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DISTRIBUTION AND SYSTEMATICS OF THE INARTICULATE BRACHIOPODS OF THE ORDOVICIAN CARBONATE MUD MOUND OF MEIKLEJOHN PEAK, NEVADA

F. F. KRAUSE AND A. J. ROWELL
The University of Kansas, Lawrence

The University of Kansas Paleontological Institute

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DISTRIBUTION AND SYSTEMATICS OF THE INARTICULATE BRACHIOPODS OF THE ORDOVICIAN CARBONATE MUD MOUND OF MEIKLEJOHN PEAK, NEVADA[1]

F. F. KRAUSE AND A. J. ROWELL
The University of Kansas, Lawrence

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ABSTRACT

The Meiklejohn carbonate mud mound is a large, asymmetric mound developed in the Ordovician Antelope Valley Limestone of southern Nevada. Formic acid etching of limestone from both the mound and its adjacent flanking beds has yielded a rich and diverse fauna of inarticulate brachiopods. Nearly 16,000 specimens are distributed among 20 genera representing 28 species. The distribution of the species relative to the mound and flanking beds is not random. Some forms are relatively common in the flanking rocks, but have not been recorded on the mound. More rarely the converse is true. Although transport of valves from off the mound to the flanks has probably caused some mixing, a recognizable pattern has emerged. The inarticulate brachiopods in the Meiklejohn area seemingly had preferred habitats, but many of the species could survive both on and off the mound. In general, the lingulides flourished most abundantly off the mound, and the acrotretides dominated the inarticulate brachiopod fauna of the mound. Exceptions to this general statement are discussed.

A systematic account of the following species known from the mound and flanking beds is given, accompanied, when possible, by descriptive multivariate statistics: *Lingulella bullata*, n. sp.; *L. amphora*, n. sp.; *L.* sp.; *Spinilingula bracteata*, n. sp.; *Rowellella margarita*, n. sp.; *R.* sp.; *Glossella livida*, n. sp.; *Ectenoglossa?* sp.; obolid, gen. et sp. indet.; *Elliptoglossa sylvanica* Cooper var. *recidiva*, n. var.; *Contreta? devota*, n. sp.; *C. mica?* Goryanskiy; *C.* sp.; *Spondylotreta* sp.; *Undiferina nevadensis* Rowell & Krause; *U.* sp.; *Eurytreta campaniformis*, n. sp.; *Hansotreta acrobela*, n. gen. and sp.; *Scaphelasma lamellosum*, n. sp.; *S. tumidatum*, n. sp.; *S. anomalatum*, n. sp.; *Rhysotreta modesta*, n. sp.; *Torynelasma papillosum*, n. sp.; *Ephippelasma spinosum* Biernat; *Eoconulus antelopensis*, n. sp.; *Schizotreta* sp.; *Multispinula* sp.; *Dictyonites* sp.

INTRODUCTION

The carbonate mud mound of Meiklejohn Peak is a conspicuous feature on the west face of Bare Mountain. It is one of three such mounds that have been reported in the Ordovician beds of Nevada (Ross & Cornwall, 1961, p. *B*231; Cornwall & Kleinhampl, 1961). The other two occur southwest of Aysees Peak in the Frenchman Lake Quadrangle, and west of Oak Spring in the northern part of the Tippipah Spring Quadrangle (Fig. 1).

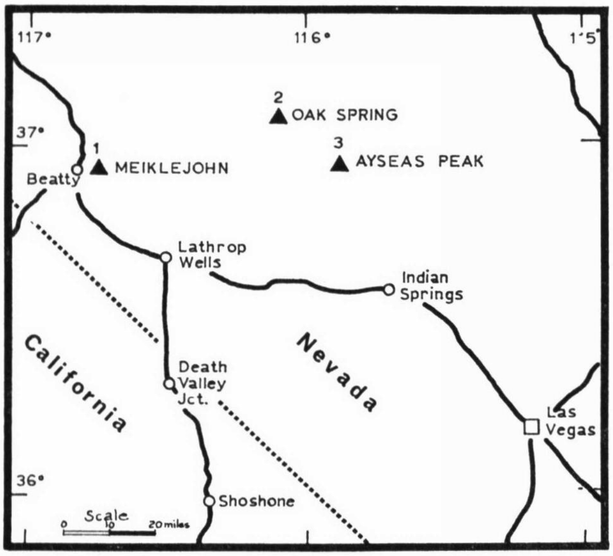

FIG. 1. Distribution of Ordovician carbonate mud mounds in Nevada.

Only the mound at Meiklejohn Peak is readily accessible; the other two are in restricted access areas, one being on a bombing range, the other on the Nevada Test Site. Consequently, this study is restricted to the Meiklejohn occurrence.

The mound is very much lighter in color than the surrounding rock, which makes it conspicuous even at considerable distances, particularly early and late in the day. It can be clearly seen along a bearing of approximately 120° from the western outskirts of the town of Beatty, Nevada, some six miles to the northwest.

The mound itself lies in the NW ¼ SE ¼ and SW ¼ NE ¼ of Section 24, T. 12 S., R. 47 E. of the Bare Mountain Quadrangle 15′ topographic map at an elevation of 5,400 feet. Access is relatively easy by a well-maintained gravel road which runs to within half a mile of the foot of the mound. The gravel road intersects Highway 95 some 1.3 miles south of Beatty and trends eastward through Fluorspar Canyon, past the Fluorspar mine to Secret Pass, where a microwave relay station is located. The last half mile is upslope and has to be covered on foot.

The stratigraphic setting and trilobite and articulate brachiopod faunas are known primarily through the work of Ross (1964; 1967; 1971; 1972). The present contribution complements his studies by providing information on the systematics and distribution of the inarticulate brachiopods. According to Ross, the mound lies within the lower unnamed member of the Antelope

Valley Limestone (Ross, 1972, p. 10); its base is some 68 feet above the bottom of the formation and it attains a maximum thickness of about 270 feet. Ross (1972, p. 1) considered that the mound lies mostly within the *Orthidiella* zone, but that the lowermost beds may be in the upper Canadian zone of *Pseudocybele nasuta.*

The structural setting of the mud mound is well shown in the Bare Mountain quadrangle map (Cornwall & Kleinhampl, 1961). Meiklejohn Peak is characterized by a series of thrust plates, which have caused rock formations ranging in age from Cambrian through Mississippian to lie in juxtaposition to each other. The Ordovician Pogonip Group, in which the mound is set, is thrust over the Devonian Fluorspar Canyon Formation, which in turn is thrust over the Mississippian Meiklejohn and Cambrian Carrara Formations.

Within the upper plate on Meiklejohn Peak, later normal faulting has displaced the sediments. Cornwall and Kleinhampl (1961) mapped a large fault about 100 yards north of the north face of the mound. This fault, referred to by Ross (1964, p. C25), can be identified as a conspicuous surface feature.

The southern portion of the west face is more broken than the northern end, and is jointed and crisscrossed by many small faults ranging in displacement from a few inches to tens of feet. The largest two faults that we have mapped (Fig. 2) define a small graben with a displacement of 30 to 50 feet. However, in view of the intensity of deformation that the Paleozoic rocks have undergone, it is surprising that the mound has been so little affected. Clearly the marked anisotropy of the stratigraphic sequence has protected it.

The collections, on which the present study is based, were made during a two-week period in May, 1971. They were supplemented by a further two days of collecting in October of the same year when we were accompanied by R. J. Ross, Jr., and I. Friedman. The location of the collections, both from the mound and the adjacent flanking beds, is shown in Figure 3. The mud mound was mapped by tape and compass traverse and the position of the collecting localities fixed by tape and compass from the nearest traverse station. As may be apparent from the distribution of the collecting localities, not all areas of the mound are equally accessible. Access to its northern and southern ends is relatively easy and the exposure is good. The exposure in the central part of the mound is perfect, but the steep, locally overhanging cliffs make collecting difficult.

Present day erosion has produced an approximately north-south cross section through the mound. In this direction the thickened part of the mound is approximately 1,100 feet long. We have relatively little informa-

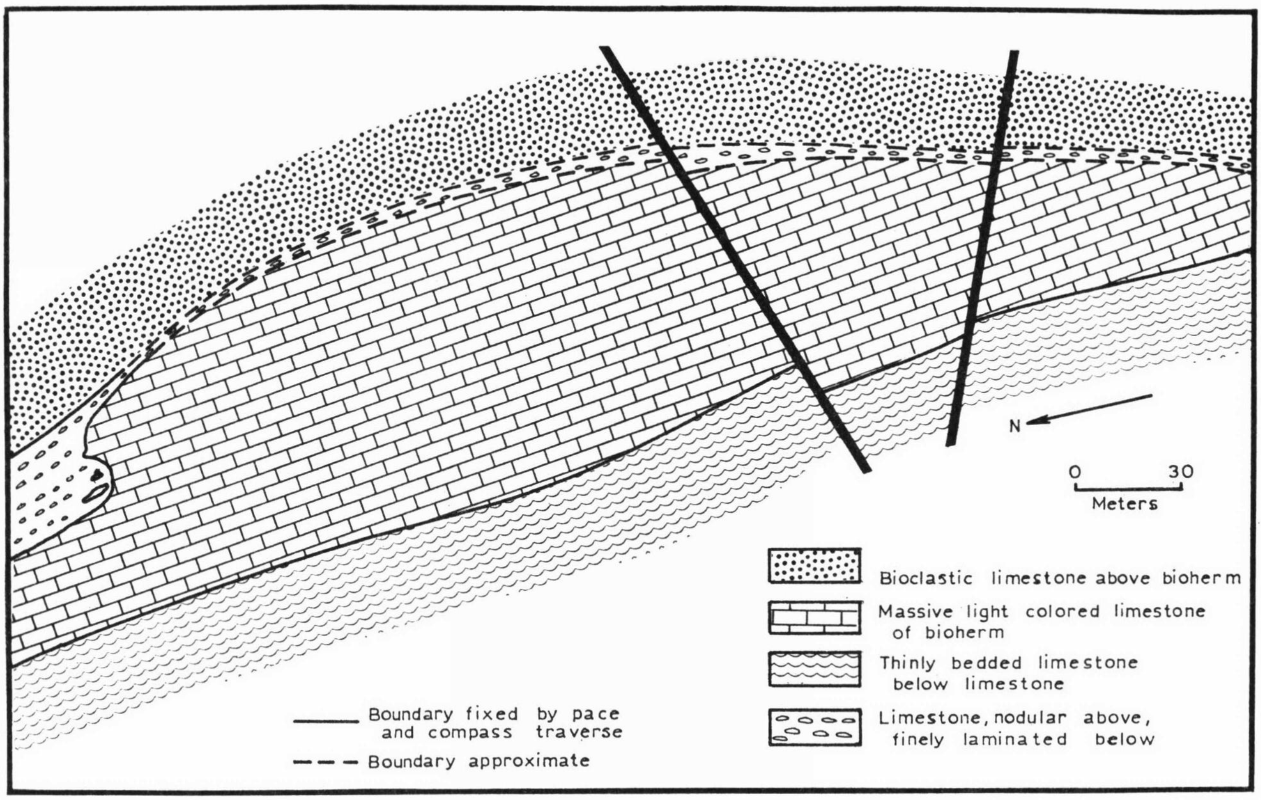

FIG. 2. Geological map of the Meiklejohn carbonate mud mound.

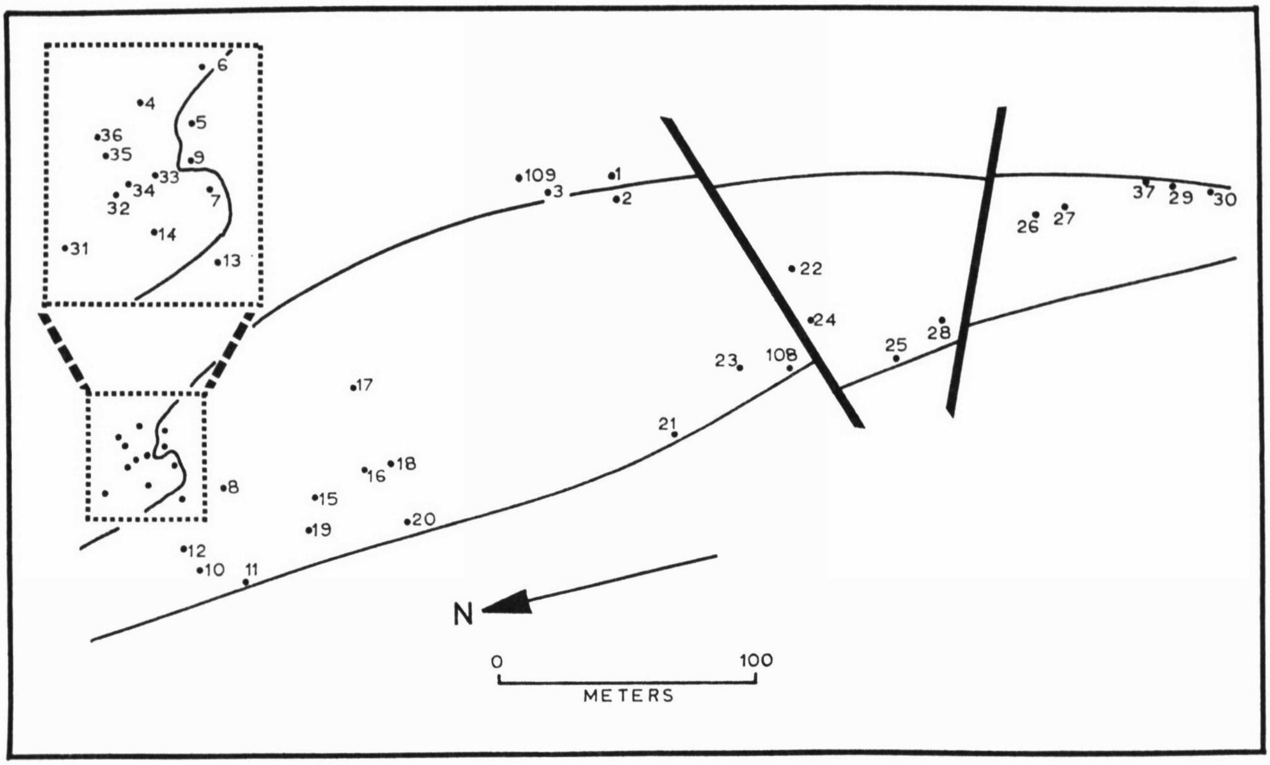

FIG. 3. Distribution of collecting localities on the Meiklejohn mud mound and its flanking beds.

tion on its dimensions in an east-west direction. The beds dip easterly into the hillside at angles between 45° and 55° and the mound is not exposed elsewhere.

ACKNOWLEDGMENTS

We are indebted to Margery Rowell for her translations from Russian of pertinent sections of Goryanskiy's (1969) monograph.

We appreciate the opportunity afforded by Dr. G. A. Cooper to study material in the collections of the National Museum of Natural History, and we are indebted to him and Mrs. Cooper for their hospitality.

We are especially grateful to Dr. Reuben J. Ross, Jr., of the United States Geological Survey, who initially drew our attention to the existence of inarticulate brachiopods in the limestones of the Meiklejohn carbonate mud mound. We have profited from numerous discussions with him. He and his co-workers are currently concluding a study of the genesis of the mound (Ross *et al.*, 1971).

The work was supported by National Science Foundation Grant GA 29143 and University of Kansas General Research Grant 3544-5038 to Rowell. Krause also gratefully acknowledges the financial support of the Wallace E. Pratt Fund of the Paleontological Institute, University of Kansas, underwritten by the Exxon U.S.A. Foundation.

REPOSITORY

All figured specimens are deposited in the Museum of Invertebrate Paleontology, University of Kansas. The majority of the unfigured material is also housed in this museum, but a representative collection of unfigured specimens is held by the U.S. National Museum, Washington, D.C.

THE INARTICULATE BRACHIOPODS

DIVERSITY

With the exception of some of the specimens of *Ectenoglossa?* sp., all the material described in this report was obtained by dissolving approximately a one-kilogram limestone sample from each collecting locality in 10 percent formic acid. The shells were picked from the dried insoluble residue. Of the 39 collections made, 35 contained an identifiable inarticulate brachiopod fauna. The average sample yielded representatives of 8.7 species, but the number ranged from 17 to zero. At the generic level, the comparable figures are an average of 7.3 per 1-kilogram sample, with a range of 13 to zero.

The mound and its flanking beds yielded a fauna of 28 species of inarticulate brachiopods distributed among 20 nominal genera. This species diversity is unusually high and is comparable to that recorded by Cooper (1956, p. 85) from the type locality of the Ordovician Pratt Ferry Formation of Alabama. No breakdown of the number of taxa from a given sample of this formation is available, but the faunal list, which is based on a rather modest-sized exposure of the limestone, contains 31 species of inarticulate brachiopods referred to 21 nominal genera. Other Ordovician rocks have also yielded diverse inarticulate brachiopod faunas (Goryanskiy, 1969; Biernat, 1973) and it is apparent that this component of the fauna was, at least locally, taxonomically more diverse during this period than it was in the Cambrian. Typically, even a very fossiliferous Cambrian limestone will produce representatives of only four or five inarticulate brachiopod species.

The Meiklejohn brachiopod fauna was not only diverse, but also rich in number of individuals. The collections yielded a total of 15,895 identifiable valves. Acrotretide[1] brachiopods are by far the most abundant inarticulates present; they account for some 13,289 valves. Lingulide brachiopods are represented by 2,598 valves and a single paterinide genus by eight valves.

The species are distributed taxonomically as follows (the numbers in parentheses are the numbers of identifiable valves produced by the etching program):

1) Ten species have been assigned to seven lingulide genera:
   - *Lingulella bullata* Krause and Rowell, sp. nov. (147)
   - *L. amphora* Krause and Rowell, sp. nov. (440)
   - *L.* sp. (534)
   - *Spinilingula bracteata* Krause and Rowell, sp. nov. (74)
   - *Glossella livida* Krause and Rowell, sp. nov. (39)
   - *Ectenoglossa?* sp. (2)
   - *Obolid,* gen. et sp. indet. (317)
   - *Rowellella margarita* Krause and Rowell, sp. nov. (71)
   - *R.* sp. (16)
   - *Elliptoglossa sylvanica* Cooper var. *recidiva* var. nov. (958)

2) Seventeen species have been assigned to twelve acrotretide genera:
   - *Conotreta? devota* Krause and Rowell, sp. nov. (5,237)
   - *C. mica?* Goryanskiy (2,759)
   - *C.* sp. (40)
   - *Spondylotreta* sp. (60)
   - *Undiferina nevadensis* Rowell & Krause (1)
   - *U.* sp. (21)
   - *Eurytreta campaniformis* Krause and Rowell, sp. nov. (236)
   - *Hansotreta acrobela* Krause and Rowell, gen. et sp. nov. (83)
   - *Scaphelasma lamellosum* Krause and Rowell, sp. nov. (362)
   - *S. tumidatum* Krause and Rowell, sp. nov. (24)
   - *S. anomalatum* Krause and Rowell, sp. nov. (748)
   - *Rhysotreta modesta* Krause and Rowell, sp. nov. (301)
   - *Torynelasma papillosa* Krause and Rowell, sp. nov. (828)
   - *Ephippelasma spinosum* Biernat (470)
   - *Eoconulus antelopensis* Krause and Rowell, sp. nov. (2,040)
   - *Schizotreta* sp. (71)
   - *Multispinula* sp. (8)

3) One species has been assigned to one paterinide genus:
   - *Dictyonites* sp. (8)

DISTRIBUTION

Ross (1972, p. 16) previously addressed the problem of the distribution of the articulate brachiopods, trilobites, and bivalves of the mound and its flanking beds. He recognized that although some twenty genera are recorded only from the mound and do not occur in its flanking beds, several of these genera are known from beds comparable to the flanking deposits elsewhere in the Great Basin. He noted the mixing that might be caused by shells characteristic of the mound being swept off it and incorporated into the flanking sediments. Nonetheless, he concluded that there was a contrast between forms that were known only from the mound and those that were restricted to the flanking beds. He also anticipated that these two lists of mutually exclusive faunas would be modified by future collecting.

A pattern is recognizable in the distribution of the species of inarticulate brachiopods, but several factors need consideration before the pattern may be adequately interpreted. Ross (1972, p. 16) raised questions about the pattern he found: was it caused by environmental control or temporal control, or was it a reflection of incomplete collecting? These questions are also pertinent to the present study. In addition, one might ask how

[1] We have employed the vernacular designations for brachiopod orders and lower suprageneric taxa advocated by Williams & Rowell (1965, p. *H*12).

faithfully the fossil fauna recovered from a given locality reflects the fauna that lived at the locality. These, of course, are not problems that are unique to the Meiklejohn carbonate mud mound, but rather are concerns that plague the majority of paleoecological work. Much has been written on the factors that may distort our image of the structure of the original life assemblage. The possible effects of differential solution of smaller shells, winnowing, breakage, transport into the area of the remains of animals that lived elsewhere, differential scavenging, and grain diminution by boring organisms (algae, fungi) are well known and obvious. Likewise, the fact that we see only part of the assemblage that is potentially capable of ready fossilization is widely appreciated. Other less conspicuous factors, however, are also involved. Unless we have some knowledge of the relative average life spans of specimens of the taxa, we are unable to interpret the relative abundances of species at a locality. The frequency of occurrence of the shorter-lived forms is biased to some unknown extent relative to those that had a longer life span.

The confidence with which we can interpret our data is dependent in part upon the number of assumptions that we are forced to make concerning them. In this study, although we have data on the relative abundance of taxa at each locality, they are not crucial to our interpretation. It is necessary, of course, that we feel reasonably secure in the belief that our samples reflect the fauna that lived in the area, and that the specimens were not generally transported into the region. The abundance of micrite in the rocks, coupled with the wide size range of the valves recovered from most localities, suggest that transport has not been excessive on the mound and its flanking beds. The occurrence in several samples of bivalved inarticulate brachiopods again suggests that the region was characterized by relatively low energy conditions. However, some evidence supports the view that shells occasionally may have been swept off the mound into the deeper water.

Studies of the local distribution of fossil faunas may also be iterative and, in a sense, self-reinforcing, yet still avoid the pitfalls of "circular" reasoning. Attributes of the rock sample together with knowledge of the size distribution of the enclosed shells may suggest, as a working hypothesis, that the fauna is essentially *in situ*. Study of the pattern of distribution of the fauna may make sense only if the above assumption is correct; that is, the pattern appears to show biological rather than merely hydrodynamic control. This iterative approach may be employed in the present study, and we believe that the distributional pattern to be discussed is a reflection of an underlying biological control that was exerted on the animals during life. We do not claim that no transportation or mixing has occurred; some samples show a clear preponderance of brachial over pedicle valves. The latter have been selectively lost. Similarly, although the collections are moderately large, there is little doubt that the details of distribution, particularly of the rarer taxa, would be modified by additional collecting. Nonetheless, the major features of the distributional pattern of the commoner taxa are strong and appear unlikely to be seriously modified by additional data. It is possible that early diagenesis of the micrites helped to preserve this pattern.

We have quantified our data, but because of the limitations discussed above, the resulting figures can at best be regarded as giving an order of magnitude impression of the resulting relative abundances. The count of the number of valves of different taxa taken from a particular sample probably describe the relative abundances of these valves in the sample more or less accurately. The samples are haphazard rather than random, however, and there is no statistical basis for extrapolating their results. If a particular taxon has 100 specimens in a given sample and a second species is represented by only two specimens, it is reasonable to conclude that in life the former was more abundant than the latter. It is most unlikely, however, that it was exactly 50 times as abundant. These limitations should be considered in any interpretation of the data.

The basic data for the study of the distribution of the taxa consist of a count of all identifiable valves recovered. A total of 15,895 valves were counted, of which 8,313 are brachial valves, and 7,582 are pedicle valves. As previously noted, acrotretides dominate the fauna, followed by lingulides and with paterinides a poor third. No one species was found at all localities. *Conotreta mica?* comes closest to being ubiquitous in its distribution, as it was found in 31 of the 39 samples. The number of valves of any one species per sample varied from zero to several hundred.

The distribution of the individual taxa is shown in the figures accompanying the systematic descriptions of the species. The maps show the distribution of brachial valves; the latter were chosen because they occur more frequently and were also more abundant. The maps were produced by first expressing the number of brachial valves of all taxa at each locality as a percentage of the total number of all brachial valves that were collected. Thus, if two species A and B were present at Locality 2 in groups of 83 and 17 brachial valves, respectively, they would be recorded as 1 percent and 0.2 percent. The occurrence of species at the collecting localities were then grouped into one of three classes, rare, common, or abundant. The scale that was used for the class boundaries is logarithmic, but the boundaries are arbitrary. Forms were regarded as rare at a given locality if they were present $> 0\% \leqq 0.1\%$. They were classed as common if their abundance expressed as a percentage of all brachial valves was $> 0.1\% \leqq 1\%$. Species present at a locality in percentages > 1% were classed as abundant.

Examination of the distribution maps suggests that the occurrence of many of the species is not random. Some forms are relatively common in the flanking beds, but have not been recorded on the mound. More rarely the converse is true. We divided the species into four groups: 1) forms whose prevalence is indeterminate because they are inadequately represented in the collections (arbitrarily defined as those species which are represented by less than 25 valves); 2) forms that are prevalent on the mound (arbitrarily defined as those species having 80 percent or more of their total number of valves recorded from localities on the mound); 3) forms that are prevalent in the flanking beds off the mound (arbitrarily defined as those species that have 80 percent or more of their total number of valves recorded from localities off the mound); and 4) forms that are present both on and off the mound (arbitrarily defined as those species having less than 80 percent of their total number of valves recorded from the mound and less than 80 percent of their total number of valves recorded off the mound). Table 1 shows the result of this grouping together with data on the total number of valves found and the number of localities from which the species has been recorded.

The assignment of *Ectenoglossa* to the group "Prevalent off the mud mound" needs explanation. It is represented in the etched collections by only two valves and application of the above criteria would place it in the group of forms whose preference is indeterminate. *Ectenoglossa?* sp. differs in size by an order of magnitude from the other inarticulates collected on the mound. In the field it is readily seen with the naked eye and is relatively common at Locality 71/31 in the flanking beds. However, the valves are cracked and, as is common with large inarticulates, they etch poorly and typically produce a large number of fragments. Field observation, rather than the results of the etching program, suggests the position in Table 1 shown for this species.

Table 1 shows some interesting features. Ninety-seven percent of the total number of valves recovered may be referred to 14 of the 28 recognized species. Five species, *Lingulella bullata,* obolid gen. et sp. indet., *Glossella livida, Ectenoglossa?* sp., and *Hansotreta acrobela* have been found only in the flanking beds of the mound. Over ninety percent of the valves of the other three species that are prevalent in the flanking beds have been found in these deposits.

Although nine species are classed as being prevalent on the mound, only two have been found exclusively in rocks from it, and one of these, *Scaphelasma anomalatum,* is known from only two localities. The distribution (Table 1) of the very abundant species like *Conotreta? devota* and *Conotreta mica?* suggests three possibilities: 1) these species in life were confined to the mound but occasionally their remains were swept off it into the flanking sediments; 2) the species preferred to live on the mound but could tolerate conditions in the flanking areas and some lived there; 3) the final alternative, and the one that we prefer, is a compromise between the first two. Although the species were dominant inhabitants of the mud mound, some lived in the flanking regions, and occasionally the remains of specimens that lived on the mound were swept off it into the adjacent flanking sediments. We prefer the third alternative because, on balance, it also seems to offer the best explana-

TABLE 1.—*Distribution of Inarticulate Brachiopod Valves Relative to the Mud Mound.*

Species	No. of localities	No. of valves	% of valves on mound
PREVALENT ON MUD MOUND			
**Conotreta? devota*	22	5,237	94
**Conotreta mica?*	31	2,759	91
**Scaphelasma lamellosum*	19	748	92
**Scaphelasma anomalatum*	2	362	100
**Torynelasma papillosum*	14	828	100
**Eoconulus antelopensis*	29	2,040	86
**Ephippelasma spinosum*	27	470	80
Spondylotreta sp.	2	60	97
Spinilingula bracteata	4	74	97
PREVALENT OFF MUD MOUND			
**Lingulella bullata*	7	147	100
**Lingulella amphora*	15	440	97
Glossella livida	4	39	100
Ectenoglossa? sp.	2	2	100
*Obolid gen. et sp. indet.	8	317	100
**Elliptoglossa sylvanica*	21	958	94
**Eurytreta campaniformis*	16	236	91
Hansotreta acrobela	8	83	100
PRESENT ON AND OFF MUD MOUND			
**Lingulella* sp.	24	534	49
Rowellella margarita	24	71	69
**Rhysotreta modesta*	10	301	57
Schizotreta sp.	15	71	23
Conotreta sp.	3	40	78
INDETERMINATE			
Undiferina nevadensis	1	1	0
Undiferina sp.	8	21	90
Multispinula sp.	5	8	75
Dictyonites sp.	3	8	100
Rowellella sp.	4	16	25
Scaphelasma tumidatum	4	24	88

* The 14 species marked with an asterisk together represent 97% of the total number of specimens collected.

tion of the distribution of the forms prevalent in the flanking deposits. These forms are typically more faithful to their preferred environment, as shown by the fact that a larger proportion are found exclusively in it. Transport of forms living on the flanks of the mound up onto it, although not impossible, would be more difficult than moving specimens by gravity off the mud mound. Although the activity of storms could have produced the mixing seen in forms like *Elliptoglossa* and *Eurytreta,* it is perhaps more probable that the species concerned were able to survive on the mound even though they flourished more profusely off it.

In summary, we believe that many of the inarticulate brachiopods in the Meiklejohn area had preferred habitats (Table 1). Some forms were more successful on the carbonate mud mound, others in the flanking regions. It is probable that many of the species could survive in both major habitats, although they were commonly more successful in one of them. This statement must surely be true at the generic level for those forms that are prevalent on the mound. Representative species of every genus within this group are known to occur elsewhere in the world in rocks that are not associated with mud mounds or bioherms.

MODE OF LIFE

Rowell and Krause (1973) recently discussed the mode of life of the acrotretaceans, including those of this region. Acrotretaceans are the dominant brachiopods on the mound, and we have little to add to the previous account except that we now believe that some of them may have been attached directly to local hard bottoms formed during early submarine diagenesis.

Lingulides, although not confined to the flanking deposits, are typically the dominant brachiopods found there. They are commonly regarded as infaunal animals, but we have not seen any specimens in burrows, and there is no direct evidence to support this point of view. The size and shape of *Ectenoglossa?* sp. is consistent with this mode of life, but whether the more numerous species of *Lingulella* lived in a comparable manner is unknown. Young postlarval stages of Recent *Glottidia* live infaunally (Paine, 1963). They are of a size comparable to these Ordovician lingulides and mechanically there is seemingly nothing to have precluded an infaunal existence. The possible exception to this statement is *Elliptoglossa sylvanica* var. *recidiva.* Detailed examination of the posterior margin of both valves of this variety of the species has not revealed any trace of a pedicle groove or notch. If the animals possessed a pedicle, it must have been extraordinarily thin, and to date, we have not recognized its impression on the shell. Possibly, they lay free on the sea floor or were tethered by a fine threadlike pedicle. It is unlikely that they possessed the stout pedicle typical of modern lingulids, which is used to control the position of the animal within its burrow.

SYSTEMATIC PALEONTOLOGY

BIOMETRICAL TREATMENT

One of the difficulties of systematic work is adequately conveying information about the organisms being studied. Traditionally, this is attempted by written description supplemented by illustrations of selected specimens. Unless the number of illustrated specimens is large, it is very difficult to convey an impression of the inherent variability of the population being studied. Descriptive statistics help to some extent to overcome this difficulty. They are not a panacea for all problems, but they describe, in a reasonably objective manner, the dimensions and variability of specific morphological features. One is commonly faced with a choice of characters to measure, and their selection is clearly a subjective matter that typically involves a mixture of taxonomic experience with the group of organisms, combined with a compromise between the desire to transmit as much information as possible, yet still complete the study!

In the present work, whenever the quality and quantity of material permitted, we have made measurements on 25 pedicle and 25 brachial valves from one population of each species. The measurements were made under a stereobinocular microscope at $\times 40$ using an eyepiece graticule. A vector of means, a variance-covariance matrix, and a matrix of sample sizes were calculated for each set of measurements. The latter matrix gives the number of specimens used in computing the comparable entry in the variance-covariance matrix. Where available, these data are provided with the systematic description of each species.

Class INARTICULATA Huxley, 1869

Discussion.—In the following account, the ordinal classification of the *Treatise* (Rowell, 1965) is employed. The basic terminology of the *Treatise* is also used, but we have adopted two of Biernat's (1973) terms and propose two additional ones. We are hesitant to add more jargon to a literature that is already heavily burdened by it; our only justification is the increase in precision and economy of words effected by its use.

Biernat (1973) used the terms **septal plate** and **surmounting plate** in describing the complex septal structures found in the brachial valve of some acrotretids (e.g., *Torynelasma, Ephippelasma*). A septal plate is similar to a median septum; it is the dorsal of the two components of the septal structure and bears a surmounting plate on its posteroventral margin (Fig. 4). The

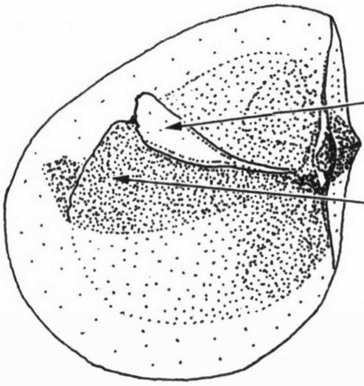

FIG. 4. Septal morphology and terminology.

surmounting plate is buttressed by the septal plate along part or all of the posteroventral margin of the latter, and is of varied outline and curvature; it may be planar, concave ventrally, or convex ventrally (Fig. 4).

In many acrotretids, the floor of the brachial valve is raised posteromedianly in a low subrectangular-triangular buttress, which we term the **median buttress.** Laterally it is bounded by the inner margins of the *vascula lateralia* that lie medially of the cardinal muscle scars; posteriorly it typically buttresses the median plate of the pseudointerarea, and anteriorly it slopes gently to the valve floor, commonly masking the posterior end of the median septum. During ontogeny, the median buttress extends anteriorly and may conceal the earlier formed posterior portion of the median septum (Fig. 5).

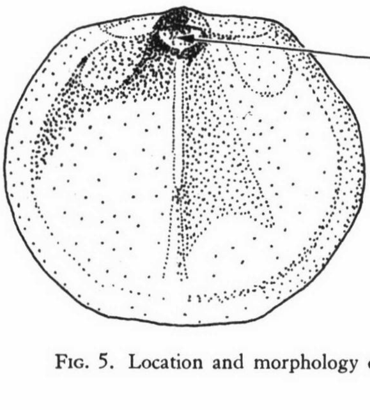

FIG. 5. Location and morphology of a median buttress.

The term **interridge** (Fig. 6) we suggest for a medial

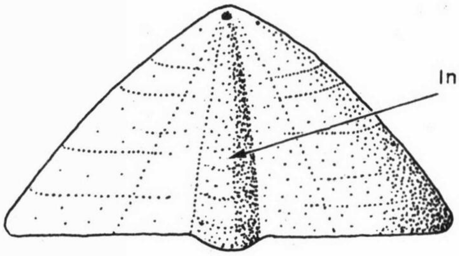

FIG. 6. Location and morphology of an interridge.

structure of the ventral pseudointerarea of some acrotretaceans. It is comparable to an intertrough, but is externally convex rather than concave. Like an intertrough, it is typically narrowly triangular and extends from the pedicle foramen to the dorsal margin of the pedicle valve. Not uncommonly the latter projects dorsally and seats in the median plate of the opposing valve. Although not constituting a true hinge mechanism, these structures restrict the freedom of relative movement of the two valves as discussed by Rowell (1966, p. 3) and Biernat (1973, p. 37).

Order LINGULIDA Waagen, 1885

Superfamily LINGULACEA Menke, 1828

Family OBOLIDAE King, 1846

Subfamily LINGULELLINAE Schuchert, 1893

Diagnosis.—Elongate obolids, dorsal pseudointerarea typically well developed, divided into two propareas by poorly defined, broadly triangular, concave median depression.

Genus LINGULELLA Salter, 1866

Discussion.—The generic name *Lingulella* has been used as a "catch-all" almost from the time the name became available. It tends to be employed for any smooth-shelled, moderately elongate lower Paleozoic obolid (the extremely elongate forms are commonly referred to *Lingulepis,* a "genus" whose type species is perhaps even less well understood). Although one may deplore this situation (simultaneously admitting one's own guilt), it is easy to recognize how it has arisen, but difficult to suggest a practical way of avoiding its perpetuation. Externally, most lingulellins have relatively few distinguishing characters; even those readily available, such as outline, convexity, and ornament, show a rather limited amount of variation. Internally, there is a greater information potential, but this potential is not always attained. Typically, the muscle bases did not produce well-defined scars and the size and distribution of the complete complement of muscles is unknown in the majority of the taxa referred to the subfamily. Nonetheless, it appears that in the type species of *Lingulella, L. davisi* Salter, the musculature is broadly comparable with that of *Obolus* (Walcott, 1912, p. 470) and shows marked similarities with that of living species of *Lingula.* Material recovered by acid etching, and less commonly, mechanically prepared specimens, may display other features of the internal surfaces of the valves. Some of these features vary markedly, for example, the form and structure of the pseudointerarea. Cooper (1956, p. 213) has used differences in the latter to distinguish the Glossellinae from the Lingulellinae. *Lingulella davisi* has a characteristic that is not commonly seen in most species referred to the genus; the internal surface of the valves, particularly in the visceral region, is strongly pitted (e.g., Rowell, 1965, fig. 161,*3a,3c,3d*). Neither the functional purpose nor the taxonomic significance of this pitting is understood. It occurs in only one of the three lingulellins from the Meiklejohn area, *Lingulella* sp. The two remaining species differ in other respects from the type species of the genus; both differ in commissural outline and *Lingulella bullata* is unusual in having a submarginal internal ridge in both valves and in seemingly possessing a posteriorly located musculature in the pedicle valve. If these features turn out to be associated in other species it may be appropriate to consider the erection of a new genus. As we know little of their distribution, we have followed the traditional practice of interpreting *Lingulella* in a broad manner.

LINGULELLA BULLATA Krause & Rowell, new species

Plate 1, figures 1-10

Diagnosis.—Characters of *Lingulella* with inflated ventral and dorsal umbones, ornament of thin irregularly distributed radiating lines. Narrow submarginal ridge in both valves.

Description.—Thin-shelled *Lingulella* with broad teardrop-shaped transverse outline. Length and width variable, in most cases about equal, but width can be about 7 percent greater than length and in some rarer instances length may be about 7 percent greater than width. Maximum width occurring anterior to midlength of valve.

Brachial valve convex. Posterior, lateral, and anterior margins rounded, lateral margins more gently so. Umbo swollen, commonly raised above rest of shell surface. Dorsal pseudointerarea narrow and arclike in outline, divided medially by depressed median plate with frontal margin concave anteriorly. Median plate separates semielliptical orthocline propareas. Low and thin median ridge anteromedially located. Pair of indistinct oval impressions, seemingly muscle scars, located slightly posterior to midlength of valve. Narrow ridge parallel and slightly internal of lateral and anterior margins.

Pedicle valve convex. Ventral beak extending posterior of dorsal margin in complete shells. Umbo swollen and raised above rest of shell surface. Lateral margins of pointed posterior subtending anteriorly an angle between 110 and 120 degrees. Anterior and lateral margins rounded, lateral margins more gently so. Maximum width occurring anterior to the midlength of valve. Ventral pseudointerarea narrow, divided medially by triangular, depressed pedicle groove with frontal margin concave anteriorly, separating semitriangular propareas. Muscle scars seemingly represented by two pairs of oval-shaped impressions located anterior of inflated umbo and posterior to midlength of valve, and arranged in an almost linear fashion across width of shell. Narrow ridge parallel and slightly inside lateral and anterior margins.

Ornament of fine growth wrinkles and fine, irregularly disposed radiating lines on inflated umbo.

Discussion.—*Lingulella bullata* resembles most closely *L. galba* Cooper from the Bromide Formation of Oklahoma and *L. spicata* Cooper from the Whittesburg Formation of Tennessee; it shares with these two species the teardrop-shaped transverse outline of the shell. The Meiklejohn species differs from both of Cooper's species in a number of respects: 1) the apical angle of the pedicle valve of *L. bullata* is much broader, almost by a factor of two, than that of the Bromide and Whittesburg species; 2) the shells of the Meiklejohn species are wider and less elongate than those of *L. spicata* and *L. galba.* A comparison among these three species based on internal morphological details cannot be made at the present time because this information is unavailable for *L. galba* and *L. spicata.* Measurements of *L. bullata* are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Holotype	Pedicle valve	KU 79818	1.32	1.26
Figured paratypes	Complete specimen	KU 79819	0.54	0.54 pedicle
			0.50	0.54 brachial
	Brachial valve	KU 79820	1.00	1.06
	Brachial valve	KU 79821	1.06	1.08
	Pedicle valve	KU 79822	1.18	1.14

Distribution.—Recorded at Localities 71/4, 71/6, 71/7, 71/31, 71/33, 71/35 and 71/36 (Fig. 7).

Descriptive statistics.—Statistics are summarized in Figures 8 and 9, and in Tables 2 and 3.

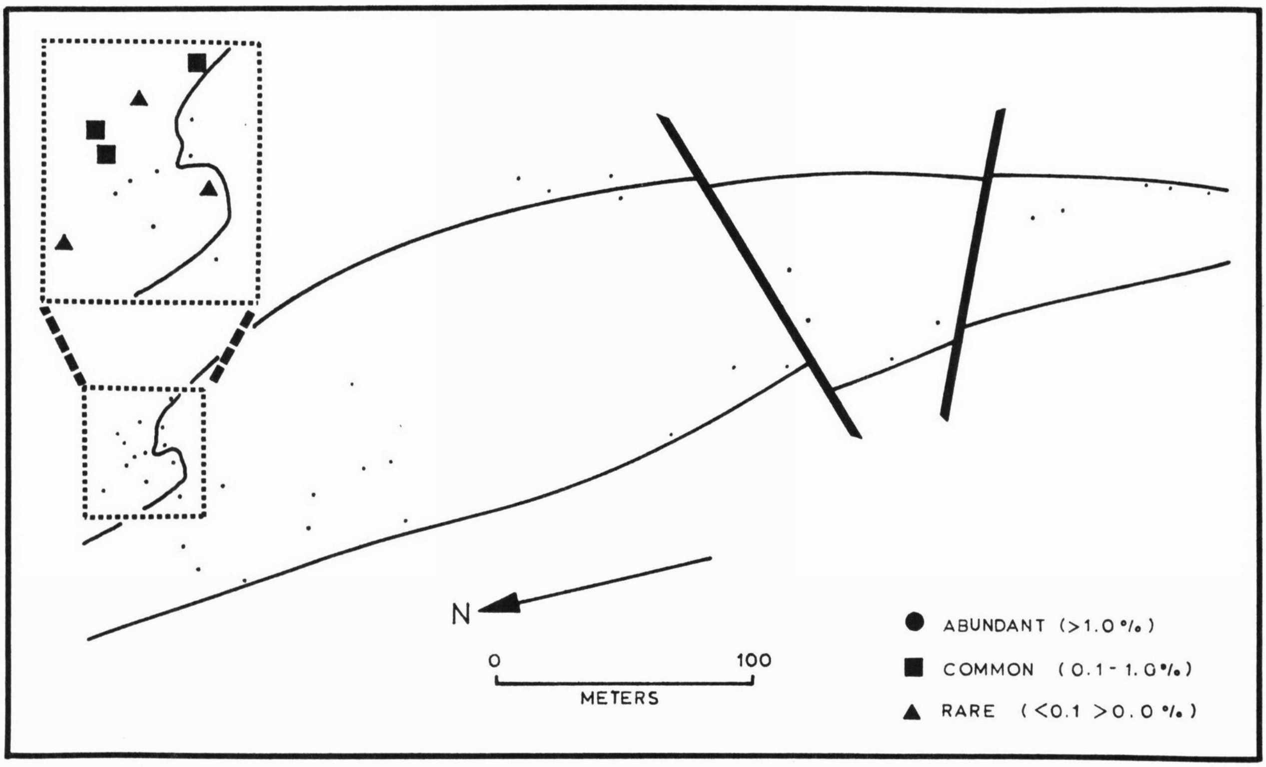

FIG. 7. Distribution of brachial valves of *Lingulella bullata*.

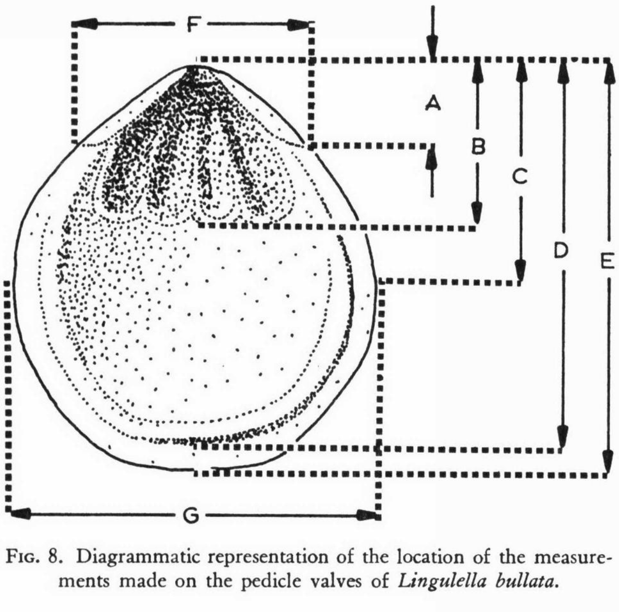

FIG. 8. Diagrammatic representation of the location of the measurements made on the pedicle valves of *Lingulella bullata*.

TABLE 2.—*Basic Statistics for Pedicle Valves of* Lingulella bullata *from Locality 71/35.* [Dimensions in mm. Location of measurements as in Fig. 8.]

VECTOR OF MEANS

A	B	C	D	E	F	G
0.24	0.46	0.65	1.05	1.14	0.61	1.11

VARIANCE—COVARIANCE MATRIX

A	0.0022						
B	0.0006	0.0023					
C	0.0008	0.0016	0.0035				
D	0.0012	0.0015	0.0023	0.0067			
E	0.0009	0.0026	0.0041	0.0042	0.0066		
F	0.0028	0.0029	0.0029	0.0032	0.0043	0.0088	
G	0.0011	0.0032	0.0045	0.0059	0.0070	0.0049	0.0101
	A	B	C	D	E	F	G

MATRIX OF SAMPLE SIZES

A	24						
B	24	24					
C	23	23	23				
D	21	21	21	21			
E	23	23	22	20	23		
F	24	24	23	21	23	24	
G	24	24	23	21	23	24	24
	A	B	C	D	E	F	G

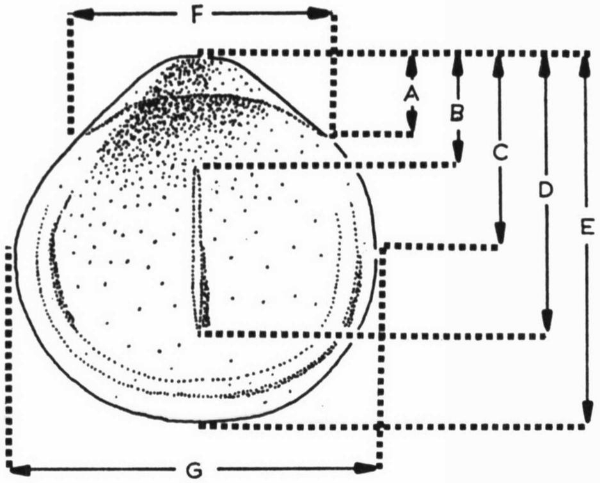

FIG. 9. Diagrammatic representation of the location of the measurements made on the brachial valves of *Lingulella bullata*.

