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THE TRACE FOSSIL ZOOPHYCOS AS AN INDICATOR OF WATER DEPTH

By

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CONTENTS

THE TRACE FOSSIL ZOOPHYCOS AS AN INDICATOR OF WATER DEPTH

RICHARD G. OSGOOD, JR.[1] AND EUGENE J. SZMUC[2]

ABSTRACT

A geographically widespread occurrence of the trace fossil *Zoophycos* is described from the Lower Mississippian Cuyahoga Formation of northeastern Ohio. Although Seilacher (1955, 1964, 1967a, 1967b) stated that *Zoophycos* is most common in "intermediate water depths," numerous environmental indicators (oscillation ripple marks, large scale cross lamination, and *Lingula)* demonstrate that in northeastern Ohio *Zoophycos* flourished in shallow water which was above wave base. At present the genus encompasses too wide a range of morphologic variables. Detailed studies are needed in order to determine the limiting factor of the environment. Water depth does not appear to provide the answer.

INTRODUCTION

As Seilacher demonstrated, one of the major values of trace fossils is that they can be used to indicate water depth in cases where other evidence is absent. In a series of papers, Seilacher (1955, 1963, 1964, 1967b) established several "ichnofacies" each with its suite of trace fossils and each indicative of a certain environment. The *Zoophycos Facies,* characterized by the roostertail-like trace fossil of the same name was proposed for an environment which was "sublittoral to bathyl, below wave base, and without turbidite sedimentation" (Seilacher 1964, p. 311). It should be noted that Seilacher (1964, fig. 7) listed four deep-water deposits containing *Zoophycos,* and that in 1967 he reported the first occurrence of *Zoophycos* in "deep-sea" cores of Recent sediments take by Lamont-Dougherty Geological Observatory. At the same time he conceded that *Zoophycos* may occasionally occur in shallower water ". . . due to local channeling or restriction" (Seilacher, 1967b, p. 418). In spite of these exceptions the authors conclude, upon analysis of Seilacher's works, that Seilacher believed that the majority of occurrences of *Zoophycos* represent intermediate water depth. Further justification for this belief will be given below.

The purpose of this paper is to discuss a *major widespread* occurrence of *Zoophycos* from the Lower Mississippian rocks of northeastern Ohio. As will be demonstrated, the body fossils, primary sedimentary structures, and the regional geologic setting, all indicate that large numbers of *Zoophycos* occur here in rocks that were deposited in shallow water that was above wave base. The validity of *Zoophycos* as a reliable depth indicator is thereby somewhat in doubt.

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MORPHOLOGY OF ZOOPHYCOS

Diagnosis — slightly helicoid trace fossils possessing a marginal tube; the *Spreite* radiating from the center frequently give the genus a "rooster-tail" like appearance.

Discussion — *Zoophycos* Massalongo, 1855 is a common form which has been reported from nearly every continent in rocks ranging from Ordovician through Tertiary in age. As Häntzschel (1962, 1965) and Simpson (1970) pointed out the genus is extremely variable in form. It is badly in need of a monographic study, and no attempt will be made here to discuss the genus in depth. For a more detailed analysis of *Zoophycos* and its taxonomic problems the reader is referred to Plička (1968, 1970), Lessertisseur (1955), Häntzschel (1965), and Simpson (1970).

Perhaps the wide range of morphology exhibited by *Zoophycos* can best be demonstrated by considering three forms figured in the literature. Sarle (1906, fig. 1) illustrated a specimen from the Silurian of New York State which resembles a "rooster-tail." The marginal tube is clearly visible as are the arcuate *Spreite*. A more typical occurrence of *Zoophycos* is shown by Häntzschel (1962, figs. 137-1a, 2a). It is a flat helix with the *Spreite* radiating from the apex of the cone. No marginal tube is present but this may be due to imperfect preservation. According to Seilacher (1967a) this form, which he had found in the Alpine Tertiary section, is a variant of a more complex Cretaceous form, which takes on a flat antler-like appearance (Seilacher, 1967a, p. 79 top). Compounding the problem is the fact that many times *Zoophycos* has a distinct three dimensional aspect. Moreover, as Sarle (1906, fig. 2) pointed out several helices can be interlaced, making study even more difficult. In its most extreme three dimensional form the *Zoophycos* structure can resemble a corkscrew with *Spreite*, where the vertical dimensions exceed the diameter of the helix. These forms are assigned by most authors to *Daedalus* Rouault, 1850.[3]

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[3] Simpson (1970) was well aware of the morphological variation included in *Zoophycos* and made some attempt to limit it by restricting the circular forms to *Spirophyton* Hall, 1963. However, as one can see, and as Simpson himself admitted, the *Zoophycos* still contains a wide variety of morphologic expressions (see Simpson, 1970, fig. 1).

The Mississippian forms from Ohio contribute little to the general knowledge of the morphology or ethology exhibited by *Zoophycos*. They closely resemble those specimens illustrated by Häntzschel (1962, fig. 137-1a) and Simpson (1970, fig. 1b). They occur in gray, micaceous siltstones and their overall pattern is somewhat masked by their three-dimensional aspect. One specimen (Pl. 1, fig. 2) retains a small fragment of the marginal tube. The tube is ovoid in cross-section and measures 5 mm by 3 mm. Because the species of *Zoophycos* are so poorly defined, no attempt at specific identification will be made here.

Interpretation — The interpretations given to *Zoophycos* are as varied as the morphology of the genus itself. Several earlier authors (*e.g.* Rouault, *in* Lebesconte, 1884) believed that it was the impression of marine algae. It has also been assigned to the Porifera by Lebesconte (1887) and to the Alcyonaria by Lucas (1938). Other workers regarded it as inorganic, caused by either current activity (Nathorst, 1886), or gas bubbles (Korn, 1929).

Today it is generally agreed that *Zoophycos* represents the feeding structure of an unknown soft-bodied wormlike organism (Häntzschel 1962, 1965; Seilacher 1967a). A notable excepton is Plička (1968, 1970) who, working with Tertiary material from the Carpathians, described the arcuate *Spreite* as the impression of the prostomia of sabellid annelids.

The present authors accept the trace fossil assignment although they are unable to comment on Plička's material. The three dimensional preservation of *Zoophycos,* as well as the lack of any microstructure, rules out a vegetable origin. Moreover, the arcuate *Spreite* are a variant of a feeding method frequently observed in trace fossils. *Phycodes* and *Rhizocorallium* could be cited as examples. Basically each arc represents the course of the organism as it moved along, ingesting the sediment. When the elastic limits of the body were reached the animal contracted and proceeded to excavate a new burrow directly adjacent to the old one. Seilacher (1967a) postulated that the antler-shaped *Zoophycos* from the Cretaceous are actually a less efficient variant of the more compact Tertiary forms. In the former the area between the horns is left unexploited whereas this does not occur in the compact forms. Because the burrows of *Zoophycos* are normally three dimensional it is probable that they were excavated below the depositional interface.

The above description of the origin of the burrow is greatly simplified. The only detailed attempts to describe the habits of the organism are those of Bischoff (1968) and Simpson (1970).

In summary, *Zoophycos* is variable in overall appearance but all forms assigned to the genus possess the arcuate *Spreite.* Because of its variability it must be regarded as a form genus. It represents a feeding burrow although the actual mechanics of formations of the burrow are still not clear for all members of the genus.

TRACE FOSSILS AS INDICES OF WATER DEPTH

Seilacher (1955) compared the trace fossils from five sections of diverse geologic ages.[4] He found some sections (*e.g.* Lower Cambrian of the Salt Range of Pakistan) were characterized by shallow resting traces (Cubichnia of Seilacher, 1953a) which probably served as places of temporary concealment. He interpreted these as indicative of a shallow-water environment well within the euphotic zone, an area where predators would be most active. Conversely other sections such as the Tertiary Alpine Flysch contained no Cubichnia but numerous grazing traces (Pascichnia of Seilacher 1953a). Seilacher interpreted Pascichnia as two-dimensional feeding trace analogous to strip mining, where the organism attempts to cover a large area with a minimum amount of effort. This can lead to unusual geometric patterns such as the tight spiral of *Helminthoida.*

Observations of Recent sediments have served largely to confirm Seilacher's hypotheses. It is difficult to observe Cubichnia in the process of formation since the organism quickly covers itself with sediment. However, Recent stelleroids and ophiuroids are known to burrow for protection (Seilacher, 1953b), and it is not unreasonable to assume that *Rusophycus,* which is abundant in lower Paleozoic sediments represents a burrow of trilobites. While Pascichnia remain unreported in photographs taken within the

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[4] For a more detailed discussion of Seilacher's ichnofacies see Osgood (1970, pp. 399-404).

euphotic zone their presence has been confirmed by photographs taken at great depth (see Seilacher 1967b, pl. II).

In 1964 Seilacher expanded his analysis to include 42 sections of varying geologic age and locality. He formally named the suite of trace fossils dominated by Pascichnia as the *"Nereites Facies"* while the Cubichnia suite was entitled the *"Cruziana Facies."* In addition he proposed the *"Zoophycos Facies"* at this time. Unlike the *Nereites* Facies and *Cruziana* Facies which normally contained several different trace fossils, *Zoophycos* was commonly the sole trace fossil. Seilacher (1964, 1967b) cited several examples from the geologic record to support his views. Moreover, in the Ordovician of Iraq there is a vertical gradation through the *Nereites-Zoophycos-Cruziana* Facies.

In subsequent papers Seilacher (1963, 1967b) enlarged the number of facies to six. These additional facies, which need not concern us here, are indicative of shallow water or special environmental conditions.

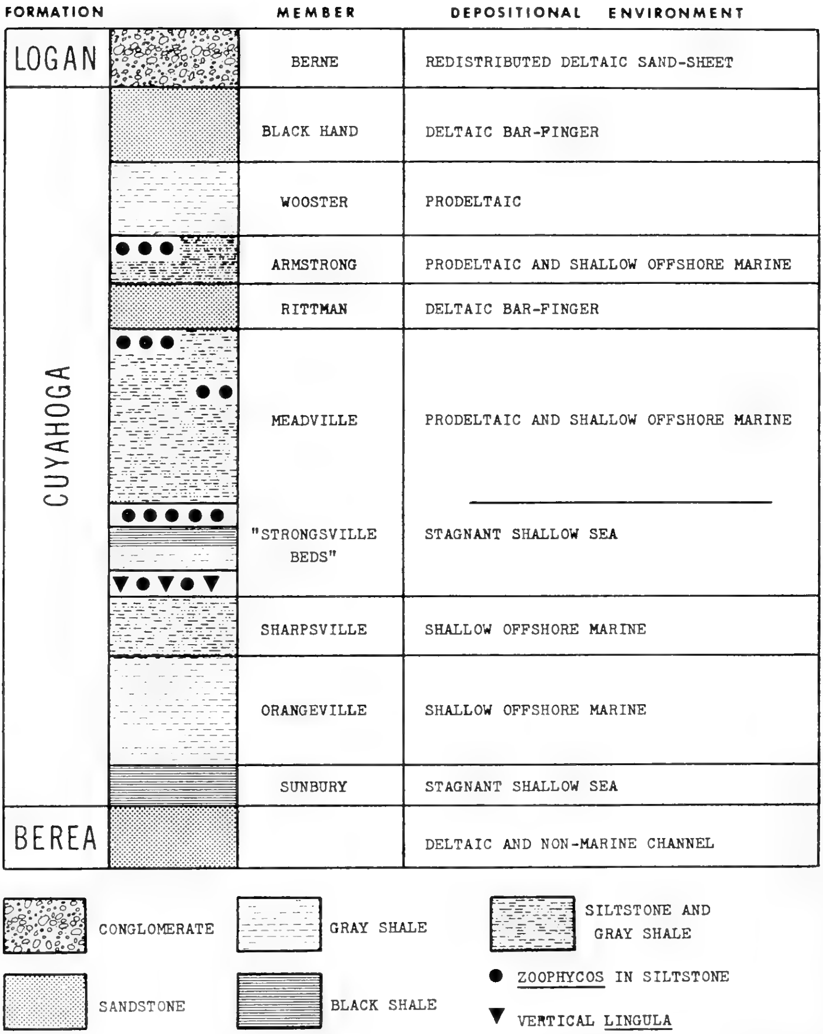
The authors of this paper take no issue with Seilacher's interpretation of the environmental significance of the *Cruziana* and *Nereites* Facies. They are supported by both well-reasoned arguments and Recent observations. The *Zoophycos* Facies rests on weaker evidence. Why should this particular three-dimensional feeding burrow be confined to "intermediate" depth water and why are there virtually no other trace fossils occurring with it?

THE LOWER MISSISSIPPIAN SECTION IN NORTHEASTERN OHIO

The Mississippian stratigraphic units in northern Ohio comprise a composite thickness of more than 300 meters of fine-to-coarse-grained clastics that were deposited in the northwestern part of the Appalachian marginal basin. They include shallow-water marine, transitional, and to a lesser degree nonmarine sediments.

The stratigraphic sequence shown in Text-figure 1 is conformable except for an erosional break of considerable relief at the base of the Berea Formation and a minor unconformity or reworked surface at the Cuyahoga-Logan contact.

Four major types of lithologic groups are shown in Text-figure 1: 1. Conglomerate, 2. Sandstone and pebbly sandstone, 3. Gray shale and siltstone, 4. Black and gray shale and siltstone.



Text-figure 1. Composite section of Lower Mississippian stratigraphic units in northern Ohio and their deduced depositional environments. Vertical dimensions of the units are not drawn to scale.

The Berne Member of the Logan Formation is a thin, widespread fine-pebble conglomerate which contains a moderately abundant marine invertebrate fauna. Hyde (1915) interpreted the conglomerate as a wave-reworked "lag concentrate" of pebbles derived from the underlying pebbily sandstones of the Black Hand Member.

The sandstones are predominately deltaic in origin. The Berea Sandstone is a channel-deltaic unit composed of nonmarine, transitional, and marine strata (Pepper, *et al.*, 1954). The Rittman Member and Black Hand Member are regarded as delta-complex deposits composed primarily of bar-finger sands which grade laterally into finer clastics of the Wooster Member and Meadville Member (Barclay, 1968; Szmuc, 1970).

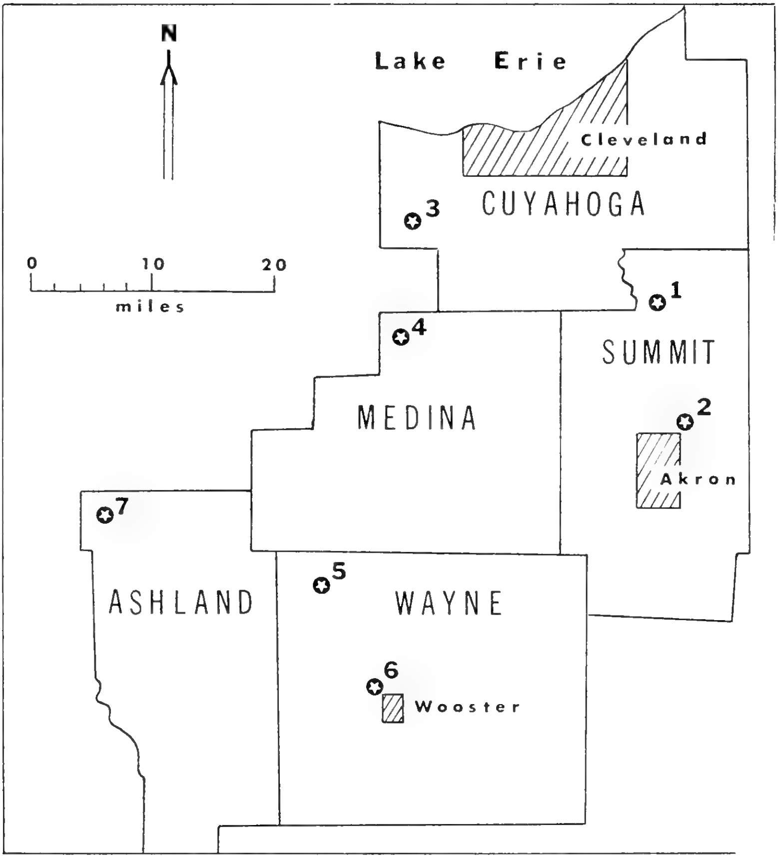
The gray shale beds and the flaggy siltstone-shale beds of the Orangeville Member, Sharpsville Member, and Wooster Member, and the upper portion of the Meadville Member are composed of prodeltaic and shallow-water offshore marine sediments (Barclay, 1968; Szmuc, 1970). A sparse to abundant marine fauna composed of brachiopods, bryozoans, corals, and many other invertebrates is dispersed irregularly throughout these units.

The black shales of the Sunbury Member and the siltstones and black and gray shales of the basal portion of the Meadville Member (here designated informally as the "Strongsville Beds") contain a depauperate biota composed of conodonts, plant debris, and inarticulate brachiopods. These strata were deposited in restricted, stagnant, and deoxygenated shallow seas.

The Strongsville Beds are noteworthy because they typically display one to six meters of gray and black shales intercalated between two areally extensive siltstone beds which at many exposures contain profuse numbers of *Zoophycos* on their upper bedding surfaces. One or both of the *Zoophycos*-bearing siltstones are prominently displayed at Brandywine Creek, Cuyahoga Falls, Strongsville, and Valley City (Sections 1, 2, 3, and 4 of this report).

OCCURRENCE OF ZOOPHYCOS IN THE MISSISSIPPIAN OF NORTHEASTERN OHIO

The main objective of this study was to locate *Zoophycos* in the field and to search for sedimentary structures, body fossils and trace fossils which would provide some evidence of water depth. Numerous exposures were sampled and described in detail in a five-county area, including the seven representative localities shown in Text-figure 2. The results of the study are presented below.



Text-figure 2. Map of five counties in northeastern Ohio showing outcrops of Lower Mississippian strata at selected localites. 1. Brandywine Creek. 2. Gorge Park, Cuyahoga Falls. 3. Strongsville. 4. Valley City. 5. Killbuck Creek. 6. Wooster Quarry. 7. Buck Creek. See Appendix at end of report for detailed locality data.

A) *Stratigraphic distribution of Zoophycos*

Zoophycos is confined to certain siltstones of the Meadville Member and Armstrong Member. The sandstones, conglomerates, and the gray and black shales are devoid apparently of *Zoophycos.*

B) *Abundance of Zoophycos*

The density of distribution of *Zoophycos* in the Strongsville Beds is comparable to certain beds in the Mississippian Borden Group of Kentucky, where their intertwined patterns locally cover entire bedding planes. Although *Zoophycos* is more sparsely represented on bedding planes in the Armstrong and upper part of the Meadville, its common presence clearly demonstrates that it is not a chance occurrence. It was usually possible to locate three to four specimens on a surface of four square meters.

The authors were able to confirm Seilacher's (1964) observation that only rarely does *Zoophycos* occur with other trace fossils. The only associated form is *Palaeophycus* sp. (as defined by Osgood, 1970). This is a common trace fossil and not diagnostic of any particular environment.

C) *Associated invertebrate and plant fossils*

Few body fossils were found in association with *Zoophycos.* This is not too surprising because the section is predominantly clastic, and fossil occurrences within this part of the Mississippian tend to be localized. Fragmented pelecypod, sponge, crinoid, and articulate brachiopod remains were found from a few centimeters to 20 meters (vertical distance) of *Zoophycos,* but not within the same or adjacent beds. There are, however, two significant exceptions: 1) At the Strongsville locality (Section 3) specimens of *Lingula* cf. *melie* Hall were found *in situ* within the *Zoophycos* beds (Pl. 2, fig. 1). As most of them assume the life position it is unlikely that they were washed into the area. It is well known that Recent *Lingula* prefers a shallow-water environment and is the only living brachiopod which can sustain itself for short periods of time in brackish waters (Rudwick, 1965). According to Hatai (1940) Recent *Lingula* extends from the low-water line to about 20 or 23 fathoms, although one specimen of *Lingula unguis* was recorded from a depth of about 50 fathoms near Seto, Japan.

2) At the Valley City locality (Section 4) a black shale two to three meters thick is in contact with the upper *Zoophycos* siltstone of the Strongsville beds. Within the shale are a few thin (2 to 3 mm thick) beds of cross-laminated siltstone. This shale is also present at the Strongsville locality and apparently represents a local basin. Its significance for this study is that it contains abundant carbonized cordaite fragments, some several centimeters long. While this is not indicative of any particular water depth, the abundance of the plant fragments would seem to demonstrate a near-shore occurrence.

D) *Sedimentary features associated with Zoophycos*

Several lines of evidence point to abundant current or wave activity.

1) Many of the siltstone beds in the Meadville Member and Armstrong Member pinch and swell and some are abruptly lenticular. Cross-laminations are common and many are large-scale sets which range from 3 to 5 meters in lateral extent and display dips of 5 to 15 degrees. While we are unable to assign the large-scale structures to a particular depositional environment *(e.g.* point bar) it seems unlikely that they originated below wave-base.

2) Oscillation ripple marks are abundant at the Killbuck Creek locality (Section 5) and occur within 5 cm (vertically) of *Zoophycos.* They have an amplitude of 1 cm and a wave length of 7 to 10 cm., and many grade laterally into interference ripple marks. It is not uncommon to find three or four ripple-marked beds within a thickness of 20 cm. While the authors realize that such ripple marks may be produced by various mechanisms (see McKee, 1965) it is difficult to visualize the origin of such large numbers below wave-base. It is worthy of note that Seilacher (1967b, fig. 2) placed *Zoophycos* below the occurrence of oscillation ripple marks.

E) *Regional geological setting*

It is instructive to look at the environmental setting of the formations both underlying and overlying the Cuyahoga. In northeastern Ohio the Berea Sandstone occurs some 45 meters below the *Zoophycos* beds (Szmuc, 1970, p. 43). Pepper, *et al.* (1954) demonstrated convincingly that the Berea and the subjacent Bedford

Formation represent a deltaic, prodeltaic, and channel-fill environment. The reader is referred to their paper for a more complete discussion.

Although the Logan Formation, which lies some 35 meters above *Zoophycos,* has not been thoroughly studied by the writers, environmental indicators are abundant. The Quarry of the Wooster Medal Brick and Tile Company at Wooster (Section 6) contains one of the best exposures of the upper Cuyahoga Formation and lower Logan Formation in northeastern Ohio. In this exposure interference ripplemarks, ripple drift, and small scale channel cross-lamination are common. Rare casts of mud cracks have also been found. The Berne Conglomerate in the basal portion of the Logan consists of quartz pebbles in a sandy matrix containing chonetid brachiopods.

The stratigraphic position of the Cuyahoga beds between deltaic and delta-derived sediments is a compelling argument for a shallow-water habitat of the Ohio *Zoophycos.* The argument is strongly enhanced by the environmental setting of the Meadville, Armstrong, Rittman, and Black Hand Members. The deduced depositional histories (see Text-fig. 1) of these units are based not only on the criteria presented in this paper, but also on their body-fossil content, geometry, and stratigraphic relations with contiguous units such as the largely nonmarine Pocono Sandstone of Pennsylvania (Hyde, 1915; Barclay, 1968; Szmuc, 1970). Environmental interpretations on these bases indicate that the *Zoophycos* in the Armstrong Member is sandwiched between the Rittman and Black Hand barfinger sands, the stratigraphic separation of which is about 35 meters. Moreover, the *Zoophycos*-bearing beds in the Armstrong and in the upper part of the Meadville are intimately associated with off-shore marine and prodeltaic deposits.

There is nothing in the Ohio Mississippian section which suggests any significant deepening of the epeiric sea during Cuyahoga sedimentation. On the contrary, all available evidence indicates that *Zoophycos* lived in shallow-water, offshore environments.

CONCLUSIONS AND PROBLEMS

1) In Ohio *Zoophycos* is closely associated with shallow-water environments, as is amply attested by our interpretation of the Strongsville Beds.

2) Seilacher's *Zoophycos* Facies apparently must be broadened or expanded from an equivocal assignment of "intermediate depth" to include deposits which form well above wave base and proximate to the outer margins of bar-finger sands. This opinion is strongly indicated by our interpretation of the Armstrong beds and upper Meadville beds and related units of the Cuyahoga Formation.

3) It seems likely that water depth, which in turn reflects many physical factors (temperature, light), is not the sole factor in determining the distribution of *Zoophycos*. This conclusion is buttressed by the presence of this genus in two different shallow-water ecological niches, the Strongsville and the Armstrong-Meadville, as well as by Seilacher's accounts of *Zoophycos* in relatively deep-water deposits.

4) Trace-fossil workers are now faced with the task of conducting a closer examination of this genus. Several questions remain unanswered, *e.g.*, why is *Zoophycos* usually not associated with other trace fossils, how much morphologic variation is to be permitted to exist within the genus, and finally what are the specific physical, chemical, and biotic factors which control its distribution?

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APPENDIX – DETAILED LOCALITY DATA

1. *Brandywine Creek locality*. Top of section is at former State Route 8 bridge at Little York, 4.2 miles south of Northfield Center; Northfield Township, Summit County, Northfield 7.5 minute Quadrangle.
2. *Gorge Park locality*. City Park in Cuyahoga Falls, outcrop is in a tributary valley on north bank of the Cuyahoga River 0.8 miles east of State Route 8 bridge; Summit County, Akron East and Akron West 7.5 minute Quadrangles.
3. *Strongsville locality*. Baker Creek, 0.1 mile west of junction of State Routes 82 and 237 and 1.25 miles west of Strongsville. Outcrop is some 300 meters south of the bridge over route 82; Strongsville Township, Cuyahoga County, Berea 7.5 minute Quadrangle.
4. *Valley City locality*. West branch of Rocky River where crossed by State Route 252 less than one mile south of intersection of State Routes 252 and 303; Medina County, West View 7.5 minute Quadrangle.
5. *Killbuck Creek locality*. Outcrop begins some 200 meters downstream from where an unnamed tributary of Killbuck Creek is crossed by Wayne County Route 36, 2.5 miles north of village of Congress; Wayne County, West Salem 7.5 minute Quadrangle.
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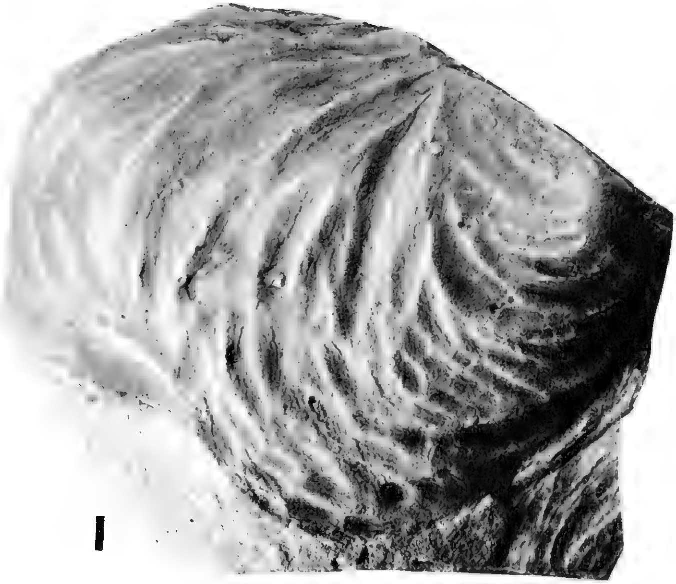
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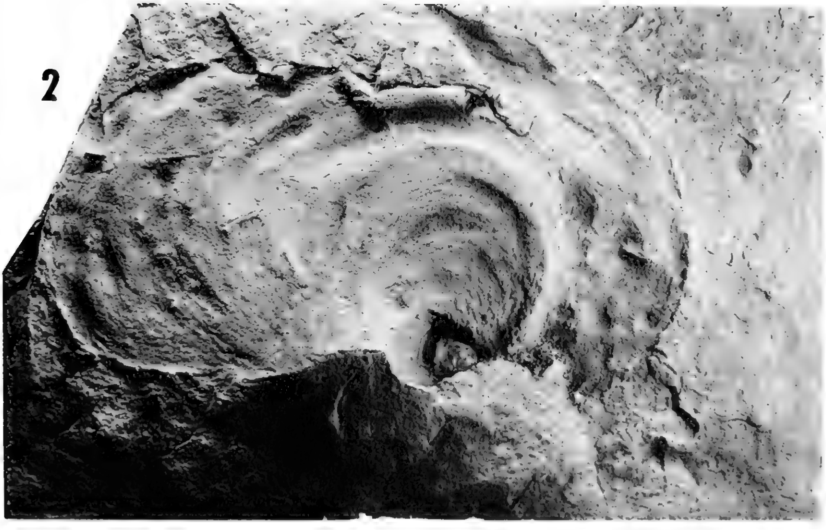
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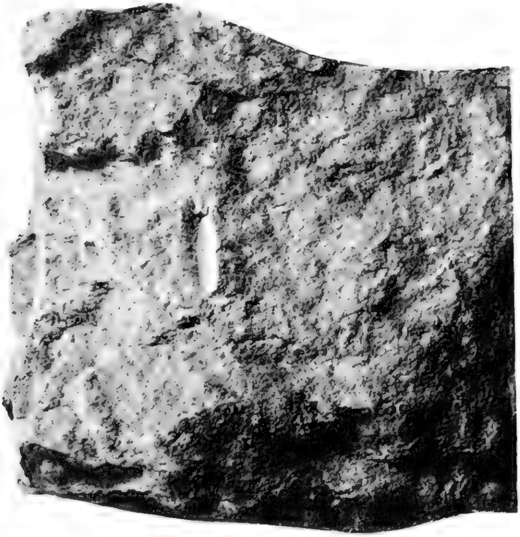

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By

Richard Arnold Davis

1972

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CONTENTS

MATURE MODIFICATION AND DIMORPHISM IN SELECTED LATE PALEOZOIC AMMONOIDS[1]

RICHARD ARNOLD DAVIS,
University of Cincinnati

ABSTRACT

Many ammonoid cephalopod taxa display late ontogenetic modifications of the shell. These modifications include any number of the following: change in coiling, modification of whorl section, change in ornament, development of an apertural constriction, development of an apertural shell thickening, formation of a characteristic ultimate peristome (with lappets or a rostrum, for example), changes in shell deposition, progressive approximation of the ultimate septa, progressive simplification of the ultimate few sutures, thickening of the last septum, and development of muscle scars. Such modifications are related to the attainment of sexual maturity. The ecologic and physiologic implications of these mature modifications are uncertain.

Long ago, sexual dimorphism was suggested to account for the widespread existence of pairs of morphologically distinct mature ammonoids which are virtually identical as juveniles. This explanation is most probably valid.

The following genera of the family Adrianitidae display mature modifications: *Adrianites, Crimites, Epadrianites, Hoffmannia, Neocrimites, Palermites, Pseudagathiceras, Sizilites,* and *Texoceras.* In specimens of all of these, changes in coiling and an apertural constriction are present. Changes in ornament are present in *Neocrimites, Pseudagathiceras, Sizilites,* and possibly *Hoffmannia.* Lappets are known in *Adrianites, Neocrimites, and Palermites.* Changes in whorl cross-section occurred in *Adrianites, Crimites, Hoffmannia, Palermites,* and *Sizilites.* Possible changes in shell secretion are known in *Adrianites* and *Texoceras.*

Agathiceras, of the family Agathiceratidae, displays changes in coiling, whorl cross-section, and ornament and has an apertural construction and lappets. Dimorphism is present in the genus; the two forms appear to differ only in mature diameter.

Three genera of the Cyclolobidae are known to bear mature modifications: *Mexicoceras, Waagenoceras,* and *Cyclolobus.* All three have an apertural constriction and changes in coiling and whorl cross-section. *Mexicoceras* has a mid-ventral salient in the peristome, and *Cyclolobus* has lappets.

Four genera of the Marathonitidae display mature modifications: *Hyattoceras, Pseudovidrioceras, Marathonites,* and *Peritrochia.* All four have an apertural constriction. *Hyattoceras* and some *Marathonites* display changes in coiling. *Hyattoceras, Pseudovidrioceras,* and some *Marathonites* show changes in whorl cross-section. *Marathonites* and *Hyattoceras* each appear to include dimorphs; in both genera, the two members of a pair differ in the nature of the mature modifications rather than just in size.

The genera *Waagenina* and *Stacheoceras* of the Vidrioceratidae show mature modifications. Both have an apertural constriction, lappets, and changes in whorl shape. *Stacheoceras* shows changes in coiling. *Waagenina* appears to include dimorphs; the two members of a pair differ in the nature of the mature modifications.

INTRODUCTION

An externally shelled cephalopod, at death, has left an auto-

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[1] Contribution No. 106, Department of Geology, University of Cincinnati.

biography of at least part of its life cycle in the form of the shell. Its growth lines, the increments between the growth lines, and, indeed, the shape of the conch, as a whole, record a life history of the anterior margin of the body; the septa and, hence, the sutures give witness to the ontogeny of the septal mantle.

Were the conch complete it would give much of the story of the architectural career of its author, but Nature has seen fit to obliterate the last chapters of most of these autobiographies, and many men have followed her lead by inadvertently destroying portions of the body chamber during preparation of the shell. The relatively few well-preserved shells that remain tell an interesting tale.

Many shells indicate that toward the end of the recorded span of life, changes in the animal occurred — the last-formed part of the shell has been modified with respect to the earlier-formed portion. These changes in some taxa apparently were minor, but in others, profound. The modifications may be present in both the septa and in the conch wall or only in the septa. Moreover, in some taxa, two conchs which were identical in early growth stages may be strikingly different after modification, revealing dimorphism.

The purpose of this work is to examine these shell modifications and any dimorphism thereby indicated.

Five ammonoid families have been studied in detail: the Adrianitidae, Agathiceratidae, Cyclolobidae, Marathonitidae, and Vidrioceratidae. At least some taxa of all of these families are known to exhibit modification in the last-formed part of the shell. That suitable material of these taxa is available for the present study is due predominately to the long-term contessorative efforts of the late A. K. Miller, of W. M. Furnish, and of Brian F. Glenister, all of the University of Iowa.

All known genera of the five families enumerated have been studied, and those with modifications are described.

This work should not be construed as an authority on taxonomy. I have not made the thorough sutural studies upon which to found a taxonomic revision. The taxonomy used in this work is based mostly on the synthesis of Bogoslovsky, Librovitch, and Ruzhencev (1962), because theirs is the most recent study of most of the taxa concerned. Newer works, when available, were used. Where the Soviet Treatise is internally inconsistent or apparently incorrect, its taxonomy has been modified. The diagnoses given are intended solely to convey my understanding (or lack thereof) of the taxa being discussed.

Some of the taxa discussed in this work originally were not designated with names conforming to the present International Code of Zoological Nomenclature (for example, *Stacheoceras (Marathonites) J. P. Smithi* Böse, 1919, and *P. tridens* form β Haniel, 1915). In order to simplify the tracing of taxonomic history, however, I have given, at least once, each taxonomic name as it was originally proposed.

This paper is, in the main, the dissertation I presented to the University of Iowa. Professor Brian F. Glenister and Professor W. M. Furnish advised me in the preparation of that thesis. I am greatly indebted for their gifts of time, experience, and enthusiasm. In addition notes and photographs they made relating to their comprehensive study of Permian ammonoid type specimens were invaluable. Revisions were done during my current employment at the University of Cincinnati.

During most of the time I worked on the thesis I held a National Science Foundation Graduate Fellowship. For that I am most grateful.

The various scientific institutions listed below graciously lent, traded, or gave specimens to the University of Iowa (SUI) or allowed them to be studied, as did Francis G. Stehli of Case-Western Reserve University and, likewise, M. Collignon of Académie Moirans (the abbreviations are those used in this work): The American Museum of Natural History (AMNH); British Museum (Natural History) (BMNH); Geologisch Instituut der Universiteit van Amsterdam (GIUA); The University of Copenhagen; Institut und Museum für Geologie und Paläontologie der Universität Tübingen (GPIT); Istituto di Geologia dell'Università Palermo (IGUP); The Geological Survey of Pakistan; Institut Teknologi Bandung (ITB); Istituto di Geologia e Paleontologia dell'Università di Pisa (MGPU); Muséum national d'Histoire naturelle, Paris (MNHN); Institut für Paläontologie der Rhein. Friedrich-Wilhelm Universität, Bonn (PIUB); University of Paris, Sorbonne (UPSM); The University of Texas (Texas); Texas Tech University; Mineralogisch Geologisch Museum Technische Hogeschool Delft (THD); The United States National Museum (USNM); Yale Peabody Museum (YPM).

Dr. Claude Spinosa (Boise State College, Boise, Idaho, USA) and Dr. Eric J. Denton (The Laboratory, Citadel Hill, Plymouth, England) both have generously provided me with unpublished information on particular aspects of their work with cephalopods. I am grateful to them.

LATE ONTOGENETIC SHELL MODIFICATION

In the externally shelled cephalopods as a whole, the changes in morphology which occurred toward the end of that span of life recorded in the shell included any number of the following:

1. changes in coiling,
2. changes in whorl section,
3. changes in ornament (including coloring),
4. development of an apertural constriction,
5. development of an apertural shell thickening,
6. formation of a characteristic ultimate peristome (with lappets or a rostrum, for example),
7. changes in shell deposition (such as, production of a black border at the terminal peristome in *Nautilus*),
8. progressive reduction of interseptal interval (approximation),
9. progressive simplification of the ultimate few sutures,
10. thickening of the last septum,
11. development of muscle scars.

Some taxa are not known to have developed modifications. This may reflect an actual lack of such modifications (Ruzhencev, 1962, p. 255) or be due to either unavailability of suitably preserved material or to inadequate study.

A modified individual generally has at least several aspects of its conch affected. Various modifications occurred at diverse times in the ontogeny of the individual; for example, a change in coiling was wrought before the formation of an apertural constriction.

Within any genus there seems to have been but one or two schemes of overall modification. Within any one such scheme, of course, the development of a particular aspect of modification varied from individual to individual.

In years past, most authors (for example, Hyatt, 1874) attributed late ontogenetic shell modifications to senility — the gerontic individual just couldn't maintain discipline in its shell-forming faculties, so chaos resulted. Hyatt (1874) also noted that what he interpreted as pathologic dwarfs commonly are modified very similarly to those he regarded to be large gerontic forms. Coëmme (1917) considered at least some modifications as indicative that their bearer was a "small, degenerate hybrid". Apparently struck by the similarity of some modifications to varices in snails, to the parabolic nodes of certain Mesozoic ammonoids, and to phragmocone constrictions, certain authors (for example, Nikitin, 1884; Siemiradzki, 1925; Davitashvili and Khimshiashvili, 1954; Sazonov, 1957; *fide* Makowski, 1962) have suggested that the modifications are not late ontogenetic features at all, but were produced early or periodically and eroded or resorbed to allow further growth. Kerr (1931) was so impressed by the apparent external uselessness of most shell modifications that he concluded ammonoid shells were internal. Only one genus of externally shelled cephalopods is extant — *Nautilus*. In this form, shell modifications occur at and are directly related to the onset of sexual maturity (Willey, 1902; Stenzel, 1964).

Interpretation of late ontogenetic shell modifications in terms of senility, pathology, and genetic problems appears to be unlikely because of the great overall uniformity of modifications within each taxon or subdivision of that taxon. Resorption and erosion should have left partially resorbed and partially eroded individuals — none are known (Makowski, 1962); and to remove all modifications would, in some cases, necessitate erosion or resorption of more than one and one-half whorls of the shell. These facts, coupled with the knowledge that the conch changes in *Nautilus* are associated with maturity, strongly indicate that the late ontogenetic shell modifications in the externally shelled cephalopods are terminal and truly are mature modifications.

("Mature" here is used as meaning sexually mature. This word has been used previously, for example, by Miller and Furnish, 1940a, apparently to indicate that an individual had attained what were considered to be its taxonomically diagnostic characteristics; in this work the word is placed in quotes when it is used in the sense of Miller and Furnish. The state of sexual maturity has been denoted previously as "fully mature".)

The various mature modifications must have served some useful purpose (or, at the very least, have been neutral in effect), otherwise these modications would not have persisted.

One could reasonably assume that mature modification prepared the animal for a mode of life different from that of its youth; this may well not have been entirely the case. It is known that at least some of the modern dibranchiate cephalopods (for example, *Loligo* and *Sepia*), reach maturity only to quickly breed and die (Lane, 1960, and personal communication, E. J. Denton). Lane (1960) and Wells (1962) pointed out that captive *Octopus* always die after brooding their eggs, and Wells noted that it is possible that cephalopods, in general, spawn only once and then die. It is known that periodically great numbers of mature *Nautilus* shells are piled onto the beaches of the southwestern Pacific Ocean, suggesting mass death, perhaps after mating. At least the possibility exists that the ammonoid had to face its environment as a mature individual for only a brief period of time; hence mature modifications may have been related mainly to sex and have had little other ecologic significance.

If the two sexes of a taxon were morphologically different and spent much of their lifespan as adults, it is difficult to envision how they could have occupied the same ecologic niche and still be of such different morphologies. But, then, perhaps the two sexes lived in different environments (Westermann, 1964, p. 39 *et seq.;* 1969). The two sexes, after all, would have needed to have been in the same place for only a short time.

Each mature modification must be examined both to suggest what sexual significance the given modification might have had and to indicate its possible nonsexual ecological implications. In order to keep such speculations from becoming completely idle, the biology of extant organisms must be borne in mind — particularly the biology of the surviving cephalopods and, of these, especially *Nautilus*.

Modifications relating to sex might include mechanisms:

1. for sex recognition,
2. for mating battles, either actual or ritual, between conspecific individuals of the same sex,
3. for the enclosure of sex organs,
4. for the accommodation of sex organs,

5. for the support of sex organs,
6. to aid copulation,
7. to aid oviposition,
8. for brooding eggs, young, or both.

(Because almost any feature could be claimed to have been used for sex recognition, this aspect will not be mentioned in the following discussion.)

Modifications (both those related to sex and those not pertaining to sex) might affect the animal's:

1. hydrodynamic and hydrostatic characteristics,
2. mobility and maneuverability,
3. sensory ability,
4. security from external organic and inorganic dangers,
5. feeding,
6. disposal of waste.

Changes in coiling most probably would have had hydrodynamic effects. Likewise the orientation of the animal would have changed; this would have altered the position and orientation of the peristome and, hence, the potential orientation of the hyponome.

Changes in whorl section also would have altered the hydrodynamic characteristics of the conch. Development of an angular venter (for example, in *Hyattoceras* and in *Cyclolobus*) or of a ventral keel would seem to be a modification for a more mobile existence. A broadening of the venter in transverse section, particularly if coupled with a change in coiling to render the venter flat as viewed laterally, would seem admirably suited for bottom dwelling (Ruzhencev, 1962). In *Nautilus* the conch of the male is broader than that of the female in order to accommodate the spadix.

Changes in ornament, like the loss of color banding ventrally and addition of coloring dorsolaterally in *Nautilus,* could have been used for camouflage (see Cowen, *et al.,* 1971). Miller (1944) speculated that the spines on the penultimate one-half whorl of *Pseudagathiceras* might have served to protect the bottom-dwelling animal from attack from above. The loss of longitudinal ornament and the appearance of transverse plications in the ultimate one-quarter volution of *Sizilites,* as well as the spines in *Pseudagathiceras* would certainly have affected the hydrodynamics. The purpose of the deep depression in each flank of the ultimate living chamber of *Agathiceras suessi* is unclear.

Development of an apertural constriction, an apertural shell thickening, or both would have strengthened the ultimate shell margin; this would have been of particular importance inasmuch as shell repair apparently ceased after mature modifications were completed. Perna (1915) pointed out that constriction of the aperture would have afforded the animal protection from outside influences, not the least of which would have been the attempt by a potential predator to wrench the cephalopod from its conch (Berry, 1928). The addition of shell material at the aperture would have affected the hydrostatic characteristics of the conch, thereby altering the orientation of the hyponome, but an even greater effect on the hyponome would have been the barricading of the aperture (Perna, 1915) — the hyponome would have needed to shoot over the constriction (or shell thickening or both) or to extend beyond it, as in *Nautilus*. The thickening of the shell material might have been simply a device to rid the body of excess calcium carbonate. A highly constricted aperture would have imposed limitations on the size of food that could have been consumed, unless the cephalopod could extrude its body as do the modern cowries. Perhaps young ammonoids were protected by living behind the apertural constriction of a parent (Schmidt, *fide* Berry, 1928). The purpose of the two pronounced depressions within the apertural constriction of *Cyclolobus* is unclear. Likewise, the purpose of the slight apertural shell thickening in *Nautilus* has not been established.

