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ARTICULATE BRACHIOPODS OF THE VIOLA FORMATION (ORDOVICIAN) IN THE ARBUCKLE MOUNTAINS, OKLAHOMA

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ARTICULATE BRACHIOPODS OF THE VIOLA FORMATION (ORDOVICIAN) IN THE ARBUCKLE MOUNTAINS, OKLAHOMA

Leonard P. Alberstadt [1]

Abstract — Thirty-seven species of articulate brachipods from the Viola Formation in the Arbuckle Mountains in Pontotoc, Coal, Johnston, Carter, and Murray Counties, south-central Oklahoma, are described. Nine new species have been described from the genera of *Hesperorthis, Glyptorthis, Austinella, Doleroides, Platystrophia, Paucicrura,* and *Megamyonia.* The various species are concentrated in the middle and upper parts of the formation, and many specimens are silicified, showing excellent detail and internal characteristics.

The Viola Formation has been divided here into three informal units on the basis of lithology (in ascending order): unit 1, composed of subunits 1L and 1C; unit 2; and unit 3, composed of subunits 3C and 3CM. Units 2 and 3 contain most of the brachiopods described in this paper, although several species are from unit 1, subunit 1C. No articulate brachiopods were found in subunit 1L.

The only persistent faunal-assemblage zone occurs in the upper part of unit 3 and can be found at numerous localities throughout the Arbuckles. the brachiopod fauna from this unit is characterized by species of *Austinella, Hesperorthis, Glyptorthis, Platystrophia, Plaesiomys, Paucicrura, Thaerodonta,* and *Lepidocyclus.* Based on genera in common, this fauna is most like the brachiopod fauna of the Montoya Group of west Texas and New Mexico, followed by that of the Maquoketa Formation of Iowa, the Richmond Group of the Ohio Valley, and the upper Bighorn Formation of Wyoming. At the species level the fauna from unit 3 is easily distinguishable from most others, making comparisons with other faunas at this level difficult to correlate. Most of the new species described in this paper are from unit 3.

Fewer specimens are available from units 1 and 2. The brachiopods from unit 2 are similar to some in the Galena Formation and some in the lower Maquoketa Formation of Iowa. However, most of the specimens from the upper part of unit 2 are poorly preserved, and few show good interiors. The small number of species that occur in the lower part of subunit 1C are most like the brachiopods in the Decorah Formation of the Midcontinent.

Based on all available faunal evidence, the upper part of unit 2 and the lower part of unit 3 are interpreted to be Edenian-Maysvillian in age, and the upper part of unit 3 and the Sylvan Shale to be Richmondian in age.

INTRODUCTION

The rocks referred to as the Viola and "Fernvale" Formations are well exposed in the Arbuckle Mountains in Pontotoc, Coal, Johnston, Carter, and Murray Counties of south-central Oklahoma (text-fig. 1). The outcrop area of the Viola and "Fernvale" is shown in text-figure 2. These strata range in age from Middle to Late Ordovician and represent a continuous sequence of marine-carbonate deposition overlain by the Sylvan Shale (Upper Ordovician, Richmondian Stage; Berry, 1960, table 2) and underlain by the Corbin Ranch (Bromide "dense") Formation (Middle Ordovician, Wilderness Stage; Cooper, 1956, chart 1). In this paper the following unit designations will be used for the Viola-"Fernvale" sequence.

Unit 3
- Subunit 3C
- Subunit 3CM

Unit 2

Unit 1
- Subunit 1L
- Subunit 1C

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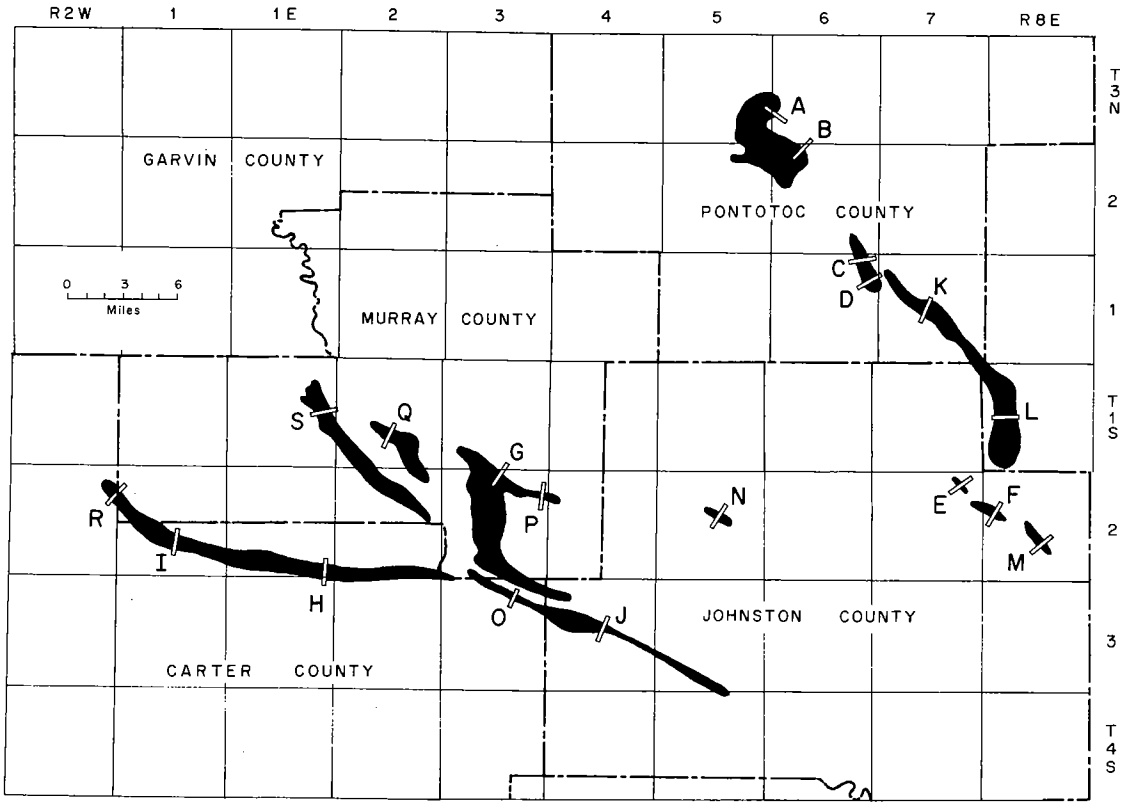
Text-figure 1. Index map of Oklahoma showing location of Arbuckle Mountains in south-central Oklahoma.



Text-figure 2. Generalized outcrop map of Viola Formation showing location of sections referred to in this study (**after** Glaser, 1965); shaded areas indicate extent of Viola.

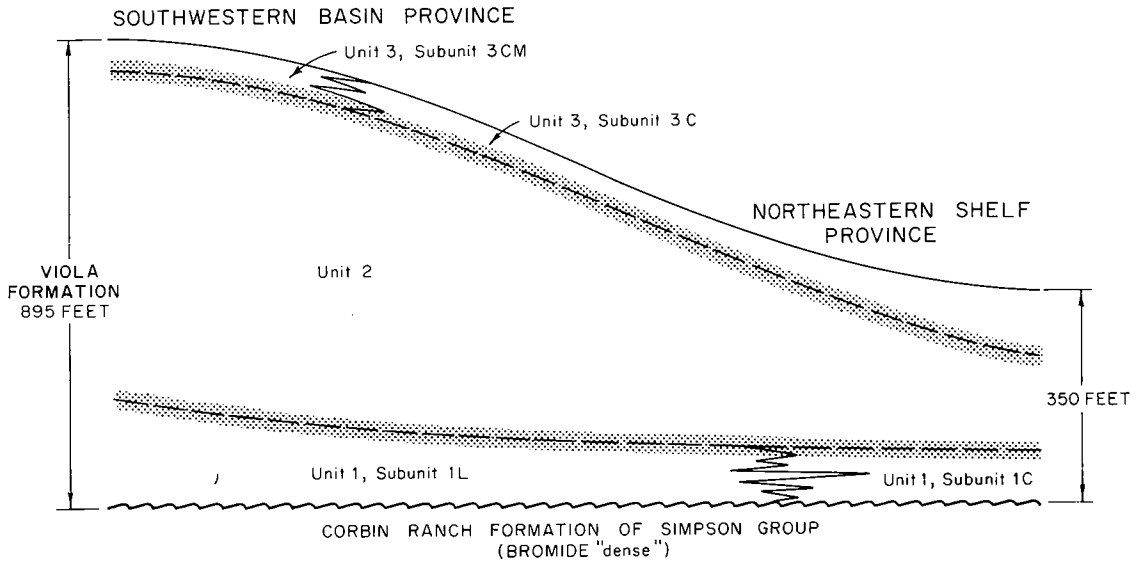
Unit 3 is the rock unit previously referred to as the "Fernvale" Formation. Units 1 and 2 are those rocks previously referred to as the Viola Formation (Ulrich, 1911; Wengerd, 1948; Twenhofel and others, 1954).

Templeton and Willman (1963) proposed the name Cape Limestone to replace the name "Fernvale" Formation in Illinois, Missouri, Arkansas, and Oklahoma. I believe that, because of the stratigraphic relationship between the "Fernvale" (unit 3) and the Viola, another name should be used.

Contacts between units of the Viola Formation are gradational, and as a result, definite boundaries cannot be designated. These gradational rocks are referred to in this paper as "transitional intervals" (text-fig. 3). Except for these "transitional intervals," which resemble both overlying and underlying rocks, the various units have distinctive lithologic aspects and can be recognized easily.

Historical Review

Taff (1902) first described the Viola Limestone from an outcrop near the village of Viola in Johnston County, Oklahoma. He recognized the limestone as a continuous but slightly variable deposit approximately 700 feet thick and included the coarsely crystalline limestone near the top ("Fernvale"; unit 3 in this paper) as part of the Viola. Taff (1903) also recognized the tripartite division of the Viola based on faunal studies made by E. O. Ulrich, with each section making up about one-third of the 700-foot thickness. Brachiopods collected from the lower unit were *Dinorthis pectinella* (Emmons) and *Rhynchotrema increbescens* Hall. The only brachiopod reported from the middle unit was *Rafinesquina deltoidea* Conrad. The upper member was described as fossiliferous only in the top 25 feet, which Taff said was characteristic of the upper Richmond deposits of Minnesota, Wisconsin, Illinois, Indiana, and Ohio. Brachiopods recognized from this upper part were *Plectorthis* (a new genus, according to Taff), *Strophomena wisconsinensis* Whitfield, *Leptaena unicostata* Meek and Worthen, *Orthis kankakensis sweeneyi* Winchell, *Dinorthis subquadrata* Hall, *Dinorthis proavita* Winchell and Schuchert, *Dalmanella macrior* Sardeson, *Platystrophia acutilarata* Conrad, *Rhynchotrema capax* Conrad, and *Parastrophia divergens* Hall. Taff stated that the fauna of this upper unit was the same as the one that occurs in the



Text-figure 3. Diagrammatic sketch of Viola Formation in the Arbuckle Mountains, showing stratigraphic positions and relationships of various units; dashed line indicates approximate boundaries between units; shaded area indicates transitional interval.

Polk Bayou Limestone of Arkansas and in the Fernvale Formation of Tennessee. However, he did not use the name Fernvale as a formational term in Oklahoma.

Ulrich (1911) postulated an early Richmondian transgression in the Midcontinent at the base of the Fernvale Formation (unit 3). He stated that on the eastern and southern flanks of Ozarkia the Fernvale overlapped beds of Mohawkian age and rested on much older pre-Ordovician rocks. Furthermore, he stated that the Fernvale (unit 3) was recognized in the Arbuckle Mountains by a 2-3-foot bed at the top of the Viola Limestone and was characterized by the same lithology and fauna as the Fernvale in southeastern Missouri.

Dake (1921) divided the Viola Formation in the Arbuckle Mountains into three units, of which the upper was about 300 feet thick. He indicated that the fauna of this upper unit was the same as the fauna in the Fernvale in Arkansas and Missouri but questioned whether the entire 300 feet should be assigned a Richmondian age. He believed that possibly the less fossiliferous beds below represented earlier Cincinnatian deposits. In a stratigraphic cross section, Dake (1921, p. 11) depicted the Fernvale of southern Illinois, Missouri, and Arkansas as unconformably overlying the Kimmswick Limestone. The extension of this diagram into Oklahoma shows the Viola-Fernvale as a continuous sequence. The unconformity is shown to die out somewhere between the Arkansas-northeastern Oklahoma section and the Arbuckle Mountains.

Edson (1927), in discussing the Oklahoma correlations, postulated an unconformity between the Viola and Fernvale Formations in the Arbuckle Mountains.

Ulrich (1927) altered his age determinations for the rocks in the Arbuckle Mountains but maintained that the Fernvale Formation (unit 3) rested unconformably on the underlying rocks. Ulrich's stratigraphic chart shows the Viola Formation as being partly Edenian and partly Maysvillian in age.

Decker and Merritt (1931) subdivided and described the underlying Simpson Group. At the top of the Simpson Group they included about 200 feet of limestone that Taff had assigned to the base of the Viola Formation. This restriction, based in part on Ulrich's work in 1927, has been accepted in all subsequent publications on the Viola Formation and the Simpson Group in the Arbuckle Mountains. These beds are in the upper part of Decker's Bromide Formation, including the Corbin Ranch Formation (Bromide "dense" of Harris, 1957) at the top.

Decker (1933) correlated part of the Viola with the Normanskill, Trenton, Utica, Lorraine, and Richmond Formations on the basis of mollusks and graptolites. Ruedemann and Decker (1934) described the graptolites from the Viola Formation and discussed their stratigraphic and geographic distribution. Their conclusions about correlations were the same as those given by Decker the year before. Clearly Decker considered the Viola to be a continuous deposit with no unconformity at the base of the Fernvale (unit 3), and he continued to use the name "Fernvale," although not as a formation.

Ireland (1936), in his work on residues, noted that the general surface section of the Viola showed three divisions: an upper 50 to 100 feet of coarsely crystalline limestone, a middle 400 to 600 feet of fine-grained, somewhat cherty limestone, and 200 feet of dense lithographic limestone.

Shideler (1937) proposed the name Ada Limestone to replace the name "Fernvale"; however, the name had been used previously for a Pennsylvanian formation. Shideler suggested that possibly the Oklahoma "Fernvale" (unit 3) was older than the type Fernvale in Tennessee.

Wengerd (1948) measured six surface sections of the Viola-"Fernvale," primarily examining subsurface cuttings and insoluble residues, and on the basis of these studies divided the Viola into four members. According to Wengerd, the "Fernvale" (unit 3) unconformably overlies this four-member Viola Formation. Wengerd's cross section (fig. 15 in his report) shows that in the subsurface of the Seminole uplift area (northeast of the Hunton anticline) the "Fernvale" (unit 3) truncates part of his upper member of the Viola Formation. This subsurface truncation was regarded as evidence that an unconformity exists at the base of the "Fernvale" (unit 3) in the Arbuckle Mountains. He did not accept the biostratigraphic evidence of Decker (1933) and Ruedemann and Decker (1934), in-

dicating that the Viola-"Fernvale" sequence shows continuous deposition. More importantly, Wengerd recognized a platform and basin type of framework for deposition of the Viola-"Fernvale" sediments.

Oberg (1966) studied conodonts from the lower 200 feet of the Viola Formation and concluded that this basal portion is early Trentonian in age.

K. V. Bordeau (Univ. of Tennessee at Martin, pers. comm., 1967) described conodonts from the upper Viola Formation in the Arbuckle Mountains and compared them to conodonts from the type Fernvale Formation in Tennessee. He concluded (pers. comm.) that no change exists in the faunal elements within the Viola sequence sufficient to postulate an unconformity between the "Fernvale" (unit 3) and Viola Formations. He also indicated that the conodont fauna of the upper Viola ("Fernvale," unit 3 included) is distinctly different from that found in the type Fernvale of Tennessee.

The chitinozoans from the Viola and "Fernvale" (unit 3) Formations were studied by Jenkins (1969), and he described a faunal break in the upper part of the Viola Limestone, concluding that the upper part of the Viola and the "Fernvale" (unit 3) were considerably younger than the lower Viola. However, Jenkins stated that the break does not coincide with the change from Viola to "Fernvale" (unit 3) lithology, but lies within the Viola lithology. He found no break in faunal continuity at the base of the "Fernvale" (unit 3).

Acknowledgments

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STRATIGRAPHY

The unit designations for the various lithologies of the Viola-"Fernvale" Limestone sequence and the general lithostratigraphic interpretation used in this paper were presented by Glaser (1965). According to Glaser, the limestones of the Viola-"Fernvale" sequence can be subdivided into three distinct units, of which two have equally distinct facies (text-fig. 3). Furthermore, these limestones represent a distinct cycle of completely marine carbonate sedimentation. Glaser postulated a southwestern basin province, ranging in thickness from 550 to 895 feet, and a northeastern shelf province, ranging in thickness from 340 to 420 feet.

Unit 1, Subunit 1L

The basal unit in the basin province is best developed in the Arbuckle and Tishomingo anticlines and is composed of highly siliceous, laminated calcite mudstones characterized by planar bedding and a fauna dominated by graptolites, sponge spicules, and trilobites. No articulate brachiopods were found in this subunit. Subunit 1L, which grades northeastward in the shelf province into subunit 1C, is characteristically developed along Delaware Creek at Camp Simpson Campground, Johnston County.

Unit 1, Subunit 1C

In the northeastern shelf province the rocks of the lower unit are coarse skeletal calcisiltites and fine skeletal calcarenites, best developed on the Hunton anticline. Subunit 1C is characterized by slightly wavy bedding, minor chert nodules, and a fauna dominated by echinoderms and locally by bryozoans. Three species of articulate brachiopods are known from this subunit: *Doleroides vescus* Alberstadt, new species, *Sowerbyella* sp., and *Onniella* sp. This rock unit is best developed along Walnut "Mosely" Creek just north of Bromide in Coal County.

Unit 2

The middle calcarenitic mudstone is the only unit that has been found throughout the Arbuckles, and it thins markedly from the basin onto the shelf. This unit, in both the basin and shelf provinces, is a skeletal calcarenitic mudstone characterized by wavy bedding, variable skeletal content, predominance of mud over spar cement, high content of irregular chert nodules, and a fauna dominated by echinoderms, trilobites, and brachiopods. The brachiopods occur in the lower and upper parts of the unit and include such species as *Platystrophia prima,* new species, *Paucicrura* cf. *P. rogata* (Sardeson), *Sowerbyella* sp., *Leptellina* sp., *Rhynchotrema increbescens* Hall, and *Dinorthis* cf. *D. transversa* Willard. This unit is excellently exposed in a canyon on Buckhorn Ranch south of Sulphur, Murray County.

Unit 3, Subunits 3C and 3CM

In the northeastern shelf province the rocks included in subunit 3C are well-washed coarse calcarenites, best developed on the Hunton anticline. The rocks in this area are usually referred to as the "Fernvale" Formation. They are characterized by massive beds, the absence of chert and calcite mud, and a fauna dominated by echinoderms, trilobites, and brachiopods that are commonly silicified. This subunit contains the greatest abundance of brachiopods in both numbers of species and numbers of individuals. Some of the more common species are *Austinella multicostella,* n. sp., *Platystrophia sutherlandi,* n. sp., *Paucicrura oklahomensis,* n. sp., *Hesperorthis rowlandi,* n. sp., *Glyptorthis glaseri,* n. sp., *Plaesiomys proavitus* (Winchell and Schuchert), *Lepidocyclus capax* (Conrad), *Lepidocyclus cooperi* Howe, *Thaerodonta* aff. *T. magna* Howe, and *Strophomena planumbona* (Hall).

Subunit 3C changes character toward the southwest and in the basin province becomes a skeletal calcarenitic mudstone interbedded with thin, fine to medium calcarenites. This sequence is referred to as subunit 3CM and has been considered by past workers to be "Fernvale," as are the clean, washed calcarenites of the northeastern shelf province (subunit 3C). These calcarenitic mudstone beds are virtually indistinguishable from those of unit 2. The calcarenites contain minor amounts of calcite mud and some chert nodules. The bedding is slightly wavy in character.

Subunit 3C is best exposed at section L. Subunit 3CM is best exposed at sections G and I.

Regional Framework and Depositional History
(*After* Glaser, 1965)

The southwestern basin province differs distinctly from the northeastern shelf province on the basis of different lithologies in the upper and lower units and substantial differences in thicknesses. Because of the absence of sharp, well-defined contacts, the boundaries between the units have been arbitrarily placed, and as a result, thicknesses for the various units are accurate only to within about 20 feet.

In the basin the total thickness for the entire sequence ranges from about 600 to 895 feet; on the shelf the thickness ranges from 340 to 420 feet. The maximum thickness of unit 1, subunit 1L, in the basin is about 382 feet, although in most sections it is about 200 feet thick; equivalent rocks on the shelf average about 150 feet. In the basin the maximum thickness for unit 2 is approximately 473 feet, with the average about 450 feet; this same unit on the shelf is about 130 feet thick. Although the trend to thicker units in the basin and thinner units on the shelf is generally true for the basal and middle units, this relationship is reversed for the upper unit. The maximum thickness for unit 3, subunit 3C, on the shelf is 112 feet, although commonly it is between 60 to 80

feet in thickness; rocks of unit 3, subunit 3CM, in the basin province range from 15 to nearly 50 feet in thickness.

The limestones of the Viola-"Fernvale" sequence represent a cycle of marine carbonate sedimentation that began with deposition of laminated mudstones throughout most of the southwestern basin province in deep and slightly agitated waters, progressed through deposition of the calcarenitic mudstones in intermediate water and energy conditions, and ended with deposition of coarse calcarenites in relatively shallow and highly agitated waters. However, a different pattern existed in the northeastern shelf province where rocks of the basal division are coarse calcisiltites and fine calcarenites (subunit 1C) instead of laminites (subunit 1L). Thus, on the shelf the sequence began with deposition of high-energy calcarenites, continued with the deposition of lower energy calcarenitic mudstones (unit 2), and then reverted to deposition of high-energy calcarenites (unit 3). Calcarenites constitute about two-thirds of the Viola-"Fernvale" sequence on the shelf but less than 10 percent in the basin.

Age and Correlation

During the past 10 years much work has been done on the lithostratigraphy and biostratigraphy of the Middle and Upper Ordovician rocks in the Ohio Valley region, but understanding of the brachiopod biostratigraphy of this region is still incomplete. One of the fundamental difficulties in evaluating the Edenian, Maysvillian, and Richmondian Stages of the Cincinnatian Series was the use of fossils by many early workers to define characteristics of formations and members. Few early workers attempted to study and define their rock units on lithology alone or to clearly separate rock and faunal concepts. Cumings was an exception.

Species such as *Lepidocyclus capax* (Conrad), *Plaesiomys subquadratus* (Hall), and *Strophomena planumbona* (Hall) have long been considered indicative of the Richmondian Stage. The stratigraphic ranges of these and other Cincinnatian species, however, have never been evaluated critically from the standpoint of modern concepts. Detailed studies of the lithostratigraphy and biostratigraphy must precede any attempt to formulate a standard stadial classification, but at this time only part of the necessary information is available for the Cincinnatian rocks of the Ohio Valley.

Weiss (1961) reviewed the history of classification of the Cincinnatian rocks in the Ohio Valley type area. He concluded that all changes since 1914 had been refinements of local boundaries, regroupings, renamings, and changes of class or rank. He summarized the problem of setting up a satisfactory standard (1961, p. 646).

> (3) In so far as we now know all elements needed for a thoroughgoing rock-stratigraphic, biostratigraphic, and time-stratigraphic classification are already recognized and named. Their mutual relations and, especially, their behavior regionally, away from metropolitan Cincinnati and the Whitewater River valley, are either misconstrued or unknown.
>
> (4) The conditions described under (3) were inherited from pre-World War I workers, and little or nothing has been done since to clarify matters. Many changes since 1914 have been only refinements of concepts that were inadequate. Such activity has really retarded understanding of the stratigraphy of the type Cincinnatian, although it has had the reputation of advancement of the science of the Ordovician. The failure to distinguish between rock and faunal units or to demonstrate the time-stratigraphic validity of faunal units has been particularly unfortunate. Not only must a reevaluation of the elements of Cincinnatian classifications be made in harmony with modern stratigraphic principles and techniques, but the significance of these elements must be tested over the region of type Cincinnatian outcrop. Only then may we have a clear standard by which to judge Upper Ordovician rocks elsewhere.

The reevaluation suggested by Weiss has been in progress (Sweet and others, 1959; Pulse and Sweet, 1960; Weiss and Norman, 1960; Fox, 1962; Weiss and Sweet, 1964; Weir and others, 1965; Weiss and others, 1965; Brown and Lineback, 1966; Bergström and Sweet, 1966; and Ford, 1967).

Fox (1962) studied the paleoecology of the Richmond Group in southeastern Indiana and discussed the distribution of several faunal zones. This is the only study of those mentioned above that gives any information about distribution of the brachiopod species; the other studies were either descriptions of the conodont faunas or lithostratigraphic investigations redefining various rock units.

Cumings (1907) presented an excellent study of the Cincinnatian rocks of Indiana in which he carefully determined the stratigraphic ranges of many fossil species and listed them in his lithologic descriptions. From this work it is possible to get a reliable understanding of the relationships between various faunal units and the rocks.

Cumings and Galloway (1913) reported the stratigraphic ranges of many Cincinnatian species from the Tanner's Creek section in Dearborn County, Indiana. Because the section at Tanner's Creek is exposed almost completely (probably from the upper Edenian to the upper Richmondian), the reported stratigraphic ranges and positions of the species seem reliable.

Caster and others (1961) described the rocks and fossils from around Cincinnati, Ohio. They determined the stratigraphic ranges of the species and plotted them against the formational units used in that region. Since then, some revision of the lithostratigraphy has been made, but the general relationships among the positions of the species are probably still correct.

Maquoketa Group.—Wang (1949) considered the Maquoketa Group of Iowa to be Late Ordovician in age; however, he made no specific comment on the relationship of the brachiopods of the Maquoketa to the brachiopods of the type Edenian, Maysvillian, and Richmondian Stages in Ohio and Kentucky. He did not mention the presence in the Maquoketa Group of Edenian, Maysvillian, or Richmondian Stages. According to Wang, the purpose of his brachiopod study was to supplement the stratigraphic work published in 1929 by Ladd, who believed that the Maquoketa Group was of Richmondian age. One can only speculate as to why Wang did not make any comparisons with the brachiopods of the Ohio Valley type region. It seems unlikely that by Late Ordovician age Wang meant that the Edenian, Maysvillian, and Richmondian are all represented in the Maquoketa. I believe that because Wang did not specifically state otherwise he accepted Ladd's interpretation that the Maquoketa Group was of Richmondian age.

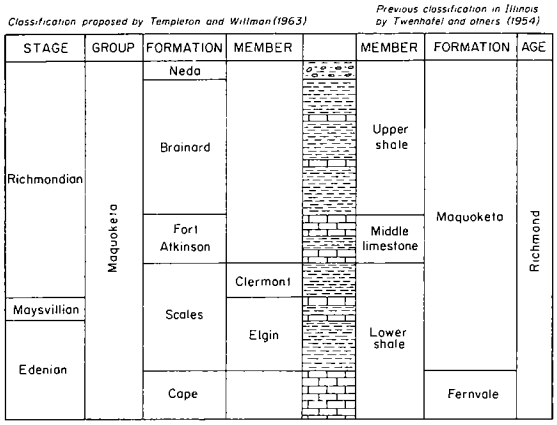
Several writers have attempted to improve and clarify correlations between the Upper Ordovician rocks of the Ohio Valley and those in Iowa. Gutstadt (1958) made a lithostratigraphic study of Upper Ordovician rocks in Indiana, Illinois, Missouri, and Iowa using surface and subsurface information. The use of subsurface information was necessary because of the large area in Indiana and Illinois in which these rocks are not exposed. Gutstadt concluded that the Maquoketa Group of Iowa contains strata of Edenian, Maysvillian, and Richmondian age.

Sweet and others (1959), in discussing the Eden conodonts from the type section, presented paleontological evidence supporting Gutstadt's interpretation (p. 1038).

> The Elgin, Clermont, and Ft. Atkinson members of the Maquoketa Formation in Iowa, which succeed the Stewartville and Dubuque stratigraphically, lack the distinctive Anglo-Scandinavian elements of the subjacent Stewartville and Dubuque, but they contain *Phragmodus undatus, Dichognathus,* and *Belodina* (in addition to other things) which suggests to us that these units are late Edenian and Lower Maysvillian in age. The lower shaly part of the Brainerd member lacks *Belodina,* but contains *Phragmodus undatus* and *Dichognathus,* indicating that it may be of upper Maysville (McMillan) age. The Brainerd limestone, on the other hand, seems to contain a "flood" of *Panderodus,* as does the type Richmond — but it also contains a few *Phragmodus,* which may indicate that it is no younger than the Arnheim (early Richmond), in which *Phragmodus* seems to make its last appearance.

Based primarily on this conodont information, Templeton and Willman (1963) revised the stratigraphic interpretation and terminology of the Maquoketa strata in Illinois. Text-figure 4 shows the previous stratigraphic subdivisions (Twenhofel and others, 1954) and those proposed by Templeton and Willman. Templeton and Willman (1963) proposed the name Cape Limestone to replace the name Fernvale in Illinois, Missouri, Arkansas, and Oklahoma. According to them the Cape Limestone is of Edenian age and is the initial deposit of the Cincinnatian Series.

Upper Ordovician rocks in Missouri.—The Upper Ordovician section in southeastern Missouri is composed of the following rock units in ascending order: Cape (Fernvale) Limestone, Maquoketa Shale, Thebes Sandstone, Orchard Creek Shale, and Girardeau Limestone. For a long time this rock sequence was considered to be entirely of Richmondian age and to overlie unconformably the Kimmswick Limestone of



Text-figure 4. Comparison of stratigraphic classifications of Maquoketa Formation in Illinois by the Ordovician Subcommittee of the Committee on Stratigraphy of the National Research Council (Twenhofel and others, 1954) and by Templeton and Willman (1963).

Trentonian age (Twenhofel and others, 1954). However, many paleontological studies showed that the rocks in southeastern Missouri were probably older than Richmondian. Keenan (1951) studied ostracodes from the Maquoketa Shale and reported 28 species—19 were new, 3 common to the lower Maquoketa of Iowa, 3 common to the Eden Group of Cincinnati, Ohio, and 3 common to the Maysville Group of the Ohio Valley. Hardy (1946) studied the conodonts of the Cape (Fernvale) Limestone of southeastern Missouri and concluded that it was either of Edenian or Maysvillian age. Branson and others (1951) made the following statement about the conodonts from the Cape (Fernvale) of southeastern Missouri (p. 4).

> A crystalline limestone known as the Fernvale lies between the Kimmswick and Maquoketa in some parts of Missouri and is commonly referred to the Richmond. This age reference has somewhat confused the conodont picture, but it is now known that the Fernvale of Missouri contains a fauna not greatly different from that of the Kimmswick or that of the overlying Maquoketa. There is a normal trend in the faunas from the Plattin, through Kimmswick and Missouri "Fernvale" to Maquoketa, and the Maquoketa fauna is a normal connecting link with the Richmond.

Sweet and others (1959) also commented on the Missouri section (p. 1039):

> The Thebes sandstone member of the Orchard Creek yielded most of Branson & Mehl's "Maquoketa" conodonts. This unit contains *Amorophognathus* and *Ambalodus triangularis*, as well as *Scolopodus insculptus*, *S.? dissimilaris*, and *Phragmodus simplex*, a species much like a *Phragmodus* that appears in the Fairview formation (early Maysville) of Ohio. Since neither *Amorphognathus* nor *Ambalodus triangularis* appears to range beyond the Fairview formation, it seems probable that the Thebes sandstone is either very late Edenian or early Maysvillian in age.

Based on conodont evidence, the basal two-thirds of the Maquoketa Group of Iowa and the Cape Limestone of Missouri seem to be of Edenian-Maysvillian age. However, evidence has been presented indicating that Middle and Upper Ordovician conodont correlations in the Midcontinent are still questionable (Bergström and Sweet, 1966). In a study of the Lexington Limestone (Middle Ordovician) of Kentucky these authors stated as follows (p. 285).

> Early in our studies of Lexington conodonts it became apparent that the large and varied fauna described on subsequent pages appeared first at or near the base of the Lexington and its equivalents and persisted with little change in form or composition through the Lexington into younger rocks. All but a few Lexington species continue upward through rocks of Maysvillian and Richmondian age and the apparent distinctions between Edenian, Maysvillian, and Richmondian faunas reported in previous studies (Sweet, *et al.*, 1959; Sweet, 1959; Pulse and Sweet, 1960; Sweet and Rust, 1962; Branson, Mehl, and Branson, 1951) result largely from vertical fluctuations in the relative abundance of species that appeared in the Cincinnati Region early in Lexington time.

Bergström and Sweet (1966) pointed out that most of the Middle and Upper Ordovician conodonts of the Midcontinent have long stratigraphic ranges. This makes it difficult if not impossible to divide the section into biostratigraphic zones that are persistent and useful for correlation either in or beyond the boundaries of the Cincinnati region. Thus, for regional biostratigraphic correlations, Bergström and Sweet were unable to use methods that depend on the total stratigraphic range of species, so they adopted a method of correlation commonly used in palynology in which vertical changes in relative abundance of dominant species are noted. The authors stated that this was a newly suggested conodont procedure and for

that reason should undergo further examination and discussion. Their regional correlations (p. 265), based on this relative-abundance method, show the Maquoketa Formation of Minnesota as being Edenian in age. Unfortunately, they did not discuss the possible ages of the Maquoketa of Iowa or the Cape Limestone of southeastern Missouri on the basis of this unorthodox conodont-correlating technique.

Maravillas Chert of Texas.—Although no detailed study of the brachiopods from the Maravillas Chert of Texas has been done, the correlations proposed by Berry (1960) for the Maravillas and the Viola Formation are biostratigraphic evidence that should be considered. Ulrich (1911) divided the Maravillas Chert, as he did other western formations, into a lower part correlated with the Trenton and an upper part correlated with the Fernvale-Richmond. Thus, as with the Viola-"Fernvale" in Oklahoma, rocks representing the Edenian and Maysvillian Stages were thought to be absent in Texas. Berry (1960, p. 31) divided the Maravillas Chert into three graptolite zones. The lowest zone was interpreted to be of Trentonian age, the middle of Edenian and Maysvillian ages, and the upper zones of Richmondian age.

Berry (1960) studied the graptolites collected by Charles Decker from the Viola Formation in the Arbuckle Mountains. Berry divided the Oklahoma section into the Viola Formation, the Fernvale Formation, and the Sylvan Formation. By comparing the graptolites from these formations to those from the Maravillas Chert in Texas, he concluded that the lower Viola Formation represented the Trentonian Stage, the upper Viola represented the Edenian-Maysvillian Stage, and the Fernvale-Sylvan represented the Richmondian Stage, the same conclusion reached by Decker (1933) and Ruedemann and Decker (1934).

The interpretation that the highest part of the Viola (unit 3; Decker's Fernvale phase and Berry's Fernvale Formation) is of Richmondian age is important. Most of the graptolite species in the Oklahoma section occur in the lower part of the Viola Formation and in the Sylvan Shale; few graptolites have been reported from the upper Viola. According to Decker (1933), the four graptolite species in the upper part of the Viola Formation that indicate a Cincinnatian age are *Diplograptus recurrens* Ruedemann (*Orthograptus truncatus* var. *recurrens* of Berry, 1960), *Climacograptus lorrainensis* Ruedemann, *Climacograptus typicalis posterus* Ruedemann, and *Diplograptus peosta* Hall. Decker correlated unit 3 (his Fernvale phase) with the Richmond on the basis of the occurrence of one graptolite species: *Diplograptus peosta.* According to Decker (1933), *Diplograptus peosta* also occurs in the Maquoketa Formation of Iowa (Ladd reported it from the lower part of the Maquoketa). Because the Maquoketa Formation of Iowa was considered to be of Richmondian age, Decker interpreted the upper Viola to be Richmondian also. It should be noted that *Diplograptus peosta* has not been reported from the type Richmond in the Ohio Valley.

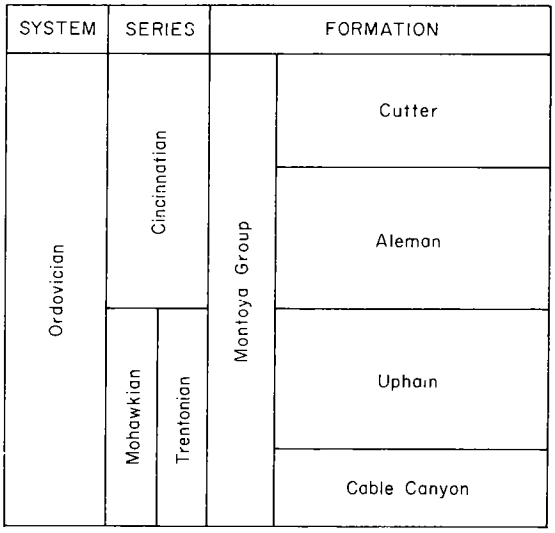
All of the other graptolites from the upper Viola, *Diplograptus recurrens* (*Orthograptus truncatus* var. *recurrens* of Berry, 1960), and *Climacograptus typicalis posterus,* indicate an Edenian or Maysvillian correlation. All of Berry's (1960) Richmondian graptolites from Oklahoma are reported from the Sylvan Shale (his zone 15); none are reported from the upper Viola (Berry's Fernvale Formation). The highest graptolite reported from the Viola Formation by Berry (unit 2) is *Orthograptus truncatus* var. *recurrens*, which according to Berry (1960) also occurs in the Lorraine Group of New York, indicating an Edenian-Maysvillian age. Berry did not report *Diplograptus peosta, Climacograptus lorrainensis,* or *Climacograptus typicalis posterus* from any of the Viola or Sylvan rocks.

In reviewing the graptolite data, the only evidence for interpreting the upper Viola (unit 3) as being Richmondian in age seems to be the reported occurrence of *Diplograptus peosta* in both the Viola and Maquoketa Formations. This age determination must be questioned because of the reevaluation of the age of the Maquoketa. Berry (1960) did not state his reasons for designating his Fernvale Formation (unit 3) as Richmondian, despite the fact that he did not report any graptolites from this unit.

