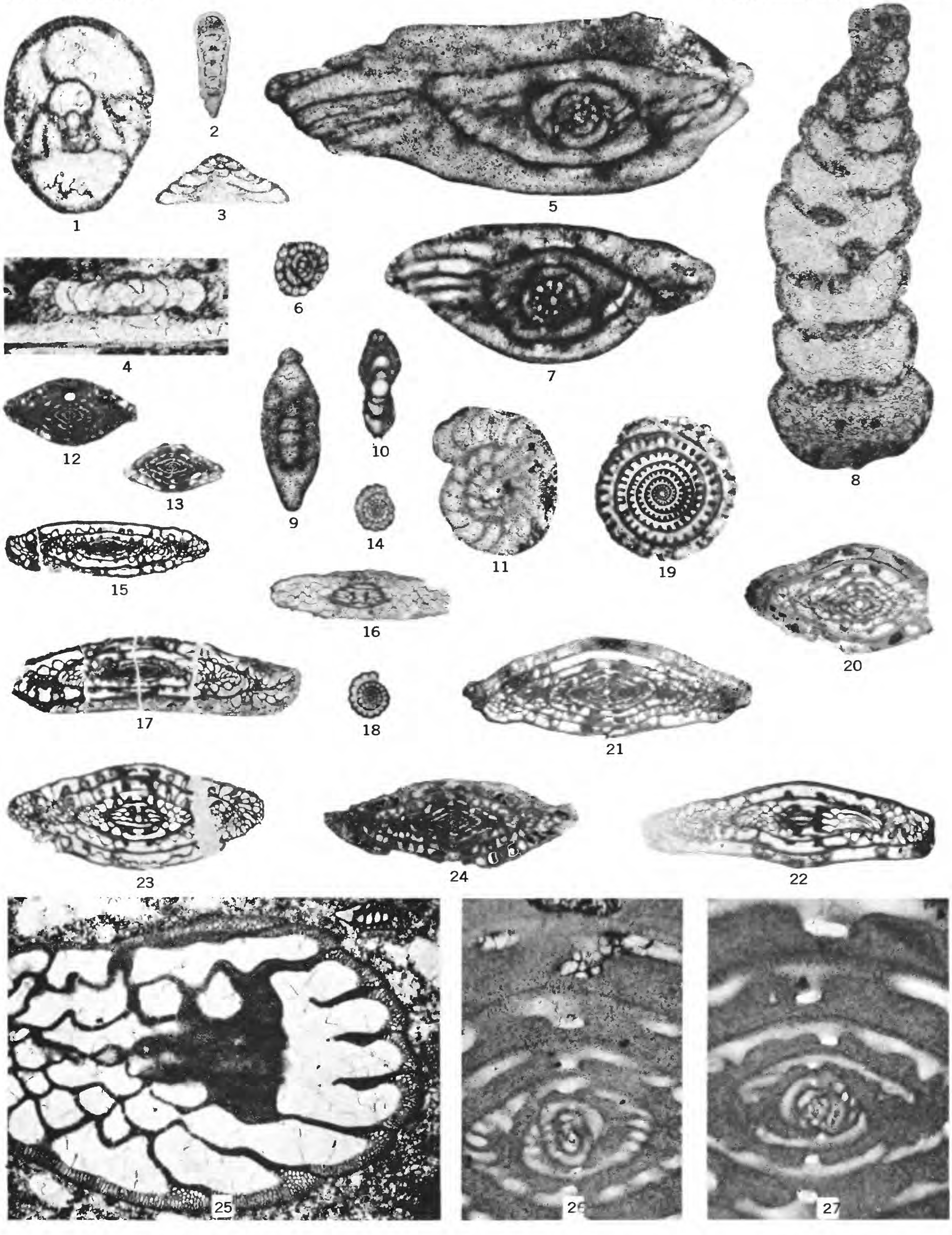
9–11. *Millerella inflata* (Thompson) (p. 59).
- 9. Tangential section. × 100. USNM 134679. From USGS loc., 13839.
- 10. Axial section. × 100. USNM 134680. From USGS loc., 13754.
- 11. Equatorial section. × 100. USNM 134681. From USGS loc. 13668.

12, 13, 26, 27. *Triticites* sp. aff. *T. eoextenta* (Thompson) (p. 61).
- 12. Deep tangential section. × 10. USNM 134682. From USGS loc. 13698.
- 13. Axial section. × 10. USNM 134683. From USGS loc. 13754.
- 26. Part of an axial section showing a staffeloid juvenarium. × 100. USNM 134684. From USGS loc. 13754.
- 27. Part of axial section. × 100. Same specimen as figure 13.

14–18. *Pseudofusulina delicata* Douglass, n. sp. (p. 64).
- 14. Equatorial section. × 10. USNM 134685. From USGS loc. 13668.
- 15. Axial section. × 10. USNM 134686. From USGS loc. 13839.
- 16. Tangential section. × 10. USNM 134687. From USGS loc. 13668.
- 17. Axial section of holotype. × 10. USNM 134688. From USGS loc. 13839.
- 18. Equatorial section. × 10. Same thin section as figure 17.

19, 20. *Triticites confertus* Thompson (p. 62).
- 19. Equatorial section. × 10. USNM 134689. From USGS loc. 13839.
- 20. Axial section. × 10. Same thin section as figure 19.

21–25. *Triticites pointensis* Thompson (p. 61).
- 21. Axial section. × 10. USNM 134690. From USGS loc. 13698.
- 22. Tangential section. × 10. USNM 134691. From USGS loc. 13836.
- 23. Tangential section. × 10. USNM 134692. From USGS loc. 13815.
- 24. Axial section. × 10. USNM 134693. From USGS loc. 13836.
- 25. Portion of a tangential section showing details of the wall structure and septal pores. × 50. From USNM 134694. USGS loc. 13754.



FUSULINIDS IN THE FIVE POINT LIMESTONE MEMBER OF THE JANESVILLE SHALE

PLATE 9

FIGURES 1, 2. *Triticites pointensis* Thompson (p. 62).

