ALBERSTADT, Leonard Philip, 1938-
BRACHIOPOD BIOSTRATIGRAPHY OF THE VIOLA AND "FERNVALE" FORMATIONS (ORDOVICIAN), ARBUCKLE MOUNTAINS, SOUTH-CENTRAL OKLAHOMA.

The University of Oklahoma, Ph.D., 1967
Geology

University Microfilms, Inc., Ann Arbor, Michigan

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

BRACHIOPOD BIOSTRATIGRAPHY OF THE VIOLA AND "FERNVALE" FORMATIONS (ORDOVICIAN), ARBUCKLE MOUNTAINS, SOUTH-CENTRAL OKLAHOMA

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

PHILIP
LEONARD P. ALBERSTADT

Norman, Oklahoma

1967

BRACHIOPOD BIOSTRATIGRAPHY OF THE VIOLA AND "FERNVALE" FORMATIONS (ORDOVICIAN), ARBUCKLE MOUNTAINS, SOUTH-CENTRAL OKLAHOMA

APPROVED BY

Charles J. Mankin

Gerald Brauer

Charles W. Harper

David B. Kitts

Patrick K. Sutherland

DISSERTATION COMMITTEE

ACKNOWLEDGMENTS

This study is submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at the University of Oklahoma. The problem was directed by Dr. Patrick K. Sutherland whose advice and supervision are gratefully acknowledged. Besides reading the manuscript, he checked the field work, and made many valuable suggestions for strengthening the study.

I am also grateful to Drs. Charles J. Mankin, George T. Stone, and Charles W. Harper, Jr., for critically reading the manuscript and offering meaningful and helpful suggestions.

The writer wishes to thank the Society of the Sigma Xi for providing funds to visit the United States National Museum for the purpose of studying pertinent collections deposited there. Also, thanks are expressed to the Oklahoma Geological Survey for helping to defray field expenses.

Special thanks are due Mr. Tom L. Rowland who helped the writer in the field with some of the more difficult collecting. The writer expresses his thanks to Dr. Gerald C. Glaser, project co-worker, who studied the lithostratigraphy of the rock units.

Finally, I am most thankful to my wife, Joan M. Alberstadt, for her help in drafting many of the diagrams presented in this study.

TABLE OF CONTENTS

Page

APPENDIX

LIST OF ILLUSTRATIONS

Figure		Page

Figure		Page

Figure | Page

BRACHIOPOD BIOSTRATIGRAPHY OF THE VIOLA AND "FERNVALE" FORMATIONS (ORDOVICIAN), ARBUCKLE MOUNTAINS, SOUTH-CENTRAL OKLAHOMA

INTRODUCTION

The investigation of the brachiopod biostratigraphy of the Viola and "Fernvale" Formations of the Arbuckle Mountains of south-central Oklahoma was conducted during the years 1964-1966. This study was undertaken with Gerald C. Glaser as a joint project to determine the litho- and biostratigraphic relationships of these two formations. Glaser reported on the lithostratigraphy in his Ph. D. Dissertation submitted to the University of Oklahoma School of Geology in 1965.

The area of the study is approximately 1,200 square miles with measured sections in Pontotoc, Johnston, Coal, Murray, and Carter Counties. Figure 1 indicates the geographic location of the area. Figure 2 shows the outcrop pattern of these rocks as they occur in the Arbuckle Mountains and indicates the location of the 18 surface sections. The sections marked with triangles are those from which brachiopods were collected.

The sequence under study was formerly designated as the Viola and "Fernvale" Formations. (See Previous Investigations). Glaser (1965) subdivided this rock sequence into three distinct lithologic units, of which the lower and upper have equally distinct facies.

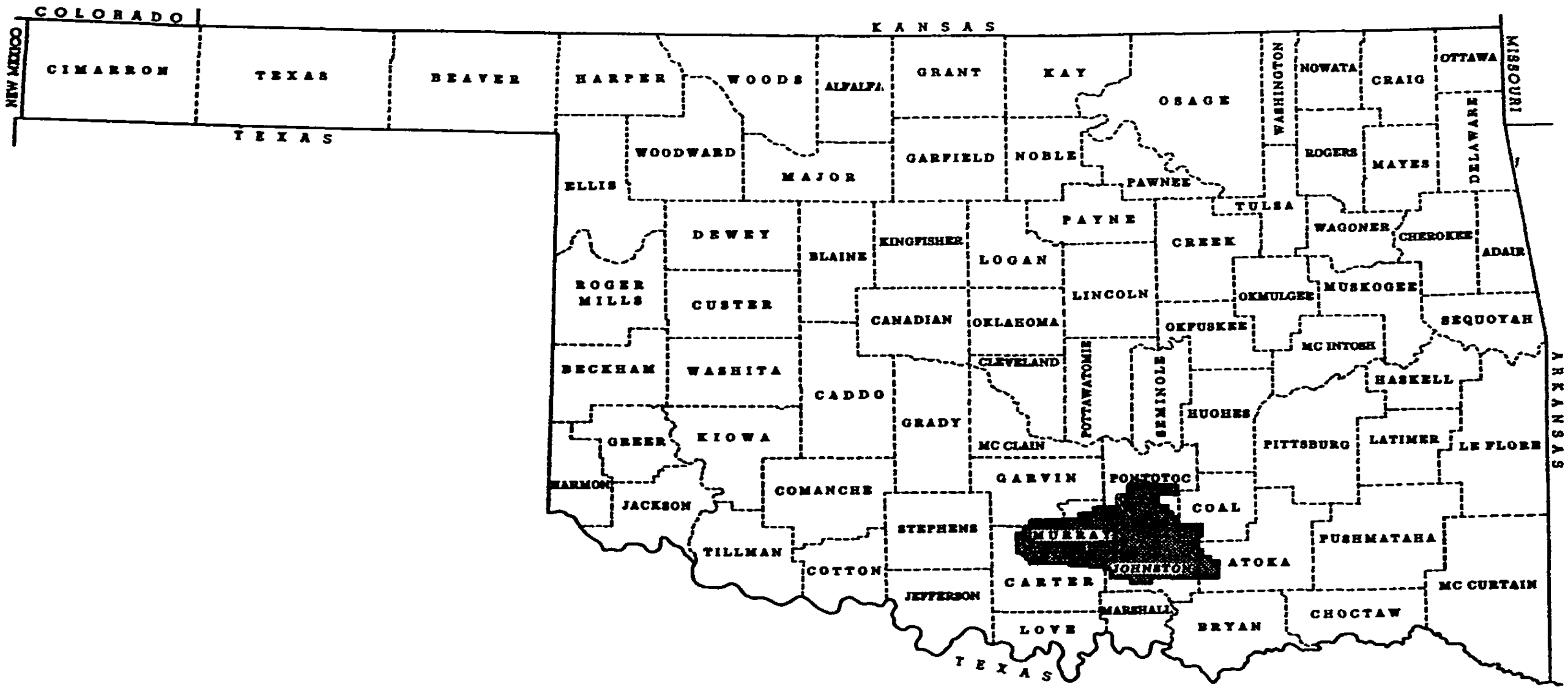
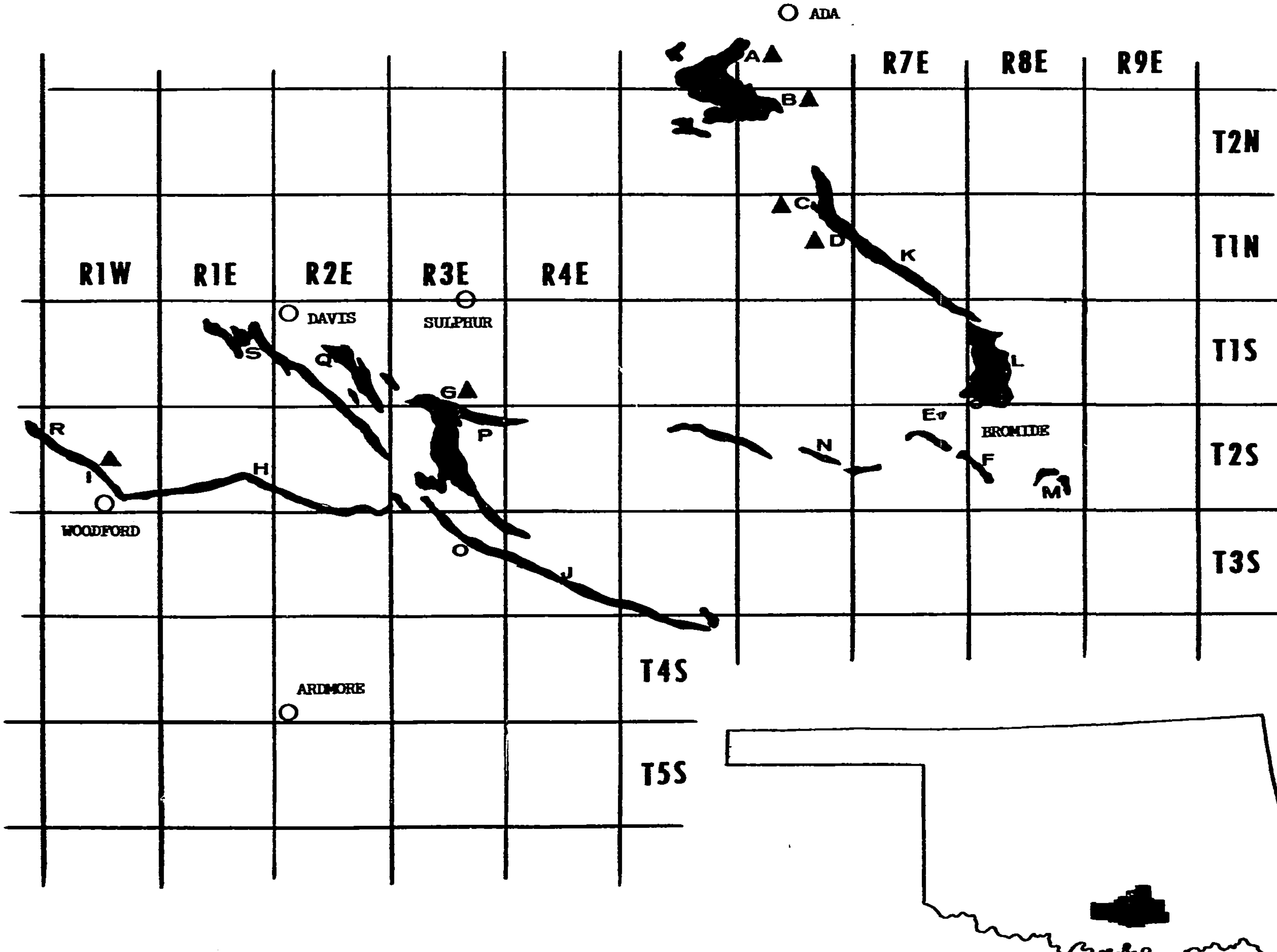


FIGURE 1

INDEX MAP OF OKLAHOMA SHOWING LOCATION OF ARBUCKLE MOUNTAINS

Figure 2

Locations of the sections studied by Alberstadt and Glaser. Glaser (1965) studied the lithological characteristics of the rock units at all localities shown. The sections indicated by triangles are the ones from which brachiopods were collected and studied for this paper.



ADA
R7E
R8E
R9E
T2N
T1N
R1W
R1E
R2E
R3E
R4E
DAVIS
SULPHUR
T1S
T2S
T3S
T4S
T5S
BROMIDE
WOODFORD
ARDMORE
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S

FIGURE 2

Figure 3 shows the stratigraphic interpretation and the unit designations proposed by Glaser for these two "formations." The reasons for which the writer believes that the name "Fernvale" should be discontinued in the Arbuckle Mountains are given in the conclusions.

In summarizing his stratigraphic interpretation Glaser stated (1965, p. 3-4):

> Unit 1L at the base is composed of siliceous laminated mudstone which, toward the northeast, pass [sic] into Unit 1C, composed of coarse-grained skeletal calcisiltites. Unit 2 is comprised of [sic] calcarenitic mudstones in both the southwest and northeast provinces and constitutes the middle of the sequence. Unit 3C is composed of coarse-grained skeletal calcarenites formerly called "Fernvale" Limestone. In the extreme southwest, the Unit 3CM facies, consisting of calcarenites, is present.

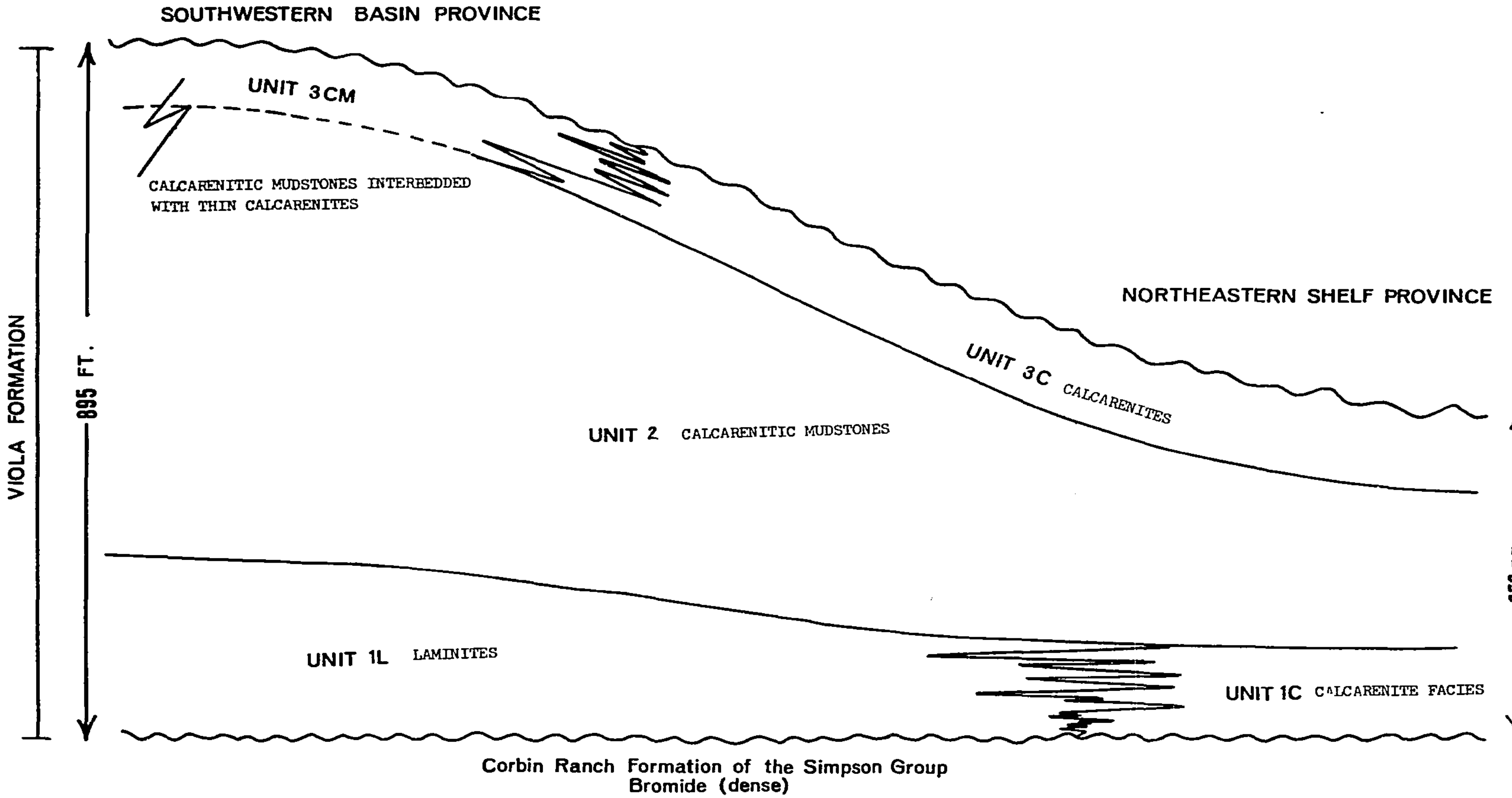
Glaser reported that the interval between these units is gradational, and that there is no lithologic method to designate definite boundaries between Unit 1L and Unit 2, or between Unit 2 and Unit 3C. The problems in nomenclature presented by these gradational boundaries are discussed more fully in the section which treats the lithostratigraphy of the Viola Formation.

Purpose of the Study

The objective of this study is to interpret the brachiopod biostratigraphy of the Viola and "Fernvale" Formations within the Arbuckle Mountain region. Such knowledge would promote a better understanding of the geologic history of these rock units by improving correlation with rocks of similar age in other geographic areas. A second objective is to present a detailed description of the brachiopod

Figure 3

The interpretation of the lithostratigraphy proposed by Glaser (1965) for the Viola Formation in the Arbuckle Mountains.



DIAGRAMMATIC SECTION OF THE VIOLA FORMATION, ARBUCKLE MOUNTAINS, OKLAHOMA
(Modified from Glaser (1965))

Figure 3

faunas so as to make possible comparisons with brachiopod faunas from other regions.

Previous Investigations

There are numerous studies which have been concerned in a general way with the Viola Limestone in the Arbuckle Mountains. A chronological presentation of some of these earlier studies was given by Glaser (1965) and therefore a duplication of that information will not be presented here. However, it is felt that two aspects of these earlier investigations should be discussed in order to compare previous stratigraphic interpretations to those made in this paper. First, it is necessary to relate the origin of the name "Fernvale" and how it came to be used in the Arbuckle Mountains. Second, stratigraphic interpretations regarding the Viola and "Fernvale" Formations proposed by other workers are considered.

The designation "Fernvale Limestone" was first proposed by Hayes and Ulrich (1903) for the beds exposed along South Harpeth River about one mile south of Fernvale Springs in Williamson County, Tennessee. The description given by Hayes and Ulrich follows (1903, p. 2):

> The Fernvale formation consists mainly of soft chocolate and green shales. Commonly the shales include one or more layers of coarsely crystalline, occasionally flesh-colored, limestones, usually with greenish specks. Not infrequently the lower of these layers is conglomeratic and highly phosphatic. In the valley of South Harpeth Creek, south of Fernvale, and on both sides of Duck Creek, in Tottys Bend and Morgan and Haley creeks, the lower part of the formation is made up of 5 or 6 feet of strongly ferruginous, often vermillion-red limestone. When the formation is thin, as along the borders and more particularly the heads of the bays in which it was deposited, the shales only are developed. In thickness the formation varies from nothing to 40 feet, the average being less than 20 feet.

Foerste (1901) named these same beds the "Leipers Creek Formation" and provided an adequate description. Hayes and Ulrich (1903) gave no explanation as to why they replaced this name with that of Fernvale. They interpreted the Fernvale as lying unconformably on their Leipers Formation. They stated (1903, p. 4):

> Two of the formations mapped, namely the Fernvale formation and the Clifton limestone <u>this is the formation above the Fernvale</u> [italics are those of the author] were deposited over only a small portion of the quadrangle, apparently in a series of embayments produced by warping of the pre-existing surface.

Wilson (1949, p. 212) redefined the Fernvale in Tennessee to include only the widespread, thick bedded, coarsely crystalline, variegated limestone. It commonly consists of a thick bedded, very coarsely crystalline, gray or flesh-colored limestone that contains varying amounts of green, brown, yellow, and red grains or a wider greenish or reddish tint. In some parts of Tennessee, it is bright red due to iron oxide. In parts of Lincoln County, the lower few feet are phosphatic and locally contain round phosphatic nodules. The Fernvale averages less than 20 feet in thickness, but attains a maximum of 45 feet in Davidson and Franklin Counties. The Fernvale Limestones and Mannie Shale represent the western facies of the thicker Sequatchie Formation of eastern Tennessee. According to Wilson (1949, p. 212) the Sequatchie and the Fernvale overlie the Leipers (Wilson's Leipers) unconformably. The many reports of shale in the Fernvale of Tennessee are thought to be portions of Mannie Shale or shale tongues of the calcareous Sequatchie Formation.

In Oklahoma, Taff (1903) reported the tripartite division of the Viola based on studies of the fauna by E. O. Ulrich. Brachiopods reported from the lower unit were Dinorthis pectinella Hall, and Rhynchotrema increbescens Hall. The only brachiopod reported from the middle member was Rafinesquina deltoidea Conrad. The upper member was reported to be fossiliferous only in the upper 25 feet which Taff said was characteristic of the upper divisions of the Richmond deposits in Minnesota, Wisconsin, Illinois, Indiana, and Ohio. Brachiopods reported from the upper part of the Viola are: Plectambonities (a new species), Strophomena wisconsinensis Whitfield, Leptaena unicostata Meek and Worthen, Orthis kankakensis sweeneyi Winchell, Dinorthis subquadrata Hall, Dinorthis proavita Winchell and Schuchert, Dalmanella macrior Sardenson, Platystrophia acutilarata Conrad, Rhynchotrema capax Conrad, and Parastrophia divergens Hall and Clarke. In discussing the fauna of this upper unit Taff stated that it is the same as the Polk Bayour Limestone of Arkansas and the Fernvale Formation of Tennessee. However, he did not use the name Fernvale as a formational term in Oklahoma. Also, there is no statement of an unconformity below the upper coarsely crystalline member of this tripartite division. The columnar section given by Taff in his report has no erosional break indicated.

Ulrich (1911) postulated an early Richmond transgression in the mid-continent at the base of the Fernvale Formation. Of this formation he said (1911, p. 305):

> On the east and southern flanks of Ozarkia, it is nearly always found where beds of Mohawkian age were deposited, and in places it overlapped these so that it rests on much older pre-Ordovician rocks. Further, it is recognized in the Arbuckle Uplift of Oklahoma as a 2 to 3 foot bed at the top of the Viola limestone by exactly the same lithologic and faunal characters that mark it in southeastern Missouri.

Ulrich further stated (1911, p. 305):

> In the bluffs of the Mississippi south of St. Louis and north of Riverside the bed can be followed for miles. Here it rests unconformably on the peneplaned Kimmswick limestone which is middle Mohawkian in age.

Ulrich again discussed the Fernvale (1911, p. 308):

> Perhaps the greatest pre-Pennsylvanian erosion of interior Paleozoic formations was in the closing stages of the Ordovician. South of Hannibal, Missouri--in the southern half of the Mississippi Valley proper--it began long before the close of the Trenton. On the east and south flanks of Ozarkia the late Black River Kimmswick, a crystalline limestone of earlier date than the Galena dolomite proper, is the last of the Ordovician deposits. On these flanks it is immediately succeeded and overlapped by the Fernvale limestone which is regarded as one of the first deposits of the Silurian submergence.

In the same context Ulrich described how the thin Fernvale maintains its 2 to 3 foot thickness, but rests on successively lower and lower horizons of the Kimmswick Limestone. This is the earliest paper in which the rocks of the Arbuckle Mountains are referred to as the Fernvale Formation.

Dake (1921), in discussing the Viola Formation of the Arbuckle Mountains, stated that it is divisible into three units of which the upper is about 300 feet thick. He listed essentially the same fauna as that given by Taff in 1903. The brachiopods of this fauna have been referred to above. Concerning this Arbuckle section and the fauna he made the following statement (1921, p. 62):

> This is a characteristic Richmond fauna, apparently equivalent to the Fernvale already described from Arkansas and Missouri. How great a thickness of this upper member belongs to the Richmond is not clear, though probably not an amount greatly in excess of the fifty feet of the more fossiliferous beds, near the top. It is quite possible that the less fossiliferous limestone immediately below may include earlier Cincinnatian beds. The presence of a Maysville fauna near Tahlequah suggests this possibility.

In a stratigraphic cross section presented by Dake (1921) as Plate II, the Fernvale of southern Illinois, Missouri, and Arkansas is depicted as unconformably overlying the Kimmswick Limestone. The continuation of this diagram into Oklahoma shows the Viola-Fernvale as a continuous sequence. The unconformity is shown to die out somewhere between Arkansas and northeastern Oklahoma and the Arbuckle Mountains.

The following quote from Edson (1927) is in marked disagreement with the above quote and cross section from Dake. She said (p. 970):

> In the Arbuckle Mountains a thick series of limestones, Trenton in age, occurs between the Richmond and upper Black River members, *the Black River members referred to in this statement are now known as the Bromide Formation. Decker and Merritt (1931) redefined it as the upper formation of the Simpson Group thus withdrawing it as the lower member of the Viola Formation. This redefinition has been followed by all later workers* [Italics are those of the author] but this Trenton series is absent in the other occurrences of the Viola lime found in Oklahoma. The absence of this middle member in Oklahoma north of the mountains, confirms the hiatus mentioned by Dake, between the Richmond and lower part of the Viola limestone in the Arbuckle Mountains, but indicates that the stratigraphic break was much greater throughout the mid-continent field than it was in the mountains.

Ulrich (1927) continued to expound his original stratigraphic interpretation, but altered his age determination. He stated (p. 29):

> As indicated in the correlation chart, in which the Oklahoma formations are set opposite the particular units of the comparable Appalachian and Mississippian Valley time scale to which they are throught to be most nearly related, the Viola is correlated wholly though somewhat indefinitely with Cincinnatian formations, hence is placed higher in the scale than in former efforts. Next above the top of the Viola, with clear evidence of a break between, comes the widely distributed early Richmond Fernvale limestone. . .

The stratigraphic diagram referred to by Ulrich shows the Viola as being partly Eden and Early Maysville in age. Ulrich did not give any specific reason for making this correlation.

Cram (1930) proposed to extend the name Fernvale into northeastern Oklahoma. The formation in that area is a coarsely crystalline fossiliferous limestone attaining an average thickness of about 10 feet. Previous to Cram's proposal it was mapped with the underlying Fite Limestone. Concerning the stratigraphic relations, Cram stated (1930, p. 22):

> The Fite limestone overlies the Tyner formation unconformably, and is unconformably overlain by the Fernvale limestone or Chattanooga formation. In all cases the contacts are extremely sharp and marked by most abrupt breaks in sedimentation, yet no discordance in dip is discernable.

Decker (1933) described several stratigraphic sections in the Arbuckle Mountains from which the graptolites had been collected. A quote from that paper follows (1933, p. 1434):

> The molluscoids and the mollusks, as well as the graptolites, correlate parts of the Viola with the Normanskill, Trenton, Utica, Lorraine, and Richmond.

The following year Ruedemann and Decker (1934) described the graptolites and discussed their stratigraphic and geographic distribution. Their conclusions as to the correlation of the Viola were the same as given by Decker the year before. It is unmistakably clear that Decker considered the Viola to be a continuous sequence with no hiatus between the "Fernvale" and the Viola. In discussing the color, texture, and composition of the Viola Limestone he made the following statement which well illustrates his interpretation (1933, p. 1410):

> Coarsely crystalline beds occur at some localities near the base, some near the middle, and more near the top where they grade into the typically coarsely crystalline dark gray limestone of the Fernvale phase.

The continuation of the term "Fernvale," although clearly not used in the formational sense, certainly did not help to clarify the relationships of these rocks in the Arbuckle Mountains.

The stratigraphic positions of some of the important graptolites used by Decker in his age determinations are shown in Figure 12. These are discussed in more detail in the conclusions. However, it seems that this biostratigraphic information has been ignored by subsequent workers concerned with the correlation of these rocks. Possibly this resulted because Decker commonly used formational names like Trenton, Utica, Lorraine, and Richmond and not terms having a stage connotation like Trenton, Eden, Maysville, and Richmond.

Wengard (1948) did a lithologic study of the Viola Formation using chert percentages, residue percentages, texture of the rock, and the color of the rock to subdivide the formation. His study was confined to the subsurface except for six surface sections in the Arbuckle Mountains. Wengard divided the Viola Formation into 4 lithologic members which in descending order were labeled 1, 2, 3, and 4. Members 1 and 3 were further divided into submembers (a) and (b). Above this four-member Viola unit is the Fernvale Limestone which as Wengard stated (1948, p. 2247):

> . . . is separated everywhere from the Viola members below by an erosional unconformity of regional extent in the Mid-Continent region.

His cross section (given as Figure 15) shows that in the subsurface of the Seminole Uplift area the Fernvale rests on submember 1b; the upper member of unit 1, unit 1a, having been truncated. South of this area there is no truncation shown. Wengard presents two cross sections depicting the unconformity at the base of the Fernvale. One cross section is a composite stratigraphic diagram extending from northeastern Oklahoma to the Arbuckle Mountains (his Figure 1), and the other is a series of stratigraphic columns (his Figure 14) extending from Ardmore to Seminole. In both diagrams the unconformity is interpreted as being regional in extent. This interpretation indicates that the biostratigraphic information presented by Decker (1933) and Ruedemann and Decker (1934) were not considered valid, although they were mentioned. Wengard stated (1948, p. 2189):

> Decker's work on the Viola limestone proved the extensive distribution of these strata by correlating the discontinuous outcrops in a wide area, and he considered, just as Taff did, that the Fernvale and Viola limestones were one formation (Decker, 1933, p. 1433).

Also, Wengard makes no reference to the data and interpretation presented by Dake (1921) in which he showed an unconformity in the northeast Oklahoma area, but continuous deposition in the Arbuckle Mountains.

Shideler (1936) proposed that the name "Ada Limestone" replace the name Fernvale. However, the name Ada had previously been used by Morgan (1924) for a Pennsylvanian formation. Shideler suggested that possibly the Oklahoma Fernvale was much older than the type Fernvale of Tennessee. Shideler stated (1936, p. 368):

> The "Fernvale" extending from Glen Park, Missouri, and Valmeyer, Illinois, to the south side of the Arbuckles in Oklahoma, is a massive, uniformly crystalline limestone with a varied fauna of ostracodes and trilobites, including _Pterygometopus_, _Onchometopus_, _Cryptolithus_, _Sphaerocorhphe_, _Cyphaspis_, etc. Bryozoa are almost entirely absent.
>
> As both lithology and faunas differ radically, _these differ from the Tennessee Fernvale_ [italics are the author's] it is concluded that deposition was in entirely disconnected basins and at different times, and the name Ada is proposed for the crystalline limestones, the best exposures being at Lawrence Quarry, seven miles southwest of Ada, Oklahoma.

The typical Fernvale is correlated with the Elkhorn of the typical Richmond section. The Ada is tentatively correlated with the Maquoketa, but may not even be Richmond.

Templeton and Wilman (1963, pp. 134-135) proposed the name "Cape Limestone" to replace the name Fernvale in Illinois, Missouri, and Oklahoma. Further reference to this paper will be made in the section on the biostratigraphy of the Viola Formation.

LITHOSTRATIGRAPHY OF THE VIOLA FORMATION

The lithostratigraphy of the Viola Group was described by Glaser (1965). The rocks of that study are those formerly called the Viola and "Fernvale" formations. In the interpretation made by Glaser (1965), the Viola and "Fernvale" were abandoned as formational terms and the entire sequence was referred to as the Viola Group. In this paper the same sequence of rocks will be referred to as the Viola Formation. The writer is of the opinion that this is the best approach because (1) the contacts between the included lithologic units are gradational, (2) the contacts are not practical for mapping purposes, (3) it is strongly advised by most geologists that a group have included formations (Code of Strat. Nomen., 1961, p. 651), (4) a change in rank of a lithologic unit should only be proposed when a much clearer and more practical stratigraphic subdivision can be substituted, and (5) the geologic history of the sequence can be discussed and interpreted just as adequately by using a less rigid formation-member or a formation-unit designation.

In discussing the nature of rock-stratigraphic units the Commission on Stratigraphic Nomenclature stated (1961, p. 650):

> Boundaries of rock stratigraphic units are placed at positions of lithologic change. Boundaries are placed at sharp contacts or may be fixed arbitrarily within zones of gradation. Both vertical and lateral boundaries are based on the lithologic

> criteria that provide the greatest unity and practical utility.

In discussing the problems of a gradational boundary the Commission stated (1961, p. 650):

> Where one rock unit passes vertically or laterally into another by intergrading or interfingering of two or more kinds of rock, the boundary is necessarily arbitrary and should be selected to provide the most practical units. For example, where a shale unit overlies a unit of interbedded limestone and shale, the boundary commonly is placed at the top of the highest readily traceable limestone bed; where a sandstone unit grades upward into shale, the boundary may be so gradational as to require completely arbitrary treatment.

The Viola situation is more analogous to the gradation of a sandstone into an overlying shale. In many areas the upward transition of one Viola unit into another occurs through a stratigraphic thickness of 50 feet or more. Such contacts are not the best or most practical for formational mapping, although they have been used. In most areas the lithologic change from one Viola unit to another is so subtle that an arbitrarily placed boundary could very easily be placed differently in different stratigraphic sections. In the transitional parts of the sequence there is no explicit lithologic characteristic or group of characteristics (for example sand grains, glauconite, chert, a key bed) which can be used as a field criterion to unambiguously assign the rocks to a particular unit.

In discussing the nature of the rock-stratigraphic term "group" the Commission on Stratigraphic Nomenclature stated (1961, p. 651):

> Groups are recognized for the purpose of expressing the natural relations of associated formations having significant lithologic features in common. A group consists wholly of

> divisions defined as formations; in this respect, it contrasts with a formation and its members, for a formation need not be divided into members, and, even if a formation contains members, not every part of it need be assigned to any member.

The writer regards the Stratigraphic Code as recommendations or guides, and not rigid "laws" to be strictly followed. Indeed, the Code is written so that rigid application is difficult if not impossible. It remains for the individual to select the best solution for any particular stratigraphic situation. The writer believes that, in the case of the Viola, the most logical solution is to use the formation-member or formation-unit designation. This is particularly true in light of the suggestion by the Stratigraphic Commission that not every part of a formation need be assigned to a member. Such an arrangement makes it much easier to deal with rocks in the transitional intervals.

The discontinuance of one formation name, "Fernvale," and the retention of a much-used formation name, Viola (with included members or informal units), is less disruptive than to elevate the sequence to group status, and introduce five new formation names. (This was not done by Glaser (1965), but would be necessary if such a scheme were adopted and formally proposed.)

Glaser (1965) interpreted the relationships of the various rock types in this formation (his group) to be that as shown in Figure 3. The different rock types are designated as units.

The Viola Formation overlies the Corbin Ranch Formation unconformably and is overlain with possible unconformity by the Sylvan Shale. The Viola limestones can be subdivided into three main rock units: (1) siliceous laminated mudstones (laminites), (2) skeletal calcarenitic mudstones, and (3) coarse skeletal calcisiltites to coarse skeletal calcarenites. The limestones are wholly of marine origin and in general represent a classic cycle of sedimentation. Primarily because of varying thicknesses, the area is divided into a southwestern basin province and a northeastern shelf province. The basal unit is composed of siliceous laminated mudstones presumably deposited in a lower energy environment, probably deeper water, than all other Viola rocks. Graptolites are the only faunal elements noted in this rock type. The middle unit consists of burrowed calcarenitic mudstones deposited in an environment of shallower water and slightly more energy than the laminites. Much of the brachiopod remains from this unit are crushed or compressed so as to be specifically unrecognizable. However, as can be seen in Figure 12, there are some beds which have yielded brachiopods sufficiently well preserved to be incorporated into this biostratigraphic study. The upper unit is comprised of coarse skeletal calcarenites probably deposited in the shallowest water and highest energy environment of the entire limestone sequence. Most of the well-preserved brachiopods come from this unit. This generalized picture of a gradual shallowing of the water is slightly complicated in the northeast where the initial deposits were coarse skeletal calcisiltites and fine calcarenites. Silicified brachiopod remains have been recovered from this rock unit in the northeastern province. Also, in the southwest (Buckhorn Ranch, Mountain Lake, West Spring Creek) the upper unit consists predominantly of calcarenitic mudstones interbedded with thin, fine to medium calcarenites. Several species of brachiopods have been found in this unit.

The increase in mud in the southwestern extension of the upper unit suggests that the water depth did not become as shallow there.

The Viola is subdivided into three units of which the basal and uppermost have distinct facies. These units are designated: Unit 1L (basin laminites) and Unit 1C (shelf calcarenites equivalent to the laminites); Unit 2C (calcarenitic mudstones found throughout the Arbuckle Mountains); Unit 3C (coarse calcarenites), and Unit 3CM (basin calcarenitic mudstones interbedded with thin calcarenites equivalent to Unit 3C).

BIOSTRATIGRAPHY OF THE VIOLA FORMATION

INTRODUCTION

The Viola Formation contains a brachiopod fauna similar to that of rocks of upper Champlainian and Cincinnatian Series. The stratigraphic distribution of the brachiopod species of the Viola Formation in the Arbuckle Mountains is given in Figure 12. In addition, this diagram shows the distribution of some of the graptolites as reported by Decker (1933) and Ruedemann and Decker (1934).

In terms of number of species, the largest part of the fauna occurs in units 3C and 3CM. The only assemblage zone which can be traced laterally for any distance occurs near the top of the formation. In the northeastern shelf province it always occurs in the upper six feet, but in the southwestern basin province it is found 40-60 feet below the top. Forms referred to *Lepidocyclus cooperi*, *Lepidocyclus capax*, *Austinella* n.sp., *Thaerodonta* cf. *magna*, *Hesperorthis* n.sp., and *Glyptorthis* n.sp. occur in such large numbers as to dominate the fauna. All six of these forms occur wherever the zone has been studied. There are a total of 17 species from this upper assemblage zone, however, all do not occur at any one locality. The brachiopod specimens making up this zone are commonly silicified in all exposures in the Arbuckle Mountains. This is true even in the southwestern basin province (particularly at West Spring Creek, Locality R and Mountain Lake, Locality I) where the zone occurs 40-60 feet below the top of the formation.

The brachiopods in Units 3C and 3CM have strong affinities to those reported and described by Wang (1949) from the Maquoketa Formation of Iowa (recently elevated to group status), the Montoya Group of West Texas and New Mexico (Howe, 1958, 1965, 1966), and the Saturday Mountain Formation of Idaho (Ross, 1959).

The brachiopod species from Units 1 and 2 are fewer in number of species and in number of individuals, although two species are represented by 100 or more specimens. Nowhere in Units 1 and 2 were any persistent biostratigraphic zones noted. All of the specimens reported from these two units come from the shelf province. Of these, the best preserved and most abundant are from Locality C, 270-280 feet below the top of the formation.

Cincinnatian Series

The Cincinnatian Series is composed of the following stages in ascending order: Edenian, Maysvillian, and Richmondian (the post-Richmondian Gamachian Stage seems to be present only in parts of Canada). For many years the stratigraphic interpretation of rocks on the Cincinnatian Series in the type area in Kentucky and Ohio remained unchanged.

Meek and Worthen (1865) first proposed the name Cincinnati Group for rocks around the Cincinnati, Ohio, area. Orton (1873) was the first to subdivide this group into formations. In ascending order he described the Point Pleasant, River Quarry, Eden, Hill Quarry, and Lebanon formations. The former two are now included in the Trenton

Group. The last three are approximately equivalent to the Eden, Maysville, and Richmond Groups as used today.

Orton's originally described Eden is still considered to be the type section. The Maysville was named by Foerste (1905) for rocks near Maysville, Kentucky. They are immediately above the Eden shales and just below Orton's Lebanon beds (Richmond of today). In 1897, Winchell and Ulrich proposed the name Richmond to replace the Lebanon beds of Orton. Some workers have considered these three rock units to be groups, and others have referred to them as formations. Twenhofel and others (1954) refer to the Eden, Maysville, andRichmond rock units as groups. A most important aspect of these "groups" is that many of the "formations" which are used today and which were accepted by the Ordovician Subcommittee of the Committee on Stratigraphy of the National Research Council (Twenhofel, 1954) are actually biostratigraphic zones which were defined and named by early workers such as Foerste, Nickles, Bassler, and Cumings in several independent studies. (See Gutstadt, 1958, for a brief review of these early studies.) Thus, it quickly became established that certain species were "guides" to the various "formations." Such stratigraphic procedures were probably followed because of the nondistinctive lithologic nature of the alternating shales and limestones comprising the Cincinnatian Series in the type area. Because of this procedure it is difficult to determine the stratigraphic ranges of the various Cincinnatian brachiopod species in the type area of the Ohio Valley. It is circular reasoning to first define a "formation" on the presence of one or more species, and then claim that the species is restricted to that particular "formation."

In order to determine the stratigraphic ranges of fossil species it is necessary to have a knowledge (based on lithologic criteria) of the distribution and relationships of the rock types, and then superimpose on this lithologic framework the distribution of the fossil species.

Maquoketa Formation (Group)

Wang (1949) considered the Maquoketa Formation of Iowa to be of Upper Ordovician age. However, he made no specific comment on the relationship of the brachiopods of the Mquoketa to the brachiopods of the type sections in Kentucky and Ohio. Thus, no mention was made of the presence of Edenian, Maysvillian, or Richmondian stages. Wang stated that the purpose of his study was to supplement the stratigraphic work published by Ladd (1929). Ladd (1929) in his introduction, stated (p. 311):

> The Mquoketa shale was made the subject of the present investigation for two reasons (1) because the range of its lithology and its obscure stratigraphic relations have been interpreted in so many different ways that the literature is in great confusion, and (2) because the fossils which have been reported from the formation are abundant and of highly interesting character. It was therefore with the purpose of working out a series of persistent faunal zones and thereby correlating its varying lithologic and paleontologic units that the study was undertaken.

He comments that the Maquoketa fossils were previously identified as forms occurring in the Richmond "Group" of the Ohio Valley. However, in a discussion of the Maquoketa fauna, Ladd pointed out that, when comparing the Maquoketa species to those from the Ohio Valley (1929, p. 391): ". . . in almost every case persistent differences of at least varietal rank have been found." It was his intention to follow his stratigraphic work of 1929 with a systematic description of the

Maquoketa fauna including careful comparisons with those of the Ohio Valley. However, no such later work was ever published.

Earlier workers had noticed the difference between the faunas of the Iowa area and those of the Ohio type region. Schuchert (1910), in his paleogeographic maps, showed a landmass extending north and south along the Illinois-Indiana boundary during late Richmondian time, presumably to explain faunal differences between the Cincinnatian arch area and the Iowa outcrop area.

Because of these and other earlier studies, rocks representing Edenian and Maysvillian stages have been considered absent in the Illinois and Iowa areas. There is still some doubt as to the age (Edenian, Maysvillian, and Richmondian stages) of the Iowa rocks. Wang (1949) made only one biostratigraphic statement in this regard (1949, p. 1):

> The Maquoketa shale is part of an extensively distributed marine formation of _Upper_ _Ordovician_ _age_. [Italics are those of the writer.]

One can only speculate as to whether Wang purposely avoided comparisons with the type area of the Ohio Valley, or whether by "Upper Ordovician age" he means that the Edenian, Maysvillian, and Richmondian stages are all represented in the Maquoketa. It is the opinion of the writer that Wang accepted the age of the Iowa Maquoketa as interpreted by Ladd (1929). This belief is based on the statement (Wang, 1949, p. 1):

> . . . an extensive description of the stratigraphy which would only repeat Ladd's detailed work published in 1929.

There is no doubt that Ladd was of the opinion that the Maquoketa Formation of Iowa was of Richmond age. He concluded (1929, p. 370):

> . . . the key to the perplexing problem of the exact age of the Maquoketa faunas lies in the Fernvale and the other pre-Maquoketa Richmond rocks of the Mississippi Valley area. When these rocks have been studied more carefully we shall understand the Maquoketa more perfectly.

The statement "perplexing problem of the exact age of the Maquoketa faunas" refers to the correlation of the Maquoketa to the various "formations" (Arnheim, Waynesville, Whitwater, and others) which make up the Richmond Group in the Ohio Valley. Wang (1949) reported 47 positively identified articulate brachiopod species from the "Iowa" Maquoketa, of which 27 were new. However, there was no comparison of these forms to those of the type area of the Ohio Valley.

Recently several studies 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 of Indiana, Illinois, Missouri, and Iowa using surface and subsurface information. The use of subsurface information was necessary because of the large area of Indiana and Illinois in which these rocks are not exposed. Gutstadt concluded that the Maquoketa Formation 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 indicating that Gutstadt's interpretation is correct. They stated (1959, p. 1038):

> The Elgin, Clermont, and Ft. Atkinson members of the Maquoketa Formation of Iowa, which succeed the Stewartville and Dubuque stratigraphically, lack the distinctinve 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 Brainard member lacks *Belodina*, but contains *Phragmodus undatus*

and _Dichognathus_, indicating that it may be upper Maysvillian (McMillan) age. The Brainard 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 Wilman (1963) revised the stratigraphic interpretation and terminology of the Maquoketa strata in Illinois, which are essentially the same as the strata in Iowa. Figure 4 shows the previous stratigraphic subdivisions (Twenhofel and others, 1954) and those proposed by Templeton and Wilman. Note that the initial deposit of the Cincinnatian Series is the Cape Limestone, formerly the Fernvale. Templeton and Wilman proposed the name Cape Limestone to replace the name Fernvale in Illinois, Missouri, and Oklahoma.

Upper Ordovidian Rocks in Missouri

The Upper Ordovician section in southeast Missour is composed of the following rock units in ascending order: Fernvale (Cape Limestone), Maquoketa shale, Thebes sandstone, Orchard Creek shale, and Girardeau limestone. In spite of paleontological evidence to the contrary, the members of the Ordovocian Subcommittee (Twenhofel and others, 1954) considered this rock sequence to be entirely of Richmond age. The Subcommittee indicated it is of Richmond age, unconformably overlying the Kimmswick limestone of Trenton age. This is the same interpretation proposed by Ulrich in 1911.

Keenan (1940) studied the ostracodes of the Maquoketa shale of southeastern Missouri. He reported 28 species, 19 of which were new. Three are common to the lower Maquoketa of Iowa (now considered to be

Figure 4

Stratigraphic classification of the Maquoketa Formation in Illinois proposed by the Ordovocian Subcommittee of the Committee on Stratigraphy of the National Research Council (Twenhofel et al., 1954), and the new classification of these rock units proposed by Templeton and Wilman (1963).

CLASSIFICATION PROPOSED BY TEMPLETON AND WILLMAN (1963)

PREVIOUS CLASSIFICATION IN ILLINOIS
(Twenhofel et al., 1954)

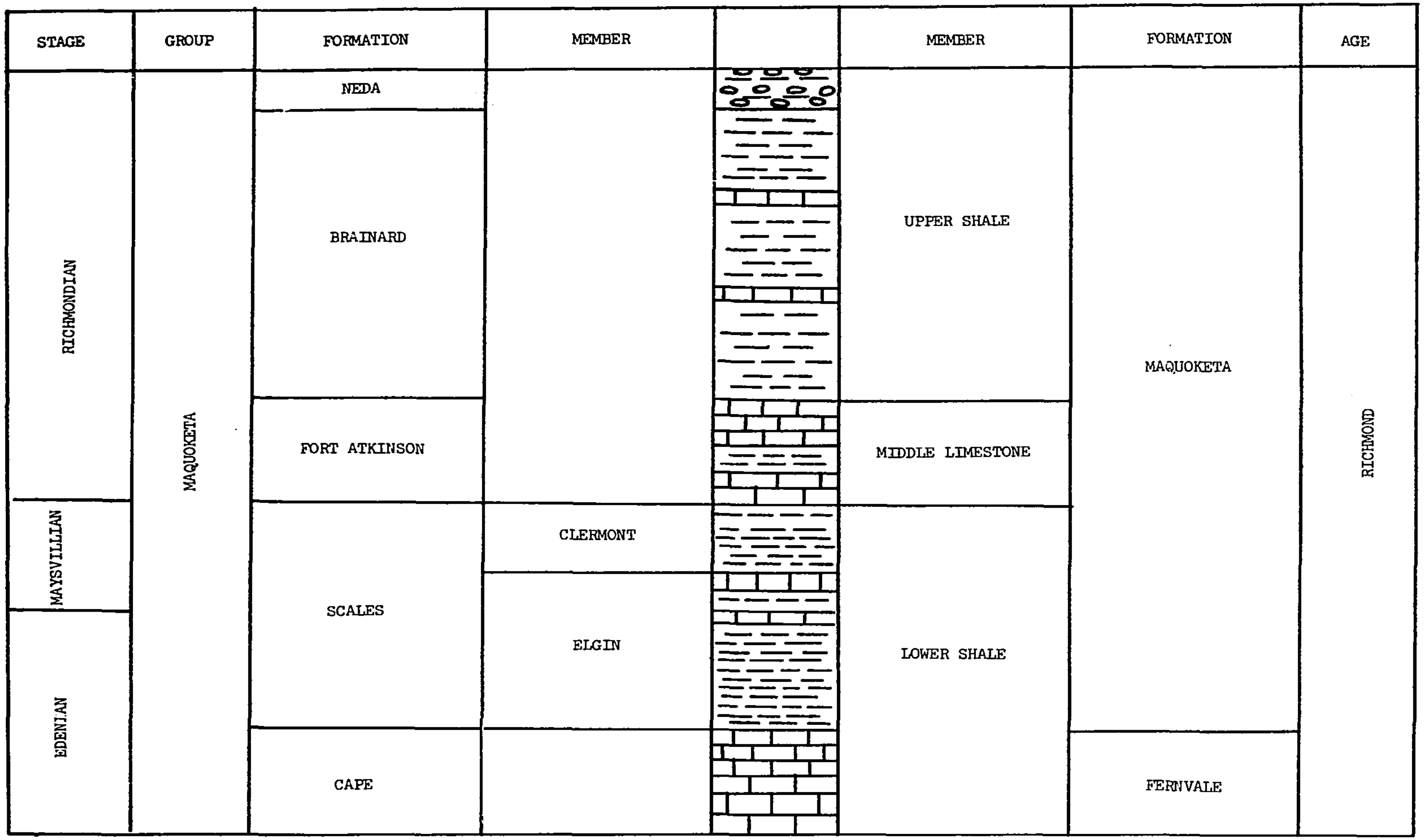


Figure 4

of Early Cincinnatian age), 3 are common to the Eden Group of Cincinnati, Ohio, and 3 are common to the Maysville Group of the Ohio Valley.

Hardy (1946) studied the conodonts of the Fernvale of southeastern Missouri, and concluded that it is either of Edenian or Maysvillian age.

Branson, Mehl, and Branson (1951) made the following statement about the conodonts of the 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) commented on the Missouri section (p. 1039):

> The Thebes sandstone member of the Orchard Creek yielded most of Branson and Mehl's "Maquoketa" conodonts. This unit contains Amorophognathus and Ambalodus triagularis, 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.

Maravillas Chert of Texas

The age of the Maravillas Chert has been the subject of much discussion. Berry (1960) studied the graptolites from this unit and discussed its correlation with rock units in other areas. His conclusions regarding the correlation of the Maravillas with the Viola Formation are important to the present study. Referring to Ulrich's

Figure 5

The stratigraphic classification of the Montoya Group of West Texas and New Mexico as interpreted by Howe (1959).

STRATIGRAPHIC NOMENCLATURE
OF THE MONTOYA GROUP OF WEST TEXAS
(After Howe, 1958)

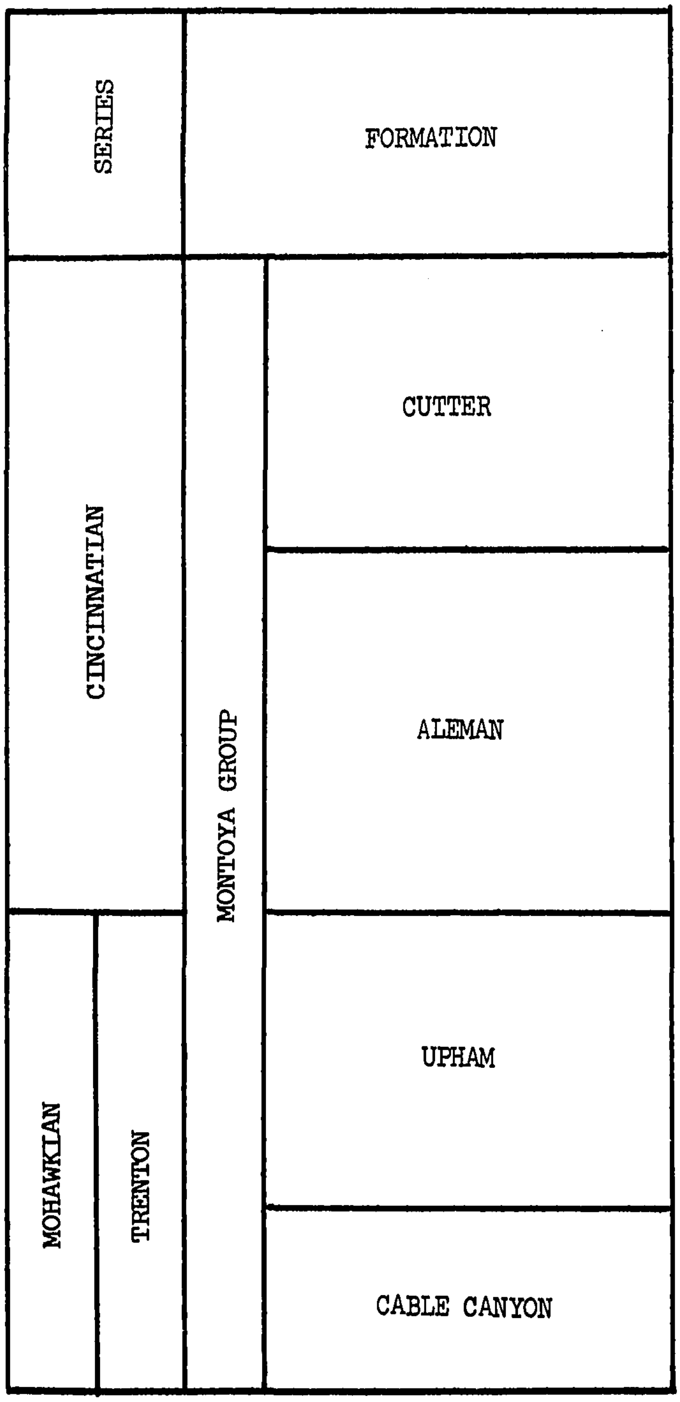


Figure 5

Figure 6

The brachiopods reported from the members of the Maquoketa Formation of Iowa by Wang (1949). The Brainard Member is divided into upper and lower submembers. Also shown are those species which occur in Units 3C and 3CM of the Viola Formation in the Arbuckle Mountains.

BRACHIOPOD SPECIES REPORTED FROM THE MAQUOKETA FORMATION OF IOWA (After Wang, 1949)	ELGIN MEMBER	CLERMONT MEMBER	FORT ATKINSON MEMBER	BRAINARD MEMBER (LOWER)	BRAINARD MEMBER(UPPER)	UNIT 3C OF THE VIOLA FORMATION	UNIT 3CM OF THE VIOLA FORMATION
AUSTINELLA WHITFIELDI	▲						
AUSTINELLA DELICATA	▲						
AUSTINELLA KANKAKENSIS		▲					
PLATYSTROPHIA EQUICONVEXA	▲						
LEPIDOCYCLUS LADDI	▲						
LEPIDOCYCLUS MANNIENSIS	▲					▲	
LEPIDOCYCLUS PERLAMELLOSUS			▲			?▲	?▲
LEPIDOCYCLUS NOTATUS			▲				
LEPIDOCYCLUS ERECTUS					▲		
LEPIDOCYCLUS RECTANGULARIS					▲		
LEPIDOCYCLUS GIGAS					▲		
THAERODONTA ASPERA	▲						
THAERODONTA RECEDENS	▲						
THAERODONTA SAXEA	▲						
THAERODONTA DIGNATA		▲					
OPIKINA LIMBRATA		▲					
DICEROMYONIA TERSA		▲		▲			
DICEROMYONIA SUBROTUNDATA				▲			
STROPHOMENA OCCIDENTALIS	▲						
STROPHOMENA cf. S. PLANOCONVEXA	▲						
STROPHOMENA BIDENTATA	▲						
STROPHOMENA PERCONCAVA		▲					
STROPHOMENA CLERMONTENSIS		▲					▲
STROPHOMENA AMOENA		▲					
STROPHOMENA RUGULIFERA		▲					
STROPHOMENA BICORNUTA		▲					
STROPHOMENA ELONGATA			▲				
STROPHOMENA PLANUMBONA				▲		▲	
TETRAPHALARELLA NEGLECTA				▲		▲	▲
TETRAPHALARELLA COOPERI	▲						
TETRAPHALARELLA PLANODORSATA	▲						
MEGOMYONIA UNICOSTATA					▲		
MEGOMYONIA KNIGHTI			▲				
MEGOMYONIA RAYMONDI	▲						
GLYPTORTHIS PULCHRA			▲				
PLAESIOMYS PROAVITA	▲					▲	
PLAESIOMYS PLANUS	▲						
PLAESIOMYS BELLILAMELLOSUS	▲						
PLAESIOMYS BELLISTRIATUS				▲		▲	▲
PLAESIOMYS SUBQUADRATA	▲					▲	
HYPSIPTYCHA HYBRIDA					▲		
HYPSIPTYCHA NEENAH					▲		
ZYGOSPIRA RESUPINATA					▲		
HESSERELLA CORPULENTA	▲						
ONNIELLA QUADRATA	▲						
RHYNCHOTREMA IOWENSE					▲		
HOLTEDAHLINA SP.			▲	▲	▲		

Figure 6

biostratigraphic interpretation of the Maravillas, Berry stated (1960, p. 30):

> Further, he stated that the fauna of bryozoa and brachiopods from Maravillas Gap was a "typical Fernvale-Richmond fauna," and he considered that the upper part of the formation had a similar relation to the Trenton part as the Fernvale-Richmond zone had to the Viola limestone in Oklahoma. Ulrich thought that the Fernvale-Richmond zone and its correlatives marked a great transgression following a period of emergence and placed it at the base of the Silurian. Thus Ulrich divided the Maravillas chert [as he did other western formations such as the Montoya limestone and Bighorn dolomite] into a lower part correlated with the Trenton and an upper part correlated with the Fernvale-Richmond.

Berry (1960, p. 31) divided the Maravillas into three graptolite zones. The lowest graptolite zone was interpreted to be of Trenton age and was correlated with the lower Viola Formation of Oklahoma. The middle zone was correlated with the Eden and Maysville stages, and the upper zone was interpreted to be Richmond in age. In his concluding comments about the age of the Maravillas chert Berry stated (1960, p. 31):

> The Maravillas chert represents late Middle Ordovician and all of Late Ordovician time. The original diagnosis by Ulrich of a Trenton fauna and a Richmond fauna in the formation is correct, but the Eden and Maysville are also represented. There is no break in time within the Maravillas chert; there seems to have been continuous deposition from late Wilderness time through the Trenton and all of the Late Ordovocian.

Berry (1960, p. 31) studied the graptolites collected by Charles Decker from the Viola Formation of the Arbuckle Mountains. In presenting his regional correlations, 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 in Texas he concluded that the Oklahoma sequence, like the Maravillas, represents one of continuous deposition. The lower Viola represents the Trenton stage, the upper Viola represents the Eden-Maysville stages, and the Fernvale and Sylvan represent the Richmond stage.

Brachiopods of the Viola Formation

There are 23 brachiopod species reported from Unit 3C and Unit 3CM; 18 are positively identified and 5 identifications are of uncertain affinity. These brachiopods have more species in common with the Maquoketa Formation than do those of the Montoya Group of the Saturday Mountain Formation. However, it should be pointed out that the Maquoketa has 47 well-defined species in comparison to only 22 in the Montoya and 11 in the Saturday Mountain. The meager brachiopod fauna of the Saturday Mountain Formation of Idaho and the brief description concerning its distribution are considered insufficient for meaningful comparison (See Figure 8.)

Figure 9 shows the percentages of genera and species of Units 3C and 3CM brachiopods which also occur in the Maquoketa Formation of Iowa. There are 4 genera which are not found in Units 3C and 3CM of the Viola Formation: Holtedahlina, Hypsiptycha, Zygospira, and Resserella (this may not be a species of Resserella). The last species is the only one occurring below the Ft. Atkinson Member of the Maquoketa. The genera in Units 3C and 3CM which are represented by the greatest number of individuals are: Austinella, Thaerodonta, Paucicrura, Glyptorthis, Hesperorthis, and Lepidocyclus. These genera occur in such large numbers that they can be said to characterize the fauna. Of these, Austinella, Paucicrura, Thaerodonta, and Glyptorthis are reported from

Figure 7

The brachiopod species reported from the Montoya Group of West Texas and New Mexico by Howe (1965a, 1965b, 1966a). The Aleman and Cutter Formations are divided into upper and lower members. Also shown are those species which are common to the various members of the Maquoketa Formation of Iowa (Elgin, Clermont, Ft. Atkinson, and Brainard), and to the Units 3C and 3CM of the Viola Formation of the Arbuckle Mountains.

Figure 8

The brachiopod species reported from the Saturday Mountain Formation of Idaho by Ross (1958). Also shown are those species which are common to the various members of the Maquoketa Formation of Iowa, the Montoya Group of West Texas and New Mexico, and Units 3C and 3CM of the Viola Formation of the Arbuckle Mountains.

BRACHIOPOD SPECIES REPORTED FROM THE SATURDAY MOUNTAIN FORMATION OF IDAHO (After Ross, 1958)	ELGIN MEMBER OF THE MAQUOKETA	CLERMONT MEMBER OF THE MAQUOKETA	FORT ATKINSON MEMBER OF MAQUOKETA	BRAINARD MEMBER OF THE MAQUOKETA	UPHAM LIMESTONE	LOWER ALEMAN LIMESTONE	UPPER ALEMAN LIMESTONE	CUTTER DOLOMITE	UNIT 3C AND UNIT 3CM OF THE VIOLA FORMATION
PLATYSTROPHIA cf. P. EQUICONVEXA		▲							
LORDORTHIS VARIABILIS									
GLYPTORTHIS cf. G. PULCHRA			▲						
PLAESIOMYS SUBQUADRATA IDAHOENSIS									
PLAESIOMYS BELLILAMELLOSUS	▲								
AUSTINELLA aff. A. WHITFIELDI	▲								
LEPIDOCYCLUS ? cf. L. RECTANGULARIS				▲					
HYPSIPTYCHA SP.									
ZYGOSPIRA cf. Z. RECURVIROSTRIS									
ZYGOSPIRA PUTILLA									
ZYGOSPIRA cf. Z. CIRCULARIS									
ZYGOSPIRA cf. Z. LEBANONENSIS									
THAERODONTA SP.									
RAFINESQUINA SP.									
STROPHOMENA SP.									
DICEROMYONIA cf. D. TERSA		▲		▲					▲

Figure 8

Figure 9

The percentages of brachiopod species from Units 3C and 3CM of the Viola Formation occurring in the Saturday Mountain Formation of Idaho, the Montoya Group of West Texas and New Mexico, and the Maquoketa Formation of Iowa. All of the genera from Units 3C and 3CM of the Viola also occur in the Saturday Mountain Formation, the Montoya Group, and the Maquoketa Formation. The Maquoketa Formation has the greatest number of species in common with the Viola units.

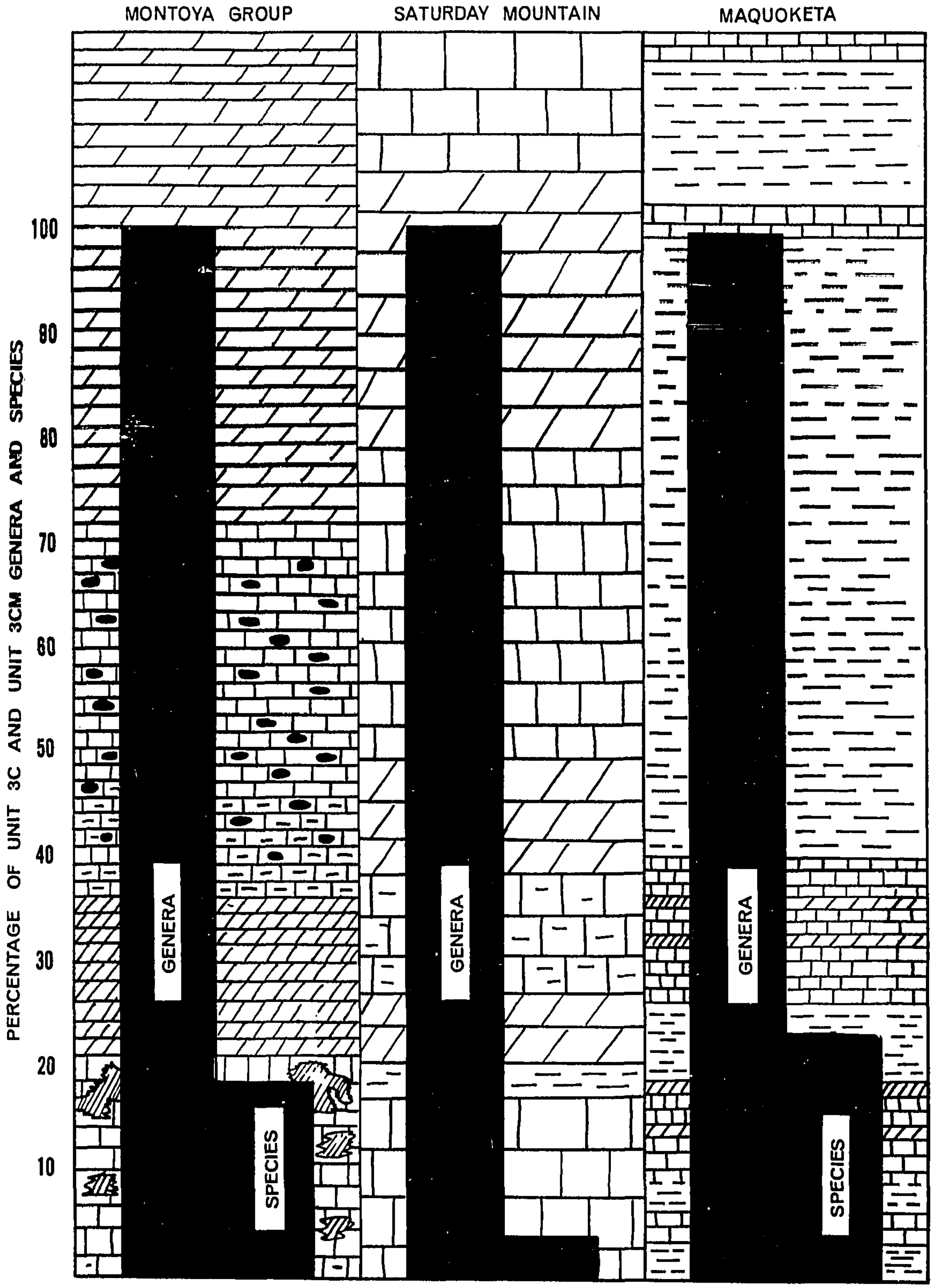

MONTOYA GROUP
SATURDAY MOUNTAIN
MAQUOKETA
PERCENTAGE OF UNIT 3C AND UNIT 3CM GENERA AND SPECIES
100
90
80
70
60
50
40
30
20
10
GENERA
SPECIES
GENERA
GENERA
SPECIES

Figure 9

only the Elgin and Clermont members of the Maquoketa. Hesperorthis was not found in the Maquoketa (Wang, 1949), but Lepidocyclus is represented throughout the Maquoketa.

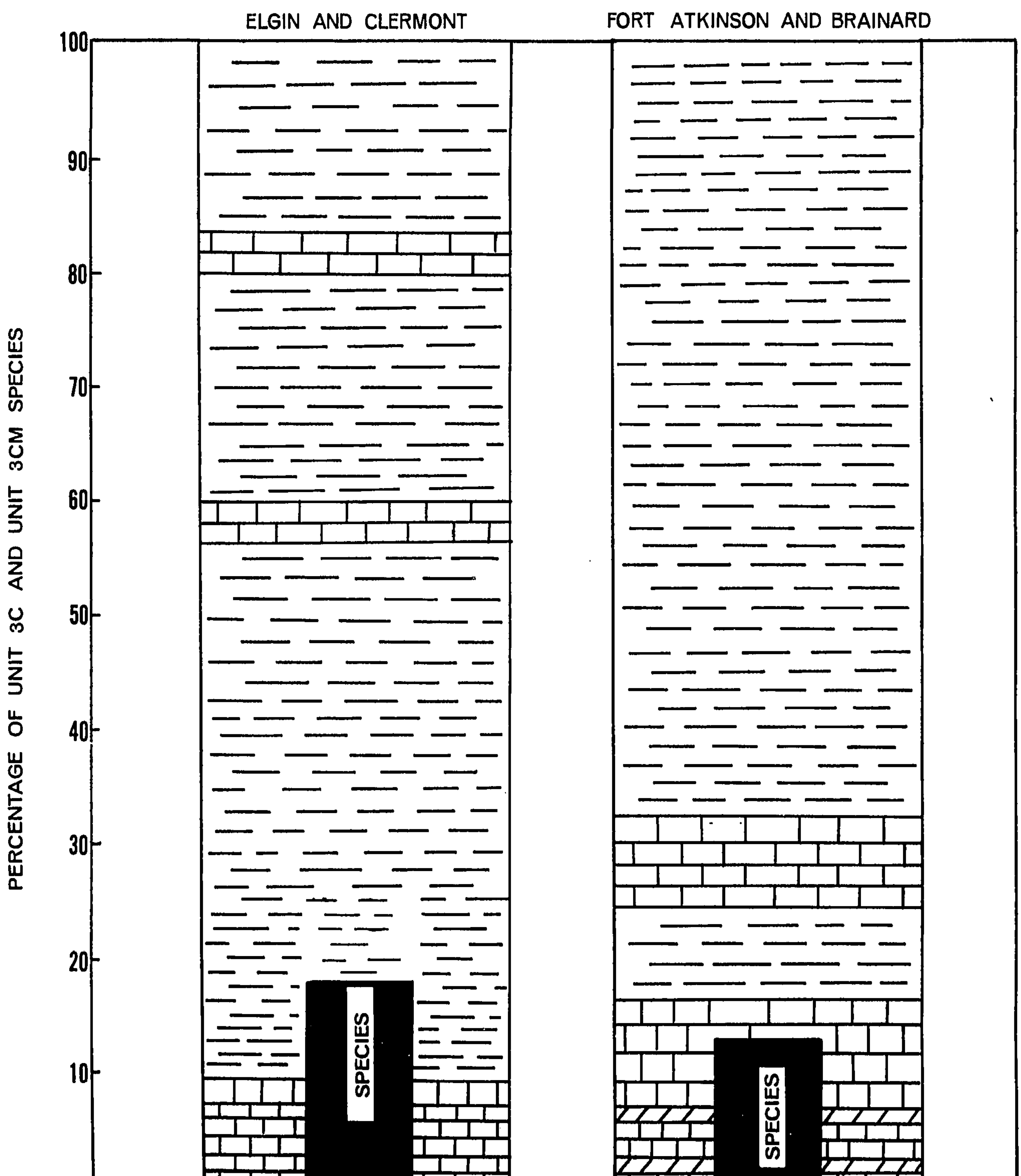
This stratigraphic distribution of genera serves as partial justification for correlating the upper Viola (Units 3C and 3CM) with the lower Maquoketa of Iowa. However, it must be pointed out that no species of these genera are common both formations.

Figure 9 shows that 22 percent of the species (excluding the questionable forms) from Units 3C and 3CM are present in the Maquoketa of Iowa. Figure 10 shows that of the 22 percent, two-thirds are in the lower part of the Maquoketa (Elgin and Clermont members). Thus, from the standpoint of relative abundance Units 3C and 3CM are more closely correlated with the lower Maquoketa. Sweet, and others, (1959) showed by a study of the conodonts that the lower Maquoketa represented the Eden and Maysville stages. (See p. 27.) Therefore, because the Viola brachiopods from Units 3C and 3CM are correlated with thelower Maquoketa, they are interpreted to be of Edenian and Maysvillian age.