Lappets might have served in mating (or other) battles; they don't appear strong enough to have functioned as real weapons, but they might have done service in bluffing such as occurs in the extant cephalopods *Loligo* and *Sepia*. They could have been utilized as supports for sex organs or perhaps for protection of eggs or young. Lappets might also have been used as supports of nonsexual organs; Gillet (1937) suggested that these structures might have supported arms. Mikesh and Glenister (1968) contemplated that hollow lateral shell extensions in *Solenochilus*, a Carboniferous nautilid, might have enclosed extensions of the mantle which served a sensory function. The development of lappets may have been to eliminate part of the weight of the shell, while still retaining some of its supporting and protective attributes. On the other hand the lappets may have added weight anteriorly to alter the orientation of the conch. Lappets might, in addition, have served a hydrodynamic function.

Ruzhencev (1962) suggested that they supported the animal when it advanced from the shell and perhaps allowed the creature to move into and out of the conch more rapidly; to him this indicated a more predational way of life.

The rostrum has been taken by many authors to indicate loss of swimming ability, but some creatures with rostra seem from other features to have been nektonic (Dunbar, 1924). As pointed out by Perna (1915) a rostrum might have served as a funnel support; in fact, the hyponome may have been bifid, one half lying on either side of the rostrum (Trueman, 1941). The rostrum could have supported the animal when it advanced from its shell. This structure may have been used as a weapon, either real or apparent, or as a support for sensory or other organs. It is likely that the rostrum would have had a hydrostatic effect, bringing the aperture down, and might also have resulted in streamlining. Dunbar (1924) suggested that a hyponomic sinus would be needless for an animal with a long muscular body which could be protruded from the shell; in fact, he said, this protrusion would displace more water so that the animal would have become more buoyant the instant it started to swim. Perhaps the rostrum served for brooding. Jeannet (1948) regarded all ammonoids bearing rostra as dibranchiates but stated no reasons.

In *Nautilus* there apparently is a change in shell deposition about the time the final aperture is formed — the "black layer" which is restricted to the dorsum in juveniles is extended to ring the aperture. Zittel (1895) equated this "black layer" with the runzelschicht of ammonoids. The raised points on the venter of the interior of the modified portion of the shell of, for example, some of the adrianitids may be a ventral extension of runzelschicht and, if so, could be homologous to the black ring of the mature *Nautilus*. Pruvot-Fol (1937) suggested that the black matter in *Nautilus* consists of metabolic wastes.

Willey (1902) noted that usually, but not always, the last few septa of *Nautilus* are progressively more crowded. Such approximation also occurred in at least some ammonoids (and fossil nautiloids, too, for that matter). Makowski (1962) reasoned (for *Quenstedtoceras*, a Mesozoic ammonoid) that lengthening of the shell stopped before septal secretion ceased; this resulted in a shortening of the body chamber and a progressive approximation of the ultimate few septa. Whether this actually occurs in *Nautilus* is unknown. Shortening of the living chamber might be linked with an enlargement in whorl cross-section. In any case there probably would have been an effect on the center of gravity and, hence, on orientation of the live animal.

In ammonoids other than those with simple sutures septal crowding was accompanied by a sutural simplification. Makowski (1962) indicated that further growth of such specimens and eventual return of the sutures to the normal shape have never been observed. He stated further that the septal crowding present at places in the phragmocones of some ammonoids is never accompanied by sutural simplification and that the phragmocone constrictions in goniatites and other forms are never accompanied by densely spaced septa and simplified sutures. (Suture simplification followed by further complication are, however, known in the early ontogenetic stages of *Agathiceras* [*fide* Miller and Furnish, 1939] and *Paraceltites* [personal communication, Claude Spinosa]). Sutural simplification accompanying septal approximation would seem to be merely a mechanical adjustment to septal crowding.

The ultimate septum of externally shelled cephalopods commonly is greatly thickened. This thickening, surely of hydrostatic import, also may have served to provide a stronger base for muscle support. Perhaps the animal disposed of excess calcium carbonate in this manner. The purpose and cause of the thickening of the ultimate septum in *Nautilus* is unknown.

Makowski (1962) reported that in certain (but not all) taxa supplementary prismatic shell material was added at the base of the ultimate body chamber for muscle attachment.

At present the physiology and ecology of *Nautilus* are virtually unknown. Until the basic research on these subjects is done, evaluation of the hypotheses concerning the physiologic and ecologic implications of ammonoid mature modifications is premature. Moreover the possibility that the ammonoid was not closely similar to any extant animal cannot be precluded completely. The various mature modifications might have been suited for anatomies not now within our sphere of knowledge.

DIMORPHISM

Since before the middle of the Nineteenth Century paleontologists working with the ammonoid cephalopods have recognized that mature individuals commonly occur in paired groups. One of each pair is larger and generally has a simple peristome; the smaller form commonly has a more ornate aperture. Particularly impressive are the facts that the pairing is widespread in time and space and that the two groups of a pair are closely similar except near and at maturity. This pairing has been attributed to sexual dimorphism.

Phenetic differences between two groups of individual ammonoids collected from the same horizon and locality could be due to any of a number of factors.

The two groups might represent two separate taxa (of any level); in other words, phyletic splitting had occurred. If the taxa are conspecific, the presence of both in one place simultaneously could be due, for example, to a recent breakdown of the barrier which led to the phyletic split, to ocean water depth stratification of the taxa, to activity at different times of the day, or to post-mortem transportation.

The two groups might indicate dimorphism (that is, the existence in one taxon of two distinct phenetic groups).

Dimorphism could seem present in the local collection because of:

1. a high proportion of pathologic individuals,
2. a high proportion of mutant individuals,
3. post-mortem deformation,
4. post-mortem sorting,
5. preferential destruction, or
6. faulty sampling.

In one area pathologic conditions could result in two groups, but such conditions would be unlikely to be widespread and long-lived. Likewise, in a small area, taxonomically unimportant but phenetically striking mutation (for example, a high proportion of six-legged frogs in a single pond) could produce apparent dimorphism, but, again, over a broad area and extended period of time such mutations would be lost or become of sufficient frequency to be taxonomically important. Post-mortem deformation could produce apparent dimorphism (for example, Davis and Campbell, 1968, discussed specimens of the longiconic nautiloid *Pseudorthoceras knoxense* from Carboniferous rock near Knoxville, Iowa, — those specimens lying horizontally are flattened, whereas those standing vertically are round in cross-section), but deformation is almost always recognizable by actual breaks in the specimen, loss of bilateral symmetry, or both, and, moreover, identical conditions of deformation would be confined to a small geographic area. Sorting or preferential destruction might, for example, remove middle-sized specimens, leaving apparent dimorphism — again studies of collections from other strata and localities would reveal the local nature of such conditions of sorting or preservation. A non-representative sample of the local fauna could give a distorted picture of even that fauna. Actual dimorphism should be recognizable throughout the whole taxon.

Dimorphism could be the result of:

1. alternation of morphologically distinct generations,
2. polymorphism, such as exhibited by certain hymenopteran insects, for example,
3. morphological differences between different ontogenetic stages (including neoteny, such as exhibited by the axolotyl, and instars), or
4. sexual dimorphism.

Of these four, only the last has been documented in the Cephalopoda.

Whether two groups are representatives of separate taxa or are sexual antidimorphs (opposite members of a dimorphic pair) is a basic question. The criteria for the identification of sexual dimorphism in ammonoids are well known (Makowski, 1962; Callomon, 1963; Westermann, 1964):

1. There should be distinct dimorphism between sexual antidimorphs.
2. Sexual antidimorphs should have identical phylogenies.
3. Sexual antidimorphs should have identical early ontogenies.
4. Sexual antidimorphs should have the same stratigraphic range.
5. The sex ratio should be consistent both with that in modern related organisms and within the total geographic and stratigraphic range of the taxon.

If sexual dimorphism is to be recognized there must be some observable difference between the two sexes. Between two sexually antidimorphic groups intermediate forms might exist either because the ranges of variability of the two groups overlap, because of the existence of intermediate mutant or pathologic individuals, or because of the presence of intersexes in the taxon.

Theoretically, at least, the two sexes of a species need not evolve in the same way or at the same rate, particularly with respect to phenetic characters directly involved with sex. Hence, sexual antidimorphs might well not have identical phylogenies and ranges. McCaleb's (1968, p. 29) conclusion that "dimorphism is a predominant feature at the inception of an evolution lineage and decreases throughout phylogeny", if generally applicable to ammonoids, may be important.

The respective ontogenies of the two sexes of a species need not be identical. Sexual characters can appear early in ontogeny. McCaleb's (1968) conclusions regarding dimorphism in *Syngastrioceras oblatum* (from the Upper Carboniferous of Arkansas), perhaps cast doubt on the almost universal application of the assumption that sexually dimorphic characters are most pronounced at maturity. What he considered to be antidimorphs differ most as juveniles, and "the conch differences decrease in the more mature forms" (p. 51).

Even if the actual sex ratios in now extinct forms were consistent with such ratios in related extant groups, there are many possible sources of deviation. Differential mortality could produce local concentrations of one or the other sex, and, likewise, different geographic distributions in life, differential preservation, and sorting could result in local deviations. In all these cases study of the taxon throughout its whole range would disclose an approximation of the actual ratio. The general collector tends to gather the more spectacular fossils, so might gather the larger or more striking of the antidimorphs or might consider poorly preserved specimens of the smaller antidimorph to be juveniles of the larger and count them as such. Moreover, the sex ratios reported for the extant cephalopods (Pelseneer, 1926; Fretter and Graham, 1966; Mangold-Wirz, 1963) vary so markedly that virtually no antidimorph ratio could be rejected as inconsistent.

In short, each criterion for the identification of sexual dimorphism can be open to serious doubt. It does, however, seem highly unlikely that paired groups of ammonoids with both members having closely similar ranges, phylogenies, and ontogenies and in a consistent ratio throughout their geographic and stratigraphic ranges could be anything but sexual antidimorphs.

The conclusion that two forms are sexual antidimorphs presupposes that the two forms are conspecific. Hence, the person making the conclusion has no alternative but to refer to both forms by the same binomen.

Makowski (1962) recognized two sorts of dimorphism in ammonoids, based primarily on number of whorls:

In Type A — one antidimorph generally has five to six whorls but may have as few as four, and the other antidimorph generally has seven to nine whorls but may have as few as six. The larger form has a relatively greater whorl height adapertural of whorl five to five and one-half.

In Type B — one antidimorph generally has seven to nine whorls but may have as few as six, and the other antidimorph has at least one whorl more than its opposite. (Guex, 1968, added a third type, 'O', in which the smaller antidimorph has but three to four whorls.)

Westermann (1964) also recognized two kinds of dimorphism, based on conch morphology. In the simpler and rarer type the antidimorphs differ only in size but not in other morphologic characters. In the more abundant type one antidimorph is smaller and has a more highly modified peristome than the other; the two antidimorphs may also differ in other mature modifications. Westermann recognized dimorphism, intermediate between the two main types, in which the antidimorphs differ both in size and in minor morphology, for example, in the transverse ribs on the mature conch.

Zeiss (1969) recognized three categories of dimorphism. In Group I, one antidimorph is large and variocostate whereas the other is small and equicostate. Both antidimorphs of Group II are ornamented similarly, but there are differences in size and in the shape of the apertural region. Dimorphism in Group III is suspected but not clearly recognizable.

The various systems do not correspond. For example, each of Makowski's dimorphism types includes representatives of both of Westermann's categories.

Beginning with De Blainville (1840), who was the first person to suggest dimorphism in ammonoids (*fide* Makowski, 1962), most workers have considered the smaller of each dimorphic pair to be the male. Makowski (1962, p. 58) stated that in all known invertebrate groups in which sexual dimorphism is expressed by notable differences in size, it is the male which is smaller: "Not a single case of opposite morphological conditions has so far been reported in this respect." Wells (1962, p. 33) in discussing extant forms noted that: "In cephalopods the males are usually larger than their mates." Being more specific, Wells (1966, p. 581) stated: "In *Octopus, Sepia, Sepiola,* and *Loligo,* at least, the occurrence of mating appears to be determined by the male, which is generally larger than the female. . .".

Mangold-Wirz (1963) gave length and age measurements for sixteen extant cephalopod species. Although in some cases the maximum size of males exceeds that of females, in every example given save one the length of the female upon reaching maturity is greater than that of the male at maturity. In that one case, *Sepia officinalis,* the female is just at the upper end of the size range of the males. (Of interest is the fact that, except in *Sepia officinalis,* the female takes longer to reach maturity. Moreover, in those cases in which the maximum length of one sex exceeds that of the other, it appears that the maximum age of the one also exceeds that of the other.)

Westermann (1969) pointed out that size relationships of the sexes of extant cephalopods are extremely variable even at the genus level. Although he gave no measurements with his examples, he concluded that "wherever marked sexual dimorphism in size ($>$ 1.5 in diameter) is present in the cephalopoda, the female is larger than the male."

Mangold, Lu, and Aldrich (1969) discussed dimorphism in the extant squids *Illex illecebrosus illecebrosus, I. illecebrosus argentinus,* and *I. illecebrosus coindetii,* in all of which it is generally accepted that females are larger than males. In all three subspecies the mean mantle length of females exceeds that of males. However, in *I. illecebrosus coindetii,* and apparently also in *I. illecebrosus argentinus,* the males and females differ in proportions; for example, in *I. illecebrosus coindetii* the arms of the male are longer, the head of the male is broader, and the diameter of the largest suckers is larger in males than in females.

In *Nautilus* the male is slightly broader than the female (Willey, 1902). Stenzel (1964) illustrated (after Willey, 1902) the maximum and minimum whorl width differences between the sexes of *Nautilus.* The male is shown to be as much as 25% wider than the female. (Westermann's 1969 statement about this illustration that the female is 50% wider is apparently a typographic error.)

Coëmme (1917, *fide* Makowski, 1962) stated that in ammonoids the smaller antidimorph of a pair is the less abundant, as are the males of modern cephalopods. Pelseneer (1926, and extracted *in* Fretter and Graham, 1966) collated reports of sex ratios for modern cephalopods varying from 3:1 in favor of males to nearly 7:1 against; most of his examples give females the majority. Mangold-Wirz (1963) gave sex ratios for 16 extant cephalopod species which range from 143 males for every 100 females to 39 males for every 100 females; she discussed that season of sampling, place of sampling, and relative susceptibility of the sexes to capture may be significant in her statistics. Westermann (1969) also discussed sex ratios in extant cephalopods, paying particular attention to migration of populations and the commonly concomitant segregation of sexes. Mangold, Lu, and Aldrich (1969) studied 382 males and 351 females of *Illex illecebrosus coindetii* as well as 452 males and 457 females of *I. illecebrosus illecebrosus.* Willey (1902) listed 150 male: 66 female *Nautilus pompilius,* but 10 male: 16 female *Nautilus macromphalus.*

One is forced to wonder whether size differences and (especially) sex ratios in modern forms are sufficiently well understood to extrapolate to fossil cephalopods.

Within the mature living chamber of an *Eleganticeras elegantulum* macroconch (the larger antidimorph of a pair) Lehmann (1966) found a cluster of spherical structures of the same size as the protoconch of the species. He cautiously interpreted these structures as egg coatings. This, if the brooding of eggs by the female in *Argonauta* and *Octopus* proves to be the general case in the extant cephalopods, might be taken to indicate that the macroconch is the female.

As related in the excellent historical surveys of Makowski (1962) and Callomon (1963), most students of ammonoid dimorphism have concentrated their attentions on Mesozoic fossils. However Foord and Crick (1897), Haug (1897), Perna (1914), Demanet (1943), McCaleb and Furnish (1964), Furnish and Knapp (1966), McCaleb (1968), and Davis, Furnish, and Glenister (1969) have all at least suggested the existence of dimorphism in ammonoids from the Paleozoic.

The greatest obstacle to study of dimorphism in Paleozoic ammonoids is the marked lack of suitably preserved faunas. In order to establish that dimorphism exists, it is necessary to study large numbers of fossils which retain mature modifications. In addition, the internal whorls must be well preserved, if ontogeny is to be deciphered and whorls counted. In none of the five families studied is any fauna known to me which fully satisfies the requirements of abundance and suitable preservation. The *Agathiceras* fauna from the Road Canyon Formation of Texas discussed by Davis, Furnish, and Glenister (1969, pp. 103, 105-107) lacks preservation of internal whorls.

Of the taxa discussed in the descriptive portion of this work only four, *Agathiceras*, *Hyattoceras*, *Marathonites*, and *Waagenina*, exhibit two distinct mature forms. Unfortunately, paucity of available mature individuals of the last three forces me to regard the dimorphism apparent in these three genera as only theoretical. On the other hand, dimorphism in *Agathiceras* seems to be statistically justifiable (Davis, Furnish, and Glenister, 1969). But even this case is established only on the basis of a single collection from one horizon and locality and, because the ontogeny and phylogeny of the studied specimens is unknown, any too positive attribution of the dimorphism apparent in *Agathiceras* to sex seems to me to be premature.

DESCRIPTIVE PART

Superfamily **ADRIANITACEAE** Schindewolf, 1931

Family **ADRIANITIDAE** Schindewolf, 1931

Diagnosis.—The Adrianitidae includes ammonoids in which the suture underwent goniatitic ontogenetic development; subsequent new elements were then added in the saddle positioned on the early adolescent umbilical seam, and these elements migrated toward the dorsum and venter respectively.

Genus **ADRIANITES** Gemmellaro, 1887

Diagnosis. — *Adrianites* includes adrianitids in which the "mature" suture on each side has six or seven lobes between the bifid ventral lobe and the umbilical shoulder.

Synonymy. — Glenister and Furnish (1961, p. 726) suggested that *Neocrimites (Sosiocrimites)* Ruzhencev, 1950, and *Aricoceras (Neoaricoceras)* Ruzhencev, 1950, are synonyms of *Adrianites.*

Specific composition. — *Adrianites elegans* Gemmellaro, 1887, is the type species of *Adrianites* by original designation. *Adrianites kingi* Gemmellaro, 1887, is the only species which was referred to *Aricoceras (Neoaricoceras)* by Ruzhencev (1950). *Adrianites insignis* Gemmellaro, 1887, and *A. insignis* var. *biassalensis* Toumanskaya, 1931, are the only two taxa which were referred to *Neocrimites (Sosiocrimites)* by Ruzhencev (1950); Furnish and Glenister (*in* Davis, Furnish, and Glenister, 1969, explanation to plate 3) considered *A. insignis* to belong in *Neocrimites.* In addition to the previously listed taxa, *A. isomorphus* Gemmellaro, 1888, is referred to *Adrianites,* and the following inadequately described taxa may belong in the genus: *A. bobkovae* Toumanskaya, 1949, *A. permicus* Toumanskaya, 1935, *A. planus* Toumanskaya, 1935, and *A. vinogradovi* Toumanskaya, 1949. *A. schmidti* Toumanskaya, 1937a, and *A. bobkowi* Toumanskaya, 1937a, are apparently *nomina nuda.*

Immature shell. — The conch of *Adrianites* has been described as discoidal to subspherical, involute, and with a small umbilicus (Ruzhencev, 1950, p. 204).

Constrictions are present in most, if not all, individuals of *Adrianities.* In the type species *A. elegans* they are prominent on the shell exterior, producing a slight but conspicuous decrease in whorl height immediately adoral of each constriction. Similar decreases in whorl height occur in representatives of *A. insignis* and *A. isomorphus,* even though the constrictions in these two taxa are less prominent than in the type species. In *A. kingi,* on the other hand, the only evidence of constrictions on the shell exterior is the periodic closer spacing of the transverse lirae. The maximum number of constrictions per whorl apparently varies from two (in *A. isomorphus*) through three (in *A. elegans* and *A. kingi*) to four (in *A. insignis*).

In the type species *Adrianites elegans* the longitudinal and transverse lirae are equally conspicuous. In the genus as a whole the relative prominence of these two features varies from that displayed by *A. isomorphus,* in which the transverse components are much the less striking, to that shown by *A. kingi,* in which the longitudinal ornament is restricted to the flanks in the form of scallops in the transverse lirae. The longitudinal lirae are weak or absent in the constrictions. In some individuals the longitudinal ornament affects both the shell exterior and interior.

The overall trend of each half of the external suture is arcuate.

Mature shell. — After about two-thirds of the ultimate whorl of *Adrianites* had been formed, there occurred a slight decrease in the radius of curvature of coiling, followed by a slightly greater increase; this resulted in the venter being somewhat flattened in longitudinal section. This change in coiling is particularly evident in the umbilici of specimens of *A. isomorphus* and *A. kingi* where it resulted in an actual decrease in the size of the umbilicus. In *A. elegans* and in at least some representatives of *A. insignis* the umbilicus seems little affected (but in these taxa, the flattening of the venter is, itself, slight). In at least some individuals, for example of *A. isomorphus* and *A. elegans,* the change in coiling was accompanied by a slight but distinct increase in relative whorl width; this bulging appears greatest in the dorsolateral portions of the flanks.

Near the adapertural end of the mature body chamber of *Adrianites* is a constriction whose trend is somewhat different from those adapical of it. Shortly before the apertural constriction was formed, a decrease in the radius of curvature of coiling occurred, leading directly into the constriction.

As in the immature constrictions of *Adrianites,* longitudinal lirae are not present in the ultimate constriction or are less prominent there than adapical of it. The growth lines are more closely spaced and are commonly less prominent in the terminal constriction than adapical of it. Beginning in the adoral portion of the apertural constriction each successive growth line shows a more accentuated ventrolateral salient on each side, forming the lappets of the ultimate peristome. The lappet figured by Gemmellaro (1888, pl. D, fig. 10) is straight. Each lappet bears an adaperturally directed branch of the ultimate constriction.

The leading edge of the dorsal shell of *Adrianites* has a distinct lip (for example, USNM-a and SUI 32442). The surface of the dorsal shell is ornamented with irregularly spaced ridges and raised points arranged in a generally radial pattern; this is interpreted as runzelschicht.

The ventral surface of the internal mold of the mature body chamber in some individuals (for example, USNM-b) bears minute, irregularly spaced pits which correspond to raised points on the inward-facing surface of the shell. In one place on USNM unnumbered specimen b the outermost portion of the shell has broken away, revealing that the raised points on the inward-facing surface of the shell correspond to globular- or rod-shaped bodies within the shell itself. The presence of these bodies in some and their absence in other individuals even in the same species remains unexplained.

Gemmellaro reported the following living chamber lengths for members of *Adrianites*: one and one-third whorls in *A. elegans* (1887, p. 44), more than one volution in *A. insignis* (1887, p. 45), and a whorl and a half in *A. kingi* (1887, p. 47) and in *A. isomorphus* (1888, p. 14). The ultimate constriction and final septum were observed by the present author in only one individual (*A. isomorphus* — SUI 32442); they lie about one and one-third whorls apart.

The maximum diameter of specimens of *Adrianites* known to the author are: *A. elegans* — 20½ mm and 21 mm, *A. kingi* — 22 mm, *A. isomorphus* — 25 mm, 26 mm, 27 mm, 27 mm, and *A. insignis* — 27 mm and 29 mm.

Material. — The preceding observations are based on study of: Gemmellaro (1887, 1888), Toumanskaya (1931, 1935, 1937a, 1949), Miller and Furnish (1940a), Ruzhencev (1950), Glenister and Furnish (1961), Bogoslovsky, Librovitch, and Ruzhencev (1962), Davis, Furnish, and Glenister (1969), three mature and one nearly mature specimens of *A. isomorphus* (USNM unnumbered, SUI 32442), two mature examples of *A.* cf. *A. insignis* (GPIT unnumbered, BMNH C 37654), and photographs and notes taken by W. M. Furnish and Brian F. Glenister in the summer of 1965.

Illustrations. — The following mature specimens of *Adrianites* are figured: two *A. elegans* — IGUP 85 (Pl. 3, figs. 1-3), (Pl. 3, figs. 5-7), two *A. insignis* — MGPU unnumbered (Pl. 5, figs. 4, 5), IGUP 84 (Pl. 6, figs. 7, 8), one *A.* cf. *A. insignis* — BMNH C37654 (Pl. 5, figs. 1-3), four *A. isomorphus* — SUI 32442 (Pl. 3, fig. 4), IGUP 86 (Pl. 4, figs. 1-3), USNM unnumbered a (Pl. 4, figs. 7, 8), USNM unnumbered b (Pl. 4, fig. 9), and one *A. kingi* — IGUP 81 (Pl. 5, figs. 6-8).

Genus **CRIMITES** Toumanskaya, 1937b

Diagnosis. — *Crimites* includes narrowly umbilicate adrianitids in which the "mature" suture on each side has three complete lobes between the bifid ventral lobe and the umbilical shoulder.

Specific composition. — The type species of *Crimites* is *Agathiceras krotowi* Karpinsky, 1889, by subsequent designation of Glenister and Furnish (1961, p. 726). In addition to the type species the following are referred to *Crimites*: *C. elkoensis* Miller, Furnish, and Clark, 1957, *C. glomulus* Ruzhencev, 1952, *C. pamiricus* var. *darensis* Toumanskaya, 1949, *C. singularis* Bogoslovskaya, 1962, and *C. subkrotowi* Ruzhencev, 1938. *Adrianites globosus* Chernov, 1939, is a synonym of *Crimites krotowi* (*fide* Ruzhencev, 1956a, p. 249). *Crimites busterensis* Toumanskaya, 1937b, *C. pamiricus* Toumanskaya, 1937b, *C. smithi* Toumanskaya, 1937b, *C. spathi* Toumanskaya, 1937b, and *C. undosus* Ruzhencev, 1952, are apparently all *nomina nuda*. *Adrianites gemmellaroi* Toumanskaya, 1931, *A. hanieli* Toumanskaya, 1931, *Agathiceras oyensi* Haniel, 1915, *A. rothpletzi* Haniel, 1915, and *Crimites subkrotovi* var. *murgabensis* Toumanskaya, 1949, may belong in *Crimites*.

Immature shell. — The conch form of *Crimites* has been described as spherical to strongly globose (Ruzhencev, 1950, p. 202). The shell is involute.

Only one individual of *Crimites* known to the author (Ruzhencev, 1956a, pl. 39, fig. 3) has immature constrictions; three shallow ones are visible in its outermost preserved whorl.

The relative prominence of the longitudinal and transverse lirae of *Crimites* is variable; the spiral ornament may be much the more striking, may be just as conspicuous as the transverse lirae, or may be represented only in the form of scallops in the growth lines. In those individuals with prominent transverse lirae, each lira is at the crest of a transverse shell plication. On the internal mold the peak of each plication is, itself, scalloped. Along the umbilical shoulder of some representatives of the genus there runs a thickening of the shell layer (Ruzhencev, 1941, p. 884).

In addition to the three lobes between the bifid ventral lobe and the umbilical shoulder of *Crimites*, on each side there are three lobes between the umbilical seam and the dorsal lobe, and there are a variable number of lobes on the umbilical wall. Each "internal lateral lobe" is tied to its respective "external lateral lobe". The lobe just ventrad of the shoulder may be bifid.

Mature shell. — Only comparatively slight changes in coiling occurred in the final stages of the ontogeny of *Crimites.* In some individuals, after all but about the last quarter of the ultimate volution was formed there was a slight decrease in the radius of curvature of coiling, followed by a like increase; this resulted in a slight flattening of the venter as viewed in longitudinal section. This change in coiling is accompanied by a gentle increase in the ratio W/D. The umbilicus appears to have been little affected.

Near the adapertural end of the mature living chamber of *Crimites* is a broad constriction.

The plications in the shell of *Crimites* do not seem to occur in the ultimate constriction, although growth lirae are present. Longitudinal ornament extends into the adapertural constriction; at least the transverse lirae there are scalloped.

No specimen of *Crimites* known to the author retains the ultimate peristome.

The ultimate constriction of *Crimites* varies from three-quarters to just less than one whorl adapertural of the ultimate septum.

All three mature specimens of *Crimites* known to the author have a diameter between 22 and 23 mm.

Material. — The preceding observations are based on study of: Haniel (1915), Toumanskaya (1931, 1937a, 1937b, 1949), Ruzhencev (1941, 1950, 1951, 1952, 1956a), Miller, Furnish, and Clark (1957), Glenister and Furnish (1961), Bogoslovskaya (1962), and two mature and one nearly mature specimen of *Crimites krotowi* (SUI 5981).

Illustrations. — Two mature specimens of *Crimites krotowi* are figured: SUI 5981a (Pl. 6, fig. 6) and SUI 5981b (Pl. 6, figs. 3-5).

Genus **EPADRIANITES** Schindewolf, 1931

Diagnosis. — *Epadrianites* includes globose, fairly broadly umbilicate adrianitids in which the "mature" suture on each side has four or five lobes between the bifid ventral lobe and the umbilical shoulder, four or five lobes between the umbilical seam and the dorsal lobe, and two or three lobes on the umbilical wall.

Synonymy. — Those specimens which have been referred to

Basleoceras Ruzhencev, 1950, are regarded as congeneric with individuals of *Epadrianites*.

Specific composition. — The type species of *Epadrianites* is *Agathiceras timorense* Boehm, 1907, by original designation. *Agathiceras beyrichi* Haniel, 1915, is the type species, and *Adrianites haueri* Gemmellaro, 1888, is the only other species referred to *Basleoceras* by Ruzhencev (1950, p. 203). In addition, *Agathiceras timorense* var. *involuta* Haniel, 1915, is referred to *Epadrianites*.

Immature shell. — The conch of *Epadrianites* has been described as moderately involute and spherical or with width greater than the diameter (Ruzhencev, 1950, p. 203).

The majority of specimens of *Epadrianites* bear no evidence of constrictions. One specimen of *E. timorense* (SUI 32439) has six gentle transverse ridges in its outermost preserved whorl on which the longitudinal lirae are less distinct than elsewhere; another individual of the same species (PIUB unnumbered) is similarly ornamented. The ridges of both of the examples are apparently constrictions.

The most striking ornamental feature of *Epadrianites* is the presence of prominent longitudinal lirae with faint transverse growth lines. *Basleoceras* and *Epadrianites* were distinguished on the basis of the difference in the spacing of the longitudinal lirae (Ruzhencev, 1950), but Haniel (1915, pl. 50, fig. 14) illustrated what is an apparently transitional form. Ruzhencev (1950, p. 203) stated that *Basleoceras* has growth lines with a weak ventral sinus, whereas in *Epadrianites* the growth lines each form a ventral salient. As far as the present author is able to determine, there is little if any difference in the trend of the growth lines of the two "genera".

Mature shell. — Only one mature specimen of *Epadrianites* is known to the author (IGUP 75). After about three-quarters of the ultimate whorl was formed, there was a slight decrease in the radius of curvature of coiling followed immediately by a slightly greater increase. Just before the apertural constriction was formed, there was a marked decrease in the radius of curvature leading directly into the constriction. These changes in coiling result in a flattening of the longitudinal section of the venter with a terminal upturning of the venter. The longitudinal ornament continues on into the ultimate constriction. The final peristome of *Epadrianites* is unknown; the growth lines seem to retain their immature trend as far as preserved.

The exact length of the mature living chamber of *Epadrianites* is not known, although Gemmellaro (1888, p. 17) stated that it is much greater than one whorl. The diameter of the one known mature individual is 66 mm.

Material. — The preceding observations are based on study of: Gemmellaro (1888), Haniel (1915), Miller and Furnish (1939), Ruzhencev (1950), Glenister and Furnish (1961), one immature individual of *Epadrianites beyrichi* (SUI 32440), three immature specimens of *E. timorense* (SUI 32439, 12321), and photographs and notes taken by W. M. Furnish and Brian F. Glenister in the summer of 1965.

Illustrations. — One mature specimen of *Epadrianites haueri* is figured — IGUP 75 (Pl. 8, figs. 1-4). One immature example of *E. timorense* is also illustrated — PIUB 21b (Pl. 9, figs. 8, 9).

Genus **HOFFMANNIA** Gemmellaro, 1887

Diagnosis. — *Hoffmannia* includes strongly evolute, transversely plicate adrianitids in which the "mature" suture on each side has five lobes between the bifid ventral lobe and the umbilical seam.

Specific composition. — The type species of *Hoffmannia* is *Adrianites (Hoffmannia) hoffmanni* Gemmellaro, 1887, by monotypy. In addition to the type species, *Adrianites (Hoffmannia) burgensis* Gemmellaro, 1888, is referred to *Hoffmannia. H. fisheri* Plummer and Scott, 1937, is probably not closely related to the genus (*fide* Miller and Furnish, 1940a, p. 110).

Immature shell. — The conch of *Hoffmannia* is serpentine, evolute, with narrow whorls and a broad umbilicus (Bogoslovsky, Librovitch, and Ruzhencev, 1962, p. 394).

All specimens of *Hoffmannia* known to the author have constrictions which extend from seam to seam. There are two or three of these constrictions per whorl.

The flanks of specimens of *Hoffmannia* are marked by conspicuous simple or dichotomizing transverse plications. These plications are restricted to the flanks, but on the venter there are delicate transverse ribs which appear to be growth lirae.

Mature shell. — Only one individual known to the author (IGUP 78) may be mature. Its venter has been eroded, and apparently the creature had been seriously injured in life, for the plications about one-eighth whorl adapical of the terminal constriction are markedly disturbed.

The apparent flattening of the venter of the last quarter volution as viewed in longitudinal section may be a mature modification or might be the result of erosion. The apparent rapid increase in whorl height in the region just adapical of the terminal constriction may be a modification, may have resulted from the animal's injury, or may be the product of erosion of the shell apical of the region. Nonetheless, there does seem to be a gradual increase in the coarseness of the ventral ribbing in an adapertural direction throughout the ultimate whorl.

The living chamber of *Hoffmannia* is one and one-half whorls long (Gemmellaro, 1887, p. 50).

The diameter of the one possibly mature individual is 24 mm.

Material. — The preceding observations are based on study of: Gemmellaro (1887, 1888), Plummer and Scott (1937), Miller and Furnish (1940a), Glenister and Furnish (1961), Bogoslovsky, Librovitch, and Ruzhencev (1962), two immature specimens of *Hoffmannia hoffmanni* (USNM unnumbered, SUI 32434), and notes and photographs taken by W. M. Furnish and Brian F. Glenister in the summer of 1965.

Illustrations. — One specimen of *Hoffmannia* is figured, a mature individual of *H. hoffmanni* — IGUP 78 (Pl. 10, figs. 1-3).

Genus **NEOCRIMITES** Ruzhencev, 1940a

Diagnosis. — *Neocrimites* includes narrowly umbilicate adrianitids in which the "mature" suture on each side has four or five lobes between the bifid ventral lobe and the umbilical shoulder, three to five lobes between the dorsal lobe and the umbilical seam, and one or two lobes on the umbilical wall.

Synonymy. — *Neocrimites (Metacrimites)* Ruzhencev, 1950, and *Neocrimites (Neocrimites)* were considered consubgeneric by Glenister and Furnish (1961, p. 726, 727); *Aricoceras (Aricoceras)* Ruzhencev, 1950, and *A. (Metaricoceras)* Ruzhencev, 1950, were referred to *Neocrimites* by the same authors (*ibid.*).

Specific composition. — The type species of *Neocrimites* is *Adrianites fredericksi* Emeliancev, 1929, by original designation.

Adrianites newelli Miller and Furnish, 1940a, the type species, and *Adrianites adamsi* Miller and Furnish, 1940a, were the only taxa referred to *Neocrimites (Metacrimites)* by Ruzhencev (1950, p. 202). In addition to the type species, Ruzhencev (1950, p. 202; 1956a, p. 255) included the following in *Neocrimites* (*Neocrimites*): *Adrianites defordi* Miller and Furnish, 1940a, *A. dunbari* Miller and Furnish, 1940a, *Waagenia koswae* Krotow, 1885, *Adrianites marathonensis* Böse, 1919, *A. nalivkini* Toumanskaya, 1949, *A. plummeri* Miller, 1944, *Agathiceras stuckenbergi* Karpinsky, 1889, and *Adrianites warreni* Miller and Crockford, 1936. Miller and Furnish (1940a, p. 116), however, believed that the type of *A. marathonensis* might be only an immature *Waagenoceras dieneri.* Ruzhencev (1950, p. 203) included the following in *Aricoceras* (*Aricoceras*): *Adrianites ensifer* Gemmellaro, 1887, the type species, *Agathiceras cancellatum* Haniel 1915 (*sensu* Haniel, p. 75), and *Adrianites* (*Neocrimites*) *meridionalis* Teichert and Fletcher, 1943. *Agathiceras martini* var. *globosa* Haniel, 1915, is apparently a synonym of *Neocrimites cancellatum* (Furnish — personal communication, 1965 notes). The type species and only taxon which has been referred to *Aricoceras (Metaricoceras)* is *Agathiceras cancellatum* form. *discoidalis* Haniel, 1915, although the suture of *Agathiceras cancellatum* form. *globosa* Haniel, 1915 (pl. 50, fig. 1c) agrees with Ruzhencev's (1950, p. 203) diagnosis of the subgenus. Furnish and Glenister (*in* Davis, Furnish, and Glenister, 1969, explanation to plate 3) included *Adrianites insignis* Gemmellaro, 1887, in *Neocrimites.*

Immature shell.—The conch form of *Neocrimites* has been described as spherical to subdiscoidal (Glenister and Furnish, 1961, p. 728). The conch is involute (*ibid.*) to comparatively involute (Ruzhencev, 1950, p. 202).

At least some individuals of *Neocrimites* bear transverse constrictions. These constrictions are irregularly spaced, which may account for their apparent lack in some individuals. The amplitudes of these features are not uniform, nor do the variations seem to follow any regular pattern. The outermost preserved whorl of one specimen (one of IGUP 82) has nine transverse bands in which the growth lines are disturbed; these apparently reflect constrictions and, if so, constitute the largest number observed by the present author in one whorl. Other than in this specimen, the maximum number of constrictions observed per volution is four. The constrictions run from shoulder to shoulder.

The shell of *Neocrimites* bears both longitudinal and transverse lirae, both of which in some individuals are so prominent as to be plications. The relative prominence of the transverse and longitudinal ornament varies. The spiral ornament of some specimens tends to fade at constrictions, and the growth lines are more closely spaced there. Along the umbilical shoulder of some representatives of the genus there runs a thickening of the shell layer (Ruzhencev, 1941, p. 884).

Mature shell — After nearly three-quarters of the ultimate whorl of *Neocrimites* had been formed there was a slight decrease in the radius of curvature of coiling, followed by a slightly greater increase. Just prior to the formation of the ultimate constriction there was another decrease in the radius of curvature which led directly into the constriction. In the majority of known specimens all of these changes in coiling are slight.

The trend of the ultimate constriction of *Neocrimites* differs from that of those adapical of it. This terminal constriction is devoid of longitudinal ornament.

After almost all of the ultimate constriction of *Neocrimites* had been formed the ventrolateral portions of each successive growth line formed a larger salient, so that the ultimate peristome has one prominent ventrolateral lappet on each side, each bearing a branch of the terminal constriction. These lappets curve toward the dorsum.

Neocrimites sp. of Glenister and Furnish (1961, pp. 729-731) was said to have a terminal flare adapertural of the ultimate constriction. The internal mold of the living chamber of *Neocrimites dunbari* was said to bear a small, low, rounded ridge or raised line along the venter of the mature living chamber (Miller, 1944, p. 99).

Gemmellaro (1887, p. 46) stated that the living chamber of *Neocrimites ensifer* is one and one-half whorls long. *Neocrimites* sp. of Glenister and Furnish (1961, pp. 729-731) was said to have a body chamber only one whorl long. In SUI 32443 the living chamber is no longer than one volution, and in SUI 32605 it is no more than one and one-quarter whorls long.

The smallest mature individual of *Neocrimites* known to the author is 27 mm in diameter (*viz. N.* sp. of Glenister and Furnish, 1961). The largest (SUI 32443) is not yet mature at a diameter of 40 mm.

Material. — The preceding observations are based on study of: Gemmellaro (1887), Haniel (1915), Böse (1919), Wanner (1932), Miller and Crockford (1936), Miller and Furnish (1940a), Ruzhencev (1940a, 1941, 1950, 1956a), Miller (1944), Toumanskaya (1949), Glenister and Furnish (1961), Bogoslovskaya (1962), Armstrong, Dear, and Runnegar (1967), Davis, Furnish, and Glenister (1969), about one hundred immature *Neocrimites* (*N.* sp. — GPIT unnumbered, SUI 32444-32448, 32221, 32601-32603, *defordi* — SUI 1398, *discoidalis* — SUI 32450, *dunbari* — SUI 1360, 1763-1765, 13595, 32443, *fredericksi* — SUI 32449, 32452, 32543, *globosus* — SUI 32451, *newelli* — SUI 1361, 1478, 13596), eight mature individuals (SUI 32443, 1360, 32600, 32604-32606), and photographs and notes taken by W. M. Furnish and Brian F. Glenister in the summer of 1965.

Illustrations. — The following mature specimens of *Neocrimites* are figured: *N. cancellatus* (*fide* Furnish and Glenister *in* Davis, Furnish, and Glenister, 1969) — PIUB unnumbered (Pl. 10, figs. 4, 5), GIUA T328 (Pl. 3, figs. 8, 9), *N. ensifer* — IGUP 82 (Pl. 7, figs. 1-3), and (Pl. 7, figs. 4, 5). In addition, one immature specimen is illustrated — *N. ensifer* — IGUP 82 (Pl. 6, figs. 1, 2).

Genus **PALERMITES** Toumanskaya, 1937a

Diagnosis. — *Palermites* includes moderately evolute adrianitids in which the "mature" suture on each side has five lobes between the bifid ventral lobe and the umbilical shoulder, five lobes between the dorsal lobe and the umbilical seam, and one or two lobes on the umbilical wall.

Specific composition. — The type species of *Palermites* is *Adrianites distefanoi* Gemmellaro, 1887, by original designation. In addition, *Adrianites distefanoi* var. *minor* Toumanskaya, 1931, is referred to *Palermites*.

Immature shell. — The conch of *Palermites* is not broad, is moderately involute, and has a large umbilicus (Ruzhencev, 1950, p. 203).

Every specimen of *Palermites* known to the author bears transverse constrictions, concave outward on both the shell exterior and the steinkern. Most individuals have three constrictions per whorl.

Each constriction continues from umbilical seam to umbilical seam.

Longitudinal lirae are restricted to the umbilical region but are absent from the umbilical wall. The lira which is most prominent is situated on the shoulder. On the more ventral portions of the conch, longitudinal ornament is present only as scallops in the transverse lirae. Transverse lirae are crowded slightly adoral of each constriction.

Mature shell. — After slightly more than half of the ultimate whorl of *Palermites* was formed there was a slight decrease in the radius of curvature of coiling followed by a slightly greater increase; this change in coiling is evident in the course of the umbilical seam but does not appear to have affected the venter. After about three-quarters of the last volution was formed, there was another pair of changes in coiling similar to the previous but affecting both the seam and the venter. Coupled with the latter changes in coiling was a gradual increase in the ratio W/H, so that the venter appears somewhat flattened both in longitudinal and transverse section. Close to the ultimate constriction the height increased relative to the width, so that the venter again took on a smaller radius of curvature in transverse section; there is also a tightening of coiling leading directly into the ultimate constriction.

The terminal constriction of *Palermites* is marked by a gentle ridge which parallels the trend of the constriction. From its broadest point on the venter the constriction becomes narrower and shallower toward the umbilical shoulders.

Ventrolateral lappets in *Palermites* were commenced after almost all of the ultimate constriction was formed. These lappets are shorter and more delicate and appear to be more strongly oblique than in other genera of the family.