TABLE 3.—*Basic Statistics for Brachial Valves of* Lingulella bullata *from Locality 71/35.* [Measurements in mm. Location of measurements as in Fig. 9.]

VECTOR OF MEANS

A	B	C	D	E	F	G
0.22	0.44	0.62	0.78	1.11	0.69	1.11

VARIANCE—COVARIANCE MATRIX

A	0.0031						
B	0.0032	0.0058					
C	0.0018	0.0026	0.0037				
D	0.0026	0.0026	0.0037	0.0063			
E	0.0021	0.0034	0.0042	0.0059	0.0081		
F	0.0042	0.0044	0.0036	0.0048	0.0052	0.0089	
G	0.0009	0.0016	0.0026	0.0031	0.0053	0.0036	0.0051
	A	B	C	D	E	F	G

MATRIX OF SAMPLE SIZES

A	17						
B	13	13					
C	17	13	17				
D	14	13	14	14			
E	17	13	17	14	17		
F	17	13	17	14	17	17	
G	17	13	17	14	17	17	17
	A	B	C	D	E	F	G

LINGULELLA AMPHORA Krause & Rowell, new species

Plate 1, figures 11-18

Diagnosis.—Characters of *Lingulella* with minute, dorsibiconvex shells and semioval-subpentagonal transverse outline, sharply tapered anteriorly and posteriorly.

Description.—Maximum width occurring at or slightly posterior to midlength of valve. Brachial valve inflated, convex. Posterior pointed with sharply rounded tip, margins subtending anteriorly an angle between 80 and 100 degrees; anterior margin pointed and sharply rounded, but less pointed than posterior margin; lateral margins rounded. Dorsal interior with distinct triangular and thickened propareas at either side of depressed concave median plate with frontal margin convex anteriorly. Valve floor traversed with very fine radiating ridges anterior to midlength of valve. Very narrow, low submarginal ridge anteriorly and laterally.

Pedicle valve convex. Posterior pointed, margins subtending anteriorly an angle between 80 and 100 degrees and projecting posterior of dorsal margin in complete shells. Ventral posterior more pointed than dorsal posterior. Ventral pseudointerarea narrow and distinct with front margin concave anteriorly; broad, triangular pedicle groove separates narrow triangular propareas. Valve floor anterior to midlength of valve traversed with fine radiating ridges. Very narrow, low submarginal ridge follows anterior and lateral margins.

Ornament of very fine growth lines.

Discussion.—*Lingulella amphora* from the Meiklejohn carbonate mud mound greatly resembles *Lingulella* sp. 1 from the Portrane Limestone of Eire (Wright, 1963, p. 230). The shells are similar to each other, 1) in outline; 2) in having strongly tapered posterior margins, and 3) in the outline of the dorsal pseudointerarea. The only detectable differences between these two species appear to be: 1) the more distinct ornamentation of *Lingulella* sp. 1 from the Portrane Limestone, and 2) the smaller size of the Meiklejohn species. Measurements of *L. amphora* are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Holotype	Complete specimen	KU 79823	1.08	0.88 (brachial)
			1.10	0.88 (pedicle)
Figured paratypes	Brachial valve	KU 79824	1.24	0.94
	Pedicle valve	KU 79825	1.20	0.90
	Pedicle valve	KU 79830	1.60	1.20

Distribution.—*Lingulella amphora* has been recorded at Localities 71/4, 71/6, 71/7, 71/14, 71/15, 71/29, 71/30, 71/31, 71/32, 71/33, 71/34 and 71/35 (Fig. 10).

Descriptive statistics.—Statistics are summarized in Figures 11 and 12, and in Tables 4 and 5.

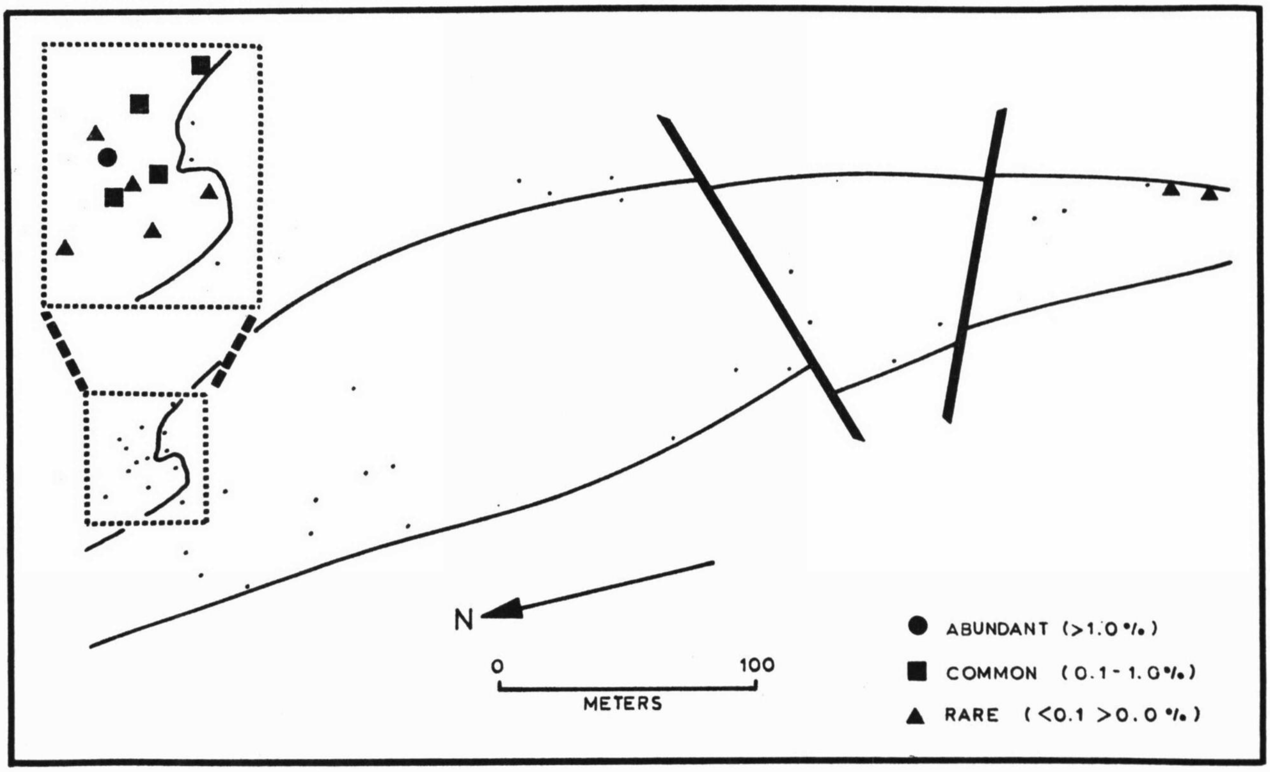

Fig. 10. Distribution of brachial valves of *Lingulella amphora*.

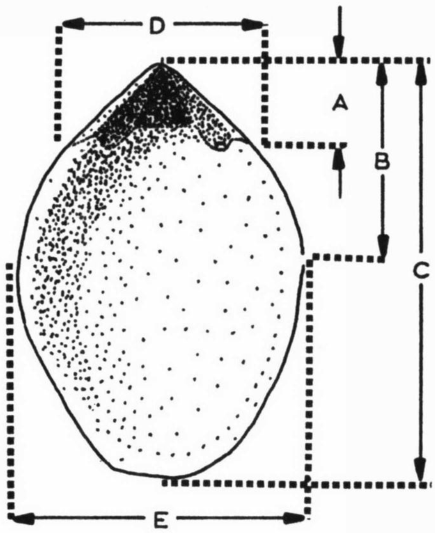

Fig. 11. Diagrammatic representation of the location of the measurements made on the pedicle valves of *Lingulella amphora*.

Table 4.—*Basic Statistics for Pedicle Valves of* Lingulella amphora *from Locality 71/35.* [Dimensions in mm. Location of measurements as in Fig. 11.]

Vector of Means

A	B	C	D	E
0.19	0.50	1.08	0.46	0.83

VARIANCE—COVARIANCE MATRIX

A	0.0024				
B	0.0014	0.0021			
C	0.0032	0.0039	0.0102		
D	0.0039	0.0031	0.0070	0.0088	
E	0.0021	0.0026	0.0069	0.0053	0.0052
	A	B	C	D	E

MATRIX OF SAMPLE SIZES

A	25				
B	25	25			
C	25	25	25		
D	25	25	25	25	
E	25	25	25	25	25
	A	B	C	D	E

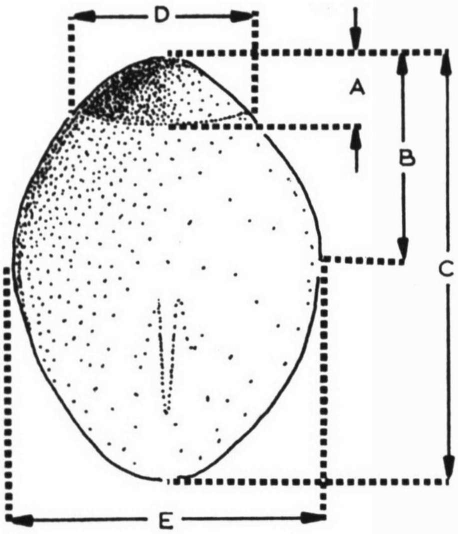

FIG. 12. Diagrammatic representation of the location of the measurements made on the brachial valves of *Lingulella amphora.*

TABLE 5.—*Basic Statistics for Brachial Valves of* Lingulella amphora *from Locality 71/35.* [Dimensions in mm. Location of measurements as in Fig. 12.]

VECTOR OF MEANS

A	B	C	D	E
0.14	0.50	1.08	0.25	0.86

VARIANCE—COVARIANCE MATRIX

	A	B	C	D	E
A	0.0005				
B	0.0002	0.0010			
C	0.0007	0.0012	0.0033		
D	0.0001	0.0001	0.0002	0.0019	
E	0.0002	0.0008	0.0016	0.0001	0.0015
	A	B	C	D	E

MATRIX OF SAMPLE SIZES

	A	B	C	D	E
A	24				
B	24	25			
C	24	25	25		
D	24	24	24	24	
E	24	25	25	24	25
	A	B	C	D	E

LINGULELLA sp.

Plate 1, figures 19-22; Plate 2, figures 1-4

Diagnosis.—Lingulella with elongate oval outline and subdued, irregular reticulate ornament. Brachial interior with low median ridge.

Description.—Posterior margin variably pointed, margins subtending anteriorly an angle between 70 and 100 degrees. Maximum width occurring anterior to mid-length of shell.

Brachial valve gently convex. Anterior and lateral margins rounded, posterior margin more sharply so. Dorsal pseudointerarea broad, crescentic in outline, divided medially by depressed median plate. Subdued elongate median ridge commonly present, arising approximately 0.2 mm anterior of pseudointerarea and extending to within one-third of valve length from anterior margin. Valve floor posteriorly bearing numerous shallow pits.

Pedicle valve convex. Anterior and lateral margins rounded, posterior margin pointed. Front margin of ventral pseudointerarea "v"-shaped; pedicle groove triangular; propareas triangular, divided by flexure lines. Valve floor posteriorly bearing numerous shallow pits.

Ornament of fine growth lines with variable, superimposed and subdued, narrow, irregular, radiating ridges that produce reticulate effect.

Discussion.—Lingulella sp. resembles most closely *L. lirata* Cooper from the Pratt Ferry Formation of Alabama. However, some differences between these two species are apparent: 1) the shell of *L.* sp. possesses a subdued reticulate ornament that appears to be absent in *L. lirata*; 2) the shell of the Meiklejohn species is seemingly thinner; 3) the ventral pseudointerarea of *L.* sp. appears to be narrower than that of the Pratt Ferry species. Measurements of *L.* sp. are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Figured specimens	Brachial valve	KU 79826	2.96	2.16
	Brachial valve	KU 79827	2.16	1.72
	Incomplete pedicle valve	KU 79828	......	......
	Incomplete pedicle valve	KU 79829	......	......

Distribution.—Lingulella sp. has been recorded at Localities 71/4, 71/5, 71/6, 71/8, 71/9, 71/10, 71/12, 71/14, 71/15, 71/16, 71/17, 71/20, 71/23, 71/25, 71/26, 71/28, 71/29, 71/30, 71/31, 71/32, 71/33, 71/34, 71/35 and 71/36 (Fig. 13).

Descriptive statistics.—Statistics are recorded in Figures 14 and 15, and in Tables 6 and 7.

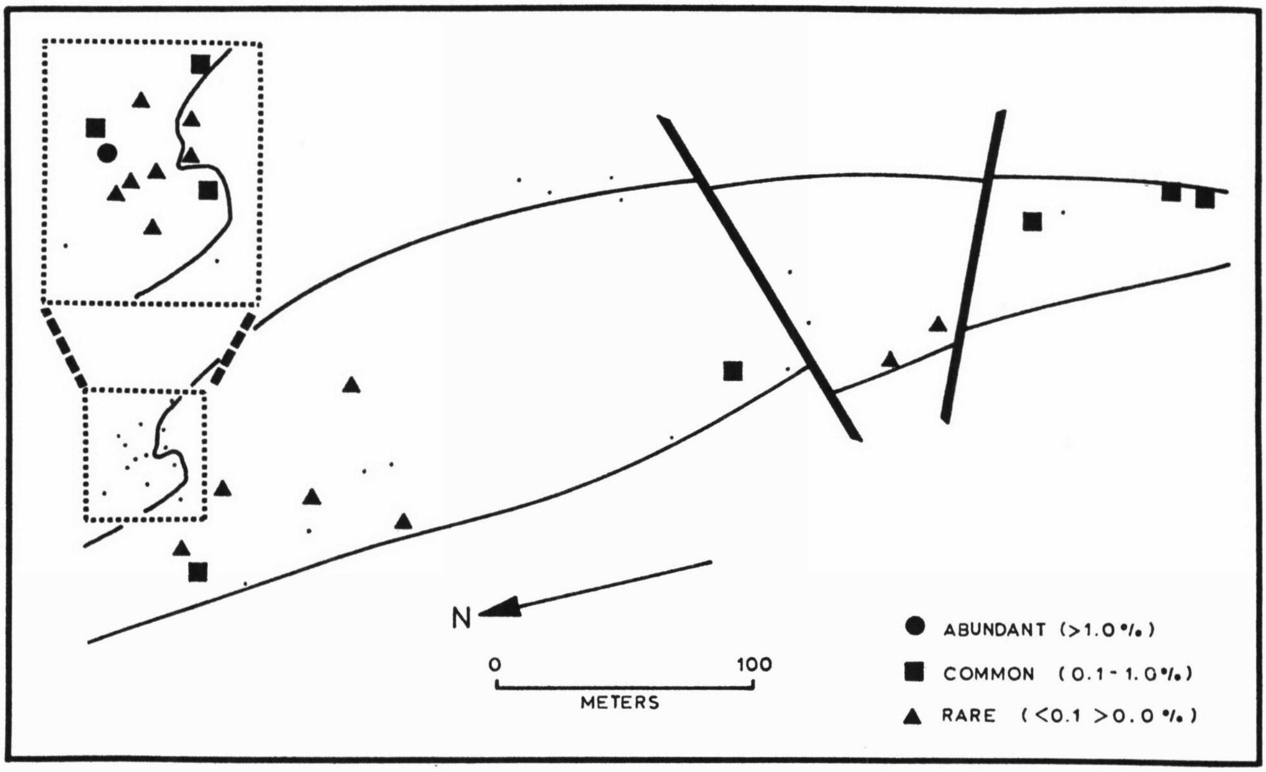

FIG. 13. Distribution of brachial valves of *Lingulella* sp.

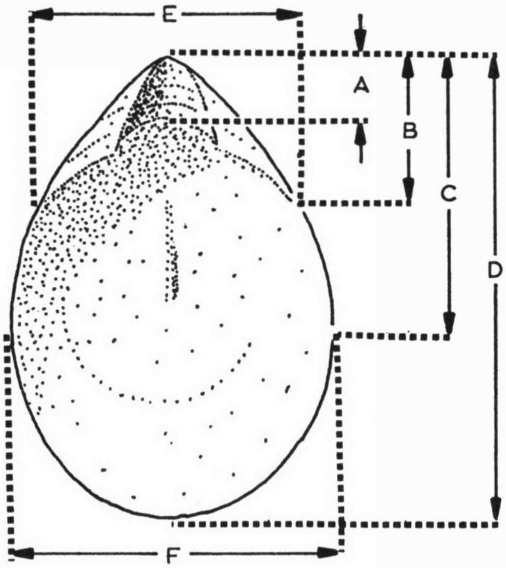

FIG. 14. Diagrammatic representation of the location of the measurements made on the pedicle valves of *Lingulella* sp.

TABLE 6.—*Basic Statistics of Pedicle Valves of* Lingulella *sp. from Locality 71/35.* [Measurements in mm. Location of measurements as in Fig. 14.]

VECTOR OF MEANS

A	B	C	D	E	F
0.25	0.44	1.21	2.13	0.92	1.54

VARIANCE—COVARIANCE MATRIX

	A	B	C	D	E	F
A	0.0058					
B	0.0067	0.0099				
C	0.0158	0.0224	0.0581			
D	0.0287	0.0415	0.1018	0.1919		
E	0.0112	0.0161	0.0406	0.0753	0.0309	
F	0.0181	0.0262	0.0685	0.1256	0.0502	0.0874

MATRIX OF SAMPLE SIZES

	A	B	C	D	E	F
A	14					
B	14	14				
C	14	14	14			
D	14	14	14	14		
E	14	14	14	14	14	
F	14	14	14	14	14	14

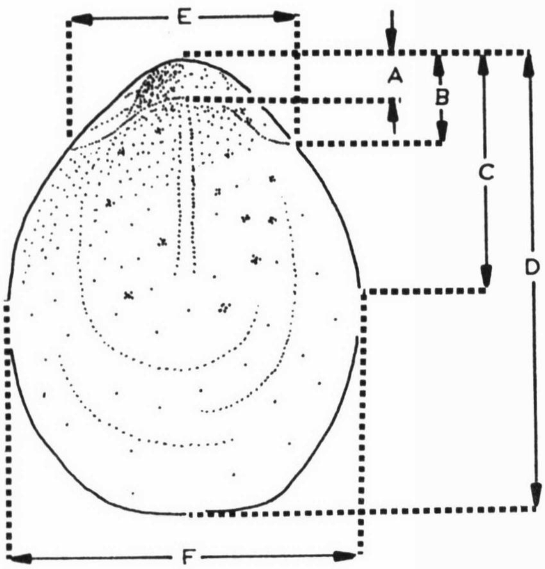

FIG. 15. Diagrammatic representation of the location of the measurements made on the brachial valves of *Lingulella* sp.

TABLE 7.—*Basic Statistics of Brachial Valves of* Lingulella *sp. from Locality 71/35.* [Measurements in mm. Location of measurements as in Fig. 15.]

VECTOR OF MEANS

A	B	C	D	E	F
0.18	0.35	1.05	1.96	0.90	1.49

VARIANCE—COVARIANCE MATRIX

A	0.0027					
B	0.0045	0.0092				
C	0.0087	0.0164	0.0411			
D	0.0162	0.0332	0.0718	0.1387		
E	0.0072	0.0152	0.0303	0.0622	0.0301	
F	0.0105	0.0217	0.0465	0.0908	0.0415	0.0649
	A	B	C	D	E	F

MATRIX OF SAMPLE SIZES

A	16					
B	16	16				
C	16	16	16			
D	16	16	16	16		
E	16	16	16	16	16	
F	16	16	16	16	16	16
	A	B	C	D	E	F

Genus SPINILINGULA Cooper, 1956

Cooper's (1956, p. 210) description of the genus is followed here.

SPINILINGULA BRACTEATA Krause & Rowell, new species

Plate 2, figures 5-12; Plate 12, figure 4

Diagnosis.—Characters of *Spinilingula* with ornament of concentric lamellae and short prone spines bearing distinct ribs. Frontal margin of dorsal pseudointerarea convex anteriorly.

Description.—Thin-shelled, dorsibiconvex, transverse outline subcircular or suboval. Length of brachial valve 10 to 20 percent greater than width, length of pedicle valve 10 to 20 percent greater than width, maximum width occurring commonly in front of midlength of shell.

Posterior dorsal margin typically rounded, interrupted medially by projecting dorsal umbo. Umbo framed by flattened posterolateral flanks. Posterior margin subtending anteriorly an angle varying between 120 and 130 degrees. Anteromedian sector of the brachial valve generally flat, rarely slightly sulcate; in anterior profile rectangularly shaped with curved, short, and moderately steep lateral slopes. Dorsal pseudointerarea concave, with growth lamellae increasing in size anteriorly, frontal margin typically anteriorly convex, less commonly quadrate in shape. Dorsal mantle canal pattern bacculate, rarely observable.

Posterior ventral margin acute, rounded and subtending an angle of 90 degrees anteriorly, posterolateral margins rectilinear, margins gently rounded anterolaterally, with rounded or subquadrate anterior margin. Triangular ventral pseudointerarea prominent, propareas separated by large and distinct pedicle groove widening anteriorly, slightly indented with respect to propareas. Propareas free except at shell margin, with gentle undulation marginally.

Ornament of concentric lamellae, free margins of lamellae spinose; spines formed by externally convex undulations of lamella, which extend in advance of the adjacent free margins of the lamella; consequently, spines continued across lamellae as narrow ribs. Posteriorly and laterally spines gently curved, pointing anteriorly and arranged in radiating and branching rows. Specimens with margins intact show a serrated edge.

Discussion.—*Spinilingula bracteata* differs from *S. intralamellata* Cooper, the type species, in several details; generally it appears to be rounder in shape, the posterior margin is less acute, in the interior the dorsal pseudointerarea is convex anteriorly, and the ventral pseudointerarea is broad. There is also a conspicuous difference in ornament; the spines of *S. bracteata* are continued across the associated lamellae as fine ribs.

Three columnar markings are sometimes visible anterior to the ventral pseudointerarea of *S. bracteata,* a larger middle one in line with the pedicle groove and bounded laterally by two smaller ones. These markings widen anteriorly and are bilaterally symmetrical. At both sides of the larger markings are a pair of elongate pits;

these may have served as muscle attachment bases. It is possible that the lateral markings are traces of the vascula lateralia, and the central depression marks the outline of the body cavity. However, better-preserved material is needed to be confident of this interpretation.

Young specimens of *S. bracteata* are much rounder and more convex than adults. The brachial valve at this early stage appears to have a thin brim posterior to the umbo.

Spinilingula has been recorded previously only in North America and only from the Pratt Ferry Formation of Alabama. Measurements of *S. bracteata* are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Holotype	Brachial valve	KU 79727	2.36	1.92
Figured paratypes	Brachial valve	KU 79726	3.4	......
	Pedicle valve	KU 79728	2.08	1.60
	Brachial valve	KU 79729	......	......
	Brachial valve	KU 89794	......	......

Distribution.—Recorded from Localities 71/7, 71/29 and 71/30 (Fig. 16).

Descriptive statistics.—Statistics are summarized in Figures 17 and 18, and in Tables 8 and 9.

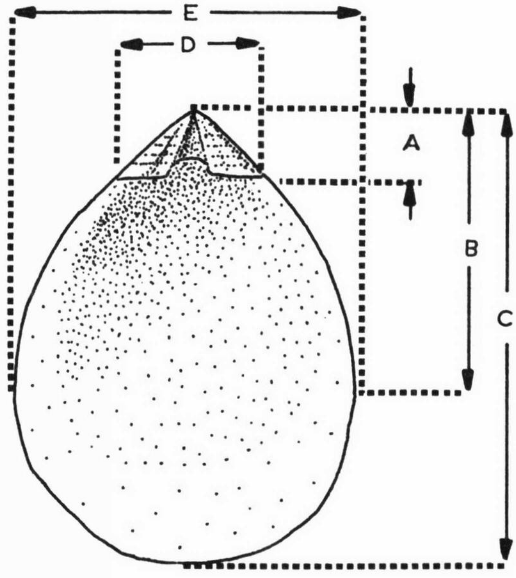

FIG. 17. Diagrammatic representation of the location of the measurements made on the pedicle valves of *Spinilingula bracteata.*

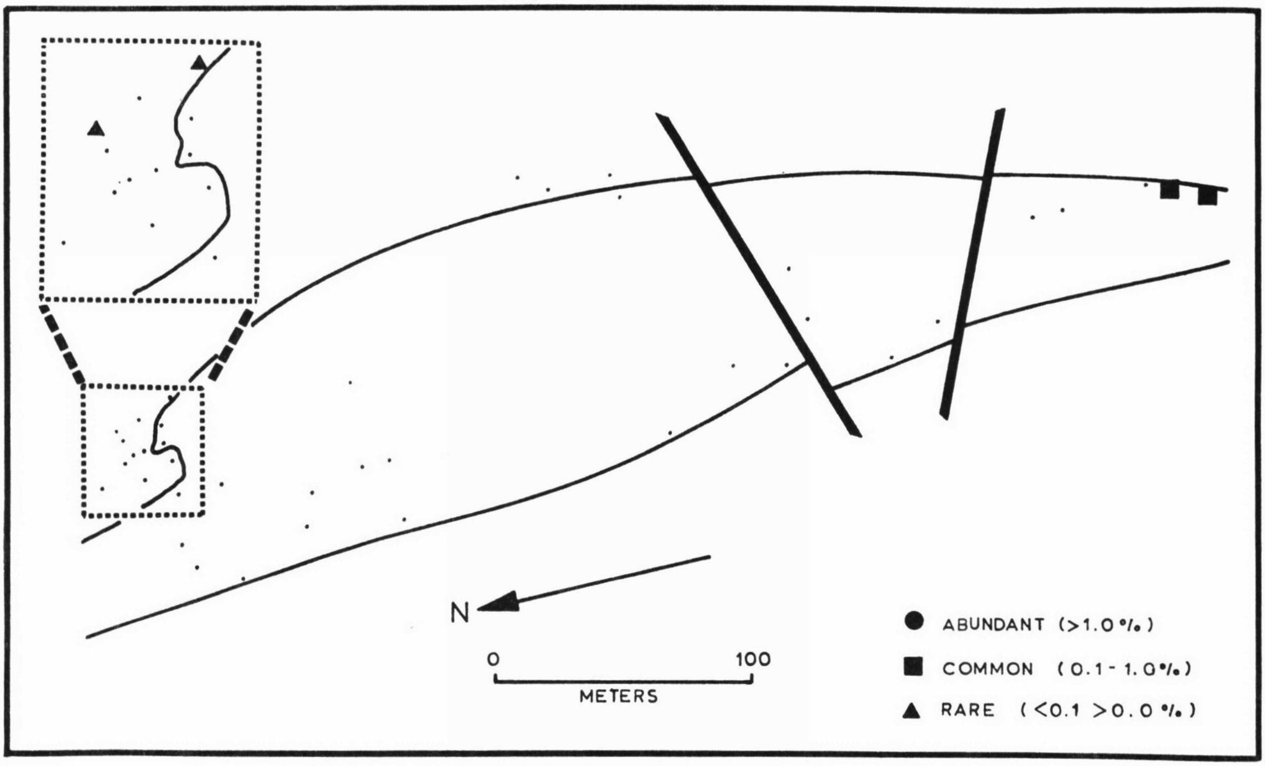

FIG. 16. Distribution of brachial valves of *Spinilingula bracteata.*

TABLE 8.—*Basic Statistics of Pedicle Valves of* Spinilingula bracteata *from Localities 71/29 and 71/30.* [Measurements in mm. Location of measurements as in Fig. 17.]

VECTOR OF MEANS

A	B	C	D	E
0.20	0.91	1.55	0.42	1.23

VARIANCE—COVARIANCE MATRIX

	A	B	C	D	E
A	0.0036				
B	0.0152	0.0828			
C	0.0267	0.1442	0.2561		
D	0.0069	0.0259	0.0469	0.0151	
E	0.0196	0.1051	0.1864	0.0352	0.1376

MATRIX OF SAMPLE SIZES

	A	B	C	D	E
A	8				
B	8	8			
C	8	8	8		
D	8	8	8	8	
E	8	8	8	8	8

TABLE 9.—*Basic Statistics of Brachial Valves of* Spinilingula bracteata *from Localities 71/29 and 71/30.* [Measurements in mm. Location of measurements as in Fig. 18.]

VECTOR OF MEANS

A	B	C	D	E
0.15	0.88	1.57	0.48	1.29

VARIANCE—COVARIANCE MATRIX

	A	B	C	D	E
A	0.0099				
B	0.0395	0.1664			
C	0.0733	0.3044	0.5701		
D	0.0169	0.0704	0.1307	0.0312	
E	0.0500	0.2082	0.3880	0.0878	0.2667

MATRIX OF SAMPLE SIZES

	A	B	C	D	E
A	10				
B	10	10			
C	10	10	10		
D	10	10	10	10	
E	10	10	10	10	10

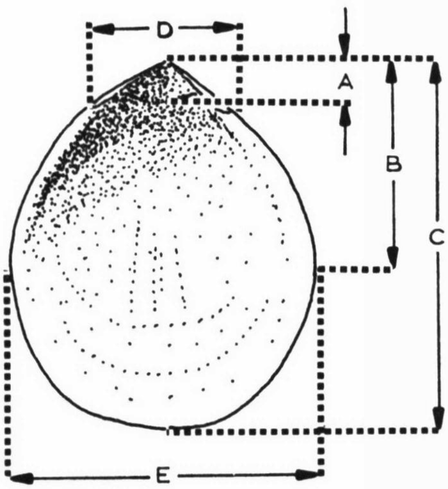

FIG. 18. Diagrammatic representation of the location of the measurements made on the brachial valves of *Spinilingula bracteata.*

Genus ROWELLELLA Wright, 1963

Diagnosis.—Dorsibiconvex, elongate, subrectangular to suboval shells with minute, marginal beaks.

Brachial valve geniculated laterally and deflected or geniculated anteriorly. Valve anterior thicker than posterior, sometimes with wide lip along anterior margin. Crescentic dorsal pseudointerarea, marginal propareas separated by abrupt flexure from wide median plate.

Pedicle valve gently convex in anterior profile, anterior slightly concave in longitudinal profile. Pseudointerarea with wide and shallow pedicle groove.

Ornament of fila, of lamellae only or of lamellae-bearing growth lines. Dorsal anterior typically more strongly ornamented than remainder of shell.

Discussion.—*Rowellella* is known to occur in North America, Ireland, Poland, Estonia, and Russia. The genus was initially named and described by Wright (1963, p. 233), who erected *R. minuta* for forms that he obtained from the Portrane Limestone of Ireland. Goryanskiy (1969, p. 48) proposed *R. rugosa* for material from the Volkhovian of the Leningrad District. More recently, Biernat (1973, p. 59) has described two unnamed forms from the Ordovician of Estonia and Poland.

Material from the Meiklejohn area has well-developed dorsal pseudointerareas with crescentic outline and medial plate. Wright (1963, p. 233) did not recognize a dorsal pseudointerarea in the type species but attributed its absence to the youth of the shells. Examination of the few complete dorsal valves of the new species *Rowellella margarita* from the Meiklejohn mud mound indicates that Wright was probably correct in this assessment. Small dorsal valves of *R. margarita* lack a well-developed pseudointerarea; at this stage, they possess a thin, indistinct band following the outline of the posterior margin, with no indication of the medial plate characteristic of the adult stage.

When Wright assigned *Rowellella* to the Glossellinae he did so because of the lack of a distinct dorsal pseudointerarea and added a word of caution regarding the probable youth of the shell. Comparisons with type material are not possible at the present time, but it is felt that the specimens collected from the Meiklejohn Peak area leave little doubt as to their identity. Since *R. margarita* and *R.* sp. have well-developed dorsal pseudointerareas, reassignment to the Lingulellinae rather than the Glossellinae appears necessary.

ROWELLELLA MARGARITA Krause & Rowell, new species

Plate 3, figures 8-15

Diagnosis.—Characteristics of *Rowellella* with elongate suboval outline. Ornament of lamellae with growth lines, lamellae more conspicuous anteriorly. Pedicle valve interior with low and wide lip along anterior margin.

Description.—Shell dorsibiconvex, elongate suboval outline, length 30 to 40 percent greater than width, maximum width occurring anteriorly to midlength of valve. Commissure with strong anteroventral deflection.

Brachial valve with rounded anterior and posterior margins, lateral margins subparallel. Valve anterior deflected ventrally, sometimes geniculated; laterally geniculated ventrally and subsequently marginally flattened. Shell thickest anteriorly. Dorsal pseudointerarea a striated crescentic plate; small, marginal propareas separated by wide, depressed median plate; lateral margins of plate defined by abrupt flexure of shell, front margin concave anteriorly. Shallow umbonal cavity formed by the partially overhanging median plate. Posterior margin of pseudointerarea interrupted medially by small pointed beak. Valve interior commonly with deep imprint of body cavity; anteriorly, cavity divided by broad medial ridge. Vascula media probably represented by pair of shallow grooves emanating from anterior of body cavity; vascula terminalia present as many fine, light grooves normal to anterior margin; a pair of elongate grooves posterolaterally probably represent vascula lateralia.

Pedicle valve with rounded anterior margin, lateral margins subparallel and widening anteriorly; anteriorly concave in lateral profile. Ventral pseudointerarea distinct, but incompletely preserved; pedicle groove wide and shallow, cemented to valve interior and extending anteriorly beyond propareas. Umbonal cavities present beneath propareas. Anterior margin with broad, low lip, traversed by fine, light grooves, which probably represent vascula terminalia. Pedicle valve thinner than brachial, particularly anteriorly.

Ornament of lamellae with growth lines, lamellae low and not distinguishable from growth lines along middle and posterior portions of shell; anterior of both valves lamellose, but brachial valve more strongly so. Anteriorly, lamellae appear to be stacked in a stepwise fashion and their frontal margins are commonly scalloped. Subdued radiating ridges may be present, particularly on lateral flanks of shell.

Discussion.—The pedicle valve of *Rowellella margarita* is less abundant in this collection than the brachial valve. Although brachial valves are common, only one partially complete pedicle valve and a few fragments of the anterior have been recovered from the etched material. Wright (1963, p. 233) also noted a similar anomaly with the type species. He speculated that the absence of pedicle valves may be due to the difference in thickness between the two valves. One might anticipate that the thin pedicle valve will not stand up as well to the postmortem-preburial rigors as will the thicker brachial valve. As expected, the most commonly recovered fragment is the thickest portion of the shell. Other mechanisms can, of course, be envisioned to account for the relative absence of pedicle valves.

Muscle-scar patterns in fossil lingulides are notoriously difficult to interpret. Only rarely in thick-shelled forms (e.g., *Obolus apollinis,* [Walcott, 1912, p. 374]) is it possible to unequivocally relate muscle scars to the known muscles of living lingulides. Commonly the scars are poorly developed and their location makes it difficult to confidently accept that they are of muscular origin. This is the situation in *R. margarita,* so it is difficult to be dogmatic about the origin of any of these impressions. The narrow anterior extension of the body cavity is common to most lingulides and one would anticipate, by analogy with living representatives of the order, that the anterior scars represent the dorsal attachment of anterior lateral muscles. Likewise, the two large scars at the posterior end of this extension of the coelom were presumably formed by differential secretion of the tissue underlying the central muscle scars (the homologues of the anterior adductors of most other inarticulate brachiopods). The remaining pits, anteromedially located, cannot be equated with any muscles known in living lingulids. The posterolateral scars are in the position that one would expect to find the transmedian, middle, and outside lateral muscles. In living lingulids these are inserted contiguously and form a composite scar; in *O. apollinis* the transmedian muscles produce separate scars located posteromedianly from the composite scar formed by the remaining pair. The available material of *R. margarita* does not show sufficient detail to enable one to decide whether this species is more like *Obolus* or living *Lingula,* or whether, indeed, it differs from both these taxa.

The posteromedian scar located in front of the dorsal pseudointerarea is thought to represent the seat of attachment of the umbonal muscle.

Preservation of scars in the pedicle valve is so poor that nothing can profitably be said about them.

Rowellella margarita differs from *R. minuta* in its outline, which is elongate suboval rather than subrectangular; the ornamentation of the former species consists of lamellae with growth lines. Its pedicle valve interior has a low anterior lip that has not been recognized in the type species. Measurements of *R. margarita* are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Holotype	Brachial valve	KU 79745	2.10	1.36
Figured paratypes	Brachial valve	KU 79746	2.14	1.24
	Pedicle valve	KU 79747	......	1.06

Distribution.—Recorded at Localities 71/1, 71/4, 71/5, 71/6, 71/7, 71/8, 71/10, 71/11, 71/12, 71/13, 71/14, 71/15, 71/18, 71/19, 71/20, 71/22, 71/23, 71/25, 71/26, 71/28, 71/29, 71/30, 71/35, 71/36 and 71/108(?) (Fig. 19).

The material is typically too fragmentary to justify biometric treatment.

ROWELLELLA sp.

Plate 3, figures 6, 7

Diagnosis.—Characters of *Rowellella* ornamented with subdued lamellae and very fine and distinct growth lines. Thick-shelled. Commonly has internal anterior margin with a fat lip.

Description.—Brachial valve with parallel to subparallel lateral margins, rounded posterior and anterior margins. Length 40 to 50 percent greater than width. Valve posterior with extremely low and rounded beak. Internally, valve anterior and lateral margins geniculated, margin thicker anteriorly; brachial valve resembles a shallow bathtub with a fattened anterior lip. Dorsal pseudointerarea a striated, irregularly crescentic plate; marginal propareas separated by wide, triangular, shallow, concave median plate; anterior of median plate, valve floor bears irregularly distributed pits laterally and medially. Outline of body cavity distinct, divided in half by a thin, longitudinal ridge; each half in turn split into anterolateral and central fields by a low and thin, curved ridge.

Pedicle valve unknown.

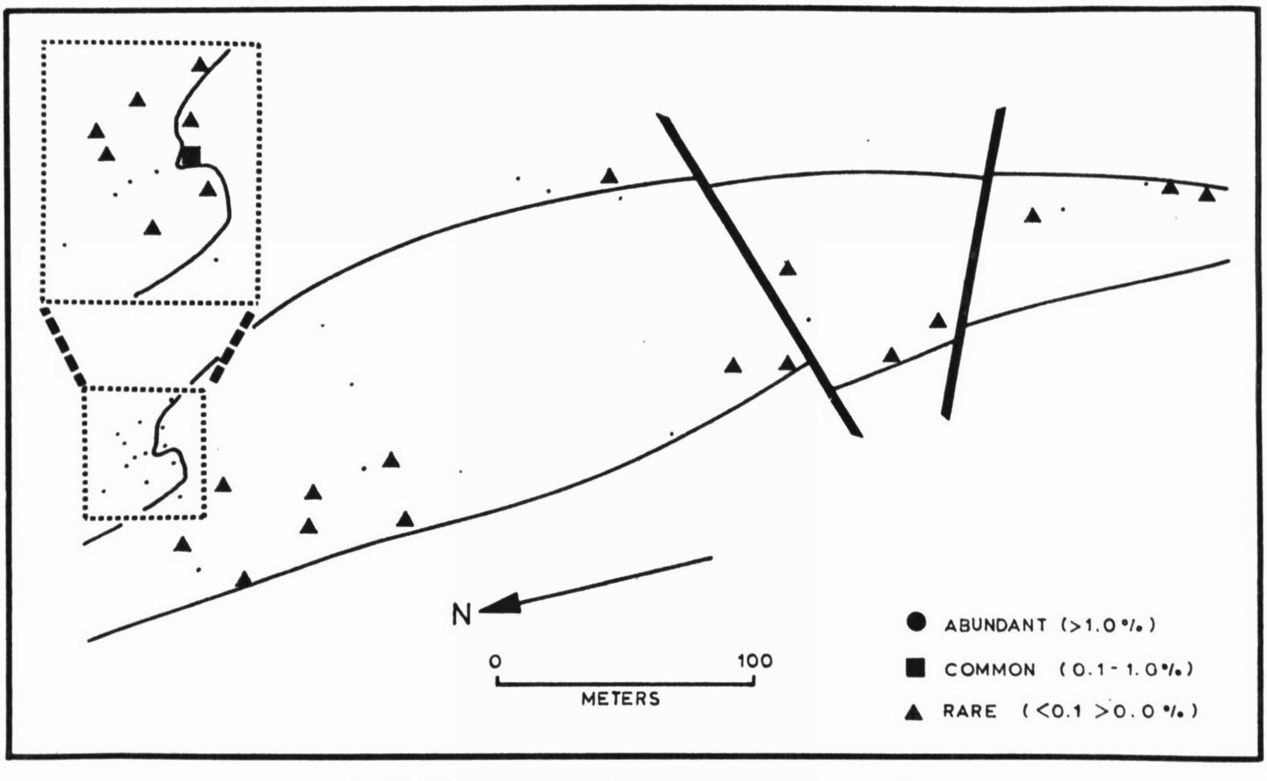

FIG. 19. Distribution of brachial valves of *Rowellella margarita*.

Ornament of subdued concentric lamellae with fine continuous and distinct growth lines.

Discussion.—While only the brachial valve is known, the valve is distinct and can be recognized from other species in the genus. *Rowellella* sp. superficially resembles the type species in having a similar broadly rectangular outline. Otherwise it is much larger than *R. minuta* and has lamellae with fine, continuous growth lines instead of lamellae only as in the type species. It is possible that *R.* sp. is conspecific with *R.* sp. 1 and *R.* sp. 2 of Biernat (1973), but the material is inadequate to be dogmatic about this relationship. *R.* sp. is easily distinguished from *R. margarita,* also found on the Meiklejohn mud mound. The former taxon is broadly rectangular and, although larger and thicker shelled, is ornamented predominantly by fine growth lines rather than by pronounced lamellae. In addition, *R.* sp. lacks the anteroventrally flexed commissural plane found in *R. margarita,* but possesses a distinct and fattened anterior lip.

As has been previously noted for other species, the dorsal anterior is the most commonly found shell fragment of *Rowellella* sp. Measurements of *R.* sp. are recorded below.

Specimen	Valve	Coll. No.	Length (mm)	Width (mm)
Figured specimen	Brachial valve	KU 79742	......	1.68

Distribution.—Recorded at Localities 71/5, 71/7, 71/9, 71/10 and 71/20 (Fig. 20). The material is inadequate for biometric treatment.

Subfamily GLOSSELLINAE Cooper, 1956

Diagnosis.—Elongate obolids, posterior margin of brachial valve thickened, platelike pseudointerarea absent.

Genus GLOSSELLA Cooper, 1956

The description of the genus by Cooper (1956, p. 228) is followed herein.

GLOSSELLA LIVIDA Krause & Rowell, new species

Plate 2, figures 13-19; Plate 12, figure 6

Diagnosis.—Characters of *Glossella* with ornament of granules along midsection and lateral portions of valve, granules absent anteromedially.

Description.—Shell elongate oval, dorsibiconvex, length 35 to 60 percent greater than width, maximum width anterior to midlength. Lateral shell margins subparallel, widening anteriorly. Anterior margin variable, circular to ellipsoidal.

Posterior dorsal margin strongly rounded. Valve narrowly convex in posterior profile, broadly convex in longitudinal profile, with greatest convexity posterior to

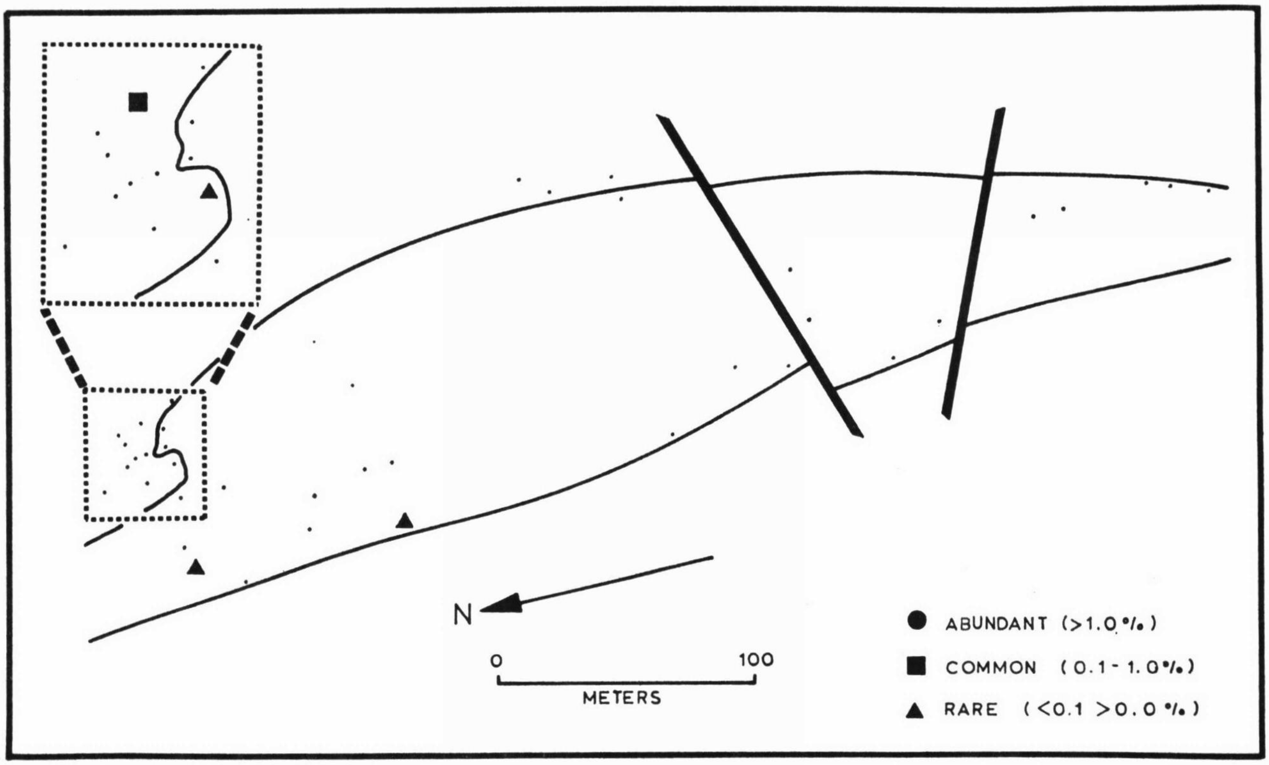

FIG. 20. Distribution of brachial valves of *Rowellella* sp.

midlength. Umbo strongly curved, bounded posterolaterally by two drumlinlike ridges, which are also reflected on the internal surface of valve; typical obolid pseudointerarea absent, slightly thickened catacline posterior margin.