Figure 5 is modified from Howe (1959) and shows his stratigraphic interpretation of the Montoya Group of West Texas. He based his interpretation on the close similarity of the brachiopod fauna of the Aleman Limestone to that of the Elgin and Clermont Members of the Maquoketa. Figure 7 shows that, of the 22 species from the Montoya Group, five occur in the Elgin and Clermont Members of the Maquoketa. Howe accepted the early Cincinnatian age for the lower Maquoketa as interpreted by Gutstadt (1958) and later substantiated by Sweet, and others (1959). The correlation of the lower Aleman with the lower

Figure 10

The percentages of species from Units 3C and 3CM of the Viola Formation which also occur in the Maquoketa Formation. The sections are divided into the lower Maquoketa (Elgin and Clermont Members) and the upper Maquoketa (Ft. Atkinson and Brainard Members), and shows that the lower Maquoketa has more species in common with Units 3C and 3CM of the Viola than does the upper Maquoketa.



ELGIN AND CLERMONT
FORT ATKINSON AND BRAINARD
PERCENTAGE OF UNIT 3C AND UNIT 3CM SPECIES
100
90
80
70
60
50
40
30
20
10
SPECIES
SPECIES

Figure 10

Maquoketa of Iowa requires that the Upham Formation be of later Trentonian age. This interpretation is supported by the evidence of Flower (1957) who noted that the cephalopods (Actinoceratida) of the Upham have a strong affinity to the faunas of the Cynthiana, Catheys, Kimmswick, and Rogers Gap formations. If this age determination is correct, then Lepidocyclus capax, L. laddi, and L. manniensis should no longer be considered characteristic Richmond or even Cincinnatian species. There are six species common to the Montoya Group and to Units 3C and 3CM of the Viola Formation. (See Figure 7.) These species are: Lepidocyclus capax, L. manniensis?, Strophomena neglecta, Thaerodonta magna, Plaesiomys bellistriatus, and P. subquadrata. Five of these species occur in the Aleman Limestone of the Montoya Group; the other, Lepidocyclus capax, occurs in the Upham Limestone. Therefore, Units 3C and 3CM are correlated with the Aleman Limestone of the Montoya Group.

The writer studied the brachiopods from the "Fernvale" (Cape) Limestone in northeastern Oklahoma and found that almost every species which occurs in Units 3C and 3CM of the Viola also occurs in the northeastern unit. The species that do not occur in the northeastern "Fernvale" (Cape) Limestone are those which are restricted to the lower parts of Unit 3C and Unit 3CM in the Arbuckle Mountains: Lepidocyclus oblongus, L. manniensis, ?L. perlamellosus, Strophomena cf. S. clermontensis, and S. perconcava. There are 17 species in the upper part of Unit 3C (the assemblage zone) in the Viola of the Arbuckle Mountains. Each of these species is also found in the "Fernvale" (Cape) Limestone in northeastern Oklahoma.

There is a large brachiopod fauna in the Fernvale (Cape) Limestone of southeast Missouri. The writer has just undertaken a study of this fauna so as to compare it to the fauna in the Viola (Units 3C and 3CM) in the Arbuckles and the "Fernvale" (Cape) Limestone in northeastern Oklahoma. As previously noted, there is faunal evidence that the "Missouri" Fernvale is Edenian-Maysvillian in age (Keenan, 1940; Hardy, 1946; Branson, Mehl, and Branson, 1951; Sweet, and others, 1959). Precisely how many of the brachiopod species of this unit are also present in the "Fernvale" (Cape) Limestone of northeast Oklahoma or in the Viola Formation of the Arbuckle Mountains is not yet known. However, two species not reported from any other formation occur in both the Missouri unit and in the Viola (Units 3C and 3CM). Because this is their only known occurrence, they may be biostratigraphically important in the correlation of these rock units. The two species are Lepidocyclus oblongus and Platystrophia n.sp. B. The latter has a characteristic adductor muscle pattern. (See Plate III, Figs. 3b and 3c; see also the discussion of this species.) At present, the writer is of the opinion that the upper Viola in the Arbuckle Mountains and the "Fernvale" (Cape) Limestone in northeast Oklahoma are correlative with the Fernvale (Cape) Limestone in southeast Missouri. After further study of the Missouri brachiopods, a more satisfactory biostratigraphic evaluation will be possible.

The stratigraphic distribution of the brachiopods in the Viola Formation at localities G and I furnishes important biostratigraphic information. At Locality G (Buckhorn Ranch), the upper 100 feet of the Viola Formation is composed of alternating beds of calcarenites, calcarenitic mudstones, and some mudstones. The brachiopod assemblage zone which is found at the top (upper 6 feet) of the formation (Unit 3C) in the shelf province is 10-15 feet below the top at Locality G. It is underlain and overlain by calcarenitic mudstones and mudstones. At this locality the lithic continuity of Unit 3C is lost; the rocks are designated Unit 2. The brachiopod assemblage zone maintains itself in one of the thin southwestern extensions of Unit 3C. Southwest of Locality G, this thin calcarenite extension is found progressively farther below the top of the formation. For example, it is 40 feet below the top at Locality I.

In addition to the characteristic assemblage zone 10-15 feet below the top of the formation at Locality G, several "key" species occur in the calcarenitic mudstone beds 60-75 feet below the top of the formation. These species, elsewhere known only from Cincinnatian rocks, are: Plaesiomys bellistriatus, Strophomena perconcava, S. neglecta, S. cf. S. clermontensis, and ?Lepidocyclus perlamellosus. This suggests that these mudstones and calcarenitic mudstones (referred to as Viola by all previous workers) are of Cincinnatian and not Trentonian age.

The section at Locality G is of critical importance. It provides both paleontological and lithological evidence which support the conclusion that the rock unit previously called "Fernvale," and thought to be of Richmondian age, is actually of Edenian-Maysvillian age, and a facies of the upper Viola (Unit 3CM). (See Figs. 3 and 15.)

The Brachiopods of the Fernvale of Tennessee

The writer collected and studied the brachiopods from the Fernvale calcarenite (as defined by Wilson, 1949) from the area of Nashville, Tennessee. The "Tennessee" Fernvale does not have as many brachiopod species as does the "Fernvale" (Unit 3C) of the Arbuckles. The following species were identified in the Tennessee Fernvale.

Lepidocyclus manniensis

L. capax

Hypsiptycha dentatum

Plaesiomys subquadrata

Strophomena sp.

Thaerodonta cf. *recedens*

Hebertella insculpta

?*Paucicrura* sp.

Lepidocyclus manniensis is the most common species in the "Tennessee" Fernvale; more than 300 specimens were collected. *Plaesiomys subquadrata*, *Hebertella insculpta*, and *Thaerodonta* cf. *recedens* are also fairly common; about 50 specimens of each were collected. The other species, *L. capax*, *Strophomena* sp., *Hypsiptycha dentatum*, and ?*Paucicrura* sp. are all represented by less than 10 specimens each.

There are marked differences between this fauna and the one from the Arbuckle Mountains. *Lepidocyclus manniensis* is represented by only a few specimens in the Arbuckle "Fernvale" (Unit 3C), but is the dominant species in Tennessee. *Plaesiomys subquadrata* is more common in the "Tennessee" Fernvale than in the Arbuckle Mountains. The other species, with the possible exception of ?*Paucicrura* sp., are not common to both units. Species such as *Austinella* n.sp., *Lepidocyclus cooperi*, *Glyptorthis*, n.sp., *Hesperorthis* n.sp., *Platystrophia* n.sp. A, *Platystrophia* n.sp. B, *Megamyonia* n.sp?, and *Diceromyonia* cf. *D. tersa*, which occur in such large numbers in Units 3C and 3CM of the Viola Formation and in the "Fernvale" (Cape Limestone) of northeast Oklahoma, are conspicuously absent from the Fernvale Formation in Tennessee.

Figure 11

Photograph of a polished section showing the unconformable contact between the Fite Limestone (below) and the "Fernvale" (Cape) Limestone (above) in northeastern Oklahoma. The "Fernvale" (Cape) Limestone in this area has the same lithology (calcarenite) as in the Arbuckle Mountains. The Fite Limestone is lithologically similar to the Bromide Formation (Corbin Ranch) of the Arbuckle Mountains and is considered correlative with it. Rocks usually referred to as Viola are missing here. Enlargement X4.

Figure 13

Ranges of the various brachiopod species from the Maquoketa Formation of Iowa. The ranges were compiled by the writer from data presented by Wang (1949).

Figure 14

Ranges of the various brachiopod species from the Montoya Group of West Texas and New Mexico. The ranges were compiled by the writer from data presented by Howe (1959, 1965a, 1965b, 1966a).

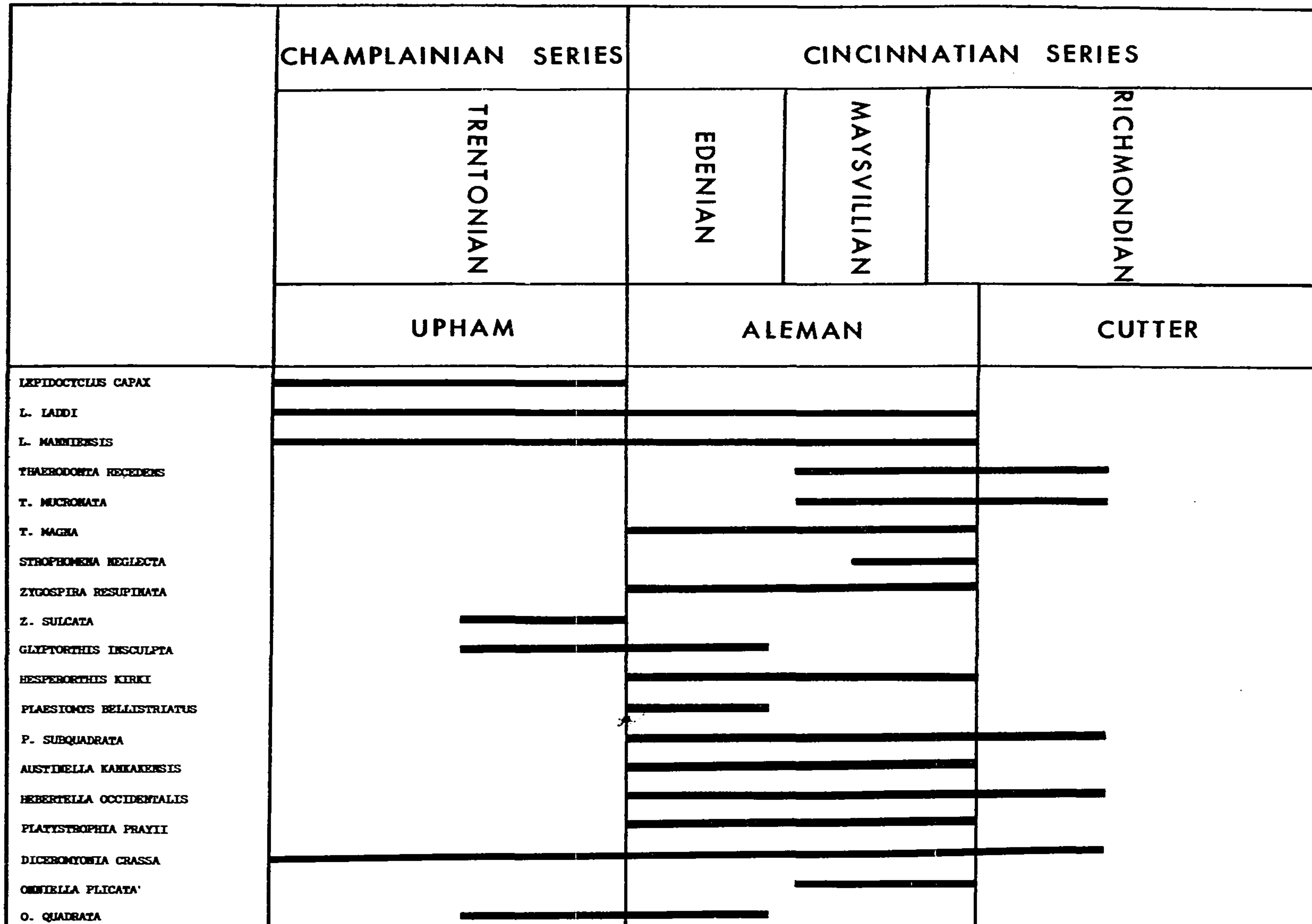

CHAMPLAINIAN SERIES
CINCINNATIAN SERIES
TRENTONIAN
EDENIAN
MAYSVILLIAN
RICHMONDIAN
UPHAM
ALEMAN
CUTTER
LEPIDOCYCLUS CAPAX
L. LADDI
L. MANNIENSIS
THAERODONTA RECEDENS
T. MUCRONATA
T. MAGNA
STROPHOMENA NEGLECTA
ZYGOSPIRA RESUPINATA
Z. SULCATA
GLYPTORTHIS INSCULPTA
HESPERORTHIS KIRKI
PLAESIOMYS BELLISTRIATUS
P. SUBQUADRATA
AUSTINELLA KANKAKENSIS
HEBERTELLA OCCIDENTALIS
PLATYSTROPHIA PRAYII
DICEROMYONIA CRASSA
ONNIELLA PLICATA'
O. QUADRATA

FIGURE 14

CONCLUSIONS

Units 3C and 3CM of the Viola Formation in the Arbuckle Mountains are correlated with the lower Maquoketa Formation of Iowa, the Aleman Limestone of West Texas and New Mexico, the "Fernvale" (Cape) Limestone of northeast Oklahoma, and the "Fernvale" (Cape) Limestone of southeast Missouri. These rocks are interpreted to represent the Edenian-Maysvillian stages of the Cincinnatian Series. The evidence furnished by brachiopods, particularly at localities G and I, supports the lithostratigraphic interpretation presented by the writer's co-worker (Glaser, 1965). There is no evidence of a hiatus in the Viola-"Fernvale" sequence. The sequence is continuous with rocks representing the Trentonian, Edenian, and Maysvillian and Richmondian stages. Figure 12 (in pocket) shows the stratigraphic distribution of some of these graptolites. The graptolite species on which Decker based his interpretation are:

(1) Climacograptus typicalis posterus in zone 2 (immediately below the lithologic unit referred to as the Fernvale) in the section north of Bromide. This form, Decker stated, indicates a Utica-Lorraine (Eden-Maysville) age for the upper Viola.

(2) Climacograptus lorrainensis in zones 2 and 3 of the Viola. It also first appears in great numbers about the middle of the Lorraine (Maysville) in New York.

(3) Diplograptus recurrens is one of the most abundant species in the upper Viola. It is found in zones 2-5 at West Spring Creek (Section R). Outside of Oklahoma, it occurs in the lower Lorraine and in the Arnheim beds of the Richmond Formation.

(4) Diplograptus peosta occurs immediately below the brachiopod assemblage zone at West Spring Creek (Section R). It also occurs in Unit 3CM (Decker's zone 1) along U. S. Highway 77 in Oklahoma. This species is found in the Maquoketa Formation of Iowa, Wisconsin, and Minnesota.

Figure 15 (in pocket) shows a regional stratigraphic interpretation consistent with the data presented in this paper. In the northeast Oklahoma area the "Fernvale" (Cape) Limestone (calcarenite) of Edenian-Maysvillian age lies unconformably on the Fite Limestone (equivalent to the Bromide Formation of the Arbuckle Mountains) of Black Riverian age. Rocks representing the Trentonian stage are absent. Figure 11 is a photograph of a polished section showing the contact between the "Fernvale" (Cape) Limestone and the Fite Limestone. In the subsurface, the "Fernvale" (Cape) Limestone lies on younger and younger rocks of Trentonian age. The unconformity terminates in the subsurface so that an uninterrupted section is exposed in the outcrop area of the Arbuckle Mountains.

The name "Fernvale" should be discontinued in Oklahoma. The name "Fernvale" has had a Richmondian age connotation which has helped to perpetuate an erroneous interpretation of the stratigraphy. Although formations can be of different ages in different areas, it cannot be demonstrated that the northeast Oklahoma-Missouri Fernvale (Cape)

Limestone of Edenian-Maysvillian age was ever continuous with the "Tennessee" Fernvale of Richmondian age. The faunal evidence that they are different in age is taken as evidence that they are not remnants of a once continuous deposit. For this reason, and to help to clarify the stratigraphy, a new name should be used. Templeton and Wilman (1963, pp. 134-135) proposed the name Cape Limestone to replace the name "Fernvale" in Illinois, Missouri, northeast Oklahoma, and the Arbuckle Mountains. The writer is of the opinion that the name Cape Limestone is a valid replacement for the name "Fernvale" in northeast Oklahoma. However, the name Cape Limestone should not be used for the rocks in the Arbuckle Mountains. The reasons for this are: (1) the contact between Unit 3C ("Fernvale," (Cape)) and Unit 2 is gradational in the northeast part of the Arbuckle Mountains, and (2) Unit 3C ("Fernvale,") (Cape)) loses its characteristic lithologic nature and interfingers with Unit 3CM in the southwest part of the Arbuckle Mountains. Because of these stratigraphic relationships the writer is of the opinion that the best solution is to refer to the entire sequence as the Viola Formation, and designate the upper calcarenite unit ("Fernvale") (Cape)) as one member. A detailed discussion as to why this solution was chosen is given in the section on the lithostratigraphy of the Viola Formation.

PALEONTOLOGY

Introduction

Brachiopods are not uniformly distributed throughout the Viola Formation. In most units there are numerous fragments present, but it is the exception rather than the rule to find specimens sufficiently well preserved for study and therefore to be of any stratigraphic value. The best material was recovered from units in which silicified brachiopods occurred. In addition, "crack-out" material was collected from the "transitional zone." This zone is defined as the lower part of Unit 3C and the upper part of Unit 2 and 3CM. This transition zone can easily be matched with zones 2, 3, and 4 of Decker (1933). Because of the nature of the rock and the great thicknesses exposed it was not possible to collect all 18 sections. Figure 12 (in pocket) shows the stratigraphic positions of the brachiopods collected and studied.

Method of Preparation

Those limestone blocks containing silicified brachiopods were dissolved in 5-10 percent hydrochloric acid. The silicified specimens were caught on an underlying screen, soaked for about a day in clear water, dried in the open air, and then dipped in a mixture of Duco Cement and acetone. This last procedure helps prevent breakage. The concentration used of acetone to Duco Cement was about 1 part Duco Cement to 10 parts acetone.

As reported by Glaser (1965) most of the rocks of this sequence are high in silica. Because of this it is difficult to extract good brachiopod specimens from most beds. Even where they occur in abundance it is almost impossible to break them out of the rock with the necessary morphological features preserved well enough for specific identification and study. It is possible that the high percentage of silica is the reason that many of the shells are silicified. It is not known why the many trilobites, corals, and bryozoans which occur with the brachiopods are not silicified.

Statistical Procedures

Many paleontologists tend to neglect the study of early growth stages and general growth studies of all types. Simpson, Roe, and Lewontin (1960) list three quantitative aspects of growth in which a zoologist might be interested. They are: (1) a knowledge of the change over time in some dimension of the animal, (2) the relative sizes of two dimensions of a single animal, and (3) changes in shape. These authors give a full treatment of relative growth.

Huxley (1932) was the first to successfully treat relative growth quantitatively. His investigations were more zoological than paleontological, but the principle can be applied successfully to fossils (Imbrie, 1956; Olson, 1951). Relative growth is the study of change in size of one variable with respect to change in size of another variable. Huxley approached the problem from a slightly different viewpoint. He was concerned with determining the relationship between the size of the body as a whole and an organ whose proportionate size changed during life. He was able to do this quantitatively by the use of the equation $Y = aX^b$. This equation is now referred to as the "law of allometry." Here (X) is the magnitude of the body, (Y) the magnitude of the differentially growing organ, and (b) and (a) are constants. The constants (a) and (b) have been given different names by different authors. Simpson calls (a) the initial growth index and (b) the constant of allometry. Imbried (1956) denotes (a) as the initial growth index and (b) the growth ratio.

Scatter diagrams of two biological variables (for instance length-width, or length-thickness) sometimes form a pattern such that the curve of best fit is of the form $Y = aX^b$. In such a situation the line of best fit is curved and the variables are showing allometric growth. Conversely, some scatter diagrams can be best represented by a curve of the form $Y = a + bX$ in which (a) is the Y intercept and (b) the slope of the line. The relative growth of the two variables in this instance is considered to be isometric. By convention X is taken as the independent variable and Y as the dependent variable, although there is no biological reason or justification for this selection.

In a scatter diagram of two growth variables of brachiopods, a straight line $Y = a + bX$ best fits the data in most cases. This is particularly true because of the absence of the very early growth stages. The line of this form is called the "regression line" or an "isometric growth curve." It can be considered the average path through which the two variables passed on the way to achieving their final position. It must be remembered that what is seen in the sample need not be the final stages of growth. Also, by using convention to designate (X) as the independent and (Y) the dependent variable it should not be assumed that the two characters are unrelated, or, that the growth of one has no influence on the growth of the other. In living organisms many characters are clearly interrelated and the growth of one affects and is affected by the growth of the other.

The two constants (a) and (b) in the regression equation are the important quantities to analyze. The values for (a) and (b) have been estimated by the method outlined by Simpson (1960, pp. 232-233). In this paper the former will be called the <u>initial growth index</u> and the latter the <u>growth ratio</u>. There are particular statistical procedures which can be applied to test the significance of the difference between two (a)s (position of the regression line), or the significance of the difference between two (b)s (slopes of the regression lines). Various workers have used such tests to help differentiate species or subspecies. Such tests of significance and the calculation of confidence limits and intervals are discussed fully by Simpson, Roe, and Lewontin (1960).

The primary reasons for incorporating regression analyses into the formal systematic descriptions are: (1) because many morphological characters of brachiopods show continuous variation and in many cases regression is a satisfactory means of showing that variation, (2) to help differentiate, if possible, similar species or subspecies from the same stratigraphic horizon, and (3) to present the variability in such a way that other workers, if they desire, can statistically compare their material to that of the Viola.

Where possible, each description is accompanied by: (1) a scatter diagram of the two variables selected, (2) the calculated regression line, and (3) the approximate 95 percent confidence limits. The 95 percent confidence limits have been calculated by the method described by Goldstein (1964, pp. 139-141). This gives a good estimate of the variability of the two characters under study. Also, the values of the constants (a) and (b) are given. It is important to remember that because the regression lines and the values of (a) and (b) have been estimated using standard statistical techniques they can be put to statistical tests by other workers when comparing their material with that presented here.

Some of the brachiopod specimens described from the Maquoketa Formation of Iowa (Wang, 1949) were borrowed from the University of Iowa. Also, the type specimens from the Montoya Group of West Texas and New Mexico (Howe, 1965, 1965a, 1966, 1966a) were studied at the United States National Museum. In addition, a small collection of brachiopods from the Fernvale (Cape) Formation of Missouri was borrowed from the Yale University Peabody Museum. These specimens were referred to by Gealey (1955), although he did not describe them.

Specimens to which University of Oklahoma catalog numbers have been assigned are designated by the prefix OU. All of the specimens from the Viola Formation, figured and unfigured, are deposited in the University of Oklahoma Geology Repository. Specimens in the repository of the State University of Iowa are designated by the prefix S.U.I., and those in the United States National Museum by the prefix U.S.N.M.

Several of Wang's figured specimens were borrowed by the writer. They are listed below.

Glyptorthis pulchra Wang; U.S.N.M. 111947, U.S.N.M. 111948a, U.S.N.M. 111948b.

Austinella delicata Wang; S.U.K. 1798, S.U.I. 1799

Austinella whitfieldi (Winchell); S.U.I. 1800, S.U.I. 1801, S.U.I. 1802

Austinella kankakensis (McChesney); S.U.I. 1803

Plaesiomys subquadratus occidentalis Ladd; S.U.I. 1807

Plaesiomys proavita (Winchell and Schuchert); S.U.I. 1808, S.U.I. 1809, S.U.I. 1810

Plaesiomys planus Wang; S.U.I. 1817, S.U.I. 1818, S.U.I. 1819

Platystrophia equiconvexa Wang; S.U.I. 1823

Rhynchotrema iowense Wang; S.U.I. 1824, S.U.I. 1825

Lepidocyclus laddi Wang; S.U.I. 1828, S.U.I. 1829a, S.U.I. 1829b, S.U.I. 1830

Lepidocyclus rectangularis Wang; S.U.I. 1832, S.U.I. 1833

Lepidocyclus erectus Wang; S.U.I. 1834, S.U.I. 1835

Lepidocyclus notatus Wang; S.U.I. 1836

Lepidocyclus manniensis (Foerste); S.U.I. 1837, S.U.I. 1838, S.U.I. 1839

Lepidocyclus perlamellosus (Whitfield); S.U.I. 1830

Opikina limbrata Wang; S.U.I. 1841, S.U.I. 1842, S.U.I. 1843

Strophomena planumbona (Hall); S.U.I. 1845, S.U.I. 1846

Strophomena elongata James; S.U.I. 1847

Strophomena cf. S. planoconvexa Hall; S.U.I. 1850

Strophomena perconcava Wang; S.U.I. 1851

Strophomena clermontensis Wang; S.U.I. 1852

Tetraphalarella cooperi Wang; S.U.I. 1860a, S.U.I. 1861

Megamyonia knighti Wang; S.U.I. 1868, S.U.I. 1869, S.U.I. 1870

Tetraphalarella neglecta (James); S.U.I. 1871

Lepidocyclus gigas Wang; S.U.I. 1880

Thaerodonta recedens (Sardeson); S.U.I. 1881, S.U.I. 1882

Thaerodonta saxea (Sardeson); S.U.I. 1883, S.U.I. 1884a, S.U.I 1884b

Thaerodonta aspera Wang; S.U.I. 1885, S.U.I. 1886

Thaerodonta dignata Wang; S.U.I. 1887, S.U.I. 1888a, S.U.I. 1888b

Diceromyonia subrotundata Wang; S.U.I. 1889

Diceromyonia tersa (Sardeson); S.U.I. 1890, S.U.I. 1891

Onniella quadrata Wang; S.U.I. 1892, S.U.I. 1893, S.U.I. 1894

The writer visited the United States National Museum and was able to study all of Howe's (1965, 1966) figured specimens from the Montoya Group. While at the Museum the writer also studied the figured specimens of Lepidocyclus cooperi Howe and Lepidocyclus oblongus Howe from the Fernvale (Cape) Limestone of Missouri and northeast Oklahoma.

For classification above the generic level the writer has followed the Treatise (Williams and others, 1965).

List of Brachiopod Species from the Viola Formation

Hesperorthis n.sp. A

Hesperorthis sp. B.

Glyptorthis n.sp.

Plaesiomys cf. P. subquadratus (Hall)

Plaesiomys subquadratus (Hall)

P. proavita (Winchell and Schuchert)

P. bellistriatus Wang

Austinella n.sp.

Dinorthis pectinella (Emmons)

Dinorthis cf. D. transversa Willard

Doleroides n.sp.

Platystrophia n.sp. A

Platystrophia n.sp. B

Platystrophia n.sp. C

Diceromyonia cf. D. tersa (Sardeson)

Paucicrura cf. P. rogata (Sardeson)

Paucicrura n.sp.

Onniella sp.

Leptellina sp.

Thaerodonta magna Howe

Sowerbyella n.sp.?

Sowerbyella sp.

Strophomena planumbona (Hall)

S. perconcava Wang

S. cf. S. clermontensis Wang

Strophomena sp.

_S_. _neglecta_ (James)

Strophomena n.sp.

Megamyonia n.sp.?

Oepikina sp.

Rafinesquina sp.

Rhynchotrema _increbescens_ Hall

Lepidocyclus _cooperi_ Howe

_L_. _capax_ (Conrad)

_L_. _oblongus_ Howe

_L_. _manniensis_? (Foerste)

?_L_. _perlamellosus_ (Whitfield)

Suborder Orthidina Schuchert and Cooper, 1932

Superfamily Orthacea Woodward, 1853

Family Dolerorthidae Öpik, 1934

Genus _Hesperorthis_ Schuchert and Cooper, 1931

Hesperorthis n.sp. A

Plate V, figs. 9, 10

Description: This species is large for the genus. The largest specimen has a length of 24 mm. and a width of 27 mm. (See Figure 16 for a complete range of sizes.) The greatest shell width is at the hinge line in both immature and mature specimens. The width is distinctly greater than the length at all growth stages. The cardinal extremities are acute in most specimens, but are at right angles in some. The lateral margins are straight and the anterior margin is broadly rounded. The anterior commissure is sulcate and the lateral commissure convex. The surface of the shell is ornamented by 30-35 elevated costae around the umbo, and depending on the size of the individual, 37-42 costae around the margin. The costae are sharply rounded in the posterior portion of the shell and gently rounded in the anterior portion. In the region of the umbo the separating grooves are about as wide as the costae, but the costae gradually become wider than the grooves in the anterior direction. At 10 mm. from the beak there are 7-8 costae in a space of 5 mm.

The pedicle valve is convex and evenly rounded in lateral profile. The greatest thickness is just posterior to the middle causing the anterior slope to be slightly gentler than the posterior slope. The anterior profile is strongly rounded with the lateral slopes almost straight. The interarea is curved and weakly apsacline to orthocline; a little more than one-fourth as long as the valve. The deltidium is narrow, subtending an angle of about 20 degrees. A pseudodeltidium covers the posterior one-half of the deltidium. The beak varies from being erect to being slightly incurved. The delthyrial cavity is deep, narrow, and almost conical in shape with the apex of the cone at the posterior extremity. The teeth are small and the dental plates are receding. The muscle field extends anteriorly as far as the hinge line and normally possesses and evenly curved and slightly elevated anterior margin. The interior margin is crenulated with each crenulation centrally cleft.

The brachial valve is concave in lateral profile. It is distinctly sulcate in anterior profile with the flanks of the valve gently convex. A sulcus is present near the umbo and expands anteriorly, extending to the anterior margin. The sulcus is occupied by about 10 costae at the anterior margin. The cardinal extremities are deflected toward the pedicle valve. The interarea is plane, hypercline, and shorter than the pedicle valve interarea. The notothyrium is covered posteriorly by chilidial plates. Each plate is convex and projects slightly higher than the level of the interarea. The plates are joined and are attached to the cardinal process forming a groove at the position of juncture. The notothyrial cavity is shallow. The cardinal process is a thin ridge which is broader at the base than at the apex which is near the level of the interarea. The process extends the full length of the cavity. The brachiophores are stout, long, and each bears a shallow socket on its inner face. The brachiophores are continuous with the walls of the notothyrial cavity although they are deflected at a slightly greater angle. The inner face of each brachiophore has a weak median ridge which extends its full length. The sockets are shallow and are partly under the interarea. The posterior adductor scars are about twice as large as the anterior scars. Neither the posterior nor anterior scars are well defined. The median septum is stout and extends anteriorly to about the middle of the valve.

Discussion: This species is like H. tricenaria (Conrad) and has been identified as such in previous works. Huffman (1958) compiled a faunal list for the "Fernvale" (Cape) in northeastern Oklahoma in which he included this species as H. tricenaria (Conrad). The author has collected the "Fernvale" (Cape) in northeastern Oklahoma and is of the opinion that the species there is the same as described here.

This new species is different from _H. tricenaria_ in possessing more numerous costae. The largest shells of _H. tricenaria_ in the National Museum collections show 30-32 marginal costae. In contrast, this new species has 37-42 marginal costae, depending on its size. In addition, the brachial valve of _H. tricenaria_ has small delicate brachiophores and a distinct anacline interarea in contrast to the strong robust brachiophores and a hypercline interarea of _Hesperorthis_ n.sp. A. In a statistical plot of pedicle width-pedicle length for _H. tricenaria_, 8 out of the 12 specimens measured fall outside of the 95 percent confidence interval for _Hesperorthis_ n.sp. A. The plot of length of the pedicle valve-length of pedicle interarea shows only 3 of the 12 specimens outside the 95 percent confidence interval for _Hesperorthis_ n.sp. A. Thus, the most important distinguishing characteristics about this species are the fairly large size and the numerous costae.

The various dimensions of _H. tricenaria_ (Conrad) from the National Museum collections are given below. These can be compared with the dimensions given for this new species (see Figures 16 and 17). All measurements are in millimeters.

Length	Width	Length of Interarea	Locality
8.2	11.3	3.0	Wisconsin
9.8	12.3	3.4	Wisconsin
11.3	11.9	3.8	Illinois
11.8	13.3	3.7	Wisconsin
12.8	13.5	4.7	Wisconsin
14.6	14.3	3.2	Wisconsin

Figure 16

Hesperorthis n.sp. A. Regression line and 95 percent confidence intervals for the length-width dimensions for the pedicle valve. The specimens are from localities A and C; Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean Length: 15.9, mean width: 18.6, initial growth index (a): 1.6, growth ratio (b): 1.1.

Figure 17

Hesperorthis n.sp. A. Regression line and 95 percent confidence intervals for length of shell-length of interarea dimensions for the pedicle valve. Specimens are from localities A and C; Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean length: 16.2, mean length of interarea: 5.1 (measurement taken along the median of the valve), initial growth index (a): 0.9, growth ratio (b): 0.3.

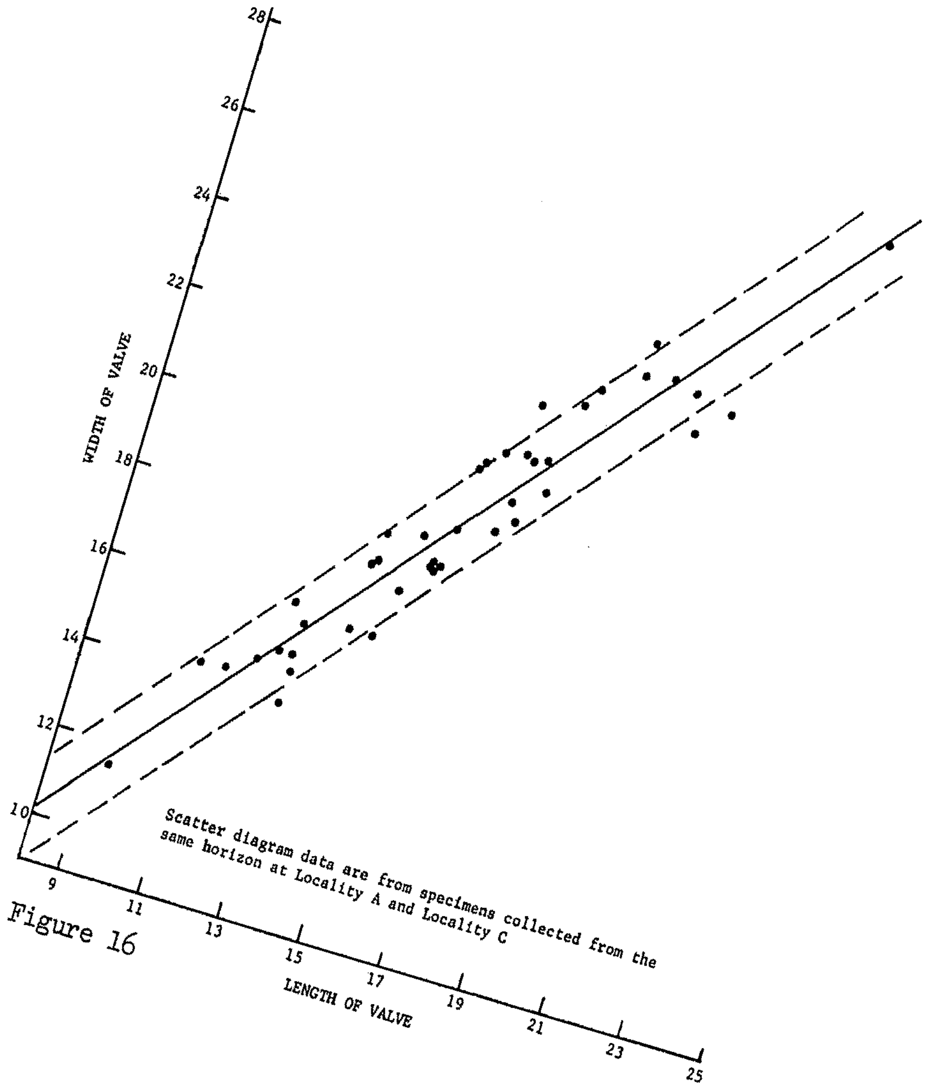


Figure 16

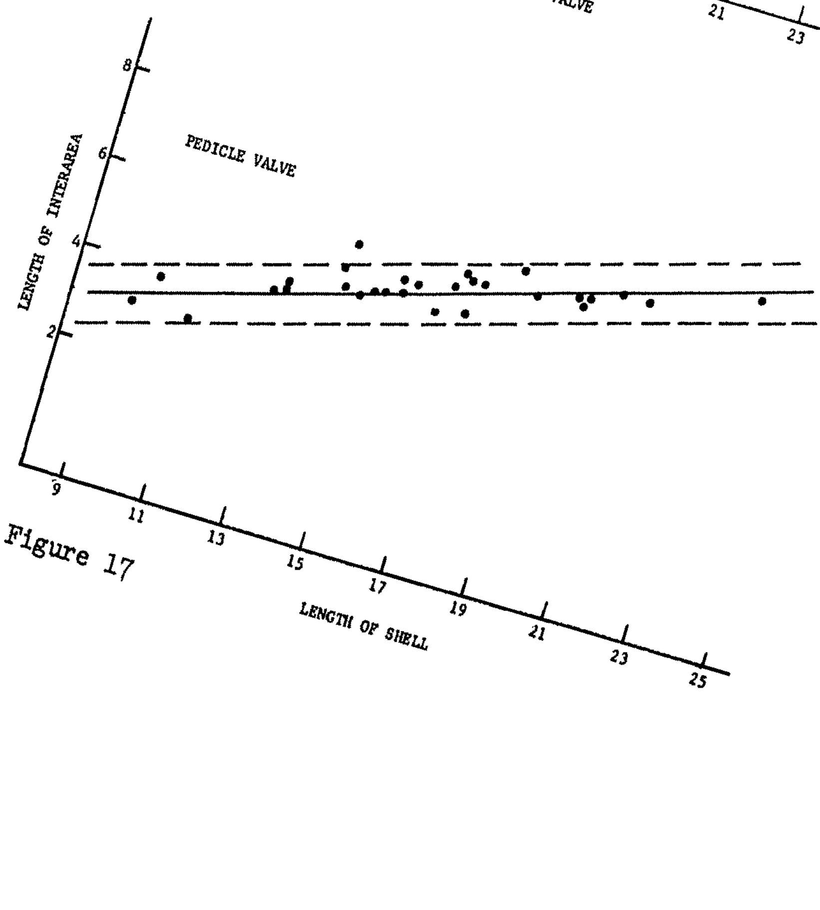


Figure 17

Length	Width	Length of Interarea	Locality
16.0	17.9	4.7	Wisconsin
16.3	16.8	5.7	Wisconsin
16.4	18.0	4.9	Illinois
17.5	18.5	6.1	Illinois
18.0	22.3	7.4	Wisconsin
19.9	20.0	6.2	Wisconsin
21.2	24.8	5.3	Wisconsin

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. The type specimens of Howe's Montoya species were studied by the writer. H. kirki Howe is characterized by its large size, most specimens reaching widths between 30-40mm. This is much larger than the widths attained by the Viola species. (See Figure 16.)

Distribution and Material: This species is represented by numerous specimens; none articulated. It is confined to the upper 6 feet of the formation at localities A, B, C, and D (Unit 3C). However, at localities G, I, and R it is confined to a 5-10 foot zone, 40-60 feet below the top of the formation (Unit 3CM). More than 50 individual valves were studied.

Hesperorthis sp. B

Plate IX, fig. 11

Description: This species is of moderate size for the genus, measuring 13.0mm. in width and 9.2mm. in length. The dorsal outline is circular with the cardinal extremities obtusely rounded and the lateral and anterior margins evenly rounded; both at about the same magnitude. The lateral commissure is rectimarginate and the anterior commissure is weakly sulcate. A sulcus is present on the brachial valve beginning at the beak and expanding and slightly increasing in depth anteriorly. The surface is costate with 6 costae in a 5mm. space at the anterior margin of a specimen measuring 9.0mm. in length.

The brachial interarea is plane and anacline. The notothyrium is open with a thin blade-like cardinal process extending the full length of the cavity. The brachiophores are prominent and pointed; not supported from beneath by much shell material. The sockets are poorly developed. The median septum is short with adductor scars poorly defined on each side. The internal margins of the valve are grooved. These internal grooves extend posteriorly a distance of about 2.7-2.9mm.

Discussion: *H. crinerensis* from the Bromide Formation (Criner Hills, Oklahoma) is the same size as this form, 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.

Hesperorthis n.sp. A differs from this species by having a larger and thicker shell, more numerous well-developed costae, and prominent, widely divergent brachiophores. (Compare Figure 10c, Plate V, with Figure 11c, Plate IX.)

Distribution and Material: Only two brachial valves were found. Since no pedicle valves are available a specific designation is questionable. This species occurs in the lower 50 feet (Unit 1C) at localities D and L.

Genus Glyptorthis Foerste, 1914

Glyptorthis n.sp.

Plate II, figs. 10, 11

Description: The shell is subquadrate in outline with the length about 2-3mm. shorter than the width. In younger shells the greetest width is attained at the hinge line, but in mature specimens the greatest width occurs at the middle or just anterior to the middle. The hinge line is straight. The shell is equally biconvex; brachial and pedicle valves showing about the same maximum thickness at all growth stages. The cardinal extremities are obtuse in mature individuals, but in young shells tend to be acute or at right angles, occasionally with a faint auricular appearance. The antero-lateral margins are rounded; the anterior margin is straight with an emarginate median.

The surface is multicostellate. There are from 7-9 costae and costellae in a space of 3mm. at a distance of 5mm. from the beak. There are from 17-20 costae around the beak region. The first generation of costellae are added at approximately 3mm. from the beak, although in a few shells bifrication occurs much closer to the beak. The costae and costellae around the margin are poorly preserved in most shells, however, a few marginal counts were obtained. These are given in the table below (all measurements are in millimeters).

Length	Marginal Count
8.4	46
12.5	66
17.4	77
18.5	83

The costae and costellae are narrow and vary in profile from almost "V-shaped" with sharply rounded tops and straight sides to narrowly rounded. There are numerous imbricated fila or growth lamellae present; about 7-8 in a distance of 5mm. At the point of intersection of the fila and the costellae the fila project upward as small "spines." These curved projections are open anteriorly. Growth lines are numerous and appear to be coincident with the fila. Some of these concentric lines are more accentuated than others.

The pedicle valve is convex in lateral profile with the maximum thickness directly over the hinge line or just anterior to it. The greatest curvature is in the umbonal region. The middle is very gently curved leading smoothly into a long gentle anterior slope. In some specimens the slope anteriorly from the highest point is almost straight. The anterior profile is evenly convex. A faint sulcus is present in the anterior quarter of some shells, while in others no undulations of any sort occur. In a few shells a slight fold appears in this position. The beak varies from being suberect, to erect, to slightly incurved. The interarea is curved, weakly apsacline, and long. It is a little less than one-third the length of the shell. (See Figure 23.) The delthyrium is triangular with the cavity moderately deep. The width of the cavity at the level of the floor is about twice as wide as the delthyrial opening above. This is due to the lateral slope of the dental plates and cavity walls. The muscle field is cuenate in shape; about one-half of the field is confined under the interarea and one-half is extended past the hinge line. The anterior margin of the field is curved and irregularly elevated. The adductor tracks are long, extending anteriorly as far as the diductors. The diductors are divergent, trapazoid in shape, and crossed diagonally by several low, rounded ridges. The adjustor scars are long narrow grooves positioned at the base of the dental plates. Weak pallial markings are visible in some shells. The vascula media project anteriorly and inward from the lateral margins of the adductor tracks. They join in front of the muscle area and continue toward the anterior margin as a single track. The teeth are short, triangular, and stout. They are situated a short distance from the delthyrial opening. The dental plates are robust; extending straight down to the floor of the valve. The inner anterior margin is crenulated.

The brachial valve is equally convex in lateral view. In some specimens the curvature of the median portion tends to flatten out. The highest point varies from being just posterior to the middle, to being in the middle, to being just anterior to the middle. The anterior profile is convex with steep lateral slopes. The postero-lateral areas are concave. The sulcus begins at the beak and extends to the anterior margin. The sulcus is well developed in all but a few shells, but in these few it is still easily visible. In smaller specimens the width of the sulcus at the anterior end is just a little less than one-half the width of the shell. From a study of a growth series it can be seen that as the shell increases in size the shell width increases faster than the sulcus width, so that in larger specimens the sulcus width is only one-third as wide as the shell. The lateral lobes bounding the sulcus are evenly rounded with the slope into the sulcus about the same as the lateral slope of the shell. The beak is small, erect, and slightly incurved. The interarea is curved, orthocline, and shorter than in the pedicle valve. There is a moderately deep notothyrial cavity situated high above the floor of the valve. The cardinal process is blade-like, but moderately thick. In well-preserved specimens the process extends the full length of the cavity, joining the curved posterior region under the beak. Such a condition divides the cavity into two equal parts. The median septum is slightly thicker than the cardinal process and extends almost to the middle of the valve. The posterior part of the septum thickens under the notothyrial cavity forming two chambers beneath the floor. The brachiophores are thick and diverge at about an angle of 70 degrees. The sockets are deep. Muscle impressions are not present. The internal margins of the valve are crenulated.

Discussion: *Glyptorthis insculpta* Hall is the common Cincinnatian species of this genus. There is one subspecies, *G. insculpta maquoketensis* Ladd from the Maquoketa Shale of Iowa. One distinguishing characteristic about the subspecies is that it is smaller. Measurements made by Howe (1966a) show for *G. insculpta* a mean length of 17.4mm. and a mean width of 21.6mm. The subspecies *G. insculpta maquoketensis* shows a mean length of 14.4mm. and a mean width of 16.6mm. The subspecies also has a more subquadrate outline and a greater thickness relative to the length. The scatter plots for the length-thickness dimensions shows them to be different. (These plots are not shown in this paper; see Howe, 1966a, p. 243.)

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

This new species is easily differentiated from G. insculpta Hall. The pedicle valve of Glyptorthis n.sp. has a different outline, being more elongate and less subquadrate than G. insculpta Hall. A statistical analysis of length-width values for G. insculpta Hall shows a regression line of about the same slope as Glyptorthis n.sp., but well outside of the 95 percent confidence interval. Because the subspecies is even smaller its regression line is farther outside the 95 percent confidence interval. (The regression lines for G. insculpta and its subspecies are not shown with that of Glyptorthis n.sp. in Figure 21.) Also, Glyptorthis n.sp. has a relatively longer and almost orthocline pedicle interarea. The pedicle interarea of G. insculpta Hall is shorter and much more strongly apsacline in attitude. G. insculpta Hall is also more coarsely costate than Glyptorthis n.sp. A tabulation of the number of marginal costae and costellae relative to the length is given below for G. insculpta Hall. These can be compared with those values given in the formal description of Glyptorthis n.sp. All measurements are in millimeters.

Figure 18

Glyptorthis n.sp. Regression line and 95 percent confidence intervals for the brachial valve. The specimens are from locality A, Unit 3C, upper 6 feet, and locality C, Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean length: 11.7, mean thickness: 4.4, initial growth index (a): -0.7, growth ratio (b): 0.4.

Figure 19

Glyptorthis n.sp. Regression line and 95 percent confidence intervals for the pedicle valve. The specimens are from localities A and C, Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean length: 13.4, mean thickness: 4.7, initial growth index (a): 1.1, growth ratio (b): 0.3.

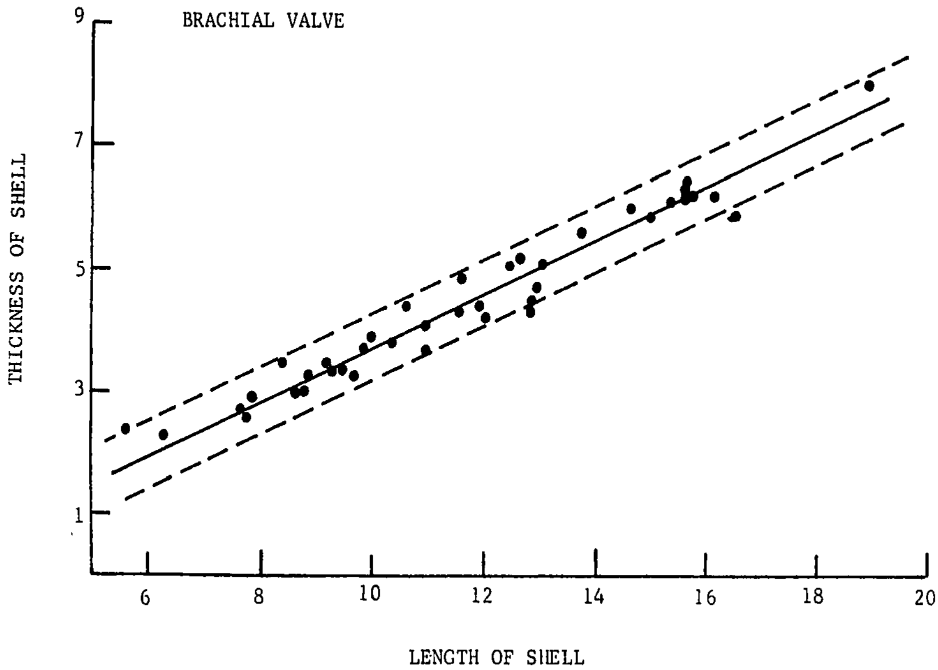


Figure 18

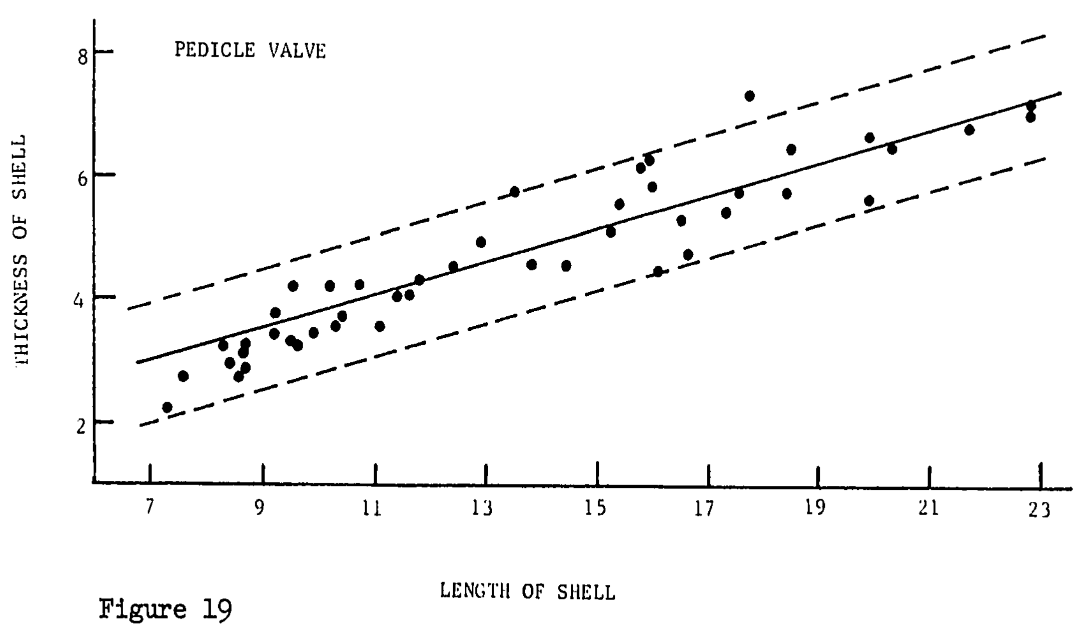


Figure 19

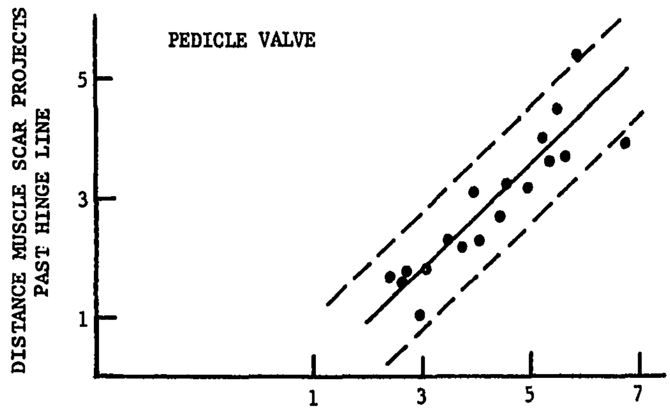


Figure 20

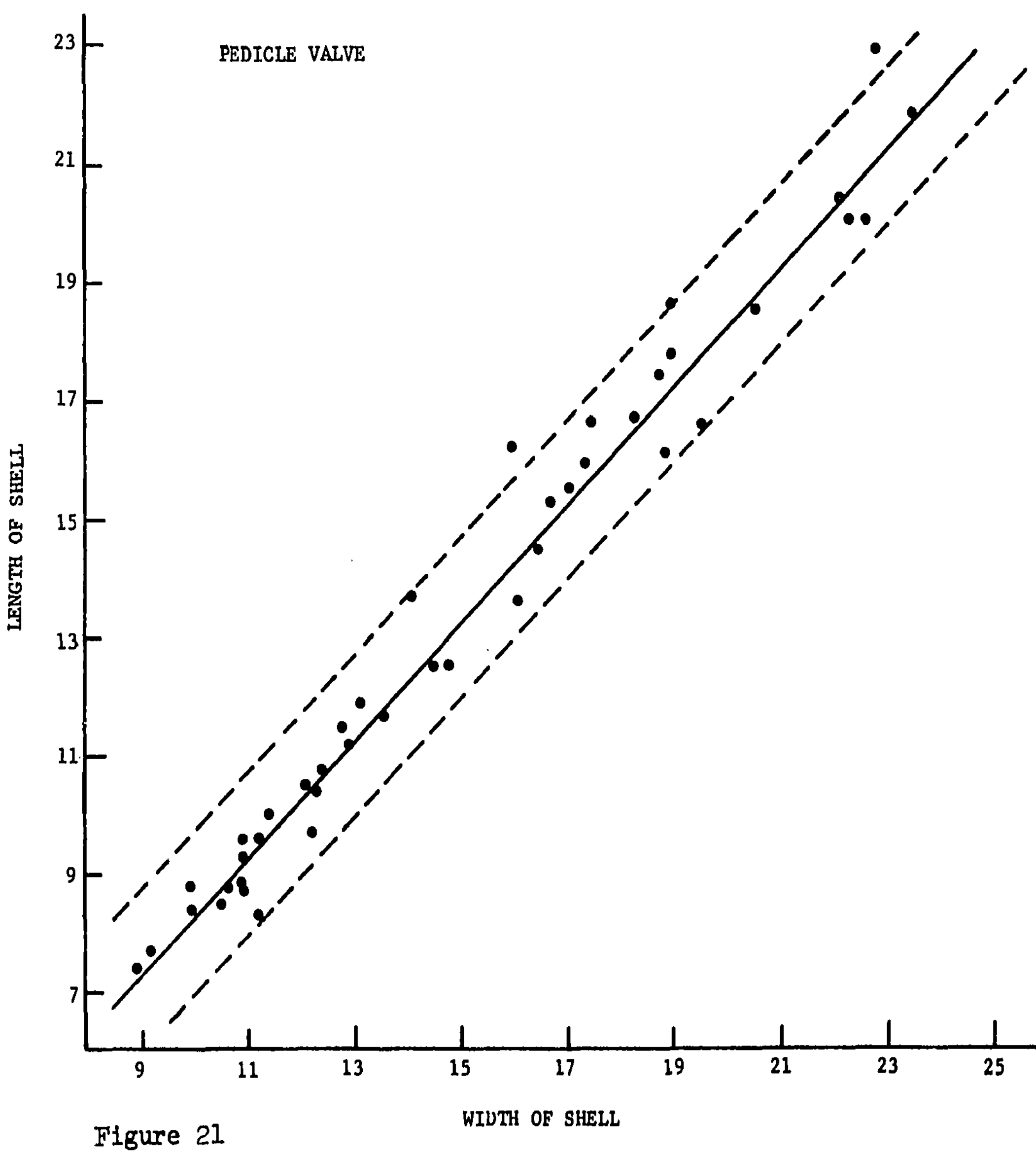


Figure 21

Figure 22

Glyptorthis n.sp. Regression line and 95 percent confidence interval for the brachial valves from Locality A, Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean width: 15.8, mean sulcus width at the anterior margin: 6.3, initial growth index (a): 1.5, growth ratio (b): 0.3.

Figure 23

Glyptorthis n.sp. Regression line and 95 percent confidence interval for the pedicle valves from Locality A, Unit 3C, upper 6 feet. The length of the interarea was measured along the median. All measurements are in millimeters.

Mean length: 13.6, mean length of interarea: 3.8, initial growth index (a): 0.0, growth ratio (b): 0.3.

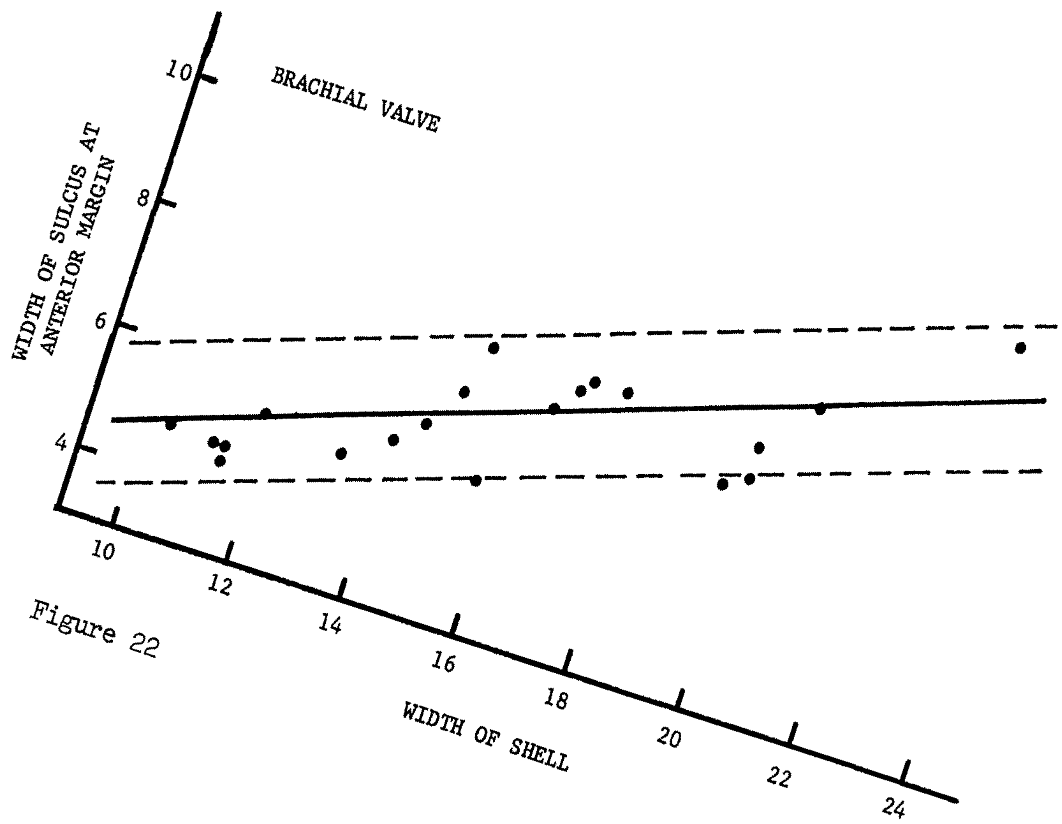


Figure 22

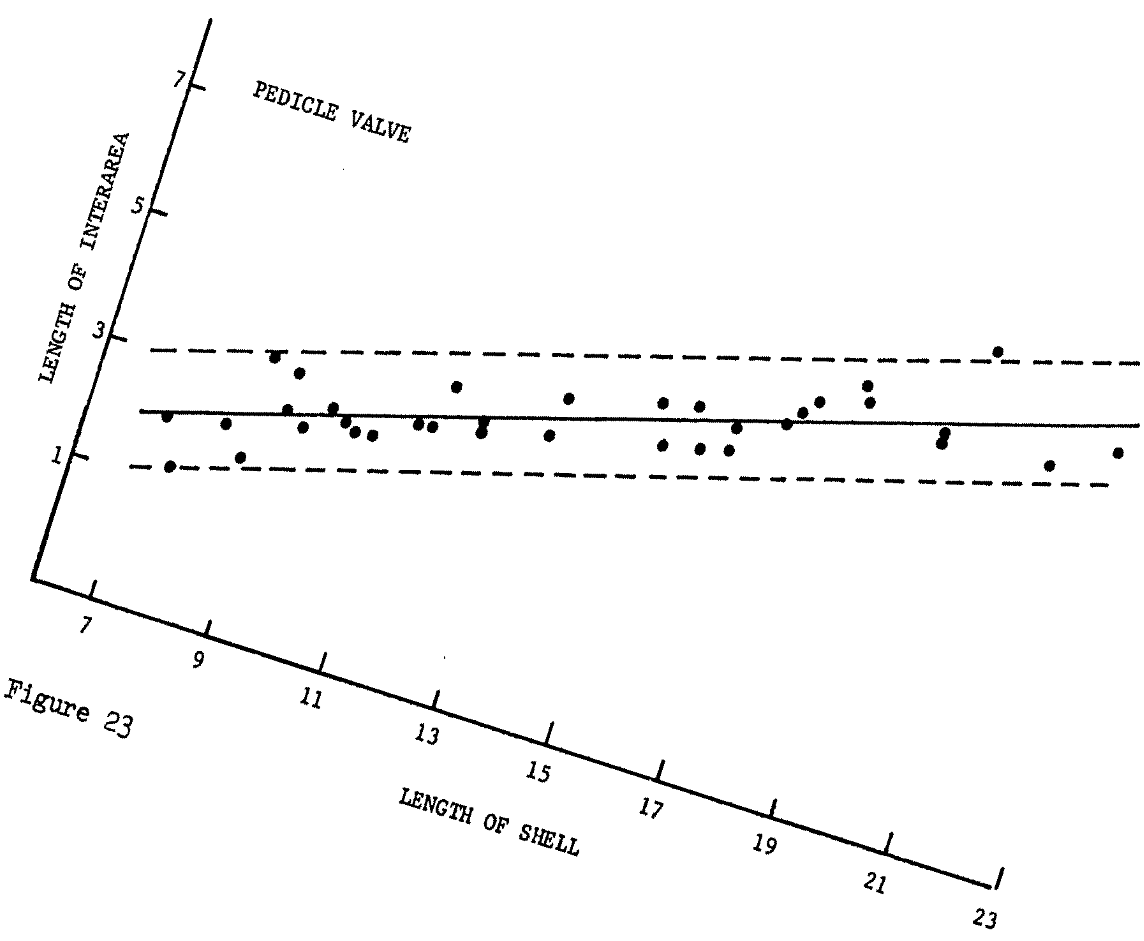


Figure 23

Length	Number of Marginal Costae
11.5	46
13.3	54
14.8	60
15.4	68
18.4	71
18.5	70
19.5	78
20.8	88
20.9	80

Huffman (1958) reported G. pulchra Wang from the "Fernvale" in northeastern Oklahoma. However, the collections made by the author from the "Fernvale" in northeastern Oklahoma show that that species is the same as the one described here from the upper Viola (Units 3C and 3CM).

Distribution and Material: This is a common species in the Viola Formation. The writer collected and studied about 50-75 specimens; none articulated.

This species is confined to the upper 6 feet of the formation (Unit 3C) at localities A, B, C, and D. At localities G, I, and R it occurs 40-60 feet below the top of the formation (Unit 3CM).

Family Plaesiomyidae Schuchert, 1913

Genus Plaesiomys Hall and Clarke, 1892

Plaesiomys cf. P. subquadratus (Hall)

Plate VII, figs. 1 and 2

Orthis Subquadrata Hall, 1847, p. 126, Pl. 32A, figs. 1a-o; Meek 1873, pp. 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: The shell is rectangular to subquadrate in outline. The hinge line is straight and a little less than the widest part, which occurs just posterior to the middle. The cardinal angles are obtusely rounded with the lateral margins very gently curved. The anterior margin is straight. In lateral profile the shell is unequally biconvex with the brachial valve the deeper. The thickest part of the shell is in the middle. The lateral commissure is rectimarginate. The surface is multicostellate with 75 costae occurring around the margin of a specimen 17.5mm. in length. At a distance of 10mm. from the beak there are 9-10 costae and costellae in a space of 5mm. The interspaces between the costae are about the same width as the costae, but some are smaller.

The pedicle beak is small and suberect. The interarea is slightly curved, longer than in the brachial valve, and strongly apsacline to catacline. The delthyrium is open, and triangular at about 90 degrees. The teeth are stout with rounded extremities. The dental plates are thick, slightly advancing. The anterior extremities are joined to the slightly raised lateral margins of the muscle field. The individual muscle scars are not pronounced, but as a group they appear to be of the plaesiomid type. The interior margins of the valve are crenulated forming a band about 3mm. wide around the lateral and anterior margins.

Only a small portion of the brachial interior was observed. The cardinal process is stout; the myophore is crenulated and centrally cleft (see Plate VII, figure 2). The brachiophores are divergent with the extremities pointed, thinned, and curved slightly inward.

Discussion: Plaesiomys cf. P. subquadratus is represented by only a few specimens. However, this species is in a critical part of the section (the upper 10 feet of Unit 2, localities B and C) in rocks which are informally called the "transitional zone." It occurs just below the rocks referred to by previous workers as the "Fernvale" (Unit 3C of this paper; see Figure 12 for its stratigraphic position). It is one of the few identifiable brachiopods from this interval.

The specimens of P. subquadratus (Hall) in the United States National Museum show variations in several characters. The shape and size of the shell, and the ornamentation (particularly in the number of costae and costellae) are characters which show the most variation. In addition, there is much variation in the shape and prominence 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 upper part of Unit 2 has 75 marginal costae.

The single partial brachial valve from the upper part of Unit 2 shows a central groove along the myophore. A study of numerous brachial valves from the United States National Museum collections showed that a cleft myophore is absent more often that it is present. These data are given below.

Locality	"Formation"	Total Number of Brachial Valves	Number Showing Grooved Myophore
Moores Hill, Ind.	Waynesville	1	1
Richmond, Ind.	Richmond	7	1
Oregonia, Ind.	Richmond	1	0
Butler Co., Ohio	Richmond	2	0
Clarksville, Ohio	Richmond	3	1

Distribution and Material: The specimens upon which the description is based occur 85 feet from the top of the formation (Unit 2) at Locality C. Fragments of specimens which the writer referred to this species also occur in the upper 10 feet of Unit 2 at localities B and L.

There is one pedicle valve showing the external and internal morphology, one brachial valve showing only the exterior, and a partial brachial valve showing the cardinalia.

Plaesiomys subquadratus (Hall)

Plate V, figs. 6-8

Description: The shape is subquadrate to subelliptical. The hinge line is straight and shorter than the greatest width which is at about the middle. The cardinal extremities are obtusely rounded. The lateral margins are broadly rounded, but the anterior margin is almost straight. The sulcus is weak in the umbonal region, but becomes wider and better developed anteriorly. In lateral profile the shell is plano-convex. The brachial valve is evenly convex with the posterior slope steeper than the longer anterior slope. The lateral commissure is rectimarginate and the anterior commissure faintly sulcate. The surface is multicostellate; 13 in a space of 10mm. at a distance 15mm. from the beak.

The brachial interarea is short and slightly anacline. The notothyrial platform is elevated. The cardinal process is elevated above the level of the interarea. It is "pitted" or crenulated along the posterior half. The brachiophores are strong and divergent. The sockets are deep.

The pedicle valve is almost flat with the lateral and anterior margins deflected in the dorsal direction. Growth lines are strong in this deflected portion. The hinge line is straight and about three-fourths as wide as the widest part of the valve. The interarea is moderately long (about 3mm.) and apsacline. The delthyrial opening is triangular and the cavity is moderately deep. The brachiophores are short and rounded. The muscle field is large (in a specimen measuring 29mm. in width, 22.5mm. in length, the muscle field is 12mm. wide at the widest part) and extends to the middle of the valve. The anterior margin of the field is sinuous with a median reentrant about one-fourth the length of the field. The diductor scars are divergent. The adductor scars are elongated; located in the middle anterior of the field just posterior to the median reentrant. The adjustor scars are a little larger than the adductors and situated between the cavity walls and the diductor scars. The internal margins are crenulated.

Discussion: Meek (1873) gave a detailed description of *Orthis subquadratus* Hall from the Ohio Valley. He comments (1873, p. 95):

> . . . striae of ventral valve nearly always increasing by bifrication (some of them dividing two or three times); while those of the dorsal valve generally increase by the intercalation of shorter ones between longer.

Hall (1843) 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 four showed this method of costellae addition. The single pedicle valve from the Viola Formation (Unit 3C) has this pattern of costellae increase.

A study of the figured hypotype of Wang (1949) shows that there are more third generation costellae than there are in the brachial valve of the Viola specimen.

Distribution and Material: Specimens confidently referred to this species are found at Locality I, 40-60 feet below the top of the formation (Unit 3CM). There are only a few complete and partial specimens from this locality. This species is rare in the Viola Formation. However, in northeastern Oklahoma ("Fernvale" (Cape) Limestone) this species is common.

Plaesiomys proavita (Winchell and Schuchert), 1892

Plate V, figs. 1-5

Orthis proavita Winchell and Schuchert, 1892, Am. Geol., vol. 9, p. 290.

Plaesiomys proavita (Winchell and Schuchert), Wang, 1949, p. 2, Pl. 2, figs. E.

Plaesiomys planus Wang, 1949, p. 6, Pl. 3, figs. C.

Description: The shell is subquadrate with the length shorter than the width at all growth stages. The hinge line is straight and shorter than the greatest width which is at about the middle of the shell. The lateral margins are broadly rounded and the anterior margin almost straight, sometimes emarginate. The surface is multicostellate. The costae and costellae are "V-shaped" in profile with the tops sharply rounded. There are about 6 costae and costellae in a space of 5mm. at a distance of 10mm. from the beak. The number of costae and costellae around the margin ranges from 37-54 depending, in some cases, on the size of the shell. The arithmetic mean is 44 marginal costae and costellae. The interspaces are about as wide as the costae.

The pedicle valve is almost flat. In lateral profile the slope from the umbo toward the anterior is gentle. An inconspicuous fold begins at the umbo and expands anteriorly. The fold is formed by 3-4 slightly elevated costae. The beak is small and suberect. The interarea is narrow, curved, and apsacline. The teeth are short and divergent. The dental plates are advancing. The adductor scars are small, lanceolate in shape, and impressed deeper than the diductors so as to form a "pit" in the center of the muscle field. The diductor scars are large and narrow, expanding slightly anteriorly. In most individuals the adjustor scars are elongate concavities at the base of the dental plates. The internal margins of the shell are crenulated with each crenulation bearing a faint, narrow groove.

The brachial valve is evenly convex with the highest point just posterior to the middle. The anterior slope is gentler than the posterior. The sulcus is shallow, beginning at the beak and expanding slightly toward the anterior margin. The sulcus is occupied by 3-4 costae. The interarea is orthocline to slightly anacline and shorter than in the pedicle valve. The notothyrial cavity is shallow; elevated above the floor. The cardinal process is strong; elevated well above the plane of the interarea. The myophore is crenulated. The brachiophores are strong and divergent with the extremities pointed and thin. The abrupt thinness of the brachiophore extremities is due to the small concavities on the exterior face at the tip of each brachiophore. The brachiophores are supported by thickened shell material. There is a shallow ridge on the top and along the entire length of each brachiophore. These ridges bound the notothyrial cavity. Small "socket-like" concavities occur on the inner face of the brachiophores. The hinge sockets are large and deep. The median septum is thick, short, thinning anteriorly. The adductor impressions are quadrate in shape with the anterior pair a little larger than the posterior pair.