Montoya Group of west Texas and New Mexico.—Howe (1959) made a lithostratigraphic study of the Montoya Group in west Texas and New Mexico in

which he included the occurrence of numerous brachiopods. Text-figure 5 shows the stratigraphic classification used by Howe for the Montoya. He concluded that Edenian, Maysvillian, and Richmondian Stages are probably represented by the Aleman Limestone, but he made no attempt to designate boundaries between the three stages. Note that this biostratigraphic conclusion was made with reservation because it was based largely on comparisons with the Maquoketa fauna studied by Wang (1949). As Howe pointed out (1959, p. 2315), the precise age determination of the Aleman Limestone will depend on a correct age determination for the Maquoketa Formation. However, Howe (1959) seems to have based his interpretation partly on the lack of physical evidence for any unconformities and partly on lithostratigraphic evidence presented by Gutstadt (1958), indicating that the Maquoketa of Iowa contains strata equivalent to the Eden, Maysville, and Richmond rocks of the Ohio Valley. The correlation of the lower Aleman Limestone with the lower Maquoketa of Iowa (?Edenian) requires that the underlying Upham Limestone be of late Trentonian age. This interpretation is supported by the evidence of Flower (1957), who noted that the cephalopods (Actinoceratida) of the Upham have strong affinities with the faunas of the Cynthiana, Catheys, Kimmswick, and Rogers Gap Formations.

Bighorn Formation of Wyoming.—Macomber (1970) described the articulate brachiopods from the Bighorn Formation of Wyoming and discussed the possible correlations with other areas, and his presentation of the reasons why discrepancies exist in Cincinnatian correlations is most valuable. He claimed that the primary reason for these discrepancies was because of the rapid migration of "arctic" forms into the Ohio Valley region. This sudden appearance of new forms gave the Richmond rocks in the Ohio Valley a completely different faunal appearance from the underlying formations. This faunal difference seems to account for the correlation of older rocks in the western United States and Canada with Richmondian rocks in the type region of the Ohio Valley. According to Macomber (1970, p. 424):



Text-figure 5. Stratigraphic classification of Montoya Group of west Texas and New Mexico (after Howe, 1959).

> The influx of exotic forms must represent a migration into the Ohio Valley area of elements related to the "arctic" fauna, as suggested by Twenhofel (1928 [1927], p. 66), for their progenitors are not found in the type area. Unfortunately, this situation makes the type Upper Ordovician of little use either in establishing a zonation or in correlation. It explains, however, why the Manitoba, New Mexico, Wyoming, Maquoketa, and other "arctic" faunas were correlated with the type Richmondian on the Ordovician Correlation Chart (Twenhofel et al., 1954) in spite of the fact that such correlations, and the attendant "Eden-Maysville hiatus," are incompatible with regional relationships and correlations based on lithologic similarity: because of the timing of the migration, the Richmond is the only unit in the Ohio Valley that contains a significant proportion of "arctic" genera.

Viola Formation of Oklahoma.—At this time, completely satisfactory age determinations based on brachiopod evidence cannot be made for the various units of the Viola Formation because (1) many parts of the Viola contain no brachiopods or only poorly preserved brachiopods, (2) many of the species from the Viola Formation are new, particularly in unit 3, and (3) some question still exists as to the age of equivalent rocks in other geographic areas. This last reason particularly refers to the Maquoketa Formation of Iowa, the Montoya Group of west Texas and New Mexico, and the Cape Limestone of southeastern Missouri.

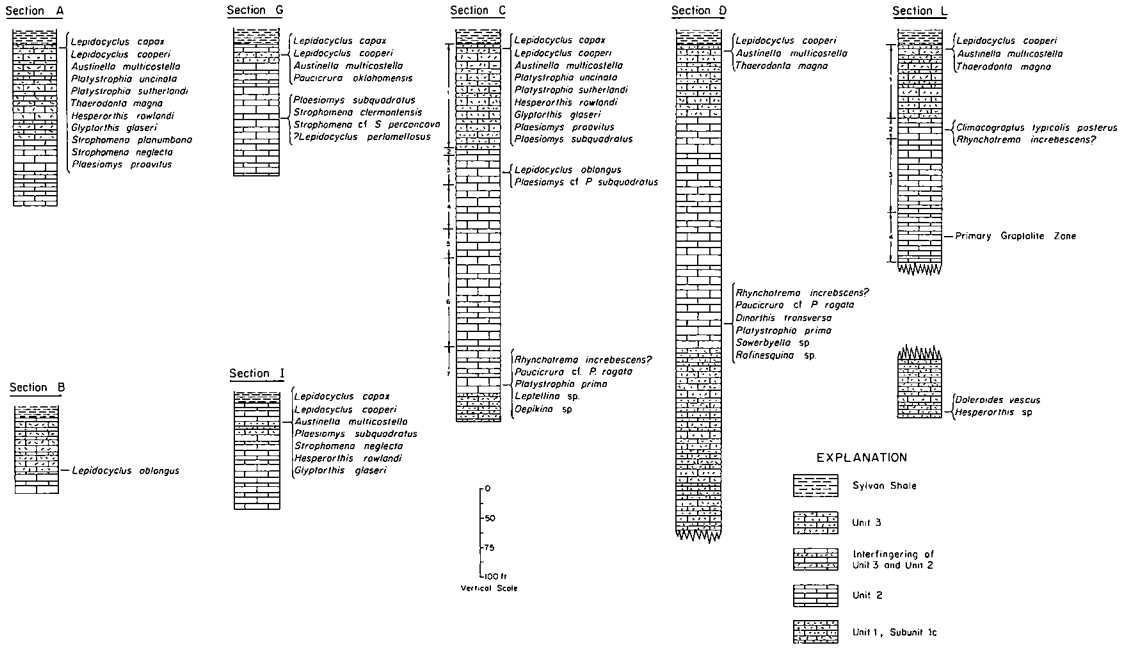
The Viola Formation contains a brachiopod fauna similar to that of rocks of the upper Champlainian and Cincinnatian Series. A generalized section showing the stratigraphic distribution of the brachiopod species of the Viola Formation in the Arbuckle Mountains is given in text-figure 6. In addition, text-figure 6 shows the distribution of some of the "key" graptolites as reported by Decker (1933) and Ruedemann and Decker (1934), as well as several of the graptolite species reported by Berry (1960) from the Sylvan Shale.

Brachiopods from units 1 and 2, Viola Formation.—The brachiopods from units 1 and 2 of the Viola Formation are fewer in number of individuals but are represented by about the same number of species as unit 3. Nowhere in either unit 1 or 2 were any persistent brachiopod zones noted. Most of the species reported from these two units come from the shelf province, and of these the best preserved and most abundant are from section C, 270-280 feet below the top of the formation. Twenty species come from these two divisions: 6 from subunit 1C and 14 from unit 2. No articulate brachiopods were found in unit 1, subunit 1L.

Those species from the lower part of unit 2 are similar to species in the Galena Formation, and those from the upper part of unit 2 compare favorably with species from the lower Maquoketa Group of Iowa. Almost none of the species from the upper part of unit 2 are represented by numerous specimens or by interiors; therefore, statements about similarities and comparisons to and differences from other faunas must be interpreted carefully.

The brachiopods from unit 1, subunit 1C, correlate this subunit with the Decorah Formation. However, because only six species were found here, this correlation is tentative at best. Berry (1960), on the basis of graptolites, believed that the lower Viola represents the upper Wilderness and lower Trentonian Stages. Cooper (1956) had made the same interpretation.

Brachiopods from unit 3, Viola Formation.—The brachiopods that occur in unit 3 of the Viola Formation have always been interpreted as representing the Richmondian Stage. However, many of the forms found in unit 3 are new species and make comparisons with other faunas at the species level tentative with regard to correlation.



Text-figure 6. Selected sections showing distribution of certain graptolites and brachiopods from Viola Formation in the Arbuckle Mountains, including several key graptolite species studied by Decker (1933) and Ruedemann and Decker (1934). Decker's zone numbers are indicated at left of some of the stratigraphic sections.

The brachiopods appear to be most closely related to those of the Montoya Group of west Texas and New Mexico, the Maquoketa Group of Iowa, and the Bighorn Formation of Wyoming. The genera that most characterize the fauna of unit 3 are *Austinella, Paucicrura, Hesperorthis, Glyptorthis, Lepidocyclus* (two species), *Platystrophia* (two species), *Thaerodonta,* and *Plaesiomys.* All except *Thaerodonta, Plaesiomys,* and *Lepidocyclus* are represented by new species. These genera are considered to characterize the fauna in that they are all present in large numbers and can be found at several localities throughout the Arbuckle Mountains.

Table 1 shows data modified from Macomber (1970), indicating the abundance of genera found at most of the Upper Ordovician localities from which brachiopods have been reported. The table shows the relationships of these faunas to the one in unit 3 of the Viola. All of the characteristic genera from unit 3 are present in the Montoya Group, all except *Hesperorthis* are present in the Maquoketa Group, and all except *Glyptorthis, Austinella,* and *Paucicrura* are present in the Bighorn Formation of Wyoming.

A similar comparison of these eight characteristic genera from unit 3 with those from the Richmond Group in the type region of the Ohio Valley shows that all but two, *Hesperorthis* and *Paucicrura,* are common. The genus *Austinella* is present in the Ohio Valley but cannot be considered one of the characteristic genera of that region because of its scarce occurrence; however, *Austinella* is probably one of the most characteristic genera in unit 3.

Based on genera in common, the unit 3 fauna is most like the Montoya fauna (all characteristic genera are common), followed by the Maquoketa (all except *Hesperorthis* are common), the Richmond in the Ohio Valley (all except *Hesperorthis* and *Paucicrura* are common), and the upper Bighorn of Wyoming (all except *Glyptorthis, Austinella,* and *Paucicrura* are common).

At the species level, however, the unit 3 brachiopod fauna is distinctly different from that in other areas. Almost all of the characteristic genera are represented by new species. *Thaerodonta* and *Plaesiomys* are two genera that occur in large numbers but are represented by species that have been described from Ordovician rocks in other areas. *Lepidocyclus* is represented by two species, *L. cooperi* Howe and *L. capax* (Conrad). The presence of *L. capax* in unit 3 has long been used as evidence that the rocks were Richmondian, an interpretation based on the fact that *L. capax* is such a characteristic species in the Richmond rocks of the Ohio Valley. Howe (1966) described *L. cooperi* from Oklahoma, and as far as I am aware, it has not been reported from localities outside Oklahoma. *Hesperorthis rowlandi* Alberstadt, n. sp., and *Glyptorthis glaseri* Alberstadt, n. sp., occur in large numbers in unit 3, but they are not as different from related species in other areas as are some of the other new species from unit 3. *Austinella multicostella* Alberstadt, n. sp., *Paucicrura oklahomensis* Alberstadt, n. sp., *Platystrophia sutherlandi* Alberstadt, n. sp., and *Platystrophia uncinata* Alberstadt, n. sp., are the most distinctive species in unit 3 and can be easily differentiated from related species.

The lower part of unit 3 (particularly at section B) contains a few brachiopods, of which *Lepidocyclus oblongus* Howe is the most abundant and the most distinctive. Howe (1966b) described this species from material collected from the Cape Limestone in southeastern Missouri. The paleontological work done on the faunas of the Cape Limestone (Keenan, 1951; Hardy, 1946; and Branson and others, 1951) all indicated that the Cape is probably Edenian-Maysvillian in age, and if this is correct, *Lepidocyclus oblongus* Howe may be representative of the Edenian-Maysvillian also. In the Viola Limestone *L. oblongus* occurs only in the basal part of unit 3 and does not stratigraphically overlap the range of *L. capax* and *L. cooperi,* which occur only in the upper part. The interpretation that *L. oblongus* indicates an Edenian-Maysvillian age is compatible with Berry's (1960) interpretation that the rocks immediately below unit 3 (upper part of unit 2) are Edenian-Maysvillian in age.

Several age interpretations can be made for unit 3. First, if the rocks immediately below unit 3 are as young as Maysvillian (graptolite data of Berry, 1960), then unit 3 and the overlying Sylvan Shale may be Richmondian. This interpretation does not agree with the suggestion that *Lepidocyclus oblongus* indicates Edenian-Maysvillian age.

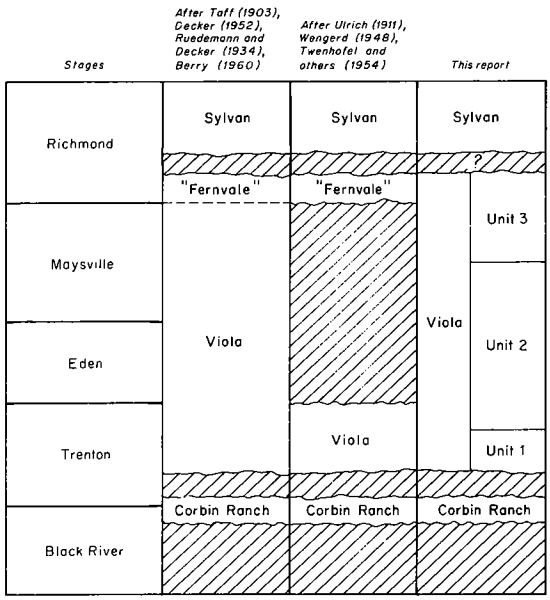
Table 1.—Geographic Distribution of Articulate Brachiopod Genera in Certain Late Ordovician Faunas of North America

All data except for Viola Formation *after* Macomber (1970); explanation used here *modified after* Macomber. Explanation: s, scarce; c, common; a, abundant; p, present, abundance not known; ?, identity uncertain; upper case used where there is more than one species. Number of specimens in scarce species ranges from 1 to 10; number in common species ranges from 11 to 50; number in abundant species ranges from 100 to 200.

Genera	Viola Fm. Unit 3	Upper Bighorn Fm.	Stoney Mt. Fm.	Red River Fm.	Anticosti (U. Ord.)	Montoya Gp.	Maquoketa Fm.	Fish Haven Fm.	Baffin I. (Ord.)	Type Cincinnatian		
										Eden	Maysville	Richmond
Hesperorthis	a	s			S	s		?	p			
Lordorthis								a				
Glyptorthis	a					c	a	s	p			a
Eridorthis										P		
Ptychopleurella					s							
Plaesiomys	C	s			c	S	C	C-S	?			a
Dinorthis		a	c	p	c	c-?	c	?	p			
Retrorsirostra												c
Austinella	a					s	c	a	c			s
Plectorthis									?	?	C	?
Hebertella					c	a	c			c	a	a
Platystrophia	C	C-S	s	p	s	A-S	s	c	p	s	A	A
Cyclocoelia										?	p	
Pionodema											s	
Diceromyonia	s	a	a	p	?	a	c	c	p			
Paucicrura s.l.	a				?	a	C		?			
Onniella s.l.										A	A	a
Mendacella					c							
Vellamo s.l.				?	p					p		
Thaerodonta	a	s	s	s	a-?	C-S	A	s	p-?	a-?		a
Strophomena	C-S	C-S	S	c	C	S	C	s	p	p	A	A
Holtedahlina				s			s				?	c
Rafinesquina			?	p-?	?		s-?	s-?	C-?	c	C	C
Megamyonia	s	a	c	c	a		C		p-?	?		
Oepikina		s	s		p-?		c		?			
Leptaena									?	?		c
Fardenia				s								
Parastrophinella				p	?		p		p			
Rhynchotrema		c	s	?		s	c		?			p
Hypsiptycha		s	c	s	c	A	C	s	?			
Lepidocyclus s.l.	A	c	c	s	c	C-S	C	s	?			a
Orthorhynchula										p	p	
Zygospira		s		c	c	a	p	A	p	a	A	A
Catazyga				s	c							p
Cyclospira		s	p		c				p			

Second, if *L. oblongus* is representative of the Edenian-Maysvillian, as the work on conodonts and ostracodes seems to indicate, then the lower part of unit 3 may be Edenian-Maysvillian as well as the upper part of unit 2 (Berry's graptolite data).

Text-figure 7 shows the age interpretations made in this paper. I believe that the upper part of unit 2 is Edenian-Maysvillian, the lower part of unit 3 is Maysvillian, and the upper part of unit 3 is early Richmondian, with the overlying Sylvan Shale representing most of the Richmondian. This age interpretation for the basal portion of unit 3 is tenuous because it is based on the occurrence of only one species, *Lepidocyclus oblongus*.



Text-figure 7. Three interpretations of ages of Viola and "Fernvale" (Cape) Formations in the Arbuckle Mountains.

PALEONTOLOGY

Introduction

Brachiopods are not uniformly distributed throughout the Viola Formation. In most units (particularly unit 1, subunit 1L, and unit 2) numerous fragments are present; few specimens are sufficiently well preserved for study, and most are therefore not of any stratigraphic value. The best material was recovered from units in which silicified brachiopods occurred; however, because of the nature of the rock and the great thicknesses exposed, it was impossible to collect from all of the sections discussed earlier. Text-figure 6 shows the stratigraphic positions of the brachiopods collected and studied.

Most of the rocks of this sequence have a high silica content, making recovery of good brachiopod specimens difficult. In order to remove specimens without destroying their morphological features, the limestone blocks containing silicified brachiopods were dissolved in a 5- to 10-percent hydrochloric-acid solution. The silicified specimens were then caught on an underlying screen, soaked for about a day in clear water, dried in the open air (those specimens that I extracted while at the U.S. National Museum were dried in an oven), and dipped in a mixture of Duco Cement and acetone in a ratio of about 1:10. This last procedure helps prevent breakage.

Statistical Procedures

The primary purpose for using statistical methods in this study is to express the limits of variability in certain morphological characters in the described species. Such methods are also helpful in evaluating the similarities or differences between brachiopods from the Viola Formation and those from other rock units, particularly when size differences are encountered. Discussions of the various biometrical methods commonly applied to fossils are presented by Burma (1948, 1949), Imbrie (1956), and Simpson and others (1960).

I have used regression lines, calculated after Simpson and others (1960), to evaluate and graphically present the variability of the linear dimensions of brachiopods. The method referred to by Simpson and others (1960, p. 232-237) for calculating regression lines is Bartlett's "Line of Best Fit." In a scatter diagram of two growth variables of brachiopods (length-width, length-thickness), a straight line $Y = a + bX$ best fits the data in many cases. Here, the constant a is the Y intercept and b is the slope of the line. Particular statistical procedures can be applied to test the significance of the difference between two a's

(position of the regression lines) or the significance of the difference between two *b*'s (slope of the regression lines). Various workers have used such tests to help differentiate species or subspecies, and such tests of significance are discussed by Simpson and others (1960).

There have been brachiopod studies in which the scatter diagram for the two variables did not conform to a straight line $Y = a + bX$ (Aitken and McKerrow, 1948; Parkinson, 1952). This is particularly true when early growth stages are present.

Where possible, each systematic description is accompanied by a scatter diagram of the two variables selected and a calculated regression line. Because the regression lines have been estimated using standard statistical techniques, other workers can use statistical tests when comparing their material to that presented here.

In some cases the 95-percent-confidence limits are estimated using the method described by Goldstein (1964, p. 139-141). Goldstein referred to this as the *error variance*, which is due to the accidental deviation of the values plotted along the ordinate above and below the regression line. Theoretically, 95 percent of all the points plotted should fall within these limits. Such statistical data are given only for the new species described. Also, statistical data are not presented for species of *Lepidocyclus* because of previous presentation in other studies (Howe, 1966b).

The stratigraphic distribution of the brachiopod species discussed here has been done in relation to the top or bottom of the formation. Whether the top or bottom is used depends on the ease of locating either one and the proximity of the species to either the top or bottom.

Systematic Descriptions

Phylum BRACHIOPODA Duméril, 1806

Class ARTICULATA Huxley, 1869

Order ORTHIDA Schuchert and Cooper, 1932

Suborder ORTHIDINA Schuchert and Cooper, 1932

Superfamily ORTHACEA Woodward, 1853

Family DOLERORTHIDAE Öpik, 1934

Genus **Hesperorthis** Schuchert and Cooper, 1931

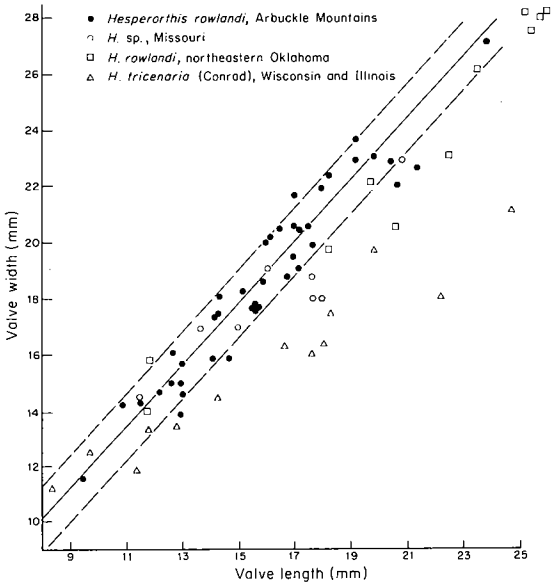
Hesperorthis rowlandi Alberstadt, n. sp.

Pl. 2, figs. 9-11

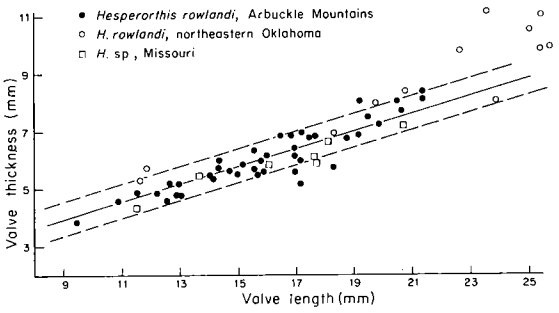
Description.—Large for genus; largest specimen from Viola Formation 24 mm long and 27 mm wide, but several specimens from northeast Oklahoma larger (*see* text-fig. 8 for complete range of sizes). Greatest width at hinge line, width distinctly greater than length at all stages; cardinal extremities acute in most specimens, right angles in some. Lateral margins straight, anterior margin broadly rounded. Anterior commissure sulcate, lateral commissure convex. Surface ornamented by 30-35 sharply rounded costae around umbo and 37-42 more gently rounded costae around margins; grooves near umbo about as wide as costae; costae wider in anterior direction, 7-8 costae per 5 mm at 10 mm from beak.

Pedicle valve convex, evenly rounded in lateral profile. Greatest thickness just posterior to midlength, making anterior slope slightly gentler than posterior slope. Anterior profile strongly rounded, lateral slopes almost straight. Interarea curved, almost orthocline, slightly more than one-fourth as long as valve. Deltidium narrow, subtending angle about 20°; covered by pseudodeltidium in posterior half. Beak varying from erect to slightly incurved. Delthyrial cavity deep, narrow, and almost conical; apex of cone at posterior extremity. Teeth small, dental plates receding. Muscle field extending anteriorly to hinge, normally possessing evenly curved and slightly elevated anterior margin. Lateral margin crenulated, each crenulation centrally cleft.

Brachial valve concave in lateral profile, distinctly sulcate in anterior profile, flanks gently convex. Sulcus present near umbo, expanding anteriorly. Cardinal extremities deflected toward pedicle valve. Interarea plane, hypercline, shorter than pedicle-valve interarea. Notothyrium covered posteriorly by chilidial plates; each plate convex, projecting slightly higher than interarea; plates joined, attached to cardinal process forming groove at position of juncture. Notothyrial cavity shallow. Cardinal process a thin ridge extending full length of cavity, rising approximately to level of interarea. Brachiophores stout, long, each bearing shallow socket on inner face; weak median ridge extending full length of inner face, sockets shallow and partly under interarea; brachiophores continuous with walls of notothyrial cavity but deflected at slightly greater angle. Posterior adductor scars



Text-figure 8. Regression line and 95-percent-confidence intervals for length-width relationships of pedicle valves of **Hesperorthis rowlandi** Alberstadt, n. sp. Mean length, 15.9 mm; mean width, 18.6 mm. Specimens are from upper 6 feet of unit 3, subunit 3C, sections A and C. Data also given for **H. rowlandi** from "Fernvale" (Cape) Limestone in northeastern Oklahoma, for **H. tricenaria** (Conrad) from Wisconsin and Illinois (U.S. National Museum collections), and for **Hesperorthis** sp. from Cape Limestone, Cape Girardeau, Missouri.



Text-figure 9. Regression line and 95-percent-confidence intervals for length-thickness relationships of pedicle valves of **Hesperorthis rowlandi** Alberstadt, n. sp. Mean length, 16.2 mm; mean thickness, 5.1 mm. Specimens are from upper 6 feet of unit 3, subunit 3C, sections A and C. Data also given for specimens of **H. rowlandi** from "Fernvale" (Cape) Limestone of northeastern Oklahoma and for **Hesperorthis** sp. from Cape Limestone, Cape Girardeau, Missouri.

about twice as large as anterior scars, neither pair well defined. Median septum stout, extending anteriorly to about middle of valve.

Discussion.—*Hesperorthis rowlandi* is similar to and has been identified as *H. tricenaria* (Conrad) by previous workers. Huffman and others (1958) compiled a faunal list for the "Fernvale" (Cape) in northeastern Oklahoma in which he included this species as *H. tricenaria* (Conrad). I have collected brachiopods from the "Fernvale" (Cape) Limestone in northeastern Oklahoma and believe that this is not *H. tricenaria* (Conrad) but should instead be referred to the new species, *H. rowlandi.*

The most important characteristics of *Hesperorthis rowlandi* are its fairly large size and numerous costae. Specimens of *H. rowlandi,* in the U.S. National Museum collections, have 37-42 marginal costae in contrast to the largest specimens of *H. tricenaria,* which have 30-32 marginal costae. In addition, the brachial valve of *H. rowlandi* has strong, robust brachiophores and a hypercline interarea in contrast to the small, delicate brachiophores and distinct anacline interarea of *H. tricenaria. H. rowlandi* also has a larger width-length ratio than *H. tricenaria,* and in a statistical plot 10 out of the 13 *H. tricenaria* pedicle valves measured fall outside the 95-percent-confidence interval for *H. rowlandi.*

Wang (1949) did not report any species of the genus *Hesperorthis* from the Maquoketa Formation of Iowa. Howe (1966a) described a new species, *H. kirki,* from the Cincinnatian rocks of the Montoya Group of west Texas and New Mexico, and I studied the type specimens of Howe's species at the U.S. National Museum. *H. kirki* can be easily distinguished from *H. rowlandi* by its much larger size and fewer costae. *H. kirki* from the Montoya Group has an average length of 26.7 mm and an average width of 36.5 mm. In addition, none of the specimens reported from the Montoya Group have more than 28 costae. The pedicle valves of the two species are also distinctly different in lateral profile.

H. rowlandi differs from the species of *Hesperorthis* I collected from the Cape Limestone, Cape Girardeau, Missouri, in that *H. rowlandi* has a larger, more robust shell and a hypercline brachial interarea as opposed to the anacline brachial interarea of

the Cape Girardeau species. The pedicle interarea of *H. rowlandi* is also sharply curved, whereas in the Cape Girardeau species it is straight and apsacline. The species from the Cape Limestone at Cape Girardeau, Missouri, is similar in many ways to *H. tricenaria* from the Plattin Limestone in Ste. Genevieve County, Missouri. The only significant morphological difference appears to be fewer, more widely spaced costae in *H. tricenaria*. *H. tricenaria* from the Plattin Limestone has an average of about 32 costae in comparison to an average of about 38 costae in the Cape Limestone species.

Distribution and material.—*H. rowlandi* is represented by about 50 specimens, none articulated. It is confined to the upper 6 feet of unit 3, subunit 3C, at sections A, B, C, and D. However, at sections G, I, and R it occurs in a 5- to 10-foot zone 40 to 60 feet below the top of the Viola Formation.

Types.—All specimens are from unit 3, subunit 3C. Holotype (pedicle valve: OU 5853, section C. Holotype (brachial valve): OU 5854, section C. Figured paratype (partial pedicle valve): OU 5855, section A. All the following specimens are from upper 6 feet of subunit 3C. Unfigured paratypes: OU 6821 (brachial valve), section C; OU 6822 (brachial valve), section C; OU 6823 (brachial valve), section A; OU 6824 (brachial valve, section A; OU 6825 (pedicle valve), section C; OU 6826 (pedicle valve), section A; OU 6827 (brachial valve), section A; OU 6828 (pedicle valve), section A; and OU 6829 (pedicle valve), section C.

Hesperorthis sp.

Pl. 9, fig. 11

Description.—Moderate size for genus, 13 mm long and 9.2 mm wide. Dorsal outline circular, cardinal extremities obtusely rounded, lateral and anterior margins evenly rounded at about same magnitude. Lateral commissure rectimarginate, anterior commissure weakly sulcate. Sulcus in brachial valve beginning at beak, expanding and slightly increasing in depth anteriorly. Surface costate, 6 costae per 5 mm at anterior margin of specimen 9 mm long.

Brachial interarea plane, anacline. Notothyrium open; cardinal process thin, bladelike, extending full length of cavity. Brachiophores prominent, pointed, not supported underneath by much shell material. Sockets poorly developed. Median septum short, adductor scars poorly defined on each side. Internal margins of valve grooved, grooves extending posteriorly 2.7-2.9 mm.

Discussion.—*Hesperorthis crinerensis* from the Bromide Formation (Criner Hills, Oklahoma) is the same size as *Hesperorthis* sp. from the Viola Formation, but it has a more acute cardinal angle and a longer median septum. This Viola species is also similar to *H. matutina* from the Tulip Creek Formation of Oklahoma. Both have about the same dimensions and number and shape of the costae.

H. rowlandi differs from this species by having a larger and thicker shell, more numerous well-developed costae, and prominent, widely divergent brachiophores (compare pl. 2, fig. 10a, with pl. 9, fig. 11a).

Distribution and material.—Only two brachial valves were found, and because no pedicle valves are available, a specific designation is questionable. This species occurs in the lower 50 feet of unit 1, subunit 1C, at sections D and L.

Figured specimen.—OU 5912 (brachial valve), unit 1, subunit 1C, section L.

Genus **Glyptorthis** Foerste, 1914

Glyptorthis glaseri Alberstadt, n. sp.

Pl. 1, figs. 10, 11

Description.—Subquadrate in outline, length 2-3 mm shorter than width. Greatest width at hinge line on smaller shells, greatest width at middle or just anterior on larger specimens; hinge line straight. Equally biconvex, brachial and pedicle valves about same thickness at all growth stages. Cardinal extremities obtuse, acute or right angles on smaller specimens. Anterolateral margins rounded, anterior margin straight with emarginate median. Surface multicostellate, 7-9 costae and costellae per 3 mm at 5 mm from beak, 17-20 costae around beak. First generation costellae added approximately 3 mm from beak; bifurcation occurs closer to beak on some shells. Costae and costellae narrow, varying in profile from

almost V-shaped with rounded tops and straight sides to narrowly rounded. Numerous imbricated fila or growth lamellae, 7-8 per 5 mm. Fila project upward at points of intersection of fila and costellae and open anteriorly. Growth lines on most specimens, about 2-3 per individual.

Pedicle valve convex in lateral profile, maximum thickness directly over hinge line or just anterior. Greatest curvature in umbonal region, slope from highest point almost straight. Anterior profile evenly convex; faint sulcus in anterior one-quarter of some specimens, no undulations in others, some with slight fold. Beak varying from suberect to erect to slightly incurved. Interarea curved, weakly apsacline, long, slightly less than one-third length of valve. Delthyrium triangular, cavity moderately deep. Muscle field cuneate; one-half of field confined under interarea and one-half extended past hinge line. Anterior margin of field curved, irregularly elevated. Adductor tracks long, extending anteriorly as far as adductors. Diductors divergent, trapezoidal, crossed diagonally by several low rounded ridges. Adjustor scars long narrow grooves at base of dental plates. Weak pallial markings in some specimens. Teeth short, stout, positioned short distance from delthyrial opening. Dental plates robust, extending straight to floor. Inner anterior margin crenulated.

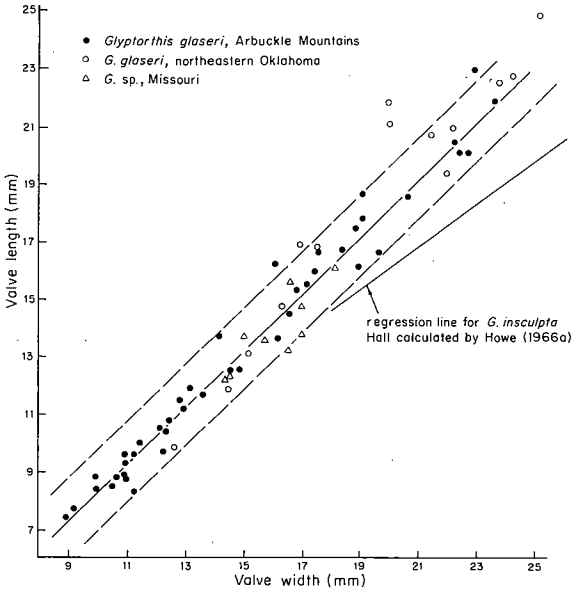
Brachial valve equally convex in lateral view; curvature of median portion tends to flatten out in some, highest point varies from just posterior to middle to middle to just anterior to middle. Anterior profile convex with steep lateral slopes. Sulcus begins at beak and extends to anterior, well developed in most specimens but visible in all. In smaller specimens, width of sulcus at anterior slightly less than width of shell; shell width increases faster than sulcus width so that, in larger specimens, sulcus width only one-third shell width. Lateral slopes bounding sulcus well developed, evenly rounded. Beak small, erect, slightly incurved in some. Interarea curved, orthocline, shorter than pedicle-valve interarea. Floor of notothyrial cavity above valve floor. Cardinal process bladelike, moderately thick; on well-preserved specimens, process extends full length of cavity joining curved posterior region under beak. Median septum slightly thicker than process, extending almost to middle of valve. Brachiophores thick, divergent; sockets deep; muscle impressions not observed; internal margins of valve crenulated.

Discussion.—*Glyptorthis insculpta* (Hall) is the common Cincinnatian species of this genus, with one subspecies, *G. insculpta maquoketensis* Ladd from the Maquoketa Formation of Iowa. The subspecies is differentiated from *G. insculpta* by being smaller in size. Measurements made by Howe (1966a) show that *G. insculpta* has a mean length of 17.4 mm and a mean width of 21.6 mm; *G. insculpta maquoketensis* shows a mean length of 14.4 mm and a mean width of 16.6 mm. The subspecies also shows a greater thickness relative to length. The scatter plots showing the relationship between length and thickness were given by Howe (1966a, p. 243).

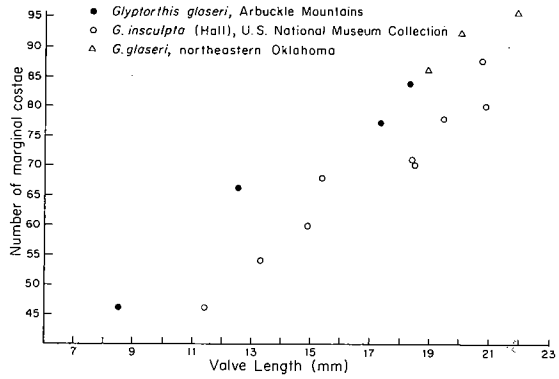
Glyptorthis pulchra Wang from the Maquoketa Formation was erected and differentiated from *G. insculpta maquoketensis* primarily because of its greater convexity. However, Howe (1966a) examined the type specimens (I have also examined these) as well as 50 additional specimens from the Maquoketa Formation of Iowa and found no appreciable difference between the two forms.

Glyptorthis glaseri is easily differentiated from *G. insculpta* by the different outline of the pedicle valve of *G. glaseri*, it being more elongate and less subquadrate than *G. insculpta*. A statistical analysis of length-width values for *G. insculpta* shows a regression line of about the same slope as *G. glaseri* but well outside the 95-percent-confidence interval (*see* text-fig. 10). Because the subspecies *G. insculpta maquoketensis* is even smaller, its regression line is even farther outside the 95-percent-confidence interval (subspecies regression line not given in text-fig. 10). Also, *G. glaseri* has a relatively longer and almost orthocline pedicle interarea, whereas the pedicle interarea of *G. insculpta* is shorter and much more strongly apsacline. *G. insculpta* is also more coarsely costate than *G. glaseri* (*see* text-fig. 11). On most of the valves the costae are worn down so much that accurate counts could not be obtained.

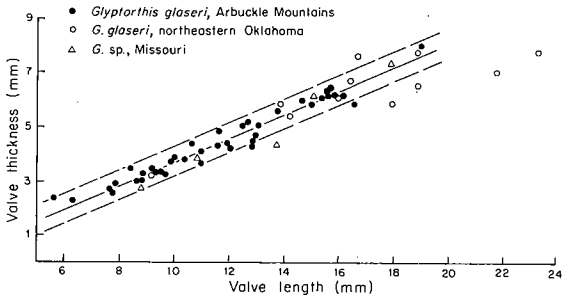
I have collected *G. insculpta maquoketensis* from the Cape Limestone at Cape Girardeau, Missouri. Huffman (1958)



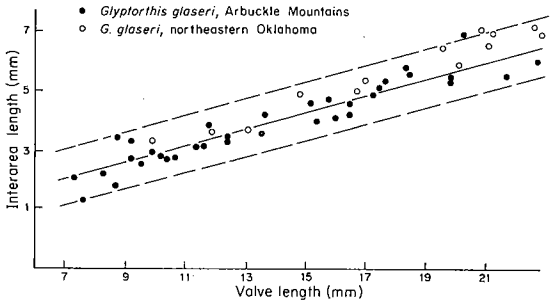
Text-figure 10. Regression line and 95-percent-confidence intervals for length-width relationships of pedicle valves of **Glyptorthis glaseri** Alberstadt, n. sp. Mean length, 13.2 mm; mean width, 15.0 mm. Specimens are from upper 6 feet of unit 3, subunit 3C, sections A and C. Data also given for **G. glaseri** from "Fernvale" (Cape) Limestone in northeastern Oklahoma and **Glyptorthis** sp. from Cape Limestone, Cape Girardeau, Missouri.