The living chamber of *Palermites distefanoi* is considerably longer than the ultimate whorl (Gemmellaro, 1887, p. 48).

Two mature individuals of *Palermites* are known to the author, both from Sicily. Their diameters are 30½ mm and 45 mm.

Material. — The preceding observations are based on study of: Gemmellaro (1887), Toumanskaya (1931, 1937a), Ruzhencev (1950), Glenister and Furnish (1961), about a dozen immature individuals (USNM unnumbered), three other immature specimens (SUI 32455), one mature example (SUI 32456), and notes and photographs taken by W. M. Furnish and Brian F. Glenister in the summer of 1965.

Illustrations. — Two mature specimens of *Palermites distefanoi* are figured: SUI 32456 (Pl. 9, figs. 3-5) and IGUP 76 (Pl. 9, figs. 6, 7).

Genus **PSEUDAGATHICERAS** Schindewolf, 1931

Diagnosis. — *Pseudagathiceras* includes large-umbilicate adrianitids in which the "mature" suture is straight in overall trend and on each side has three or four lobes between the bifid ventral lobe and the umbilical shoulder, three lobes between the dorsal lobe and the umbilical seam, and one or two lobes on the umbilical wall.

Specific composition. — The type species of *Pseudagathiceras* is *Agathiceras (Doryceras?) wichmanni* Haniel, 1915, by original designation. In addition, *P. difuntense* Miller, 1944, and *P. spinosum* Miller, 1944, are referred to *Pseudagathiceras.*

Immature shell. — The shell of *Pseudagathiceras* has been described as very broad and evolute or moderately involute, with a fairly large umbilicus (Ruzhencev, 1950, p. 203). The umbilical shoulders are rounded.

Every specimen of *Pseudagathiceras* known to the author with the possible exception of the holotype of the type species bears transverse constrictions. These extend from umbilical seam to umbilical seam. The maximum number of constrictions observed in any one whorl is five; the majority have but three per volution, but these are smaller specimens.

Pseudagathiceras, with the possible exception of the holotype of the type species, bear irregularly spaced transverse plications. The plications are stronger near the umbilicus, so much so that some individuals appear nodose.

All specimens of *Pseudagathiceras* in which shell is preserved bear longitudinal lirae. These lirae seem to fade out on the umbilical walls. In most specimens the transverse lirae are much less prominent than the longitudinal ornament, but in one specimen available to the author the lirae in the two directions are equally distinct.

Mature shell. — After about two-thirds of the ultimate whorl was formed there was a slight decrease in the radius of curvature of coiling followed by a slightly greater increase in the radius of coiling. Just prior to the formation of what may be an apertural constriction there was a decrease in the radius of curvature of coiling. The umbilicus displays only a gradual increase in the radius of curvature followed by decrease in the vicinity of the apertural (?) constriction. There seems to be a constriction or particularly prominent plication just where the first change in coiling occurs.

The transverse plications are more prominent on the ultimate living chamber of *Pseudagathiceras* than on the phragmocone. In the adapical half of the living chamber certain of the plications bear a ventrolateral spine on each side. Not every plication is so favored, and the spines do not seem to be regularly positioned on the circumference. In the adapertural half of the living chamber no spines were formed, but the plications are prominent.

Miller (1944, pp. 101, 103) reported that the living chamber of *Pseudagathiceras* is almost one whorl long.

The maximum diameter (exclusive of spines) of the *Pseudagathiceras* figured by Miller (1944, pl. 29, figs. 1, 2) is 21 mm.

Material. — The preceding observations are based on study of: Haniel (1915), Miller (1944), Ruzhencev (1950), Glenister and Furnish (1961), about one and one-half dozen immature specimens of *Pseudagathiceras difuntense* (SUI 32457, 1363, 1362, 1770, 13621), and photographs and notes taken by W. M. Furnish and Brian F. Glenister in the summer of 1965.

Illustrations. — One mature specimen of *Pseudagathiceras spinosum* is figured — YPM 16310 (Pl. 9, figs. 1, 2). One immature example of *P. wichmanni* is also illustrated — THD 12752 (Pl. 10, figs. 6-8).

Genus **SIZILITES** Toumanskaya, 1937a

Diagnosis. — *Sizilites* includes large-umbilicate adrianitids in which the "mature" suture is arcuate in overall trend and on each side has four lobes between the bifid ventral lobe and the umbilical seam and has four lobes between the dorsal lobe and the seam.

Specific composition. — The type species of *Sizilites* is *Adrianites affinis* Gemmellaro, 1888, by original designation. In addition, *A. craticulatus* Gemmellaro, 1888, is referred to the genus.

Immature shell. — The conch of *Sizilites* is described as not wide, moderately involute, and with a large umbilicus (Ruzhencev, 1950, p. 204). The umbilical shoulder has a large radius or is absent.

Every specimen of *Sizilites* known to the author bears two to four constrictions in the outermost preserved whorl. These constrictions tend to fade out on the venter and on the umbilical wall portions of the conch, but they are prominent elsewhere.

In some individuals of *Sizilites* longitudinal lirae occur on all but the umbilical wall portions of the shell, but in other specimens these lirae fade on the venter to become merely scallops in the transverse lirae. The longitudinal ornament fades at constrictions.

Mature shell. — After about one-half of the ultimate whorl of *Sizilites* was formed there was a slight decrease in the radius of curvature of coiling followed by a slightly greater increase. After about two-thirds of the whorl was formed there occurred another pair of changes in coiling similar to the first pair. These latter changes were apparently followed by a gradual relative increase in width. Just prior to the formation of the apertural constriction a decrease in the radius of curvature of the coiling occurred, leading directly into the constriction.

The apertural constriction of *Sizilites* is much more prominent and of a somewhat different trend from those adapical of it.

The longitudinal ornament ceases about one-quarter whorl adapical of the apertural constriction. The growth lines, on the other hand, become more prominent, to the extent of becoming plications in the last quarter volution.

The mature living chamber of *Sizilites craticulatus* was stated by Gemmellaro (1888, p. 15) to be one and one-half whorls long.

The two mature specimens of *Sizilites* known to the author are each 15½ mm in diameter.

Material. — The preceding observations are based on study of: Gemmellaro (1888), Toumanskaya (1937a), Ruzhencev (1950), Glenister and Furnish (1961), seventeen immature specimens (six USNM unnumbered, five SUI 32454, and six GPIT unnumbered), one mature individual (GPIT unnumbered) and photographs and notes taken by W. M. Furnish and Brian F. Glenister in the summer of 1965.

Illustrations. — One mature specimen of *Sizilites craticulatus* is figured: IGUP 87 (Pl. 11, figs. 1, 2). Two immature examples of *Sizilites* are also illustrated: *S. craticulatus* — MGPU unnumbered (Pl. 11, figs. 8-10) and *S. affinis* — IGUP 88 (Pl. 11, figs. 3-5).

Genus **TEXOCERAS** Miller and Furnish, 1940a

Diagnosis. — *Texoceras* includes adrianitids in which the "mature" suture on each side has three complete lobes between the bifid ventral lobe and the umbilical seam, two complete lobes between the dorsal lobe and the seam, and one lobe on the seam.

Specific composition. — The only species which has been referred to *Texoceras* is *Agathoceras* [sic] *texanum* Girty, 1908. This species was made the type species of the genus by original designation. *Marathonites delawareanus* Plummer and Scott, 1937, is a synonym (*fide* Miller and Furnish, 1940a, p. 111).

Immature shell. — The conch of *Texoceras* is sublenticular to thickly subdiscoidal and is deeply involute, with an open, moderately small umbilicus (Miller and Furnish, 1940a, p. 111).

Most individuals of *Texoceras* examined display no constrictions. Two specimens (SUI 32462, 32461) have four constrictions per whorl at a diameter of about 6 mm; but another example (SUI 32437) displays no constrictions on a whorl of the same diameter. Available larger specimens lack constrictions except at the ultimate peristome.

The growth lines of *Texoceras* are prominently scalloped; the points of these scallops extend orad to form discontinuous longitudinal lirae. This spiral ornament is absent from the umbilical walls. Each growth lira lies at the crest of a gentle plication; these plications, as displayed on the internal mold, are crenulate. Each side of the conch bears about ten coarse transverse plications per whorl; these are restricted to the dorsolateral portions of the conch and are quite distinct from the smaller plications which bear growth lines. The larger plications are not everywhere evenly spaced.

The internal molds of all *Texoceras* living chambers known to the author display a gentle longitudinal ridge in mid-ventral position. In some individuals (for example, SUI 32461 R, Z, and AE) this ridge extends the full length of the living chamber; in others (such as SUI 32461 N and AF, and 13609) it is discontinuous. Only a few suitably preserved phragmocones were examined by the author; all of them seem to bear the ventral longitudinal ridge on the internal mold. Miller and Furnish (1940a, p. 111) stated that this ridge is present only on some specimens of *Texoceras*.

Mature shell. — After about three-quarters of the ultimate whorl of *Texoceras* had been formed there occurred a slight decrease in the radius of curvature of coiling, followed by a slightly greater increase; this resulted in a flattening of the venter of the last quarter-volution as viewed laterally. Just before the ultimate peristome was reached another decrease in the radius of curvature of coiling occurred, leading directly into an apertural constriction. These changes in coiling are also visible in the umbilical region.

The ornament of the immature portion of the shell continues to the adapertural end of the mature living chamber. In most individuals the apertural constriction is relatively deep and distinct. In SUI 32461 M and AG, however, it is relatively shallow, but the peristome is flared and thus apparently mature.

As pointed out by Miller and Furnish (1940a, p. 113), the inner surface of the test of *Texoceras* is pustulose; this has produced pits in the surface of the steinkern. The pits (and, hence, the pustules) appear to have no regular arrangement and, indeed, vary as to size and spacing from individual to individual. Every known specimen with a distinct apertural constriction bears these features; they seem to be most distinct and closely spaced in the ultimate constriction, fading apically so that they are apparently restricted to the ultimate one-quarter whorl. In the two specimens with indistinct constrictions (SUI 32461 M and AG), the pits in the internal mold appear to be present only in patches in the vicinity of the aperture (*i.e.* for about ⅛ whorl).

The ultimate peristome of *Texoceras* is immediately adjacent and parallel to the ultimate constriction. In SUI 32461 P and Z the peristome is apparently scalloped and is situated approximately ¼ mm from the constriction.

The last few septa of *Texoceras* are approximated, and the characteristically rounded lobes become shallower and more pointed.

The ultimate living chamber of *Texoceras* varies from seven-eighths of one whorl to just under one volution in length.

In 15 mature specimens of *Texoceras* the diameter varies from a minimum of 22 mm to a maximum of 29 mm, with the majority clustering toward the low end of the range.

Material. — The preceding observations are based on study of: Girty (1908), Plummer and Scott (1937), Miller and Furnish (1940a), Ruzhencev (1950), Glenister and Furnish (1961), Bogoslovsky, Librovitch and Ruzhencev (1962), about 40 immature individuals, and about 40 mature specimens (SUI 13609, 32435-32438, 32461, and 32462).

Illustrations. — Eight mature specimens of *Texoceras texanum* are figured: SUI 13609 (Pl. 11, fig. 15), 32461 I (Pl. 11, fig. 12), 32461 M (Pl. 11, fig. 7), 32461 P (Pl. 11, figs. 13, 14), 32461 Z (Pl. 11, fig. 6), 32461 AA (Pl. 10, fig. 9), 32461 AG (Pl. 11, fig. 11), and 32461 AJ (Pl. 10, fig. 10).

Superfamily **AGATHICERATACEAE** Arthaber, 1911

Family **AGATHICERATIDAE** Arthaber, 1911

Diagnosis. — The Agathiceratidae comprises ammonoids in which the suture underwent goniatitic ontogenetic development; following this, the adolescent lateral lobe became trifid, but the internal lobe remained undivided.

Genus **AGATHICERAS** Gemmellaro, 1887

Diagnosis. — *Agathiceras* comprises agathiceratids with "mature" sutures in which the three subdivisions of the primary lateral lobe are discrete and subequal in size.

Synonymy. — *Agaticeras* Gregorio, 1930, and *Agathoceras* Girty, 1908, are apparently merely typographic errors.

Taxonomic composition. — Ruzhencev (1950) recognized three subgenera: *Agathiceras (Agathiceras), A. (Gaetanoceras)* Ruzhencev, 1938, and *A. (Paragathiceras)* Ruzhencev, 1950. Glenister and Furnish (1961) questioned the validity of the latter two but apparently revised their opinion in Davis, Furnish, and Glenister (1969).

The type species of *Agathiceras* is *A. suessi* Gemmellaro, 1887, by original designation. In addition, the following are referred to *Agathiceras: A. anceps* Gemmellaro, 1887, *A. anceps* var. *kitschiensis* Toumanskaya, 1931, *A. anceps* var. *sarabansis* Toumanskaya, 1931, *A. applanatum* Teichert, 1944, *A. applini* Plummer and Scott, 1937, *A. asiaticum* Toumanskaya, 1935, *A. asselicum* Ruzhencev, 1938 (junior synonym of *A. uralicum* - *fide* Ruzhencev, 1950), *A. beschui* Toumanskaya, 1931, *A. bodraki* Toumanskaya, 1931, *A. brouweri* Smith, 1927, *A. ciscoense* Smith, 1903, *A. contractum* Plummer and Scott, 1937, *A. frechi* Böse, 1919, *A. frechi* var. *ircutensis* Toumanskaya, 1949. *A. girtyi* Böse, 1919, *A. katschae* Toumanskaya, 1931, *A. martini* Haniel, 1915, *A. planum* Toumanskaya, 1931, *A. sundai-*

cum Haniel, 1915, *A. tornatum* Gemmellaro, 1887, and *Goniatites uralicus* Karpinsky, 1874. A number of other taxa, inadequately described, may also belong in *Agathiceras: Goniatites fultonensis* Miller and Gurley, 1896, *Ammonites hildrethi* Morton, 1836, *Agathiceras kinshanensis* Grabau, 1924, *Agathiceras mediterraneum* Toumanskaya, 1949, and *Agathiceras tegengreni* Grabau, 1924.

Furnish (personal communication, 1965) concluded that the holotype of *Agathiceras martini* var. *globosa* Haniel, 1915, is an adrianitid, as are the specimens described and figured by Wanner (1932).

Immature shell. — Glenister and Furnish (1961, p. 695) described the conch form of *Agathiceras* as generally ellipsoidal in cross-section but noted that some individuals are parabolic or circular. W/D decreased in ontogeny, and Dixon (1960, p. 54) concluded that the seven species he studied *(A. applini, A. frechi, A. girtyi, A. suessi, A. sundaicum, A. tornatum,* and *A. uralicum)* can best be differentiated on the basis of differences in the rates of ontogenetic change of W/D.

The constrictions of the phragmocone of *Agathiceras* are predominantly internal thickenings of the shell but are expressed as depressions on the shell exterior of some individuals. As many as six constrictions have been observed in a single whorl, but some individuals (for example, *A. applanatum* of Glenister and Furnish, 1961, p. 696, and "*A. asselicum*" of Ruzhencev, 1938, p. 263) apparently bear no constrictions. There does seem to have been an ontogenetic increase in the number of constrictions per whorl.

Except for *Agathiceras martini,* the genus is characterized by longitudinal lirae which are present on the ventral and lateral portions of the conch and even on the umbilical wall; at least some individuals bear traces of these "lirae" on the internal mold. The number of such lirae per individual seems to have remained essentially constant throughout ontogeny, and the lirae are evenly spaced. This longitudinal ornament is present as far back as the second whorl.

The siphuncle of *Agathiceras* was not ventral in the earliest growth stages, so that the earliest formed sutures lack the bifurcation of the ventral lobe. The umbilical lobe of the "mature" sutures resulted from an ontogenetic coalescence of the two lobes adjacent to the early adolescent umbilical seam. At "maturity" the prongs of the ventral lobe are about the same size as the lateral lobes and are straight.

Mature shell. — After two-thirds to three-quarters of the length of the mature living chamber of *Agathiceras* had been formed, a slight decrease in the radius of curvature of coiling occurred, followed by a slightly greater increase. This resulted in a flattening of the venter as viewed in longitudinal section. In at least some forms (for example, *A. suessi*) the changes in coiling were accompanied by a distinct increase in the whorl width; this bulging is greatest on the dorsolateral portions of the flanks but is discernible across the venter where it resulted in a slight increase in the radius of curvature of the venter as viewed in transverse section. In at least some individuals (for example, many SUI 32460) the umbilical wall portion of the shell just adapical of the mature peristome flares dorsad, resulting in a decrease in the size of the umbilicus.

In *Agathiceras suessi* each flank bears a deep depression about one-quarter whorl adapical of the adaperturalmost constriction. The position of the deep depression corresponds to the change in spiral and the initiation of the lateral bulge. These depressions affect both the shell exterior and the internal mold more profoundly than any ordinary constriction, are elongate in a radial direction, and occupy about the middle third of the flanks. Other species of the genus apparently lack these depressions: one specimen of *A.* sp. (SUI 12297) has an ordinary constriction in a position corresponding to that of the depressions of *A. suessi*, but over one hundred individuals of *A. uralicum* (*fide* Furnish and Glenister *in* Davis, Furnish, and Glenister, 1969) have neither constrictions nor depressions between the apertural constriction and slightly less than one-half whorl adapical of it (SUI 32460).

The adapertural constriction of *Agathiceras* has a trend somewhat different from that of all the constrictions preceding it; moreover, the adapertural constriction has a greater amplitude, strongly affecting both the shell exterior and the internal mold. In *Agathiceras suessi* there is a distinct ventrolateral bulge on each side immediately adapical of the ultimate constriction and corresponding in position to each ventrolateral lappet of the terminal peristome; in the constriction itself there is one pit on each side just ventral of the ventrolateral bulge.

At least some specimens possess small raised points on the shell interior. These points seem to lie in definite radial rows near the umbilicus, whereas their arrangement is random on the flanks and venter. The significance of these features is not apparent at present.

The mature living chamber of *Agathiceras* is seven-eighths of a whorl to one whorl in length.

The mature diameters of seven *Agathiceras* sp. are 16, 21, 23, 25, 33, 55, and about 55 mm. The maximum diameters of seven *Agathiceras suessi* are 20, 35, 36, 37, 37, about 40, and 42 mm. One mature *A. uralicum* is 33 mm in diameter.

A sample (SUI 32460) consisting of 110 mature specimens of *Agathiceras uralicum* (*fide* Furnish and Glenister *in* Davis, Furnish, and Glenister, 1969) from one horizon in the Road Canyon Formation at one location in the Glass Mountains region of Texas has been studied statistically. Within this population of 110 specimens two distinct size groupings are recognizable (see Davis, Furnish, and Glenister, 1969):

1. one group of 28 individuals with an average diameter of 20.7 mm (as calculated from measurement of 19 specimens), and
2. another group of 82 individuals with a mean diameter of 30.0 mm (as calculated from measurement of 38 specimens).

Conch proportions, ornament, and mature modifications in both groups appear the same. Poor internal preservation precludes ontogenetic study and even the determination of the number of whorls.

Material. — The preceding observations are based on study of: Morton (1836), Karpinsky (1874, 1889), Krotow (1885), Gemmellaro (1887, 1888), Miller and Gurley (1896), Haug (1898), Smith (1903, 1927), Girty (1908), Haniel (1915), Böse (1919), Fredericks (1921), Grabau (1924), Gregorio (1930), Toumanskaya (1931, 1935, 1939b, 1939c, 1949), Plummer and Scott (1937), Ruzhencev (1938, 1950, 1951, 1962), Miller and Furnish (1939, 1940a, 1957b), Miller (1944, 1945a), Teichert (1944), Miller and Youngquist (1947), Gerth (1950), Miller and Downs (1950), Glenister and Furnish (1961), Unklesbay (1962), Hayasaka (1963, 1965), Chao (1965), Davis, Furnish, and Glenister (1969), about

1500 immature specimens (*Agathiceras sp.* — SUI unnumbered, *applini* — SUI 1386, 1766, 1768, 13612, *brouweri* — SUI 32429, *ciscoense* — SUI 13764, 17025, *frechi* — SUI 13765-13767, 32420, 32421, *girtyi* — SUI 1400, 1966, 2126, 13623, 32418, 32419, *suessi* — GPIT unnumbered, SUI 8297, 12613, 32424, 32426-32428, 32432, 32433, USNM unnumbered, F. Stehli loan, *sundaicum* — SUI 13615, *tornatum* — SUI 32423, USNM unnumbered, *uralicum* — SUI 1387, 1767, 10567-10570, 13611, 32413-32415, 32417), about 250 mature *Agathiceras* (*A.* sp. — BMNH C73338, GPIT 24543, GPIT PV24409, SUI 12297, 32432, 32458, F. Stehli loan, *suessi* — GPIT 24543, SUI 32433, USNM unnumbered, F. Stehli loan, *uralicum* — SUI 10569, 32460), and photographs and notes taken by W. M. Furnish and Brian F. Glenister in the summer of 1965.

Illustrations. — Eight mature specimens of *Agathiceras* are figured: two *A.* sp. — SUI 12297 (Pl. 14, fig. 9), SUI 32458 (Pl. 13, figs. 8, 9), three *A. suessi* — IGUP 119 (Pl. 12, figs. 1-4, Pl. 12, figs. 7, 8), and MGPU unnumbered (Pl. 12, figs. 5, 6), three *A. uralicum* (*fide* Furnish and Glenister *in* Davis, Furnish, and Glenister, 1969), SUI 32460 BA (Pl. 13, figs. 1, 2), SUI 32460 BE (Pl. 13, figs. 5-7), SUI 32460 BN (Pl. 13, figs. 3, 4). One immature specimen of *A. martini* is also illustrated — THD 12735 (Pl. 14, fig. 8).

Superfamily **CYCLOLOBACEAE** Zittel, 1903

Diagnosis. — The Cyclolobaceae includes those ammonoids with sutures that underwent goniatitic development, following which the umbilical, internal lateral, and dorsal lobes each split into three, and the lateral lobe split into three or two resulting in the formulas:

$$(V_1 V_1) L_2 L_1 L_2 U_2 U_1 U_2 : I_2 I_1 I_2 (D_2 D_1 D_2)$$

or

$$(V_1 V_1) L_1 L_1 U_2 U_1 U_2 : I_2 I_1 I_2 (D_2 D_1 D_2)$$

In the first case, subsequent new elements were added by successive bifurcation of that subdivision of the lateral lobe nearest the umbilicus, according to the scheme:

$$L_2 L_1 L_2 \rightarrow L_2 L_1 (L_{2\text{-}1} \quad L_{2\text{-}1}) \rightarrow L_2 L_1 L_{2\text{-}1} \quad (L_{2\text{-}1\text{-}1} \quad L_{2\text{-}1\text{-}1}) \text{ etc.}$$

In the second case the subdivision of the lateral lobe nearest to the ventral lobe bifurcated once; other subsequent new elements were added by successive bifurcation of the subdivision of the lateral lobe nearest the umbilicus.

Family **CYCLOLOBIDAE** Zittel, 1903

Diagnosis. — The Cyclolobidae includes cyclolobaceans with a "mature" suture in which the lateral and internal lobes are denticulate both at their bases and also on the sides.

Genus **MEXICOCERAS** Ruzhencev, 1955

Diagnosis. — *Mexicoceras* includes cyclolobids in which initial subdivision of the primary lateral lobe was through bifurcation; the "mature" suture includes five or six pairs of digitate external lateral lobes.

Specific composition. — The type species of *Mexicoceras* is *Waagenoceras cummingsi* var. *guadalupense* Girty, 1908, by original designation (*W. clavatum* Plummer and Scott, 1937, is a synonym). This is the only species which has been referred to the genus aside from *M. globosum* Chao, 1965, a *nomen nudum.*

Miller and Furnish (1940a) recognized three sympatric subspecies of *Mexicoceras guadalupense: W. guadalupense guadalupense* Girty, 1908, *W. guadalupense smithi* Miller and Furnish, 1940a, and *W. guadalupense thompsoni* Miller and Furnish, 1940a.

Immature shell. — The conch of *Mexicoceras* is subspherical (Bogoslovsky, Librovitch, and Ruzhencev, 1962). The three subspecies of the type species were defined mainly on differences in conch proportions (Miller and Furnish, 1940a): *Mexicoceras guadalupense smithi* has W greater than D in "moderate sized specimens"; *M. g. thompsoni* has W about two-thirds of D in "moderate sized specimens"; in the typical subspecies W/D is between the ratios of the other two in "moderate sized specimens". Miller and Furnish (1940a) stated that the three subspecies are completely intergradational and that "large individuals" have a greater uniformity in conch proportions than "moderate sized individuals".

The majority of individuals of *Mexicoceras* examined by the author have at least one constriction visible in the outermost preserved whorl. There does not seem to be a regular pattern for the spacing of constrictions. In SUI 1782, for example, the first constriction occurs one whorl beyond the protoconch, at a diameter of

0.9 mm; the next constriction is about 255° further, at a diameter of 1.4 mm; the third is about 780° (2 whorls + 60°) further, at a diameter of 3.8 mm; and the fourth is about 175° further, at a diameter of 4.8 mm. Apparently the lack of constrictions in the outermost preserved whorl of some individuals may be merely a function of irregular spacing of constrictions, rather than an actual lack of constrictions.

The shell is thicker at a constriction than between constrictions, but constrictions as observed in median longitudinal sections of individuals of *Mexicoceras* vary considerably. In some instances (for example, the first constriction in SUI 1782) both the shell exterior and the internal mold are concave outward at the venter. At other constrictions (such as the second constriction of SUI 1782) the shell exterior is convex outward, and the internal mold seems affected little if any. At the third constriction of SUI 1782 the shell exterior is virtually unaffected, but the internal mold is concave outward. And at the fourth constriction of SUI 1782 the internal mold is concave outward at the venter, but the shell exterior appears to be slightly convex outward.

In the majority of examined specimens which seem to fall within *Mexicoceras guadalupense smithi* (for example, most of the SUI 12612 series) immediately adapical of each definite constriction are first a ridge and then a groove, both of which parallel the constriction. The groove is more distinct near the umbilicus than on the venter, where it may disappear entirely; the groove is everywhere more shallow than the immediately adjacent constriction.

In general a constriction is shallower and broader at the venter than at the umbilicus.

Most well-preserved individuals of *Mexicoceras* display transverse undulations in the internal mold. Some of these undulations are due to shell plication, but some are also due to thickenings in the shell. The undulations (hence, the plications, the shell thickenings or both) are irregularly spaced and of different amplitudes, but there does not seem to be a regular pattern for these differences in amplitude. As with constrictions, these undulations are commonly less prominent at the venter than near the umbilicus.

Those ammonoids which Miller and Furnish (1940a) referred to *Mexicoceras guadalupense smithi* are characterized by nodes on the umbilical shoulders, which are longitudinally elongate. In plicate individuals not every plication has a node. In some individuals (for example, SUI 12612AE) only the inner whorls bear nodes, and no individual of the species of diameter larger than 25 mm has been observed to bear nodes. In SUI 12612AB the nodes lie slightly ventral of the shoulder so that this individual seems to have two shoulders on each side.

Growth lines in *Mexicoceras* parallel the trend of the closest constriction.

Mature shell. — The approach to maturity in *Mexicoceras* is heralded by a slight decrease in the radius of curvature of coiling followed by a slightly greater increase; this occurs about two-thirds of the way through the ultimate whorl. These changes in coiling appear to coincide with a change in conch proportions: the whorl height decreases in the last third of the living chamber, whereas the width continues to increase.

Miller and Furnish (1940a, p. 163) reported that mature *Mexicoceras guadalupense* has a constriction just adapical of the ultimate peristome. Seven specimens available to the author display a body chamber which terminates in a constriction. Miller and Furnish further stated (*ibid.*, p. 161) that specimens of the species rarely if ever have constrictions on the fully mature portion of the conch except at the aperture. Of the seven specimens only one (Texas-k) has a constriction in the living chamber other than that at the apertural end; in this individual the second constriction is about 230° adapical of the first. Texas-k's adapertural constriction apparently lacks the ventral salient present in the apertural constrictions of the other six individuals.

No individual examined possesses a recognizable ultimate peristome. Growth lines and plications in the shell of the living chamber of SUI 12614 indicate that the ventral salient developed late in the ontogeny.

There is a decrease in the septal interval towards the mature body chamber. The ultimate septum of a mature individual is distinctly thicker than those adapical of it.

Six of the seven individuals with the apertural constriction preserved have living chambers slightly less than one whorl in length; the body chamber of Texas-k is about one and one-quarter volutions in length. Plummer and Scott (1937, p. 161) reported specimens of *Waagenoceras clavatum* having living chambers longer than one volution and with the last three or four septa crowded. The significance of Plummer and Scott's specimens and of Texas-k is unclear.

The maximum diameter of mature individuals ranges from 48 mm (USNM 144423) to at least 200 mm (unidentified individual mentioned by Miller and Furnish, 1940a, p. 163).

Material. — The preceding observations are based on study of: Girty (1908), Böse (1919), Diener (1921), Plummer and Scott (1937), Miller and Furnish (1940a), Miller and Unklesbay (1943), Miller (1944), Ruzhencev (1955, 1956b), Bogoslovsky, Librovitch, and Ruzhencev (1962), Chao (1965), Furnish (1966), Davis, Furnish, and Glenister (1969), Furnish and Glenister (1970), about 70 immature individuals (AMNH unnumbered, SUI 1781, 1782, 12609, 12610, 12612, 12616-12619, 13598, Univ. Texas unnumbered, USNM 144419, 144422, 144437) and about ten mature specimens (AMNH unnumbered, SUI 12614, 12615, Univ. Texas unnumbered, USNM 144423).

Illustrations. — One mature specimen of *Mexicoceras guadalupense guadalupense* is figured — USNM 144423 (Pl. 15, figs. 1-4). Two immature individuals of *Mexicoceras* are illustrated: *M. guadalupense guadalupense* — USNM 144422 (Pl. 15, fig. 7; Pl. 17, figs. 1, 2), and *M. guadalupense thompsoni* — USNM 144419 (Pl. 15, figs. 5, 6).

Genus **WAAGENOCERAS** Gemmellaro, 1887

Diagnosis. — *Waagenoceras* includes globose cyclolobids in which initial subdivision of the primary lateral lobe produced three lobes; the "mature" suture includes seven or eight external lateral lobes.

Synonymy. — *Wanneroceras* Toumanskaya, 1937c, a *nomen nudum* based on *W. gemmellaroi* Toumanskaya, 1937c, another *nomen nudum,* is listed as a synonym of *Waagenoceras* by Bogoslovsky, Librovitch, and Ruzhencev (1962) and of *Timorites* by Miller, Furnish, and Schindewolf (1957).

Specific composition. — The type species of *Waagenoceras* is *W. mojsisovicsi* Gemmellaro, 1887, by subsequent designation (Diener, 1921, p. 25). In addition to the type species the following taxa are referred to *Waagenoceras: W. dieneri* Böse, 1919, *W. dieneri girtyi* Miller and Furnish, 1940a, *W. dieneri karpinskyi* Miller, 1944, *W. lidacense* Roever, 1940, *W. nikitini* Gemmellaro, 1888, and *W. stachei* Gemmellaro, 1887. *W. adrianense* Gregorio 1930, *W. minutum* Gregorio, 1930, and *W. nikitini* var. *perglobosum* Gregorio, 1930, may belong in *Waagenoceras. W. coahuila* Toumanskaya, 1937c, is apparently a *nomen nudum. W. gemmellaroi* Haniel, 1915, was retained in *Waagenoceras* by Ruzhencev (1955); other authors (for example, Miller and Furnish, 1940a) have referred this species to *Timorites. W. richardsoni* Plummer and Scott, 1937 (*W. dieneri richardsoni* of Miller and Furnish, 1940a) was recognized as being transitional between *Waagenoceras* and *Timorites* by the latter two authors; Glenister and Furnish (*in* Davis, Furnish, and Glenister, 1969) based a new genus, *Newellites,* on *W. richardsoni.*

Immature shell. — The conch of *Waagenoceras* is globose (Gemmellaro, 1887, p. 11) to subspherical (Bogoslovsky, Librovitch, and Ruzhencev, 1962, p. 396), is involute, and has a small and deep umbilicus (Gemmellaro, 1887, p. 11).

Most individuals of *Waagenoceras* examined display two to four constrictions in the outermost preserved whorl. The constrictions seem to be variably spaced; for example, in SUI 1784 the first constriction is 346° from the protoconch, the second is 514° further, and the third is 280° further.

The shell in a constriction is thicker than between constrictions, but constrictions, as observed in median longitudinal sections of individuals of *Waagenoceras,* are variable. In some instances (for example, the first constriction of SUI 1784) the shell exterior is unaffected, and the internal mold is concave outward at a constriction; in other cases (such as the second and third constrictions of SUI 1784) both the shell exterior and the internal mold are concave outward at a constriction.

Most individuals of *Waagenoceras* examined by the author bear transverse undulations in the surface of the internal mold. Although many of these are due to plications in the shell, at least some are the result of thickenings in the shell. Generally these undulations are of low amplitude, but their amplitude and spacing are variable. In SUI 1402 the outermost preserved whorl has a non-undulate surface, but the next whorl within bears strong transverse plications.

Well-preserved individuals of *Waagenoceras* bear transverse growth lines. These lines are crowded at constrictions; in one unnumbered individual from AMHN, for example, just adapical of a constriction at a diameter of about 40 mm there are 3½ growth increments per millimeter of circumference, but about 1 mm after the constriction there are 20/mm. As noted by Gemmellaro (1888, p. 4) in some individuals clusters of growth lines occur in various places not corresponding to constrictions.

Waagenoceras dieneri karpinskyi was defined on the basis of the presence of reticulate ornament (in three individuals).

Gemmellaro (1887, p. 11) described the runzelschicht of *Waagenoceras* as consisting of fine "dotting" connected to one another by subtle undulating striations.

Mature shell.—In at least some individuals of *Waagenoceras,* after formation of two-thirds of the ultimate whorl there occurred a slight decrease in the radius of curvature of coiling followed by a slightly greater increase, so that the venter appears slightly flattened in longitudinal section in the final one-third volution; these changes in coiling are likewise apparent in the course of the umbilical wall.

Gemmellaro (1887, p. 12, 13; 1888, p. 4) reported that the ventral portion of at least the first two-thirds of the ultimate whorl of *Waagenoceras* is narrow, whereas in the ultimate one-third whorl the conch is wide and depressed.

In specimens SUI 32317 and 32318 the mature shell is geniculate and has a narrow, almost angular venter. Although sutural details are not preserved in either of the specimens at hand nor in similar specimens from the same locality (Texas Tech unnumbered), on the basis of associated fossils and sutural generalities, Furnish (1967, personal communication) referred these specimens to *W. richardsoni.* The conch form of these two individuals may be due, at least in part, to postmortem deformation; the conch form certainly is unlike that of any other known cyclolobid. The two examples and others from the same locality may well not be congeneric with *Waagenoceras* at all (indeed, Furnish and Glenister, in a footnote *in* Davis, Furnish, and Glenister, 1969, erected the genus *Newellites* for "*Waagenoceras*" *richardsoni);* on the other hand, SUI 32317 and 32318 may possibly represent the antidimorph of "ordinary" *Waagenoceras,* or, perhaps, they are referable to *Timorites.* (A thorough study of the Cyclolobidae is necessary before this can be resolved.)

No known individual of *Waagenoceras* bears any constrictions in the wall of the ultimate body chamber except for that at the adapertural end. Striations and undulations in the shell are present in the living chamber, however.

The internal mold of most mature *Waagenoceras* living chambers bears numerous, irregularly arranged and spaced, minute pits, but these are absent in some individuals. In those individuals possessing these pits, they mark an area extending a variable distance adapical from the ultimate constriction (1/4 whorl in SUI 32405; between 1/3 and 1/2 whorl in SUI 32410; nearly one full whorl in an unnumbered AMNH specimen).

As in many other taxa, the interseptal distance of *Waagenoceras* decreases in the space occupied by the last several septa. Likewise, the ultimate septum is thickened.

The ultimate peristome of *Waagenoceras* lacks either lappets or a ventral prolongation.

The ultimate living chamber of *Waagenoceras* was reported by Gemmellaro (1887, p. 11) to be one and one-half volutions long, and that of *W. dieneri* was reported by Miller and Furnish (1940a, p. 171) to be about one whorl long. In the four specimens available to the author in which both the apertural constriction and the ultimate septum are visible, the living chamber is about one and one-quarter whorls long.

The maximum diameter of mature individuals of *Waagenoceras* ranges from about 90 mm (AMNH unnumbered) to 160 mm (IGUP 32). The diameters of SUI 32317 and 32318 are 190 mm and 170 mm respectively.

Material. — The preceding observations are based on study of: Gemmellaro (1887, 1888), Mojsisovics (1888), White (1891), Smith (1903), Böse (1919), Diener (1921, 1927), Berry (1928), Gregorio (1930), Miller (1933, 1944, 1945a, 1945b, 1953), Greco (1935), Toumanskaya (1937c), Plummer and Scott (1937), Marez Oyens (1938), Roever (1940), Miller and Furnish (1940a, 1957a), Miller and Unklesbay (1943), Hayasaka (1947, 1965), Ruzhencev (1955, 1956b), Miller, Furnish, and Schindewolf (1957), Bogoslovsky, Librovitch, and Ruzhencev (1962), Furnish (1966), Davis, Furnish, and Glenister (1969), Furnish and Glenister (1970), about 25 immature undifferentiated *Waagenoceras dieneri* (AMNH unnumbered, SUI 1401, 12492, 13601, 13602, 16690, 32402, 32406-32410), about 10 mature undifferentiated *W. dieneri* (AMNH unnumbered, SUI 32405, 32410, 32411), 1 immature *W. dieneri dieneri* (SUI 16690), about 20 immature *W. dieneri girtyi* (SUI 1366-1370, 1779, 1780, 1783, 1784, 12611, 13599, 13600), 1 mature *W. dieneri girtyi* (SUI 12613), 1 immature *W. lidacense* (GIUA drawer E229 uncatalogued), 1 immature and 2 mature specimens of *W. richardsoni* (SUI 1402, 32317, 32318 respectively), and notes and photographs taken by W. M. Furnish and Brian F. Glenister in the summer of 1965.

Illustrations. — Three mature specimens of *Waagenoceras* are figured: *W. mojsisovicsi* — IGUP 32 (Pl. 16, fig. 1), IGUP 34 (Pl. 16, figs. 2, 3), and *W. richardsoni* — SUI 32318 (Pl. 16, figs. 6, 7). One immature specimen of *W. stachei* is also illustrated — IGUP 37 (Pl. 16, figs. 4, 5).

Genus **CYCLOLOBUS** Waagen, 1879

Diagnosis. — *Cyclolobus* includes those narrow, ellipsoidal to lenticular cyclolobids in whose "mature" suture nine to fourteen pairs of external lateral lobes are present. L^1 divides the first lateral saddle medially, and U is relatively inconspicuous and is not subdivided.

Synonymy. — Bogoslovsky, Librovitch, and Ruzhencev (1962) listed *Godthaabites* Frebold, 1932, and *Procyclolobus* Toumanskaya, 1939a, as synonyms of *Cyclolobus.* Nassichuk, Furnish, and Glenster (1965) considered *Cyclolobus (Cyclolobus)* and *Cyclolobus (Krafftoceras)* Diener, 1903, to be consubgeneric.

Specific composition. — The type species of *Cyclolobus* is *Phylloceras oldhami* Waagen, 1872, by original designation and by monotypy; Furnish and Glenister (1970) considered *C. insignis* Diener, 1903, to be a junior synonym. In addition, the following taxa are referred to *Cyclolobus: Godthaabites kullingi* Frebold, 1932, *Arcestes (Cyclolobus* Waag.) *persulcatus* Rothpletz, 1892, *C. teicherti* Furnish and Glenister, 1970, and *C. walkeri* Diener, 1903. Furnish and Glenister (1970) suppress all the following as junior synonyms of *C. walkeri: C. astrei* Besairie, 1936, *C. (Krafftoceras) haydeni* Diener, 1903, *C. (Krafftoceras) kraffti* Diener, 1903, and

C. walkeri madagascariensis Besairie, 1936. The relationships of *Cyclolobus hoshanensis* Sun, 1939, are unclear. *Cyclolobus subcumminsi* Haniel, 1915, is a perrinitid.

Immature shell. — The conch of *Cyclolobus* is thinly ellipsoidal to lenticular (Bogoslovsky, Librovitch, and Ruzhencev, 1962).

Most individuals of *Cyclolobus* formed constrictions at least sometime in their ontogeny, but the spacing and, even, shape of these structures seem to be quite variable. In *C. walkeri (sensu* Vaillant-Couturier-Treat, 1933, and Besairie, 1936) there are up to four constrictions per whorl, generally restricted to diameters of less than 25 mm, but constrictions may occur up to a diameter of 80 mm, albeit very slightly prominent; near the ultimate septum of nearly all these specimens is a depression which Vaillant-Couturier-Treat (1933, p. 25) thought could be considered a constriction. In "*C. kraffti*" constrictions are restricted to the early whorls. In "*C. haydeni*" there are four to five constrictions per whorl persisting in the adult. The holotype of the type species bears six constrictions in a whorl of about 105 mm diameter. In *C. walkeri (sensu* Vaillant-Couturier-Treat, 1933) and *C.* cf. *C. kullingi* the constrictions in the earliest whorls are falciform, but in later whorls these structures became biconvex. The constrictions of the holotype of the type species are falciform at a diameter of about 105 mm.

At least some specimens of *Cyclolobus* have prominent transverse plications in their early volutions; these fade out by a diameter of 10 mm in *C. oldhami,* by 30 mm in *C. kullingi,* and by 5 mm in "*C. kraffti*" according to Nassichuk, Furnish, and Glenister (1965). In *C. walkeri (sensu* Vaillant-Couturier-Treat, 1933) barely perceptible ribs may be present even at maturity.

The transverse growth lines of specimens of *Cyclolobus* parallel the constrictions, and at least in "*C. insignis*" they are bunched in places (Diener, 1903, p. 165).

The suture of *Cyclolobus* is strongly arched at "maturity".

Mature shell. — After about two-thirds of the ultimate whorl of *Cyclolobus* was formed, there occurred a slight decrease in the radius of curvature of coiling followed by a slightly greater increase. The changes in coiling are much more prominently displayed in the outline of the umbilicus than in the whorl periphery. In at least *C. walkeri (sensu* Vaillant-Couturier-Treat, 1933) these changes in coiling were accompanied by an accentuation of the angularity of the shoulder and by development of a dorsal bulge which covers the preceding whorl and masks part of the umbilicus; in addition the venter became keeled in the last three-fourths to two-thirds of the ultimate volution (Vaillant-Couturier-Treat, 1933, p. 25).

Some individuals of *Cyclolobus* display constrictions in the ultimate living chamber in addition to the terminal constriction. In "*C. insignis*" these features extend across the venter (5/whorl); in *C. oldhami* they are restricted to the umbilical region; constrictions are obsolete in *C. walkeri* (*sensu* Vaillant-Couturier-Treat, 1933). In "'*C. haydeni*" there are four to five constrictions per whorl persisting in the adult (Besairie 1936, p. 105).

The mature living chamber of *Cyclolobus* terminates in a biconvex constriction. The two convexities closer to the venter form a pair of lappets. Within the constriction, just ventrad of each lappet, is a deep pit, apparently affecting both the shell exterior and the internal mold.

At least some *Cyclolobus walkeri* (*sensu* Vaillant-Couturier-Treat, 1933) bear gentle biconvex ribs in the living chamber.

The length of the ultimate living chamber of *Cyclolobus* varies from eight-ninths of a whorl to one full whorl.

The mature diameter of *Cyclolobus* is variable: "*C. haydeni*" — 57 mm (Diener, 1903, p. 168), "*C. insignis*" — 66 mm (*ibid.*, p. 165), *C. walkeri* (*sensu* Vaillant-Couturier-Treat, 1933) — 90 mm (UPSM #28) to nearly mature at 160 mm (MNHN Vaillant-Couturier-Treat, 1933, pl. 2, fig. 1).