Discussion: In regard to the number of marginal costae and costellae this species shows a modal class of 43-44, a median of 44, and an arithmetic mean of 44. Figure 24 is a plot of the shell width against

Figure 24

Plaesiomys proavita. Scatter diagram showing the relationship between the size of the shell and the number of marginal costae in specimens confidently referred to Plaesiomys proavita and specimens questionably referred to P. planus. For a more detailed explanation of the relationship of these two species see the discussion in the paleontological section under Plaesiomys proavita. The specimens are from localities A and C, Unit 3C, upper 6 feet.

Figure 25

Plaesiomys proavita. The regression lines and 95 percent confidence intervals for specimens of P. proavita and specimens questionably referred to P. planus. All specimens are from the upper 6 feet of the Viola Formation; localities A and C, Unit 3C, upper 6 feet.

P. proavita: mean length: 15.3, mean width: 19.8, initial growth index (a): 3.6, growth ratio (b): 1.0.

P. planus ?: mean length: 15.7, mean width: 19.8, initial growth index (a): -1.9, growth ratio (b): 1.4.

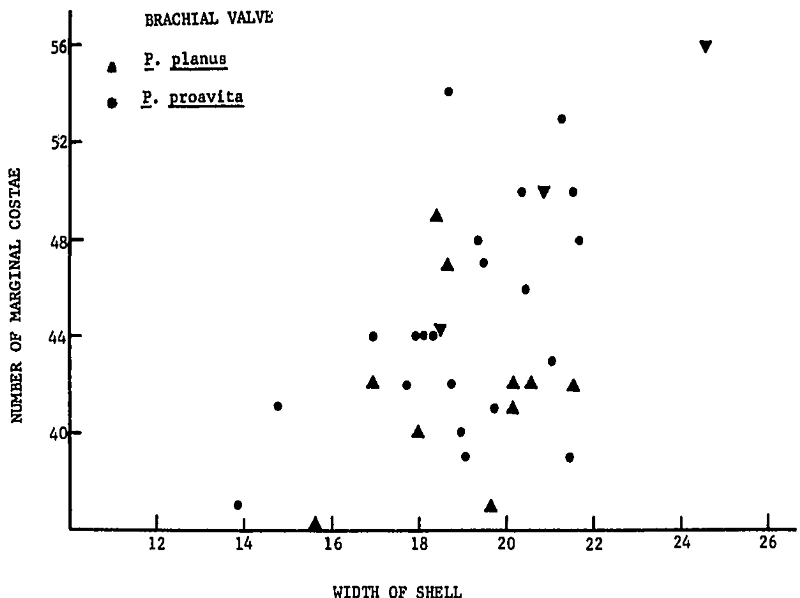


Figure 24

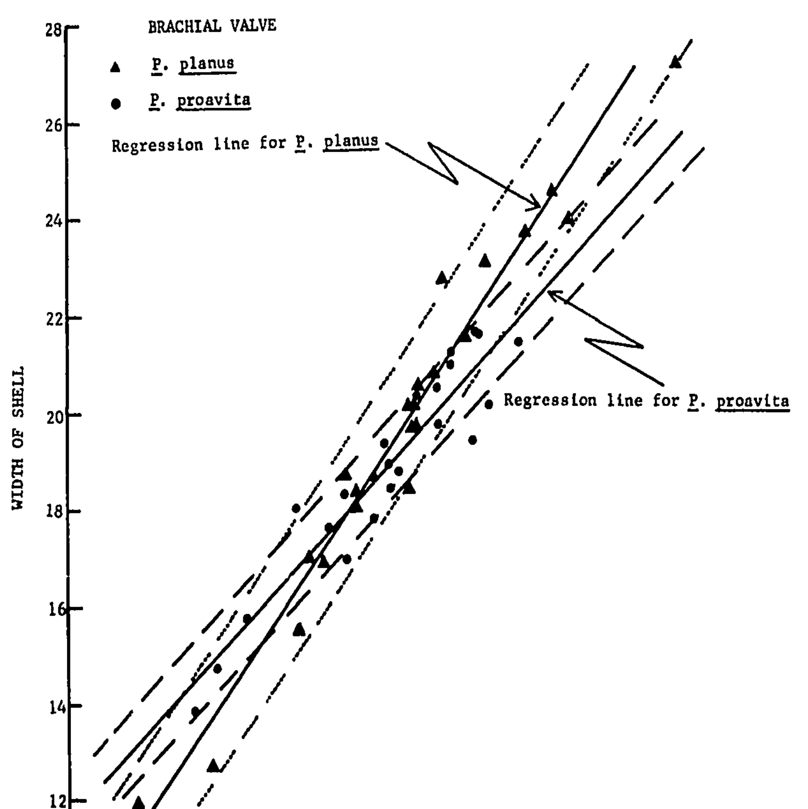


Figure 25

the number of marginal costae. The diagram clearly shows that for this species the bifrication of costae and costellae is not in all instances a direct function of growth. There are about an equal number of small shells having many costae as there are large shells having few costae. The number of costae increases by bifrication as growth continues, but the frequency of bifrication depends on the individual.

Wang (1949) described P. proavita (Winchell and Schuchert) as being characterized by strong mesial costae. However, in order to use such a criterion to characterize a species it would be essential to make statistical studies of a large number of specimens in order to determine its consistency. Wang (1949) did not report the number of individuals in which this character exists. Thus, it is difficult to evaluate the reliability of this character as far as its usefulness in differentiating the species.

The mesial costae in the Viola specimens bifricate, but do so very close to the beak. Only one specimen from the Viola clearly shows the mesial costae extending unbifricated from the beak to the anterior margin.

The basic costation pattern is one in which the 10-12 costae in the middle of the valve originate at or very close to the beak. These extend essentially unbifricated to the anterior margin of the shell. However, in well-preserved specimens early bifrication (near beak) of these mesial costae can be detected. Most bifrication occurs in the postero-lateral regions of the shell, and is almost always directed away from the median. Occasionally costae branch toward the median.

It is difficult to separate this species from P. planus Wang. One reportedly diagnostic feature about P. planus Wang is a groove on each side of the notothyrial platform which sets off the brachiophores. Internally, this seems to be the only way to separate the brachial valves of the two species. There are some specimens from the Viola Formation that have brachiophores which are clearly set off from the notothyrial platform by grooves (see figures 2b and 2e of Plate V). However, relying on this feature as a means of differentiation leads to uncertainty because there are specimens that have well-defined grooves, some with poorly defined grooves, and some with no grooves at all. P. planus Wang is also described as being characterized by the deep impressions of the pedicle adductor scars. Again there are some specimens from the Viola Formation that show this feature. However, a population of shells, all from the same locality and stratigraphic horizon, shows that the depth of impression is of varying magnitude. Thus, it is also difficult to separate species as being P. planus or P. proavita on the basis of the depth of the adductor muscle impressions.

In the Viola Formation there are shells occurring in the same 12 inch bed which possibly can be referred to these two species. This close association makes it very likely that they were members of the same biological population. Wang (1949) reported P. proavita from the Upper Elgin Member of the Maquoketa Formation in Springfield Township, and P. planus from the Upper Elgin Member in Orleans Township. From this information it seems that these two species are from the same stratigraphic horizon and are only geographically separated. The evidence from the Viola collections indicates that both could be members of the same species. Because of this the author has preferred to assign all the specimens to the older species, P. proavita, rather than to P. planus.

For purposes of comparison the author has designated as P. planus all those specimens that show either a deeply impressed adductor region in the pedicle valve, or well-developed grooves on the nothyrial platform. Using this differentiating technique the overlap in other characters (length, width, thickness, number of marginal costae and costellae) can be depicted. This overlap is shown in Figures 24, 25, and 26.

Distribution and Material: This is a fairly common species (40-50 specimens were collected and studied; most are dis-articulated, there is one articulated specimen). The species is restricted to the upper 6 feet of the formation at localities A, C, and D (shelf province). However, at localities G, I, and R (basin province) the species occurs 40-60 feet below the top of the formation. (See Figure 12.) P. proavita also occurs in the "Fernvale" (Cape) Limestone in northeastern Oklahoma.

Plaesiomys bellistriatus Wang, 1949

Plate III, figs. 6 and 7

Dinorthis subquadrata (Hall), Bassler, 1932, Pl. 24, fig. 14

Plaesiomys bellistriatus Wang, 1949, p. 7, Pl. 3, figs. D. H. J. Howe, 1966a, p. 245, Pl. 29, figs. 13, 15, 16, 17, 18.

Description: This species is large (36.5mm. in width, 32.0mm. in length). It is subquadrate in outline with the length slightly

Figure 26

The regression lines and 95 percent confidence intervals for specimens confidently referred to *Plaesiomys proavita* and specimens questionably referred to *P. planus*. For a more detailed explanation as to how these two species were differentiated see the discussion of *P. proavita* in the paleontological section. The specimens are from the upper 6 feet of Unit 3C at localities A and C. All measurements are in millimeters.

Plaesiomys proavita: *mean width*: 18.8, *mean thickness*: 4.2, *initial growth index* (a): -2.6, *growth ratio* (b): 0.4.

Plaesiomys planus ?: *mean width:* 20.1, *mean thickness*: 4.2, *initial growth index* (a): -0.7, *growth ratio* (b): 0.2.

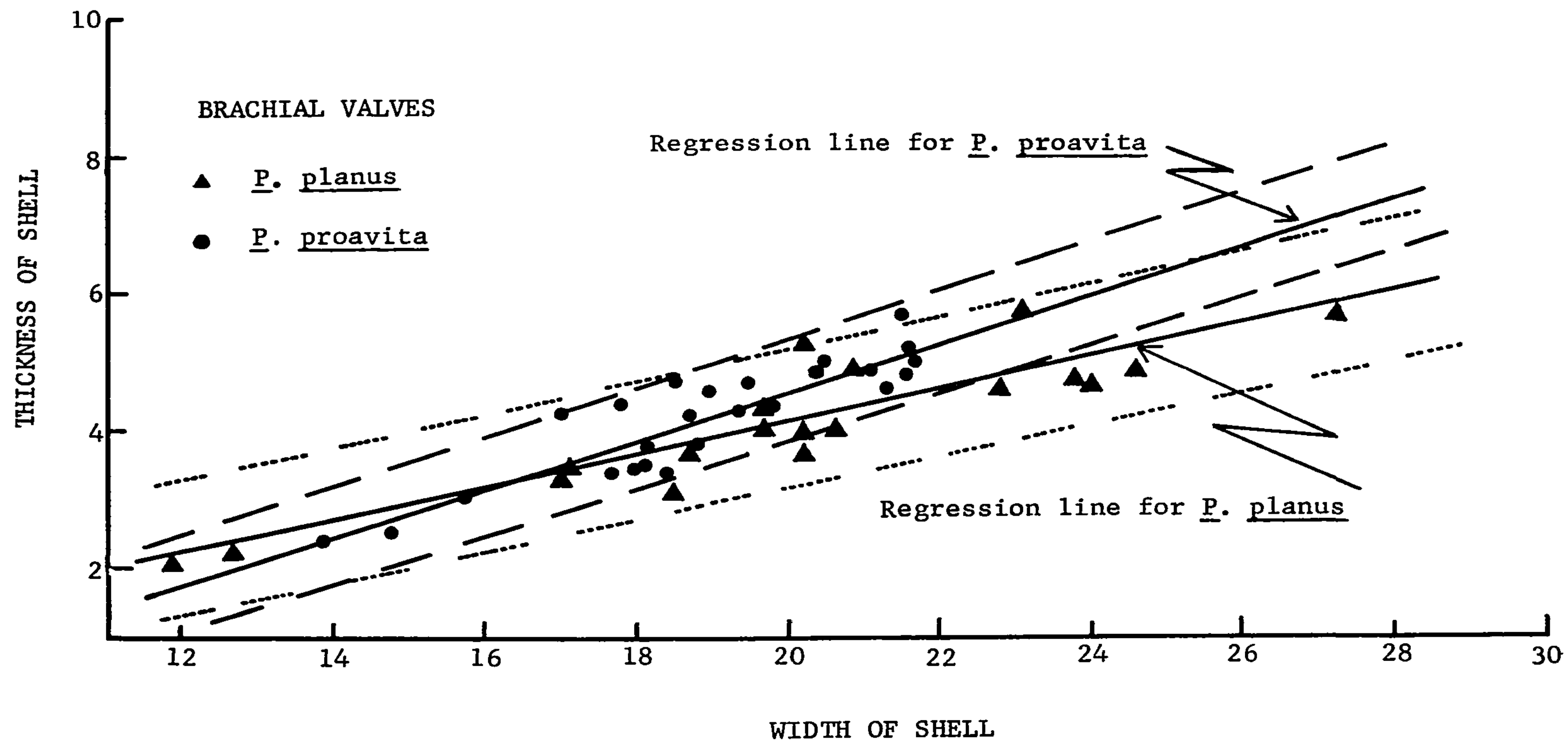

BRACHIAL VALVES
P. planus
P. proavita
Regression line for P. proavita
Regression line for P. planus
THICKNESS OF SHELL
WIDTH OF SHELL
10
8
6
4
2
12
14
16
18
20
22
24
26
28
30

Figure 26

shorter than the width. The hinge line is straight and two-thirds as wide as the maximum width. The cardinal extremities are at right angles and very sharply rounded. The lateral margins are broadly rounded while the anterior margin is straight and emarginate near the middle. The surface is multicostellate with about 150 costae and costellae around the margin of the largest individual (length: 32.0mm., width: 36.5mm.).

The pedicle valve is plane to very slightly convex with a narrow, slightly elevated fold extending from the beak to the anterior margin. The fold expands very little in an anterior direction and in most shells maintains about the same width throughout its extent. The umbonal region is swollen and the beak is extended past the interarea in a nearly straight position. The interarea is short and apsacline. The delthyrium is open and widely triangular with some secondary shell material added around the anterior margins tending to reduce the angle of opening. This condition is found in only one large specimen and is probably an old-age feature. The teeth are large, thick, and supported by massive, advancing dental plates. Crural fossettes are poorly developed, although a low subtle ridge is present in a few individuals. The delthyrial cavity is deep, and because of the lateral slope of the cavity walls it is much wider across the floor than across the opening. The muscle field is large (about 17.0mm. long and 17.0mm. wide), extending about half the length of the valve. (See figure 6b of Plate III.) It is essentially subquadrate in outline with the anterior margin emarginate. In the larger shells the muscle field is well defined due to the increase in shell material around the margins. The adductor track is obscure in most shells, and in the largest specimen is represented only by a low elongate elevation along the middle of the field. It is narrow and does not widen toward the anterior. The diductor scars are the largest in the field. They are divergent and expand anteriorly. The adjustor scars are large; almost as large as the diductors. They are widely divergent and expand in an antero-lateral direction. These scars are well embedded, positioned between the diductors and the dental plates. The adjustor scars are divisible into three parts, particularly in the anterior portion of the field. In addition, the scars are grooved and show a more roughened surface than the diductors. The extreme margins of the shell are crenulated, with each crenulation the same size as the surface costae. The width of this corrugated band is only 2mm.

In lateral profile the brachial valve is convex with the highest point in the middle. The degree of curvature from posterior to anterior remains about the same. There is a broad shallow sulcus which is first perceptible just posterior to the middle. It expands slightly and becomes deeper anteriorly. The postero-lateral regions are weakly concave due to the upturned nature of the cardinal extremities. The interarea is short and orthocline. The margins of the notothyrium form an angle of about 80 degrees. The floor of the notothyrial cavity is highly elevated and almost completely occupied by a robust cardinal process. The process is curved in a postero-ventral direction. The highest and widest point of the process is in the middle of the cavity at which position it is above the level of the interarea. The junction of the shaft and myophore is also at this position. The myophore is grooved throughout. (See figs, 7f, Pl. III.) From its highest point it thins rapidly toward the posterior of the notothyrial cavity. (See

Pl. III, figs. 7e and 7f.) The shaft is rounded and thick; at its thickest point almost as wide as the cavity. The brachiophores are stout and divergent; supported laterally by additional shell material. The sockets are large and deep. The median septum is thick immediately below the cavity floor, but flattens and disappears in a short distance. There were no muscle scars observed. A narrow rounded ridge, about 2-3mm. wide, extends around the lateral and anterior margins of the shell. Lying just outside this ridge and exactly at the edge of the shell is a thin band of corrugations; the same as in the pedicle valve. (See Pl. III, fig. 7b.)

Discussion: Plaesiomys bellistriatus provides important biostratigraphic information. It occurs in the Aleman Limestone of West Texas and New Mexico and also in the Brainard Member of the Maquoketa Formation of Iowa. The occurrence of this species in Unit 2 of the Viola Formation at Locality G, 60-75 feet below the top of the formation, suggests a Cincinnatian and not a Trentonian age for the upper part of Unit 2.

Wang (1949), in erecting this species did not describe figure specimens showing interiors. Howe (1966a) reported the occurrence of this species from the Montoya Group, but gave no information on the character of the internal features.

Distribution and Material: This species is not very abundant in the Viola Formation of the Arbuckle Mountains. It has been found at Locality G, 60-75 feet below the top of the formation (Unit 2). It also occurs at Locality I, 50-60 feet below the top of the Viola Formation

(Unit 3CM). P. bellistriatus seems to occur in slightly greater numbers in the "Fernvale" (Cape) Limestone in northeastern Oklahoma.

There is one complete brachial valve, one complete pedicle valve, and several partial valves. The description above is based on only this small collection.

Genus Austinella Foerste, 1909

Austinella n.sp.

Plate II, figs. 1-9

Description: The shell is large (see Figure 27 for length and width dimensions) and subquadrate in outline. The largest specimen attains a width of almost 35mm. In most specimens the cardinal margins are obtuse or at right angles. The antero-lateral margins are gently rounded with the anterior margin broadly rounded. In lateral profile the shell is unequally biconvex with the pedicle valve more convex than the brachial (on the average the pedicle valve measures 1-2mm. more in thickness). The lateral commissure is rectimarginate and the anterior commissure is gently sulcate. The hinge line is straight. The widest part of the shell is at the middle or just posterior to the middle. The surface is multicostellate. There are seven costae and costellae in a space of 2mm. at a distance of 6.5mm. from the beak. The number of costae and costellae around the margins varies with the shell size. The first generation of costellae arise within 2-3mm. of the umbo. Strong growth lines are rare and in a few specimens growth lines are completely absent.

Figure 27

Austinella n.sp. Regression line and 95 percent confidence interval for the width-length dimensions for the brachial valves from Locality A, Unit 3C, upper 6 feet. The width measurements were taken as maximum widths which in almost all specimens were about equal to the hinge line widths. The dashed line represents the growth pattern taken from one specimen of A. kankakensis (McChesney) figured by Wang (1949) as figure B on Plate 2. The three length-width values were taken from the three well-defined growth lines on the specimens. The width measurements were taken along the hinge line.

Mean width: 23.1, mean length: 18.4, initial growth index (a): -0.1, growth ratio (b): 0.8.

Figure 28

Austinella n.sp. Regression line and 95 percent confidence interval for the length of shell-length of inter-area dimensions for the pedicle valves from Locality A, Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean length: 20.5, mean length of interarea: 3.6, initial growth index (a): 0.9, growth ratio (b): 0.2.

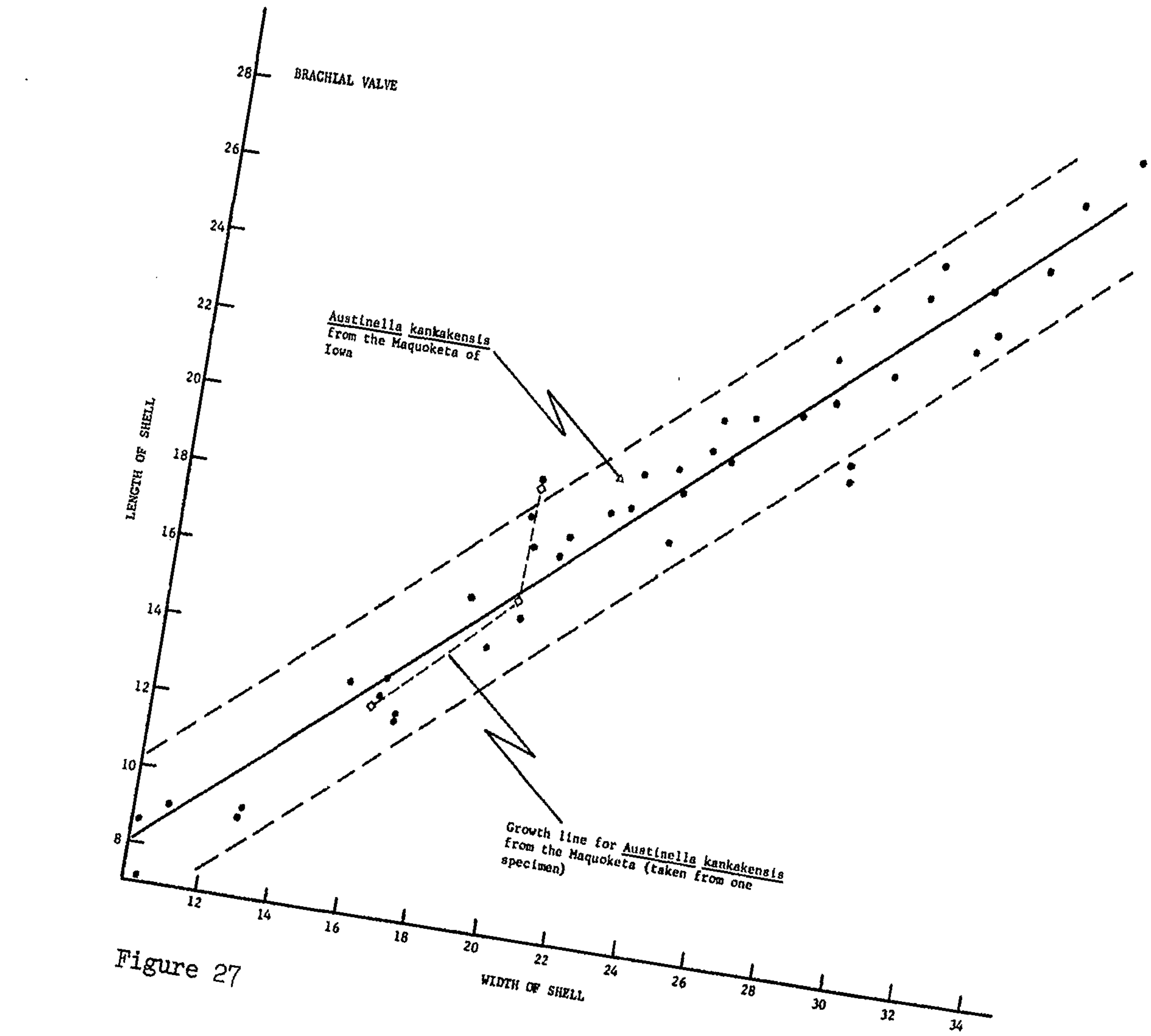


Figure 27

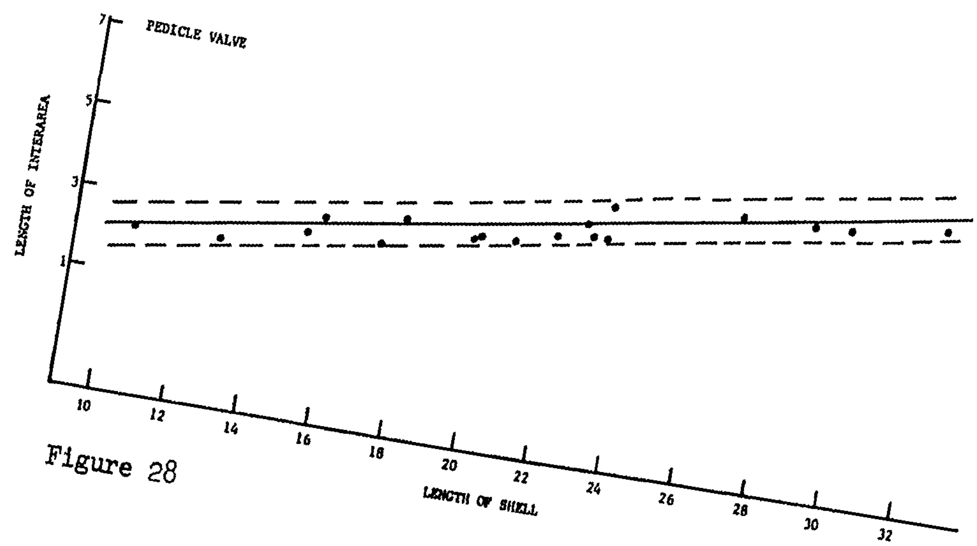


Figure 28

Length (mm.)	Width (mm.)	Number of Marginal Costae
17.7	23.8	64
12.2	16.9	63
29.3	35.3	97
24.4	28.6	75

The dorsal valve is very evenly convex with the highest point just posterior to the middle. A shallow sulcus is present immediately anterior to the beak and remains weak as it extends toward the anterior margin. The interarea is short, slightly curved, and anacline. The notothyrial cavity is shallow and raised above the floor of the valve. The cardinal process is stout and about half as thick as the median septum. A blade-like extension connects the process to the posterior of the cavity. In some specimens faint crenulations are visible along the myophore. The brachiophores are sharp, long, and triangular in shape with the extremities pointed. There is a slight groove or elongated concavity along the inner face of each brachiophore. The posterior adductor scars are elevated slightly above the level of the anterior scars. On each posterior scar there are two faint ridges which extend anteriorly to about the middle of the scar. The posterior scars are a little larger than the anterior ones. The muscle field is about one-third the length of the shell. (See Plate II, fig. 2b.) A thick median ridge extends anteriorly the full length of the muscle field. Along the anterior top of the septum there is a small secondary keel-like ridge. (See Plate II, figs. 9b and 2c.) The dental sockets are triangular and small.

The pedicle valve is evenly convex in lateral profile. (See Plate II, fig. 5d.) The interarea is curved and apscaline; longer than in the brachial valve. The delthyrial opening is triangular and the cavity deep. The dental plates are strong and advancing. The teeth are small. The muscle field is triangular in shape and deeply impressed. The field is bounded by thick shell deposits causing it to be elevated around the anterior and lateral margins. This additional shell material joins and is continuous with the forward projection of the dental plates. The adductor track is elongated and expands anteriorly. The diductor scars are elongate and divergent. In younger specimens the diductor tracks extend farther anteriorly than the adductors, thereby giving the anterior margin of the muscle field a concave appearance. In older shells, however, the adductor tracks extend as far as the diductors giving a sinuous pattern to the anterior margin of the field. Plate II, figures 5a, 6a, 7a, and 8a show the variation in the shape of the pedicle muscle field.

Discussion: The specimens from the Viola Formation compare most closely to *Austinella kankakensis* (McChesney) from the Maquoketa Formation of Iowa. The Viola species differs from *A. kankakensis* primarily by having a greater number of costae and costellae. However, the greater overall size, the different growth pattern, and the lack of strong, numerous growth lines in Austinella n.sp. are features which may or may not be distinctive in differentiating the species.

The figured hypotype of Wang (1949) has a maximum size approaching that of the average Viola species. Figure 27 shows the length-width data for a group of specimens from Locality A. Figure 33 shows that the largest specimens of Austinella n.sp. are slightly larger than A. kankakensis and A. whitfieldi, although there is overlap.

By studying the growth lines on the figured hypotype of Wang (1949) it appears that growth laterally along the hinge lines ceased when the shell length reached approximately 15.5mm. Growth continued, however, in the anterior, antero-lateral, and postero-lateral directions, although at decreasing rates from the anterior to the postero-lateral regions. Such a growth pattern gives the lateral margins a rounded appearance when viewed dorsally. However, many of the specimens in the United States National Museum do not show this growth pattern, but rather one similar to Austinella n.sp.

Strong growth lines, particularly in the larger individuals, are found in many specimens of A. kankakensis. Wang (1949) characterized A. kankakensis by these growth lines, but the taxonomic value of such a feature is doubtful. The shells of Austinella n.sp. seldom have growth lines and none are developed to the extent that they are in A. kankakensis.

The only difference between A. kankakensis (McChesney) and A. whitfieldi (Winchell) is reported to be the more numerous costae in the former. Although the majority of the specimens from the Viola compare more favorably with A. kankakensis, there are shells which show a gradation from smaller, more numerous costae resembling A. kankakensis, to fewer, more widely-spaced costae resembling A. whitfieldi. Plate II, figures 1a, 2a, 3a, and 4a show the variation in the costation of Austinella n.sp.

Austinella n.sp. is set apart from all others previously described primarily because of its *finer*, *more numerous* costae and costellae. Figure 33 shows the relationship between the number of marginal costae and the size of the valve of *A. kankakensis*, *A. whitfieldi*, *Austinella* n.sp. (from the Viola Formation, Arbuckle Mountains), and *Austinella* n.sp. (from the "Fernvale" (Cape) Limestone in northeastern Oklahoma). This figure is not definitive in itself for it 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 *Austinella* n.sp. (A segment is defined (Bancroft, 1928) as all those costae related to a primary costae. A primary costae is one that originates at the beak. Therefore, a segment is composed of all those costae which branch from the primary costae as well as all those costae which arise from these initial and subsequent branches.) In the following table all the counts were made at a distance of 6.5 mm. from the beak.

Austinella kankakensis	*Austinella n.sp.*
10	11
10	12
11	15
12	15
12	15
12	15
12	17

Austinella kankakensis	Austinella n.sp.
12	17
13	18
13	18
13	18
13	18
15	19
17	19
--	19
--	19
--	20
--	20
--	20

Distribution and Material: This species is confined to the upper 6 feet of the Viola Formation at localities A, C, D, and L (Unit 3C). At sections I and R it occurs 40-60 feet below the top of the formation (Unit 3CM).

This is one of the most common species in the Viola Formation. More than 100 individual valves were collected and studied. No articulated specimens were found.

Austinella n.sp. occurs in large numbers in the "Fernvale" (Cape) Limestone in northeast Oklahoma. The writer studied many specimens of this species from northeast Oklahoma and found them to be identical to the ones in the Arbuckle Mountains.

Figure 29

Austinella n.sp. The regression line and 95 percent confidence interval for the length of shell-length of interarea dimensions for the brachial valves from Locality A, Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean length: 18.1, mean length of interarea: 2.2, initial growth index (a): 0.4, growth ratio (b): 0.1.

Figure 30

Austinella n.sp. The regression line and 95 percent confidence interval for the length of shell-length of muscle area dimensions for the pedicle valves from Locality A, Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean length: 22.6, mean length of muscle area: 8.7, initial growth index (a) -0.8, growth ratio (b): 0.4.

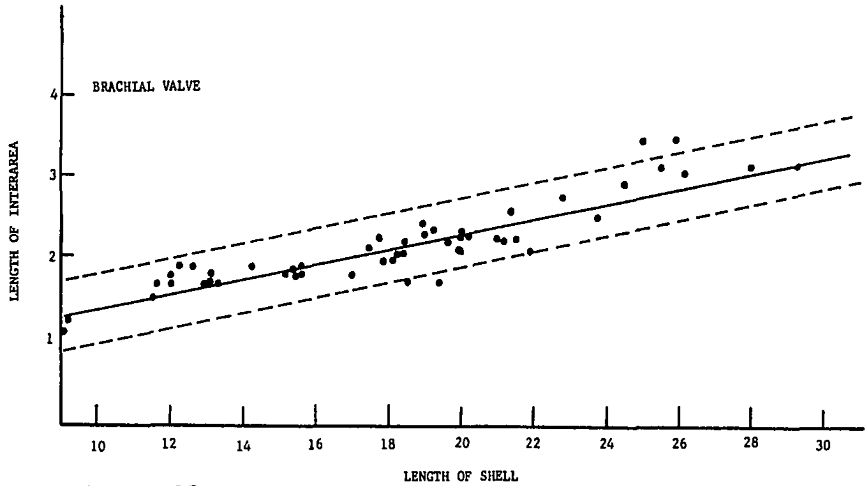


Figure 29

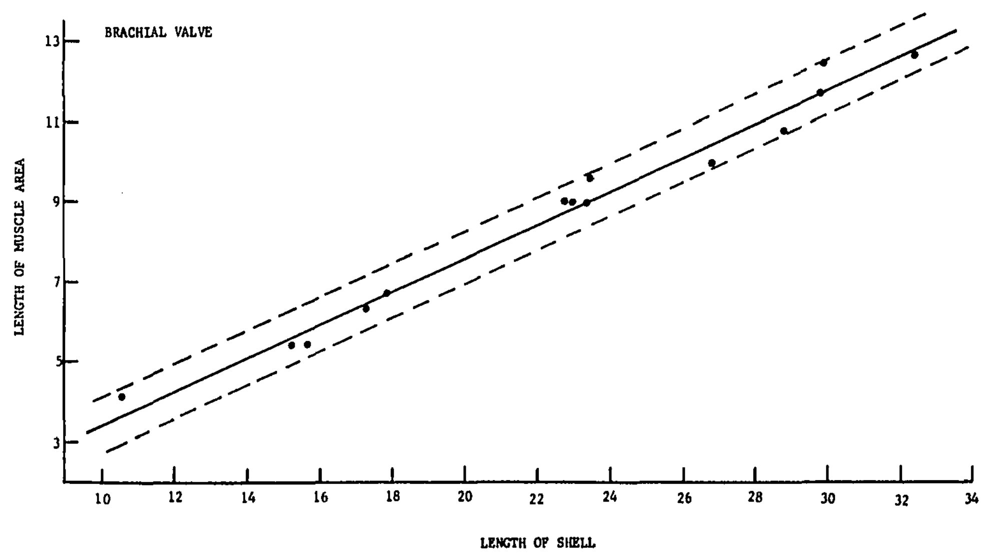


Figure 30

Figure 31

Austinella n.sp. The regression line and the 95 percent confidence interval for the length-thickness dimensions for the brachial valves from Locality A, Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean length: 18.0, mean thickness: 3.6, initial growth index (a): -0.3, growth ratio (b): 0.2.

Figure 32

Austinella n.sp. The regression line and the 95 percent confidence interval for the length-thickness for the pedicle valves from Locality A, unit 3C, upper 6 feet. All measurments are in millimeters.

Mean length: 20.7, mean thickness: 5.9, initial growth index (a): 0.5, growth ratio (b): 0.3.

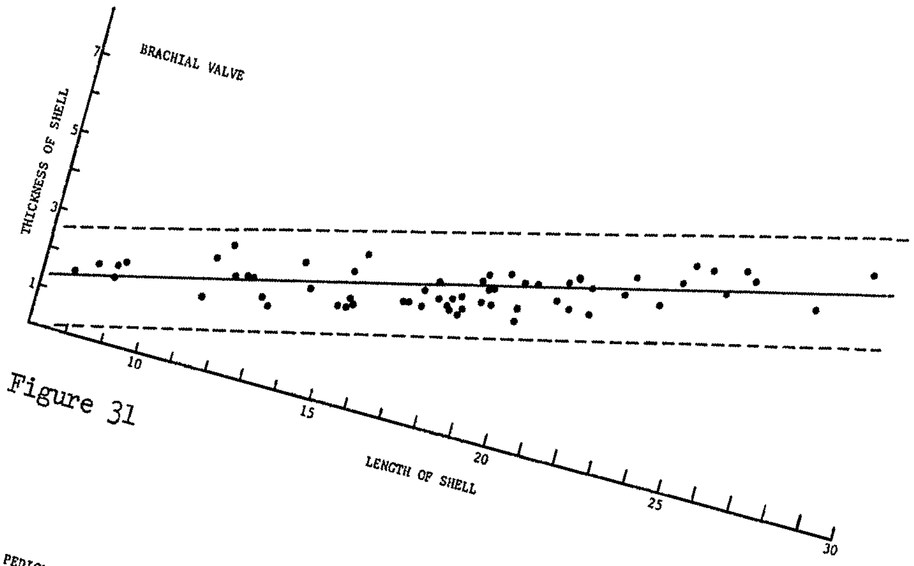


Figure 31

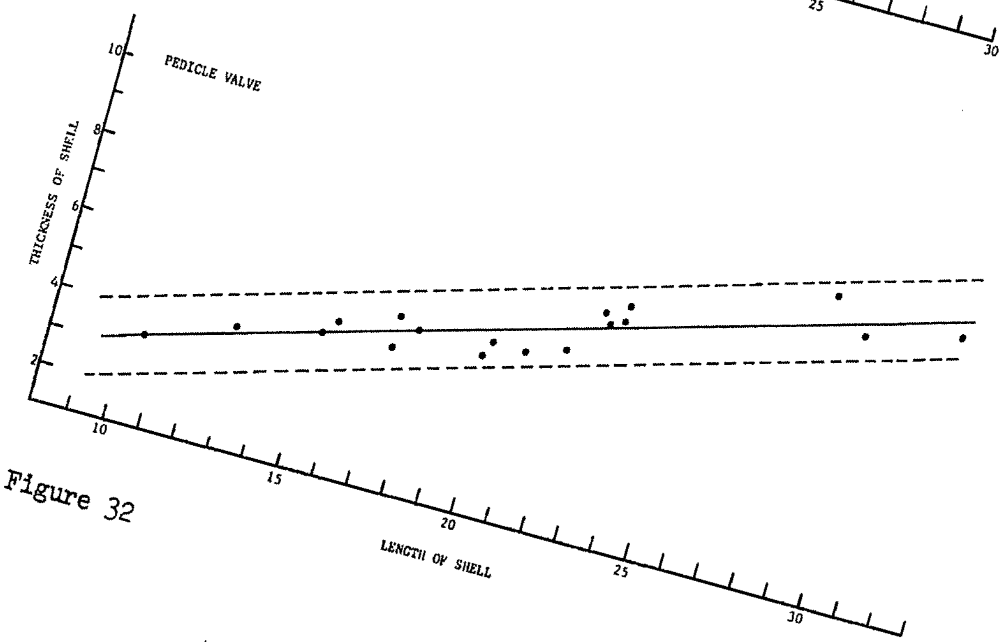


Figure 32

Figure 33

Scatter diagram showing the relationship between the number of marginal costae and the size of the shell (expressed in terms of the length of the brachial valve) for specimens of *Austinella* n.sp., *A. whitfieldi*, and *A. kankakensis*. Although there is a slight overlap the specimens of *Austinella* n.sp. attain a larger size than the other species. See the discussion of this new species in the paleontological section for a more detailed explanation of its characteristic features.

The length of the brachial valve is expressed in millimeters.

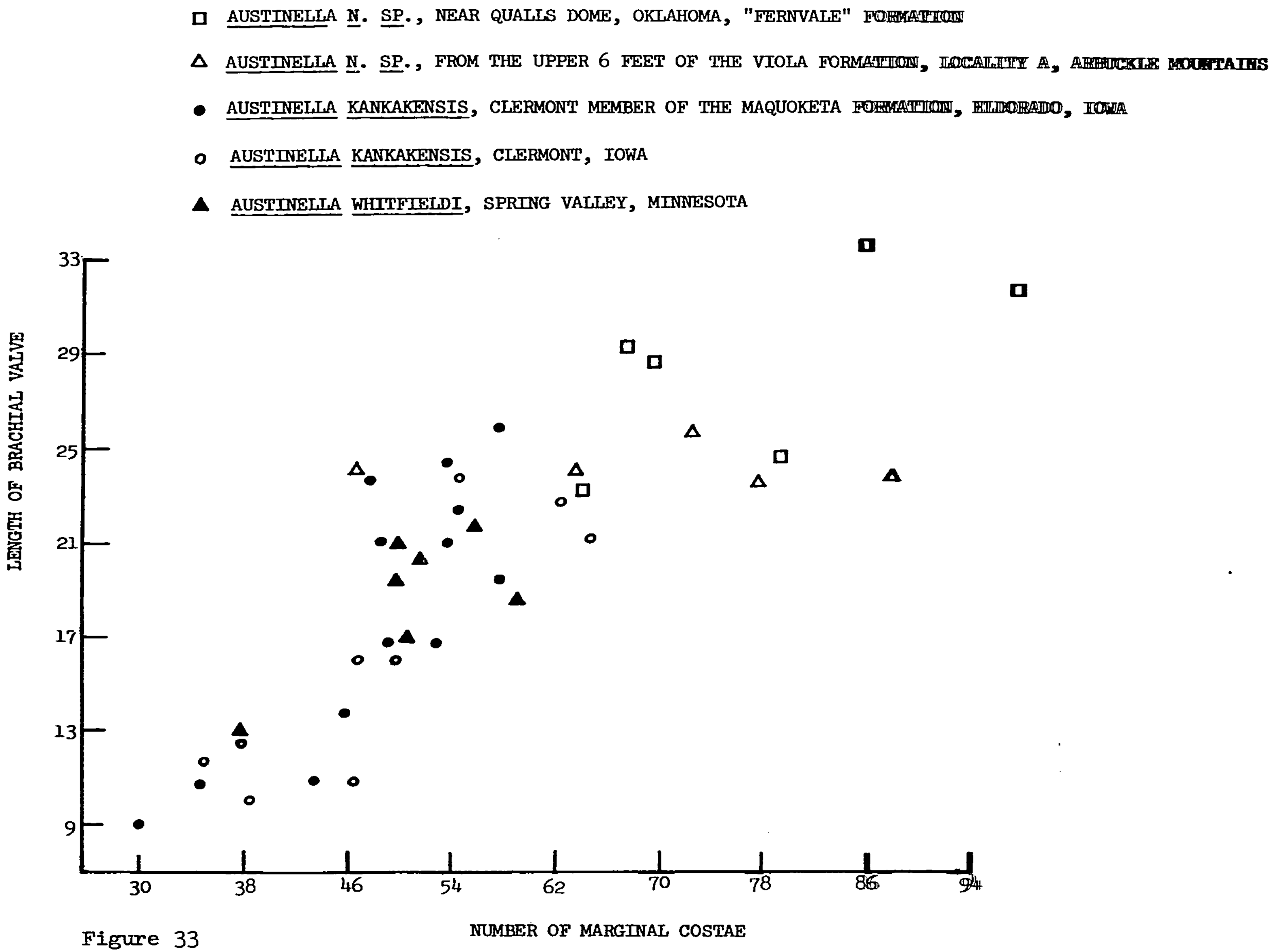

AUSTINELLA N. SP., NEAR QUALLS DOME, OKLAHOMA, "FERNVALE" FORMATION
AUSTINELLA N. SP., FROM THE UPPER 6 FEET OF THE VIOLA FORMATION, LOCALITY A, ARBUCKLE MOUNTAINS
AUSTINELLA KANKAKENSIS, CLERMONT MEMBER OF THE MAQUOKETA FORMATION, ELDORADO, IOWA
AUSTINELLA KANKAKENSIS, CLERMONT, IOWA
AUSTINELLA WHITFIELDI, SPRING VALLEY, MINNESOTA
LENGTH OF BRACHIAL VALVE
33
29
25
21
17
13
9
30
38
46
54
62
70
78
86
94
NUMBER OF MARGINAL COSTAE

Figure 33

Genus Dinorthis Hall and Clarke, 1892

Dinorthis pectinella (Emmons), 1842

Plate VIII, 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: The shell is moderate in size and almost circular in outline (dimensions are given below). The hinge line is straight and shorter than the width of the shell. The cardinal extremities are rounded. The curvature of the lateral and anterior margins is of about the same magnitude. Both the lateral and anterior commissures are rectimarginate. In lateral profile the brachial valve has an even curvature from posterior to anterior. The surface is paucicostate. At 10mm. from the beak there are about four costae in a space of 5mm. The costae are low with broadly rounded tops. In one specimen the interspaces between the costae are about the same width as the costae. In another specimen these interspaces, particularly around the shell margin, are twice as wide as the costae. In profile, the costae and interspaces form a smooth sinumous curve.

The brachial interarea is short, plane, and orthocline. The cardinal process is a rounded knob which does not protrude much above the level of the interarea. The cardinal process is separated from the interarea by concavities. The brachiophores are short and rounded; joined to the floor of the valve by thick shell deposits. A low median septum extends anteriorly from just below the cardinal process to about one-fourth the valve length. No muscle scars were observed. The anterior and lateral margins of the valve are crenulated.

Discussion: There were only two brachial valves well enough preserved for study. Their measurements are given below.

Length	Width	Thickness	Hinge Line Width	No. of Marginal Costae
18.0mm.	19.2mm.	--	--	20
20.4mm.	21.8mm.	6.8mm.	12.5mm.	25

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

Length	Width	Hinge Line Width	Number of Marginal Costae
8.8mm.	11.0mm.	6.9mm.	22
9.8mm.	9.6mm.	6.3mm.	19
10.1mm.	12.8mm.	9.0mm.	21
11.5mm.	13.9mm.	14.2mm.	21
11.5mm.	13.8mm.	9.8mm.	24

Length	Width	Hinge Line Width	Number of Marginal Costae
11.8mm.	14.6mm.	11.0mm.	25
13.0mm.	15.0mm.	9.4mm.	24
14.1mm.	16.4mm.	13.5mm.	25
15.2mm.	18.9mm.	14.4mm.	24
15.4mm.	17.0mm.	12.1mm.	22
16.0mm.	20.0mm.	11.4mm.	25
17.0mm.	20.0mm.	11.9mm.	24
17.5mm.	20.8mm.	14.8mm.	20
17.8mm.	20.6mm.	12.0mm.	20
18.2mm.	22.0mm.	16.6mm.	18

Distribution and Material: This species is found only at Locality D, 120-160 feet above the base of the formation (Unit 2).

This species is fairly common in Unit 2 at Locality D. About 15-20 valves and partial valves were collected. All of the specimens had to be cracked out of the rock and cleaned with a needle and vibratool. No pedicle valves were found.

Dinorthis cf. D. transversa Willard, 1928

Plate VIII, figs. 6, 7, and 8

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

Description: This species is subcircular in outline with the hinge line straight and just about the widest part of the shell. The cardinal extremities are at right angles. The lateral and antero-lateral margins form a gentle smooth curve leading into a more gently curved or straight anterior margin. In lateral profile the shell is unequally biconvex, almost plane-convex with the thickest part occurring just posterior to the middle. There is a broad shallow sulcus along the median anterior two-thirds of the pedicle valve. The lateral commissure is rectimarginate to weakly sulcate. The anterior commissure is broadly uniplicate, although there is no fold as well defined in the brachial valve as there is a sulcus in the pedicle valve. The surface is multicostellate with about 18-20 costae around the beak in a specimen measuring 15.5mm. in length and 21.3mm. in width. In profile the costae and costellae have evenly rounded tops and sides. At a distance of 5mm. from the beak there are three costae in a space of 2mm.

The pedicle interarea is plane, about three times as long as the brachial interarea, strongly apsacline to almost catacline. The delthyrium is triangular and open. The cavity is shallow and even with the floor of the valve. The teeth are short with rounded extremities. The dental plates are thin, divergent, and receding. They join with the posterior part of the margins of the muscle field. The muscle field is cordate in shape with a slightly elevated ridge extending down the middle from posterior to anterior. The lateral margins of the field are slightly raised and joined posteriorly to the dental plates. The diductor scars are large, ellipsoidal in shape, and separated by the median elevation. The position of the adductor scars is obscure, but weak impressions appear to be present on the posterior one-half of the ridge. These narrow "scars" are about one-half the length of the field.

The brachial interarea is short, plane, and orthocline. The cardinal process extends in a postero-ventral direction. The myophore is crenulated and circular in shape. The delthyrium is triangular, wide, and open. The cavity is wide and moderately deep; elevated above the floor of the valve. The shaft portion of the process is about one-third as wide as the cavity. The brachiophores are short and divergent. The sockets are well developed. The tops of the brachiophores slope laterally toward the sockets and form part of the socket floor. Part of the sockets extend beneath the interarea. There is a low, rounded median septum which extends anteriorly about 2-3mm. The anterior two-thirds of the valve interior faintly reflects the external costation.

Discussion: There are only a few specimens from the Viola Formation; all of which have the numerous bifricating costae as does *D. transversa* Willard. However, there are no specimens showing the flattened or concave pedicle valve like *D. transversa* Willard. In lateral profile the Viola specimens are more similar to *D. sweeneyi* (Winchell). However, that species has costae which rarely bifricate; costae increase in size as the shell increases in size.

The majority of specimens of *D. transversa* Willard in the United States National Museum are from the Benbolt and Ottosee Formations.

Distribution and Material: This species is found only at Locality D; Unit 2, 275-280 feet below the top of the formation.

Only one articulated specimen was found. Several partial brachial and pedicle valves were also collected.

Family Plectorthidae Schuchert and LeVene, 1929

Genus Doleroides Cooper, 1930

Doleroides n.sp.

Plate IX, figs. 1 and 2

Description: The shell is ellipsoidal in outline with the width greater than the length. The cardinal extremities are obtuse to rounded. The lateral margins are rounded with the widest part of the shell at the middle. The anterior margin is broadly rounded to straight. The hinge line is straight and a little more than one-half the maximum width of the shell. The lateral commissure is rectimarginate and the anterior commissure is faintly uniplicate. In lateral profile the shell is equally biconvex. The surface is covered by numerous fine costae which are weakly developed in the umbonal region, but become more pronounced in the anterior. There are numerous costellae, most of which arise by bifrication. The poor preservation of the surface elements makes it difficult to tell if there are any intercalated costellae. There are 4-5 costae and costellae in a space of 2mm. at a distance of 9mm. from the beak.

In lateral profile the thickest part of the pedicle valve is posterior to the middle. The interarea is plane, long (about 2.4mm.), and apsacline. The delthyrium is triangular and open. The cavity is moderately deep and just about at the same level as the valve floor. The teeth are short rounded knobs extending very little past the hinge line. The dental plates are well developed and slightly advancing. They join with the floor of the valve and are continuous with the margins of the muscle field. The field is elongate in shape. The diductor scars are ellipsoidal in shape, not divergent, and impressed deeper than the laterally positioned adjustor scars. The adductor scars are not well defined, but there is a rather wide, slightly elevated area in the center of the field separating the diductor scars. The adjustor scars are partially impressed into the bases of the dental plates. The entire muscle field, from the posterior tip of the cavity to the anterior most edge, is about 5.6mm. long. The anterior margin does not reach to the middle of the valve. No pallial markings were observed.

In lateral profile the thickest part of the brachial valve is in the middle. The interarea is short, plane, and orthocline to slightly anacline. The notothyrium is open. The cardinal process has a thick shaft and a triangular-shaped crenulated myophore. The myophore thins toward the posterior and does not extend above the level of the interarea. The process is separated from the interarea by deep concavities, the floors of which are curved and continuous with the stout brachiophores. At the base of the cardinal process there are two distinct grooves which may have been the position of attachment of the diductor muscles (not all specimens have these grooves). The sockets are thin, slit-like grooves positioned on top of the brachiophores and partially beneath the hinge. The muscle field is quadrate in shape with the posterior and anterior scars about equal in size. There is a low, poorly-developed median septum extending almost to the middle of the valve.

Discussion: The table below are the dimensions for the brachial and pedicle valves figured on Plate IX (figs. 1a, 1b, 1c, 2a, and 2c).

Brachial Valve		Pedicle Valve	
Thickness	. . 4.2mm.	Thickness	. . 4.1mm.
Length	. . 11.0mm.	Length	. . 11.7mm.
Interarea	. . 1.0mm.	Width	. . 14.4mm.
		Interarea	. . 2.4mm.

This species is similar to *D. oklahomensis* Cooper from the Bromide Formation. The primary difference between *D. oklahomensis* Cooper and this species from the lower Viola is in the finer and more weakly developed costae and costellae in the Viola species. *D. oklahomensis* Cooper has well-developed costae in the posterior parts of the shell, particularly around the beak. The species from the lower Viola Formation has poorly-developed costae around the beak, and in most specimens this area of the shell is almost smooth. (See Plate IX, figs. 1a and 2a.)

Cooper (1956, p. 120-121) subdivided the upper part of the Bromide Formation in the Arbuckle Mountains into several biostratigraphic zones. The *D. oklahomensis* zone is the second one from the top of the formation. The thicknesses of the zones varies from locality to locality, and at some localities one or more of the zones are missing. Cooper (1956) gave no absolute thicknesses for any of these biostratigraphic zones and therefore, it is difficult to say just how much rock is present between the *D. oklahomensis* zone and the base of the Viola Formation.

The United States National Museum collections contain specimens identical to those described here as being from the lower Viola, but labeled as being from the top of the Bromide Formation. These National Museum specimens apparently are not from the D. oklahomensis zone which is lower in the Bromide. It is possible that the National Museum specimens (labeled as being from the top of the Bromide) could be mislabeled, and are actually from the lower Viola Formation.

The specimens collected and described by the writer are from the lower one foot of the Viola Formation at localities D and L. At both localities the unconformable contact between the Viola and the Bromide is marked by a welded contact. At these localities the Bromide is a dense lithographic micritic limestone, and 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. The writer has no personal knowledge of the possible presence of this species below the Viola Formation.

Distribution and Material: This species was found only at localities D and L; in the lower one foot of the formation (Unit 1C).

About 20 silicified valves were collected. There were no articulated specimens found.

Genus *Platystrophia* King, 1850

Platystrophia n.sp. A

Plate III, figs. 4 and 5

Description: This species is spiriferoid in outline with the widest part of the shell at the hinge line. The cardinal extremities are pointed forming an angle of about 50 degrees. Some shells do not show this acute an angle, although no shells have a cardinal angle greater than 80-90 degrees. The shell is biconvex with the brachial valve a little deeper. The greatest thickness is in the middle or just posterior to the middle. The lateral commissure is faintly convex and the anterior commissure is strongly uniplicate. There is a well-developed, moderately deep sulcus on the pedicle valve. It originates at the beak and expands anteriorly; occupied by three plications. The brachial valve bears a prominent fold having four plications. The fold originates at the beak and expands toward the anterior. The flanks bounding the fold and sulcus are gently convex and ornamented by 10-12 plications.

The pedicle interarea is apsacline, slightly curved near the beak, but plane over its greater portion. It is a little longer than in the brachial valve. The beak is suberect. A foramen is present; permesothyroid. The delthyrium is triangular and open; the cavity deep. The teeth are short, triangular, and positioned at the side of the delthyrium. The dental plates are rather thick and advancing. These are joined and continuous with the lateral margins of the ellipsoid-shaped muscle field. The field extends a little less than one-half the length of the valve. (See Figure 38.) The anterior end of the field is convex and elevated. A low, frail ridge is present in the anterior two-thirds of the muscle field. The adductor scars are not clearly visible. The diductor scars are large and elongate, expanding slightly anteriorly. The adjustor scars are large and triangular, positioned at the base and somewhat on the walls of the cavity. The crural fossettes are shallow.

The internal margins of the valve are crenulated. These crenulations are the internal reflections of the external plications.

The brachial interarea is shorter than in the pedicle valve and more strongly curved, orthocline. The beak is slightly incurved. The notothyrium is triangular and open. The cavity is moderately deep and elevated above the level of the valve floor. The cardinal process is a well-defined, narrow ridge which extends the entire length of the cavity. It does not reach the level of the interarea at its highest posterior end. The brachiophores are thick, with rounded extremities. The sockets are rounded and deep, causing the brachiophores to appear "hooked." The inner faces of the brachiophores are strongly swollen to form distinct ridges. The median septum is broad and rounded beneath the notothyrial cavity, but thins to a sharp ridge at the anterior end of the muscle field. (See Plate III, fig. 5b.) The anterior adductor scars are triangular and larger than the posterior pair which are small elongated "pits." An oblique ridge separates the posterior and anterior pairs. There is a third set of muscle scars situated just under the brachiophores and posterior to the normal four adductor impressions. These are very small "pits" which could represent another set of adductor scars, or a set of adjustor scars. Thus, there are six muscle scars in the brachial valve of this species.

Discussion: Schuchert and Cooper (1932) noted that the brachial valves of some Orthid genera have six scars. They state (p. 39):

> In many genera the anterior adductor impressions are clearly divisible each into two parts (notably true in Productorthis, see pl. 3, fig. 11), so that there are evidently six scars in the adductor field. This third "adductor" set may represent adjustor

> muscles whose ventral attachments are on the pedicle and are thus not recorded by a corresponding set of impressions on the ventral valve. It is possible also that the adductor muscles trifurcate in their passage from the ventral to the dorsal valve.

As far as the writer knows this is the first reported occurrence of six "adductor" scars in the brachial valve of a species of Platystrophia.

This species is easily distinguished from Platystrophia n.sp. B by having a thinner shell, less elongate pedicle muscle field (compare figure 4b to figure 1b on Plate III), a spiriferoid shape (compare Figure 35 with Figure 43), and a different length-width growth pattern (compare Figure 34 with Figure 42).

Platystrophia n.sp. A resembles Platystrophia n.sp. C, particularly in external appearance. However, Platystrophia n.sp. C has only four adductor muscle scars in the brachial valve. (See figure 3b, Plate VIII.)

This new species differs from P. equiconvexa Wang from the Maquoketa Formation by having an inequivalved lateral profile and a spiriferoid outline.

Platystrophia n.sp. A is similar in outline to an unnamed species of Platystrophia reported by Howe (1966a) from the Montoya Group of West Texas and New Mexico.

Distribution and Material: This species is represented by only 10-15 specimens. There are no articulated specimens. The species is confined to the upper 6 feet of the Viola Formation at localities A, C, and D (Unit 3C). In the basin province it is found 40-60 feet below the top of the formation at localities I and R (Unit 3CM).

Platystrophia n.sp. A also occurs in the "Fernvale" (Cape) Limestone in northeastern Oklahoma.

Figure 34

Platystrophia n.sp. A. The regression line and the 95 percent confidence interval for the length-width dimensions for the pedicle and brachial valves from localities A and C, Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean length: 12.3, mean width: 23.7 (maximum width), initial growth index (a): 7.0, growth ratio (b): 1.4.

Figure 35

Platystrophia n.sp. A. The regression line and the 95 percent confidence interval for the hinge line width-length of shell dimensions for the pedicle and brachial valves from localities A and C, Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean hinge line width: 23.7, mean shell length: 12.3, initial growth index (a): -1.9, growth ratio (b): 0.6.

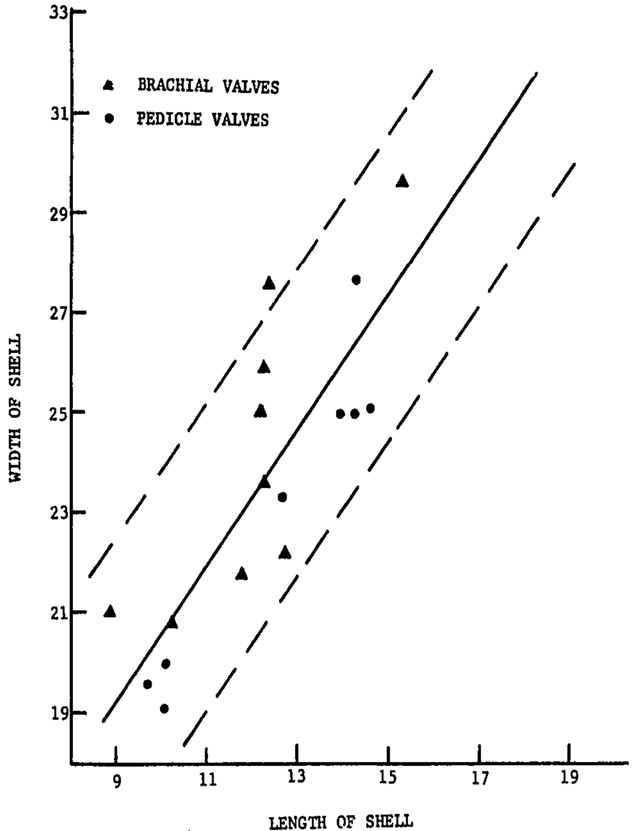


Figure 34

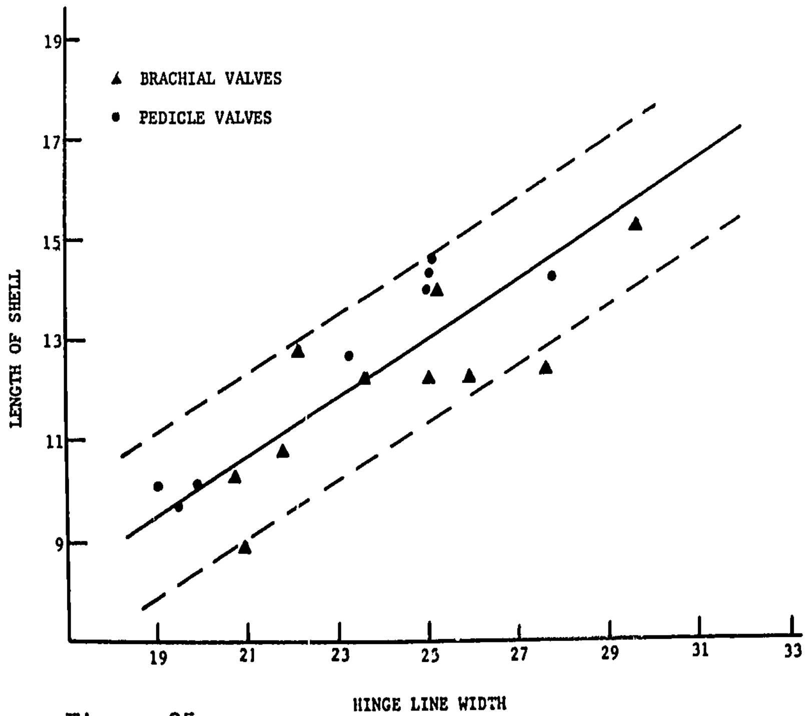


Figure 35

Figure 36

Platystrophia n.sp. A. The regression line and 95 percent confidence interval for length of shell-length of muscle area dimensions for pedicle valves. Specimens are from localities A and C, Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean length: 12.2, mean length of muscle area: 5.2, (the length of the scar is taken from the beak of the valve the anterior margin of the muscle area), initial growth index (a): -0.9, growth ratio (b): 0.5.

Figure 37

Platystrophia n.sp. B. The regression line and 95 percent confidence interval for the length of shell-length of interarea dimensions for the pedicle valves. Specimens are from localities A and C, Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean length: 16.2, mean length of interarea: 2.8 (measurements were taken along the median of the valve), initial growth index (a): -3.8, growth ratio (b): 0.4.

Figure 38

Platystrophia n.sp. B. The regression line and 95 percent confidence interval for length of shell-length of muscle area dimensions for the pedicle valves. The specimens are from localities A and C,Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean length: 17.1, mean length of scar: 7.2, initial growth index (a): 3.1, growth ratio (b): 0.2.

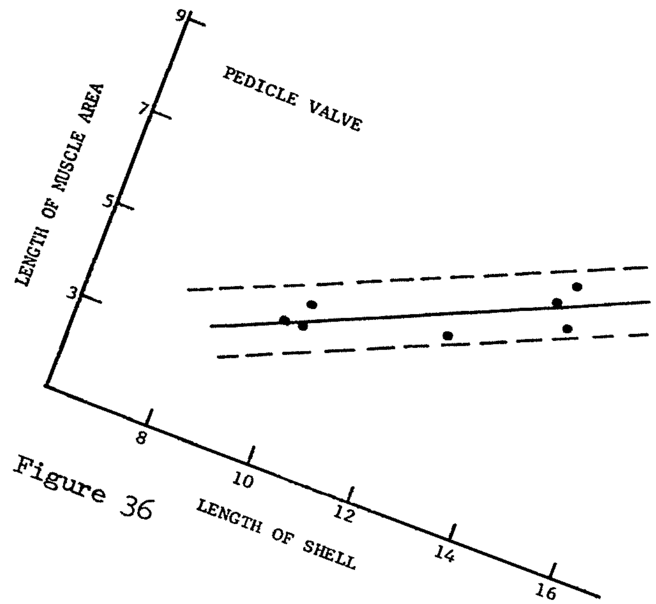


Figure 36

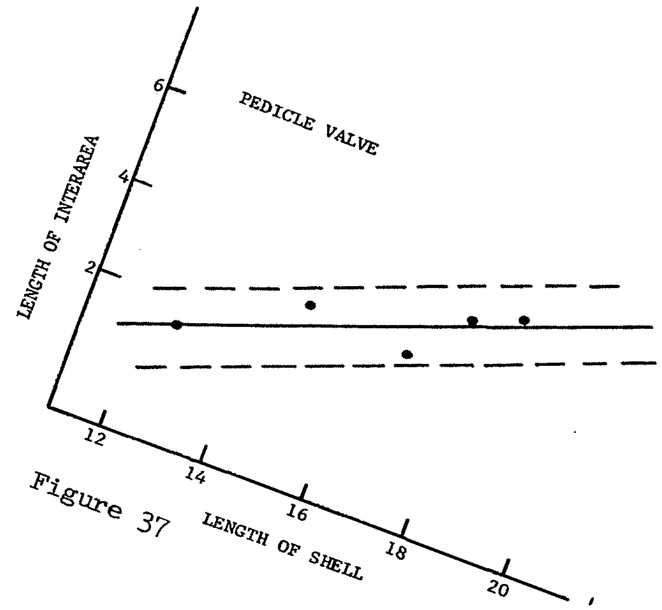


Figure 37

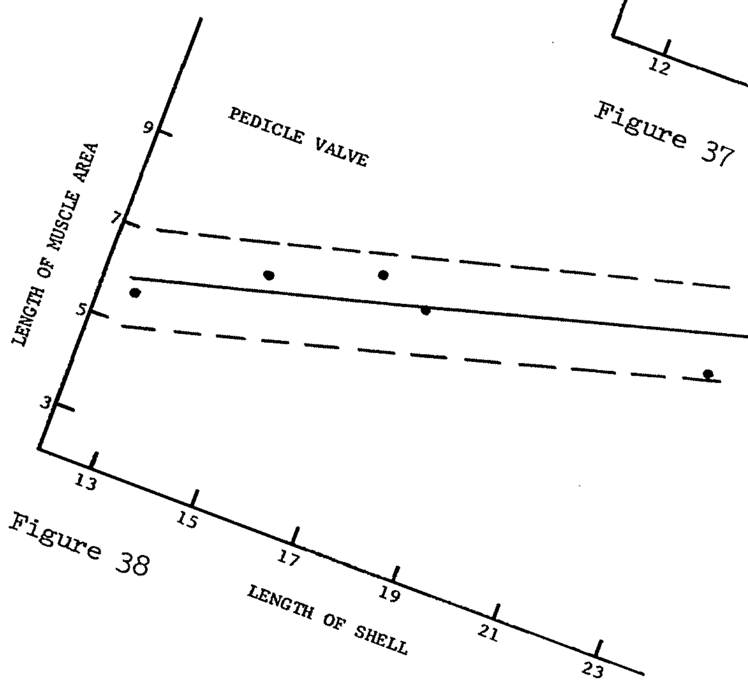


Figure 38

Figure 39

Platystrophia n.sp. A. Regression line and 95 percent confidence interval for the length of shell-length of interarea dimensions for the pedicle valves from localities A and C, Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean length of shell: 12.7, mean length of interarea (measured along the median of the valve): 2.4, initial growth index: -0.4, growth ratio: 0.2.

Figure 40

Platystrophia n.sp. A. The regression line and 95 percent confidence interval for the length of shell-length of interarea for the brachial valves from localities A and C, Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean length of shell: 12.2, mean length of interarea: 1.7, initial growth index: -0.6, growth ratio: 0.2.

Figure 41

Hesperorthis n.sp. The regression line and 95 percent confidence interval for the length of shell-thickness of shell dimensions for the pedicle valves from localities A and C, Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean length of shell: 15.9, mean thickness: 6.1, initial growth index: 1.4, growth ratio: 0.3.

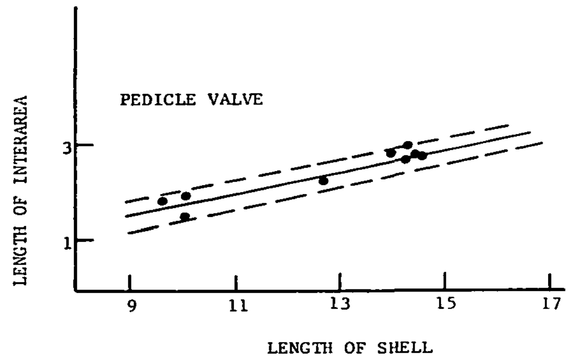


Figure 39

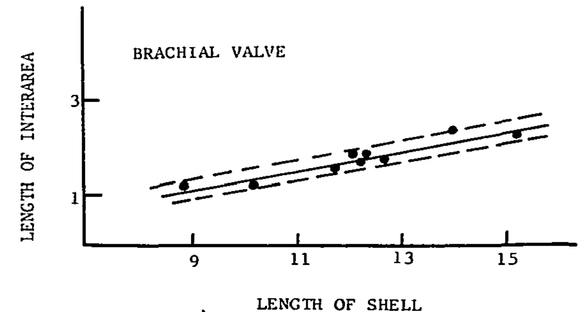


Figure 40

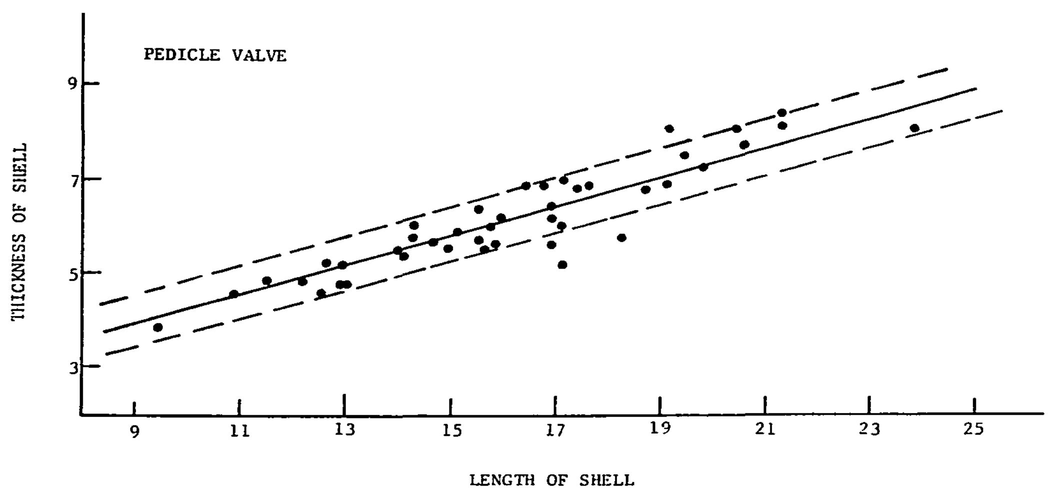


Figure 41

All of the specimens (10-15) from the Viola Formation are deposited in the University of Oklahoma Geology Repository.

Platystrophia n.sp. B

Plate III, figs. 1, 2, and 3

Description: The shell is thick, of medium size (see Figures 42 and 43 for length-width data), and subrectangular in outline. The cardinal extremities are obtuse or at right angles. The lateral margins are gently curved and the anterior margin is straight. The hinge line is straight and not quite as wide as the maximum width which occurs at the middle of the shell. In lateral profile the shell is unequally biconvex with the brachial valve about twice as deep as the pedicle valve. The highest point is in the middle or just anterior to it. The lateral commissure is rectimarginate and the anterior commissure is strongly uniplicate. The surface is marked by numerous plications; 9-10 on the flanks, 3 in the sulcus, and 4 on the fold. The plications are angular with sharply rounded tops. Growth lines are present around the anterior margins of some specimens.