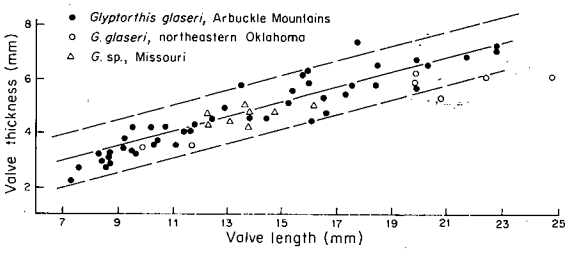
Text-figure 12. Scatter diagram showing relationships between length of pedicle valve and number of marginal costae of **Glyptorthis glaseri** Alberstadt, n. sp., from unit 3, subunit 3C, upper 6 feet; of **G. insculpta** (Hall), from U.S. National Museum collections; and of **G. glaseri**, from "Fernvale" (Cape) Limestone of northeastern Oklahoma.



Text-figure 13. Regression line and 95-percent-confidence intervals for length-thickness relationships of brachial valves of **Glyptorthis glaseri** Alberstadt, n. sp. Mean length, 11.7 mm; mean thickness, 4.4 mm. Specimens are from upper 6 feet of unit 3, subunit 3C, sections A and C. Data also given for specimens of **G. glaseri** from "Fernvale" (Cape) Limestone in northeastern Oklahoma and of **Glyptorthis** sp. from Cape Limestone, Cape Girardeau, Missouri.



Text-figure 11. Regression line and 95-percent-confidence intervals for length of pedicle valve-length of pedicle interarea relationships of **Glyptorthis glaseri** Alberstadt, n. sp. Mean pedicle-valve length, 13.6 mm; mean interarea length, 3.8 mm. Specimens are from upper 6 feet of unit 3, subunit 3C, section A. Data also given for **G. glaseri** from "Fernvale" (Cape) Limestone of northeastern Oklahoma.



Text-figure 14. Regression line and 95-percent-confidence intervals for length-thickness relationships of pedicle valves of **Glyptorthis glaseri** Alberstadt, n. sp. Mean length, 13.4 mm; mean thickness, 4.7 mm. Specimens are from upper 6 feet of unit 3, subunit 3C, sections A and C. Data also given for specimens of **G. glaseri** from "Fernvale" (Cape) Limestone in northeastern Oklahoma and of **Glyptorthis** sp. from Cape Limestone, Cape Girardeau, Missouri.

reported *G. pulchra* from the "Fernvale" (Cape) Limestone of northeastern Oklahoma; however, my collection from northeastern Oklahoma shows that species to be *G. glaseri.*

Distribution and material.—This is a common species in unit 3 of the Viola Formation. None of the 50-60 specimens collected and studied were articulated. *G. glaseri* is confined to the upper 6 feet of unit 3 at sections A, B, C, and D. At sections G, I, and R it occurs 40-60 feet below the top. I have collected over 100 complete brachial and pedicle valves from the "Fernvale" (Cape) Limestone in northeastern Oklahoma.

Types.—All specimens are from unit 3, subunit 3C. Holotype (pedicle valve): OU 5819, section C. Holotype (brachial valve): OU 5820, section C. All the following specimens are from the upper 6 feet of subunit 3C; unfigured paratypes: OU 6858 (brachial valve), section C; OU 6859 (brachial valve), section A; OU 6860 (pedicle valve), section C; OU 6861 (brachial valve), section A; OU 6862 (pedicle valve), section C; OU 6863 (pedicle valve), section A; and OU 6864 (brachial valve), section A.

Family PLAESIOMYIDAE Schuchert, 1913

Genus **Plaesiomys** Hall and Clarke, 1892

Plaesiomys cf. **P. subquadratus** (Hall, 1847)

Pl. 7, fig. 8

Orthis subquadrata HALL, 1847, p. 126, pl. 32A, figs. 1a-o; MEEK, 1873, p. 94-96, pl. 9, figs. 2b-g.
Plaesiomys subquadrata (Hall), HALL and CLARKE, 1892, p. 196-197, pl. 5A, figs. 17-19; COOPER, 1944, p. 298, pl. 111, figs. 54-58.
Orthis (Dinorthis) subquadrata Hall, WINCHELL and SCHUCHERT, 1895, p. 428, pl. 32, figs. 46-50.
Dinorthis (Plaesiomys) subquadrata (Hall), SCHUCHERT and COOPER, 1932, pl. 10, figs. 15, 17, 18, 24-26.
Plaesiomys subquadratus ROSS, 1959, pl. 55, figs. 1, 6, 12, 14, 15, 18, 19, 23.

Description.—Shell rectangular to subquadrate in outline; hinge line straight, little shorter than widest part, which is just posterior to middle. Cardinal angles obtusely rounded, lateral margins gently curved, anterior margin straight. Unequally biconvex in lateral profile, brachial valve deeper; thickest part in middle. Surface multicostellate, 75 costae around specimen 17.5 mm long, 9-10 costae and costellae per 5 mm at 10 mm from beak. Interspaces between costae same width as costae, some smaller.

Pedicle beak small, suberect; interarea slightly curved, longer than in brachial valve, strongly apsacline, almost catacline. Delthyrium open, triangular at about 90°. Teeth stout, rounded extremities; dental plates thick, slightly advancing; anterior extremities joined to slightly raised margins of muscle field. Individual muscle scars not pronounced but appear to be plaesiomid type. Interior margins of pedicle valve crenulated, forming band about 3 mm wide around lateral and anterior margins.

Only small portion of brachial valve observed. Cardinal process stout; myophore crenulated, centrally cleft (pl. 7, fig. 8c). Brachiophores divergent, extremities pointed, thinned, slightly curved inward.

Discussion.—*Plaesiomys* cf. *P. subquadratus* is represented by only a few specimens; however, it is one of the few identifiable brachiopods from the critical part of the section just below unit 3 (rocks which in this paper are called "transitional interval").

The specimens of *P. subquadratus* in the U.S. National Museum show variations in several characters, mainly the shape and size of the shell, the ornamentation (particularly in the number of costae and costellae), and the shape and size of the pedicle muscle field. Howe (1966a) determined that for representative samples of *P. subquadratus* from the Ohio Valley the number of marginal costae range from 61 to 104 with the mean being 81. The one pedicle valve described here from the "transitional interval" has 75 marginal costae.

The single partial brachial valve from the "transitional interval" shows a central groove along the myophore. A study of numerous brachial valves from the U.S. National Museum collections showed that a cleft myophore is absent more often than present.

Distribution and material.—The specimens upon which the description is based occur in the "transitional interval" 85 feet below the top of the formation at section C. Fragments of specimens referred to this species also occur just below unit 3 at sections B and L.

One pedicle valve shows the external and internal morphology, one brachial valve shows only the exterior, and one partial brachial valve shows the cardinalia.

Figured specimen.—OU 5868 (pedicle valve), unit 2, 34 feet below the top of the unit, section C.

Plaesiomys subquadratus (Hall, 1847)
Pl. 2, figs. 6-8

Description.—Subquadrate to subelliptical in outline; hinge line straight, shorter than greatest width, which is at middle. Cardinal extremities obtusely rounded, lateral margins broadly rounded, anterior margin almost straight. Sulcus weak in umbonal region, becoming wider and better developed anteriorly. Lateral profile plano-convex. Brachial valve evenly convex, posterior slope steeper than longer anterior slope. Lateral commissure rectimarginate, anterior commissure faintly sulcate. Surface multicostellate, 13 per 10 mm at 15 mm from beak.

Pedicle valve almost flat, lateral and anterior margins deflected in dorsal direction, growth lines strong in deflected region. Hinge line straight, about three-fourths as wide as widest part of valve; Interarea apsacline; delthyrial opening triangular, cavity moderately deep. Brachiophores short and rounded; muscle field large, extending to middle of valve (in specimen 29 mm long and 22.5 mm wide, muscle field is 12 mm at widest part). Anterior margin of field sinuous, median reentrant about one-fourth the field. Diductor scars divergent; Adductor scars elongated, located in middle anterior of field just posterior to reentrant; adjustor scars slightly larger than adductors, positioned between cavity walls and diductor scars. Internal margins crenulated.

Brachial interarea short, slightly anacline; notothyrial platform elevated above floor; myophore crenulated, raised slightly above level of interarea; brachiophores strong, divergent; sockets deep.

Discussion—Meek (1873) gave a detailed description of *Orthis subquadratus* Hall from the Ohio Valley in which he described how the costae of the ventral valve nearly always increase by bifurcation, some dividing two or three times. On the dorsal valve, however, the costae usually increase by the intercalation of costae. Hall (1847), in the original description, did not observe such a difference in costellae addition. Howe (1966a) reported that out of about 30 specimens from the Aleman Limestone (Montoya Group of west Texas and New Mexico) 4 showed this method of costellae addition. The single pedicle valve from the Viola Formation unit 3 has this pattern of costellae increase.

Distribution and material.—Specimens confidently referred to this species occur at section I in the lower part of unit 3, subunit 3CM, 40-60 feet below the top of the formation. Only a few complete and partial specimens appear from this section.

Figured specimens.—All are from unit 3, subunit 3CM, section I: OU 5850 (pedicle valve), OU 5851 (brachial valve), and OU 5852 (partial pedicle valve).

Plaesiomys bellistriatus? Wang, 1949
Pl. 3, figs. 6, 7

Dinorthis subquadrata (Hall), BASSLER, 1932, pl. 24, fig. 14.
Plaesiomys bellistriatus WANG, 1949, p. 7, pl. 3, fig. D.; HOWE, 1966a, p. 245, pl. 29, figs. 13, 15, 16, 17, 18.

Description.—Species large, subquadrate outline, length slightly shorter than width. Hinge line straight, two-thirds as wide as maximum shell width. Cardinal extremities at right angles, sharply rounded, lateral margins broadly rounded, anterior margin straight and emarginate near middle. Surface multicostellate, about 150 costae and costellae around specimen 32 mm long and 36.5 mm wide.

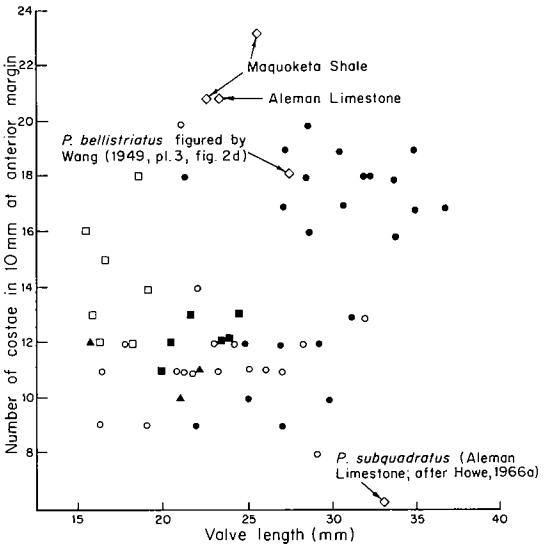
Pedicle valve plane to slightly convex; narrow slightly elevated fold extending from beak to anterior margin, expanding a little in anterior direction. Interarea short, apsacline. Delthyrium open, widely triangular; some secondary material around anterior margins, reducing angle of opening in larger specimens. Teeth large, thick, supported by massive advancing dental plates. Crural fossettes poorly developed, a low subtle ridge in a few specimens. Delthyrial cavity deep; muscle field large, about 17 mm long and 17 mm wide, extending to middle of valve (pl. 3, fig. 6b), subquadrate in outline with anterior margin emarginate. Well-

defined field in larger specimens because of added shell material. Adductor track obscure in most, in largest specimen is represented by low elongate elevation along middle of field. Diductor scars largest in field, diverge and expand anteriorly; adjustor scars large, almost as large as diductors, widely divergent, expanding in antero-lateral direction, deeply embedded, positioned between diductors and dental plates. Margins of shell crenulated, each crenulation same size as surface costae. Width of corrugated band about 2 mm.

Lateral profile of brachial valve convex, highest point in middle, curvature from posterior to anterior about same. Broad sulcus begins just posterior to middle, expanding slightly and deepening anteriorly. Posterior-lateral regions weakly concave due to upturned nature of cardinal extremities. Interarea short, orthocline. Margins of notothyrium form angle about 80°, floor of cavity highly elevated and almost completely occupied by robust cardinal process. Myophore grooved throughout, thins rapidly from highest point toward posterior of cavity (pl. 3, fig. 7f), shaft rounded and thick, at its thickest point almost as wide as cavity. Brachiophores stout, divergent, supported laterally by additional shell material; sockets large, deep; median septum thick immediately below cavity floor but flattens and disappears in short distance; no muscle scars observed. Narrow rounded ridge, 2-3 mm wide, extending around lateral and anterior margins of valve; thin band of corrugations around edge of valve just outside rounded ridge.

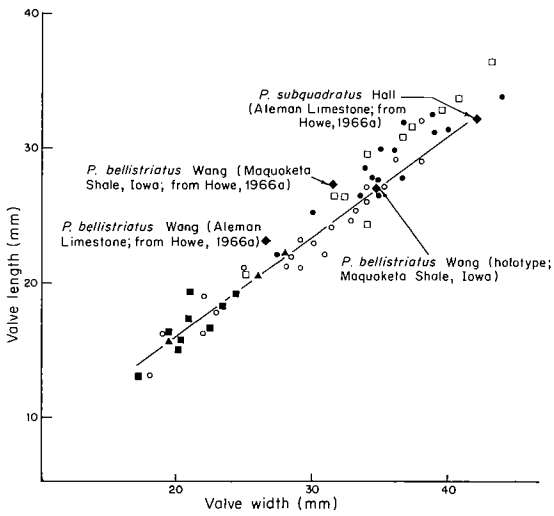
Discussion.—*Plaesiomys bellistriatus* is similar in almost every respect to *P. subquadratus*. One of the primary differences between these two species is in the number of costae and costellae; however, even in this respect they are closely similar. Text-figure 15 shows the similarity in regard to the number of costae. I have collected only a few specimens of *P. bellistriatus*? from the Viola Formation and, therefore, used a population from the "Fernvale" (Cape) Limestone in northeastern Oklahoma for comparison.

The population is separated into two distinct clusters. The lower cluster compares favorably with specimens of *P. subquadratus* from the Ohio Valley (specimens measured by Shaler, 1876). The upper cluster compares well with the type specimen described by Wang (1949) from the Maquoketa Formation of Iowa. None of the specimens from the population have 14 or 15 marginal costae in a 10-mm space; however, the specimens of *P. bellistriatus* reported by Howe (1966a) from the Aleman Limestone and Maquoketa Shale are much smaller and have a few more marginal costae in a 10-mm space (*see* text-fig. 16). These specimens, at the U.S. National Museum, can be easily distinguished from specimens in the "Fernvale" (Cape) Limestone population; however, the holotype of *P. bellistriatus* from the Maquoketa Formation is well within the limits of variation for the "Fernvale" (Cape) Limestone population (*see* text-fig. 16). The holotype is the only specimen of this species reported by Wang (1949) from the Maquoketa Formation, and if he had examined numerous specimens he might have found that it was only an end



- Population of large plaesiomid shells (most are *Plaesiomys bellistriatus*? Wang) from "Fernvale" (Cape) Limestone northeastern Oklahoma.
- ▲ *P. subquadratus* Hall; original type specimens refigured by Ross (1959, pl. 55, figs. 1, 6, 12, 14, 15, 18, 19, 22).
- ○ *P. subquadratus* Hall; selected specimens from the Ohio Valley measured by Shaler (1876, table IX).
- □ *P. subquadratus idahoensis* Ross, 1957; Saturday Mountain Formation, Idaho.
- ■ *P. subquadratus* Hall; specimens studied by Howe (1966a); Richmond Group, 1 mile east of Versailles, Indiana.

Text-figure 15. Scatter diagram showing relationships between pedicle-valve length and number of costae in a 10-mm distance at anterior margin for **Plaesiomys subquadratus** (Hall) and **P. bellistriatus**? Wang.



▲ *Plaesiomys subquadratus* Hall; original type specimens figured by Ross (1959, pl. 55, figs. 1, 6, 12, 14, 15, 18, 19, 22).

○ *P. subquadratus* Hall; specimens from the Ohio Valley measured by Shaler (1876, table IX).

■ *P. subquadratus idahoensis* Ross; Saturday Mountain Formation, Idaho.

● *P. bellistriatus?* Wang; pedicle values from "Fernvale" (Cape) Limestone, northeastern Oklahoma.

□ *P. bellistriatus?* Wang; brachial valves from "Fernvale" (Cape) Limestone, northeastern Oklahoma.

Text-figure 16. Scatter diagram showing length-width relationships for pedicle valves of **Plaesiomys subquadratus** (Hall), **P. subquadratus idahoensis** Ross, and **P. bellistriatus**? Wang.

member of *P. subquadratus.* However, Wang (1949) did not describe any other specimens from the Maquoketa Formation as *P. subquadratus,* and, therefore, this interpretation is questionable. The holotype of *P. bellistriatus* may actually be an isolated specimen of the highly variable species *P. subquadratus,* and, therefore, the specimens presented by Howe (1966a) may be valid members of a different species, *P. bellistriatus.* If this assumption is correct, then *P. bellistriatus* not only differs from *P. subquadratus* by having more costae but also by being smaller in size. None of the specimens of *P. bellistriatus* described by Howe (1966a) are over 28 mm long, and, in comparison, more than two-thirds of the "Fernvale" (Cape) Limestone population are over 28 mm long. In order to help clarify the validity of *P. bellistriatus,* a population study of this species, either from the Aleman Limestone or the Maquoketa Formation, is essential.

I cannot definitely determine at this time whether the specimens from the Viola Formation are actually members of *P. subquadratus* or *P. bellistriatus*; nevertheless, they furnish important biostratigraphic information. Their occurrence in the upper part of unit 2, 60-75 feet below the top of the formation, suggests a Cincinnatian age for the rocks.

Distribution and material.—This species is not common in the Viola Formation but does occur at section G, 60-75 feet below the top of the formation in the upper part of unit 2, and also at section I, in unit 3, subunit 3CM, 50-60 feet below the top of the Viola Formation.

Figured specimens.—OU 5826 (pedicle valve) and OU 5827 (brachial valve), both from unit 3, subunit 3CM, section I.

Plaesiomys proavitus (Winchell and Schuchert, 1892)

Pl. 2, figs. 1-5

Orthis proavita WINCHELL and SCHUCHERT, 1892, p. 290.

Plaesiomys proavita (Winchell and Schuchert), WANG, 1949, p. 4, pl. 2, fig. E.

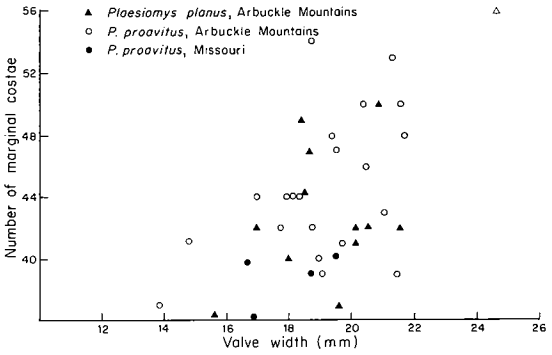
Plaesiomys planus WANG, 1949, p. 6, pl. 3, fig. C.

Description.—Shell subquadrate in outline, length shorter than width at all stages; hinge line straight, shorter than greatest width, which is at about middle of shell; lateral margins broadly rounded, anterior margin almost straight, sometimes emarginate. Surface multicostellate, about 6 costae and costellae per 5 mm at 10 mm from beak; costae and costellae around margin range from 37-54 depending in some cases on size of shell (arithmetic mean, 44 marginal costae), interspaces about as wide as costae.

Pedicle valve almost flat, slope from umbo toward anterior gentle; inconspicuous fold beginning at umbo, expanding anteriorly, formed by 3-4 slightly elevated costae. Beak small, suberect; interarea narrow, curved, apsacline; teeth short, divergent; dental plates advancing. Adductor scars small, lanceolate, impressed deeper than diductors so as to form "pit" in center of field. Diductors large, narrow, expanding slightly anteriorly. In most specimens adjustors are elongate concavities at base of dental plates. Internal margins of shell crenulated, each crenulation bearing faint narrow groove.

Brachial valve evenly convex, highest point just posterior to middle; anterior slope gentler than posterior. Shallow sulcus

beginning at beak, expanding slightly anteriorly, occupied by 3-4 costae. Interarea orthocline to slightly anacline, shorter than pedicle valve. Notothyrial cavity shallow, elevated above floor. Cardinal process strong, elevated above plane of interarea, myophore crenulated. Brachiophores strong, divergent, extremities pointed; abrupt thinness of brachiophore extremities due to small concavities on exterior face at tip. Brachiophores supported by thickened shell material; each brachiophore bears shallow ridge on top and along entire length; ridges bound notothyrial cavity; small "socketlike" concavities on inner face of brachiophore. Hinge sockets large, deep. Median septum thick, short, thinning anteriorly. Adductor impressions quadrate, anterior pair little larger than posterior pair.



Text-figure 17. Scatter diagram showing relationships between brachial-valve width and number of marginal costae for specimens of **Plaesiomys proavitus** (Winchell and Schuchert) and specimens previously referred to **P. planus** Wang. Arbuckle Mountain specimens are from unit 3, subunit 3C, upper 6 feet; Missouri specimens of **P. proavitus** are from Cape Limestone, Cape Girardeau.

Discussion.—This species shows a modal class of 43-44 marginal costae and costellae, a median of 44, and an arithmetic mean of 44. Text-figure 17 is a plot of the shell width compared to the number of marginal costae and clearly shows that the bifurcation of the costae is not in all instances a direct function of growth. About as many small shells have many costellae as large shells have few costellae. The number of costae increases by bifurcation as growth continues, but the frequency of bifurcation depends on the individual.

Wang (1949) characterized *P. proavitus* (Winchell and Schuchert) as having strong mesial costae; however, to use such a criterion to characterize a species, statistical studies of a large number of specimens are essential in order to determine its consistency. Wang (1949) did not state the number of individuals in which this character exists, and, as a result, the reliability of this character in differentiating the species cannot be evaluated. The mesial costae in the Viola specimens bifurcate very close to the beak, and only one specimen from the Viola clearly shows the mesial costae extending unbifurcated from the beak to the anterior margin.

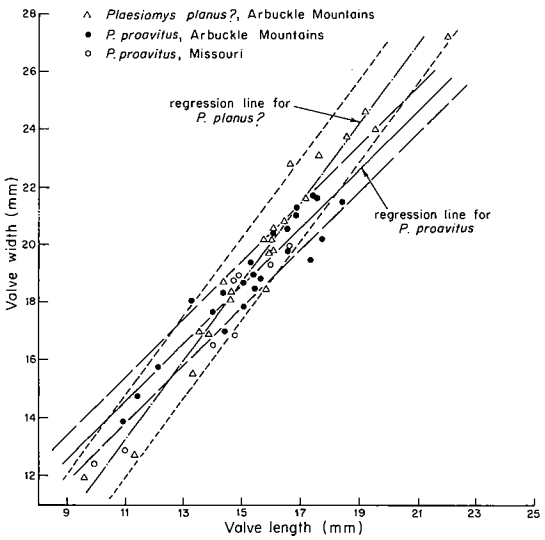
For the Viola specimens the basic costation pattern is 10-12 costae, in the middle of the valve, originating at or very close to the beak and extending essentially unbifurcated to the anterior margin of the shell. However, in well-preserved specimens, early bifurcation (near beak) of these mesial costae can be detected. Most bifurcation occurs in the postero-lateral regions of the shell and is almost always directed away from the median, although in some specimens costellae branch toward the median.

This species is difficult to separate from *P. planus* Wang. One reportedly diagnostic feature about *P. planus* Wang is a groove on each side of the notothyrial platform setting the platform off from the brachiophores. Internally, this seems to be the only way to distinguish the brachial valves of the two species. Some specimens from the Viola Formation have brachiophores that are clearly set off from the platform by grooves (*see* pl. 2, figs. 2d, 2e); however, relying on this feature as a means of differentiation is questionable because some specimens have well-defined grooves, some have poorly defined grooves, and some have no grooves at all. *P. planus* Wang is also characterized as having deep impressions of the pedicle adductor scars. Again some specimens from the Viola Formation show this feature; however, a population of shells, all from the same section and same stratigraphic horizon, shows that impression depth varies, making distinction between specimens of *P. planus* and *P. proavitus* on this basis difficult.

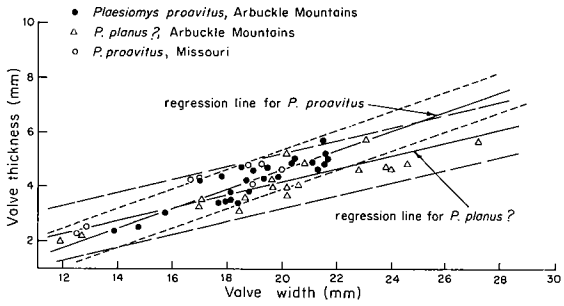
In the Viola Formation, shells that can possibly be referred to these two species occur in the same 12-inch bed, indicating that they were members of the same

biological population. Wang (1949) reported *P. proavitus* from the upper part of the Elgin Member of the Maquoketa Formation in Springfield Township, Iowa, and *P. planus* from the upper part of the Elgin Member in Orleans Township, Iowa. Thus, these two species are apparently from the same stratigraphic horizon and are only geographically separated. The evidence from the Viola collection indicates that both are members of the same species, and because of this I have chosen to assign all the specimens to the older species, *P. proavitus,* rather than *P. planus.*

For purposes of comparison, I have designated as *P. planus* all those specimens that show either a deeply impressed adductor region in the pedicle valve or well-defined grooves adjacent to the notothyrial platform. Using this differentiating technique, the overlap in other characters (length, width, thickness, and number of marginal costae and costellae) can be depicted (*see* text-figs. 17, 18, 19).



Text-figure 18. Regression lines and 95-percent-confidence intervals for length-width relationships of brachial valves of **Plaesiomys proavitus** (Winchell and Schuchert) and for valves questionably referred to **P. planus** Wang. **P. proavitus** mean length, 15.3 mm; mean width, 19.8 mm. **P. planus**? mean length, 15.7 mm; mean width, 19.8 mm. Arbuckle specimens are from upper 6 feet of unit 3, subunit 3C, sections A and C. Missouri specimens from Cape Limestone at Cape Girardeau are also included for comparison. (For more explanation of differences between these two species, **see** section on **Plaesiomys proavitus.**)



Text-figure 19. Regression lines and 95-percent-confidence intervals for length-width relationships of brachial valves of **Plaesiomys proavitus** (Winchell and Schuchert) and for valves questionably referred to **P. planus** Wang. **P. proavitus** mean width, 18.8 mm; mean thickness, 4.2 mm. **P. planus**? mean width, 20.1 mm; mean thickness, 4.2 mm. Arbuckle specimens are from upper 6 feet of unit 3, subunit 3C, at sections A and C. Missouri specimens from Cape Limestone at Cape Girardeau are also included for comparison.

Distribution and material.—This is a fairly common species in the Viola Formation; 40-50 specimens were collected, 1 articulated. *P. proavitus* is restricted to the upper 6 feet of unit 3, subunit 3C, at sections A, C, and D. In the basin province at sections I and R, the species occurs 40-60 feet below the top of the unit. *P. proavitus* occurs in the "Fernvale" (Cape) Limestone in northeastern Oklahoma and in the Cape Limestone at Cape Girardeau, Missouri.

Figured specimens.—All specimens are from unit 3, subunit 3C: OU 5845 (pedicle valve), section A; OU 5846 (brachial valve), section C; OU 5847 (articulated specimen), section A; OU 5848 (pedicle valve), section C; and OU 5849 (brachial valve), section A.

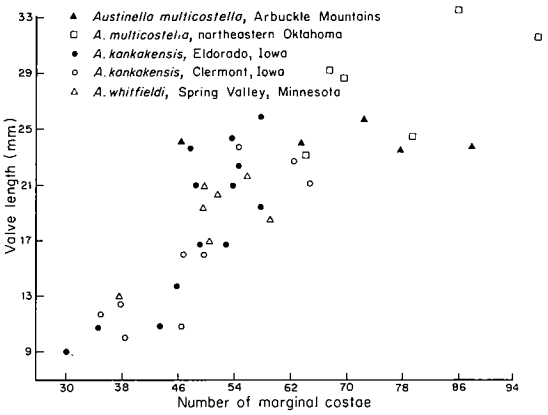
Genus **Austinella** Foerste, 1909
Austinella multicostella Alberstadt, n. sp.

Pl. 1, figs. 1-9

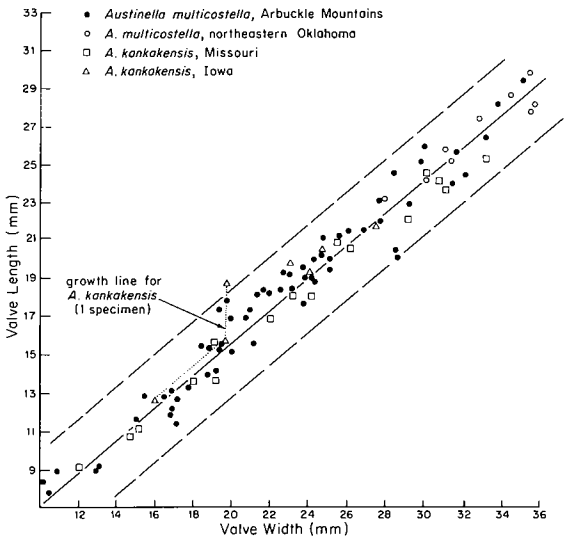
Description.—Shell large (*see* text-fig. 20 for length-width dimensions), subquadrate in outline. In most specimens cardinal margins obtuse or right angles, antero-lateral margins gently rounded, anterior margin broadly rounded. Unequally biconvex in lateral profile, pedicle valve more convex than brachial (average brachial valve measures 1-2 mm more in thickness). Lateral commissure rectimarginate, anterior commissure gently sulcate. Hinge line

straight. Widest part of shell near middle or just posterior to middle. Surface multicostellate, 7 costae and costellae per 2 mm at 6.5 mm from beak. Number of costae and costellae vary with shell size (text-fig. 21 shows number of marginal costellae and shell-size relationship). First generation costae arise 2-3 mm from umbo. Strong growth line rare, in few specimens growth lines absent.

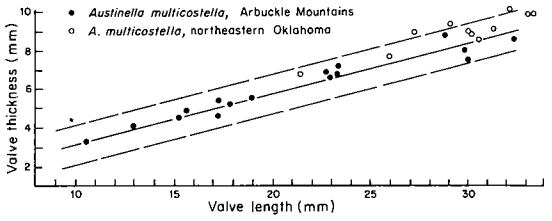
Pedicle valve evenly convex in lateral profile. Interarea curved, apsacline, longer than in brachial valve. Open delthyrium, triangular, cavity deep. Dental plates strong, advancing; teeth small. Muscle field triangular, deeply impressed, bounded by thick shell deposits causing it to be elevated around its anterior and lateral margins; this border continuous with forward projection of



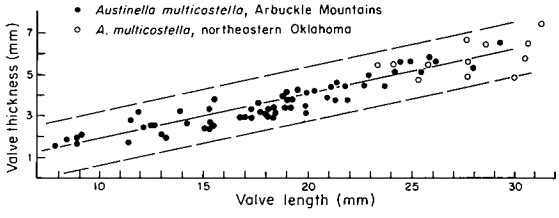
Text-figure 21. Scatter diagram showing relationships between number of marginal costae and length of brachial valves for **Austinella multicostella** Alberstadt, n. sp., from upper 6 feet of unit 3, subunit 3C, section A, and from "Fernvale" (Cape) Limestone in northeastern Oklahoma. Data also given for **A. kankakensis** (McChesney) from Iowa and **A. whitfieldi** (Winchell) from Minnesota.



Text-figure 20. Regression line and 95-percent-confidence intervals for length-width relationships of brachial valves of **Austinella multicostella** Alberstadt, n. sp. Mean width, 23.1 mm; mean length, 18.4 mm. Specimens are from upper 6 feet of unit 3, subunit 3C, section A. Width measurements were taken as maximum widths, which in almost all specimens were about equal to hinge-line widths. Growth line for **A. kankakensis** (McChesney) taken from specimen from Maquoketa Formation figured by Wang (1949, pl. 2, fig. B). Three length-width values for this growth line taken from the three well-defined growth lines. Width measurements taken along hinge lines. Also included in diagram are values for **A. multicostella** from "Fernvale" (Cape) Limestone in northeastern Oklahoma; for **A. kankakensis** from Cape Limestone, Cape Girardeau, Missouri; and for **A. kankakensis** from Maquoketa Formation in Iowa.



Text-figure 22. Regression line and 95-percent-confidence intervals for length-thickness relationships of pedicle valves of **Austinella multicostella** Alberstadt, n. sp., from unit 3, subunit 3C, upper 6 feet, and from "Fernvale" (Cape) Limestone in northeastern Oklahoma. Mean length, 20.7 mm; mean thickness, 5.9 mm.



Text-figure 23. Regression line and 95-percent-confidence intervals for length-thickness relationships of brachial valves of **Austinella multicostella** Alberstadt, n. sp., from unit 3, subunit 3C, upper 6 feet, and from "Fernvale" (Cape) Limestone in northeastern Oklahoma. Mean length, 18.0 mm; mean thickness, 3.6 mm.

dental plates. Adductor scars elongate, expanding anteriorly; diductor scars elongate, divergent. In smaller specimens diductor tracks extend farther anteriorly than adductors, thereby giving anterior margin of field concave appearance; in larger specimens adductor tracks extend as far as diductors, giving sinuous pattern to anterior margin of field (*see* pl. 6, figs. 5a, 6a, 7a, 8a for variation in muscle-field shape).

Brachial valve evenly convex, highest point just posterior to middle. Shallow sulcus immediately anterior to beak, remaining weak as it extends to anterior margin. Interarea short, slightly curved, anacline. Notothyrial cavity shallow, raised above floor of valve. Cardinal process stout, about one-half as thick as median septum; bladelike extensions connect process to posterior of cavity. Myophore faintly crenulated in some specimens. Brachiophores sharp, long, triangular in shape, extremities pointed, inner face bearing slight groove or elongate concavity. Each posterior adductor scar bears two faint ridges extending anteriorly to about middle of scar; posterior scars slightly larger than anterior ones. Muscle field about one-third length of shell; thick median ridge extends anteriorly full length of muscle field; small secondary keel-like ridge extends along anterior top of septum (*see* pl. 1, figs. 2b, 2c, 9a, 9b). Dental sockets triangular, small.

Discussion.—*Austinella multicostella*, n. sp., is most like *A. kankakensis* (McChesney) from the Maquoketa Formation of Iowa. However, *A. multicostella* differs from *A. kankakensis* in having more costae and costellae. Also, the greater overall size and the lack of strong growth lines in *A. multicostella* are features that may or may not be distinctive.

The figured hypotype of Wang (1949) has a maximum size close to the average size of Viola species. Text-figure 20 shows the length-width data for specimens of *A. multicostella* from the Viola Formation and specimens of *A. kankakensis* from the Maquoketa Formation of Iowa and the Cape Limestone at Cape Girardeau, Missouri. This figure shows that the largest specimens of *A. multicostella* are slightly larger than *A. kankakensis* and *A. whitfieldi*, although there is some overlap.

The only difference reported between *A. kankakensis* and *A. whitfieldi* (Winchell) is the more numerous costae in the former. Although most of the specimens of *A. multicostella* from the Viola Formation are similar to *A. kankakensis*, there are shells that show a gradation from smaller, more numerous costae, resembling *A. kankakensis*, to fewer, more widely spaced costae, resembling *A. whitfieldi*. Plate 1 (figs. 1a, 2a, 3a, 4a) shows the variation in costation of *A. multicostella*.

Austinella multicostella is differentiated primarily by its finer, more numerous costae and costellae. Text-figure 21 shows the relationship between the number of marginal costae and costellae and the size of the valves for *A. kankakensis*, *A. whitfieldi*, and *A. multicostella*. This figure, however, only shows that the larger shells have more costae and costellae. A better comparison is given by the table below. This table gives the number of costae and costellae occurring throughout the first five segments of the right half of the brachial valve of *A. kankakensis* and *A. multicostella*. A segment is defined (Bancroft, 1928) as all those costellae related to a primary costa. A primary costa is one that originates at the beak. Therefore, a segment is composed of all those costellae that branch from a primary costa as well as those costellae that arise from these initial and subsequent branches. All the counts were made at a distance of 6.5 mm from the beak.

Austinella kankakensis	*Austinella multicostella*
10	11
10	12
11	15
12	15
12	15
12	15
12	17
12	17
13	18
13	18
13	18
13	18
15	19
17	19
..	19
..	19
..	20
..	20
..	20

Distribution and material.—*A. multicostella* is confined to the upper 6 feet of unit 3, subunit 3C, at sections A, C, D, and L. At sections I and R the species occurs

40-60 feet below the top of the unit. *A. multicostella* is very abundant in the "Fernvale" (Cape) Limestone in northeastern Oklahoma and is one of the most common species in unit 3. I have collected and studied more than 100 valves from this unit and over 300 valves from the "Fernvale" (Cape) Limestone in northeastern Oklahoma.

Types.—All specimens are from unit 3, subunit 3C. Holotype (pedicle valve): OU 5814, section A. Holotype (brachial valve): OU 5811, section A. Figured paratypes (pedicle valve): OU 5817, section A; OU 5815, section A; and OU 5816, section A. Figured paratypes (brachial valve): OU 5810, section A; OU 5813, section A; OU 5818, section A; and OU 5812, section A. All the following specimens are from the upper 6 feet of subunit 3C; unfigured paratypes: OU 6851 (pedicle valve), section A; OU 6852 (pedicle valve), section C; OU 6853 (brachial valve), section A; OU 6854 (brachial valve), section C; OU 6855 (brachial valve), section A; OU 6856 (pedicle valve), section A; and OU 6857 (pedicle valve), section A.

Genus **Dinorthis** Hall and Clarke, 1892
Dinorthis pectinella (Emmons, 1842)

Pl. 8, fig. 17

Orthis pectinella EMMONS, 1842, p. 394, fig. 2 [*fide*, R. S. Bassler, 1915, p. 444].
Dinorthis pectinella (Emmons), HALL and CLARKE, 1892, p. 195, pl. 5, figs. 27-33.

Description.—Shell moderate in size, almost circular in outline. Hinge line straight, shorter than shell width. Cardinal extremities rounded, curvature of lateral and anterior margins about same magnitude. Lateral and anterior commissures rectimarginate. Brachial valve has even curvature in lateral profile. Surface paucicostate, about 4 costae per 5 mm at 10 mm from beak; costae low, broadly rounded tops; in one specimen interspaces between costae about same width as costae, but in another interspaces about twice as wide as costae, particularly around shell margin.