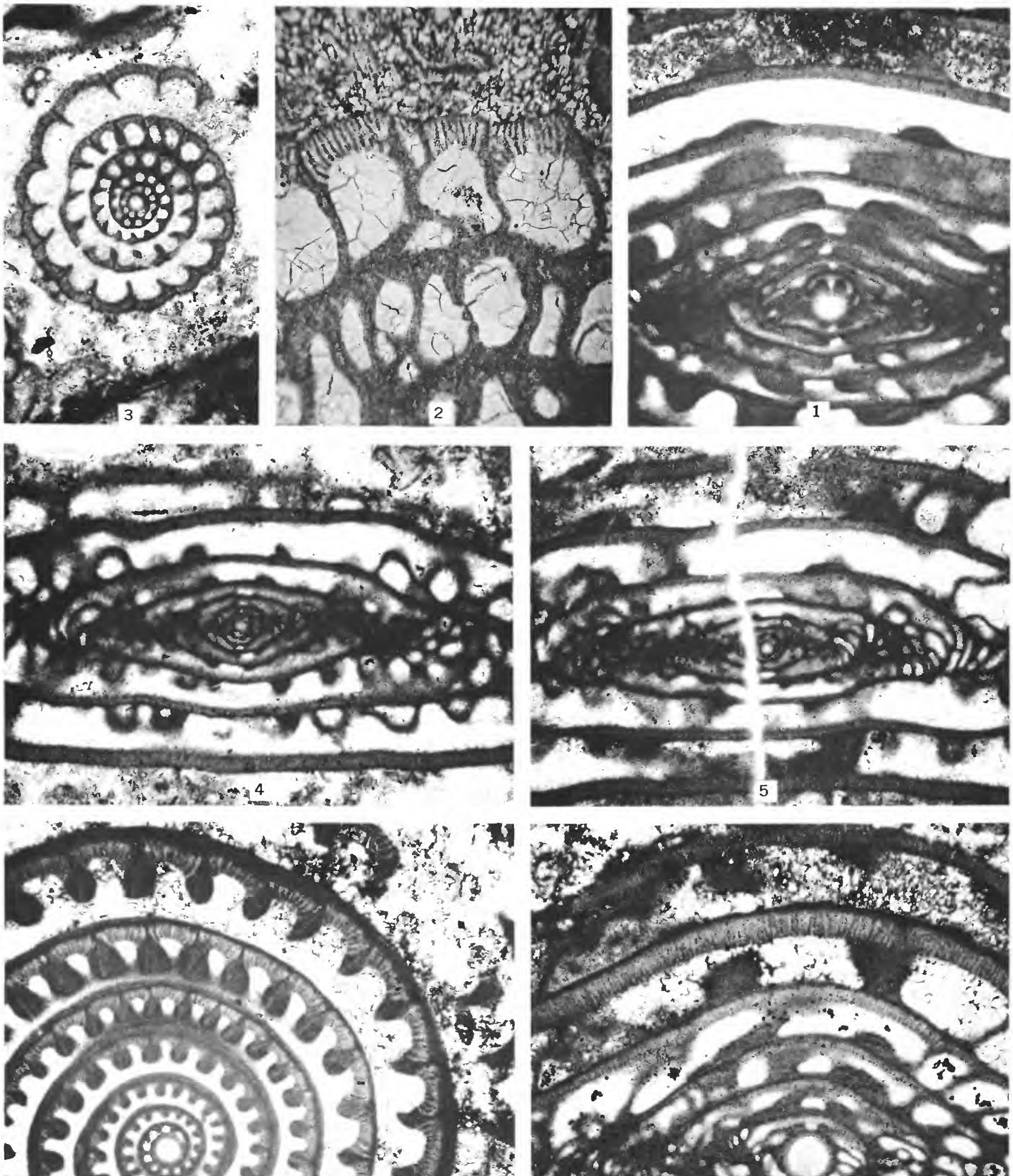
1. Part of axial section shown on plate 8, figure 21. × 50.
2. Part of an excentric equatorial section showing character of the keriatheca. × 100. USNM 134695. From USGS loc., 13754, Five Point limestone member, Janesville shale.

3–5. *Pseudofusulina delicata* Douglass, n. sp. (p. 64).

3. Equatorial section. Same specimen as plate 8, figure 18. × 50.
4. Part of axial section. Same specimen as plate 8, figure 15. × 50.
5. Part of axial section of the holotype. Same specimen as plate 8, figure 17. × 50.

6, 7. *Triticites confertus* Thompson (p. 62).

6. Part of equatorial section. Same specimen as plate 8, figure 19. × 50.
7. Part of axial section. Same specimen as plate 8, figure 20. × 50.



FUSULINIDS IN THE FIVE POINT LIMESTONE MEMBER OF THE JANESVILLE SHALE

PLATE 10

FIGURES 1–3, 16. *Triticites* sp. aff. *T. eoextenta* (Thompson) (p. 61).

1. Axial section. × 10. USNM 134696. From USGS loc. 13757.
2. Tangential section roughly paralleling the lateral slope, showing development of the epitheca. × 10. USNM 134697. From USGS loc. 13726.
3. Deep tangential section. × 10. USNM 134698. From USGS loc. 13796.
16. Part of axial section showing microspheric juvenarium. Same specimen as figure 1. × 50.

4. *Tetrataxis* sp.
× 50. USNM 134699. From USGS loc. 13726.

5, 6. *Geinitzina* sp.
× 100. USNM 134700, 134701. From USGS loc. 13676.

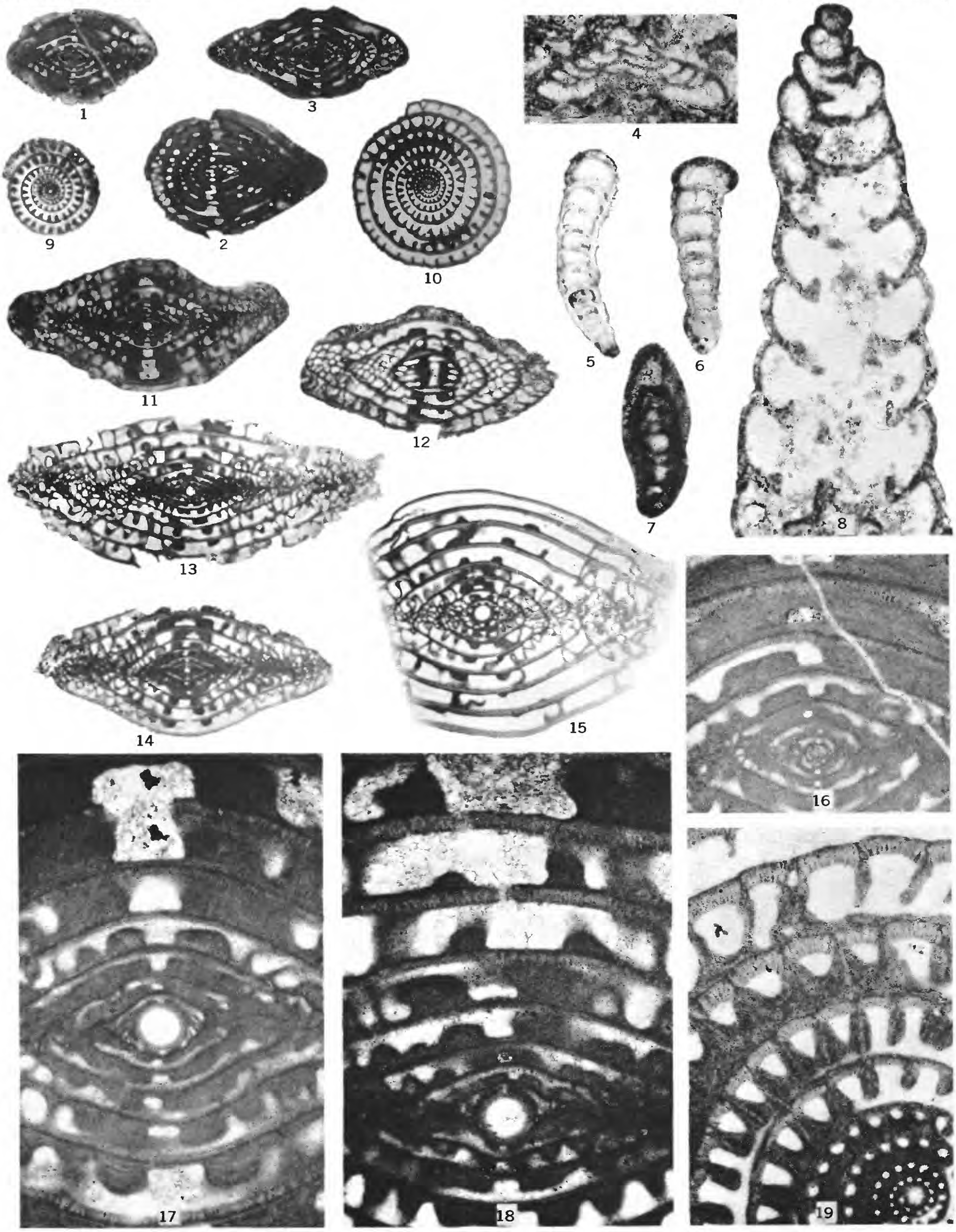
7. *Millerella inflata* (Thompson) (p. 59).
Axial section. × 100. USNM 134702. From USGS loc. 13663.

8. *Climacammina* sp.
× 50. USNM 134703. From USGS loc. 13705.

9–14, 17–19. *Triticites eoextenta* (Thompson) (p. 61).

9, 10. Equatorial section. × 10. USNM 134704, 134705. From USGS loc. 13817.
11. Axial section. × 10. USNM 134706. From USGS loc. 13817.
12. Tangential section. × 10. USNM 134707. From USGS loc. 13705.
13. Axial section. ×10. USNM 134708. From USGS loc. 13494.
14. Axial section. × 10. USMN 134709. From USGS loc. 13817.
17. Part of axial section showing extensive development of chomata and other epitheca. Same specimen as figure 11. × 50.
18. Part of axial section. Same specimen as figure 13. × 50.
19. Part of equatorial section. Same specimen as figure 10. × 50.