The pedicle valve has a well-defined sulcus which begins at the beak; expands and deepens anteriorly. The width and depth of the sulcus are accentuated by a long tongue which protrudes in a direction at right angles to the line of commissure. The beak is suberect. The interarea is curved, apsacline, and wider than in the brachial valve. The pedicle foramen is permesothyroid. The delthyrium is triangular and open. The cavity is deep. The teeth are short; located a short distance from the cavity walls. Weak crural fossettes are present in

Figure 42

Platystrophia n.sp. B. The regression line and 95 percent confidence interval for the length of shell-maximum width of shell dimensions. The specimens are from localities A and C, Unit 3C, upper 6 feet, and both pedicle and brachial valves were used. All measurements are in millimeters.

Mean length of shell: 17.0, *mean maximum width*: 21.5, *initial growth index*: 9.9, *growth ratio*: 0.7.

Figure 43

Platystrophia n.sp. B. The regression line and 95 percent confidence interval for the hinge line width-length of shell dimensions. The specimens are from localities A and C, Unit 3C, upper 6 feet, and both pedicle and brachial valves were used. All measurements are in millimeters.

Mean hinge line width: 16.9, *mean shell length*: 15.9, *initial growth index*: -0.3, *growth ratio*: 0.9.

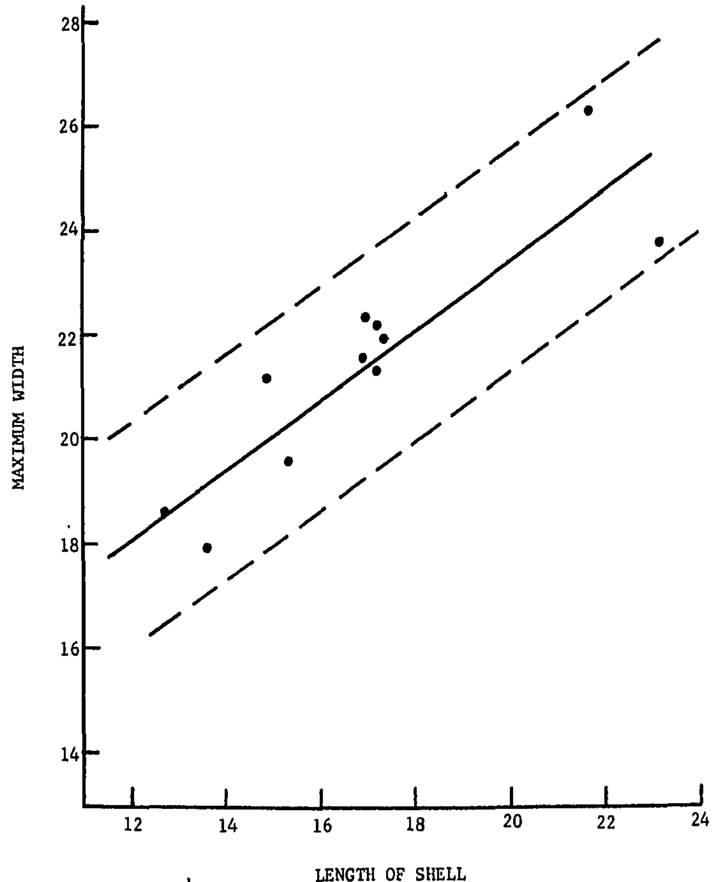


Figure 42

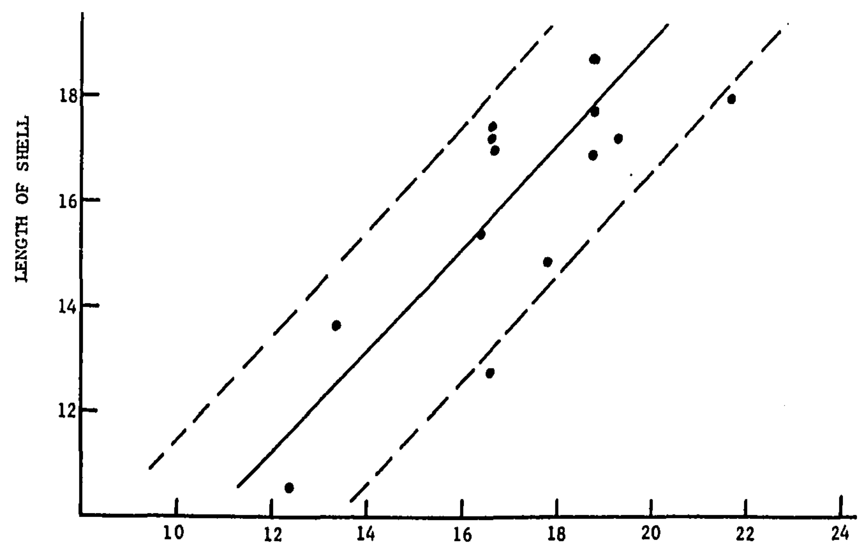


Figure 43

some shells. The teeth are supported from below by moderate shell deposits; the dental plates do not appear to be fully developed. In specimens which do have well-developed plates, they are slender, advancing, and continuous with the lateral margins of the ellipsoid-shaped muscle field. The anterior end of the muscle field is strongly convex and slightly elevated. The individual scars could not be differentiated, however, part of the adjustor scars are situated high on the cavity walls.

The fold of the brachial valve begins at the beak and expands anteriorly. The umbonal region is inflated so as to extend beyond the posterior margin of the interarea. The beak is incurved. The interarea is shorter and more acutely curved than in the pedicle valve. The notothyrium is triangular and open, subtending an angle of about 45 degrees. The cavity is deep and elevated above the floor of the valve. The cardinal process is a slender, delicate blade extending the full length of the cavity. The elevation above the cavity floor remains the same throughout its extent, and it never approaches the level of the interarea. The brachiophores are robust and triangular; each bearing a shelf-like ridge on its inner face. The top portion of each ridge is continuous with the floor of the notothyrial cavity. The sockets are deep and in some specimens partly entrenched beneath the surface of the interarea. The median septum is absent or poorly developed. The adductor muscle field has six scars, the smallest of which are posterior and just under the brachiophores. These scars are so entrenched as to make the shell material around them appear "pinched" or "infolded." (See figure 3c, Plate III.) The medium size scars are also under the brachiophores, but they are not as deeply embedded as the posterior pair. Each anterior scar is trapezoidal in shape and the largest in the field. (See figure 3c, Plate III.) The muscle scars are separated by a prominent shell elevation which can be considered a median septum. This septum is only present in the region of the anterior scars. It is wider and higher posteriorly, thins and becomes lower until it disappears at the anterior edge of the muscle field. The anterior margin of the shell is crenulated. These crenulations reflect the external plications. (See figures 1b and 3a, Plate III.) They are easily visible around the margins, but become weaker in the posterior direction until at about the middle they can no longer be seen.

Discussion: Schuchert and Cooper (1932), in discussing the genotype state (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.

The writer has examined the brachial interiors of numerous species of the genus in the United States National Museum collections, and found no similar muscle impressions except for one small collection of an unnamed species (this small collection is reported to have been made from the top of the Kimmswick Formation in Jefferson County, Missouri). The few valves in the collection have the identical shell shape, shell thickness, brachiophore supports, and most importantly the "J-shaped" posterior adductor muscle scars.

Platystrophia n.sp. B differs from *P. equiconvexa* Wang from the Maquoketa Formation of Iowa in having a distinctly unequally biconvex shell, and a much longer pedicle muscle field. Also, _Platystrophia_ n.sp. B has a thicker shell than _P_. _equiconvexa_ Wang. The thinness of the shell of the Maquoketa species allows for the external plications to be reflected through to the inside where they extend up to the muscle field. This is not true of _Platystrophia_ n.sp. B. (See figures 1b and 3a, Plate III.)

This species has a completely different shape than _Platystrophia_ n.sp. C. In addition, the unique brachial muscle field distinguishes it from _Platystrophia_ n.sp. C. (Compare figure 3b, Plate III to figure 3b, Plate VIII).

Platystrophia _prayi_ Howe from the Montoya Group of West Texas and New Mexico is much smaller in size.

Distribution _and_ _Material_: _Platystrophia_ n.sp. B is found only in the upper part of the Viola Formation. In the shelf province it is in the upper 6 feet (Unit 3C, localities A, C, and D), while in the basin province it occurs in the brachiopod assemblage zone 40-60 feet below the top of the formation (Unit 3CM, localities I and ?R).

This is not a common form as far as numbers are concerned. There were only 13-15 individual valves collected; no articulated specimens.

Platystrophia n.sp. C

Plate VIII, figs. 1, 2, 3, and 4

Description: The shell is spiriferoid in shape with the hinge line straight and the widest part. The cardinal extremities are acute in most individuals, but alate in some. In the smaller individuals the lateral, antero-lateral, and anterior margins lead smoothly into one another forming a continuous curve. In larger shells the anterior margin is more truncated and set off from the curvature of the lateral margins. In lateral profile the shell is biconvex with the brachial valve a little deeper than the pedicle valve. This difference is more pronounced in the larger specimens. The lateral commissure is rectimarginate and the anterior commissure is uniplicate. The curvature of the pedicle valve is gentle and even, with the median portion flattened a little. The brachial valve has a posterior and anterior curvature which is much steeper than in the pedicle valve. There is a well-developed brachial fold and pedicle sulcus. Both features begin at the beak and increase in prominence toward the anterior margin. In the beak region there is only one plication in the sulcus and two corresponding plications on the fold. From this initial two-plication fold there arise two additional plications, thereby making a four-plication fold. When viewed from the posterior, the original plication on the right gives rise to the first of these secondary plications. This occurs at a distance of 3.0mm. from the beak, and the secondary plication branches toward the outside. The original plication on the left gives rise to a secondary plication which also branches toward the outside. This bifrication occurs a little more than 3.0mm. from the beak. The width of the sulcus at the anterior margin is given in the following table. All measurements are in millimeters. The number of plications on the flanks ranges from 7 to 12, depending on the size of the valve.

Length of Shell	Width of Sulcus
7.4	4.2
8.7	5.2
10.2	5.8
11.5	7.2
12.9	8.6

The beak of the pedicle valve is erect to suberect. The interarea is longer than in the brachial valve, curved, and apsacline. The delthyrium is triangular and open, with a partial foramen at the apex. The teeth are stout, short, and turned slightly in an upward and outward direction. There are small crural fossettes in addition to slightly larger accessory dental sockets. The dental plates are receding. The delthyrial cavity is deep with the walls of the cavity sloping gently outward, thereby making the width across the floor greater than at the top. The muscle field is cuenate in shape (for quantitative data on the length of the field; see Figure 47). No distince markings were observed within the field and therefore no separation into adductor, diductor, or adjustor scars was possible. The interior of the valve is corrugated in the antero-lateral one-half of the valve. The external plications in the region of the sulcus are not strongly reflected in the valve interior.

The brachial beak is erect. The interarea is short and orthocline. The notothyrium is open. The cavity is deep, but elevated above the floor of the valve. The cardinal process is a low, thin ridge which extends the full length of the cavity. The brachiophores are short, stout, and pointed. The inner face of each brachiophore is weakly concave. Small sockets are also present. The cordate-shaped anterior adductor scars are slightly larger than the posterior scars. In some individuals the anterior and antero-lateral margins of the posterior scars are so deeply impressed as to form grooves which when accentuated become "J-shaped" scars. This configuration masks the normal ellipsoidal shape of the posterior adductor scars.

Discussion: This species is distinguished from Platystrophia n.sp. A primarily by the difference in the position of the brachial muscle field, and the normal ellipsoidal shape of the posterior adductor scars. In that species (see figure 5b on Plate III) the posterior scars are positioned well beneath the brachiophores, thus out of view. In P. n.sp. C (see figure 3a on Plate VIII) all four scars are easily visible. Both photographs were taken normal to the plane of commissure and neither specimen was tilted.

Distribution and Material: This species is only found at two localities; C and D. At Locality C it occurs in Unit 2, 270-280 feet below the top of the formation. At Locality D its stratigraphic range is slightly greater; 170-200 feet above the base of the formation. At both localities this species occurs at the same horizon. The distribution at Locality 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 sections.)

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

Figure 44

Platystrophia n.sp. C. The regression line and 95 percent confidence interval for the length of shell-length of interarea for the pedicle valves. The specimens are from Locality C, Unit 2, 275-283 feet below the top of the formation. All measurements are in millimeters.

Mean length of shell: 11.5, mean length of interarea: 1.6, initial growth index (a): -0.2, growth ratio (b): 0.2.

Figure 45

Platystrophia n.sp. C. The regression line and 95 percent confidence interval for the hinge line width-length of shell dimensions. These data are for the pedicle valves, 275-283 feet below the top of the formation; Locality C, Unit 2. All measurements are in millimeters.

Mean hinge line width: 19.6, mean length: 10.8, initial growth index (a): 2.2, growth ratio (b): 0.4.

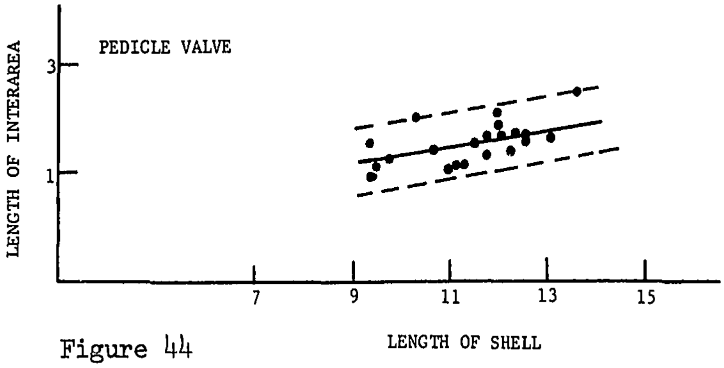


Figure 44

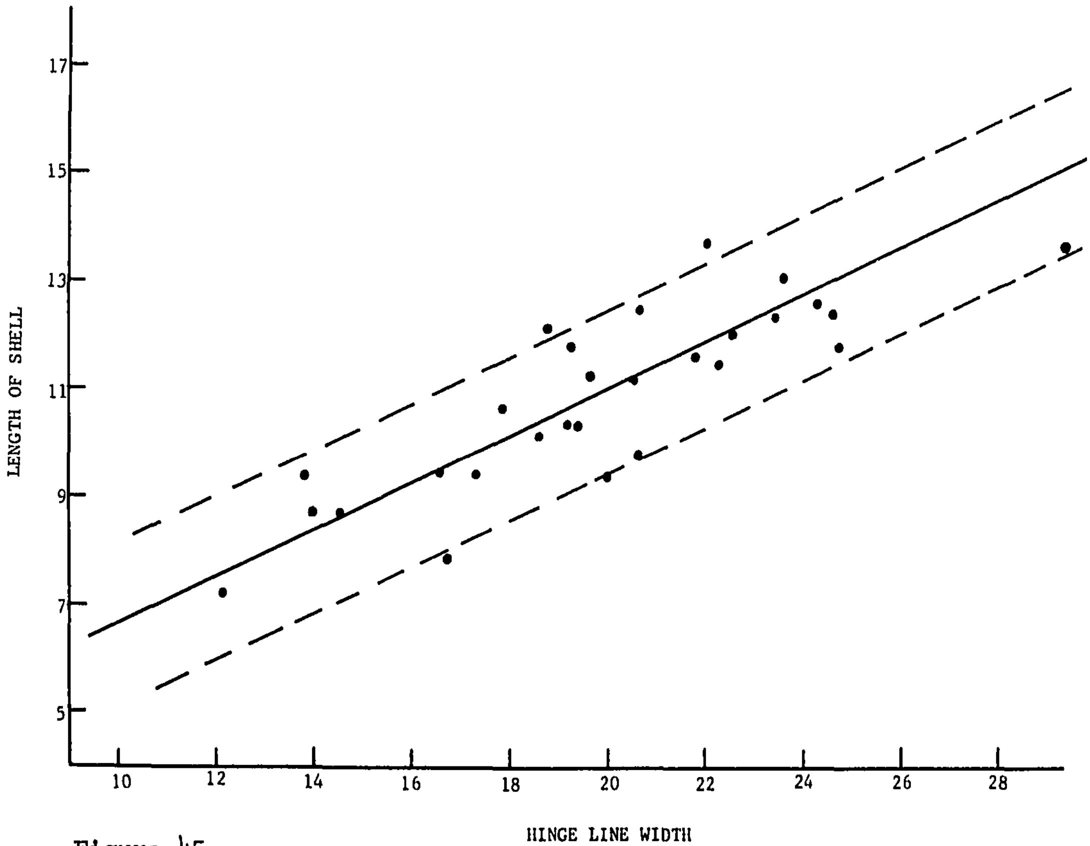


Figure 45

Figure 46

Platystrophia n.sp. C. The regression line and 95 percent confidence interval for the length of shell-length of interarea dimensions. These data are from the brachial valve from Locality C; Unit 2, 275-283 feet below the top of the formation. All measurements are in millimeters.

Mean length of shell: 12.0, mean length of interarea (measured along the median): 1.3, initial growth index (a): 0.4, growth ratio (b): 0.1.

Figure 47

Platystrophia n.sp. C. The regression line and 95 percent confidence interval for the length of shell-length of muscle area dimensions. These data are for the pedicle valves from Locality C, Unit 2, 275-283 feet below the top of the formation. All measurements are in millimeters.

Mean length of shell: 11.3, mean length of muscle area: 4.6, initial growth index (a): -0.1, growth ratio (b): 0.4.

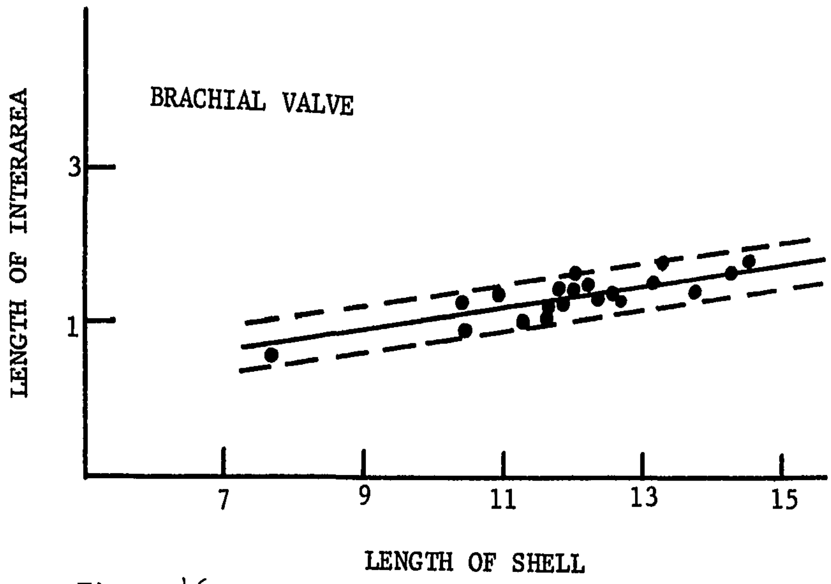


Figure 46

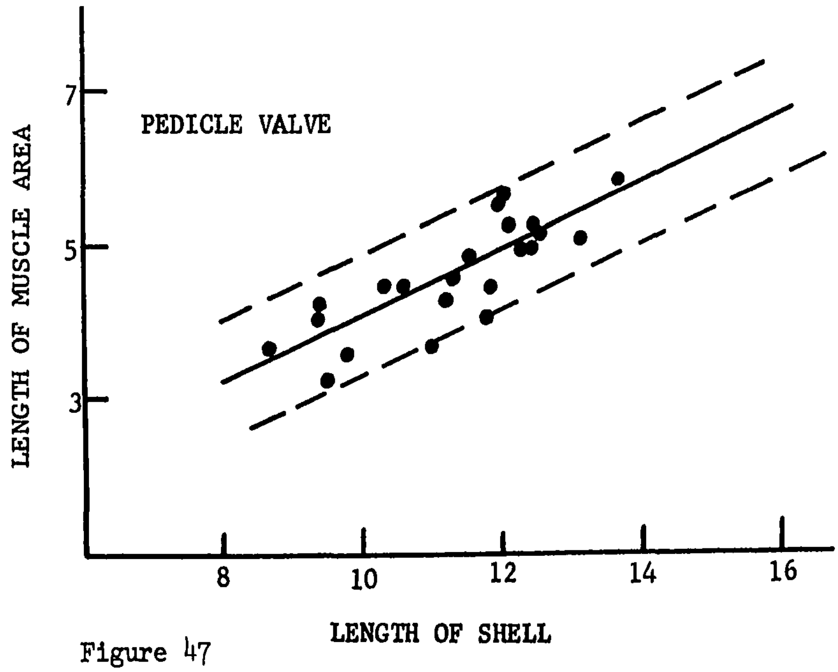


Figure 47

Superfamily Enteletacea Waagen, 1884

Family Dalmanellidae Schuchert, 1913

Genus _Diceromyonia_ Wang, 1949

Diceromyonia cf. _D_. _tersa_ (Sardeson)

Plate IV, figs. 15, 16, and 17

Orthis tersa Sardeson, 1892, v. 3, pp. 331-332, pl. 5, figs. 11-13 (_fide_ Y. Wang, 1949, p. 36). Sardeson, 1897, pp. 101-102, pl. 5, figs. 8-13.

Dalmanella tersa (Sardeson), Schuchert and Cooper, 1932, pl. 17, figs. 26 and 30.

Rhipidomella tersa (Sardeson), Gregor and Born, 1936, pl. 75, figs. 11 and 12.

Diceromyonia tersa (Sardeson), Wang, 1949, pl. 12B, figs. 1-7.

Description: The shell is large for the genus with the width greater than the length. (See Discussion for quantitative data.) In outline it is subquadrate to subrectangular. The cardinal extremities are obtusely rounded. The postero-lateral margins are straight, but diverge away from the median. The antero-lateral margins are moderately rounded and smoothly join a more broadly curved anterior margin. The hinge line is straight, short; a little less than one-third the maximum width which is reached anterior to the middle. In lateral profile the shell is plano-convex, although there may be a slight convexity to the brachial valve. The lateral commissure is rectimarginate to very faintly convex. The anterior commissure is rectimarginate, although one specimen shows a weak undulation. The thickest part of the shell is in the middle. The anterior slope from this high point is rather steep and almost straight. There is a very slight curvature to the highest part of the valve. The most intense curvature is in the umbonal region. The brachial valve has a shallow, narrow sulcus which begins at the beak. It expands, but does not deepen appreciably anteriorly. In a specimen measuring 14mm. in length there are 8-9 costellae within the sulcus at the anterior margin. The pedicle beak is small, suberect, and projects a little past the posterior margin of the brachial valve. The interarea is short, curved, and apsacline to orthocline. The maximum length of the pedicle interarea was measured in the only available specimen to be 1.3mm. The delthyrium is triangular and open. In an articulated specimen the cardinal process projects through and fills the entire opening. The cavity is moderately deep with the posterior portion raised slightly above the muscle area. The teeth are strong, triangular, with sharp, keel-like anterior margins. The teeth are strengthened by well-developed, advancing dental plates which join with the lateral margins of the muscle field. Crural fossettes are conspicuous and take the form of ledges positioned just beneath the teeth and on top of the dental plates. There are also triangular shallow accessory dental sockets on the top portion of the teeth and anterior to the hinge line. The muscle field has the outline of an elongated ellipse; about twice as long as wide. The field extends about two-thirds the shell length. The adductor scars are small, elliptical, and fixed in the center immediately posterior to the middle. The diductor impressions are large. They do not expand or diverge anteriorly, but nevertheless appear to enclose the smaller adductor scars. In the only well-preserved pedicle interior there is a low ridge anterior to the adductor impressions. It is possible that this ridge prevented the complete enclosure of the adductor muscles. No adjustor scars were observed. The inner margins of the valve are crenulated.

The brachial interarea is plane, very weakly apsacline, almost orthocline. The cardinalia is strong. The shaft is thick, rounded, and joins with the median septum. The brachiophores are strong, divergent, with the posterior margins narrow and separated from the cardinal process by a groove. Fulcral plates are lacking. The sockets are large and moderately deep; impressed very little into the sides of the brachiophores. The median septum is wide and rounded, extending to the anterior edge of the muscle field. The field is about as wide as it is long. The posterior adductor impressions are circular to subquadrate in outline; smaller than the anterior pair. The anterior and posterior scars are about the same shape.

Discussion: The specimens from the Viola Formation (Arbuckle Mountains) have the following dimensions.

Length	Width	Thickness (articulated)
13.8mm.	16.5mm.	5.8mm.
19.4mm.	22.2mm.	8.2mm.
18.3mm.	21.6mm.	--
16.4mm.	20.0mm.	--
19.8mm.	27.6mm.	8.0mm.

The specimen of *D. tersa* figured by Wang (1949) measured 15.5mm. in length, 19.3mm. in width, and 5.7mm. in thickness. The following table gives the dimensions for a representative sample of specimens referred to D. tersa (Sardeson) from the Richmond Formation at Wilmington, Illinois (United States National Museum collection).

Length	Width	Thickness (articulated)
9.0mm.	10.0mm.	4.5mm.
9.3mm.	10.2mm.	4.9mm.
9.0mm.	11.0mm.	4.0mm.
11.0mm.	13.0mm.	4.7mm.
10.7mm.	12.8mm.	5.0mm.
13.0mm.	16.4mm.	5.3mm.
12.8mm.	16.2mm.	5.1mm.
12.8mm.	15.1mm.	--
15.3mm.	18.3mm.	5.7mm.

This species (D. cf. tersa) is represented in the "Fernvale" (Cape) Limestone of northeastern Oklahoma by more numerous specimens. No articulated specimens were found.

There is no difference between the specimens of this species from the Arbuckle Mountains and those from the "Fernvale" (Cape) Limestone in northeastern Oklahoma. A comparison of the table below (northeast Oklahoma specimens) with the table for the Arbuckle Mountain specimens shows that they are the same size.

Overall size is the only conspicuous difference between the Viola specimens and D. tersa (Sardeson). The large size of the Viola specimens also sets them apart from D. ignota (Sardeson) and D. crassa

Howe. This larger size could have a genetic cause, but it also could be the result of ecology. Because no other characteristic difference was detected the writer prefers, for the present, to refrain from designating this a new species.

Length	Width
19.0mm.	22.9mm.
18.5mm.	23.2mm.
16.0mm.	22.7mm.
20.0mm.	24.0mm.
19.6mm.	23.8mm.
14.9mm.	19.4mm.
18.9mm.	23.4mm.
19.8mm.	25.0mm.
17.5mm.	20.9mm.
20.6mm.	24.3mm.
20.5mm.	25.7mm.

Distribution and Material: *D*. cf. *tersa* (Sardeson) occurs in Unit 3C at localities A and C (upoer 6 feet of the formation). It was not found in any of the basin province sections.

Only five specimens were collected from the Viola Formation in the Arbuckle Mountains. However, in northeastern Oklahoma, approximately 40 individual valves were collected. There were no articulated specimens.

Genus Paucicrura Cooper, 1956

Paucicrura cf. P. rogata (Sardeson)

Plate VIII, 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, 7, 13, 31.

Paucicrura rogata (Sardeson), Cooper, 1956, p. 957, pl. 157F, figs. 18-24.

Description: The shell is small. (See Figures 48-50 for various dimensions.) In lateral profile it is plano-convex with the thickest part being posterior to the middle. The radius of curvature of the pedicle beak and umbonal region is smaller than that of the broad, gently curved anterior slope. The lateral commissure is rectimarginate and the anterior commissure is weakly sulcate. The shell is subquadrate in outline with the width a little greater than the length. (See Figure 50.) The widest part occurs in the middle or just anterior to the middle. The cardinal extremities are rounded. The lateral margins are broadly curved and join smoothly with the anterior margin. The hinge line is straight and slightly more than half as wide as the maximum width of the shell. The brachial valve has a very narrow and shallow sulcus which begins at the beak. It expands anteriorly, but does not deepen appreciably. In anterior profile the pedicle valve has a gently rounded top with straight, and rather steeply sloping sides. The surface is multicostellate. There are 60 marginal costae and costellae on a specimen 8.0mm. long, and 8.5mm. wide. In a 2mm. space there are approximately 7.8 costellae at a distance of 5mm. from the brachial beak.

The pedicle beak is erect to slightly incurved, and projects about 1mm. past the posterior margin of the brachial valve. The pedicle interarea is curved, short, and apsacline. The delthyrium is triangular and open. There is a small shelf structure in the apex of the delthyrial cavity and depressed a little below the level of the interarea. This structure is developed to various degrees and in many individuals it is completely absent. The cavity is deep with the walls sloping outward. The teeth are thick and short. The dental plates are advancing and join the margins of the muscle field. The inner face of each plate is inflated so as to form well-developed crural fossettes. The muscle field is ovate to ellipsoidal in shape, and a bilobed anterior margin. In many individuals the median reentrant extends to the middle of the field, but in most it is less. The field itself extends about one-third to one-half the length of the valve. Some specimens display a broadly rounded median ridge in the anterior one-half of the field. The lateral margins of the field are gently curved, or straight. The border of the field is made visible by elevated shell material. The large diductors are the only scars visible. They diverge very slightly in some individuals, but in others not at all. The anterior margins of these scars are curved to various intensities, and some are almost "pointedly" rounded. The inner margins of the valve are corrugated; each corrugation showing the same magnitude as the surface costae.

These costae reflections are visible around the anterior one-third of the valve margins.

The brachial interarea is plane, orthocline to slightly anacline; shorter than in the pedicle valve. The cardinalia is strong. The notothyrial cavity is shallow; occupied almost completely by the cardinal process which in most specimens projects above the level of the interarea. The shaft is thinner than the median septum. The myophore is poorly preserved. The brachiophores are stout and vary from being thin, with sharp, pointed margins to being thick with rounded extremities. In some, the posterior face of the brachiophore has a narrow groove extending its full length. The sockets are large. A prominent broad median septum divides the quadrate muscle field. The field averages 3-4mm. in width and in length. The posterior adductor scars are circular to subcircular in outline and a little smaller than the circular anterior adductors. Both pair are moderately impressed.

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

Distribution and Material: This species is common at Locality C where numerous silicified specimens have been collected. At this locality it is confined to 275-280 feet below the top of the formation. It is also abundant at Locality D, 170-200 feet above the base of the formation. At both of these localities it is confined to Unit 2.

Several hundred specimens have been collected, mostly from Locality C. Many are articulated.

Figure 48

Paucicrura cf. *P*. *rogata*. The regression line and 95 percent confidence interval for the length-thickness dimensions. These data are for the articulated specimens from Locality D, Unit 2, 275-283 feet below the top of the formation. The lower and upper horizons referred to in the diagram are at the top and bottom of this 10-foot interval. All measurements are in millimeters.

Mean length: 7.6, *mean thickness*: 3.3, *initial growth index* (a): 0.9, *growth ratio* (b): 0.3.

Figure 49

Paucicrura cf. *P*. *rogata*. The regression line and 95 percent confidence interval for the width of shell-width of hinge line dimensions. The specimens are from Locality C, Unit 2, 275-283 feet below the top of the formation. All measurements are in millimeters.

Mean width of shell: 8.6, *mean hinge line width*: 5.4, *initial growth index* (a): 8.6, *growth ratio* (b): 0.8.

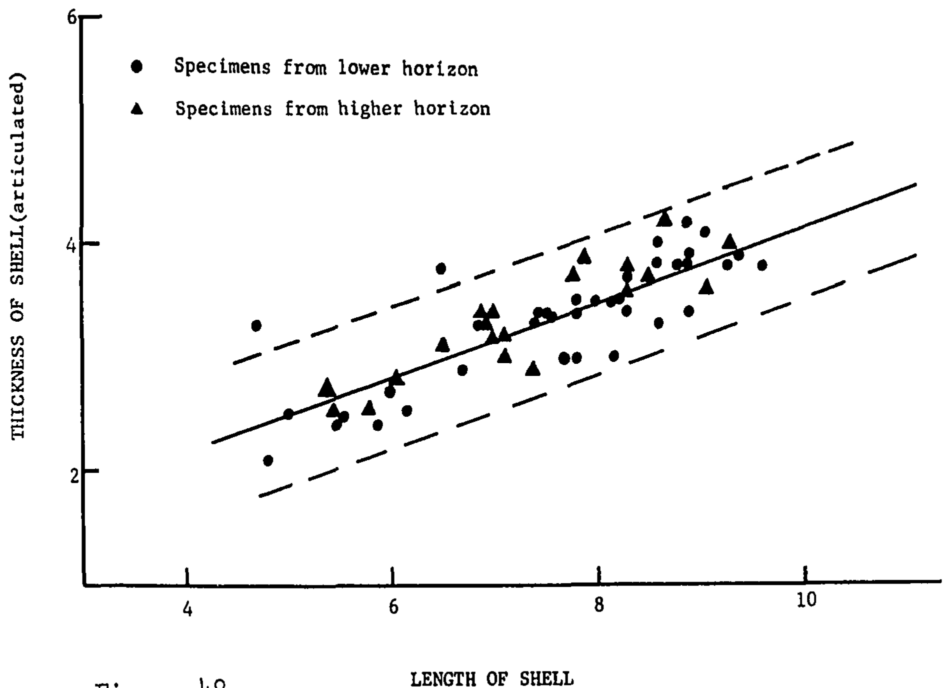


Figure 48

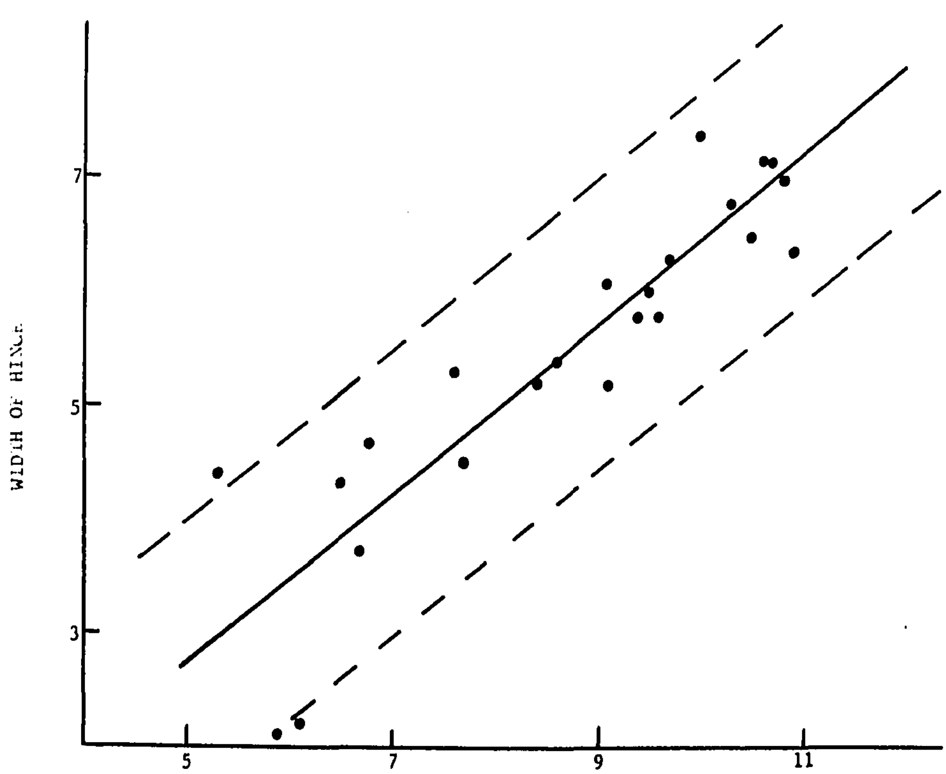


Figure 49

Figure 50

Paucicrura cf. *rogata*. The regression line and 95 percent confidence interval for the length-width dimensions. The specimens are from Locality C, Unit 2, 275-283 feet below the top of the formation. The triangular symbols represent those specimens from the top of this 10-foot interval and the circular symbols are specimens from the bottom of the interval. All measurements are in millimeters.

Mean length: 7.4, mean width: 8.3, initial growth index (a): 0.9, growth ratio (b): 1.0.

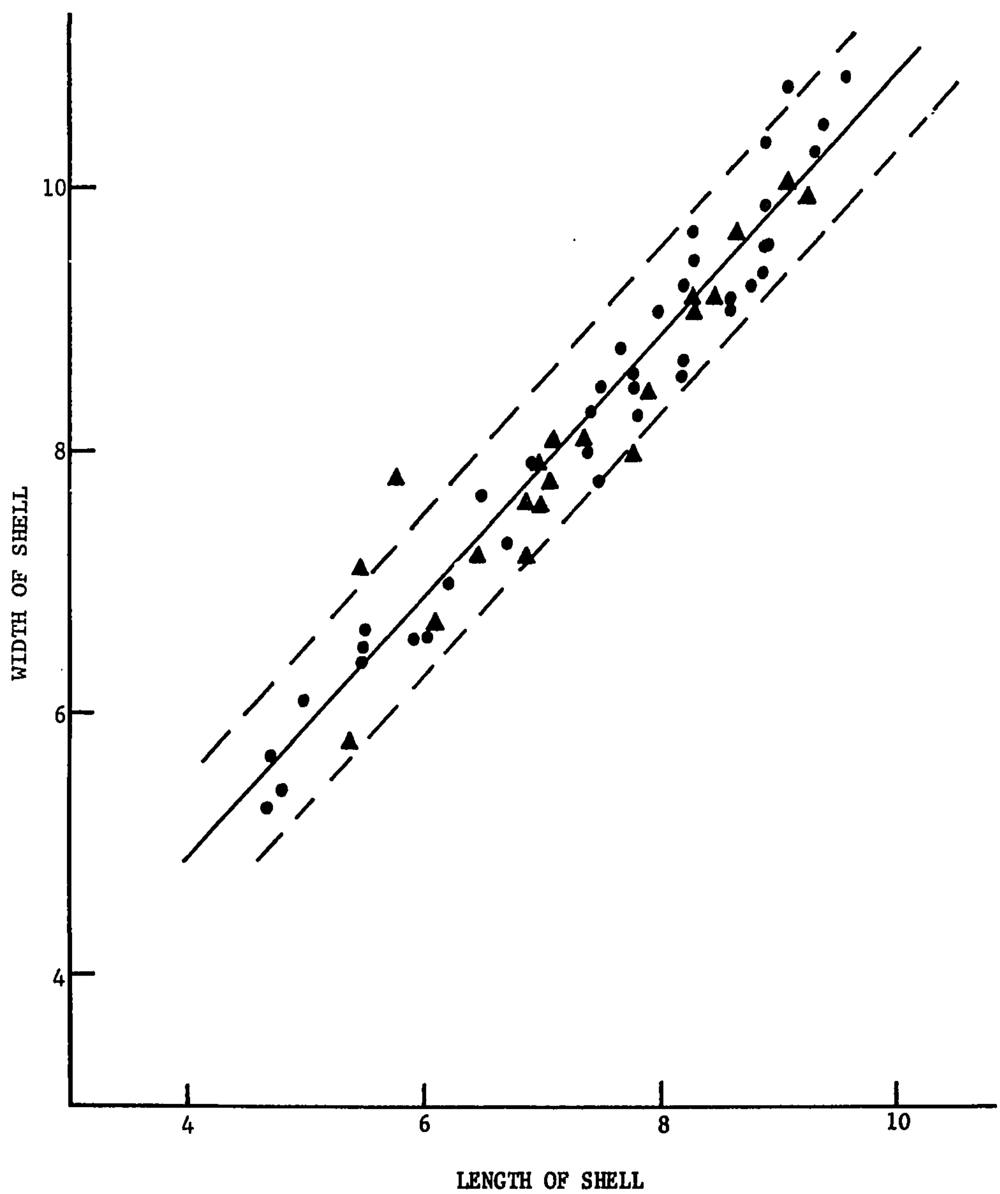


Figure 50

Paucicrura n.sp.

Plate IV, figs. 11-14

Description: The shell is small (see Figures 51, 52, and 54 for the various dimensions), subquadrate in outline. The greatest width is just anterior to the hinge line. The hinge line is straight and about two-thirds as wide as the maximum shell width. The cardinal extremities are acutely rounded. The lateral margins are straight or broadly rounded; in some specimens the sides are parallel while in others they are inclined toward the median. The anterior margin is narrowly to broadly rounded depending on the inclination of the lateral margins. In lateral profile the shell is plano-convex. The curvature of the pedicle valve from a point just anterior to the umbo to the anterior margin. The curvature in the umbonal region is rather acute. The sulcus in the brachial valve makes that valve appear almost concave. The lateral commissure is rectimarginate and the anterior commissure is broadly sulcate. The fold in the pedicle valve has a narrowly rounded top with flanks that slope gently and continuously to the lateral margins. In posterior or anterior profile this valve is "V-shaped". (See Plate IV, figs. 11c and 11d.) The brachial sulcus begins at the beak where it is shallow and very narrow. It expands and deepens anteriorly. Taken together, the sulcus and the flanks of the shell form a smooth-curved undulation; there being no sharp angulations marking changes in slope except at the bottom of the sulcus when crossing from one flank to the other.

The surface is multicostellate. The greater number of specimens have the costellation destroyed. However, one sufficiently well-preserved specimen showed 10 costellae in a space of 3mm. at the anterior margin. This individual measured 9mm. in length and 10.1mm. in width.

The pedicle interarea is plane and apsacline, longer than in the brachial valve. The delthyrium is triangular and open; the anterior portion of which is filled by the cardinal process. The cavity is deep. The teeth are divergent and moderately strong, supported by thick advancing dental plates. These plates are continuous with the margins of the muscle field and are extended anteriorly to various distances. Crural fossettes are well developed. The muscle field is elongate in outline, extending about two-thirds the length of the valve. The adductor impressions were not observed, but there is a slight elevated area in the center of the field to which these muscles were probably attached. In outline, each diductor scar is an elongated ellipse. The two scars diverge at various degrees. Due to the poor preservation it is difficult to determine whether the diductors enclose the adductors. The position, shape, and size of the adjustor scars could not be determined with certainty. In some valves, however, there is a small "overhang" just under the teeth and on the dental plates indicating the possible position of adjustor attachment. The inner margins of the valve are crenulated.

The brachial interarea is very short; anacline to orthocline. The cardinalia is strong. The cardinal process is stout, with a thick shaft that merges with the median septum. The myophore is trilobed. The brachiophores are stout and divergent to various degrees. The median septum extends to the anterior of the muscle field, but in some individuals it is absent at some distance posterior to this margin.

The adductor scars are set close under the brachiophores and separated by the median septum. The scars are not well defined, but appear to be subcircular in outline. The inner margins of the valve are crenulated, each centrally cleft.

Discussion: As defined in the Treatise (Williams and others, 1965, p. 336) the genus *Onniella* has a bilobed cardinal process and the genus *Paucicrura* a trilobed 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. Following the Treatise then, these forms referred to *Onniella* by Wang and Howe are members of the genus *Paucicrura*.

The distinctive features which separate this new species from *Paucicrura quadrata* (Wang) from the Maquoketa and Montoya rocks are the fineness of the costae, the smaller thickness of the articulated shell, and the less prominent sulcus. Figure 51 shows that as a population group the Viola species is less thick than the typical *P. quadrata* from the Montoya Group. This species is also found in the "Fernvale" (Cape) Limestone in northeastern Oklahoma. The specimens from northeastern Oklahoma are identical in all respects to those from the Arbuckle Mountains.

Distribution and Material: This species occurs in the upper 6 feet of the formation, Unit 3C, at localities A, C, and D. In the basin province it is found in Unit 3CM at Locality I, 40-60 feet below the top. This species is also abundant in the "Fernvale" (Cape) Limestone in northeastern Oklahoma.

Several hundred specimens were collected.

Figure 51

Paucicrura n.sp. The regression line and 95 percent confidence interval for the length of shell-thickness of shell dimensions. These data are of articulated valves from localities A and C, Unit 3C, the upper 6 feet. All measurements are in millimeters. The diagram shows some differences between this species and the similar well-known Upper Ordovician species referred to by Wang (1949) and Howe (1966a) as *Onniella quadrata*. The writer believes that the specimens referred to by Wang and Howe are members of the genus *Paucicrura* (see the discussion in the paleontology section).

Mean length: 8.0, mean thickness: 2.6, initial growth index (a): 0.8, growth ratio (b): 0.2.

Figure 52

Paucicrura n.sp. The regression line and 95 percent confidence interval for the length-width dimensions. The specimens are from localities A and C, Unit 3C, upper 6 feet. All measurements are in millimeters. The regression line for *Onniella quadrata* was taken from Howe (1966a).

Mean length: 8.2, mean width: 9.3, initial growth index (a): 2.6, growth ratio (b): 0.8.

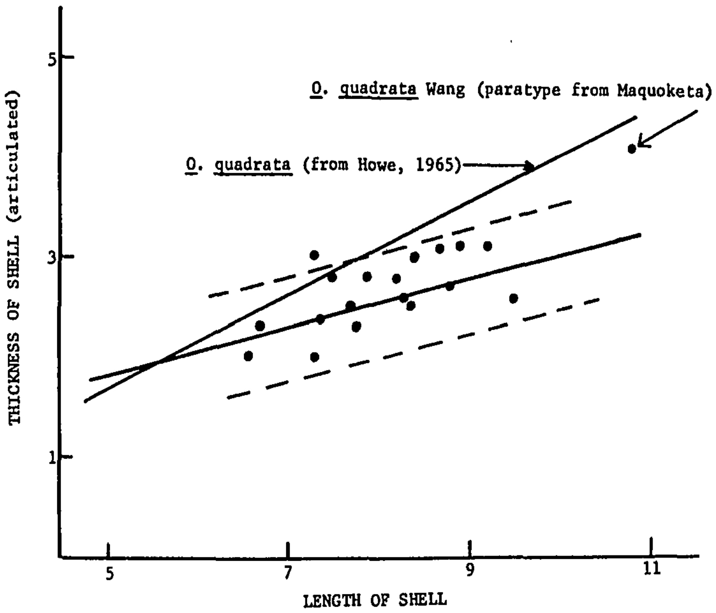


Figure 51

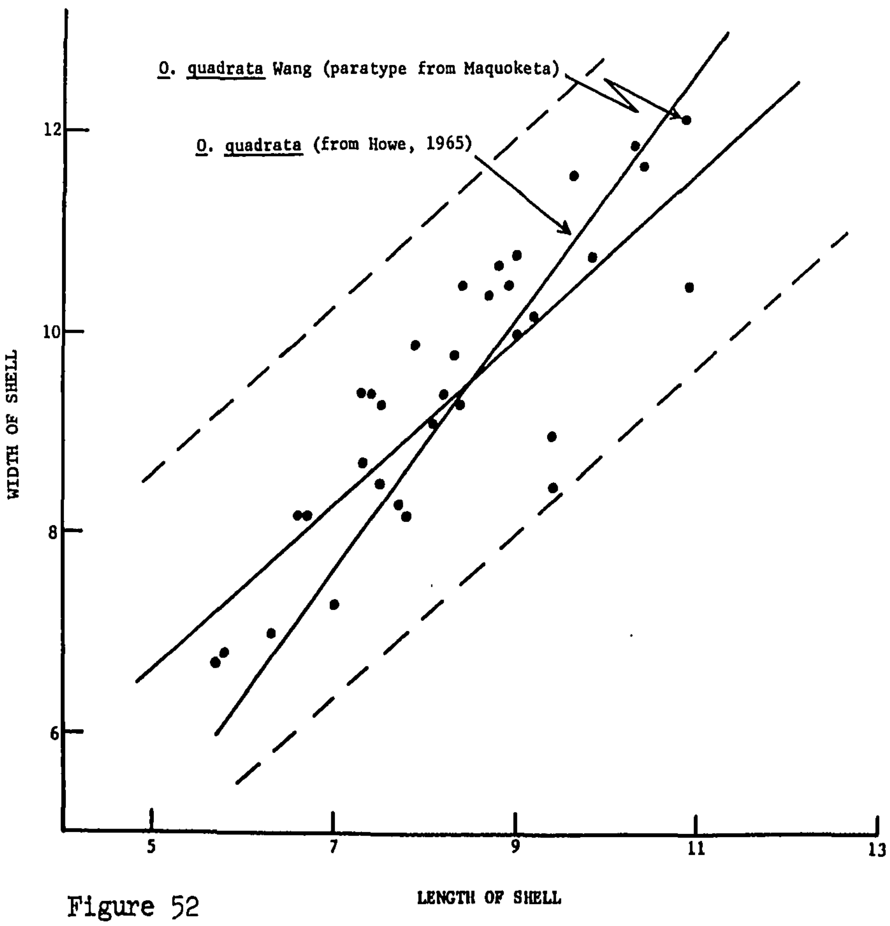


Figure 52

Figure 53

Thaerodonta magna. The regression line and 95 percent confidence interval for the pedicle valves from localities A and C, Unit 3C, upper 6 feet. All measurements are in millimeters.

Mean length of shell: 9.0, mean length of pedicle interarea: 1.1, initial growth index (a): 0.1, growth ratio (b): 0.1.

Figure 54

Paucicrura n.sp. The regression line and 95 percent confidence interval for specimens from localities A and C, Unit 3C, upper 6 feet. All measurements are in millimeters. The regression line for Onniella quadrata was taken from Howe, 1965).

Mean width of shell: 9.6, mean hinge line width: 6.6, initial growth index (a): -0.4, growth ratio (b): 0.7.

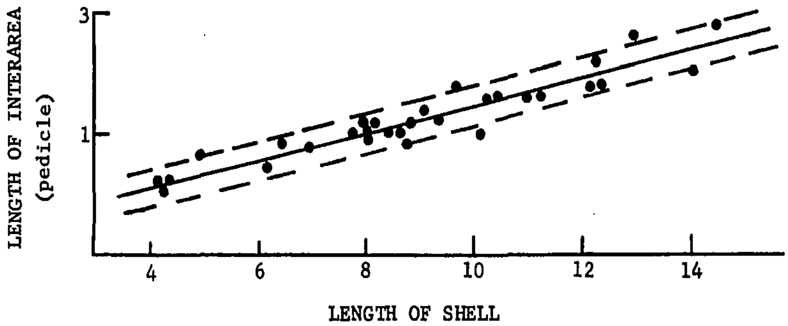


Figure 53

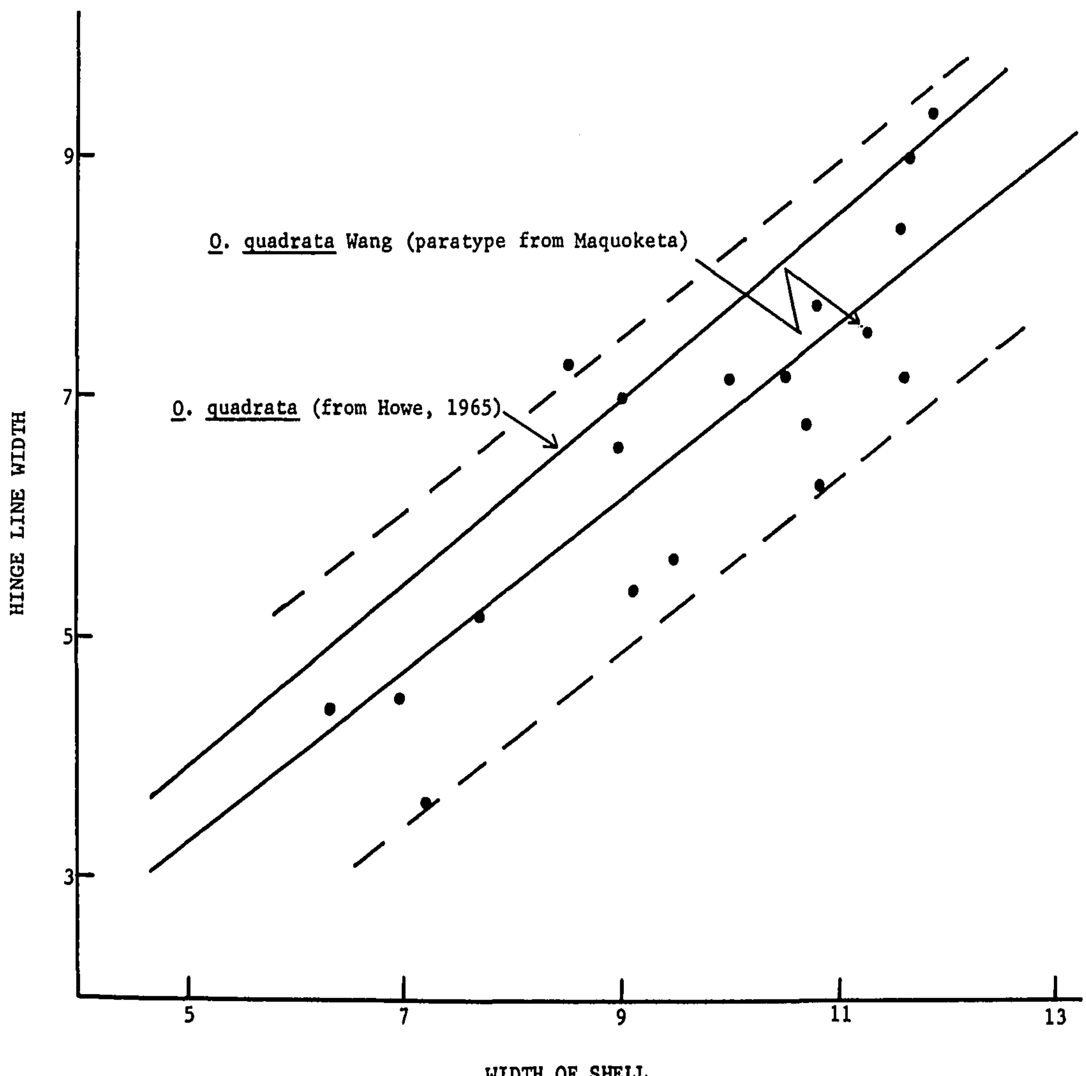


Figure 54

Genus Onniella Bancroft, 1928

Onniella sp.

Plate IX, figs. 5, 6, 7, and 12

Description: The shell is almost circular in outline. The hinge line is straight and a little more than one-half the maximum width of the shell. The cardinal extremities are obtusely rounded. The lateral and anterior margins are evenly rounded; both at about the same magnitude. In anterior profile the pedicle valve has a sharply rounded middle and straight sloping sides. The anterior commissure is broadly but distinctly sulcate. In lateral profile the shell is unequally biconvex with the pedicle valve twice as deep as the brachial. The lateral commissure is rectimarginate. The surface is finely costellate. There are about 7 costellae in a 2mm. space at a distance of 4mm. from the beak.

The pedicle interarea is slightly curved and apsacline. The delthyrium is triangular and open. There is a small callosity at the apex of the opening. The teeth extend about .5-.6mm. anterior of the hinge line. They are supported by well-developed, advancing dental plates. The plates are continuous with the lateral margins of the muscle field. The field is elongate in shape with a median reentrant. The diductor part of the field extends about 3.8mm. anterior of the pedicle beak.

The sulcus in the brachial valve begins at the beak; it expands but does not deepen anteriorly. The interarea is short (.5mm.) and anacline. The notothyrium is open and occupied almost completely by the cardinal process. The shaft is short and the myophore is bilobed and crenulated. The brachiophores are strong and project about 1mm. anterior of the hinge line. They are sharp, pointed, with flat, sloping external faces. A prominent median septum extends 3.5mm. anterior from the hinge line. The ventral posterior one-half of the septum bears a single groove. The posterior and anterior scars could not be differentiated. The field does not extend past the anterior end of the septum.

Because of the coarseness of the silicification many of the delicate characters necessary for the identification of the species have been obliterated. This is particularly true of the cardinalia and the surface ornamentation.

Discussion: The specimens upon which this description is based have a distinct bilobed cardinal process and an absence of fulcral plates; thus they are referred to *Onniella* and not *Dalmanella*. The writer is unaware of another species of *Onniella* which has such a pronounced division of the shaft portion of the process. (See Plate IX, fig. 12.)

Distribution and Material: This species is represented by 20-25 specimens from the lower 50 feet of the formation (Unit 1C) at localities D and L. All of the specimens studied were silicified. Some were collected from the lower 1 foot of Unit 1C at localities D and L. Others were collected from 40 feet above the base of Unit 1C at Locality L.

The writer collected 25-30 specimens (mostly silicified) from these localities.

Suborder Strophomenidina Opik, 1934

Superfamily Plectambonitacea Jones, 1928

Family Leptellinidae Ulrich and Cooper, 1936

Genus Leptellina Ulrich and Cooper, 1936

Leptellina sp.

Plate VIII, fig. 5

Description: The brachial valve is concave; subcircular to subelliptical in outline. The hinge line is straight and the widest part of the shell. The cardinal extremities are acute with the lateral margins broadly rounded leading smoothly into the curved anterior margin. The sulcus extends the full length of the valve; expanding toward the anterior. The sulcus does not increase much in depth and there are no angulations marking off the sulcus from the flanks of the valve. However, this transition becomes more acute in the posterior regions. The surface is unequally parvicostellate; 203 costellae between two larger ones. This differentiation is less conspicuous away from the sulcus. The interarea is short and anacline. The notothyrium is closed by a thick chilidium which is joined to the floor of the valve. It is separated from each brachiophore by a groove. The cardinal process is a small elevated ridge situated on the antero-ventral face of the massive chilidium. The brachiophores are short, pointed, and divergent. The lophophore platform is large and elevated prominently around the lateral and anterior margins. The lateral margins of the platform are parallel to the margins of the valve; the anterior margin is marked by a sharp indentation giving it a bilobed appearance. There is a well-developed ridge extending from just anterior of the cardinal process to the anterior margin of the platform; increasing in prominence at the anterior end. In one specimen it is greatly thickened giving that specimen a very robust appearance.

Discussion: The description of this species is based on only three brachial valves all of which show the interiors. There were no pedicle valves found.

An unnamed species of Leptellina figured by Cooper (1956) from the Edinburg Formation (Cyrtonella Zone) of Virginia is the only species from the Chazy rocks which attains the size of the Viola species. The measurements for Cooper's specimen is: length, 16.3mm., hinge line width, 27.1mm., and mid-width, 26.1mm. The most complete Viola specimen measures: length, 13.5mm., hinge line width, 25.2mm., and mid-width, 20.0mm.

All of the species described by Cooper (1956) from the Chazy and related rocks have hypercline interareas. As described above the Viola species has an anacline interarea.

Distribution and Material: All of the specimens of Leptellina sp. were collected from Locality C, Unit 2, 280 feet from the top of the formation.

Only three brachial valves were found.

Family Sowerbyellidae Opik, 1930

Genus Thaerodonta Wang, 1949

Thaerodonta magna Howe, 1965

Plate IV, figs. 1-10

Description: The shell is semicircular in outline with the hinge line straight and the widest part of the shell at all growth stages. The maximum width is almost twice the maximum length. The cardinal extremities are acute. The lateral margins are gently curved, and in some individuals progress smoothly into the curvature of the anterior margin. These are the truly semicurcular shells. In other individuals the lateral margins are rather straight and the transition to the anterior margin is not a smooth curve, but rather sharp, thereby accentuating the lateral and anterior margins. In such shells the anterior margin is slightly curved or truncated, causing the shell to exhibit a more subrectangular outline. In lateral profile the shell is concavo-convex with the thickest part in the middle. The lateral commissure is slightly convex and the anterior commissure is slightly concave. The surface ornamentation is unequally costellate with 3-4 fine costellae between two larger ones. (See Plate IV, figs. 4a, 4b, and 4c.) On a specimen measuring 9.3mm. in length, 18.0mm. in width there are 58 large costellae around the margin. A specimen measuring 12.5mm. in length, and 22.3mm. in width has 68 large costellae around the margin.

The pedicle interarea is wide and apsacline to various degrees; in some shells strongly apsacline and in others weakly apsacline almost approaching the orthocline position. The pedicle interarea is longer than in the brachial valve. Numerous cardinal fossettes are present along the hinge line. (See Plate IV, fig. 5a.) The delthyrium is triangular and covered in the posterior half by a slightly-arched pseudodeltidium. The primary teeth are short with rounded extremities. Some specimens have smaller, but well-developed, secondary teeth. The crural fossettes are large. In a few specimens they appear as "grooves" or "V-shaped" notches. The dental plates are thick and descend directly to the floor of the valve, joining with the lateral margins of the muscle field. The floor of the cavity is a horizontal plate supported along the middle by a septum. This keeps the plate above the floor of the valve so as to form two small conical cavities beneath the plate; one on each side of the septum. The margins of the platform near the dental plates join and are continuous with the floor of the valve. The horizontal platform does not extend anteriorly past the hinge line, although the septum extends various distances before it bifricates and disappears. The adductor scars are situated partially in the cavities beneath the platform and separated by the supporting septum. The diductor impressions are oval in shape and a little larger than the adductor scars. They are located immediately anterior and below the level of the adductor impressions. They are separated by the septum. The adjustor scars are large and divergent; the largest scars in the field. There is an elongate ridge along the inside of each adjustor scar. The lateral and anterior margins of the shell are tuberculate.

The brachial interarea is short and hypercline. The cardinal denticles are numerous and increase in size toward the extremities. The cardinal process is strong, elevated, and in well-preserved specimens distinctly trilobed. The sockets are large and deep. Some specimens have a second set of smaller sockets positioned outside the primary sockets. The brachiophores are widely divergent; extremities sharply pointed. Chilidial plates cover the posterior part of the process and seem to be fused to the process and the interarea. There is no evidence of a foramen. The median septum is wide and slightly bilobed just beneath the cardinal process. This septum soon bifricates into two prominent ridges which diverge slightly and extend about two-thirds the length of the valve. They reach their highest point in the anterior one-third from where they slope rather abruptly to the floor. The muscle field is large and orbiculate in outline. The field is divided by the two median septa; two adductor scars on each side. Each adductor pair is also separated by a less prominent ridge. Of the four septa crossing the muscle field the middle two are higher and longer. A few shells have a smaller septum between the two larger middle septa. This smaller septum is only one-half as long and one-fourth as high as those on its flanks.

Discussion: The largest specimens from the Viola attain sizes equal to *T. magna* Howe from the Montoya Group. However, only two specimens from the Viola collections show a rough lamellose exterior (see Plate IV, figs. 9 and 10) similar to *T. magna*.

If the larger specimens are excluded from the scatter plot (this was done in Figures 55 and 56 in order to compare these specimens to *T. aspera*) the resulting length-thickness and length-width data are similar to *T. aspera* Wang (see Howe, 1965a for data on *T. aspera* Wang). The Viola species has a smaller thickness than *T. recedens* (Sardeson).

Figure 55

Thaerodonta magna. The regression line and 95 percent confidence interval (length of shell-thickness of shell) for the articulated valves from Locality A, Unit 3C, upper 6 feet. All measurements are in millimeters. The larger specimens have been omitted from this scatter diagram.

Mean length: 0.9, mean thickness: 2.7, initial growth index (a): -0.6, growth ratio (b): 0.4.

Figure 56

Thaerodonta magna. The regression line and 95 percent confidence interval (length of shell-width of shell) for the specimens from Locality A, Unit 3C, upper 6 feet. All measurements are in millimeters. The larger specimens have been omitted from this scatter diagram.

Mean length: 9.0, mean width: 16.2, initial growth index (a): 1.8, growth ratio (b): 1.6.

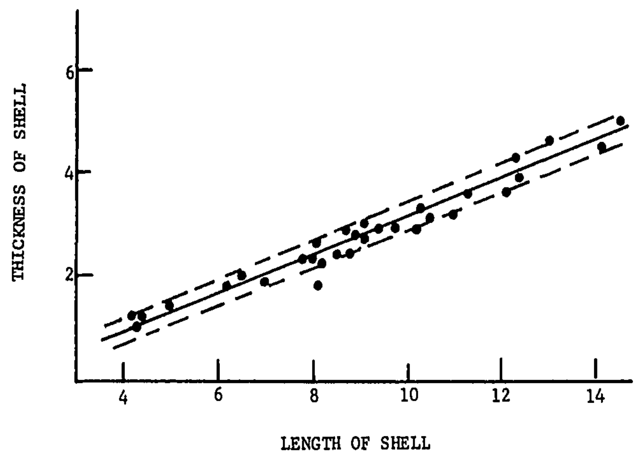


Figure 55

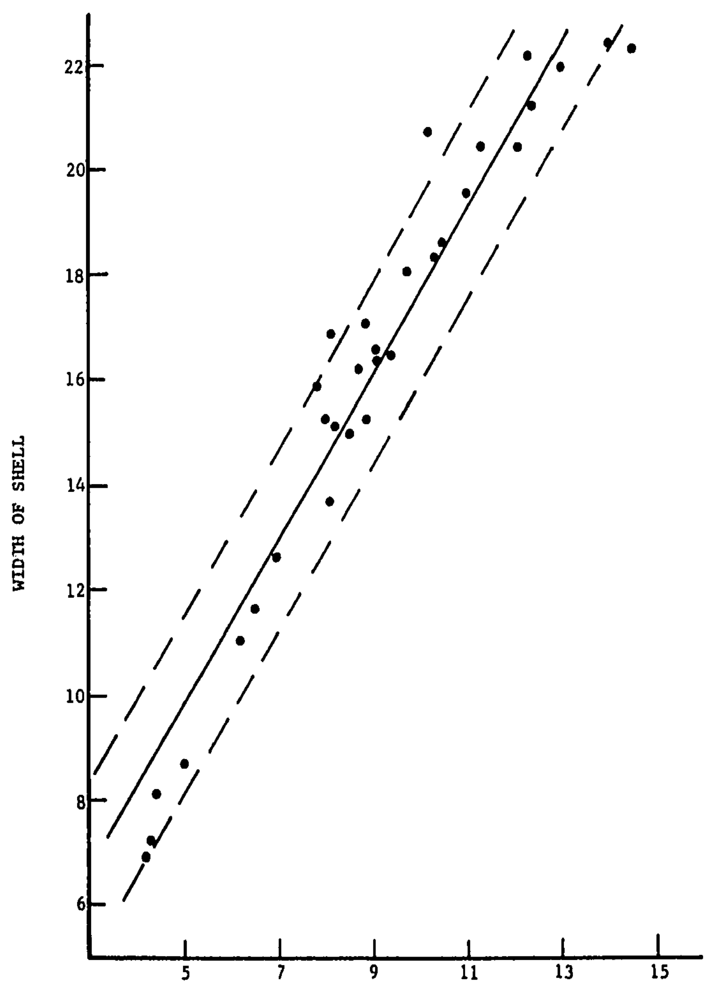


Figure 56

(See Howe, 1965a for data on T. recedens (Sardeson).) Although the Viola specimens have dimensions more like T. aspera,they do not show the roughly lamellose exterior so characteristic of that species. However, the surface ornamentation of the Viola species is more like T. aspera (3-4 finer costellae between 2 larger).

The writer has examined Howe's specimens of T. magna in the United States National Museum and is of the opinion that the Viola and Montoya forms are the same.

The writer considered all specimens of Thaerodonta from the Viola Formation to be members of one population. (All came from the same 2-3 foot bed.) Because T. magna is characterized primarily by its large size it is difficult to designate the smaller specimens as T. magna. This may be why Howe (1965a, p. 651, Figure 3) only gave dimensions for six of the larger specimens. The scatter diagram presented by Howe (1965a, p. 651, Text-figure 3) shows that for length-width dimensions specimens designated as T. recedens, T. saxea, and T. magna grade one into the other. Howe (1965a, p. 651) stated the fact that there is a complete gradation in size between T. recedens and T. saxea. However, he did not comment on the gradation in size from T. saxea to T. magna. After examining many specimens it is the opinion of the writer that there is much gradation between the species T. aspera, T. recedens, T. saxes, and T. magna. It is possible that "differences" between these species resulted from different ecologies. This is particularly true for the differences in size. It is also true that such differences are accentuated when only small samples are available.

Distribution and Material: This species is a common form in the upper Viola in the Arbuckle Mountains. It occurs in Unit 3C (upper 6 feet) at localities A, C, and D. At Locality I it occurs in Unit 3CM, 40-60 feet below the top of the formation.

There are over 300 specimens of this species. There are about an equal number of articulated and disarticulated specimens.

Genus Sowerbyella Jones, 1928

Sowerbyella n.sp. ?

Plate VIII, figs. 14-16

Description: The shell is moderate in size for the genus. (See Figure 60 for length-width data.) In outline it is rectangular to semicircular with the hinge line straight and the widest part. The cardinal extremities are at right angles or slightly acute. The lateral margins in some individuals are straight, but in others they are curved. In lateral profile the shell is concavo-convex. The convexity of the pedicle valve accounts for all the thickness of an articulated specimen. The highest point occurs in the middle, and the magnitude of curvature is gentle and even throughout. (See Plate VIII, fig. 14b.) The lateral and anterior commissures are rectimarginate. The surface is unequally parvicostellate with 4-5 smaller costellae between two larger ones. There are about four larger costellae in a space of 2mm. at a distance of 5mm. from the beak.

The pedicle beak is small. The interarea is flat, apsacline, and a little longer than in the brachial valve. The delthyrium is open

Figure 57

Sowerbyella n.sp. ?. The regression line and 95 percent confidence interval (length of shell-thickness of shell, articulated). The specimens are from Locality C, Unit 2, 270-280 feet below the top of the formation. All measurements are in millimeters.

Mean length of shell: 8.1, mean thickness: 2.9, initial growth index (a): -1.7, growth ratio (b): 0.6.

Figure 58

Sowerbyella n.sp. ?. Scatter diagram showing the relationship between the length of the pedicle interarea and the length of the brachial interarea. All measurements are in millimeters. All specimens are from Locality C, Unit 2, 270-280 feet below the top of the formation.