Material. — The preceding observations are based on study of: Waagen (1872, 1879), Mojsisovics (1873, 1882), Rothpletz (1892), Diener (1903, 1904, 1921, 1927), Haniel (1915), Grabau (1924), Vaillant-Couturier-Treat (1926, 1933), Smith (1927), Besairie (1930, 1936), Frebold (1932), Wanner (1932), Miller (1933), Toumanskaya (1939a), Sun (1939), Miller and Furnish (1940b), Ruzhencev (1955), Jeannet (1959), Bogoslovsky, Librovitch, and Ruzhencev (1962), Nassichuk, Furnish, and Glenister (1965), Furnish (1966), Davis, Furnish, and Glenister (1969), Furnish and Glenister (1970), about three dozen immature examples of *Cyclolobus* sp. (BMNH C34155, Collignon unnumbered, Copenhagen unnumbered, SUI 12313, 12343, 12344, 32397-32401, 32403, 32404), two mature *Cyclolobus* sp. (Collignon unnumbered, SUI 32396), about ten immature specimens of *C. oldhami* (BMNH C10459, GPIT unnumbered, Geological Survey of Pakistan unnumbered, USNM unnumbered), three immature individuals of *C. walkeri* (BMNH C36641-C36643), and photographs and notes taken by W. M. Furnish and Brian F. Glenister in the summer of 1965.

Illustrations. — Two mature specimens of *Cyclolobus walkeri* are figured: MNHN B7520 (Pl. 17, fig. 7), and BMNH C36642 (Pl. 17, fig. 8). Two immature examples of *Cyclolobus* are also illustrated: *C. walkeri* — MNHN B7517 (Pl. 17, figs. 3-5), and "*C. astrei*" — UPSM unnumbered (Pl. 17, fig. 6).

Family **VIDRIOCERATIDAE** Plummer and Scott, 1937

Diagnosis. — The Vidrioceratidae comprises cyclolobaceans with "mature" sutures in which there are three to ten pairs of external lateral lobes which are denticulate only at the base.

Subfamily **VIDRIOCERATINAE** Plummer and Scott, 1937

Diagnosis. — Vidrioceratinae comprises ellipsoidal vidrioceratids.

Genus **WAAGENINA** Krotow, 1888

Diagnosis. — *Waagenina* comprises vidrioceratins in which four or five lobes arose from each primary lateral lobe; of these four or five lobes of the "mature" suture, the dorsal component is bifid.

Synonymy. — The following were considered synonyms of *Waagenina* by Bogoslovsky, Librovitch, and Ruzhencev (1962): *Grioceras* Toumanskaya, 1939a, *Martoceras* Toumanskaya, 1938, *Pamirites* Toumanskaya, 1938, and *Waagenia* Krotow, 1885 (*non* Kriechbaumer, 1874, *fide* Bogoslovsky, Librovitch, and Ruzhencev, 1962) (*non* Neumayr, *fide* Diener, 1897b).

Specific composition. — The type species of *Waagenina* is *Waagenia subinterrupta* Krotow, 1885. (*Popanoceras krasnopolyskyi* Karpinsky, 1889, *Marathonites krasnopolskyi* var. *asymmetrica* Ruzhencev, 1933, *M. k.* var. *bidentata* Ruzhencev, 1933, *M. k.* var. *quadridentata* Ruzhencev, 1933, *M. k.* var. *tridentata* Ruzhencev, 1933, *M. k.* forms, α, β, γ, and Δ of Voinova, 1934, and *M. k.* formae a, b, c, d, e, and f of Maximova, 1935, are synonyms.) In addition to the type species, the following are referred to *Waagenina*: *Stacheoceras benedictinum* Gemmellaro, 1887, *Pamirites clinei* Toumanskaya, 1938, *Stacheoceras darae* Gemmellaro, 1887, *Marathonites dieneri* Smith, 1927 (= *Popanoceras timorense* form β Haniel, 1915), *Stacheoceras perspectivum* Gemmellaro, 1887, and *P. timorense form* γ Haniel, 1915. *P. tridens* form β and *P. t.* form γ Haniel, 1915, and *Waagenia jazwae* Krotow, 1885, may belong in *Waagenina.*

Immature shell. — The conch of *Waagenina* is inflated, ellipsoidal, involute, and has a narrow umbilicus (Ruzhencev, 1940d, p. 118).

In specimens of *Waagenina perspectivum* the constrictions are narrow, affect both the shell exterior and the internal mold, and extend neither across the venter nor to the umbilical shoulders. In other species the constrictions are shallow and broad, extend from shoulder to shoulder, but affect the shell exterior only slightly. The occurrence and spacing of these constrictions are variable.

In some specimens of *Waagenina* the internal mold is marked by gentle transverse undulations which correspond in position to the growth lines. In some individuals (for example, SUI 32597, 32598) there are stronger undulations in the internal mold; they are restricted to the flanks of the conch and correspond in spacing to the interseptal intervals. Growth lines are more closely spaced at constrictions than between.

In some individuals of *Waagenina* (such as, SUI 10588, 32595) there is a definite shell thickening in the umbilicus. This thickening is bordered by a distinct edge which approximately corresponds to the umbilical shoulder.

In a number of examples of *Waagenina* (for example, SUI 10588, 32595) there are numerous minute holes on the flanks of the phragmocone steinkern. Other individuals (such as, SUI 32596) lack these features. In size, shape, and arrangement, these small pits are similar to those near the ultimate constriction of many adrianitids. The pits do not correspond in form to the runzelschicht observed in some specimens (for example, GPIT PV24409).

Mature shell. — The only mature representatives of *Waagenina* known to the author were studied by Gemmellaro and referred by him to *Stacheoceras darae*. In these specimens there was little, if any, change in coiling in the ultimate whorl. However, the venter of the ultimate portion of the conch appears more broadly rounded than in inner whorls.

The mature living chamber of *Waagenina darae* terminates in a constriction. There appear to be two distinct trends of the ultimate constrictions in this genus: in the specimen of Gemmellaro's 1887 plate 4, figures 2 and 3 (IGUP 68) there is a distinct ventral reëntrant, whereas in that of his 1887 plate 4, figure 11 (IGUP 41) the reëntrant is slight. The ultimate peristome is marked by a ventrolateral lappet on each side, flanking a ventral sinus.

The ultimate living chambers of *Waagenina perspectivum* and *W. darae* were stated by Gemmellaro (1887, pp. 36, 39) to be longer than the ultimate whorl and only as long as the terminal volution, respectively.

Maximum diameters of only two individuals (of *Waagenina darae*) are known to the author: 54½ mm (IGUP 64) and 78 mm (IGUP 68).

Material. — The preceding observations are based on study of: Krotow (1885), Gemmellaro (1887), Karpinsky (1889), Diener (1897b), Smith (1927), Schindewolf (1931), Ruzhencev (1933, 1938, 1940d, 1951, 1956a, 1962), Voinova (1934), Greco (1935), Maximova (1935), Toumanskaya (1938, 1939a, 1949), Bogoslovskaya (1962), Bogoslovsky, Librovitch, and Ruzhencev (1962), about 20 immature specimens of *Waagenina* (*subinterrupta* — SUI 10588, 32595-32598, *darae* — GPIT PV24397, PV24409, *perspectivum* — GPIT PV24409), and photographs and notes taken by W. M. Furnish and Brian F. Glenister in the summer of 1965.

Illustrations. — Three mature specimens of *Waagenina darae* are figured: IGUP 64 (Pl. 18, figs. 5, 6), (Pl. 18, figs. 9, 10), and IGUP 68 (Pl. 18, figs. 11-13). In addition, three immature individuals of *Waagenina* are illustrated: *W. subinterrupta* — SUI 32597 (Pl. 18, figs. 3, 4), SUI 32597 (Pl. 19, fig. 9), and *W. perspectivum* — IGUP 66 (Pl. 18, figs. 1, 2).

Genus **STACHEOCERAS** Gemmellaro, 1887

Diagnosis. — *Stacheoceras* comprises vidrioceratins with "mature" sutures in which there are six to twelve subdivisions of the primary lateral lobe on each side.

Synonymy. — *Neostacheoceras* Schindewolf, 1931, is a synonym of *Stacheoceras.*

Specific composition. — The type species of *Stacheoceras* is *S.*

mediterraneum Gemmellaro, 1887, by subsequent designation (Diener, 1921, p. 22), but Smith (1927) and Schindewolf (1931) considered *Arcestes antiquus* Waagen, 1879, to be the type species of *Stacheoceras* by original designation. In addition, the following species are referred to the genus: *Stacheoceras andrussowi* Toumanskaya, 1931, *S. arthaberi* Smith, 1927 (= *Popanoceras tridens* form δ and ε of Haniel, 1915), *S. boesei* Toumanskaya, 1931, *S. borissiaki* Toumanskaya, 1931, *Popanoceras collignoni* Besairie, 1936, *S. mediterraneum* Gemmellaro var. *crimensis* Toumanskaya, 1931, *S. diblasii* Gemmellaro, 1887, *S. gaudryi* Gemmellaro, 1888, *S. gemmellaroi* Miller, 1944, *S. gordoni* Miller, Furnish, and Clark, 1957, *S. gruenewaldti* Gemmellaro, 1887 (= *S. gruenwaldti* of Hayasaka, 1965), *Neostacheoceras hanieli* Schindewolf, 1931 (= *Popanoceras timorense* form ϑ of Haniel, 1915), *Stacheoceras iwaizakiense* Mabuti, 1935, *S. karpinskyi* Gemmellaro, 1887, *S. rothi* Miller and Furnish, 1940a, *S. sexlobatum* Miller and Cline, 1934, *Popanoceras timorense* form δ, ζ, and η of Haniel, 1915, *Stacheoceras toumanskyae* Miller and Furnish, 1940a, *Arcestes tridens* Rothpletz, 1892, *Popanoceras tridens* form ζ Haniel, 1915, *Stacheoceras trimurti* Diener, 1897a, *Popanoceras tschernyschewi* Stoyanow, 1910, and *Stacheoceras vogti* Toumanskaya, 1931. The following may also belong in *Stacheoceras*: *S. discoidale* Toumanskaya, 1935, *S. globosum* Gemmellaro, 1887, *S. globulinum* Gregorio, 1930, *S. pelagicum* Gemmellaro, 1887, *S. quadridens* Hayasaka, 1947, *S. sosiense* Gregorio, 1930, *S. tepense* Toumanskaya, 1931, and *S. tietzei* Gemmellaro, 1887. *Stacheoceros* [sic] *marcoui* Gemmellaro, 1887, and *Stacheoceras trimarti* Diener, 1899, of Furnish (1966) are both apparently *nomina nuda*.

Immature shell.—The immature conch of *Stacheoceras* is subglobular to subdiscoidal, with a small umbilicus (Miller and Furnish, 1940a, p. 129).

Constrictions in the shell of *Stacheoceras* are predominantly internal thickenings in the shell and, therefore, affect the shell exterior slightly, if at all. The number of constrictions per whorl varies from zero to four, with no apparent orderly relation between diameter and the number of constrictions per volution.

Growth lines in *Stacheoceras* parallel the constrictions.

In some individuals there is a shell thickening in the umbilicus. This thickening is bordered by a distinct edge.

Mature shell. — In at least some specimens of *Stacheoceras,* after about three-quarters of the ultimate whorl was formed, there was a decrease in the radius of curvature of coiling followed by a slightly greater increase. In SUI 32610A an earlier change in coiling occurred after slightly less than two-thirds of the ultimate volution had been produced. There is a terminal dorsal flaring of the shell into the umbilicus displayed by SUI 1364W and 32608D.

The ultimate living chamber of *Stacheoceras* terminates in a constriction. In addition to this terminal constriction, the body chambers of IGUP 71 and SUI 16652 each bear a constriction about one-half whorl adapical of the peristome and another about three-quarters adapical of the ultimate constriction.

There are gentle transverse undulations in the steinkern of the final living chamber of *Stacheoceras.*

There is one short, broad, ventrolateral lappet on each side in the ultimate peristome of *Stacheoceras.* Each lappet bears a branch of the terminal constriction.

The length of the ultimate living chamber in *Stacheoceras* is variable. Gemmellaro (1887, p. 29 *et seq.*) reported the body chamber lengths in *S. mediterraneum* and *S. diblasii* as one and one-half and one and one-third whorls, respectively. Wanner (1932, p. 272) noted that the body chamber of *S. tridens* is one and two-fifths volutions long. One specimen of *S. gemmellaroi* (SUI 32612) has an ultimate living chamber of just less than one whorl in length. Two specimens of *S. toumanskyae* (SUI 32607E, 16652F) have body chambers of one and one-eighth and seven-eighths whorls, respectively.

Wanner (1932, p. 272) reported the mature diameter of one specimen of *Stacheoceras tridens* as 125½ mm. One *S. tietzei* (IGUP 71) is mature at a diameter of 47½ mm. One *S. gemmellaroi* (SUI 32612) is mature at 65 mm. One *S. toumanskyae* has a mature diameter of about 85 mm. Three specimens of *S.* sp. (SUI 32610D, 32608D, 32610A) have maximum diameters of about 90 mm, about 90 mm, and 107 mm, respectively.

Material. — The preceding observations are based on study of: Waagen (1879), Krotow (1885), Gemmellaro (1887, 1888), Rothpletz (1892), Haug (1894, 1898), Diener (1897a, 1921), Stoyanow (1910) Haniel (1915), Smith (1927), Gregorio (1930), Schindewolf (1931), Toumanskaya (1931, 1935), Wanner (1932), Miller and Cline (1934), Mabuti (1935), Greco (1935), Besairie (1936), Plummer and Scott (1937), Hayasaka (1940, 1947, 1965), Miller and Furnish (1940a, 1957a, 1957b), Miller and Unklesbay (1943), Miller (1944, 1945a), Miller, Furnish, and Clark (1957), Trümpy (1960), Gordon and Merriam (1961), Bogoslovsky, Librovitch, and Ruzhencev (1962), Shevyrev (1965), Furnish (1966), Davis, Furnish, and Glenister (1969), about 130 immature specimens of *Stacheoceras* (*S.* sp. — Copenhagen unnumbered, SUI 12314, 13597, 32608-32611, 32613, *antiquum* — GPIT unnumbered, *gemmellaroi* — SUI 1365, 13610, 13656, *sexlobatum* — SUI 706, *tridens* — SUI 32615, *toumanskyae* — SUI 1364, 16652, 32607), about ten mature individuals (*S.* sp. — SUI 32608, 32610, *gemmellaroi* — SUI 32612, *toumanskyae* — SUI 1364, 16652, 32607), and photographs and notes taken by W. M. Furnish and Brian F. Glenister in the summer of 1965.

Illustrations. — Four mature specimens of *Stacheoceras* are figured: two *S.* sp. — SUI 32608D (Pl. 19, fig. 5), SUI 32610A (Pl. 19, figs. 6-8), one *S. tietzei* — IGUP 71 (Pl. 4, figs. 4, 5), and one *S. toumanskyae* — SUI 13640 (Pl. 19, figs. 3, 4). In addition, three immature individuals of *Stacheoceras* are illustrated: *S. gaudryi* — IGUP 59 (Pl. 4, fig. 6), *S. mediterraneum* — IGUP 62 (Pl. 19, figs. 1, 2), and *S. pelagicum* — MGPU unnumbered (Pl. 18, figs. 7, 8).

Superfamily **MARATHONITACEAE** Ruzhencev, 1938

Family **MARATHONITIDAE** Ruzhencev, 1938

Diagnosis. — The Marathonitidae comprises ammonoids whose suture underwent goniatitic development, following which the primary lateral, umbilical, and internal lateral lobes each split into three, producing the basic formula:

$$(V_1 V_1)L_2 L_1 L_2 U_2 U_1 : U_2 I_2 I_1 I_2 D.$$

Subsequent complication arose through denticulation of the lobes with a bifurcation of the dorsad L_2 and the ventrad I_2 or a trifurcation of D, or with all three.

Subfamily **MARATHONITINAE** Ruzhencev, 1938

Diagnosis. — The Marathonitinae comprises marathonitids with sutures in which the dorsal lobe is trifid and the three (or four) subdivisions of the initial lateral lobe are primarily trifid; during phylogeny this latter trifidity developed into complex subdivision, particularly in the ventrad two or three subdivisions of the primary lateral lobe.

Genus **HYATTOCERAS** Gemmellaro, 1887

Diagnosis.—*Hyattoceras* comprises marathonitins with "mature" sutures in which each branch of the ventral lobe has denticles on its dorsad side; there are four subdivisions of the primary lateral lobe of which the ventrad three are strongly subdivided.

Synonymy.—*Abichia* Gemmellaro, 1887, (not *Abichia* as used by Andrussow, 1907) is considered to be congeneric with *Hyattoceras.*

Familial assignment.—Furnish and Glenister (*in* Davis, Furnish, and Glenister, 1969) considered *Hyattoceras* to belong in a family Hyattoceratidae.

Specific composition.—The type species of *Hyattoceras* is *H. geinitzi* Gemmellaro, 1887, by subsequent designation (Diener, 1921, p. 25). In addition to the type species, the following are referred to *Hyattoceras: H. (Abichia) abichi* Gemmellaro, 1887, *H. guembeli* Gemmellaro, 1888, *H. subgeinitzi* Haniel, 1915, and *H. turgidum* Gemmellaro, 1887.

Immature shell.—The immature conch of *Hyattoceras* is ellipsoidal to discoidal, involute, and has a narrow umbilicus (Bogoslovsky, Librovitch, and Ruzhencev, 1962).

The only ornament characteristic of immature *Hyattoceras* is the transverse striae.

Mature shell.—As the middle one-third of the ultimate volution of *Hyattoceras geinitzi* was formed there was a progressive narrowing of the venter. The narrowest place is at the end of this middle one-third and corresponds to two changes in coiling, first a slight decrease in the radius of curvature of coiling, followed immediately by a slightly greater increase. These changes in coiling caused the venter of the ultimate one-third whorl to appear flattened in lateral view. The venter of this ultimate one-third whorl also became progressively more flattened in transverse section, for, after the marked narrowing of the venter in the middle one-third of the ultimate whorl, the venter became progressively broader. Also in the last one-third of the terminal volution there developed a dorsad flaring of the peristome, completely closing the umbilicus.

In *Hyattoceras guembeli* and *H. turgidum* the changes in coiling are less striking, and the narrowing of the venter followed by a flattening appears to be less pronounced or even absent.

The mature conch of *Hyattoceras abichi* is markedly geniculate, with a narrowing of the venter followed by a broadening similar to that of *Hyattoceras geinitzi.* Haug (1897) suggested that *Abichia* is the antidimorph of *Hyattoceras,* the former being male and the latter, female.

The ultimate living chamber of *Hyattoceras* terminates in a pronounced constriction. In the ventral region of *H. geinitzi* this constriction is immediately adoral of a tranverse ridge, and the ventral part of the constriction is depressed, producing a slight mid-ventral salient in the peristome.

The mature living chamber of *Hyattoceras geinitzi* was reported by Gemmellaro (1887, p. 16) to be one and one-third whorls long, of *H. abichi* to be one and one-third volutions long (1887, p. 18), and of *H. guembeli* to be almost one and one-half whorls long (1888, p. 7).

The maximum diameter of three mature *Hyattoceras geinitzi* is about 40 mm, of one mature *H. guembeli* is 67 mm, of one mature *H. turgidum* is 23½ mm, and of five mature *H. abichi* is between 18 mm and 23 mm.

Material. — The preceding observations are based on study of: Gemmellaro (1887, 1888), Haug (1897), Haniel (1915), Smith (1927), Plummer and Scott (1937), Miller and Furnish (1940a), Toumanskaya (1949), Bogoslovsky, Librovitch, and Ruzhencev (1962), Davis, Furnish, and Glenister (1969), two immature specimens of *Hyattoceras* sp. (GIUA Dr. 511 no. T581, SUI 32581), three immature (BMNH C33681, C73335, C73336) and three mature (GPIT unnumbered, USNM unnumbered) examples of *H. geinitzi,* three mature individuals of *H. abichi* (USNM unnumbered), about ten immature specimens of *H. subgeinitzi* (GIUA Dr. 551 no. T582, PIUB unnumbered, SUI 12322, 32463) and photographs and notes taken by W. M. Furnish and Brian F. Glenister in the summer of 1965.

Illustrations. — Six mature specimens of *Hyattoceras* are figured: two *H. abichi* — IGUP 55 (Pl. 21, figs. 1-3), USNM unnumbered (Pl. 21, figs. 4, 5), two *H. geinitzi* — IGUP 52 (Pl. 20, figs. 5-8), GPIT unnumbered (Pl. 21, figs. 10), one *H. guembeli* — IGUP *unnumbered* (Pl. 20, figs. 3, 4), and one *H. turgidum* — IGUP 51 (Pl. 20, figs. 1, 2).

Genus **PSEUDOVIDRIOCERAS** Ruzhencev, 1936

Diagnosis. — *Pseudovidrioceras* comprises those marathonitins with "mature" sutures in which the prongs of the ventral lobe are undenticulate, in which each of the subdivisions of the primary lateral lobe terminates in three denticles, and in which there are three complete lobes plus part of a fourth on each side between the bifid ventral lobe and the umbilical shoulder. (Furnish and Glenister [*in* Davis, Furnish, and Glenister, 1969] considered *Pseudovidrioceras* to be a subgenus of *Marathonites*.)

Specific composition. — The type species of *Pseudovidrioceras* is *Vidrioceras girtyi* Miller and Cline, 1934, by original designation. The only other species which has been referred to *Pseudovidrioceras* is *Stacheoceras pygmeum* Gemmellaro, 1887. *Peritrochia novomexicana* Miller and Parizek, 1948, and *P. dunbari* Miller and Furnish, 1940a, may belong in *Pseudovidrioceras.*

Immature shell. — The conch of *Pseudovidrioceras* is subdiscoidal (Miller and Cline, 1934, p. 290) to discoidal (Gemmellaro, 1887, p. 41). The venter is rounded, and the conch is compressed laterally. The umbilical shoulders are rounded, and the umbilicus is closed. In the one known specimen of *P. girtyi* W is greater than H in all whorls save the last; in *P. pygmeum* the height is greater than the width.

In *Pseudovidrioceras pygmeum* the only ornament on the immature shell consists of the fine, radial striae which are sinuous in the ventral region.

Mature shell. — There were apparently no changes in coiling in the growth of the mature living chambers of *Pseudovidrioceras* before the formation of the apertural constriction. In *P. girtyi,* however, there was a change of conch proportions such that H exceeds W in the ultimate whorl. In *P. pygmeum* the dorsal part of the ultimate one-third volution extends over the umbilicus, completely covering it.

The living chamber of the type species of *Pseudovidrioceras* lacks constrictions except for that at the aperture. On the other hand, in *P. pygmeum* (according to Gemmellaro, 1887) the internal mold of the ultimate whorl bears a few broad and superficial "*strangolamenti*" (apparently minor constrictions) which extend from the umbilicus straight across the venter without sinuations.

A transverse bulge is present in at least *Pseudovidrioceras pygmeum* just orad of the ultimate constriction. Miller and Cline (1934, p. 290) concluded that the aperture of *P. girtyi* is large and flaring; the aperture of *P. pygmeum* is neither.

The interseptal spacing of the last several septa of *Pseudovidrioceras girtyi* decreases progressively.

The length of the mature living chamber of *Pseudovidrioceras* is one whorl.

The maximum diameter of many specimens of *P. pygmeum* doesn't exceed 9 mm (Gemmellaro 1887, p. 41), but one specimen is at least 11, and another, 12 mm in diameter (*ibid.*). The solitary known specimen of *P. girtyi* has a mature diameter of 15¼ mm.

Material. — The preceding observations are based on study of: Gemmellaro (1887), Toumanskaya (1931), Miller and Cline (1934), Ruzhencev (1936, 1950), Miller and Furnish (1940a), Miller and Parizek (1948), Bogoslovsky, Librovitch, and Ruzhencev (1962), Davis, Furnish, and Glenister (1969), and photographs and notes taken by W. M. Furnish and Brian F. Glenister in the summer of 1965.

Illustrations. — One mature specimen of *Pseudovidrioceras pygmeum* is figured — IGUP 65 (Pl. 21, figs. 11-13).

Genus **MARATHONITES** Böse, 1919

Diagnosis. — *Marathonites* comprises marathonitins with "mature" sutures in which each branch of the ventral lobe is bifid and each of the three subdivisions of the primary lateral lobe is trifid.

Familial assignment. — Furnish and Glenister (*in* Davis, Furnish, and Glenister, 1969) considered *Marathonites* to belong in the family Vidrioceratidae.

Taxonomic composition.—The type species of *Marathonites* was *Stacheoceras (Marathonites) J. P. Smithi* Böse, 1919, by original designation. Plummer and Scott (1937) and Miller and Furnish (1940a) considered *S. (M.) J. P. Smithi* Böse, 1919, to be a junior synonym of *Popanoceras ganti* Smith, 1903; if the two names denote the same taxon, then the type species of the genus should be called *Marathonites ganti* (Smith, 1903). In addition to the type species, the following taxa are referred to *Marathonites: M. (Almites) busterensis* Toumanskaya, 1949, *M. electraensis* Plummer and Scott, 1937, *M. gracilis* Smith, 1927, *M. arathonites invariabilis* Ruzhencev, 1933, *Stacheoceras kussicum* Toumanskaya, 1931, *S. k.* var. *djidairensis* Toumanskaya, 1931, *M. (Almites) pamiricus* Toumanskaya, 1949, *M. (A.) pressulus* Ruzhencev, 1956a, *Popanoceras romanowskyi* Karpinsky, 1889, *M. sellardsi* Plummer and Scott, 1937, *Stacheoceras suevi* Toumanskaya, 1931, *M. sulcatus* Böse, 1919, *M. (M.) uralensis* Ruzhencev, 1940d, *Stacheoceras uralicum* Fredericks, 1921, and *M. vidriensis* Böse, 1919.

Two subgenera of *Marathonites* have been recognized: *Marathonites (Almites)* Toumanskaya, 1941, and *Marathonites (Marathonites)* Böse, 1919. In addition, Furnish and Glenister (*in* Davis, Furnish, and Glenister, 1969) considered the previously discussed *Pseudovidrioceras* to be a subgenus of *Marathonites*.

Immature shells. — The conch of *Marathonites* is subglobose, strongly involute, and narrowly umbilicate (Ruzhencev, 1940d, p. 125). The ratio W/D decreases during ontogeny.

Most immature specimens of *Marathonites* exhibit at least one constriction in the outermost preserved whorl. The distance between constrictions varies (for example, in SUI 1065, a specimen of *M. ganti,* there are three constrictions in one whorl, but two of the interconstrictional distances are one-quarter whorl). Nonetheless there seems to be a general increase in the number of constrictions per whorl with ontogeny up to a maximum of six. The constrictions affect the internal mold only.

Commonly individuals of *Marathonites* bear transverse undulations in the surface of the internal mold. These undulations apparently correspond in position and trend to the growth lines on the shell exterior. These shell plications are much more prominent immediately adapical of a constriction than adapertural of it; this latter position corresponds to a crowding of growth lines. In the region adapical of a constriction the plications are not absolutely parallel to that constriction, but each successive plication in an adapertural direction has a trend which is more closely similar to that of the constriction.

In at least some individuals of *Marathonites* the shell exhibits longitudinal lirae. These structures are present only on the flanks in specimens of *M. ganti* and are less prominent than the growth lines. In *M. sellardsi* there is one striking rib on each shoulder and one single, less prominent lira just dorsal and another just ventral of each main rib. Development of this rib is even more pronounced in *M. uralensis* in which there are two very prominent ribs, one on each shoulder.

Mature shell. — There are two distinct mature conch morphologies displayed by representatives of *Marathonites.*

In at least *M. ganti, M. invariabilis,* and *M. pressulus* the mature living chamber is distinguished only by a prominent apertural constriction.

In four specimens of *Marathonites* sp. from Timor (SUI 12301, 12304-12306) the mature living chamber also has an apertural constriction, but the conch is geniculate with the venter broad and rounded except at the more adapertural of the two changes in coiling. Here the venter is narrow. (Furnish and Glenister [*in* Davis, Furnish, and Glenister, 1969] referred these four specimens to *Pseudovidrioceras,* which they considered a subgenus of *Marathonites.*)

In both groups of mature forms the length of the living chamber is slightly less than one whorl to approximately one whorl. A group of three mature specimens of *M. ganti* varies from 28 to 33 mm in diameter. One individual of *M. invariabilis* (Ruzhencev, 1956a, pl. 37, fig. 3) has a mature diameter of 50 mm; three others (SUI 10594B, 32616B, 10594A) have diameters of 39 mm, 49 mm, and 51 mm, respectively. One mature example of *M. pressulus* (*ibid.*, pl. 38, fig. 2) is 34 mm in diameter. Three of the four specimens of the other mature form of *Marathonites* are 28 or 29 mm in diameter.

The significance of these two mature forms of *Marathonites* is unclear in the light of the material available. However, if the differences are of subgeneric taxonomic value, they are at variance with the subgenera of *Marathonites* as currently defined [*viz. M. (M.) ganti, M. (Almites) invariabilis* and *M. (A.) pressulus* all have the same type of modification]. Perhaps the two forms are antidimorphs.

Material. — The preceding observations are based on study of: Karpinsky (1889), Smith (1903, 1927), Böse (1919), Fredericks (1921), Schindewolf (1931), Toumanskaya (1931, 1939b, 1941, 1949), Miller and Cline (1934), Plummer and Scott (1937), Ruzhencev (1938, 1940c, 1940d, 1950, 1956a, 1962), Miller and

Furnish (1940a), Miller and Youngquist (1947), Miller and Downs (1950), Bogoslovsky, Librovitch, and Ruzhencev (1962), Davis, Furnish, and Glenister (1969), about 60 immature specimens of *Marathonites* (*M.* sp. — SUI 32589, *ganti* — SUI 1061-1067, 1898, 10525, 11046, 13817-13819, 17033, 17034, 32588, 32590, 32594, *invariabilis* — SUI 10594, 32616, 32617, *J. P. Smithi* — SUI 13821, *sellardsi* — SUI 1396, 1406, 32591, John Britts Owen Collection 695), and about ten mature examples of *Marathonites* (*M.* sp. — SUI 12301, 12304-12306, *ganti* — SUI 1063, 13817, *invariabilis* — SUI 10594, 32616).

Illustrations. — Four mature specimens of *Marathonites* are figured: two *M.* sp. — SUI 12301 (Pl. 14, fig. 7, Pl. 21, figs. 7-9), SUI 12305 (Pl. 21, fig. 6), one *M. ganti* — SUI 1063 (Pl. 22, figs. 5-7), and one *M. invariabilis* — SUI 10594 A (Pl. 22, figs. 8-10). In addition, one immature specimen of *M. ganti* is illustrated — SUI 17033 (Pl. 22, figs. 1, 2).

Subfamily **KARGALITINAE** Ruzhencev, 1960

Diagnosis. — The Kargalitinae comprises marathonitids with sutures in which the dorsal lobe is either bifid or trifid and the ventrad lobe of the three (or four) subdivisions of the primary lateral lobe is primarily bifid.

Genus **PERITROCHIA** Girty, 1908

Diagnosis. — *Peritrochia* includes kargalitins with "mature" sutures in which the branches of the ventral lobe are not subdivided; the dorsad of the three subdivisions of the primary lateral lobe and the ventrad of the three subdivisions of the primary internal lateral lobe each bifurcated during ontogeny; the dorsal lobe is entire.

Familial assignment. — Furnish and Glenister (*in* Davis, Furnish, and Glenister, 1969) considered *Peritrochia* to belong in the family Vidrioceratidae.

Synonymy. — *Paratrochia* Diener (1921, p. 10) is apparently a typographic error.

Specific composition. — The type species and only named species referred to *Peritrochia* is *P. erebus* Girty, 1908, by monotypy.

Immature shell. — The conch of *Peritrochia* is parabolic (Bogoslovsky, Librovitch, and Ruzhencev, 1962, p. 392), subdiscoidal to subglobular with a small umbilicus.

There are up to five constrictions per whorl in *Peritrochia.* These features affect only the internal mold. In addition to constrictions, most individuals display gentle transverse plications as well as growth lines. From the Bone Spring Limestone in Texas one specimen of *Peritrochia* (SUI 32584) was recovered which apparently is a new species; this individual bears transverse plications which are relatively conspicuous. The trends of the growth lines, plications, and contrictions are parallel; early in ontogeny all three are essentially straight, becoming more sinuous with ontogenetic development.

In addition to the transverse ornament, well-preserved shells and internal molds of *Peritrochia* exhibit faint longitudinal undulations.

In the immediate vicinity of the umbilicus is an area in which the shell appears thicker than ventrad of this area. This thickened shell forms a distinct edge on the umbilical shoulder.

Mature shell. — There is little if any change in coiling, in conch proportions, or in both in the ultimate living chamber of *Peritrochia.*

Constrictions are lacking on the ultimate whorl save for the apertural modification. Transverse plications, striations, and longitudinal ornament are present in the ultimate living chamber, as is the spire of thickened shell at the umbilicus.

The ultimate body chamber of *Peritrochia* appears to be just less than one whorl long.

The maximum diameter of *Peritrochia* varies from 18 to 24 mm.

Material. — The preceding observations are based on study of: Gemmellaro (1887), Girty (1908), Toumanskaya (1931), Greco (1935), Plummer and Scott (1937), Miller and Furnish (1940a, 1957b), Ruzhencev (1940c, 1940d), Mullerried, Miller, and Furnish (1941), Miller (1945a), Miller and Youngquist (1947), Miller and Parizek (1948), Miller and Downs (1950), Unklesbay (1962), Bogoslovsky, Librovitch, and Ruzhencev (1962), Davis, Furnish, and Glenister (1969), about 20 immature (SUI 32583) and eight mature (SUI 32583, 32585, 32586) representatives of *Peritrochia erebus,* and one immature specimen of a new species of *Peritrochia* (*fide* W. M. Furnish, 1967, personal communication).

Illustrations. — Two mature specimens of *Peritrochia erebus* are figured: SUI 32585 (Pl. 14, figs. 4-6) and SUI 32586 (Pl. 14, figs. 1, 2). In addition, two immature specimens of *Peritrochia* are illustrated: *P.* n. sp. — SUI 32584 (Pl. 14, fig. 3) and *P. erebus* — SUI 32583 E (Pl. 22, figs. 3, 4).

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PLATES

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Enlargements stated to nearest 0.1×.

EXPLANATION OF PLATE 3

Figure Page

1-7. **Adrianites** Gemmellaro, 1887 .... **43**

1-3. *A. elegans,* syntype (IGUP 85, Gemmellaro, 1887, pl. 6, figs. 14, 15), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—20½ mm, ×2.0; the specimen is mature; 5-7. *A. elegans,* syntype (IGUP 85, Gemmellaro, 1887, pl. 7, fig. 23), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—21 mm, × 2.0; the specimen is mature; 4. *A. isomorphus* Gemmellaro, (SUI 32442), Sosio Limestone, near Palazzo Adriano, Sicily, maximum width—17 mm, × 2.0; the ultimate peristome of the dorsal shell is shown.

8,9. **Neocrimites** Ruzhencev, 1940a **51**

8,9. *N. cancellatus* (Haniel) (*fide* Furnish and Glenister *in* Davis, Furnish, and Glenister, 1969), hypotype (GIUA Drawer 55, No. T328, *ibid.,* pl. 3, figs. 4, 5), Maoen Mollo, Timor, × 2.0; the specimen is mature.


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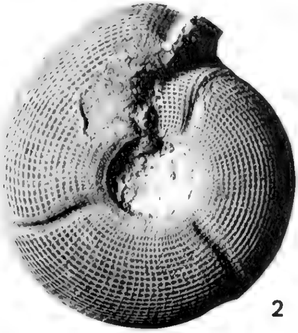
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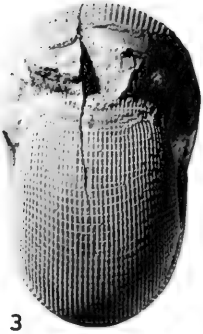
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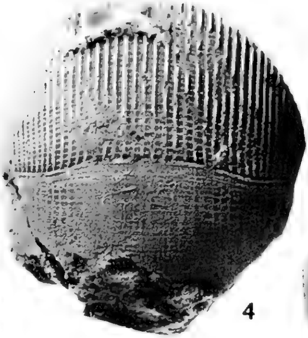
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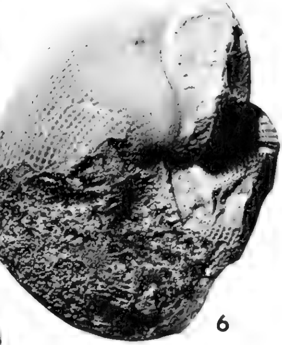
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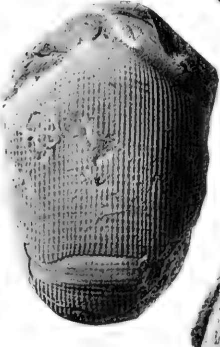
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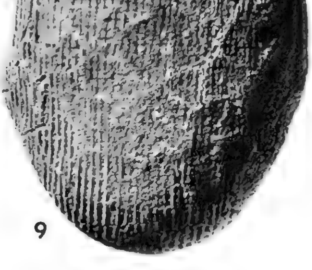
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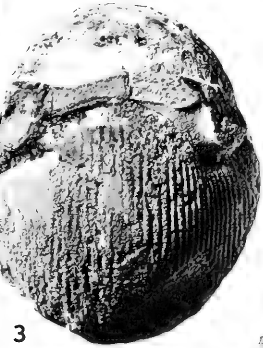
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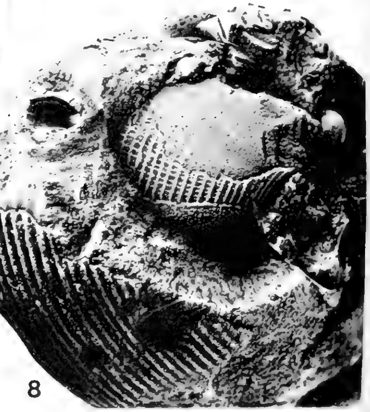
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EXPLANATION OF PLATE 4

Figure Page

1-3,7,8,9. **Adrianites** Gemmellaro, 1887 43

1-3. *A. isomorphus,* syntype (IGUP 86, Gemmellaro, 1888, pl. B, figs. 5,6), Sosio Limestone, Rupe di San Benedetto, Province of Palermo, Sicily, maximum diameter —25 mm, × 2.0; the specimen is mature. (Designated lectotype by Furnish and Glenister in the explanation of plate 3 of Davis, Furnish, and Glenister, 1969). 7,8. *A. isomorphus* (USNM Unnumbered specimen a), Sosio Limestone, Rocca di Salomone, Province of Palermo, Sicily, × 2.5; figure 7 shows a thickening of the dorsal shell at a constriction, and figure 8 shows the ultimate peristome of the dorsal shell. 9. *A. isomorphus* (USNM unnumbered specimen b), Sosio Limestone, Rupe di San Cologero, Province of Palermo, Sicily, × 3.7; the figure shows the pits in the internal mold at the ultimate constriction and the spherical bodies in the shell which correspond to these pits.

4-6. **Stacheoceras** Gemmellaro, 1887 78

4,5. *S. tietzei,* syntype (IGUP 71, Gemmellaro, 1887, pl. 5, figs. 1-3), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—47½ mm, × 1.0; the specimen is mature. 6. *S. gaudryi,* syntype (IGUP 59, Gemmellaro, 1888, pl. D, fig. 1), Sosio Limestone, Pietra di Salamone, Province of Palermo, Sicily, maximum diameter—34 mm, × 1.2; the specimen is immature.

EXPLANATION OF PLATE 5

Figure Page

1-8. **Adrianites** Gemmellaro, 1887 43

1-3. *Adrianites* cf. *A. insignis* Gemmellaro, (BMNH C37654), Sosio Limestone, Province of Palermo, Sicily, maximum diameter—21½ mm, × 2.0; the specimen is mature. (This specimen is figured as pl. 3, figs. 6-8, of Davis, Furnish, and Glenister, 1969, but was referred to *Neocrimites* by Furnish and Glenister.) 4,5. *A. insignis,* hypotype (MGPU unnumbered, Greco, 1935, pl. 3, figs. 12a,b), Sosio Limestone, Pietra di Salomone, Province of Palermo, Sicily, maximum diameter—29 mm, × 2.0; the specimen is mature. 6-8. *A. kingi,* syntype (IGUP 81, Gemmellaro, 1887, pl. 9, figs. 31,32), Sosio Limestone, Rocca di San Benedetto, Province of Palermo, Sicily, maximum diameter—22 mm, × 2.0; the specimen is mature.


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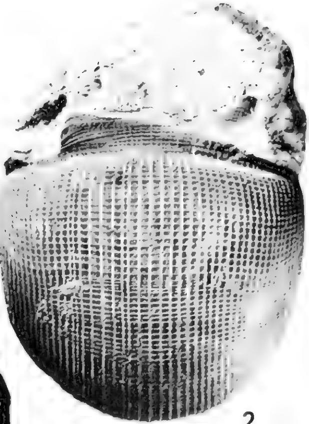
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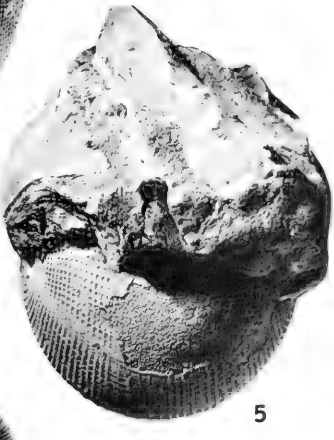
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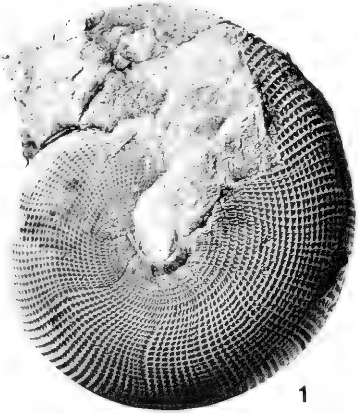

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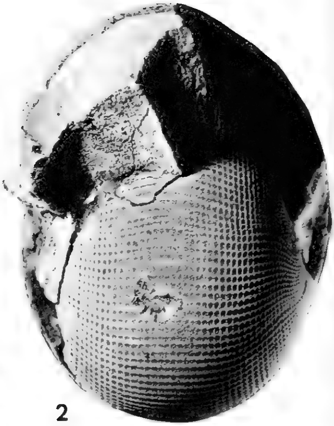

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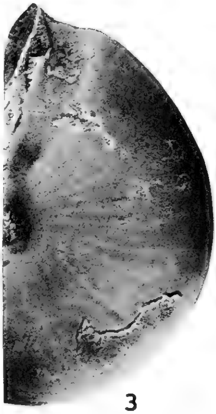

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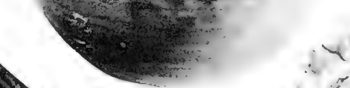

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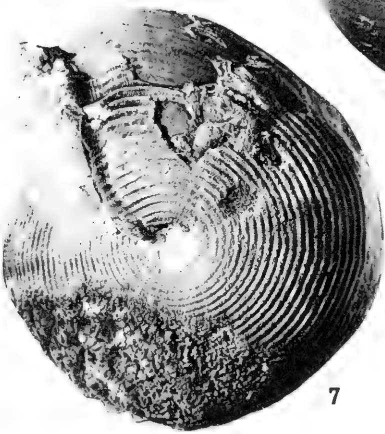

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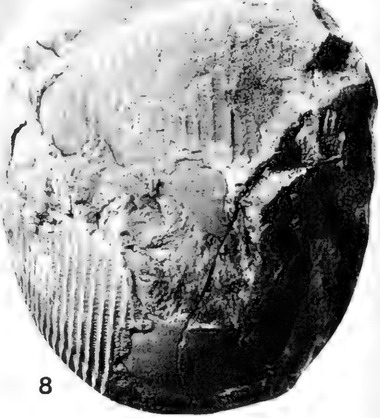

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EXPLANATION OF PLATE 6

Figure — Page

1,2. **Neocrimites** Ruzhencev, 1940a ... 51

1,2. *N. ensifer,* syntype (IGUP 82, Gemmellaro, 1887, pl. 6, figs. 11,12), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—24½ mm, × 2.0; the specimen is immature.