15. *Triticites* sp. aff. *T. creekensis* Thompson (p. 63).
Axial section. × 10. USNM 134710. From USGS loc. 13818.



FUSULINIDS IN THE AMERICUS LIMESTONE MEMBER OF THE FORAKER LIMESTONE

PLATE 11

FIGURES 1, 2. Lophophyllidid coral (p. 65).
Views of an alar side of a relatively symmetrical ceratoid corallum and its calyx × 1. Figured specimen. USNM 134550. From USGS loc. 13775, Florena shale member, Beattie limestone.

3, 4. Lophophyllidid coral (p. 65).
Views of an alar side of an attached corallum and the floor of its broken calyx. × 3. Figured specimen. USNM 134551. From USGS loc. 13744, Pillsbury shale.

5. Dibunophyllid coral (p. 66).
Exhibiting asexual increase: × 1. Figured specimen. USNM 134552. From USGS loc. 13712, Bennett shale member, Red Eagle limestone.

6. "*Axophyllum*" sp. (p. 66).
Transverse section just below floor of calyx of a fragmentary corallum, showing the solid axial structure and part of the lonsdaleoid dissepimentarium. × 3. Figured specimen USNM 134553. From USGS loc. 13496, Tarkio limestone member, Zeandale limestone.

7, 8. *Dibunophyllum exigum* Jeffords (p. 66).
Transverse sections through late and early ephebic parts of the same corallum. × 3. Hypotype. USNM 134554a, 134554b. From USGS loc. 13691, Dover limestone member, Stotler limestone.

9. "*Axophyllum*" sp. (p. 66).
Transverse section through a fragment of a nearly cylindrical corallum, showing the solid axial structure and part of the broad lonsdaleoid dissepimentarium. × 3. Figured specimen. USNM 134555. From USGS loc. 13441, Dover limestone member, Stotler limestone.

10. "*Axophyllum*" sp. (p. 66).
Worn calyx of a large form. × 1. Figured specimen. USNM 134556. From USGS loc. 14861, Grandhaven limestone member, Stotler limestone.

11. "*Axophyllum*" sp. (p. 66).
Side view of broken corallum showing turbinate shape and strong axial structure. × 2; compare with transverse section (fig. 6). Figured specimen. USNM 134557. From USGS loc. 14861, Grandhaven limestone member, Stotler limestone.

12–14. Echinoid remains.
× 1. USNM 134558a, 134558b, 134558c. From USGS loc. 13731. Bennett shale member, Red Eagle limestone.

15. *Orbiculoidea missouriensis* (Shumard) (p. 74).
Hypotype. × 2. USNM 134559. From USGS loc. 14908, Hamlin shale member, Janesville shale.

16. *Orbiculoidea tenuilineata* (Meek and Hayden) (p. 74).
Holotype. × 1. USNM 1102. From Cottonwood Creek, Kans.; possibly from the Matfield shale.

17. *Petrocrania modesta* (White and St. John) (p. 75).
Hypotype. × 3. USNM 134560. From USGS loc. 13455, unit 2, Hughes Creek shale member, Foraker limestone.

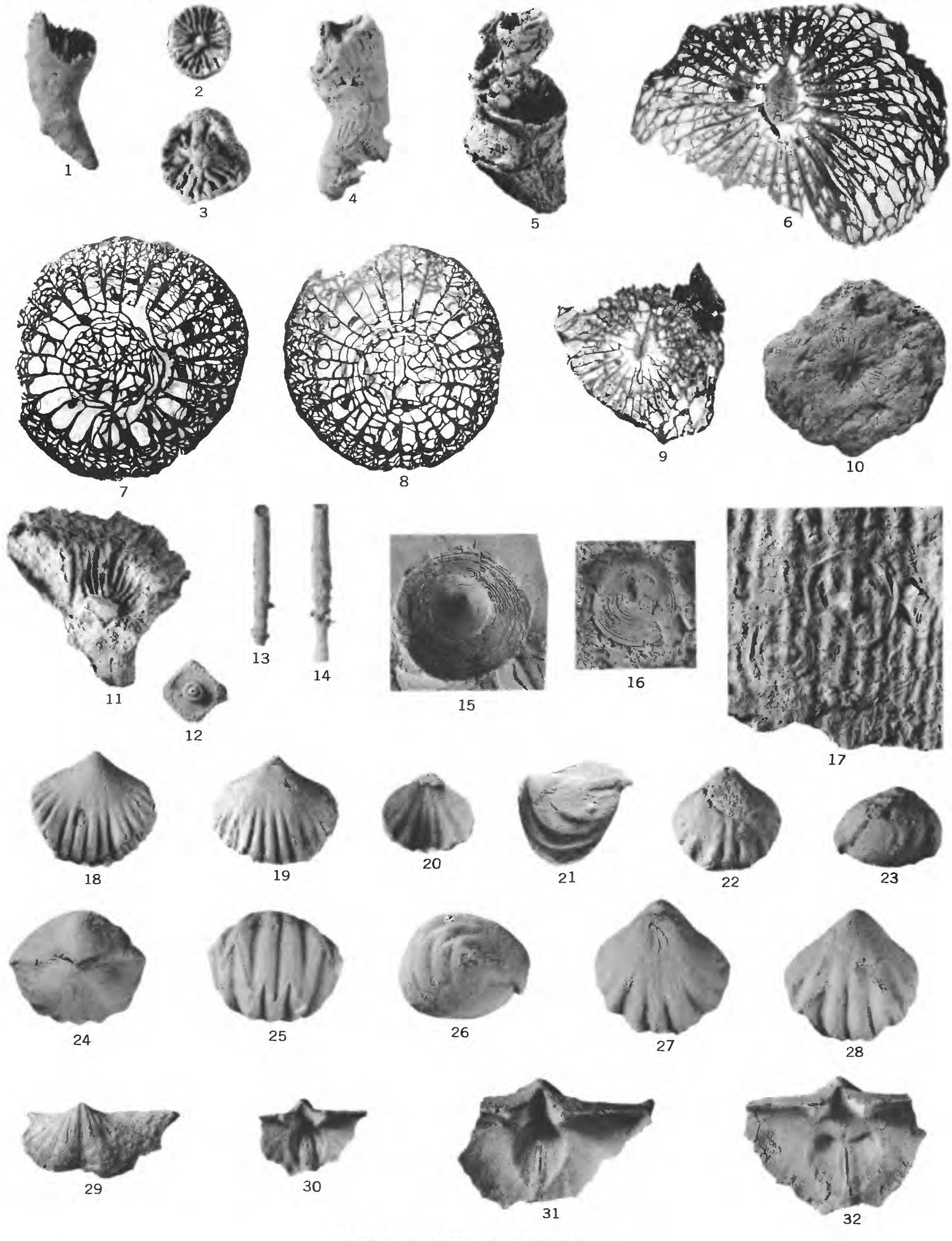
18–20. *Wellerella osagensis* (Swallow) (p. 75).
Hypotypes. × 2. USNM 134561, 134711. From USGS locs. 13443, Grandhaven limestone member, Stotler limestone, and 13666, units 5 and 6, Hughes Creek shale member, Foraker limestone.

21. *Wellerella truncata* Dunbar and Condra (p. 75).
Hypotype. × 2. USNM 134562. From USGS loc. 14894, unit 3, Hughes Creek shale member, Foraker limestone.

22, 23. *Wellerella*, cf. *W. delicatula* Dunbar and Condra (p. 76).
Hypotype. × 2. USNM 134563. From USGS loc. 13777, unit 2, Neva limestone member, Grenola limestone.

24–28. *Wellerella cooperi* Yochelson, n. sp. (p. 76).
Holotype. × 4. USNM 134564. From USGS loc. 13775, Florena shale member, Beattie limestone.