Brachial interarea short, plane, orthocline. Cardinal process rounded knob, does not extend above level of interarea, separated from interarea by concavities. Brachiophores short, rounded, joined to floor by thick shell deposits. Low median septum extending anteriorly from just below cardinal process to about one-fourth valve length. No muscle scars observed. Anterior and lateral margins of valve crenulated.

Discussion.—Only two brachial valves collected were sufficiently well preserved for study, and their measurements are given below.

Length (mm)	Width (mm)	Thickness (mm)	Hinge-line width (mm)	Number of marginal costae
18.0	19.2	..	..	20
20.4	21.8	6.8	12.5	25

The only observable difference between these Viola specimens and those from the Ion Member of the Decorah Formation of Minnesota (U.S. National Museum collections) is in the dorsal outline. The Viola specimens are more circular because of the obtusely rounded cardinal extremities, but although some of the Decorah specimens have rounded cardinal extremities, most are more subquadrate in dorsal outline. Data given below are for specimens from the Ion Member of the Decorah Formation of Minnesota, south edge of Cannon Falls (U.S. National Museum collections).

Length (mm)	Width (mm)	Hinge-line width (mm)	Number of marginal costae
8.8	11.0	6.9	22
9.8	9.6	6.3	19
10.1	12.8	9.0	21
11.5	13.9	14.2	21
11.5	13.8	9.8	24
11.8	14.6	11.0	25
13.0	15.0	9.4	24
14.1	16.4	13.5	25
15.2	18.9	14.4	24
15.4	17.0	12.1	22
16.0	20.0	11.4	25
17.0	20.0	11.9	24
17.5	20.8	14.8	20
17.8	20.6	12.0	20
18.2	22.0	16.6	18

Distribution and material.—This species is found only at section D, upper part of unit 1, subunit 1C, 120-160 feet above the base of the Viola Formation. In addition to the two complete valves discussed above, I have collected about 15 partial valves. All of the specimens had to be cracked out of the rock and cleaned with a needle and vibratool. No pedicle valves were found.

Figured specimen.—OU 5896 (brachial valve), unit 1, subunit 1C, section D.

Dinorthis cf. **D. transversa** Willard, 1928

Pl. 8, figs. 6-8

Dinorthis transversa WILLARD, 1928, p. 271, pl. 2, figs. 1, 2, 6 [*fide*, G. A. Cooper, 1956, p. 398].

Description.—Subcircular in outline. Hinge line straight and about widest part of shell. Cardinal extremities right angles; lateral and antero-lateral margins form gentle, smooth curve leading into more gently curved or straight anterior margin. Unequally binconvex in lateral profile, almost plano-convex, thickest part just posterior to middle. Broad shallow sulcus in median anterior two-thirds of pedicle valve. Lateral commissure rectimarginate to weakly sulcate; anterior commissure broadly uniplicate, fold not as well defined as sulcus. Surface multicostellate, 18-20 costae around beak in specimen 15.5 mm long and 21.3 mm wide, 3 costae per 2 mm at 5 mm from beak.

Pedicle interarea plane, strongly apsacline, about 3 times as long as brachial interarea. Triangular delthyrium, open, cavity shallow and even with floor of valve. Teeth short, rounded extremities; dental plates thin, divergent, receding and joining with posterior portion of muscle field. Field cordate, slightly elevated ridge extending to middle from posterior to anterior; lateral margins of field slightly raised, joining posteriorly to dental plates. Diductor scars large, ellipsoidal, separated by median septum; position of adductor scars obscure, weak impressions on posterior one-half of ridge are about one-half length of field.

Brachial interarea short, plane, orthocline. Myophore circular, crenulated. Delthyrium triangular, wide, open. Cavity wide, moderately deep, elevated above valve floor. Shaft portion of process about one-third as wide as cavity. Brachiophores short, divergent; sockets well developed; tops of brachiophores slope laterally toward sockets and form part of socket floor. Median septum low, rounded, extending anteriorly 2-3 mm. Anterior two-thirds of valve interior faintly reflects external costation.

Discussion.—Only a few specimens of this species were collected from the Viola Formation, all of which have numerous bifurcating costae as does *D. transversa* Willard. None of the specimens, however, show the flattened or concave pedicle valve like that of *D. transversa.* In lateral profile the specimens from the Viola Formation are more like *D. sweeneyi* (Winchell); however, the costae of *D. sweeneyi* seldom bifurcate (costae increase in size as shell size increases).

Most specimens of *D. transversa* in the U.S. National Museum collections are from the Benbolt and Ottosee Formations.

Distribution and material.—This species is found at section D, unit 2, 275-280 feet below the top of the Viola Formation. Only one articulated specimen was found along with several partial brachial and pedicle valves.

Figured specimens.—All are from unit 2: OU 5885 (articulated specimen), section D; OU 5886 (brachial valve), section C; OU 5887 (pedicle valve), section C.

Family PLECTORTHIDAE Schuchert and Levene, 1929

Genus **Doleroides** Cooper, 1930

Doleroides vescus Alberstadt, n. sp.

Pl. 9, figs. 1, 2

Description.—Ellipsoidal in outline, width greater than length. Cardinal extremities obtuse to rounded. Lateral margins rounded, widest part of shell near middle; anterior margin broadly rounded to straight. Hinge line straight, slightly more than one-half maximum shell width. Lateral commissure rectimarginate, anterior commissure faintly uniplicate. Unequally biconvex in lateral profile. Surface having numerous fine costae weakly developed in umbonal region, becoming more pronounced anteriorly; numerous costellae, 4-5 costae and costellae per 2 mm at 9 mm from beak. Unable to determine if intercalated costellae present because of poor preservation.

Thickest part of pedicle valve posterior to middle. Interarea plane, long, apsacline. Delthyrium open, triangular; cavity moderately deep and about same level as valve floor. Teeth short rounded knobs extending slightly past hinge line; dental plates well developed, slightly advancing, joining lateral margins of muscle field. Field elongate (about 5.6 mm), anterior margin does not reach middle of valve. Diductor scars ellipsoidal, not divergent, impressed deeper than laterally positioned adjustors; adductor scars well defined; adjustor scars slightly impressed into base of dental plates.

Muscle field has slight elevated portion in center separating diductor scars.

Thickest part of brachial valve in middle. Interarea short, plane, orthocline to slightly anacline. Notothyrium open. Cardinal process thick, triangular-shaped crenulated myophore thinning toward posterior. Process does not extend above level of interarea, but separated from interarea by deep concavities. Base of process bears two distinct grooves that may have been position of diductor muscle attachment. Sockets thin slitlike grooves positioned on top of brachiophores and partially beneath hinge. Muscle field quadrate, posterior and anterior scars about equal in size. Median septum low, poorly defined, extending almost to middle of valve.

Discussion.—Dimensions for the brachial and pedicle valves of *D. vescus* figured on plate 9 (figs. 1a-2c) are as follows. OU 5910 (brachial valve): thickness, 4.2 mm; length, 11.0 mm. OU 5911 (pedicle valve): thickness 4.1 mm; length, 11.7 mm; width, 14.4 mm.

Doleroides vescus is similar to *D. oklahomensis* Cooper from the Bromide Formation in the Arbuckle Mountains. *D. vescus* has finer, more weakly developed costae and costellae than does *D. oklahomensis,* which has well-developed costae in the posterior parts of the shell, particularly around the beak. In contrast, *D. vescus* from the lower Viola Formation has poorly developed costae around the beak and in most specimens this area is almost smooth (pl. 14, figs. 1a, 2a).

Cooper (1956, p. 120-121) subdivided the upper part of the Bromide Formation in the Arbuckle Mountains into several biostratigraphic zones. The zone characterized by the brachiopod species *D. oklahomensis* is the second one from the top of the formation. The thicknesses of these biostratigraphic zones vary from section to section, and at some sections one or more of the zones are missing. Cooper (1956) gave no absolute thicknesses for any of these biostratigraphic zones, and therefore rock thickness between the *D. oklahomensis* zone and the base of the Viola Formation is difficult to determine.

The U.S. National Museum collections contain specimens identical to those described here from the lower part of the Viola Formation as *D. vescus.* However, these museum specimens are labeled as being from the *top* of the Bromide Formation. Cooper (1956) did not describe any similar species from the upper Bromide Formation of the Arbuckle Mountains, and it is possible that these U.S. National Museum specimens are mislabeled and are actually from the lower part of the Viola Formation.

The specimens I collected and described as *D. vescus* are from the lower foot of the Viola Formation at sections D and L, and at both of these sections the unconformable contact between the Viola and Bromide is sharp (welded contact). The Bromide at these sections is a dense, lithographic, micritic limestone; the Viola is a coarse-grained calcarenite. Because of these distinctly different lithologies, the contact can be easily placed. The specimens described here are silicified, and the limestone blocks from which they came were taken in place from above this welded contact. I am unaware of the possible presence of this species below the Viola Formation.

Distribution and material.—This species was found only at sections D and L in the lower foot of unit 1, subunit 1C. About 20 silicified valves were recovered, but no articulated specimens.

Types.—Holotype (brachial valve), OU 5910, and holotype (pedicle valve), OU 5911, both from unit 1, subunit 1C, section D.

Genus **Platystrophia** King, 1850

Platystrophia sutherlandi Alberstadt, n. sp.

Pl. 3, figs. 4, 5

Description.—Shell speriferoid in outline, widest part at hinge line; cardinal extremities pointed. Biconvex with brachial valve slightly deeper, greatest thickness in middle or just posterior to middle. Lateral commissure faintly convex, anterior commissure strongly uniplicate. Sulcus well developed and moderately deep on pedicle valve, occupied by three plications throughout most of length. Prominent fold on brachial valve, four plications throughout. Flanks bounding fold and sulcus gently convex, each having 10-12 plications.

Pedicle interarea apsacline, mostly

plane but slightly curved near beak, slightly longer than in brachial valve. Beak suberect. Delthyrium triangular, open, cavity deep. Teeth short, triangular, on side of delthyrium; dental plates thick, advancing, joining margins of muscle field. Field extends less than one-half length of valve (*see* pl. 3, fig. 4b), anterior margin of field convex, elevated; low ridge on anterior two-thirds of field. Adductor scars not clearly visible; diductor scars long, elongate, expanding slightly anteriorly; adjustor scars large, triangular, positioned at base and somewhat on walls of cavity. Crural fossettes shallow. Inside anterior one-third of valve crenulated; crenulations are internal reflections of external plications.

Brachial interarea shorter than pedicle valve, more strongly curved, orthocline. Beak slightly incurved. Notothyrium open, triangular, cavity moderately deep, elevated above valve floor. Cardinal process well developed, narrow ridge extending entire length of cavity does not reach level of interarea at highest posterior end. Brachiophores thick, rounded extremities. Sockets deep, round, causing brachiophores to appear "hooked." Inner faces of brachiophores strongly swollen to form distinct ridges. Median septum broad, rounded beneath notothyrial cavity, thinning to sharp ridge at anterior end of muscle field. Anterior adductor scars subtriangular, larger than curved J-shaped posterior adductor scars. Two posterior scars on some specimens so strongly curved and so deeply impressed that appear as four small "pits." Brachial valves with this peculiarity appear to have six adductor scars.

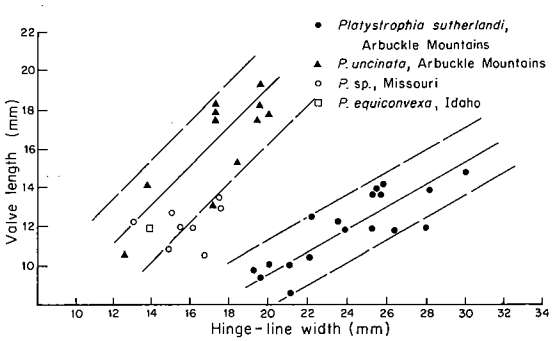
Discussion.—Schuchert and Cooper (1932, p. 39) noted that the anterior adductor scars on brachial valves of some orthid genera each appear to be divided into two parts (notably in the genus *Productorthis*), making six scars in the adductor field. The brachial valves of *Platystrophia sutherlandi* from unit 3, subunit 3C, and the "Fernvale" (Cape) Limestone in northeastern Oklahoma all appear to have bipartite posterior scars. (*P. uncinata,* n. sp., from unit 3, subunit 3C, and the "Fernvale" (Cape) Limestone, also shows bipartite posterior adductor scars.) To my knowledge, this is the first reported occurrence of six "adductor" scars in the brachial valve of a species of *Platystrophia.*

Platystrophia sutherlandi occurs in the same stratigraphic zone as *P. uncinata.* However, *P. sutherlandi* can be easily distinguished from *P. uncinata* by its thinner shell, less elongate pedicle muscle field (*see* text-fig. 26), and spiriferoid outline (*compare* fig. 4a to fig. 1a, pl. 3). The difference in shape is clearly shown by the scatter plot of hinge-line width—shell length in text-figure 24.

Platystrophia sutherlandi externally resembles *P. prima,* from unit 2 of the Viola Formation. However, *P. prima* has four equal-sized adductor muscle scars on the brachial valve in contrast to the hook-shaped posterior scars on the brachial valve of *P. sutherlandi.*

P. sutherlandi externally resembles some specimens of *P. acutilarata* Conrad from the Whitewater Formation (Richmond) of Indiana; however, *P. acutilarata* attains a much larger size than *P. sutherlandi.* No valves of *P. acutilarata* appear in the U.S. National Museum collections showing the internal characteristics.

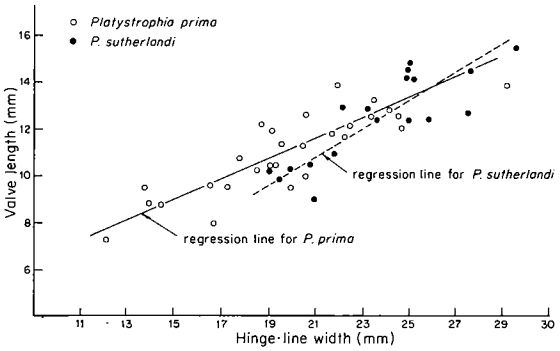
Distribution and material.—This species is represented by 10-15 specimens from unit 3, subunit 3C; no articulated specimens were collected. *P. sutherlandi* is confined to the upper 6 feet of the unit at



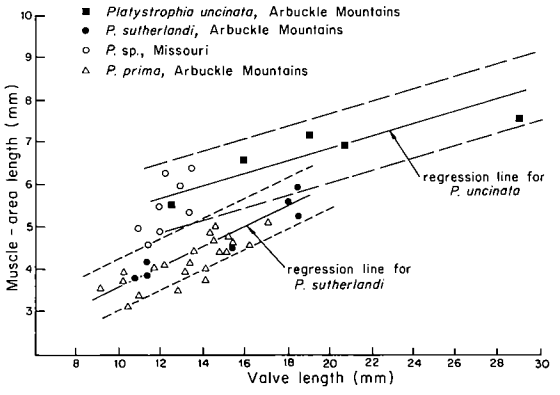
Text-figure 24. Regression lines and 95-percent-confidence intervals for valve-length to hinge-line-width relationships of pedicle and brachial valves of **Platystrophia sutherlandi** Alberstadt, n. sp., and **P. uncinata** Alberstadt, n. sp. **P. sutherlandi** mean hinge width, 23.7 mm; mean valve length, 12.3 mm. **P. uncinata** mean hinge width, 16.9 mm; mean valve length, 15.9 mm. Specimens from unit 3, subunit 3C, upper 6 feet. Data also given for specimens of **Platystrophia** sp. from Cape Limestone, Cape Girardeau, Missouri, and for **P. equiconvexa** Wang from Saturday Mountain Formation, Idaho.

sections A, C, and D. In the basin province, unit 3, subunit 3CM, is found 40-60 feet below the top of the formation at sections I and R.

About 60 specimens of this species have also been collected from the "Fernvale" (Cape) Limestone in northeastern Oklahoma.



Text-figure 25. Regression lines for valve-length to hinge-line-width relationships of pedicle and brachial valves of **Platystrophia sutherlandi** Alberstadt, n. sp., and **P. prima** Alberstadt, n. sp. **P. sutherlandi** mean hinge-line width, 23.7 mm; mean valve length, 12.3 mm. **P. prima** mean hinge-line width, 19.6 mm; mean shell length, 10.8 mm. **P. sutherlandi** specimens are from unit 3, subunit 3C, upper 6 ft.; **P. prima** specimens are from unit 2, 170-200 feet above base of Viola Formation.



Text-figure 26. Regression lines and 95-percent-confidence intervals for length of pedicle valve-length of muscle area of **Platystrophia uncinata** Alberstadt, n. sp., and **P. sutherlandi** Alberstadt, n. sp. **P. uncinata** mean valve length, 17.1 mm; mean muscle-area length, 7.2 mm. **P. sutherlandi** mean valve length, 12.2 mm; mean muscle-area length, 5.2 mm. Specimens are from unit 3, subunit 3C, upper 6 feet. Data also given for specimens of **Platystrophia** sp. from Cape Limestone, Cape Girardeau, Missouri, and **P. prima** Alberstadt, n. sp., from unit 2, 170-200 feet above base of Viola Formation.

Types.—All specimens are from unit 3, subunit 3C. Holotype (pedicle valve): OU 5824, section A. Holotype (brachial valve): OU 5825, section C. Unfigured paratypes: OU 6845 (pedicle valve), OU 6846 (brachial valve); both from section A, upper 6 feet of subunit 3C. OU 6847 (pedicle valve), OU 6848 (pedicle valve), OU 6849 (brachial valve), and OU 6850 (brachial valve); all from section C, upper 6 feet of subunit 3C.

Platystrophia uncinata Alberstadt, n. sp.

Pl. 3, figs. 1-3

Description.—Shell thick, medium size for genus (*see* text-fig. 24 for length-width data), subrectangular in outline. Cardinal extremities obtuse or at right angles, lateral margins gently curved, anterior margin straight. Hinge line straight, not as wide as maximum width of shell, which occurs at middle. Unequally biconvex in lateral profile; brachial valve about twice as deep as pedicle, highest point in middle or just anterior to it. Lateral commissure rectimarginate, anterior commissure strongly uniplicate. Surface plicate, 9-10 on flanks, 3 in sulcus, 4 on fold. (This species is a member of the triplicate group of Schuchert and Cooper, 1932.) Plications angular with sharply rounded tops. Growth lines around anterior margins of some specimens.

Well defined sulcus in pedicle valve, beginning at beak, expanding and deepening anteriorly; width and depth accentuated by long tongue protruding at right angles to line of commissure. Interarea curved, apsacline, wider than in brachial valve. Delthyrium triangular, open. Teeth short, located short distance from cavity walls. Crural fossettes weak, only present in some specimens. Teeth supported by moderate shell deposits; Dental plates poorly developed, when present are slender, advancing, continuous with lateral margins of ellipsoidal muscle field. Anterior end of field strongly convex, slightly elevated. Individual scars not differentiated; part of adjustor scars positioned high on cavity walls.

Brachial fold begins at beak, expands anteriorly. Umbonal region inflated, extending beyond posterior margin of interarea. Interarea shorter and more acutely curved than in pedicle valve. Notothyrium

triangular, open, subtending angle about 45°; cavity deep, elevated above valve floor. Cardinal process slender, delicate blade extending full length of cavity, does not approach level of interarea. Brachiophores robust, triangular, each bearing shelflike ridge on inner face; top parts of each ridge continuous with floor of notothyrial cavity. Sockets deep, some entrenched beneath level of interarea. Median septum absent or poorly developed. Anterior adductor scars largest in field, trapezoidal (*see* pl. 3, fig. 3b). Posterior adductor scars J-shaped, in some larger specimens are so well embedded as to appear pinched or infolded (*see* pl. 3, fig. 3c). Median septum wider and higher in posterior part of valve, thinning and becoming lower until it disappears at anterior edge of muscle field. Anterior margin of shell crenulated, crenulations reflect external plications (*see* pl. 3, figs. 1b, 3a); are visible around margins, becoming weaker posteriorly until disappear at middle of valve.

Discussion.—The adductor muscle pattern found in *Platystrophia uncinata* is the same as in *P. sutherlandi*, but this pattern does not agree with the genus *Platystrophia* given by Schuchert and Cooper (1932). They stated (p. 65):

> . . . adductor scars unequal in size, the posterior pair the larger, divided from the anterior adductor impressions by low ridges at right angles to the median ridge.

I have examined the brachial interiors of several species of *Platystrophia* from the U.S. National Museum collections and found the muscle pattern to be like that described for the genus. One collection is labeled as being from the top of the Kimmswick Formation in Jefferson County, Missouri, and shows an adductor muscle pattern like that described here for *P. uncinata.* I collected from the Cape Limestone at Cape Girardeau, Missouri (the Cape Limestone is directly above the Kimmswick Formation), and found a species of *Platystrophia* identical to the one in the U.S. National Museum labeled as being from the top of the Kimmswick. In my opinion, all these specimens are from the Cape Limestone and not the top of the Kimmswick Formation.

The species from the Cape Limestone of southeastern Missouri has the same adductor muscle pattern as *P. uncinata* in addition to the same general shape and outline. However, the Cape Limestone species has a much thinner shell and does not reach as large a size as *P. uncinata* (*see* text-fig. 24). Also, the size of the pedicle muscle field is relatively smaller than that of *P. uncinata* (*see* text-fig. 25; *also compare* fig. 4b with fig. 1b in pl. 3).

The species from the Cape Limestone of southeastern Missouri is very similar to *P. equiconvexa* Wang from the Maquoketa Formation of Iowa and the Saturday Mountain Formation of Idaho. However, *P. equiconvexa* does not appear to have the J-shaped posterior adductor scars as does the Missouri species. Wang (1949) described the posterior adductor scars of *P. equiconvexa* as being oval in shape, with the median portion elevated to form a ridge. Specimens of *P. equiconvexa* I examined from the Saturday Mountain Formation (U.S. National Museum collections) did not show the J-shaped adductor scars.

P. uncinata differs from *P. equiconvexa* in having a distinctly unequally biconvex shell, a much longer pedicle muscle field, and a thicker shell. The thinness of the shell of *P. equiconvexa* allows the external plications to be reflected through to the inside where they extend up to the muscle field; this is not true of *P. uncinata* (*see* pl. 3, figs. 1b, 3a).

P. uncinata has a completely different shape from *P. prima* from unit 2 of the Viola Formation.

Distribution and material.—*Platystrophia uncinata* is found in the upper 6 feet of unit 3, subunit 3C, at sections A, C, and D. At sections I and R, unit 3, subunit 3CM, it occurs 40-60 feet below the top of the unit.

Only 13-15 brachial and pedicle valves were collected from the Viola Formation, and no articulated specimens. I also collected about 30 valves from the "Fernvale" (Cape) Limestone in northeastern Oklahoma.

Types.—All specimens are from unit 3. Holotype (pedicle valve: OU 5821, subunit 3C, section C. Holotype (brachial valve): OU 5823, subunit 3CM, section I. Figured paratype (brachial valve): OU 5822, subunit 3CM, section I. All the following specimens are from the upper 6 feet of subunit 3C;

unfigured paratypes: OU 6830 (pedicle valve), section A; OU 6831 (pedicle valve), section A; OU 6832 (pedicle valve), section C; OU 6833 (brachial valve), section C; OU 6834 (brachial valve), section A; and OU 6835 (brachial valve), section C.

Platystrophia prima Alberstadt, n. sp.
Pl. 8, figs. 1-4

Description.—Shell speriferoid, hinge line straight and widest part of shell. Cardinal extremities acute in most, alate in some. On small individuals lateral, anterolateral, and anterior margins lead smoothly into one another. On larger specimens anterior margin more truncated and set off from curvature of lateral margins. Biconvex in lateral profile, brachial valve slightly deeper than pedicle; this difference more pronounced on larger specimens. Lateral commissure rectimarginate, anterior commissure uniplicate. Well-developed brachial fold and pedicle sulcus; both begin at beak, increase in prominence anteriorly. Near beak one plication in sulcus, two on fold; typical triplicate pattern (Schuchert and Cooper, 1932) developing from plications. Sulcus widths at anterior margins of five pedicle valves given in table below. Plications on flanks range from 7 to 12 depending on individual size of specimen.

Valve length (mm)	Sulcus width (mm)
7.4	4.2
8.7	5.2
10.2	5.8
11.5	7.2
12.9	8.6

Pedicle beak erect to suberect. Interarea longer than on brachial valve, curved, apsacline. Delthyrium triangular, open. Teeth short, stout, turned slightly upward and outward. Crural fossettes small, slightly larger accessory dental sockets; dental plates receding. Delthyrial cavity deep, walls of cavity slope gently outward. Muscle field cuneate (text-fig. 25 shows data for length of field). Interior of valve corrugated in anterolateral half. External plications near sulcus not strongly reflected on valve interior.

Brachial beak erect. Interarea short, orthocline. Notothyrium open; cavity deep, elevated above valve floor. Cardinal process low thin ridge, extending full length of cavity. Brachiophores stout, pointed, inner face of each weakly concave; sockets present. Cordate anterior adductors slightly larger than posterior scars.

Discussion.—This species is differentiated from *P. sutherlandi* primarily by the different position of the brachial muscle field and by the ellipsoidal shape of the posterior adductor muscle scars. On *P. sutherlandi* (*see* pl. 3, fig. 5b) the posterior scars are positioned well beneath the brachiophores out of view; on *P. prima* (*see* pl. 8, fig. 3a) all four scars are easily visible. Both photographs were taken normal to the plane of commissure, and neither specimen was tilted.

P. prima is very similar to *P. acutilarata,* but does not attain the large size shown by that species.

Distribution and material.—This species was collected from sections C and D. At section C, unit 2, the species occurs 270-280 feet below the top of the formation. At section D the stratigraphic range is slightly greater: 170-200 feet above the base of the formation. At both sections *P. prima* occurs in the same stratigraphic zone. The distribution at section D is given with the base of the formation as the reference because the upper part of the formation is faulted (*see* description of measured section).

This species is represented by over 150 specimens, 4 or 5 of which are articulated.

Types.—All specimens are from unit 2, section C. Holotype (articulated specimen): OU 5880. Holotype (pedicle valve): OU 5881. Holotype (brachial valve): OU 5883. Figured paratype: OU 5882 (pedicle valve). Unfigured paratypes: OU 6836 (brachial valve), OU 6839 (pedicle valve), OU 6840 (pedicle valve), OU 6841 (pedicle valve), OU 6842 (pedicle valve), OU 6843 (pedicle valve), and OU 6844 (pedicle valve).

Superfamily ENTELETACEA Waagen, 1884

Family DALMANELLIDAE Schuchert, 1913

Genus **Diceromyonia** Wang, 1949

Diceromyonia cf. **D. tersa** (Sardeson, 1892)
Pl. 4, figs. 15-17; pl. 5, figs. 1-2

Orthis tersa SARDESON, 1892, p. 331-332, pl. 5, figs. 11-13 [*fide*,Wang, 1949, p. 36]; SARDESON, 1897, p. 101-102, pl. 5, figs. 8-13.

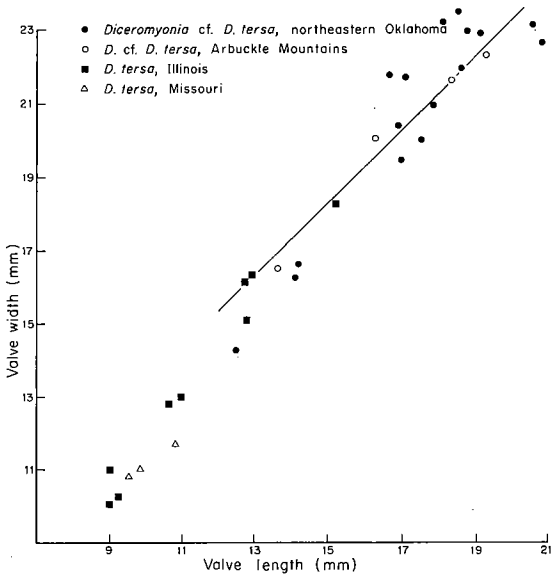
Dalmanella tersa (Sardeson), SCHUCHERT and COOPER, 1932, p. 17, figs. 26, 30.
Rhipidomella tersa (Sardeson), GREGER and BORN, 1936, pl. 1, figs. 10-12.
Diceromyonia tersa (Sardeson), WANG, 1949, p. 36, pl. 12, figs. B1-8.

Description.—Large for genus, width greater than length (largest specimen from Viola 19.8 mm long, 27.6 mm wide, and 8.0 mm thick). Subquadrate to subrectangular in outline. Cardinal extremities rounded, postero-lateral margins straight but diverge away from median; antero-lateral margins moderately rounded, smoothly joining more broadly curved anterior margin. Hinge line straight, short, slightly less than one-third maximum width of shell, which is just anterior to middle. Plano-convex in lateral profile, some brachial valves slightly convex. Lateral commissure rectimarginate to slightly convex, anterior commissure rectimarginate. Thickest part in middle. Brachial valve with shallow, narrow sulcus beginning at beak, expanding but not deepening anteriorly. Sulcus contains 8-9 costellae at anterior margin in specimen 14 mm long.

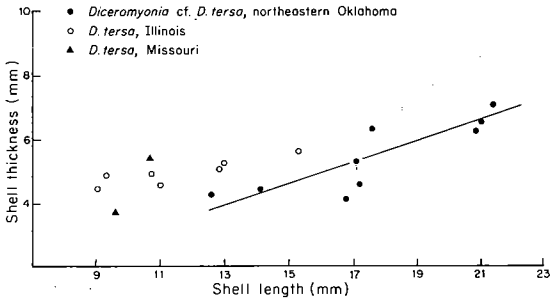
Pedicle beak small, suberect, projecting slightly beyond posterior margin of brachial valve. Interarea short (about 1.3 mm on larger specimens), curved, weakly apsacline. Cavity moderately deep, posterior margin raised slightly above muscle area. Teeth strong, triangular, sharp keel-like anterior margins; teeth strengthened by well-developed advancing dental plates that join lateral margins of muscle field. Crural fossettes conspicuous, appearing as ledges positioned just beneath teeth and on top of dental plates. Accessory dental sockets triangular, shallow, positioned on top portion of teeth and anterior to hinge line. Muscle field has elongated ellipse outline, about twice as long as wide, extending about two-thirds shell length. Adductor scars small, elliptical, positioned in center immediately posterior to middle. Diductors large, not expanding or diverging anteriorly, appear to enclose smaller adductor scars; low ridge anterior to adductors possibly prevented complete enclosure. Adjustors not observed. Inner margin of valve crenulated.

Brachial interarea plane, weakly apsacline, almost orthocline. Cardinalia strong; process undifferentiated, trilobed, shaft thick, rounded, joining median septum. Brachiophores strong, divergent, posterior margins narrow and separated from process by groove. Fulcral plates lacking. Sockets large, moderately deep, impressed slightly into sides of brachiophores. Median septum wide, rounded, extending to anterior of muscle field. Field about as wide as long. Posterior adductors circular to subquadrate, smaller than anterior pair. Anterior adductors circular in outline.

Discussion.—The specimens described here from the Viola Formation are identical to those from the "Fernvale" (Cape) Limestone in northeastern Oklahoma. To my knowledge, these are the largest specimens so far reported for the genus. Overall size is the only conspicuous difference between the Viola species and *D. tersa* (Sardeson). The large size of *Diceromyonia* cf. *D. tersa* also sets it apart from *D. ignota* (Sardeson) and *D. crassa* Howe. Text-figure 27 shows the magnitude of difference between the specimens from the Arbuckle Mountains and northeastern Oklahoma and those of *D. tersa* from Illinois. Because no other characteristic differences are evident, I am reluctant to designate this a new species.



Text-figure 27. Regression line for length-width relationships of brachial valves of **Diceromyonia** cf. **D. tersa** (Sardeson) from "Fernvale" (Cape) Limestone in northeastern Oklahoma and from unit 3, subunit 3C, upper 6 feet. Data also given for specimens of **D. tersa** (Sardeson) from Richmond Formation, Illinois, and from Cape Limestone, Cape Girardeau, Missouri.



Text-figure 28. Regression line for length-thickness relationships of articulated specimens of **Diceromyonia** cf. **D. tersa** (Sardeson) from "Fernvale" (Cape) Limestone in northeastern Oklahoma. Data also presented for specimens of **D. tersa** (Sardeson) from Richmond Formation, Illinois, and Cape Limestone, Cape Girardeau, Missouri.

Distribution and material.—*Diceromyonia* cf. *D. tersa* occurs in the upper 6 feet of unit 3, subunit 3C, sections A and C. In the basin province it is found 40-60 feet below the top of unit 3, subunit 3CM, sections I and R.

Only 5 specimens were collected from the Arbuckle Mountain region, but over 50 were collected from the "Fernvale" (Cape) Limestone in northeastern Oklahoma.

Figured specimens.—These specimens are from unit 3, subunit 3C: OU 5842 (articulated specimen), section A; OU 5843 (pedicle valve), section C; and OU 5844 (brachial valve), section C. These specimens are from the "Fernvale" (Cape) Limestone, northeastern Oklahoma, sec. 25, T. 16 S., R. 22 E., and sec. 30, T. 16 S., R. 23 E., upper foot of 14-foot section measured along Illinois River, Cherokee County: USNM 163600 (pedicle valve) and USNM 163601 (brachial valve).

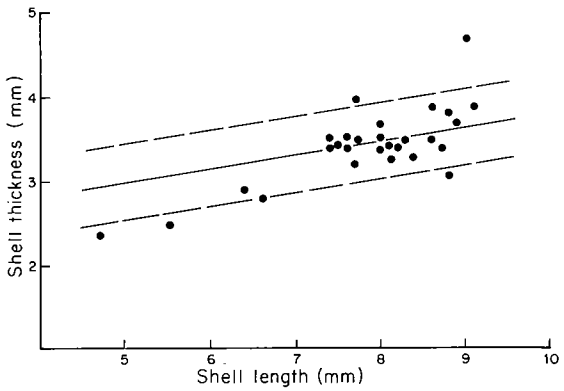
Genus **Paucicrura** Cooper, 1956
Paucicrura cf. **P. rogata** (Sardeson, 1892)

Pl. 8, figs. 11-13

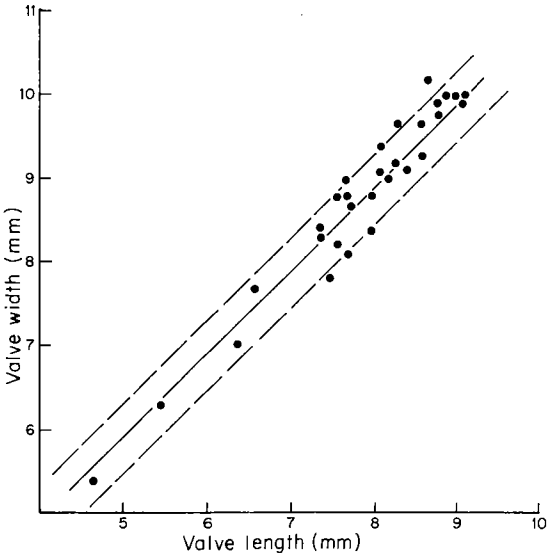
Orthis rogata SARDESON, 1892, p. 331, pl. 5, figs. 1-4 [*fide*, Cooper, 1956, p. 957].
Orthis (*Dalmanella*) *testudinaria* (Winchell and Schuchert [not Dalman]), WINCHELL and SCHUCHERT, 1895, p. 441, pl. 33, figs. 17-22.
Dalmanella rogata (Sardeson), SCHUCHERT and COOPER, 1932, p. 120, pl. 17, figs. 2-5, 13, 31.
Paucicrura rogata (Sardeson), COOPER, 1956, p. 957, pl. 157F, figs. 18-24.

Description.—Shell small (text-figs. 29-31 show size data). Plano-convex in lateral profile, thickest part just posterior to middle. Lateral commissure rectimarginate, anterior commissure weakly sulcate. Subquadrate in outline, width slightly greater than length (text-fig. 30), widest part just anterior to middle or at middle. Cardinal extremities rounded; lateral margins broadly curved joining smoothly with anterior margin. Hinge line straight, slightly more than one-half as wide as maximum shell width. Brachial valve bears narrow, shallow sulcus, beginning at beak, expanding but not deepening appreciably anteriorly. Gently rounded top and steep sloping sides on pedicle valve in anterior profile. Surface multicostellate, 60 marginal costae and costellae in specimen 8 mm long and 8.5 mm wide, 7-8 costae and costellae per 2 mm at 5 mm from brachial beak.

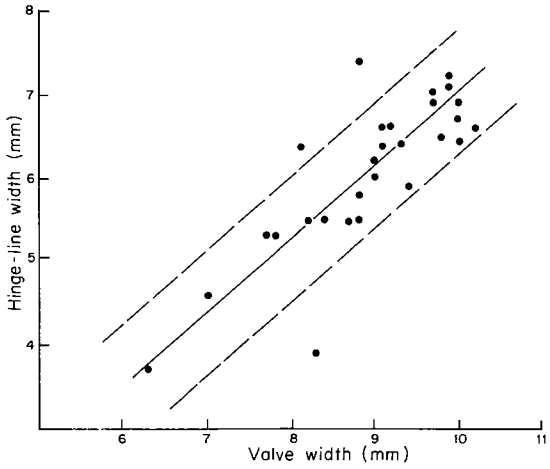
Pedicle beak erect to slightly incurved, projecting about 1 mm past posterior margin of brachial valve. Interarea curved, short, apsacline. Delthyrium triangular, open; small shelf structure in apex of cavity just below level of interarea, developed to various degrees, on some specimens absent. Cavity deep, walls sloping outward. Teeth thick, short; dental plates advancing, joining margins of muscle field; inner face of each plate inflated to form well-developed crural fossettes. Muscle field ovate to ellipsoidal, anterior margin bilobed; median reentrant



Text-figure 29. Regression line and 95-percent-confidence intervals for length-thickness relationships of articulated specimens of **Paucicrura** cf. **P. rogata** (Sardeson). Mean thickness, 3.4 mm; mean length, 7.7 mm. All specimens are from 275-283 feet below top of Viola Formation, unit 2, section C.



Text-figure 30. Regression line and 95-percent-confidence intervals for length-width relationships of pedicle valves of **Paucicrura** cf. **P. rogata** (Sardeson). Mean length, 7.7 mm; mean width, 8.9 mm. Specimens are from 275-283 feet below top of Viola Formation, unit 2, section C.