Pedicle valve strongly convex in posterior profile, broadly convex in longitudinal profile, maximum convexity occurring posterior to midlength. Valve posterior more pointed than brachial valve. Ventral pseudointerarea with deep pedicle groove separating triangular propareas bearing elevated flexure lines. Pedicle groove bluntly pointed anteriorly and extending in front of the propareas, supported by cardinal buttress separating two umbonal cavities, cavities large and deep. Propareas in contact laterally with angled and geniculated projections of posterior shell margin. Body cavity outline visible in some valves, accompanied by very fine striae extending to anterior margin.

Shell ornament consisting of small granules arranged in radial and concentric rows. Umbonal and anteromedial regions of both valves lacking granules, which typically develop anterior to first major growth wrinkle. Granules densely crowded on midsection of shell and spreading and increasing in size toward margins. On midsection of shell, granules small and rhomblike in outline, marginally becoming concentrically elongated, wedgelike mounds with steeper surface facing medially, mounds separated by rounded depression. Change in size and radial pattern of granules gradational. Shell surface also bearing concentric wrinkles and concentric growth lines.

Discussion.—Glossella livida appears to develop an infolded posterior margin during the later stages of its ontogeny. Young brachial valves seemingly have only a thin marginal brim along the dorsal posterior.

Cooper (1956, p. 228) indicated in the description of the genus that the ventral pseudointerarea has a shallow concave plate suspended between narrow propareas. This feature appears to be present in young pedicle valves of *Glossella livida,* but seemingly is modified in the one adult pedicle valve fragment in this collection. During growth, the concave pedicle groove becomes supported by a septum, which subsequently develops into a stout cardinal buttress, the buttress dividing the space beneath the pseudointerarea into two relatively large umbonal cavities. Lying within the pedicle groove is a small, medially located furrow, which is scarcely visible in the young stages, but readily observable in the largest specimen in the collection. This furrow conceivably marks the actual passage of the pedicle.

Glossella is a widely distributed genus, having been previously recorded in Alabama, Oklahoma, Virginia, Scotland, and Russia. Cooper (1956, p. 228) described *G. liumbona* from the Bromide Formation of Oklahoma, *G. papillosa* from the Pratt Ferry Formation of Alabama and recognized the genus in the Botetourt Formation of Virginia. Williams (1962, p. 85) has recognized it in the Girvan District of Scotland where *G. pulcherrima* was erected by Reed (1917, p. 809) on material from the Balclatchie and Ardwell mudstones. Goryanskiy has tentatively referred *G.? umbonata* from the Idaverian and Levian of the northwest Russian Platform to the genus.

The Meiklejohn *Glossella* most closely resembles other North American forms, but differs from *G. papillosa* in outline of shell, pseudointerarea, and details of microornament (cf. Pl. 12, fig. 3, 6). Externally it resembles *G. liumbona,* but differs from this species in generally lacking granules on its anterior region. Comparisons of interiors between *G. liumbona* and *G. livida* are prevented because they are unknown in the former species. Measurements of *G. livida* are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Holotype	Brachial valve	KU 79716	4.92	2.08
Figured paratypes	Pedicle valve	KU 79717	2.60	1.36
	Pedicle valve	KU 79718	......	......
	Pedicle valve	KU 79740	......	......
	Brachial valve	KU 89918	3.58	2.10

Distribution.—Recorded at Localities 71/6, 71/30, 71/35 and 71/36; two fragments with a *Glossella*-like ornament have been recorded at Localities 71/20 and 71/23 (Fig. 21). Material inadequate for biometric treatment.

Genus ECTENOGLOSSA Sinclair, 1945

The description of the genus by Cooper (1956, p. 217) is followed herein.

ECTENOGLOSSA ? sp.

Plate 3, figures 20-23

Several very large fragments belonging to an elongate lingulide were recovered as "crack out" material from the limestones flanking the bioherm. Much of the shell material has been lost to exfoliation while splitting, leaving mainly the impressed outline of the valve with exception of the dorsal and ventral posteriors, which are missing consistently. The valves appear to be elongate elliptical in transverse outline and have a broadly rounded anterior margin. The incomplete nature of the valves makes it very difficult to distinguish dorsum from venter. The largest fragment measuring about 4.8 cm in length and about 2.2 cm in width also possesses a median ridge running along the midlength of the valve and extending seemingly to about one-third the length

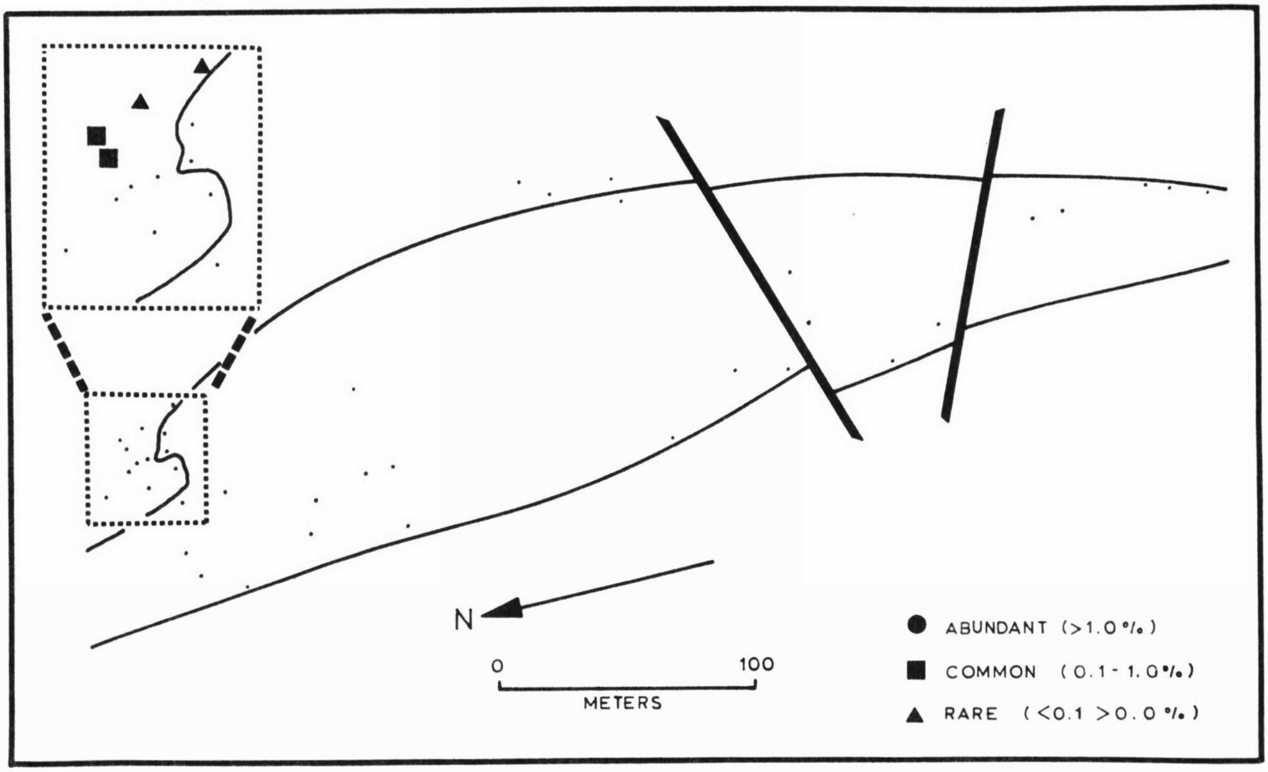

FIG. 21. Distribution of brachial valves of *Glossella livida*.

from the anterior and posterior margins. A median ridge has been described in the brachial valve of several Ordovician lingulides (e.g., *Paleoglossella, Lingulella,* and *Ectenoglossa*) (Cooper, 1956, p. 207, 218, 221), and it is assumed (but unproven) that these valves that have a median ridge are brachial valves.

The median ridge found on the (?)brachial valve, combined with the outline and size of the valves, suggests that the material belongs to the genus *Ectenoglossa.* Previously described species of *Ectenoglossa* rank among the largest known Paleozoic lingulaceans. Cooper (1956, p. 218) has reported dimensions of 5.21 cm in length and 2.53 cm in width for complete specimens of *E. nymphoidea,* and has noted even greater size for several fragments of the same species.

One immature pedicle valve of a lingulide seemingly belonging to *Ectenoglossa* has been recovered from the etchings. This valve measures about 0.6 cm in length and 0.33 cm in width. The lateral margins are almost parallel, the anterior margin is rounded and flattened medially and possibly sulcate, the posterior margin is pointed, the flanks subtending anteriorly an angle close to 60 degrees. The valve is convex in lateral and anterior profile, and the posterior slope is steeper than the anterior slope. Internally a pedicle groove is bounded by a pair of thin, elongate, triangular propareas that are elevated above the shell interior and are almost flush with the plane of commissure. The outline of the ventral body cavity is also visible and extends to about the midportion of the valve where it is bounded anteriorly by a very low and broad ridge shaped like an open "v" and pointing anteriorly.

Ornament consists of fine growth lines and steep undulations.

Ectenoglossa is known predominantly from North America, but has been recorded recently by Goryanskiy (1969, p. 42) from the northwestern Russian Platform. Measurements of *E.* sp. are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Figured specimens	(?)Brachial valve fragment	KU 79794	......	......
	Pedicle valve	KU 79795	6.04	2.52

Distribution.—This inarticulate has been recorded at Localities 71/31 and 71/35. Several fragments, probably belonging to this species, have also been recorded at Localities 71/4 and 71/25 (Fig. 22). Material inadequate for biometric treatment.

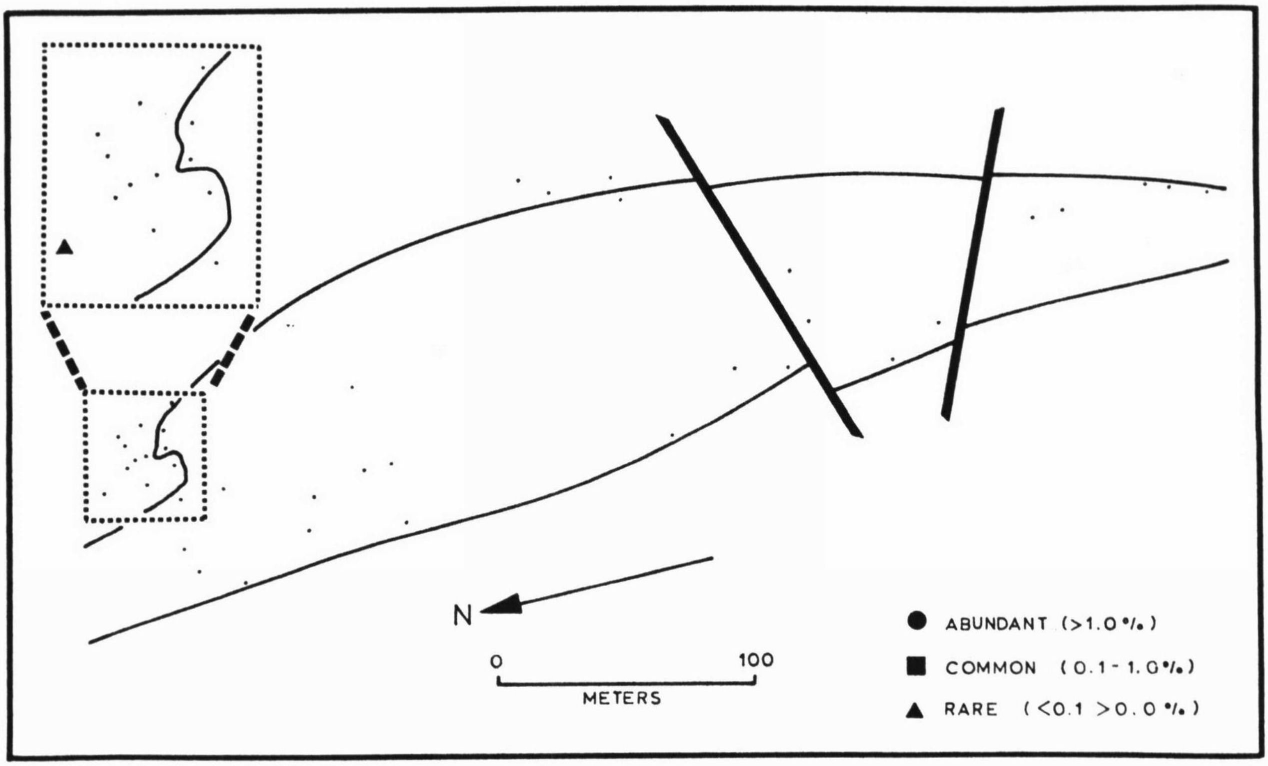

FIG. 22. Distribution of brachial valves of *Ectenoglossa?* sp.

Family OBOLIDAE King, 1846

Gen. et sp. indet.

Plate 3, figures 1-5

This species is seemingly restricted to the flanking beds of the Meiklejohn mound and is often found in the insoluble residues as complete shells. Free valves are also common, brachial valves being more abundant than pedicle valves in a ratio close to 8:1. In spite of being relatively abundant, two independent factors have caused severe problems in identifying the material; the internal surfaces of most valves are obscured by a dark (?)phosphatic mineralization and the posterior margins of both brachial and pedicle valves are relatively featureless. The shells are small, but although small lingulide species are known, the lack of pseudointerareas in both valves suggests that they may be immature stages of a larger form. If such is the case, we have been unable to recognize the adult shell.

We know of no species whose adults show close resemblance to the Meiklejohn material, nor of any described genus to which the forms may be readily referred. Probably the closest similarity is with *Leptobolus*, but there are a number of striking differences. *Leptobolus* (e.g., Cooper, 1956, p. 213) characteristically is thick-shelled; the Meiklejohn material possesses thin shells. The pedicle valve of *Leptobolus* has a well-developed pseudointerarea crossed by a pedicle groove, but these features are lacking in our material. Additionally, low ridges in both valves, comparable to those described for the genus, are seemingly missing in the Nevada material. Rather than risk the creation of a new taxon based on immature growth stages, we have not identified the material below the level of family.

The shells are dorsibiconvex and transversely oval to subcircular in outline, length being about 1 to 10 percent greater than width. The brachial valve is convex, with the maximum convexity occurring posterior to midlength of the valve. The posterior margin is short, with the flanks subtending an angle greater than 150 degrees, and is interrupted medially by a ventrally projecting beak. The cardinal extremities are flattened lateral of the swollen umbo. The dorsal anterior and lateral margins are rounded. Internal features preserved in a few clean valves suggest that a pseudointerarea is absent. Muscle scars seemingly are represented by two small elliptical mounds posterior to the midlength of the valve. Also recognized are a pair of faintly preserved, anteriorly diverging ridges that extend from a low, indistinct platform in the dorsal posterior and terminate against the two elliptical muscle scars. A narrow, flattened brim extends anteriorly from the cardinal extremities to slightly past the midlength of the valve.

The pedicle valve is convex, with the maximum convexity occurring at the midlength of the valve. The flanks of the posterior margin subtend anteriorly an angle greater than 150 degrees and the margin is divided medially by a low, short, and posteriorly blunted beak. The anterior and lateral margins are rounded. Internally, propareas are seemingly absent and an undefined and broad pedicle groove is developed. The majority of shells lack ornament and are basically smooth; more rarely, some individuals have faint growth lines peripherally.

One brachial valve was found that belongs to an individual seemingly older than the rest of the shells in the collection. This valve differs in that it is distinctly elongate oval and the ornament toward the anterior becomes lamellar. This valve in every other respect greatly resembles other brachial valves of this species. Measurements of these obolid valves are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Figured specimens	Brachial valve	KU 79815	1.36	1.08
	Pedicle valve	KU 79816	......	......
	Complete specimen	KU 79817	0.88	0.82

Distribution.—Recorded at Localities 71/4, 71/6, 71/31, 71/32, 71/33, 71/34, 71/35 and 71/36 (Fig. 23).

Family PATERULIDAE Cooper, 1956

Diagnosis.—Small, elongate elliptical to subcircular in outline, gently biconvex, limbus in both valves. Typically with small pedicle notch in pedicle valve.

Genus ELLIPTOGLOSSA Cooper, 1956

The description of the genus by Cooper (1956, p. 241) is followed here.

ELLIPTOGLOSSA SYLVANICA Cooper var. RECIDIVA Krause & Rowell, new variety

Plate 3, figures 16-19

Diagnosis.—Characters of *Elliptoglossa* but lacking minutely radiate umbo; equivalved and elliptical.

Description.—Thin-shelled, lustrous, biconvex, equivalved and elliptical outline. Length 40 to 50 percent greater than width, maximum width and maximum convexity occurring at midlength of shell. Shell gently convex in longitudinal profile, moderately convex in anterior profile. Anterior and posterior margins almost equally rounded, but posterior margin slightly pointed. Lateral

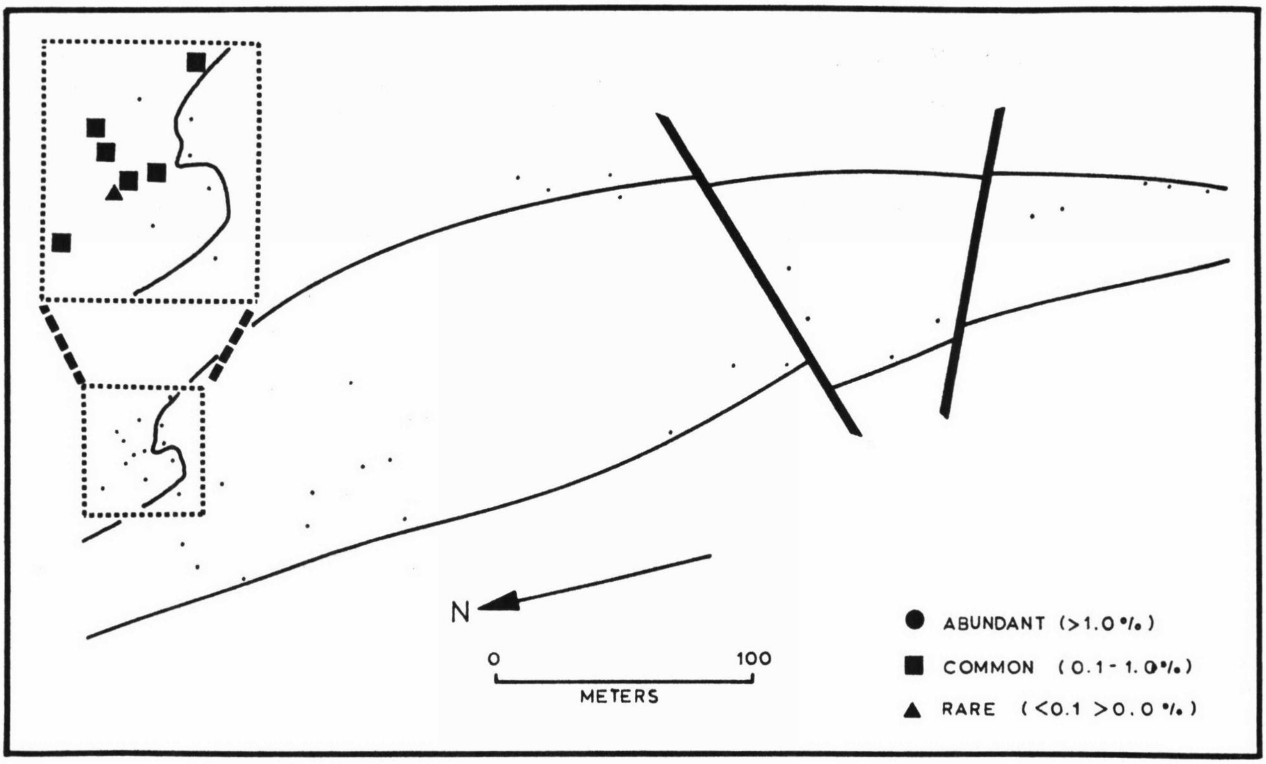

FIG. 23. Distribution of brachial valves of an obolid, gen. et sp. indet.

margins gently rounded. Umbo small, short and narrowly swollen.

Interior of both valves with marginal brim, flattened along plane of commissure, brim thicker and wider posteriorly. Brim tip partially covered by small, triangular, orthocline pseudointerarea.

Details of interior morphology indistinct, some markings present, but not common and distinct enough to separate pedicle valve from brachial valve. Body cavity outline linguloid and extending into anterior region of shell, divided anteriorly by faint medial ridge. Series of shallow pits occurring in central portion of valve may have served as bases for muscle attachment. Pair of barely distinct elongate impressions occurring laterally may be vascula lateralia. Ornament of fine concentric undulations, sometimes accentuated at regularly spaced intervals by concentric wrinkles.

Discussion.—Elliptoglossa sylvanica var. *recidiva* differs from *E. sylvanica* in not having the umbo ornamented with fine radiating lines, the shell being equivalved, and a pedicle notch not being present. Resemblance of the Meiklejohn material to *Elliptoglossa sylvanica* figured by Cooper (1956, Pl. 23) is strong and the Nevada specimens are regarded by us as being conspecific. The varietal name is used to draw attention to the morphological differences, but as we know nothing of their geographic or chronologic significance it seems appropriate that the name has no standing in zoological nomenclature.

It appears that *Elliptoglossa* may not have had a pedicle, or, if one was present, it must have been extremely thin and may have just tethered rather than firmly anchored the animal. A distinct pedicle groove or notch on the brim posterior is not apparent in the Meiklejohn specimens and seems to be barely manifest in the material described and figured by Cooper (1956, p. 241).

Separated pedicle and brachial valves of *Elliptoglossa sylvanica* var. *recidiva* are extremely difficult to distinguish from each other. This is because in size, shape, and preserved internal morphological detail the valves are basically identical; for the most part the shell is equivalved. Occasionally, when whole specimens are preserved, minor differences can be made out between the valves, e.g., the pedicle valve is less convex and more pointed, and its tip is larger than the brachial valve.

In general, *Elliptoglossa* is a distinct genus and easily distinguished from other linguloids. It appears to be a common and widespread form in Ordovician rocks of North America, having been previously recorded from the Quebec City Formation of Canada, the Pratt Ferry Formation, Botetourt Formation, Oranda Formation, and Martinsburg Shale of the Appalachians, from the Maquoketa Formation of Missouri, and from the Sylvan

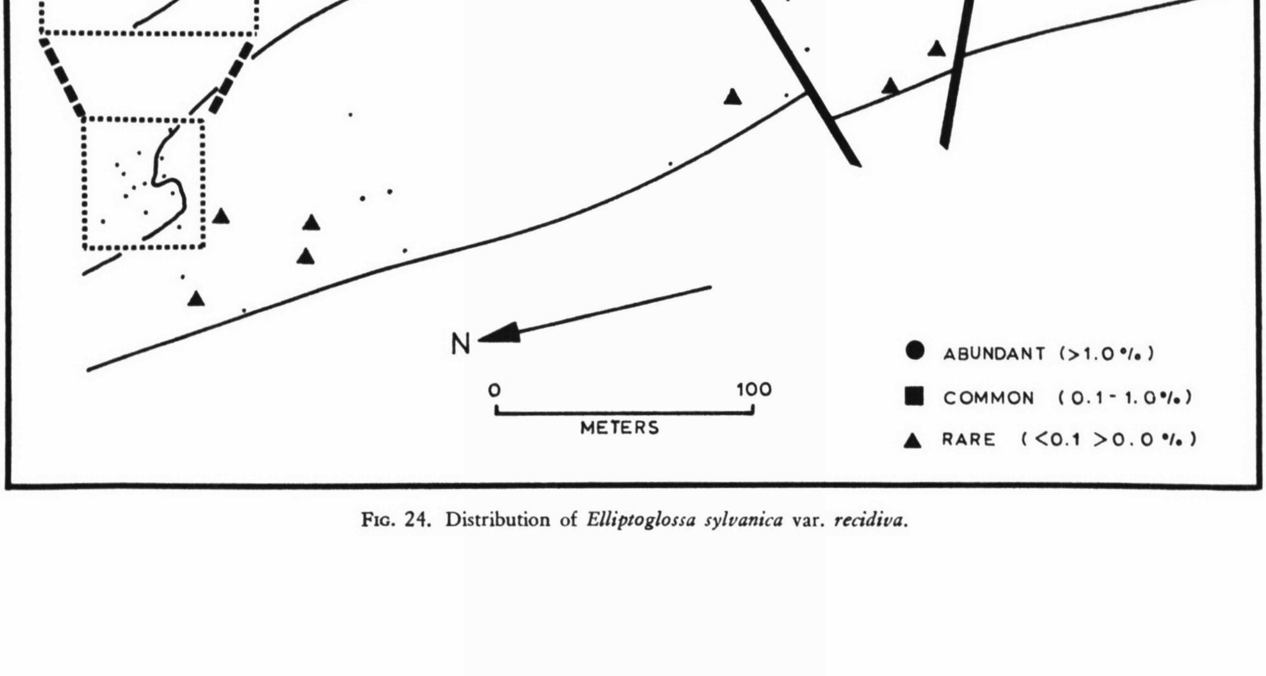

FIG. 24. Distribution of *Elliptoglossa sylvanica* var. *recidiva*.

Shale of Oklahoma. Measurements of *E. sylvanica* var. *recidiva* are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Figured specimens	Brachial valve	KU 79760	2.02	1.36
	Pedicle valve	KU 79761	1.40	1.12

Distribution.—Recorded at Localities 71/5, 71/6, 71/7, 71/8, 71/10, 71/14, 71/15, 71/19, 71/23, 71/25, 71/28, 71/29, 71/30, 71/31, 71/32, 71/33, 71/34, 71/35 and 71/36 (Fig. 24).

Descriptive statistics.—Statistics are summarized in Figure 25 and Table 10.

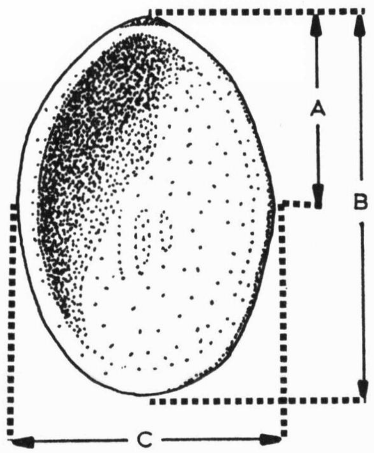

FIG. 25. Diagrammatic representation of the location of the measurements made on valves of *Elliptoglossa sylvanica* var. *recidiva.*

TABLE 10.—*Basic Statistics of* Elliptoglossa sylvanica *var.* recidiva *from Locality 71/35.* [Measurements in mm. Location of measurements as in Fig. 25. (The valves of this variety are virtually indistinguishable and the statistics are for mixed brachial and pedicle valves.)]

VECTOR OF MEANS

A	B	C
0.80	1.59	1.08

VARIANCE—COVARIANCE MATRIX

	A	B	C
A	0.0115		
B	0.0218	0.0436	
C	0.0120	0.0241	0.0147

MATRIX OF SAMPLE SIZES

	A	B	C
A	50		
B	50	50	
C	50	50	50

Order ACROTRETIDA Kuhn, 1949
Suborder ACROTRETINA Kuhn, 1949
Superfamily ACROTRETACEA Schuchert, 1893
Family ACTROTRETIDAE Schuchert, 1893

The diagnosis given in the *Treatise* (Rowell, 1965, p. *H*276) is accepted herein.

The acrotretids are unusual among inarticulate brachiopods in possessing a relatively large number of morphological characters. Moreover, they are readily identified, and, being diminutive, are often recovered from small samples of limestone. In the Cambrian, they have already proven to be stratigraphically useful (Kurtz, 1971; McBride & Rowell, 1973) and they offer a comparable potential in the Ordovician. During the past decade they have been studied by several investigators in both Europe and North America (e.g., Wright, 1963; Bednarczyk, 1964; Rowell, 1966; Goryanskiy, 1969; Kurtz, 1971; Biernat, 1973; Rowell & Krause, 1973; McBride & Rowell, 1973). These studies, most of them based on acid residues from limestones, have begun to reveal something of the diversity of the family. In the *Treatise,* Rowell (1965) recognized 21 available generic names; today we know of 31 such names. Eleven, possibly 12, genera are recorded from Cambrian rocks, 17 genera have been found in Ordovician deposits, and two have been described from Silurian beds. The family is sparsely represented in the Devonian by one genus (Ludvigsen, 1974).

In part, increased knowledge of the acrotretids has occurred because of improvements in the techniques of recovering them by acid treatment of limestones, and more recently, cherts (Biernat, 1973). Additionally, the use of S.E.M. microscopy, particularly on the small specimens, has revealed detail that was either invisible or scarcely perceptible when using conventional optical methods. The uses of S.E.M. in studies of inarticulate brachiopods may conveniently be divided into two groups utilizing different advantages of the instrument. Some studies (e.g., Biernat & Williams, 1970, 1971; Poulsen, 1971) have been directed towards ultrastructure of the shell and have used magnifications in the order of a few thousand to reveal detail of, for example, the protegular ornament of acrotretides. Such magnifications, although trivial in comparison with the potential of transmission electron microscopy, are beyond the limits of light optics. Other studies, or facets of studies, have employed magnifications well within the range of that possible with the binocular microscope, but have taken advantage of the other useful attribute of the S.E.M., its relatively enormous depth of focus (Biernat & Williams, 1971; Biernat, 1973). In the later phases of this study when an S.E.M. became available, we found this latter attribute of great advantage, both in studying specimens and in preparing illustrations. Although the use of S.E.M. does solve many difficulties, it does create a new problem that we have not yet overcome. Most acrotretids are delicate and readily broken, and we do not know of a method of removing a specimen from its mount after it has been gold-coated, without severe risk of destroying the shell. Consequently, we have found it impossible using S.E.M. to either study or illustrate both internal and external surfaces of any one specimen.

Variations in shell morphology.—Williams & Rowell (1965) and Biernat (1973) have discussed various aspects of the morphology of the acrotretids. The Ordovician material from the Meiklejohn mud mound together with Cambrian material from the Great Basin provides some new data that need to be considered in a study of the taxonomy of the family.

a) Median structure of brachial valve. A median structure, typically a septum or ridge, is a characteristic feature of the brachial valve of the majority of adult acrotretids. Only rarely is it completely absent; close examination of those forms that seem to lack the structure commonly reveals a very low ridge in front of the median buttress.

Biernat (1973, p. 40), purely for convenience, recognized three types of "median septa." Her Type I consists of a medianly located ridge or blade disposed normal to the commissure plane, the "typical" septum of brachiopod morphology. Biernat's Type II is comprised of a triangular or subtriangular plate that is inclined posterodorsally and is attached to the valve only at its dorsal or posterior end. This form, as she observed, is relatively rare. Her Type III may be regarded mechanically as a combination of Types I and II; a vertical septum supports, to varying degree, a plate on its upper posterior margin, the plate corresponding to that of the Type II structure. Biernat coined the useful term "surmounting plate" for this upper, supported plate.

As Biernat realized (1973), there is not a one-to-one correspondence between septal type and genus. Although with many genera, all the species-level taxa may be characterized by having a septum of only one type, this is not invariably the case, and several genera, and even species, may include animals with different septal types.

The variation in septal morphology and the conventional taxonomic level at which it occurs seems to vary with time.

Insofar as we know the Cambrian acrotretids, they consist predominantly of forms with a median ridge or simple median septum. Rarely, as in some forms of *Linnarssonella,* the structure is absent. *Prototreta* Bell and *Angulotreta* Palmer are the only two Cambrian genera known to have a complex septum. In the former genus, at least one species has a median septum supporting a triangular surmounting plate; the plate consists of three or more spines that are fused posteriorly, but which project forward free of each other at the anterior margin of the plate. A comparable structure is found in some individuals assigned to *Angulotreta triangularis* Palmer. In this species, however, not all the individuals referred to the taxon have a surmounting plate; the variation is seemingly intraspecific. Individuals with and without the plate are found in samples from one locality and this seems to be the only feature significantly different among the brachial valves. Pedicle valves, associated with the two types of brachial valve, are indistinguishable from each other. No currently recognized Cambrian genus consists entirely of forms that have a complex septum.

In the Ordovician, although the majority of species and genera are characterized by a simple septum, forms with a more complex septal structure are abundant. Some species of genera whose septum is typically simple may develop a spinose septum (e.g., *Conotreta? devota,* sp. nov.). A single spine may occur on the ventroposterior margin of the septum, but forms with two or even three spines are not rare in this species. The second and third spines are embedded in the septum (Pl. 11, fig. 5). A similar condition has been reported by Biernat (1973, fig. 17) in a species of *Myotreta.* Spines are known to occur rather rarely in other Ordovician acrotretids, but they are extravagantly developed in species of *Ephippelasma* Cooper and are associated with a complex surmounting plate (e.g., Pl. 10, fig. 7, 8). Biernat (1973, p. 46) has discussed their form in *E. spinosum* Biernat, a species that also occurs in some abundance on the Meiklejohn mud mound. As she noted, the spines in this species are hollow (Pl. 11, fig. 2); she believed that they were secreted, in a manner comparable to the hollow spines that are found on the outer surface of the shell of some brachiopods, by tissue that lined the axial canal of the spine. We find it difficult to accept this interpretation. The septal spines are clearly features of the internal surface of the shell and we would anticipate that they were secreted, like other features within the shell, by epithelium that was adjacent to their outer surface. This epithelium would be a rather complex infold of the dorsal body wall which was draped around the entire septum in a manner analogous to the tissue-loop relationships of living terebratulides.

A septal modification that is unknown in Cambrian forms is seen in *Myotreta* Goryanskiy. Species of this genus, which to date has been recorded only from the Ordovician of Europe (Goryanskiy, 1969; Biernat, 1973), have a septum that is convoluted so the latter has a more or less sinuous outline when viewed anterodorsally. The degree of folding increases with increasing age of the individual, but according to Biernat (1973, p. 43), there is substantial variation in the form of the septum in adults of comparable size.

A broadly comparable septal plate forms the lowermost part of the complex septal structure in some species of *Ephippelasma*. In this genus, the convoluted septal plate (Pl. 10, fig. 3, 4), which is commonly spinose, buttresses a surmounting plate that is a very conspicuous feature of the brachial interior of adult shells (Pl. 10, fig. 7, 8). The lower convoluted plate is variably developed within the genus and is absent or greatly reduced in the type species *E. minutum* Cooper. In contrast, the lower convoluted plate forms the majority of the septal structure in immature specimens of *E. spinosum* (Pl. 10, fig. 1-3). In this latter species, the septal plate appears relatively early in ontogeny, and it is only at later stages of development that the surmounting plate dominates the structure. The surmounting plate arises as lateral spinose projections from the posteroventral margin of the septal plate, which subsequently grow anteriorly and dorsally to form a spinose saddle that is draped dorsally, almost concealing its supporting septal plate (Pl. 8, fig. 11-15; Pl. 10, fig. 7, 8). If the brachial valve is damaged and the surmounting plate lost, the remnant of the septal structure, consisting predominantly of the septal plate, may be readily confused with the folded septum of *Myotreta* (Pl. 10, fig. 4).

The genus *Torynelasma* Cooper also has a complex septal structure belonging to Biernat's Type III. The lower septal plate is essentially a simple planar median septum that supports a narrowly triangular surmounting plate, commonly along the full length of its posteroventral margin. Unlike the surmounting plate in other acrotretid genera, that of *Torynelasma* does not project significantly in front of the highest point of the supporting septal plate. It arises in ontogeny as a thickening of the posteroventral margin of the early median septum and increases in size with increasing age of the individual. Minor differences exist between species in the degree of support of the surmounting plate. Anteriorly it is unsupported by the septal plate in *T. minor* Cooper, but is supported along its full length in *T. toryniferum* Cooper and *T. papillosum* sp. nov. In *T. rossicum* Goryanskiy there appears to be greater intraspecific variation in this feature, but the majority of adult forms figured by Biernat (1973) seemingly have the extreme anterior part of the surmounting plate unsupported. Perhaps of greater significance is the direction of curvature of the surmounting plate. As Biernat (1973, p. 91) observed, the European species consistently possess a surmounting plate that is ventrally convex, its lateral margins turned down toward the brachial valve. The North American material, on the other hand, has a spoon-shaped surmounting plate that is ventrally concave. The new species *T. papillosum* from the Meiklejohn mound conforms to this pattern. Whether this consistent difference should be reflected in the formal taxonomy of the group is to some extent a matter of opinion. We have followed Biernat (1973) in using the same generic name for both stocks, but recognize that the difference may have significance.

b) Apical process. If the European Lower Ordovician genus *Clistotrema* Rowell is excluded, Ordovician acrotretids do not display the diversity of form of apical process that is seen in Cambrian species of the family. *Ditreta* Biernat is exceptional in having the apical part of the pedicle valve plugged by lamellose shell. Seemingly, in that genus, the pedicle was confined to a tube that pierced the lamellose process (Biernat, 1973, p. 67) and the apical process, as described, is not unlike that of the Middle Cambrian form *Prototreta* Bell. The remainder of the known Ordovician species either lack a process entirely, or it is represented by an apical swelling that is continued a variable distance along the anterior slope of the valve. The detailed form of the process varies from one taxon to another; it is commonly subquadrate and often bears a central pit or depression. It is always relatively low and never attains the strong bosslike form characteristic of the Middle Cambrian *Linnarssonia* Walcott.

c) Apical foramen. In the great majority of acrotretids, the external pedicle foramen is a circular opening located at or immediately posterior of the beak. In the few species that have been examined at a sufficiently high magnification, the foramen is within the protegulum and lies close to the posterior margin of this first-formed shell. In many species, the foramen is continued externally by a short pedicle sheath in a manner reminiscent of that of young strophomenides. This sheath is commonly not retained in adult specimens; presumably, it is either broken or resorbed during later growth of the individual.

The Cambrian genus *Ceratreta* Bell and the Lower Ordovician *Clistotrema* Rowell are both characterized by a slitlike pedicle foramen that lies in the bottom of the intertrough and extends down approximately half the posterior slope of the pedicle valve. An opening of this form may be developed in one of two ways: 1) the pedicle opening of the protegular stage may be an open triangle, remaining as a slot, not closed dorsally, until it attains its final length; only in the latest stages of growth is shell material added to the entire periphery of the pedicle valve; 2) alternatively, a slitlike pedicle opening may be developed from a foramen that was initially circular and confined to the protegulum by subsequent dorsally directed resorption at the dorsal margin of the foramen. Complete growth stages of the shells are needed to select confidently between these alternatives, but such series are not available. However, more limited information does suggest that the slit grows by resorption. *Rhysotreta* and most species of *Scaphelasma* have a pedicle foramen that is tear-shaped or elongate suboval in outline in adult forms. Although much shorter than the foramen of *Ceratreta* or *Clistotrema*, it would appear that their foramen has also enlarged by resorption. The foramen is limited to the protegulum in young specimens of *Scaphelasma subquadratum* Biernat (1973, pl. 19, fig. 1), and typically is larger in later growth stages of many of the species than it is early in ontogeny.

Subfamily ACROTRETINAE Schuchert, 1893

Diagnosis.—Pedicle valve commonly conical, rarely convex; circular apical pedicle foramen; apical process typically present; dorsal pseudointerarea well developed, divided into two propareas by concave median plate; median septum commonly triangular blade, may be reduced or virtually absent, typically simple, rarely bearing digitate surmounting plate. Majority of forms pediculate as adults, rarely attached by cementation of pedicle valve.

Genus CONOTRETA Walcott, 1889

The description of the genus by Cooper (1956, p. 247) is followed herein.

CONOTRETA? DEVOTA Krause & Rowell, new species

Plate 4, figures 1-16; Plate 11, figures 4-6; Plate 12, figure 5

Diagnosis.—Like *Conotreta* but with strongly convex brachial valve; dorsal margin posteriorly pointed, distinct and deeply concave median plate, low elongate median septum with incurved posteroventral margin. Pedicle valve low cone with strongly rounded apex and distinct interridge. Mantle canal system not definitely known, probably bacculate.

Description.—Shell oval in transverse outline, width 10 to 30 percent greater than length.

Brachial valve convex in lateral and anterior profiles, more gently so in anterior profile; maximum convexity occurring slightly posterior to midlength of valve. Posterior margin subtending anteriorly an angle greater than 140 degrees, interrupted medially by wide, curved, large, projecting beak; lateral and anterior margins rounded. Valve gently sulcate. Dorsal interior with broad pseudointerarea, commonly with front margin anteriorly convex. Median plate strongly depressed, concave and separating broadly triangular propareas. Propareas commonly anacline, rarely procline. Cardinal muscle scars in front of pseudointerarea, raised, outline like that of a Spanish wineskin, overhung by anterior margin of propareas and commonly with deep, concave depressions next to posterior of median septum. Small, rounded tubercles adjacent to median septum and posterior to midlength of valve commonly present, probably anterior muscle scars. Median septum elongate triangular blade, posteroventral and anteroventral margins concave ventrally. Posteroventral margin thickened, commonly projecting anteriorly as spine; anteroventral margin typically bearing an additional spine (more rarely two spines), whose growth track produces rib on septum. Maximum height at about two-thirds length of valve in front of beak. Septum arising about 0.1 mm in front of median plate and extending to about 0.15 mm from anterior margin. Brim commonly present along anterior and lateral margins.

Pedicle valve low cone with strongly rounded apex and gently curved anterior and lateral slopes, posterior slope shorter than anterior, apical angle about 80 degrees. Foramen slightly posterior of apex, about 0.05 mm in diameter. Apical protegular node divided medially by short groove. Short beak overhanging flattened, broad, triangular, procline pseudointerarea. Margin of ventral pseudointerarea directed dorsally, subtending ventrally an angle of about 140 degrees. Pseudointerarea divided medially by distinct wide interridge, which terminates in a rounded, dorsally directed projection. Ventral interior with distinct, stubby apical process at apex and anterior of foramen. Mantle canal pattern probably bacculate. Cardinal muscle scars commonly present, slightly raised and elliptical in outline, positioned medially on posterolateral sectors of valve.

Ornament of concentric lamellae with very fine growth lines. The lamellae on the brachial valve are characteristically deflected dorsally and appear like very thin fila; this pattern is rarely observed on the pedicle valve, where the ornament is commonly of distinct and wide lamellae separated by bands with very fine, discontinuous growth lines (Pl. 11, fig. 4).

Discussion.—*Conotreta? devota* occurs in great abundance on the mound, but valves belonging to immature stages are the ones most often recovered. The morphologic details described for the species are present early in the development of the shell, aiding in the identification of the more immature stages. Very thin fila are present on the exterior of very young brachial valves, although this region may be abraded in the adult forms. The dorsal beak is not as conspicuous as in the adult stage. The development of the anterior margin of the pseudointerarea and of the median blade shows more variation than might be expected. The front margin of the dorsal pseudointerarea, although typically anteriorly convex when adult, can be slightly concave, straight, or convex anteriorly during ontogeny. The median blade varies in height, length, amount of curvature of the ventral margin, and in the development of spines. Several spines can be present in early growth stages, but generally they appear later in development. The pedicle valve can be recognized by the dorsal extension of the interridge, the broadly rounded apex and, less readily, by the distinctly lamellar ornament on its exterior.

The species is referred tentatively to *Conotreta*. It differs from the type species and many other taxa placed in the genus by its seeming lack of a pinnate mantle

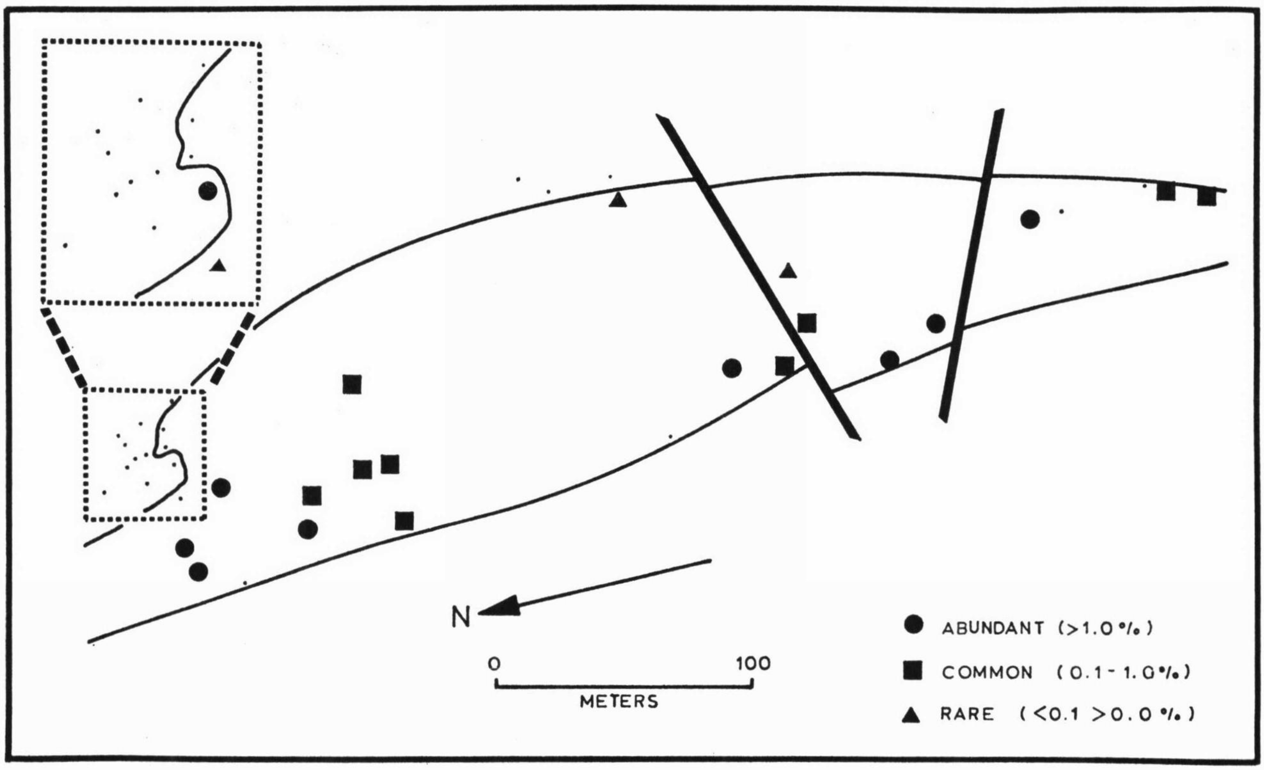

FIG. 26. Distribution of brachial valves of *Conotreta*? *devota*.

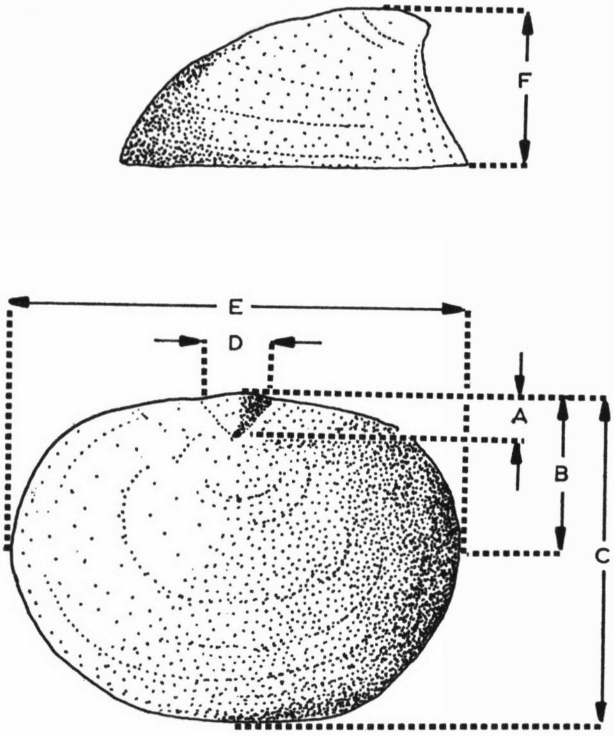

FIG. 27. Diagrammatic representation of the location of measurements on the pedicle valves of *Conotreta*? *devota*.