29–32. *Neospirifer dunbari* R. H. King (p. 76).
Hypotypes. × 1. USNM 134565, 134566a, 134566b, and 134567. From USGS locs. 13659, unit 3, Neva limestone member, Grenola limestone; 13821, unit 5, Hughes Creek shale member, Foraker limestone; and 13729, unit 3, Hughes Creek shale member, Foraker limestone. Note worn condition of shells and increase in amount of callus with increasing age.



CORALS AND BRACHIOPODS

PLATE 12

FIGURES 1–4. *Graphiocrinus*? *kansasensis* Strimple, n. sp. (p. 73).
Holotype viewed from posterior, anterior, summit, and base. × 3. USNM 134647. From USGS loc. 14806, Bennett shale member, Red Eagle limestone.

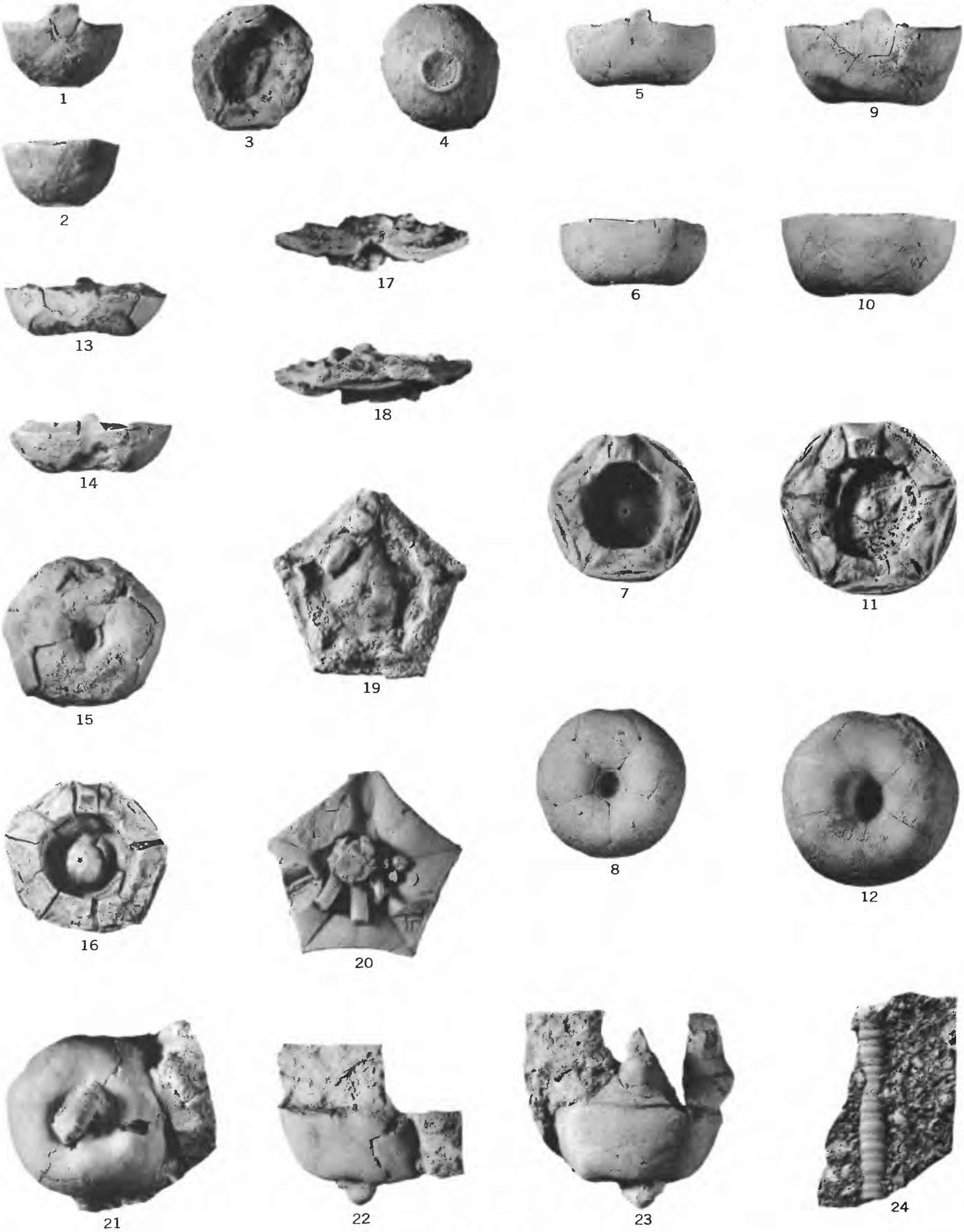
5–8. *Endelocrinus rotundus* Strimple, n. sp. (p. 71).
Holotype viewed from posterior, anterior, summit, and base. × 2. USNM 134648. From USGS loc. 13792, Aspinwall limestone member, Onaga shale.

9–12. *Delocrinus admirensis* Strimple, n. sp. (p. 69).
Holotype viewed from posterior, anterior, summit, and base. × 1. USNM 134649. From USGS loc. 13476, Aspinwall limestone member, Onaga shale.

13–16. *Delocrinus doveri* Strimple, n. sp. (p. 70).
Holotype viewed from anterior, posterior, base, and summit. × 1. USNM 134650. From USGS loc. 13442, Dover limestone member, Stotler limestone.

17–20. *Oklahomacrinus cirriferous* Strimple, n. sp. (p. 71).
Holotype viewed from posterior, anterior, summit, and base. × 2. USNM 134651. From USGS loc. 13606, Five Point limestone member, Janesville shale.

21–24. *Delocrinus densus* Strimple, n. sp. (p. 70).
Holotype. × 1. USNM 134652. From USGS loc. 13528. Five Point limestone member, Janesville shale.
21–23 viewed from base, posterior, and anterior.
24. Associated part of column.



CRINOIDS

PLATE 13

FIGURE 1. *Neospirifer* cf. *N. kansasensis* (Swallow) (p. 76).
Hypotype. × 1. USNM 134568. From USGS loc. 14854, unit 3, Hughes Creek shale member, Foraker limestone.

2, 3. *Crurithyris expansa* (Dunbar and Condra) (p. 77).
Hypotypes. × 3. USNM 134569 and 134570. From USGS locs. 13631, unit 5, Neva limestone member, Grenola limestone, and 13478, unit 1, Hughes Creek shale member, Foraker limestone.

4–7. *Composita subtilita* (Hall) (p. 77).
Hypotypes. × 1. USNM 134571, 134572a, 134572b. From USGS locs. 13803 Florena shale member, Beattie limestone, and 13500, Florena shale member, Beattie limestone.

8. *Derbyia* cf. *D. hooserensis*. Dunbar and Condra (p. 79).
Hypotype. × 1. USNM 134573. From USGS loc. 13609, Florena shale member, Beattie limestone.

9. *Derbyia crassa* (Meek and Hayden) (p. 78).
Hypotype. × 1. USNM 134574. From USGS loc. 13615, Nebraska City limestone member, Wood Siding formation.

10, 11. *Derbyia wabaunseensis* Dunbar and Condra (p. 78).
Hypotype. × 1. USNM 134575. From USGS loc. 13758, unit 1, Hughes Creek shale member, Foraker limestone.