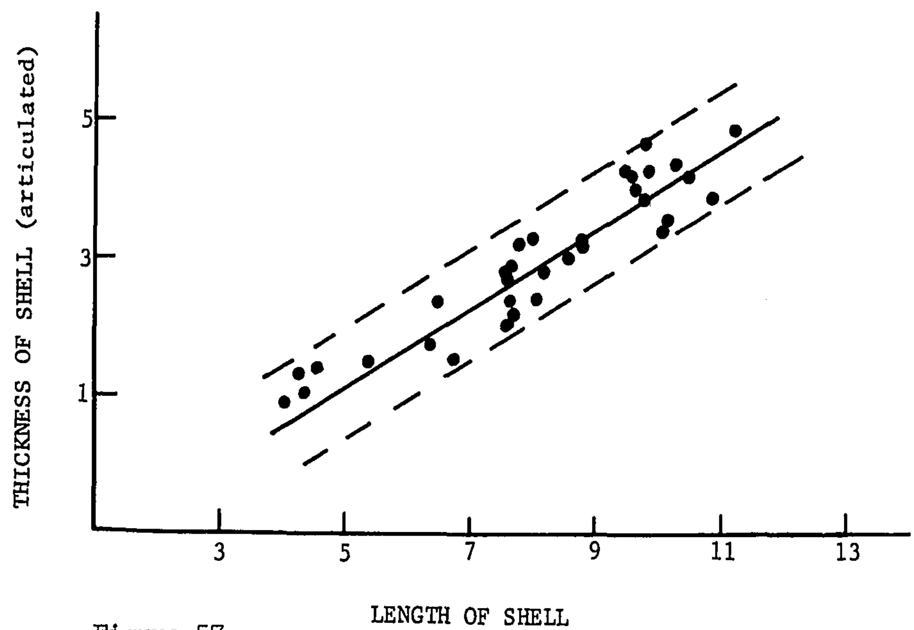


Figure 57

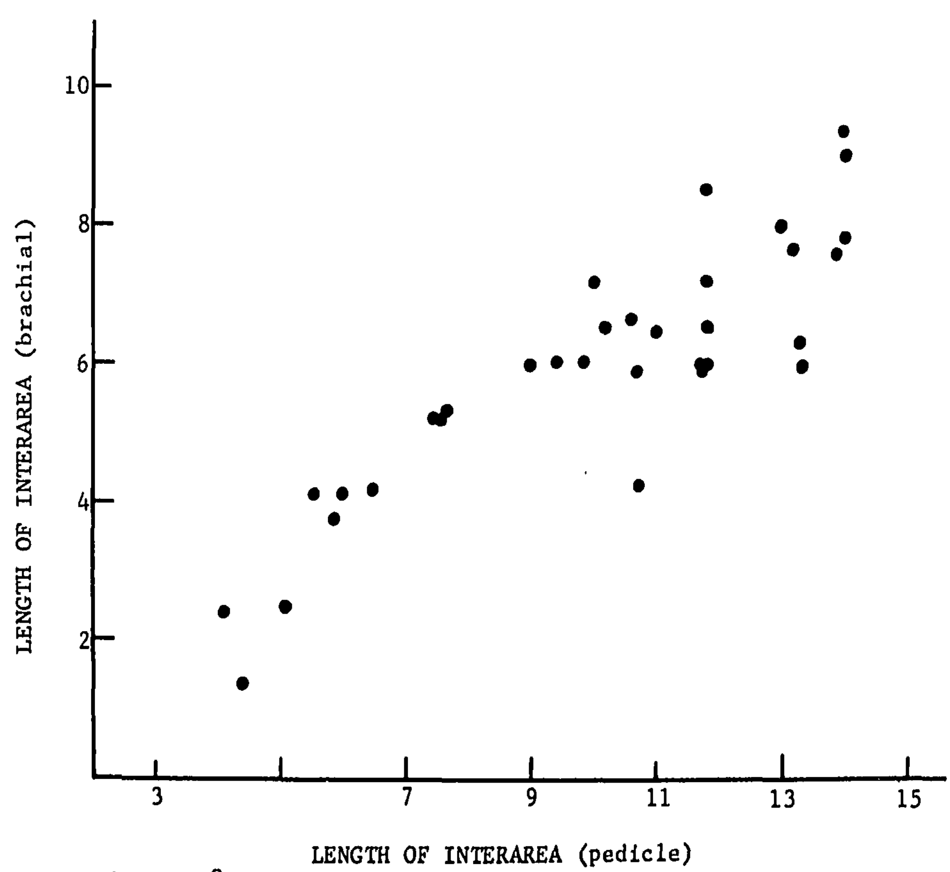


Figure 58

Figure 59

Sowerbyella n.sp. ?. The regression line and 95 percent confidence interval (length of shell-length of pedicle interarea). The specimens are from Locality C, Unit 2, 270-280 feet below the top of the formation. All measurements are in millimeters.

Mean length of shell: 8.0, mean length of interarea: 1.0, initial growth index (a): -0.2, growth ratio (b): 0.2.

Figure 60

Sowerbyella n.sp ?. The regression line and 95 percent confidence interval (hinge line width-length of shell) for specimens from Locality C, Unit 2, 270-280 feet below the top of the formation. All measurements are in millimeters.

Mean hinge line width: 12.8, mean length: 8.2, initial growth index(a): -0.2, growth ratio (b): 0.7.

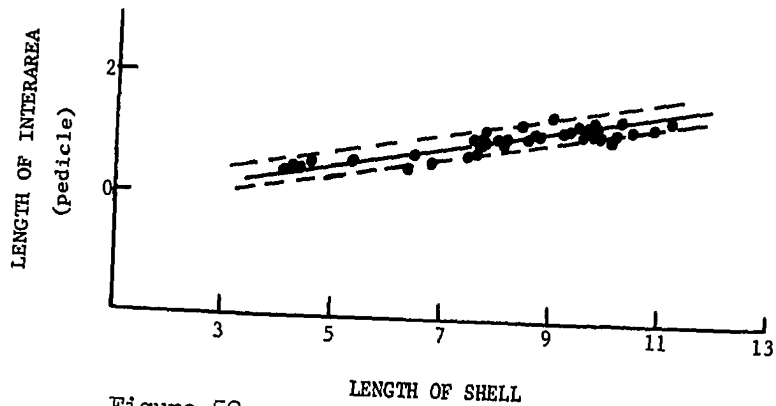


Figure 59

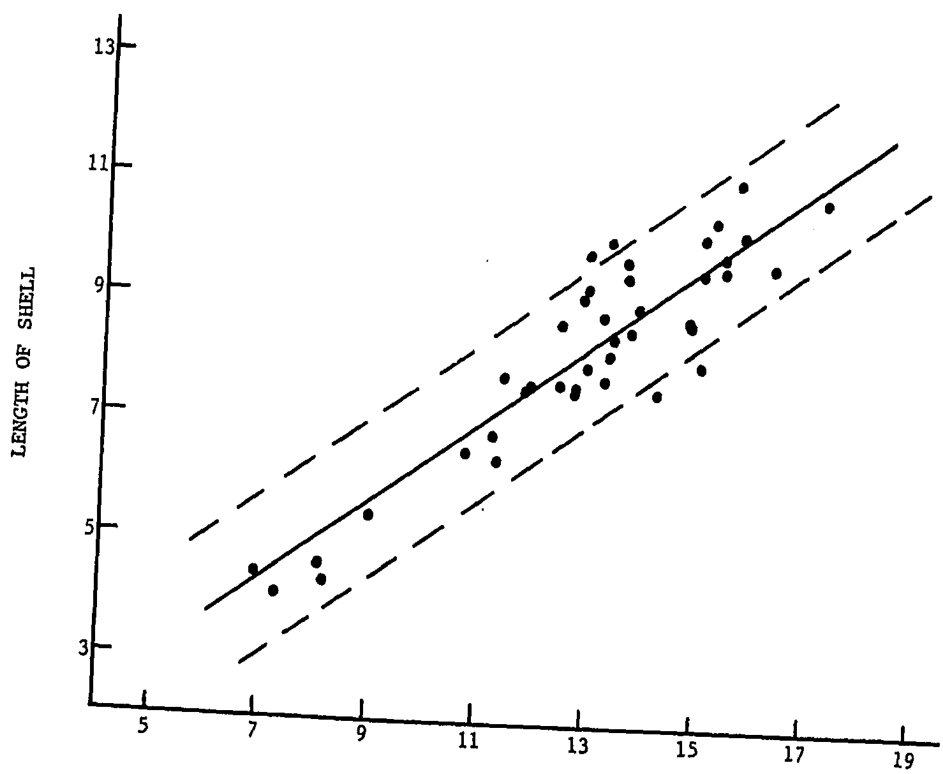


Figure 60

in the majority of specimens, but in a few there is a small apical arch similar to a deltidium. The delthyrial opening is wide and the cavity moderately deep. The teeth are short with rounded extremities. The dental plates are thick, but rather indistinct, and almost inseparable from the floor of the valve. The diductor impressions are large, slightly divergent, and ellipsoidal in outline. They are well defined and moderately impressed. A prominent ridge separates the two diductor scars in the posterior part of the field. This ridge bifricates at its anterior end, about half way across the muscle field. The ridge extends posteriorly into the delthyrial cavity and joins to the posterior wall. Just posterior to the two large diductor scars are the two well-impressed, small, adductor scars. These are separated from each other by the posterior extension of the ridge. These scars actually occupy the delthyrial cavity. They are partially covered by shell material which also fills the posterior half of the opening.

The brachial interior is not well preserved. The brachial interarea is flat, short, and anacline. The cardinal process is preserved only as a simple knob projecting in a postero-ventral direction. The crural processes diverge at a wide angle and help define the narrow, elongate sockets.

Discussion: Because of the poor preservation of the brachial interior this is questionably described as a new species.

Distribution and Material: This species is common in Unit 2 at localities C and D; 275-285 feet below the top of the formation.

Over 500 specimens were collected.

Sowerbyella sp.

Plate IX, figs. 8, 9, and 10

Description: In doesal outline the shell is semielliptical with the cardinal extremities acute. The lateral margins are straight and inclined toward the median. The anterior margin is broadly curved; almost straight. The hinge line is straight and the widest part of the shell. The anterior profile is almost "V-shaped" with the middle of the pedicle valve sharply curved and the lateral slopes straight. In lateral profile the shell is concavo-convex; the thickest part being posterior to the middle. The lateral and anterior commissures are rectimarginate. The surface is unequally parvicostellate. At 5mm. from the beak there are about six of the larger costellae in a space of 2mm. Normally two, and sometimes three of the smaller costellae are between the larger ones.

The pedicle interarea is plane, apsacline, and measures 4mm. in length in an average adult specimen. The umbonal region is slightly swollen. The delthyrium is triangular and covered in the apical region by an arched pseudodeltidium. The teeth are short with rounded extremities. They extend about 2mm. anterior of the hinge line. Beneath the teeth and along the sides of the interarea and facing in the direction of the open delthyrium are two distinct, fine grooves; one on each side of the delthyrium. The apex of the cavity is filled with shell material. Just under this material and level with the floor of the valve are two small, conical muscle impressions. They are separated by a median ridge which maintains itself for about 1.5mm. anteriorly from this apical shell material. The diductor scars are elliptical in outline, divergent, and in their posterior half are separated by the median ridge.

The brachial interarea is plane, catacline, and about .5-.6mm. long. There are two submedian ridges extending and rising from just anterior to the cardinalia to a high point just anterior to the middle of the valve. The muscle areas on each side of the double septa are ellipsoidal in shape (3.2mm. x 5.4mm.) elevated. Each area is rimmed by shell material. The lateral and anterior margins of the valve interior are raised above the valve floor. This raised rim is about 2.0mm. wide and maintains a constant height all around the valve.

Discussion: The acid etching process has obliterated many of the shell features and therefore a positive identification is impossible.

Distribution and Material: This species has been found at two localities: D and L. At both localities it is in Unit 1C. At Locality D the species occurs in the basal one foot of Unit 1C; at Locality L it occurs in Unit 1C in the basal one foot, and 40 feet above the base. About 30-40 specimens were collected.

Superfamily Strophomenacea King, 1846

Family Strophomenidae King, 1846

Genus Strophomena Rafinesque in de Blanville, 1825

Strophomena planumbona (Hall), 1825

Plate VI, figs. 2 and 3

Leptaena planumbona Hall, 1847, v. 1, p. 112, Pl. 31B, 4a-e.

Strophomena planumbona (Hall), Foerste, 1912, v. 17, pp. 73-81, Pls. 4, figs. 3a-b; 8, figs. 1a-e; 9, figs. 3a-b. Wang, 1949, p. 23, Pl. 6D, figs. 1-7.

Description: The shell is moderate in size (see Discussion for various dimensions) and subrectangular in outline with the width always a little greater than the length. The hinge line is straight and just about the widest part. The cardinal angles vary from being at right angles to being acute. The lateral margins are straight and the anterior margin broadly rounded. The beak is small and sharply pointed a little past the posterior margin of the interarea. The umbo is slightly swollen. In lateral profile the curvature of the pedicle valve is even, there being no prominent geniculations. The pedicle interarea is long, plane, and apsacline. The pseudodeltidium is convex and distinctly above the level of the interarea. The foramen is circular, apical in position, and almost "pin-point" in size. There is considerable shell thickening beneath and along the lateral two-thirds of the interarea. This supporting shell material is absent immediately adjacent to the teeth and dental plates. The teeth are divergent and supported by thick dental plates which continue anteriorly, thus forming the border of the prominent, almost circular muscle area. The height of this border decreases anteriorly so that in some specimens the anterior portion of the field has a very low shell border. In other shells, the height of the border is maintained completely around the field except for a small gap at the anterior. The muscle field is bisected by a thin ridge which extends from the posterior of the delthyrial cavity to the anterior of the field. This ridge is higher posteriorly and connected to the under side of the pseudodeltidium. In the center of the ridge and close to the pseudodeltidium there is a small opening which must have allowed for the passage of the pedicle. The adductor scars are long and narrow; one scar on each side of the ridge. The diductor scars are large, but do not enclose the adductors. The adjustor scars were not observed. The interior of the valve is covered by numerous pustules, randomly arranged.

The brachial interarea is short, plane, and anacline. In lateral profile the valve is convex. The posterior two-thirds is flat, leading into a moderate geniculation of the anterior one-third. The cardinal process is bilobed, with each lobe having a concave posterior face. Adjacent to the process on each side are prominent triangular sockets. No muscle scars were observed.

Discussion: The following table gives the various dimensions for the pedicle valves from the Viola Formation. There was only one brachial found. All measurements are in millimeters.

The writer has found no prior reference to the small opening located at the posterior of the ridge which bisects the muscle field. Arber (1940) discusses the foramen in the genus Strophomena and asserts

Length	Width	Length of Pedicle Muscle Field	Width of Pedicle Muscle Field	Length of Interarea
18.4	26.2	9.0	9.0	4.5
--	20.3	6.5	7.2	3.6
17.4	22.6	7.2	7.3	3.8
19.0	27.0	7.3	8.0	4.9
17.2	25.0	--	--	--
18.8	25.2	--	8.1	4.0
17.3	26.0	--	--	4.5
18.9	27.3	--	--	--

(p. 166) that in S. planumbona (Hall)". . . the pedicle must have survived into the neanic phase, but subsequently atrophied, since the foramen is still small and plugged with shell substance." The Viola specimens show the foramen to be open throughout (although they are small and could be considered reduced in size) and could possibly have allowed for the passage of a functional pedicle.

Distribution and Material: This species is confined to the upper 6 feet of Unit 3C at localities A and C. In Unit 3CM it occurs 40-60 feet below the top of the formation (Unit I).

Eight to ten pedicle valves and one brachial valve were collected.

Strophomena perconcava Wang, 1949

Plate VII, fig. 4

Strophomena perconcava Wang, 1949, p. 26, Pl. 7C, figs. 1-5.

Description: In dorsal view the shell is subcircular to subelliptical in outline; the curvature from the cardinal extremities to the anterior margin is of about the same magnitude. The hinge line is straight and the widest part of the shell. In anterior profile the curvature is even, with the lateral slopes steep. In lateral profile the shell is convexi-concave. The pedicle interarea is plane, fairly wide (maximum width is 4.3mm.), and catacline. The triangular delthyrium is covered by an arched pseudodeltidium.

The brachial valve has a flat posterior portion extending approximately 8.0mm. before the curvature increases sharply across the middle of the valve leading smoothly into the steep anterior slope. The interarea is short, about one-fourth to one-fifth the width of the pedicle interarea.

In the umbonal region all of the costae are about the same size; about 12 in a 2mm. distanct at 5mm. from the brachial beak. Away from the beak, and on the curved portion of the valve, the costae can be differentiated into large and small. Here there are five larger costae in a distance of 2mm. with larger costae having 2-3 smaller costae between them.

Discussion: No specimens showing the interiors were found. The Viola species is more subcircular in outline than the species from the Maquoketa Formation of Iowa. Also, the Maquoketa species has more numerous growth lines around the anterior margin.

Distribution and Material: There was only one specimen collected at Locality G; Unit 3CM. The collecting interval from which this specimen came is 60-75 feet below the top of the formation.

Strophomena cf. S. clermontensis Wang, 1949

Plate VII, fig. 3

Strophomena clermontensis Wang, 1949, Pl. 7D, figs. 1-4.

Description: The shell is subquadrate in dorsal outline. The hinge line is straight. The lateral margins are straight and turn sharply into the straight anterior margin. In anterior profile the brachial valve is flat across the middle with steeply sloping sides, almost normal to the plane of commissure. There is a broad, shallow brachial sulcus. The posterior of the brachial valve is flat for about 13mm. at which point a sharp, almost 90 degree geniculation occurs and extends for another 10-12mm. to the anterior margin. The brachial interarea is short; about one-fourth that of the pedicle interarea, orthocline.

The pedicle valve is concave. The interarea is plane, long, and apsacline. The umbonal region is swollen for a distance of 6-7mm. outward from the beak. The costellae are all about the same size with 8-9 in a space of 2mm. at a distance of 5mm. from the beak.

Discussion: The few specimens from the Viola Formation differ from S. clermontensis of the Maquoketa Formation in 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 on the Viola specimens.

Distribution and Material: Only 3-4 specimens of this species were collected at Locality G, Unit 3CM, 60-75 feet below the top of the formation.

Strophomena sp.

Plate IX, fig. 3

Description: The shell is subquadrate in outline with the width greater than the length. The hinge line is straight and the widest part. In dorsal view the cardinal areas are concave. The curvature of the brachial valve is broad and even in both lateral and anterior profile. In lateral profile the shell is convexi-concave with the highest point in the middle. The posterior 5-6mm. of the brachial valve has a slight sulcus. This is accompanied by a fold on the pedicle valve. There are approximately 30 costae originating at the beak. In the posterior one-third of the shell there are costae of two sizes, however, on the anterior and antero-lateral slopes the costae are all of about the same size. At 5mm. from the beak there are 14 costae in a 2mm. space. At the anterior margin there are seven costae in a 2mm. distance.

The pedicle interarea is plane and apsacline, having a maximum length of 2mm. The delthyrium is covered completely by an arched pseudodeltidium. There is a small, circular foramen at the apex.

The brachial interarea is short and orthocline.

Discussion: No specimens showing the interiors were found. The dimensions for the only complete specimen are given below:

Width of Hinge Line	Length	Thickness
26.0mm.	19.2mm.	4.5mm.

Distribution and Material: The only specimen found is from Locality D, Unit 1C, 1-2 feet above the base of the formation.

Strophomena neglecta (James), 1881

Plate VI, figs. 4, 5, 6, 7, and 8

Streptorhynchus neglectum James, 1881, v. 5, p. 41.

Strophomena neglecta (James), Foerste, 1912, pp. 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. 9G.

Strophomena neglecta (James), Howe, 1965b, p. 652, pl. 82, figs. 13, 15.

Description: The shell is large (dimensions are given in the Discussion), subrectangular to subquadrate in outline; hinge line straight and the widest part of the shell. The cardinal extremities form right angles; the lateral margins are straight. The anterior margin is broadly rounded. The surface is ornamented by an alternating sequence of one large and one small costae. There are about 28 costae in a distance of 5mm. at a distance of 8mm. from the beak. The pseudodeltidium extends from the apex to the hinge line. It is flatly convex, barely rising above the level of the interarea. The foramen is small, circular, and apical. On each side of the pseudodeltidium, where it joins the interarea, there is a narrow groove marking the junction. The interarea is long, plane, and apsacline. The lateral two-thirds of the interarea is supported by shell material. The area beneath the interarea and next to the teeth is open, showing the thin nature of the interarea. The teeth are long and divergent, each bearing a groove along the dorsal face. The dental plates slope laterally and join the elevated border around the muscle field. The prominence and shape of this border is highly variable. In some specimens there is a gap at the anterior margin. The floor of the delthyrial cavity is elevated slightly. The myophragm is low, narrow, and extends to the anterior edge of the muscle field. At the apex of the cavity there is a small opening for the passage of the pedicle. The adductor scars are ellipsoidal in shape, positioned in the posterior one-third of the field. In most specimens they are well impressed. The diductor scars are large and enclose the adductors anteriorly. The whole field is crossed by wide radiating grooves giving it a flabellate appearance. The area outside the field is pustulose.

In lateral profile the posterior two-thirds of the brachial valve is flat. At a distance of about 20mm. anterior to the beak the valve turns sharply in the ventral direction. This geniculated portion extends for about 15mm. The interarea is short, plane, and anacline to almost orthocline. The cardinal process is bilobed with the lobes diverging so as to become more separated anteriorly. Each lobe is concave. The sockets are long, triangular in shape, and fairly deep. The median septum is a low rounded ridge which extends about 8-10mm. toward the anterior. No muscle scars were observed in the brachial valve.

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

Length	Hinge Line Width	Mid-valve Width
28.3mm.	41.3mm.	34.0mm.
--	44.8mm.	--
27.1mm.	38.0mm.	--
29.0mm.	--	--
32.5mm.	--	--
35.0mm.	44.0mm.	40.0mm.
31.8mm.	40.0mm.	33.9mm.
25.0mm.	38.0mm.	--

The genus Tetraphalarella was erected by Wang (1949) and separated from Strophomena. According to Wang, one of the primary differentiating characteristics was the complete enclosure of the adductor scars by the diductor scars in the genus Tetraphalarella. In discussing this problem Howe (1965b) states (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 interior of Tetraphalarella planodorsata Winchell and 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 show much variation in the size, shape, and prominence of the pedicle muscle area. Also, many of the other characters vary greatly. Because of this variation the writer prefers to refer the species to the genus Strophomena and not Tetraphalarella.

Distribution and Material: This species has been found at several localities. At localities A and C it occurs in the upper 6 feet of the formation (Unit 3C). At Locality G it is found 60-75 feet below the top of the formation (Unit 3CM). Farther to the southwest, at Locality I, it is fairly common 50-60 feet below the top of the formation (Unit 3CM).

About ten specimens (mostly pedicle valves) were collected from the Arbuckle Mountains.

Strophomena n.sp.?

Plate VI, fig. 1

Description: The shell is thin and subquadrate in outline. The hinge line is straight and the widest part of the shell. The cardinal extremities are at about right angles; the lateral margins not parallel, but slightly converging toward the median. The anterior margin is evenly rounded and there is no sharp antero-lateral angle. The umbo is moderately swollen. In lateral profile the pedicle valve is almost flat with the greatest curvature occurring in the anterior one-third. The surface is parvicostellate. In the umbonal region two sizes of costae are present, alternating one with the other. There are about 10-11 costae and costellae in a space of 5mm. at a distance of 10mm. from the beak. The difference in the size of the costae becomes impreceptible outside of the umbonal region. The pedicle interarea is plane and apsacline. The pseudodeltidium is convex with the foramen apical in position. The teeth are long and divergent with a concavity along the dorsal face. The dental plates are delicate and advancing. The muscle field is widely cordate in shape. The adductor scars are small and somewhat elongate. They are positioned in the posterior one-third of the field. The diductor scars are large and may not enclose the adductors. A border is present only in the posterior one-half of the field.

Discussion: There was only one pedicle valve of this species found in the Arbuckle Mountains; there were no brachial valves. However, several identical specimens have been found in northeastern Oklahoma ("Fernvale" Cape Limestone). This species is characterized by its thin, delicate shell, and flat lateral profile.

Distribution and Material: The single pedicle valve is from Locality C, Unit 3C, the upper 6 feet of the formation.

Genus Megamyonia Wang, 1949

Megamyonia n.sp?

Plate VI, figs. 9-11

Description: The shell is small (dimensions are given in Discussion section) and subquadrate in outline. The hinge line is straight and the widest part. The cardinal extremities are acute with the lateral margins straight and inclined toward the median. The anterior margin is narrowly rounded. There are no sharp changes in the curvature of the lateral and anterior margins. In lateral profile the shell is concavo-convex. Along the median line the posterior part of the valve is flat for a distance of about 10mm. at which point a sharp geniculation occurs. The surface ornamentation appears to have been obliterated.

The pedicle interarea is plane and apsacline; much longer than in the brachial valve. The pseudodeltidium is convex and covers the posterior one-half of the triangular delthyrial opening. The teeth are divergent, short, and well-rounded. The median portion of the cavity floor is strongly elevated. The posterior apex of the diductor scars isolates this elevation from the walls of the cavity. The muscle area is very large. (See Plate VI, figure 10b.) The adductor scars are centrally located. They are small, ellipsoidal, and well impressed; separated by a ridge which rises posteriorly. This ridge ends at the anterior margin of the adductor scars. The diductor impressions are large, divergent, and greatly expanded anteriorly. The anterior margin of these scars is at the position of geniculation of the valve. The diductor scars do not enclose the adductors. (See Plate VI, figure 10b.) The adjustor scars were not observed.

The cardinal process is stout and bilobed; the faces of the lobes extending normal to the plane of commissure. The muscle field is triangular in shape, widest at the posterior and nearly pointed at the anterior. The adductor scars are all about the same size. The anterior pair are ellipsoidal and separated by a flat ridge. The posterior scars are located a little behind and to the sides of the anterior scars. The field extends slightly past the middle of the valve.

Discussion: This species is very similar to 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 in the pedicle valve. In M. knighti, the median septum is strong and extends all the way to the anterior margin of the valve. In the Viola species, the median septum is present only in the posterior of the valve. (See Plate VI, fig. 11a.) In addition, the Viola specimens are larger than M. knighti and have a different dorsal outline; the Viola species is longer relative to the width.

The general dimensions for this species are given below:

Length	Hinge Line Width	Mid-Width
12.3mm.	18.0mm.	13.2mm.
14.6mm.	16.3mm.	15.4mm.
12.8mm.	16.2mm.	13.9mm.
11.4mm.	16.2mm.	--

Distribution and Material: This species occurs at localities A and C; Unit 3C, the upper 6 feet. There were only 3-4 specimens collected.

Genus Oepikina Salmon, 1942

Oepikina sp.

Plate VIII, figs. 9 and 10

Description: The shell is moderate to large for the genus. The single articulated specimen collected has the following measurements: length: 22.9mm., hinge line width: 27.1mm., mid-width: 25.0mm., thickness: 12.3mm. In dorsal view it is subcircular to subelliptical in outline. The hinge line is straight and the widest part. The cardinal extremities are at right angles. The lateral margins are weakly rounded and lead evenly into the more narrowly rounded anterior margin. In lateral view the shell is concavo-convex. The thickest part of the shell is immediately posterior to the middle. The posterior one-third of the pedicle valve is flat with a very sharp geniculation 12-13mm. anterior from the beak. The anterior two-thirds of the valve is gently rounded. The angle of geniculation is about 110 degrees. The surface is parvicostellate; approximately six costellae in a space of 2mm. at a distance of 6mm. from the beak.

The pedicle interarea is flat, orthocline, and about three times as long as in the brachial valve. The delthyrium is triangular, the posterior one-third covered by an arched pseudodeltidium. The cavity is moderately deep. There is a prominent foramen at the apex of the pseudodeltidium. The teeth are short and divergent. The dental plates are thin and advancing. The margins of the muscle field are oblique to the direction of dental plate extension. The lateral margins of the field are straight and are directed inward toward the middle of the valve.

The interarea of the brachial valve is short and anacline. The cardinal process is prominent, bilobed, and extends posteriorly past the interarea. Each lobe is distinctly separate from the other. The sockets are large, shallow, and triangular in shape. The brachiophores are weak and poorly developed. They are situated on the ridge which forms the anterior border of the sockets. A median septum is present, but weak. Antero-lateral septa are thin and more prominent than the median septum. The muscle field is subelliptical in shape. The area outside the muscle field is finely pustulose, almost granular in appearance. Around the margins of the valve there is a well-developed, beaded ridge with rounded top. (See Plate VIII, figure 10a.) This ridge, as well as the area just posterior to it, is crossed by numerous grooves presumably caused by the strong vascular system. The area along the outside of the ridge is deflected sharply toward the brachial valve.

Discussion: The Viola species strongly resembles *Oepikina limbrata* Wang in size and shape. However, there are several differences of which the most outstanding is the nature of the ornamentation. *O. limbrata* is unequally costellate with 8-9 costellae between two larger costae. In the Viola species there is no clear separation into these two size groups. These two species also differ in lateral profile. The pedicle valve of *O. limbrata* is smooth and even. The curvature of the pedicle valve of the Viola species is angular.

Distribution and Material: The writer collected one articulated specimen, two brachial valves, and one partial pedicle valve. The species was collected from the lower part of Unit 2 at Locality C, 275-280 feet below the top of the formation.

Genus Rafinesquina Hall and Clarke, 1892

Rafinesquina sp.

Plate IX, fig. 4

Description: The shell is subelliptical in outline with the hinge line straight and the widest part. The cardinal margins are at right angles. The lateral margins are gently curved with the anterior margin more sharply rounded. In an immature specimen the curvature is about the same all around. The surface is parvicostellate with 3-6 smaller costellae between two larger ones. The number of finer costellae depends on how far anterior from the beak the observation is taken. However, even at the same distance from the beak, but at different places, it is possible for the number of finer costellae to vary. In lateral profile the posterior two-thirds of the shell is flat with a geniculation occurring 17-18mm. from the beak (measured along the median). The angle of geniculation is about 45-50 degrees. When measured along the median the trail is 11-12mm. in length.

The pedicle interarea is short, faintly curved, and apsacline. The beak is small and pointed. The delthyrium is triangular and open.

Discussion: This species was collected from the lower part of Unit 2, localities C and D. At Locality C, 2-3 silicified specimens were collected, 280-283 feet below the top of the formation. At Locality D this species is represented mostly by impressions 220-236 feet below the top of the formation.

Distribution and Material: This species occurs in the lower part of Unit 2.

Order Rhynchonellida Kuhn, 1949

Superfamily Rhynchonellacea Gray, 1848

Family Rhynchotrematidae Schuchert, 1913

Genus Rhynchotrema Hall, 1860

Rhynchotrema increbescens Hall

Plate VII, fig. 10

Rhynchotrema increbescens Hall, 1847, p. 146, pl. 33, figs. 13c, and d.

Description: The outline of the shell is subrectangular to subtriangular. The widest part occurs at about the middle. In lateral profile it is unequally biconvex with the brachial valve about twice as deep as the pedicle valve. The beak is small, suberect, and protrudes posteriorly about 1mm. past the brachial valve. The anterior commissure is uniplicate. There are 6-7 plications on the flanks, 4 on the brachial fold, and 3 in the pedicle sulcus. Most shells bear imbrications along the anterior and antero-lateral one-half of the shell. The delthyrium is small, triangular, and open. The sulcus begins about 2-4mm. from the beak; widens and deepens anteriorly. At the anterior margin it averages about 6mm. in width. The tongue is about 5-6mm. in length depending on the growth direction in this part of the shell. During the early growth stages the brachial valve has a very shallow, but distinct sulcus. This early sulcus is formed by 1-2 depressed plications which later become the two inner plications of the fold.

Internally, the brahiophores are slender, divergent, and curved concave toward the pedicle valve. There is a prominent median septum extending to about the middle of the valve. The septum is positioned opposite the external inner trough of the fold; this trough being bounded on each side by the two fold plications. It is this trough and normally the adjacent plications which are depressed in the umbonal region of the valve. No muscle scars were observed. In some shells the cardinal process is present, and in others it is poorly developed or absent.

Discussion: Weiss (1955) classifies *R. wisconsinensis* Fenton and Fenton as a subspecies of *R. increbescens*. Weiss claims that *R. wisconsinensis* and *R. increbescens* grade into each other in collections from a single bed. If this is correct it seems to the writer that a more reasonable biological solution would be to note the limits of variation and treat "both" as one variable species, *R. increbescens*.

The dimensions for this species from the Viola Formation are given below. The measurements are given in millimeters.

Length	Width	Thickness
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: This species occurs in Unit 2 at localities C, D, and L. In Unit 2 at other localities there are fragments of a small rhynchonellid, presumably *R. increbescens*.

Only 8-10 specimens were collected.

Genus *Lepidocyclus* Wang, 1949

Type species: *Lepidocyclus laddi* Wang, 1949, p. 12; Upper Elgin Member of the Maquoketa formation; along east-west road in southwest quarter of section 17, Orleans township, Winnishiek County, Iowa.

Diagnosis: Variable in outline, but usually globose. Internally a deep pedicle cavity, large flabellate muscle field in the 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 which had previously been referred to *Rhynchotrema*. According to Wang (1949) the chief distinguishing characteristics of *Lepidocyclus* which set it apart from *Rhynchotrema* 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 (1964, p. 96) many of these distinguishing characteristics exhibit much wider variation than previously recognized. Several of these are now known to occur in both genera. For example, 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 (1964, 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 there are 10 species of Lepidocyclus. Wang (1949) described seven species from the Maquoketa Formation of Iowa. However, it is possible that with larger and better collections some of these may prove to be only form species. Howe (1966b) described two new species from the Cape (Fernvale) Limestone of Missouri and northeast 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.

The plylogenetic relationships among the various species is difficult to assess at this time. Much more detailed collecting is needed in some geographic areas before any definitive picture of the phylogenetic relationships can be attempted.

Lepidocyclus cooperi Howe, 1966

Plate I, figs. 4-8

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

Description: This species is of moderate to large size (see Figures 66 and 67 for dimensions) with the length and width dimensions about equal. The greatest width occurs anterior to the middle in most shells. The outline of most specimens when viewed from the ventral is subpentagonal (see Plate 1, figure 4b), but in a few specimens it is subrectangular. The lateral margins are gently curved and almost parallel, the anterior margin straight. In dorsal view, the outline is almost circular in specimens having a thickness greater than 13mm. (See Plate 1, figures 4a and 4f.) Those specimens less than 13mm. thick have a more subpentagonal to subquadrate outline. (See Plate I, figs. 8a and 8b.) In lateral profile the shell is unequally biconvex with the brachial valve nearly twice as deep as the pedicle valve. (See Plate I, fig. 4d.) Again, those specimens less than 13mm. thick show a more equally biconvex profile with the brachial valve just a little deeper (see Plate I, fig. 8a). In most of the specimens the anterior commissure is strongly uniplicate, but in the more equally biconvex specimens it is more gently uniplicate.

The fold on the brachial valve is first preceptible at about 5mm. from the beak, whereas the sulcus of the pedicle valve first appears at 7-8mm. Both expand and increase in prominence toward the anterior. The majority of individuals have four plications on the fold and three in the sulcus. However, there are two specimens in the collection, both of average size, one of which shows five and the other six plications on the fold. There are from seven to nine plications on the flanks. In profile, the plications together with the intervening troughs form a smooth sinuous curve. Along the anterior margins of the shell the tops of the plications become flat or concave. The surface of the shell is covered by numerous fine filae; about 16-18 in 10mm. at almost any position away from the beak.

In lateral profile the pedicle valve is very gently convex with the intensity of curvature about the same from posterior to anterior. The beak is prominent and suberect. (See Plate I, fig. 5b.) The hinge line is short, slightly curved, and one-third to one-half the width of the valve. The foramen is large, circular, with a mesothyroid or sub-mesothyroid position. The deltidial plates are faintly concave, each sloping gently toward the anterior. The two plates join just anterior to the foramen forming a distinct groove. (See Plate I, fig. 7a.) The teeth are very stout appearing as nodes over the extremities of the hinge line. They are raised above the hinge line and supported by thick shell material. These shell supports assume divers degrees of "inflation" causing the teeth not to be positioned the same in all valves. The difference in the amount of shell material and the configuration taken by this material results in the posterior of the valve being extremely variable in appearance. The pedicle muscle field is large (see Figure 62 for dimensions), and in most valves easily visible (see Plate I, fig. 7a). The adductor scars in most valves are positioned in the center or just posterior to the middle of the field. However, a few specimens have them in the extreme posterior of the field. The diductor scars are flabellate and enclose the adductors anteriorly (see Plate I, fig. 7a). The adjustor impressions are deeply fixed along the postero-lateral margins of the field. The degree to which these scars are impressed depends on the amount of "swelling" in the shell material supporting the teeth. Most valves have this "swelling" such that the material overhangs the postero-lateral margins of the field. The anterior and antero-lateral margins of the valves are serrated.

In overall appearance of the brachial valve is "bulbous" or "subconical" depending on the height of the fold. The beak is small, incurved, and concealed by the pedicle valve. The cardinalia is robust with a blade-like cardinal process. (See Plate I, fig. 6b.) The sockets are large and deep, separated from the notothyrial cavity by massive hinge plates. The crural processes are thin, about twice as wide as thick. They are attached to the inner anterior corner of the hinge plate. The processes are curved concave ventrally. A median septum extends from just beneath the cardinalia to a little past the middle of the valve. The adductor scars are impreceptible in most valves. However, one specimen showed these scars to be small ellipsoidal pits located well below the cardinalia, separated by the median septum. (See Plate I, fig. 6d.)

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. Figures 63 and 65 show the variation in the fold height. In many cases the longer, and therefore older shells (the writer is assuming that the shell length is some indication of age) have the higher folds. A large specimen showing a high fold is shown in figure 4d of Plate I. Here, the fold height increases as the shell length increases. In contrast to this, and to illustrate the other extreme in shell growth, figure 5b of Plate I 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 a change in the growth vectors; a problem which has been discussed by Rudwick (1959). All of the specimens examined, including both those with low and high folds, have the fold beginning at about the same distance from the beak.

Lepidocyclus cooperi occurs in the same stratigraphic horizon as Lepidocyclus 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 of the specimens of L. cooperi show a slightly curved pedicle valve. L. capax is best characterized by having no deltidial plates. (Compare figure 3g of Plate I with figure 7b of Plate I.)

Howe (1965c) discussed the presence or absence of deltidial plates in the genus Lepidocyclus. He stated (1965c, 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.

Nikoforova (1961, reported in Treatise, 1965) proposed that the name Lepidocycloides be used for those forms similar to Lepidocyclus, but lacking deltidial plates and lacking a cardinal process. All of the specimens from the Viola formation which were studied by the writer 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 which are concave ventrally.

Figure 61

Lepidocyclus cooperi. The regression line and 95 percent confidence interval for the articulated specimens from localities A and C. All the specimens are from the upper 6 feet of Unit 3C. All measurements are in millimeters.

Mean thickness: 11.4, mean length: 16.0, initial growth index (a): 11.1, growth ratio (b): 0.4.

Figure 62

Lepidocyclus cooperi. The regression line and 95 percent confidence interval (length of pedicle valve-width of pedicle muscle field). The specimens are from the upper 6 feet of Unit 3C at localities A and C. All measurements are in millimeters.

Mean length: 17.9, mean width of muscle field: 8.8, initial growth index (a): 3.4, growth ratio (b): 0.3.

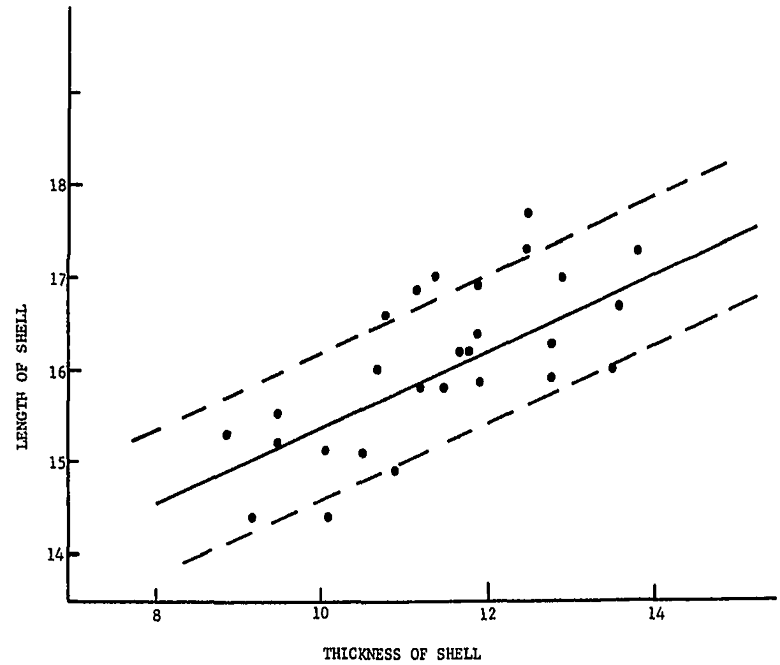


Figure 61

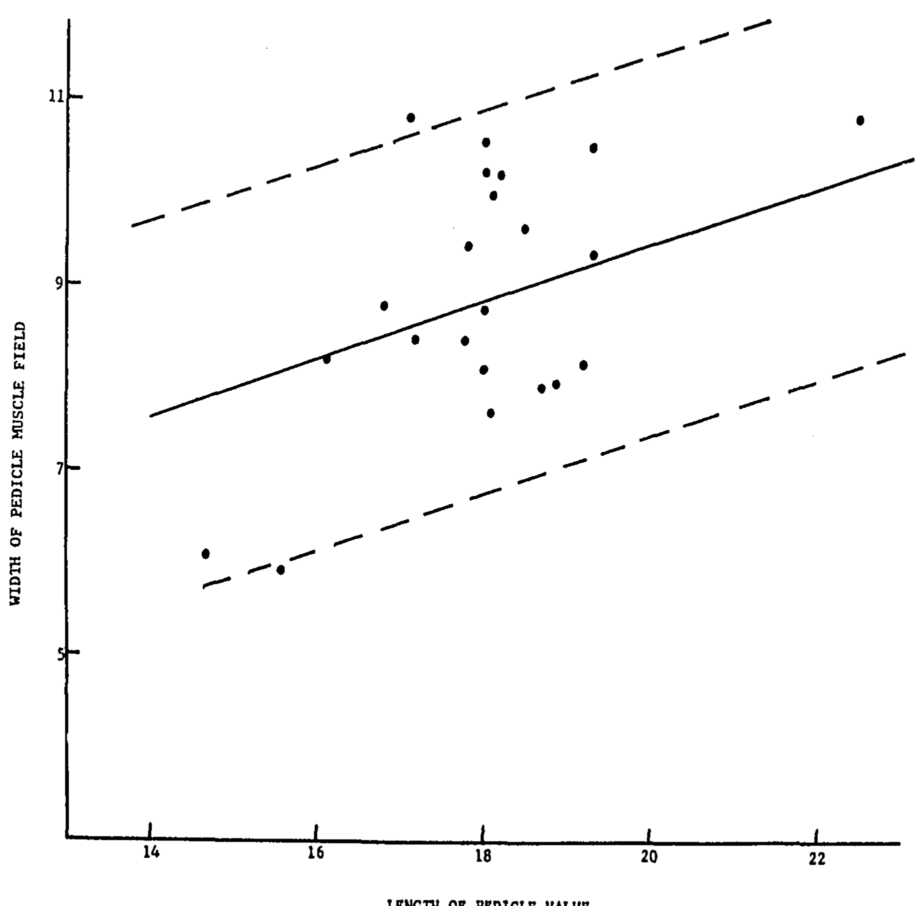


Figure 62

Figure 63

Lepidocyclus cooperi. The regression line and 95 percent confidence interval (length of shell-height of fold) for the specimens from the upper 6 feet of Unit 3C at Locality A. All measurements are in millimeters.

Mean length: 15.9, mean height of fold 3.2, initial growth index (a): -6.3, growth ratio (b): 0.6.

Figure 64

Lepidocyclus cooperi. The regression line and 95 percent confidence interval (width of shell-width of fold). All the specimens are from the upper 6 feet of Unit 3C at Locality A. All measurements are in millimeters.

Mean width of shell: 18.0, mean width of fold: 9.0, initial growth index (a): 2.5, growth ratio (b): 0.4.

Figure 65

Lepidocyclus cooperi. The regression line and 95 percent confidence interval (height of fold-width of fold) for specimens from the upper 6 feet of Unit 3C at Locality A. All measurements are in millimeters.

Mean fold height: 3.2, mean fold width: 9.1, initial growth index (a): 7.0, growth ratio (b): 0.7.

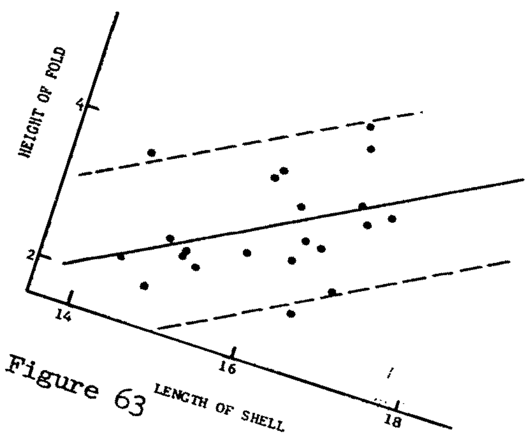


Figure 63

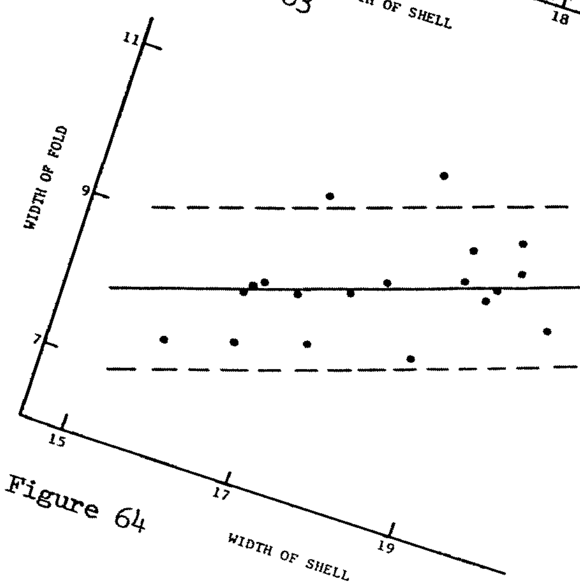


Figure 64

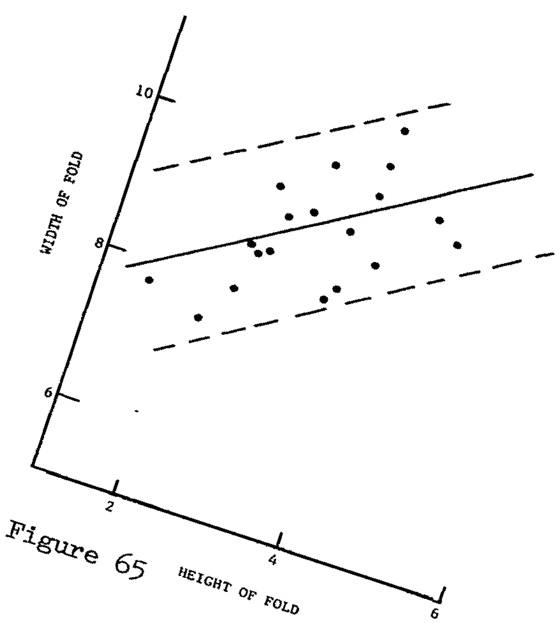


Figure 65

Figure 66

Lepidocyclus cooperi. The regression lines and 95 percent confidence intervals (length-width) for the articulated specimens (triangles), and for the brachial valves (dots). All of the specimens are from the upper 6 feet of Unit 3C at Locality A. All measurements are in millimeters. It should be noted that because the pedicle beak projects behind the brachial valve the length measurement taken from an articulated specimen is in effect the same as the length of the pedicle valve.

Brachial valves. *Mean length*: 16.0, *mean width*: 18.0, *initial growth index* (a): -2.3, *growth ratio* (b): 1.3.

Articulated specimens. *Mean length*: 18.7, *mean width*: *initial growth index* (a): 2.2, *growth ratio* (b): 0.9.

Figure 67

Lepidocyclus cooperi. The regression line and 95 percent confidence interval (length-thickness) for articulated specimens from the upper 6 feet of Unit 3C at Locality A. All measurements are in millimeters.

Mean length: 17.2, *mean thickness* 13.1, *initial growth index* (a): -12.3, *growth ratio* (b): 1.4.

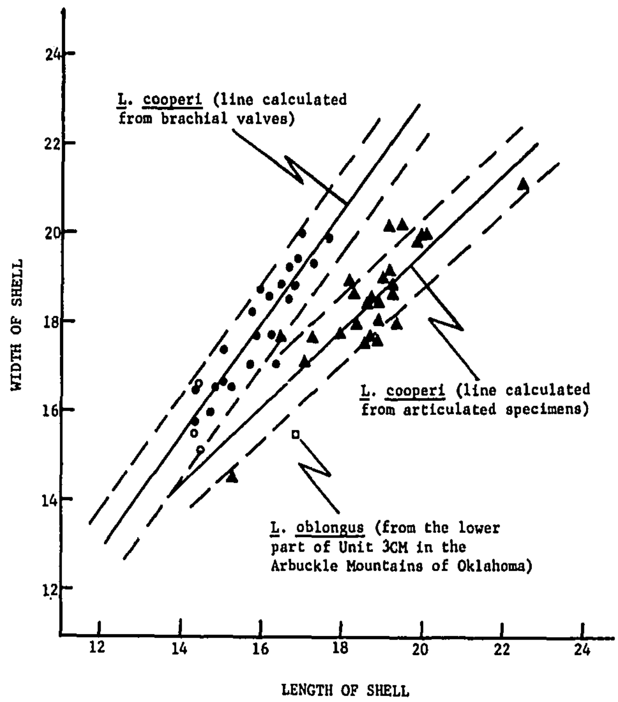


Figure 66

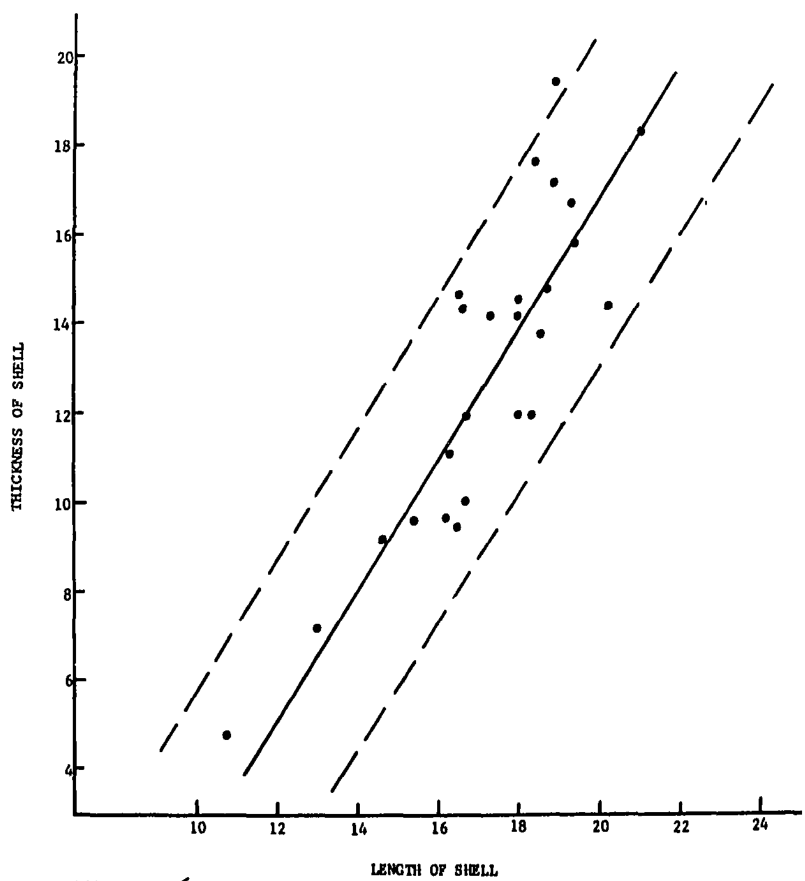


Figure 67

Distribution: This is probably the most characteristic species in the upper part of the Viola Formation. It occurs in the upper 6 feet of Unit 3C at localities A, B, C, D, and L. It occurs in such great numbers, and is so robust that it usually is the first species noted on the outcrop. It also occurs in Unit 3CM at localities I and R, 40-60 feet below the top of the formation. Over 200 specimens were collected.

Lepidocyclus capax (Conrad)

Plate I, figs. 1-3, 9

Atrypa capax Conrad, 1842, p. 264, pl. 14, fig. 21 (fide H. J. Howe, 1966, p. 263, pl. 31, figs. 15-20.

Rhynchonella capax (Conrad), Meek, 1873, p. 123, pl. 11, fig. 2a-f.

Rhynchotrema capax (Conrad), Hall and Clarke, 1894, p. 825, pl. 42, figs. 11, 12, and 16. Winchell and Schuchert, 1895, p. 462, pl. 34, figs. 30-33.

Lepidocyclus capax (Conrad), Howe, 1966b, p. 263, pl. 31, figs. 15-20.

Description: The shell is large. (See Figures 68 and 69 for dimensions.) The dorsal outline is circular to subtriangular to subrectantular. (Compare figures 1a, 2a, 3a, and 9a of Plate I.) The postero-lateral margins diverge from the beak and are straight or weakly rounded. The lateral margins are rounded and the anterior margin is broadly rounded to straight. In lateral profile the shell is subequally biconvex with the brachial valve a little deeper. This difference is due to the brachial fold. The curvature of both valves is of about the same intensity throughout. The anterior commissure is uniplicate. In anterior profile the lateral slopes are steep and in some specimens normal to the plane of commissure, thereby helping to give the shell a globular appearance. The surface is covered by fine zigzag filae which in the anterior part of the shell become prominent and seem more imbricated.

The thickest part of the pedicle valve is in the middle or just posterior to the middle. The curvature from here to the beak is much sharper than from the high point to the anterior. The intensity of the anterior slope increases although it never becomes as acute as the posterior. The sulcus begins about 6mm. from the beak; deepens and widens anteriorly. The width at the anterior margin is about one-half the width of the shell. The majority of specimens have three plications in the sulcus. However, two individuals show only two plications in the sulcus with a faint third plication high on the lateral plication bounding the sulcus. Both of these specimens are average in size (20-21 millimeters in length). The beak is incurved and pressed against the brachial valve. The foramen is apical in position. The hinge line is short and about one-third the width of the valve. The delthyrial cavity is wide and deep, but still elevated above the level of the muscle area. The palintrope is small and inclined toward the cavity. It joins and is continuous with the cavity walls. The teeth are large rounded knobs, positioned a short distance from the ends of the hinge line. Crural fossettes are present to varying degrees. The dental plates are rudimentary; receding whenever developed to their fullest. The muscle field is subcircular in outline, extending to about the middle of the valve. The adductor scars are ellipsoidal in outline, well impressed, and positioned in the center of the field just posterior to the middle. They are about twice as long as wide and extend anteriorly to the middle of the field. The diductors enclose the adductors anteriorly. The adjustor scars are embedded so as to cause some "overhang" along the outer posterior margins of the field. (See Plate I, fig. 1h.)

The brachial beak is small and incurved; hidden by the pedicle valve. The fold expands and rises slightly toward the anterior. In the umbonal region there is a faint depression which at about 3mm. from the beak becomes elevated anteriorly and becomes the early part of the fold. The sockets are large, deep, and almost circular in outline. They are bounded on the inside by stout hinge plates which bear the crural processes. The cardinal process is a thin blade; thicker anteriorly. The crural processes are curved ventrally. A thick median septum is below the cardinalia, but thins to a sharp ridge with 4-5mm. The ridge maintains itself as much until about the middle of the valve. The adductor scars are ellipsoidal in outline; separated by the median septum. They are located immediately below and anterior to the cardinalia. (See Plate I, fig. 1d.)

Discussion: This species shows much variation in its lateral profile and dorsal outline. This variation is indicated somewhat by the length-width and length-thickness scatter diagrams; Figures 68 and 69. Figures 1a, 2a, and 3a of Plate I show the variation in the dorsal outline. Figures 1e, 2b, 3d, and 9b of Plate I show the variation in lateral profile.

Figure 68

Lepidocyclus capax. The regression line and 95 percent confidence interval for articulated specimens from localities A and C. All specimens are from the upper 6 feet of Unit 3C. All measurements are in millimeters.

Mean length: 22.0mm., mean thickness: 18.3mm., initial growth index (a): -29.4, growth ratio (b): 2.2

Figure 69

Lepidocyclus capax. The regression line and 95 percent confidence interval for the articulated specimens from localities A and C. All specimens are from the upper 6 feet of Unit 3C. All measurements are in millimeters.

Mean length: 22.0mm., mean width: 22.7mm., initial growth index (a): -3.0, growth ratio (b): 1.2.

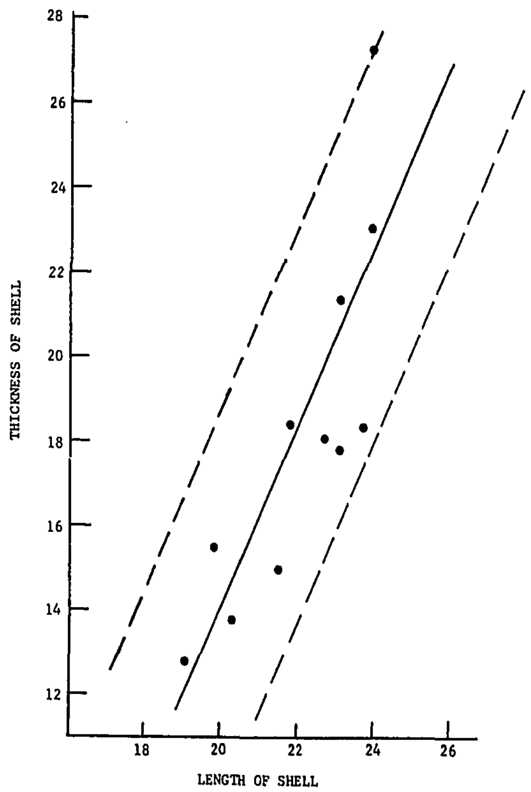


Figure 68

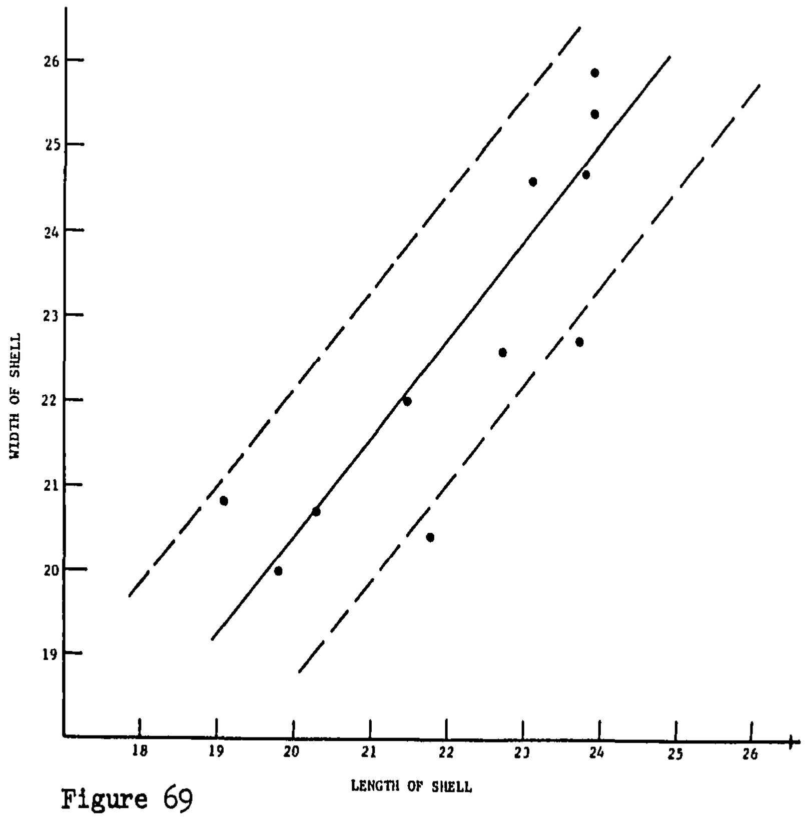


Figure 69

Distribution and Material: This species occurs in the upper 6 feet of Unit 3C at localities A, B, C, D, and L. It is also found in Unit 3CM at localities 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 oblongus Howe, 1966

Plate VII, figs. 5, 6, and 7

Rhynchonella capax Keyes, 1894, pl. 41, fig. 12b (not 12a) (fide, Howe, 1966b, p. 261.).

Lepidocyclus oblongus Howe, 1966, p. 261, pl. 31, figs. 11-14.

Description: The shells are of moderate size for the genus (see Discussion for dimensions). The length is about one-fourth greater than the width. The greatest width is anterior to the middle. In lateral profile the shell is equally biconvex forming an almost circular shell. In some specimens the strong curvature of the posterior and middle portions increases in magnitude and becomes less curved in the anterior part of the valve. (See Plate VII, fig. 7e.) From the highest points on each valve the slopes to the anterior margins are almost straight, there being little curvature. Therefore, when viewed laterally there is a slight anterior projection to the profile in the region of valve junction. (See Plate VII, fig. 7e.) The anterior commissure is uniplicate. The pedicle beak is small, incurved, and pressed against the brachial valve. The foramen is small.

The brachial fold bears four plications and begins 2mm. anterior of the pedicle beak. It increases in height and width toward the anterior.

At a distance of 6-7mm. from the pedicle beak the two inner fold plications are raised slightly higher than the lateral plications. This difference in height between the lateral and inner plications increases toward the anterior margin so that at the margin the inner plications are well above the lateral fold plications. This is what Howe is referring to when he states (1966b, p. 263) that the species has "weak lateral plications on the fold and sulcus."

The pedicle sulcus is first present 5-6mm. anterior of the pedicle beak. It expands and deepens anteriorly. There are 7-8 plications on the flanks of the valve.

The interiors of the Viola specimens are known from serial sections only. (See Figure 70.) The cardinalia is strong with a well developed single thin ridge as a cardinal process. Below the cardinalia there is a stout median septum which does not extend very far anteriorly.

Discussion: This species has been found in the Viola Formation at only two localities; B and C. At both localities it is confined to the upper 2-3 feet of Unit 2 and the lower 15-20 feet of Unit 3C. It is the only species studied by the writer which can be carefully collected bed-by-bed across the "transitional" boundary between Unit 2 and Unit 3C. Plate VII, figures 5, 6, and 7 show specimens collected across this boundary at Locality 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 one foot of Unit 3C. The figures given as 7a-e are of a specimen which is most like L. oblongus. It occurs 15 feet above the base of Unit 3C. These three specimens have the following dimensions.

Figure 70

Serial sections of Lepidocyclus oblongus Howe. Specimen is from the lower 1 foot of Unit 3C at Locality B. 1.--2.9mm. from the beak; 2.--3.1mm. from the beak; 3.--3.5mm. from the beak; 4.--4.4mm. from the beak; 5.--5.1mm. from the beak; 6.--6.1mm. from the beak.

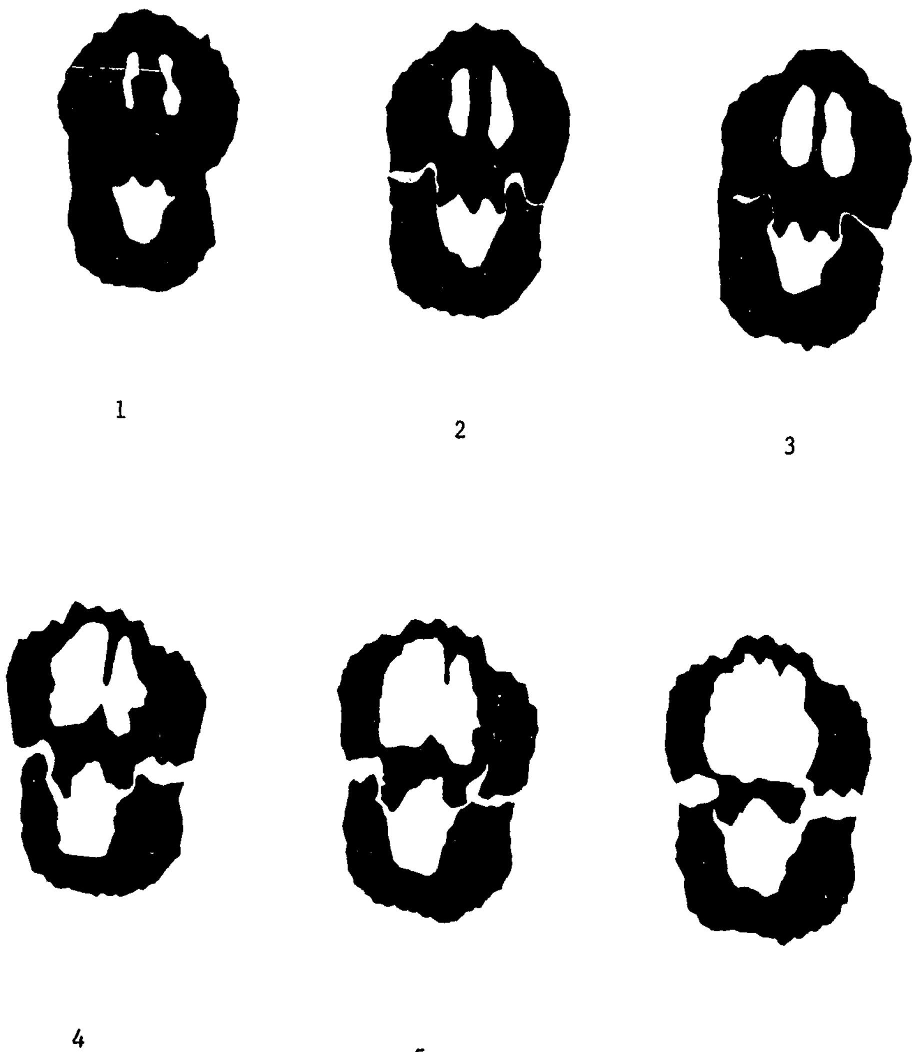


Figure 70

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

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

Distribution and Material: This species has only been found in the upper 2-3 feet of Unit 2 at Locality B, and in the lower 15-20 feet of Unit 3C at localities B and C. About 10 specimens were collected and studied.

Lepidocyclus manniensis ? (Foerste), 1909

Plate VII, fog. 8

Rhynchotrema manniensis Foerste, 1909, p. 315, pl. 7, fig. 4.

Lepidocyclus manniensis (Foerste), Wang, 1949, p. 14, pl. 5D, figs. 1-12.

Description: The shell is moderate in size (see Discussion for dimensions), globous in shape with the width a little greater than the length. In dorsal view the shell is subtriangular with the greatest width just anterior to the middle. In lateral profile the shell is biconvex with the brachial valve slightly deeper. The curvature of the valves is such that the anterior portion is straight. The pedicle beak is erect and incurved; pressed against the posterior of the brachial valve. The shell is circular to ellipsoidal in anterior view. The anterior commissure is uniplicate.

The pedicle foramen is small. The pedicle umbo is slightly swollen with the sulcus first visible at 5-6mm. anterior from the beak. It deepens and widens anteriorly; the anterior width being 8mm.

The brachial umbo is flat. The fold remains low throughout the growth of the shell, although it is well defined in any specimen. The fold has four plications at all stages of growth; all developed to about the same height. There are 6-7 plications on the flanks of the valve. There are fine zigzag filae ornamenting each valve. In the region posterior to the middle and well away from the lateral margins there occur about four filae in a distance of 2mm. The number of filae increases toward the lateral margins where there are a maximum of 9-10 in a distance of 2mm. This is due to the differential growth rate in the different regions of the shell.

No interiors were found. Serial sections show that a well developed cardinal process is present as a single plate. It is most prominent in the posterior of the cardinalia, but slopes downward and rapidly disappears toward the anterior. A prominent median septum is just below the cardinalia. The muscle scars are deeply impressed, at least in the posterior portion of the pedicle valve. The adjustor scars in the posterior portion of the field are elevated above the others.

<u>Discussion</u>: There are four specimens which are questionably referred to this species. They occur in the same stratigraphic horizon

and same locality as L. oblongus. It differs from L. oblongus in being shorter in relation to its width (compare fig. 8, pl. VII to fig. 7, pl. VII). In addition, the fold is not as high and the lateral fold plications are as well developed as the two inner fold plications. L. manniensis is reported to be characterized by flattened or concave costae around the anterior margin. This feature is not seen in the Viola specimens.

Wang (1949) differentiated L. manniensis from L. capax by general form and long ventral tongue in the former. Many of the specimens in the U. S. National Museum collections examined by the writer show a normal tongue length almost identical to L. capax.

Figures 71 and 72 show the dimensions of L. manniensis? from the Viola Formation and from other rock units in other geographic regions.

Distribution and Material: This species is represented by only four specimens; all confined to the lower 15-20 feet of Unit 3C at Locality B.

?Lepidocyclus perlamellosus (Whitfield), 1877

Plate VII, figs. 9, 11

Rhynchonella perlamellosa Whitfield, 1877, p. 73, 1832, p. 265, pl. 12, figs. 23-25.

Lepidocyclus perlamellosus (Whitfield), Wang, 1949, p. 14, pl. 6A, figs. 1-5.

Discussion: There is no formal description given because most of the specimens questionably referred to this species were few in number,

Figure 71

Lepidocyclus manniensis? from the Viola formation; Unit 3C, the lower 15-20 feet. This scatter diagram compares the length-width dimensions of the Viola specimens to those from the Richmond Formation in Illinois, and the Mannie Shale in Tennessee. All measurements are in millimeters.

Figure 72

Lepidocyclus manniensis? from the Viola Formation; Unit 3C, the lower 15-20 feet. The symbols in this figure are the same as those in Figure 71 above. This diagram shows that the specimens from the Viola compare favorably in width-thickness dimensions to specimens of *L. manniensis* from other areas. All measurements are in millimeters.

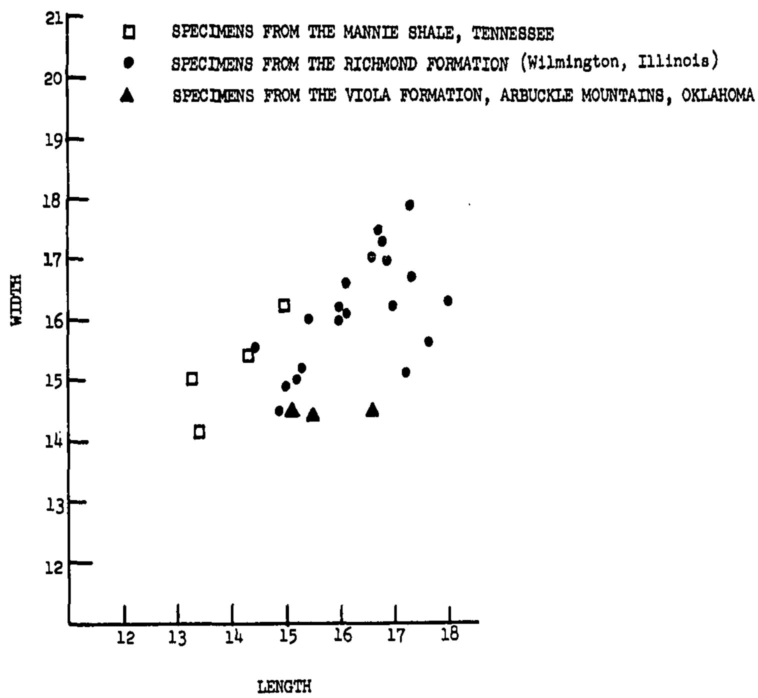


Figure 71

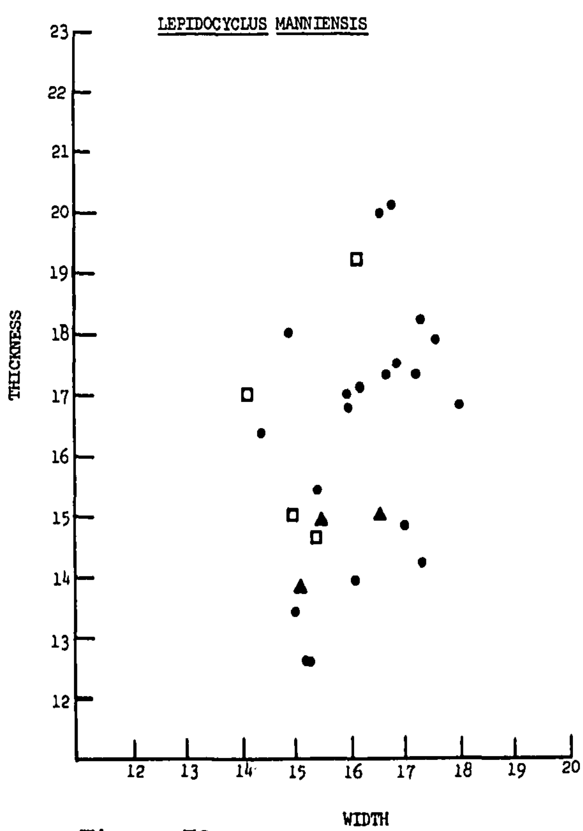


Figure 72

all of which were crushed or damaged in some way. All of the specimens were from "crack-out" material. There were no interiors found. Most exteriors were partially destroyed. There were no specimens having the beak region preserved well enough to allow serial sections to be made. Because of the poor preservation and lack of interiors the identification of this species is in doubt.