TABLE 11.—*Basic Statistics of Pedicle Valves of* Conotreta? devota *from Locality 71/8.* [Measurements in mm. Location of measurements as in Fig. 27.]

VECTOR OF MEANS

A	B	C	D	E	F
0.17	0.42	0.93	0.21	1.18	0.44

VARIANCE—COVARIANCE MATRIX

A	0.0016					
B	0.0000	0.0066				
C	0.0000	0.0101	0.0192			
D	0.0000	0.0022	0.0040	0.0014		
E	0.0000	0.0119	0.0229	0.0049	0.0287	
F	0.0000	0.0049	0.0097	0.0022	0.0119	0.0063
	A	B	C	D	E	F

MATRIX OF SAMPLE SIZES

A	25					
B	25	25				
C	25	25	25			
D	23	23	23	23		
E	25	25	25	23	25	
F	25	25	25	23	25	25
	A	B	C	D	E	F

canal system and relatively low pedicle valve with rounded apex.

Conotreta depressa Cooper shows some similarity to *C.? devota*, but the Meiklejohn material differs from the Pratt Ferry specimens in several details. 1) *C.? devota* has a large, raised dorsal beak extending posteriorly and generating a distinctly pointed posterior margin, which subtends anteriorly an angle greater than 140 degrees. In *C. depressa* the dorsal beak is small, marginal and the posterior margin is seemingly rectilinear or subtends anteriorly an angle close to 170 degrees; 2) the brachial valve of the Nevada species is also much more convex than that of the Alabama forms; 3) the median plate of the Meiklejohn material is large, deeply concave, and dominates the dorsal posterior, whereas, in the Pratt Ferry species, the median plate is small and shallowly concave; 4) the pedicle valve of *C.? devota* is distinctly procline, but commonly apsacline and sometimes catacline in the Pratt Ferry species; 5) the ventral pseudointerarea of *C.? devota* has a wide, strongly convex interridge with a dorsally directed extension. In the Alabama species, the pseudointerarea is undivided and the posterior margin is straight; 6) the ventral mantle canal pattern of the Meiklejohn species is seemingly bacculate, but is pinnate in *C. depressa*; 7) ornamentation in *C. depressa* consists of subdued growth lines. In *C.? devota* ornamentation is distinct, and growth lines, particularly on the brachial valve, are well developed. Measurements of *C.? devota* are recorded below.

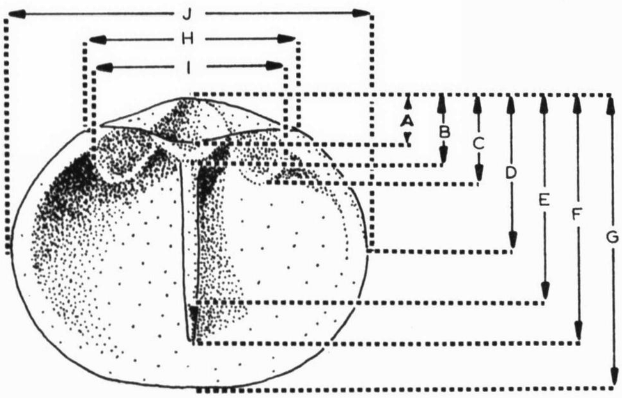

FIG. 28. Diagrammatic representation of the location of measurements on the brachial valves of *Conotreta? devota.*

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Holotype	Brachial valve	KU 79785	1.18	1.44
Figured paratypes	Pedicle valve	KU 79786	1.12	1.34
	Brachial valve	KU 79787	1.28	1.46
	Pedicle valve	KU 79788	0.68	0.82
	Brachial valve	KU 79789	0.66	0.78
	Brachial valve	KU 92857	0.92	......
	Brachial valve	KU 92858	1.05	1.25
	Pedicle valve	KU 95148	1.07	1.42
	Pedicle valve	KU 92853	broken in photography	

Distribution.—Recorded at Localities 71/2, 71/7, 71/8, 71/10, 71/12, 71/13, 71/15, 71/16, 71/17, 71/18, 71/19, 71/20, 71/22, 71/23, 71/24, 71/25, 71/26, 71/28, 71/29, 71/30, 71/37 and 71/108 (Fig. 26).

Descriptive statistics.—Statistics are summarized in Figures 27 and 28, and in Tables 11 and 12.

TABLE 12.—*Basic Statistics of Brachial Valves of* Conotreta? devota *from Locality 71/8.* [Measurements in mm. Location of measurements as in Fig. 28.]

VECTOR OF MEANS

A	B	C	D	E	F	G	H	I	J
0.16	0.30	0.34	0.49	0.64	0.83	0.97	0.54	0.65	1.18

VARIANCE—COVARIANCE MATRIX

	A	B	C	D	E	F	G	H	I	J
A	0.0013									
B	0.0013	0.0025								
C	0.0008	0.0016	0.0017							
D	0.0013	0.0019	0.0015	0.0030						
E	0.0019	0.0031	0.0019	0.0034	0.0061					
F	0.0022	0.0032	0.0021	0.0041	0.0056	0.0076				
G	0.0022	0.0034	0.0021	0.0048	0.0065	0.0086	0.0102			
H	0.0023	0.0031	0.0016	0.0031	0.0048	0.0059	0.0064	0.0082		
I	0.0017	0.0013	0.0013	0.0019	0.0025	0.0036	0.0038	0.0036	0.0048	
J	0.0030	0.0042	0.0020	0.0052	0.0075	0.0097	0.0112	0.0086	0.0050	0.0141
	A	B	C	D	E	F	G	H	I	J

MATRIX OF SAMPLE SIZES

	A	B	C	D	E	F	G	H	I	J
A	25									
B	25	25								
C	19	19	19							
D	25	25	19	25						
E	25	25	19	25	25					
F	25	25	19	25	25	25				
G	25	25	19	25	25	25	25			
H	25	25	19	25	25	25	25	25		
I	19	19	19	19	19	19	19	19	19	
J	25	25	19	25	25	25	25	25	19	25
	A	B	C	D	E	F	G	H	I	J

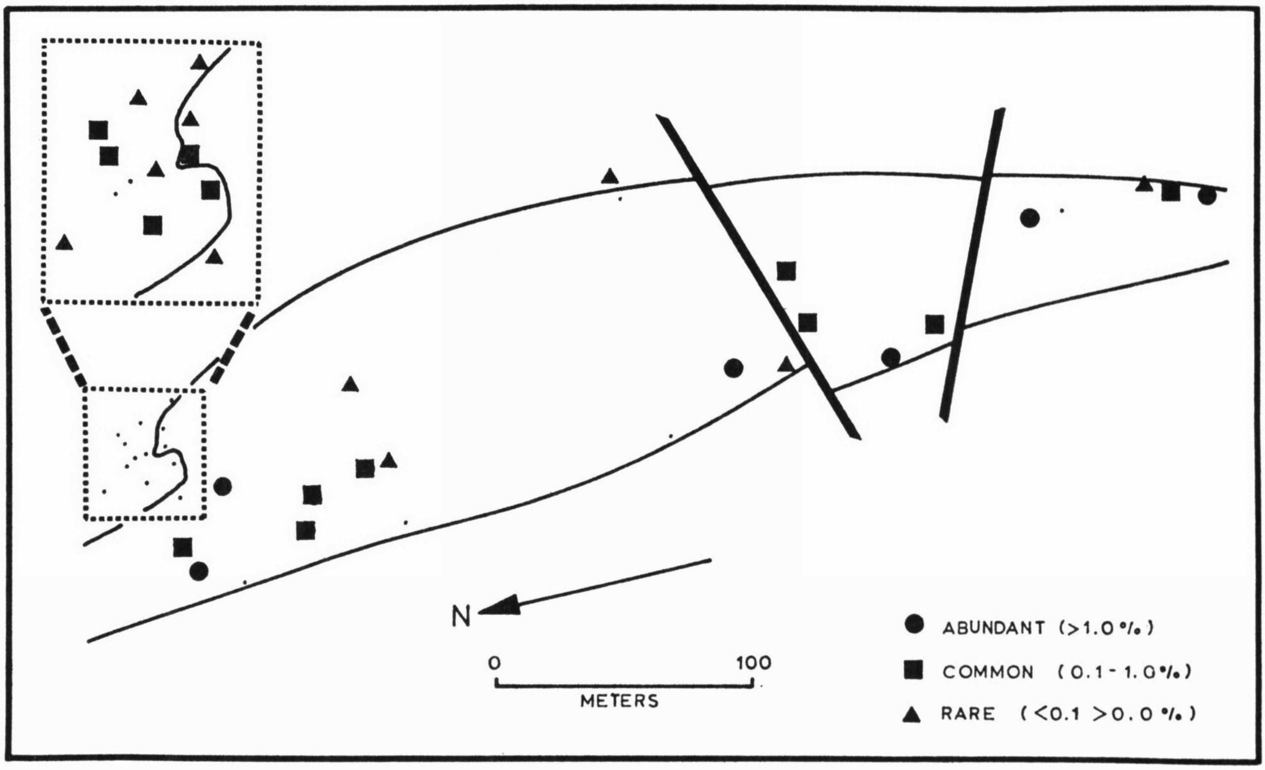

FIG. 29. Distribution of brachial valves of *Conotreta mica?*.

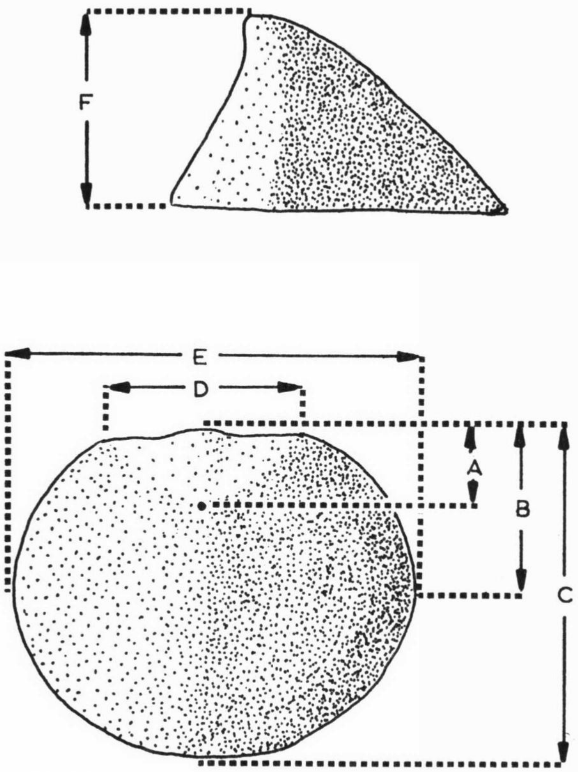

FIG. 30. Diagrammatic representation of the location of measurements on the pedicle valves of *Conotreta mica?*.

TABLE 13.—*Basic Statistics of Pedicle Valves of* Conotreta mica? *from Locality 71/10.* [Measurements in mm. Location of measurements as in Fig. 30.]

VECTOR OF MEANS

A	B	C	D	E	F
0.13	0.42	1.02	0.55	1.19	0.64

VARIANCE—COVARIANCE MATRIX

	A	B	C	D	E	F
A	0.0026					
B	0.0021	0.0070				
C	0.0055	0.0142	0.0354			
D	0.0024	0.0075	0.0184	0.0141		
E	0.0061	0.0150	0.0384	0.0204	0.0419	
F	0.0034	0.0094	0.0245	0.0132	0.0266	0.0227

MATRIX OF SAMPLE SIZES

	A	B	C	D	E	F
A	25					
B	25	25				
C	25	25	25			
D	25	25	25	25		
E	25	25	25	25	25	
F	25	25	25	25	25	25

CONOTRETA MICA? Goryanskiy, 1969

Plate 4, figures 17-24

Diagnosis.—Characters of small *Conotreta* with procline pedicle valve bearing narrow interridge. Shell surface lustrous and ornamented with very fine indistinct growth lines.

Description.—Shell oval to subcircular in transverse outline, width 5 to 20 percent greater than length.

Brachial valve convex in lateral and anterior profiles, more gently so in anterior profile. Maximum convexity occurring at or slightly posterior to midlength of valve. Posterior margin straight or subtending anteriorly an angle greater than 160 degrees, interrupted medially by short, small projecting beak; lateral and anterior margins rounded. Dorsal protegulum small and raised above rest of shell surface. Cardinal extremities commonly flattened. Valve very gently sulcate. Dorsal interior with small pseudointerarea, anteriorly pointed anacline and projecting propareas separated by triangular, concave, median plate whose front margin is anteriorly concave. Cardinal muscle scars in front and lateral of pseudointerarea, slightly raised and wineskin-shaped in outline. Median septum arising about 0.2 mm in front of pseudointerarea from a median buttress and extending nearly to anterior margin. Septum bladelike, triangular in outline, maximum height occurring at or slightly anteriorly to midlength of valve; posteroventral margin thickened towards apex of septum, commonly concave, rarely straight and terminating anteriorly in a spiny projection. Base of septum may be thickened posterolaterally to double its size; anterior margin steep and commonly concave, widening slightly at base and toward anterior margin of valve. Thin marginal brim commonly present anteriorly and laterally, widening at cardinal extremities.

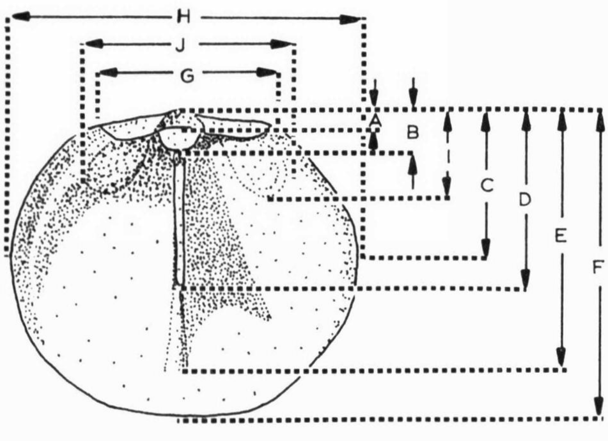

FIG. 31. Diagrammatic representation of the location of measurements on the brachial valves of *Conotreta mica?*.

Pedicle valve conical, height about 40 to 50 percent less than width of shell. Posterior slope commonly flattened, rarely gently concave, anterior slope longer than posterior slope and gently convex. Commissural plane with gentle ventrally directed undulation along anterior. Foramen posteroapically located, with short, stubby pedicle sheath. Apical angle about 45 degrees. Apex with gently swollen protegulum. Pseudointerarea procline divided medially by low interridge. Ventral interior

TABLE 14.—*Basic Statistics of Brachial Valves of* Conotreta mica? *from Locality 71/10.* [Measurements in mm. Location of measurements as in Fig. 31.]

VECTOR OF MEANS

A	B	C	D	E	F	G	H	I	J
0.08	0.21	0.49	0.54	0.80	0.99	0.53	1.16	0.33	0.62

VARIANCE—COVARIANCE MATRIX

	A	B	C	D	E	F	G	H	I	J
A	0.0007									
B	0.0011	0.0022								
C	0.0022	0.0038	0.0104							
D	0.0023	0.0038	0.0102	0.0106						
E	0.0043	0.0073	0.0196	0.0196	0.0390					
F	0.0049	0.0080	0.0214	0.0215	0.0418	0.0471				
G	0.0033	0.0056	0.0150	0.0150	0.0296	0.0321	0.0236			
H	0.0054	0.0091	0.0240	0.0241	0.0471	0.0517	0.0361	0.0590		
I	0.0018	0.0035	0.0081	0.0082	0.0151	0.0159	0.0104	0.0180	0.0077	
J	0.0024	0.0053	0.0139	0.0132	0.0280	0.0289	0.0188	0.0329	0.0125	0.0264

MATRIX OF SAMPLE SIZES

	A	B	C	D	E	F	G	H	I	J
A	25									
B	25	25								
C	25	25	25							
D	25	25	25	25						
E	25	25	25	25	25					
F	25	25	25	25	25	25				
G	25	25	25	25	25	25	25			
H	25	25	25	25	25	25	25	25		
I	17	17	17	17	17	17	17	17	17	
J	15	15	15	15	15	15	15	15	15	15

with short apical process. Pinnate mantle canal pattern. Cardinal muscle scars positioned slightly above midline on posterolateral sector of valve.

Ornament of very fine indistinct growth lines and wrinkles on a lustrous shell surface.

Discussion.—These shells greatly resemble *C. mica* Goryanskiy and are tentatively here regarded as belonging to this species, which was erected by Goryanskiy (1969, p. 64) for shells from the Tallinian and Kundian of the northwest Russian Platform. Biernat (1973, p. 67) has also recognized the species in northeast Poland.

The Meiklejohn *Conotreta* also bears some resemblance to *C. apicalis* (Cooper, 1956, p. 249) from the Pratt Ferry Formation of Alabama. It differs from this species in some details; the pedicle valve of *C. apicalis* can be procline, catacline, and apsacline and is taller than that of *C. mica?* which is invariably procline. Measurements of *C. mica?* are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Figured specimens	Brachial valve	KU 79796	1.56	1.78
	Pedicle valve	KU 79797	1.24	1.48

Distribution.—Recorded at Localities 71/1, 71/4, 71/5, 71/6, 71/7, 71/8, 71/9, 71/10, 71/12, 71/13, 71/14, 71/15, 71/16, 71/17, 71/18, 71/19, 71/22, 71/23, 71/24, 71/25, 71/26, 71/28, 71/29, 71/30, 71/31, 71/33, 71/34, 71/35, 71/36, 71/37 and 71/108 (Fig. 29).

Descriptive statistics.—Statistics are summarized in Figures 30 and 31 and in Tables 13 and 14.

CONOTRETA sp.

Plate 4, figures 25-30; Plate 11, figure 3

Diagnosis.—Very large, thick-shelled *Conotreta* ornamented with fine irregular growth lines, concentric wrinkles, and characteristic minute, conical, ribbed pustules arranged in irregularly radiating rows.

Description.—Shell subcircular in transverse outline. Brachial valve initially convex, later becoming flat or gently concave. Posterior margin nearly straight, interrupted medially by small, swollen, projecting dorsal beak, anterior and lateral margins rounded. Shallow sulcus may be present. Dorsal interior with large, broad, orthocline pseudointerarea; triangular, concave, median plate separates large, initially triangular (later trapezoidal) propareas. Anterolateral margins of trapezoid concave and tapering along margin of shell to a thin point. Median septum short and thick, wedgelike in lateral profile, arising from median buttress, extending a short distance beyond midlength of valve. Maximum height

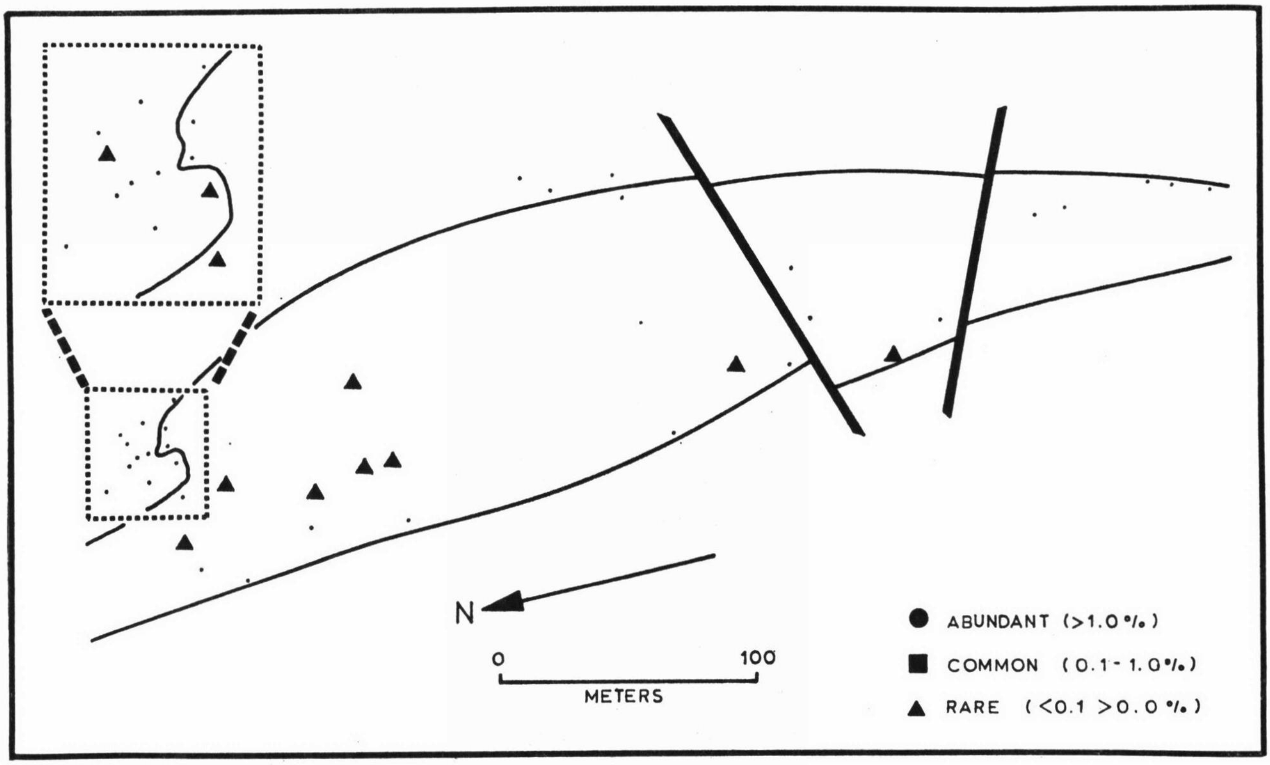

FIG. 32. Distribution of brachial valves of *Conotreta* sp.

of septum occurring close to midlength of valve, ventroanterior slope gently concave, tapering to a low ridge. Cardinal muscle scars recessed impressions, wineskin-shaped in outline and positioned in front of pseudointerarea.

Pedicle valve known only from fragments, conical, seemingly lower than shell is wide; posterior slope flat, anterior slope initially gently concave, later seemingly strongly convex. Circular foramen posteroapically located on small, raised knob. Ventral pseudointerarea large, procline, divided medially by indistinct interridge. Ventral interior with low, broad apical process and short pedicle tube posteriorly. Pinnate mantle canal pattern.

Ornament of very fine, irregular growth lines, concentric wrinkles, and numerous, minute, conical, ribbed pustules arranged in irregularly radiating rows. Pustules seemingly absent from ventral pseudointerarea. Thick-shelled.

Discussion.—The description of this species is based on several fragments and a few immature brachial valves. The species is rather rare in these collections, but its large size and characteristic ornament make it easy to distinguish from other *Conotreta*.

This species is reminiscent of *Conotreta gigantea* Cooper from the Pratt Ferry Formation of Alabama in its size, transverse outline and internal features of the brachial valve. It differs from the Alabama species in the outline of the pedicle valve and the ornament of the shell. Measurements of *C.* sp. are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Figured specimens	Brachial valve	KU 79807	3.38	3.64
	Incomplete pedicle valve	KU 79809	......	......
	Incomplete pedicle valve	KU 79810	......	......
	Incomplete brachial valve	KU 100696	......	......

Distribution.—Recorded at Localities 71/7, 71/8, 71/13, 71/15, 71/16, 71/17, 71/18, 71/22, 71/23, 71/25, 71/28 and 71/35 (Fig. 32). Material inadequate for biometric treatment.

Genus SPONDYLOTRETA Cooper, 1956

The description of the genus by Cooper (1956, p. 255) is followed herein.

SPONDYLOTRETA sp.

Plate 5, figures 1-11

The Meiklejohn *Spondylotreta* seemingly resembles the material figured and described by Cooper (1956, p. 255) as *S. concentrica* from the Pratt Ferry Formation of Alabama. Attempts to clearly establish the similarities or differences between these two forms will be dependent on obtaining better preserved material, since the shells from the Meiklejohn mound are fragmented, exfoliated, and slightly deformed by diagenesis.

The shells are subcircular in transverse outline. The brachial valve has rounded lateral and anterior margins; the posterior margin may be straight or subtend anteriorly an angle greater than 160 degrees. The umbo is broad and gently swollen. The cardinal extremities are flat or flexed dorsally and the valve is shallowly sulcate. The dorsal interior possesses a broad pseudointerarea with a large, concave, triangular median plate that separates wide, triangular orthocline or anacline propareas. Cardinal muscle scars are wineskin-shaped in outline. Median septum arises from grooved median buttress some 0.2 mm in front of beak. Septum is triangular, elongate, and rarely sinuous and extends to within one-eighth of valve length from anterior margin of shell. The maximum height of the septum occurs anterior to midlength of the valve; its ventroanterior slope is inclined and slightly concave. Lateral and anterior margins of valve flattened as a brim.

Several brachial valves belonging to juvenile individuals are represented in this collection. Valves are distinctly convex, with the maximum convexity occurring posterior to the midlength of the valve. Cardinal extremities are flat. The dorsal pseudointerarea is thin, with a wide, shallow, and convex median plate that separates very small anacline propareas. The brim, present in older specimens, is absent, giving the impression that the median septum almost touches the anterior margin.

The adult pedicle valves are conical, their posterior slope is flat and shorter than the gently convex anterior slope; the apical angle measures about 80 degrees. The straight posterior margin is rarely interrupted medially by an extension of the interridge; the anterior and lateral margins are rounded. A large procline ventral pseudointerarea is interrupted medially by a distinct interridge. The posteroapical pedicle opening may have a thin and very small pedicle sheath. The ventral interior possesses a pedicle tube that extends dorsoposteriorly as a forked ridge and is supported apically by a median septum. The forked ridge dies out gradually and seemingly extends almost to the posterior margin of the valve. The median septum extends to about midlength of the anterior slope. A pair of ovoid cardinal muscle scars are placed laterally and close to the apex.

The ornament consists of fine, elevated growth lines.

Two representatives of this genus are known from North America. *Spondylotreta concentrica* Cooper from the Pratt Ferry Formation of Alabama and *S.? declivis* (Willard) from the Effna Formation of Virginia (Cooper, 1956, p. 255). Wright (1963, p. 238) has recorded a third species, *S. parva,* from the Portrane Limestone of Eire. Recently Goryanskiy (1969, p. 66) has erected a fourth species, *S. faceta,* from the Leyetsian and Volkhovian of the northwestern Russian Platform, and Biernat (1973) has described the new form, *S. dissimilis,* from the Tremadocian of Poland. Measurements of *S.* sp. are summarized below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Figured specimens	Incomplete pedicle valve	KU 79811	......	......
	Incomplete pedicle valve	KU 79812	......	......
	Brachial valve	KU 79813	1.16	1.34
	Incomplete brachial valve	KU 79814	2.26	......

Distribution.—Recorded at Localities 71/2 and 71/14 (Fig. 33). Material inadequate for biometric treatment.

Genus UNDIFERINA Cooper, 1956

The description and diagnosis of the genus by Rowell and Krause (1973, p. 796) is followed herein.

UNDIFERINA NEVADENSIS Rowell & Krause, 1973

Plate 5, figures 14, 15

The diagnosis and description of the species by Rowell and Krause (1973, p. 797) is followed herein.

Discussion.—A single, incomplete brachial valve, KU 79793, belonging to this species has been recovered.

Distribution.—Recorded at Locality 71/34 in the flanking beds of the Meiklejohn mound (Fig. 34).

UNDIFERINA sp.

Plate 5, figures 12, 13, 16-19

Diagnosis.—Characters of *Undiferina* with small, concave median plate and low median septum. Shell with scalloped and irregularly rounded margins.

Description.—Shells irregularly oval in transverse outline. Width being 25 to 30 percent greater than length and occurring anterior or posterior to the midlength of valve.

Brachial valve with rounded and scalloped lateral and anterior margins. Posterior margin scalloped, straight, or subtending anteriorly an angle greater than 160 degrees, interrupted medially by projecting dorsal beak. Umbo raised. Valve convex in anterior and lateral profiles. Commissural plane anteriorly and laterally sinuous, posteriorly with dorsally directed undulation. Dorsal interior with small, indistinct, poorly defined propareas separated by distinct, depressed, dorsally concave median plate that has rounded, broadly triangular, or diamond shaped outline. Median plate overhangs umbonal cavity, supported by median buttress. In older

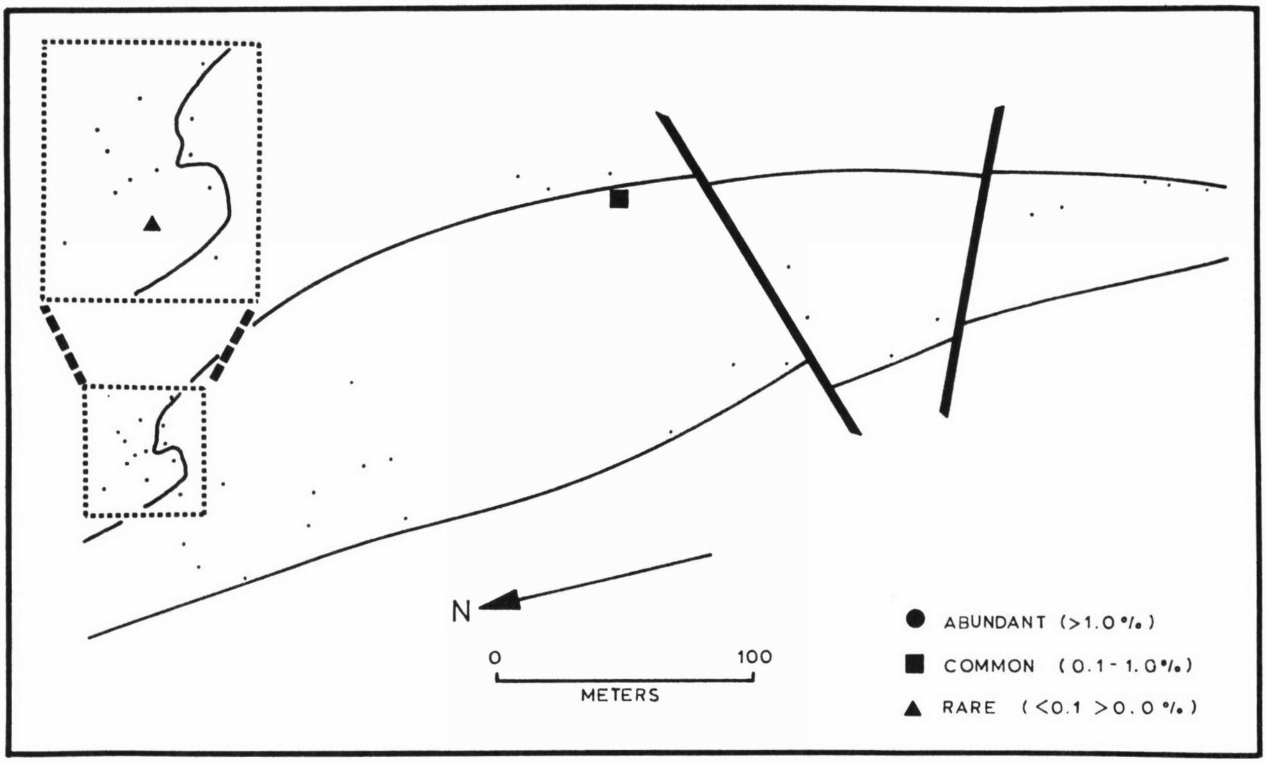

FIG. 33. Distribution of brachial valves of *Spondylotreta* sp.

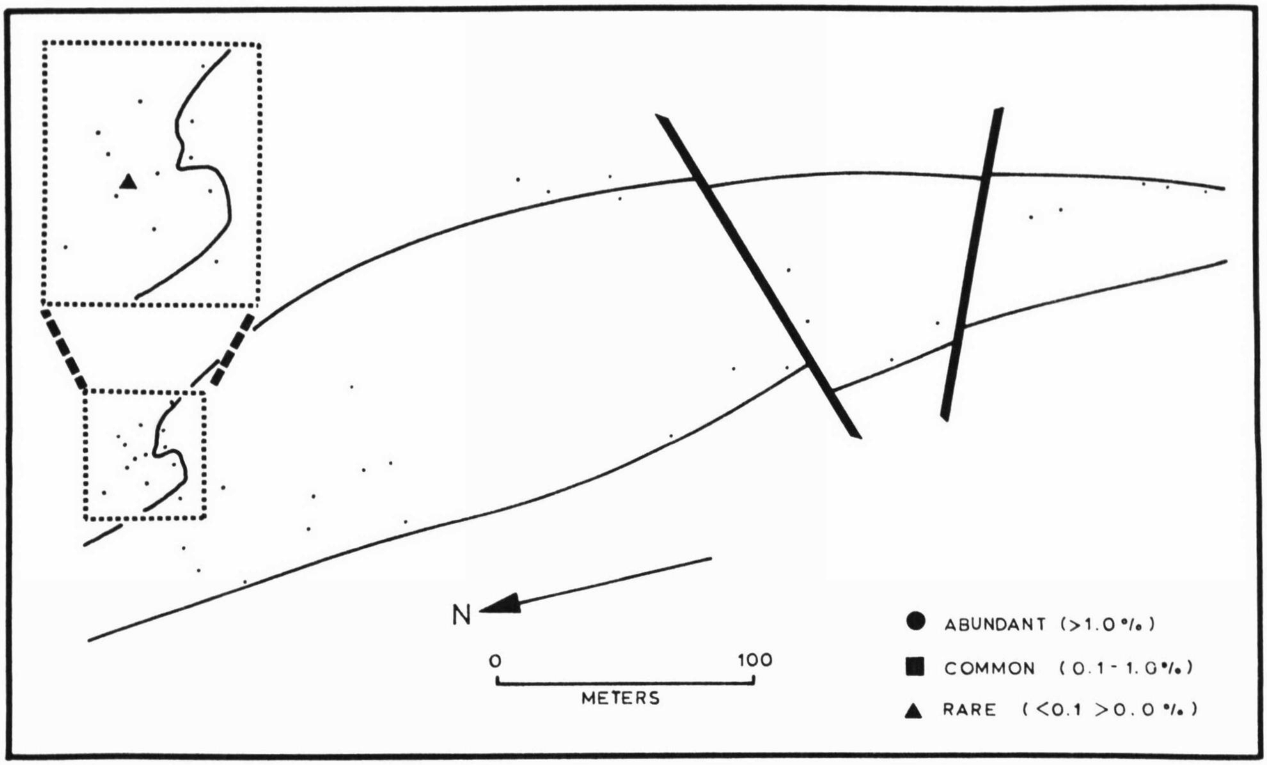

FIG. 34. Distribution of brachial valves of *Undiferina nevadensis*.

specimens buttress fills umbonal cavity. Cardinal muscle scars faintly impressed in front of pseudointerarea, wine-skin-shaped in outline. Median septum thin, low wedge, reaching maximum height anterior to midlength of valve, length variable.

Pedicle valve unknown.

Ornament of distinct, well-developed growth lines superimposed over irregular shell undulations.

Discussion.—A small number of brachial valves assigned tentatively to the genus *Undiferina* have been recovered from the mound and its flanking beds. These valves are in various states of preservation and represent individuals at different stages of ontogenetic development; however, all seemingly are immature shells. Even though these shells do not bear much resemblance to *U. nevadensis* the possibility that they may be conspecific cannot be eliminated; the observed differences may be a result of preservation and their immaturity.

These shells differ from *Undiferina nevadensis* in several respects: 1) the anterior and lateral margins are irregular and scalloped, and 2) the median plate, median septum and cardinal muscle scars are much smaller and less developed. *U.* sp. seems to resemble more *U. rugosa* from Pratt Ferry, Alabama, except for distinct internal differences: 1) the median septum is less developed and lacks the posteroventral plate found on the septum of *U. rugosa,* and 2) the propareas are less developed in the Meiklejohn species and lack the anterior projections found in the Alabama species. Measurements of *U.* sp. are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Figured specimens	Incomplete brachial valve	KU 79790	......	......
	Brachial valve	KU 79791	0.76	1.00
	Incomplete brachial valve	KU 79792	1.20	......

Distribution.—Undiferina sp. has been recorded at Localities 71/8, 71/10, 71/25, 71/26, 71/30, 71/35, 71/36 and 71/108 (Fig. 35). The material is inadequate for biometric treatment.

Genus EURYTRETA Rowell, 1966

The description of the genus by Rowell (1966, p. 9) is followed herein.

The recently erected genus *Paratreta* Biernat, 1973, from Poland shows many similarities with *Eurytreta.* The significant differences, if any, would appear to lie

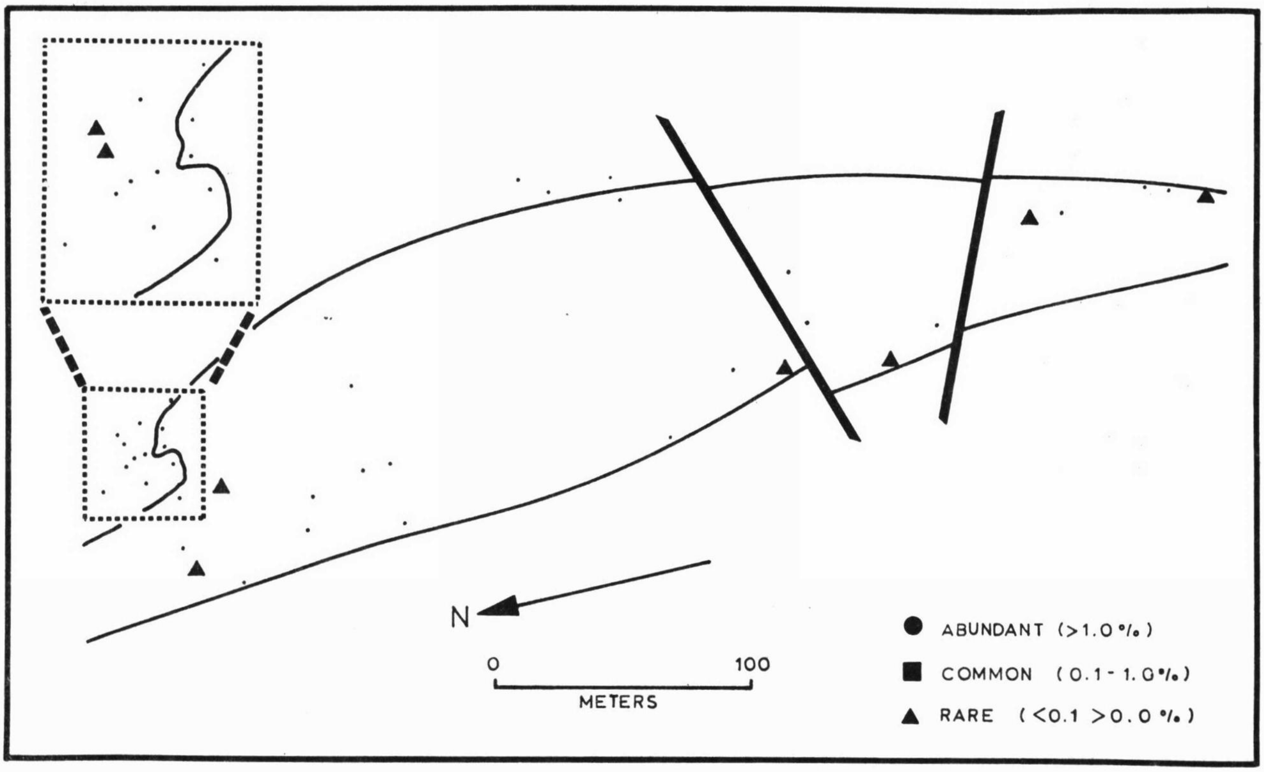

FIG. 35. Distribution of brachial valves of *Undiferina* sp.

in the relative heights of the dorsal median septum and perhaps in the orientation of the ventral pseudointerarea.

EURYTRETA CAMPANIFORMIS Krause & Rowell, new species

Plate 5, figures 20-27

Diagnosis.—Species of *Eurytreta* with elongate conical pedicle valve. Brachial valve with anacline propareas and front margin of median plate anteriorly convex.

Description.—Shell transversely oval or subcircular in outline, maximum width 15 percent greater than length and occurring near midlength of valve.

Brachial valve convex in anterior and lateral profiles, maximum convexity occurring slightly posterior to midlength; commonly sulcate, sulcus rarely with longitudinal medial groove. Cardinal extremities commonly convex, rarely flattened. Posterior margin straight or subtending an angle greater than 150 degrees, interrupted medially by projecting dorsal beak; lateral and anterior margins rounded. Beak small, somewhat inflated. Dorsal interior with small pseudointerarea, both anterior and posterior margins convex; depressed, concave median plate separates short, triangular, anacline propareas. Cardinal muscle scars small, prominent, directly in front of pseudointerarea, contiguous with median buttress. Buttress bearing shallow median depression. Median septum a low, narrow, distinct ridge originating from anterior end of median buttress, and extending to within quarter of valve length from anterior margin. Septum typically slightly wider anteriorly than posteriorly and commonly wedgelike in lateral profile, with maximum height of wedge towards anterior.

Pedicle valve conical, commonly distinctly apsacline, rarely catacline; anterior slope very gently convex and less steep than posterior slope, apical angle about 45 degrees. Foramen at apex of posteriorly projecting, elongate pedicle sheath. Pseudointerarea narrow, triangular, poorly defined, subdivided medially by wide interridge. Posterior margin of valve commonly straight, sometimes interrupted medially by dorsally directed projection of interridge. Ventral interior commonly with low apical process. Cardinal muscle scars posterolaterally placed, rarely observable.

Ornament of very fine, indistinct growth lines.

Discussion.—The shell of very young specimens is subcircular in transverse outline. Their pedicle valve is distinctly apsacline and is dominated by a long, posteriorly elongated apex. The juvenile brachial valve is known from a single specimen and is gently convex, its posterior margin interrupted medially by a broad beak. The median plate of this specimen is broad and concave-convex in outline, its lateral propareas are very small and pointed ventrally. The median septum is seemingly extremely short and appears as a small projection on the valve floor.

Eurytreta campaniformis differs from *E. curvata,* the type species of the genus, in several details: 1) the pedicle valve is steeper and higher than that of *E. curvata,* which has a more strongly curved anterior slope; 2) the pedicle valve of *E. campaniformis* has a prominent and very elongate apex, whereas *E. curvata* has a nipplelike beak incurved over the pseudointerarea; 3) the apical angle for the Meiklejohn species is about 45 degrees, but is close to 80 degrees in *E. curvata*; 4) the dorsal pseudointerarea of *E. campaniformis* is anacline, in contrast to the orthocline condition typical of the Eureka species; 5) the front margin of the dorsal median plate is anteriorly convex in *E. campaniformis* and anteriorly concave in *E. curvata.*

Eurytreta has been previously recorded only once in North America, at the base of the "Pogonip Limestone" in the Eureka District of Nevada. Our own unpublished studies, however, show that the genus occurs commonly in Lower Ordovician beds in the Great Basin.

Biernat (1973, p. 72) has described two species from Lower and Middle Ordovician beds in Poland. They both differ markedly from *Eurytreta campaniformis* in having a much larger apical angle at the ventral apex. Additionally, both Polish species seemingly have catacline-procline ventral pseudointerareas. Measurements of *E. campaniformis* are given below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Holotype	Brachial valve	KU 79778	0.82	0.94
Figured paratypes	Brachial valve	KU 79777	0.70	0.90
	Pedicle valve	KU 79779	0.68	0.86

Distribution.—Recorded at Localities 71/1, 71/4, 71/5, 71/6, 71/9, 71/11, 71/14, 71/23, 71/24, 71/30, 71/31, 71/32, 71/33, 71/34, 71/35 and 71/36 (Fig. 36).

Descriptive statistics.—Statistics are summarized in Figures 37 and 38 and in Tables 15 and 16.

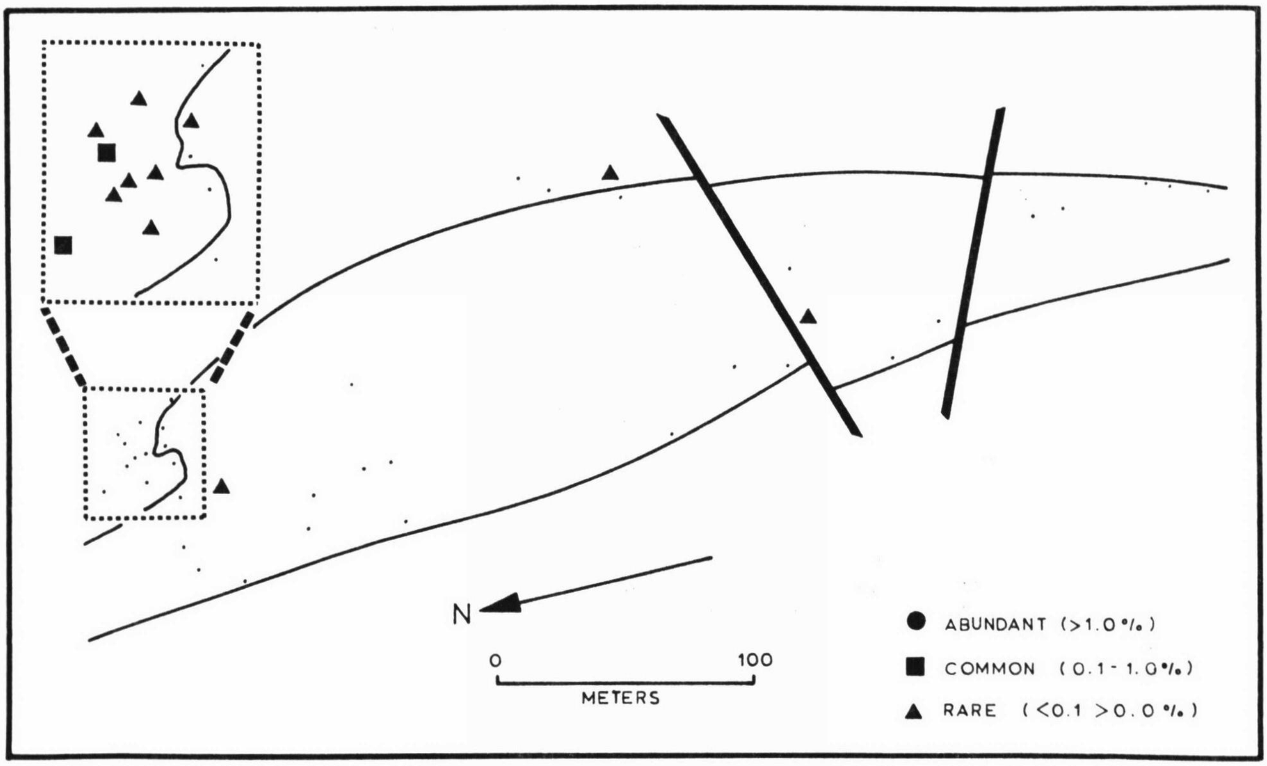

FIG. 36. Distribution of brachial valves of *Eurytreta campaniformis*.