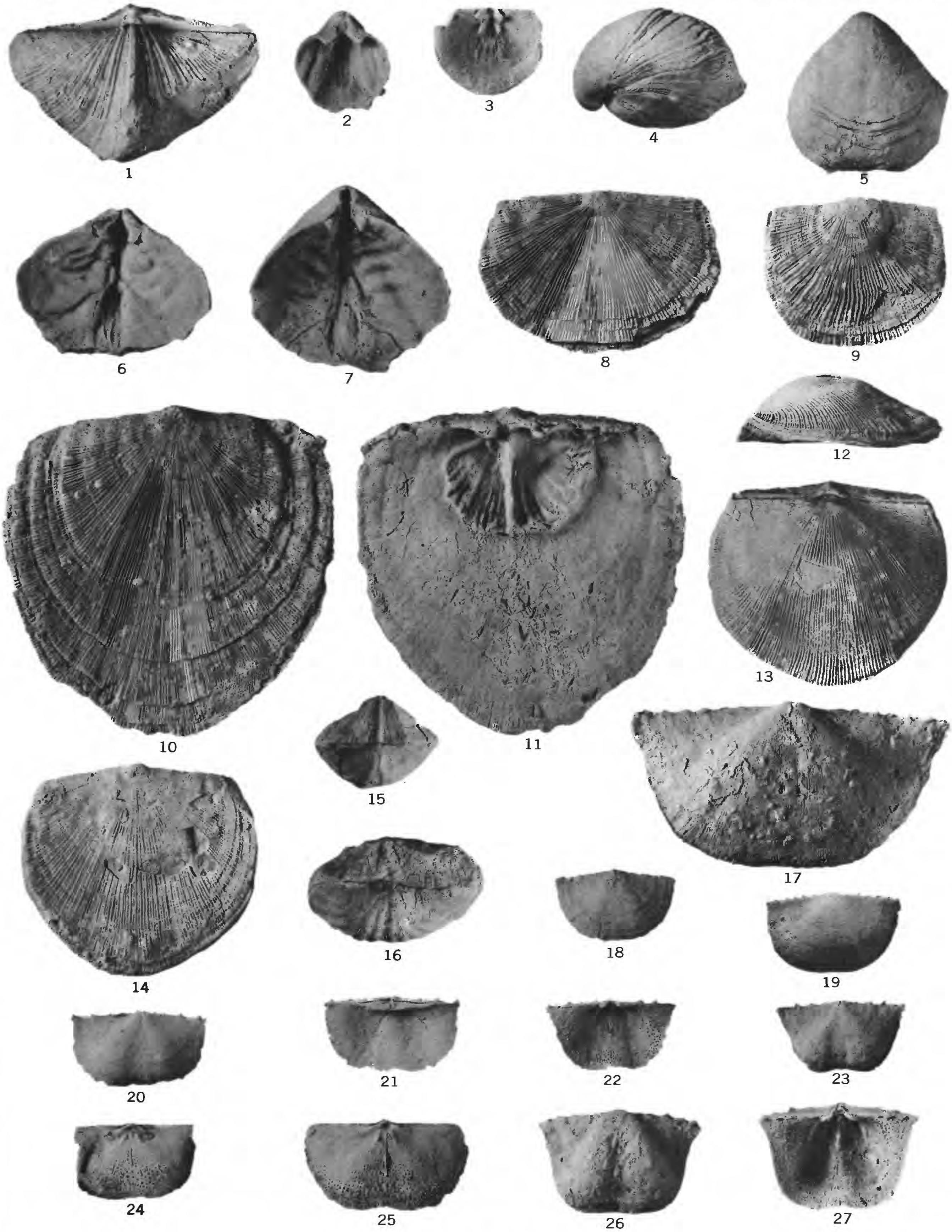
12–14. *Derbyia cymbula* Hall and Clarke (p. 78).
Hypotype. × 1. USNM 134576. From USGS loc. 13775, Florena shale member, Beattie limestone.

15, 16. *Meekella striatocostata* (Cox) (p. 79).
Hypotypes. × 1. USNM 134577a, and 134577b. From USGS loc. 13775, Florena shale member, Beattie limestone.

17–19. *Chonetes granulifer* Owen (p. 79).
Hypotypes. USNM 134579a, and 134579b. 17. × 2; note incrusting *Tolypammina*-like tubes. USNM 134578. From USGS loc. 13606, Five Point limestone member, Janesville shale. 18, 19. × 1. USNM 134579a and 134579b. From USGS loc. 13539, Florena shale member, Beattie limestone.

20–25. *Lissochonetes geinitzianus* (Waagen) (p. 80).
All specimens from Division C (Pillsbury? shale), Nebraska City, Nebr.
20, 21. Lectoparatype, × 2. Harvard M. C. Z. 94096. Original of Geinitz (1866, pl. 4, fig. 16).
22, 23. Lectotype. × 2. Harvard M. C. Z. 9408. Original of Geinitz (1866, pl. 4, fig. 18).
24, 25. Hypotypes. × 2. USNM 134580a and 134580b.

26, 27. *Lissochonetes geronticus* (Dunbar and Condra) (p. 81).
Hypotype. × 3. USNM 134581. From USGS loc. 13695, unit 2, Neva limestone member, Grenola limestone.



BRACHIOPODS

PLATE 14

FIGURE 1. *Leptalosia ovalis* Dunbar and Condra (p. 81).
Hypotype. × 4. USNM 134582. From USGS loc. 13767, Johnson shale.

2–5. *Dictyoclostus huecoensis* (R. E. King) (p. 81).
Hypotypes. All × 1, except figure 5, × 3. USNM 134583, 134584, and 134585. From USGS locs. 13775, Florena shale member, Beattie limestone; 13641, Five Point limestone member, Janesville shale, and 13440, Pillsbury shale.

6–8. *Juresania nebrascensis* (Owen) (p. 82).
Hypotypes. × 3 and × 1. USNM 134586, 134587. From USGS locs. 13767, Johnson shale, and 13775, Florena shale member, Beattie limestone.

9, 10. *Juresania* sp. 1 (p. 82).
Figured specimen. × 1. USNM 134588. From USGS loc. 13511, Brownville limestone member, Wood Siding formation.

11. *Echinoconchus moorei* Dunbar and Condra (p. 83).
Hypotype. × 1. USNM 134589. From USGS loc. 13784, Dover limestone member, Stotler limestone.

12, 16. *Marginifera histricula* Dunbar and Condra (p. 83).
Hypotypes. × 2. USNM 134590 and 134591. From USGS locs. 13484, Unit 3, Hughes Creek shale member, Foraker limestone, and 14891, Unit 5, Hughes Creek shale member, Foraker limestone.