There are several collections in the U. S. National Museum referred to Lepidocyclus perlamellosus (Whitfield). All of these collections are reported to be from the upper Trenton of New York near Ellisburg. All of the specimens are articulated with the majority having the external shell layers worn away. There is a marked variability in dorsal outline and lateral profile. This is indicated somewhat by the measurements given below.

Length (mm.)	Width (mm.)	Thickness (mm.)
12.8	14.7	7.6
11.7	14.5	7.1
13.7	16.1	8.2
15.5	19.4	9.9
15.5	18.9	11.9
18.0	22.3	13.1
15.4	19.5	10.3
14.5	17.8	10.6
15.7	18.0	11.9
16.0	20.0	10.9

Length (mm.)	Width (mm.)	Thickness (mm.)
14.5	18.2	12.0
15.5	16.8	11.3
15.1	15.5	10.3
15.0	16.6	11.6

In dorsal outline the shells range from being subpentagonal to elliptical. The thickest specimens seem to be those which have the more subpentagonal outline.

The stratigraphic occurrence of ?L. perlamellosus in the Arbuckle Mountains (Locality G) in the same rocks with Plaesiomys bellistriatus, Strophomena perconcava, S. clermontensis, and S. neglecta indicates a Cincinnatian age and not Trentonian.

Distribution and Material: This species occurs in the upper ten feet on Unit 2 at localities B, C, and L. It also is fairly abundant (10-15 specimens) at Locality G, 60-75 feet below the top of the formation; Unit 3CM. About 20 specimens were collected.

SELECTED REFERENCES

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

Aitken, W. G., and W. S. McKerrow, 1948, Rhynchonellids of the Bonet Bed of the Great Oolite Series of Langton Herring, Dorset: A study in variation: Geol. Magazine, v. 85, p. 19-32.

American Commission on Stratigraphic Nomenclature, 1961, Code of stratigraphic nomenclature; Amer. Assoc. Petroleum Geologists, v. 45, p. 645-665.

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

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

_______, 1942, The pseudodeltidium of the Strophomenid brachiopods: Geol. Magazine, 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, 18p.

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

_______, 1945, The brachiopod zonal indices of the stages Costonian and Onnian in Britain: Jour. Paleontology, v. 19, p. 181-252.

Barnes, V. E., P. E. Cloud, and H. Duncan, 1953, Upper Ordovician of central Texas: Amer. 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 and 2.

_______, 1932, The stratigraphy of the central basin of Tennessee: Tenn. Division Geol., Bull., v. 38, p. 1-268.

Bell, W. C., 1950, Stratigraphy: a factor in paleontologic taxonomy: Jour. Paleontology, v. 24, p. 492-496.

_______, 1959, Uniformitarianism-or Uniformity: Amer. Assoc. Petroleum Geologists, Bull., v. 43, p. 2862-2865.

Berry, W. B. N., 1960, Graptolite faunas of the Marathon Region, West Texas: Bureau of Econ. Geology, Univ. of Texas, Bull. 6005.

Bradley, J. H., 1921, The brachiopoda of the Maquoketa of Iowa: Harvard Mus. Comp. Zoology, Bull., v. 64, p. 503-525.

_______, 1925, Stratigraphy of the Kimmswick limestone of Missouri and Illinois: Jour. Geol., v. 33, p. 49-74.

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

Branson, E. B., 1944, The geology of Missouri: Univ. of Missouri Studies, v. 19.

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

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

Cloud, P. E., 1942, Terebratulid brachiopods of the Silurian and Devonian: Geol. Soc. America, Special Paper 38.

Cooper, G. A., 1956, Chazyan and related brachiopods: Smithsonian Miscell. Coll., v. 127, No. 12, pt. 1 (text), 1024 p., pt. 2 (plates), 269 pls.

Cram, I. H., 1930, Cherokee and Adair counties: Okla. Geol. Surv., Bull., v. 40QQ, p. 531-586.

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

Cumings, E. R., 1903, The morphogenesis of Platystrophia: Am. Jour. Sci., 4th Series, v. 15, p. 1-48.

_______, 1907, Stratigraphy and paleontology of the Ordovician of Indiana: 32nd. Ann. Rept. of the Dept. of Geol. and Nat. Resources of Ind., p. 634-637.

Cumings, E. R., 1908, The stratigraphy and paleontology of the Cincinnatian Series of Indiana: Ind. Dept. Geol., Ann. Rept., 32, p. 605-1188.

________, and A. V. Mauck, 1902, A quantitative study of variation in the fossil brachiopod Platystrophia lynx: Amer. Jour. Sci., v. 14, p. 9-16.

Dake, C. L., 1921, The problem of the St. Peter sandstone: Missouri School of Mines and Metallurgy, Bull. 6.

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

Decker, C. E., 1933, Viola limestone, primarily of the Arbuckle and Wichita mountain regions: Amer. Assoc. Petroleum Geologists, Bull., v. 17, p. 1405-1435.

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

________, 1936, Table of tentative lower Paleozoic correlations on the bases of graptolites: Amer. Assoc. Petroleum Geologists, Bull., v. 20, p. 1252-1257.

DuBois, E. P., 1944, Subsurface relations of the Maquoketa and "Trenton" formations in Illinois: Ill. Geol. Surv., Rept. of Invest. 105, p. 7-34.

Eagar, R. M. C., 1951, Growth and variation in the non-marine lamellibranch fauna above the sand rock mine of the Lancashire Millstone Grite: Geol. Soc. London, Quat. Jour., v. 107, p. 339-373.

Edson, Fanny, C., 1927, Ordovician correlation in Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., v. 11, p. 967-975.

Fenton, C. L., 1928, Forms of Strophomena from the Black River and Richmond formations: Amer. Mid. Nat., v. 11, p. 144-159.

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

________, 1903, The Richmond Group along the western side of the Cincinnati Anticline in Indiana and Kentucky: Amer. Geol., v. 31, p. 333-361.

________, 1903, The Cincinnati Group in western Tennessee between the Tennessee River and the Central Basin: Jour. Geol., v. 11, p. 29-45.

Foerste, A. F., 1905, Notes on the distribution of brachiopods in the Arnheim and Waynesville beds (Cincinnati region): Amer. Geol., v. 36, p. 244-250.

________, 1909, Preliminary notes on Cincinnatian fossils: Denison University, Sci. Lab., Bull., v. 14, p. 208-232.

________,1909, Preliminary notes on Cincinnatian and Lexington fossils: Denison Univ. Sci. Lab., Bull., v. 14, p. 289-334.

________, 1010, Preliminary notes on Cincinnatian and Lexington fossils in Ohio, Indiana, Kentucky, and Tennessee: Denison Univ. Sci. Lab., Bull., v. 16, p. 17-100.

________, 1912, Strophomena and other fossils from Cincinnatian and Mohawkian horizons, chiefly in Ohio, Indiana, and Kentucky: Denison Univ. Sci. Lab., Bull., v. 17, p. 17-172.

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

________, 1925, Upper Ordovician faunas of Ontario and Quebec: Cand. Geol. Surv., Mem. 138.

Gealey, J. R., 1955, Geology of Cape Girardeau and Jonesboro quadrangles, southeastern Missouri: Yale University unpublished Doctoral Dissertation.

Glenister, Anne, T., 1957, Conodonts of the Maquoketa formation: Jour. Paleontology, v. 31, p. 715-736.

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

Gregor, D. K., and K. E. Born, 1936, Stratigraphy and fauna of the Fernvale formation (Illinois): Washington Univ. (St. Louis), Cont. in Geol., n.s., No. 9, p. 67-77.

Gutstadt, A. M., 1958, Upper Ordovidian stratigraphy in the eastern interior region: Amer. Assoc. Petroleum Geologists, Bull., v. 42, p. 531-547.

Hall, Donald D., 1962, Dalmanellidae of the Cincinnatian: Paleontographica Americana, v. 4, p. 131-165.

Hall, J., 1843, Natural History of New York, paleontology: N. Y. Geol. Surv., v. 1.

________, 1847, Paleontology of New York, v. 1, Containing descriptions of the organic remains of the lower division of the New York System: Albany, C. van Benthuysen, Natural History of New York, 338 p. 87 pls.

Hall, J., 1858-59, Contributions to paleontology: N. Y. State Cabinet of Natural History, Ann. Rept.

_______, 1894, Paleontology, an introduction to the study of paleozoic brachiopoda: N. Y. Geol. Surv., v. 8, pt. 1 and 2.

Hall, J., and J. M. Clarke, 1892, An introduction to the study of the genera of paleozoic brachiopoda: N. Y. State Geol. Surv. Paleontology, v. 8, pt. 1, 367 p. 20 pls.

_______, 1894, An introduction to the study of the brachiopoda intended for a handbook for the use of students, pt. 2: N. Y. State Geol. Surv., Ann. Rept. 13, p. 749-1015, pls. 21-54.

Hardy, R. P., 1946, Conodonts of the Fernvale of eastern Missouri: University of Missouri, Master of Science Thesis (unpublished).

Hayes, W. C., and E. O. Ulrich, 1903, U. S. Geol. Survey, Atlas, Columbia Folio, Tennessee, 95.

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

_______, 1965a, Dalmanella of the Montoya Group (Ordovician): Jour. Paleontology, v. 39, p. 235-247.

_______, 1965b, Plectambonitacea, Strophomenacea, and Atrypacea from the Montoya Group (Ordovocian) of Trans-Pecos Texas: Jour. Paleontology, v. 39, p. 647-656.

_______, 1965c, Morphology of the Brachiopod Genera Rhynchotrema, Hypsiptycha, and Lepidocyclus: Jour. Paleont., v. 39, p. 1125-1128.

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

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

Howe, W. B., 1961, The stratigraphic succession in Missouri: Missouri Geol. Surv. and Water Resources, v. 40, 2nd. series.

Huffman, G. G., 1958, Geology of the west and south flanks of the Ozark Uplift, northeastern Oklahoma: Okla. Geol. Surv., Bull., v. 77.

Huxley, J., 1931, Problems of relative growth: Lincoln MacVeagh, The Dial Press.

Imbrie, J., 1956, Biometrical methods in the study of invertebrate fossils: Amer. Mus. Nat. Hist., Bull., v. 108, p. 217-252.

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

Jones, O. T., 1928, Plectambonites and some allied genera: Geol. Surv. Great Britain, v. 1, pt. 5.

Kay, G. M., 1937, Stratigraphy of the Trenton Group: Geol. Soc. Amer., Bull., v. 48, p. 233, 302.

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

Kermack, K. A., and Haldane, J. B. S., 1950, Organic correlation and allometry: Biometrika, v. 37, p. 30-41.

Ladd, H. S., 1925, Depauperate fauna of the Maquoketa: Geol. Soc. Amer., Bull., v. 36, p. 228.

________, 1928, Maquoketa faunas: Geol. Soc. Amer., Bull., v. 39, p. 291-292.

________, 1929, Stratigraphy and paleontology of the Maquoketa shale of Iowa: Iowa Geol. Surv., v. 34, p. 305-448.

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

________, 1920, The Ordovician of Madison Indiana: Amer. Jour. Sci., 4th ser., v. 50, p. 154-158.

Meek, F. B., 1873, Geol. Surv. Ohio (Paleontology) Rept.: v. 1, pt. 2, 399 p.

Olson, E. C., 1951, Diplocaulis, a study in growth and variation: Fieldiana: Geology, v. 11, p. 59-154.

Olson, E. C., and R. L. Miller, 1951, Relative growth in paleontological studies: Jour. Paleontology, v. 25, p. 212-223.

Parkinson, D., 1952, Allometric growth in Dielasma bastata from Treak Cliff, Derbyshire: Geol. Magazine, v. 89, p. 201-216.

________, 1954, Quantitative studies of brachiopods from the Lower Carboniferous limestones of England: Jour. Paleontology, v. 28, p. 367-563.

Phleger, F. G., Jr., 1940, Relative growth and vertebrate phylogeny: Amer. Jour. Sci., v. 238, p. 643-662.

Ross, R. B., 1959, Brachiopod fauna of the Saturday Mountain formation, southern Lamhi Range, Idaho: U. S. Geol. Surv., Prof. Paper 294-L, p. 441-461.

Ruedemann, R., and C. E. Decker, 1934, The graptolites of the Viola limestone: Jour. Paleontology, v. 8, p. 303-327.

Salman, E. S., 1943, Mohawkian Rafinesquinae: Jour. Paleontology, v. 16, p. 564-603.

Sardeson, F. W., 1896, The Galena and Maquoketa Series: Amer. Geologists, v. 18, p. 356-368.

________, 1897, Nomenclature of the Galena and Maquoketa Series: Amer. Geol., v. 19, p. 330-336.

Savage, T. E., 1908, On the lower Paleozoic stratigraphy of southwestern Illinois: Amer. Jour. Sci., 4th ser. v 25, p. 433-443.

________, 1910, The faunal succession and correlation of the Pre Devonian formations of southern Illinois: Ill. Geol. Surv., Bull., v. 16, p. 315-318.

________, 1913, Stratigraphy and paleontology of the Alexandrian Series in Illinois and Missouri: Ill. Geol. Surv., Bull., v. 23, p. 1-124.

________, 1918, Thebes sandstone and Orchard Creek shale and their faunas in Illinois: Ill. Acad.Sci., Trans., v. 10, p. 261-275.

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

Schuchert, C., and G. A. Cooper, 1932, Brachiopod genera of the suborders Orthacea and Pentameridae: Peabody Mus. Nat. Hist., Mem., v. 4, pt. 1.

Shideler, N. H., 1937, Fernvale correlations (abs.): Geol. Soc. Amer., Proc., p. 367-368.

Simpson, G. G., 1940, Types in modern taxonomy: Amer. Jour. Sci., v. 238, p. 413-431.

________, A. Roe, and R. C. Lewontin, 1960, Quantitative Zoology: Harcourt, Brace, and Company, Inc., 2nd. ed.

Swinnerton, H. H., 1939, Paleontology and the mechanics of evolution: Geol. Soc. London, Quart. Jour., v. 95, p. 33-70.

________, 1939, A study of variation in fossils: Geol. Soc. London, Quart. Jour., v. 96, p. 76-118.

Taff, J. A., 1903, U. S. Geol. Surv. Atlas, Tishomingo Folio, Indian Territory, 98.

_______, 1928, Preliminary report on the geology of the Arbuckle and Wichita mountains in Indian Territory and Oklahoma: Okla. Geol. Surv., Bull., v. 12.

Templeton, J. S., and H. B. Wilman, 1963, Champlainian Series (Middle Ordovician) in Illinois: Ill. Geol. Surv., Bull., v. 89.

Twenhofel, W. H., et al., 1954, Correlations of the Ordovician formations of North America: Geol. Soc. Amer., Bull., v. 65, p. 247-298.

Ulrich, E. O., 1911, Revision of the Paleozoic Systems: Geol. Soc. Amer., Bull., v. 22, p. 281-680.

_______, 1927, Fossiliferous boulders in the Ouachita "Caney" shale and the age of the shale containing them: Okla. Geol. Surv., Bull., v. 45.

Wang, Y., 1949, Maquoketa brachiopoda of Iowa: Geol. Soc. Amer., Mem., 42.

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

Weller, S., 1907, The Pre-Richmond unconformity in the Mississippi Valley: Jour. Geol., v. 15, p. 523-524.

_______, and S. St. Clair, 1928, Geology of the Genevieve County, Missouri: Bur. Geol. and Mines, 2nd. ser., v. 22, 352 p.

Wengard, S., 1948, Fernvale and Viola limestones of south-central Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., v. 32, p. 2183-2253.

Whitfield, R. P., 1877, Preliminary descriptions of new species of fossils from the lower geological formations of Wisconsin: Wisc. Geol. Surv., Ann. Rept., p. 50-89.

_______, 1882, Geology of Wisconsin: Wisc. Geol. Surv., v. 4, p.162-363.

Williams, A., 1962, The Barr and lower Ardmillan Series (Caradoc) of the Girvin District, South-West Ayrshire, with descriptions of the brachiopods: Geol. Soc. London, Mem. 8.

_______, et al., 1965, Brachiopoda, pt. H <u>of</u> Moore, R. C., ed., Treatise on invertebrate paleontology: Geol. Soc. Amer., and Univ. Kans. Press.

Wilson, A. E., 1946, Brachiopoda of the Ottawa formation of the Ottawa-St. Lawrence lowland: Cand. Geol. Surv., Bull. 8.

Wilson, C. W., 1949, Pre-Chattanooga stratigraphy of central Tennessee: Tenn. Dept. Conserv., Div. of Geol., Bull. 56.

Winchell, N. H., and C. Schuchert, 1892, New brachiopoda from the Trenton and Hudson River Groups in Minnesota: Amer. Geol., v. 9, p. 284-294.

________, 1893, The lower Silurian brachiopoda of Minnesota: Minn. Geol. Surv., Final Rept., v. 3, p. 333-474.

________, 1895, Sponges, graptolites, and corals from the lower Silurian in Minnesota, and the lower Silurian brachiopoda of Minnesota: Geology Minnesota, v. 3, pt. 1.

Zuckerman, S., 1951, A discussion on the measurement of growth and form: Proc. Royal Soc., Ser. B, v. 137, p. 433-523.

VIOLA BRACHIOPODS

Plates 1-9

The species presented in the following plates are not grouped zoologically. The plates are presented in a stratigraphic manner. Plates I-VI show those species which occur in the upper part of the Viola Formation (Units 3C and 3CM). Plate VII shows those species which occur in the lower part of Unit 3C and the upper part of Unit 2. Plate VIII shows those species which occur in the lower part of Unit 2. Plate IX shows the species from Unit 1C.

Plate I

1. Lepidocyclus capax (Conrad). Specimen OU 5810; locality A, Unit 3C, upper 6 feet. a. dorsal view, b. ventral view, c. interior of brachial valve, d. interior of brachial valve showing adductor scars beneath the cardinalia, e. lateral view, f. anterior view, g. posterior view, h. interior of pedicle valve.

2. Lepidocyclus capax (Conrad). Specimen OU 5802; locality A, Unit 3C, upper 6 feet. a. dorsal view, b, lateral view showing the low convexity of the brachial valve.

3. Lepidocyclus capax (Conrad). Specimen OU 5803; locality A, Unit 3C, upper 6 feet. a. dorsal view showing the subquadrate outline, b. ventral view, c. anterior view, d. lateral view showing the low convexity of the valves, e. interior of brachial valve, f. interior of pedicle valve, g. (X3) posterior of pedicle valve.

4. Lepidocyclus cooperi Howe. Specimen OU 5804; locality A, Unit 3C, upper 6 feet. a. dorsal view, b. ventral view, c. anterior view, d. lateral view, e. posterior view, f. dorsal view with the specimen tilted so as to show the deltidial plates.

5. Lepidocyclus cooperi Howe. Specimen OU 5805; locality A, Unit 3C, upper 6 feet. a. anterior view, b. lateral view showing the low convexity of the brachial valve, particularly the low prominence of the fold throughout growth.

6. Lepidocyclus cooperi Howe. Specimen OU 5806; locality A, Unit 3C, upper 6 feet. a. interior of brachial valve, b. interior of brachial valve tilted so as to show the adductor scars positioned well away from the base of the cardinalia; compare this figure with that of 1d.

7. Lepidocyclus cooperi Howe. Specimen OU 5807; locality C, Unit 3c, upper 6 feet. a. interior of pedicle valve showing the large flabellate muscle area; compare this figure with that of 3f, b. (X3) interior of pedicle valve.

8. Lepidocyclus cooperi Howe. Specimen OU 5808; locality C, Unit 3C, upper 6 feet. a. lateral view showing the low convexity of the valves, b. dorsal view showing the subquadrate outline; compare this with figure 4a.

9. Lepidocyclus capax (Conrad). Specimen OU 5809; locality A, Unit 3C, upper 6 feet. a. dorsal view showing the subquadrate outline, b. lateral view showing the low convexity of the valves; compare the outline of this specimen with that of 2a.

PLATE I

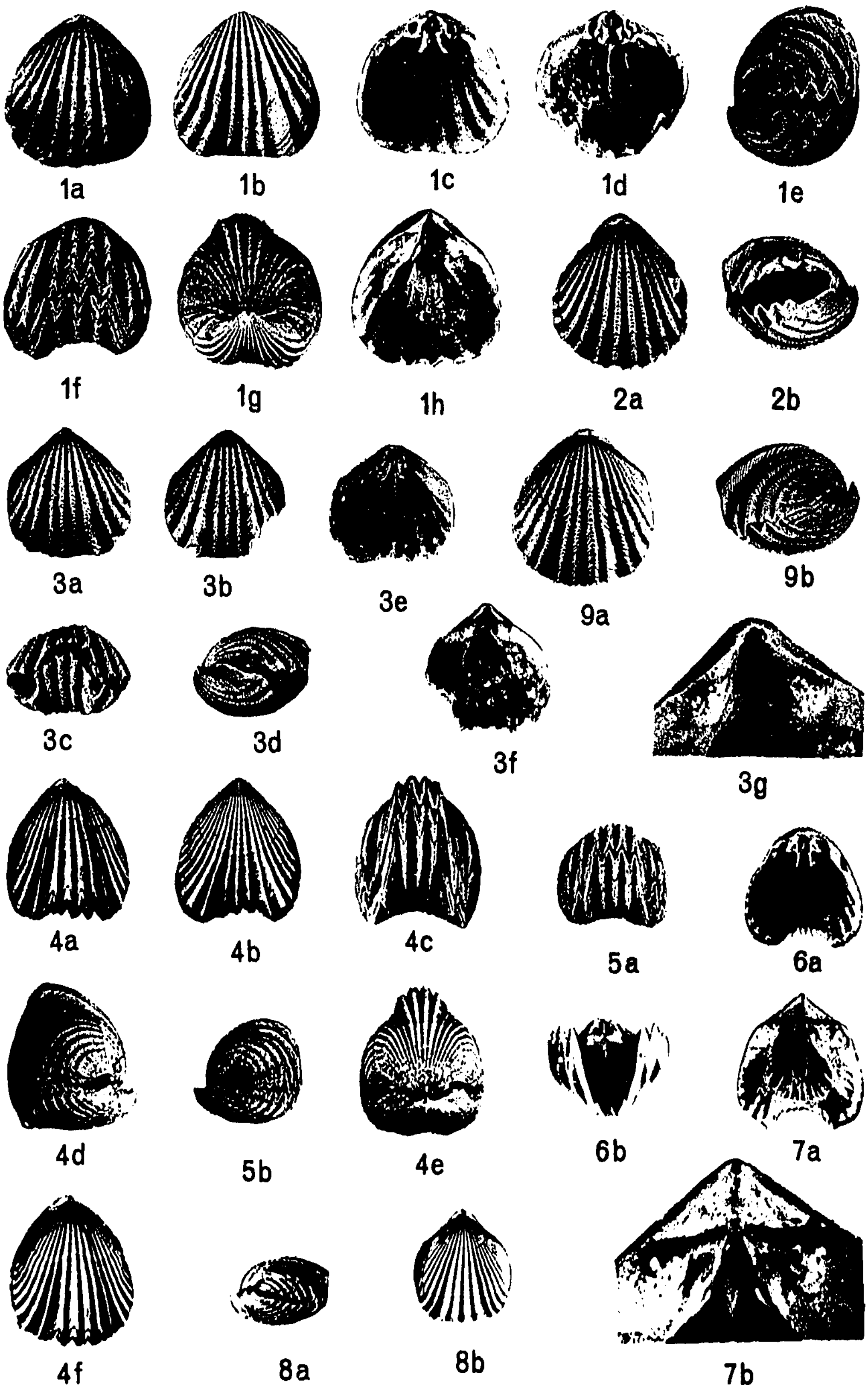

1a
1b
1c
1d
1e
1f
1g
1h
2a
2b
3a
3b
3e
9a
9b
3c
3d
3f
3g
4a
4b
4c
5a
6a
4d
5b
4e
6b
7a
4f
8a
8b
7b

Plate II

1. Austinella n.sp. Specimen OU 5801; locality A, Unit 3C, upper 6 feet, a. dorsal view of a brachial valve showing the fine nature of the costae and costellae, b. anterior view of brachial valve, c. lateral view of the brachial valve.

2. Austinella n.sp. Specimen OU 5811; locality A, Unit 3C, upper 6 feet. a. dorsal exterior showing the nature of the costae, b. interior of a brachial valve (X1), c. interior of a brachial valve (X2).

3. Austinella n.sp. Specimen OU 5812; locality A, Unit 3C, upper 6 feet. a. dorsal exterior showing the coarser nature of the costae and costellae.

4. Austinella n.sp. Specimen OU 5813; locality A, Unit 3C, upper 6 feet. a. dorsal exterior showing the coarsest costae found in any specimen. Note the variation in the costae size shown by specimens 1-4.

5. Austinella n.sp. Specimen OU 5814; locality A, Unit 3C, upper 6 feet. a. interior of a pedicle valve, b. exterior of a pedicle valve, c. anterior view of a pedicle valve, d. lateral view of a pedicle valve.

6. Austinella n.sp. Specimen OU 5815; locality A, Unit 3C, upper 6 feet. a. interior of a pedicle valve showing the muscle area with a concave anterior margin, b. pedicle muscle area (X3).

7. Austinella n.sp. Specimen OU 5816; locality A., Unit 3C, upper 6 feet. a. interior of a pedicle valve.

8. Austinella n.sp. Specimen OU 5817; locality A, Unit 3C, upper 6 feet. a. interior of a pedicle valve, b. pedicle muscle area (X2). Note the size and shape variation in the muscle areas shown by figures 5-8.

9. Austinella n.sp. Specimen OU 5818; locality A, Unit 3C, upper 6 feet. a. interior of a brachial valve (compare this figure with that of 2b, Plate II), b. cardinalia (X3).

10. Glyptorthis n.sp. Specimen OU 5819; locality C, Unit 3C, upper 6 feet. a. ventral view, b. interior of a pedicle valve, c. anterior view of a pedicle valve, d. lateral view of a pedicle valve.

11. Glyptorthis n.sp. Specimen OU 5820; locality C, Unit 3C, upper 6 feet. a. dorsal exterior, b. interior of a brachial valve, c. anterior view of a brachial valve, d. cardinalia showing a faint cleft in the cardinal process (X4).

PLATE II

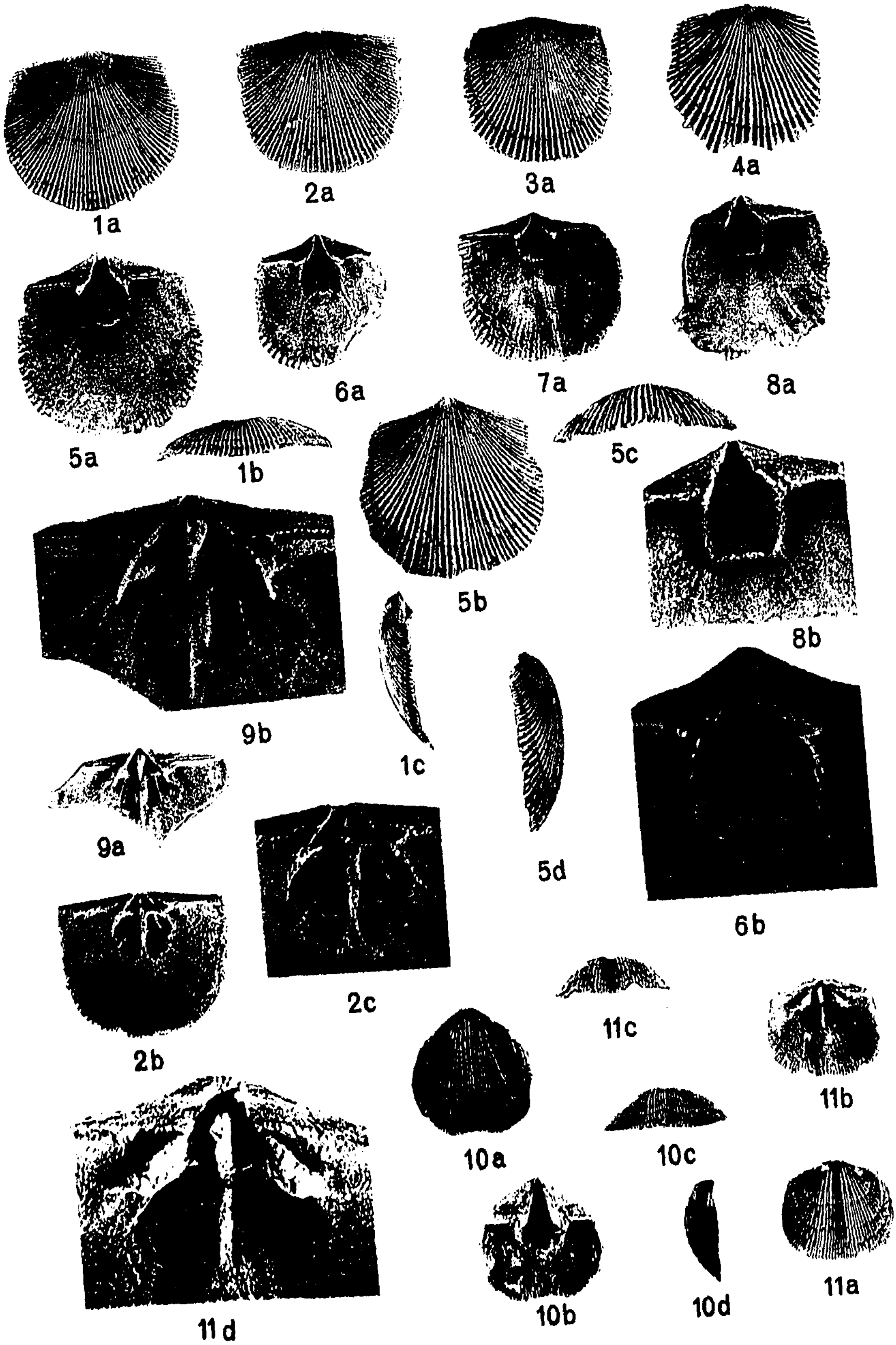

1a
2a
3a
4a
5a
6a
7a
8a
1b
5c
5b
8b
9b
1c
9a
5d
6b
2c
2b
11c
11b
10a
10c
11d
10b
10d
11a

Plate III

1. Platystrophia n.sp. B. Specimen OU 5821; locality C, Unit 3C, upper 6 feet. a. ventral view, b. interior of a pedicle valve, c. posterior view of a pedicle valve showing the interarea and the teeth, d. anterior view of a pedicle valve, e. lateral view of a pedicle valve.

2. Platystrophia n.sp. B. Specimen OU 5822; locality I, Unit 3CM, 40 feet from top. a. dorsal view, b. lateral view of a brachial valve.

3. Platystrophia n.sp. B. Specimen OU 5823; locality I, Unit 3CM, 40 feet from top. a. interior of a brachial valve looking normal to the plane of commissure, b. interior of a brachial valve tilted so as to show the posterior adductor scars, c. interior of a brachial valve tilted (X3), d. interior of a brachial valve (X3) looking normal to the plane of commissure.

4. Platystrophia n.sp. A. Unit 3C, upper 6 feet. Specimen OU 5824; locality A, a. ventral view, b. interior of a pedicle valve, c. lateral view of a pedicle valve.

5. Platystrophia n.sp. A. Specimen OU 5825; locality C, Unit 3C, upper 6 feet. a. dorsal view, b. interior of a brachial valve, c. lateral view.

6. Plaesiomys bellistriatus Wang. Specimen OU 5826; locality I, Unit 3CM, 40 feet from top. a. ventral view, b. interior of a pedicle valve, c. anterior view, d. lateral view, e. muscle area of the pedicle valve (X2).

7. Plaesiomys bellistriatus Wang. Specimen OU 5827; locality I, Unit 3CM, 40 feet from top. a. dorsal view, b. interior of a brachial valve, c. lateral view, d. posterior view, e. the cardinalia (X2), f. a specimen tilted so as to show the crenulated myophore (X2).

PLATE III

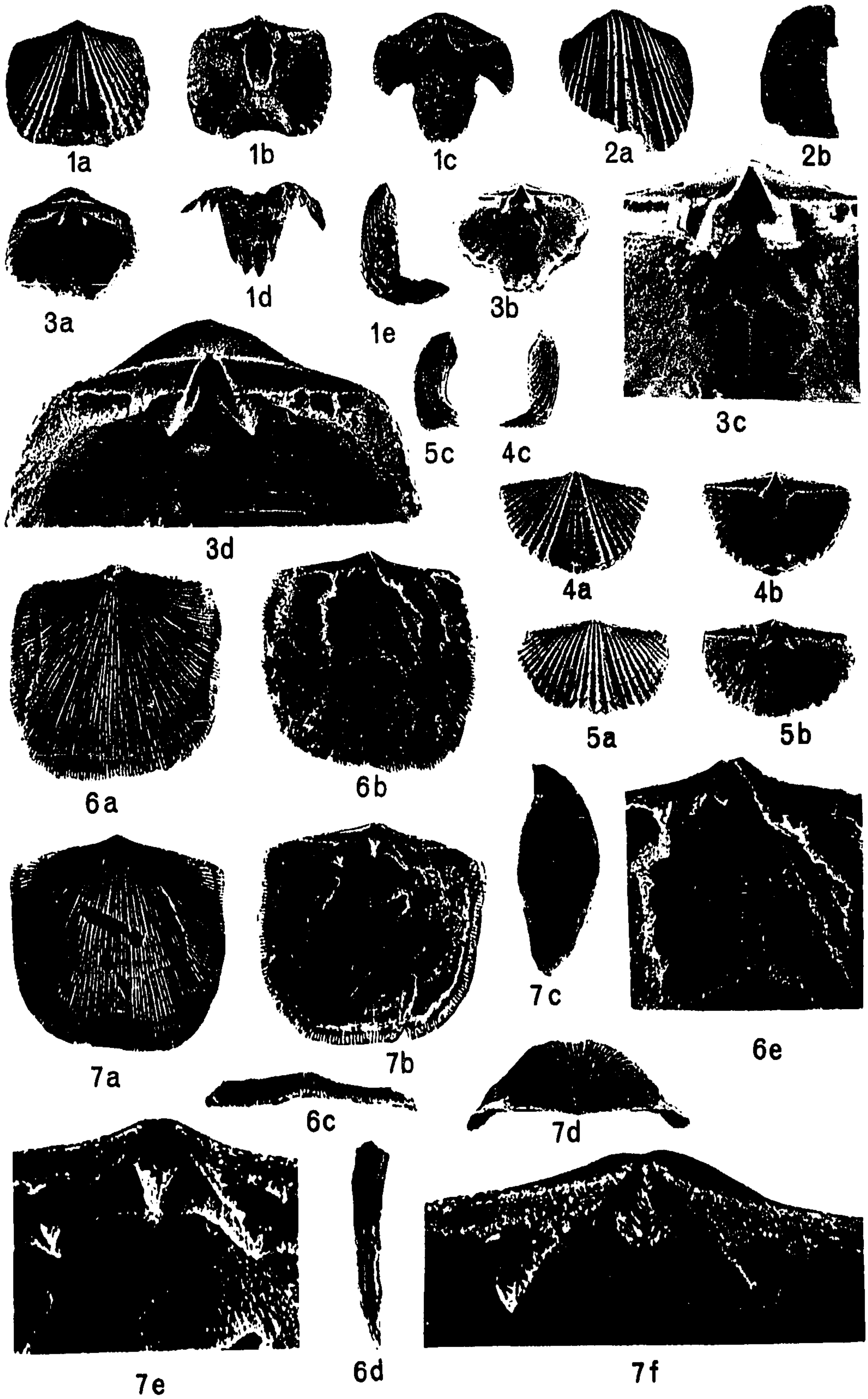

1a
1b
1c
2a
2b
3a
1d
1e
3b
3c
3d
5c
4c
4a
4b
5a
5b
6a
6b
7c
6e
7a
7b
6c
7d
7e
6d
7f

Plate IV--(Continued)

12. Paucicrura n.sp. Specimen OU 5839; locality A, Unit 3C, upper 6 feet. a. interior of a pedicle valve (X2).

13. Paucicrura n.sp. Specimen OU 5840; locality A, Unit 3C, upper 6 feet. a. interior of a pedicle valve (X2).

14. Paucicrura n.sp. Specimen OU 5841; locality A, Unit 3C, upper 6 feet. a. interior of a brachial valve (X2).

15. Diceromyonia cf. D. tersa (Sardeson). Specimen OU 5842; locality A, Unit 3C, upper 6 feet. a. ventral view, b. dorsal view, c. anterior view.

16. Diceromyonia cf. D. tersa (Sardeson). Specimen OU 5843; locality C, Unit 3C, upper 6 feet. a. interior of a pedicle valve.

17. Diceromyonia cf. D. tersa (Sardeson). Specimen OU 5844; locality C, Unit 3C, upper 6 feet. a. interior of a brachial valve, b. posterior view of the cardinalia (X6), c. interior of a brachial valve (X2).

Plate IV

1. Thaerodonta magna Howe. Specimen OU 5828; locality A, Unit 3C, upper 6 feet. a. ventral view, b. dorsal view, c. lateral view.

2. Thaerodonta magna Howe. Specimen OU 5829; locality A, Unit 3C, upper 6 feet. a. interior of a pedicle valve, b. interior of a pedicle valve showing the muscle scars (X4).

3. Thaerodonta magna Howe. Specimen OU 5830; locality C, Unit 3C, upper 6 feet. a. interior of a brachial valve, b. cardinalia (X2), c. posterior view of the cardinalia and sockets (X4).

4. Thaerodonta magna Howe. Specimen OU 5831; locality A, Unit 3C, upper 6 feet. a. exterior view showing the ornamentation, b. exterior ornamentation (X2), exterior ornamentation (X4).

5. Thaerodonta magna Howe. Specimen OU 5832; locality C, Unit 3C, upper 6 feet. a. interior of a pedicle valve showing the numerous sockets along the hinge (X2).

6. Thaerodonta magna Howe. Specimen OU 5833; locality A, Unit 3C, upper 6 feet. a. pedicle interior showing the deep muscle impressions (X3).

7. Thaerodonta magna Howe. Specimen OU 5834; locality I, Unit 3CM, 40 feet from top. a. ventral exterior (compare the outline of this specimen to that illustrated as figure 8a, Plate IV, b. posterior view showing the flatness of an articulated specimen (compare this figure to that of 8b, Plate IV).

8. Thaerodonta magna Howe. Specimen OU 5835; locality I, Unit 3C, 40 feet from top. a. ventral view illustrating the variation in the outline, b. posterior view illustrating the maximum thickness of an articulated specimen.

9. Thaerodonta mucronata scabra? Howe. Specimen OU 5836; locality I, Unit 3CM, 40 feet from top. a. ventral view showing the lamellose nature of the exterior.

10. Thaerodonta mucronata scabra? Howe. Specimen OU 5837; locality I, Unit 3CM, 40 feet from top. a. specimen showing a lamellose exterior.

11. Paucicrura n.sp. Specimen OU 5838; locality A, Unit 3C, upper 6 feet. a. dorsal view, b. ventral view, c. posterior view, d. anterior view, (figures a, b, c, and d are all at X2).

PLATE IV

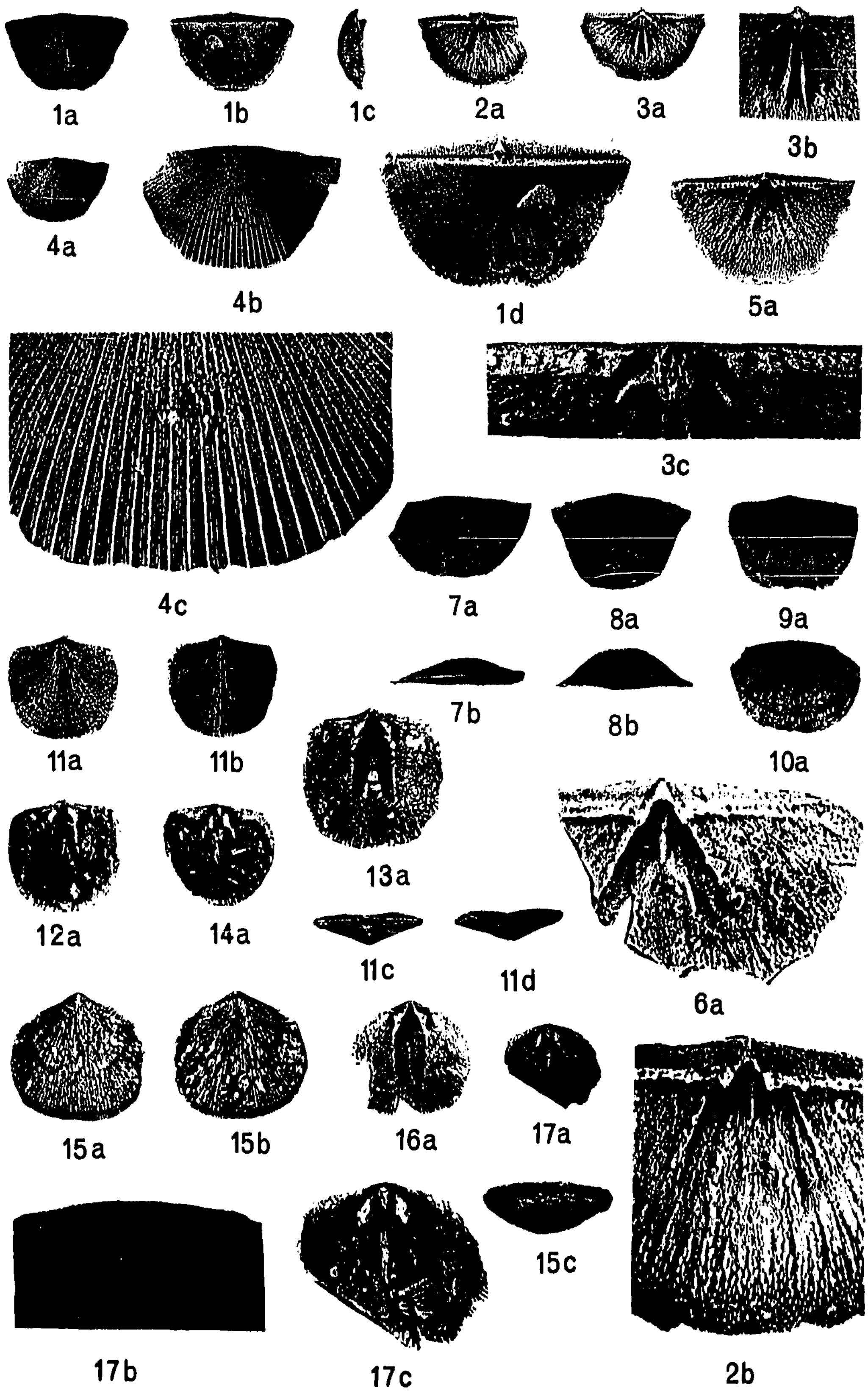

1a
1b
1c
2a
3a
3b
4a
4b
1d
5a
4c
3c
7a
8a
9a
7b
8b
10a
11a
11b
13a
12a
14a
11c
11d
6a
15a
15b
16a
17a
15c
17b
17c
2b

Plate V

1. Plaesiomys proavita (Winchell and Schuchert). Specimen OU 5845; locality A, Unit 3C, upper 6 feet. a. ventral view, b. posterior view of a pedicle valve, c. interior of a pedicle valve, d. lateral view.

2. Plaesiomys proavita (Winchell and Schuchert). Specimen OU 5845; locality C, Unit 3C, upper 6 feet. a. dorsal view, b. lateral view of a brachial valve, c. posterior view of a brachial valve, d. interior of a brachial valve, e. cardinalia showing the grooves along the margins of the notothyrial platform (X4).

3. Plaesiomys proavita (Winchell and Schuchert). Specimen OU 5847; locality A, Unit 3C, upper 6 feet. a. dorsal view, b. ventral view, c. lateral view, d. posterior view, e. anterior view.

4. Plaesiomys proavita (Winchell and Schuchert). Specimen OU 5848; locality C, Unit 3C, upper 6 feet. a. interior of a pedicle valve, b. pedicle muscle area showing the small adductor impressions (X4).

5. Plaesiomys proavita (Winchell and Schuchert). Specimen OU 5849; locality A, Unit 3C, upper 6 feet. a. interior of a brachial valve, b. cardinalia showing the weak groove offsetting the brachiophores from the notothyrial platform (X3).

6. Plaesiomys subquadrata (Hall). Specimen OU 5850; locality I, Unit 3CM, 40 feet from top. a. ventral view, b. interior of a pedicle valve, c. lateral view of a pedicle valve, d. posterior view of a pedicle valve.

7. Plaesiomys subquadrata (Hall). Specimen OU 5851; locality I, Unit 3CM; 40 feet from top. a. interior of a brachial valve.

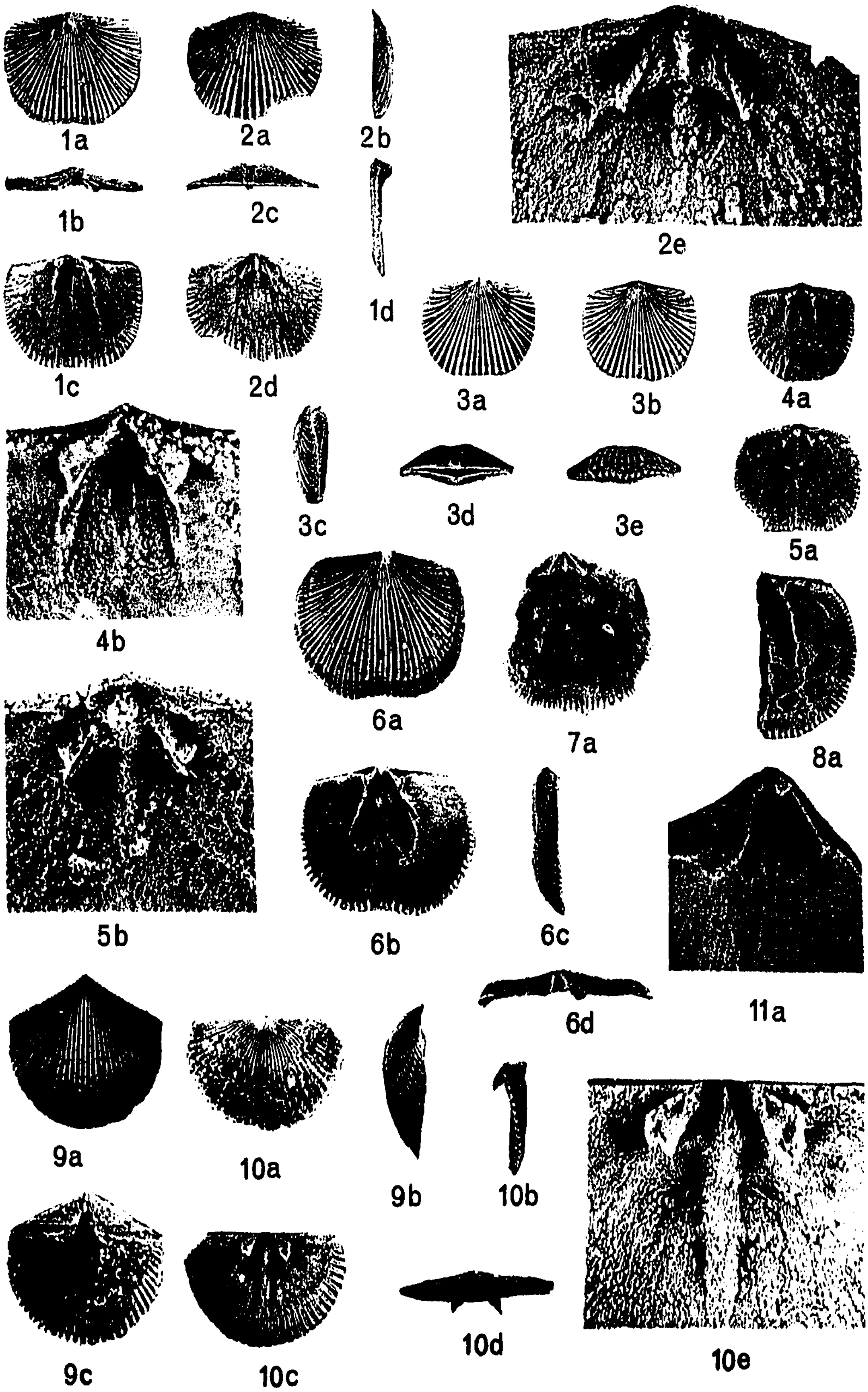
8. Plaesiomys subquadrata (Hall). Specimen OU 5852; locality I, Unit 3CM, 40 feet from top. a. interior of a pedicle valve showing the pallial markings.

9. Hesperorthis n.sp. A. Specimen OU 5853; locality A, Unit 3C, upper 6 feet, a. ventral view, b. lateral view of a pedicle valve, c. interior view of a pedicle valve.

10. Hesperorthis n.sp. A. Specimen OU 5854; locality C, Unit 3C, upper 6 feet. a. dorsal view, b. lateral view of a brachial valve, c. interior of a brachial valve, d. posterior view showing the cardinal process, e. interior of a brachial valve showing the brachiophores, cardinal process, and posterior and anterior adductor muscle scars (X3).

11. Hesperorthis n.sp. A. Specimen OU 5855; locality A, Unit 3C, upper 6 feet. a. interior of a pedicle valve showing the muscle area positioned well under the interarea (X3).

PLATE V



1a
2a
2b
2e
1b
2c
1c
2d
1d
3a
3b
4a
4b
3c
3d
3e
5a
6a
7a
8a
5b
6b
6c
11a
6d
9a
10a
9b
10b
10e
9c
10c
10d

Plate VI

1. Strophomena n.sp.?. Specimen OU 5856; locality C, Unit 3C, upper 6 feet. a. interior of a pedicle valve, b. ventral exterior, c. lateral view of a pedicle valve, d. view of the interarea and pseudodeltidium (X2), e. costation (X6).

2. Strophomena planumbona (Hall). Specimen OU 5837; locality A, Unit 3C, upper 6 feet. a. interior of a pedicle valve, b. view showing the pedicle opening at the apex of the delthyrial cavity, c. view normal to the interarea showing the delthyrial covering and the interarea, d. same as (c), (X3).

3. Strophomena planumbona (Hall). Specimen OU 5858; locality A, Unit 3C, upper 6 feet, a. interior of a brachial valve, b. dorsal exterior, c. anterior view of the cardinal process, d. cardinal process (X2).

4. Strophomena neglecta (James). Specimen OU 5859; locality I, Unit 3CM, 40 feet from top, a. interior of a pedicle valve, b. view normal to the interarea showing the pseudodeltidium and interarea.

5. Strophomena neglecta (James). Specimen OU 5860; locality I, Unit 3CM, 40 feet from top, a. interior of a pedicle valve.

6. Strophomena neglecta (James). Specimen OU 5861; locality I, Unit 3CM, 40 feet from top, a. interior of a pedicle valve, b. ventral exterior, c. ornamentation (X2).

7. Strophomena neglecta (James). Specimen OU 5862; locality I, Unit 3CM, 40 feet from top, a. interior of a brachial valve, b. cardinalia (X2), c. posterior view of the cardinal process.

8. Strophomena neglecta (James). Specimen OU 5863; locality C, Unit 3C, upper 6 feet, a. interior showing the pustulose structure of shell (X4), b. ornamentation.

9. Megamyonia n.sp.?. Specimen OU 5864; locality A, Unit 3C, upper 6 feet, a. ventral view of an articulated specimen.

10. Megamyonia n.sp.?. Specimen OU 5865; locality C, Unit 3C, upper 6 feet, a. interior of the pedicle valve, b. interior of the pedicle valve (X2).

11. Megamyonia n.sp.?. Specimen OU 5866; locality A, Unit 3C, upper 6 feet, a. interior of the pedicle valve showing the impressions of the adductor muscles, also the deeper impressions of the diductor scars as compared to those illustrated in figure 10a of Plate VI.

12. Rafinesquina sp. Specimen OU 5867; locality A, unit 3C, upper 6 feet, a. ventral view, b. interior of the pedicle valve.

PLATE VI

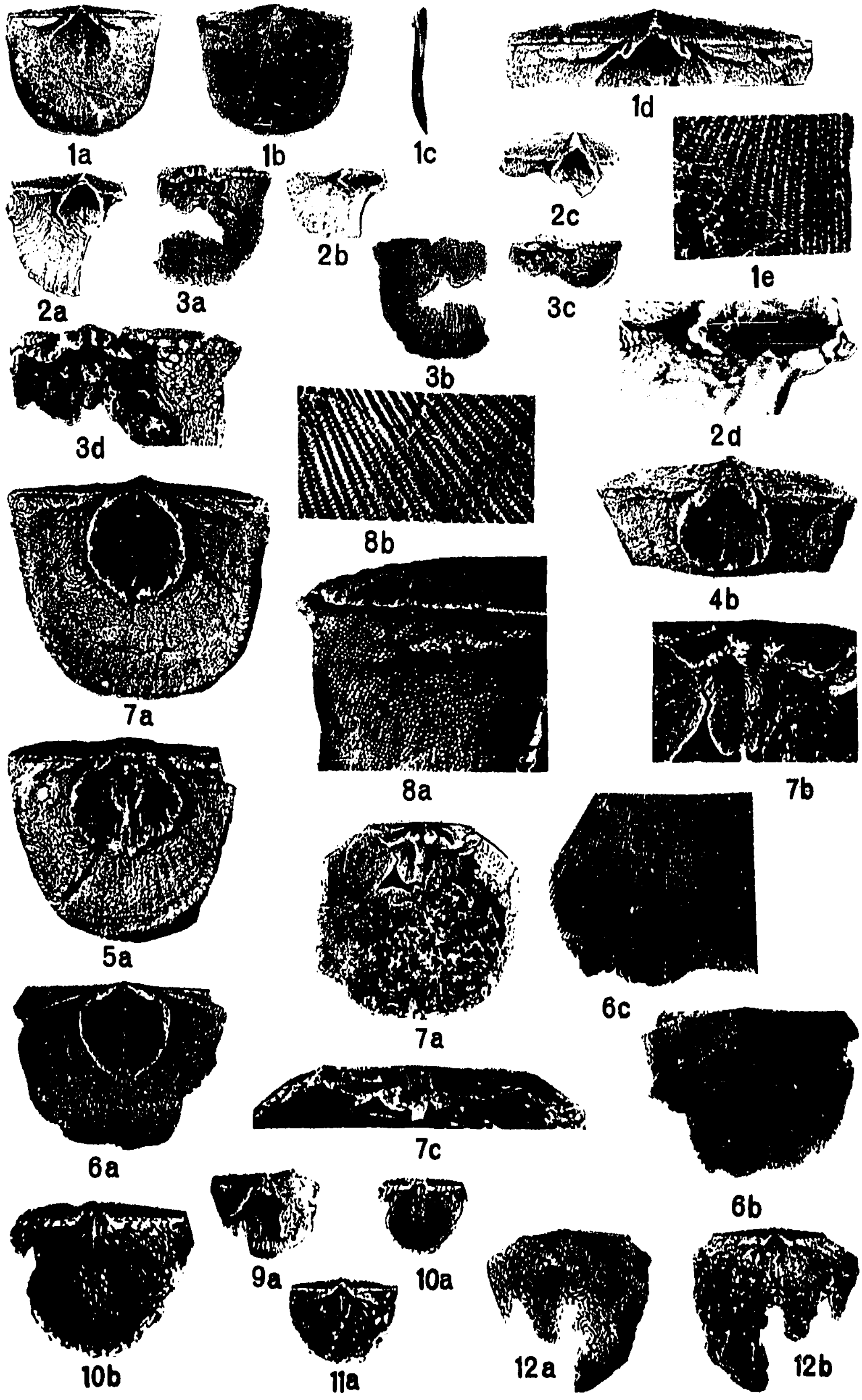

1a
1b
1c
1d
1e
2a
2b
2c
2d
3a
3b
3c
3d
4b
5a
6a
6b
6c
7a
7a
7b
7c
8a
8b
9a
10a
10b
11a
12a
12b

Plate VII

1. Plaesiomys cf. P. subquadrata (Hall). Specimen OU 5868; locality C, Unit 2, 34 feet below the top of the unit, a. ventral view, b. interior of a pedicle valve, c. posterior view of a pedicle valve.

2. Plaesiomys cf. P. subquadrata (Hall). Specimen OU 5869; locality C, Unit 2, 34 feet below the top of the unit, a. view normal to the line of commissure showing the bilobed cardinal process (X2), b. brachial valve tilted, again showing the bilobed nature of the process (X2).

3. Strophomena cf. S. clermontensis Wang. Specimen OU 5870; locality G, Unit 2, 45 feet below the top of the unit, a. dorsal view, b. lateral view, c. ventral view.

4. Strophomena perconcava Wang. Specimen OU 5871; locality G, Unit 2, 45 feet below the top of the unit, a. dorsal view, b. lateral view, c. posterior view.

5. Lepidocyclus oblongus Howe. Specimen OU 5872; locality B, Unit 2, 10 feet from top of unit, a. ventral view, b. dorsal view, c. posterior view, d. anterior view, e. lateral view.

6. Lepidocyclus oblongus Howe. Specimen OU 5873; locality B, Unit 2, upper 1 foot of unit, a. ventral view, b. dorsal view, c. posterior view, d. anterior view, e. lateral view.

7. Lepidocyclus oblongus Howe. Specimen OU 5874; locality B, Unit 3C, lower 1 foot of unit, a. dorsal view, b. ventral view, c. posterior view, d. anterior view, e. lateral view.

8. Lepidocyclus manniensis? (Foerste). Specimen OU 5875; locality B, Unit 3C, 10 feet from base of unit, a. ventral view, b. dorsal view, c. posterior view, d. anterior view, e. lateral view.

9. ?Lepidocyclus perlamellosus (Whitfield). Specimen OU 5876; locality G, Unit 2, 45 feet below the top of the unit, a. dorsal view, b. ventral view, c. lateral view, d. anterior view.

10. Rhynchotrema increbescens Hall. Specimen OU 5877; locality D, Unit 2, 18 feet above the base of the unit, a. dorsal view, b. ventral view, c. lateral view, d. posterior view, e. anterior view.

11. ?Lepidocyclus perlamellosus (Whitfield). Specimen OU 5878; locality B, Unit 2, upper 2 feet, a. dorsal view, b. ventral view, c. lateral view, d. posterior view, e. interior of a pedicle valve.

12. Strophomena sp. Specimen OU 5879; locality B, Unit 2, upper 2 feet, a. posterior view, b. dorsal view.

PLATE VII

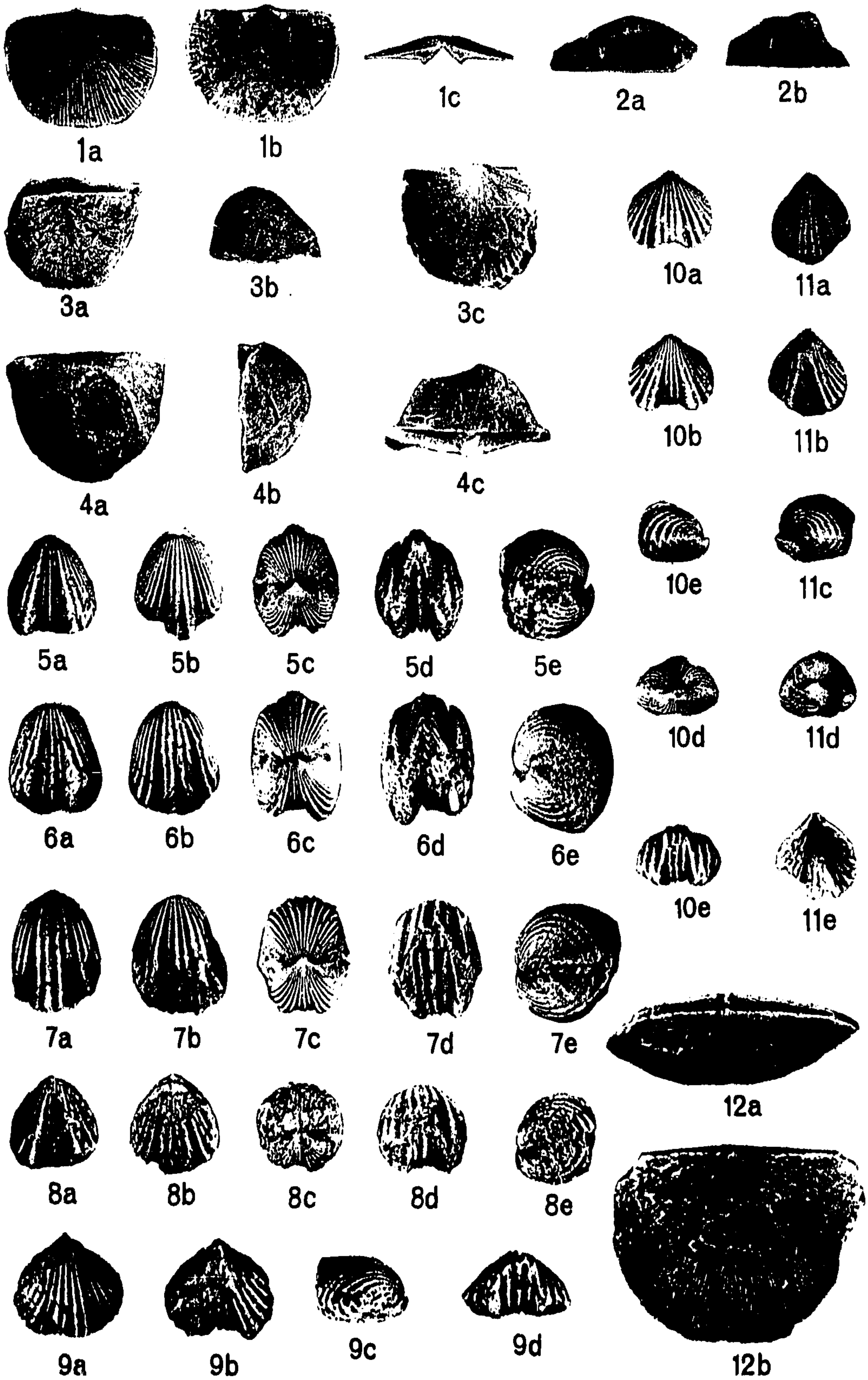

1a
1b
1c
2a
2b
3a
3b
3c
4a
4b
4c
5a
5b
5c
5d
5e
6a
6b
6c
6d
6e
7a
7b
7c
7d
7e
8a
8b
8c
8d
8e
9a
9b
9c
9d
10a
11a
10b
11b
10e
11c
10d
11d
10e
11e
12a
12b

Plate VIII--(Continued)

14. Sowerbyella n.sp.?. Specimen OU 5893; locality C, Unit 2, 15 feet above base of unit, a. dorsal view (X2), b. lateral view (X2), c. lateral view (X1).

15. Sowerbyella n.sp.?. Specimen OU 5894; locality C, Unit 2, 15 feet above base of unit, a. interior of a brachial valve (X2), b. posterior view of the cardinalia (X2), c. interior of a brachial valve (X1).

16. Sowerbyella n.sp.?. Specimen OU 5895; locality C, Unit 2, 15 feet above base of unit, a. interior of a pedicle valve (X2), b. interior of a pedicle valve (X1).

17. Dinorthis pectinella (Emmons). Specimen OU 5896; locality D, Unit 1C, 10 feet from top of unit, a. dorsal view, b. interior of a brachial valve, c. lateral view of a brachial valve, d. posterior view of a brachial valve, e. interior showing the cardinalia (X2).

Plate VIII

1. Platystrophia n.sp. C. Specimen OU 5880; locality C, Unit 2, 10 feet above base of unit, a. dorsal view, b. ventral view, c. posterior view, d. anterior view, e. lateral view.

2. Platystrophia n.sp. C. Specimen OU 5881; locality C, Unit 2, 10 feet above base of unit, a. interior of a pedicle valve.

3. Platystrophia n.sp. C. Specimen OU 5882; locality C, Unit 2, 10 feet above base of unit, a. interior of a brachial valve, b. interior of a brachial valve tilted so as to show the posterior adductor scars.

4. Platystrophia n.sp. C. Specimen OU 5883; locality C, Unit 2, 10 feet above base of unit, a. a posible variant that does not have the alation of the cardinal extremities.

5. Leptellina sp. Specimen OU 5884; locality C, Unit 2, 15 feet above base of unit, a. interior of a brachial valve, b. dorsal view, c. lateral view of a brachial valve, d. posterior view of a brachial valve.

6. Dinorthis transversa Willard. Specimen OU 5885; locality D, Unit 2, 25 feet above base of unit, a. dorsal view, b. ventral view, c. lateral view, d. anterior view.

7. Dinorthis transversa Willard. Specimen OU 5886; locality C, Unit 2, 10 feet above base of unit, a. interior of a brachial valve.

8. Dinorthis transversa Willard. Specimen OU 5887; locality C, Unit 2, 10 feet above base of unit, a. interior of a pedicle valve.

9. Oepikina sp. Specimen OU 5888; locality C, Unit 2, 10 feet above base of unit, a. ventral view, b. lateral view, c. dorsal view.

10. Oepikina sp. Specimen OU 5889; locality C, Unit 2, 10 feet above base of unit, a. interior of a brachial valve.

11. Paucicrura cf. P. rogata (Sardeson). Specimen OU 5890; locality C, Unit 2, 15 feet above base of unit, a. dorsal view, b. ventral view, c. posterior view, d. anterior view, e. lateral view.

12. Paucicrura cf. P. rogata (Sardeson). Specimen OU 5890; locality C, Unit 2, 15 feet above base of unit, a. interior of a brachial unit.

13. Paucicrura cf. P. rogata (Sardeson). Specimen OU 5892; locality C, Unit 2, 15 feet above base of unit, a. interior of a pedicle valve.

PLATE VIII

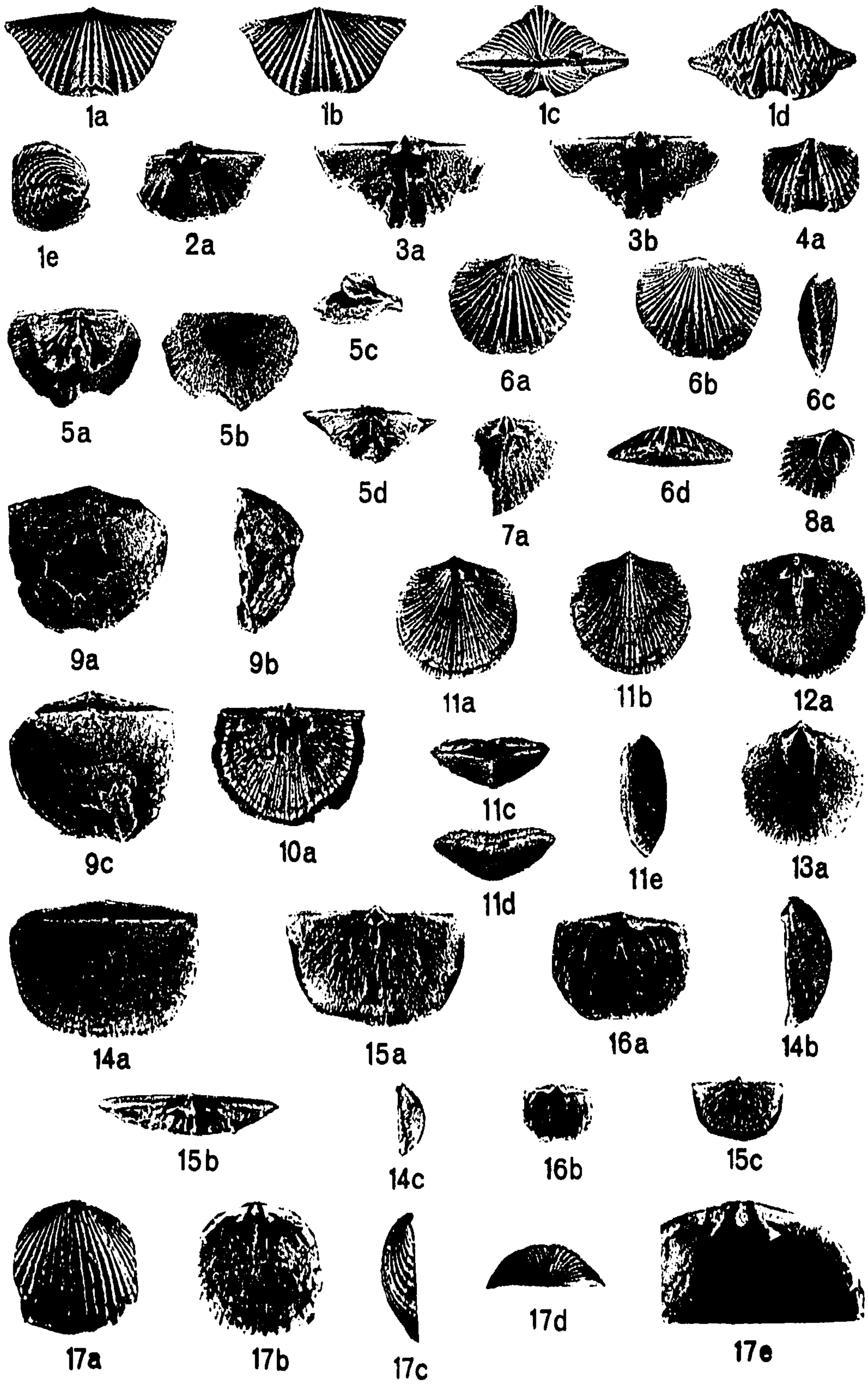

1a
1b
1c
1d
1e
2a
3a
3b
4a
5c
6a
6b
6c
5a
5b
5d
7a
6d
8a
9a
9b
11a
11b
12a
11c
9c
10a
11e
13a
11d
14a
15a
16a
14b
15b
14c
16b
15c
17a
17b
17c
17d
17e

Plate IX

1. Doleroides n.sp. Specimen OU 5910; locality D, Unit 1C, basal 1 foot of unit, a. dorsal view, b. interior of a brachial valve, c. lateral view of a brachial valve, d. interior of a brachial valve (X2).

2. Doleroides n.sp. Specimen OU 5911; locality D, Unit 1C, basal 1 foot of unit, a. ventral view, b. interior of a pedicle valve, c. interior of a pedicle valve (X2).

3. Strophomena sp. Specimen OU 5913; locality D, Unit 1C, basal 1 foot of unit, a. dorsal view.

4. Rafinesquina sp. Specimen OU 5914; locality C,

5. Onniella sp. Specimen OU 5900; locality L; Unit 1C, 40 feet above base of unit, a. dorsal view, b. ventral view, c. dorsal view (X2).

6. Onniella sp. Specimen OU 5909; locality L, Unit 1C, 40 feet above base of unit, a. interior of a pedicle valve, b. interior of a pedicle valve (X2).

7. Onniella sp. Specimen OU 5910; locality L, Unit 1C, 40 feet above base of unit, a. interior of a brachial valve, b. interior of a brachial valve (X2).