3-6. **Crimites** Toumanskaya, 1937b ... 47

3-5. *C. krotowi* (Karpinsky), (SUI 5981b), Artinsk Stage, Aktasty River, Aktyubinsk District, USSR, maximum diameter—23 mm, × 2.0; the specimen is mature. 6. *C. krotowi* (Karpinsky), (SUI 5981a), Artinsk Stage, Aktasty River, Aktyubinsk District, USSR, maximum diameter—24½ mm, × 2.0; the specimen is mature.

7,8. **Adrianites** Gemmellaro, 1887 ... 43

7,8. *A. insignis,* syntype (IGUP 84, Gemmellaro, 1887, pl. 6, figs. 8,9), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—27 mm, × 2.0; the specimen is mature.

EXPLANATION OF PLATE 7

Figure Page

1-5. **Neocrimites** Ruzhencev, 1940a 51

1-3. *N. ensifer,* syntype (IGUP 82, Gemmellaro, 1887, pl. 7, fig. 25), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—32 mm, × 2.0; the specimen is mature. 4,5. *N. ensifer* (IGUP 82), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—31 mm, × 2.0; the specimen is mature.

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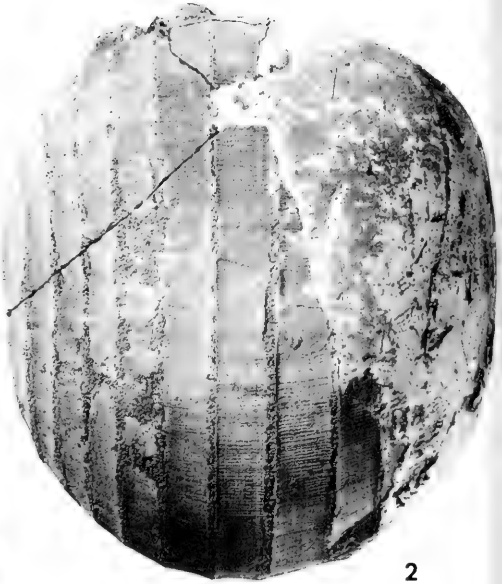

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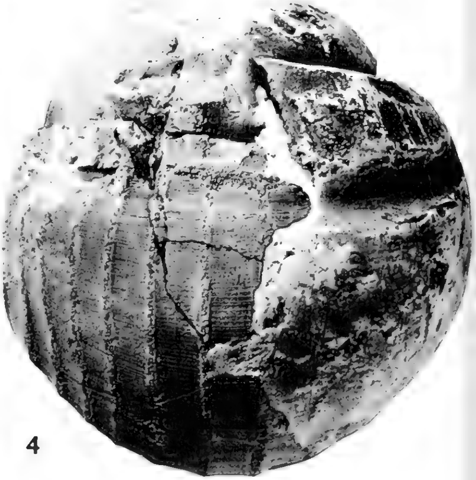

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EXPLANATION OF PLATE 8

Figure		Page
1-4.	**Epadrianites** Schindewolf, 1931	48
	1-4. *E. haueri,* syntype (IGUP 75, Gemmellaro, 1888, pl. C, figs. 13,15), Sosio Limestone, Rupe de San Benedetto, Province of Palermo, Sicily, maximum diameter—66 mm, × 1.0; the specimen is mature.	

EXPLANATION OF PLATE 9

Figure Page

1,2. **Pseudagathiceras** Schindewolf, 1931 56

1,2. *P. spinosum,* holotype (YPM 16310, Miller, 1944, pl. 29, figs. 1,2), zone of *Waagenoceras* (beds 5, 6, and 7 of the Malascachas Section), 1200 m S17°W of Noria de Malascachas, Valle de Las Delicias, Coahuila, Mexico, maximum diameter—21 mm, × 2.0; the specimen is mature.

3-7. **Palermites** Toumanskaya, 1937a 54

3-5. *P. distefanoi* (Gemmellaro), hypotype (SUI 32456, Miller, Furnish, and Schindewolf, 1957, fig. 2, ill. 5a, 5b), Sosio Limestone, Palazzo Adriano, Province of Palermo, Sicily, maximum diameter—45 mm, × 1.2; the specimen is mature. 6,7. *P. distefanoi,* syntype (IGUP 76, Gemmellaro, 1887, pl. 9, figs. 36,37), Sosio Limestone, Rupe di San Benedetto, Province of Palermo, Sicily, maximum diameter—30½ mm, × 1.2; the specimen is mature.

8,9. **Epadrianites** Schindewolf, 1931 48

8,9. *E. timorense* (Boehm), hypotype (PIUB 21b, Haniel, 1915, pl. 5, figs. 7a,b), Koeafeoe, Timor, maximum diameter (*fide* Haniel)—30 mm, × 1.2; the specimen is immature.

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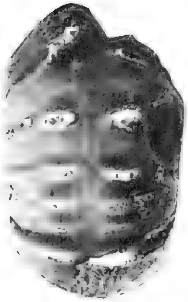

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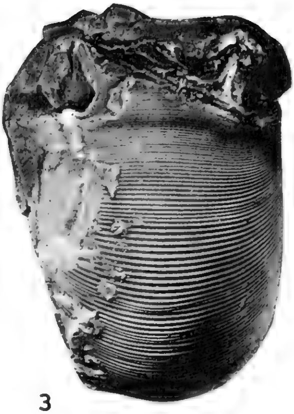

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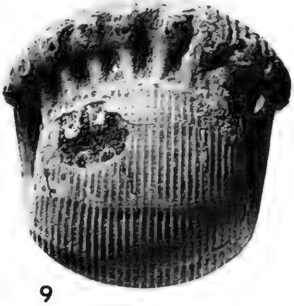

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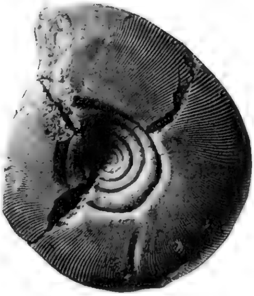

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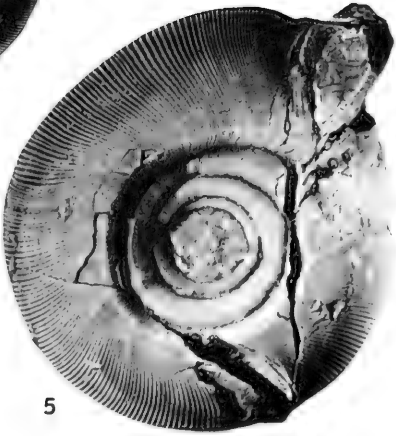

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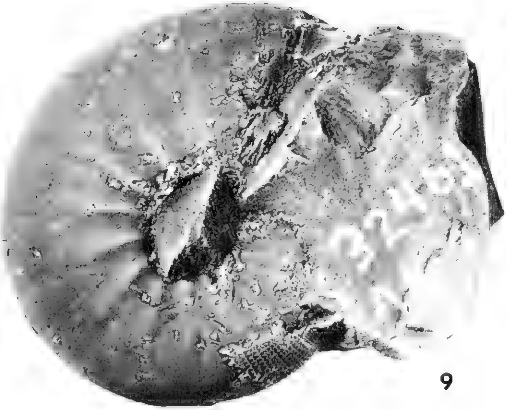
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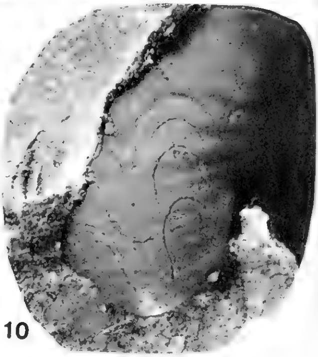
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EXPLANATION OF PLATE 10

Figure Page

1-3. **Hoffmannia** Gemmellaro, 1887 50

1-3. *H. hoffmanni,* syntype (IGUP 78, Gemmellaro, 1887, pl. 7, fig. 3), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—27 mm, × 2.0; the specimen apparently is mature.

4,5. **Neocrimites** Ruzhencev, 1940a 51

4,5. *N. cancellatus* (Haniel) (*fide* Furnish and Glenister *in* Davis, Furnish, and Glenister, 1969), hypotype (PIUB unnumbered, Wanner, 1932, pl. 9, figs. 3a,b; Davis, Furnish, and Glenister, 1969, pl. 3, fig. 3), Basleo, Timor, maximum dimension—22 mm, × 2.0; the specimen is mature.

6-8. **Pseudagathiceras** Schindewolf, 1931 56

6-8. *P. wichmanni,* holotype (THD 12752, Haniel, 1915, pl. 5, figs. 15a-c), Basleo, Timor, maximum diameter—16½ mm, × 2.0; the specimen is immature.

9,10. **Texoceras** Miller and Furnish, 1940a 59

9. *T. texanum* (Girty), (SUI 32461 AA), Bone Spring Limestone, road cut on the west side of US 62-180, 1.8 mi. NNE of the junction of US 54 & US 62-180, Culberson County, Texas, maximum diameter—26½ mm, × 2.0; the specimen is mature. 10. *T. texanum* (Girty), (SUI 32461 AJ), Bone Spring Limestone, road cut on the west side of US 62-180, 1.8 mi. NNE of the junction of US 54 & US 62-180, Culberson County, Texas, × 5.1; figure shows approximation and simplification of the ultimate few sutures.

EXPLANATION OF PLATE 11

Figure		Page
1-5,8-10.	**Sizilites** Toumanskaya, 1937a 1,2. *S. craticulatus,* syntype (IGUP 87, Gemmellaro, 1888, pl. C, fig. 16), Sosio Limestone, Rupe di San Benedetto, Province of Palermo, Sicily, maximum diameter—15½ m, × 2.0; the specimen is mature. 3-5. *S. affinis* (Gemmellaro), syntype (IGUP 88, Gemmellaro, 1888, pl. D, figs. 6,7), Sosio Limestone, Rupe di San Benedetto, Province of Palermo, Sicily, maximum diameter—14 mm, × 2.0; the specimen is immature. 8-10. *S. craticulatus,* hypotype (MGPU unnumbered, Greco, 1935, pl. 3, figs. 13a-f), Sosio Limestone, Pietra di Salomone, Province of Palermo, Sicily, maximum diameter—10½ mm, × 2.0; the specimen is immature.	57
6,7,11-15.	**Texoceras** Miller and Furnish, 1940a 6. *T. texanum* (Girty), (SUI 32461 Z), Bone Spring Limestone, road cut on the west side of US 62-180, 1.8 mi. NNE of the junction of US 54 & US 62-180, Culberson County, Texas, maximum diameter—24 mm, × 2.0; the specimen is mature. 7. *T. texanum* (Girty), SUI 32461 M), Bone Spring Limestone, road cut on the west side of US 62-180, 1.8 mi. NNE of the junction of US 54 & US 62-180, Culberson County, Texas, maximum diameter—21½ mm, × 2.0; the specimen apparently is mature. 11. *T. texanum* (Girty), (SUI 32461 AG), Bone Spring Limestone, road cut on the west side of US 62-180, 1.8 mi. NNE of the junction of US 54 & US 62-180, Culberson County, Texas, × 2.0; the specimen apparently is mature. 12. *T. texanum* (Girty), (SUI 32461 I), Bone Spring Limestone, road cut on the west side of US 62-180, 1.8 mi. NNE of the junction of US 54 & US 62-180, Culberson County, Texas, × 2.0; the specimen is mature. 13,14. T. *texanum* (Girty), (SUI 32461 P), Bone Spring Limestone, road cut on the west side of US 62-180, 1.8 mi. NNE of the junction of US 54 & US 62-180, Culberson County, Texas, maximum diameter—22½ mm, × 2.0; the specimen is mature. 15. *T. texanum* (Girty), hypotype (SUI 13609, Miller and Furnish, 1940a, pl. 26, figs. 1,2), Bone Spring Limestone, near Bone Springs, Guadalupe Mountains, Texas, maximum diameter—25½ mm, × 2.0; the specimen is mature.	59

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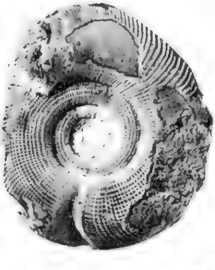

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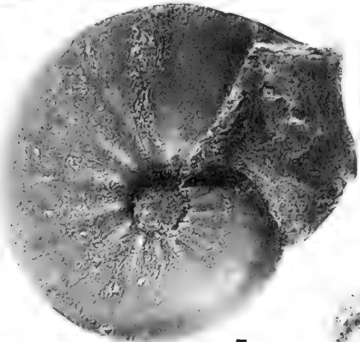

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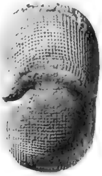

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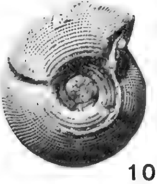

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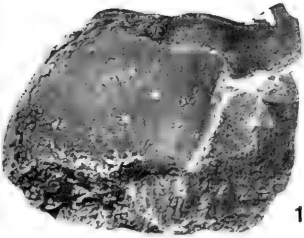

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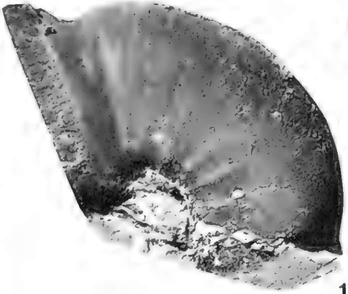

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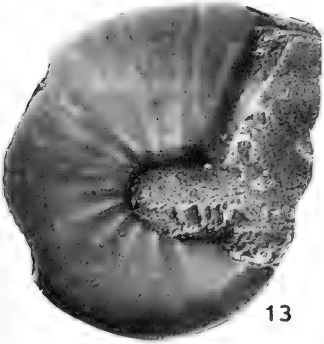

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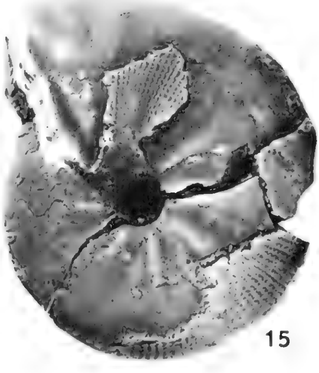

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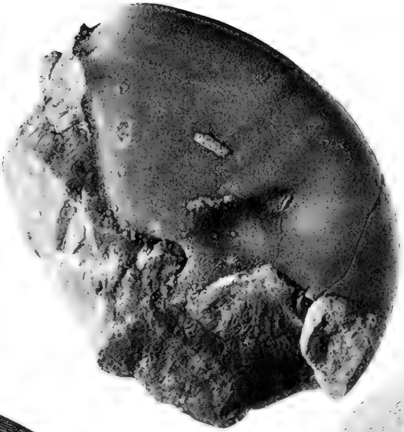

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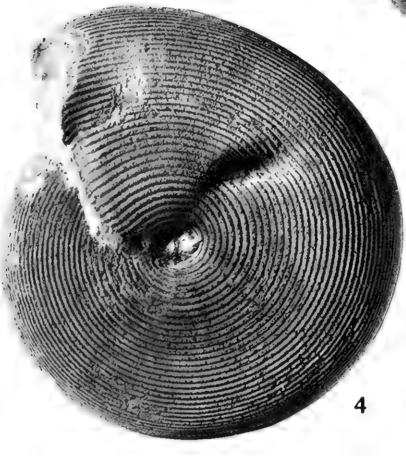

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EXPLANATION OF PLATE 12

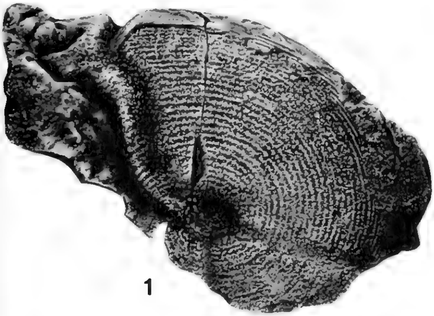
Figure		Page
1-8.	**Agathiceras** Gemmellaro, 1887	61

1-4. *A. suessi,* syntype (IGUP 119, Gemmellaro, 1887, pl. 6, figs. 1,2), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—35 mm, × 1.6; the specimen is mature (designated lectotype by Furnish and Glenister in the explanation of plate 2 of Davis, Furnish, and Glenister, 1969). 5,6. *A. suessi,* hypotype (MGPU unnumbered, Greco, 1935, pl. 3, figs. 14a,b; Davis, Furnish, and Glenister, 1969, pl. 2, fig. 8), Sosio Limestone, Rocca di San Benedetto, Province of Palermo, Sicily, maximum diameter—37 mm, × 1.6; the specimen is mature. 7,8. *A. suessi,* syntype (IGUP 119, Gemmellaro, 1887, pl. 6, fig. 4), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, × 1.6; the specimen is mature.

EXPLANATION OF PLATE 13

Figure		Page
1-9.	**Agathiceras** Gemmellaro, 1887	61

1,2. *A. uralicum* (*fide* Furnish and Glenister *in* Davis, Furnish, and Glenister, 1969), (SUI 32460 BA), Road Canyon Formation, saddle and slope W of Dugout Mountain, 0.3 mi. NNW of hill 4861 (USNM loc. 732z), Glass Mountains Uplift, Brewster County, Texas, × 1.6; the specimen is mature. 3,4. *A. uralicum* (Karpinsky) (*fide* Furnish and Glenister *in* Davis, Furnish, and Glenister, 1969), hypotype (SUI 32460 BN, *ibid.,* pl. 2, figs. 3,4), Road Canyon Formation, saddle and slope W of Dugout Mountain, 0.3 mi. NNW of hill 4861 (USNM loc. 732z), Glass Mountains Uplift, Brewster County, Texas, maximum diameter—19 mm, × 1.6; the specimen is mature. 5-7. *A. uralicum* (Karpinsky) (*fide* Furnish and Glenister *in* Davis, Furnish, and Glenister, 1969), hypotype (SUI 32460 BE, *ibid.,* pl. 2, figs. 1,2), Road Canyon Formation, saddle and slope W of Dugout Mountain, 0.3 mi. NNW of hill 4861 (USNM loc. 732z), Glass Mountains Uplift, Brewester County, Texas, maximum diameter—32 mm, × 1.6; the specimen is mature. 8,9. *A.* sp., (SUI 32458), *Waagenoceras*—zone shale, about 1 km S of Noria de las Malascachas near a goat trail on west side of draw, Valle de Las Delicias, Coahuila, Mexico, maximum diameter—30 mm, × 1.6; the specimen is mature.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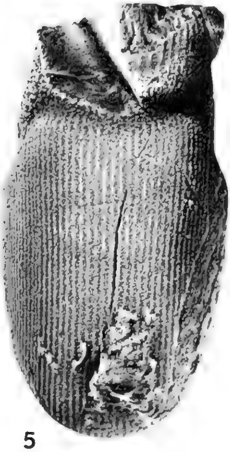
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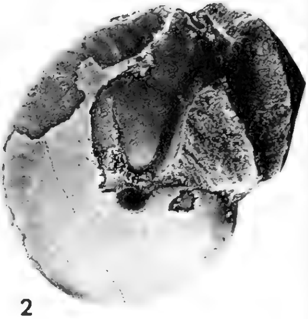
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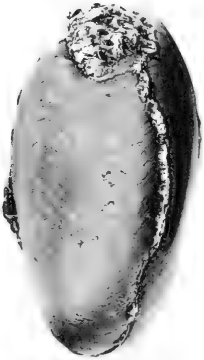
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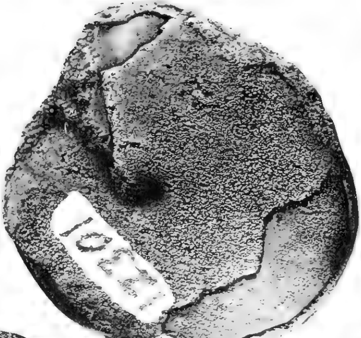
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EXPLANATION OF PLATE 14

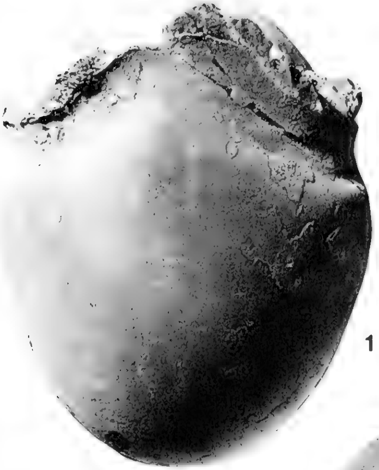
Figure		Page
1-6.	**Peritrochia** Girty, 1908	88
	1,2. *P. erebus* Girty, (SUI 32586), upper black limestone member of Bone Spring Limestone, about 3½ mi. SSE of El Capitan on west side of US 62 just N of the bend in road where it starts into Guadalupe Pass, Culberson County, Texas, maximum diameter—18½ mm, × 2.0; the specimen is mature. 3. *Peritrochia* n. sp., (SUI 32584), upper black limestone member of Bone Spring Limestone, about 3½ mi. SSE of El Capitan on west side of US 62 just N of the bend in road where it starts into Guadalupe Pass, Culberson County, Texas, × 2.3; the specimen is immature. 4-6. *P. erebus*, (SUI 32585), Cut-off Shale Member of the Bone Spring Formation, pipe line road S of El Capitan, Culberson County, Texas, maximum diameter—21½ mm, × 2.0; the specimen is mature.	
7.	**Marathonites** Böse, 1919	85
	7. *M.* sp., (SUI 12301), Bitauni horizon, Bitauni, Timor, maximum diameter—29 mm, × 1.6, (see other views on plate 21); the specimen is mature.	
8,9.	**Agathiceras** Gemmellaro, 1887	61
	8. *A. martini*, syntype (THD 12735, Haniel, 1915, pl. 4, figs. 18a-c), Bitauni, Timor, maximum diameter—35½ mm, × 1.6; the specimen is immature. 9. *A.* sp., (SUI 12297), Bitauni horizon, Bitauni, Timor, maximum diameter—37½ mm, × 1.6; the specimen is mature.	

EXPLANATION OF PLATE 15

Figure Page

1-7. **Mexicoceras** Ruzhencev, 1955 66

1-4. *M. guadalupense guadalupense* (Girty), hypotype (USNM 144423, Miller and Furnish, 1940a, pl. 41, figs. 3,4, pl. 42, fig. 6; Davis, Furnish, and Glenister, 1969, pl. 5, figs. 4,5), South Wells Limestone, about 2 mi. SE of D Ranch, South Wells, Culberson County, Texas (USGS loc. 7649), maximum diameter —48 mm, × 1.4; the specimen is mature. 5,6. *M. guadalupense thompsoni* (Miller and Furnish), syntype (USNM 144419, Miller and Furnish, 1940a, pl. 25, figs. 4-6), South Wells Limestone, about 2 mi. SE of D Ranch, South Wells, Culberson County, Texas (USGS loc. 7649), maximum diameter—18 mm, × 1.4; the specimen is immature. 7. *M. guadalupense guadalupense* (Girty), hypotype (USNM 144422, Miller and Furnish, 1940a, pl. 41, figs. 1,2), South Wells Limestone, about 2 mi. SE of D Ranch, South Wells, Culberson County, Texas (USGS loc. 7649), maximum diameter—30 mm, × 1.4 (see other views on Plate 17); the specimen is immature.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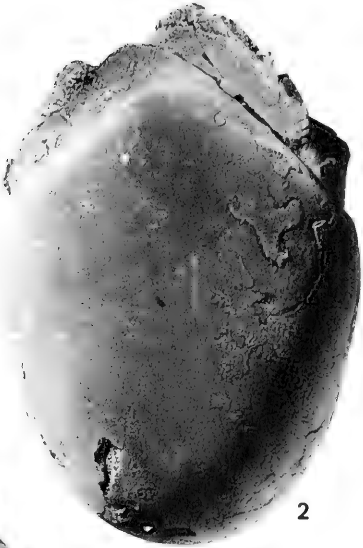
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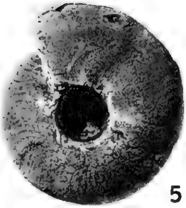
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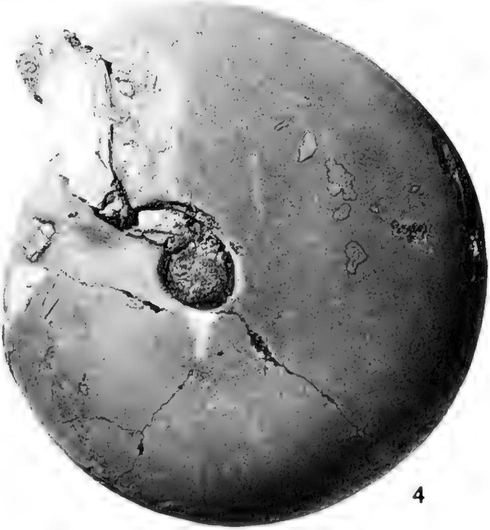
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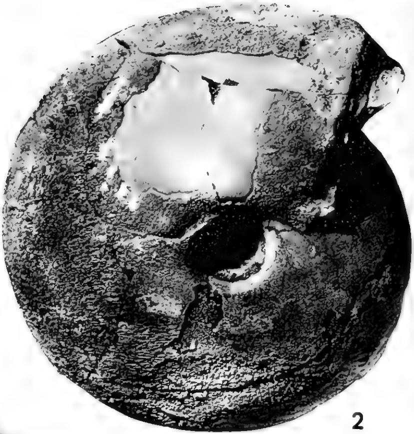
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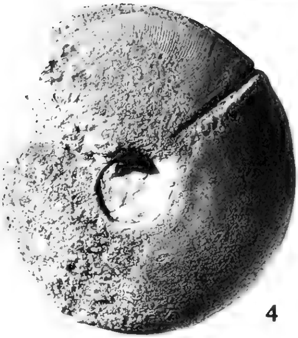
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EXPLANATION OF PLATE 16

Figure		Page
1-7.	**Waagenoceras** Gemmellaro, 1887	69

1. *W. mojsisovicsi,* syntype (IGUP 32, Gemmellaro, 1887, pl. 1, figs. 1-3), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—160 mm, × 0.4; the specimen is mature (designated lectoparatype by Furnish and Glenister in the explanation of plate 5 of Davis, Furnish, and Glenister, 1969). 2,3. *W. mojsisovicsi,* syntype (IGUP 34, Gemmellaro, 1887, pl. 2, figs. 1,2), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—95 mm, × 0.6; the specimen is mature (designated lectotype by Furnish and Glenister in the explanation of plate 5 of Davis, Furnish, and Glenister, 1969). 4,5. *W. stachei,* syntype (IGUP 37, Gemmellaro, 1887, pl. 1, figs. 4-6), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—35 mm, × 1.2; the specimen is immature. 6,7. *W. richardsoni* (Plummer and Scott), hypotype (SUI 32318, Davis, Furnish, and Glenister, 1969, pl. 5, fig. 7), very top of a big channel sand just below grey limestone beds, Manzanita Member, Cherry Canyon Formation, halfway up slope some 1500 ft. ESE of Last Chance Wells, Sibley Ranch, Culberson County, Texas, maximum diameter—170 mm, × 0.4; the specimen is mature.

EXPLANATION OF PLATE 17

Figure Page

1,2. **Mexicoceras** Ruzhencev, 1955 .... **66**

1,2. *M. guadalupense guadalupense* (Girty), same specimen as Plate 15, figure 7, × 1.4; the specimen is immature.

3-8. **Cyclolobus** Waagen, 1879 .... **73**

3-5. *C. walkeri* Diener, hypotype (MNHN B 7517, Vaillant-Couturier-Treat, 1933, pl. 2, fig. 6), Ankitohazo, Madagascar, maximum diameter—23 mm, × 1.6; the specimen is immature. 6. *"C. astrei"*, holotype (UPSM unnumbered, Besairie, 1930, pl. 5, fig. 4), Ankitohazo, Madagascar, maximum diameter—45 mm, × 1.2; the specimen is immature. 7. *C. walkeri* Diener, hypotype (MNHN B 7520, Vaillant-Couturier-Treat, 1933, pl. 1, fig. 4; Davis, Furnish, and Glenister, 1969, pl. 5, fig. 1; Furnish and Glenister, 1970, pl. 2, fig. A), Ankitohazo, Madagascar, maximum diameter—93 mm, × 0.6; the specimen is mature. 8. *C. walkeri* Diener, (BMNH C36642), Ankitohazo, Ambilobe, Madagascar, maximum diameter—104 mm, × 0.6; the specimen is mature.


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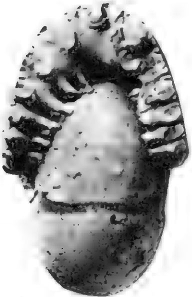
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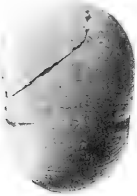
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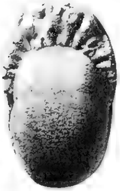
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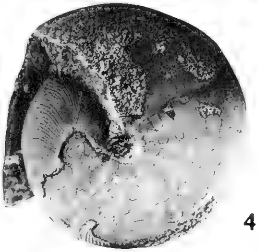
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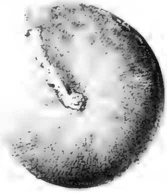
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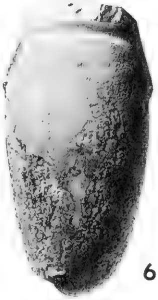
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EXPLANATION OF PLATE 18

Figure		Page
1-6,9-13.	**Waagenina** Krotow, 1888 1,2. *W. perspectivum,* syntype (IGUP 66, Gemmellaro, 1887, pl. 8, figs. 12-14), Sosio Limestone, Rocca di San Benedetto, Province of Palermo, Sicily, maximum diameter—12 mm, × 2.0; the specimen is immature. 3,4. *W. subinterrupta,* (SUI 32597), upper Artinsk Stage, western slope of the southern Urals, Kyaly-Coorty River, Soonyduk-Say, USSR, maximum diameter—15½ mm, × 2.0; the specimen is immature. 5,6. *W. darae,* syntype (IGUP 64, Gemmellaro, 1887, pl. 4, fig. 11), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, × 0.8; the specimen is mature. 9,10. *W. darae,* syntype (IGUP 64, Gemmellaro, 1887, pl. 4, figs. 7,8), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—54½ mm, × 0.8; the specimen is mature. 11-13. *W. darae,* syntype (IGUP 68, Gemmellaro, 1887, pl. 4, figs. 2,3), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—78 mm, × 0.8; the specimen is mature.	76
7,8.	**Stacheoceras** Gemmellaro, 1887 7,8. *S. pelagicum* Gemmellaro, hypotype (MGPU unnum-Pietra di Salomone, Province of Palermo, Sicily, maximum diameter—9¾ mm, × 2.3; the specimen is immature.	78

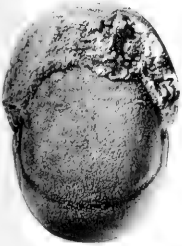
EXPLANATION OF PLATE 19

Figure		Page
1-8.	**Stacheoceras** Gemmellaro, 1887	78

1,2. *S. mediterraneum,* syntype (IGUP 62, Gemmellaro, 1887, pl. 7, figs. 11-13), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—12¾ mm, × 2.3; the specimen is immature. 3,4. *S. toumanskyae* Miller and Furnish, (SUI 1364 O), concretionary shale (beds 5 and 7 of Difunta section), along strike between Cerro Wencelao on the south to 300 m W of El Indio on the north, Valle de Las Delicias, Coahuila, Mexico (King's loc. 20), × 0.6; the specimen is mature. 5. *S.* sp. (SUI 32608 D), *Timorites*-zone shale, King's locality 20, Las Delicias, Coahuila, Mexico, maximum diameter—85 mm, × 0.6; the specimen is mature. 6-8. *S.* sp., (SUI 32610 A), *Timorites*-zone shale, 1 km NE of Cerro El Indio, Las Delicias, Coahuila, Mexico (near King's loc. 10), maximum diameter—107 mm, × 0.6; the specimen is mature.

9.	**Waagenina** Krotow, 1888	76

9. *W. subinterrupta* (Karpinsky) (Krotow), (SUI 32597), upper Artinsk Stage, western slope of southern Urals, Kyaly-Coorty River, Soonyduk-Say, USSR, maximum diameter—17½ mm, × 2.0; the specimen is immature.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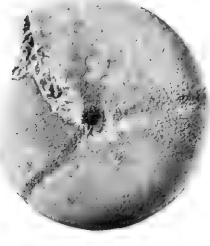
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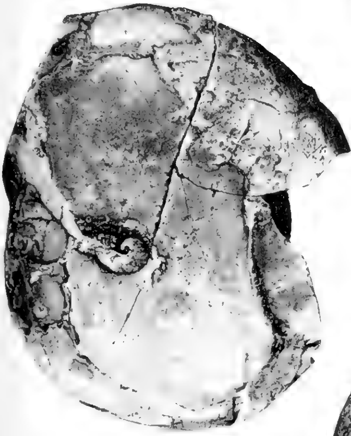
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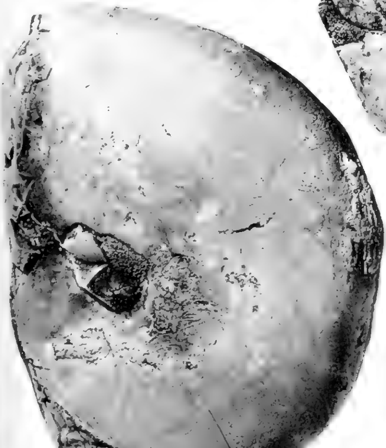
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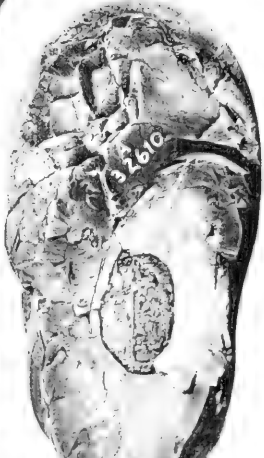

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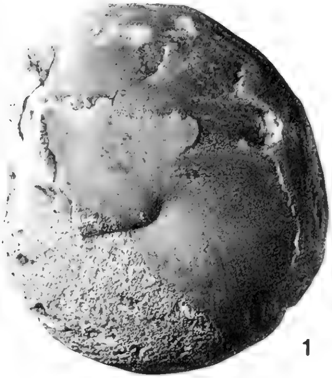
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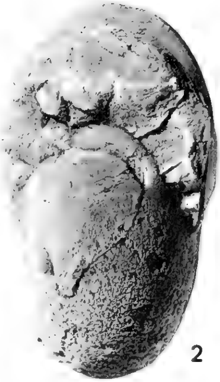
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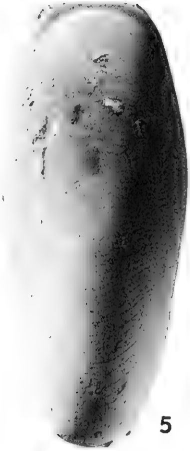
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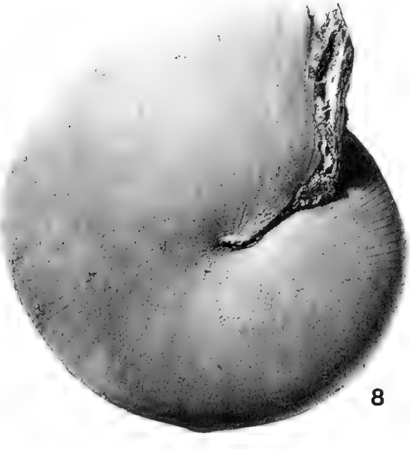
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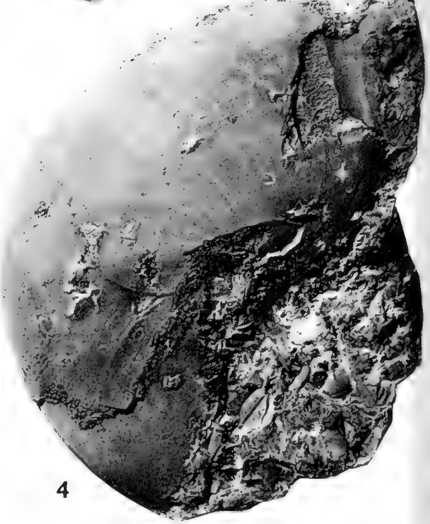
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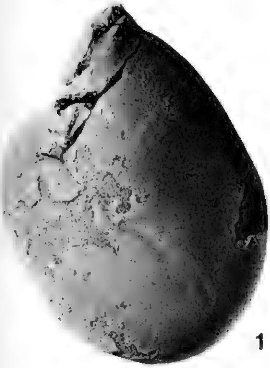
EXPLANATION OF PLATE 20

Figure		Page
1-8.	**Hyattoceras** Gemmellaro, 1887	82

1,2. *H. turgidum,* holotype (IGUP 51, Gemmellaro, 1887, pl. 2, figs. 8,9), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—23½ mm, × 2.0; the specimen is mature. 3,4. *H. guembeli* Gemmellaro, hypotype (IGUP unnumbered, Davis, Furnish, and Glenister, pl. 4, fig. 7), Sosio Limestone, Pietra di Salomone, Province of Palermo, Sicily, maximum diameter—67 mm, × 1.0; the specimen is mature. 5-8. *H. geinitzi,* syntype (IGUP 52, Gemmellaro, 1887, pl. 8, figs. 1-3), Sosio Limestone, Rocca di San Benedetto, Province of Palermo, Sicily, maximum diameter—40 m, × 1.4; the specimen is mature (designated lectotype by Furnish and Glenister in the explanation of plate 4 of Davis, Furnish, and Glenister, 1969).

EXPLANATION OF PLATE 21

Figure		Page
1-5,10.	**Hyattoceras** Gemmellaro, 1887	82
	1-3. *H. abichi,* syntype (IGUP 55, Gemmellaro, 1887, pl. 2, figs. 10-13), Sosio Limestone, Passo di Burgio, Province of Palermo, Sicily, maximum diameter—22 mm, × 2.0; the specimen is mature (designated lectotype by Furnish and Glenister in the explanation of plate 4 of Davis, Furnish, and Glenister, 1969). 4,5. *H. abichi* Gemmellaro, (USNM unnumbered), Sosio Limestone, Rocca di Salomone, Province of Palermo, Sicily, × 2.0; the specimen is mature. 10. *H. geinitzi* Gemmellaro, hypotype (GPIT unnumbered, Davis, Furnish, and Glenister, 1969, pl. 4, fig. 3), unlabelled, but almost certainly from Sosio, × 1.4; the specimen is mature.	
6,7-9.	**Marathonites** Böse, 1919	85
	6. *M.* sp., (SUI 12305), Bitauni horizon, Bitauni, Timor, × 1.6; the specimen is mature. 7-9. *M.* sp., same specimen as Plate 14, figure 7, × 1.6; the specimen is mature.	
11-13.	**Pseudovidrioceras** Ruzhencev, 1936	84
	11-13. *P. pygmeum,* syntype (IGUP 65, Gemmellaro, 1887, pl. 8, figs. 15-17), Sosio Limestone, Rocca di San Benedetto, Province of Palermo, Sicily, maximum diameter—11½ mm, × 3.9; the specimen is mature.	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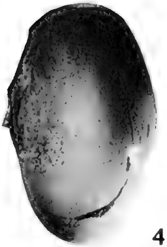
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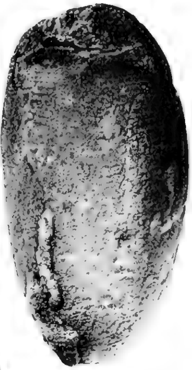
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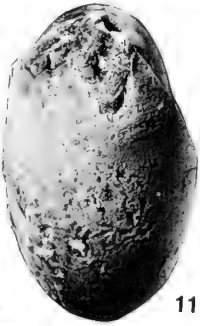
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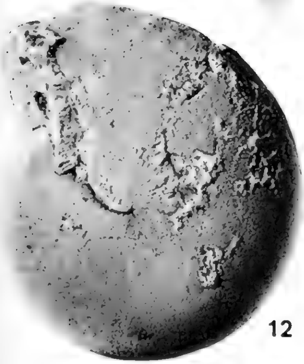
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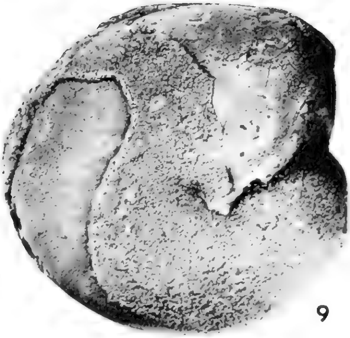
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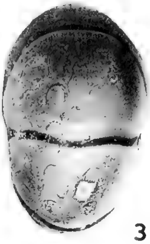
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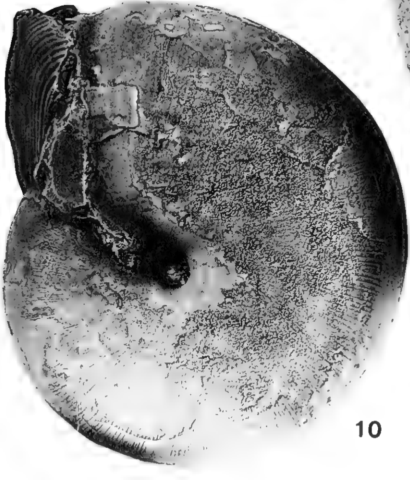
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EXPLANATION OF PLATE 22

Figure Page

1,2,5-10. **Marathonites** Böse, 1919 85

1,2. *M. ganti* (Smith), (SUI 17033), Graham (Wayland) Shale, 6½ mi. NW of Jacksboro, Texas, maximum diameter—16 mm, × 2.0; the specimen is immature. 5-7. *M. ganti* (Smith), (SUI 1063), Finis Shale, 3½ mi. E of Jacksboro, Texas, maximum diameter—31½ mm, × 1.6; the specimen is mature. 8-10. *M. invariabilis* Ruzhencev, (SUI 10594 A), Artinsk Stage, Aktyubinsk District, Aktasty River, USSR, maximum diameter—51½ mm, × 1.2; the specimen is mature.

3,4. **Peritrochia** Girty, 1908 88

3,4. *P. erebus* Girty, (SUI 32583 E), Bone Spring Limestone, road cut on the west side of US 62-180, 1.8 mi. NNE of the junction of US 54 & US 62-180, Culberson County, Texas, maximum diameter—11 mm, × 2.3; the specimen is immature.

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By

HSIN YI LING

1972

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UPPER CRETACEOUS AND CENOZOIC SILICOFLAGELLATES AND EBRIDIANS*

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ABSTRACT

This comprehensive examination of silicoflagellates and ebridians is based on samples mainly from deep-sea sediments, including experimental Mohole drilling and Legs I-III of the Deep Sea Drilling Project as well as land outcrops, their ages ranging from the late Cretaceous (Maestrichtian) to Recent.

A detailed account of systematics is given and 56 taxa are discussed with illustrations included from reference samples of type localities for these forms. Stratigraphic occurrences are compared with those of other microplanktonic groups; planktonic Foraminifera, calcareous nannoplankton, and Radiolaria.

Silicoflagellates and ebridians are grouped into seven assemblages and two horizons are additionally recognized. Mediterranean samples are also examined to evaluate the use of these microfloral assemblages in the middle latitude region of Europe.

INTRODUCTION

The recent upsurge of micropaleontologic research has resulted in the establishment of numerous biostratigraphic zones by means of different microfossil groups from the late Mesozoic to Recent. Coupled with the advancement of paleomagnetic stratigraphy and the method of radiometric determination, these zones have been combined (Berggren, 1969, table 2).