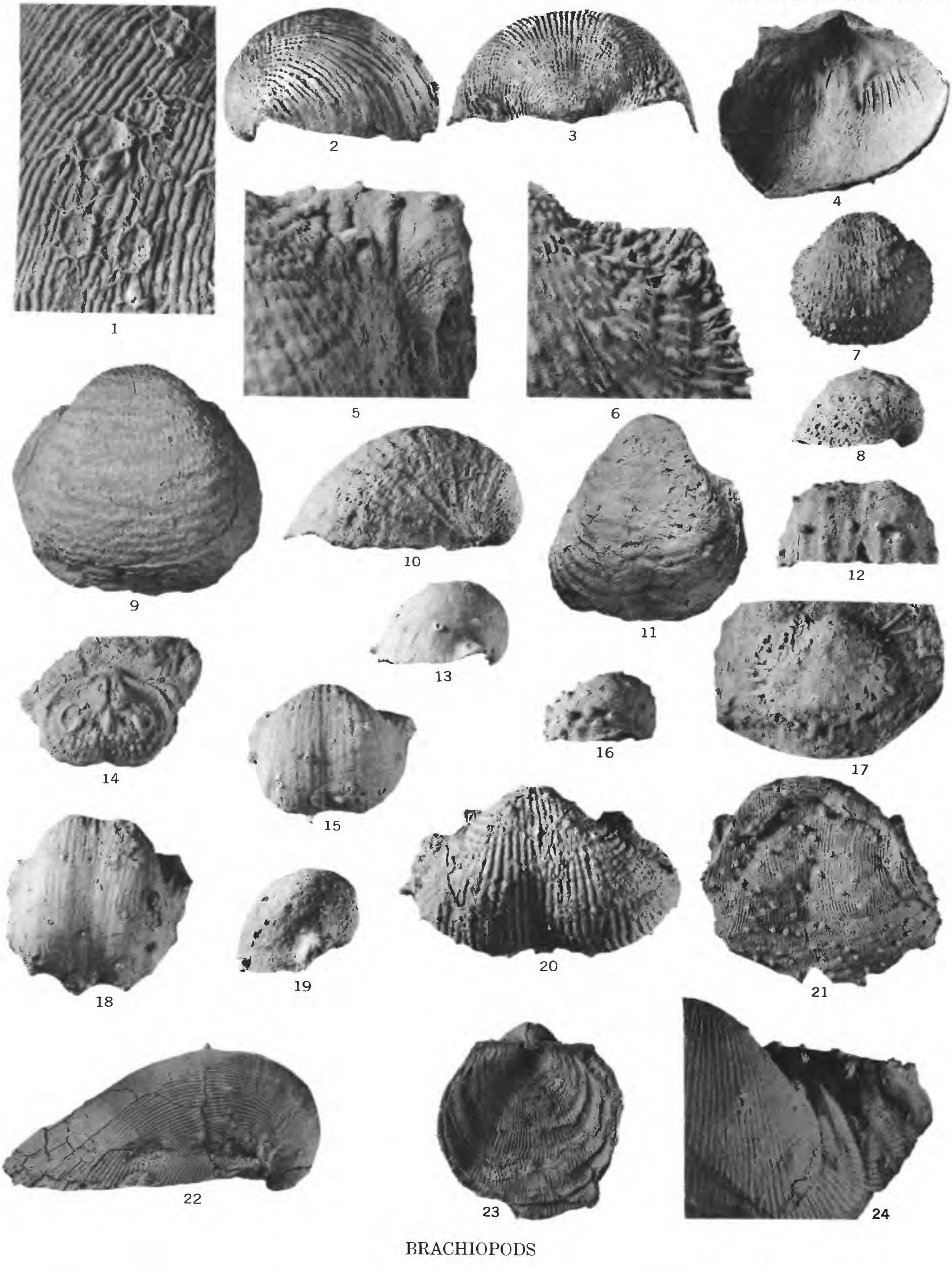
13–15. *Marginifera wabashensis* (Norwood and Pratten) (p. 83).
Hypotypes. × 2. USNM 134592, 134593. From USGS locs. 13445, Brownville limestone member, Wood Siding formation, and 13528, Five Point limestone member, Janesville shale.

17. *Cancrinella boonensis* (Swallow) (p. 84).
Hypotype. × 2. USNM 134594. From USGS loc. 13519, Falls City limestone.

18–20. "*Marginifera*" *lasallensis* (Worthen) (p. 84).
Hypotypes. × 1½, × 1, and × 2. USNM 134595, 134596, and 134597. From USGS locs. 13441, Dover limestone member, Stotler limestone, 13628, unit 1, Neva limestone member, Grenola limestone; and 13744, Pillsbury shale.

21. *Linoproductus prattenianus* (Norwood and Pratten) (p. 84).
Hypotype. × 1. USNM 134598. From USGS loc. 13809, Pony Creek shale member, Wood Siding formation.

22–24. *Linoproductus magnispinus* Dunbar and Condra (p. 84).
Hypotypes. × 1 and ×3. USNM 134599a, 134599b. From USGS locs. 13767, Johnson shale, and 13606, Five Point limestone member, Janesville shale.



BRACHIOPODS

PLATE 15

FIGURE 1–3. *Rhipidomella carbonaria* (Swallow) (p. 85).
Hypotype. × 3. USNM 134601. From USGS loc. 13665, unit 3, Hughes Creek shale member, Foraker limestone.

4, 5. *Enteletes* cf. *E. hemiplicatus* (Hall) (p. 85).
Hypotype. × 1. USNM 134602. From USGS loc. 13511, Brownville limestone member, Wood Siding formation.

6–8. *Hustedia mormoni* (Marcou) (p. 85).
Hypotype. × 3. USNM 134603. From USGS loc. 13727, unit 1, Hughes Creek shale member, Foraker limestone.

9. *Dielasma bovidens* (Morton) (p. 85).
Hypotype. × 2. USNM 134604. From USGS loc. 13511, Brownville limestone member, Wood Siding formation.

10–12. *Punctospirifer kentuckensis* (Shumard) (p. 86).
Hypotypes. × 2. USNM 134605a, 134605b, 134605c. From USGS loc. 13611, Friedrich shale member, Root shale.

13. *Edmondia nebrascensis* (Geinitz) (p. 86).
Hypotype. × 2. USNM 134606. From USGS loc. 13612, Friedrich shale member, Root shale.

14, 15. *Yoldia subscitula* (Meek and Hayden) (p. 87).
Syntypes. × 2. USNM 3957. From "Smoky Hill fork of Kansas River."

16. *Anthraconeilo* sp. (p. 87).
Figured specimen. × 2. USNM 134607. USGS loc. 13674, Florena shale member, Beattie limestone.

17. *Pteria* cf. *P. longa* (Geinitz) (p. 87).
Hypotype. × 2. USNM 134608. From USGS loc. 13720, Falls City limestone.

18. *Volsellina subelliptica* (Meek) (p. 88).
Hyptoype. × 2. USNM 134609. From USGS loc. 13691, Dover limestone member, Stotler limestone.

19. *Promytilus vetulus* Newell (p. 88).
Hypotype. × 2. USNM 134610. From USGS loc. 14888, Falls City limestone.

20. *Septimyalina scitula* Newell (p. 88).
Rubber squeeze of hypotype. × 1. USNM 134611. From USGS loc. 13688, Aspinwall limestone member, Onaga shale.

21. *Septimyalina burmai* Newell (p. 88).
Hypotype. × 2. USNM 134612. From USGS loc. 13775, Florena shale member, Beattie limestone.

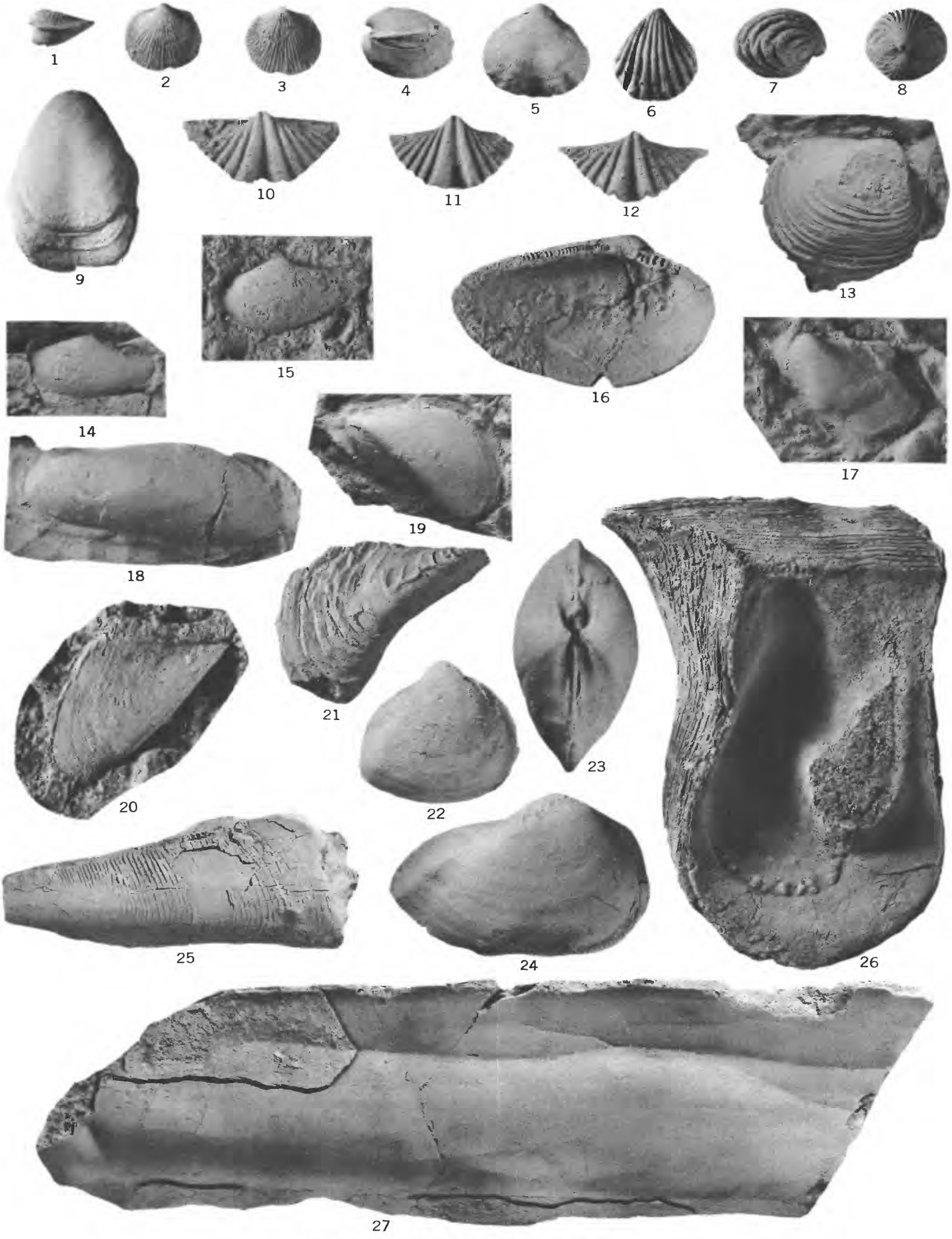
22, 23. *Schizodus* cf. *S. wheeleri* (Swallow) (p. 89).
Hypotypes. × 1 and × 2. USNM 134613a, 134613b. From USGS loc. 13775, Florena shale member, Beattie limestone.