Text-figure 31. Regression line and 95-percent-confidence intervals for valve-width to hinge-line-width relationships of pedicle valves of **Paucicrura** cf. **P. rogata** (Sardeson). Mean valve width, 8.9 mm; mean hinge width, 6.2 mm. Specimens are from 275-283 feet below top of Viola Formation, unit 2, section C.

extending to middle of field in some. Field extending about one-third to one-half valve length. Broadly rounded median ridge on some, positioned in anterior half of field. Lateral margins of field gently curved, some straight. Diductors large, only scars visible, divergent in some. Anterior margins of scars curved to various intensities, some almost pointed. Inner margins of valve corrugated, each corrugation same magnitude as surface costae; reflections of costae visible around anterior one-third of valve margin.

Brachial interarea plane, orthocline, shorter than in pedicle valve. Cardinalia strong, process undifferentiated, trilobed; shaft thinner than median septum. Myophore poorly preserved in most. Brachiophores stout, varying from thin with sharp, thin, pointed margins to thick with rounded extremities. In some, posterior face of brachiophore bears narrow groove extending full length. Sockets large. Prominent broad median septum dividing quadrate muscle field. Posterior adductor scars circular to subcircular; slightly smaller than circular anterior scars. Both pairs moderately impressed.

Discussion.—*Paucicrura rogata* (Sardeson) is a common Middle Ordovician brachiopod found in the Ion Member of the Decorah Formation and in the Prosser Formation in Minnesota and Wisconsin. It has also been reported from the Auburn Chert of Missouri.

Distribution and material.—This species is common at section C, unit 2, 275-280 feet below the top of the formation. It is also abundant at section D, unit 2, 170-200 feet from the base of the formation.

Several hundred specimens were collected, mostly from section C.

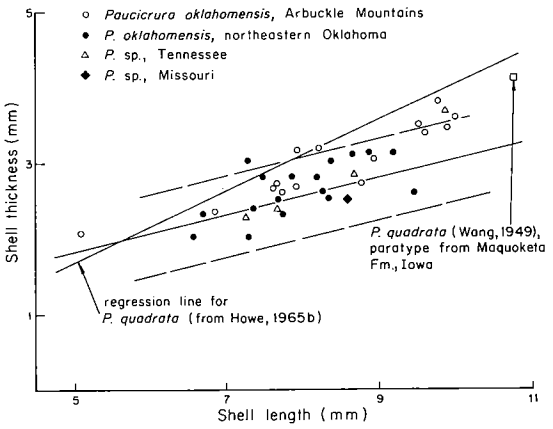
Figured specimens.—These specimens from unit 2, section C: OU 5890 (articulated specimen), OU 5891 (brachial valve), and OU 5892 (pedicle valve).

Paucicrura oklahomensis Alberstadt, n. sp.
Pl. 4, figs. 11-14

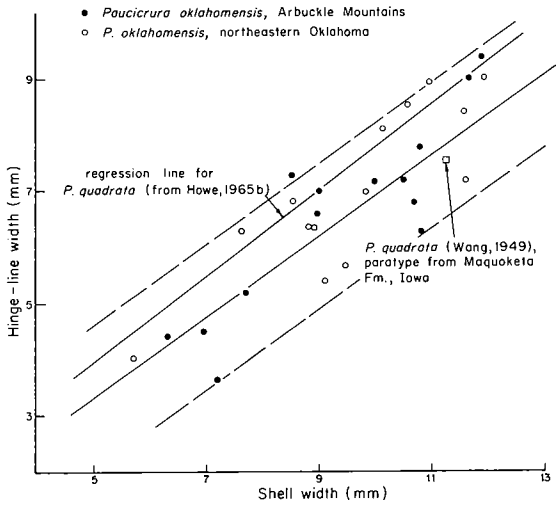
Description.—Shell small (text-figs. 32, 33, 34, show size data); subquadrate in outline, greatest width just anterior to hinge line. Hinge line straight and about two-thirds as wide as maximum shell width.

Cardinal extremities acutely rounded; lateral margins straight or broadly rounded, in some sides parallel, others inclined toward median. Anterior margins narrowly to broadly rounded depending on inclination of lateral margins. Plano-convex in lateral profile. Brachial sulcus makes valve almost concave. Lateral commissure rectimarginate, anterior commissure broadly sulcate. Pedicle fold with narrowly rounded top, flanks sloping gently and continuously to margins. Posterior and anterior profiles V shaped (pl. 4, figs. 11c, 11d). Brachial sulcus beginning at beak where shallow and narrow, widening and deepening anteriorly. Surface multicostellate, 10 costae and costellae per 3 mm at anterior margin in specimen 9 mm long and 10 mm wide.

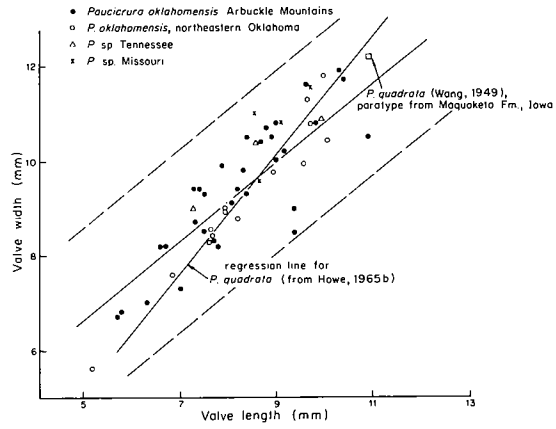
Pedicle interarea plane, apsacline, longer than in brachial valve. Delthyrium triangular, open; cavity deep. Teeth divergent, moderately strong, supported by thick, advancing dental plates; plates continuous with margins of muscle field, extending anteriorly to various distances. Crural fossettes well developed. Muscle field elongate, extending about two-thirds length



Text-figure 33. Regression line and 95-percent-confidence intervals for length-thickness relationships of articulated specimens of **Paucicrura oklahomensis** Alberstadt, n. sp. Mean length, 8.0; mean thickness, 2.6 mm. Line calculated using all articulated specimens from upper 6 feet of unit 3, subunit 3C, sections A and C. Data also given for specimens of **Paucicrura** sp. from Fernvale Formation, Nashville, Tennessee, and Cape Limestone, Cape Girardeau, Missouri, and for specimens of **P. oklahomensis** from "Fernvale" (Cape) Limestone in northeastern Oklahoma.



Text-figure 32. Regression line and 95-percent-confidence intervals for shell-width to hinge-line-width relationships of articulated specimens of **Paucicrura oklahomensis** Alberstadt, n. sp. Mean shell width, 9.6 mm; mean hinge-line width, 6.6 mm. Specimens are from upper 6 feet of unit 3, subunit 3C, sections A and C. Data also given for specimens of **P. oklahomensis** from "Fernvale" (Cape) Limestone in northeastern Oklahoma.



Text-figure 34. Regression line and 95-percent-confidence intervals for length-width relationships of pedicle valves of **Paucicrura oklahomensis** Alberstadt, n. sp. Mean length, 8.2 mm; mean width, 9.3 mm. Specimens are from unit 3, subunit 3C, upper 6 feet. Data also given for specimens referred to **Paucicrura** sp. from Fernvale Formation, Nashville, Tennessee, and Cape Limestone, Cape Girardeau, Missouri, and for specimens of **P. oklahomensis** from "Fernvale" (Cape) Limestone in northeastern Oklahoma.

of valve. Adductor impressions not observed, but slight elevation in center of field may have been position of attachment. Diductor scars elongated ellipse, two scars diverging at various degrees, difficult to determine whether diductors completely enclosed adductors. Position, shape, size of adjustors not determined with certainty; small overhang just under teeth and on dental plates suggests possible position for adjustor attachment. Inner margin of valve crenulated.

Brachial interarea short, anacline, almost orthocline. Cardinalia strong. Cardinal process stout, trilobed, thick shaft merging with median septum. Brachiophores stout, diverging to various degrees. Median septum extends to anterior of muscle field, in some specimens absent posterior to margin of field. Adductor scars set close under brachiophores, separated by median septum; not well defined, appear circular in outline.

Discussion.—Williams and Wright (1963) defined the genus *Onniella* as having an undifferentiated bilobed cardinal process and the genus *Paucicrura* as having a differentiated trilobed process. Hall (1962) described the cardinal process in *Onniella* as being generally bilobed, but trilobed and quadrilobed in some specimens, and therefore placed *Paucicrura* in synonomy with *Onniella.* I studied the brachial interiors of almost 100 specimens of *Paucicrura oklahomensis* from the "Fernvale" (Cape) Limestone in northeastern Oklahoma, and the posterior portion of the cardinal process is distinctly trilobed in every one. Howe (1967) suggested that the name *Paucicrura* be retained until a thorough study is made of the variation in its cardinal process.

Onniella quadrata Wang from the Maquoketa Formation of Iowa and *O. quadrata variata* Howe and *O. plicata* Howe from the Montoya Group of west Texas and New Mexico all have trilobed processes. Because of this I prefer to consider these species as members of the genus *Paucicrura.*

Paucicrura oklahomensis is distinguished from *P. quadrata* by the fineness of the costae, the smaller thickness of the articulated shell, and the less prominent sulcus. Text-figure 33 shows that, as a population, *P. oklahomensis* is less dense than *P. quadrata* from the Montoya Group.

A few specimens from the Fernvale Formation near Nashville, Tennessee, appear to be the same as *P. oklahomensis.*

Distribution and material.—*P. oklahomensis* occurs in the upper 6 feet of unit 3, subunit 3C, at sections A, C, and D. In the basin province, subunit 3CM, at section I, it occurs 40-60 feet below the top of the unit.

Types.—All specimens are from unit 3, subunit 3C. Following specimens are from section A; holotype (articulated specimen): OU 5838; holotype (pedicle valve): OU 5840; holotype (brachial valve): OU 5841; figured paratype (pedicle valve): OU 5839. Following specimens are from upper 6 feet of subunit 3C; unfigured paratypes: OU 6865 (articulated specimen), section C; OU 6866 (articulated specimen), section A; OU 6867 (brachial valve), section C; and OU 6868 (pedicle valve), section A.

Genus **Onniella** Bancroft, 1928

?**Onniella** sp.

Pl. 9, figs. 5-7, 12

Description.—Shell almost circular, hinge line straight and little more than half maximum width. Cardinal extremities obtusely rounded, lateral and anterior margins evenly rounded at about same magnitude. In anterior profile pedicle valve has sharp rounded middle, straight sloping sides. Anterior commissure broadly sulcate, lateral commissure rectimarginate. Lateral profile unequally biconvex, almost planoconvex, pedicle valve about twice as deep as brachial. Surface costellate, about 7 costae and costellae per 2 mm at 4 mm from beak. Pedicle interarea slightly curved, apsacline. Delthyrium triangular, open. Teeth extending about 5-6 mm anterior of hinge line, supported by well-developed, advancing dental plates, continuous with lateral margins of muscle field. Field elongate with median reentrant. Diductor part of field extends about 3.8 mm anterior of pedicle beak.

Brachial sulcus begins at beak, expanding but not deepening anteriorly. Interarea short (0.5 mm), anacline. Notothyrium open. Shaft short, myophore bilobed and crenulated. Brachiophores strong, projecting about 1 mm anterior of

hinge, sharp, pointed, with flat, sloping external faces. Prominent median septum extends 3.5 mm anterior of hinge line; posterior half of septum bears conspicuous groove. Posterior and anterior adductor scars not differentiated.

Discussion.—This species is questionably referred to *Onniella* because of its distinct bilobed cardinal process and the absence of fulcral plates. However, none of the specimens have the widely cordate ventral muscle field described for *Onniella* but rather one that is elongate and bilobed like that of *Diceromyonia.*

Distribution and material.—This species is represented by 20-25 specimens from unit 1, subunit 1C. All of the specimens collected were silicified. Some were collected 1 foot above the base of the unit at sections D and L. Others were collected from 40 feet above the base at section L.

Figured specimens.—All specimens are from unit 1, subunit 1C: OU 5900 (pedicle valve), section L; OU 5909 (pedicle valve), section L; OU 5910 (brachial valve), section L; and OU 5896 (brachial valve), section D.

Suborder STROPHOMENIDINA Öpik, 1934
Superfamily PLECTAMBONITACEA Jones, 1928
Family LEPTELLINIDAE Ulrich and Cooper, 1936
Genus **Leptellina** Ulrich and Cooper, 1936

Leptellina sp.

Pl. 8, fig. 5

Description.—Brachial valve concave, subcircular to subelliptical in outline. Hinge line straight, widest part of shell. Cardinal extremities acute, sometimes rounded, lateral margins broadly rounded leading smoothly into curved anterior margin. Sulcus extends full length of valve, expanding anteriorly but not deepening, no strong angulations mark off sulcus from flanks; however, transition more acute in posterior parts of valve. Surface unequally parvicostellate, 2-3 costellae between 2 larger ones; differentiation of costellae more difficult away from sulcus. Interarea short, anacline. Notothyrium closed by thick chilidial plates separated from brachiophores by groove. Cardinal process small elevated ridge on antero-ventral face of massive chilidium. Brachiophores short, pointed, divergent. Lophophore platform large, elevated prominently around lateral and anterior margins. Lateral margins of platform parallel to margins of valve; anterior margin has sharp indentation giving it bilobed appearance. Well-developed ridge extends from just anterior of cardinal process to anterior margin of platform, increasing in prominence anteriorly. Robust ridge on one specimen.

Discussion.—The description of this species is based on only three brachial valves; no pedicle valves were found.

Leptellina pulchra Cooper has a shell of about the same dimensions as this Viola species but has distinctly different surface ornamentation. *L. pulchra* has 8-10 threadlike costae that stand out over a field of very fine costellae. *Leptellina* sp. has 2-3 fine costellae between 2 larger costae. An unnamed species of *Leptellina* described by Cooper (1959) from the Edinburg Formation of Virginia is a little larger than the Viola species but differs more significantly in having the median septum begin 2.5 mm anterior to the cardinal process. The septum in the Viola species begins at the base of the process.

To my knowledge, this is the first reported presence of *Leptellina* in the Viola Formation of Oklahoma. The youngest species reported by Cooper (1956) were *L. abbreviata* from the Oranda Formation (upper Wilderness) in Virginia and *L. incompta* from just below the Eureka Quartzite (upper Wilderness) in Nevada. *Leptellina* from the Viola is at least this young and possibly a little younger.

Distribution and material.—Three brachial valves were collected from unit 2 at section C, 280 feet below the top of the Viola Formation.

Figured specimen.—OU 5884 (brachial valve), unit 2, section C.

Family Sowerbyellidae Öpik, 1930
Genus **Thaerodonta** Wang, 1949

Thaerodonta aff. **T. magna** Howe, 1965

Pl. 4, figs. 1-10; pl. 5, figs. 3, 12

Description.—Shell semicircular to subrectangular, hinge line straight, widest

part at all growth stages. Maximum width almost twice maximum length. Cardinal extremities acute, lateral margins gently curved. In semicircular specimens lateral margins progress smoothly into anterior margin. Anterior margin on subrectangular specimens slightly curved or truncated with lateral margins straight; thus, transition from lateral margins to anterior margin not smooth curve but sharp, thereby accentuating margins. Concavo-convex in lateral profile, thickest part in middle. Lateral commissure slightly convex, anterior commissure slightly concave. Surface unequally costellate and variable; anterolateral portion more likely to have 2-4 smaller costellae between 2 larger ones, anterior region from 2-7 (more often 4-7) smaller costellae between 2 larger ones. In some specimens all costellae about same size and differentiation into large and small difficult.

Pedicle interarea wide, in some specimens strongly apsacline, in others almost orthocline. Numerous cardinal fossettes along hinge line, average 12.5 in 5 mm (pl. 4, fig. 5a). Delthyrium triangular, covered in posterior by slightly arched pseudodeltidium. Primary teeth short, rounded extremities; some specimens have smaller, well-developed secondary teeth. Crural fossettes large, in some appear as grooves or V-shaped notches. Dental plates thick, descending directly to floor. Cavity floor horizontal plate supported along median by septum, keeping plate above floor of valve and forming two small conical cavities beneath plate, one on each side of septum. Platform does not extend past hinge line, septum extends various distances before bifurcating and disappearing. Adductor scars partially in cavities beneath platform, separated by supporting septum. Diductor impressions oval, larger than adductors, positioned immediately anterior and below level of adductors, separated by septum. Lateral and anterior portions of valve bear numerous papillae.

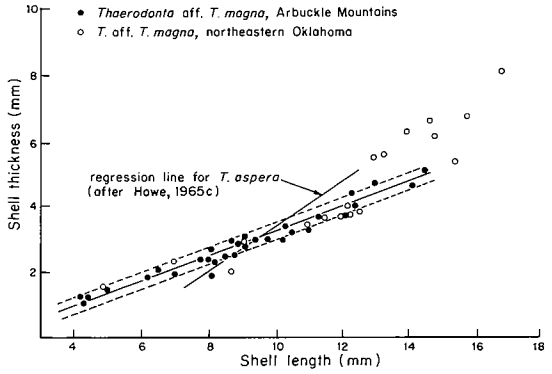
Brachial interarea short, hypercline. Cardinal denticles numerous, increasing in size toward extremities. Cardinal process strong, distinctly trilobed on well-preserved specimens. Sockets deep, large; some individuals have smaller accessory sockets located outside primary ones. Brachiophores widely divergent, extremities sharply pointed. Chilidial plates cover posterior part of process, appear fused to process and interarea. Muscle field large, orbiculate, crossed by 4 bladelike ridges, middle 2 being higher and longer. A few specimens have smaller septum between two larger ones.

Discussion.—The largest specimens of *Thaerodonta* aff. *T. magna* from the Viola Formation attain the size of *T. magna* Howe from the Montoya Group. Specimens of *Thaerodonta* aff. *T. magna* from the "Fernvale" (Cape) Limestone in northeastern Oklahoma reach this large size also (*see* text-fig. 36). However, only two specimens from the Viola and a very few from the "Fernvale" (Cape) Limestone show the rough lamellose exterior similar to *T. magna.*

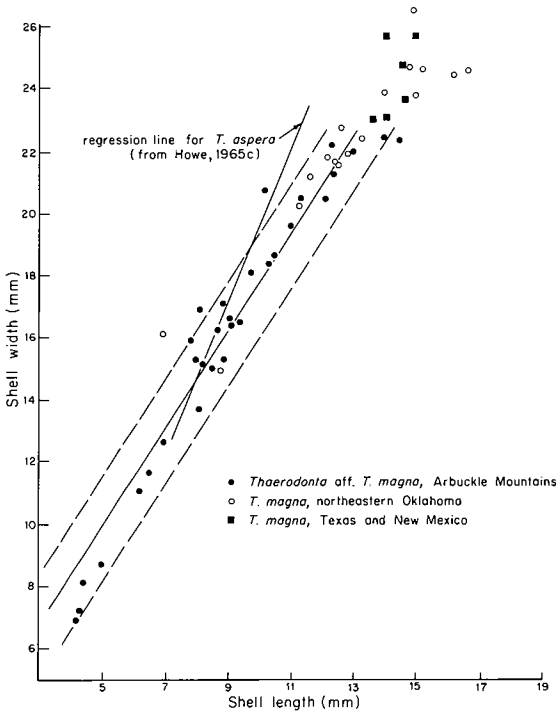
Wang (1949) described *T. aspera, T. recedens,* and *T. saxea* from the Maquoketa Formation of Iowa, all from the same horizon and section. Howe (1965b) studied large populations of *T. recedens* and *T. saxea* from the Maquoketa and concluded that they are not significantly different. The scatter diagram presented by Howe (1965b, p. 651, text-fig. 3) shows that, for length-width dimensions, specimens designated *T. recedens, T. saxea,* and *T. magna* grade into each other. Howe (1965b) stated that a complete size gradation occurs between *T. recedens* and *T. saxea* but did not comment on the gradation between *T. saxea* and *T. magna.* According to Howe (1965b), *T. magna* resembles *T. saxea* in outline but differs by its larger shell, smaller and more closely spaced fossettes, more coarsely lamellose exterior, and nonsulcate ventral valve.

The specimens of *Thaerodonta* aff. *T. magna* from unit 3, subunit 3C, and also those from the "Fernvale" (Cape) Limestone in northeastern Oklahoma show significant variation in the size and number of cardinal fossettes and in the size and spacing of accessory teeth. In specimens of *Thaerodonta* aff. *T. magna* from the "Fernvale" (Cape) Limestone in northeastern Oklahoma, the number of cardinal fossettes in a 5-mm distance ranges from 11 to 15 and averages 12.5. Howe's figured specimen (1965b, pl. 82, fig. 7) has 15 cardinal fossettes in a 5-mm distance.

T. aspera resembles *Thaerodonta* aff. *T.*



Text-figure 35. Regression line and 95-percent-confidence intervals for length-thickness relationships of **Thaerodonta** cf. **T. magna** Howe. Mean length, 8.9 mm; mean thickness, 2.7 mm. Specimens from upper 6 feet of unit 3, subunit 3C, section A. All articulated specimens from section A were used to calculate this line. Data also given for specimens of **Thaerodonta** cf. **T. magna** Howe from "Fernvale" (Cape) Limestone in northeastern Oklahoma.



Text-figure 36. Regression line and 95-percent-confidence intervals for shell length-width relationships of **Thaerodonta** cf. **T. magna** Howe. Mean length, 9.0 mm; mean width, 16.2 mm. Specimens from upper 6 feet of unit 3, subunit 3C, section A. All articulated specimens from section A were used to calculate this line. Data also given for specimens of **Thaerodonta** cf. **T. magna** Howe from "Fernvale" (Cape) Limestone in northeastern Oklahoma and for **T. magna** Howe from Aleman Limestone in Texas and New Mexico.

magna but does not reach the large size.

Distribution and material.—This is a common species in unit 3, subunit 3C (about 300 specimens were collected) at sections A, C, and D, upper 6 feet of the unit. In unit 3, subunit 3CM, at section I, it occurs 40-60 feet below the top of the unit.

Figured specimens.—The following specimens are from unit 3, subunit 3C: OU 5828 (articulated specimen), section A; OU 5829 (pedicle valve), section A; OU 5830 (brachial valve), section C; OU 5831 (pedicle valve), section A; OU 5832 (pedicle valve), section C; and OU 5833 (pedicle valve), section A. The following specimens are from unit 3, subunit 3CM, section I: OU 5834 (articulated specimen) and OU 5835 (articulated specimen). The following specimens are from the "Fernvale" (Cape) Limestone, northeastern Oklahoma, sec. 25, T. 16 S., R. 22 E., and sec. 30, T. 16 S., R. 23 E., upper foot of 14-foot section along Illinois River, Cherokee County: USNM 163602 (brachial valve) and USNM 163603 (brachial valve).

Genus **Sowerbyella** Jones, 1928

Sowerbyella cf. **S. curdsvillensis** (Foerste, 1912)

Pl. 9, figs. 8-10

Plectambonites curdsvillensis FOERSTE, 1912, p. 122, pl. 10, figs. 15A, B.

Description.—Shell semielliptical in dorsal outline. Cardinal extremities acute, lateral margins straight and inclined toward median, anterior margin broadly curved, almost straight. Hinge line straight, widest part. Almost V shaped in anterior profile; middle of pedicle valve sharply curved, lateral slopes straight. Concavo-convex in lateral profile, thickest part posterior to middle. Lateral and anterior commissures rectimarginate. Surface unequally parvicostellate; 6 large costellae at 5 mm from beak, normally 2, sometimes 3 smaller costellae between 2 larger ones.

Pedicle interarea plane, apsacline, about 4 mm long in average specimen. Delthyrium triangular, covered in apical region by arched pseudodeltidium. Teeth short, rounded extremities. Apex of cavity filled with shell material over two small conical muscle impressions, separated by median ridge that

maintains itself for about 1.5 mm anteriorly. Diductor scars elliptical, divergent, separated by median ridge in posterior half.

Brachial interarea plane, catacline, about 0.5-0.6 mm long. Two submedian ridges extend and rise from just anterior to cardinalia to high point just anterior to middle of valve. Ellipsoidal muscle areas on each side of double septa. Subperipheral rim (about 2 mm wide) extends around lateral and anterior margins of valve.

Discussion.—The only difference between *S. curdsvillensis* (Foerste) and *Sowerbyella* cf. *S. curdsvillensis*, from the lower Viola Formation, is that the latter does not show the small pallial distributaries around the anterior margin.

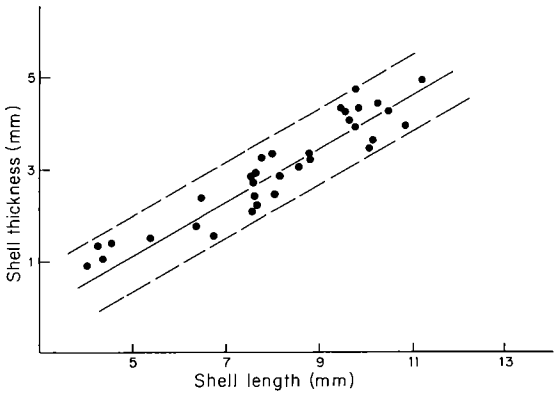
Distribution and material.—At section D this species occurs in the basal foot of unit 1, subunit 1C. At section L it occurs in unit 1, subunit 1C, in the basal foot and 40 feet above the base. About 30 to 40 specimens were collected from both localities.

Figured specimens.—The following specimens are from unit 1, subunit 1C, section L: OU 5897 (articulated specimen), OU 5899 (pedicle valve), and OU 5898 (brachial valve).

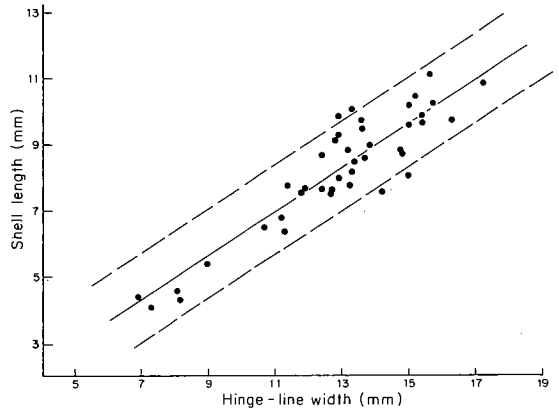
Sowerbyella sp.
Pl. 8, figs. 14-16

Description.—Shell moderate size for genus (*see* text-figs. 37, 38, for length-width data). Rectangular outline, some semicircular with hinge line straight and widest part. Cardinal extremities at right angles or slightly acute. Lateral margins straight in some, slightly curved in others. Concavo-convex in lateral profile; convexity of pedicle valve accounts for all thickness of articulated specimens, highest point in middle with magnitude of curvature same throughout. Lateral and anterior commissures rectimarginate. Surface unequally parvicostellate, 4-5 small costellae between 2 larger ones, about 4 larger costellae per 2 mm at 5 mm from beak.

Pedicle interarea flat, apsacline, longer than brachial valve. Delthyrium open in most, few specimens have small apical arch similar to deltidium. Delthyrial opening wide, cavity moderately deep, teeth short, rounded extremities. Dental plates thick, rather indistinct; almost inseparable from valve floor. Diductor impressions large, slightly divergent, ellipsoidal in outline, well defined, moderately impressed. Prominent ridge separates two diductor scars in posterior half of field. Ridge bifurcates at anterior end about halfway across muscle field, extending posteriorly into delthyrial cavity and joining posterior wall. Two well-impressed adductor scars positioned just posterior to two diductor scars, occupying delthyrial cavity and separated from each other by posterior extension of median ridge. Adductor scars partially covered by shell material filling posterior half of opening.



Text-figure 37. Regression line and 95-percent-confidence intervals for length-thickness relationships of articulated specimens of **Sowerbyella** sp. Mean length, 8.1 mm; mean thickness, 2.9 mm. Specimens are from 270-280 feet below top of Viola Formation, unit 2, section C.



Text-figure 38. Regression line and 95-percent-confidence intervals for hinge-line-width to shell-length relationships of articulated specimens of **Sowerbyella** sp. Mean hinge-line width, 12.8 mm; mean shell length, 8.2 mm. Specimens are from 270-280 feet below top of Viola Formation, unit 2, section C.

Brachial interarea flat, anacline, short. Cardinal process preserved only as simple knob projecting in postero-ventral direction; in some, process well preserved and typical sowerbyelloid with median elevation more prominent than either of lateral elevations. Crural processes, diverging at wide angle, help define narrow elongate sockets.

Discussion.—Because of the poor preservation of the brachial interior, the identity of this species is doubtful. In outline and profile the species resembles *S. curdsvillensis* (Foerste) from the basal Martinsburg in Tennessee. However, internally this Viola species does not have a subperipheral rim or well-developed adductor impressions. Also, *S. curdsvillensis* (Foerste) attains a larger size than *Sowerbyella* sp.

S. punctostriata (Mather) is larger in size and has a beaded ornamentation.

Distribution and material.—This species is common in the lower part of unit 2 at sections C and D. At section C this species occurs 275-285 feet below the top of the formation, and at section D it occurs 175-200 feet above the base of the formation. Over 500 specimens of this species were collected.

Figured specimens.—Following specimens are all from unit 2, section C: OU 5893 (articulated specimen), OU 5894 (brachial valve), and OU 5895 (pedicle valve).

Superfamily STROPHOMENACEA King, 1846
Family STROPHOMENIDAE King, 1846
Genus **Strophomena** Rafinesque *in* de Blainville, 1825
Strophomena planumbona (Hall, 1825)
Pl. 5, figs. 13, 14

Leptaena planumbona HALL, 1847, p. 112, pl. 31B, figs. 4a-e.
Strophomena planumbona (Hall), FOERSTE, 1912, p. 73-81, pl. 4, figs. 3a-b; pl. 8, figs. 1a-e; pl. 9, figs. 3a-b; WANG, 1949, p. 23, pl. 6, figs. D1-7.

Description.—Shell moderate in size (*see* discussion for various dimensions), subrectangular, width always slightly greater than length. Hinge line straight, about widest part. Cardinal angles vary from right angle to acute. Lateral margins straight, anterior margin broadly rounded. Curvature of pedicle valve even in lateral profile, no prominent geniculations. Pedicle interarea long, plane, apsacline. Pseudodeltidium convex, distinctly above level of interarea. Foramen circular, apical in position, almost pinpoint in size. Teeth divergent, supported by thick dental plates that continue anteriorly with lateral margins of muscle field. Height of border decreases anteriorly in some specimens, in others height maintained completely around field except for small anterior gap. Field bisected by thin ridge extending from posterior of cavity to anterior of field. Ridge higher in posterior, connecting to underside of pseudodeltidium; small opening for passage of pedicle in center of ridge and close to pseudodeltidium. Adductor scars long, narrow, one on each side of ridge; diductor scars large, not enclosing adductors; adjustor scars not observed. Interior covered by numerous randomly arranged pustules.

Brachial interarea short, plane, anacline. Valve convex in lateral profile, posterior two-thirds flat, leading into moderate geniculation anteriorly. Cardinal process bilobed, bounded by prominent triangular sockets. No muscle scars observed.

Discussion.—The following table gives the various dimensions for pedicle valves from the Viola Formation; only one brachial valve was found.

Length (mm)	Width (mm)	Length of muscle field (mm)	Width of muscle field (mm)
18.4	26.2	9.0	9.0
....	20.3	6.5	7.2
17.4	22.6	7.2	7.3
19.0	27.0	7.3	8.0
17.2	25.0	...	...
18.8	25.2	...	8.1
17.3	26.0	...	...
18.9	27.3	...	...

Distribution and material.—This species is confined to the upper 6 feet of unit 3, subunit 3C, sections A and C. In unit 3, subunit 3CM, at section I, it occurs 40-60 feet below the top of the formation.

Eight to 10 pedicle valves and 1 brachial valve were collected.

Figured specimens.—OU 5858 (brachial valve) and OU 5857 (pedicle valve), both from unit 3, subunit 3C, section A.

Strophomena perconcava Wang, 1949

Pl. 7, fig. 10

Strophomena perconcava WANG, 1949, p. 26, pl. 7, figs. C1-5.

Description.—Shell subcircular to subelliptical in dorsal outline, curvature from cardinal extremities to anterior margin about same magnitude. Hinge line straight and widest part. Curvature even in anterior profile, lateral slopes steep. Convexo-concave in lateral profile. Pedicle interarea plane, moderately wide (maximum width 4.5 mm), catacline. Triangular delthyrium, covered by arched pseudodeltidium.

Posterior portion of brachial valve flat, extending approximately 8 mm before curvature increases abruptly across middle of valve leading smoothly into steep anterior slope. Interarea short, about one-fourth to one-fifth length of pedicle interarea. All costae in umbonal region about same size, about 12 per 2 mm at 5 mm from brachial beak; away from beak and on curved portion of valve 5 large costae per 2 mm, larger costae have 2-3 smaller costellae between.

Discussion.—No specimens showing the interiors were found. *Strophomena perconcava* from the Viola Formation is more subcircular in outline than the species from the Maquoketa Formation of Iowa. The Maquoketa species also has more numerous growth lines around the anterior margin.

Distribution and material.—Only 1 specimen was collected from the Viola Formation, 45 feet below the top of unit 2 at section G.

Figured specimen.—OU 5871 (articulated specimen), unit 2, section G, 45 feet below the top of the unit.

Strophomena cf. **S. clermontensis** Wang, 1949

Pl. 7, fig. 9

Strophomena clermontensis WANG, 1949, p. 27, pl. 7, figs. D1-4.

Description.—Shell subquadrate in dorsal outline, hinge line straight. Lateral margins straight, turn sharply into straight anterior margin. Brachial valve flat across middle in anterior profile, steeply sloping sides almost normal to plane of commissure. Broad, shallow brachial sulcus. Posterior portion of brachial valve flat for about 13 mm at which point almost 90° geniculation; shell extends another 10-12 mm. Brachial interarea orthocline, about one-fourth length of pedicle interarea.

Pedicle valve concave. Interarea plane, long, apsacline. Umbonal region swollen for distance 6-7 mm away from beak. Costellae about same size, 8-9 per 2 mm at 5 mm from beak.

Discussion.—The few specimens of *Strophomena* cf. *S. clermontensis* from the Viola Formation differ from *S. clermontensis* from the Maquoketa Formation by being more quadrate in dorsal outline. Also, the costellae do not appear to be subequal in size as they are in *S. clermontensis.* The strong growth lines reported to occur in *S. clermontensis* are not present in the Viola specimens.

Distribution and material.—Only four specimens of this species were collected from the Viola Formation, 45 feet below the top of unit 2 at section G.

Figured specimen.—OU 5870 (articulated specimen), unit 2, section G, 45 feet below the top of the unit.

Strophomena neglecta (James, 1881)

Pl. 5, figs. 18-20

Streptorhynchus neglectum JAMES, 1881, p. 41.
Strophomena neglecta (James), FOERSTE, 1912, p. 90-95, pl. 5, figs. 1, 2A-B, 3; pl. 7, fig. 5; pl. 9, figs. 1, 10; pl. 11, fig. 10.
Tetraphalarella neglecta (James), WANG, 1949, p. 30, pl. 9, figs. G1-4.
Strophomena neglecta (James), HOWE, 1965c, p. 652, pl. 82, figs. 13, 15.

Description.—Shell large (*see* discussion for size data), subrectangular to subquadrate in outline. Hinge line straight, widest part. Cardinal extremities right angles, lateral margins straight, anterior margin broadly rounded. Surface parvicostellate, 28 costae and costellae per 5 mm at 8 mm from beak. Pseudodeltidium extends from apex to hinge line, flatly convex, barely rising above level of interarea. Foramen small, circular, apical. Interarea long, plane, apsacline. Teeth long, divergent, each with groove along dorsal face. Dental plates slope laterally, joining elevated border

around muscle field; shape and prominence of border highly variable; some specimens have gap at anterior end of muscle field. Adductor scars ellipsoidal, positioned in posterior one-third of field, well impressed in most; diductor scars large, enclose adductors anteriorly. Entire field crossed by radiating grooves, giving it flabellate appearance. Area outside field pustulose.

Posterior two-thirds of brachial valve flat in lateral profile; at about 20 mm anterior from beak valve turns sharply in ventral direction, geniculated portion extends about 15 mm. Interarea short, plane, anacline to almost orthocline. Sockets long, triangular, fairly deep. Median septum low rounded ridge extending about 8-10 mm anteriorly. No muscle scars observed.

Discussion.—The dimensions for some complete and partially complete pedicle valves are given below.

Length (mm)	Hinge-line width (mm)	Mid-valve width (mm)
28.3	41.3	34.0
....	44.8	....
27.1	38.0	....
29.0	....	....
32.5	....	....
35.0	44.0	40.0
31.8	40.0	33.9
25.0	38.0	....

The genus *Tetraphalarella* was erected by Wang (1949) and separated from the genus *Strophomena*. According to Wang, one of the primary differentiating characteristics was the complete enclosure of the adductor scars by the diductor scars in *Tetraphalarella*. In discussing this problem Howe (1965c) stated (p. 652):

> This criterion is unreliable for generic differentiation because the ventral muscle pattern varies widely in the same species; for example, compare the ventral interiors of *Tetraphalarella planodorsata* Winchell & Schuchert which are illustrated in Foerste (1912, pl. 7, figs. 6 and 8) and in the same paper compare illustrations of *T. neglecta* (pl. 7, fig. 5 and pl. 5, fig. 3b).

However, because Foerste's figured specimens show greatly dissimilar ventral interiors, all referred to the same species, is no proof of this variation, although it may well be an indication. This could also have resulted if Foerste had several species referred under the same name. The specimens from the Viola Formation (all from the same 6-foot stratigraphic zone) show significant variation in size, shape, and prominence of the pedicle muscle area, and many of the other characters vary greatly. Because of this variation I prefer to refer the species to the genus *Strophomena* and not *Tetraphalarella*.

Distribution and material.—This species was found at several sections. At sections A and C it occurs in the upper 6 feet of unit 3, subunit 3C. One specimen was found at section G in the upper part of unit 2, 70 feet below the top of the formation. Farther to the southwest at section I it is fairly common in the lower part of unit 3, subunit 3CM, 55 feet below the top of the formation.

About 10 complete specimens (mostly pedicle valves) were collected in the Arbuckle Mountains. In addition to these complete specimens, numerous fragments were found (particularly at section I), and for this reason the species is reported to be fairly common.

Figured specimens.—The following specimens are from unit 3, subunit 3CM, section I: OU 5861 (pedicle valve), OU 5862 (brachial valve), and OU 5860 (pedicle valve).