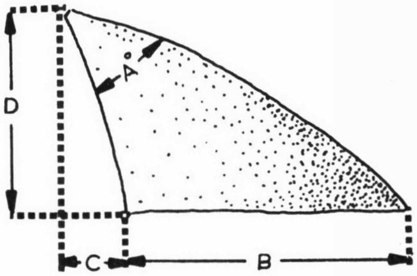

FIG. 37. Diagrammatic representation of the location of measurements on the pedicle valves of *Eurytreta campaniformis.*

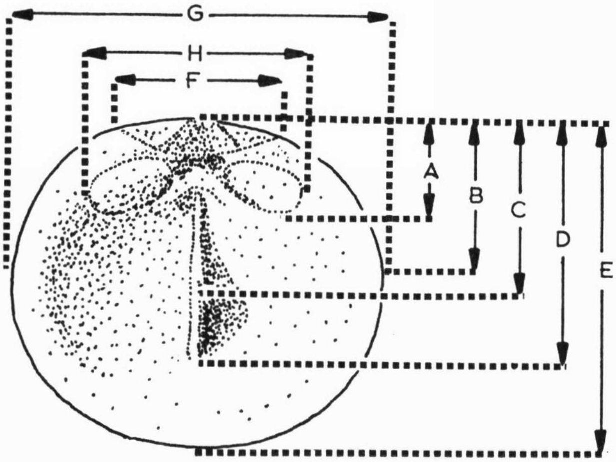

FIG. 38. Diagrammatic representation of the location of measurements on the brachial valves of *Eurytreta campaniformis.*

TABLE 15.—*Basic Statistics of Pedicle Valves of* Eurytreta campaniformis *from Locality 71/35.* [Measurements in mm except where noted. Location of measurements as in Fig. 37.]

VECTOR OF MEANS

A*	B	C	D
0.47	0.74	1.24	0.54

VARIANCE—COVARIANCE MATRIX

	A	B	C	D
A	0.45			
B	0.0000	0.0035		
C	0.0000	0.0009	0.0030	
D	0.0000	0.0020	0.0016	0.0032

MATRIX OF SAMPLE SIZES

	A	B	C	D
A	25			
B	25	25		
C	25	25	25	
D	25	25	25	25

* A is measured in degrees.

Genus HANSOTRETA Krause & Rowell, new genus

Type species.—*Hansotreta acrobela* Krause & Rowell, sp. nov.

Diagnosis.—Pedicle valve very tall, conical, apex pointed; pseudointerarea poorly defined, procline to apsacline, interridge narrow; foramen apical. Extreme apical region of pedicle valve thickened, thickening continued on anterior slope of valve as elongate, triangular apical process. Brachial valve suboval to subcircular in transverse outline, distinctly convex in lateral profile, posteriorly pointed, anterior and lateral margins rounded, passing imperceptibly into posterior margin. Posterior

TABLE 16.—*Basic Statistics of Brachial Valves of* Eurytreta campaniformis *from Locality 71/35.* [Measurements in mm. Location of measurements as in Fig. 38.]

VECTOR OF MEANS

A	B	C	D	E	F	G	H
0.18	0.41	0.43	0.56	0.78	0.34	0.89	0.43

VARIANCE—COVARIANCE MATRIX

	A	B	C	D	E	F	G	H
A	0.0006							
B	0.0004	0.0016						
C	0.0006	0.0003	0.0012					
D	0.0014	0.0021	0.0018	0.0059				
E	0.0006	0.0023	0.0009	0.0044	0.0047			
F	0.0004	0.0011	0.0004	0.0020	0.0018	0.0011		
G	0.0007	0.0022	0.0009	0.0039	0.0041	0.0018	0.0040	
H	0.0003	0.0000	0.0001	0.0008	0.0004	0.0001	0.0000	0.0029

MATRIX OF SAMPLE SIZES

	A	B	C	D	E	F	G	H
A	12							
B	12	13						
C	11	12	12					
D	12	13	12	13				
E	12	13	12	13	13			
F	12	13	12	13	13	13		
G	12	13	12	13	13	13	13	
H	12	12	11	12	12	12	12	12

sector at either side of beak gently concave. Beak small and gently swollen. Dorsal pseudointerarea raised, median plate triangular, gently concave and separating strongly anacline propareas. Cardinal muscle scars depressed, elongate, tonguelike in outline, directed anterolaterally, bounded posterolaterally by small, curved ridge. Anterior muscle scars commonly present on lobate elevations near center of valve. Median septum high ridge, wider anteriorly than posteriorly, wedgelike in lateral profile with highest part anterior to midlength of valve, ventroanterior margin of septum concave and grading gently into valve floor.

Ornament of fine, subdued growth lines.

Discussion.—In overall appearance *Hansotreta* is strongly suggestive of the Acrotretinae. The closest comparison may perhaps be made with the genus *Eurytreta*; both genera have comparable brachial valves. They possess very low and elongate dorsal median septa, and their dorsal and ventral pseudointerareas are similar in shape. The overall differences are probably more marked than are the resemblances: 1) the dorsal surface of the interridge in *Hansotreta* is concave apically and receives the strongly incurved, projecting beak of the opposing brachial valve. In *Eurytreta,* as in many acrotretids, the dorsal surface of the interridge is bowed dorsally and the resulting projection seats in the concave median plate of the brachial valve; 2) the dorsal cardinal muscle scars are elongate and directed anterolaterally in *Hansotreta* and round and positioned in front of the pseudointerarea in *Eurytreta*; 3) the pedicle valve of *Hansotreta* is a tall, erect cone with a procline-apsacline pseudointerarea, and a ventrally directed apex. The pedicle valve of *Eurytreta* although conical has a rounded anterior slope, a pseudointerarea that is commonly apsacline, rarely catacline, and a posteroventrally directed apex. A similar tall, acute, and conical pedicle valve is also known in another acrotretid species, *Torynelasma toryniferum* Cooper from Pratt Ferry, Alabama, but in the latter species an apical process is absent; moreover, there are gross differences in the structure of the associated brachial valves.

Semitreta Biernat (1973, p. 75) has a pedicle valve whose morphology is closely comparable to that of *Hansotreta,* but the dorsal surface of the interridge of the former genus is not concave apically. Associated with this feature, the brachial valve of *Semitreta* lacks the strongly incurved apex characteristic of *Hansotreta.* In the latter genus, the dorsal propareas are strongly anacline and nearly catacline; in this respect they are unique among known acrotretids.

HANSOTRETA ACROBELA Krause & Rowell, new species

Plate 6, figures 1-12; Plate 10, figures 5-6

Diagnosis.—Characters of *Hansotreta* with tall, conical pedicle valve, and apical angle about 30 degrees. Brachial valve with elevated pseudointerarea, propareas strongly anacline, cardinal scars lobate and median septum clubshaped in outline. Commissure sinuous and convex dorsally.

Description.—Shell suboval to subcircular in transverse outline, width 10 to 20 percent greater than length. Commissure dorsally convex.

Brachial valve strongly convex in lateral profile. Valve rarely slightly sulcate and in some instances with central groove in apposition to median septum. Valve posterior pointed, subtending anteriorly an angle greater than 140 degrees; posterior margin grading imperceptibly into lateral margins, interrupted medially by small, gently swollen and slightly projecting beak. Anterior and lateral margins rounded, anterior margin more gently so. Posterior sectors lateral of beak gently concave. Dorsal interior with raised pseudointerarea, median plate slightly concave and triangular in outline, and with gently concave anterior margin. Propareas strongly anacline, broadly triangular, smaller than median plate and very gently concave. Cardinal muscle scars elongate, tonguelike, anterolaterally directed, subtending anteriorly an angle close to 90 degrees, slightly concave, bounded posterolaterally by small, curved ridge and inclined toward central interior. Anterior muscle scars near center of valve on lobate elevations, rarely depressed. Median septum wider anteriorly than posteriorly, wedgelike in lateral profile with anterior slope concave and grading gently into valve floor, septum arising from low median buttress about 0.1 mm behind median plate and extending forward about two-thirds length of valve. Brim posterolaterally reflecting concavity of posterolateral sectors of valve.

Pedicle valve is an erect tall cone, procline to apsacline, with apical angle of about 30 degrees, posterior slope steeper than anterior slope. Margin of valve sinuous, anterior margin with ventrally directed undulation, lateral margins with dorsally directed undulation, and posterior margin v-shaped, directed ventrally. Ventral pseudointerarea poorly defined; comprising flattened, narrow, apically convergent strip on valve posterior; divided by indistinct and narrow interridge. Foramen at apex of projecting, short pedicle sheath. Ventral interior constricted apically by strong, anteriorly located, elongate triangular apical process, with dorsally facing platform divided medially by prismatic ridge that tapers dorsally and seemingly grades into valve anterior.

Ornament of thin, subdued growth lines.

Discussion.—Fragments of the ventral apex generally represent the most frequently recovered portion of the pedicle valve. This may be because the reinforcement offered by the massive apical process permits the apical portion of the valve to survive destruction more readily than the thinner and wider portion below the apical process. Measurements of *Hansotreta acrobela* are recorded on following page.

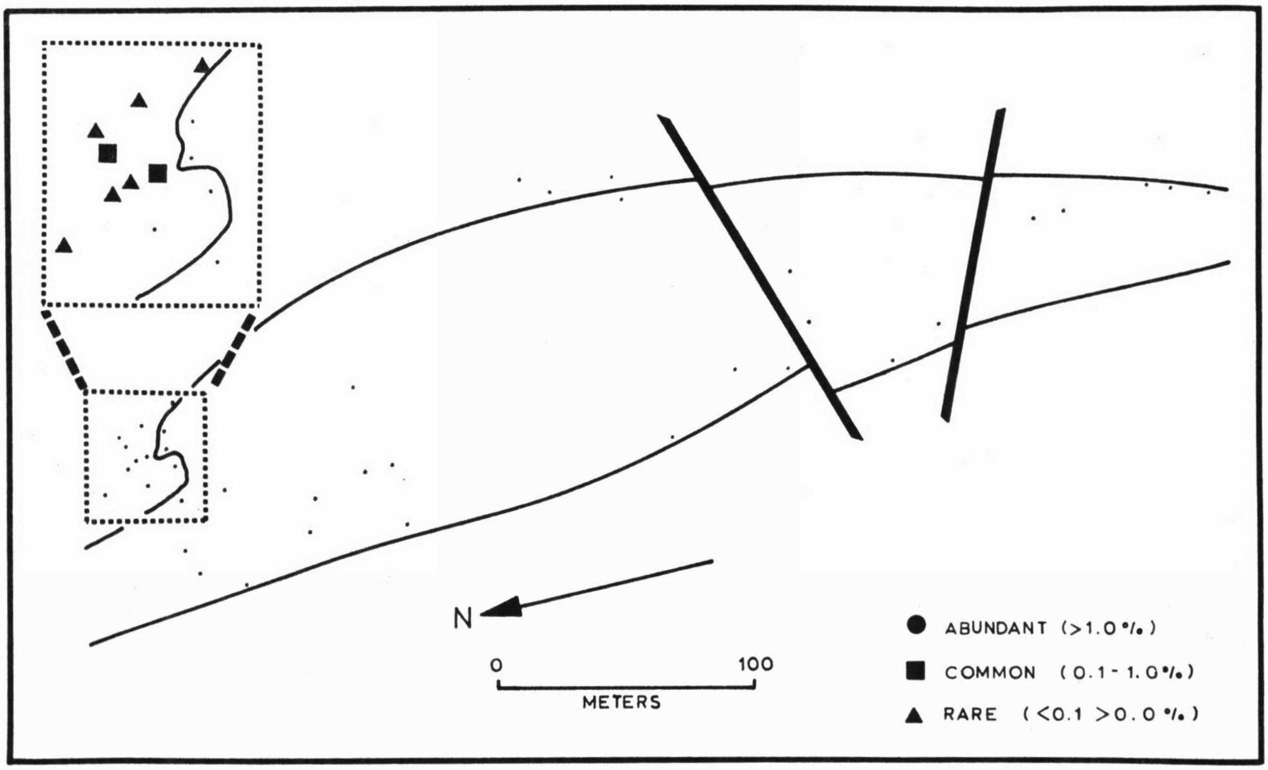

FIG. 39. Distribution of brachial valves of *Hansotreta acrobela.*

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Holotype	Brachial valve	KU 79780	1.40	......
Figured paratypes	Pedicle valve	KU 79781	0.96	1.26
	Brachial valve	KU 79782	0.84	0.98
	Pedicle valve fragment	KU 79783	......	......
	Brachial valve	KU 91464	1.35	1.50

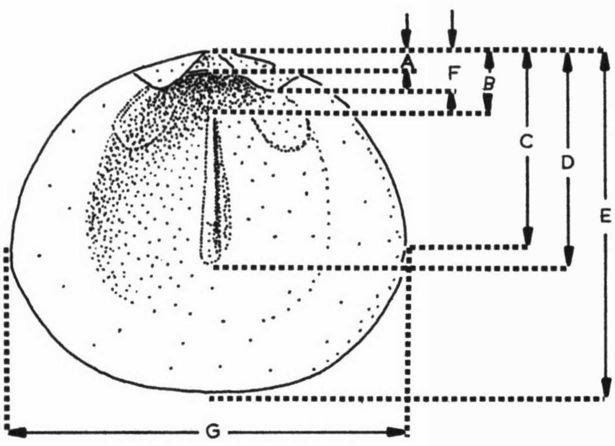

FIG. 40. Diagrammatic representation of the location of measurements on the brachial valves of *Hansotreta acrobela.*

Distribution.—Recorded at Localities 71/4, 71/6, 71/31, 71/32, 71/33, 71/34, 71/35 and 71/36 (Fig. 39).

Descriptive statistics.—Statistics are summarized in Figure 40 and Table 17.

TABLE 17.—*Basic Statistics of Brachial Valves of* Hansotreta acrobela *from Locality 71/35.* [Measurements in mm. Location of measurements as in Fig. 40.]

VECTOR OF MEANS

A	B	C	D	E	F	G
0.12	0.21	0.51	0.71	1.03	0.06	1.10

VARIANCE—COVARIANCE MATRIX

	A	B	C	D	E	F	G
A	0.0007						
B	0.0000	0.0039					
C	0.0017	0.0007	0.0044				
D	0.0018	0.0072	0.0062	0.0310			
E	0.0023	0.0076	0.0084	0.0360	0.0436		
F	0.0002	0.0003	0.0009	0.0019	0.0022	0.0002	
G	0.0028	0.0014	0.0083	0.0147	0.0206	0.0018	0.0231

MATRIX OF SAMPLE SIZES

	A	B	C	D	E	F	G
A	7						
B	7	7					
C	6	6	6				
D	7	7	6	7			
E	7	7	6	7	7		
F	7	7	6	7	7	7	
G	6	6	6	6	6	6	6

Subfamily SCAPHELASMATINAE Rowell, 1965

Pedicle valve conical, commonly with rounded apex; intertrough typically well developed, foramen posterior of apex; apical process, if present, low swelling anterior to foramen. Dorsal propareas commonly small, median buttress absent, septum triangular blade arising in front of median plate.

Genus SCAPHELASMA Cooper, 1956

Diagnosis.—Pedicle valve with rounded apex; pseudointerarea typically procline; intertrough present, narrow to deep; foramen elongate oval, apical process low rim surrounding foramen or absent, muscle scars unknown. Brachial valve umbonally convex, remainder typically flat to gently concave, more rarely gently convex; internally, median plate relatively short connecting poorly defined propareas; cardinal scars laterally located, rarely bounded medially by low ridges.

Ornament umbonally of fine growth lines, lamellose anteriorly; lamellae straight or incurved toward shell distally.

Discussion.—When erected, *Scaphelasma* was a monotypic genus as was *Rhysotreta.* Both were initially described only from the Pratt Ferry Formation at Pratt Ferry, Alabama (Cooper, 1956, p. 259). The two type species are markedly different and there is little possibility of confusing adult specimens with each other.

Although now known from several other parts of the Appalachians, no new material referred to *Rhysotreta* has been described or figured. *Scaphelasma,* however, has been recorded from elsewhere. Wright (1963, p. 240) doubtfully referred one brachial valve from the Portrane Limestone of Eire to the genus. More recently, Goryanskiy (1969, p. 69) has recognized the type species in the Volkhovian and Kundian of northwestern U.S.S.R. and erected a new subspecies, *S. septatum rugosum,* from the Tallinian of the same region. Biernat (1973, p. 89) has recorded a form comparable to the type species from Poland and erected a new species, *S. subquadratum,* from upper Lower and Middle Ordovician deposits of Poland and Estonia.

Several hundred valves referred to *Scaphelasma* have been recovered from the Meiklejohn mud mound. They show a considerable variation in morphology and three new species level taxa are recognized and discussed below. Not surprisingly, because the genus was initially based on one species, these new taxa require some modification of the concept of the genus. Four points are noteworthy: 1) an apical process is not invariably developed; indeed, its existence is unknown in these western forms; 2) the median plate, although commonly short and depressed, is relatively larger in at least one taxon (*S. anomalatum*) and is fused essentially coplanar with the dorsal propareas; 3) the cardinal scars in the brachial valve are typically not conspicuous, but in *S. anomalatum* they are bounded medially by short, low ridges; 4) although commonly concave in front of the dorsal umbo, some forms retain a convex brachial valve throughout life.

The second and third features recall the morphology of *Rhysotreta* and the distinction between the two genera is not as marked as it was formerly thought to be. Even the ornament, which is conspicuously dissimilar in the two type species, can be misleading if it is employed as the sole discriminant feature of *Scaphelasma* and *Rhysotreta.* In etched topotype material of the type species (*R. corrugata*) of the latter genus, the strong concentric rings described by Cooper (1956, p. 260) seemingly are formed by growth lamellae. The lamellae, instead of growing at an approximately constant angle from the shell (as is typical in lamellose brachiopods) curl through nearly 180 degrees when viewed in longitudinal cross section. The dorsal margin of each concentric ring of the pedicle valve is a free edge of a lamella and the concentric ring is essentially hollow. It is recognized that this appearance may be an artifact of the preparatory technique caused by the formic acid selectively removing shell material from beneath the outer layer of the ring. Such an explanation appears unlikely, for in all the material examined, it was always the dorsal margin that was free. To establish this point conclusively will require sectioning of specimens that have not been subjected to acid treatment. To date, no identifiable "crack out" material of *Rhysotreta* is known to be available. A closely comparable ornament, differing only in detail, is known for two taxa of *Scaphelasma. S. septatum rugosum* Goryanskiy is ornamented by strong concentric ridges or rings also formed by the incurling of growth lamellae (Goryanskiy, 1969) and *S. lamellosum* sp. nov. has a very similar ornament.

The concept of the two genera must be polythetic and be based on frequency distributions of attributes rather than upon their exclusive presence or absence. The degree of morphological overlap hints that the taxa may be cladistically closely related. Certainly, immature individuals, particularly isolated brachial valves, may be difficult to identify even to generic level.

SCAPHELASMA LAMELLOSUM Krause & Rowell, new species

Plate 6, figures 13-29

Diagnosis.—Characters of *Scaphelasma,* with anterior development of strong concentric rings, brachial valve with shallow median sulcus, and dorsal cardinal muscle scars not bounded by ridges.

Description.—Transversely oval in outline, maximum width being 25 to 30 percent greater than length and occurring near midlength of valve. Posterior margin of brachial valve variable from straight to subtending an angle of 160 degrees posteriorly, interrupted medianly by projecting dorsal umbo. Lateral margins strongly curved, anterior margin more gently rounded. Valve typically flat to gently convex in both lateral and anterior profiles. Umbo convex, divided medianly by very shallow sulcus extending to anterior margin of valve where it may be expressed as a posteriorly directed indentation of the valve outline. Lateral of umbo, valve gently concave to shell margin. Internally, dorsal pseudointerarea narrow; median plate relatively small except in gerontic specimens, typically projecting forward about 0.1 mm from beak, separating narrow propareas. Median septum strong, narrow, high, rounded triangular blade arising with little variation about 0.3 mm in front of beak, extending to about 0.1 mm from anterior margin of valve. Valve flattened marginally. Cardinal muscles posterolaterally located, scars rarely observed.

Pedicle valve procline, nearly catacline. Pedicle foramen an elongate slit behind apex of valve, pseudointerarea indistinct, intertrough narrow and shallow. Apical process not developed.

Ornament of brachial valve of two elements, concentric rings formed by anteriorly incurled growth lamellae and fine, threadlike ridges. The latter are relatively uniformly spaced, about 10 in 0.1 mm, and occur between concentric rings and over the otherwise smooth posterior part of valve. There is some variation in size, at which the first concentric ring appears, but typically it is developed between 0.35 and 0.5 mm from the beak. Number of concentric rings, commonly between four and six, is a function of valve size. Ornament of the pedicle valve basically similar, but the rings less conspicuous, the growth lamellae being more strongly incurved.

Discussion.—The only described taxon that closely resembles *Scaphelasma lamellosum* is *S. septatum rugosum* Goryanskiy. The Nevada material differs from the Russian specimens in several details. The latter is seemingly nonsulcate, the concentric rings commence much nearer the beak of the brachial valve, and the median plate of the dorsal pseudointerarea of *S. septatum rugosum* is relatively larger, projecting farther into the valve. Measurements of *S. lamellosum* are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Holotype	Complete shell	KU 79705	0.88	1.16
Figured paratypes	Complete shell	KU 79702	1.07	1.52
	Pedicle valve	KU 79703	0.82	1.10
	Brachial valve	KU 79704	1.16	1.54
	Pedicle valve	KU 79715	0.94	1.28

Distribution.—Recorded from Localities 71/5, 71/9, 71/10, 71/11, 71/12, 71/13, 71/15, 71/16, 71/19, 71/23, 71/24, 71/25, 71/26, 71/29, 71/30 and 71/35. Al-

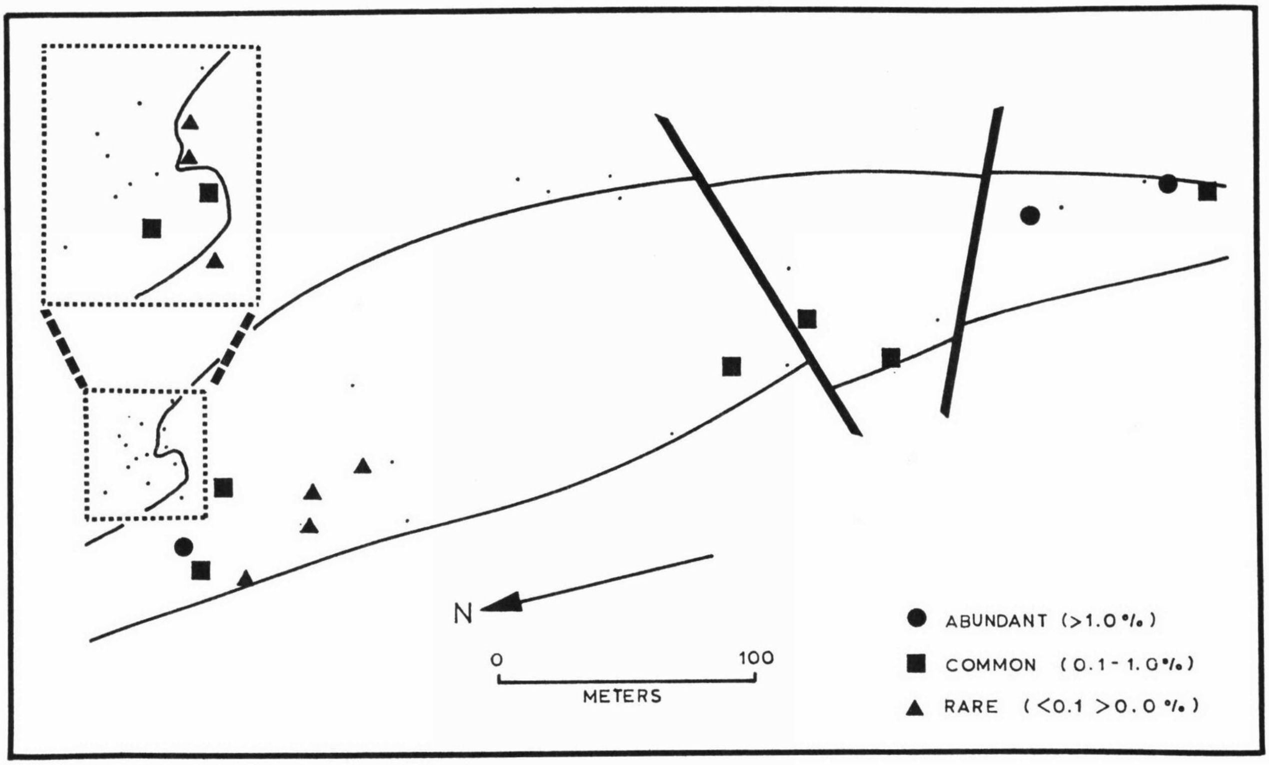

FIG. 41. Distribution of brachial valves of *Scaphelasma lamellosum*.

though data are perhaps still inadequate, present evidence suggests that this species does not occur in the uppermost part of the mound (Fig. 41).

Descriptive statistics.—Statistics are summarized in Figure 42 and Table 18.

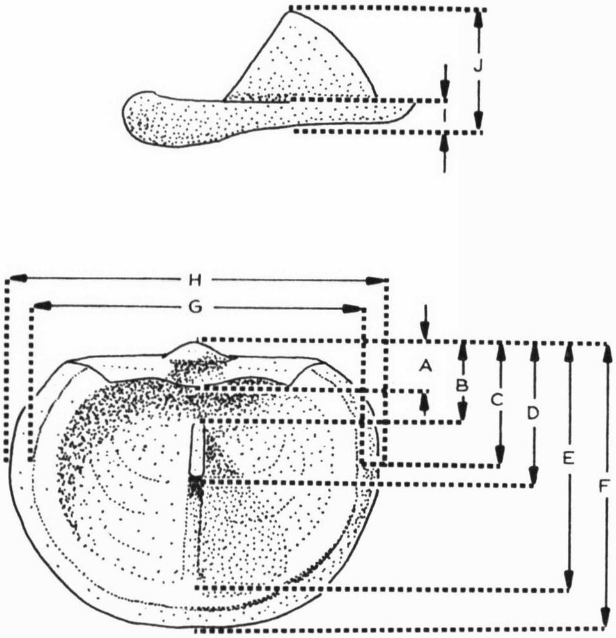

FIG. 42. Diagrammatic representation of the location of measurements on the brachial valves of *Scaphelasma lamellosum.*

SCAPHELASMA TUMIDATUM Krause & Rowell, new species

Plate 7, figures 7-14

Diagnosis.—Characters of *Scaphelasma,* with ornament of subdued concentric rings; thin shelled; brachial valve strongly convex, sulcate, and with oval, trapezoidal transverse outline.

Description.—In transverse outline an oval trapezoid, width being 15 to 20 percent greater than length and occurring anterior to midlength of valve. Posterior margin of brachial valve typically straight, interrupted medially by projecting dorsal umbo. Valve margins very strongly rounded anterolaterally, front margin nearly straight but slightly concave anteriorly. Valve gently or more commonly strongly convex. In more convex forms umbo swollen, swelling extending anteriorly along folds. Cardinal extremities flat or gently concave. Dorsal pseudointerarea narrow, seemingly consisting only of small median plate, generally lenticular in outline and concave. Median septum narrow, approximately one-third as high as valve is wide. Septum a triangular blade with rounded apex, ventroanterior margin gently convex with straight to slightly concave posteroventral edge, which may be slightly thickened. Septum arises about one-third valve length in front of beak and extends to within about 0.2 of anterior margin of valve. Anteriorly convex growth lines in blade. Valve with thin, flattened marginal brim. Cardinal muscles posterolaterally located, scars rarely visible.

TABLE 18.—*Basic Stastistics of Brachial Valves of* Scaphelasma lamellosum *from Locality 71/29.* [Measurements in mm. Location of measurements as in Fig. 42.]

VECTOR OF MEANS

A	B	C	D	E	F	G	H	I	J
0.10	0.30	0.43	0.53	0.78	0.91	0.88	1.18	0.13	0.38

VARIANCE—COVARIANCE MATRIX

	A	B	C	D	E	F	G	H	I	J
A	0.0007									
B	0.0001	0.0006								
C	0.0009	0.0002	0.0029							
D	0.0021	0.0008	0.0035	0.0092						
E	0.0032	0.0011	0.0053	0.0124	0.0216					
F	0.0036	0.0012	0.0066	0.0130	0.0228	0.0272				
G	0.0038	0.0012	0.0055	0.0134	0.0230	0.0269	0.0274			
H	0.0051	0.0018	0.0094	0.0179	0.0328	0.0394	0.0391	0.0582		
I	0.0010	0.0001	0.0018	0.0032	0.0053	0.0064	0.0069	0.0092	0.0025	
J	0.0026	0.0008	0.0044	0.0088	0.0182	0.0192	0.0188	0.0272	0.0058	0.0203

MATRIX OF SAMPLE SIZES

	A	B	C	D	E	F	G	H	I	J
A	25									
B	25	25								
C	25	25	25							
D	24	24	24	24						
E	25	25	25	24	25					
F	25	25	25	24	25	25				
G	22	22	22	21	22	22	22			
H	25	25	25	24	25	25	22	25		
I	25	25	25	24	25	25	22	25	25	
J	24	24	24	24	24	24	21	24	24	24

Pedicle valve incompletely known, catacline, probably also procline. Pedicle foramen an elongate slit behind apex of valve. Pseudointerarea indistinct, intertrough elongate and shallow. Ventral protegulum consists of a pair of anteriorly fused nodes. Apical process not developed. Anterior margin with ventrally directed undulation. Valve slightly sulcate.

Ornament of both valves consists of concentric, evenly spaced, ridgelike growth rings, spaced approximately every 0.1 mm.

Discussion.—Growth lines appear early in the umbonal area; coarser lines become dominant approximately 0.3 mm from the beak in the brachial valve and about 0.2 mm from the apex of the pedicle valve. The number of concentric rings varies with the shell size; in the brachial valve there are commonly 22 to 25. Finer threadlike rings are apparent on the anterior slope of the valve, between the coarser rings. Rings in the pedicle valve become more conspicuous towards the valve margin; some of the larger rings are lamellar rather than ridgelike.

Scaphelasma tumidatum differs from *S. lamellosum* and *S. septatum* in its ornament, the rings being more ridgelike than lamellose; its shell is characteristically thinner and the umbo is distinctly swollen. The dorsal median septum of *S. lamellosum* has generally a thickened ventral apex, not apparent in *S. tumidatum*. *S. subquadratum* Biernat shows the greatest resemblance to *S. tumidatum* in ornament. The two forms may be distinguished by the markedly more oval, transverse outline of the Polish species coupled with a less inflated brachial valve that lacks a sulcus. Measurements of *S. tumidatum* are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Holotype	Brachial valve	KU 79713	0.84	1.06
Figured paratype	Pedicle valve	KU 79714	0.87	1.22

Distribution.—Recorded at Localities 71/2, 71/6, 71/29 and 71/36. Although data are perhaps inadequate, it appears that this species is restricted to the uppermost part of the mound (Fig. 43).

Descriptive statistics.—Statistics are summarized in Figure 44 and Table 19.

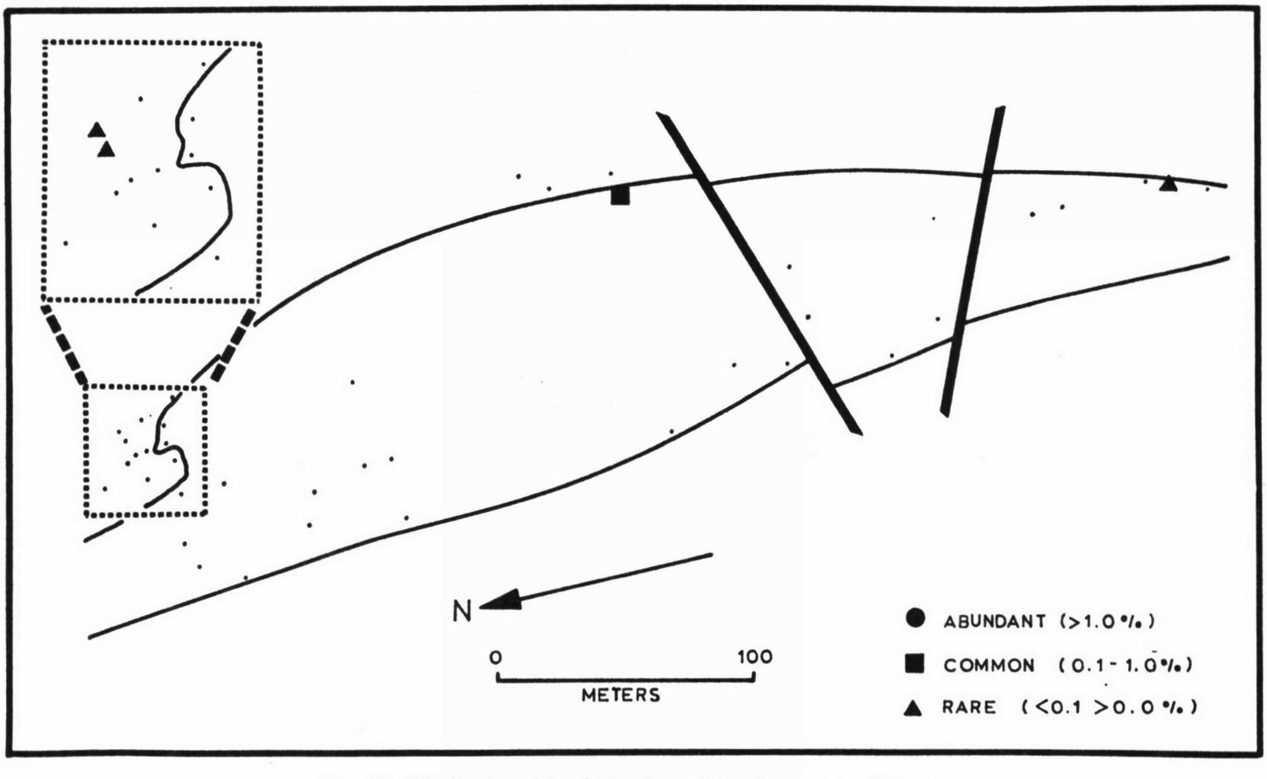

FIG. 43. Distribution of brachial valves of *Scaphelasma tumidatum*.

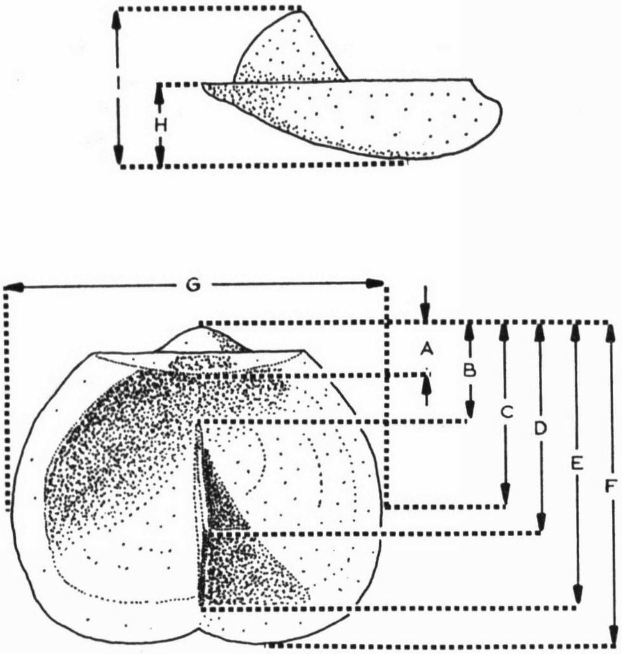

FIG. 44. Diagrammatic representation of the location of measurements on the brachial valves of *Scaphelasma tumidatum*.

SCAPHELASMA ANOMALATUM Krause & Rowell, new species

Plate 7, figures 1-6

Diagnosis.—Species of *Scaphelasma* with characters diagnostic of the genus except for the common development on the brachial valve of broad, shelflike pseudointerarea and cardinal scars generally bounded medially by low ridges; in the latter features this species resembles *Rhysotreta.*

Description.—Shell subcircular to slightly oval in outline, maximum width being approximately 15 percent greater than length and occurring near midlength of valve. Posterior margin of brachial valve variable, straight or subtending an angle of 160 degrees anteriorly or posteriorly; interrupted medially by projecting dorsal umbo. Shell margin strongly curved along lateral extremities; more gently curved anteriorly. Valve gently to strongly convex; anterior to midlength may be concave, sulcus present or absent. Cardinal extremities flat or gently concave. Dorsal pseudointerarea variable, narrow or broad and shelflike, seemingly undivided; if present, propareas extremely narrow. Median septum bladelike, approximately half as high as shell is wide, triangular in lateral profile, ventral apex rounded, posteroventral margin straight to slightly concave, anteroventral margin irregularly convex; septum arising about

TABLE 19.—*Basic Statistics of Brachial Valves of* Scaphelasma tumidatum *from Locality 71/2.* [Measurements in mm. Location of measurements as in Fig. 44.]

VECTOR OF MEANS

A	B	C	D	E	F	G	H	I
0.09	0.30	0.46	0.60	0.76	0.83	1.00	0.10	0.29

VARIANCE—COVARIANCE MATRIX

A	0.0005								
B	0.0001	0.0006							
C	0.0004	0.0008	0.0038						
D	0.0017	0.0011	0.0041	0.0111					
E	0.0022	0.0018	0.0052	0.0118	0.0166				
F	0.0020	0.0016	0.0041	0.0106	0.0149	0.0138			
G	0.0031	0.0017	0.0054	0.0146	0.0194	0.0179	0.0252		
H	0.0003	0.0001	0.0008	0.0013	0.0014	0.0008	0.0017	0.0006	
I	0.0018	0.0009	0.0024	0.0042	0.0087	0.0069	0.0099	0.0016	0.0098
	A	B	C	D	E	F	G	H	I

MATRIX OF SAMPLE SIZES

A	8								
B	8	8							
C	8	8	8						
D	8	8	8	8					
E	8	8	8	8	8				
F	8	8	8	8	8	8			
G	8	8	8	8	8	8	8		
H	8	8	8	8	8	8	8	8	
I	8	8	8	8	8	8	8	8	8
	A	B	C	D	E	F	G	H	I

0.3 mm in front of beak and extending almost to anterior margin of valve. Typically, valve margin with flattened and slightly raised brim. Cardinal muscles posterolaterally located and commonly bounded medially by short, low ridges.

Pedicle valve procline to catacline. Pedicle foramen an elongate slit behind apex of valve; pseudointerarea seemingly absent, intertrough narrow and shallow. Ventral protegulum consists of a pair of anteriorly fused mounds.

Ornament of brachial valve consists of concentric rings formed by anteriorly incurled growth lamellae and fine, threadlike growth lines. Former relatively uniformly spaced, about 5 in 0.2 mm in anterior part of valve. Latter also uniformly spaced on posterior of valve in front of raised dorsal protegulum and also in between incurled growth lamellae.

Ornament of pedicle valve similar, except rings and growth lamellae less well defined in the area of intertrough.

Discussion.—The number of larger lamellae ornamenting the shell is a function of size of valve and development of the lamellae; shells commonly possess between four and nine lamellae.

Scaphelasma anomalatum differs from *S. lamellosum*, *S. subquadratum*, and *S. tumidatum* in its development of a shelflike dorsal pseudointerarea and its cardinal scars demarcated by low ridges. However, smaller differences may also be detected, such as the development of a median septum that is seemingly higher than in the other two Meiklejohn species and growth lamellae that appear to follow a regular pattern; commonly, fine threadlike growth lines occur immediately anterior of the umbo and concentric growth lamellae dominate the anterior half of the shell.

The resemblance of this species with *Rhysotreta* has been discussed earlier (p. 49). Measurements of *S. anomalatum* are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Holotype	Brachial valve	KU 79710	1.08	1.22
Figured paratypes	Brachial valve	KU 79709	0.84	0.96
	Brachial and partial pedicle valve	KU 79712	0.76	0.92

Distribution.—Recorded at Localities 71/17 and 71/22. Although data are perhaps inadequate, it appears that this species is restricted to the middle part of the mound (Fig. 45).

Descriptive statistics.—Statistics are presented in Figure 46 and Table 20.

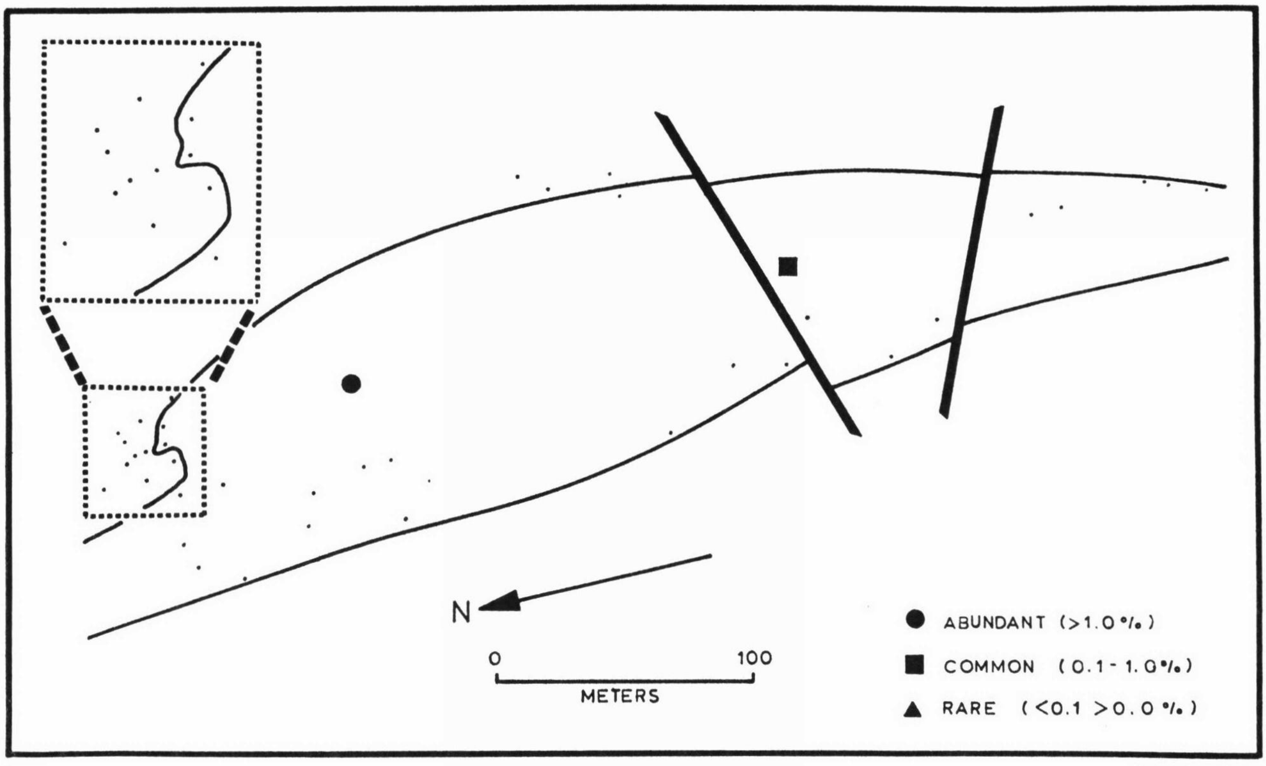

Fig. 45. Distribution of brachial valves of *Scaphelasma anomalatum*.

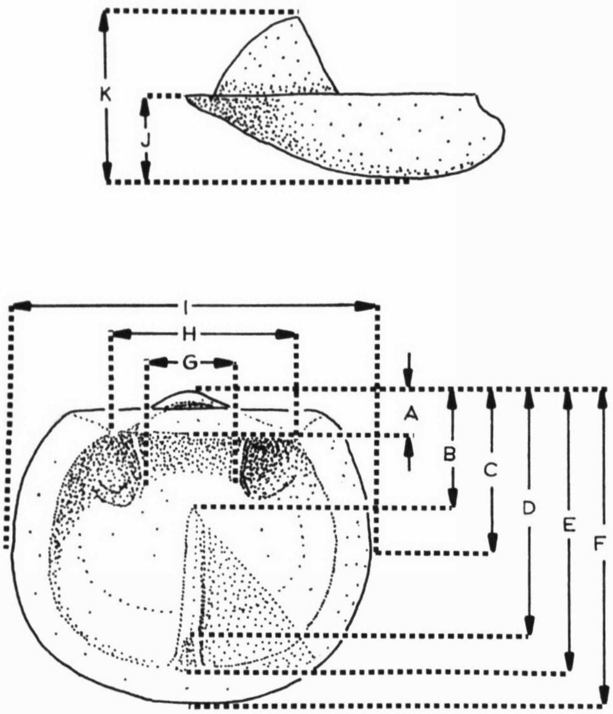

FIG. 46. Diagrammatic representation of the location of measurements on the brachial valves of *Scaphelasma anomalatum*.

Genus RHYSOTRETA Cooper, 1956

Diagnosis.—Pedicle valve conical, slightly apsacline to procline. Ornament typically of concentric rings formed by incurled lamellae; foramen slightly posterior of apex, tear-shaped, intertrough relatively narrow; apical process absent, muscle scars unknown. Brachial valve anterior of convex umbo typically concave, more rarely flat; internally, median plate well developed and broad, poorly demarcated from propareas; commonly projecting anteriorly as shelf; median septum high, arising in front of beak; cardinal muscle scars laterally located, bounded medially by thickened shell floor or ridges.

Discussion.—The similarities of *Rhysotreta* and *Scaphelasma* have been discussed previously. The new species from Meiklejohn causes only slight modification of the previous concept of the genus because in many features it is very similar to the type. We now know that the pedicle valve can be apsacline and that, although a concave brachial valve is perhaps typical, flat valves may occur.

RHYSOTRETA MODESTA Krause & Rowell, new species

Plate 7, figures 15-23

Diagnosis.—*Rhysotreta* having catacline-procline ventral pseudointerarea; brachial valve flat to very gently

TABLE 20.—*Basic Statistics of Brachial Valves of* Scaphelasma anomalatum *from Locality 71/17.* [Measurements in mm. Location of measurements as in Fig. 46.]

VECTOR OF MEANS

A	B	C	D	E	F	G	H	I	J	K
0.11	0.32	0.38	0.59	0.76	0.85	0.29	0.75	0.99	0.07	0.41

VARIANCE—COVARIANCE MATRIX

A	0.0008										
B	0.0002	0.0014									
C	0.0006	0.0004	0.0013								
D	0.0011	0.0004	0.0013	0.0036							
E	0.0019	0.0006	0.0025	0.0051	0.0105						
F	0.0019	0.0006	0.0029	0.0055	0.0106	0.0118					
G	0.0009	0.0001	0.0008	0.0018	0.0026	0.0038	0.0026				
H	0.0017	0.0000	0.0022	0.0049	0.0088	0.0097	0.0034	0.0098			
I	0.0021	0.0003	0.0029	0.0061	0.0110	0.0119	0.0041	0.0113	0.0143		
J	0.0005	0.0000	0.0006	0.0013	0.0021	0.0022	0.0011	0.0026	0.0030	0.0011	
K	0.0023	0.0000	0.0021	0.0046	0.0088	0.0086	0.0031	0.0086	0.0107	0.0028	0.0004
	A	B	C	D	E	F	G	H	I	J	K

MATRIX OF SAMPLE SIZES

A	25										
B	25	25									
C	25	25	25								
D	25	25	25	25							
E	25	25	25	25	25						
F	25	25	25	25	25	25					
G	11	11	11	11	11	11	11				
H	25	25	25	25	25	25	11	25			
I	25	25	25	25	25	25	11	25	25		
J	25	25	25	25	25	25	11	25	25	25	
K	25	25	25	25	25	25	11	25	25	25	25
	A	B	C	D	E	F	G	H	I	J	K

concave anterior of umbo; relatively fine concentric ornament, on brachial valve 9 to 13 rings in anterior 0.5 mm of valve, on pedicle valve 8 to 11 rings in anterior 0.5 mm of valve.