24. *Schizodus* sp. (p. 89).
Figured specimen. × 1. USNM 134614. From USGS loc. 13767, Johnson shale.

25. *Aviculopinna* sp. (p. 87).
Figured specimen. × 1. USNM 134615. From USGS loc. 14819, Johnson shale.

26. *Myalina* (*Orthomyalina*) *subquadrata* (Shumard) (p. 88).
Hypotype. × 1. USNM 134616. From USGS loc. 13612, Friedrich shale member, Root shale.

27. *Aviculopinna peracuta* (Shumard) (p. 87).
Hypotype. × 0.75. USNM 134617. From USGS loc. 13675, Americus limestone member, Foraker limestone.



BRACHIOPODS AND PELECYPODS

PLATE 16

FIGURE 1. *Aviculopecten arctisulcatus* Newell (p. 89).
Hypotype. × 1. USNM 134618. From USGS loc. 13627, Burr limestone member, Grenola limestone.

2. *Aviculopecten nodocostata* Newell (p. 89).
Hypotype. × 1. USNM 134619. From USGS loc. 13519, Falls City limestone.

3. *Clavicosta* sp. (p. 90).
Figured specimen. × 1. USNM 134620. From USGS loc. 13751, Falls City limestone.

4. *Streblochondria* sp. indet. (p. 90).
Figured specimen. × 1. USNM 134621. From USGS loc. 13507, Falls City limestone.

5, 6. *Allorisma terminale* Hall (p. 90).
Hypotype. × 1. USNM 134622. From USGS loc. 14898, Grandhaven limestone member, Stotler limestone.

7, 8. *Permophorus subcostatus* (Meek and Worthen) (p. 90).
Hypotype. × 1. USNM 134623. From USGS loc. 13770, Burr limestone member, Grenola limestone.

9, 10. *Permophorus* sp. 2 (p. 91).
Figured specimen. × 3. USNM 134624. From USGS loc. 13532, Tarkio limestone member, Zeandale limestone.

11, 12. *Permophorus oblongus* (Meek) (p. 91).
Two of Meek's three syntypes. × 2. USNM 6499. From Rockford, Nebraska City, Nebr.

13. *Permophorus* sp. 1 (p. 90).
Figured specimen. × 1. USNM 134625. From USGS loc. 13672, Hawxby shale member, Onaga shale.

14, 15. *Anthraconeilopsis kansana* Tasch (p. 91).
Hypotype. × 4. USNM 134626. From USGS loc. 14873, Grandhaven limestone member, Stotler limestone.

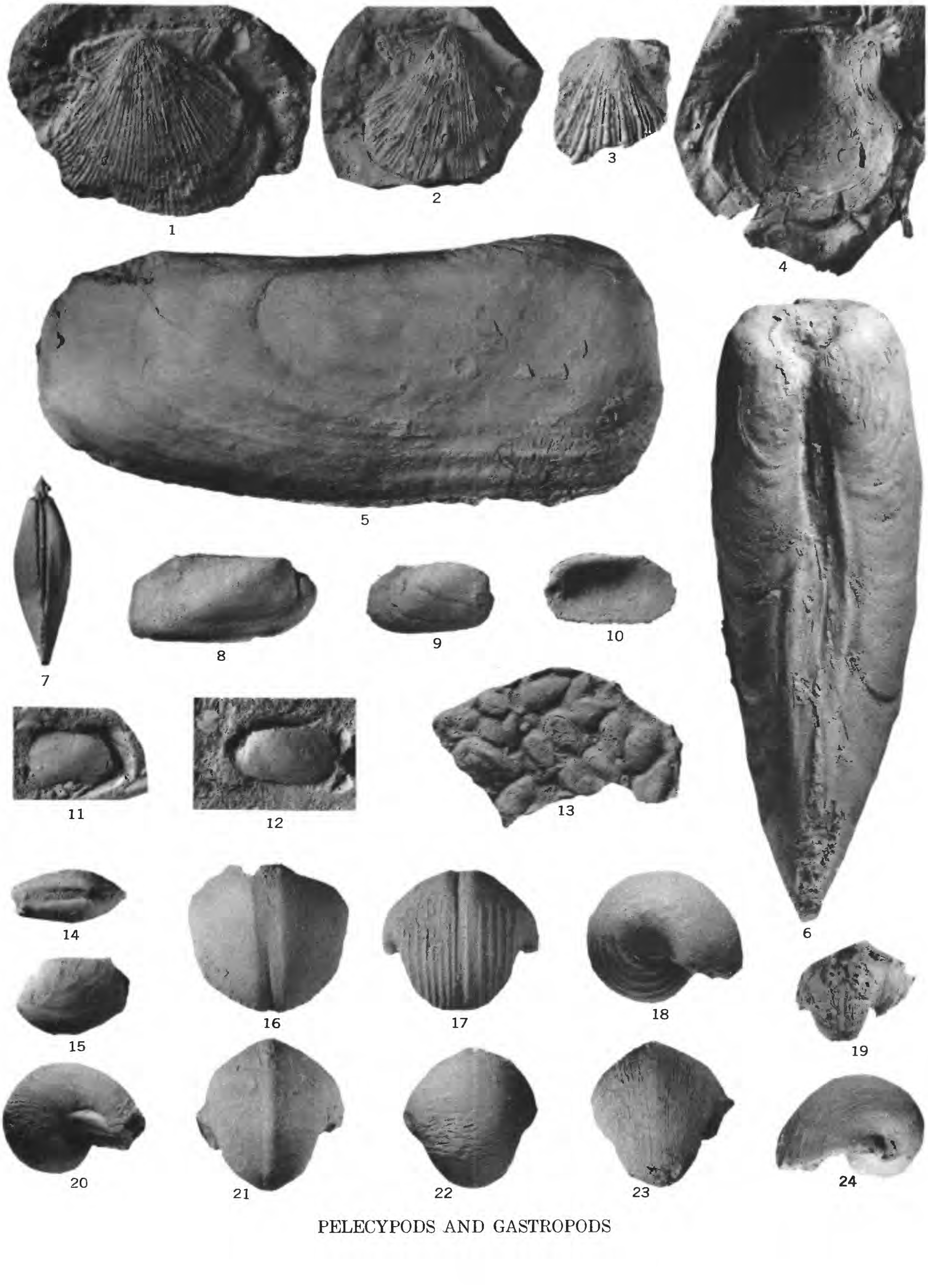
16–18. *Euphemites* sp. (p. 91).
Figured specimen. × 3. USNM 134627. From USGS loc. 14874, Wamego shale member, Zeandale limestone.