One group of siliceous microorganic remains, silicoflagellates and ebridians, first described by Ehrenberg (1839), has not been recognized for its potentiality by biostratigraphers. One of the main reasons is that earlier investigators placed their emphasis on describing new forms rather than on investigating their stratigraphic occurrences.

Hanna (1928) and more recently Stradner (1961), Mandra (1968), Bachmann and Papp (1968) suggested and attempted some zonations using land outcrops from various parts of the world; and Hays (*et al.,* 1969) included one silicoflagellate species in their study of the Plio-Pleistocene deep-sea sediments from the equatorial Pacific which brackets the Jaramillo Event within the Pleistocene. Jousé (1963, 1969, 1971), Muhina (1963, 1966, 1969), Ling (1970), and Martini (1971b) subsequently recorded the importance of silicoflagellates in their studies of Pacific sediments, and the author also found the same low-latitude species from mid-latitude central north Pacific sediments.

The successful recovery of long cores by the Deep Sea Drilling

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*Contribution No. 620, Department of Oceanography, University of Washington.

Project (DSDP or JOIDES) provides a unique opportunity to define the range of microfossils and to seek the phylogenic relationship of various microfossils. This project also coordinates the efforts of micropaleontologists in achieving accurate correlation. By comparison with the biostratigraphic framework thus refined by other groups of planktonic microfossils, the value of silicoflagellates and ebridians as a possible biostratigraphic index can be tested.

The present study is undertaken with the following objectives in mind: (1) to define the range of taxa mainly from deep-sea sediments; (2) to decipher the relationship or evolutionary lineage, if any, among silicoflagellates and ebridians; and (3) if possible, to recognize assemblages based on the occurrence of these siliceous microfossils.

ACKNOWLEDGMENTS

The author is indebted to William R. Riedel of Scripps Institution of Oceanography, University of California at San Diego, for kindly providing the samples as well as the pertinent biostratigraphic data upon which the present paper is based. Without his assistance, the work could not have been accomplished at this time. Thanks are also due to the Sample Distribution Panel of the Deep Sea Drilling Project (DSDP), who kindly made samples available from Leg I to Leg III, carried out under the financial support of the National Science Foundation.

Sincere appreciation is due to Alfred Bachmann and Herbert Stradner of Austria, N. de B. Hornibrook and A. R. Edwards of New Zealand, York T. Mandra, Alfred R. Loeblich, Jr., and John W. Ruth of the United States, for their graciously providing reference samples and unpublished data which are of great assistance in clarifying the taxonomic problems; to Erlend Martini of West Germany for his information on the unpublished data from DSDP Leg VII; and to Thomas R. Worsley of the Department of Oceanography at the University of Washington, for identifying some calcareous nannofossil assemblages.

Initial phase of this study was assisted by Mrs. Carol J. Stadum, and the completion by Mrs. Linda M. McPherson and Mrs. Shirley A. Verzosa.

The study was supported financially by National Science Foundation grants (GA-11308, GA-26499) and Office of Naval Research contract Nonr 477 (37), Project NR 083 012.

SAMPLES STUDIED

The deep-sea sediments and land outcrop samples used for the present study are listed in alphabetical order (Table 1) and their geographic locations are shown in Text-figure 1.

For deep-sea samples from the Scripps Institution of Oceanography collection, the abbreviations used by the Institution are followed, and the position of the samples is the depth measured (in centimeters) from the top of the core. For designating the Deep Sea Drilling Project (DSDP) samples, the general format that appeared in the Initial Reports of the Project is here adopted; namely, hole number — core number — section number, followed by sample level (in centimeters) from the top of the section. The samples from the core sediments recovered during the experimental deep-sea drilling phase of the Mohole Project at Guadalupe site are designated by the abbreviation "EM" to conform with the original description (Riedel, *et al.*, 1961), followed by the number of the hole — the number of the core run, and the depths of the sample, in centimeters, below the surface sediments of the particular core.

The stratigraphic positions of these samples are show in Text-figures 2 and 3, except for some DSDP samples (marked with an asterisk in Table 1) and a sample WR TR 39 H (*Thyrsocyrtis bromia* Zone; Riedel, personal communication) which were barren of these siliceous microfossils, to avoid an unnecessary overcrowding in the figures. The scheme proposed by Berggren (1969, table 2) relating radiometric time scale, European and West Coast (California) marine stages, and the Cenozoic planktonic foraminiferal zonation is adopted here. Calcareous nannoplankton zonations proposed by Martini (1970) and Martini and Worsley (1970), and the radiolarian zonation proposed by Riedel and Sanfilippo (1970, 1971) are included; the appropriate stratigraphic position of the samples was then decided.

Despite these considerations, the sample position shown in Text-figures 2 and 3 should still be regarded as merely an approximate indication based on available knowledge. Inevitably a few difficulties are encountered. According to Riedel and Sanfilippo (1970), sample RIS 111P, 280-281 cm, belongs to Zone N.4 of planktonic Foraminifera but is regarded as the upper part of the *Theocyrtis tuberosa* Zone of Radiolaria. The examination of calcareous nannoplankton microflora of the sample by Thomas R. Worsley (personal com-

TABLE 1. LIST OF SAMPLES STUDIED

Sample and Intervals (cm)		Longitude	Latitude	Depth (m)
AMPH 6P	17-18	128°21′W	4°52′N	4460
	50-51	128°21′W	4°52′N	4460
37P	250-251	121°05′W	18°16′S	3720
	350-351	121°05′W	18°16′S	3720
CAS 1144 (California Academy of Science Loc. 1144)		120°45′W	36°40′N	
CHUB 15	78-82	125°25′W	8°31′N	4462
EM (Experimental Mohole drilling at Guadalupe site)		117°30′W	29°59′N	3566
JYN V 16 P	231-233	149°44′W	7°44′N	5168
	248-250	149°44′W	7°44′N	5168
DSDP (Deep Sea Drilling Project)				
1P-1-6	40-41*	92°11′W	25°52′N	2827
2-1-3	115-116*	92°35′W	23°27′N	3572
2-2-1	130-131*	92°35′W	23°27′N	3572
2-3-1	45-46*	92°35′W	23°27′N	3572
2-3-2	100-101*	92°35′W	23°27′N	3572
2-4-2	15-16*	92°35′W	23°27′N	3572
3-5-3	62-63*	92°01′W	23°01′N	3737
3-7-1	50-51*	92°01′W	23°01′N	3737
3-10-2	45-46*	92°01′W	23°01′N	3737
4-4-1	10-11*	73°48′W	24°29′N	5319
5-1-1	33-34*	73°38′W	24°44′N	5361
5-1-2	73-74*	73°38′W	24°44′N	5361
6-4-1	6-8	67°39′W	30°50′N	5125
	115-117	67°39′W	30°50′N	5125
6-4-2	7-10	67°39′W	30°50′N	5125
	125-128	67°39′W	30°50′N	5125
6-4-3	92-94	67°39′W	30°50′N	5125
	110-112	67°39′W	30°50′N	5125
6-5-1	33-35	67°39′W	30°50′N	5125
6-6-2	1-2	67°39′W	30°50′N	5125
7-1-2	48-49*	68°18′W	30°08′N	5185
7A-3-2	51-52*	68°18′W	30°08′N	5185
9-5-1	8-9	59°12′W	32°46′N	4981
9-5-2	99-100	59°12′W	32°46′N	4981
9-5-4	117-118*	59°12′W	32°46′N	4981
10-9-2	60-61*	52°13′W	32°52′N	4612
10-9-3	55-56*	52°13′W	32°52′N	4612
13-3-1	120-121	18°14′W	06°02′N	4585
13A-1-1	115-116	18°14′W	06°02′N	4585
13A-2-1	90-91*	18°14′W	06°02′N	4585
13A-4-1	95-96*	18°14′W	06°02′N	4585

13A-5-1	40-41*	18°14′W	06°02′N	4585
LSDH 78P	100-101	168°02E′	4°31′S	3208
	516-517	168°02E′	4°31′S	3208
LSDA 101G	38-39	73°12′E	2°41′S	2960
MP 5-1	25-30	133°07′W	14°22′N	4700
MSN 126G	66-67	154°45′W	24°41′S	4542
MSN 149P	294-296	145°15′W	9°23′N	5100
PROA 88P	275-276	167°14′E	2°56′N	4428
RIS 111P	280-281	133°29′W	14°55′N	4770
WAH 7P	259-260	153°02′W	3°58′N	4992
	516-517	153°02′W	3°58′N	4992
WR TR 11 Low (Bo. 202)		Hermitage Quarry, south Trinidad, B.W.I. (Bolli, 1957, p. 101)		
WR TR 23 (K9391)		Near the Retrench trigonometrical station, Golconda Estate, Trinidad, B.W.I. (Bolli, 1957, p. 101; Riedel and Sanfilippo, 1970, p. 510)		
WR TR 39F		Lower Oligocene part of the Oceanic Formation at Bath, Barbados		
WR TR 39F (J.S. 1068)		Oceanic Formation at Bath, Barbados		
WR TR 39H*		Uppermost Eocene part of the Oceanic Formation at Bath, Barbados		

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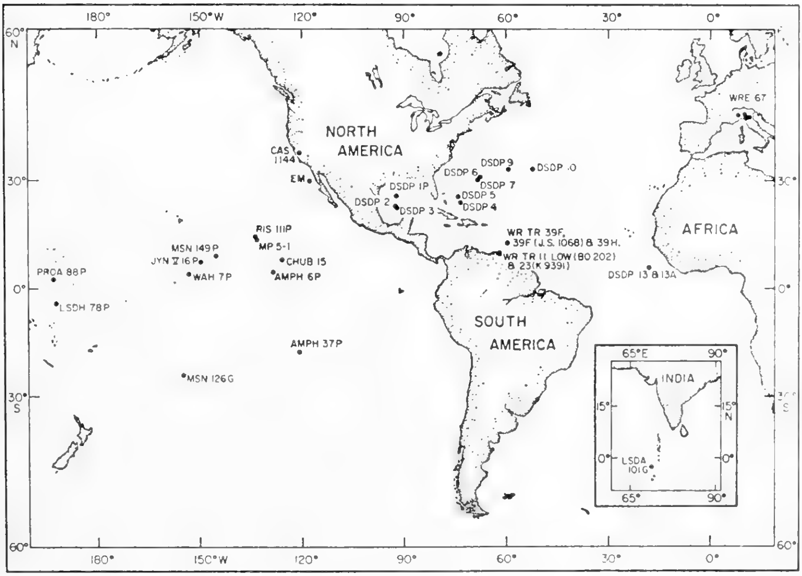
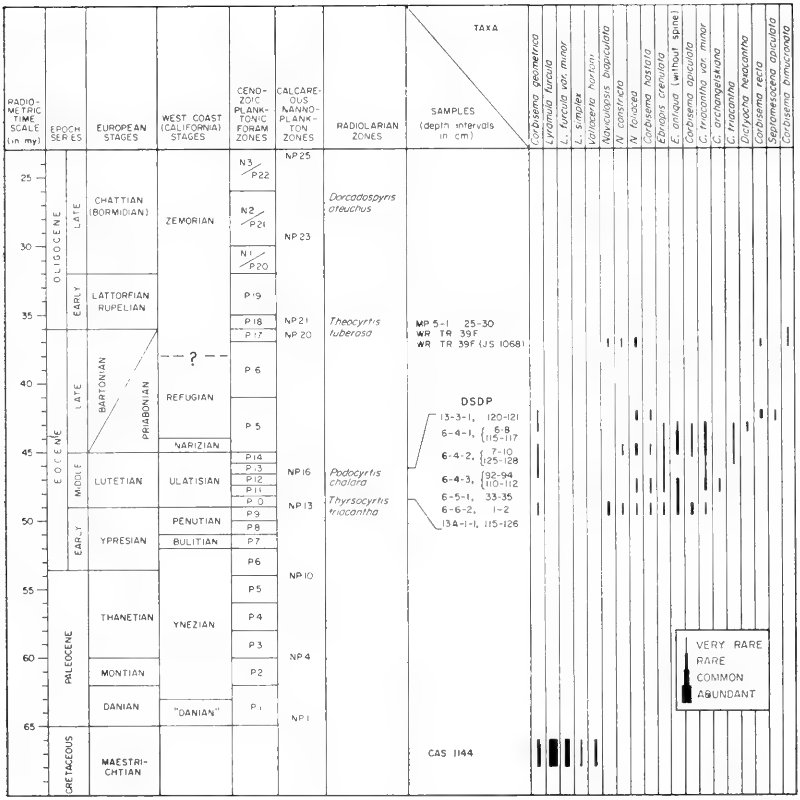
*Samples examined but were barren of silicoflagellates and ebridians, therefore not listed in Text-figures 2 and 3.

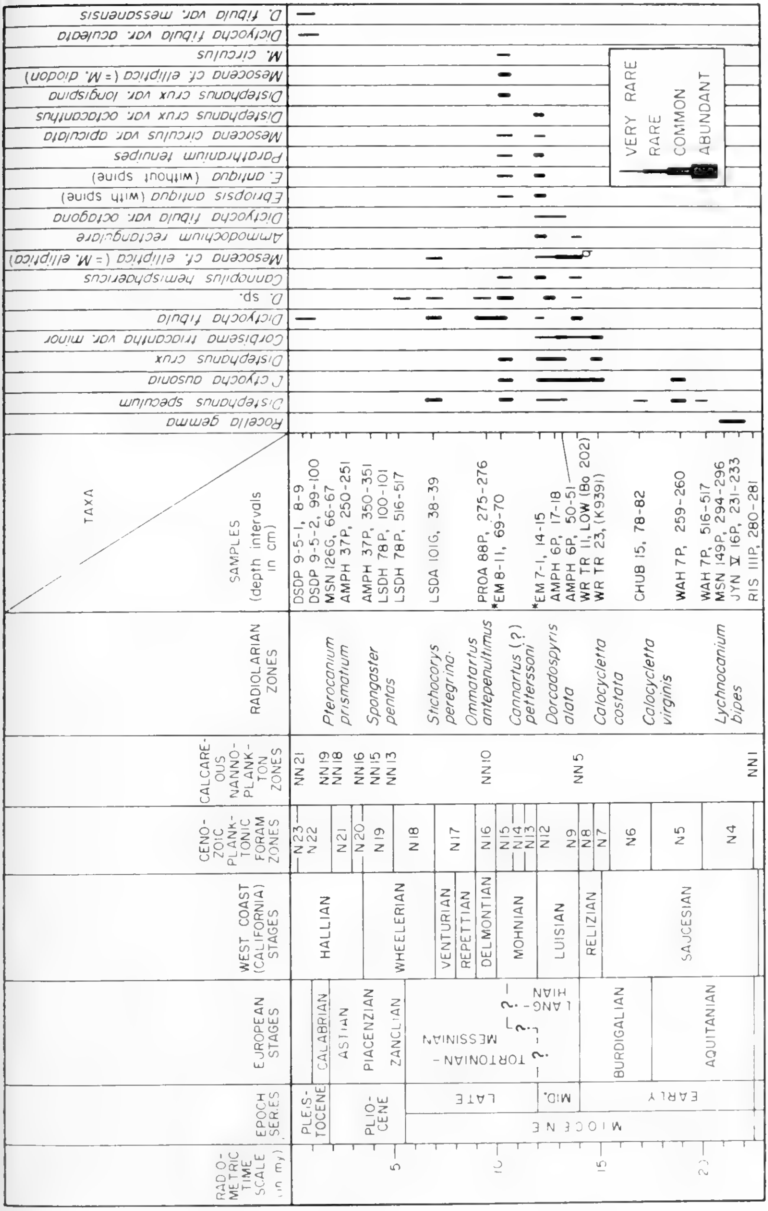


Text-figure 1—Index map showing the geographic location of samples investigated.



Text-figure 2.—Distribution of silicoflagellates and ebridians in Upper Cretaceous and Paleogene section. The figure is compiled based on the data of Berggren (1969), Martini (1970), and Riedel and Sanfilippo (1970, 1971).

munication) indicated that the sediment is Zone NN.1 of calcareous nannoplankton, and thus is in agreement with that of Foraminifera. The sample is, therefore, placed at the base of Miocene in Text-figure 3 of this paper. The Oligocene-Miocene boundary is placed by Berggren (1969, table 2) at the *Globigerinoides Datum, i.e.* 22.5 m.y. and is between N.3 and N.4 Zones of planktonic Foraminifera which falls within NN.1 Zone of calcareous nannoplankton (Martini and Worsley, 1970, p. 289). Riedel (1971) placed this boundary within N.4 planktonic Foraminifera and NN.1 calcareous nannoplanktonic Zones, and between *Calocycletta virginis* above and



Text-figure 3.—Distribution of silicoflagellates and ebridians in Neogene section. The figure is compiled based on data of Berggren (1969), Martini and Worsley (1970), and Riedel and Sanfilippo (1970, 1971). For samples with asterisk mark, see also Text-figure 4; q = occurrence of a specimen of *Mesocena polymorpha* var. *quadrangula* Lemmermann.

Lychnocanium bipes below of the radiolarian Zones. For convenience, two samples, JYN V 16 P, 231-233 cm and MSN 149 P, 294-296 cm, are also placed at the base of the Miocene in Text-figure 3.

In Text-figure 4, a combined sequence of the experimental Mohole drilling samples is shown together with the biostratigraphic subdivision of the sequence determined by means of calcareous nannoplankton by Martini and Bramlette (1963), planktonic Foraminifera by Parker (1964), Bandy and Ingle (1970), and diatoms by Kanaya (1971).

In addition, samples from the following locations were examined, and some specimens are illustrated in the present paper for comparison of the taxa:

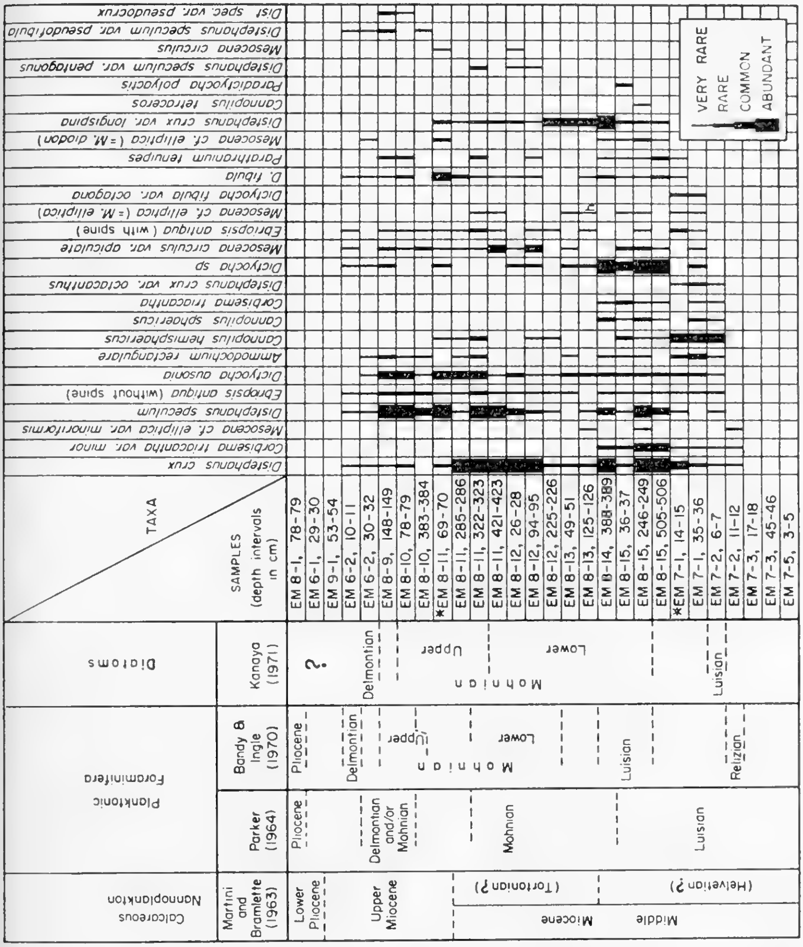
Oamaru Diatomite: Near Oamaru, South Island, New Zealand. A. R. Edwards kindly provided the samples from the following three sections; all the sample numbers are those of the New Zealand Geological Survey:

Bain's Farm (North of Fault) section; S 136/963-970
Forrester's Hill section; S 136/1096, 1195 and 994
Jackson's Paddock section; S 136/1194, 914 and 878-882.

Kellogg Shale (KEL): West of Byron, Contra Costa County, California. According to John W. Ruth of the Standard Oil Company of California, samples were collected by Alfred R. Loeblich, Jr., of Chevron Oilfield Research Company from the location where Mandra (1968, p. 272) sampled, and they were approximately at 4- or 5-foot intervals from the bottom (#1) to the top (#10) of the present exposure. Thus the total thickness of outcrop is slightly different from that which Mandra measured in 1948.

Sidney Shale (SID): South of Antioch, Contra Costa County, California. The samples were collected by John W. Ruth from the old quarry where Mandra (*op. cit.*) collected his samples. The seven samples are: #1, at the base of the exposure; #2, 5 feet; #3, 60 feet; #3-A, 61 feet; #4, 63 feet; #5, 65-73 feet (composite); #6, 74-83 feet (composite); #7, approximately 88 feet from the base (the top of the exposure).

Austrian samples: Alfred Bachmann kindly sent me the following samples which he had examined for silicoflagellate assemblages; they are:



Text-figure 4.—Distribution of silicoflagellates and ebridians in experimental Mohole drilling section. For samples with asterisk mark, see also Text-figure 3; h = occurrence of a specimen of *Mesocena hexagona* Haeckel.

AUS 1: "sample G, Walbersdorf im Burgenland (Jungeren Badener Serie)."

AUS 2: "Limberg bei Maissau (Luschitzer Serie)."

AUS 3: "Ziegelei Ernstbrunn, Waschbergzone (Eggenburger Serie, Burdigal)."

AUS 4: "Steiehang E Wallern a.d. Trattnach (Oberoligozän)."

A detailed description of these samples has already been presented by Bachmann and Papp (1968).

Finally a series of outcrop samples from Italy studied recently by Sanfilippo (1971) were analyzed to evaluate silicoflagellate occurrences in the Mediterranean region (see discussion and Text-figure 7).

LABORATORY PROCEDURES

A sample of sediment was trated routinely with hydrogen peroxide (30%) to remove organic matter. The sediment was then treated with concentrated HCl to dissolve any calcareous microfossils that might mask or dilute the siliceous microfossils. The remaining residue was then decanted and sieved through a 74-μ sieve. Since silicoflagellates and ebridians are generally smaller than 74 μ, this provides an easy way to concentrate and separate them from larger siliceous microfossils, such as Radiolaria and diatoms. Strewn slides were made from this residue and dried. Canada balsam was then used to adhere the cover glass of 22 x 40 mm size.

Counts were made on these strewn slides to determine the relative abundance of silicoflagellate and ebridian species. Measurements for an individual taxon were generally made on the major axis on the basis of at least 20 specimens.

Temporary or wet slides were also prepared by removing the strewn slides from the oven before the mounting medium became completely solid. By gently applying pressure in one direction on the cover glass, specimens in the slide will rotate within the mounting medium and thus permit an observation from various orientations.

The location for the illustrated specimens in the strewn slides is indicated by the sample designation (as discussed earlier), followed by the slide number, the location by the England finder reading as previously described (Ling and Anikouchine, 1967).

All the slides examined during the present study will be deposited permanently in the micropaleontology collection, Department of Oceanography, University of Washington, Seattle, Washington.

SYSTEMATIC MICROPALEONTOLOGY

In spite of an apparently simple configuration in comparison with other microfossils, the systematics of silicoflagellates are not so simple as one would expect. The enormous number of *variety* or *forma* proposed by previous workers has created a large number of names, and this fact has hindered the utilization of silicoflagellates and ebridians as biostratigraphic indicators.

It is here considered that these microfossils belong to plant origin (Loeblich and Tappan, 1968) and thus are discussed according to the International Code of Botanical Nomenclature adopted in Utrecht (Lanjouw, *et al.*, 1966). In the following section, the classification scheme proposed by Frenguelli (1940), Deflandre (1950a), Papenfuss (1955), Glezer (1966), and more recently by Bachmann (1970b), is generally followed. However, genera and species of each genus are arranged in alphabetical order. Illustrations of *Septamesocena apiculata* are placed immediately next to *Mesocena* for the convenience of comparison.

Inasmuch as many of the previously reported taxa are involved during the present study, it has become necessary to review them critically from the biostratigraphic point of view. Consideration has been given to these taxa which had been recorded by the workers as *variety* and *forma* or *forma,* and recognized here whenever they seem to have either stratigraphic importance or possible paleoecological implication. In addition, to facilitating better understanding of previous authors' observations, specimens from the reference materials of well-known localities are presented for comparison. A detailed analysis of microfossils from these localities is currently being undertaken by the author, and the results will be reported in later papers as the work progresses.

SILICOFLAGELLATES

Perhaps because of the simple configuration, the terminology of the siliceous skeletal elements of silicoflagellates has not changed much since it was first introduced by Gemeinhardt (1930). The short description prepared here and also Text-figure 5 uniformize and introduce some new terms used in the later discussion.

Terminology — The typical skeleton of a silicoflagellate consists of a polygonal *basal body ring* with *radial spines* at each corner extending generally horizontally. From the basal side of the polygon, *basal accessory spines* project down- and inwardly. In some species (such as *Dictyocha fibula* var. *messanensis*), there are short *accessory spines* at the exterior side of the basal body ring.

The structure within or above the basal body ring is referred to as an *apical structure,* which may be in the form of a ring, *apical ring;* with an opening or openings; *apical window* or several *apical windows;* or a simple straight bar, an *apical bar;* or a flattened thin plate, *apical plate.* Occasionally short spine(s), *apical accessory spine(s),* are present on an apical ring or on an apical bar. The apical structure and the basal body ring are connected by *lateral rods.*

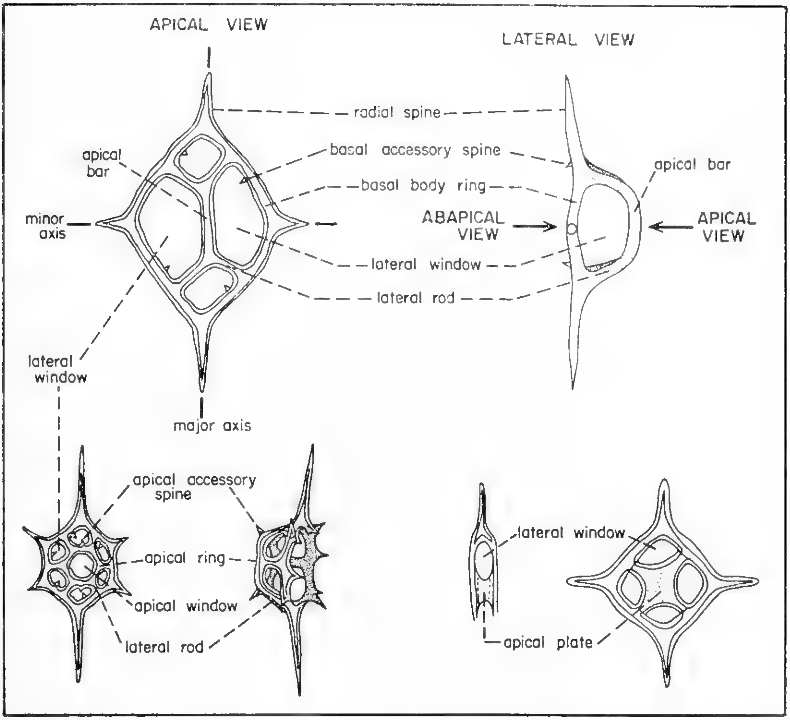
The spaces delineated by the apical structure, the basal body ring and also by lateral rods are called *lateral window(s)* ("Basalfenster" of Gemeinhardt, 1930, p. 21) or *basal window* of Glezer (1966, p. 9).

Orientation — The shape of the basal body ring and the position of the apical structure serve to orient the silicoflagellate specimens. Except for circular or triangular forms, generally the silicoflagellate skeleton is longer in one direction; this is called the *major axis,* and the shorter one, the *minor axis.* When a silicoflagellate is orientated in such a way that the basal body ring, radial spines and lateral rods are on a plane and with the apical structure form a shape of truncated pyramid, it is called *lateral view* (*edge view* of Loeblich, III, *et al.,* 1968; Ling, 1970); the view directly facing the apical structure is called an *apical view* and the opposite is termed as *abapical view* (Marshall, 1934; Loeblich, III, *et al.,* 1968, p. 7).

Order SIPHONOTESTALES Lemmermann, 1901a

Genus **CANNOPILUS** Haeckel, 1887, emend. Bachmann, 1967

Remarks. — As discussed earlier Ling (1970), Loeblich, III, *et al.* (1968) and more recently Lipps (1970) considered that Haeckel's name should be regarded as a junior synonym of *Halicalyptra* by Ehrenberg (1847), on the basis of samples from the Barbados Island and Richmond, Virginia. Furthermore, Lipps (1970, pp. 975-976) suggested that another form, *Clathropyxidella* described by Deflandre (1938) also from Barbados, is probably synonymous. Three of the samples studied are from Barbados; special attention was made during the microscopic examination to find forms similar to those previously described, but the search was unsuccessful. Undoubtedly further investigation is needed to determine the exact



Text-figure 5.—Terminology of the silicoflagellate skeleton (Modified after Deflandre, 1950a)

nature of these forms and to resolve this taxonomic problem, and in the present paper the long-recognized Haeckel's name is applied.

Cannopilus hemisphaericus (Ehrenberg) Pl. 23, figs. 1-5

Remarks. — As discussed earlier (Ling, 1970), the synonymy of this species has been presented by various investigators; however, despite their painstaking efforts, the present species has not been satisfactorily defined. This is apparently due to the fact that some of the specimens assignable to the species demonstrate intermediate characteristics by possessing a basal body ring like *Distephanus speculum;* and yet the complex nature of the apical structure, hemispherical outline and varying numbers of apical windows are common in the genus *Cannopilus*. Thus Glezer (1966) and Bachmann (1970a, b) make a special effort to differentiate between those with the diameter of the apical structure equal to or less than that of the basal body ring as *Distephanus speculum* var. *canopiloides,* and those with the larger diameter as *Cannopilus hemisphaericus.*

As has been noted from the central north Pacific sediments (Ling, *op. cit.*), it is not necessary to have a larger diameter of the apical structure in order to have a hemispheric outline. It is also apparent that the number of apical windows cannot be the valid taxonomic criteria as Ehrenberg or Lemmermann once proposed; thus it is somewhat puzzling that Glezer (1966, p. 280) again considered an apical structure with six or more windows as one of the criteria for *Cannopilus*; and the taxonomic names of Ehrenberg or Lemmermann, based on the number of apical windows, appeared recently (McManus, *et al.,* 1970, particularly for the description of Hole 32-34) which had already been well discussed as early as 1964 by Bachmann.

Perhaps the above discussion can be elucidated by Bachmann (1970b, p. 10) at the end of his emended description of *Distephanus speculum* var. *cannopiloides* which states "Abgrenzung zum nahe verwandten *Cannopilus hemisphaericus* vorgenommen werden."

Therefore, following the previous central north Pacific study, the specimens showing hemispheric outline of the apical structure in the lateral view and generally possessing two or more apical windows and larger than ordinary related forms, such as *Distephanus speculum,* are all included under the present species. The only exceptions to the present taxon are those specimens with two small windows, the size of one window divided by an apical bar, and with the apical structure definitely not hemispherical but parallel to the basal body ring. These such as *Dictyocha bipartita* Ehrenberg (1844a; 1854), are found in Recent surface sediments from various parts of the world, including the Bering Sea and Antarctic waters.

Dimensions. — Length of basal body ring, 28-40 μ; of radial spine, 14-26 μ.

Known geologic range. — Miocene.

Occurrence. — *C. hemisphaericus* is found between the interval from WR TR 11, Low (Bo. 202), *Globorotalia fohsi barisanensis*

Zone or *Dorcadospyris alata* Zone (Riedel and Sanfilippo, 1970) in Text-figure 3, and from EM 7-2, 6-7 cm, Luisian (Parker, 1964) or Helvetian ? (Martini and Bramlette, 1963) in Text-figure 4, to EM 8-11, 69-70 cm, N.12 planktonic foraminiferal Zone or *Ommatartus antepenultimus-Cannartus (?) petterssoni* Zone (Riedel and Sanfilippo, *op. cit.*). It is interesting to note here that Mandra (1968) recorded the occurrence of the present species from Relizian and Mohnian stage samples. A sample EM 7-2, 7-10 cm, which is identified as Relizian by Bandy and Ingle (1970, p. 140, fig. 3; p. 167), did not yield the present species.

Cannopilus picassoi Stradner Pl. 23, figs. 6, 7

Cannopilus picassoi Stradner, 1961, Erdöl u. Kohle, vol. 14, No. 2, p. 92, figs. 101-104.

Cannopilus picassoi Stradner, Bachmann, 1963, in Bachmann *et al.*, Geol. Ges. Wien, Mitt., vol. 56, No. 1, p. 153, pl. 20, figs. 74-81; pl. 22, figs. 17-19.

Cannopilus picassoi Stradner, Bachmann and Papp, 1968, Giorn. di Geol., (2), vol. 35, pl. 3, fig. 16.

Cannopilus picassoi Stradner, Hajos, 1968, Geol. Hungarica, ser. Paleont., fasc. 37, p. 70, pl. 6, fig. 5.

Cannopilus picassoi Stradner, Bachmann, 1970, *in* Cat. Fossil, Austriae, No. 1b, p. 14.

Remarks. — When Stradner (1961) originally described the present species from the Miocene ("Unteres Torton") of Frättingsdorf, Austria, it seems that two morphologically different forms were included: one with well-developed apical accessory and radial spines (his figs. 101-102), and the other with both spines poorly developed, particularly the radial spines (his figs. 103, 104). The Italian specimens are the only forms found during the present study which show only the latter type; however, the general form, including numerous apical windows and the overall size, agrees with the specimens from Austria.

Dimensions. — Diameter of apical structure, 30-40 μ.

Known geologic range. — Miocene.

Occurrence. — This species is found rarely and only from Italian samples.

Cannopilus sphaericus Gemeinhardt Pl. 23, figs. 8-10

Cannopilus sphaericus Gemeinhardt, 1931a, Deutsch, Bot. Ges., Ber., vol. 49, No. 2, p. 104, pl. 10, figs. 3, 4.

Cannopilus sphaericus Gemeinhardt, Frenguelli, 1940, Rev. Mus. La Plata, n.s., vol. 2, Paleont., No. 7, pp. 48-51, fig. 6e.

Cannopilus sphaericus Gemeinhardt, Deflandre, 1950a, Microscopie, vol. 2, figs. 95, 96, 97 (?).
Cannopilus sphaericus Gemeinhardt, Stradner, 1961, Erdöl. u. Kohle, vol. 14, No. 2, p. 92, figs. 99, 100.
Cannopilus sphaericus Gemeinhardt, Bachmann, 1963, *in* Bachmann, *et al.*, Geol. Ges. Wien, Mitt., vol. 56, No. 1, p. 153, pl. 20, figs. 69-73; pl. 22, fig. 16.
Cannopilus sphaericus Gemeinhardt, Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 281, pl. 27, fig. 5.
Cannopilus sphaericus Gemeinhardt, Bachmann and Papp, 1968, Giorn. di Geol., ser. 2, vol. 35, fasc. 2, p. 122.
Cannopilus sphaericus Gemeinhardt, Hajos, 1968, Geol. Hungarica, ser. Paleont., fasc. 37, p. 70, pl. 6, figs. 1-4, 6.
Cannopilus sphaericus Gemeinhardt, Mandra, 1968, California Acad. Sci., Proc., ser. 4, vol. 36, No. 9, pp. 247-248, figs. 66(?), 70.

Remarks. — The present species is characterized by the presence of larger and consequently fewer numbers of apical windows than *C. picassoi* or *C. tetraceros,* and by the presence of five or six down- and outwardly directed basal radial spines. Lateral windows are frequently larger in size than the apical windows. Apical accessory spines at the top and the sides of the spherical apical structure are either present or absent.

Dimensions. — Diameter of apical structure, 28-40 μ.

Known geologic range. — Miocene.

Occurrence. — The specimens assigned to the present species are found only from experimental Mohole samples during the present study, and from EM 7-2, 6-7 cm to EM 8-14, 388-389 cm interval. Thus the top seems to coincide with the boundary of Helvetian? — Tortonian? in middle Miocene of calcareous nannofossils by Martini and Bramlette (1963); and approximately Luisian-Mohnian of planktonic Foraminifera by Parker (1964) and Bandy and Ingle (1970). On the basis of studies mainly from the land sections of California, the present species is considered as one of the indices for the Mohnian stage by Mandra (1968), but recently Ruth (1971) recorded that it ranges from middle Luisian to almost the top of middle Mohnian.

Cannopilus tetraceros Bachmann and Ichikawa Pl. 23, figs. 11, 12

Cannopilus tetraceros Deflandre, 1949, *nomen nudum.*
Cannopilus tetraceros Deflandre *ex* Bachmann and Ichikawa, 1962, Kanazawa Univ., Sci. Rept., vol. 8, No. 1, p. 172, pl. 5, figs. 73-75; pl. 9, figs. 8, 11.

Remarks. — When Bachmann and Ichikawa described the present species in their investigation from the Wakura Beds (1962, p. 172), of Miocene (late) (Fuji and Bachmann, 1969), they indicated that Deflandre found a similar specimen from Moron, Spain, and, therefore, they credited the authorship to Deflandre and dated it as 1949. Until now no description or figure has been presented by Deflandre; therefore the date of 1949 should be considered as *nomen nudum* and as invalid. The species should be *Cannopilus tetraceros* Deflandre *ex* Bachmann and Ichikawa or its abbreviated form as above and dated as 1962 (Lanjouw, *et al.*, 1966, ICBN Art. 46; Recommendation 46C).

Dimensions. — Diameter of apical structure, 42 μ.

Known geologic range. — Miocene.

Occurrence. — Throughout the present study, the species is found in sample EM 8-15, 246-249 cm only.

Genus **CORBISEMA** Hanna, 1928, emend. Frenguelli, 1940

Remarks. — The genus was first proposed by Hanna (1928); and the emended diagnosis given by Frenguelli (1940, p. 69) which was later accepted by Deflandre (1950a, p. 47/82), is followed here. Glezer (1966, p. 223; pp. 252-253) restricted the present genus to those forms in which the basal accessory spines are "on the lateral rods at the corners of apical widening," and thus Glezer considered only *C. geometrica* Hanna as belonging to the present genus, indicating that specimens which have basal accessory spines on the basal body ring are regarded as belonging to the genus *Dictyocha.*

Corbisema apiculata (Lemmerman) Pl. 23, figs. 13-17

Dictyocha triacantha var. *apiculata* Lemmerman, 1901b, Deutsch. Bot. Ges., Ber., vol. 19, p. 259, pl. 10, figs. 19-20.

Dictyocha triacantha var. *apiculata* Lemmermann, Schulz, 1928, Bot. Archiv., vol. 21, No. 2, pp. 247-249, fig. 27.

Dictyocha triacantha var. *apiculata* fa. *aspera* Schulz, 1928, Bot. Archiv., vol. 21, No. 2, pp. 247-249, fig. 28.

Dictyocha triacantha var. *apiculata* fa. *late-radiata* Schulz, 1928, Bot. Archiv., vol. 21, No. 2, p. 281, fig. 73.

Dictyocha triacantha var. *apiculata* Lemmermann, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, pp. 41-42, fig. 30.

Dictyocha triacantha var. *apiculata* fa. *aspera* Schulz, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, pp. 41-42.

Dictyocha triacantha var. *apiculata* fa. *late-radiata* Schulz, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, p. 43, fig. 32.

Corbisema apiculata (Lemmermann), Hanna, 1931, Mining in California, vol. 27, No. 2, p. 198, pl. D, fig. 2.

Dictyocha triacantha var. *apiculata* Lemmermann, Deflandres, 1932a, Soc. France, Microsc., Bull., vol. 1, No. 1, fig. 32.
Corbisema apiculata (Lemmermann), Frenguelli, 1940, Rev. Mus., La Plata, n.s., vol. 2, Paleont., No. 7, fig. 12h.
Corbisema apiculata (Lemmermann), Stradner, 1961, Erdöl u. Kohle, vol. 14, No. 2, p. 89, figs. 26, 27, 33.
Dictyocha triacantha var. *apiculata* fa. *apiculata* Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, pp. 228-229, pl. 6, fig. 5.
Dictyocha triacantha var. *apiculata* fa. *late-radiata* Schulz, Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., pp. 229-230, pl. 6, fig. 1.
Corbisema apiculata (Lemmermann), Mandra, 1968, California Acad. Sci., Proc., ser. 4, vol. 36, No. 9, p. 248, figs. 25, 30(?), 35.

Remarks. — The specimens referable to the present species show a triangular basal body ring with short radial spines at three rounded apices. Basal accessory spines generally present, short or occasionally strong and distinct.

Dimensions. — Length of basal body ring, 30-60 μ.

Known geologic ranges. — Cretaceous (late) to Eocene (late).

Occurrence. — Throughout the present study, the species is found in samples from DSDP Hole 6, and in reference samples from Bain's Farm section of Oamaru Diatomite, New Zealand, as well as from Kellogg and Sidney Shale of California.

Corbisema archangelskiana (Schulz) Pl. 23, fig. 18

Dictyocha triacantha var. *archangelskiana* Schulz, 1928, Bot. Archiv., vol. 21, No. 2, pp. 250-251, fig. 33 a-c; p. 281, figs. 77, 78(?).
Dictyocha triacantha var. *archangelskiana* Schulz, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, pp. 45-46, fig. 37a, b(?).
Corbisema archangelskiana (Schulz), Frenguelli, 1940, Rev. Mus., La Plata, n.s., vol. 2, Paleont., No. 7, fig. 12a.
Corbisema archangeskiana (Schulz), Stradner, 1961, Erdöl u. Kohle, vol. 14, No. 2, p. 89, fig. 25 (only).
Dictyocha triachantha var. *archangelskiana* Schulz, Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, pp. 48-49, pl. 9, fig. 1; pl. 22, fig. 14.
Dictyocha archangelskiana (Schulz), Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, pp. 232-233, pl. 8, figs. 6, 7.

Remarks. — Glezer (1966) correctly assigned figure 6 from Oamaru, New Zealand, and figure 7 from the eastern slope of the Urals to the present species, but erred by referring to Gemeinhardt's figure 34, which is *Dictyocha triacantha* var. *inermis* fa. *late-radiata* Schulz (= *Corbisema geometrica* Hanna, in this paper). The species is characterized by three elongated triangular lateral windows, sides of which are subparallel and with narrow but not pointed apices.

Dimensions. — Length of basal body ring, 50 μ.

Known geologic range. — Cretaceous (late) to Eocene (late).

Occurrence. — Found rarely and only from DSDP sample, 6-4-3, 110-112 cm.

Corbisema bimucronata Deflandre Pl. 24, fig. 1

Corbisema bimucronata Deflandre, 1950a, Microscopie, vol. 2, pp. 63/82-64/82, figs. 174-177.
Dictyocha bimucronata (Deflandre), Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, p. 50, pl. 9, fig. 6.
Dictyocha bimucronata (Deflandre), Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 233, pl. 9, fig. 2.

Remarks. — This small species possesses sharply truncated apices with short spines at both edges. Basal accessory spines are short but generally present. Glezer (1966, p. 233) indicated that the early Oligocene (?) form from the Ukrainian area, the only occurrence from Russia, did not possess the basal accessory spines and she is of the opinion that "arrangement of the supporting spines (= basal accessory spines in this paper) cannot serve as the major criterion in defining the genus *Corbisema* as does Deflandre."

Dimensions. — Length of the basal body ring, 38 μ.

Known geologic range. — Eocene to Oligocene (?).