Strophomena sp. 1

Pl. 5, figs. 8-10

Description.—Shell thin, subquadrate in outline, hinge line straight, widest part. Cardinal extremities right angles; lateral margins not parallel but converging slightly toward median, anterior margin evenly rounded, no sharp antero-lateral angle. Pedicle valve almost flat in lateral profile, greatest curvature occurring in anterior third. Surface parvicostellate; two sizes costae and costellae in umbonal region, alternating one large and one small; 10-11 costae and costellae per 5 mm at 10 mm from beak. Outside umbonal region size differences are imperceptible. Pedicle interarea plane, apsacline. Pseudodeltidium gently convex, foramen apical in position. Teeth long, divergent, concavity along dorsal face. Delicate dental plates, advancing. Muscle field widely cordate. Adductor scars small, somewhat elongate, positioned in posterior third of field; diductors large, may not

enclose adductors. Muscle-field border present only in posterior half.

Discussion.—Only one pedicle valve of this species was found in the Arbuckle Mountains and no brachial valves. The only brachial valve collected and referred to this species is from the "Fernvale" (Cape) Limestone in northeastern Oklahoma. However, the surface ornamentation of this one brachial valve differs from that on the pedicle valve. In the anterior half of the brachial valve the costae and costellae are of 2 distinct sizes such that 2-3 small costellae occur between 2 larger ones. This is in contrast to the ornamentation on the pedicle valve in which the costae and costellae become equal in size in the anterior direction.

This species is characterized by its thin, delicate shell, flat lateral profile, and lack of a well-developed border around the pedicle muscle field. The different ornamentation on the pedicle and brachial valves may be an important characteristic, but many more valves will have to be examined in order to determine its consistency.

This species is similar to *S. cooperi* (Wang), particularly in the lack of a well-defined border around the pedicle muscle area; however, *S. cooperi* is larger and not as quadrate in outline.

I collected 3 complete pedicle valves and 1 complete brachial valve from the "Fernvale" (Cape) Limestone in northeastern Oklahoma. The dimensions of these valves along with those for the pedicle valve from the Arbuckles are given below. The first four specimens are pedicle valves and the last is a brachial valve.

Length (mm)	Hinge width (mm)	Midwidth (mm)	Thickness (mm)	Location
20.3	26.5	19.7	2.3	Arbuckles
21.0	28.3	19.2	3.0	NE Okla.
24.0	29.4	....	...	NE Okla.
22.0	26.2	22.8	2.5	NE Okla.
22.9	29.8	26.8	4.6	NE Okla.

Distribution and material.—The single pedicle valve collected from the Arbuckle Mountains was from section C, the upper 6 feet of unit 3, subunit 3C.

Figured specimens.—OU 5856 (pedicle valve), unit 3, subunit 3C, section C. The following specimens are from the "Fernvale" (Cape) Limestone, northeastern Oklahoma, sec. 25, T. 16 S., R. 22 E., and sec. 30, T. 16 S., R. 23 E., upper foot of 14-foot section along Illinois River, Cherokee County: USNM 163606 and USNM 163607.

Strophomena sp. 2

Pl. 9, fig. 3

Description.—Shell subquadrate, width greater than length. Hinge line straight, widest part. Cardinal areas concave in dorsal view. In lateral and anterior view curvature of brachial valve broad and even. Convexo-concave in lateral profile, highest point in middle. Faint sulcus in posterior 5-6 mm of brachial valve, faint fold on pedicle valve. Surface parvicostellate, approximately 30 costae around beak; costae of two sizes in posterior third, 1-2 smaller ones between 2 larger ones; costae and costellae about same size on anterior and antero-lateral slopes; 14 costae per 2 mm at 5 mm from beak; 7 costae and costellae per 2 mm at anterior margin.

Pedicle interarea plane, apsacline, maximum length 2 mm. Delthyrium covered completely by arched pseudodeltidium. Small circular foramen at apex.

Brachial interarea short, orthocline.

Discussion.—No specimens were collected showing the interiors. The dimensions for the only complete specimen (articulated) are: length, 19.2 mm; thickness, 4.5 mm; hinge-line width, 26.0 mm.

Distribution and material.—The one complete specimen is from section D, unit 1, subunit 1C, 1 foot above base of the unit.

Figured specimen.—OU 5913 (articulated specimen), unit 1, subunit 1C, section D.

Strophomena sp. 3

Pl. 7, fig. 11

Description.—Shell moderate size, subquadrate, hinge line straight, widest part. Cardinal extremities right angles; lateral and anterior margins evenly rounded. Lateral profile resupinate. Pedicle interarea narrow, plane, apsacline. Brachial interarea half length of pedicle interarea. Surface parvicostellate, 30-33 costae and costellae per 10 mm at anterior margin; costae and costellae easily differentiated in umbonal region, size differences not as pronounced

near anterior margin.

Discussion.—Only one complete specimen was collected from "crack-out" material in the upper part of unit 2 at section B. No interiors were found. The one complete specimen measures: length, 30 mm; hinge-line width, 41 mm; midwidth, 37 mm; thickness, 6 mm.

Distribution and material.—The one complete specimen of this species was collected from "crack-out" material from the upper 2 feet of unit 2 at section B.

Figured specimen.—OU 5879 (articulated specimen), unit 2, section B.

Genus **Megamyonia** Wang, 1949

Megamyonia mankini Alberstadt, n. sp.

Pl. 5, figs. 4-7

Description.—Shell small (dimensions given in discussion), subelliptical in outline. Hinge line straight, widest part. Cardinal extremities acute, lateral margins gently curved toward median, anterior margin narrowly rounded. In lateral and anterior profile no sharp changes in curvature. Concavo-convex in lateral profile, median posterior of valve flat for about 10 mm after which sharply geniculated. Surface ornamentation lost because of coarse silicification.

Pedicle interarea plane, apsacline, longer than brachial interarea. Pseudodeltidium convex, covering posterior one-half of triangular delthyrial opening. Teeth divergent, short, well rounded. Median portion of cavity floor elevated; posterior apex of diductor scars isolates this elevation from walls of cavity. Muscle area large; adductor scars positioned along median of valve just anterior of cavity. Adductor scars small, ellipsoidal, well impressed, separated by thin ridge extending to their anterior margin. Diductor impressions large, divergent, greatly expanded anteriorly; anterior margin of scars at position of geniculation of valve. Diductors do not enclose adductors; adjustor scars not observed.

Cardinal process stout, bilobed, faces of lobes extending normal to plane of commissure. Muscle field triangular, widest at posterior, nearly pointed at anterior. Adductor scars all about same size, posterior scars behind and little to side of anterior scars. Muscle field does not reach middle of valve.

Discussion.—*Megamyonia mankini* resembles *M. knighti* from the Maquoketa Formation of Iowa. Wang (1949) erected *M. knighti* and characterized it by several features, one of which was a strong median septum on the pedicle valve. The septum on *M. knighti* extends to the anterior margin of the valve, but in *M. mankini* it is present only on the posterior of the valve (*see* pl. 5, fig. 5a). In addition, *M. mankini* has a slightly different dorsal outline and is larger than *M. knighti.* None of Wang's specimens are larger than 10 mm long and 14 mm wide, but all of the specimens from the Viola Formation in the Arbuckle Mountains are larger than this, as shown by the dimensions of the four specimens given below.

Length (mm)	Hinge width (mm)	Midwidth (mm)
12.3	18.0	13.2
14.6	16.3	15.4
12.8	16.2	13.9
11.4	16.2	....

In size and shape *M. mankini* resembles most closely *Megamyonia* sp. described by Wang (1949, p. 34). However, Wang did not describe or figure a pedicle valve, so a complete comparison is impossible. *M. mankini* is particularly like *Megamyonia* sp. in the occurrence of strong pustules around the muscle field and the presence of crenulations along the line of geniculation.

Distribution and material.—Only 4 specimens were collected from the upper 6 feet of unit 3, subunit 3C, sections A and C. Thirty-four specimens were collected from the "Fernvale" (Cape) Limestone in northeastern Oklahoma.

Types.—Holotype (articulated specimen): OU 5864, unit 3, subunit 3C, section A. Holotype (pedicle valve), USNM 163604, and holotype (brachial valve), USNM 163605, both from "Fernvale" (Cape) Limestone, northeastern Oklahoma, sec. 25, T. 16 S., R. 22 E., and sec. 30, T. 16 S., R. 23 E., upper foot of 14-foot section along Illinois River, Cherokee County. Figured specimen (pedicle valve): OU 5865, unit 3, subunit 3C, section C.

Genus **Oepikina** Salmon, 1942
Oepikina sp.
Pl. 8, figs. 9, 10

Description.—Shell moderate to large for genus. Single articulated specimen collected measures 22.5 mm long, 27.1 mm wide at hinge line, 25.0 mm midwidth, and 12.3 mm thick. Subcircular in dorsal view, hinge line straight, widest part. Cardinal extremities right angles. Lateral margins weakly rounded leading evenly into more narrowly rounded anterior margin. Concavo-convex in lateral profile, thickest part immediately posterior to middle. Posterior third of pedicle valve flat, sharp geniculation 12-13 mm anterior from beak. Anterior two-thirds of valve gently rounded. Angle of geniculation about 110°. Surface parvicostellate, approximately 6 costae and costellae per 2 mm at 6 mm from beak.

Pedicle interarea flat, orthocline, about 3 times longer than brachial interarea. Delthyrium triangular, arched pseudodeltidium covers posterior third. Prominent foramen at apex. Teeth short, divergent; dental plates thin, advancing. Lateral margins of field straight, directed inward toward middle of valve.

Brachial interarea short, anacline. Cardinal process prominent, bilobed, extends posteriorly past interarea. Sockets large, shallow, triangular. Brachiophores weak, positioned on ridge forming anterior border of sockets. Median septum weak. Antero-lateral septa thin, more prominent than median septum. Muscle field subelliptical. Area outside field finely pustulose, almost granular. Rounded beaded ridge around margins of valve, fairly well developed (*see* pl. 8, fig. 10a). Ridge and area posterior to it crossed by numerous grooves presumably caused by strong vascular system. Area along outside of ridge deflected sharply dorsally.

Discussion.—*Oepikina* sp. from the Viola Formation resembles *Oepikina limbrata* Wang in size and shape; however, several differences exist. The most outstanding distinction is the nature of the ornamentation; *O. limbrata* is unequally parvicostellate with 8-9 costae and costellae between 2 larger ones, but the Viola species has no clear size separation. These two species also differ in lateral profile, with the pedicle valve of *O. limbrata* being smooth and even and that of the Viola species being angular.

Distribution and material.—One articulated specimen, 2 brachial valves, and 1 pedicle valve were collected from the lower part of unit 2, section C, 275-280 feet below the top of the formation.

Figured specimens.—OU 5888 (articulated specimen) and OU 5889 (brachial valve), both from unit 2, section C.

Genus **Rafinesquina** Hall and Clarke, 1892
Rafinesquina sp.
Pl. 9, fig. 4

Description.—Shell subelliptical in outline, longer than wide, hinge line straight and widest part. Cardinal extremities right angles, lateral margins gently curved, anterior margin more sharply rounded. On a small specimen curvature similar all around. Surface parvicostellate, 3-6 smaller costellae between 2 larger ones; number of finer costellae depends on where observation is taken anterior to beak, but number still varies at same distance from beak. In lateral profile posterior two-thirds flat, geniculation occurring 17-18 mm from beak (measured along median). Trail about 11-12 mm long (measured along median).

Pedicle interarea short, weakly curved, apsacline. Beak small, pointed. Delthyrium triangular, open.

Discussion.—This species is similar to *R. deltoidea* but does not have the alate cardinal extremities.

Distribution and material.—Several specimens of this species were collected from the lower part of unit 2 at sections C and D. At section C three silicified specimens were collected 280-285 feet below the top of the formation. At section D, 220-236 feet below the top of the formation this species is represented mostly by impressions.

Figured specimen.—OU 5914 (articulated specimen), unit 2, section C.

Order RHYNCHONELLIDA Kuhn, 1949
Superfamily RHYNCHONELLACEA Gray, 1848
Family RHYNCHOTREMATIDAE Schuchert, 1913

Genus **Rhynchotrema** Hall, 1860

Rhynchotrema increbescens? Hall, 1860

Pl. 7, figs. 6, 7

Rhynchotrema increbescens HALL, 1860, pl. 33, figs. 13c-d.

Description.—Shell subtriangular, widest part at about middle. Unequally biconvex in lateral profile, brachial valve twice as deep as pedicle. Beak small, suberect, protruding posteriorly about 1 mm past brachial valve. Anterior commissure uniplicate, 6-7 plications on flank, 4 on fold, 3 in pedicle sulcus. Most bear imbrications along anterior and antero-lateral portions. Delthyrium small, triangular, open. Sulcus begins about 2-4 mm from beak, widening and deepening anteriorly, averaging 6 mm wide at anterior margin. Tongue about 5 mm long, depending on growth direction. Pedicle valve contains shallow but distinct sulcus in early stages, formed by 1-2 depressed plications that later become 2 inner plications of fold.

Brachiophores slender, divergent, curved concave toward pedicle valve. Prominent median septum extends to about middle of valve. No muscle scars observed. In some specimens cardinal process present as single plate, in others poorly developed or absent.

Discussion.—Weiss (1955) considered *R. wisconsinensis* Fenton to be a subspecies of *R. increbescens.* He claimed that *R. wisconsinensis* and *R. increbescens* in the Decorah Formation in Minnesota grade into each other in collections from a single bed. Cooper (1956) referred the specimens from the Ion Member of the Decorah Formation in Minnesota and Wisconsin to *R. wisconsinensis* but did not discuss Weiss' interpretation. If the interpretation of this gradation is correct, I think a more reasonable biological solution would be to note the limits of variation and treat both as one variable species.

The dimensions for articulated specimens of this species from the Viola Formation are given below.

Length (mm)	Width (mm)	Thickness (mm)
9.4	10.7	8.5
10.8	13.0	8.7
11.2	12.5	10.0
11.4	11.8	9.0
11.9	13.0	8.3
11.9	14.3	9.2
12.4	15.4	9.5

Distribution and material.—Specimens of this species occur in unit 2, mostly in the upper part at sections C, D, and L. Fragments of a small rhynchonellid, presumably *R. increbescens,* are found in unit 2 at other sections.

Figured specimens. — OU 5877 (articulated specimen), unit 2, section D, 18 feet above base of unit; and OU 5878 (articulated specimen), unit 2, section B, upper 2 feet of unit.

Genus **Lepidocyclus** Wang, 1949

Type species.—*Lepidocyclus laddi* Wang, 1949, p. 12; upper Elgin Member of Maquoketa Formation along east-west road in SW1/4 sec. 17, Orleans Township, Winneshiek County, Iowa.

Diagnosis.—Variable in outline, usually globose. Deep pedicle cavity; large flabellate muscle field in pedicle valve; conspicuous hinge plates. Teeth stout, supported by strong shell thickening. Cardinalia strong. Hinge plates strongly developed. Cardinal process thin, well developed. Crural processes long, slender, curved concave ventrally.

Discussion.—Wang (1949) erected the genus *Lepidocyclus* for certain shells that had been previously referred to *Rhynchotrema.* According to Wang the chief distinguishing characteristics of *Lepidocyclus* are the deltidial plates, long crural processes, the situation of the teeth and muscle field, the absence of dental plates, and the presence of a well-developed cardinal process. However, according to Howe (1965a, p. 96) many of the distinguishing characteristics exhibit much wider variation than had been previously recognized. Several of these are now known to occur in both *Lepidocyclus* and *Rhynchotrema*: rudimentary deltidial plates occur in at least one species of *Rhynchotrema; Lepidocyclus capax,* the best known and probably the most widely dispersed species of the genus, has a *Rhynchotrema*-like pedicle cavity and open delthyrium; the cardinal process in *Rhynchotrema* is well developed; and the ventral muscle field is similar in the two genera. Howe (1965a, p.

96) suggested that the definition for each genus be amended so as to allow for these overlaps. As yet this has not been done.

At the present time 10 species of *Lepidocyclus* have been identified; Wang (1949) described 7 species from the Maquoketa Formation of Iowa. With larger and better collections, however, some of these may prove to be only form species. Howe (1966b) described two new species from the Cape Limestone of Missouri and the "Fernvale" (Cape) Limestone of northeastern Oklahoma, *Lepidocyclus cooperi* and *L. oblongus*. *Lepidocyclus capax* was not reported from the Maquoketa of Iowa, but it is common in the Upper Ordovician rocks of the Ohio Valley. It also occurs in the Fernvale Formation of Tennessee and in the Viola Formation of Oklahoma.

Lepidocyclus cooperi Howe, 1966

Pl. 6, figs. 4-9

Lepidocyclus cooperi HOWE, 1966b, p. 259, pl. 31, figs. 1-6, 8-10.

Description.—Shell moderate to large, average about 19 mm long, 18 mm wide, and 14 mm thick. Greatest width anterior to middle in most. Ventral outline of most is subpentagonal (*see* pl. 6, fig. 4b), in some subrectangular. Lateral margins gently curved, almost parallel, anterior margin straight. Almost circular outline in dorsal view for specimens with thickness greater than 13 mm; specimens less than 13 mm more subpentagonal to subquadrate. Unequally biconvex in lateral profile, brachial valve nearly twice as deep as pedicle (*see* pl. 6, fig. 4d). Again, specimens less than 13 mm thick have more equally biconvex profile, with brachial valve slightly deeper than pedicle (*see* pl. 6, fig. 8a). Anterior commissure strongly uniplicate in most, more gently uniplicate in more equally biconvex specimens.

Brachial fold first perceptible at about 5 mm from beak, sulcus first visible at 7-8 mm; both expanding and increasing in prominence anteriorly. Most specimens have 4 plications on fold, 3 in sulcus; however, 2 average-sized specimens have 5 plications in fold of one and 6 in fold of other. Most specimens with 7-9 plications on flanks. In anterior portions of shell plication tops flat and concave. Surface covered by numerous fine fila, about 16-18 per 10 mm at any position away from beak.

In lateral profile pedicle valve gently convex, intensity of curvature about same from posterior to anterior. Beak prominent, suberect (*see* pl. 6, fig. 4d). Hinge short, slightly curved, one-third to one-half width of valve. Foramen large, circular, mesothyroid to submesothyroid in position. Deltidial plates faintly concave, each sloping gently toward anterior, joining just anterior to foramen forming distinct groove (*see* pl. 6, fig. 7a). Teeth stout, appearing as nodes over extremity of hinge line, raised above hinge line and supported by thick shell material. Shell supports assume varying degrees of "inflation" causing teeth not to be positioned same in all valves. Difference in amount of shell material and configuration of such material results in posterior of valve being extremely variable in appearance. Pedicle muscle field large (average specimen 8-9 mm wide), easily visible in most valves (*see* pl. 6, fig. 7a). Adductor scars in center or just posterior to middle of field; however, a few specimens have scars in extreme posterior of field. Diductor scars flabellate, enclosing adductors anteriorly (*see* pl. 6, fig. 7a). Adjustor impressions deeply fixed along postero-lateral margins of field. Anterior and antero-lateral margins of valve serrated.

Overall appearance of brachial valve bulbous or subconical depending on height of fold. Beak small, incurved, concealed by pedicle valve. Cardinalia robust, bladelike cardinal process (*see* pl. 6, fig. 6a). Sockets large, deep, separated from notothyrial cavity by massive hinge plates. Crural processes thin, about twice as wide as thick, attached to inner anterior corner of hinge plate. Processes curved concave ventrally. Median septum extends from just beneath cardinalia to slightly past middle of valve. Adductor scars imperceptible in most specimens; one valve showed scars to be small ellipsoidal pits positioned well below cardinalia and separated by median septum (*see* pl. 6, fig. 6b).

Discussion.—This species shows much variation in its outline and lateral profile. The fold is the most prominent character and, depending on its height, can alter drastically the overall appearance of an

individual shell. In many cases the longer and therefore older shells (assuming that the shell length is indicative of age) have higher folds. A specimen showing a high fold is shown in plate 6, figure 4d; in this specimen the fold height increases as the shell length increases. Plate 6, figure 5b, illustrates the other extreme of shell growth and shows a shell in which the fold height remains the same throughout growth. The variability in the height of the fold and therefore the shape of the shell is related to the change in growth vectors, a problem that has been discussed by Rudwick (1959). All of the specimens examined, including those with both low and high folds, have the fold beginning at about the same distance from the beak.

Lepidocyclus cooperi occurs in the same stratigraphic zone as *L. capax* at all localities where brachiopods were collected. *L. cooperi* is differentiated from *L. capax* by having well-developed deltidial plates and a shallow, almost flat, pedicle valve; however, some specimens of *L. cooperi* show a slightly curved pedicle valve. *L. capax* is best characterized by having no deltidial plates (*compare* pl. 6, figs. 3g, 7b).

Howe (1965d) discussed the presence or absence of deltidial plates in the genus *Lepidocyclus*. He stated (1965d, p. 1128):

> The *Rhynchotrema*-like open delthyrium and large pedicle cavity of *Lepidocyclus*? *capax* differs so markedly from the long, tubular pedicle cavity and concave, deltidial plates found in other species of *Lepidocyclus*, the generic assignment of this species is in doubt.

Nikiforova (1961, *reported in* Williams and others, 1965) proposed that the name *Lepidocycloides* be used for those forms similar to *Lepidocyclus* but lacking deltidial plates and a cardinal process. All of the specimens from the Viola Formation that I studied have well-developed cardinal processes.

Wang (1949), in erecting the genus *Lepidocyclus*, stated that the long, slender crural processes are curved dorsally. This is probably a mistake in orientation because the few specimens of brachial interiors figured by Wang (particularly *L. laddi* Wang) show crural processes that are curved (concave) ventrally.

Distribution and material.—This is one of the most characteristic species in the upper part of the Viola Formation. It occurs in the upper 6 feet of unit 3, subunit 3C, at sections A, B, C, D, and L. It occurs in such large numbers and is so robust that it is usually the first species noted on the outcrop. *L. cooperi* also occurs in subunit 3CM at sections I and R, 40-60 feet below the top of the formation. Over 200 specimens were collected in the Arbuckle Mountains. *L. cooperi* is also a characteristic species in the "Fernvale" (Cape) Limestone in northeastern Oklahoma.

Figured specimens.—All from unit 3, subunit 3C. OU 5804 (articulated specimen), OU 5805 (articulated specimen), and OU 5806 (brachial valve) are all from section A. OU 5807 (pedicle valve) and OU 5808 (articulated specimen) are from section C.

Lepidocyclus capax (Conrad, 1842)
Pl. 6, figs. 1-3

Atrypa capax CONRAD, 1842, p. 264, pl. 14, fig. 21 [*fide*, H. J. Howe, 1966b, p. 263, pl. 31, figs. 15-20].
Rhynchonella capax (Conrad), MEEK, 1873, p. 123, pl. 11, figs. 2a-f.
Rhynchotrema capax (Conrad), HALL and CLARKE, 1894, p. 825, pl. 42, figs. 11, 12, 16; WINCHELL and SCHUCHERT, 1895, p. 462, pl. 32, figs. 30-33.
Lepidocyclus capax (Conrad), HOWE, 1966b, p. 263, pl. 31, figs. 15-20.

Description.—Shell large, average specimen 22 mm long, 23 mm wide, and 18 mm thick. Circular to subtriangular in dorsal outline, some subrectangular (*compare* pl. 6, figs. 1a, 2a, 3a, 9a). Postero-lateral margins diverging from beak, straight or weakly rounded. Lateral margins rounded, anterior margin broadly rounded or straight. Subequally biconvex in lateral profile, brachial valve slightly deeper due to fold; curvature of both valves about same throughout. Anterior commissure uniplicate. Lateral slopes steep in anterior profile, in some normal to plane of commissure helping give shell globular appearance. Surface covered by fine zigzag fila, more prominent in anterior of shell, appear imbricated.

Pedicle valve thickest in middle or just posterior to middle, curvature from here to beak sharper than from middle to anterior. Intensity of anterior slope increases, never as acute as posterior. Sulcus begins about 6 mm from beak, deepening and widening anteriorly, width at anterior margin about half shell width. Most specimens with 3

plications in sulcus; however, 2 specimens have only 2 plications with faint 3d plication positioned high on lateral plication bounding sulcus, both specimens average 20-21 mm long. Foramen apical; beak incurved, pressed against brachial valve; hinge line short, about one-third valve width. Delthyrial cavity deep, wide, elevated above level of muscle area. Palintrope small, inclined toward cavity, continuous with cavity walls. Teeth large, rounded knobs, positioned short distance from ends of hinge line. Crural fossettes exist to varying degrees. Dental plates rudimentary, receding wherever developed fullest. Muscle field subcircular, extending to about middle of valve. Adductor scars ellipsoidal, well impressed, in center of field just posterior to middle, about twice as long as wide, extending anteriorly to middle of field. Diductors enclose adductors anteriorly. Adjustor scars embedded so as to cause some overhang along outer posterior margins of field (*see* pl. 6, fig. 1h).

Brachial beak small, incurved, hidden by pedicle valve. Fold expands and rises slightly anteriorly. Faint impression in umbonal region, at about 3 mm from beak becoming slightly elevated as early part of fold. Sockets large, deep, almost circular, bounded on inside by stout hinge plates that bear crural processes. Cardinal process thin blade, thicker anteriorly. Crural processes curved ventrally. Thick median septum below cardinalia, thinning to sharp ridge within 4-5 mm and is maintained as such until about middle of valve. Adductor scars ellipsoidal, separated by median septum, positioned just below and anterior to cardinalia (*see* pl. 6, fig. 1d).

Discussion.—This species shows much variation in its lateral profile and dorsal outline. Plate 6, figures 1a, 2a, and 3a, show the variation in the dorsal outline, and plate 6, figures 1e, 2b, 3d, and 9b, show the variation in lateral profile.

The regression lines for the various dimensions of this species were presented by Howe (1966b) and therefore are not duplicated here.

Distribution and material.—This species occurs in the upper 6 feet of unit 3, subunit 3C, at sections A, B, C, D, and L. It is also found in subunit 3CM at sections I and R, 40-60 feet below the top of the formation. Like *L. cooperi,* shells of this species are conspicuous on the outcrop.

Lepidocyclus capax also occurs in the "Fernvale" (Cape) Limestone in northeastern Oklahoma.

Figured specimens.—The following specimens are from unit 3, subunit 3C, section A: OU 5801 (articulated specimen), OU 5802 (articulated specimen), OU 5803 (articulated specimen but valves can be separated), and OU 5809 (articulated specimen).

Lepidocyclus oblongus Howe, 1966

Pl. 7, figs. 1-3

Rhynchonella capax KEYES, 1894, pl. 41, fig. 12b (not 12a) [*fide,* Howe, 1966b, p. 261].
Lepidocyclus oblongus HOWE, 1966b, p. 261, pl. 31, figs. 11-14.

Description.—Shell moderate size (size data given in discussion), length about one-fourth more than greatest width, which is just anterior to middle of valve. Equally biconvex in lateral profile forming almost circular shell. In some, strong curvature of posterior and middle portions increasing in magnitude and becoming less curved in anterior (*see* pl. 7, fig. 3e). From highest points on each valve slopes anteriorly almost straight, thus, slight anterior projection in lateral view (*see* pl. 7, fig. 3e). Anterior commisure uniplicate. Pedicle beak small, incurved, pressed against brachial valve. Foramen small.

Brachial fold bears 4 plications beginning 2 mm anterior of pedicle beak, increasing in height and width anteriorly; 6-7 mm from pedicle beak 2 inner plications rise higher than 2 lateral plications, difference in height increases to anterior margin so at margin inner plications well above laterals. (This is what Howe, 1966b, referred to when he stated, p. 263, that the species had "weak lateral plications on the fold and sulcus.")

Pedicle sulcus first present 5-6 mm anterior of pedicle beak, expanding and deepening anteriorly. Flanks of valve bear 7-8 plications.

Interiors of Viola specimens known from serial sections only. Cardinalia strong, well-developed single ridge as cardinal process. Below cardinalia is stout median septum that does not extend far anteriorly.

Discussion.—This species was found in the Viola Formation only at sections B and C, and at both it is confined to the upper 2-3 feet of unit 2 and the lower 20 feet of unit 3, subunit 3C. It is the only species studied that could be carefully collected bed by bed across the "transitional interval" between the two members. Plate 7, figures 5, 6, and 7, show specimens collected across this interval at section B. Figures 5a-e are of a specimen from the upper 2-3 feet of unit 2; figures 6a-e are of a specimen from the lower foot of unit 3, subunit 3C; and figures 7a-e are of a specimen from 15 feet above the base of unit 3, subunit 3C. The specimen in figures 7a-e is most like specimens of *L. oblongus* described by Howe (1966b) from the Cape Limestone in southeastern Missouri. The table below shows the dimensions of these three specimens.

Specimen	Length (mm)	Width (mm)	Thickness (mm)
OU 5872	15.5	15.2	17.0
OU 5873	16.8	15.2	19.6
OU 5874	18.6	16.2	17.8

Lepidocyclus oblongus is easily distinguishable from *L. cooperi* and *L. capax* in being longer relative to its width. It also differs from *L. cooperi* in having the pedicle beak pressed close to the posterior of the brachial valve.

Distribution and material.—*L. oblongus* was found only in the upper 2-3 feet of unit 2 at section B and in the lower 20 feet of unit 3, subunit 3C, at sections B and C. I collected about 10 specimens from both sections.

Figured specimens.—OU 5872 (articulated specimen), upper 10 feet of unit 2, section B; OU 5873 (articulated specimen), upper foot of unit 2, section B; and OU 5874 (articulated specimen), lower foot of unit 3, subunit 3C, section B.

?**Lepidocyclus perlamellosus** (Whitfield, 1878)

Pl. 7, fig. 5

Rhynchonella perlamellosa WHITFIELD, 1878, p. 73; 1882, p. 265, pl. 12, figs. 23-25.
Lepidocyclus perlamellosus (Whitfield), WANG, 1949, p. 14, pl. 6A, figs. 1-5.

Discussion.—No formal description is given because most of the specimens questionably referred to this species are few in number. All of the specimens are from "crack-out" material and are crushed or damaged in some way; no interiors were found. On most of the specimens the beak region was poorly preserved, and serial sections could not be made. Because of the poor preservation and the lack of interiors the identification of this species is in doubt.

Distribution and material.—This species occurs in the upper 10 feet of unit 2 at sections B, C, and L and also at section G, 45 feet below the top of unit 2. About 20 specimens were collected from all sections.

Figured specimens.—OU 5876 (articulated specimen), unit 2, section G, 45 feet from top of unit.

Lepidocyclus sp.

Pl. 7, fig. 4

Description.—Shell moderate in size (16 mm long, 16 mm wide, 14.5 mm thick), globular in shape. Subtriangular in dorsal view, greatest width just anterior to middle. Biconvex in lateral profile, brachial valve slightly deeper. Pedicle beak erect, pressed against posterior of brachial valve. Circular to ellipsoidal in anterior view, anterior commissure uniplicate.

Pedicle foramen small, umbo slightly swollen with sulcus first visible 5-6 mm anterior from beak; sulcus about 8 mm wide at anterior margin.

Brachial umbo flat. Fold remains low throughout, but well defined in all specimens; 4 plications in fold at all growth stages, all developed to about same degree. Flanks bear 6-7 plications. Fine zigzag fila ornament valve about 4 fila per 2 mm in region posterior to middle and away from lateral margins; number of fila increases toward lateral margins to maximum of 9-10 per 2 mm.

No interiors observed. Serial sections show well-developed cardinal process in form of single plate. Prominent median septum just below cardinalia. Muscle scars deeply impressed, at least in posterior of valve.

Discussion.—Four specimens have been questionably referred to this species, and they occur in the same stratigraphic horizon and same section as *L. oblongus*. This species differs from *L. oblongus* in being

shorter in relation to its width (*compare* pl. 7, figs. 4a, 3a). In addition, the fold is not as high, and the lateral fold plications are as well developed as the two inner fold plications.

This species is similar to some of the specimens in the U.S. National Museum collections referred to *L. manniensis*.

Distribution and material.—The 4 specimens described here are from the lower 15-20 feet of unit 3, subunit 3C, at section B.

Figured specimen. — OU 5875 (articulated specimen), 10 feet from the base of unit 3, subunit 3C, section B.

MEASURED STRATIGRAPHIC SECTIONS

Gerald C. Glaser and I measured and made field descriptions of 18 stratigraphic sections during 1964-65; however, the formal descriptions that appear here were first presented by Glaser (1965). The stratigraphic occurrence of the brachiopods is also included. Most of the sections were marked with yellow paint at various intervals.

Section A

NE1/4 sec. 36, T. 3 N., R. 5 E., Pontotoc County; in Ideal Portland Cement quarry, 5.9 miles southwest of southwest corner of Ada along State Highway 12, as measured from junction of State Highways 12 and 19. Bottom 100 feet of exposed section measured on west quarry face from lower and upper levels; top 40 feet measured on east quarry face. All measurements made along east-west line where ramp from upper to lower level reaches quarry floor; this line approximates northern boundary of sec. 36. This section is on Lawrence uplift. Strata strike N. 12° E. and dip 4° SE., as measured in east quarry face. Measured by Alberstadt and Glaser, October 1964.

	Feet
Unit 3, subunit 3C	
Coarse skeletal calcarenite, light-gray, slightly wavy-bedded, massive, containing silicified brachiopods; contact with overlying Sylvan Shale covered	88

Following species occur in upper 6 feet of unit:

Lepidocyclus capax
Lepidocyclus cooperi
Austinella multicostella
Glyptorthis glaseri
Plaesiomys proavitus
Platystrophia sutherlandi
Platystrophia uncinata
Thaerodonta magna
Paucicrura oklahomensis
Diceromyonia cf. *D. tersa*
Hesperorthis rowlandi
Strophomena neglecta
Strophomena sp.
Strophomena planumbona
Megamyonia mankini
Rafinesquina sp.

Unit 2	
Calcarenitic mudstone, olive-gray, wavy-bedded; slightly sandy with irregular chert nodules and minor dolomite in lowest 36 feet. Base covered	52
Total	140

Section B

SW1/4 NW1/4 sec. 6, T. 2 N., R. 6 E., Pontotoc County; measured along northeast-flowing tributary to South Fork Creek. To reach section, drive approximately 6.2 miles southwest of Ada on State Highway 12; turn east on unpaved road to Lawrence and proceed 1.7 miles (0.9 mile beyond Lawrence). Exposure can be reached from this point by walking approximately 0.6 mile south across open field to creek. Measurements of upper Viola Formation made in and along creek bed. Section is on Lawrence uplift, approximately 1 mile north of Franks graben. Strata strike N. 40° W. and dip 7° NE. Measured by Alberstadt and Glaser, October 1964.

	Feet
Unit 3, subunit 3C	
Coarse skeletal calcarenite, olive-gray to pinkish-gray, wavy-bedded, sandy in lower 12 feet; contact with overlying Sylvan Shale covered	49

Following species occur in lower 20 feet of unit:

Lepidocyclus oblongus
Lepidocyclus manniensis?

Unit 2	
Calcarenitic mudstone, dark-gray, wavy-bedded, sandy; near top, gradational with fine, muddy calcarenites transitional to unit 3; honeycomb network of solution holes 1/4 to 1/2 inch in diameter toward top; base poorly exposed and not measured	15

Following species occur in upper 10 feet of unit:

Lepidocyclus oblongus?
Lepidocyclus perlamellosus
Strophomena sp. 3
Plaesiomys cf. *P. subquadratus*

Total 64

Section C

NE1/4 NW1/4 sec. 2, T. 1 N., R. 6 E., Pontotoc County; measured along northeast-flowing tributary to Sheep Creek. To reach section, drive 1.5 miles south of Fittstown on State Highway 99; turn west on unpaved county-line road for approximately 0.6 mile to gate on south side of road bounding open pasture. Walk south approximately 0.2 mile to creek. Section is faulted at base farther upstream to west and at top near point of entrance. Lower 213 feet measured in and along creek bed; remaining 84 feet measured over low rounded hill in offset section approximately 200 yards south of point where stream turns toward east. Section is on north limb of Hunton anticline south of Franks graben. Strata strike N. 10° W. and dip 18° NE. This is type section for unit 3. Measured by Alberstadt and Glaser, October 1964.

	Feet
Unit 3, subunit 3C	
Coarse skeletal calcarenite, light-gray, slightly wavy-bedded, containing silicified fossils near top in friable weathered portion; sandy near base; contact with overlying Sylvan Shale faulted out	84

Following species occur in upper 6 feet of unit:

Lepidocyclus capax
Lepidocyclus cooperi
Austinella multicostella
Glyptorthis glaseri
Plaesiomys proavitus
Platystrophia sutherlandi
Platystrophia uncinata
Thaerodonta magna
Paucicrura oklahomensis
Diceromyonia cf. *D. tersa*
Hesperorthis rowlandi
Strophomena neglecta
Strophomena sp.
Strophomena planumbona
Megamyonia mankini

Unit 2	
Calcarenitic mudstone, light-gray, wavy-bedded, slightly sandy; honeycomb network of solution holes in top 17 feet; near top, gradational, with fine muddy calcarenites transitional to unit 3	23

Following species occur in upper 35 feet of unit:

Plaesiomys cf. *P. subquadratus*
Lepidocyclus perlamellosus
Lepidocyclus oblongus

Conglomeratic intraclast calcarenite, pinkish-gray, slightly wavy-bedded, containing echinoderms, trilobites, and bryozoans	1
Calcarenitic mudstone, yellowish-gray, wavy-bedded, burrowed, cherty, containing small gastropods	27
Covered	122
Calcarenitic mudstone, light-gray, wavy-bedded, burrowed, dolomitic, cherty, with abundant brachiopods covering certain bedding planes	26

Following species occur in lower 15 feet of unit:

Platystrophia prima
Leptellina sp.
Paucicrura cf. *P. rogata*
Sowerbyella sp.
Dinorthis cf. *D. transversa*
Oepikina sp.
Rafinesquina sp.

Unit 1	
Coarse skeletal calcarenite, yellowish-gray, slightly wavy-bedded, noncherty, containing abundant bryozoans and echinoderms and some large gastropods; slightly crossbedded and burrowed in basal few feet; basal beds in fault contact with McLish(?) Formation of Middle Ordovician age	14
Total	297

Section D

NW1/4 SW1/4 sec. 12, and NE1/4 SE1/4 sec. 11, T. 1 N., R. 6 E., Pontotoc County; measured basal 212 feet up to high-angle fault near northern limit of exposure along west side of State Highway 99, 3.3 miles south of Fittstown; base of section is in N1/2 SW1/4 sec. 12. Remaining 190 feet of offset section measured just east of Sheep Creek in sec. 11 along north-south line approximating east boundary of sec. 11 (west boundary of sec. 12). To reach offset section, drive 2.7 miles south of Fittstown; then walk west across open field approximately 0.3 mile. Rocks in this clearing represent upper unit; beginning of offset approximately 200 yards south of clearing. Section is on north limb of Hunton anticline south of Franks graben. Strata strike N. 57° W. and dip 19° NE. Measured by Alberstadt and Glaser, October 1964 and January 1965.