Description.—In outline shell subcircular to slightly transversely oval, maximum width about 10 percent greater than length and occurring near midlength of valve. Posterior margin of brachial valve nearly straight, dorsal beak projecting slightly. Lateral margins strongly curved and anterior margin more gently rounded. In both lateral and anterior profile valve is almost flat except for small, convex, umbonal region. In front of umbo, median sector typically gently concave, more rarely flat. Internally, dorsal pseudointerarea well developed and anacline, median plate variably demarcated from adjacent propareas; in some shells boundary not discernable. Median plate projects forward as a shelf, which may partially overhang posterior end of median septum in large specimens. Septum strong and initially bladelike, becoming thickened in old specimens. Septum high, originating some 0.3 mm in front of dorsal beak, triangular in outline with anteroventral slope nearly in contact with internal surface of pedicle valve and extending to thickened brim of valve. Brim characteristic feature of older valves, emphasized in forms which approach geniculation. Cardinal muscle scars in front of propareas bounded laterally by brim and medially by ridges, which in old shells may coalesce, burying posterior part of median septum.

Pedicle valve incompletely known. Valve conical and high, adult forms having a height greater than twice the length of valve. Pseudointerarea typically slightly apsacline in larger valves. Intertrough relatively narrow and marked by reduction in height of ornament rather than by inward deflection of the valve.

Ornament consists of strong incurved growth lamellae.

Discussion.—In many brachial valves there is an abrupt change in growth during later stages of life; shell increments are added dominantly ventrally rather than radially and the valve becomes almost geniculate. This change in growth pattern typically commences when the valve is about 1 mm long, but the observed range is between 0.9 and 1.3 mm. Nothing is known of the form of the pedicle foramen because none of the pedicle valves retain the apical region.

In addition to the difference in orientation of the ventral pseudointerarea, which is slightly apsacline, and the reduced concavity of the brachial valve, ***Rhysotreta modesta*** is distinguished from *R. corrugata* Cooper by possessing a finer and somewhat less regular ornament. In eight topotype brachial valves, the number of con-

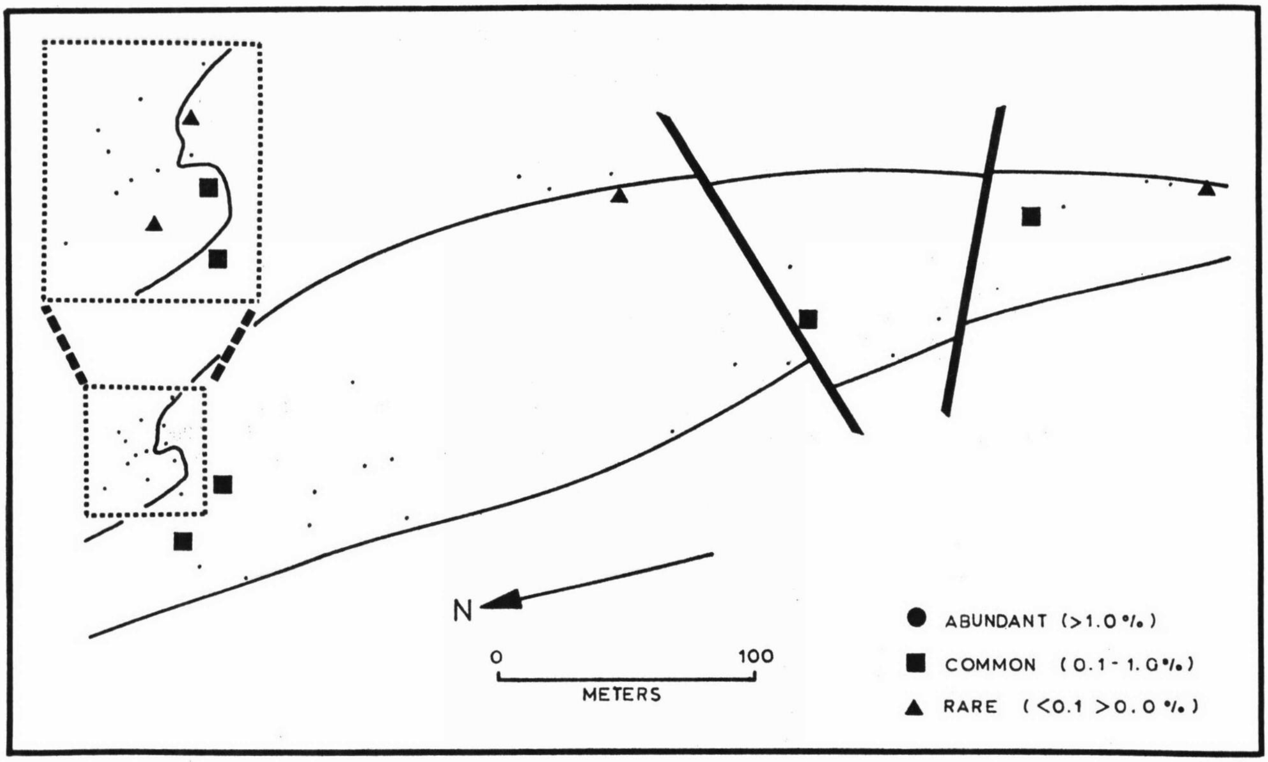

FIG. 47. Distribution of brachial valves of *Rhysotreta modesta*.

centric rings within the annulus 0.5 mm-1.0 mm from the beak was:

no. of rings	no. of specimens
10	2
11	2
12	2
13	2

Elsewhere on the mound, the number shows even greater variation, the observed range being between eight and 14 rings in the above distance. The irregularity in the ornament is seemingly in part associated with its closer packing. The concentric rings, some of which are impersistent laterally, are formed by incurved growth lamellae and commonly in *Rhysotreta modesta* they are incurved less than the 180 degrees that is typical of *R. corrugata.*

In general form the species is much like *Rhysotreta corrugata,* but there are several consistent differences between the Nevada and Alabama populations. It is appreciated that these may be of no more significance than geographical variation of essentially synchronous populations, but until such time as the latter may be demon-

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Holotype	Brachial valve	KU 79707	1.32	1.40
Figured paratypes	Brachial valve	KU 79708	1.04	1.24
	Incomplete pedicle valve	KU 79706	1.00	1.18

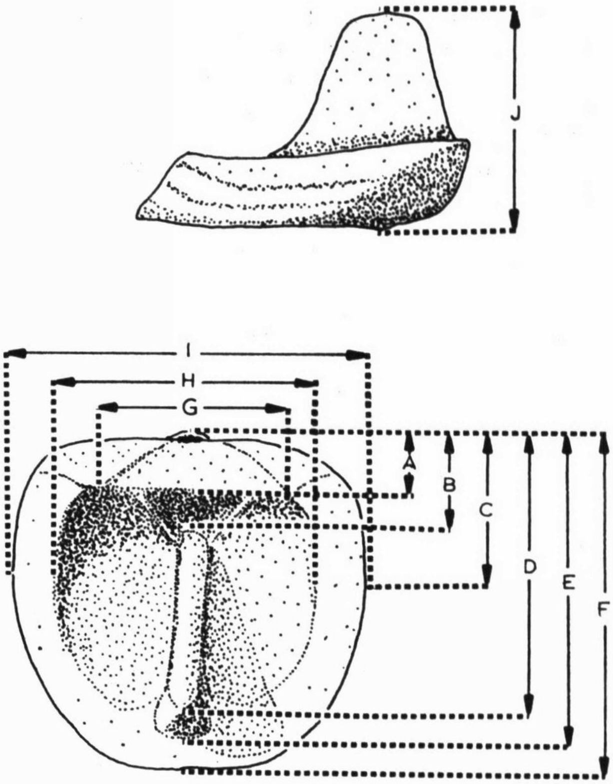

FIG. 48. Diagrammatic representation of the location of measurements on the brachial valves of *Rhysotreta modesta.*

TABLE 21.—*Basic Statistics of Brachial Valves of* Rhysotreta modesta *from Locality 71/7.* [Measurements in mm. Location of measurements as in Fig. 48.]

VECTOR OF MEANS

A	B	C	D	E	F	G	H	I	J
0.15	0.31	0.47	0.72	0.99	1.11	0.50	0.94	1.27	0.58

VARIANCE—COVARIANCE MATRIX

A	0.0011									
B	0.0000	0.0012								
C	0.0004	0.0000	0.0051							
D	0.0019	0.0008	0.0029	0.0086						
E	0.0023	0.0001	0.0038	0.0086	0.0125					
F	0.0022	0.0000	0.0039	0.0084	0.0127	0.0136				
G	0.0018	0.0000	0.0007	0.0062	0.0081	0.0071	0.0122			
H	0.0018	0.0001	0.0031	0.0068	0.0109	0.0111	0.0086	0.0136		
I	0.0024	0.0004	0.0032	0.0088	0.0136	0.0142	0.0096	0.0166	0.0203	
J	0.0024	0.0000	0.0027	0.0069	0.0099	0.0096	0.0094	0.0102	0.0121	0.0121
	A	B	C	D	E	F	G	H	I	J

MATRIX OF SAMPLE SIZES

A	25									
B	25	25								
C	25	25	25							
D	25	25	25	25						
E	25	25	25	25	25					
F	25	25	25	25	25	25				
G	25	25	25	25	25	25	25			
H	23	23	23	23	23	23	23	23		
I	25	25	25	25	25	25	25	23	25	
J	25	25	25	25	25	25	25	23	25	25
	A	B	C	D	E	F	G	H	I	J

strated, they are here regarded as discrete taxa. Measurements of *R. modesta* are given below.

Distribution.—Recorded at Localities 71/2, 71/5, 71/7, 71/8, 71/12, 71/13, 71/14, 71/24?, 71/26 and 71/30 (Fig. 47).

Descriptive statistics.—Statistics are summarized in Figure 48 and Table 21.

Subfamily TORYNELASMATINAE Rowell, 1965

Diagnosis.—Conical pedicle valve, apical foramen at or posterior of apex, apical process absent or a low anteroapical swelling. Brachial valve with median blade bearing ventrally concave, flat, or convex triangular surmounting plate.

Genus TORYNELASMA Cooper, 1956

Diagnosis.—Pseudointerarea small or large, variably defined, apsacline to procline; intertrough narrow, shallow and indistinct.

Brachial valve convex in lateral profile; median septum a triangular blade, originating a short distance behind dorsal pseudointerarea and posteroventral slope bearing a triangular surmounting plate that broadens anteriorly; cardinal scars posterolaterally located.

Ornament of thin, concentric, growth lines with or without radially arranged pustules.

Discussion.—The genus *Torynelasma* as we presently understand it is more variable and diverse than has previously been suspected. The new species *T. papillosum* is morphologically quite different from other described species of the genus in its ornament and the shape of the pedicle valve. The surmounting plate on the median septum, which Cooper (1956, p. 257) described as a unique character, is still the most characteristic feature of the genus, but other characters show greater variation. The profile and acute beak of the pedicle valve, while still noteworthy and typical of several species, are not invariably present. If *T. papillosum* is included, the pedicle valve can also be procline and have a large apical angle as well as a large pseudointerarea. Goryanskiy's (1969, p. 71, footnote) comment: "The pedicle valve figured by Cooper in Pl. 28, fig. 16, possibly belongs to the shell of another genus, since it has not only a low conical form but also a distinct pseudointerarea," while probably true for the figured species, would, with the above concept, no longer bar it from the genus.

The possibility of erecting a new genus with *Torynelasma papillosum* as its type species was considered but rejected at the present time for the following reasons:

1) The genus would at best be monotypic.

2) Introduction of a new genus may prove to be a barrier extremely difficult to surmount subsequently. When larger and more complete collections become available it may be possible to subdivide the stock further in a more meaningful manner than is presently possible.

3) Wright (1972, p. 3) points out, "if any degree of order is to prevail in systematic taxonomy, the proposers of new genera must realize that they have a responsibility to erect taxa which are unequivocally identifiable by all workers as well as being biologically defensible." The morphological characters exhibited by *T. papillosum* are very similar to those for the genus it has been placed in and until more is known of variation among related forms, the erection of a new genus to receive it would be premature.

Torynelasma is found in North America at Pratt Ferry, Alabama, in the Pratt Ferry Formation (Cooper, 1956, p. 257). Goryanskiy (1969, p. 71) has recorded a new subspecies *T. minor rossicum* from the Volkhov and Kukruse of the northwest Russian Platform. He also has tentatively referred several pedicle valves to (?) *T. magnum*, which he collected from the Pakerort and Leyetsian of the same region. Biernat (1973, p. 93) has elevated Goryanskiy's subspecies to a species and noted its occurrence in the Lower and Middle Ordovician of northeast Poland. She also erected a new species, *T. rarum*, from upper Middle Ordovician deposits of northeast Poland. Both of these species differ from at least the majority of North American specimens referred to the genus in possessing a surmounting plate that is strongly concave dorsally. The lateral margins of this plate droop down to become subparallel with the supporting septum in old individuals. Seemingly, the surmounting plate of all European specimens has this shape (Biernat, 1973, p. 91), in contrast to the typical flat or dorsally convex form of the plate in North American material. Biernat took the view that we need to know more about the geographic distribution of this character difference before relating it to the supraspecific classification, a position with which we concur.

TORYNELASMA PAPILLOSUM Krause & Rowell, new species

Plate 7, figures 24-27; Plate 8, figures 1-6; Plate 11, figures 1, 7

Diagnosis.—Species of *Torynelasma*, with ornament of very fine concentric growth lines with small pustules arranged linearly and radiating from the valve apex. Pedicle valve squat, procline with a nipplelike apex and wide pseudointerarea.

Description.—Transverse semicircular outline, maximum width being 30 to 35 percent greater than length and occurring posterior to midlength of valve. Posterior margin of brachial valve subtending an angle of 160 to 170 degrees anteriorly, interrupted medially by projecting beak. Cardinal extremities strongly rounded, anterior margin more gently rounded. Valve convex in lateral profile and broadly convex in anterior profile, anteriorly sulcate, typically with flattened band extending from lateral extremities of pseudointerarea and running

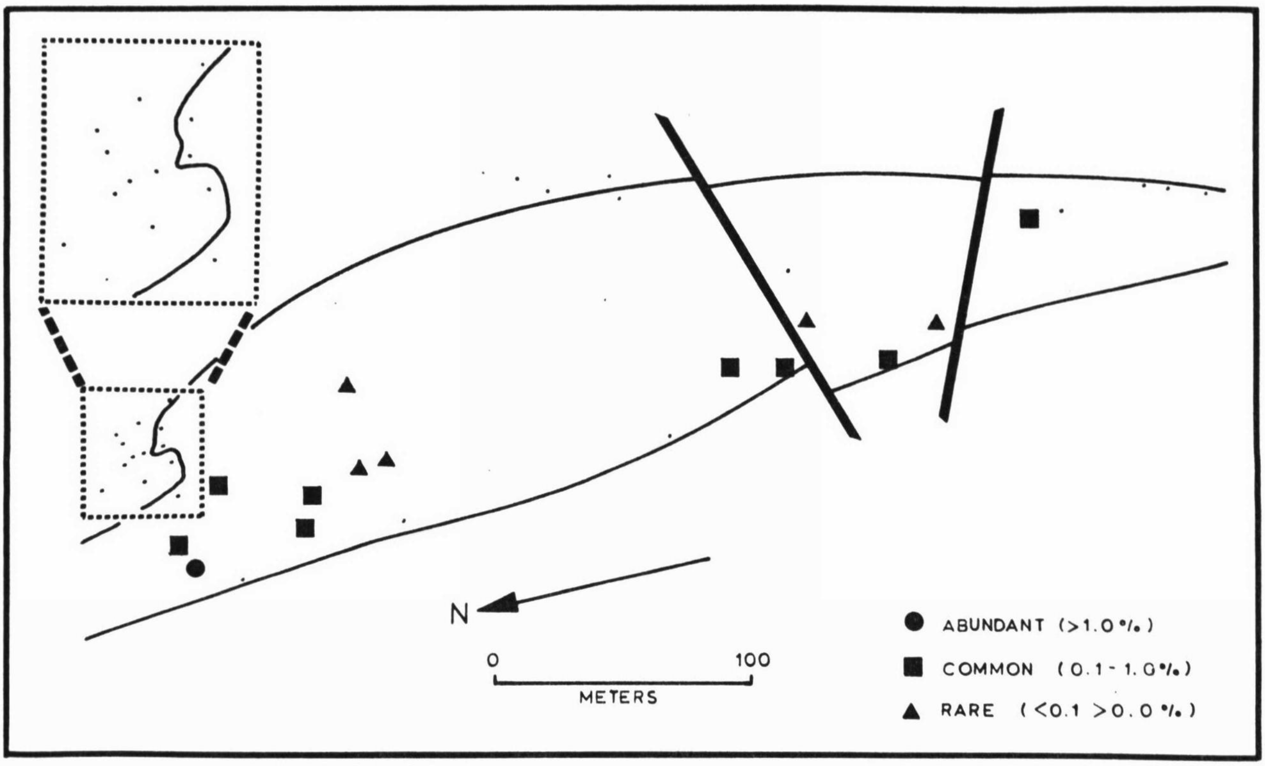

FIG. 49. Distribution of brachial valves of *Torynelasma papillosum*.

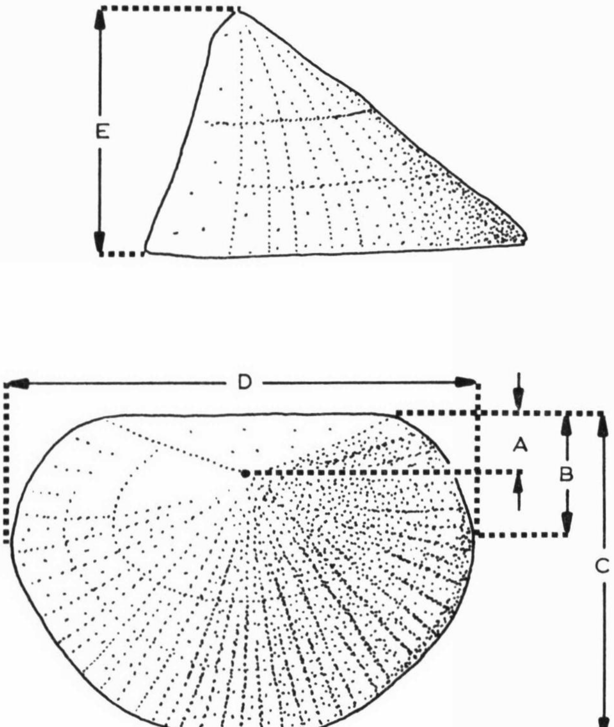

FIG. 50. Diagrammatic representation of the location of measurements on the pedicle valves of *Torynelasma papillosum*.

TABLE 22.—*Basic Statistics of Pedicle Valves of* Torynelasma papillosum *from Locality 71/10.* [Measurements in mm. Location of measurements as in Fig. 50.]

VECTOR OF MEANS

A	B	C	D	E
0.26	0.33	0.92	1.27	0.62

VARIANCE—COVARIANCE MATRIX

	A	B	C	D	E
A	0.0025				
B	0.0023	0.0054			
C	0.0043	0.0101	0.0295		
D	0.0057	0.0126	0.0362	0.0471	
E	0.0021	0.0062	0.0179	0.0229	0.0129

MATRIX OF SAMPLE SIZES

	A	B	C	D	E
A	25				
B	25	25			
C	25	25	25		
D	25	25	25	25	
E	25	25	25	25	25

length of lateral and anterior margins. Dorsal umbo convex, with raised protegulum. Internally dorsal pseudointerarea narrow, broadly triangular in outline and with slightly raised margins; median plate depressed, concave and separating narrow propareas. Median buttress depressed medially. Cardinal muscle scars prominent, posterolaterally placed and shaped like a Spanish wineskin. Median septal plate, narrow, high, anteroventral margin anteriorly convex, posteroventral edge supporting triangular surmounting plate. Septum extending to about 0.1 mm from anterior margin. Maximum height of septum close to midlength of valve. Surmounting plate triangular with apex originating on posteroventral margin of septum, widening anteroventrally, generally with medial depression and raised lateral margins.

Pedicle valve procline, broadly conical and with straight posterior margin. Pedicle foramen round, located posteriorly of nipplelike protegular node. Ventral pseudointerarea large and flat, propareas separated by indistinct interridge. Commonly with an apical process that may be expressed as a thickening of the shell apically or as a low buttress anteroapically. Subdued muscle (?) platforms apparent laterally and midway up the cone. Margin of the valve gently undulated anteriorly to accept sulcus of brachial vave.

Ornament of very fine growth lines and minute pustules. Pustules formed by localized swellings of growth lines arranged in lines radiating from the beak. Pustules most prominent on anterolateral and anterior sectors of the shell.

Discussion.—The brachial valve of young shells of *Torynelasma papillosum*, i.e., shells measuring approximately 0.7 mm in width and 0.5 mm in length, show most of the features displayed by the larger valves, except

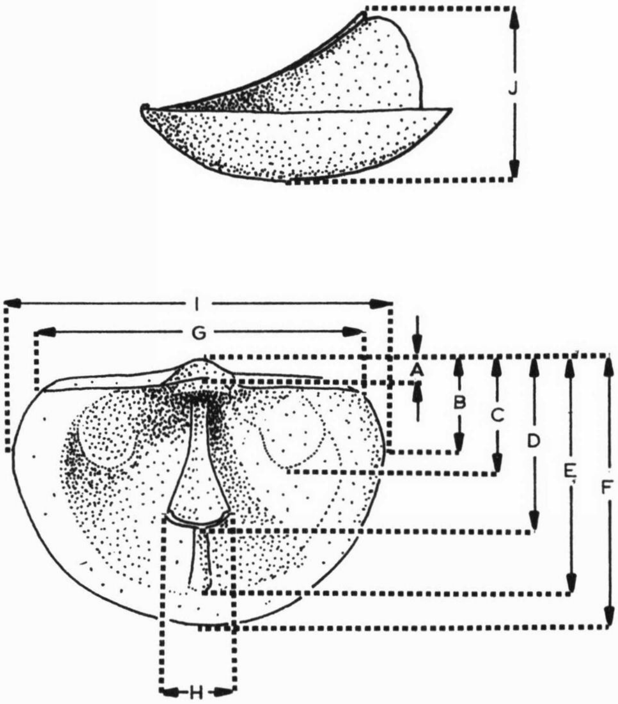

FIG. 51. Diagrammatic representation of the location of measurements on the brachial valves of *Torynelasma papillosum*.

TABLE 23.—*Basic Statistics of Brachial Valves of* Torynelasma papillosum *from Locality 71/10.* [Measurements in mm. Location of measurements as in Fig. 51.]

VECTOR OF MEANS

A	B	C	D	E	F	G	H	I	J
0.07	0.33	0.30	0.49	0.76	0.88	0.75	0.14	1.18	0.34

VARIANCE—COVARIANCE MATRIX

A	0.0006									
B	0.0006	0.0033								
C	0.0002	0.0008	0.0014							
D	0.0012	0.0030	0.0019	0.0048						
E	0.0022	0.0057	0.0035	0.0079	0.0161					
F	0.0024	0.0071	0.0045	0.0098	0.0196	0.0246				
G	0.0022	0.0039	0.0041	0.0069	0.0157	0.0191	0.0243			
H	0.0009	0.0013	0.0012	0.0022	0.0046	0.0054	0.0045	0.0021		
I	0.0030	0.0087	0.0061	0.0121	0.0249	0.0311	0.0247	0.0073	0.0409	
J	0.0009	0.0029	0.0024	0.0037	0.0087	0.0106	0.0081	0.0031	0.0142	0.0065
	A	B	C	D	E	F	G	H	I	J

MATRIX OF SAMPLE SIZES

A	23									
B	23	25								
C	14	15	15							
D	23	25	15	25						
E	23	25	15	25	25					
F	23	25	15	25	25	25				
G	19	20	12	20	20	20	20			
H	23	25	15	25	25	25	20	25		
I	23	25	15	25	25	25	20	25	25	
J	23	25	15	25	25	25	20	25	25	25
	A	B	C	D	E	F	G	H	I	J

that the surmounting plate just covers the posteroventral tip of the septal plate. At this stage, the nipplelike protegulal node is the dominant element of the pedicle valve; a relatively large foramen in the posterior sector of the protegulum is also characteristic. On the interior, although the pedicle valve is thickened around the apex, an apical process, visible in some of the larger valves, is not apparent at this stage.

The Meiklejohn specimens differ from previously described species in possessing a characteristic and unusual papillose ornament. The shape of the pedicle valve is also unusual in that it is a low cone with a broad apical angle and a squat profile. Some resemblance is seen between the brachial valves of *Torynelasma papillosum* and *T. toryniferum* in the transverse semicircular outline and convexity. The surmounting plate of the Nevada species resembles that of *T. minor*, but otherwise *T. papillosum* is morphologically quite distinct. Measurements of *T. papillosum* are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Holotype	Brachial valve	KU 79721	1.08	1.40
Figured paratypes	Brachial valve	KU 79722	0.60	0.86
	Brachial valve	KU 101049	0.92	1.22
	Pedicle valve	KU 101057	0.80	1.12
	Pedicle valve	KU 79726	1.00	1.40

Distribution.—Recorded from Localities 71/8, 71/10, 71/12, 71/15, 71/16, 71/17, 71/18, 71/19, 71/23, 71/24, 71/25, 71/26, 71/28 and 71/108 (Fig. 49).

Descriptive statistics.—Statistics are presented in Figures 50 and 51 and in Tables 22 and 23.

Subfamily EPHIPPELASMATINAE Rowell, 1965

Diagnosis.—Pedicle valve conical, typically high, beak incurved, intertrough indistinct. Foramen apical or slightly posterior of apex, circular; apical process absent or narrow septum on anterior slope. Dorsal propareas small, short; median plate concave. Dorsal septal structure consisting of spinose, saddlelike surmounting plate arising from valve floor anterior of median plate and buttressed by commonly convoluted median septal plate; septal plate or surmounting plate may be absent.

Discussion.—The above diagnosis differs rather markedly from that of Rowell (1965) and Biernat (1973), particularly with regard to the septal structure in the brachial valve. Previously, the subfamily has been regarded as monotypic and its known members all referred to the genus *Ephippelasma*. Our present concept of the subfamily would include *Myotreta* Goryanskiy and, thus, the Myotretinae Biernat. Although the septal structures in the brachial valves of the type species of *Myotreta* (*M. crassa* Goryanskiy) and *Ephippelasma* (*E. minutum* Cooper) differ rather conspicuously from each other, the majority of features of both valves are very similar. Moreover, species of *Ephippelasma* are known (e.g., *E. spinosum* Biernat, *E. latior* Biernat) in which the saddlelike surmounting plate is supported by a median septal plate. In the former species, the septal plate is crenulated and reminiscent of the median septum of *Myotreta estoniana* Biernat.

Genus EPHIPPELASMA Cooper, 1956

Diagnosis.—Ephippelasmatinae with dorsal septal structure consisting of saddlelike, spinose surmounting plate, attached to valve floor posteriorly. Buttressing septal plate may be absent.

Discussion.—When erected, *Ephippelasma* was monotypic and Cooper considered its type species, *E. minutum*, a unique and rather unusual inarticulate brachiopod and in its description stated, "No other species of the genus is known, and no other genus has a species quite like it." As a species, *E. minutum* is still unique, but Biernat's (1973) record of rather similar forms from Poland and the new material from the Meiklejohn mud mound do necessitate some consideration. The Polish material and specimens from Nevada differ from topotype material of *E. minutum* from the Pratt Ferry Formation of Alabama in having the surmounting plate buttressed by an underlying median septal plate. Whereas some might consider this difference to be of sufficient magnitude to warrant the erection of a new genus, we have preferred to follow Biernat (1973) in expanding the concept of *Ephippelasma* to include such forms. Ultimately, when more is known of the stratigraphic and geographic distribution of ephippelasmatins, it may be possible to subdivide them in a meaningful manner.

EPHIPPELASMA SPINOSUM Biernat, 1973

Plate 8, figures 7-22; Plate 10, figures 1-4, 7, 8; Plate 11, figure 2

Diagnosis.—Like *Ephippelasma* with spinose surmounting plate supported by short septal plate, high conical pedicle valve.

Description.—Shell elliptical in transverse outline, maximum width approximately 25 to 30 percent greater than length and occurring near midlength of shell.

Brachial valve with rounded lateral and anterior margins, posterior margin straight or subtending anteriorly an angle greater than 160 degrees, interrupted medially by projecting dorsal beak. Valve may be flattened marginally to produce lateral and anterior brim. Umbo raised, with distinct protegular node. Valve commonly gently concave in anterior profile, commonly flat in lateral profile, more rarely gently convex. Sulcus shallow and distinct, typically with longitudinal groove. Cardinal extremities generally flat. Dorsal pseudointerarea narrow; depressed median plate broad and concave, separating narrow, triangular, anacline propareas. Cardinal muscle scars commonly present, lateral and in front of propareas, wineskin-like in outline. Small oval muscle scar may be preserved on either side of median plate near center of valve. Arborescent surmounting plate, originating about 0.1 mm in front of median plate as narrow blade generally with thickened posterior margin, flaring ventrally and anteriorly as a cupped and variably forked spinose structure, which overhangs apically truncated and pronged anterior portion of its supporting septal plate. Number of projecting spines variable, maximum number observed 31. Spines seemingly hollow. Septal plate commonly extending to about 0.15 mm from anterior margin of adult valve.

Pedicle valve elongate and stoutly conical, commonly apsacline, more rarely catacline. Foramen circular, small, situated on posterior of umbo and slightly posterior of small, nipplelike beak. Foramen with very faint posterior lip. Ventral pseudointerarea large, much higher than wide, with indistinct intertrough terminating apically against beak. Posterior margin interrupted medially by small, dorsally projecting tongue. Anterior and posterior margins with apically directed undulations. Anterior undulation accepts sulcus of brachial valve; posterior undulation less pronounced than anterior undulation. Short pedicle tube and small septum confined to apical interior, tube located posteroapically and with triangular outer wall. Margin of septum apically convex, terminating anteriorly against generally low and triangular platform along inner anterior wall. Tube diameter increases internally, being slightly wider at interior opening than at foramen.

Ornament of fine, densely packed growth lines. Growth lines on brachial valve seemingly smaller and more closely spaced than on pedicle valve.

Discussion.—Brachial valves that are roughly equal in size display much variability in the complexity and robustness of the arborescent surmounting plate. The greatest observed variation occurs in the number of spines on this plate; two brachial valves (with the largest septal structures), one measuring 0.76 mm in length and 1.08 mm in width, the other 0.8 mm in length and 1.04 mm in width, have 22 and 31 spiny projections, respectively; many smaller nodes and knobs are also present, indicating that a greater number of spines can be present in older individuals.

The most striking changes that can be observed in the ontogeny of the species are in the development of the dorsal septal structure. In the smallest identified brachial valves (forms approximately 0.3 mm long and 0.4 mm wide) the structure consists of a triangular blade with a thickened posteroventral margin terminating in a single anteroventrally directed spine; the tip of the spine is nodose rather than smoothly terminated. A brachial valve of this size is strongly convex, and the propareas are prominent and markedly anacline; the posterior margin is interrupted medially by a narrow and wide overhanging brim. Even though the pedicle valve at this stage is incompletely known, some differences are noteworthy: the anterior slope is gentler than is otherwise found in older, larger specimens, and a protuberant ventral beak overhangs a wide, but indistinct, pseudointerarea. The ventral median septum appears to be missing when valves are this small. The size and complexity of the dorsal median septal structure increases with growth, but for a given length and width of the brachial valve it will be at variable stages of development. The single spine found in the smallest brachial valves grows several anterolaterally deflected spines whose forks are filled with shell material, like the webbed toes of a duck (Pl. 10, fig. 1-3). This is the beginning of the development of the surmounting plate. The anterolateral deflection of the spines is compensated during later growth by their slow anteriorly directed deflection so that they come to attain a position more or less parallel to the septal plate and consequently become cupped. This curvature of the surmounting plate is further accentuated in older shells by continual addition of spines along its dorsal margin, until they touch or almost touch the valve floor. Commonly, the surmounting plate may be asymmetric in anterior profile, because one side has added more spines or spread them more widely. Spines also occur on the supporting median septal plate anteriorly and beneath the surmounting plate (Pl. 10, fig. 3, 7). The septal plate may have one spine or several alternating, stacked, and/or branching spines; frequently, four or five spines are present. Spines on the septal plate directly beneath the tip of the surmounting plate are generally the most complex ones found; they commonly bifurcate and sometimes are multiforked. The median septal plate is quite thin, almost translucent in the younger valves, but is much more robust and thicker in the largest valves found.

The material from the Meiklejohn mound is very similar to the type material of *Ephippelasma spinosum* described and figured by Biernat (1973, p. 96) from the Llanvirnian of northeast Poland. *E. spinosum* differs markedly from the type species of the genus, *E. minutum* Cooper, in several details, the most striking being the form of the septal structure in the brachial valve. The surmounting plate of *E. spinosum* has more numerous and longer spines than that of *E. minutum;* moreover, the surmounting plate of the latter is not buttressed by a median septal plate.

The sulcus on the brachial valve of *Ephippelasma spinosum* is commonly accompanied by a longitudinal groove, which is apparently absent in the Pratt Ferry species. The pedicle valve of the Meiklejohn species seemingly differs internally from *E. minutum* in that it possesses a small apical pedicle tube and a small median blade. The latter have not been reported in the type

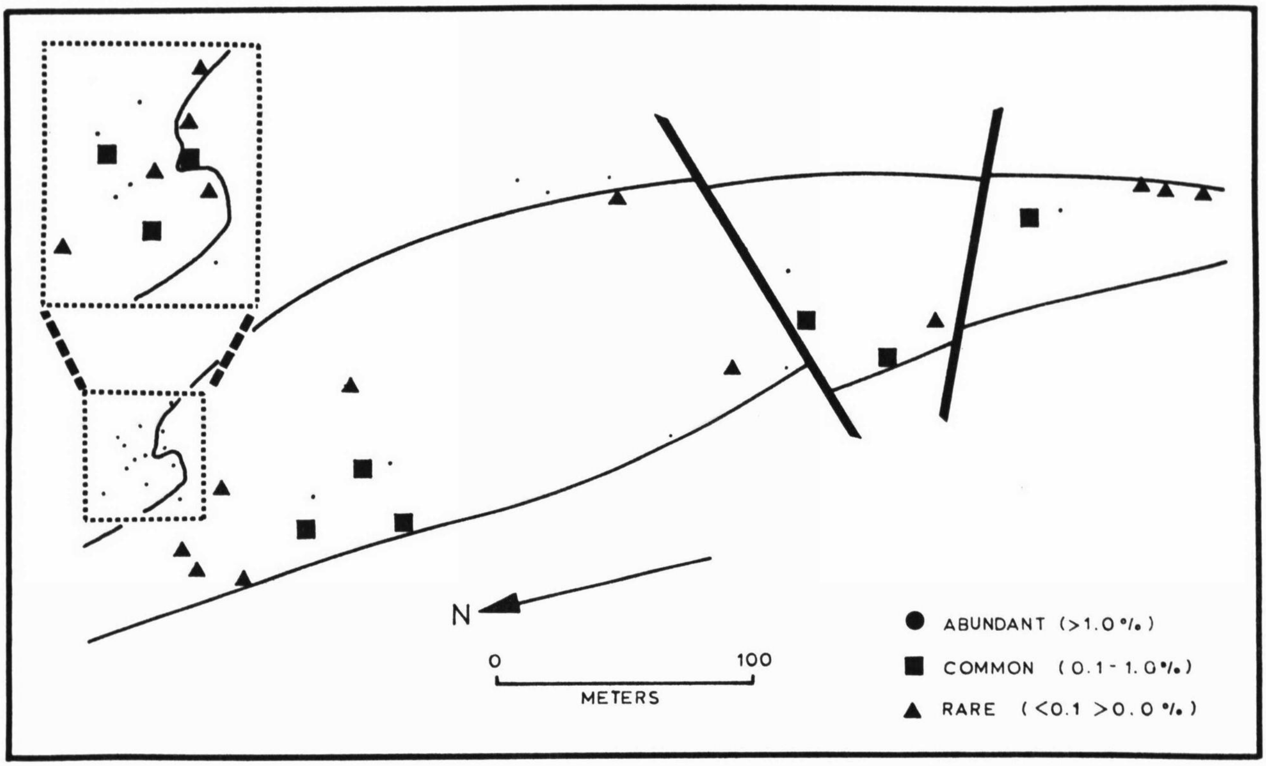

FIG. 52. Distribution of brachial valves of *Ephippelasma spinosum.*

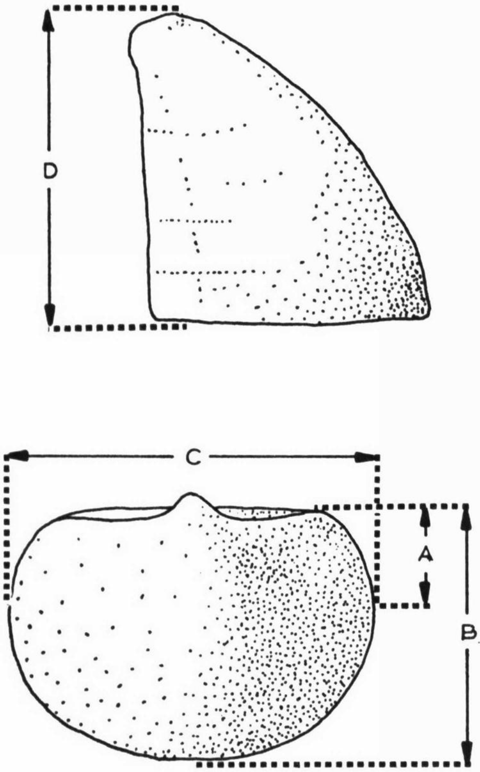

FIG. 53. Diagrammatic representation of the location of measurements on the pedicle valves of *Ephippelasma spinosum.*

species. Measurements of *E. spinosum* are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Figured specimens	Brachial valve	KU 79771	0.76	1.08
	Complete specimen	KU 79831	0.60	0.80
	Brachial valve	KU 91119	0.62	0.78
	Brachial valve	KU 79765	0.40	0.52
	Brachial valve	KU 79766	0.52	0.70
	Brachial valve	KU 79767	0.68	0.88
	Brachial valve	KU 79770	0.74	1.02
	Brachial valve	KU 79772	0.80	1.00
	Pedicle valve	KU 79775	0.62	0.94

TABLE 24.—*Basic Statistics of the Pedicle Valves of* Ephippelasma spinosum *from Locality 71/9.* [Measurements in mm. Location of measurements as in Fig. 53.]

VECTOR OF MEANS

A	B	C	D
0.25	0.56	0.78	0.60

VARIANCE—COVARIANCE MATRIX

A	0.0029			
B	0.0036	0.0086		
C	0.0073	0.0158	0.0304	
D	0.0064	0.0154	0.0275	0.0296
	A	B	C	D

MATRIX OF SAMPLE SIZES

A	4			
B	4	4		
C	4	4	4	
D	4	4	4	4
	A	B	C	D

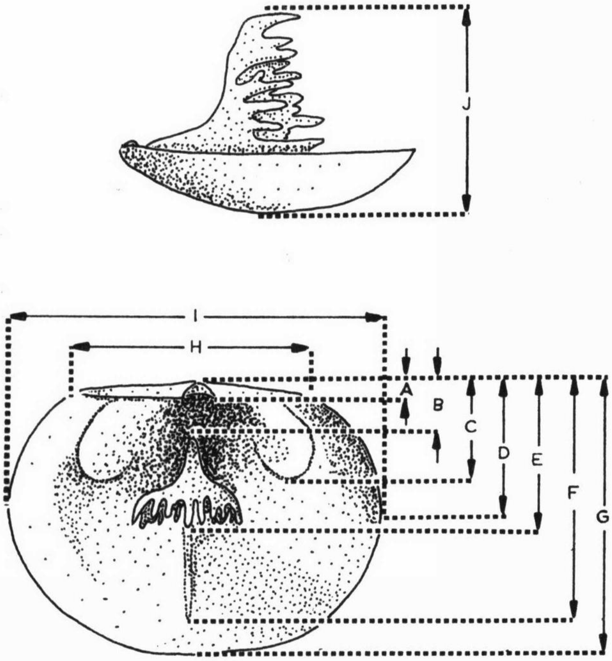

FIG. 54. Diagrammatic representation of the location of measurements on the brachial valves of *Ephippelasma spinosum*.

Distribution.—Recorded at Localities 71/2, 71/5, 71/6, 71/7, 71/8, 71/9, 71/10, 71/11, 71/12, 71/13, 71/14, 71/15, 71/16, 71/18, 71/19, 71/20, 71/23, 71/24, 71/25, 71/26, 71/28, 71/29, 71/30, 71/31, 71/33, 71/34, 71/35 and 71/37 (Fig. 52).

Descriptive statistics.—Statistics are presented in Figures 53 and 54 and Tables 24 and 25.

? Superfamily ACTROTRETACEA Schuchert, 1893

Family EOCONULIDAE Rowell, 1965

Genus EOCONULUS Cooper, 1956

Diagnosis.—Cemented by pedicle valve which may or may not be mineralized. When preserved, bears typically flat cementation scar of suboval outline; later growth may give valve form of truncated cone, posterior slope not modified by pseudointerarea. Internally, two large posterolaterally located muscle scars separated by prominent apical boss. Brachial valve low, often irregular, cone, apex subcentral, outline varying from subquadrate to transversely suboval. Internally, pair of posterolateral cardinal muscle scars variably expressed, commonly strongly developed. Both valves ornamented by concentric growth lines, which may be irregular.

Discussion.—Rowell and Krause (1973, p. 798) have discussed the genus and some of the problems associated with it. Biernat (1973, p. 111) has also considered it and the family Eoconulidae; she referred the family to the Craniacea following Cooper (1956) and Rowell (1965), but did so only tentatively. She also erected a new

TABLE 25.—*Basic Statistics of the Brachial Valves of* Ephippelasma spinosum *from Locality 71/9.* [Measurements in mm. Location of measurements as in Fig. 54.]

VECTOR OF MEANS

A	B	C	D	E	F	G	H	I	J
0.04	0.15	0.21	0.29	0.36	0.49	0.66	0.38	0.84	0.25

VARIANCE—COVARIANCE MATRIX

A	0.0002									
B	0.0002	0.0005								
C	0.0004	0.0004	0.0014							
D	0.0002	0.0005	0.0005	0.0021						
E	0.0003	0.0001	0.0003	0.0001	0.0009					
F	0.0005	0.0001	0.0013	0.0000	0.0014	0.0038				
G	0.0004	0.0001	0.0014	0.0000	0.0008	0.0035	0.0043			
H	0.0006	0.0004	0.0028	0.0000	0.0018	0.0044	0.0038	0.0068		
I	0.0006	0.0002	0.0032	0.0000	0.0018	0.0058	0.0056	0.0080	0.0104	
J	0.0005	0.0000	0.0021	0.0000	0.0018	0.0040	0.0027	0.0062	0.0074	0.0072
	A	B	C	D	E	F	G	H	I	J

MATRIX OF SAMPLE SIZES

A	9									
B	9	9								
C	6	6	6							
D	9	9	6	9						
E	9	9	6	9	9					
F	9	9	6	9	9	9				
G	9	9	6	9	9	9	9			
H	9	9	6	9	9	9	9	9		
I	9	9	6	9	9	9	9	9	9	
J	9	9	6	9	9	9	9	9	9	9
	A	B	C	D	E	F	G	H	I	J

species, *Eoconulus semiregularis,* based on material from an erratic boulder of probable late Ordovician age from the Baltic coast of Poland. This species, as the three previously named species (*E. rectangulatus* Cooper, *E. transversus* Wright, and *E. cryptomyus* Goryanskiy), is known only from its brachial valve. Biernat (1973, p. 111) mentioned the possibility that the pedicle valve was entirely organic and not mineralized, a possibility that Goryanskiy (1969, p. 107) briefly considered. A comparable situation exists for the craniids *Philhedrella* Kozłowski and *Acanthocrania* Williams, which are also known only from their brachial valves. There is no doubt that many, perhaps all living *Crania anomala* Müller pass through a stage in their ontogeny during which only the brachial valve is mineralized. The dorsal mantle secretes calcite earlier than the ventral one and although a thin calcite valve is developed dorsally on forms greater than 0.2 mm, it is not until the animals are about 1 mm long that a mineralized pedicle valve is discernible (Rowell, 1960, p. 48). Even at this stage only a marginal annulus of calcite is present. It is not known whether this difference in developmental stage at which calcite is secreted by the two mantles is characteristic of all craniaceans; it would appear unlikely in free-living forms like *Orthisocrania* Rowell.

Rowell and Krause (1973, p. 799) described as *Eoconulus* sp., a form that has been recovered from Ordovician beds near Wells and from the mud mound at Meiklejohn Peak. Since that date, better preserved material has been examined and the form is described subsequently herein as a new species, *Eoconulus antelopensis.* It is unusual among eoconulids in that it has a well-developed phosphatic pedicle valve. There is no doubt that the pedicle and brachial valves are associated; many specimens from the mound retain both valves in contact (Pl. 8, fig. 27, 30). Equally, there is little doubt that the internal morphology of the brachial valve of *E. antelopensis* is closely comparable to that of *E. rectangulatus,* the type species of the genus. Unless one were to take the position that the possession of the pedicle valve was sufficient to debar the species from *Eoconulus,* there would seem little justification for not placing it there.

As we have previously discussed (Rowell & Krause, 1973, p. 798), the gross morphology of the pedicle valve suggests that the Eoconulidae should perhaps be transferred to the Acrotretacea. We still feel that this position can be regarded only as tentative.

EOCONULUS ANTELOPENSIS Krause & Rowell, new species

Plate 8, figures 23-32; Plate 9, figures 1-4; Plate 12, figures 1, 2

Diagnosis.—Like *Eoconulus* with irregular, subquadrate, transverse outline. Apical region of brachial valve conical, peripherally irregularly convex, flat, or even concave. Pedicle valve mineralized.

Description.—Brachial valve rounded subquadrate in transverse outline, commonly rather irregular with posterior margin wider than anterior margin, low conical with apex subcentral or slightly behind center of valve. Apical region conical, peripherally irregularly convex, flat, or even concave. Internally lacking pseudointerarea and rather featureless except for two weakly expressed, posterolateral, cardinal muscle scars. Lateral and anterior margin of valves may be gently flattened to form narrow limbus.