Occurrence. — Until now the species has been reported, except in Russia, only from "Radiolarite à Diatomées de Springfield et de Newcastle, île de la Barbade", and was regarded as "?Miocene inférieur" but is now considered as Eocene by Loeblich, III, *et al.* (1968, p. 18). The specimens found during the present study were also from Barbados samples, WR TR 39 F (J.S. 1068) and 39 F, which are both from the *Theocyrtis tuberosa* Zone, and the stratigraphic position for the former is also identified as slightly above the *Isthmolithus recurvus* Zone (Riedel and Sanfilippo, 1970). Apparently the present species has a limited geologic, as well as geographic distribution, because no specimen was found from other areas, including Oamaru, New Zealand, and California.

Corbisema geometrica Hanna Pl. 24, figs. 2-4

Dictyocha triacantha var. *inermis* Lemmerman, 1901b, Deutsch. Bot. Ges., Ber., vol. 19, p. 259, pl. 10, fig. 21.
Corbisema geometrica Hanna, 1928, Jour. Paleont., vol. 1, No. 4, p. 261, pl. 41, figs. 1, 2.
Dictyocha triacantha var. *inermis* Lemmerman, Schulz, 1928, Bot. Archiv., vol. 21, No. 2, p. 249, fig. 30a, b; p. 281, fig. 75.

Dictyocha triacantha var. *inermis* fa. *late-radiata* Schulz, 1928, Bot. Archiv., vol. 21, No. 2, p. 281, fig. 74.

Dictyocha triacantha var. *inermis* Lemmermann, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, p. 43, fig. 33.

Dictyocha triacantha var. *inermis* fa. *late-radiata* Schulz, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, p. 43, fig. 34.

Dictyocha triacantha var. *inermis* Lemmerman, Deflandre, 1932a, Soc. France Microsc., Bull., vol. 1, No. 1, fig. 31.

Corbisema geometrica Hanna, Deflandre, 1940a, Acad. Sci. Paris, C. R., vol. 211, No. 19, p. 446, figs. 3-4, 6-8.

Corbisema geometrica Hanna, Deflandre, 1950a, Microscopie, vol. 2, pp. 53-82—54-82, figs. 134, 136-139.

Corbisema archangelskiana Stradner, 1961 (not Schulz or Deflandre), Erdöl u. Kohle, vol. 14, No. 2, p. 89, figs. 19, 24 (only).

Dictyocha geometrica (Hanna), Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, pl. 9, figs. 4, 5; pl. 22, figs. 15-16.

Corbisema geometrica Hanna, Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 253, pl. 9, fig. 7.

Dictyocha triacantha var. *inermis* fa. *inermis* Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 230, pl. 8, figs. 1, 2; pl. 32, fig. 1.

Corbisema geometrica Hanna, Mandra, 1968, California Acad. Sci., Proc., ser. 4, vol. 36, No. 9, p. 248, figs. 3-5.

Remarks. — The present species was described originally from Cretaceous materials of California. Careful examination of more than ten slides, including both larger and smaller than 74 μ fractions made from topotypic material, CAS 1144, yielded only a few specimens and with apical plate only (Pl. 24, fig. 2). Deflandre (1940a) illustrated that the position of basal accessory spines is variable, ranging from on the lateral rods near the hyaline apical plate to on the basal body ring. Glezer (1966), on the other hand, was of the opinion that the present species should be for those with basal accessory spines on the lateral rods only, and she also reported basal accessory spines up to 10 μ long. Consequently Glezer considered the present species to be the only form belonging to the present genus, and she limited the range for the genus as Cretaceous (late), while for those *Dictyocha triacantha* var. *inermis* fa. *inermis*, early Paleocene is additionally mentioned.

Hanna included a specimen without hyaline apical plate as a deviated form within the present species. Apparently the inclusion of such a latter form led Deflandre to combine those described previously by Lemmermann (1901b) as *Dictyocha triacantha* var. *inermis* from "Fuur in Jutland" under the present species. Unfortunately no such specimen was observed from the topotypic material. There is a possibility that future detailed study of Cretaceous materials from California might yield such a specimen as Mandra (1968) illustrated; therefore, Hanna's concept is followed here.

Although Deflandre (1950a, p. 54/82) indicated that *Dictyocha triacantha* var. *archangelskiana* Schulz (1928, pp. 250-251, fig. 33a-c) may also belong to the present species, and Stradner (1961) apparently followed such an opinion, this is not accepted in the present study.

Dimensions. — Length of basal body ring, 70-90 μ.

Known geologic range. — Cretaceous (late) to Eocene.

Occurrence. — *C. geometrica* as here recognized is found in Cretaceous California and middle Eocene DSDP materials.

Corbisema hastata (Lemmermann) Pl. 24, fig. 5

Dictyocha triacantha var. *hastata* Lemmermann, 1901b, Deutsch. Bot. Ges., Ber., vol. 19, p. 259, pl. 10, figs. 16, 17.

Dictyocha triacantha var. *hastata* Lemmermann, Schulz, 1928, Bot. Archiv., vol. 21, No. 2, pp. 249-250, figs. 31a-c; 29b (only).

Dictyocha triacantha var. *hastata* Lemmermann, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, p. 43, fig. 35a-c.

Dictyocha triacantha var. *hastata* Lemmermann, Deflandre, 1932a, Soc. France, Microsc., Bull., vol. 1, No. 1, fig. 28.

Dictyocha triacantha var. *hastata* Lemmermann, Frenguelli, 1940, Rev. Mus., La Plata, n.s., vol. 2, Paleont., No. 7, fig. 12c (only).

Dictyocha triacantha var. *hastata* Lemmermann, Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, pp. 231-232, pl. 6, figs. 6-8; pl. 7, figs. 1-8; pl. 31, figs. 8, 9.

Dimensions. — Length of the basal body ring, 24-30 μ.

Known geologic range. — Paleocene (early) to Eocene (late). Numerous locations are listed for the occurrence of the present species from Russia by Glezer (1966).

Occurrence. — Found from the samples of DSDP 6-6-2, 1-2 cm, *Thyrsocyrtis triacantha* Zone, to DSDP 13-3-1, 120-121 cm, *Podocyrtis chalara* Zone (Riedel, 1971).

Corbisema recta (Schulz) Pl. 24, figs. 6, 7

Dictyocha triacantha var. *recta* Schulz, 1928, Bot. Archiv., vol. 21, No. 3, p. 250, fig. 32a, b.

Dictyocha triacantha var. *recta* Schulz, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, p. 45, fig. 36.

Phyllodictyocha recta (Schulz), Deflandre, 1946, Soc. Bot. France, Bull., vol. 93, No. 9, pp. 335-337, fig. 1.

Phyllodictyocha recta (Schulz), Deflandre, 1950a, Microscopie, vol. 2, p. 45/82, figs. 112, 113.

Dictyocha recta (Schulz), Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, p. 49, pl. 9, fig. 2; pl. 22, fig. 8.

Description. — Basal body ring, triangular either smooth or slightly convex; radial spines short at each corner; short basal accessory spines at the abapical side of the basal body ring directly below where the lateral rods join with basal body ring; apical structure simple, consisting of three equal lateral rods meeting at the center and in some specimens, slightly expanding to form a small apical plate.

Remarks. — Deflandre's new genus, *Phyllodictyocha,* with Schulz's *variety* as the type species, is characterized by having a flattened and non-tubular basal body (1935, 1946), and Tsumura (1963, p. 49) stated that no lumen (or hollow structure) can be found within the basal body. The specimens found from the DSDP samples failed to show any particular flattened nature of the basal body ring and the lumen was present in contrast to illustrations by Deflandre and Tsumura; furthermore the basal accessory spines seem heavier than those shown by them.

Dimensions. — Length of basal body ring, 30-38 μ.

Known stratigraphic range. — Eocene.

Occurrence. — The present taxon is found from samples DSDP 13-3-1, 120-121 cm, *Thyrsocyrtis triacantha* Zone and Barbados, WR TR 39 F (J. S. 1068), *Theocyrtis tuberosa* Zone and is just above the top of *Isthmolithus recurvus* Zone (= NP.19 Zone of Martini, 1970) (Riedel and Sanfilippo, 1970).

Corbisema triacantha (Ehrenberg) Pl. 24, figs. 8-13

Dictyocha triacantha Ehrenberg, 1844a, Verh. K. Preuss. Akad. Wiss. Berlin, Ber., Jahrg. 1844, p. 80.

Not *Dictyocha triommata* Ehrenberg, 1845, Verh. K. Preuss. Akad. Wiss. Berlin, Ber., Jahrg. 1845, pp. 56, 76.

Not *Dictyocha triommata* Ehrenberg, Ehrenberg, 1854, Mikrogeologie, pl. 33, No. 15, fig. 11.

Dictyocha trigona Zittel, 1876, Deutsch. Geol. Ges., Zeitschr., vol. 28, pl. 83, pl. 2, figs. 6, 6a.

Dictyocha trigona Zittel, Rüst, 1888, Palaentographica, vol. 34, No. 5/6. p. 213.

Dictyocha triacantha Ehrenberg, Lemmermann, 1901b, Deutsch. Bot. Ges., Ber., vol. 19, p. 258, pl. 10, fig. 18.

Dictyocha triacantha Ehrenberg, Schulz, 1928, Bot. Archiv., vol. 21, No. 2, p. 247, figs. 24, 25a.

Dictyocha triacantha Ehrenberg, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, p. 40, figs. 28a (?), b (?), c; 29a (?).

Corbisema triacantha (Ehrenberg), Hanna, 1931, Mining in California, vol. 27, pl. D, fig. 1.

Corbisema triacantha (Ehrenberg), Zanon, 1934, Acta Pont. Acad. Sci. Nov. Lincei, vol. 87, p. 66, pl. n, fig. 8.

Corbisema triacantha (Ehrenberg), Frenguelli, 1940, Rev. Mus., La Plata, n.s., vol. 2, Paleont., No. 7, fig. 12g.

Corbisema hastata Frenguelli, 1940 (not Lemmermann), Rev. Mus., La Plata, n.s., vol. 2, Paleont., No. 7, fig. 12b (only).

Corbisema trigona Zittel, Deflandre, 1950a, Microscopie, vol. 2, pp. 52/82-53/82, fig. 130.

Dictyocha triacantha fa. *minor* Desikachary and Maheshwari, 1956 (not Schulz), Ind. Bot. Soc., Jour., vol. 35, No. 3, p. 258, text-fig. 2.

Dictyocha triacantha var. *triacantha* fa. *triacantha* Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, pp. 226-227, pl. 4, figs. 1-6; pl. 5, figs. 1-4.

Corbisema triacantha (Ehrenberg), Mandra, 1968, Calif. Acad. Sci., Proc., ser. 4, vol. 36, No. 9, p. 249, figs. 28, 31.

Remarks. — The basal body ring of this species is triangular in shape and is on a plane, in comparison with the following taxon; and the apical plate, if present, is definitely rarely developed. Because of considerable variation in size and shape, as well as in length of radial spines, some smaller specimens with less well-developed radial spines cannot satisfactorily be differentiated from those of *Dictyocha triacantha* var. *minor.*

A good example of such a case is a specimen illustrated by Schulz (his fig. 25 a) as *D. t.* fa. *minor.* It should be noted that Schulz's figure 24 for the present species illustrates that the lumen of the basal body ring is clear at the three corners as well as in the radial spines but is lost completely at the middle of the basal ring. Gemeinhardt's specimen (fig. 28 a) from Mors Island even shows the septal structure at the apices. Ehrenberg's *D. triommata* is considered synonymous by Gemeinhardt and Glezer but is considered as *D. triacantha* var. *minor* in this paper. Gemeinhardt also included another of Ehrenberg's species, *D. trifenestra,* with the present taxon, but judging from the original figure, it may be related to *D. fibula;* therefore, *D. trifenestra* is excluded from the above synonymy list.

Dimensions. — Length of basal body ring, 18-35 μ.

Known geologic range. — Cretaceous to Miocene (late).

Occurrence. — The present species is recovered from middle Eocene DSDP sediments and Italian samples. From the experimental Mohole section, the species is recovered from the Luisian interval only (Parker, 1964; Bandy and Ingle, 1970).

Corbisema triacantha var. **flexuosa** Stradner Pl. 24, figs. 14-17

Corbisema triacantha var. *flexuosa* Stradner, 1961, Erdöl u. Kohle, vol. 14, No. 2, p. 89, pl. 1, figs. 1-8.

Dictyocha triacantha var. *flexuosa* (Stradner), Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 228, pl. 5, figs. 5 (?), 10 (only).
Corbisema triacantha var. *flexuosa* fa. II Bachmann, 1970b, *in* Cat. Fossil. Austriae, No. 1b, p. 16.

Remarks. — One of the samples that Alfred Bachmann provided the writer is from Wallern, Austria, the type locality for the present *variety* and typical of such specimens is here presented with both apical and lateral views (Pl. 24, figs. 14, 15). During the present study, this taxon was found only from Italian land samples. Glezer (1966) recorded the occurrences in Russia as late Eocene to late Oligocene, but only figure 10 from Mangyshlak Peninsula of late Oligocene age seems to agree with the original concept of Stradner; while figure 5, an early Oligocene Ukrainian specimen has a dentate basal body ring, but such is never observed by Stradner nor so far by the present author from Wallern samples. Figures 6 and 8 of Glezer (*op. cit.*) are from the Ural-Caspian area and are of late Eocene age, but the former shows a straight triangular basal body ring with strongly crenulate (?) surface ornamentation, which is unusual for these forms. Nevertheless it is better considered as *C. triacantha* var. *triacantha*, while the latter has short radial spines as well as a smoothly concaved basal body ring, and may be regarded as *C. t.* var. *minor*. Therefore, some of the above-discussed questionable specimens of Glezer have been excluded from the present taxon.

Dimensions. — Diameter of basal body ring, 20-30 μ.

Known geologic range. — Possible Oligocene (late) only.

Occurrence. — Found the present taxon only from Italian outcrop samples between sample WRE 67-99 and -95 which is identified as *Calocycletta virginis* Zone (Sanfilippo, 1971).

Corbisema triacantha var. **minor** (Schulz) Pl. 24, figs. 18-23

Dictyocha triacantha fa. *minor* Schulz, 1928, Bot. Archiv., vol. 21, No. 2, p. 247, fig. 25b (only).
Dictyocha triacantha fa. *minor* Schulz, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, p. 41 (not fig. 29a or b).
Not *Dictyocha triacantha* fa. *minor* Schulz, Desikachary and Maheshwari, 1956, Ind. Bot. Soc., Jour., vol. 35, No. 3, p. 258, text-fig. 2.
Corbisema trigona (Zittel), Tynan, 1957, Micropaleont., vol. 3, No. 2, pp. 130-131, pl. 1, fig. 1 (only).
Corbisema triacantha fa. *minor* (Schulz), Bachmann, 1963, *in* Bachmann, *et al.*, Geol. Ges. Wien, Mitt., vol. 56, No. 1, p. 151, pl. 17, figs. 28-32 (not fig. 33).

Dictyocha crux Ehrenberg, Bachmann, 1964 (part), *in* Ichikawa, *et al.*, Kanazawa Univ., Sci. Rept., vol. 9, No. 1, p. 103, pl. 4, figs. 38-39 (only) (as trigonale Abwandlungen).
Dictyocha triacantha var. *triacantha* fa. *minor* Schulz, Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, pp. 227-228, pl. 5, figs 7-9.
Dictyocha crux fa. *trigona* Frenguelli, Bachmann, 1967, *in* Ichikawa *et al*., Kanazawa Univ., Sci. Rept., vol. 7, No. 1, p. 157, pl. 4, figs. 1-6, 8 (only).

Remarks. — The above synonymy list is presented as a first approach to prepare this taxon for future possible stratigraphic use. The specimens here considered are smaller than other *varieties* of the species, generally with shorter radial spines, and furthermore they generally have convex sides with rounded apices showing a roundly triangular basal body ring. Apical structure consists of lateral rods forming a Y, or occasionally with a small apical plate. Basal accessory spines are short, if present. Size range and some larger specimens admittedly approach to its type *C. triacantha,* and in some cases the separation is difficult.

Thus Schulz's figure 25a is considered in the present paper as *C. triacantha,* and similar consideration is applied to some of Bachmann's illustrations from Austria and Japan. Schulz's figure 26b from Mors Island clearly possesses an apical accessory spine and so far no such specimen has been observed; the specimen from Mors Island is excluded from the present taxon.

Dimensions. — Length of basal body ring, 16-25 μ.

Known geological range. — Eocene (early) to Miocene.

Occurrence. — The latest occurrence for the present taxon in the experimental Mohole section is the same as *C. triacantha,* and *Cannopilus sphaericus;* however in the Mediterranean region, it is found slightly higher than that of *C. triacantha.*

Genus **DICTYOCHA** Ehrenberg, 1839

Dictyocha ausonia Deflandre Pl. 25, figs. 1-10

Dictyocha pons Ehrenberg, 1844a, Verh. K. Preuss. Akad. Wiss. Berlin, Ber., Jahrg. 1844, pp. 64 (in table, name only), 80.
Dictyocha pons Ehrenberg, 1854, Mikrogeologie, pl. 21, fig. 40.
Dictyocha navicula var. *pons* (Ehrenberg), Lemmermann, 1901b, Deutsch. Bot. Ges., Ber., vol. 19, p. 258.
Not *Dictyocha ausonia* Deflandre, Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 252, pl. 9, fig. 1.
Dictyocha ausonia Deflandre, Hajos, 1968, Geol. Hungarica, ser. Paleont., fasc. 37, pp. 65-66, pl. 3, fig. 11 (only).
For others, see Ling (1970, pp. 88-90) as *D.* cf. *ausonia* Deflandre.

Remarks. — The present species, Deflandre (1950a) originally described from Miocene Diatomite of Italy, and at the same time presented a series of variations. On the basis of central north Pacific deep-sea sediments, Ling (1970) discussed in detail the present taxon, as D. cf. *ausonia,* and expressed some hesitation in accepting completely Deflandre's species concept mainly because no complete range of intraspecific variation was observed at that time. The present study now reveals that there is a wide range of intraspecific variation as Deflandre claimed, but radial spines on the minor axis do not disappear as readily as Deflandre illustrated. Actually, if radial spines disappear completely, it is perhaps after the gradual disappearance of two lateral windows on the minor axis (see Pl. 25, figs. 5-8). A middle Miocene species, *Dictyocha pons,* proposed and illustrated by Ehrenberg from Oran, Algeria, which is similiar to Plate 25, figure 7 here, is thus considered as a part of variation for the present species. Judging from the illustration, the size also seems to agree with such a conclusion.

On the other hand, *D. regularis* Carnevale (1908) is not considered as conspecific with the present species, as Deflandre (1950a) indicated and Ling (1970) suggested as a possibility, because of the definitely much longer radial spines on the major axis; the species is transferred to genus *Naviculopsis* and discussed later.

Glezer (1966) recorded the only Russian occurrence and referred to Deflandre's taxon; but judging from the illustration, as well as the remarks that Sakhalin specimens possess longer radial spines on the major axis, and such is not the case for the present species, the Russian specimens are excluded from the present taxon.

Dimensions. — Length of the basal body ring, 30-50 μ; of radial spines, 6-14 μ.

Known geologic range. — Miocene.

Occurrence. — Apparently the present species ranges from WAH 7P, 259-260 cm, *Calocycletta virginis* Zone and N.5 planktonic foraminiferal Zone (Riedel and Sanfilippo, 1970) to EM 6-2, 30-32 cm, which is the top of Delmontian and Mohnian or Mohnian (Parker 1964) and the boundary between Mohnian and Delmontian stages (Bandy and Ingle, 1970).

Dictyocha fibula Ehrenberg Pl. 25, figs. 11-15

Remarks. — As in the previous investigation of central north

Pacific sediments, this species encompasses the wide variation and *forma* previously reported by various workers from all over the world (see Mandra 1968; Glezer, 1966).

Dimensions. — Length of basal body ring, 30-45 μ; of radial spine, 5-16 μ.

Known geologic range. — Eocene to Recent.

Occurrence. — Found from WR TR 11, Low (Bo. 202), *Dorcadospyris alata* Zone (Riedel and Sanfilippo, 1970), to modern sediments in many parts of the world.

Dictyocha fibula var. **aculeata** Lemmermann Pl. 25, figs. 16, 17

Remarks. — The synonymy list, discussions and dimensions were presented previously by the present writer (Ling, 1970).

Known geologic range. — Quaternary.

Occurrence. — This *variety* is recovered from DSDP 9-5-2, 99-100 cm, N.22 planktonic foraminiferal Zone (Blow, 1970, pp. 357, 360) to Recent.

Dictyocha fibula var. **messanensis** (Haeckel) Pl. 25, figs. 18, 19

Remarks. — The detailed taxonomic consideration was presented by the author (Ling, 1970).

Known geologic range. — Quaternary.

Occurrence. — Like *D. f.* var. *aculeata,* this *variety* is recovered from DSDP 9-5-2, 99-100 cm to Recent.

Dictyocha fibula var. **octagona** Tsumura Pl. 26, figs. 1, 2

Not *Dictyocha octonaria* Ehrenberg, 1844b, Verh. K. Preuss. Akad. Wiss. Berlin, Ber., Jahrg. 1844, p. 201.

Not *Dictyocha octonaria* Ehrenberg, Deflandre, 1950a (part), Microscopie, vol. 2, fig. 37 (only).

Dictyocha fibula var. Tsumura, 1959, Yokohama Munic. Univ., Bull., vol. 11, Nat. Sci., No. 1, p. 66, pl. 4, figs. 47-49 (*fide* Tsumura, 1963).

Dictyocha fibula var. *octagona* Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, p. 55, pl. 10, figs. 11-13; pl. 23, figs. 8-10 (as *D. octagona* on p. 55).

Remarks. — The illustrated specimens agree with the species proposed by Tsumura from Tsubaki, Sado Island, Niigata Prefecture of Japan.

Tsumura questionably correlated his present species with Ehrenberg's *D. octonaria,* but in the original description, Ehrenberg indicated its close relationship with another form, *D. ornamentum,* which in turn is related to *Distephanus speculum.* Tsumura also correlated his specimen with one (fig. 37) of Deflandre's *Dictyocha octonaria,* but judging from the illustration, Deflandre's specimen possesses small apical accessory spines on an apical bar, lateral rods, and basal accessory spines, and no such specimen has been found during the present study; therefore, both Ehrenberg's and Deflandre's species are excluded from the present *variety.*

Dimensions. — Length of basal body ring, 20-30 μ; of radial spines, 10-14 μ.

Known geologic range. — Listed only as fossil, according to Tsumura.

Occurrence. — This *variety* is found from AMPH 6P, 50-51 cm, *Dorcadospyris alata* Zone and N.11 planktonic foraminiferal Zone (Riedel and Sanfilippo, 1970), to EM 7-1, 14-15 cm, N.12 planktonic foraminiferal Zone, according to Riedel and Sanfilippo (*op. cit.*). Martini (1971b) indicated his *Dictyocha octagona* horizon from the Deep Sea Drilling Project Leg VII in the equatorial Pacific region, but did not list it in another article (1971a).

Dictyocha hexacantha Schulz **Pl. 26, fig. 3**

Dictyocha hexacantha Schulz, 1928, Bot. Archiv., vol. 21, No. 2, p. 255, fig. 43.

Dictyocha hexacantha Schulz, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, pp. 55-56, fig. 46.

Dictyocha hexacantha Schulz, Hanna, 1931, Mining in California, vol. 27, No. 2, p. 198, pl. D, fig. 7.

Dictyocha deflandrei fa. *hexacantha,* Frenguelli, 1940, Rev. Mus. La Plata, n.s., vol. 2, Paleont., No. 7, p. 65, fig. 14g (only).

Corbisema hexacantha (Schulz), Deflandre, 1950a, Microscopie, vol. 2, pp. 65/82-66/82, figs. 183-187.

Dictyocha hexacantha Schultz, Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 239, pl. 10, fig. 12.

Description. — Basal body ring, triangular with convex side; three radial spines, short, at the apices; apical structure simple, consisting of three lateral rods that meet near the center and extend the distal ends beyond the basal body ring, thus showing six radial spines in apical or abapical view; basal and apical accessory spines absent.

Remarks. — Schulz (1928) described and illustrated the present species from Oamaru, and a specimen here presented (Pl. 26, fig. 3) is from sample S136/964, Forrester's Hill section of Oamaru Diatomite, New Zealand.

Results of the preliminary observation so far made, including some Eocene samples from California and New Zealand, reveal that the shape of the present species is better considered basically as triangular rather than hexagonal. The so-called six radial spines from which the name of the present species was apparently derived actually are three radial spines at the three apices and three extensions of lateral rods of apical structure that intersect approximately at the middle of the basal body ring. Thus, it may not be surprising that the apical structure and such distal extension are similar to "propeller-like structure" that Mandra (1969, lower-right figure on p. 173) observed from Antarctic deep-sea samples.

Dimensions. — Length of basal body ring, 20-26 μ.

Known geologic range. — Eocene to Oligocene (early ?). In addition to Schulz's finding from Oamaru Diatomite, Hanna (1931) reported the present species from Kreyenhagen Shale (Eocene) of California. Although Mandra (1968) failed to find the present species during his study, this author found the present species from Sidney Shale during preliminary examination. Deflandre (1950a) added the Springfield, Barbados occurrence, which is now regarded as Eocene age (Loeblich, III, *et al.*, 1968, p. 18), and not Miocene (early ?) as indicated by Deflandre (*op. cit.*) or Glezer (*op. cit.*, p. 239). The "early Oligocene (?)" occurrence is reported by Glezer from Ukrainian, Russian.

Occurrence. — This species is recovered only from DSDP 6-4-1, 6-8 cm, upper part of the *Globigerapsis kugleri* Zone (Ewing, *et al.*, 1969) and the *Thyrsocyrtis triacantha* Zone (Riedel, 1971). The species is observed in the reference samples from Oamaru Diatomite, New Zealand, and Sidney Shale, California.

Dictyocha sp. Pl. 26, figs. 4-8

Dictyocha fibula var. *fibula* fa. *rhombica* Glezer, 1966 (not Schulz, Lemmermann nor Ling), *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 249, pl. 15, figs. 5, 7 (?), 9 only.

Description. — Basal body ring, rhombic with almost straight sides; radial spines present, two on the major axis always longer, sometimes longer than those on the minor axis; apical bar along the minor axis like *D. ausonia;* four lateral windows of approximately similar size or two on the minor axis slightly smaller but so far never disappearing as *D. ausonia.* Basal accessory spines, either present on abapical side of junction of lateral rods and basal body ring, or slightly to the side of the junction, or sometimes absent.

Remarks. — Because of the nature of radial spines, particularly those on the major axis, the shape of skeleton is extremely variable, but the basal body ring is definitely rhomboid.

A similar silicoflagellate was discussed as *D. fibula* var. *rhombica* by Schulz (1928, fig. 37) and Ling (1970), and *D. fibula* var. *rhombus* by Lemmermann (1901b), but none of them are related to the forms illustrated here. Glezer (1966) recorded a few Russian specimens that seem to be conspecific, but it is believed that Glezer erred by referring to Schulz's or Lemmermann's species. Furthermore Glezer's figure 4, which is from Mondaino (?), Italy, seems to belong to *D. ausonia;* therefore, comparison with Russian material will be definitely necessary before the new name can be established for the present species.

Another Russian Eocene form, *D. fibula* var. *fibula* fa. *eocaenica* Krotov, according to Glezer (*op. cit.,* p. 249, pl. 15, fig. 6; pl. 32, fig. 5), is synonymous with *D. fibula* fa. *rhombica* Schulz *sens* Gemeinhardt, fig. 40a (only) but has dentate surface and is larger than the present taxon.

Dimensions. — Length of basal body ring, 26-40 μ; of radial spine 6-20 μ.

Occurrence. — This species is found in samples ranging from WR TR 11, Low (Bo. 202), in many Mohole samples to LSDH 78 P, 516-517 cm, *Spongaster pentas* Zone (Riedel and Sanfilippo, 1970).

Genus **DISTEPHANUS** Stöhr, 1880

Distephanus crux (Ehrenberg) Pl. 26, figs. 9-16

Remarks. — As in previous studies (Ling, 1970, 1971), wide intra- and infraspecific variation is recognized under the present species, except those *varieties* recognized below.

Dimensions. — Length of basal body ring, 24-36 μ; of radial spines, 8-24 μ.

Known geologic range. — Eocene to Miocene (late). Pliocene (?), Quaternary (?). Late Miocene to Pliocene occurrence recorded by Glezer (1966, p. 262) from Noto Peninsula and Kanzawa area, Honshu Island, Japan, is more likely to be Miocene (late) only. Quaternary occurrences reported by Glezer (*op. cit.*) from intermoraine layer, Ladoga area, Raukhiala, Russia, and interglacial deposits from Finland need to be reexamined.

Occurrence. — This species is found during the present study from sample WR TR 23, (K9391), *Calocycletta costata* Zone (Riedel and Sanfilippo, 1970), to EM 6-2, 10-11 cm which is considered as Delmontian by Bandy and Ingle (1970) or upper Miocene by Martini and Bramlette (1963). Mandra (1968) reported the Californian occurrence for the present species from Relizian, Mohnian and Delmontian stages.

Distephanus crux var. **longispina** Schulz Pl. 26, figs. 17-19

Distephanus crux fa. *longispina* Schulz, 1928, Bot. Archiv., vol. 21, No. 2, p. 256, fig. 44.

Distephanus crux var. *longispina* Schulz, Stradner, 1961, Erdöl u. Kohle, vol. 14, No. 2, p. 92, fig. 56 (only).

Dictyocha crux fa. *longispina* (Schulz), Bachmann and Ichikawa, 1962, Kanazawa Univ., Sci. Rept., vol. 8, No. 1, p. 169, pl. 2, figs. 16, 17 (?), 18, 19 (only).

Dictyocha crux fa. *longispina* (Schulz), *Bachmann,* 1963, in Bachmann *et al.*, Geol. Ges. Wien, Mitt., vol. 56, No. 1, p. 148, pl. 16, fig. 16.

Dictyocha crux Ehrenberg, Hajos, 1968 (part), Geol. Hungarica, ser. Paleont., fasc. 37, p. 65, pl. 3, figs. 8, 9 (only).

Dictyocha crux var. *longispina* (Schulz), Bachmann, 1970a, Verh. Geol. B.-A., Jahrg. 1970, No. 2, p. 287, pl. 4, figs. 15-17; pl. 5, figs. 1-9.

Distephanus crux var. *longispina* Schulz, Bachmann, 1970b, *in* Cat. Fossil. Austriae, No. Ib, p. 9.

Remarks. — The present *variety* is characterized, as Bachmann described (1970a, p. 287), by the relatively long radial spines along the major axis, relatively large apical ring, and above all, by a highly arched apical structure which is in turn supported by high-angled lateral rods (see Pl. 26, fig. 17).

The sudden and common appearance of this *variety* in the experimental Mohole section is significant. With the consideration that Schulz's original figure for his *forma* came from Santa Monica, California, which is considered as Helvetian stage by Loeblich, III, *et al.* (1968), the specimens from Mohole sediments are assumed to be identical with that of Schulz.

Dimensions. — Length of basal body ring, 28-36 μ; of radial spines, 16-28 μ.

Known geologic range. — Miocene.

Occurrence. — Throughout the present study, the specimens referred to the present taxon are found only from experimental Mohole samples, from EM 8-15, 505-506 cm, to EM 8-11, 69-70 cm, the latter of which is recorded as *Ommatartus antepenultimus* - *Cannartus (?) petterssoni* Zone and N.15 planktonic foraminiferal Zone (Riedel and Sanfilippo, 1970).

Distephanus crux var. **octacanthus** Desikachary and Maheshwari
Pl. 26, figs. 20-22

Distephanus crux var. *octacanthus* Desikachary and Maheshwari, 1956, Ind. Bot. Soc., Jour., vol. 35, No. 3, pp. 260-261, text-figs. 10, 12, 13; pl. 13, figs. 8, 9.

Remarks. — As discussed by Desikachary and Maheshwari from upper Miocene samples of Nicobar Island, the present taxon is characterized by an octagonal basal body ring; and two radial spines on the major axis are much longer than the other six. The specimens found during the present study agree with the above original description and illustrations. Apparently the size and shape demonstrated during the present study show limited infraspecific variation.

Glezer (1966, p. 263) included the present *variety* within a part of *Distephanus stauracanthus* (Ehrenberg), but they are different morphologically and should be regarded as separate taxa (compare with Ling, 1970, pl. 19, figs. 7, 8).

Dimensions. — Length of basal body ring, 24-30 μ; of radial spines, 8-16 μ

Known geologic range. — Miocene.

Occurrence. — Martini (1971a, b) noticed the limited occurrence of the present taxon in the DSDP Leg VII samples and placed his *Dictyocha octacantha* horizon near the top of his *Corbisema triacantha* Zone. This horizon, according to him, is time equivalent with the middle of NN.6 calcareous nannoplankton, approximately at the bottom of N.12 planktonic foraminiferal and middle part of *Dorcadospyris alata* radiolarian Zones. Throughout the present study this *variety* has occurred in the experimental Mohole samples, interval between EM 7-2, 6-7 cm and EM 7-1, 14-15 cm.

Distephanus speculum (Ehrenberg) Pl. 26, figs. 23, 24; Pl. 27, figs. 1, 2

Remarks. — As pointed out in previous studies from the central north Pacific deep-sea sediments and Shinzan diatomaceous member, Akita Prefecture, Japan (Ling, 1970, 1971), the synonymy for the present species has been presented by numerous workers on this subject.

Dimensions. — Length of basal body ring, 18-40 μ; of radial spines, 6-30 μ.

Known geologic range. — Eocene to Recent.

Occurrence. — *D. speculum* is found from sample WAH 7P, 516-517 cm, N.4 foraminiferal and *Calocycletta virginis - Lychnocanium bipes* Zones (Riedel and Sanfilippo, 1970), throughout many of the Mohole and Mediterranean samples to LSDA 101G, 38-39 cm sample, which is N.17 or 18 foraminiferal and *Spongaster pentas* radiolarian zones (Riedel and Sanfilippo, 1970). Occurrence of the present species is recognized in various parts of the world by many investigators.

Distephanus speculum var. **pentagonus** Lemmermann Pl. 27, figs. 3, 4

Distephanus asteroides Haeckel, 1887, Rept. Voy. *Challenger,* Zool., vol. 18, p. 1564.
Distephanus speculum var. *pentagonus* Lemmermann, 1901b, Deutsch. Bot. Ges., Ber., vol. 19, p. 264, pl. 11, fig. 19.
Distephanus speculum var. *pentagonus* Lemmermann, Schulz, 1928, Bot. Archiv., vol. 21, No. 2, pp. 263-264, fig. 57.
Distephanus speculum var. *pentagonus* Lemmermann, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, pp. 65-67.
Dictyocha speculum Ehrenberg, Stradner, 1961 (part), Erdöl u. Kohle, vol. 14, No. 2, p. 92, figs. 72, 73 (only).
Dictyocha speculum fa. *pentagona* (Lemmermann), Bachman, 1963, *in* Bachmann *et al.,* Geol. Ges. Wien, Mitt., vol. 56, No. 1, p. 150, pl. 21, fig. 3.
Distephanus speculum var. *pentagonus* Lemmermann, Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, pp. 267-268, pl. 21, figs. 1-5.
Distephanus speculum var. *pentagonus* Lemmermann, Bachmann, 1970b, *in* Cat. Fossil. Austriae, No. Ib, p. 10.

Remarks. — In contrast to the previous work from the central north Pacific deep-sea sediments (Ling, 1970), an attempt was made during the present study to examine the biostratigraphic distribution of the present *variety* by recognizing it as an independent taxon. At least in the experimental Mohole samples, the present *variety* has a limited stratigraphic occurrence (see below).

Haeckel (1887) proposed the new species from *Challenger* station 272 but did not give any illustration. As the sample contains numerous Tertiary Radiolaria (Riedel, 1957), and judging from the size, it seems that the species named by Haeckel may be considered synonymous and, therefore, it is included here. Apparently Glezer regarded the present *variety* in a broader sense by including Lemmermann's *Distephanus speculum* var. *pentagonus* fa. *armata* (1901b, pp. 264-265, pl. 11, fig. 20) which possesses apical accessory spines on the apical ring. So far no such specimen has been recovered in the present study; hence the *forma* of Lemmermann's is not included. Glezer (1966) also synonymized a part of Hanna's *Distephanus variabilis* (1931, pl. E, fig. 8 only), but the size for the latter is much bigger and the basal body is much thicker than for the present species. Eocene samples from California need to be studied in the future, and therefore, Hanna's species name is excluded from the present taxon at this time.

Dimensions. — Length of basal body ring, 20-26 μ; of radial spine, 8-16 μ.

Known geologic range. — Eocene to Neogene, Quaternary (?). Occurrence for the *variety* reported by Glezer (1966) from the intermoraine layer of Ladoga area needs to be reexamined.

Occurrence. — During the present study, specimens identified as the present taxon are found only in samples from experimental Mohole drilling material from EM 8-12, 94-95 cm to EM 8-11, 322-323 cm. Thus from the analysis of the Mohole samples, they are recovered from the middle (Parker, 1964) or lower (Bandy and Ingle, 1970) Mohnian stage. Whether such limited stratigraphic occurrence is a local phenomenon needs to be examined in the future in other areas. Mandra (1968) observed the California land occurrence only from Delmontian samples.

Distephanus speculum var. **pseudocrux** Schulz Pl. 27, figs. 5-7

Distephanus speculum fa. *pseudocrux* Schulz, 1928, Bot. Archiv., vol. 21, No. 2, p. 263, fig. 52a, b.
Distephanus speculum fa. *pseudocrux* Schulz, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, p. 64, fig. 55.
Distephanus speculum fa. *pseudocrux* Schulz, Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, p. 63, pl. 11, figs. 2, 3.
Distephanus japonicus fa. *pseudofibula* Glezer, 1966 (part), *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 276, pl. 25, figs. 1, 3, 5 (?) (only).
Distephanus speculum (Ehrenberg), Mandra, 1968 (part), Calif. Acad. Sci., Proc., ser. 4, vol. 36, No. 9, p. 262, fig. 76 (only).

Remarks. — The figure (see Pl. 27, fig. 5) illustrated here agrees with the form originally described by Schulz. Similar apical structure can be found also in specimens with a pentagonal basal body ring but rarely, while another figure (see Pl. 27, fig. 6) is considered as an example of morphological variation for the present *variety.*

Glezer (1966) combined the present and the following taxon as *Distephanus japonicus* (Deflandre), which possesses the characteristic apical accessory spine(s) according to original species diagnosis but no such specimen was encountered during the present study. Furthermore as can be seen from the distribution chart (Text-figure 4), the two *varieties* are not always found together, such as in the eastern Bering Sea margin samples (see below); therefore, they are considered as separate taxa in the present study.

Dimensions. — Length of basal body ring, 24-30 μ; of radial spine, 8-12 μ.

Known geologic range. — Neogene, most likely only Miocene.

Occurrence. — The present taxon is found only from the Mohole samples interval between EM 8-10, 78-79 cm, and EM 8-9, 148-149 cm. The age of this part is identified as upper Mohnian by Bandy and Ingle (1970), Delmontian and Mohnian or Mohnian by Parker (1964), and upper Miocene by Martini and Bramlette (1963).

Distephanus speculum var. **pseudofibula** Schulz Pl. 27, figs. 8-13

Distephanus speculum fa. *pseudofibula* Schulz, 1928, Bot. Archiv., vol. 21, No. 2, pp. 262-263, fig. 51a, b.
Distephanus speculum fa. *pseudofibula* Schulz, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, p. 64, fig. 54.
Distephanus speculum fa. *pseudofibula* Schulz, Deflandre, 1932a, Soc. France, Microsc., Bull., vol. 1, No. 1, fig. 46.
Dictyocha pseudofibula (Schulz), Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, pp. 55-56, pl. 11, figs. 1-3; pl. 24, fig. 2.
Dictyocha pseudofibula var. *complexa* Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, pp. 56-57, pl. 11, fig. 4; pl. 24, fig. 1.
Distephanus japonicus fa. *pseudofibula* Schulz, Glezer, 1966 (part), *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 276, pl. 24, figs. 4, 6-8, 10.

Remarks. — As indicated under the preceding taxon, the combination by Glezer *(op. cit.)* seems undesirable as well as misleading; therefore, Glezer's usage is not followed in this study.

This *variety* is described originally by Schulz from San Pedro and Redondo, California, Abashiri of Japan, and Ngemegy of Hungary, and all are fossil forms. Tsumura found his *var. complexa* from a Modern sea sample near Japan, and it is the only Quaternary record.

Recently Hopkins *(et al.,* 1968) reported the *variety* (as *Dicty-*

ocha pseudofibula) from the eastern margin of the continental slope of the Bering Sea. By courtesy of David W. Scholl of the U.S. Geological Survey at Menlo Park, the TT-2 and -4 samples (TT18-02 and TT18-04 respectively) were examined, and they are illustrated here (Pl. 27, figs. 11-13) for comparison.

Dimensions. — Length of basal body ring, 26-32 μ; of radial spine, 7-14 μ.

Known geologic range. — Miocene to Quaternary (?).

Occurrence. — Throughout the present study, the present *variety* is found only from experimental Mohole samples, and the interval between samples of EM 8-10, 78-79 cm, and EM 6-2, 10-11 cm, upper Mohnian to Delmontian. Martini (1971a, b) recognized his *Dictyocha pseudofibula* horizon from the DSDP Leg VII, which is correlated with NN.10 calcareous nannoplankton, N.16 foraminiferal and lower part of *Ommatartus antepenultimus* radiolarian Zones. Judging from the stratigraphic position, it is possible that occurrence within the Mohole section is time-equivalent with that of the above western equatorial Pacific. The Bering Sea dredge haul samples are, therefore, regarded as of late Miocene age rather than late middle Miocene as previously assumed *(op. cit.,* p. 1475).

Genus **LYRAMULA** Hanna, 1928

Remarks. — Since the genus and two species were first described by Hanna (1928), the exact nature of the forms has remained uncertain. Thus, Gemeinhardt (1930) and Frenguelli (1940) excluded the genus, and Lipps (1970) regarded them as questionable silicoflagellates and suggested their possible affinities as "the setae of several species of *Chaetoceros*-like diatoms, from which the frustule has been dissolved." This may be possible because of selective dissolution, the delicate frustules of *Chaetoceros* are rarely found in bottom sediments despite the fact that they are abundant in plankton both in numbers of species and individuals (Kanaya and Koizumi, 1966). However *Chaetoceros* frustule with setae, but not the setae alone, have been reported from deep-sea sediments and Tertiary deposits by several diatom researchers; such as Koizumi (1968), Kozlova (1964), Jousé (1962), Sheshukova-Poretzkaya (1967), and the author has also found such specimens from surface sediments of various parts of the world oceans. Therefore, the forms illustrated here from Cretaceous materials under the present genus *Lyramula* are too distinctive to be considered as a part of diatoms at present.

At the same time, microfossils similar to the *Lyramula* species have been described by Tsumura (1963) as *L. tenuipertica* Kokubo et Tsumura (pp. 30-31, pl. 3, fig. 3; pl. 16, fig. 5) from Japan and *L. tenuipertica* var. *laevis* Tsumura (p. 31, pl. 3, fig. 5; pl. 16, fig. 3) from California. Recently Hopkins (*et al.*, 1969, p. 1477) recorded the occurrence of *L. tenuipertica* from the dredge haul of TT18-3 (as TT-3) from the continental margin of the Bering Sea.

Numerous specimens were observed similar to Tsumura's species during the present study, and an example is shown here. One specimen is from a sample, DSDP 9-5-2, 99-100 cm, identified as belonging to the N.22 planktonic foraminiferal Zone (Blow, 1970), and possessing the surface structure of "roughly an alternate scalariform" (Tsumura, 1963, p. 30). Under careful examination, the specimen does not show the hollow structure of the rods like the *Lyramula* species from Upper Cretaceous, and such difference is apparent under phase contrast microscopy (compare Pl. 27, figs. 14, 15 vs. 16, 17). The affinity of *Lyramula tenuipertica* remains uncertain, and therefore, is excluded from the present paper.