	Feet
Unit 3, subunit 3C	
Coarse skeletal calcarenite, light-gray, slightly wavy-bedded, friable when weathered, containing silicified brachiopods; contact with Sylvan Shale covered or faulted	66

Following species seen on outcrop but not collected:

Lepidocyclus cooperi
Austinella multicostella
Plaesiomys proavitus
Thaerodonta magna

Unit 2	
Calcarenitic mudstone, light-gray, wavy-bedded, burrowed, dolomitic, irregular chert nodules common in lower half; honeycomb network of solution holes in	

top 32 feet; dolomite-shaly material appears as "pasty" infilling (?plastic clay of Wengerd, 1948) between nodular limestone; certain bedding planes covered with brachiopod shells about 100 feet above base of unit; heavy iron stain from oxidizing pyrite along bedding surface 6 feet above unit base 174

Following species collected from 25 feet above base of unit:

Dinorthis transversa

Following species occur in lower 40 feet of unit:

Platystrophia prima
Sowerbyella sp.
Rhynchotrema increbescens?
Paucicrura cf. *P. rogata*
Rafinesquina sp.

Unit 1, subunit 1C
Coarse skeletal calcarenite, pinkish-gray, slightly wavy-bedded, noncherty, containing abundant bryozoans 45

Following species occurs in upper 10-15 feet of unit:

Dinorthis pectinella

Coarse skeletal calcisiltite and fine skeletal calcarenite, pinkish-gray, slightly wavy-bedded; chert in layers and discrete nodules; skeletal debris mostly hash with ostracodes locally abundant 85

Fine to medium calcarenite, pinkish-gray, slightly wavy-bedded; chert in layers; ostracodes, echinoderms, and small brachiopods dominate fauna 5

Coarse skeletal calcisiltite, pinkish-gray, slightly wavy-bedded, chert in layers and as nodules; skeletal hash 25

Faintly laminated mudstone, gray, slightly siliceous, planar-bedded, with burrowed, highly irregular bedding surface near middle suggestive of small unconformity; cherty; contains graptolites; represents temporary incursion of unit 1, subunit 1L, sediments into area .. 2

Coarse skeletal calcarenite, brown, slightly wavy-bedded, cherty, abundant skeletal phosphatization; irregular contact with olive-green, claylike material suggestive of unconformable break; graptolites abundant along bedding surface; echinoderms dominate calcarenite 0.3

Following species occur in basal foot of unit:

Doleroides vescus
Onniella sp.
Sowerbyella sp.

Total 402

Section E

NE1/4 SW1/4 sec. 2, T. 2 S., R. 7 E., Johnston County; measured on and near Delaware Creek at Witch Hole (Camp Simpson Campground). To reach section, drive 2 miles south of Connerville on State Highway 99 to Dolese Bros. Bromide quarry sign at unpaved road; turn east on unpaved road and proceed 5.9 miles to campground on north side of road. Go approximately 0.3 mile from entrance to caretaker's quarters. Section measured along east-west line beginning directly behind caretaker's home; just west of small dam on Delaware Creek, section measured up steep cliff face along path. Base of section faulted and top contact (covered) occurs on dip slope beyond cliff face. Section is on north limb of Belton anticline. Strata strike N. 35° W. and dip 19° SW. Measured by Alberstadt and Glaser, October 1964.

	Feet
Unit 3, subunit 3C Coarse skeletal calcarenite, pinkish-gray, slightly wavy-bedded, containing abundant echinoderms, sandy near base; contact with overlying Sylvan Shale	56
Unit 2 Calcarenitic mudstone, light-gray, wavy-bedded, burrowed; sandy near top, dolomitic near bottom; honeycomb network of solution holes in top 19 feet; nodular chert in all but upper 33 feet	69
Covered	50
Unit 1, subunit 1L Siliceous laminated mudstone, brown, planar-bedded, containing graptolites, trilobites, sponge spicules, and linguloid brachiopods; chert in layers and as nodules; interbedded 1- to 2-inch-thick limestones with shaly structure	125
Fine to medium calcarenite, light-brown, slightly wavy-bedded, containing echinoderms and ostracodes; in fault contact with McLish(?) Formation of Middle Ordovician age; represents temporary incursion of sediments of unit 1, subunit 1C, into area	0.3+
Total	300.3+

Section F

NW1/4 NE1/4 sec. 19, T. 2 S., R. 8 E., Johnston County; measured in and along west bank of Robertson Creek in upper part of section and on low rounded hill west of creek in lower part of section. To reach section, drive 6 miles south of Connerville on State Highway 99 to junction with State Highway 7; turn east on State Highway 7 and proceed 8.4 miles to State Highway 7D; proceed north 0.3 mile and turn west on unpaved road for approximately 0.2 mile to small cow path to creek on south side of road. From this point, exposures can be reached by crossing fence and walking southwest along path for approximately 150 yards. First rocks observed represent upper part of section. Base of formation is on

second ridge to south and can be reached by walking south along western slopes bordering stream. Section is on north limb of Belton anticline and south edge of Wapanucka syncline. Strata strike N. 58° W. and dip 65° NE. Measured by Alberstadt and Glaser, October 1964.

	Feet
Unit 3, subunit 3C	
Coarse skeletal calcarenite, pinkish-gray, slightly wavy-bedded, containing abundant echinoderms; sandy near base; contact with overlying Sylvan Shale covered; represents maximum thickness for this unit in Arbuckle Mountains	112
Unit 2	
Calcarenitic mudstone, tan to dark-gray, wavy-bedded, burrowed; nodular chert in all but upper 55 feet; near top, gradational with fine muddy-sandy calcarenites transitional to unit 3, subunit 3C; these fine calcarenites, light-gray mottled, dark-brown, burrowed, are same as rocks from this part of sequence at section M, approximately 3-1/2 miles southeast	173
Unit 1, subunit 1L	
Siliceous laminated mudstone, tan, planar-bedded, containing sponge spicules and graptolites; chert in layers; excellent exposure of sharp contact with underlying Corbin Ranch Formation	137
Total	422

Section G

NW1/4 NE1/4 sec. 4, T. 2 S., R. 3 E., Murray County; measured in and along north-flowing tributary to Little Buckhorn Creek on Buckhorn Ranch. Base of measured section is 400 yards south of north boundary and 780 yards west of east boundary of sec. 4. To reach section, drive south on U.S. Highway 177 7.4 miles from junction with State Highway 7 in Sulphur; turn west on unpaved road leading to Buckhorn Ranch and proceed 2.2 miles to ranch headquarters; turn northwest along winding road and go approximately 0.6 mile to Arbuckle Reservoir. From here proceed northeast on foot approximately 0.4 mile along creek to first beds measured in this section. Section is on north limb of Tishomingo anticline. Strata range in strike from N. 33° to N. 72° W.; dip increases from 9° to 40° NE. toward top of section. Section measured by Alberstadt and Glaser, October 1964.

	Feet
Unit 3, subunit 3C	
Coarse skeletal calcarenite, pinkish-gray to gray, wavy-bedded, nodular, slightly dolomitic, containing abundant echinoderms and trilobites; top bed is fine skeletal calcarenite that looks like calcarenitic mudstone in hand specimen; exact contact with overlying Sylvan Shale covered, although typical Sylvan occurs in stream cut approximately 100 yards farther downstream	19
Following species seen on outcrop but not collected (all on bedding plane, 13 feet below top of unit): *Lepidocyclus cooperi*, *Lepidocyclus capax*, *Paucicrura oklahomensis*, *Thaerodonta magna*, *Strophomena planumbona*, *Austinella multicostella*	
Unit 2	
Calcarenitic mudstone, yellowish-gray, wavy-bedded, nodular; chert in layers and as nodules	105
Following species occur in interval 41-56 feet below top of unit: *Plaesiomys bellistriatus*, *Strophomena* cf. *S. perconcava*, *Strophomena clermontensis*, ?*Lepidocyclus perlamellosus*	
Calcarenitic mudstone, yellowish-gray, wavy-bedded, noncherty	96
Calcarenitic mudstone, yellowish-gray, wavy-bedded, burrowed, containing abundant brachiopods and pinkish-red trilobite hash in some beds; chert as nodules; thin layers that are medium muddy calcarenites with high skeletal content and less than 50 percent mud occur near top and bottom	99
Calcarenitic mudstone, yellowish-gray, wavy-bedded, sandy; noncherty except for few nodules in lower 25 feet; extensively burrowed; dolomitic; interbedded with 1/2- to 1-inch-thick limestones with shaly structure; contains abundant brachiopods in some beds; probably close to base of unit although base not exposed	101
Unit 1, subunit 1L	
Upper part partially exposed (about 10 feet) approximately 400 yards upstream, but not measured; typical siliceous laminated mudstone	--
Total	420+

Section H

C E1/2 sec. 25, T. 2 S., R. 1 E., Carter County; measured along U.S. Highway 77 on east side of road and in Tulip Creek to west of road. Section approximately 11 miles south of junction of State Highway 7 and U.S. Highway 77 southwest of Davis. Approximately basal 100 feet measured in bed of Tulip Creek; next 150 feet measured on highway exposures; remainder of section measured in and along Tulip Creek. Section on south limb of Arbuckle anticline. Strata strike N. 68° W. and dip 49° SW. Measured by Alberstadt and Glaser, October 1964.

	Feet
Unit 3, subunit 3CM	
Calcarenitic mudstone, light-brown, slightly wavy-bedded, containing abundant trilobite hash and echinoderms; contact with overlying Sylvan Shale covered	21
Coarse skeletal calcarenite, light-gray, slightly wavy-bedded, slightly dolomitic, containing abundant echinoderms	5
Unit 2	
Calcarenitic mudstone, dark-tan, wavy-bedded, burrowed, containing trilobite *Cryptolithus* sp.; nodular chert; slightly sandy	266
Calcarenitic mudstone, dark-tan, wavy-bedded, burrowed, noncherty, containing graptolites and trilobites; slightly sandy	194
Unit 1, subunit 1L	
Siliceous laminated mudstone, dark-tan, planar-bedded, containing abundant graptolites, sponge spicules, and trilobites; chert in layers; interbedded with numerous 1/2- to 1-inch-thick layers of limestone with shaly structure; basal 65 feet bituminous, has asphaltic odor when broken open; contact with underlying Corbin Ranch Formation sharp	229
Total	715

Section I

E1/2 SW1/4 sec. 22, T. 2 S., R. 1 W., Carter County; measured 0.3 mile northwest of dam on Mountain Lake. To reach section, drive 12.5 miles south of Davis on U.S. Highway 77; turn west on State Highway 53 and go 8 miles to Woodford; turn north and proceed approximately 3 miles to Mountain Lake. Ascend steps on west side of dam and walk 0.3 mile to base of section. Section on south limb of Arbuckle anticline. Strata strike N. 50° W. and dip 27° SW. Measured by Alberstadt and Glaser, October 1964.

	Feet
Unit 3, subunit 3CM	
Calcarenitic mudstone, tan, wavy-bedded, burrowed, dolomitic, containing echinoderms and trilobites; nodular chert near base; contact with overlying Sylvan Shale covered	37
Coarse skeletal calcarenite, dark-tan, slightly wavy-bedded, dolomitic, containing echinoderms, trilobites, and a few large cephalopods	7
Following species collected from lower 7 feet of unit:	
Lepidocyclus cooperi	
Lepidocyclus capax	
Austinella multicostella	
Thaerodonta magna	
Platystrophia sutherlandi	
Platystrophia uncinata	
Hesperorthis rowlandi	
Glyptorthis glaseri	
Paucicrura oklahomensis	
Megamyonia mankini	
Diceromyonia cf. *D. tersa*	
Plaesiomys proavitus	
Plaesiomys subquadratus	
Plaesiomys bellistriatus?	
Unit 2	
Calcarenitic mudstone, dark-tan, wavy-bedded, burrowed, slightly dolomitic	150
Covered	23
Calcarenitic mudstone, dark-tan, wavy-bedded, burrowed; nodular chert	75
Calcarenitic mudstone, tan, wavy-bedded, burrowed, sandy, noncherty	148
Calcarenitic mudstone, dark-tan, wavy-bedded, burrowed, sandy; nodular chert	77
Unit 1, subunit 1L	
Siliceous laminated mudstone, brownish-gray, planar-bedded, containing graptolites and chert in layers; interbedded with 1/2- to 1-inch-thick layers of limestone with shaly structure; basal 50 feet bituminous, has asphaltic odor when broken open; excellent exposure of sharp contact with underlying Corbin Ranch Formation	200
Total	717

Section J

NW1/4 SE1/4 sec. 27, T. 3 S., R 4 E., Johnston County; measured in and along Sycamore Creek. To reach section, drive 17.5 miles south of Sulphur on U.S. Highway 177; turn east on unpaved road at south edge of Baum and proceed 4 miles; take north fork in road and proceed 2.5 miles; then take right fork in road for another 1.5 miles. From here, walk east 0.4 mile to outcrops on Sycamore Creek. Section is on south limb of Sycamore Creek anticline. Strata strike N. 74° W. and dip 60° SW. Measured by Alberstadt and Glaser, November 1964.

	Feet
Unit 3, subunit 3C	
Coarse skeletal calcarenite, light-gray, slightly wavy-bedded, slightly dolomitic, containing abundant trilobites, echinoderms, and some bryozoans; top bed burrowed and covered with iron stain from oxidizing pyrite; excellent exposure of sharp contact with overlying Sylvan Shale	17
Unit 2	
Calcarenitic mudstone, dark-tan, wavy-bedded, burrowed, slightly dolomitic, containing echinoderms, trilobites, and nodular chert	247

	Feet
Calcarenitic mudstone, light-gray, wavy-bedded, burrowed, sandy to silty, non-cherty, containing trilobite hash	187
Unit 1, subunit 1L	
Siliceous laminated mudstone, dark-tan, planar-bedded, containing graptolites and sponge spicules, interbedded with 1/4- to 1/2-inch-thick layers of limestone with shaly structure; good exposure of sharp contact in stream with underlying Corbin Ranch Formation	203
Total	654

Section K

SW1/4 SE1/4 sec. 16, T. 1 N., R. 7 E., Pontotoc County; measured on Rhyne Ranch. To reach section, drive 2.5 miles south of Fittstown on State Highway 99 and turn east on State Highway 61 for 3.8 miles; turn south on unpaved section-line road for 1 mile. Top of section is 0.6 mile southwest of this point. Exposures poor. Section is on north limb of Hunton anticline south of Franks fault zone. Strata strike N. 42° W. and dip 12° NE. Measured by Alberstadt and Glaser, November 1964.

	Feet
Unit 3, subunit 3C	
Coarse skeletal calcarenite, light-gray, slightly wavy-bedded, containing echinoderms, trilobites, and silicified brachiopods; sandy at base; contact with overlying Sylvan Shale covered	64
Unit 2 and unit 1, subunit 1C	
(Poorly exposed and undifferentiated) Calcarenitic mudstone, yellowish-gray, wavy-bedded, burrowed; occurs in upper half of undifferentiated sequence	150-170 est.
Coarse skeletal calcarenite, yellowish-gray, slightly wavy-bedded, containing abundant bryozoans in basal 27 feet; contacts with overlying calcarenitic mudstone and underlying Corbin Ranch Formation difficult to judge	140-160 est.
Total	374 est.

Section L

S1/2 secs. 19, 20, T. 1 S., R. 8 E., Coal County; measured in and along Mosely Creek. To reach section, drive 2 miles south of Connerville on State Highway 99 and turn east on unpaved road leading to Dolese Bros. Bromide quarry. Drive 8 miles to Bromide and then 0.5 mile east of Bromide; turn north for approximately 3 miles following winding road past Bromide school. Rocks at this point represent upper unit. To reach base of formation, walk west along Mosely Creek approximately 1.5 miles. Section is on western margin of Clarita anticline. Strata strike N. 11° E. and dip 3° SE. Measured by Alberstadt and Glaser, February and March 1965.

	Feet
Unit 3, subunit 3C	
Coarse skeletal calcarenite, gray, slightly wavy-bedded, containing silicified brachiopods; top bed almost completely dolomitized in places; contact with overlying Sylvan Shale covered	64
Following species seen on outcrop in upper 6 feet of unit:	
Lepidocyclus cooperi	
Austinella multicostella	
Thaerodonta magna	
Unit 2	
Calcarenitic mudstone, tan to gray, wavy-bedded, burrowed, containing gastropods, brachiopods, trilobites, and a few large cephalopods; nodular chert common; near top, gradational with fine, muddy calcarenites transitional to unit 3	121
Following species collected from upper 20 feet of unit:	
?Lepidocyclus perlamellosus	
Rhynchotrema increbescens?	
Unit 1, subunit 1L	
Dolomite, pinkish-gray, wavy-bedded, original texture and fabric almost wholly obliterated, although what remains suggests original rocks throughout sequence probably were coarse calcarenites interbedded with some calcarenitic mudstones; nodular chert in some beds; fauna consists of ostracodes, brachiopods, and trilobites; represents only occurrence of practically pure dolomite in any appreciable thickness in Viola Formation throughout studied sections in Arbuckles. Other replacement occurrences generally patchy, less than 15 percent of rock, usually confined to mud fraction	101
Calcarenitic mudstone, dark-brown, wavy-bedded, containing trilobites; exposed in stream	7
Coarse skeletal calcisiltite, light-gray, wavy-bedded, containing fossil hash and some nodular chert	10
Siliceous laminated mudstone, dark-gray, planar-bedded; interbedded with layers of coarse skeletal calcisiltite 1-2 mm thick; represents temporary incursion of sediments of unit 1, subunit 1L, into area	10
Coarse skeletal calcisiltite and fine skeletal calcarenite, pinkish-gray, slightly wavy-bedded, cherty, containing abundant bryozoans in some beds, but mostly fine fossil hash; exposure of contact with underlying Corbin Ranch Formation sharp, although formation appears thinner at this section, indicating possibly more truncation here than seen at other sections	40

	Feet
Following species collected from lower foot of unit: *Doleroides vescus*, *Sowerbyella* sp., ?*Onniella* sp.	
Following species collected from 40 feet above base of unit: ?*Onniella* sp., *Hesperorthis* sp.	
Total	353

Section M

NE1/4 SE1/4 sec. 27, T. 2 S., R. 8 E., Johnston County; measured along dry tributary to Sandy Creek. To reach section, drive south on State Highway 48 2 miles beyond its junction with State Highway 7 in Wapanucka; turn west for 1 mile, then north for approximately 0.5 mile to gate leading to open field on west side of road. From southwest edge of field, walk southwest approximately 300 yards along cow path to exposures. Rocks at this point represent upper unit; base of group is approximately 100 yards farther southwest. Section is on south limb of Wapanucka syncline. Strata strike N. 31° W. and are vertical. Measured by Alberstadt and Glaser, March 1965.

	Feet
Unit 3, subunit 3C Coarse skeletal calcarenite, dark-gray, slightly wavy-bedded, containing echinoderms and trilobites; contact with overlying Sylvan Shale covered	80
Unit 2 Calcarenitic mudstone, dark-gray to tan, wavy-bedded, burrowed, sandy; nodular chert in all but upper 53 feet; near top, gradational with fine muddy calcarenites transitional to unit 3; these fine calcarenites are light gray mottled, dark brown, burrowed, like rocks from same part of sequence at section F, approximately 3-1/2 miles northwest	117
Unit 1, subunit 1L Siliceous laminated mudstone, brown, planar-bedded, containing graptolites; chert in layers; exposure of contact with underlying Corbin Ranch Formation sharp	147
Total	344

Section N

SE1/4 SE1/4 sec. 15, T. 2 S., R. 5 E., Johnston County; poor exposures measured over low, rounded hill. To reach section, follow State Highway 7 southeast for 4.3 miles from southeast edge of Mill Creek. At this point road turns southeast and small farm road continues east. Follow farm road for approximately 0.1 mile, then go north for 0.3 mile on winding road leading to small house and barn. Rocks at this point represent contact between Corbin Ranch Formation and basal part of Viola Formation. Section is on south limb of Mill Creek syncline. Strata strike N. 75° W. and dip 40° NE. Exposures are poor and middle part of section is covered. Measured by Alberstadt and Glaser, April 1965.

	Feet
Unit 3, subunit 3C Coarse skeletal calcarenite, tan, slightly wavy-bedded, containing trilobites and echinoderms; slightly muddy in top bed; contact with overlying Sylvan Shale covered	62
Unit 2 Poorly exposed calcarenitic mudstone, tan, wavy-bedded	76
Covered	63 est.
Unit 1, subunit 1L Siliceous laminated mudstone, light-gray, planar-bedded; chert in layers; contact with overlying unit covered; excellent exposure of sharp contact with underlying Corbin Ranch Formation	138
Total	339 est.

Section O

SE1/4 NW1/4 sec. 11, T. 3 S., R. 3 E., Carter County; measured along U.S. Highway 177. To reach section, drive south from Sulphur on U.S. Highway 177 for 13.5 miles. Rocks exposed on east side of highway represent basal unit and lower part of middle unit; remainder of section well exposed in high hill on west side of road. Section measured by plane table and alidade. Section is on south limb of Sycamore Creek anticline. Strata strike N. 68° W. and dip SW. Measured by Alberstadt and Glaser, April 1965. Section measured by Wengerd (1948, 616 feet). Rocks not examined in detail and only approximate thicknesses given.

	Feet
Unit 3, subunit 3C Coarse skeletal calcarenite; exact contact with overlying Sylvan Shale covered, although typical Sylvan observed in stream cut approximately 100 yards west of highway	22 est.
Unit 2 Calcarenitic mudstone, wavy-bedded, containing nodular chert	400 est.
Unit 1, subunit 1L Siliceous laminated mudstone, planar-bedded, with chert in layers; graptolites common; contact with underlying Corbin Ranch Formation not observed	200 est.
Total	622 est.

Section P

SE1/4 SE1/4 sec. 2, T. 2 S., R. 3 E., Murray County. To reach section, drive south of Sulphur on U.S. High-

way 177 for 7.3 miles; turn west 0.2 mile on unpaved road leading to Buckhorn Ranch. Basal part of Viola Formation exposed on north side of road approximately 100 yards beyond this point. Exposures poor. Section is on north limb of Tishomingo anticline. Strata strike N. 20° E. and dip 33° NW. Measured by Alberstadt and Glaser, April 1965.

Exposures too poor for exact measurements of individual units. Section measured solely to obtain total thickness of Viola Formation, which is 530 feet.

Section Q

NW1/4 NE1/4 sec. 28, T. 1 S., R. 2 E., Murray County; measured on west wall in lower level of Dolese Bros. Rayford quarry. To reach section, go east from Davis on State Highway 7 for approximately 3 miles and turn south on unpaved road at quarry sign; proceed south for about 5 miles, turn west for about 2 miles, then north for about 2 miles to quarry. Section is on south limb of Dougherty anticline. Strata strike N. 45° W. and dip 63° SW. Measured by Alberstadt and Glaser, April 1965.

	Feet
Unit 3, subunit 3C Coarse to medium skeletal calcarenite, greenish-gray, with thin shaly partings between uneven subnodular beds; trilobite fragments common; 3- to 4-inch layer of pyritic phosphate conglomerate containing abundant small shells of a linguloid brachiopod separates this unit from the excellent exposures of overlying graptolitic Sylvan Shale	20
Unit 2 Calcarenitic mudstone, light-gray to olive-gray; interbedded with lensing 1- to 2-inch-thick shaly limestones; irregular chert nodules common in upper half	459
Unit 1, subunit 1L Siliceous laminated mudstone, light-gray to dark-gray, planar-bedded, containing chert layers and disseminated silica; graptolites common; excellent exposure of sharp contact with underlying Corbin Ranch Formation	143
Total	622

Section R

NW1/4 SW1/4 sec. 6, T. 2 S., R. 1 W., and SE1/4 SE1/4 sec. 1, and NE1/4 NE1/4 sec. 12, T. 2 S., R. 2 W., Murray and Carter Counties; measured in and along West Spring Creek. To reach section, drive west on State Highway 53 8 miles from its junction with U.S. Highway 77; at Woodford turn north and go approximately 2.3 miles, then turn west along winding unpaved road for approximately 5.5 miles to West Spring Creek. Directions very general, as roads are overgrown and section can be reached only with jeep. Section is on south limb of Arbuckle anticline at southwest edge of Arbuckles. Strata strike N. 35° W. and dip SW. from 33° in basal unit to 27° in upper units. Measured by Alberstadt, Glaser, and W. E. Ham, June 1965.

	Feet
Unit 3, subunit 3CM Coarse skeletal calcarenite, light-bluish-gray, slightly wavy-bedded, containing minor mud; echinoderm and trilobite fragments common; excellent exposure of sharp contact with overlying Sylvan Shale	3
Calcarenitic mudstone, gray-brown, wavy-bedded, cherty, containing large specimens of *Lepidocyclus* sp.	37
Coarse skeletal calcarenite, light-gray, wavy-bedded, slightly muddy; comminuted remains of trilobites, brachiopods, and echinoderms; contact with underlying mudstone fairly sharp	9
Unit 2 Calcarenitic mudstone, gray to dark-tan, wavy-bedded; irregular chert nodules common except for 50-foot interval near middle; fossils variable throughout and predominantly trilobites, graptolites, and brachiopods	464
Unit 1, subunit 1L Siliceous laminated mudstone, dark-tan, planar-bedded; chert layering and disseminated silica common; 1/4- to 1/2-inch-thick interbeds of limestone with shaly structure; contact with underlying Corbin Ranch Formation covered; represents maximum thickness for unit in Arbuckles	382
Total	895

Section S

NW1/4 sec. 24, T. 1 S., R. 1 E., Murray County; Lake Classen area, approximately 1.75 miles west of U.S. Highway 77. Section is on north limb of Arbuckle anticline. Strata strike N. 27° W. and dip SE. from 63° near base to 43° toward top. Measured and described by Dunham (1951). Descriptions of Dunham paraphrased below with equivalent names used in this text in parentheses.

	Feet
Unit 3, subunit 3C Coarsely crystalline limestone, light-gray, massive, with slight wavy bedding, noncherty. (Coarse skeletal calcarenite.)	0-15
Unit 2 Finely crystalline limestone, light-gray, flaggy, with very wavy bedding along which lenticular partings of calcareous shale are distributed, containing many large chert nodules in all but lowest part. (Calcarenitic mudstone.)	460-475

	Feet
Unit 1, subunit 1L	
Very finely crystalline limestone, flat-bedded in 6- to 12-inch-thick layers alternating with gray-brown laminated chert in 1/2- to 1-inch-thick layers. (Siliceous laminated mudstone.)	135
Total maximum thickness	610

REFERENCES CITED

Agnew, A. F., 1955, Facies of Middle and Upper Ordovician rocks of Iowa: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 1703-1752.

Aitken, W. G., and **McKerrow, W. S.**, 1948, Rhynchonellids of the Boueti Bed of the Great Oolite Series of Langton Herring, Dorset: a study in variation: Geol. Mag., v. 85, p. 19-32, pls. 2, 3.

Arber, M. A., 1939, The nature and significance of the pedicle-foramen of *Leptaena* Dalman: Geol. Mag., v. 76, p. 82-92.

——— 1940, The relation of the valves to the pedicle in the Strophomenid brachiopods: Geol. Mag., v. 77, p. 161-174.

——— 1942, The pseudodeltidium of the Strophomenid brachiopods: Geol. Mag., v. 79, p. 179-187.

Austin, G. M., 1927, Richmond faunal zones in Warren and Clinton counties, Ohio: U.S. Natl. Mus. Proc., v. 70, art. 22, 18 p.

Bancroft, B. B., 1928, On the notational representation of the rib-system in Orthacea: Manchester Lit. Philos. Soc. Mem., v. 72, p. 53-90, pls. 1-3.

——— 1945, The brachiopod zonal indices of the stages Costonian to Onnian in Britain: Jour. Paleontology, v. 19, p. 181-252, pls. 22-38.

Barnes, V. E., Cloud, P. E., Jr., and **Duncan, Helen**, 1953, Upper Ordovician of central Texas: Am. Assoc. Petroleum Geologists Bull., v. 37, p. 1030-1043.

Bassler, R. S., 1915, Bibliographic index of American Ordovician and Silurian fossils: U.S. Natl. Mus. Bull. 92, v. 1, 718 p.; v. 2, p. 719-1521, 4 pls.

——— 1932, The stratigraphy of the Central Basin of Tennessee: Tennessee Div. Geology Bull. 38, 268 p., 49 pls.

Bergström, S. M., and **Sweet, W. C.**, 1966, Conodonts from the Lexington limestone (Middle Ordovician) of Kentucky, and its lateral equivalents in Ohio and Indiana: Bulls. Am. Paleontology, v. 50, no. 229, p. 271-441, pls. 28-35.

Berry, W. B. N., 1960, Graptolite faunas of the Marathon region, West Texas: Texas Univ. Bur. Econ. Geology Pub. 6005, 179 p., 20 pls.

Bradley, J. H., Jr., 1921, The Brachiopoda of the Maquoketa of Iowa: Harvard Univ. Mus. Comp. Zoology Bull., v. 64, p. 503-525, 2 pls.

Branson, E. B., Mehl, M. G., and **Branson, C. C.**, 1951, Richmond conodonts of Kentucky and Indiana: Jour. Paleontology, v. 25, p. 1-17, pls. 1-4.

Brown, G. D., Jr., and **Lineback, J. A.**, 1966, Lithostratigraphy of the Cincinnatian Series (Upper Ordovician) in southeastern Indiana: Am. Assoc. Petroleum Geologists Bull., v. 50, p. 1018-1023.

Burma, B. H., 1948, Some aspects of the theory and practice of quantitative paleontology, *pt. 1 of* Studies in quantitative paleontology: Jour. Paleontology, v. 22, p. 725-761.

——— 1949, Multivariate analysis—a new analytical tool for paleontology and geology, *pt. 2 of* Studies in quantitative paleontology: Jour. Paleontology, v. 23, p. 95-103.

Caster, K. E., Dalve, E. A., and **Pope, J. K.**, 1961, Elementary guide to the fossils and strata of the Ordovician in the vicinity of Cincinnati, Ohio: Cincinnati Mus. Nat. History, 47 p., 8 pls.

Cloud, P. E., Jr., 1942, Terebratuloid Brachiopoda of the Silurian and Devonian: Geol. Soc. America Spec. Paper 38, 182 p., 26 pls.

Conrad, T. A., 1842, Description of new species of organic remains belonging to the Silurian, Devonian, and Carboniferous Systems of the United States: Acad. Nat. Sci. Philadelphia Jour., v. 8, pt. 2, p. 235-279, pls. 12-17.

Cooper, G. A., 1944, Phylum Brachiopoda, *chap. 9 in* Shimer, H. W., and Shrock, R. R., Index fossils of North America: Cambridge, Mass., Technology Press, p. 277-365, pls. 105-143.

——— 1956, Chazyan and related brachiopods: Smithsonian Misc. Colln., v. 127, pt. 1 (text), 1024 p.; pt. 2 (plates), p. 1025-1245, 269 pls.

Cram, I. H., 1930, Cherokee and Adair counties, *in* Oil and gas in Oklahoma: Oklahoma Geol. Survey Bull. 40, v. 3, p. 531-586. [This information originally published as Bull. 40-QQ, 1930.]

——— 1932, Correlation of the eastern Oklahoma Ordovician section with that of the Arbuckle region (abs.): Geol. Soc. America Bull., v. 43, p. 286.

Cumings, E. R., 1903, The morphogenesis of *Platystrophia*. A study of the evolution of a Paleozoic brachiopod: Am. Jour. Sci.,4th ser.,v. 15,p.1-48.

——— 1907, The stratigraphy and paleontology of the Cincinnati series of Indiana, *in* Thirty-second annual report: Indiana Dept. Geology and Nat. Resources, p. 605-1189, 55 pls.

Cumings, E. R., and **Galloway, J. J.**, 1913, The stratigraphy and paleontology of the Tanner's Creek section of the Cincinnatian series of Indiana, *in* Thirty-seventh annual report: Indiana Dept. Geology and Nat. Resources, p. 353-479, pls. 1-20.

Cumings, E. R., and **Mauck, A. V.**, 1902, A quantitative study of variation in the fossil brachiopod *Platystrophia lynx*: Am. Jour. Sci., 4th ser., v. 14, p. 9-16, pls. 2, 3.

Dake, C. L., 1921, The problem of the St. Peter sandstone: Missouri Univ. School Mines and Metallurgy Bull., tech. ser., v. 6, p. 1-225, 30 pls.

Dake, C. L., and **Bridge, Josiah**, 1927, Early diastrophic events in the Ozarks (abs.): Geol. Soc. America Bull., v. 38, p. 157-158.

Decker, C. E., 1933, Viola limestone, primarily of Arbuckle and Wichita Mountain regions, Oklahoma: Am. Assoc. Petroleum Geologists Bull., v. 17, p. 1405-1435, pls. 1-3.

——— 1936a, Some tentative correlations on the basis of graptolites of Oklahoma and Arkansas: Am. Assoc. Petroleum Geologists Bull., v. 20, p. 301-311.

——— 1936b, Table of tentative lower Paleozoic correlations on basis of graptolites: Am. Assoc. Petroleum Geologists Bull., v. 20, p. 1252-1257.

——— 1952, Stratigraphic significance of graptolites of Athens shale: Am. Assoc. Petroleum Geologists Bull., v. 36, p. 1-145.

Decker, C. E., and **Merritt, C. A.**, 1931, The stratigraphy and physical characteristics of the Simpson group: Oklahoma Geol. Survey Bull. 55, 112 p., 15 pls.

DuBois, E. P., 1944, Subsurface relations of the Maquoketa and "Trenton" formations in Illinois: Illinois Geol. Survey Rept. Inv. 105, pt. 1, p. 7-33.

Dunham, R. J., 1951, Structure and orogenic history of the Lake Classen area, Arbuckle Mountains, Oklahoma: Oklahoma Univ. unpub. M.S. thesis, 108 p.

Edson, F. C., 1927, Ordovician correlations in Oklahoma: Am. Assoc. Petroleum Geologists Bull., v. 11, p. 967-975.

Fenton, C. L., 1928, Forms of *Strophomena* from Black River and Richmond formations: Am. Midland Naturalist, v. 11, p. 144-159, 3 pls.

Flower, R. H., 1957, Studies of the Actinoceratida: New Mexico Bur. Mines and Mineral Resources Mem. 2, 101 p., 13 pls.

Foerste, A. F., 1901, Silurian and Devonian limestones of Tennessee and Kentucky: Geol. Soc. America Bull., v. 12, p. 395-444, pls. 35-41.

——— 1903a, The Richmond group along the western side of the Cincinnati anticline in Indiana and Kentucky: Am. Geologist, v. 31, p. 333-361, pls. 20-22.

——— 1903b, The Cincinnati group in western Tennessee, between the Tennessee River and the Central Basin: Jour. Geology, v. 11, p. 29-45.

——— 1905, Notes on the distribution of Brachiopoda in the Arnheim and Waynesville beds [Cincinnati region]: Am. Geologist, v. 36, p. 244-250.

——— 1909a, Preliminary notes on Cincinnatian fossils: Denison Univ. Sci. Lab. Bull., v. 14, p. 208-231, pl. 7.

——— 1909b, Preliminary notes on Cincinnatian and Lexington fossils: Denison Univ. Sci. Lab. Bull., v. 14, p. 289-333, pls. 7-11.

——— 1910, Preliminary notes on Cincinnatian and Lexington fossils in Ohio, Indiana, Kentucky, and Tennessee: Denison Univ. Sci. Lab. Bull., v. 16, p. 17-99, pls. 1-6.

——— 1912, *Strophomena* and other fossils from Cincinnatian and Mohawkian horizons, chiefly in Ohio, Indiana, and Kentucky: Denison Univ. Sci. Lab. Bull., v. 17, p. 17-173, pls. 1-18.

——— 1920, The Kimmswick and Plattin limestones of northeastern Missouri: Denison Univ. Sci. Lab. Bull., v. 19, p. 175-224, pls. 21-23.

——— 1924, Upper Ordovician faunas of Ontario and Quebec: Canada Geol. Survey Mem. 138, 255 p., 46 pls.

Ford, J. P., 1967, Cincinnatian geology in southwest Hamilton County, Ohio: Am. Assoc. Petroleum Geologists Bull., v. 51, p. 918-936.

Fox, W. T., 1962, Stratigraphy and paleoecology of the Richmond Group in southeastern Indiana: Geol. Soc. America Bull., v. 73, p. 621-641.

Gealey, J. R., 1955, Geology of Cape Girardeau and Jonesboro quadrangles, southeastern Missouri: Yale Univ. unpub. Ph.D. dissert.

Glaser, G. C., 1965, Lithostratigraphy and carbonate petrology of the Viola Group (Ordovician), Arbuckle Mountains, south-central Oklahoma: Oklahoma Univ. unpub. Ph.D. dissert., 197 p., 8 pls.

Glenister, A. T., 1957, The conodonts of the Ordovician Maquoketa formation in Iowa: Jour. Paleontology, v. 31, p. 715-736, pls. 85-88.

Goldstein, A., 1964, Biostatistics, an introductory text: New York, Macmillan Co., 272 p.

Greger, D. K., and **Born, K. E.**, 1936, Stratigraphy and fauna of the Fernvale formation (Illinois), *in* Tolman, Carl (ed.), Contributions in geology: Washington Univ. Studies, new ser., science and technology, no. 9, paper 89, p. 67-77, 2 pls.

Gutstadt, A. M., 1958, Upper Ordovician stratigraphy in Eastern Interior region: Am. Assoc. Petroleum Geologists Bull., v. 42, p. 513-547.

Hall, D. D., 1962, Dalmanellidae of the Cincinnatian: Palaeontographica Americana, v. 4, p. 131-165, pls. 19-21.

Hall, James, 1847, Paleontology of New York: New York Nat. History Survey, v. 1, 338 p., 87 pls. [Additional title page: Natural history of New York, 1843.]