19. *Knightites* (*Retispira*) sp. (p. 92).
Rubber squeeze of figured specimen. × 1. USNM 134628. From USGS loc. 13617, Falls City limestone.

20, 22. *Bellerophon singularis* Moore (p. 91).
Hypotype. × 3. USNM 134629. From USGS loc. 14841, Wamego shale member, Zeandale limestone.

21. *Bellerophon* cf. *B. graphicus* Moore (p. 92).
Hypotype. × 3. USNM 134630. From USGS loc. 14841, Wamego shale member, Zeandale limestone.

23, 24. *Knightites* (*Retispira*) *tenuilineata* (Gurley) (p. 92).
Hypotype. × 2. USNM 134631. From USGS loc. 14841, Wamego shale member, Zeandale limestone.



PELECYPODS AND GASTROPODS

PLATE 17

FIGURES 1, 2. *Amphiscapha muricata* (Knight) (p. 92).
Hypotype. × 2. USNM 134632. From USGS loc. 13501, Dover limestone member, Stotler limestone.

3, 4. *Omphalotrochus obtusispira* (Shumard) (p. 92).
Hypotype. × 1. From Kansas University loc. 2874, NE¼ sec. 16, T. 31 S., R. 8 E., Cowley County, Kans. Florena shale member, Beattie limestone.

5, 6. *Omphalotrochus wolfcampensis* Yochelson (p. 93).
Figured specimen. × 1. USNM 134633. From USGS loc. 14883, unit 4, Neva limestone member, Grenola limestone.

7. *Araeonema* sp. (p. 94).
Figured specimen. × 15. USNM 134634. From USGS loc. 13532, Tarkio limestone member, Zeandale limestone.

8, 9, 15. *Glabrocingulum* sp. (p. 93).
Figured specimens. × 3. USNM 134635a, 134635b. From USGS loc. 14872, Dry shale member, Stotler limestone.

10–12. *Phymatopleura* aff. *P. brazoensis* (Shumard) (p. 93).
Hypotype. × 4. USNM 134636. From USGS loc. 13746, Friedrich shale member, Root shale.

13, 14, 17–19. *Naticopsis* spp. (p. 94).

13, 14. Figured specimen. × 2. USNM 134637. From USGS loc. 13526, Aspinwall limestone member, Onaga shale.

17. Figured specimen. × 4. USNM 134638. From USGS loc. 13532, Tarkio limestone member, Zeandale limestone.

18, 19. Figured specimen. × 2. USNM 134639. From USGS loc. 14924, Dry shale member, Stotler limestone.

16. *Naticopsis subovata* Worthen *in* Meek and Worthen (p. 94).
Hypotype. × 2. USNM 134640. From USGS loc. 13532, Tarkio limestone member, Zeandale limestone.

20. *Dentalium* sp. indet. (p. 94).
Figured specimen. × 2. USNM 134641. From USGS loc. 13842, Friedrich shale member, Root shale.

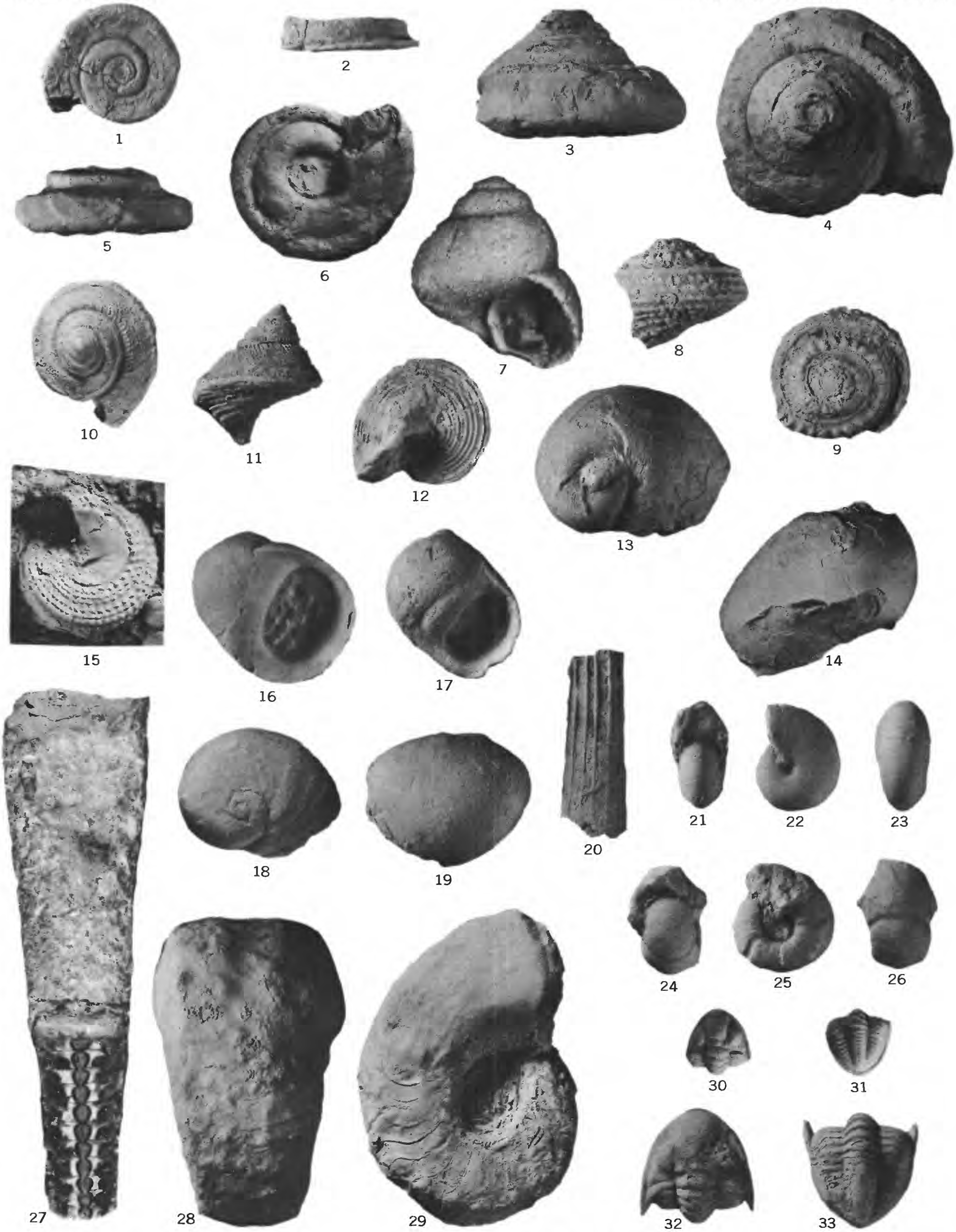
21–23. *Neoaganides grahamense* Plummer and Scott (p. 96).
Hypotype. × 6. USNM 134642. From USGS loc. 14873, Grandhaven limestone member, Stotler limestone.

24–26. *Gonioloboceras goniolobum* (Meek) (p. 96).
Hypotype. × 6. USNM 134643. From USGS loc. 14873, Grandhaven limestone member, Stotler limestone.

27. *Pseudorthoceras knoxense* (McChesney) (p. 95).
Hypotype. × 2. The lower part has been ground and polished to show the siphuncle. USNM 134644. From USGS loc. 13693, Wamego shale member, Zeandale limestone.

28, 29. *Tainoceras* sp. (p. 95).
Hypotype. × 1. USNM 134645. From SW¼, sec. 35, T. 28 N., R. 8 E., Greenwood County, Kans. lower part of Burr limestone member of Grenola limestone.

30–33. *Ditomopyge*? *decurtata* (Gheyselinck) (p. 96).
Hypotypes. × 2. USNM 134646a, 134646b. From USGS loc. 13775, Florena shale member, Beattie limestone.



GASTROPODS, CEPHALOPODS, AND TRILOBITES