Pedicle valve with conspicuous cicatrix of attachment; typically, attachment scar of comparable outline and slightly smaller than brachial valve, more rarely taking form of mold of cylindrical object. Such specimens only slightly distorted and revealing subconical adult pedicle valve with rounded apex, procline posterior slope, lateral and anterior margin nearly normal to commissure plane. More commonly, flat attachment scar truncating upper part of cone, scar being either subparallel with commissure plane or inclined toward it posteriorly. No external modification of posterior slope observed. Anterior slope rarely sulcate. Pedicle valve bearing strong cardinal muscle scars posterolaterally, inner (median) margins of scars commonly elevated above adjacent shell and appearing as two laterally diverging ridges. Between scars, dorsally projecting boss resembling some acrotretid apical process. No internal pedicle foramen observed. Numerous small pits arranged in a horseshoelike fashion marginally may occur on interior apical surface.

Ornamentation of very fine growth lines.

Discussion.—*Eoconulus antelopensis* seemingly differs from previously described taxa in outline of brachial valve and the development of the dorsal cardinal muscle scars.

The significance of the pedicle valve has been discussed earlier. In addition, several pedicle valves of *Eoconulus antelopensis* have been recovered that contain the outer surface of a second pedicle valve variably superimposed on the inner surface of another one (Pl. 8, fig. 31, 32); in some rare instances a third pedicle valve has also been observed. This condition was initially thought to be an artifact related to the depositional history of these valves; two valves could have accidentally come into contact, buried shortly thereafter and later cemented through diagenetic processes. Although this possibility can not be completely ruled out for all of the multiply attached pedicle valves, it is thought provoking that doubly attached brachial valves have not been observed. If this event were one dependent solely on sedimentological parameters, then the likelihood of it occurring to a brachial valve should be comparable to that for a pedicle valve. The probability might be even greater because the pedicle valve would tend to remain cemented to its host after death of the brachiopod, while the brachial valve would be lost almost immediately to be incorporated in the sediment. It appears more likely

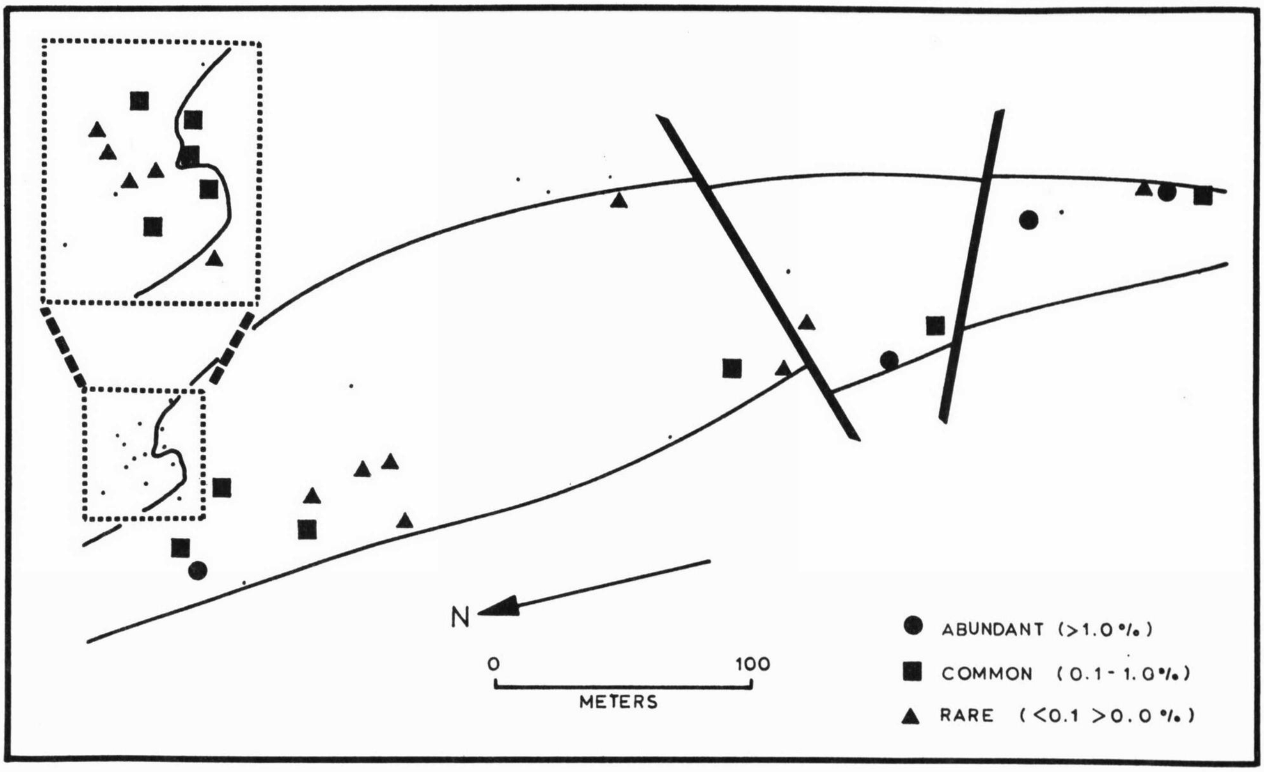

FIG. 55. Distribution of brachial valves of *Eoconulus antelopensis*.

that larvae of *E. antelopensis* found the empty and still attached pedicle valve of one of its own kind a suitable substrate. Close examination of double valves indicates that the inner valve may in some cases be wrapped around an edge of the older valve, or may mantle and replicate the internal features of the first valve. Measurements of *E. antelopensis* are given below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Holotype	Complete specimen	KU 79798	0.70	0.80
Figured paratypes	Pedicle valve	KU 79800	0.70	0.70
	Pedicle valve	KU 103435	0.82	1.00
	Pedicle valve	KU 79802	0.84	0.86
	Pedicle valve	KU 79803	0.80	1.06
	Brachial valve	KU 103119	0.90	0.85
	Brachial valve	KU 79805	0.76	0.84
	Brachial valve	KU 79806	0.78	1.04

Distribution.—Recorded at Localities 71/4, 71/5, 71/7, 71/8, 71/9, 71/10, 71/12, 71/13, 71/14, 71/15, 71/16, 71/18, 71/19, 71/20, 71/23, 71/24, 71/25, 71/26, 71/28, 71/29, 71/30, 71/31, 71/33, 71/34, 71/35, 71/36, 71/37 and 71/108 (Fig. 55). The same form has also been recorded as *Eoconulus* sp. by Rowell and Krause (1973, p. 799) from approximately contemporaneous beds near Wells, Nevada.

Descriptive statistics.—Statistics are summarized in Figures 56 and 57 and in Tables 26 and 27.

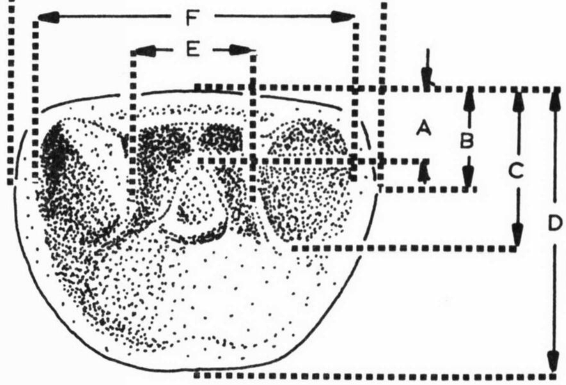

FIG. 56. Diagrammatic representation of the location of measurements on the pedicle valves of *Eoconulus antelopensis*.

TABLE 26.—*Basic Statistics of the Pedicle Valves of* Eoconulus antelopensis *from Locality 71/29.* [Measurements in mm. Location of measurements as in Fig. 56.]

VECTOR OF MEANS

A	B	C	D	E	F	G	H	I
0.24	0.36	0.30	0.82	0.35	0.72	0.97	0.66	0.56

VARIANCE—COVARIANCE MATRIX

	A	B	C	D	E	F	G	H	I
A	0.0036								
B	0.0023	0.0039							
C	0.0000	0.0005	0.0091						
D	0.0015	0.0031	0.0014	0.0058					
E	0.0016	0.0019	0.0016	0.0053	0.0154				
F	0.0015	0.0030	0.0000	0.0061	0.0111	0.0129			
G	0.0016	0.0038	0.0006	0.0068	0.0064	0.0088	0.0098		
H	0.0037	0.0062	0.0000	0.0088	0.0113	0.0134	0.0121	0.0262	
I	0.0000	0.0033	0.0041	0.0065	0.0007	0.0025	0.0056	0.0029	0.0236

MATRIX OF SAMPLE SIZES

	A	B	C	D	E	F	G	H	I
A	25								
B	25	25							
C	25	25	25						
D	25	25	25	25					
E	25	25	25	25	25				
F	25	25	25	25	25	25			
G	25	25	25	25	25	25	25		
H	25	25	25	25	25	25	25	25	
I	25	25	25	25	25	25	25	25	25

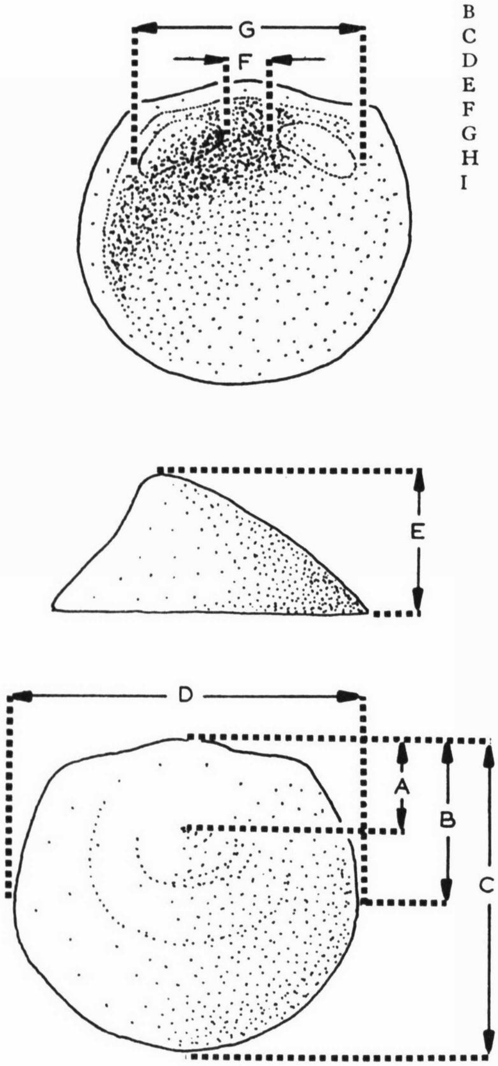

FIG. 57. Diagrammatic representation of the location of measurements on the brachial valves of *Eoconulus antelopensis*.

TABLE 27.—*Basic Statistics of the Brachial Valves of* Eoconulus antelopensis *from Locality 71/29.* [Measurements in mm. Location of measurements as in Fig. 57.]

VECTOR OF MEANS

A	B	C	D	E	F	G
0.24	0.30	0.75	0.85	0.30	0.26	0.60

VARIANCE—COVARIANCE MATRIX

	A	B	C	D	E	F	G
A	0.0017						
B	0.0000	0.0098					
C	0.0001	0.0005	0.0037				
D	0.0007	0.0000	0.0022	0.0048			
E	0.0000	0.0000	0.0000	0.0000	0.0058		
F	0.0008	0.0000	0.0000	0.0032	0.0000	0.0042	
G	0.0008	0.0000	0.0014	0.0049	0.0000	0.0039	0.0074

MATRIX OF SAMPLE SIZES

	A	B	C	D	E	F	G
A	13						
B	13	13					
C	13	13	13				
D	13	13	13	13			
E	13	13	13	13	13		
F	9	9	9	9	9	9	
G	11	11	11	11	11	9	11

Superfamily SIPHONOTRETACEA Kutorga, 1848

Family SIPHONOTRETIDAE Kutorga, 1848

Diagnosis.—Biconvex, typically ornamented by hollow spines, pedicle foramen circular and apical or may extend by resorption onto anterior slope of valve, producing elongate triangular opening. Posterior part of elongate opening commonly closed by plate that may be continued interiorly as a pedicle tube, anterodorsally directed. Pseudointerarea of pedicle valve small to absent, beak of brachial valve marginal; pseudointerarea may be clearly divided into two propareas by small pit or median plate.

Genus MULTISPINULA Rowell, 1962

Rowell's (1962, p. 147) description of the genus is followed herein.

MULTISPINULA sp.

Plate 9, figures 13-17

Several fragments, possibly not conspecific, can be identified as belonging to *Multispinula*. Specific identification is precluded because of the nature and small number of the available fragments.

The posterior margin of the brachial valve is nearly straight and is interrupted medially by the projecting beak. This valve is convex and has a swollen umbo; some fragments have been flattened after burial and could lead one to believe, mistakenly, that the brachial valve is flat. The dorsal pseudointerarea in adult forms is narrow, anacline, and has a low, indistinct, triangular median ridge separating wide but short propareas. The pseudointerarea in young forms is probably absent, or if present, is vestigial and follows the outline of the posterior margin. The pseudointerarea in adult specimens is formed by stacking shell lamellae along the posterior margin, normal to the plane of commissure.

The pedicle valve has a large foramen, tear shaped in outline. The apex of the triangular foramen is directed posteriorly and is associated with a very small beak that overhangs a relatively large pseudointerarea. The foramen is continued internally by a pedicle tube that is only partially preserved in the available material. The ventral pseudointerarea is apsacline, broad, gently convex, and is ornamented with horizontal growth wrinkles and spines. The spines are associated with the growth wrinkles and increase in number toward the posterior margin.

Ornament consists of concentric, discontinuous growth wrinkles and hollow spines also arranged concentrically. The spines point marginally and increase in number toward the shell margin and anterior sector. Measurements of *M.* sp. are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Figured specimens	Incomplete pedicle valve	KU 79730	......	......
	Incomplete brachial valve	KU 79731	4.84	......

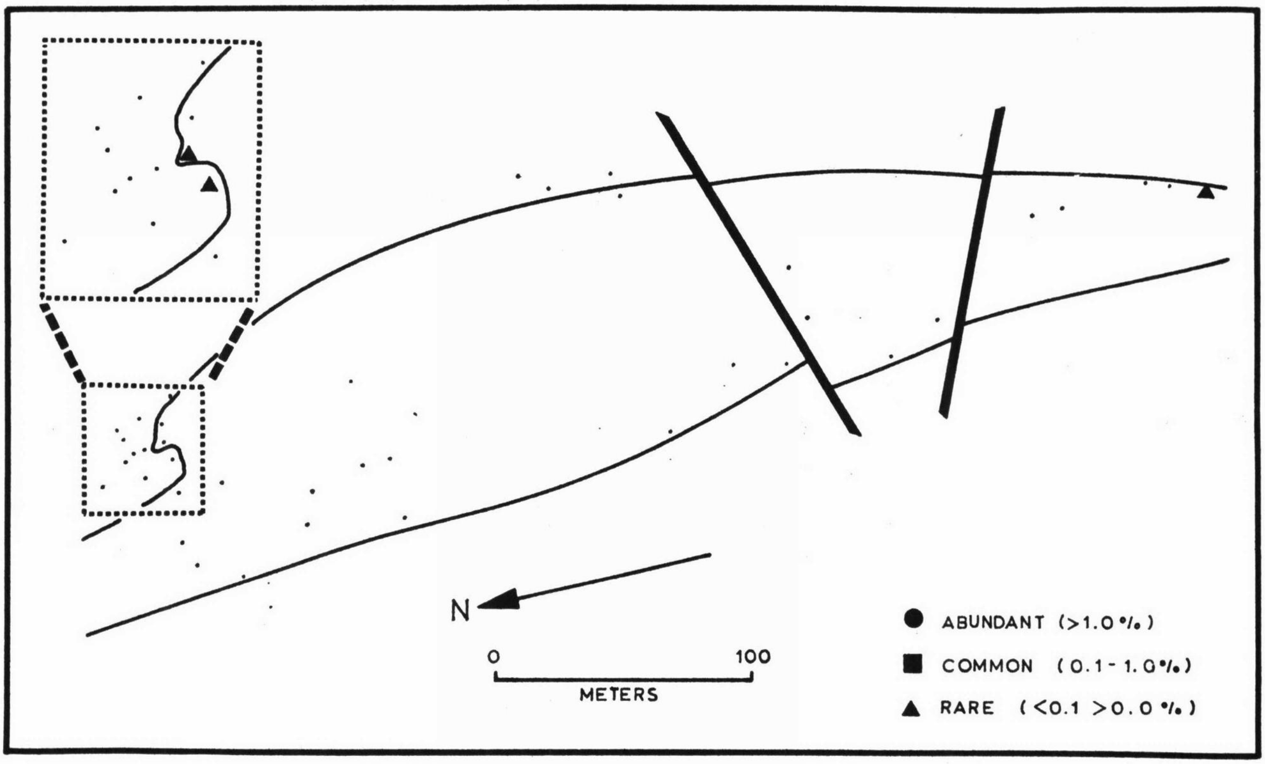

FIG. 58. Distribution of brachial valves of *Multispinula* sp.

Distribution.—Recorded at Localities 71/2(?), 71/5(?), 71/7, 71/9, 71/14(?), 71/19, 71/29 and 71/30(?) (Fig. 58). The material is inadequate for biometric treatment.

Superfamily DISCINACEA Gray, 1840

Family DISCINIDAE Gray, 1840

Subfamily ORBICULOIDEINAE Schuchert & LeVene, 1929

Diagnosis.—Adult pedicle notch not open at posterior margin, pedicle track relatively narrow; listrium may almost completely close pedicle track leaving only small posterior foramen, commonly continued internally as dorsoposteriorly directed pedicle tube adnate to inner surface of valve.

Genus SCHIZOTRETA Kutorga, 1848

The description of the genus by Cooper (1956, p. 277) is followed herein.

SCHIZOTRETA sp.

Plate 9, figures 5-12

Specimens of *Schizotreta* occur as a rather small component of the fauna at nearly two-thirds of the collecting localities on the mud mound and its adjacent flanking beds. The specimens are either immature individuals or fragments of larger shells. The biggest complete specimen recovered is a brachial valve, some 3.5 mm in length, which is relatively small for the genus. The material shows the characteristic submarginal brachial beak of the genus and rather depressed, subconical pedicle valve. The available material cannot be specifically identified. The outline of some of the young brachial valves is reminiscent of that of *S. corrugata* Cooper, but none are large enough to have developed the conspicuous, rather lamellose ridges, typical of adult forms of the species. The ornament differs rather markedly between some specimens in the available collections, likewise there is seemingly some variability in the shape and location of the pedicle foramen. There is a real possibility that the material belongs to more than one species of the genus, but until more complete, larger specimens are found, it will not be possible to confidently assert or deny this proposition. Measurements of *S.* sp. are recorded below.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Figured specimens	Brachial valve	KU 79750	3.42	3.00
	Incomplete pedicle valve	KU 79754	......	......
	Incomplete brachial valve	KU 79756	......	......
	Incomplete pedicle valve	KU 79757	......	......

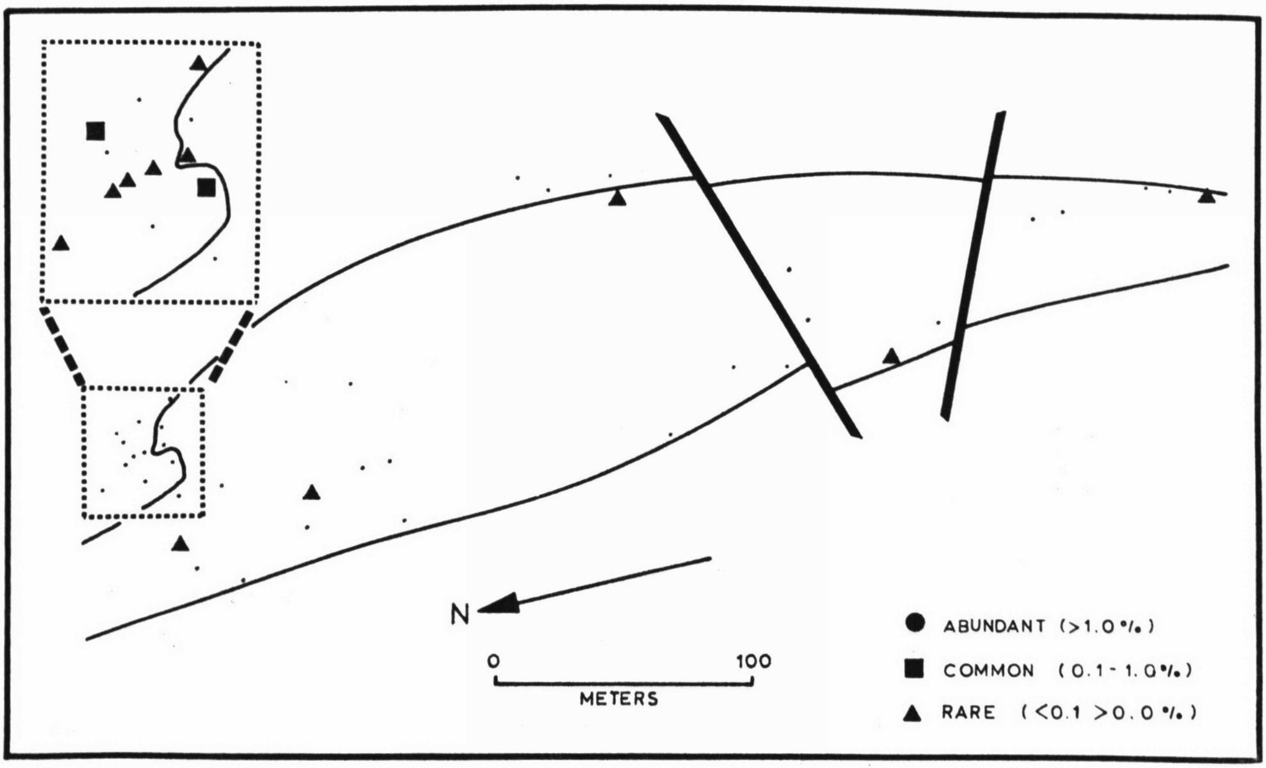

FIG. 59. Distribution of brachial valves of *Schizotreta* sp.

Distribution.—*Schizotreta* has been recorded at Localities 71/2, 71/4, 71/6, 71/7, 71/9, 71/12, 71/15, 71/25, 71/30, 71/31, 71/32, 71/33, 71/34, 71/35 and 71/36. Fragments ornamented with fila and probably belonging to *Schizotreta* have also been recorded at Localities 71/5, 71/10, 71/14, 71/19, 71/23 and 71/29 (Fig. 59). Material inadequate for biometric treatment.

Order PATERINIDA Rowell, 1965

Superfamily PATERINACEA Schuchert, 1893

Family PATERINIDAE Schuchert, 1893

Diagnosis.—Ventribiconvex or hemiconical, ventral pseudointerarea typically well developed, commonly procline to apsacline, homeodeltidium covering variable proportion of apical region of delthyrium, externally convex and arched. Dorsal pseudointerarea smaller than ventral, homeochilidium present or absent.

Genus DICTYONITES Cooper, 1956

The description of the genus by Cooper (1956, p. 187) is followed herein.

DICTYONITES sp.

Plate 9, figures 18-22

Dictyonites is represented in this collection by several fragments with the characteristic reticulate-perforate ornament and raised umbones of the genus. Specific identification is hindered by the incomplete nature of the fragments. A cursory examination of the fragments would lead one to believe that resemblance with *Dictyonites perforata* Cooper from the Pratt Ferry Formation of Alabama is strong. However, a comparison of this nature is dependent upon finding better preserved material, which is unavailable at the present time.

The posterior dorsal margin is straight and the brachial valve is convex or hemiconical, with a raised umbo that is bounded anteriorly by a frontally convex ridge. The umbonal area is divided by a low wrinkled ridge bounding areas with shallow rhomboidal depressions. The triangular ridge that divides the umbo of *Dictyonites perforata* appears to be absent. The dorsal pseudointerarea is poorly preserved and there is no evidence for the existence or absence of a homeochilidium. A thick band of shell material is present internally along the upper margins of the pseudointerarea; this band is thickest along the umbonal region where it is concave and anteriorly directed.

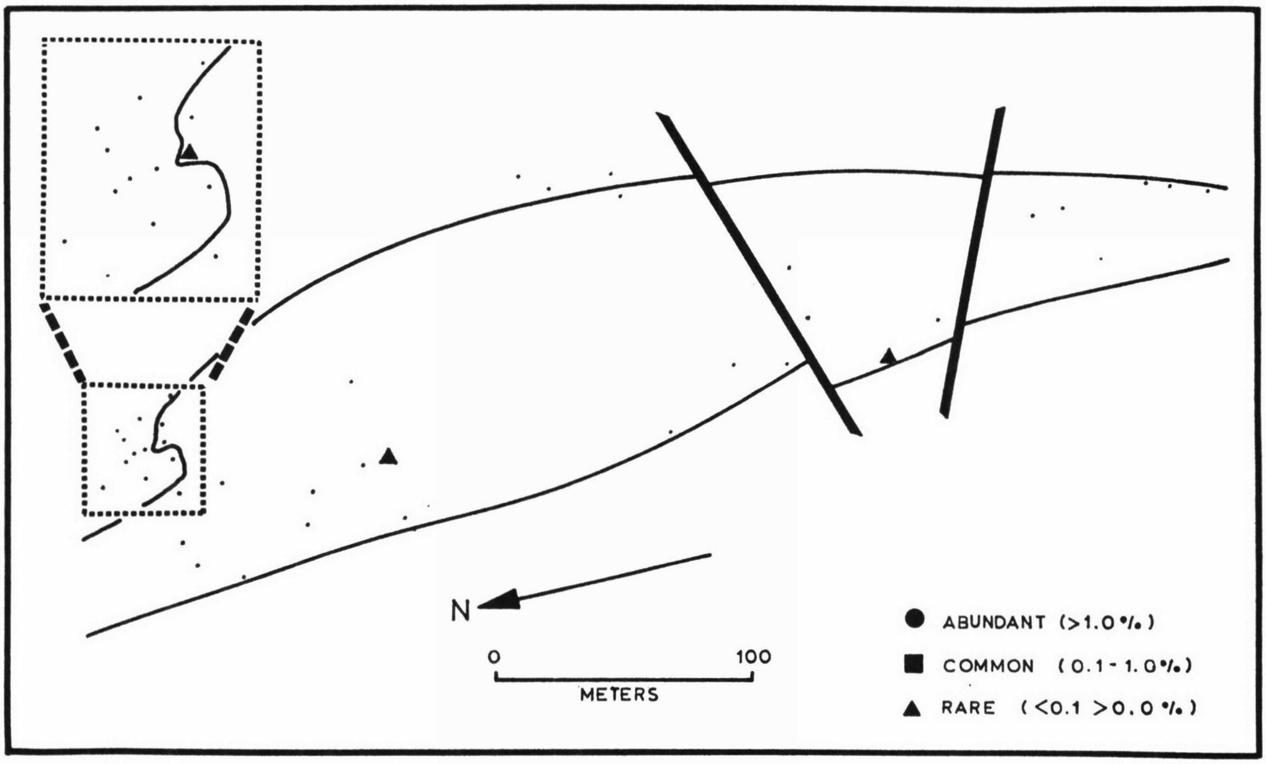

FIG. 60. Distribution of brachial valves of *Dictyonites* sp.

The pedicle valve is convex, much more so than the brachial valve. The ventral umbo has an arched ridge anteriorly. A pair of low and broad ridges subtending an angle of 25 to 30 degrees anteriorly are in contact with the convex ridge frontally and posteriorly grade into the homeodeltidium. This system of ridges bounds shallow and depressed areas laterally and medially. The ventral pseudointerarea is relatively large and is divided by a strongly arched and elevated homeodeltidium. The umbonal interior is gently convex medially. Internally the short median septum, which occurs in *D. perforata*, has not been observed.

The shell is ornamented with a strong reticulate-perforate pattern, except for the umbonal regions and the pseudointerarea. Concentric growth wrinkles and faint concentric growth lines are also present, but they are overshadowed by the reticulae.

Cooper (1956, p. 187) suggests that *Dictyonites* did not maintain its perforations through its entire substance in life. Some fragments in the present material appear to indicate that the openings were at least partially covered interiorly by a very thin layer of shell substance. Where present, the shell material commonly is found covering the posterior half of the reticulae; it is translucent and has horizontal growth lines, resembling a window with Venetian blinds. In some cases the translucent shell material has smooth and rounded edges around an opening, indicating that the reticulae may have been partially open in their anterior parts. If this was indeed the situation in life, the mantle was presumably protected by the periostracum.

Dictyonites has been recorded previously only in North America at Pratt Ferry, Alabama. Specimens of *D.* sp. recorded below could not be measured, due to their fragmented nature.

Specimens	Valve	Coll. No.	Length (mm)	Width (mm)
Figured specimens	Incomplete brachial valve	KU 79733	......	......
	Incomplete pedicle valve	KU 79735	......	......
	Shell fragment	KU 79737	......	......

Distribution.—Recorded at Localities 71/9, 71/18 and 71/25 (Fig. 60). Material inadequate for biometric treatment.

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F. F. Krause
Present address:
Department of Geology
University of Calgary
Calgary, Alberta, Canada

A. J. Rowell
Department of Geology and
Museum of Paleontology
University of Kansas
Lawrence, Kansas 66045

EXPLANATION OF PLATES

PLATE 1

FIGURE

1-10. *Lingulella bullata* Krause & Rowell, n. sp.——1, 2. External view of pedicle valve showing inflated umbo, internal view of same valve, Locality 71/35, holotype, UKMIP 79818, ×23.——3, 4. Internal view of pedicle valve showing distinct muscle scars and well-developed marginal ridge, external view of same valve, Locality 71/35, UKMIP 79822, ×23.——5, 6. Internal view of brachial valve showing narrow, elongate median septum and well-developed marginal ridge, external view of same valve showing inflated umbo, Locality 71/35, UKMIP 79821, ×23.——7, 8. Immature individual with conjoined valves, external views of pedicle and brachial valves, Locality 71/36, UKMIP 79819, ×37.——9, 10. Internal and external views of brachial valve, Locality 71/35, UKMIP 79820, ×24.

11-18. *Lingulella amphora* Krause & Rowell, n, sp.——11, 12. Valves conjoined, external views of pedicle and brachial valves, Locality 71/35, holotype, UKMIP 79823, ×30.——13, 14. External and internal views of brachial valve, Locality 71/24, UKMIP 79824, ×22.——15, 16. External view of pedicle valve, internal view of same valve showing muscle scars and bacculate mantle canal pattern, Locality 71/23, UKMIP 79830, ×22.——17, 18. External and internal views of pedicle valve, Locality 71/35, UKMIP 79825; 17, ×30; 18, ×28.

19-22. *Lingulella* sp.——19, 20. External view of brachial valve showing subdued irregular reticulate ornamentation, internal view of same valve, Locality 71/6, UKMIP 79827, ×16.——21, 22. External and internal views of brachial valve, Locality 71/35, UKMIP 79826, ×13.

PLATE 2

FIGURE

1-4. *Lingulella* sp.——1, 2. Internal view of pedicle valve fragment, external view of same valve fragment showing subdued irregular reticulate ornamentation, Locality 71/35, UKMIP 79828, ×13.——3, 4. External and internal views of pedicle valve fragment, Locality 71/35, UKMIP 79829; 3, ×12; 4, ×13.

5-12. *Spinilingula bracteata* Krause & Rowell, n. sp.——5, 6. Internal and external views of pedicle valve, Locality 71/30, UKMIP 79728; 5, ×16; 6, ×14.——7, 8. External view of brachial valve showing ornament of ribbed spines, internal view of same valve, Locality 71/29, UKMIP 79726, ×11.——9, 10. Internal and external views of brachial valve, Locality 71/29, holotype, UKMIP 79727, ×13.——11, 12. External view of brachial valve fragment, internal view of same valve showing impressions of bacculate mantle canal pattern, Locality 71/30, UKMIP 79729; 11, ×17; 12, ×21.

13-19. *Glossella livida* Krause & Rowell, n. sp.——13. Internal view of pedicle valve fragment showing imbricated development of shell lamellae along pedicle groove, Locality 71/35, UKMIP 79740, ×20.——14. Internal view of fragment of immature pedicle valve, Locality 71/36, UKMIP 79718, ×15.——15. Internal view of brachial valve, specimen subsequently broken, Locality 71/36, UKMIP 89933, ×5.——16, 17. External and internal views of immature pedicle valve, Locality 71/35, UKMIP 79717, ×20.——18, 19. External view of brachial valve, internal view of same valve, Locality 71/35, holotype UKMIP 79716, ×9.

PLATE 3

FIGURE

1-5. ? Obolid, gen. et sp. indet.——1, 4. External and internal views of pedicle valve fragment, Locality 71/35, UKMIP 79816, ×33.——2, 3. External and internal views of brachial valve, Locality 71/35, UKMIP 79815, ×25.——5. External view of brachial valve, individual with conjoined valves (pedicle valve not shown), Locality 71/36, UKMIP 79817, ×33.

6, 7. *Rowellella* sp.; external and lateral view of brachial valve fragment, Locality 71/5, UKMIP 79742; 6, ×11; 7, ×16.

8-15. *Rowellella margarita* Krause & Rowell, n. sp.——8-10. Lateral, external, and internal views of brachial valve, Locality 71/36, holotype, UKMIP 79745; 8, ×20; 9, 10, ×18.——11-13. Lateral, internal, and external views of pedicle valve, Locality 71/35, UKMIP 79747; 11, ×20; 12, 13, ×18.——14, 15. External and internal views of brachial valve, Locality 71/4, UKMIP 79746; 14, ×14; 15, ×18.

16-19. *Elliptoglossa sylvanica* Cooper var. *recidiva* Krause & Rowell, n. var.——16, 17. External and internal views of (?)brachial valve, Locality 71/35, UKMIP 79760, ×18.——18, 19. Internal and external views of (?)pedicle valve, Locality 71/23, UKMIP 79761; 18, ×24; 19, ×27.

20-23. *Ectenoglossa?* sp.——20, 21. View of brachial valve ("crack-out" material), Locality 71/31, UKMIP 79794A, ×0.8.——22, 23. External and internal views of immature pedicle valve, Locality 71/35, UKMIP 79795, ×7.5.

PLATE 4

FIGURE

1-16. *Conotreta? devota* Krause & Rowell, n. sp.——1-4. External view showing characteristic ornamentation, internal showing prominent pseudointerarea, posterior, and lateral views of brachial valve, Locality 71/8, UKMIP 79787, ×22.——5-8. Posterior, lateral, internal, and external views of brachial valve, Locality 71/8, holotype, UKMIP 79785, ×22.——9, 10. Internal and external views of immature brachial valve, Locality 71/23, UKMIP 79789, ×32.——11-14. Internal, latero-posterior views of pedicle valve, external apical view showing characteristically subdued ornament, and posterior of same valve showing prominent interridge and dorsally convex posterior margin, Locality 71/23, UKMIP 79786, ×22.——15, 16. Internal and external apical views of immature pedicle valve, Locality 71/23, UKMIP 79788, ×32.

17-24. *Conotreta mica?* Goryanskiy.——17-20. External apical view of pedicle valve, internal view of same valve showing pinnate mantle canal pattern, posterior, and lateral views of same valve, Locality 71/23, UKMIP 79797, ×21.——21-24. Internal, external, latero-interior, and lateral views of brachial valve, Locality 71/23, UKMIP 79796; 21-23, ×16; 24, ×21.

25-30. *Conotreta* sp.——25, 26. Internal and external views of immature pedicle valve fragment, Locality 71/25, UKMIP 79810, ×23.——27, 28. External view of pedicle valve fragment showing characteristic finely pustulose ornament, internal view of same fragment showing pinnate mantle canal pattern, Locality 71/15, UKMIP 79809, ×10.——29, 30. External view of brachial valve showing characteristic finely pustulose ornament, and internal view of same valve showing prominent pseudointerarea and low median septum, Locality 71/7, UKMIP 79807, ×5.5.

PLATE 5

FIGURE

1-11. *Spondylotreta* sp.——1, 2. Internal and external views of immature brachial valve, Locality 71/2, UKMIP 79813, ×21.——3-6. Internal, external, lateral, and posterior views of brachial valve, Locality 71/2, UKMIP 79814; 3, 4, ×13; 5, 6, ×21.——7-9. Lateral, internal, and external views of pedicle valve fragment, Locality 71/2, UKMIP 79812; 7, ×16; 8, 9, ×21.——10, 11. External and internal views of pedicle valve fragment, Locality 71/2, UKMIP 79811, ×21.

12, 13, 16-19. *Undiferina* sp.——12, 13. External and internal views of brachial valve, Locality 71/25, UKMIP 79792, ×17.——16, 17. External and internal views of brachial valve, Locality 71/25, UKMIP 79791, ×34.——18, 19. External and internal views of brachial valve, Locality 71/30, UKMIP 79790, ×32.

14, 15. *Undiferina nevadensis* Rowell & Krause.——14, 15. Internal and external views of brachial valve, Locality 71/34, UKMIP 79793; 14, ×17; 15, ×19.

20-27. *Eurytreta campaniformis* Krause & Rowell, n. sp.——20-23. Lateral, posterior, internal, and external apical views of pedicle valve, Locality 71/35, UKMIP 79779, ×26.——24, 25. External and internal views of brachial valve, Locality 71/35, holotype, UKMIP 79778, ×31.——26, 27. External and internal views of brachial valve, Locality 71/35, UKMIP 79777, ×31.

PLATE 6

FIGURE

1-12. *Hansotreta acrobela* Krause & Rowell, n. gen., n. sp.——1-3. Brachial valve external, internal, and posterior views of same valve showing raised pseudointerarea and strongly anacline propareas, Locality 71/35, holotype, UKMIP 79780, ×19.——4-7. Lateral, external apical, anterior, and posterior views of pedicle valve, Locality 71/36, UKMIP 79781, ×21.——8-10. Posterolateral and internal views of pedicle valve fragments showing massive apical process, lateral of same valve, Locality 71/36, UKMIP 79783, ×26.——11, 12. Internal and external views of immature brachial valve, Locality 71/35, UKMIP 79782, ×26.

13-29. *Scaphelasma lamellosum* Krause & Rowell, n. sp.——13-16. Individual with conjoined valves, brachial and pedicle posterior showing distinct intertrough, external apical view of pedicle valve, external view of brachial valve, and lateral view of same shell, Locality 71/29, UKMIP 79702, ×25.——17, 18. External views of conjoined pedicle and brachial valves showing characteristic ornament of lamellar rings and concentric threadlike ridges, Locality 71/29, holotype, UKMIP 79705, ×28.——19-22, 24. Posterior, lateral, latero-internal, internal, and external views of brachial valve, Locality 71/29, UKMIP 79704, ×22.——23, 25-26. Pedicle valve posterior, internal, and apical external views of same valve showing elongate pedicle opening, Locality 71/29, UKMIP 79703, ×31.——27-29. Posterior, anterior, and internal views of pedicle valve, Locality 71/6, UKMIP 79715, ×28.

PLATE 7

FIGURE

1-6. *Scaphelasma anomalatum* Krause & Rowell, n. sp.——1, 2. Brachial valve external and internal showing shelflike pseudointerarea and ridges bounding cardinal scars, Locality 71/17, holotype UKMIP 79710, ×21.——3-4. Internal and external views of brachial valve, Locality 71/17, UKMIP 79709, ×27.——5, 6. Valves conjoined, apical external view of pedicle valve and external of brachial valve, Locality 71/17, UKMIP 79712, ×30.

7-14. *Scaphelasma tumidatum* Krause & Rowell, n. sp.——7-10. External view of brachial valve showing ornament of subdued concentric ridges and inflated umbo, internal, posterior, and lateral views of same valve, Locality 71/35, holotype, UKMIP 79713, ×30.——11-14. Posterior, lateral, external apical, and internal views of pedicle valve, Locality 71/36, UKMIP 79714, ×28.

15-23. *Rhysotreta modesta* Krause & Rowell, n. sp.——15-18. Anterior, external, internal, and lateral views of brachial valve, Locality 71/7, holotype, UKMIP 79707, ×20.——19, 20. External and internal views of brachial valve, Locality 71/7, UKMIP 79708, ×25.——21-23. Lateral, posterior showing pseudointerarea marked by reduction in height of ornament and external apical views of pedicle valve, Locality 71/7, UKMIP 79706, ×20.

24-27. *Torynelasma papillosum* Krause & Rowell, n. sp.; brachial valve internal, posterior, postero-internal, and external showing ornament of growth lines and small radiating pustules, Locality 71/10, holotype, UKMIP 79721, ×25.

PLATE 8

FIGURE

1-6. *Torynelasma papillosum* Krause & Rowell, n. sp.——1, 2, 5, 6. Internal view of pedicle valve showing low apical process, external apical view of same valve showing nipple-like apex and ornament of growth lines and small radiating pustules, posterior and lateral views of same valve. Locality

71/23, UKMIP 79726, ×25.——3, 4. Internal and external views of immature brachial valve, Locality 71/10, UKMIP 79722, ×36.

7-22. *Ephippelasma spinosum* Biernat.——7, 8. Brachial valve anterior and internal views showing median septum with approximately 31 spines, Locality 71/29, UKMIP 79772, ×33.——9. Internal of immature brachial valve, septum with approximately 5 spines, Locality 71/9, UKMIP 79766, ×35.——10. Brachial valve internal view, Locality 71/9, UKMIP 79767, ×33.——11. Brachial valve internal view, Locality 71/9, UKMIP 79770, ×33.——12-16. Internal, posterior, anterior, lateral, and external views of brachial valve, Locality 71/29, UKMIP 79771, ×33.——17-20. Pedicle valve external apical, lateral, and internal views showing apical septum, posterior showing indistinct intertrough, Locality 71/9, UKMIP 79775, ×32.——21, 22. Valves conjoined, anterior and posterior views, Locality 71/26, UKMIP 79831, ×33.

23-32. *Eoconulus antelopensis* Krause & Rowell, n. sp.——23-25. Brachial valve external apical, lateral, and internal views, Locality 71/7, UKMIP 79805, ×32.——26. External apical view of brachial valve, Locality 71/9, UKMIP 79806, ×32.——27-30. Valves conjoined, posterior and pedicle valve showing complex attachment scar, brachial valve and anterior of brachial and pedicle valves, Locality 71/29, holotype, UKMIP 79798, ×32.——31, 32. Shell with conjoined valves attached to internal of second pedicle valve, top view of same specimen, Locality 71/5, UKMIP 79799, ×32.

PLATE 9

FIGURE

1-4. *Eoconulus antelopensis* Krause & Rowell, n. sp.——1, 2. Internal view of pedicle valve showing apical process and muscle scars, external apical view showing attachment scar, Locality 71/5, UKMIP 79803, ×32.——3. Internal view showing attachment of younger pedicle valve to earlier one, Locality 71/5, UKMIP 79802, ×32.——4. Pedicle internal showing multiple attachment sequence (3 valves), Locality 71/5, UKMIP 79800, ×32.

5-12. *Schizotreta* sp.——5, 6. External and internal views of pedicle valve fragment, Locality 71/30, UKMIP 79754, ×13.——7, 8. Brachial valve internal and external views, Locality 71/36, UKMIP 79750, ×8.——9, 10. Internal and external views of pedicle valve fragment, Locality 71/7, UKMIP 79757, ×7.——11, 12. External and internal views of brachial valve fragment, Locality 71/30, UKMIP 79756, ×7.

13-17. *Multispinula* sp.——13, 14. Internal and external view of brachial valve fragment, Locality 71/7, UKMIP 79731, ×7. ——15-17. Posterior, apical external and internal views of pedicle valve fragment, Locality 71/19, UKMIP 79730, ×9.

18-22. *Dictyonites* sp.——18. Fragment showing shell material between reticulae, Locality 71/25, UKMIP 79737, ×12. ——19, 20. Internal and external views of brachial valve fragment, Locality 71/9, UKMIP 79733, ×24.——21, 22. External and internal views of pedicle valve fragment, Locality 71/25, UKMIP 79735, ×24.

PLATE 10

FIGURE

1-4. *Ephippelasma spinosum* Biernat.——1-3. Oblique lateral, oblique anterior, and oblique posterior views, respectively, of interior of juvenile brachial valve, Locality 71/24, UKMIP 79765, ×120.——4. Oblique anterior view of internal of brachial valve, surmounting plate broken off revealing crenulated septal plate, Locality 71/19, UKMIP 91119, ×60.

5, 6. *Hansotreta acrobela* Krause & Rowell, n. gen. n. sp.; oblique view of brachial valve interior to show form of propareas and low median septum, brachial valve interior, respectively, Locality 71/35, UKMIP 91464, ×30.

7, 8. *Ephippelasma spinosum* Biernat; oblique anterior and oblique posterior views, respectively, of brachial valve interior of specimen with very spinose septal structure, Locality 71/29, UKMIP 79772, ×60.

PLATE 11

FIGURE

1. *Torynelasma papillosum* Krause & Rowell, n. sp.; detail of ornament of anterolateral sector of pedicle valve showing form of pustules, Locality 71/25, UKMIP 101357, ×400.

2. *Ephippelasma spinosum* Biernat; detail of damaged septal plate showing hollow spines, Locality 71/19, UKMIP 91119, ×200.

3. *Conotreta* sp.; detail of ornament showing structure of pustules from anterolateral part of brachial valve, Locality 71/16, UKMIP 100696, ×850.

4-6. *Conotreta? devota* Krause & Rowell, n. sp.——4. Detail of ornament of pedicle valve, Locality 71/23, UKMIP 95148, ×400.——5. Oblique view of brachial valve interior, median septum with two spines, Locality 71/8, UKMIP 92857, ×60.——6. Oblique view of brachial valve interior, median septum with one spine, Locality 71/8, UKMIP 92858, ×60.

7. *Torynelasma papillosum* Krause & Rowell, n. sp.; oblique view of brachial valve interior showing ventrally concave surmounting plate, Locality 71/10, UKMIP 101049, ×60.