8. Sowerbyella sp. Specimen OU 5897; locality L, Unit 1C, basal 1 foot, a. ventral view, b. dorsal view (X2).

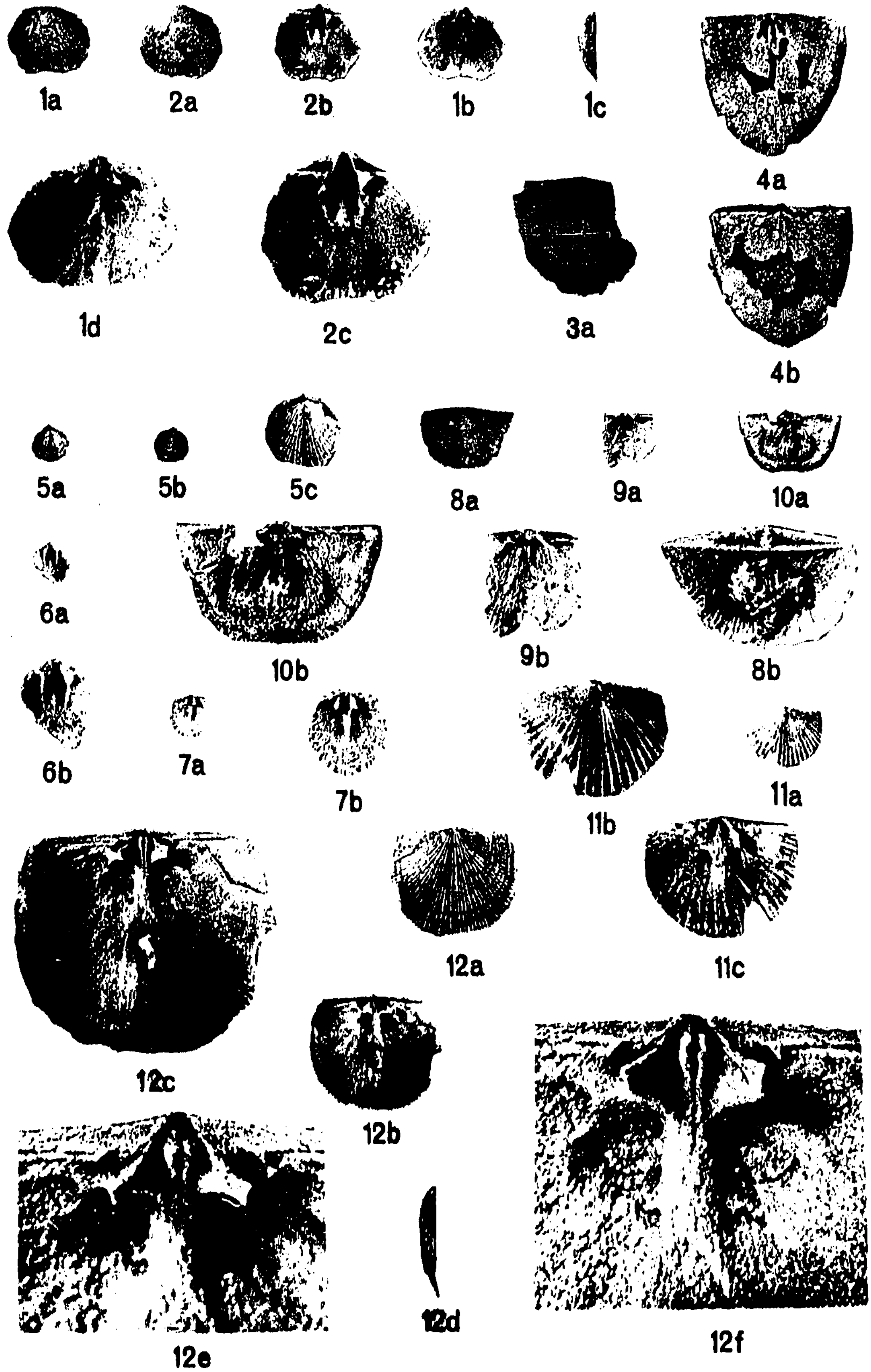
9. Sowerbyella sp. Specimen OU 5899; locality L, Unit 1C, basal 1 foot, a. interior of a pedicle valve, b. interior of a pedicle valve (X2).

10. Sowerbyella sp. Specimen OU 5898; locality L, Unit 1C, basal 1 foot, a. brachial interior, b. brachial interior (X2).

11. Hesperorthis sp. B. Specimen OU 5912; locality L, Unit 1C, 40 feet above base, a. dorsal view, b. dorsal view (X2), c. brachial interior (X2).

12. Onniella sp. Specimen OU 5896; locality D, Unit 1C, basal 1 foot of unit, a. dorsal view, b. interior of a brachial valve (X1), c. brachial interior (X2), d. lateral view of a brachial valve, e. cardinalia, specimen tilted so as to show the myophore (X4), f. cardinalia, view is normal to the plane of commissure (X4).

PLATE IX



1a
2a
2b
1b
1c
4a
1d
2c
3a
4b
5a
5b
5c
8a
9a
10a
6a
10b
9b
8b
6b
7a
7b
11b
11a
12a
11c
12c
12b
12e
12d
12f

APPENDIX I

Stratigraphic Sections

Introduction: Eighteen stratigraphic sections were measured by the writer and G. Glaser. These sections were described by Glaser (1965). The following descriptions are taken from Glaser (1965), but include only those sections from which brachiopods were collected. The stratigraphic positions of the brachiopods are given after the description of the unit in which they are found.

Section A: NE 1/4 sec. 36, T. 3 N., R. 5 E., Pontotoc County; in Ideal Portland Cement Quarry 5.9 miles southwest of the southwest corner of Ada along State Highway 12 as measured from the junction between that highway and State Highway 19. The bottom 100 feet of the exposed section was measured on the west quarry face from the lower and upper levels; the top 40 feet was measured on the east quarry face. All measurements were made along an east-west line where the ramp from the upper to lower level reaches the quarry floor; this line is essentially coincident with the northern boundary of section 36. This locality is on the Lawrence uplift. The strata strike N 12° E. and dip 4° SE, as measured by three point problem in the east quarry face. Section measured by L. Alberstadt and G. Glaser, October 1964.

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

The following species occur in the upper 6 feet of the unit. Lepidocyclus capax, L. cooperi, Austinella n.sp., Glyptorthis n.sp., Plaesiomys

Section A: Unit 3C--(Continued) Feet

proavita, Platystrophia n.sp. A, Platystrophia n.sp. B, Thaerodonta magna, Paucicrura n.sp., Diceromyonia cf. D tersa, Hesperorthis n.sp. A, Strophomena neglecta, Strophomena n.sp.?, Strophomena planumbona, Megamyonia n.sp.?, 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: SW 1/4 NW 1/4 sec. 6, T. 2 N., R. 6 E., Pontotoc County; measured along northeastward-flowing tributary to South Fork Creek. To reach this section go approximately 6.2 miles southwest from Ada on State Highway 12 and turn eastward on the unpaved road leading to Lawrence and proceed 1.7 miles (0.9 miles beyond Lawrence) by winding road. From this point the exposure is reached by walking approximately 0.6 miles due south across an open field to the creek. Measurements of the upper part of the Viola Formation in and along the creek bed. This locality is on the Lawrence uplift approximately 1 mile north of the Franks graben. The strata strike N. 40° W. and dip 7° NE. Section measured by L. Alberstadt and G. Glaser, October 1964.

Feet

Unit 3C

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

The following species occur in the lower 20 feet of the unit. Lepidocyclus oblongus, L. manniensis?.

Unit 2

Calcarenitic mudstone, dark gray, wavy-bedded, snady; near top, gradational with fine muddy calcarenites which are transitional to Unit 3C; honeycomb network of solution holes 1/4 to

Section B: Unit 2--(Continued) | Feet

1/2-inch in diameter toward top; base poorly exposed and not measured. 15

The following species occur in the upper 10 feet of the unit. Lepidocyclus oblongus,? L. perlamellosus, Strophomena sp., Plaesiomys cf. P. subquadratus.

Total 64

Section C: NE 1/4 NW 1/4 sec. 2, T. 1 N., R. 6 E., Pontotoc County; measured along northeastern flowing tributary to Sheep Creek. To reach this section, go 1.5 miles south of Fittstown on State Highway 99 and turn westward on the unpaved county line road for about 0.6 miles to where a gate on the south side of the road bounds an open pasture. From this point, the creek is reached by walking due south approximately 0.2 miles. This section is faulted at the base farther upstream to the west and at the top near the point of entrance. Measurements of the lower 231 feet were made in and along the creek bed; the remaining 84 feet were measured over a low rounded hill in an offset section approximately 200 yards south of the stream where it assumes a more easterly course. This locality is on the north limb of the Hunton anticline just south of the Franks graben. The strata strike N. 10° W. and dip 18° NE. Section measured by L. Alberstadt and G. Glaser, October 1964.

Feet

Unit 3C

Coarse skeletal calcarenite, light gray, slightly wavy-bedded, containing silicified brachiopods near the top in friable weathered portion; sandy near base; contact with overlying Sylvan Shale faulted out. 84

The following species occur in the upper 6 feet of the unit. Lepidocyclus capax, L. cooperi, Austinella n.sp., Glyptorthis n.sp., Plaesiomys proavita, Platystrophia n.sp. A, Platystrophia n.sp. B, Thaerodonta magna, Paucicrura n.sp., Diceromyonia cf. D. tersa, Hesperorthis n.sp. A, Strophomena neglecta, Strophomena n.sp.?, Strophomena planumbona, Megamyonia n.sp?.

Section C:--(Continued) Feet

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 which are transitional to Unit 3C.	23
The following species occur in the upper 35 feet of the unit. *Plaesiomys* cf. *P. subquadratus*, *Lepidocyclus perlamellosus*.	
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
The following species occur in the lower 15 feet of this unit. *Platystrophia* n.sp. C, *Leptellina* sp., *Paucicrura* cf. *P. rogata*, *Sowerbyella* n.sp.?, *Dinorthis* cf. *D. transversa*, *Oepikina* sp., *Rafinesquina* sp.	
Total	199

Unit 1C

Coarse skeletal calcarenite, yellowish-gray, slightly wavy-bedded, noncherty, containing abundant bryozoans and echinoderms, and a few large gastropods; slightly cross-bedded and burrowed in basal few feet; basal beds in fault contact with Ordovician McLish (?) Formation.	14
Total	297

Section D: NW 1/4 SW 1/4 sec. 12 and NE 1/4 SE 1/4 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; the base of the section is in the northern half of the SW 1/4 of section 12. The remaining 190 feet of offset section were measured just east of Sheep Creek in section 11 along a north-south line approximately coincident with the east boundary of section 11 (west boundary of section 12). To reach this offset section, proceed 2.7 miles south of Fittstown; then walk due west across the grassy field approximately 0.3 miles. The rocks in this clearing represent the upper unit; the beginning of the offset is approximately 200 yards due south of this clearing. This locality is on the north limb of the Hunton anticline just south of the Franks graben. The strata strike N. 57° W. and dip 19° NE. Section measured by L. Alberstadt and G. Glaser, October 1964 and January 1965.

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

The following species were seen on the outcrop, but were not collected: *Lepidocyclus cooperi*, *Austinella* n.sp., *Plaesiomys proavita*, and *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 Wengard, 1948) between nodular limestone; certain bedding planes covered with brachiopod shells at about 100 feet above base of unit; heavy iron stain from oxidizing pyrite along bedding surface 6 feet above unit base.	174

The following species was collected from 25 feet above the base of the unit: *Dinorthis transversa*. The following species occur in the lower 40 feet of the unit: *Platystrophia* n.sp. C, *Sowerbyella* n.sp.?, *Rhynchotrema increbescens*, *Paucicrura* cf. *P. rogata*, *Rafinesquina* sp.

Section D:--(Continued)	Feet
Unit 1C	
Coarse skeletal calcarenite, pinkish-gray, slightly wavy-bedded, noncherty, containing abundant bryozoans.	45
The following species occurs in the upper 10-15 feet of the 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, echioderms, and small brachiopods dominate the 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, planan-bedded, with burrowed highly irregular bedding surface near middle suggestive of small unconformity; cherty, graptolites. This represents a temporary incursion of Unit 1L rocks into this area.	2
Coarse skeletal calcarenite, brown, slightly wavy-bedded, cherty, abundant skeletal phosphatization, irregular contact with olive green clay-like material suggestive of unconformable break; graptolites abundant along bedding surface; echinoderms dominate the calcarenite.	
The following species occur in the basal 1 foot of the unit: Doleroides n.sp., Onniella sp., Sowerbyella sp.	
Total	162
Total	402

Section G: NW 1/4 NE 1/4 sec. 4, T. 2 S., R. 3 E., Murray County; measured in and along the northward-flowing tributary to Little Buckhorn Creek on Buckhorn Ranch. The base of the measured section is 400 yards south of the north boundary and 780 yards west of the east boundary to section 4. To reach this section, go south from Sulphur on U. S. Highway 177 (formerly State Highway 18) 7.4 miles from the junction with State Highway 7 at the north entrance to Platt National Park; then turn westward on the unpaved road leading to Buckhorn Ranch and proceed 2.2 miles to the ranch headquarters. From this point, turn northwestward along a winding road and go about 0.6 miles to a man-made lake. From this point proceed northeastward by foot approximately 0.4 miles along the creek to the first beds measured in this section. This locality is on the north limb of the Tishomingo anticline. The strata range in strike from N. 33° to N. 72° W. and increase in dip from 9° to 40° NE. toward the top of the section. Section measured by L. Alberstadt and G. Glaser, October 1964.

	Feet
Unit 3C	
Coarse skeletal calcarenite, pinkish-gray to gray, wavy-bedded, nodular, slightly dolomitic, containing abundant echinoderms and trilobites; topmost bed is fine skeletal calcarenite which 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
The following species were seen on the outcrop but were not collected: Lepidocyclus cooperi, L. capax, Paucicrura n.sp., Thaerodonta magna, Strophomena planumbona, Austinella n.sp. All were on a bedding plane 13 feet below the top of the unit.	
Unit 2	
Calcarenitic mudstone, yellowish-gray, wavy-bedded, nodular; chert in layers and as nodules.	105
The following species occur in an interval 41-56 feet below the top of the unit: Plaesiomys bellistriatus, Strophomena cf. S. perconcava, Strophomena clermontensis, and ?Lepidocyclus perlamellosus.	
Calcarenitic mudstone, yellowish-grah, wavy-bedded, noncherty.	96

Section G: Unit 2--(Continued)	Feet
Calcarenitic mudstone, yellowish-gray, wavy-bedded, burrowed, containing abundant brachiopods and pinkish-red trilobite hash in some beds; chert as nodules; near the top and bottom occur thin layers with high skeletal content and less than 50 percent mud which are medium muddy calcarenites.	99
Calcarenitic mudstone, yellowish-gray, wavy-bedded, sandy, noncherty except a few nodules in the 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 it is not exposed.	101
Total	401

Unit 1L

Upper part partially exposed (about 10 feet) approximately 400 yards upstream, but not measured. It is the typical laminated mudstone.	---	
Total		420

Section I: E 1/2 SW 1/4 sec. 22, T. 2 S., R. 1 W., Carter County; measured 0.3 miles northwest of the dam on Mountain Lake. To reach this locality, go 12.5 miles south of Davis on U. S. 77 and turn westward onto State Highway 53 and go 8 miles to Woodford; then turn northward and proceed about 3 miles to Mountain Lake. The section may be reached by ascending the steps on the west side of the dam and walking 0.3 miles to the base of the section in the NE 1/4 of the SW 1/4 of the section. This locality is on the south limb of the Arbuckle anticline. The strata strike N. 50° W. and dip 27° SW. Section measured by L. Alberstadt and G. Glaser, October 1964.

	Feet
Unit 3CM	
Calcarenitic mudstone, tan, wavy-bedded, burrowed, dolomitic, containing echinoderms and trilobites; nodular chert near base; contact with overlying Sylvan Shale covered.	37

Section I: Unit 3CM--(Continued)		Feet
Coarse skeletal calcarenite, dark tan, slightly wavy-bedded, dolomitic, containing echinoderms, trilobites, and a few large cephalopods.		7
The following species were collected from the lower 7 feet of this unit: *Lepidocyclus cooperi*, *L. capax*, *Austinella* n.sp., *Thaerodonta magna*, *Platystrophia* n.sp. A, *Platystrophia* n.sp. B, *Hesperorthis* n.sp. A, *Glyptorthis* n.sp., *Paucicrura* n.sp. *Megamyonia* n.sp.?, *Diceromyonia* cf. *D. tersa*, *Plaesiomys proavita*, *P. subquadratus*, *P. bellistriatus*.		
	Total	44
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
	Total	473
Unit 1L		
Siliceous laminated mudstone, brownish-gray, planar-bedded, containing graptolites, chert in layers; interbedded with 1/2 to 1-inch layers of limestone with shaly structure; basal 50 feet is bituminous and has asphaltic odor when broken open; excellent exposure of sharp contact with underlying Corbin Ranch Formation.		200
	Total	717

Section L: S 1/2 secs. 19 and 20, T. 1 S., R. 8 E., Coal County; measured in and along Mosley Creek. To reach this locality, go 2 miles south of Connerville on State Highway 99 and turn eastward on an unpaved road leading to the Dolese Brothers Bromide Quarry for 8 miles; then go 0.5 miles east of Bromide and turn northward for approximately 3 miles following the winding road past the Bromide school. The rocks at this point represent the upper unit. To reach the base of the formation, walk westward along Mosley Creek for about 1.5 miles. This locality is on the western margin of the Clarita anticlina. The strata strike N. 11° E. and dip 3° 38' SE as determined by three-point problem on the outcrop. Section measured by L. Alberstadt and G. Glaser, February and March 1965.

	Feet
Unit 3C Coarse skeletal calcarenite, gray, slightly wavy-bedded, containing silicified brachiopods; topmost bed almost completely dolomitized in places; contact with overlying Sylvan Shale covered.	64

The following species were seen on the outcrop in the upper 6 feet of the unit: Lepidocyclus cooperi, Austinella n.sp., 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 which are transitional to Unit 3C.	121

The following species were collected from the upper 20 feet of the unit: ?Lepidocyclus perlamellosus, Rhynchotrema increbescens.

Unit 1C

Dolomite, pinkish-gray, wavy-bedded, original texture and fabric almost wholly obliterated although what remains suggests original rock throughout this sequence probably was coarse calcarenites interbedded with a few calcarenitic mudstones; nodular chert in some beds; fauna consists of ostracodes, brachiopods, and trilobites. This represents the only occurrence of practically pure dolomite in any appreciable thickness in the Viola Formation throughout the

Section L: Unit 1C--(Continued)	Feet
area studied in the Arbuckle Mountains. Other replacement occurrences generally are patchy, less than 15 percent of the rock, and usually are confined to the 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, planan-bedded; interbedded with layers of coarse skeletal calcisiltite 1- to 2-millimeters thick. This represents a temporary incursion of Unit 1L into this 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 that formation appears to be thinner at this locality indicating possible greater amount of truncation here than seen at other sections.	40
The following species were collected from the lower 1 foot of the unit: Doleroides n.sp., Sowerbyella sp., Onniella sp. The following species were collected from 40 feet above the base of the unit: Onniella sp., Hesperorthis sp. B.	
Total	168
Total	353

APPENDIX II

TABULATION OF DATA

All measurements are given in millimeters. The writer did not measure all of the specimens collected from the Arbuckle Mountains. The data given below for each species is a representative sample for that species. This means that whenever possible, the writer assembled a growth series from the available shells.

Hesperorthis n.sp. A

Locality A, Unit 3C, upper 6 feet; pedicle valve

Length	Width	Thickness	Number of Marginal Costae	Length of Interarea
9.5	11.5	3.9	37	3.1
10.9	14.2	4.6	40	3.0
13.0	14.9	4.8	38	4.3
13.0	13.8	4.8	--	4.4
12.7	16.0	5.3	39	4.9
14.7	15.8	5.7	41	4.6
14.3	18.0	6.0	39	5.7
14.3	17.4	5.8	40	4.8
14.2	17.3	5.4	40	5.1

Length	Width	Thickness	Number of Marginal Costae	Length of Interarea
15.2	18.2	5.9	41	4.9
15.0	16.9	5.5	41	4.8
15.6	17.7	6.4	41	5.2
15.6	17.6	5.7	--	---
15.7	17.5	5.5	40	5.0
17.0	18.8	6.5	42	5.1
16.8	18.7	6.9	33	5.4
17.2	19.0	7.0	39	5.4
16.0	19.9	6.2	42	5.2
16.1	20.1	---	--	---
17.5	20.5	6.8	42	5.7
16.5	20.4	6.9	40	4.8
17.2	20.4	5.2	39	5.6
17.0	20.5	5.6	39	5.8
18.3	22.3	5.7	41	6.2
19.9	23.0	7.3	40	5.9
18.8	21.9	6.8	39	5.8
19.7	--	7.5	36	5.9
21.4	22.6	8.1	40	6.3
20.7	22.0	7.7	40	6.3
20.6	24.0	8.0	--	---
23.9	27.1	8.1	42	7.0

- - - - - - - - -

Locality C, Unit 3C, upper 6 feet; pedicle valve

Length	Width	Thickness	Number of Marginal Costae	Length of Interarea
19.2	22.9	8.1	--	---
20.5	22.8	8.1	--	---
17.7	19.8	6.9	--	---
11.5	14.2	4.9	--	---
12.2	14.6	4.9	--	---
13.0	14.5	4.8	--	---
12.6	14.9	4.6	--	---
13.0	15.6	5.2	--	---
14.1	15.8	5.5	--	---
15.9	18.5	5.6	--	---
15.8	17.6	6.0	--	---
--	19.3	6.9	--	---
17.0	19.4	6.2	--	---
17.0	21.6	6.4	--	---
19.2	23.6	6.9	--	---

Locality A, Unit 3C, upper 6 feet; brachial valve

Length	Width	Length of Interarea	Length of Brachiophore
11.9	17.9	2.7	1.4
14.8	20.9	2.5	1.4
12.6	18.6	2.3	---
13.2	--	3.0	---

Length	Width	Length of Interarea	Length of Brachiophore
12.6	21.2	3.2	1.4
13.0	19.2	---	---
14.1	21.2	3.4	2.7
14.4	23.3	3.1	---
16.6	24.0	3.5	---
15.1	--	3.2	---
11.0	17.4	2.9	---
10.5	19.6	2.0	1.5
11.4	20.6	2.7	1.8
13.1	19.5	3.1	3.0
11.7	20.1	3.0	---
12.9	19.8	1.7	3.1
15.3	20.6	3.4	3.1
17.4	27.2	3.7	1.8

- - - - - - - - - -

<u>Glyptorthis</u> n.sp.

<u>Locality</u> <u>A</u>, Unit 3C, upper 6 feet; <u>pedicle</u> <u>valve</u>

Length	Width	Thickness	Length of Interarea	Distance Muscle Scar Extends Past Interarea	No. Costae in 3mm. at 5mm. from Beak
7.7	9.3	2.8	1.3	---	13
7.4	9.0	2.3	2.0	---	7
8.8	10.0	2.9	1.8	---	8
8.4	10.0	3.3	2.2	---	8

Length	Width	Thickness	Length of Interarea	Distance Muscle Scar Extends Past Interarea	No. Costae in 3mm. at 5mm. from Beak
9.6	11.0	4.3	2.5	1.7	8
9.3	11.0	3.5	2.7	1.6	9
10.0	11.5	3.5	2.9	---	7
10.3	12.4	4.3	2.8	1.7	8
10.5	12.2	3.8	2.7	---	9
10.8	12.5	4.3	2.7	---	8
11.7	13.7	4.1	3.1	1.8	9
11.5	12.9	4.1	3.1	1.8	7
12.5	14.9	5.0	3.3	1.0	8
12.5	14.6	4.2	3.4	---	8
13.7	14.2	---	4.1	---	--
13.6	16.2	5.8	3.5	2.3	9
15.9	17.5	6.2	4.6	3.2	7
15.5	17.2	5.6	3.9	---	8
16.1	19.0	5.9	4.0	3.1	--
20.0	22.8	6.7	5.4	3.6	6
16.6	17.6	6.3	4.5	2.7	7
17.8	19.1	7.4	5.3	4.0	8
18.7	18.6	6.5	5.5	4.5	8
18.5	20.7	5.8	5.7	3.7	7
22.9	23.0	7.1	---	---	--
21.8	23.7	6.9	5.4	---	6
22.9	24.9	7.3	5.9	5.4	8

- - - - - - - - -

Locality C, Unit 3C, upper 6 feet; pedicle valve

Length	Width	Thickness	Length of Interarea	Distance Muscle Scar Extends Past Interarea
20.0	22.0	5.7	5.2	---
20.4	22.3	6.5	6.8	3.9
17.4	18.9	5.5	4.8	---
15.3	16.8	5.2	4.5	---
8.8	10.7	3.2	3.4	---
9.6	11.3	3.4	---	---
9.3	11.3	3.8	3.3	---
14.5	16.6	4.6	---	---
10.4	12.4	3.6	---	---
11.9	13.2	4.4	3.8	2.2
16.2	16.1	4.5	---	---
16.7	18.4	4.8	---	---
8.7	11.0	2.8	---	---
8.8	11.0	3.3	---	---
11.2	13.0	3.6	---	---
16.6	19.7	5.3	4.1	2.3
9.7	12.3	3.3	---	---
8.5	10.6	3.0	---	---
13.8	--	4.6	---	---
17.6	19.1	5.8	5.0	3.2

- - - - - - - - - -

<u>Locality A</u>, <u>Unit 3C</u>, upper 6 feet; <u>brachial valve</u>

In measuring the width of the sulcus the writer considered the margins of the sulcus to be the highest points above the lowest median portion. Because this limit cannot always be defined accurately, the measurements are given only to the nearest whole number.

Length	Width	Thickness	Width of Sulcus at Anterior Margin
5.6	8.0	2.4	---
7.9	10.4	2.9	5
7.7	11.4	2.7	5
8.9	11.4	3.3	5
8.8	11.3	3.0	5
9.2	12.2	3.5	---
8.4	11.9	3.5	5
8.7	11.9	---	---
9.9	13.3	3.8	5
10.4	14.1	3.8	6
11.0	14.5	4.1	6
12.5	15.2	5.1	7
12.9	15.0	4.3	7
11.6	15.6	4.3	5
13.8	17.6	5.6	7
12.7	16.8	5.2	7
13.1	16.2	5.1	---
--	18.0	5.1	---
12.1	16.5	4.2	7

Length	Width	Thickness	Width of Sulcus at Anterior Margin
15.0	17.0	5.9	7
16.6	--	5.9	8
15.7	19.6	6.3	7
16.2	20.0	6.2	7
15.8	20.0	6.2	7
15.7	20.8	6.4	8
19.0	23.7	8.0	10

Locality C, Unit 3C, upper 6 feet; brachial valve

Length	Width	Thickness	Width of Sulcus at Anterior Margin
7.8	10.5	2.6	---
12.0	16.4	4.4	---
11.0	15.5	3.7	---
12.9	17.3	4.5	---
10.0	14.7	3.9	---
15.2	19.4	6.2	---
15.4	19.5	6.1	---
8.7	--	3.0	---
9.5	13.3	3.4	---
14.7	19.7	6.0	---
13.1	16.7	4.7	---
10.7	14.8	4.4	---
11.7	15.5	4.9	---
9.4	--	---	---

Length	Width	Thickness	Width of Sulcus at Anterior Margin
--	19.6	5.3	---
9.4	--	3.4	---
9.7	--	3.3	---
6.3	9.1	2.3	---

- - - - - - - - -

Plaesiomys proavita

Locality A, Unit 3C, upper 6 feet; pedicle valve

Because the pedicle valve is nearly flat the writer did not take any thickness measurements. The one thickness measurement that is reported below is for an articulated specimen.

Length	Width	Thickness
9.1	11.0	---
9.8	12.6	---
11.0	13.4	---
11.0	--	---
--	18.0	---
12.9	--	---
14.6	18.7	---
15.0	18.6	---
14.6	18.9	---
15.8	18.5	---

Length	Width	Thickness
14.6	19.5	---
15.0	18.0	---
17.3	--	---
16.0	21.8	---
15.0	19.1	6.1
15.3	20.5	---
16.7	20.7	---
15.7	21.8	---

\- - - - - - - -

Locality A, Unit 3C, upper 6 feet; brachial valve

Length	Width	Thickness	No. Costae in 5mm. at 10mm. from Beak	No. Costae Around Margin
9.7	11.9	---	-	41
10.9	13.9	2.4	-	37
11.4	14.8	2.5	6	41
13.3	15.6	---	5	36
13.5	17.1	3.5	5	34
13.2	18.1	3.5	6	44
14.4	18.7	3.7	6	47
15.8	18.5	3.1	6	44
15.0	17.8	4.4	6	42
15.0	18.7	4.2	6	54
15.9	19.7	4.1	5	40
15.4	18.5	4.7	6	44

Length	Width	Thickness	No. Costae in 5mm. at 10mm. from Beak	No. Costae Around Margin
15.9	20.2	3.7	6	41
15.8	20.2	4.0	5	42
17.0	19.6	6.0	5	45
17.3	19.5	4.7	6	47
16.0	19.7	4.4	5	37
17.5	21.6	5.2	6	50
15.4	19.0	4.6	6	40
15.8	20.4	3.5	8	59
17.7	20.2	5.3	6	--
16.8	21.3	4.6	6	53
17.1	21.6	4.8	5	42
16.8	21.1	4.9	5	43
16.5	20.5	5.0	6	46
18.4	21.5	5.7	6	39
18.5	23.8	4.8	6	57

\- - - - - - - - - -

Locality C, Unit 3C, upper 6 feet; brachial valve

Length	Width	Thickness	No. Costae in 5mm. at 10mm. from Beak	No. Costae Around Margin
9.6	11.9	2.1	--	--
14.0	--	3.2	--	--
11.3	12.7	2.2	--	--
12.1	15.8	3.0	--	--

Length	Width	Thickness	No. Costae in 5mm. at 10mm. from Beak	No. Costae Around Margin
13.8	17.0	3.4	6	42
15.6	18.8	3.8	5	42
14.3	18.4	3.4	6	44
14.6	18.0	3.5	5	40
14.0	17.7	3.4	5	--
16.5	19.8	4.6	5	41
16.4	20.9	4.9	6	50
16.0	20.6	4.1	5	42
16.0	20.4	4.9	6	50
17.4	21.7	5.0	6	48
19.1	24.6	4.9	6	56
22.0	27.2	5.8	--	54
14.4	17.0	4.3	6	44
15.3	19.4	4.3	6	48
14.6	18.4	3.9	5	50
14.5	18.2	3.8	7	44

Plaesiomys subquadratus

Locality I, Unit 3CM, the lower 7 feet of the unit; pedicle valve

Length	Width	Thickness	No. Costae in 10mm. at 10mm. from Beak
--	--	--	15
22.7	29.3	--	13

Locality I, Unit 3CM, the lower 7 feet of the unit; brachial valve

Length	Width	Thickness	No. Costae in 10mm. at 10mm. from Beak
24.8	31.8	8.7	16

Austinella n.sp.

Locality A, Unit 3C, upper 6 feet, pedicle valve

The length of the pedicle muscle filed is the distance from the beak of the valve to the anterior margin of the field.

Length	Width	Thickness	Length of Muscle Field	No. Costae Around Margin
10.6	12.7	3.3	4.1	--
13.0	17.0	4.1	---	--
--	21.0	5.0	7.2	--
15.3	18.5	4.5	5.4	55
15.7	18.6	4.9	5.4	--
17.3	18.8	4.6	6.3	59
17.3	20.2	5.4	---	--
17.9	20.3	5.2	6.7	65
--	21.6	5.0	7.2	--
18.9	21.6	5.5	7.2	53
--	23.2	5.4	7.0	70
--	23.0	5.4	---	--
--	--	5.7	7.6	--
--	24.0	5.5	8.5	--

Length	Width	Thickness	Length of Muscle Field	No. Costae Around Margin
23.0	27.2	6.6	9.2	70
22.8	26.0	6.9	9.5	--
23.4	26.0	6.8	9.6	73
23.4	27.4	7.2	9.8	--
--	24.4	---	10.0	--
26.9	30.3	---	10.0	73
--	29.2	8.5	9.6	--
30.0	32.0	7.0	12.2	--
28.9	--	8.8	10.2	--
29.9	33.3	8.0	11.0	86
32.5	37.0	8.6	12.7	--

Locality A, Unit 3C, upper 6 feet; brachial valve

Length	Width	Thickness	Length of Interarea	No. Costae Around Margin
8.5	10.0	1.9	---	--
9.0	10.9	2.0	1.2	--
7.9	10.4	1.6	1.0	--
9.2	13.0	2.1	1.3	--
9.0	12.9	1.7	1.2	--
11.6	15.0	2.8	1.8	--
11.5	17.2	1.8	1.6	--
13.3	17.8	2.0	1.8	--
12.6	16.4	2.6	2.0	--
12.9	15.5	2.5	1.7	--

Length	Width	Thickness	Length of Interarea	No. Costae Around Margin
12.2	16.9	2.5	2.0	62
--	15.8	2.5	1.5	--
12.0	16.9	3.2	1.8	--
13.1	16.5	2.2	1.8	63
14.3	19.2	2.7	2.0	--
15.2	20.0	2.5	1.8	--
--	20.5	3.0	1.8	--
15.5	18.5	2.7	1.8	--
15.6	19.4	2.6	1.8	--
17.0	20.0	3.0	1.8	69
16.9	20.8	3.0	---	--
17.8	19.8	3.3	2.1	--
17.4	21.0	3.0	2.2	--
17.7	23.8	3.7	2.4	65
18.4	22.6	3.5	2.2	--
19.6	23.8	4.4	2.3	--
19.3	22.8	3.5	---	--
--	27.2	4.3	2.1	--
21.0	24.8	4.0	2.4	72
21.2	25.7	4.5	2.3	--
24.5	28.6	5.8	3.0	--
25.9	30.2	6.0	3.6	--
23.8	31.6	4.6	2.7	--
26.2	33.3	5.8	3.2	--

Length	Width	Thickness	Length of Interarea	No. Costae Around Margin
28.0	34.0	5.5	3.3	77
29.3	35.3	6.7	3.3	--
18.4	21.7	3.0	2.3	--
21.9	27.9	4.5	2.2	--
18.2	22.0	3.4	2.2	--
19.0	24.2	4.2	2.4	--
22.8	29.4	4.6	2.9	--
--	26.6	3.6	2.3	--
--	27.4	4.3	2.8	--
25.5	31.8	5.3	3.3	--
21.5	27.0	4.7	2.3	--
--	32.1	5.8	3.6	--
21.4	26.2	3.9	2.7	--
--	31.2	5.7	2.9	--
25.0	30.0	5.8	3.6	--
20.0	28.7	3.6	2.5	--
20.4	28.6	4.3	2.2	--
--	24.6	6.3	2.1	--
20.0	24.4	3.8	---	--
20.0	25.2	4.3	2.4	66
--	24.2	5.0	2.8	--
18.1	--	3.2	2.1	--
19.4	25.2	3.9	1.8	--
--	23.2	2.9	1.8	--

Length	Width	Thickness	Length of Interarea	No. Costae Around Margin
18.5	23.2	3.2	1.8	--
24.3	32.2	5.3	---	--
23.0	27.8	5.2	---	--
18.9	24.4	4.0	2.5	--
15.6	21.2	3.9	2.0	--
20.2	24.7	3.9	2.4	--
18.2	21.4	3.1	1.8	--
19.0	24.0	3.5	2.1	--
15.4	18.8	3.4	1.8	--
17.4	19.4	3.4	1.8	--
19.2	23.1	3.9	2.5	--
--	25.6	3.8	2.2	--
15.4	19.3	2.5	1.9	--
19.2	--	---	2.0	--
14.0	18.8	3.3	1.8	--
12.7	17.2	2.6	1.8	--

Platystrophia n.sp. A

Locality A, Unit 3C, upper 6 feet; pedicle valve

Length	Width	Length of Interarea	Length of Muscle Scar	Width Sulcus at Anterior Margin	Number Plications on Flanks
14.3	25.0	2.7	6.3	10.2	10
14.6	25.1	2.8	5.9	10.2	12

Length	Width	Length of Interarea	Length of Muscle Scar	Width Sulcus at Anterior Margin	Number Plications on Flanks
10.1	20.0	1.9	4.5	7.3	10
14.5	16.5	2.8	6.8	10.8	13

- - - - - - - - -

Locality C, Unit 3C, upper 6 feet; pedicle valve

Length	Width	Length of Interarea	Length of Muscle Scar	Width Sulcus at Anterior Margin	Number Plications on Flanks
10.1	19.1	1.5	4.0	7.1	10
--	27.0	2.9	6.1	---	11
9.7	19.5	1.8	4.0	---	10
12.7	23.3	2.3	4.9	7.9	11
14.0	25.0	2.9	---	7.9	12
14.3	27.8	3.0	---	11.2	12

- - - - - - - - - -

Locality A, Unit 3C, upper 6 feet; brachial valve

Length	Width	Length of Interarea	Maximum Height of Fold Above Flanks
14.0	25.2	2.3	6.4
15.2	29.6	2.2	8.3
12.3	25.9	1.7	6.1
11.8	21.8	1.5	3.8
12.2	25.0	1.8	---

- - - - - - - - - -

Locality C, Unit 3C, upper 6 feet; brachial valve

Length	Width	Length of Interarea	Maximum Height of Fold Above Flanks
12.8	22.2	1.7	6.2
12.3	23.6	1.7	6.4
8.9	21.0	1.2	2.9
10.3	20.8	1.2	---
12.4	27.6	1.8	8.4
4.7	7.2	---	---

\- - - - - - -

Platystrophia n.sp. B

Locality A, Unit 3C, upper 6 feet; pedicle valve

Length	Width	Interarea Length	Length Muscle Field	Number Costae on Flanks	Width Sulcus (Anterior Margin)
18.7	23.9	4.0	8.3	11	11.9
12.7	18.7	1.5	5.7	10	8.3
14.9	21.2	2.8	7.0	9	9.6

\- - - - - - - -

Locality C, Unit 3C, upper 6 feet; pedicle valve

Length	Width	Interarea Length	Length Muscle Field	Number Costae on Flanks	Width Sulcus (Anterior Margin)
--	14.2	1.3	3.6	10	--
10.5	--	---	---	--	--

\- - - - - - - -

Locality A, Unit 3C, upper 6 feet; brachial valve

Length	Width	Interarea Length	No. Costae on Flanks	Width of Fold (Ant. Margin)
13.6	18.0	1.5	8	6.5
15.4	19.6	1.3	9	9.0
16.9	21.6	1.8	9	10.0
17.2	21.4	2.0	-	10.2

- - - - - - - - -

Locality C, Unit 3C, upper 6 feet; brachial valve

Length	Width	Interarea Length	No. Costae on Flanks	Width of Fold (Ant. Margin)
17.0	22.4	1.8	10	---
17.2	22.3	1.8	--	---
17.4	22.0	2.4	8	10.0

- - - - - - - - -

Platystrophia n.sp. C

Locality C, Unit 2, the lower 15 feet of the unit; articulated specimens

Length	Width	Thickness
7.2	12.2	4.4
8.7	14.0	7.0
10.1	18.5	8.2
11.6	21.8	8.3
13.7	29.5	13.7
7.9	16.8	--
10.3	19.4	9.5

- - - - - - - - -

Locality C, Unit 2, the lower 15 feet of the unit; pedicle valve

Length	Width	Interarea Length	Length of Muscle Scar
11.2	20.5	1.2	4.3
11.8	24.8	1.8	4.5
12.3	23.4	1.5	5.0
11.3	19.6	1.2	4.7
9.5	16.6	1.2	3.3
9.4	13.8	1.0	4.1
12.1	18.8	1.8	5.3
12.0	--	2.2	5.7
8.7	14.5	---	3.6
9.8	20.6	1.3	3.6
11.0	--	1.1	3.7
12.4	24.6	1.8	5.0
11.5	22.3	1.6	4.8
9.4	17.3	1.6	4.3
12.6	24.3	1.7	5.2
10.3	19.2	2.1	4.5
13.1	23.6	1.8	5.2
12.5	20.6	1.8	5.3
10.6	17.9	1.5	4.5
13.7	22.0	2.6	5.9
11.8	19.2	1.4	4.1
12.0	22.6	2.0	5.6
13.4	--	2.7	---

- - - - - - - - -

Locality C, Unit 2, the lower 15 feet of the unit; brachial valve

Length	Interarea Length
11.9	1.3
12.0	1.4
12.6	1.4
10.5	1.0
14.3	1.6
13.2	1.5
12.7	1.2
11.8	1.4
11.3	1.0
11.0	1.3
10.4	1.2
12.4	1.3
12.3	1.4
12.0	1.6
7.7	.8
11.7	1.2
13.8	1.3
13.3	1.7
14.6	1.8

- - - - - - -

Paucicrura cf. rogata

Locality C, Unit 2, the lower 15 feet of the unit; articulated specimens

Length	Width	Thickness
9.4	10.5	3.9
8.6	9.1	4.0
8.9	9.4	3.8
7.8	8.5	3.0
7.8	8.3	3.4
8.8	9.3	3.8
5.9	6.6	2.4
8.9	9.6	3.8
7.5	7.8	3.4
6.5	7.7	3.8
5.5	6.4	2.5
9.1	10.8	4.1
8.9	10.4	3.4
9.6	10.9	3.8
8.6	9.2	3.8
7.4	8.0	3.3
8.2	8.7	3.5
6.0	6.6	2.7
8.2	8.6	3.5
5.5	6.5	2.4
8.9	9.6	4.2

Length	Width	Thickness
8.6	9.1	3.3
7.4	8.3	3.4
8.9	9.9	3.9
4.7	5.3	2.3
4.7	5.3	2.3
4.7	5.7	2.3
6.2	7.0	2.5
5.5	6.6	---
4.8	5.4	2.1
6.9	7.9	3.3
8.0	9.1	3.5
---	5.3	2.4
8.2	9.3	3.0
8.3	9.7	3.7
7.5	8.5	3.4
6.7	7.3	2.9
9.3	10.3	3.8
8.3	9.5	3.4
5.0	6.1	2.5
7.8	8.6	3.5
7.7	8.8	3.0
7.8	8.0	3.7
9.1	10.1	3.6
8.3	9.2	3.6

Length	Width	Thickness
7.0	7.6	3.2
7.9	8.5	3.9
6.1	6.7	2.8
---	6.5	3.1
5.5	7.1	2.5
7.1	7.8	3.2
5.8	7.8	2.5
8.3	9.1	3.8
5.4	5.8	2.7
7.1	8.1	3.0
8.7	9.7	4.2
6.5	7.2	3.1
6.9	7.2	3.4
8.5	9.2	3.7
7.0	7.9	3.4
7.4	8.1	2.9
9.3	10.0	4.0
6.9	7.6	3.3

- - - - - - - -

Paucicrura n.sp.

Locality A, _Unit 3C_, upper 6 feet; _articulated specimens_

Length	Width	Thickness
8.4	10.5	2.5
8.8	10.7	2.7

Length	Width	Thickness
7.9	9.9	2.8
9.2	10.2	3.1
6.7	8.2	2.3
7.5	8.5	2.8
7.3	9.4	2.0
7.3	8.7	3.0
9.0	10.8	2.6
8.9	10.5	3.1
7.7	8.3	2.5
7.4	9.4	2.4
7.8	8.2	2.3
8.7	10.4	3.1
8.4	9.3	3.0
6.6	8.2	2.0
8.3	9.8	2.6
8.2	9.4	2.8

\- - - - - -

Locality A, Unit 3C, upper 6 feet; pedicle valves

Maximum Width	Hinge Line Width
10.0	7.2
10.8	6.3
10.8	7.8
10.5	7.2
9.1	5.4

Maximum Width	Hinge Line Width
8.5	7.3
9.0	6.6
11.6	7.2
10.7	6.8
11.9	9.4
11.7	9.0
11.6	8.4
9.0	7.0
7.0	4.5
6.3	4.4
7.7	5.2
7.2	3.6
9.5	5.7

- - - - - - - - -

Thaerodonta magna

Locality A, Unit 3C, upper 6 feet; articulated specimens

Length	Maximum Width	Thickness	Length of Pedicle Interarea
4.2	6.9	1.2	.6
5.0	8.7	1.4	.8
4.3	7.2	1.0	.5
4.4	8.1	1.2	.6
6.2	11.0	1.8	.7

Length	Maximum Width	Thickness	Length of Pedicle Interarea
6.5	11.6	2.0	.9
7.0	12.7	1.9	.9
8.1	13.7	1.8	.9
8.0	15.3	2.3	1.1
8.2	15.1	2.2	1.1
8.5	15.0	2.4	1.0
8.8	17.1	2.4	.9
7.8	15.9	2.3	1.0
8.7	16.2	2.9	1.0
8.1	16.9	2.6	1.0
9.1	16.4	2.7	1.2
8.9	15.3	2.8	1.1
10.3	18.4	3.3	1.3
9.4	16.5	2.9	1.1
9.1	16.6	3.0	1.2
9.7	18.1	2.9	1.4
10.2	20.8	2.9	1.0
10.5	18.7	3.1	1.3
11.0	19.6	3.2	1.3
11.3	20.5	3.6	1.3
12.1	20.5	3.6	1.4
12.3	22.2	4.3	1.6
12.4	21.3	3.9	1.4

Length	Maximum Width	Thickness	Length of Pedicle Interarea
13.0	22.0	4.6	1.8
14.1	22.5	4.5	1.5
14.5	22.4	5.0	1.9

- - - - - - - -

Sowerbyella n.sp.?

Locality A, Unit 2, the lower 15 feet of the unit; articulated specimens

Length	Hinge Width	Thickness	Length of Brachial Interarea	Length of Pedicle Interarea
4.1	7.3	.9	.2	.4
4.4	6.9	1.0	.1	.4
4.6	8.1	1.4	.4	.6
7.7	12.7	2.9	---	.9
4.3	8.2	1.3	.3	.5
6.4	11.3	1.7	.4	.6
10.9	17.2	3.0	.8	1.3
11.2	15.6	4.9	.9	1.4
9.8	16.3	4.7	.9	1.4
7.6	12.7	2.0	.5	.7
7.7	11.9	2.4	.6	.9
6.8	11.2	1.5	.4	.7
7.8	13.2	3.2	.7	1.2
9.9	12.9	4.3	.7	1.1

Length	Hinge Width	Thickness	Length of Brachial Interarea	Length of Pedicle Interarea
8.1	15.0	2.4	.6	.9
9.8	15.4	3.9	.8	1.4
5.4	9.0	1.5	.4	.6
10.1	13.3	3.4	.4	1.1
7.6	14.2	2.8	.7	1.0
10.5	15.2	4.2	.8	1.3
10.3	15.7	4.4	.8	1.4
6.5	10.7	2.4	.5	.8
7.7	12.4	2.2	.6	1.0
8.2	13.3	2.8	.7	1.0
9.6	15.0	4.2	.7	1.2
10.2	15.0	3.6	.9	1.2
8.6	13.7	3.0	.7	1.1
9.7	15.4	4.0	.6	1.3
8.8	14.8	3.3	.6	1.2
9.2	12.8	4.0	.6	1.2
8.8	13.2	3.2	.6	1.2
8.0	12.9	3.3	.6	1.1
9.5	13.6	4.3	.6	1.3
9.0	13.8	---	--	1.5
8.5	13.4	---	--	1.3
8.7	12.4	---	--	1.2
7.8	11.4	---	--	1.0
9.8	13.6	---	--	1.2
9.3	12.9	---	--	1.2

- - - - - - - - -

Lepidocyclus capax

Locality A, Unit 3C, upper 6 feet; articulated specimens

Length	Width	Thickness
19.2	20.8	12.8
20.2	20.7	13.8
21.5	22.0	15.1
19.9	20.0	15.5
21.8	20.4	18.4
22.7	22.7	18.0
23.2	24.7	17.8
23.8	24.8	18.4
23.7	22.8	21.3
23.9	25.5	23.1
23.9	26.0	27.3

- - - - - - -

Lepidocyclus cooperi

Locality A, Unit 3C, upper 6 feet; brachial valves

Length	Width	Thickness	Maximum Width of Fold	Maximum Height of Fold
17.3	19.4	13.8	10.1	3.6
16.4	17.1	11.9	9.9	3.4
15.1	16.7	10.5	8.6	2.4
15.8	18.3	11.2	10.6	3.2

Length	Width	Thickness	Maximum Width of Fold	Maximum Height of Fold
16.7	18.6	--	--	---
16.9	19.5	11.2	9.7	4.0
16.2	18.6	11.8	8.2	---
17.0	20.0	12.7	9.1	3.3
14.9	16.6	10.9	8.5	2.8
16.6	19.2	10.8	9.3	3.2
15.9	17.7	12.8	8.8	3.8
16.7	19.3	13.6	9.4	4.9
17.7	19.9	12.5	9.7	4.7
21.8	20.4	18.4	---	---
16.9	18.9	11.9	9.4	2.7
15.8	17.1	11.5	8.6	3.0
15.1	17.4	10.1	8.0	2.1
14.4	16.5	10.1	8.4	3.6
15.3	16.6	8.9	7.7	1.6
14.4	15.8	9.2	7.5	2.2
16.3	17.8	12.8	9.1	2.5
16.5	18.9	11.1	9.8	2.4

\- - - - - - - -

Locality A, Unit 3C, upper 6 feet; pedicle valves

Length	Width	Thickness	Width of Pedicle Muscle Field
13.8	14.4	3.8	--
14.7	14.9	4.4	6.1

Length	Width	Thickness	Width of Pedicle Muscle Field
15.0	16.0	4.8	--
15.6	16.0	5.0	6.0
16.1	16.5	4.4	8.2
17.2	18.4	5.0	8.4
18.0	16.8	5.8	10.2
18.1	18.6	6.0	7.6
16.8	18.8	5.9	8.8
18.2	18.8	6.1	10.2
18.0	19.7	6.0	8.7
17.8	19.0	5.6	9.5
19.3	19.2	5.8	10.5
18.9	19.6	6.0	7.9
19.3	18.9	---	9.3
17.8	19.1	5.5	8.4
18.1	18.8	7.2	9.9
18.5	19.0	6.0	9.6
18.0	18.3	6.9	10.5
18.5	19.2	5.3	8.1
17.2	17.6	5.3	10.8

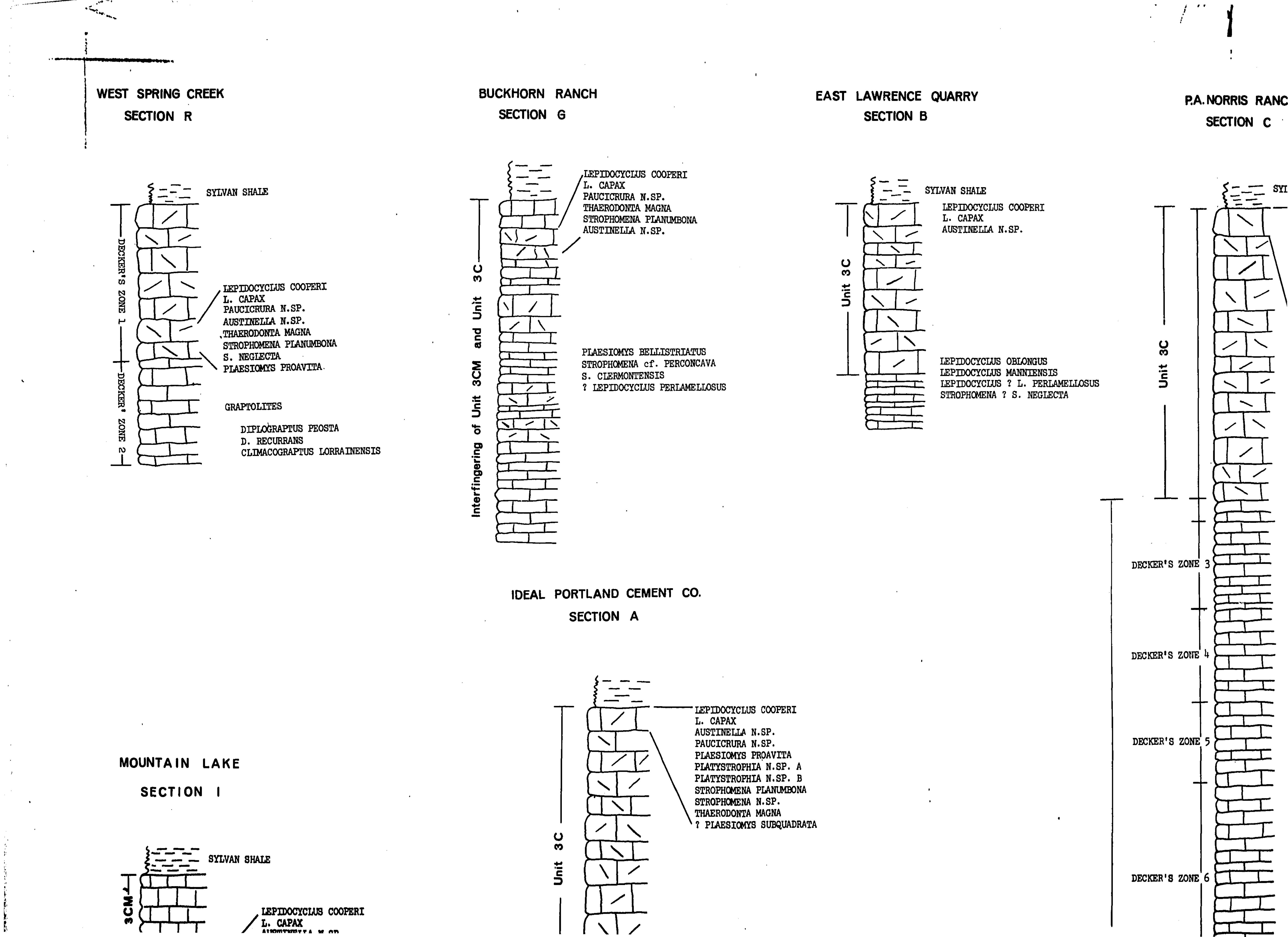
- - - - - - - - -

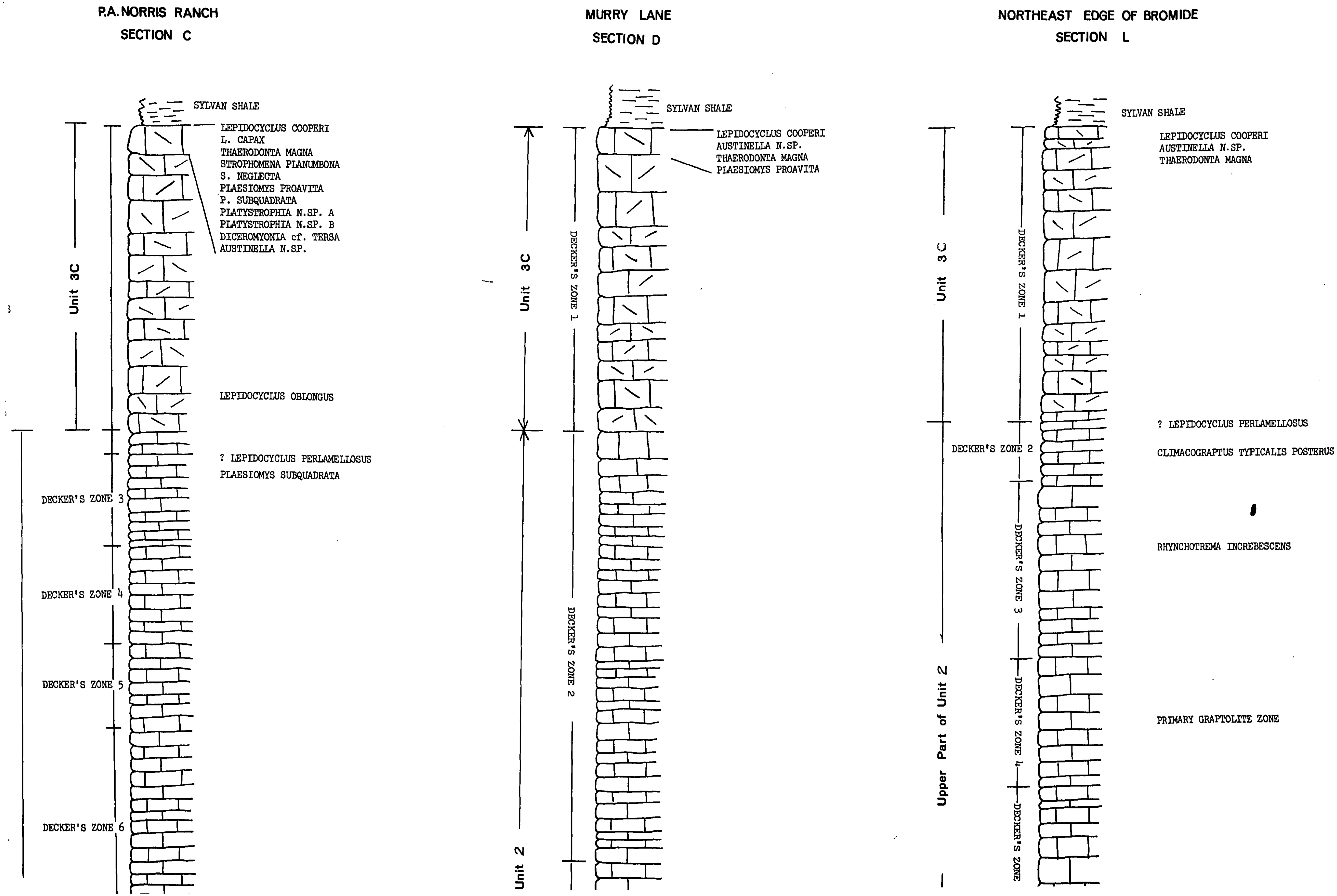
Locality A, Unit 3C, upper 6 feet; articulated specimens

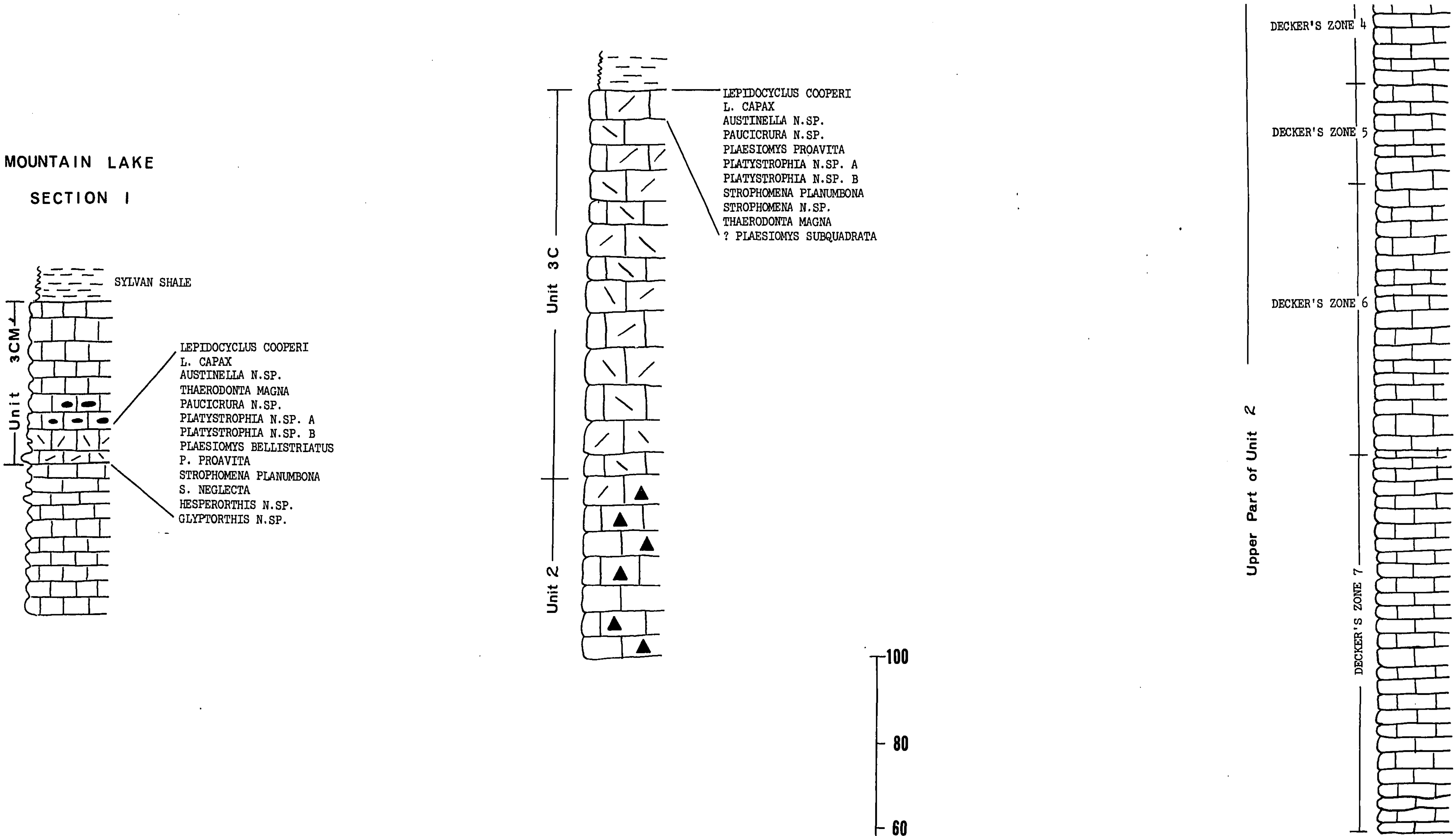
Length	Width	Thickness
15.3	14.5	13.1
17.1	17.1	--

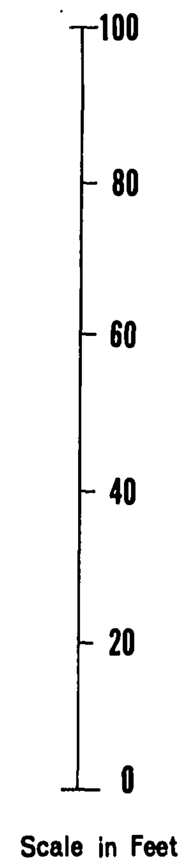
Length	Width	Thickness
18.9	18.5	17.2
18.3	18.7	--
20.0	20.0	18.5
20.1	20.0	19.5
18.4	18.0	--
19.5	20.2	18.0
19.0	19.0	18.8
19.3	18.9	16.7
19.3	18.7	--
19.2	20.2	--
19.2	18.8	--
19.2	19.2	18.6
19.9	19.9	19.2
18.2	19.0	19.1
18.6	17.6	17.1
18.9	18.1	--
17.5	17.0	15.0
18.4	18.7	17.7
19.4	19.1	17.8
20.4	19.5	17.7
19.2	20.0	16.7
21.0	21.5	18.4
16.9	18.6	17.2

- - - - - - -

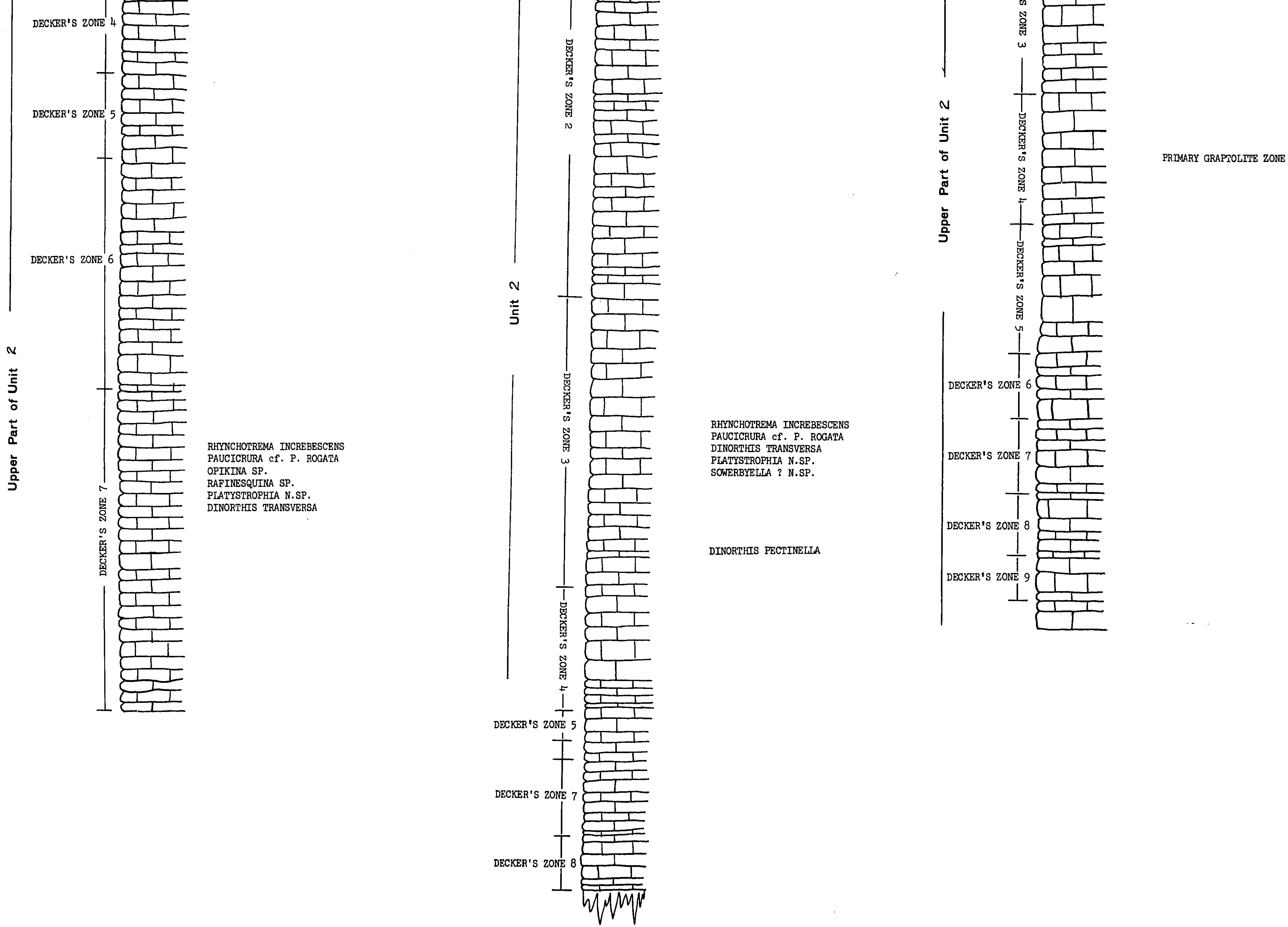

WEST SPRING CREEK
SECTION R
SYLVAN SHALE
DECKER'S ZONE 1
DECKER' ZONE 2
LEPIDOCYCLUS COOPERI
L. CAPAX
PAUCICRURA N.SP.
AUSTINELLA N.SP.
THAERODONTA MAGNA
STROPHOMENA PLANUMBONA
S. NEGLECTA
PLAESIOMYS PROAVITA
GRAPTOLITES
DIPLOGRAPTUS PEOSTA
D. RECURRANS
CLIMACOGRAPTUS LORRAINENSIS
BUCKHORN RANCH
SECTION G
Interfingering of Unit 3CM and Unit 3C
LEPIDOCYCLUS COOPERI
L. CAPAX
PAUCICRURA N.SP.
THAERODONTA MAGNA
STROPHOMENA PLANUMBONA
AUSTINELLA N.SP.
PLAESIOMYS BELLISTRIATUS
STROPHOMENA cf. PERCONCAVA
S. CLERMONTENSIS
? LEPIDOCYCLUS PERLAMELLOSUS
EAST LAWRENCE QUARRY
SECTION B
SYLVAN SHALE
Unit 3C
LEPIDOCYCLUS COOPERI
L. CAPAX
AUSTINELLA N.SP.
LEPIDOCYCLUS OBLONGUS
LEPIDOCYCLUS MANNIENSIS
LEPIDOCYCLUS ? L. PERLAMELLOSUS
STROPHOMENA ? S. NEGLECTA
P.A. NORRIS RANC
SECTION C
SYI
Unit 3C
DECKER'S ZONE 3
DECKER'S ZONE 4
DECKER'S ZONE 5
DECKER'S ZONE 6
IDEAL PORTLAND CEMENT CO.
SECTION A
Unit 3C
LEPIDOCYCLUS COOPERI
L. CAPAX
AUSTINELLA N.SP.
PAUCICRURA N.SP.
PLAESIOMYS PROAVITA
PLATYSTROPHIA N.SP. A
PLATYSTROPHIA N.SP. B
STROPHOMENA PLANUMBONA
STROPHOMENA N.SP.
THAERODONTA MAGNA
? PLAESIOMYS SUBQUADRATA
MOUNTAIN LAKE
SECTION I
SYLVAN SHALE
3CM
LEPIDOCYCLUS COOPERI
L. CAPAX


P.A. NORRIS RANCH
SECTION C
SYLVAN SHALE
LEPIDOCYCLUS COOPERI
L. CAPAX
THAERODONTA MAGNA
STROPHOMENA PLANUMBONA
S. NEGLECTA
PLAESIOMYS PROAVITA
P. SUBQUADRATA
PLATYSTROPHIA N.SP. A
PLATYSTROPHIA N.SP. B
DICEROMYONIA cf. TERSA
AUSTINELLA N.SP.
Unit 3C
LEPIDOCYCLUS OBLONGUS
? LEPIDOCYCLUS PERLAMELLOSUS
PLAESIOMYS SUBQUADRATA
DECKER'S ZONE 3
DECKER'S ZONE 4
DECKER'S ZONE 5
DECKER'S ZONE 6
MURRY LANE
SECTION D
SYLVAN SHALE
LEPIDOCYCLUS COOPERI
AUSTINELLA N.SP.
THAERODONTA MAGNA
PLAESIOMYS PROAVITA
Unit 3C
DECKER'S ZONE 1
DECKER'S ZONE 2
Unit 2
NORTHEAST EDGE OF BROMIDE
SECTION L
SYLVAN SHALE
LEPIDOCYCLUS COOPERI
AUSTINELLA N.SP.
THAERODONTA MAGNA
Unit 3C
DECKER'S ZONE 1
? LEPIDOCYCLUS PERLAMELLOSUS
DECKER'S ZONE 2
CLIMACOGRAPTUS TYPICALIS POSTERUS
DECKER'S ZONE 3
RHYNCHOTREMA INCREBESCENS
Upper Part of Unit 2
DECKER'S ZONE 4
PRIMARY GRAPTOLITE ZONE
DECKER'S ZONE

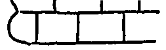


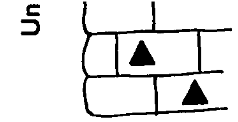


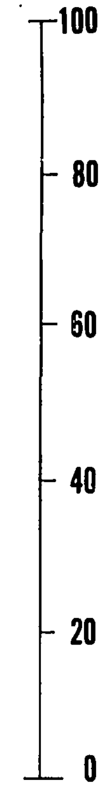
STRATIGRAPHIC DIAGRAM OF SELECTED SECTIONS SHOWING THE STRATIGRAPHIC DISTRIBUTION OF THE GRAPTOLITES AND BRACHIOPODS OF THE VIOLA FORMATION WITHIN THE ARBUCKLE MOUNTAIN REGION



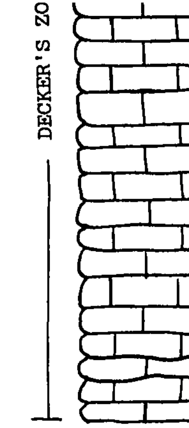
Upper Part of Unit 2
DECKER'S ZONE 4
DECKER'S ZONE 5
DECKER'S ZONE 6
DECKER'S ZONE 7
RHYNCHOTREMA INCREBESCENS
PAUCICRURA cf. P. ROGATA
OPIKINA SP.
RAFINESQUINA SP.
PLATYSTROPHIA N.SP.
DINORTHIS TRANSVERSA
Unit 2
DECKER'S ZONE 2
DECKER'S ZONE 3
DECKER'S ZONE 4
DECKER'S ZONE 5
DECKER'S ZONE 7
DECKER'S ZONE 8
RHYNCHOTREMA INCREBESCENS
PAUCICRURA cf. P. ROGATA
DINORTHIS TRANSVERSA
PLATYSTROPHIA N.SP.
SOWERBYELLA ? N.SP.
DINORTHIS PECTINELLA
Upper Part of Unit 2
S ZONE 3
DECKER'S ZONE 4
DECKER'S ZONE 5
DECKER'S ZONE 6
DECKER'S ZONE 7
DECKER'S ZONE 8
DECKER'S ZONE 9
PRIMARY GRAPTOLITE ZONE







Scale in Feet



STRATIGRAPHIC DIAGRAM OF SELECTED SECTIONS SHOWING THE STRATIGRAPHIC DISTRIBUTION OF THE GRAPTOLITES AND BRACHIOPODS OF THE VIOLA FORMATION WITHIN THE ARBUCKLE MOUNTAIN REGION

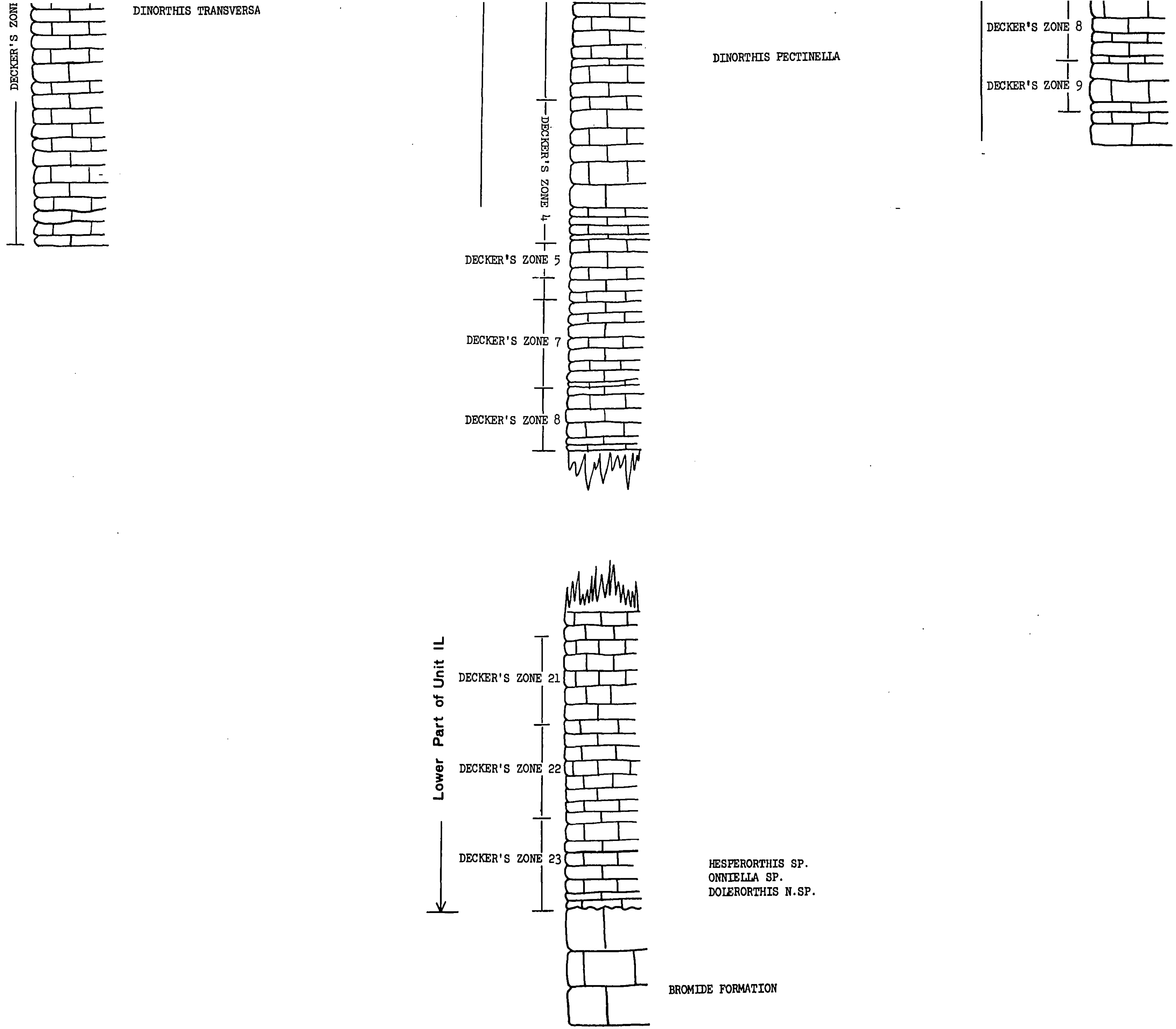
by

Leonard P. Alberstadt

EXPLANATION

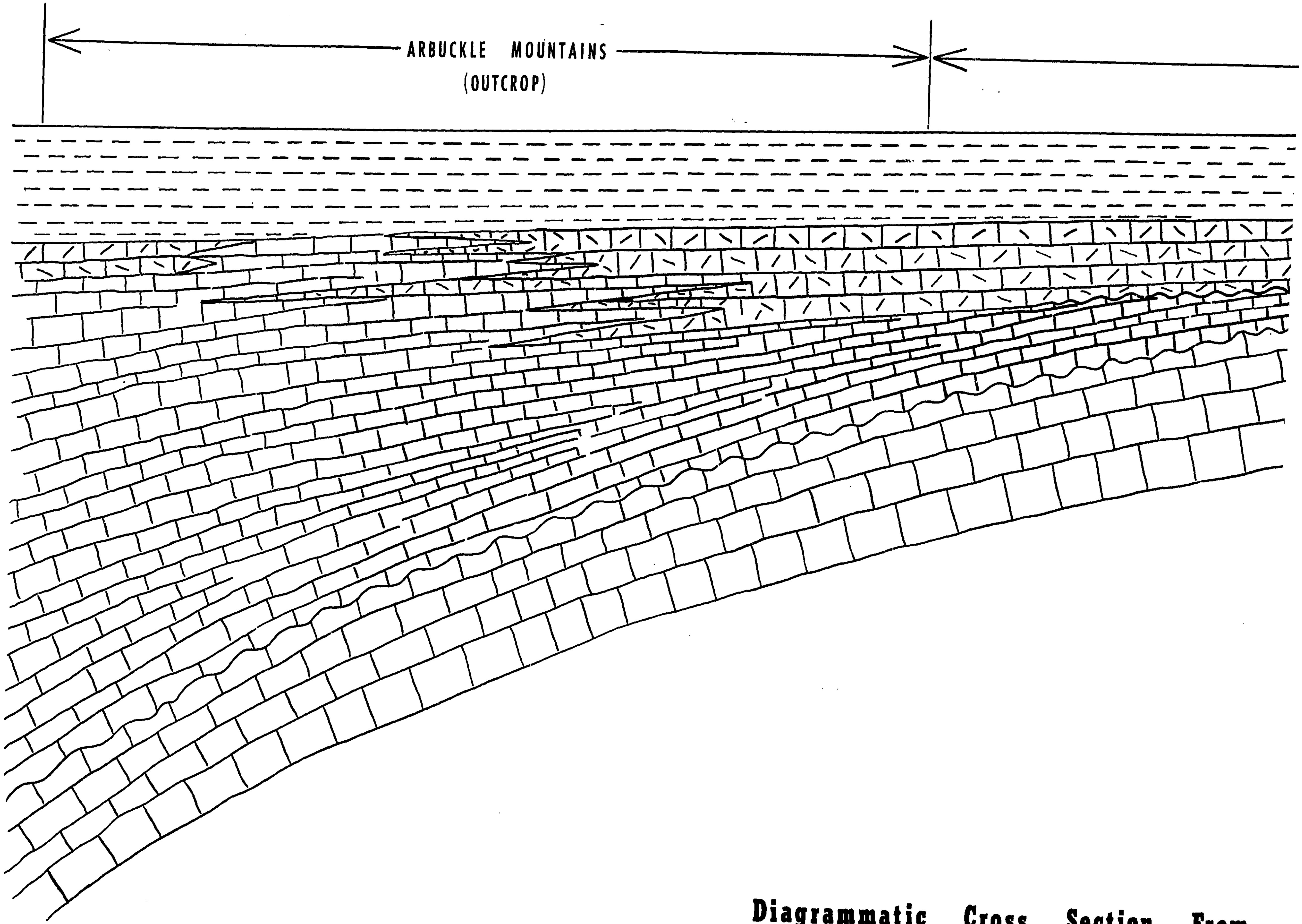
The sections that are illustrated show the distribution of the brachiopod species described in this paper, and several of the "key" graptolites studied and described by Decker (1933) and Ruedemann and Decker (1934). Decker (1933) measured and described some of the same sections studied by Alberstadt and Glaser. The vertical extent of Decker's zones are shown so as to allow .omparison with the units designated by Glaser (1965). The biostratigraphical importance of the graptolites are discussed in detail in the section on Viola biostratigraphy.