——— 1860, Contributions to paleontology, 1858 & 1859, *in* Thirteenth annual report of the Regents of the University of the State of New York, on the condition of the State Cabinet of Natural History: Albany, New York Univ., p. 55-128.

Hall, James, and **Clarke, J. M.**, 1892, An introduction to the study of the genera of Paleozoic Brachiopoda, *pt. 1 in* Palaeontology of New York: New York Geol. Survey, v. 8, 367 p., pls. 1-20.

——— 1894, An introduction to the study of the genera of Paleozoic Brachiopoda, *pt. 2 in* Palaeontology of New York: New York Geol. Survey, v. 8, 394 p., pls. 21-84.

Hardy, R. P., 1946, Conodonts from the Fernvale of eastern Missouri: Missouri Univ. unpub. M.S. thesis.

Harris, R. W., 1957, Ostracoda of the Simpson group of Oklahoma: Oklahoma Geol. Survey Bull. 75, 333 p., 10 pls.

Hayes, C. W., and **Ulrich, E. O.**, 1903, Description of the Columbia quadrangle [Tenn.]: U.S. Geol. Survey Geol. Atlas, Folio 95, 6 p.

Howe, H. J., 1959, Montoya group stratigraphy (Ordovician) of Trans-Pecos Texas: Am. Assoc. Petroleum Geologists Bull., v. 43, p. 2285-2332.

——— 1965a, Reassessment of *Rhynchotrema, Lepidocyclus,* and *Hypsiptycha* (abs.), *in* Abstracts for 1964: Geol. Soc. America Spec. Paper 82, p. 96.

——— 1965b, Dalmanellidae from the Montoya Group (Ordovician) of Trans-Pecos Texas: Jour. Paleontology, v. 39, p. 235-247, pl. 36.

——— 1965c, Plectambonitacea, Strophomenacea, and Atrypacea from the Montoya Group (Ordovician) of Trans-Pecos Texas: Jour. Paleontology, v. 39, p. 647-656, pls. 81, 82.

——— 1965d, Morphology of the brachiopod genera *Rhynchotrema, Hypsiptycha,* and *Lepidocyclus:* Jour. Paleontology, v. 39, p. 1125-1128, pl. 134.

——— 1966a, Orthacea from the Montoya Group (Ordovician) of Trans-Pecos Texas: Jour. Paleontology, v. 40, p. 241-257, pls. 28-30.

——— 1966b, The brachiopod genus *Lepidocyclus* from the Cape (Fernvale) Limestone (Ordovician) of Oklahoma and Missouri: Jour. Paleontology, v. 40, p. 258-268, pl. 31.

——— 1967, Rhynchonellacea from the Montoya Group (Ordovician) of Trans-Pecos Texas: Jour. Paleontology, v. 41, p. 845-860, pls. 103-105.

Huffman, G. G. [and others], 1958, Geology of the [south and west] flanks of the Ozark Uplift, northeastern Oklahoma: Oklahoma Geol. Survey Bull. 77, 281 p., 6 pls.

Imbrie, John, 1956, Biometrical methods in the study of invertebrate fossils: Am. Mus. Nat. History Bull., v.

108, art. 2, p. 211-252.

Ireland, H. A., 1936, Use of insoluble residues for correlation in Oklahoma: Am. Assoc. Petroleum Geologists Bull., v. 20, p. 1086-1121.

James, U. P., 1881, Fossils of the Lower Silurian formation, Ohio, Indiana, and Kentucky: Paleontologist, no. 5, p. 33-44.

Jenkins, W. A. M., 1969, Chitinozoa from the Ordovician Viola and Fernvale Limestones of the Arbuckle Mountains, Oklahoma: Palaeont. Assoc. Spec. Paper 5, 44 p., 9 pls.

Jones, O. T., 1928, *Plectambonites* and some allied genera: Great Britain Geol. Survey Mem., v. 1, pt. 5, p. 367-527, pls. 21-25.

Keenan, J. E., 1951, Ostracodes from the Maquoketa shale of Missouri: Jour. Paleontology, v. 25, p. 561-574, pls. 78, 79.

Keyes, C. R., 1894, Paleontology of Missouri: Missouri Geol. Survey Repts., v. 5, pt. 2, 226 p., pls. 33-56.

Ladd, H. S., 1925, Depauperate fauna of the Maquoketa (abs.): Geol. Soc. America Bull., v. 36, p. 228.

——— 1928, Maquoketa faunas (abs.): Geol. Soc. America Bull., v. 39, p. 291-292.

——— 1929, The stratigraphy and paleontology of the Maquoketa shale of Iowa, *pt. 1 in* Annual report, 1928: Iowa Geol. Survey Rept., v. 34, p. 309-448, pls. 4-17.

Macomber, R. W., 1970, Articulate brachiopods from the upper Bighorn Formation (Late Ordovician) of Wyoming: Jour. Paleontology, v. 44, p. 416-450, pls. 75-80.

McEwan, E. D., 1919, A study of the brachiopod genus *Platystrophia:* U.S. Nat. Mus. Proc., v. 56, p. 383-448, pls. 42-52.

Meek, F. B., 1873, Descriptions of invertebrate fossils of the Silurian and Devonian systems, *in* Report of the Geological Survey of Ohio: Ohio Geol. Survey, v. 1, pt. 2, p. 1-243, 23 pls.

Oberg, Rolland, 1966, The condont fauna of the Viola Formation (Ordovician) of Oklahoma: Iowa Univ. unpub. Ph.D. dissert.

Parkinson, Donald, 1952, Allometric growth in *Dielasma hastata* from Treak Cliff, Derbyshire: Geol. Mag., v. 89, p. 201-216.

——— 1954, *Schizophoria resupinata* (Martin), *pt. 1 of* Quantitative studies of brachiopods from the Lower Carboniferous reef limestones of England: Jour. Paleontology, v. 28, p. 367-381.

Peck, J. H., 1966, Upper Ordovician formations in the Maysville area, Kentucky: U.S. Geol. Survey Bull. 1244-B, 30 p.

Pulse, R. R., and **Sweet, W. C.**, 1960, Conodonts from the Fairview and McMillan formations of Ohio, Kentucky and Indiana, *pt. 3 of* The American Upper Ordovician standard: Jour. Paleontology, v. 34, p. 237-264, pls. 35-37.

Ross, R. J., Jr., 1959, Brachiopod fauna of Saturday Mountain formation, southern Lemhi Range, Idaho: U.S. Geol. Survey Prof. Paper 294-L, p. 441-461, pls. 54-56.

Rudwick, M. J. S., 1959, The growth and form of brachiopod shells: Geol. Mag., v. 96, p. 1-24.

Ruedemann, Rudolf, and **Decker, C. E.**, 1934, The graptolites of the Viola limestone: Jour. Paleontology, v. 8, p. 303-327, pls. 40-43.

Salmon, E. S., 1942, Mowhawkian Rafinesquinae: Jour. Paleontology, v. 16, p. 564-603, pls. 85-87.

Sardeson, F. W., 1892, The range and distribution of the Lower Silurian fauna of Minnesota with descriptions of some new species: Minnesota Acad. Nat. Sciences Bull., v. 3, p. 326-343, pls. 4-6.

——— 1896, The Galena and Maquoketa series, pt. 1: Am. Geologist, v. 18, p. 356-368.

——— 1897, The Galena and Maquoketa series, pt. 3: Am. Geologist, v. 19, p. 91-111, pls. 4, 5.

Savage, T. E., 1908, On the lower Paleozoic stratigraphy of southwestern Illinois: Am. Jour. Sci., 4th ser., v. 25, p. 431-443.

——— 1910, The faunal succession and the correlation of the pre-Devonian formations of southern Illinois, *in* Year-Book for 1909: Illinois Geol. Survey Bull. 16, p. 302-341, pls. 33-37.

——— 1913, Stratigraphy and paleontology of the Alexandrian series: Illinois Geol. Survey, Extract Bull. 23, 124 p., 7 pls. [Reprinted, 1917, in Biennial report for 1911 and 1912: Illinois Geol. Survey Bull. 23, p. 67-160, pls. 3-9.]

——— 1918, The Thebes sandstone and Orchard Creek shale and their faunas in Illinois: Illinois Acad. Sci. Trans., v. 10, p. 261-275, 2 pls.

——— 1924, Richmond rocks of Iowa and Illinois: Am. Jour. Sci., 5th ser., v. 8, p. 411-427.

Schuchert, Charles, and **Cooper, G. A.**, 1932, Brachiopod genera of the suborders Orthoidea and Pentameroidea: Yale Univ. Peabody Mus. Nat. History Mem., v. 4, pt. 1, 270 p., 29 pls.

Shaler, N. S., 1876, On the fossil brachiopods of the Ohio Valley: Kentucky Geol. Survey Mem. 1, pt. 3, 44 p.

Shideler, W. H., 1937, Fernvale correlations (abs.): Geol. Soc. America Proc. 1936, p. 367-368.

Simpson, G. G., Roe, Anne, and **Lewontin, R. C.**, 1960, Quantitative zoology (rev. ed.): New York City, Harcourt, Brace, and Co., 440 p.

Sweet, W. C., 1959, Distribution and stratigraphic significance of conodonts in the type section of the Cincinnatian series (abs.): Geol. Soc. America Bull., v. 70, p. 1684.

Sweet, W. C., and **Rust, C. C.**, 1962, Ordovician conodont succession in the Middletown core, southwestern Ohio (abs.), *in* Abstracts for 1961: Geol. Soc. America Spec. Paper 68, p. 282.

Sweet, W. C., Turco, C. A., Warner, Earl, Jr., and **Wilkie, L. C.**, 1959, Eden conodonts from the Cincinnati region of Ohio and Kentucky, *pt. 1 of* The American Upper Ordovician standard: Jour. Paleontology, v. 33, p. 1029-1068, pls. 130-133.

Taff, J. A., 1902, Description of the Atoka quadrangle [Indian Terr.]: U.S. Geol. Survey Geol. Atlas, Folio 79, 8 p.

——— 1903, Description of the Tishomingo quadrangle [Indian Terr.]: U.S. Geol. Survey Geol. Atlas, Folio 98, 8 p.

——— 1928, Preliminary report on the geology of the Arbuckle and Wichita Mountains in Indian Territory and Oklahoma: Oklahoma Geol. Survey Bull. 12, 95 p., 7 pls.

Templeton, J. S., and **Willman, H. B.**, 1963, Champlainian Series (Middle Ordovician) in Illinois: Illinois Geol. Survey Bull. 89, 260 p.

Twenhofel, W. H., 1927, Geology of Anticosti Island: Canada Geol. Survey Mem. 154, 481 p., 60 pls.

Twenhofel, W. H. (chm.), and others, 1954, Correlation of the Ordovician formations of North America: Geol. Soc. America Bull., v. 65, p. 247-298, 1 pl.

Ulrich, E. O., 1911, Revision of the Paleozoic systems: Geol. Soc. America Bull., v. 22, p. 281-680, pls. 25-29.

———1927, Fossiliferous boulders in the Ouachita "Caney" shale and the age of the shale containing them: Oklahoma Geol. Survey Bull. 45, 48 p., 6 pls.

Wang, Yü, 1949, Maquoketa Brachiopoda of Iowa: Geol. Soc. America Mem. 42, 55 p., 12 pls.

Weir, G. W., Greene, R. C., and **Simmons, G. C.**, 1965, Calloway Creek Limestone and Ashlock and Drakes Formations (Upper Ordovician) in south-central Kentucky: U. S. Geol. Survey Bull. 1224-D, 36 p.

Weiss, M. P., 1955, Some Ordovician brachiopods from Minnesota and their stratigraphic relations: Jour. Paleontology, v. 29, p. 759-774, pls. 69-72.

———1961, A critical appraisal of the classification of the typical Cincinnatian beds, *pt. 5 of* The American Upper Ordovician standard: Geol. Soc. America Bull., v. 72, p. 645-647.

Weiss, M. P., Edwards, W. R., Norman, C. E., and **Sharp, E. R.**, 1965, Stratigraphy and petrology of the Cynthiana and Eden Formations of the Ohio Valley, *pt. 7 of* The American Upper Ordovician standard: Geol. Soc. America Spec. Paper 81, 76 p., 8 pls.

Weiss, M. P., and **Norman, C. E.**, 1960, Classification of the limestones of the type Cincinnatian, *pt. 4 of* The American Upper Ordovician standard: Jour. Sed. Petrology, v. 30, p. 283-296.

Weiss, M. P., and **Sweet, W. C.**, 1964, Kope formation (Upper Ordovician): Ohio and Kentucky: Science, v. 145 (Sept. 18), p. 1296, 1301-1302.

Weller, Stuart, 1907, The pre-Richmond unconformity in the Mississippi Valley: Jour. Geology, v. 15, p. 519-525.

Wengerd, S. A., 1948, Fernvale and Viola limestones of south-central Oklahoma: Am. Assoc. Petroleum Geologists Bull., v. 32, p. 2183-2253, pls. 1-12.

Whitfield, R. P., 1878, Preliminary descriptions of new species of fossils from the lower geological formations of Wisconsin, *in* Annual report of the Wisconsin Geological Survey for the year 1877: Wisconsin Geol. Survey, p. 50-89.

———1882, Paleontology, *pt. 3 of* Geology of Wisconsin: Wisconsin Geol. Survey, v. 4, p. 163-363.

Willard, Bradford, 1928, The brachiopods of the Ottosee and Holston formations of Tennessee and Virginia: Harvard Mus. Comp. Zoology Bull., v. 68, p. 255-292, 3 pls.

Williams, Alwyn, and **Wright, A. D.**, 1963, The classification of the "*Orthis testudinaria* Dalman" group of brachiopods: Jour. Paleontology, v. 37, p. 1-32, pls. 1, 2.

Williams, Alwyn, and others, 1965, Brachiopoda, *pt. H of* Moore, R. C. (ed.), Treatise on invertebrate paleontology: Geol. Soc. America and Univ. Kansas Press, v. 1, 521 p.; v. 2, p. 523-927.

Wilson, A. E., 1926, An Upper Ordovician fauna from the Rocky Mountains, British Columbia, *in* Contributions to Canadian paleontology: Canada Geol. Survey Mus. Bull. 44, p. 1-34, pls. 1-8.

———1946, Brachiopoda of the Ottawa formation of the Ottawa-St. Lawrence Lowland: Canada Geol. Survey Bull. 8, 149 p., 11 pls.

Winchell, N. H., and **Schuchert, Charles**, 1892, Preliminary descriptions of new Brachiopoda from the Trenton and Hudson River groups of Minnesota: Am. Geologist, v. 9, p. 284-294.

———1895, The Lower Silurian Brachiopoda of Minnesota, *in* The geology of Minnesota: Minnesota Geol. and Nat. History Survey Final Rept., 1885-1892, v. 3, pt. 1, p. 333-474, pls. 29-34.

PLATES

The fossil specimens figured on plates 1-9 are figured stratigraphically according to the unit in which they occur and are presented in the following order: unit 3 (subunits 3C and 3CM), unit 2, and unit 1 (subunit 1C). All figures are x 1 unless specified otherwise. Specimens labeled "OU" are deposited in the repository at the School of Geology and Geophysics, The University of Oklahoma, Norman, Oklahoma; those labeled "USNM" are deposited in the repository of the U.S. National Museum in Washington, D.C.; and those labeled "VU" are in the repository of the Department of Geology, Vanderbilt University, Nashville, Tennessee.

Plate 1

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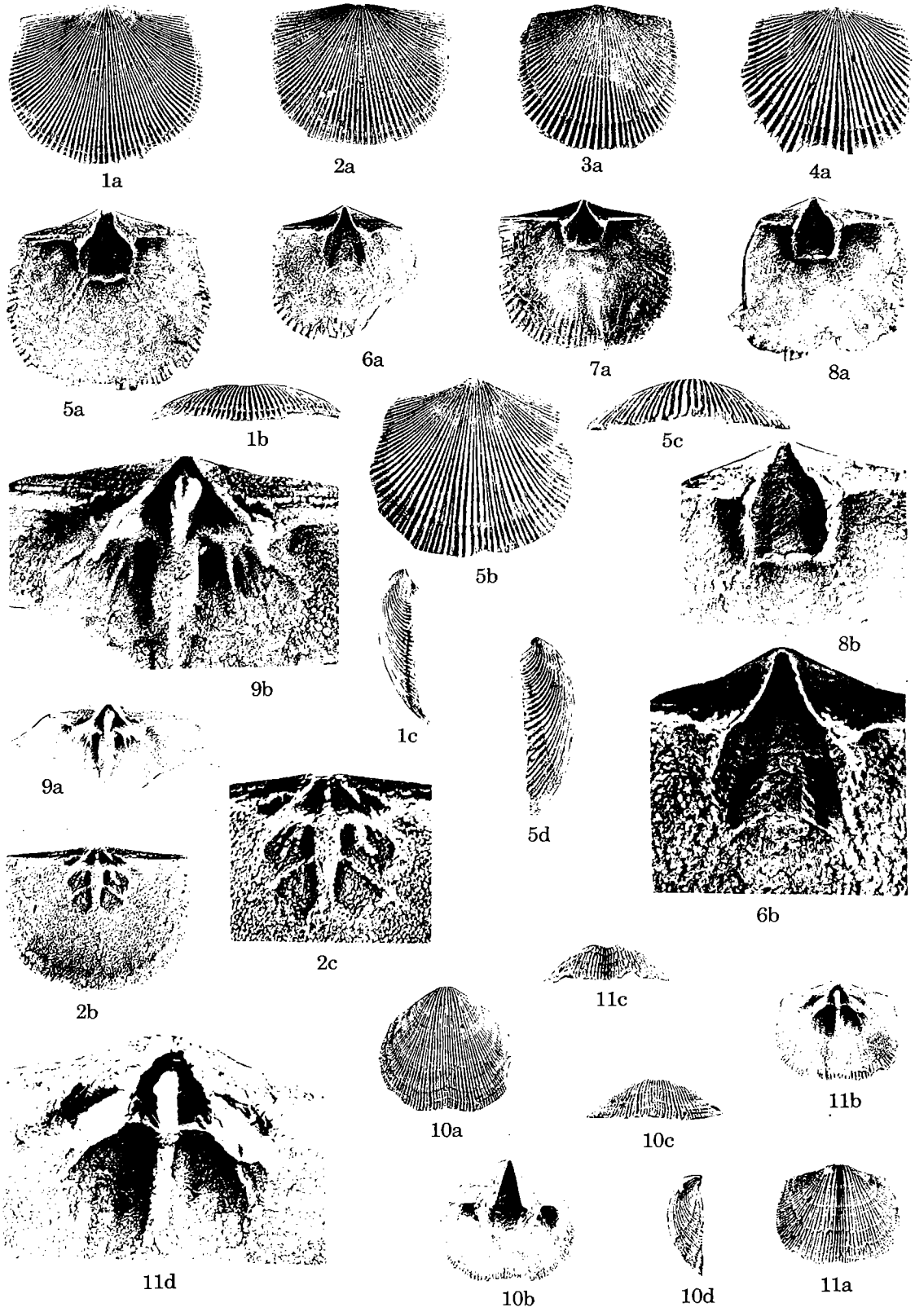
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Plate 2

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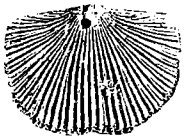
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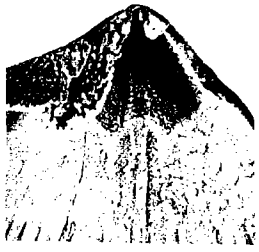
6c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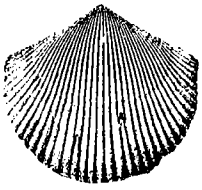
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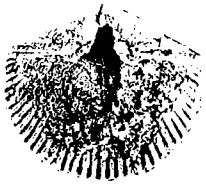
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Plate 3

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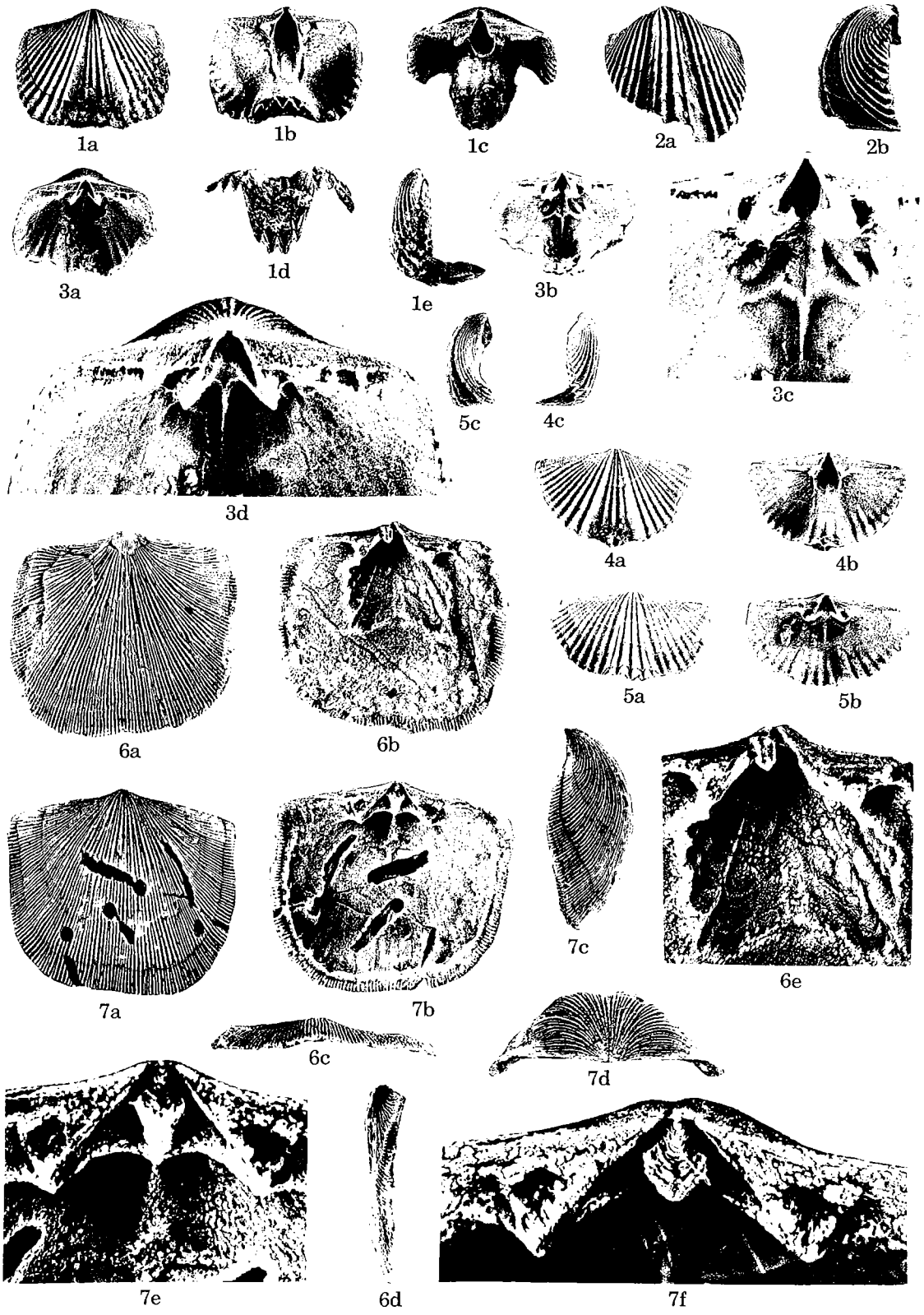
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Plate 4


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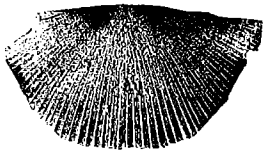
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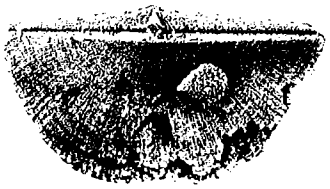
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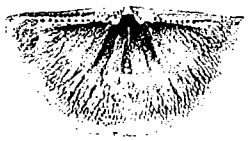
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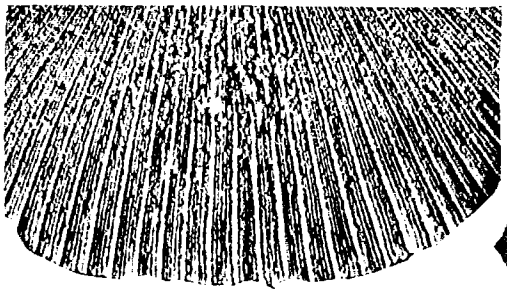
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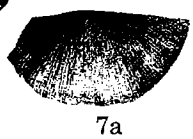
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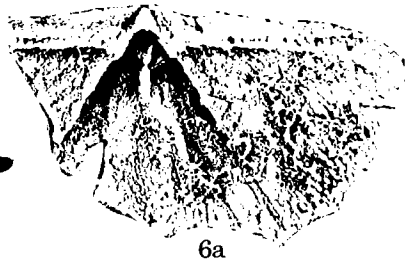
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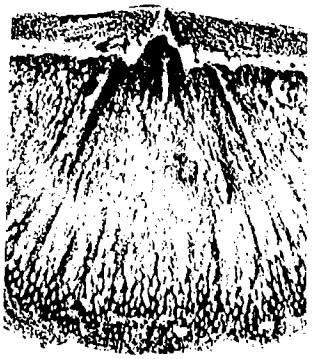
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Plate 5

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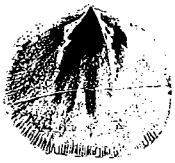
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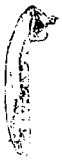
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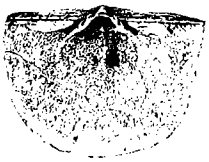
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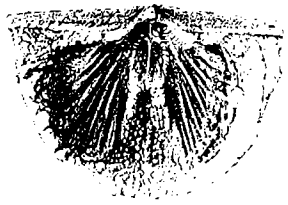
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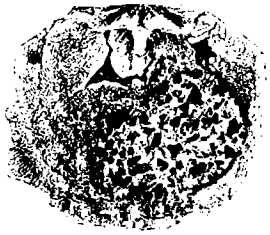
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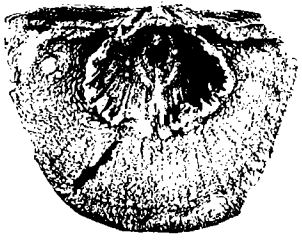
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Plate 6

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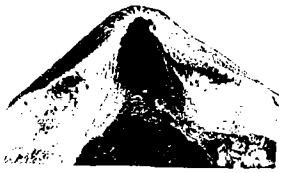
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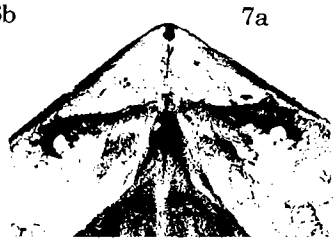
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Plate 7

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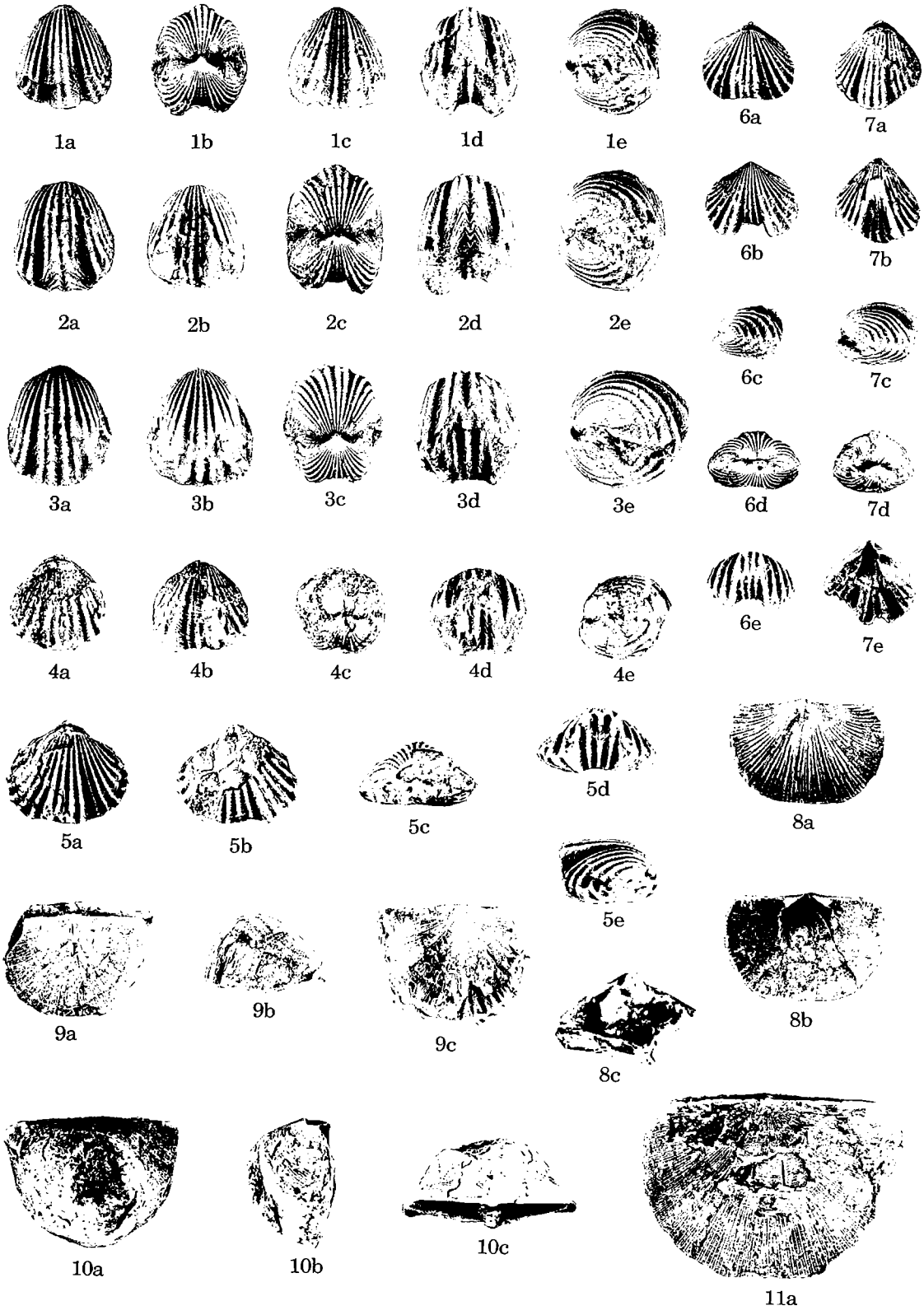
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Plate 8

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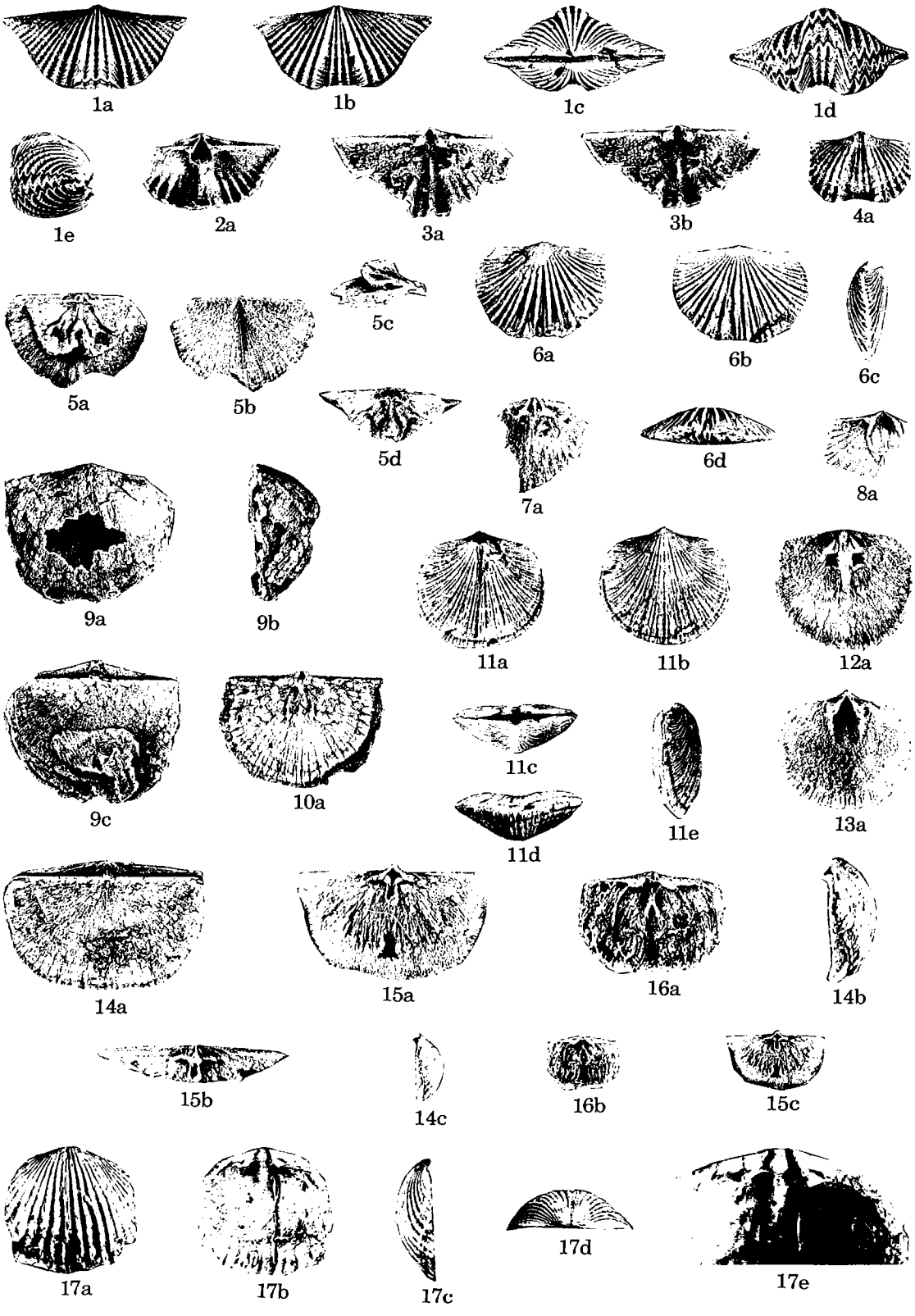
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Plate 9

Page

Figures 1a-d. *Doleroides vescus* Alberstadt, n. sp. Section D, unit 1, subunit 1C, lower 1 foot; OU 5910 30
- a. Exterior of brachial valve.
- b. Interior of brachial valve.
- c. Lateral view of brachial valve.
- d. Interior of brachial valve, X2.

Figures 2a-c. *Doleroides vescus* Alberstadt, n. sp. Section D, unit 1, subunit 1C, lower 1 foot; OU 5911 30
- a. Exterior of pedicle valve.
- b. Interior of pedicle valve.
- c. Interior of pedicle valve, X2.

Figure 3a. *Stophomena* sp. 2. Section D, unit 1, subunit 1C, lower 1 foot; OU 5913 48
- a. Exterior view of brachial valve.

Figures 4a, b. *Rafinesquina* sp. Section C, unit 2, 280-285 feet below top of Viola Formation; OU 5914 50
- a. Exterior of pedicle valve.
- b. Exterior of brachial valve.

Figures 5a, b. ?*Onniella* sp. Section L, unit 1C, 40 feet above base; OU 5900 40
- a. Exterior of brachial valve.
- b. Exterior of pedicle valve.
- c. Exterior of brachial valve, X2.

Figures 6a, b. ?*Onniella* sp. Section L, unit 1, subunit 1C, 40 feet above base; OU 5909 40
- a. Interior of pedicle valve.
- b. Interior of pedicle valve, X2.

Figures 7a, b. ?*Onniella* sp. Section L, unit 1, subunit 1C, 40 feet above base; OU 5910 40
- a. Interior of brachial valve.
- b. Interior of brachial valve, X2.

Figures 8a, b. *Sowerbyella* cf. *S. curdsvillensis* (Foerste). Section L, unit 1, subunit 1C, basal 1 foot; OU 5897 43
- a. Exterior of pedicle valve.
- b. Exterior of brachial valve, X2.

Figures 9a, b. *Sowerbyella* cf. *S. curdsvillensis* (Foerste). Section L, unit 1, subunit 1C, basal 1 foot; OU 5899 43
- a. Interior of pedicle valve.
- b. Interior of pedicle valve, X2.

Figures 10a, b. *Sowerbyella* cf. *S. curdsvillensis* (Foerste). Section L, unit 1, subunit 1C, basal 1 foot; OU 5898 43
- a. Interior of brachial valve.
- b. Interior of brachial valve, X2.

Figures 11a-c. *Hesperorthis* sp. Section L, unit 1, subunit 1C, 40 feet above base; OU 5912 18
- a. Exterior of brachial valve.
- b. Exterior of brachial valve, X2.
- c. Interior of brachial valve, X2.

Figures 12a-f. ?*Onniella* sp. Section D, unit 1, subunit 1C, basal 1 foot; OU 5896 40
- a. Exterior of brachial valve.
- b. Interior of brachial valve.
- c. Interior of brachial valve, X2.
- d. Lateral view of brachial valve.
- e. Cardinalia, specimen tilted to show myophore, X4.
- f. Cardinalia, showing plane of commissure, X4.

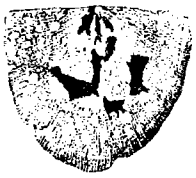

1a


2a

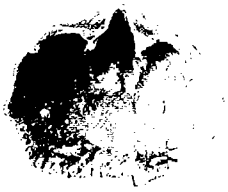

1b


2b

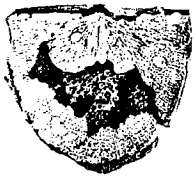

1c


4a


1d


2c


3a


4b


5a


5b


6b


8a


9a


10a


6a


10b


9b


8b

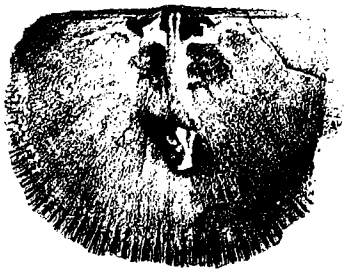

7b


7a


5c


11b


11a


12c


12a


11c


12b


12f


12e


12d

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(**Boldface** number indicates main reference; brackets indicate plate explanations; parentheses indicate figure explanations)