PLATE 12

FIGURE

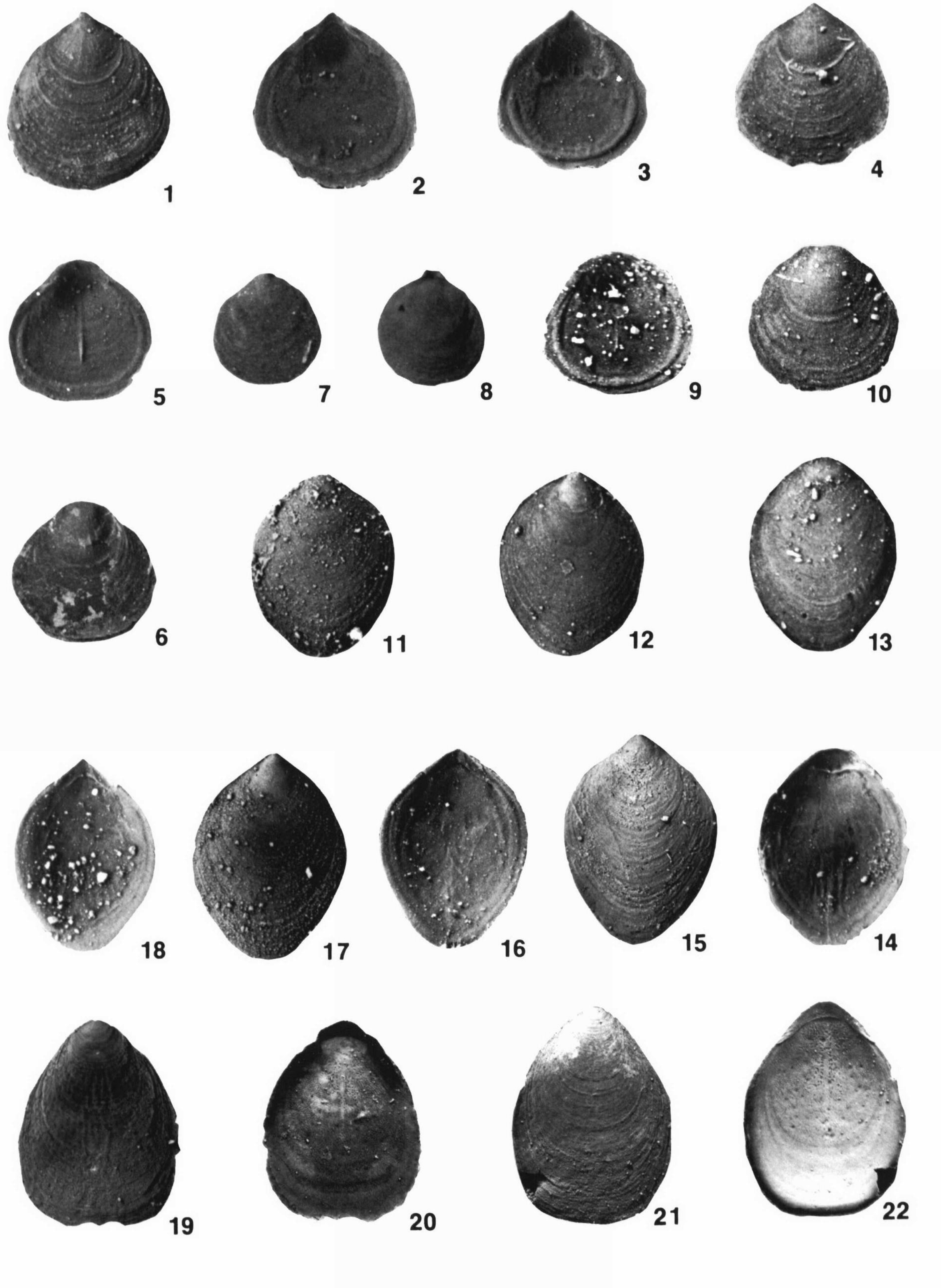
1, 2. *Eoconulus antelopensis* Krause & Rowell, n. sp.——1. Detail of ornament of anteromedian sector of brachial valve, Locality 71/29, UKMIP 103119, ×400.——2. Interior of pedicle valve with well-developed pits, Locality 71/30, UKMIP 103435, ×50.

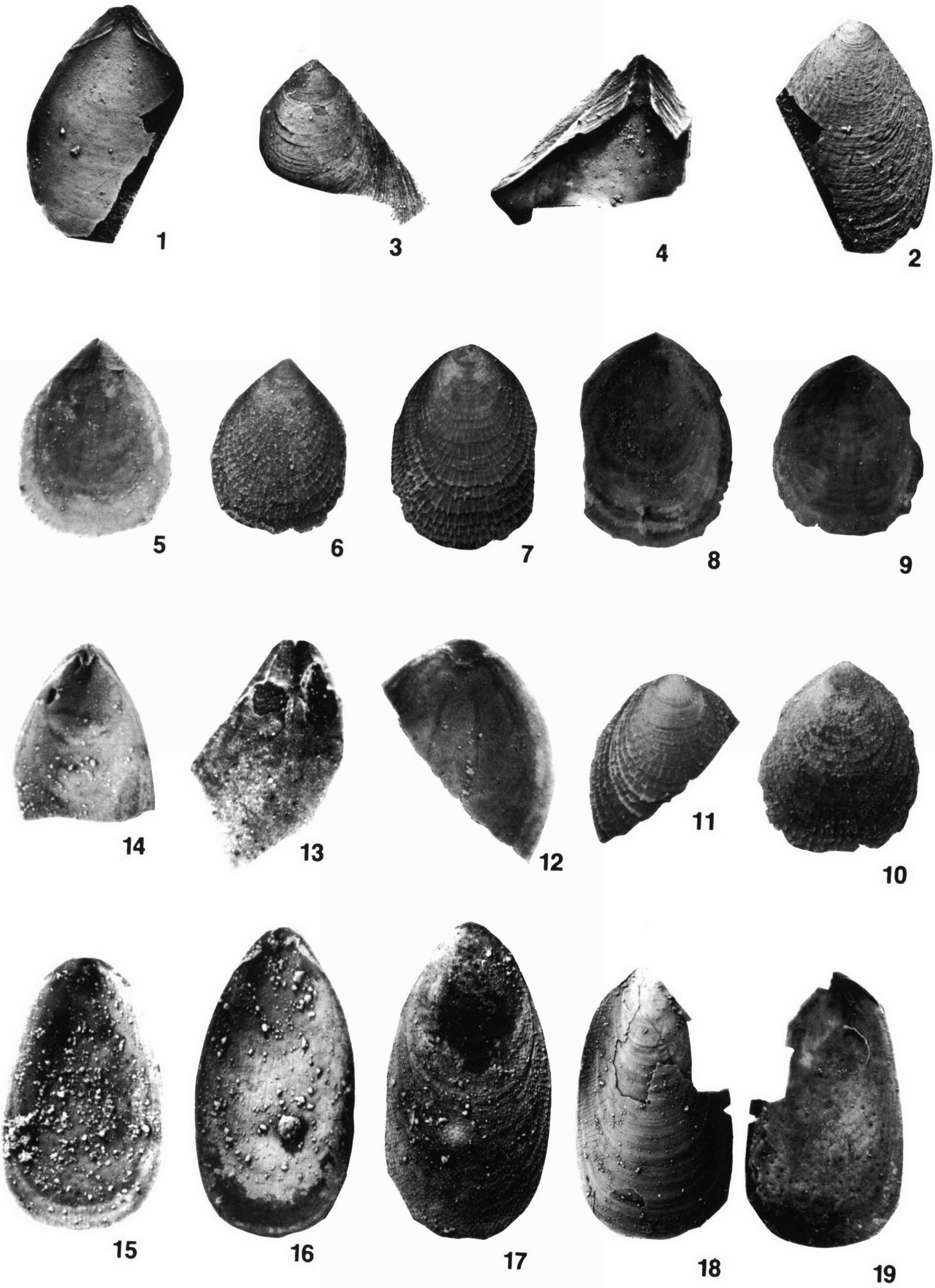
3. *Glossella papillosa* Cooper; detail of ornament of anterolateral sector of brachial valve, Pratt Ferry Formation, Middle Ordovician, Pratt Ferry, Alabama, UKMIP 105747, ×250.

4. *Spinilingula bracteata* Krause & Rowell, n. sp.; detail of ornament of anterolateral sector of brachial valve showing ribs traversing growth lamellae and prolonged anteriorly as spines, Locality 71/29, UKMIP 89794, ×120.

5. *Conotreta? devota* Krause & Rowell, n. sp.; interior of pedicle valve showing internal foramen and apical process, Locality 71/8, UKMIP 92853, ×30.

6. *Glossella livida* Krause & Rowell, n. sp.; detail of ornament of anterolateral sector of brachial valve, Locality 71/30, UKMIP 89918, ×250.

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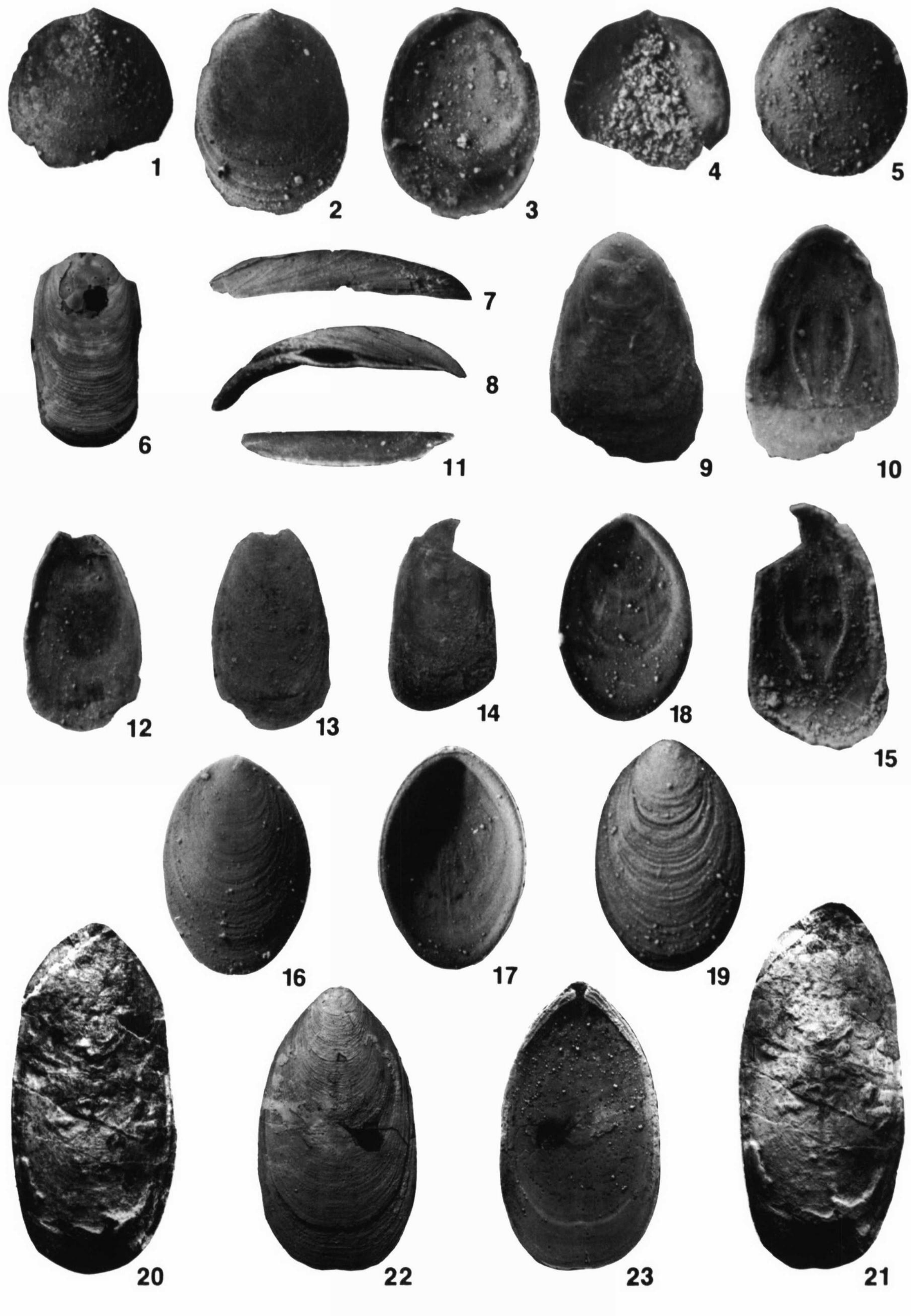
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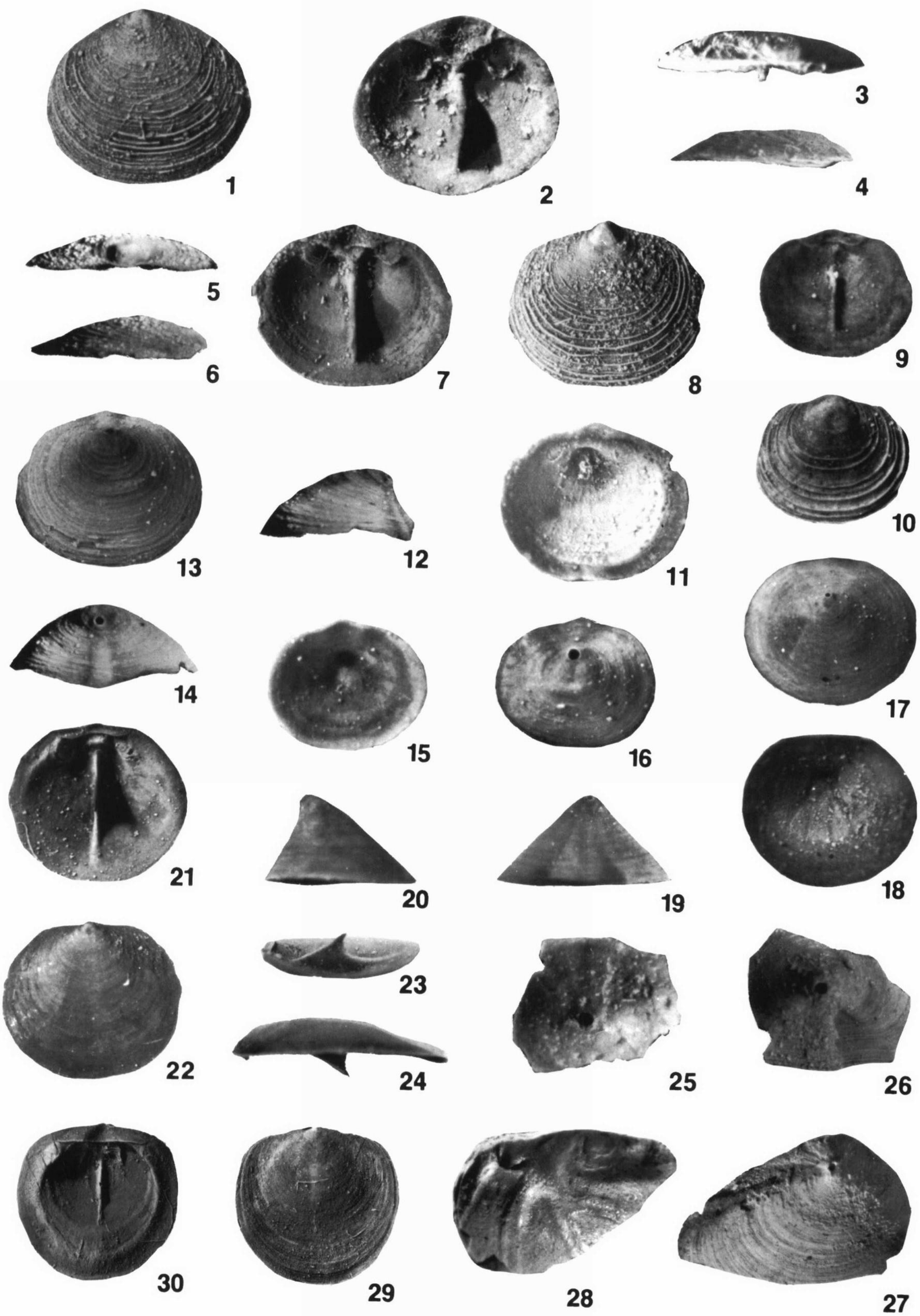

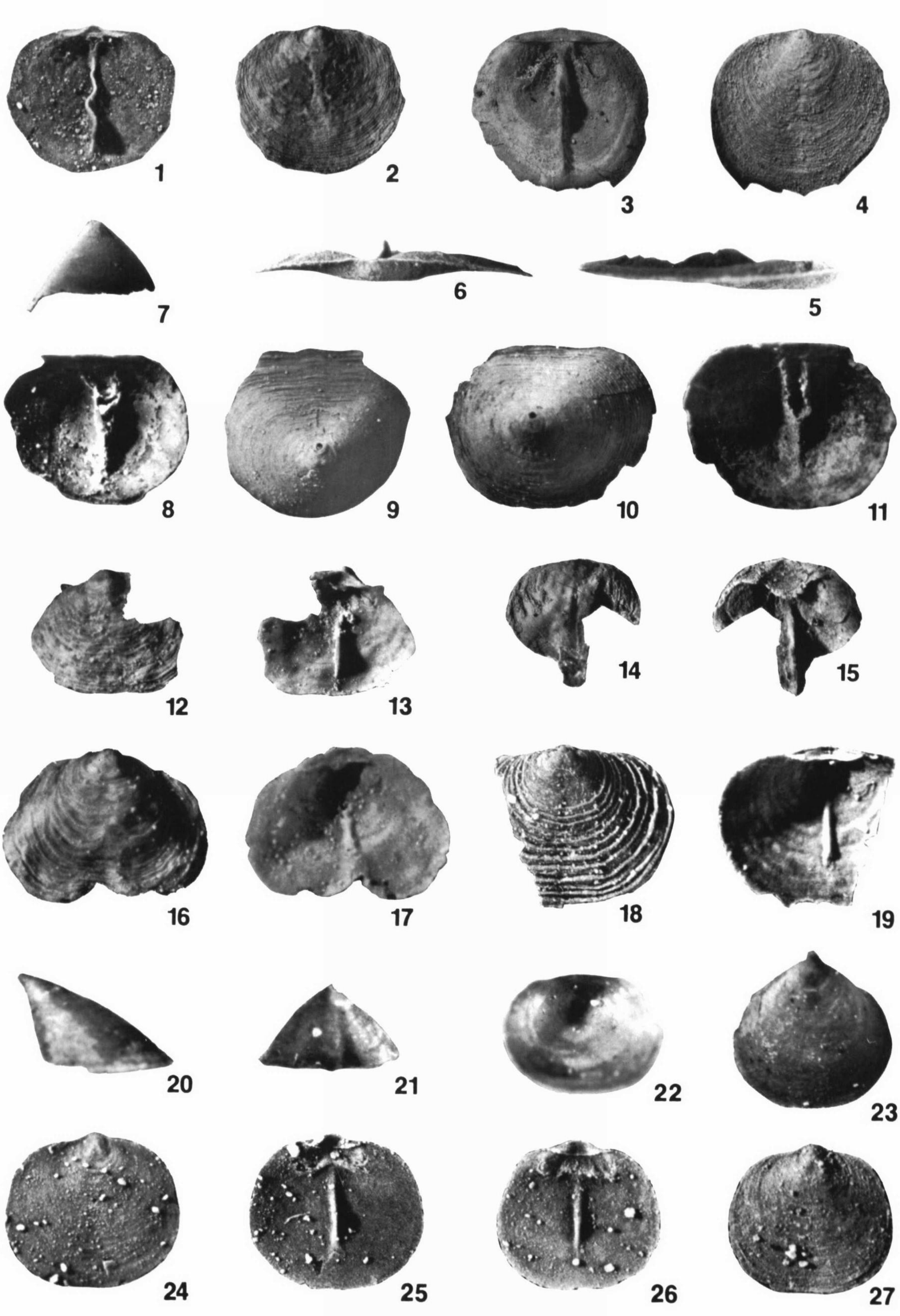
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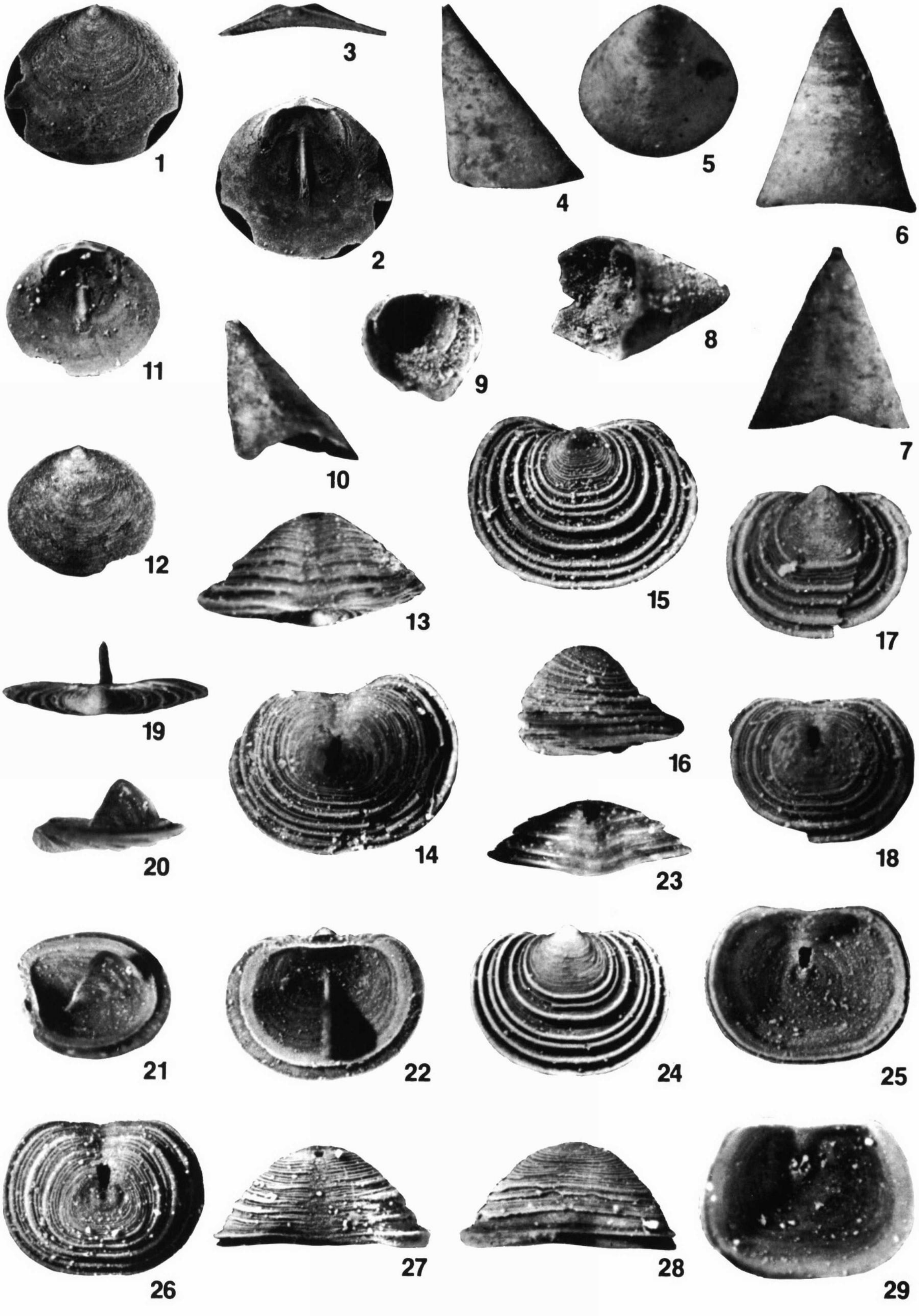
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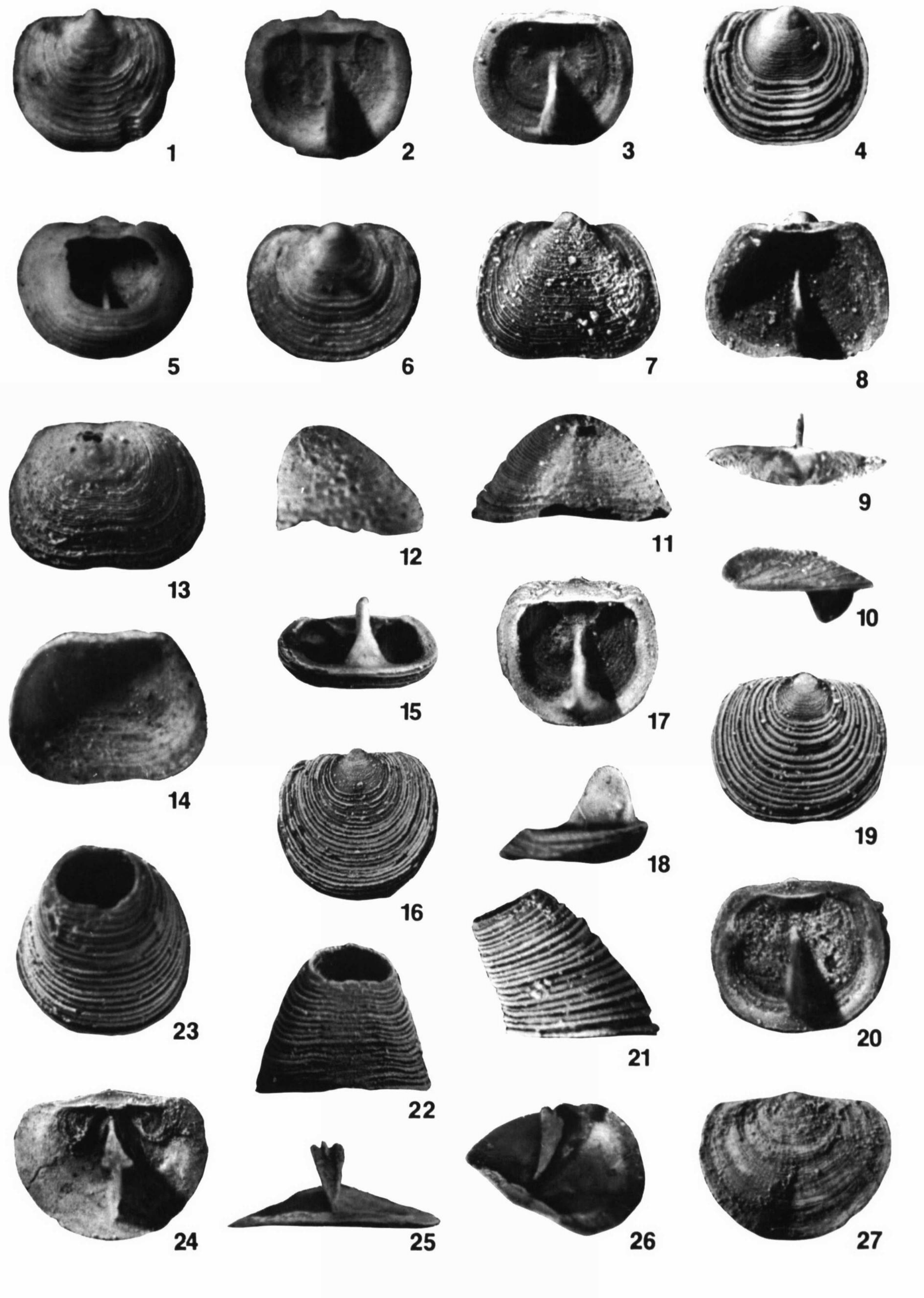
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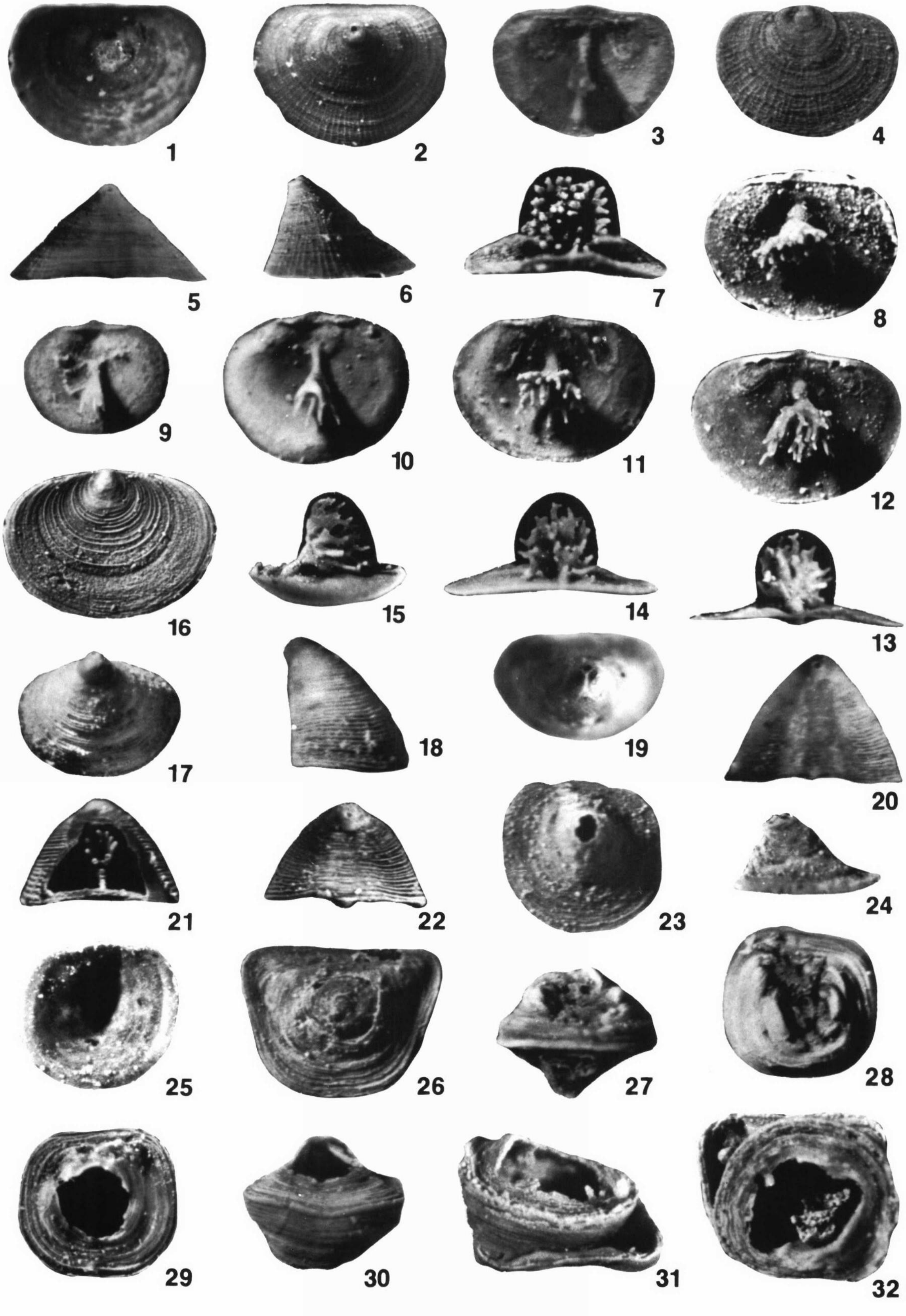

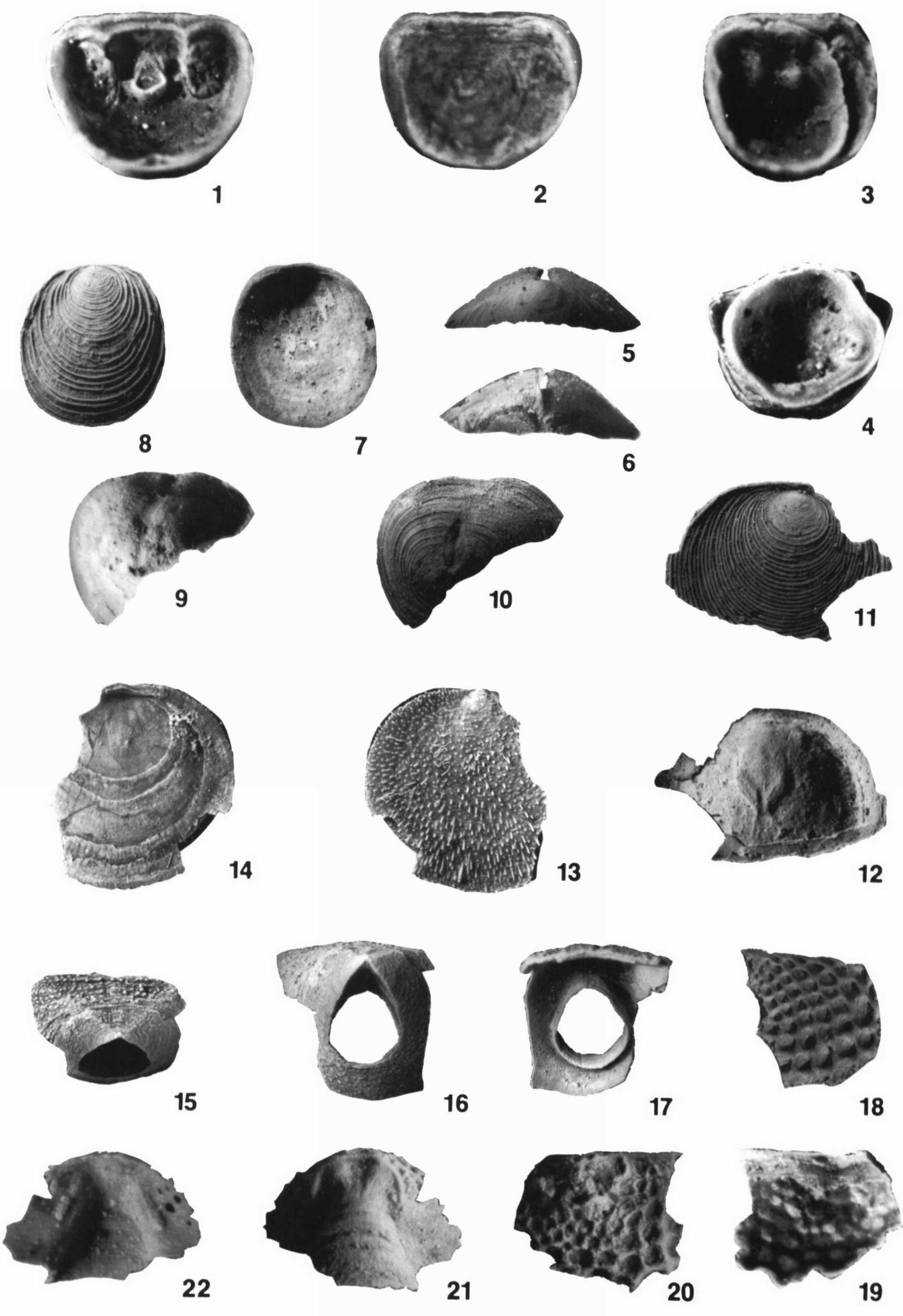

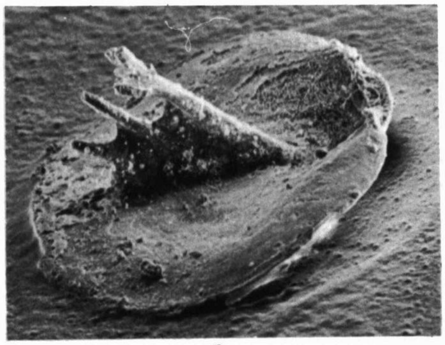
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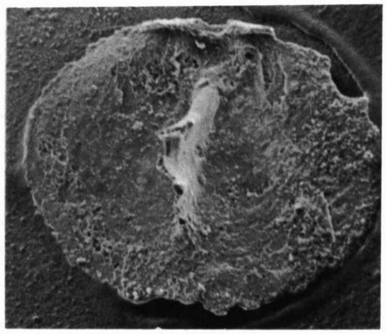
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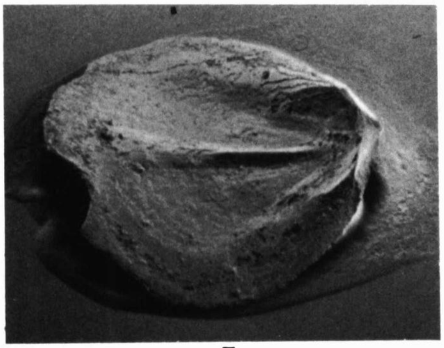
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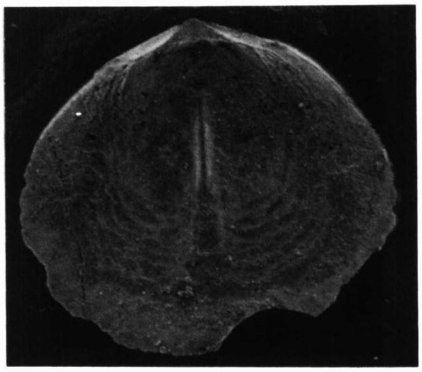
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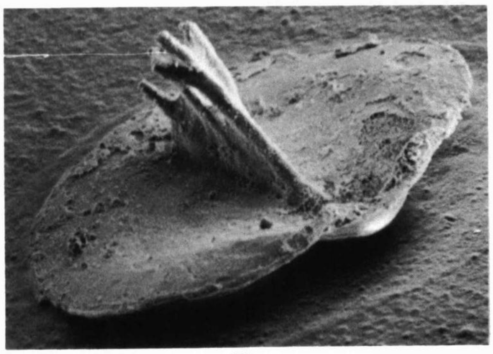
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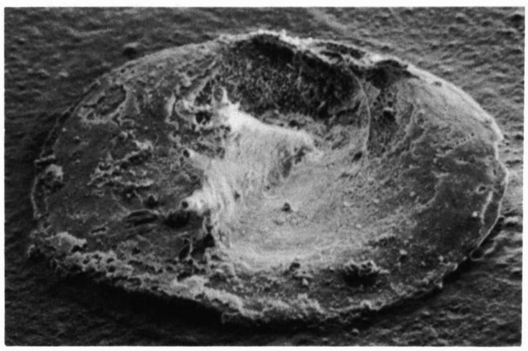
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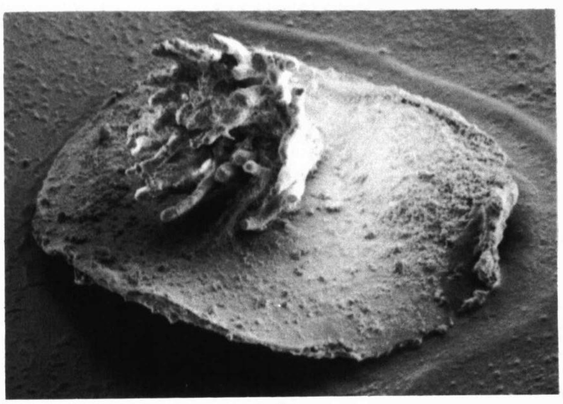
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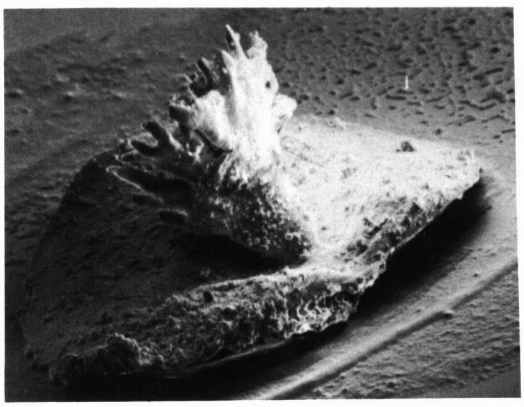
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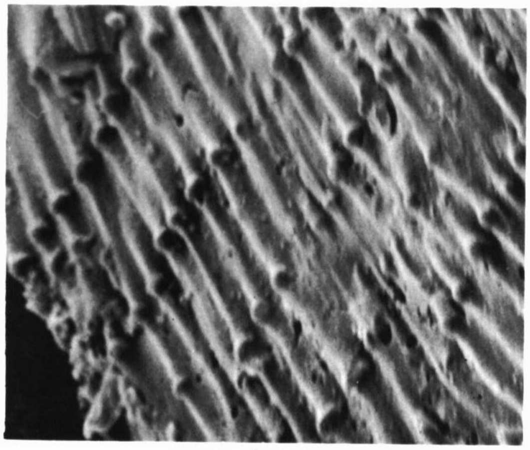

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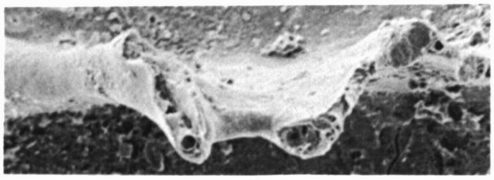

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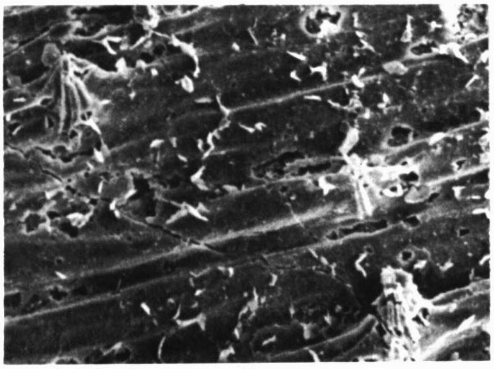

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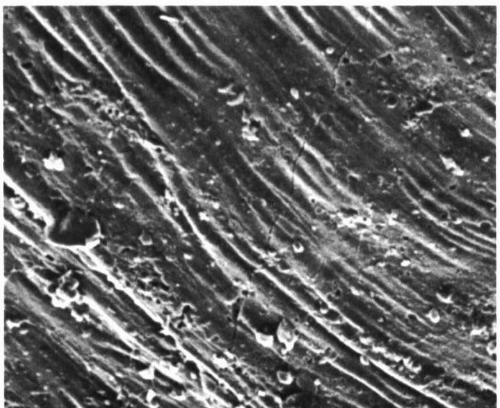

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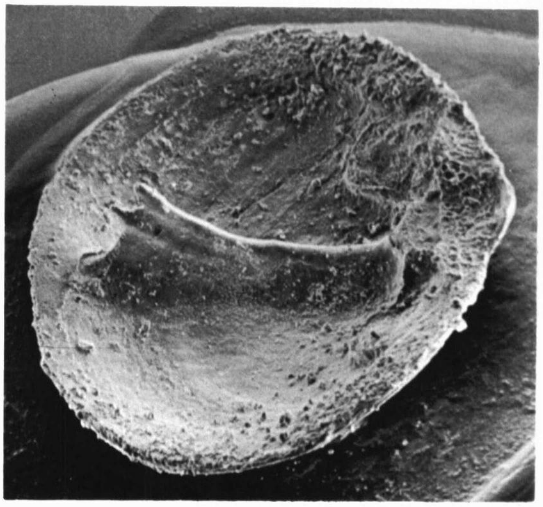

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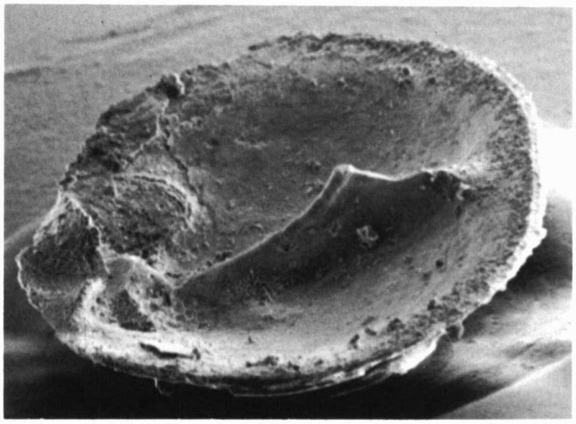

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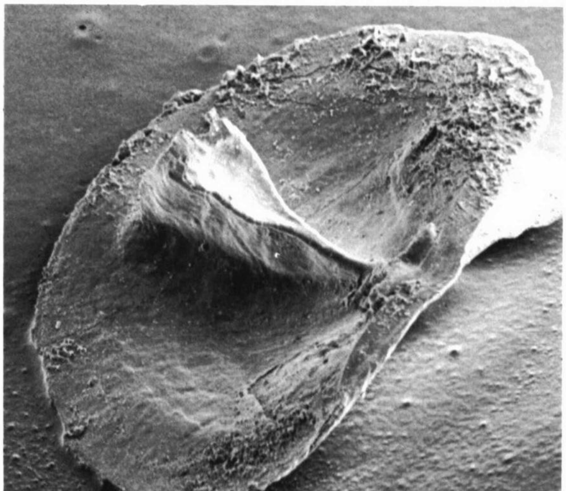

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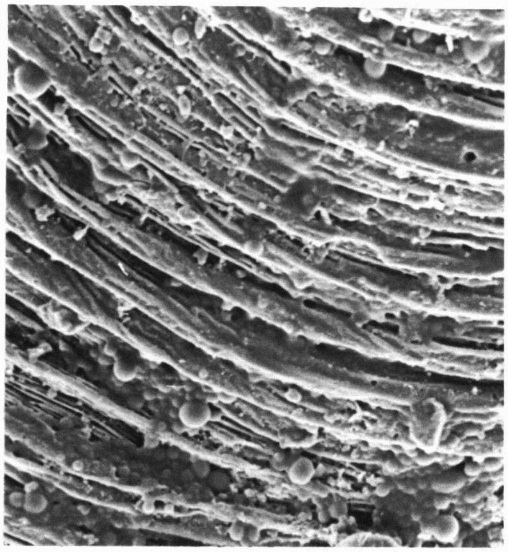

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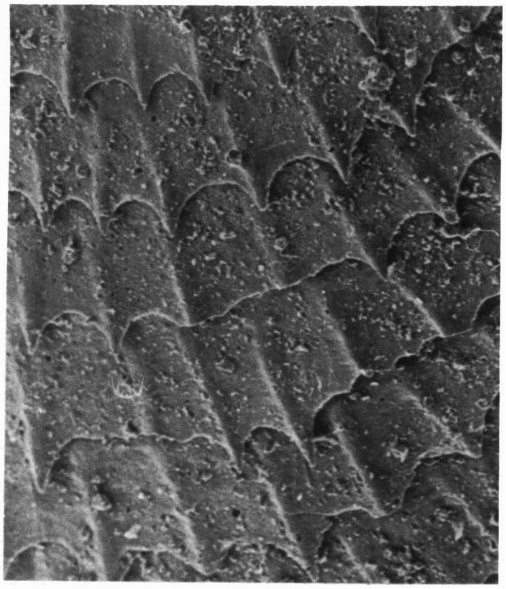

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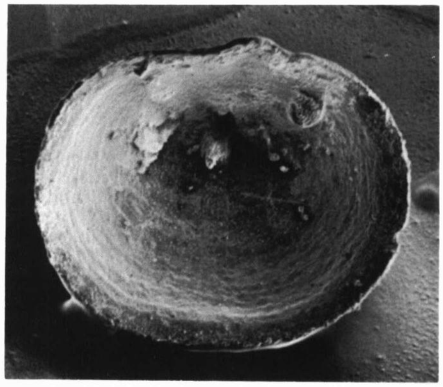

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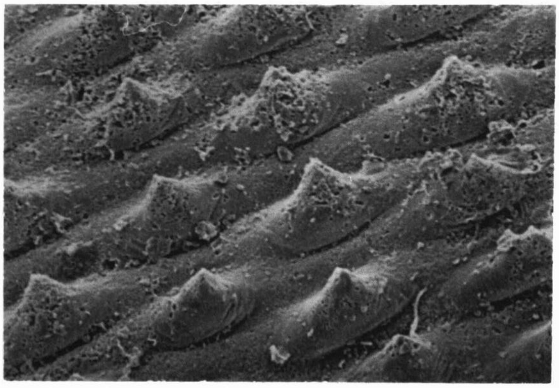

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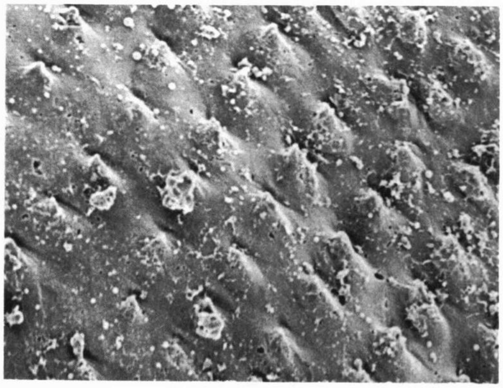

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