FIGURE 12

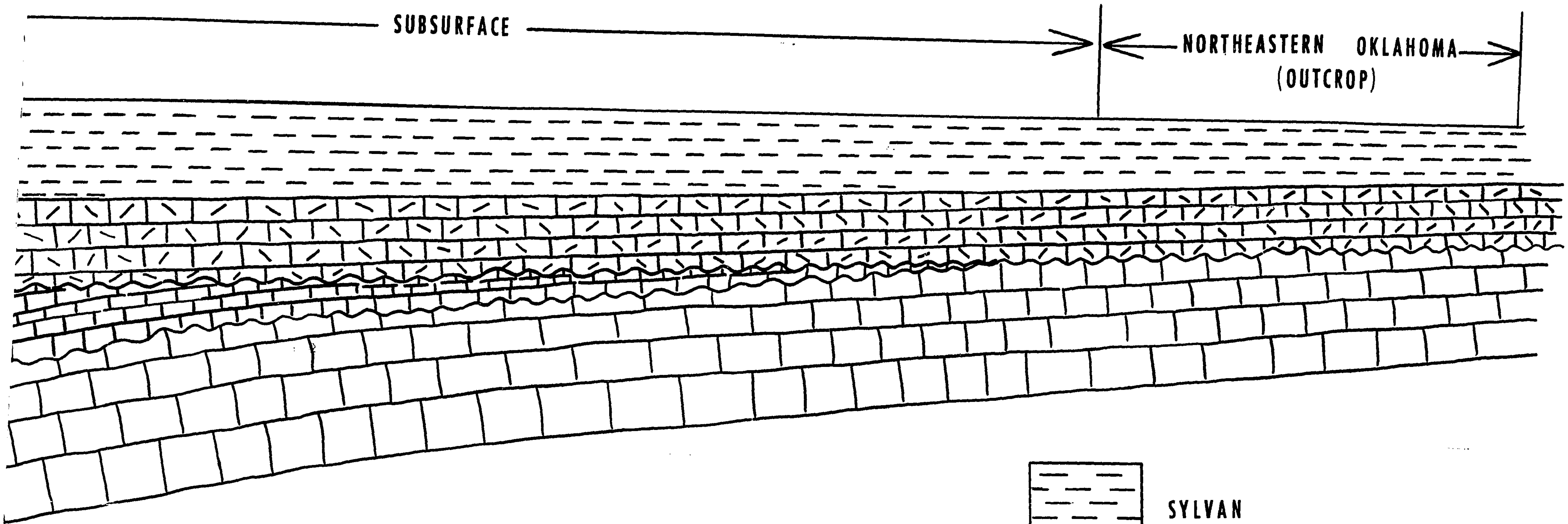


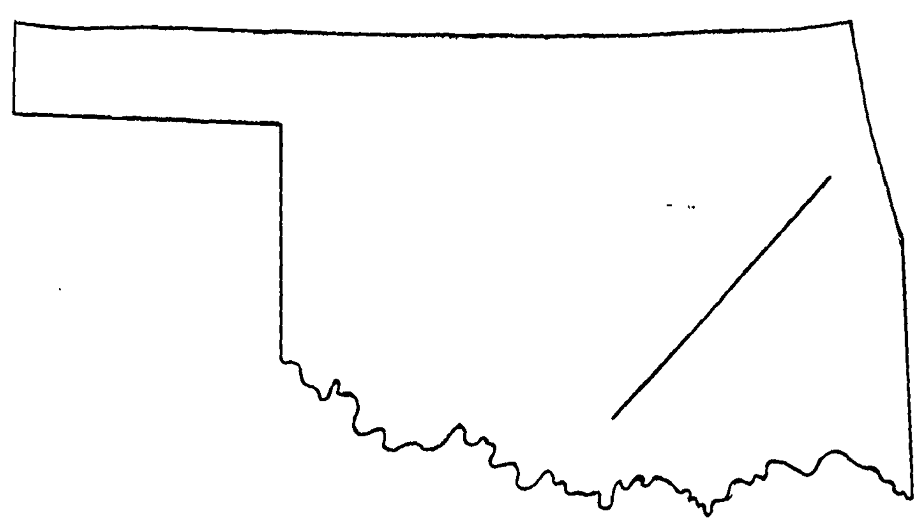
DECKER'S ZONE
DINORTHIS TRANSVERSA
DECKER'S ZONE 4
DECKER'S ZONE 5
DECKER'S ZONE 7
DECKER'S ZONE 8
DINORTHIS PECTINELLA
DECKER'S ZONE 8
DECKER'S ZONE 9
Lower Part of Unit IL
DECKER'S ZONE 21
DECKER'S ZONE 22
DECKER'S ZONE 23
HESPERORTHIS SP.
ONNIELLA SP.
DOLERORTHIS N.SP.
BROMIDE FORMATION

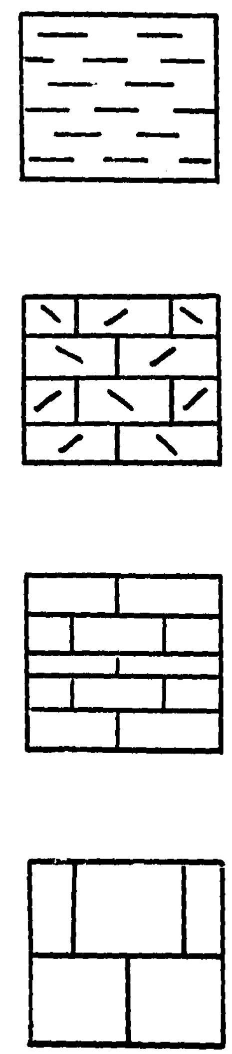
FIGURE 12



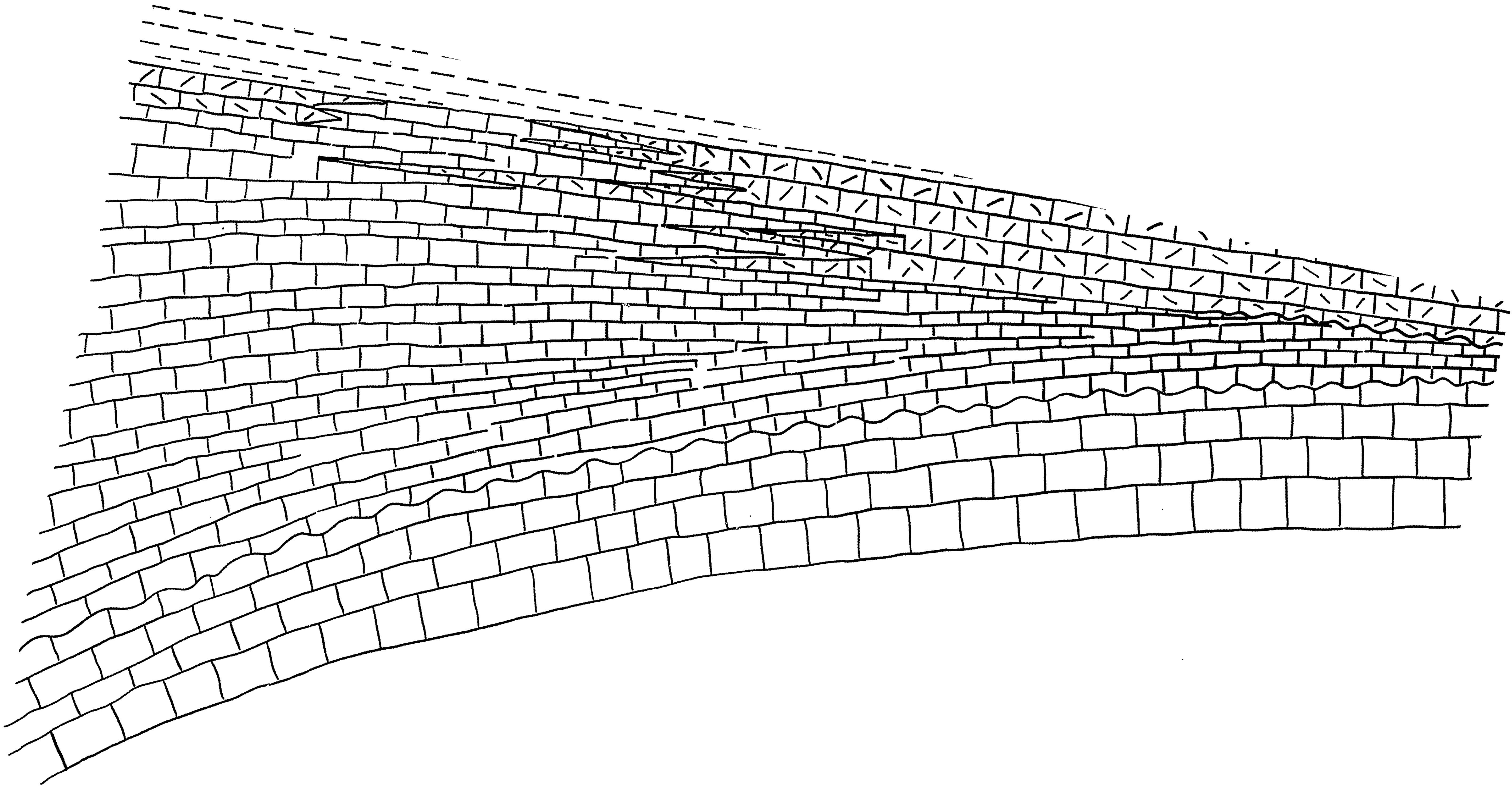
Diagrammatic Cross Section From





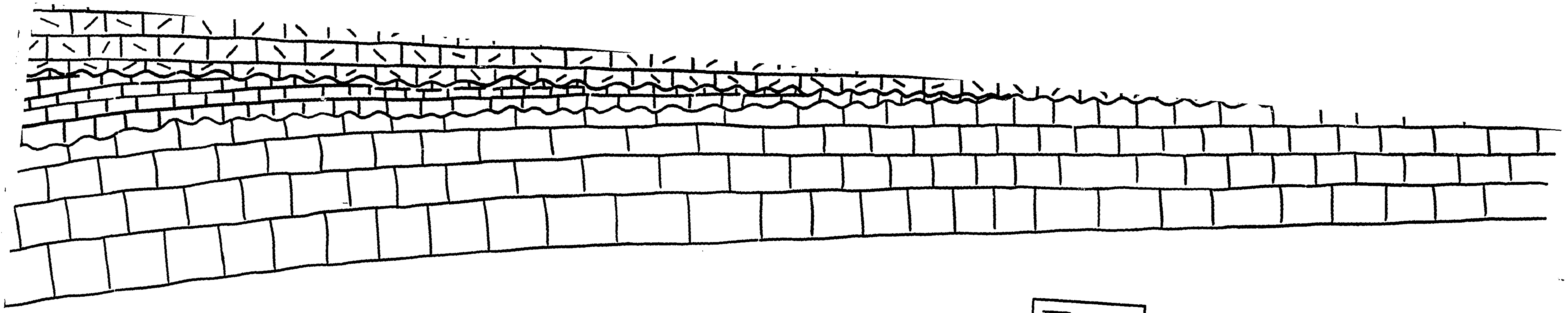


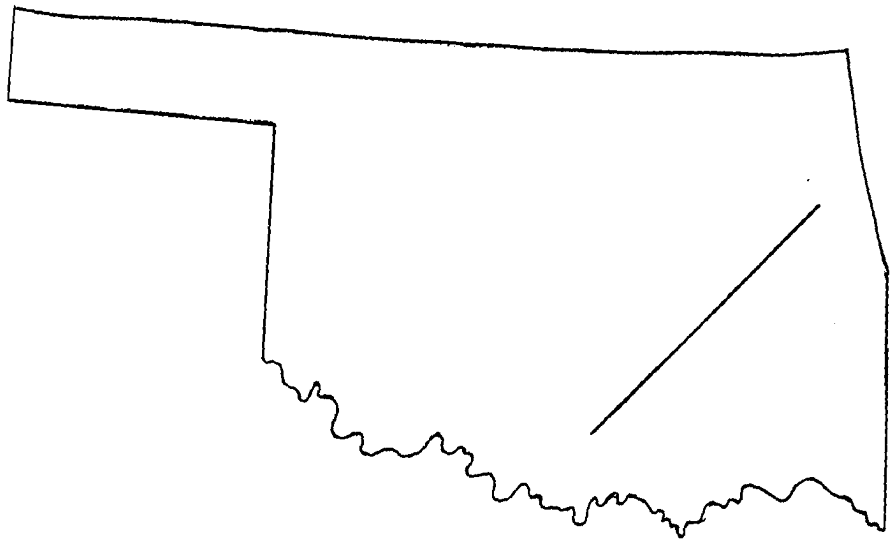
ection From Northeast Oklahoma To The

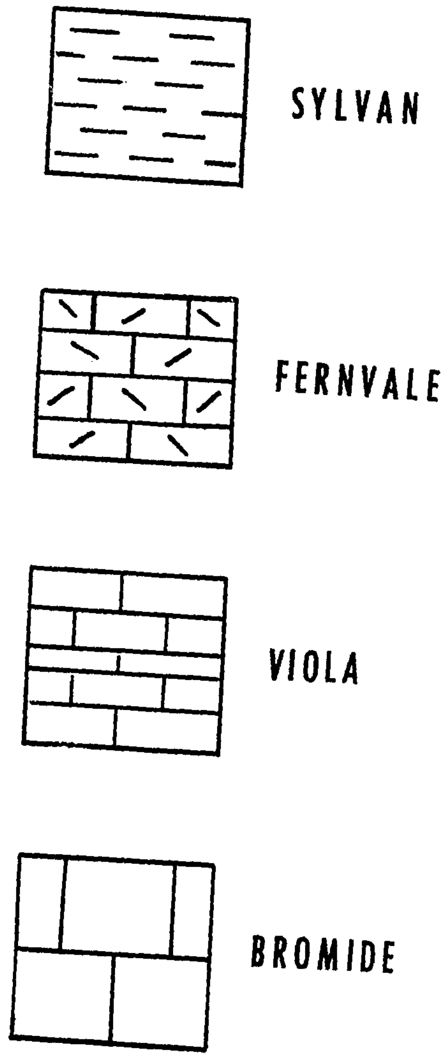


Diagrammatic Cross Section From
Arbuckle Mountains Showing The
Of The Viola And ''Fe

TEXT FIGU

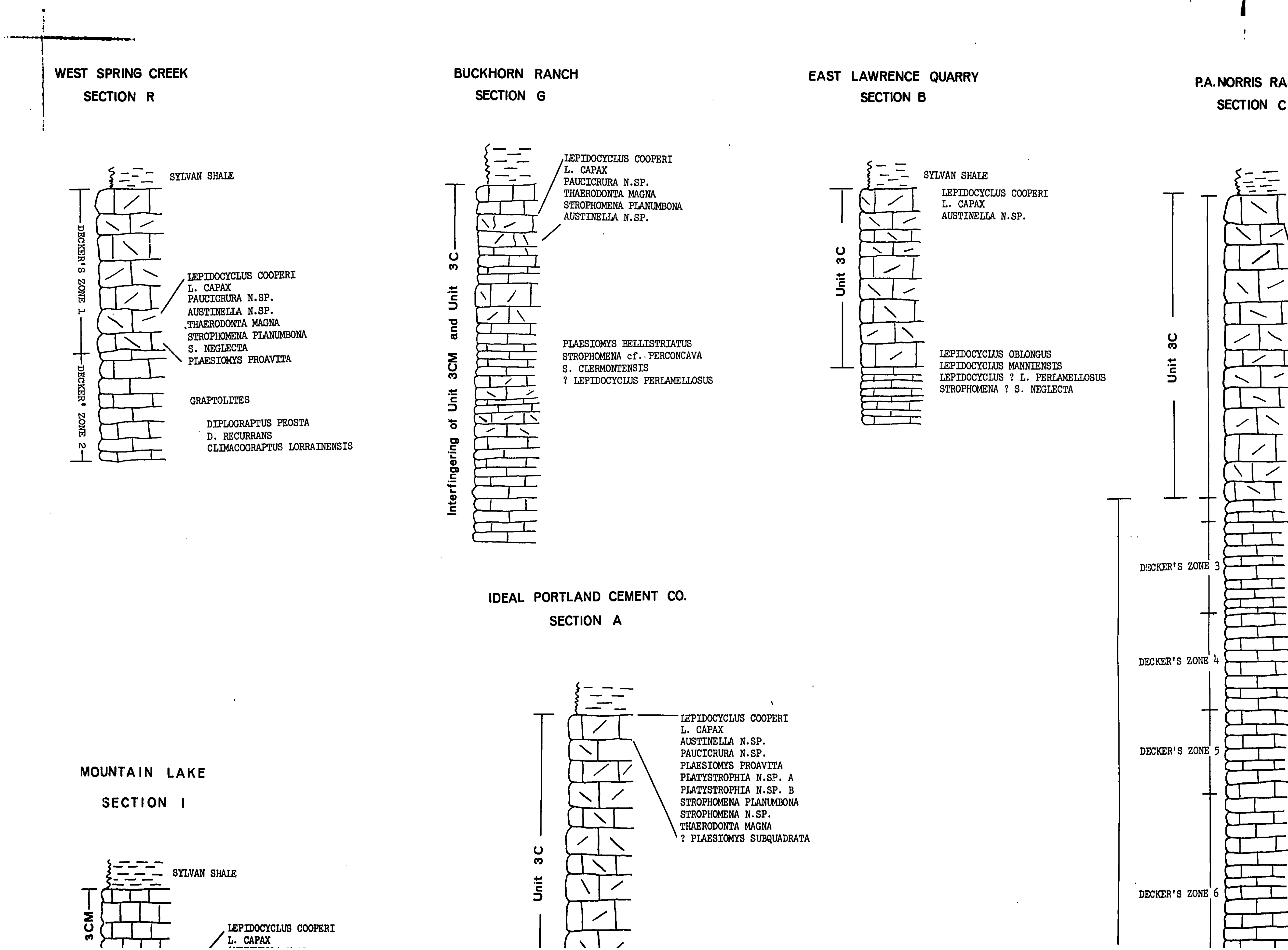


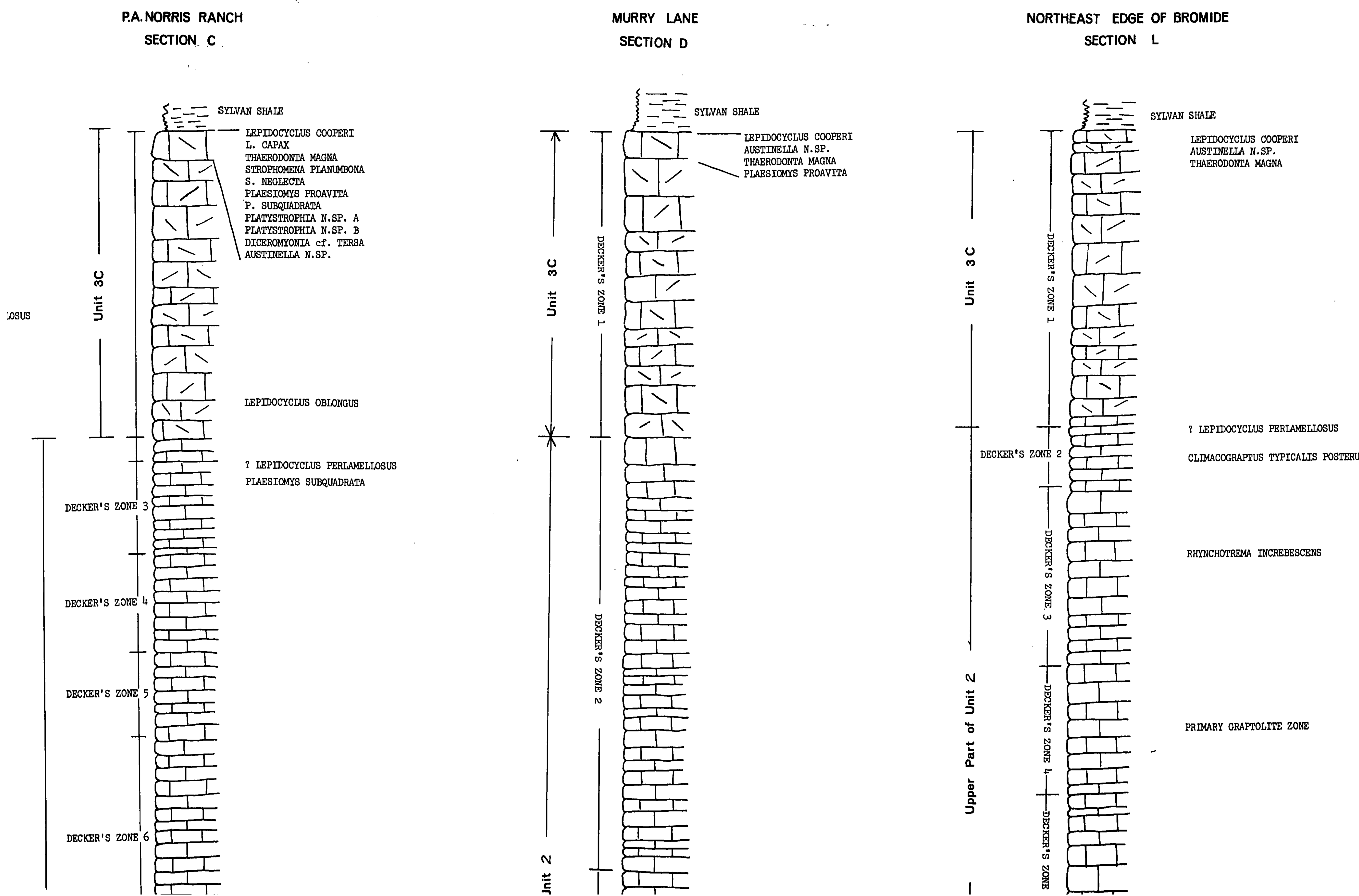


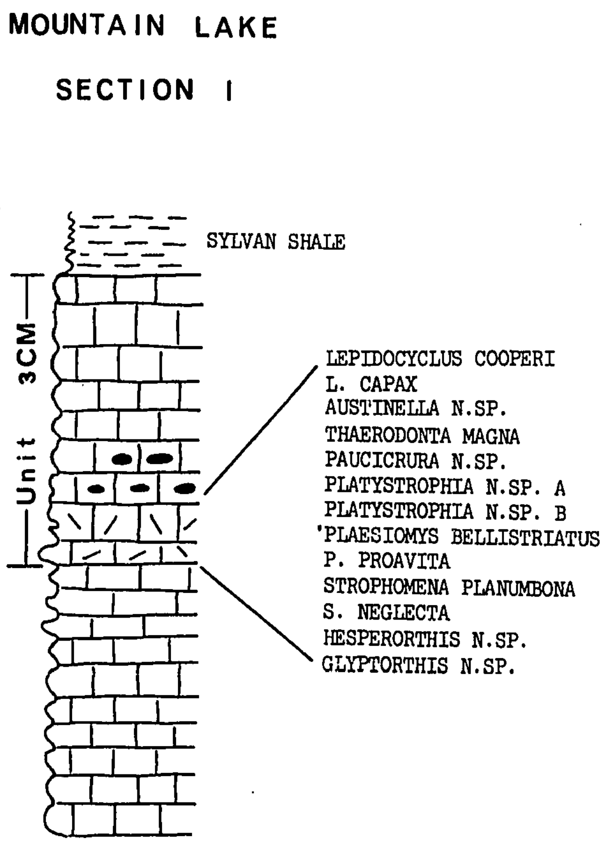


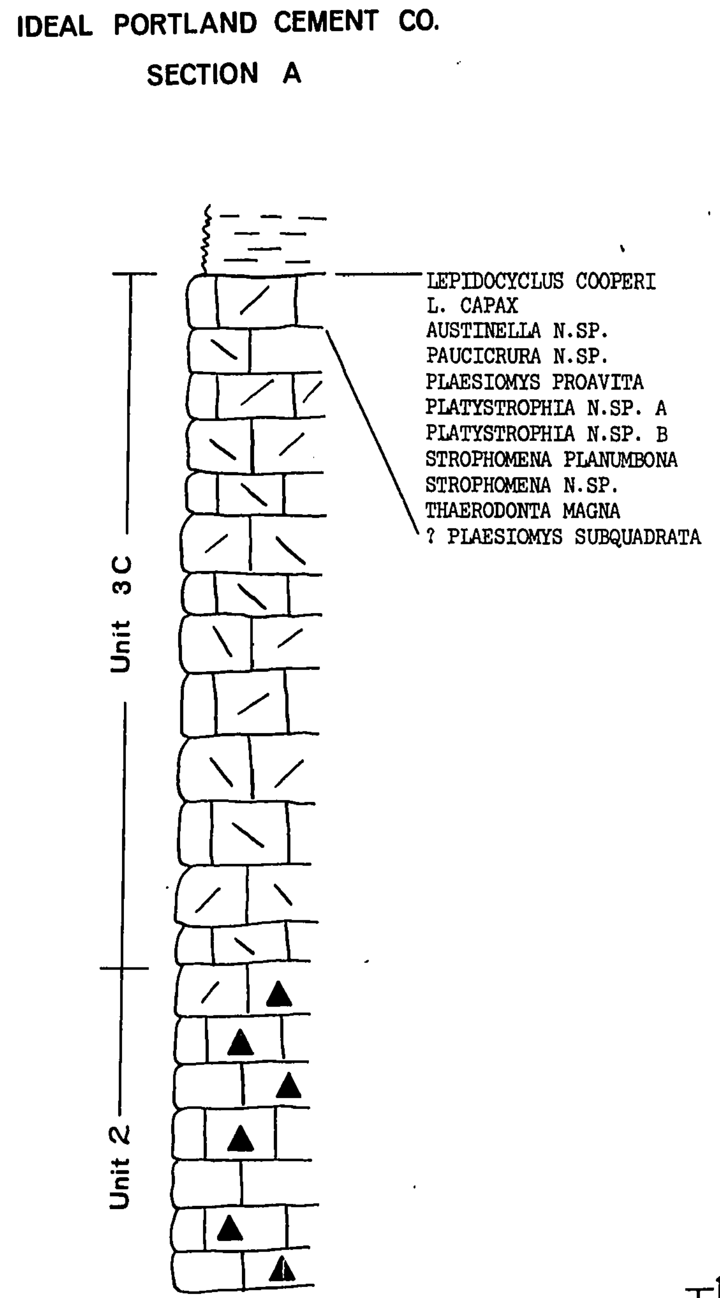
ection From Northeast Oklahoma To The
Showing The Stratigraphic Relationships
la And ''Fernvale'' Formations

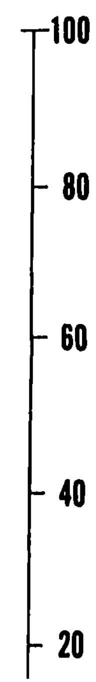
TEXT FIGURE 15

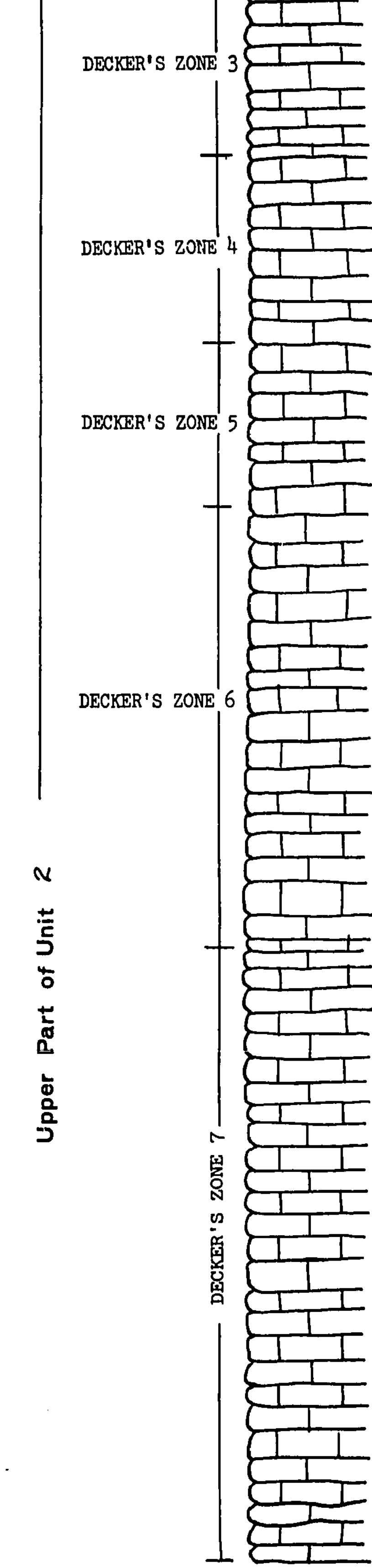

WEST SPRING CREEK
SECTION R
SYLVAN SHALE
DECKER'S ZONE 1
DECKER' ZONE 2
LEPIDOCYCLUS COOPERI
L. CAPAX
PAUCICRURA N.SP.
AUSTINELLA N.SP.
THAERODONTA MAGNA
STROPHOMENA PLANUMBONA
S. NEGLECTA
PLAESIOMYS PROAVITA
GRAPTOLITES
DIPLOGRAPTUS PEOSTA
D. RECURRANS
CLIMACOGRAPTUS LORRAINENSIS
BUCKHORN RANCH
SECTION G
Interfingering of Unit 3CM and Unit 3C
LEPIDOCYCLUS COOPERI
L. CAPAX
PAUCICRURA N.SP.
THAERODONTA MAGNA
STROPHOMENA PLANUMBONA
AUSTINELLA N.SP.
PLAESIOMYS BELLISTRIATUS
STROPHOMENA cf. PERCONCAVA
S. CLERMONTENSIS
? LEPIDOCYCLUS PERLAMELLOSUS
EAST LAWRENCE QUARRY
SECTION B
SYLVAN SHALE
Unit 3C
LEPIDOCYCLUS COOPERI
L. CAPAX
AUSTINELLA N.SP.
LEPIDOCYCLUS OBLONGUS
LEPIDOCYCLUS MANNIENSIS
LEPIDOCYCLUS ? L. PERLAMELLOSUS
STROPHOMENA ? S. NEGLECTA
P.A. NORRIS RA
SECTION C
Unit 3C
DECKER'S ZONE 3
DECKER'S ZONE 4
DECKER'S ZONE 5
DECKER'S ZONE 6
IDEAL PORTLAND CEMENT CO.
SECTION A
Unit 3C
LEPIDOCYCLUS COOPERI
L. CAPAX
AUSTINELLA N.SP.
PAUCICRURA N.SP.
PLAESIOMYS PROAVITA
PLATYSTROPHIA N.SP. A
PLATYSTROPHIA N.SP. B
STROPHOMENA PLANUMBONA
STROPHOMENA N.SP.
THAERODONTA MAGNA
? PLAESIOMYS SUBQUADRATA
MOUNTAIN LAKE
SECTION I
SYLVAN SHALE
3CM
LEPIDOCYCLUS COOPERI
L. CAPAX


P.A. NORRIS RANCH
SECTION C
SYLVAN SHALE
LEPIDOCYCLUS COOPERI
L. CAPAX
THAERODONTA MAGNA
STROPHOMENA PLANUMBONA
S. NEGLECTA
PLAESIOMYS PROAVITA
P. SUBQUADRATA
PLATYSTROPHIA N.SP. A
PLATYSTROPHIA N.SP. B
DICEROMYONIA cf. TERSA
AUSTINELLA N.SP.
Unit 3C
LOSUS
LEPIDOCYCLUS OBLONGUS
? LEPIDOCYCLUS PERLAMELLOSUS
PLAESIOMYS SUBQUADRATA
DECKER'S ZONE 3
DECKER'S ZONE 4
DECKER'S ZONE 5
DECKER'S ZONE 6
MURRY LANE
SECTION D
SYLVAN SHALE
LEPIDOCYCLUS COOPERI
AUSTINELLA N.SP.
THAERODONTA MAGNA
PLAESIOMYS PROAVITA
Unit 3C
DECKER'S ZONE 1
DECKER'S ZONE 2
Unit 2
NORTHEAST EDGE OF BROMIDE
SECTION L
SYLVAN SHALE
LEPIDOCYCLUS COOPERI
AUSTINELLA N.SP.
THAERODONTA MAGNA
Unit 3C
DECKER'S ZONE 1
? LEPIDOCYCLUS PERLAMELLOSUS
DECKER'S ZONE 2
CLIMACOGRAPTUS TYPICALIS POSTERU
DECKER'S ZONE 3
RHYNCHOTREMA INCREBESCENS
DECKER'S ZONE 4
PRIMARY GRAPTOLITE ZONE
Upper Part of Unit 2
DECKER'S ZONE

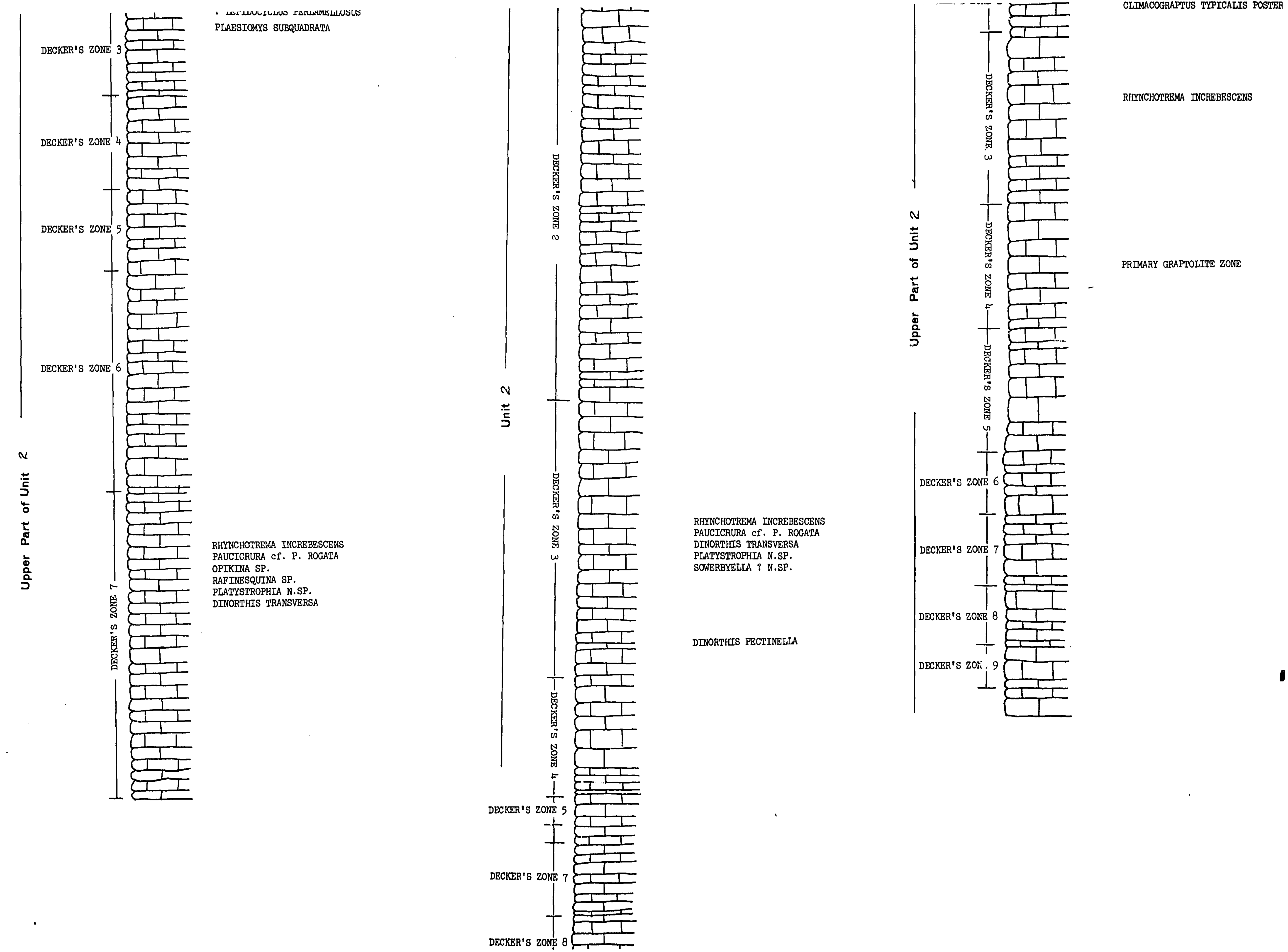






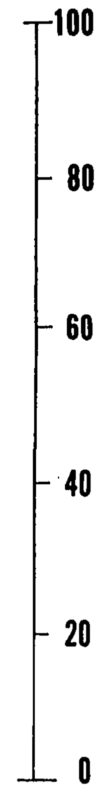


STRATIGRAPHIC DIAGRAM OF SELECTED SECTIONS SHOWING THE STRATIGRAPHIC DISTRIBUTION OF THE GRAPTOLITES AND

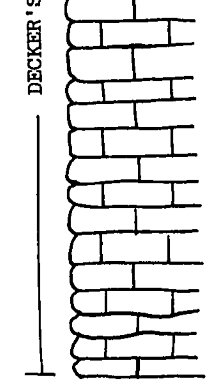


PLAESIOMYS SUBQUADRATA
Upper Part of Unit 2
DECKER'S ZONE 3
DECKER'S ZONE 4
DECKER'S ZONE 5
DECKER'S ZONE 6
DECKER'S ZONE 7
RHYNCHOTREMA INCREBESCENS
PAUCICRURA cf. P. ROGATA
OPIKINA SP.
RAFINESQUINA SP.
PLATYSTROPHIA N.SP.
DINORTHIS TRANSVERSA
Unit 2
DECKER'S ZONE 2
DECKER'S ZONE 3
DECKER'S ZONE 4
DECKER'S ZONE 5
DECKER'S ZONE 7
DECKER'S ZONE 8
RHYNCHOTREMA INCREBESCENS
PAUCICRURA cf. P. ROGATA
DINORTHIS TRANSVERSA
PLATYSTROPHIA N.SP.
SOWERBYELLA ? N.SP.
DINORTHIS PECTINELLA
Upper Part of Unit 2
DECKER'S ZONE 3
DECKER'S ZONE 4
DECKER'S ZONE 5
DECKER'S ZONE 6
DECKER'S ZONE 7
DECKER'S ZONE 8
DECKER'S ZONE 9
CLIMACOGRAPTUS TYPICALIS POSTER
RHYNCHOTREMA INCREBESCENS
PRIMARY GRAPTOLITE ZONE

STRATIGRAPHIC DIAGRAM OF SELECTED SECTIONS SHOWING THE STRATIGRAPHIC DISTRIBUTION OF THE GRAPTOLITES AND BRACHIOPODS OF THE VIOLA FORMATION WITHIN THE ARBUCKLE MOUNTAIN REGION



Scale in Feet



by

Leonard P. Alberstadt

EXPLANATION

The sections that are illustrated show the distribution of the brachiopod species described in this paper, and several of the "key" graptolites studied and described by Decker (1933) and Ruedemann and Decker (1934). Decker (1933) measured and described some of the same sections studied by Alberstadt and Glaser. The vertical extent of Decker's zones are shown so as to allow comparison with the units designated by Glaser (1965). The biostratigraphical importance of the graptolites are discussed in detail in the section on Viola biostratigraphy.

FIGURE 12

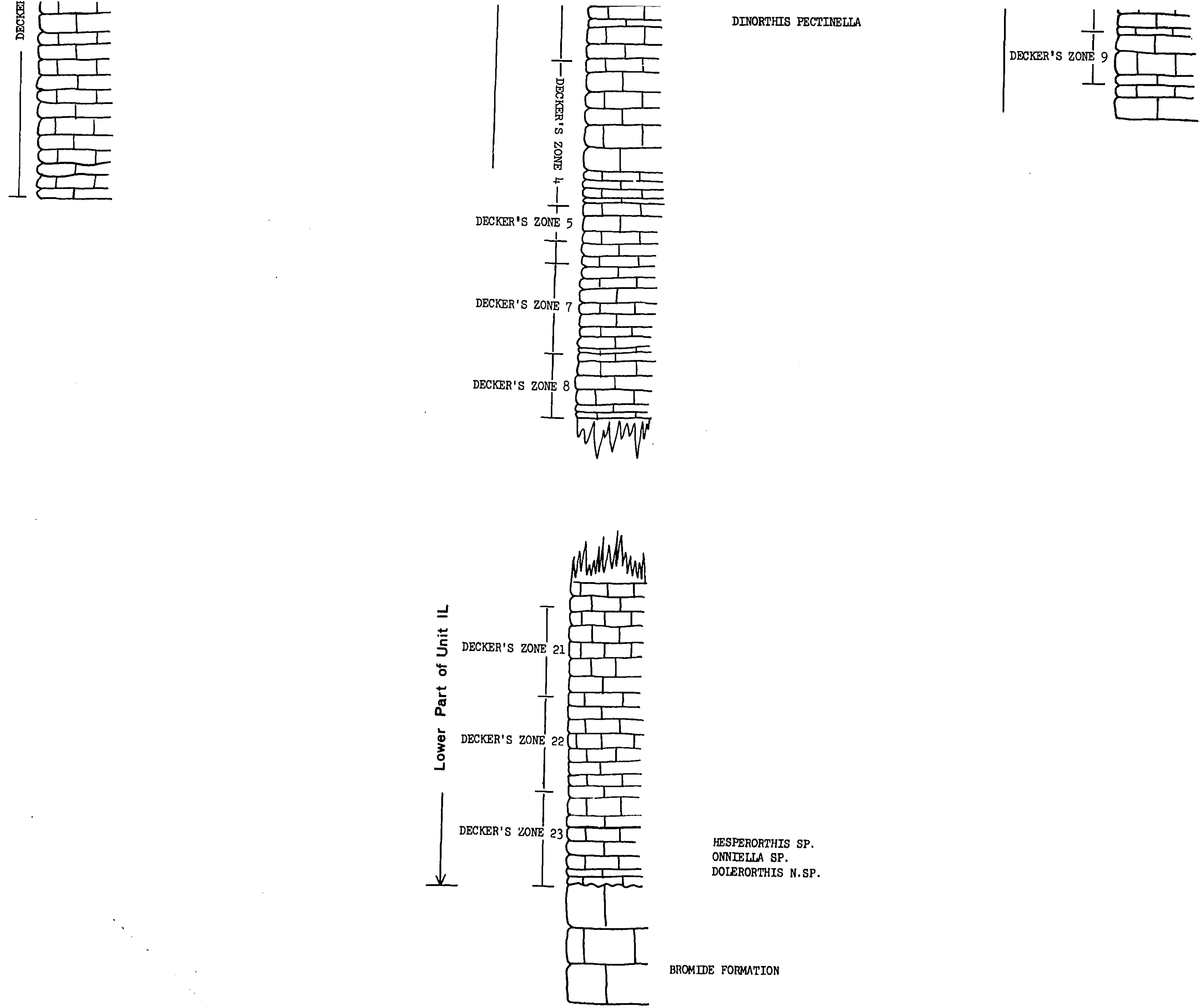
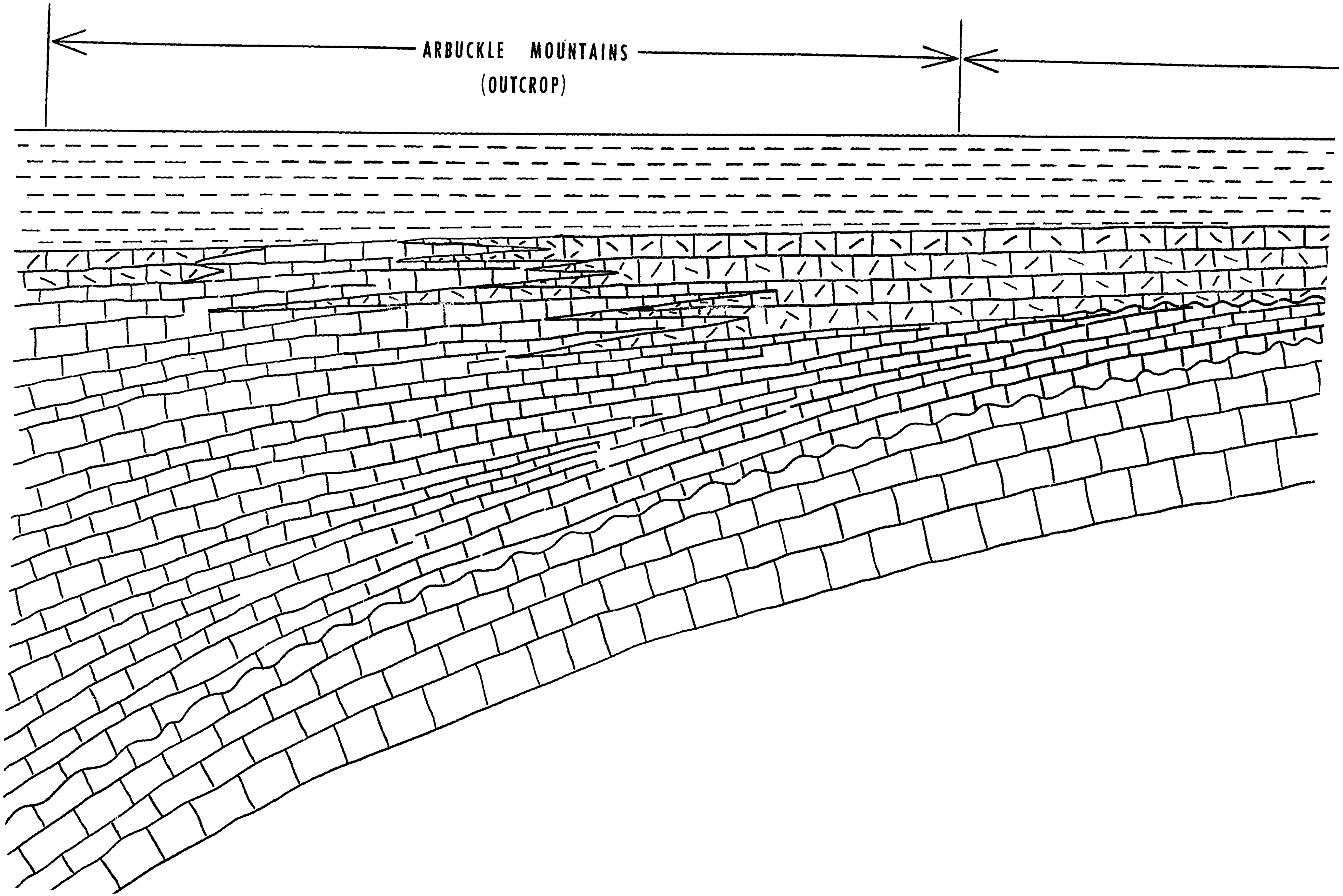
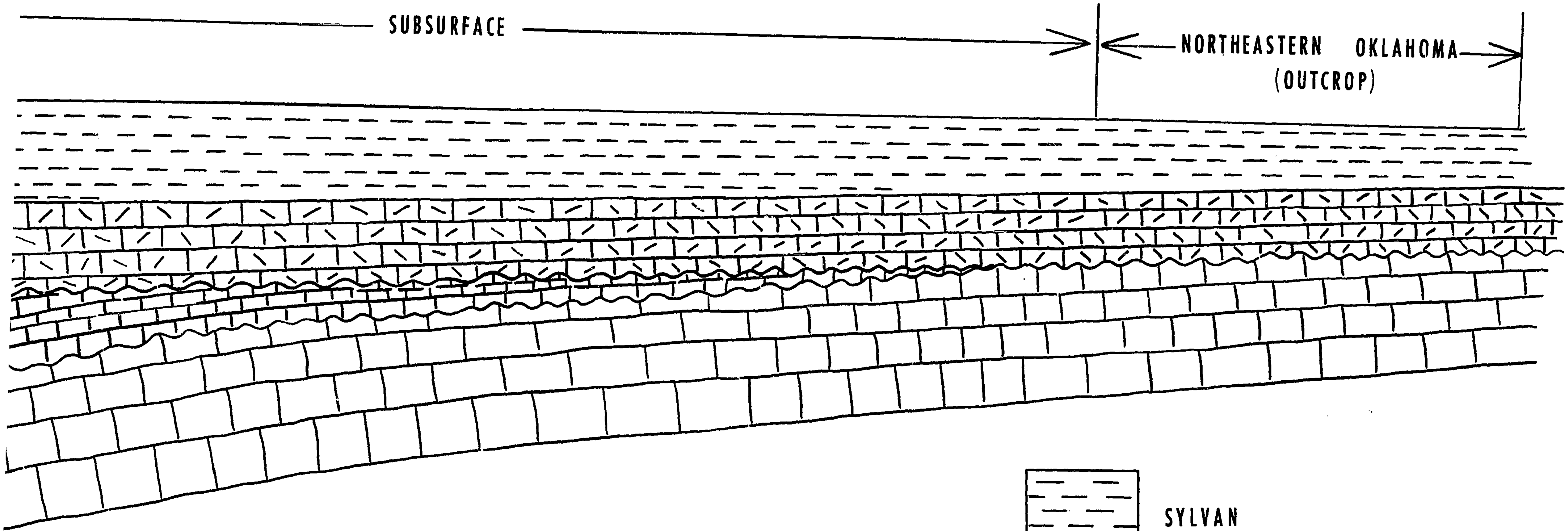
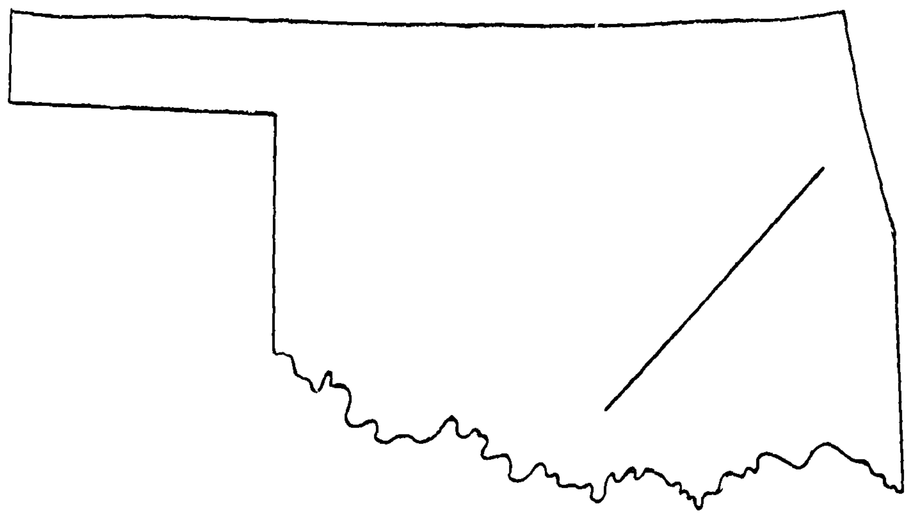

DINORTHIS PECTINELLA
DECKER'S ZONE 9
DECKER'S ZONE 5
DECKER'S ZONE 7
DECKER'S ZONE 8
Lower Part of Unit IL
DECKER'S ZONE 21
DECKER'S ZONE 22
DECKER'S ZONE 23
HESPERORTHIS SP.
ONNIELLA SP.
DOLERORTHIS N.SP.
BROMIDE FORMATION

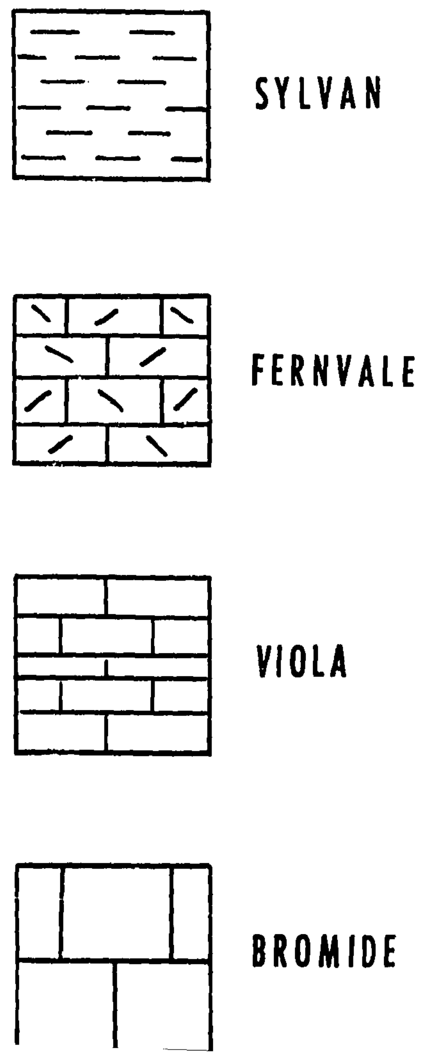
FIGURE 12



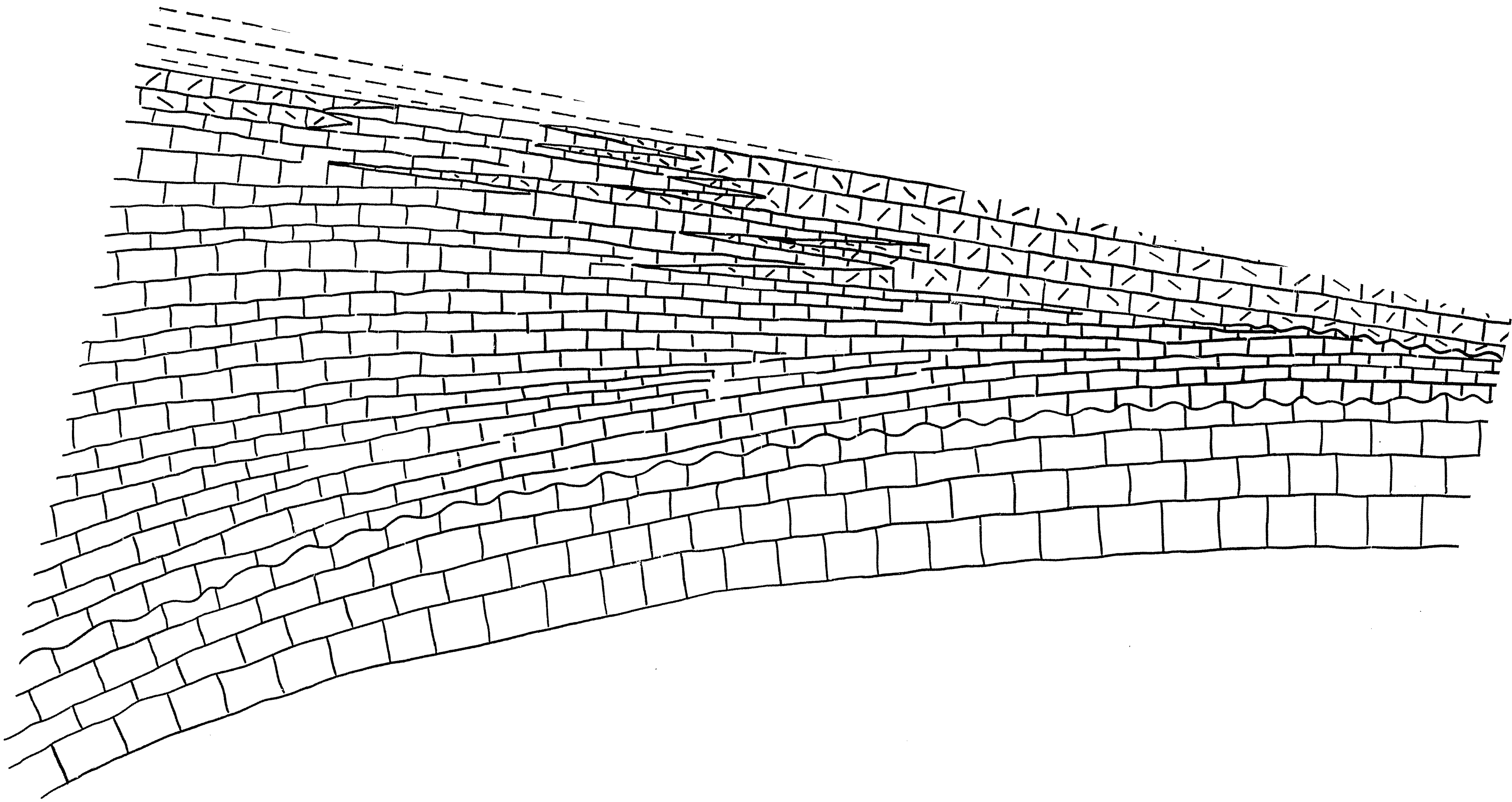
Diagrammatic Cross Section From





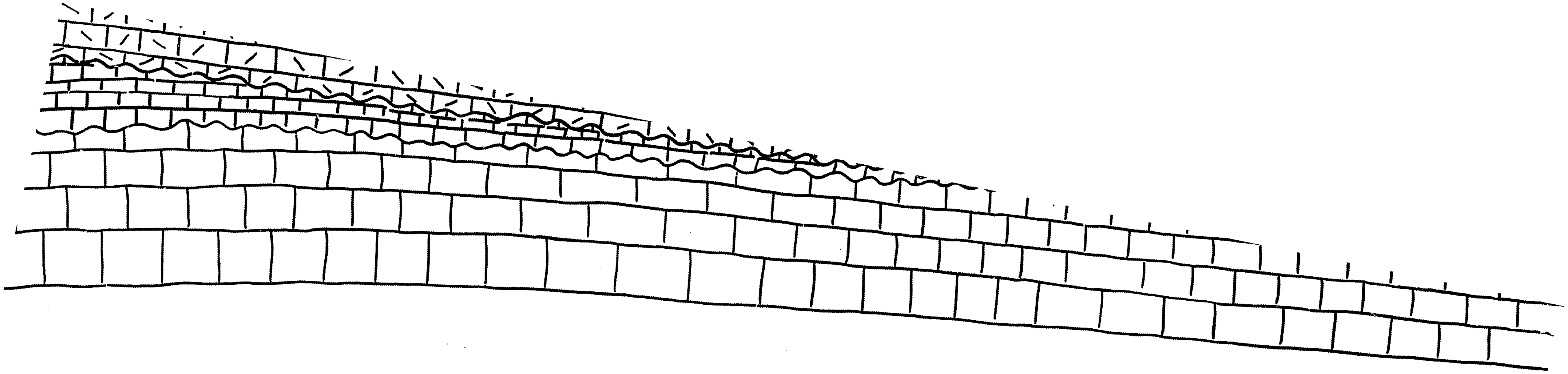


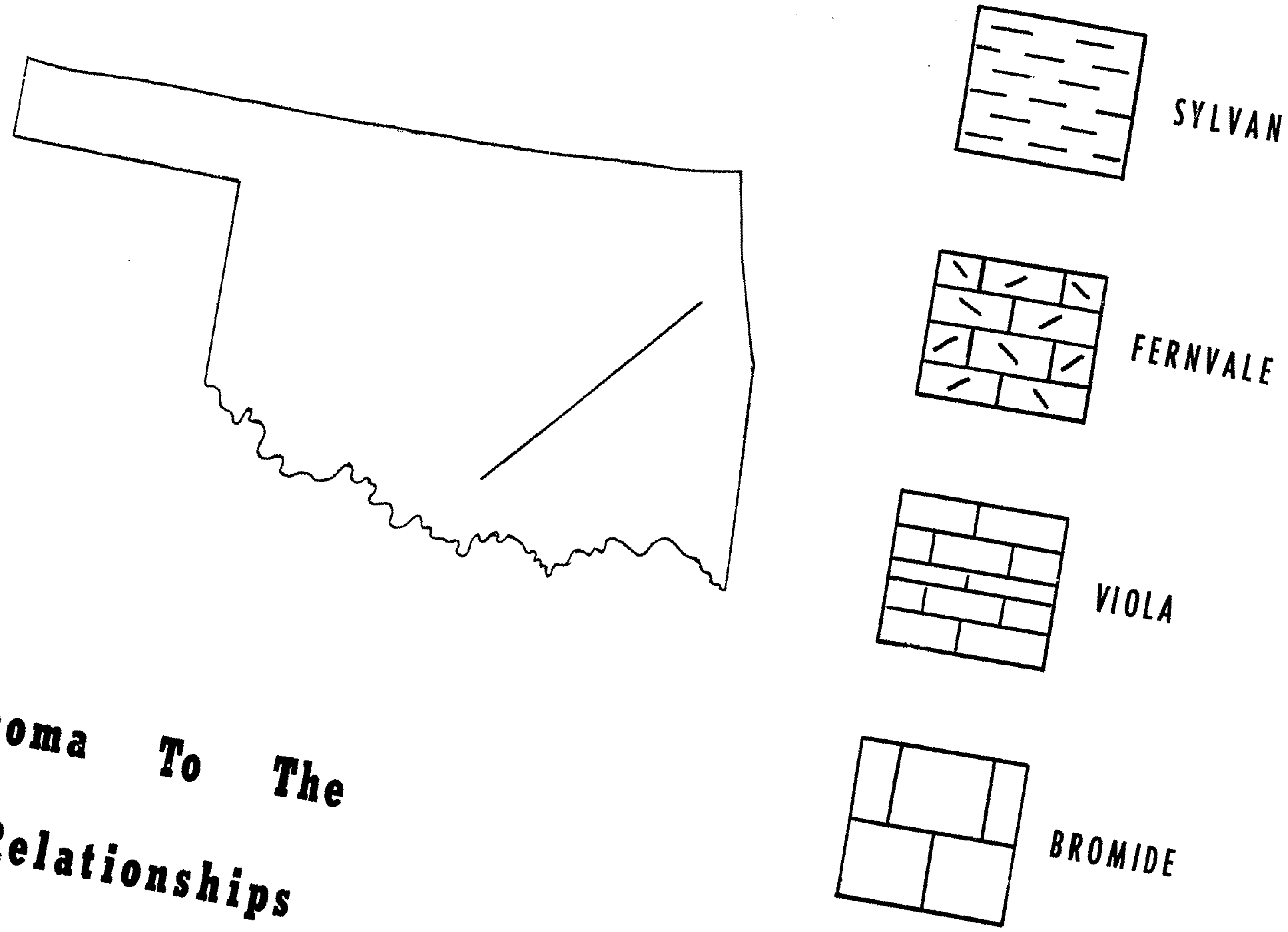
tion From Northeast Oklahoma To The



Diagrammatic Cross Section From
Arbuckle Mountains Showing Th
Of The Viola And "

TEXT FIG





tion From Northeast Oklahoma To The
owing The Stratigraphic Relationships
And ''Fernvale'' Formations

TEXT FIGURE 15