Lyramula furcula Hanna — Pl. 27, figs. 16-18

Lyramula furcula Hanna, 1928, Jour. Paleont., vol. 1, No. 4, p. 262, pl. 41, figs. 4, 5.
Lyramula furcula Hanna, Deflandre, 1940b, Acad. Sci. Paris, C. R., vol. 211, No. 21, p. 509, figs. 1-4.
Lyramula furcula Hanna, Deflandre, 1950a, Microscopie, vol. 2, p. 61/82, figs. 163, 165, 167, 169.
Lyramula furcula Hanna, Tsumura, 1959, Yokohama Munic. Univ., Bull., vol. 11, Nat. Sci., vol. 1, p. 43, pl. 1, figs. 1-2 (*fide* Tsumura, 1963).
Lyramula furcula Hanna, Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-44, No. 146, pp. 29-30, pl. 1, figs. 1; pl. 3, figs. 1-2; pl. 16, figs. 1-2.
Lyramula furcula Hanna, Mandra, 1968, California Acad. Sci., Proc., ser. 4, vol. 36, No. 9, p. 256, figs. 7, 8, 13.
Lyramula furcula Hanna, Glezer, 1966 (part), *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 221, pl. 2, figs. 3, 5-7.

Remarks. — Deflandre (1950a, figs. 167-169) illustrated specimens with one or more lateral rods as a premutant form of the present species, but the topotypic sample, CAS 1144, did not yield such specimens.

Dimensions. — Length of lateral rods (from the base of Y), 45-55 μ.

Known geologic range. — Cretaceous (late) to Paleocene (early). Glezer reported the early Paleocene occurrence from western Siberia, Russia.

Occurrence. — The species is found to be abundant but only in the topotypic material from California. Therefore, Mandra (1968, p. 242) concluded that the present species seems to be restricted stratigraphically to the late Cretaceous, at least from California.

Lyramula furcula var. **minor** Deflandre Pl. 27, figs. 19-21

Lyramula furcula var. *minor* Deflandre, 1940b, Acad. Sci. Paris, C. R., vol. 211, No. 21, p. 509, figs. 7-10.
Lyramula furcula Deflandre, 1950a, Microscopie, vol. 2, pp. 62/82-63/82, figs. 170-173.
Lyramula furcula Hanna, Glezer, 1966 (part), *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 221.

Remarks. — Similar to the preceding taxon except that the present *variety* is smaller in size (approximately one-half), and frequently has a third lateral rod; thus the three rods are approximately 120° apart (see Pl. 27, fig. 21). Glezer (1966) considered that the present small size is within the range of variation of the type.

Dimensions. — Length of lateral rods (from the base of Y), 28-35 μ.

Known geologic range. — Cretaceous (late).

Occurrence. — *L. furcula* var. *minor* is found only from the CAS locality 1144 and rarely. Mandra studied a sample which came from nearby this locality but failed to find the *variety*.

Lyramula simplex Hanna Pl. 28, fig. 1

Lyramula simplex Hanna, 1928, Jour. Paleont., vol. 1, No. 4, p. 262, pl. 41, fig. 6.
Lyramula simplex Hanna, Deflandre, 1940b, Acad. Sci. Paris, C. R., vol. 211, No. 21, p. 506, figs. 5, 6.
Lyramula simplex Hanna, Deflandre, 1950a, Microscopie, vol. 2, pp. 62/82-62/82, figs. 164, 165.
Lyramula simplex Hanna, Tsumura, 1959, Yokohama Munic. Univ., Bull., vol. 11, Nat. Sci., vol. 1, p. 46, pl. 1, fig. 4 (*fide* Tsumura, 1963).
Lyramula simplex Hanna, Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, p. 31, pl. 1, fig. 2; pl. 3, fig. 4; pl. 16, fig. 4.
Lyramula simplex Hanna, Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 221, pl. 2, figs. 1, 2, 4.
Lyramula simplex Hanna, Mandra, 1968, Calif. Acad. Sci., Proc., ser. 4, vol. 36, No. 9, pp. 256-257, figs. 9, 10.

Remarks. — Specimen referred to here has thicker rods than the *L. furcula* and clearly possesses fine surface ornamentation, as Hanna (1928) originally described.

Dimensions. — Length of rods (from base of U), 82-90 μ.

Known geologic range. — Cretaceous (late).

Occurrence. — So far the present species is recovered rarely from CAS 1144, the type locality for the present species.

Genus **MESOCENA** Ehrenberg, 1839, emend. Deflandre, 1950a

Remarks. — In a previous article, Ling (1970) discussed in detail the taxonomic problems involved for a species, *Mesocena* cf. *elliptica*. At that time, the observation was based only on deep-sea sediments from the central north Pacific and also on the illustrations of the reference. Since then the study has been expanded by including many reference samples, and it is now possible to present additional data of the detailed investigation.

The occurrence of a silicoflagellate form referable to *Mesocena* was first described by Ehrenberg (1839, p. 129), and the figure was illustrated by Ehrenberg (1854, pl. 22, fig. 41) as *Dictyocha triangula* from Caltanisetta, Sicily.

It was Stradner who noticed in 1956 and 1961 for the first time that some of the *Mesocena* specimens possess septa ("Scheidewand" of Stradner) in the basal body ring. The structure can be detected if the specimen is carefully examined under the microscope but it is more easily detected and clearly illustrated by utilizing a phase contrast attachment. Stradner further stated that *Mesocena* with septa *(Mesocena septatae)* were derived from the genus *Corbisema*, while those without septa *(Mesocena aseptatae)* came from *Dictyocha*. Bachmann (1970b), then proposed the new genus *Septamesocena* for the former.

Mesocena apiculata (Schulz) Pl. 28, figs. 2-4

Mesocena oamaruensis var. *apiculata* Schulz, 1928, Bot. Archiv., vol. 21, No. 2, p. 240, fig. 11.

Mesocena polymorpha var. *triangula* Lemmermann, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, p. 28, fig. 12a (only).

Mesocena apiculata Schulz, Hanna, 1931, Mining in California, vol. 27, No. 2, pl. D, fig. 3.

Not *Mesocena apiculata* (Schulz), Deflandre, 1932c, Soc. Bot. France, Bull., vol. 79, Nos. 5, 6, p. 499, figs. 34, 35.

Not *Mesocena apiculata* (Schulz), Tynan, 1957, Micropaleont., vol. 3, No. 2, p. 134, pl. 1, fig. 10.

Not *Mesocena apiculata* (Schulz), Stradner, 1961, Erdöl u. Kohle, vol. 14, No. 2, p. 89, figs. 28, 29, 32.
Not *Mesocena apiculata* (Schulz), Bachmann, 1962, Geol. B.-A., Verh., Jahrg. 1962, No. 2, p. 379, figs. 10, 11.
Not *Mesocena apiculata* (Schulz), Bachmann, 1963, *in* Bachmann, *et al.*, Geol. Ges. Wien, Mitt., p. 152, pl. 19, figs. 60-62.
Not *Mesocena apiculata* (Schulz), Bachmann, 1964, *in* Ichikawa, *et al.*, Kanazawa Univ., Sci. Rept., vol. 9, No. 1, p. 107, pl. 4, fig. 36.
Mesocena aff. apiculata (Schulz), Glezer, 1966 (part), *in* Cryptogamic plants of the US.S.R., vol. 7, p. 282, pl. 28, fig. 5 (?); pl. 33, fig. 7, (not pl. 29, fig. 9).
Not *Mesocena apiculata* (Schulz), Hajos, 1968, Geol. Hungarica, ser. Paleont., fasc. 37, p. 67, pl. 4, fig. 3.
Not *Mesocena apiculata* (Schulz), Bachmann and Papp, 1968, Giorn. di Geol., ser. 2, vol. 35, fasc. 2, pl. 3, figs. 1, 2.
Not *Mesocena apiculata* (Schulz), Bachmann, 1970a, Geol. B.-A. Verh., Jahrg. 1970, pp. 280, 282, 284.

Remarks. — The above synonymy list is prepared to record that the various forms were referred to this species by numerous workers from many parts of the world. *M. apiculata* is differentiated from another species, *Septamesocena apiculata* Bachmann, which will be discussed later, by the absence of septal structure at the apices.

Dimensions. — Diameter of basal body ring, 36-46 μ; of radial spines, 2-6 μ.

Known geologic range. — Paleocene (?), Eocene, Miocene (?). The type locality for the present species is Oamaru Diatomite, New Zealand, of Eocene. The oldest occurrence, Paleocene, is reported by Glezer (1966) from the eastern slope of the Ural region, and it possesses a dentate basal body ring (pl. 28, fig. 5); such a specimen has not yet been observed from samples of Oamaru Diatomite. Another Paleocene specimen (pl. 33, fig. 7) from the same Russian location has a smooth basal body ring, but the structure at the three apices is obscured. It is conceivable that previous students of silicoflagellates may have overlooked the septal structure, and occurrence of the present species may be limited only to the Eocene age.

Occurrence. — *M. apiculata* is not found in the deep-sea sediments examined during the present study. The specimens here illustrated are from Bain's Farm (Pl. 28, figs. 2, 3) and Jackson's Paddock (Pl. 28, fig. 4) sections of Oamaru Diatomite, New Zealand, for comparison with similar forms, particularly with *Septamesocena apiculata.*

Mesocena circulus Ehrenberg Pl. 28, figs. 5, 6

Dictyocha (Mesocena) circulus Ehrenberg, 1840, Verh. K. Preuss. Akad. Wiss. Berlin, Ber., p. 208.
Mesocena circulus Ehrenberg, Ehrenberg, 1844a, Verh. K. Preuss. Akad. Wiss. Berlin, Ber., p. 65.
Dictyocha circulus Ehrenberg, Ehrenberg, 1854, Mikrogeologie, pl. 19, fig. 44.
Not *Mesocena circulus* Ehrenberg, Lemmermann, 1901b, Deutsch. Bot. Ges. Ber., vol. 19, p. 257.
Not *Mesocena circulus* Ehrenberg, Schulz, 1928, Bot. Archiv., vol. 21, No. 2, p. 242, fig. 14.
Not *Mesocena circulus* Ehrenberg, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, p. 33, fig. 18.
Mesocena circulus Ehrenberg, Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, p. 41 (not pl. 7, fig. 1).
Not *Mesocena circulus* Ehrenberg, Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, pp. 285-286, pl. 29, fig. 8.

Remarks. — This species is characterized by a circular to oval-shaped basal body ring with one series of radial spines generally in a plane.

Confusion about the present species has resulted from the beginning when Ehrenberg gave the original description of the present species as "*D. cellula unica circulari margine dentata* Diam. - 1/48. Fossils in marga Graeciae." The first illustration given by Ehrenberg (1854) came from upper Miocene, Aegina, Greece, and the margin can be interpreted as either coarsely dentate or as possessing about 17 short radial spines. The diameter of the specimen is over 50 μ according to Loeblich, III (*et al.*, 1968, p. 217, fig. 20). Lemmermann (1901b) added the Barbados and Caltanisetta (Sicily) as additional localities, and although referring to Ehrenberg's description and figure, he indicated the species as "Gehäuse kreisrund, 20-30 μ gross, glatt oder am äussern Rande schwach gezähnt." It is thus apparent that Lemmermann's specimens are about ½ the size of Ehrenberg's. Schulz (1928) followed Lemmermann's description, and the figure given from Mors Island is oval-shaped. Schulz at the same time observed that a specimen from Kusnetzk, Russia, has only a 14 μ diameter. Gemeinhardt (1930) followed Lemmermann's and Schulz's concept. Tsumura (1963) also recorded the present species, but his specimen (pl. 7, fig. 1) seems to possess two series of radial spines and should be transferred to *M. circulus* var. *apiculata*. Glezer (1966) also referred a specimen from the Ural (pl. 29, fig. 8) to the present species, but it shows a finely dentate margin and not radial spines. A similar form is reported by Hajos (1968) and classified as *M. elliptica* var. *circulus* which is later followed by Bachmann (1970b).

Dimensions. — Diameter of basal body ring, 68-72 μ; of radial spines, 3-6 μ.

Known geologic range. — Eocene to Miocene.

Occurrence. — The present species is recovered from two samples, EM 8-12, 26-28 cm, and EM 8-11, 69-70 cm only which are within Mohnian age by Parker (1964), Bandy and Ingle (1970), and Tortonian (?) of middle Miocene by Martini and Bramlette (1963).

Mesocena circulus var. **apiculata** Lemmermann Pl. 28, figs. 7, 8

Mesocena circulus var. *apiculata* Lemmermann, 1901b, Deutsch Bot. Ges., Ber., vol. 19, p. 257, pl. 10, figs. 9, 10.

Mesocena circulus var. *apiculata* Lemmermann, Schulz, 1928, Bot. Archiv., vol. 21, No. 2, pp. 242-243, fig. 15a, b, c.

Mesocena circulus var. *apiculata* Lemmermann, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, pp. 33-34, fig. 19.

Distephanus polyactis fa. *mesocenoidea* Deflandre, 1932c, Soc. Bot. France, Bull., vol. 79, Nos. 5, 6, fig. 41 (only).

Mesocena circulus var. *apiculata* Lemmermann, Zanon, 1934, Acta Pont. Acad. Sci. Nov. Lincei, vol. 87, p. 65, fig. 5.

Paradictyocha polyactis fa. *mesocenoidea* (Deflandre), Frenguelli, 1940, Rev. Mus. La Plata, n.s., vol. 2, Paleont., No. 7, p. 53, fig. 8b, d, e (?) (only).

Paradictyocha apliculata Lemmermann, Frenguelli, 1940, Rev. Mus., La Plata, n.s., vol. 2, Paleont., No. 7, p. 53, fig. 7h.

Mesocena circulus var. *apiculata* Lemmermann, Tsumura, 1959, Yokohama Munic. Univ., Bull., vol. 11, Nat. Sci., No. 1, p. 55, pl. 2, figs. 19-21 (*fide* Tsumura, 1963).

Mesocena circulus var. *apiculata* Lemmermann, Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, p. 41, pl. 6, figs. 7, 8; pl. 20, figs. 1-2.

Mesocena circulus Ehrenberg, Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, p. 41, pl. 7, fig. 1.

Paradictyocha polyactis fa. *mesocenoidea* Frenguelli, Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 278, pl. 28, fig. 1.

Remarks. — Ling (1971) discussed the present taxon in detail on the basis of Japanese Miocene specimens. Frenguelli's *Paradictyocha apiculata* from Sendai, Japan, seems likely to belong to the present taxon judging from the illustration.

Dimensions. — Diameter of basal body ring, 64-74 μ; of radial spines, 3-5 μ.

Known geologic range. — Eocene to Miocene. Schulz *(op. cit.,* fig. 15c) described the only Eocene form for the present *variety* from Oamaru, New Zealand. Examination of Oamaru Diatomite by the author so far has failed to recover such a specimen.

Occurrence. — Specimens identified as belonging to the present *variety* were found only from experimental Mohole samples from EM 7-1, 35-36 cm, to EM 6-2, 10-11 cm, with their occurrence apparently limited to only middle and late Miocene.

Mesocena cf. **elliptica** Ehrenberg Pl. 28, figs. 9-15; Pl. 29, figs. 1-3

Remarks. — As discussed by Deflandre (1932c), Glezer (1966), and Ling (1970), the taxonomy of the present species is one of the most uncertain among silicoflagellates. On the one hand, different taxonomic names were proposed, based on the number of radial spines (Ehrenberg, Lemmermann); and on the other hand, all these forms are grouped in only one species (Deflandre, Glezer). Because of this and because of the limited number of samples observed at that time, Ling (1970, 1971) referred to these forms as *M.* cf. *elliptica.* It is extremely unfortunate that Hajos (1968) and later Bachmann (1970b) proposed a new combination and grouped them as *M. elliptica,* apparently following Deflandre's practice (1932c), but then proposed *M. e.* var. *quadrangula* Bachmann and Ichikawa (1962) in place of *M. e.* var. *elliptica* (see Lanjouw, *et al.,* 1966, ICBN, Art. 25). Furthermore inclusion of *M. circulus* as one of the *variety* within this species also seems undesirable.

During microscopic examination, an effort was made to seek the biostratigraphic occurrences of the taxa even by recognizing separately those distinguished on the basis of the number of radial spines (see Text-figs. 3, 4, 7).

The following is apparent from the present study:

1. No specimen with three radial spines that may be referable to *Dictyocha triangula* and not *M. apiculata* or *Septamesocena apiculata* has been found.

2. The four-spine form, "*M. elliptica*", stratigraphically appears earlier and ends slightly later than the two-spine "*M. diodon*".

3. Only one specimen assignable to *M. hexagona* Haeckel (see Ling, 1971) is found from sample EM 8-13, 49-51 cm ("h" in Text-fig. 4).

4. Only a single specimen similar to *M. polymorpha* var. *quad-*

rangula Lemmermann (1901b) is found from sample WR TR 11, Low (Bo. 202) ("q" in Text-fig. 3).

As in previous articles, a wide range is considered for the present taxon.

Dimensions. — Length of basal body ring, 43-70 μ.

Known geologic range. — Eocene to Pleistocene

Occurrence. — In the Mediterranean section of Italy (see Text-figure 7), the initial appearance of so-called "*M. elliptica*" starts with the beginning of the *Calocycletta costata* radiolarian Zone (Sanfilippo, 1971), and apparently this seems the earliest for this form so far recognized during the present investigation. From other samples, the first occurrence is noticed from Trinidad sample, WR TR 11, Low (Bo. 202), which is assigned to the *Dorcadospyris alata* Zone by Riedel and Sanfilippo (1970). The highest stratigraphic occurrence of the four-spine form is in LSDA 101G, 38-39 cm which is N.17 or 18 foraminiferal Zone or *Spongaster pentas* Zone (Riedel and Sanfilippo, 1970).

On the other hand, the two-spine form *("M. diodon")* is found only from the Mohole samples, the interval between EM 8-15, 505-506 cm, to EM 6-2, 30-32 cm, ranging fom Luisian to Mohnian. Mandra (1968) indicated the range of his *M. crenulata* var. *diodon* from Valmonte Diatomite (Mohnian) to Buttle Diatomite (Delmontian).

The specimen of the "*M. hexagona*" is found in a sample of the lower Mohnian stage, but Mandra found his specimens from the Buttle Diatomite (Delmontian) of California.

Mesocena cf. **elliptica** var. **minoriformis** Bachmann and Papp

Pl. 29, figs. 4-7

Mesocena elliptica minoriformis Bachmann and Papp, 1968, Giorn. di Geol., ser. 2, vol. 35, pl. 3, p. 121, fig. 9.

Mesocena elliptica var. *minoriformis* Bachmann and Papp, Bachmann, 1970b, *in* Cat. Fossil. Austriae, No. 1b, p. 13.

Remarks. — Bachmann kindly sent the author possible topotypic material from Ernstbrunn, Austria (Aus. 3 in this paper). The author agrees that the size of the present *variety* is definitely smaller than that of *M.* cf. *elliptica,* and also accepts that the present *variety* has "relativ starken Basalringteile wesentlich von der geologisch jüngeren Art . . ." *M.* cf. *elliptica* was also found in the sample Bachmann sent, although he did not indicate such occurrence in his table.

Dimensions. — Diameter of basal body ring, 28-50 μ.

Known geologic range. — Miocene (Burdigalian).

Occurrence. — Similar to *M.* cf. *elliptica,* this Bachmann's *variety* is found earlier in Italian samples of the *Calocycletta virginis* Zone than in another part of the area of the present study, WR TR 23 (K9391), which is the *Calocycletta costata* Zone (Riedel and Sanfilippo, 1970) from Trinidad. The highest occurrence is from sample EM 8-13, 125-126 cm which is lower Mohnian according to Bandy and Ingle (1970) and Parker (1964) or lower part of Tortonian (?) by Martini and Bramlette (1963).

Mesocena oamaruensis Schulz Pl. 29, figs. 8-10

Mesocena oamaruensis Schulz, 1928, Bot. Archiv., vol. 21, No. 2, p. 240, fig. 10a, b.
Mesocena oamaruensis Schulz, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, p. 34, fig. 20.
Mesocena oamaruensis Schulz, Deflandre, 1932a, Soc. France, Microsc., Bull., vol. 1, No. 1, fig. 11.
Corbisema oamaruensis (Schulz), Frenguelli, 1940, Rev. Mus., La Plata, n.s., vol. 2, Paleont., No. 7, p. 64, fig. 13c.
Mesocena oamaruensis Schulz, Tsumura, 1959, Yokohama Munic. Univ., Bull., vol. 11, Nat. Sci., No. 1, p. 56, pl. 2, fig. 22 (*fide* Tsumura, 1963).
Not *Mesocena oamaruensis* Schulz, Stradner, 1961, Erdöl u. Kohle, vol. 14, No. 2, p. 89, figs. 30, 31.
Not *Mesocena oamaruensis* Schulz, Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, p. 42, pl. 7, fig. 2; pl. 21, fig. 12.
Not *Mesocena oamaruensis* Schulz, Bachmann, 1964, in Ichikawa *et al.*, Kanazawa Univ., Sci. Rept., vol. 9, No. 1, pl. 4, fig. 37.
Mesocena oamaruensis Schulz, Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 285, pl. 28, fig. 3.

Remarks. — One of the forms illustrated here (Pl. 29, fig. 8) is from sample S136/1096 of the Forrester's Hill section of Oamaru Diatomite, New Zealand. It is apparent that the basal body ring is smooth, without either radial spines or accessory spines. Lumen is apparent in the specimen but no septa. The specimens from Kellogg and Sidney Shales of California (see Pl. 29, figs. 9, 10) beyond any doubt are conspecific with that of Oamaru Diatomite, except that the Californian specimens are slightly smaller in size.

Stradner's form is illustrated as having septa as also does Bachmann's specimen from the Hojuji diatomaceous mudstone of Japan; therefore, they are excluded from the present species (see below). Tsumura also described specimens from Jackson's Paddock, Oamaru, New Zealand, but his illustration (pl. 7, fig. 2) can be interpreted as having septa, and another specimen (pl. 21, fig. 12) as having spines at the radial corners; therefore they are excluded from the present species.

Dimensions. — Length of basal body ring, 60-90 μ.

Known geologic range. — Eocene (late), Oligocene (early ?). As discussed by Loeblich, III (*et al.*, 1968, p. 18) and is accepted here, several localities or sections from the so-called Oamaru Diatomite are now considered as late Eocene age. The only Oligocene but questionable record for the present species is reported by Glezer (1966) from Dnepropetrovsk of European Russia. Thus it is conceivable that the present species has limited stratigraphic range of only late Eocene.

Occurrence. — During the present study, no specimen referable to the present species was recovered from the deep-sea sediments. The present species is discussed here and illustrated for comparison purposes to differentiate it clearly from the very similar form, *Septamesocena apiculata,* that previous workers assigned erroneously.

Genus **NAVICULOPSIS** Frenguelli, 1940

Remarks. — The silicoflagellate with naviculoid basal body ring was named by Ehrenberg (1839) as *Dictyocha navicula* from Miocene sediments of Zante, Greece. The detailed structure of these specimens was discussed by Frenguelli (1940, p. 60), who first noticed that in some specimens the middle part of the basal body ring where the apical structure joins is sometimes transformed into a thin flattened form thus losing the general tubular nature; therefore, in either apical or abapical view, the tubular skeleton is suddenly narrowed to capillary form in the middle of the basal body ring. Deflandre (1950a) later concurred in this opinion, although both Frenguelli and Deflandre failed to mention that the middle of the basal body ring frequently shows some constriction. Schulz observed such a phenomenon and described it as *Dictyocha navicula* var. *constricta.* As can be seen in the illustrations of different taxa within the present genus, such constriction is found rather commonly.

Another important point that deserves attention for its taxonomic significance has been neglected. In 1950, Deflandre (p. 36/82) indicated that in rare cases there are some specimens that show flattening of the two apices of the major axis, and he indicated that he found such forms in samples from Zante, Greece and Saint-Laurent-La Vernede, France, but only those from Zante were illustrated under the name of *Naviculopsis navicula* (Ehrenberg) (his figs. 241-243). Later Stradner (1956, 1961) also noticed this structure, called "Endflächen", which exhibits small projections or spines from both sides of the plates (see 1961, abb. 1 A; figs. 46, 47). Bachmann (1970a) also illustrated such specimens from his Ernstbrunn, Austria sample. Note that in these specimens, no radial spines were observed. The taxonomic significance of such flattened nature of the apices is apparent and should not be confused with the small flattened hyaline area found between the tubular basal body ring of the apices as discussed by Glezer (1966, p. 254) for *N. foliacea.*

Finally it should be pointed out here that in some naviculoid forms these two transformations just described never take place and thus the tubular nature is preserved completely throughout the basal body ring.

These three different types within the genus of *Naviculopsis* may suggest different phylogenic lineages. However, the author prefers to await further study of these forms, particularly examination of Eocene samples from New Zealand and California.

Naviculopsis biapiculata (Lemmermann) Pl. 30, figs. 1-4

Dictyocha navicula var. *biapiculata* Lemmermann, 1901b, Deutsch. Bot. Ges., Ber., vol. 19, p. 258, pl. 10, figs. 14 (?), 15.

Dictyocha navicula var. *biapiculata* Lemmermann, Schulz, 1928, Bot. Archiv., vol. 21, No. 2, pp. 244-245, figs. 18, 19.

Dictyocha navicula var. *biapiculata* fa. *aspera* Schulz, 1928, Bot. Archiv., vol. 21, No. 2, p. 246, fig. 20a, b.

Dictyocha navicula var. *biapiculata* Lemmermann, Gemeinhardt, 1930, *in* Kryptogamen Flora, vol. 10, pt. 2, pp. 36-37, fig. 24a (only).

Dictyocha (?) *biapiculata* Lemmermann, Hanna, 1931, Mining in California, vol. 27, No. 2, pl. D, figs. 5 (?), 6.

Dictyocha navicula var. *biapiculata* Lemmermann, Deflandre, 1932a, Soc. France, Microsc., Bull., vol. 1, No. 1, figs. 15-17 (not fig. 18).

Not *Dictyocha navicula* var. *biapiculata* Lemmermann, Zanon, 1934, Acta Pont. Acad. Sci. Nov. Lincei, vol. 87, p. 65, fig. 6.

Naviculopsis biapiculata (Lemmermann), Frenguelli, 1940, Rev. Mus., La Plata, n.s., vol. 2, Paleont., No. 7, p. 60, fig. 11c, d (as fa. normal) (only).

Dictyocha navicula var. *apiculata* Lemmermann, Tsumura, 1959, Yokohama Munic. Univ., Bull., vol. 11, Nat. Sci., No. 1, p. 58, pl. 3, figs 24-26 (*fide* Tsumura, 1963).

Dictyocha navicula var. *biapiculata* Lemmermann, Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, p. 45, pl. 8, figs. 1-3; pl. 21, figs. 7-9.

Naviculopsis biapiculata var. *biapiculata* Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, pp. 255-256, pl. 16, figs. 2, 4-5.

Naviculopsis biapiculata (Lemmermann), Mandra, 1968 (part), California Acad. Sci., Proc., ser. 4, vol. 36, No. 9, p. 264, figs. 20, 21 (only).

Remarks. — As described and illustrated in his original figure 15, when Lemmermann (1901b) proposed this species, he indicated that the apical structure was in the form of an apical bar ("Kieselbalken"). Although no reference samples are available from Dolje, Yugoslavia, Fuur Island or Kusnetzk, Russia, the localities from which Lemmermann's new taxon was proposed, samples from Jackson's Paddock section of the Oamaru Diatomite are here illustrated (Pl. 30, figs. 1, 2) in lateral view to show the nature of the transition of the basal body ring to the apical bar. Also as will be demonstrated later, the basal body ring of the specimens belonging to the present genus always remains on the same plane of the radial spines in lateral view, and is never warped or curved upward as Lipps (1970, fig. 3, bottom figure) illustrated.

The above synonymy is prepared by adhering to the original definition. Thus, Gemeinhardt, although referring his specimen to that of Lemmermann's, described the apical structure of his as "kleineren mitunter besonders breit, bandartig, nach der mitte zu schmalerwerdend." Therefore, his figure 24b, which clearly shows such a broad apical structure is excluded from the present species. One of Mandra's specimens (1968, fig. 22) is also excluded on the same basis and is referred to as *N. foliacea.* In addition, as Deflandre (1950a) indicated, Schulz's fa. *aspera* is included as a morphologic variation of the present species.

Dimensions. — Length of basal body ring, 40-54 μ; of radial spine, 34-50 μ.

Known geologic range. — Eocene to Oligocene (early ?). Possible early Oligocene occurrence is reported by Glezer (1966) from several locations of western Siberia.

Occurrence. — The present species is found rarely and from DSDP 6-6-2, 1-2 cm, upper part of *Hantkenina aragonensis* planktonic foraminiferal Zone (Ewing, *et al.*, 1969), or *Thyrsocyrtis tri-*

acantha Zone (Riedel, 1971) and WR TR 39 F (J.S. 1068) from Barbados, which is the *Theocyrtis tuberosa* Zone (Riedel and Sanfilippo, 1970).

Naviculopsis constricta (Schulz) Pl. 30, figs. 5-8

Dictyocha navicula var. *biapiculata* fa. *constricta* Schulz, 1928, Bot. Archiv., vol. 21, No. 2, p. 246, fig. 21.

Dictyocha navicula var. *biapiculata* fa. *constricta* Schulz, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, p. 38, fig. 25.

Naviculopsis constricta (Schulz), Frenguelli, 1940, Rev. Mus., La Plata, n.s., vol. 2, Paleont., No. 7, fig. 11a, b.

Not *Naviculopsis constricta* (Schulz), Stradner, 1961, Erdöl u. Kohle, vol. 14, No. 2, p. 89, pl. 2, figs. 49-52.

Not *Dictyocha* var. *biapiculata* fa. *constricta* Schulz, Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, p. 46, pl. 8, fig. 8.

Naviculopsis biapiculata var. *constricta* (Schulz), Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, pp. 257-258, pl. 17, fig. 4.

Description. — Basal body ring, oval, frequently constricted at the middle where the apical structure joins; two long radial spines at each end of the major axis; apical structure in the form of an arched band with more or less uniform width throughout except broadened slightly where connected with the basal body ring; no apical nor basal accessory spines present.

Remarks. — Schulz (1928) indicated when he proposed his new fa. *contricta* that the middle part of the basal body ring is, in either apical or abapical view, constricted. As already noted by Frenguelli (1940) when he discussed the present genus, such a phenomenon is common among the naviculoid silicoflagellates because of transformation of the basal body ring from tubular to flattened nature. The present species can be recognized by the band-form apical structure and generally shows uniform width throughout; thus it can be differentiated from those either with an apical bar like *N. biapiculata* or with a foliated apical plate such as *N. foliacea.* Depending on the width of the apical band, the size of lateral windows is variable.

Dimensions. — Length of basal body ring, 26-34 μ; of radial spines, 18-36 μ.

Known geologic range. — Eocene (late). Glezer listed the age of Kreyenhagen Formation of California and Oamaru Diatomite, New Zealand as "late Eocene or early Oligocene" but they are now regarded as Eocene (see Loeblich, III *et al.*, 1968, p. 18). Therefore, the geologic range for the present species seems limited to middle and late Eocene.

Occurrence. — Like the preceding taxon, this species is found only from samples of DSDP and Barbados.

Naviculopsis foliacea Deflandre Pl. 30, figs. 9-11

Dictyocha (?) *biapiculata* Lemmermann, Hanna, 1931 (part), Mining in California, vol. 27, No. 2, pl. E, fig. 10 (only).

Dictyocha (?) *biapiculata* Lemmermann, Clark and Campbell, 1945 (part), Geol. Soc. Amer., Mem. 10, p. 3, pl. 5, fig. 8 (not others).

Naviculopsis foliacea Deflandre, 1950a, Microscopie, vol. 2, pp. 76/82-77/82, figs. 235-240.

Naviculopsis foliacea Deflandre, Stradner, 1961, Erdöl u. Kohle, vol. 14, No. 2, p. 89, fig. 53.

Naviculopsis foliacea Deflandre, Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 258, pl. 7, fig. 5.

Naviculopsis biapiculata (Lemmermann), Mandra, 1968 (part), Calif. Acad. Sci., Proc., ser. 4, vol. 36, No. 9, p. 264, fig. 22 (only).

Remarks. — The specimens found during the present study from the Deep Sea Drilling Project (Pl. 31. fig. 11) agree with the description and illustration originally given by Deflandre from Barbados. Although no sample is available from the Kreyenhagen Shale where Hanna apparently described the present species, specimens from the Kellogg Shale and Sidney Shale of California are illustrated (Pl. 31, figs. 10, 11). The nature of the foliated apical plate and the size variation of the apical plate in contrast to that of basal body ring can be seen in these figures.

Note here also that in DSDP samples, there is a flattened hyaline area between the basal body ring at the apices which is not evident in specimens from California. Therefore, Glezer is of the opinion that the present species should be limited to those with the flattened area. As indicated earlier, however, the significance of such a flattened area should not be confused with that of the completely flattened end plate found in *N. navicula.* It is the author's opinion that the presence of the foliated apical plate, from which the name of the present species is apparently derived, is characteristic; and the value of the flattened area needs to be confirmed in the future after more specimens are studied. The California specimens are, therefore, included in the present species.

Dimensions. — Length of basal body ring, 40-56 μ; of radial spine, 30-36 μ.

Known geologic range. — Eocene. The age of "Diatomo-radiolarite de Springfield, Ile de la Barbade," which was considered as "Oligocène-Miocène ?" by Deflandre (1950a, p. 76/82) and which is followed by Glezer (1966), is now regarded as Eocene by Loeblich, III *(et al.,* 1968, p. 18).

Occurrence. — *N. foliacea* here discussed is found in several DSDP samples of middle Eocene age. With consideration of the Californian specimens, this species has the highest occurrence at the top of Eocene or bottom of Oligocene from the Barbados sample WR TR 39 F (J.S. 1068).

Naviculopsis lata (Deflandre) Pl. 30, figs. 12-16

Dictyocha biapiculata var. *lata* Deflandre, 1932c, Soc. Bot. France, Bull., vol. 79, p. 500, figs. 30, 31.
Dictyocha navicula var. *biapiculata* Lemmermann, Zanon, 1934, Acta Pont. Acad. Sci. Nov. Lincei, vol. 87, p. 65, pl. n, fig. 6.
Naviculopsis lata (Deflandre), Frenguelli, 1940, Rev. Mus., La Plata, n.s., vol. 2, Paleont., No. 7, p. 61, fig. 11h (?).
Dictyocha ausonia var. *regularis* Carnevale, Deflandre, 1950a, Microscopie, vol. 2, pp. 68/82-69/82, fig. 197 (only).
Naviculopsis robusta Deflandre, Stradner, 1961, Erdöl u. Kohle, vol. 14, No. 2, p. 89, pl. 2, figs. 39-41, 43-45 (not fig. 42).
Naviculopsis robusta Deflandre, Bachmann and Papp, 1968, Giorn. di Geol., ser. 2, vol. 35, fasc. 2, p. 119, pl. 3, figs. 3, 4.
Naviculopsis lata (Deflandre), Bachmann, 1970a, Verh. Geol. B.-A., Jahrg. 1970, No. 2, pp. 278-279, pl. 2, figs. 1-20; pl. 3, figs. 1-15.

Remarks. — As discussed in detail by Bachmann (1970a), the present species is apparently similar to another species, *Naviculopsis robusta,* from the Eocene Diatomite of Singhiliewski, Russia, but the latter is characterized by possessing a small triangular, foliated lateral plate where the basal body ring and apical bar meet. So far in this study, a specimen with this structure as Deflandre (1950a) and Glezer (1966) illustrated has not been seen; therefore, it is agreed that *N. robusta* has a limited biogeographic distribution.

Some of the present species show a slight constriction in the middle of the basal body ring where an apical bar forked and merged, and such a phenomenon can be observed easily from the abapical view, particularly under phase contrast (Pl. 30, fig. 14), but in no case does the basal body ring show a flattened nature.

Apparently Deflandre (1950a), by considering the wide range of variation for *Dictyocha ausonia,* regarded the specimen of the present species as within its variation. As discussed earlier, the variation of a gradual narrowing and the disappearance of radial spines on the minor axis is not so readily as shown by Deflandre for *Dictyocha ausonia* (figs. 194-196) or *D. mutabilis* (figs. 203-208).

Dimensions. — Length of basal body ring, 42-52 μ; of radial spine, 10-16 μ.

Known geologic range. — Oligocene (late).

Occurrence. — During the present study, *N. lata* is found only from Mediterranean Italian samples ranging from near the bottom of *Calocycletta virginis* Zone to the highest available samples of *Calocycletta costata* Zone (Sanfilippo, 1971).

Naviculopsis navicula (Ehrenberg) Pl. 30, figs. 17-19; Pl. 31, fig. 1

Dictyocha navicula Ehrenberg, 1839, K. Preuss. Akad. Wiss. Berlin, Abh., Jahrg. 1838, p. 129.
Dictyocha ponticulus Ehrenberg, 1844c, Verh. K. Preuss. Akad. Wiss. Berlin, Ber., p. 267.
Dictyocha ponticulus Ehrenberg, Bailey, 1845, Amer. Jour. Sci. Arts., vol. 48, No. 2, p. 328, pl. 4, fig. 21.
Dictyocha navicula Ehrenberg, Ehrenberg, 1854, Mikrogeologie, pl. 20, No. 1, fig. 43.
Dictyocha navicula Ehrenberg, Haeckel, 1887, Rept. Voy. *Challenger,* Zool., vol. 18, p. 1559.
Dictyocha navicula Ehrenberg, Lemmermann, 1901b, Deutsch. Bot. Ges., Ber., vol. 19, pp. 257-258, pl. 10, figs. 12-13 (only).
Dictyocha navicula Ehrenberg, Lemmermann, 1903, *in* Nordisches Plankton, Bot. No. 21, p. 27, fig. 90.
Dictyocha navicula Ehrenberg, Schulz, 1928, Bot. Archiv., vol. 21, No. 2, p. 243, fig. 16b (only).
Dictyocha navicula Ehrenberg, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, pp. 35-36, fig. 22.
Not *Dictyocha navicula* (Ehrenberg), Deflandre, 1932a, Soc. France, Microsc., Bull., vol. 1, No. 1, fig. 13.
Not *Corbisema apiculata* fa. *naviculoidea* Frenguelli, 1940, Rev. Mus., La Plata, n.s., vol. 2, Paleont., No. 7, fig. 12i.
Not *Corbisema apicuata* var *inermis* Lemmermann, Deflandre, 1950a, Microscopie, vol. 2, fig. 88.
Naviculopsis navicula (Ehrenberg), Deflandre, 1950a, Microscopie, vol. 2, p. 77, figs. 241-243.
Naviculopsis navicula (Ehrenberg), Stradner, 1961, Erdöl u. Kohle, vol. 14, No. 2, p. 89, fig. 47 (only).
Dictyocha navicula var. *naviculopsis* (Deflandre), Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, p. 44, pl. 7, fig. 5.
Not *Dictyocha navicula* Ehrenberg, Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, pp. 233-235, pl. 9, figs. 4, 5.
Naviculopsis navicula (Ehrenberg), Bachmann, 1970a, Verh., Geol. B.-A., Jahrg. 1970, No. 2, fig. 2b (only).

Remarks. — The specimens recovered from Northern Italy agree in general with the first figure for the present species illustrated by Ehrenberg from Zante, Greece, except that they are slightly smaller in size.

In the illustration of Deflandre (1950a), the flattened structure at the apices of the major axis and the rudimentary spines are seen for the first time. As shown here the degree of development of such a structure differs among the specimens but can be found only after careful examination (see Pl. 30, fig. 19). Therefore, it is the author's opinion that such a structure perhaps escaped notice by previous workers particularly prior to 1950. The above synonymy is prepared with this in mind.

In addition to listing the fossil locations, Haeckel reported (1887, p. 1559) the present species "living in the Atlantic, Stations 352, 354 and off Bermuda, surface"; and later workers such as Lemmermann and Gemeinhardt, apparently followed these records. Judging from geological occurrence of the present species (see below), it seems likely that the above record of living forms for the present species has been either reworked from nearby land deposits or may be outcrops of Tertiary deposits at the ocean bottom.

Glezer referred Russian specimens all to Eocene, but her illustrations clearly show they are different from the present taxon by possessing the basal accessory spines, as well as a much wider basal body ring along the minor axis.

Dimensions. — Length of basal body ring, 18-24 μ.

Known geologic range. — Miocene.

Occurrence. — The specimen referable to the present *N. navicula* is found, in the present study, only from the Italian samples and only from WRE 67-77 and -76 samples of the *Calocycletta costata* Zone. Apparently this species has a limited biogeographic as well as stratigraphic range.

Naviculopsis quadrata (Ehrenberg) Pl. 31, fig. 2

Dictyocha quadrata Ehrenberg, 1844c, Verh. K. Preuss. Akad. Wiss. Berlin, Ber., Jahrg., 1844, pp. 258, 267.

Dictyocha quadrata Ehrenberg, Bailey, 1845, Amer. Jour. Sci. Arts, vol. 48, No. 2, p. 328, pl. 4, fig. 22.

Dictyocha quadrata Ehrenberg, Haeckel, 1887, Rept. Voy. *Challenger,* Zool., vol. 18, p. 1559.

Dictyocha quadrata Ehrenberg, Lemmermann, 1901b, Deutsch. Bot. Ges., Ber., vol. 19, p. 259.

Dictyocha quadrata Ehrenberg, Lemmermann, 1903, *in* Nordisches Plankton, Bot., No. 1, p. 27.

Dictyocha navicula var. *rectangulare* Schulz, 1928 (part), Bot. Archiv., vol. 21, No. 2, pp. 243-244, fig. 17a (only).

Dictyocha navicula var. *rectangulare* Schulz, Gemeinhardt, 1930 (part), *in* Kryptogamen-Flora, vol. 10, pt. 2, p. 36 (not fig. 23).

Naviculopsis rectangularis (Schulz), Frenguelli, 1940, Rev. Mus., La Plata, n.s., vol. 2, Paeont. No. 7, p. 60, fig. 11j, k.

Dictyocha biapiculata (Lemmermann) var. *iberica* Deflandre, Colom, 1940, Las Ciencias, vol. 5, No. 2, p. 351, fig. 9 *(fide* Deflandre, 1950a).

Naviculopsis iberica Deflandre, 1950a, Microscopie, vol. 2, pp. 74/82-76/82, figs. 231-234.
Naviculopsis rectangularis (Schulz), Stradner, 1961, Erdöl u. Kohle, vol. 14, No. 2, p. 89, pl. 2, fig. 48.
Dictyocha navicula var. *rectangularis* Schulz, Tsumura, 1963, Yokohama Munic, Univ., Jour., ser. C-45, No. 146, pp. 45-46, pl. 7, figs. 8-10; pl. 21, figs. 1-3.
Naviculopsis rectangularis (Schulz), Bachmann, 1970a, Verh, Geol. B.-A., Jahrg. 1970, No. 2, p. 284, abb. 3, figs. a-f.
Naviculopsis rectangularis (Schulz), Bachmann, 1970b, *in* Cat. Fossil. Austriae, No. 1b, p. 17.

Remarks. — The present species is described by Ehrenberg (1844c) from "Bermuda-Inseln" and is illustrated by Bailey (1845) from "Bermuda." These locations are now regarded as actually from Nottingham, Maryland, and the age as Helvetian stage according to Loeblich, III (*et al.*, 1968, pp. 16-17). These, however, have escaped the attention of previous investigators. Thus Schulz in 1928 when he proposed his *Dictyocha navicula* var. *rectangulare* from the same locality, failed to mention Ehrenberg's description or Bailey's illustration, and Schulz's name has been adopted by various students since that time. It should be mentioned here that Schulz included two morphologically different forms under his name. The form considered here is only that with a rectangular-shaped basal body ring (fig. 17a only). It is possible that *N. iberica* described by Deflandre (1950a) from Spain and Majorca is a somewhat irregular shape of the present species but still within the range of intraspecific variation and, therefore, is considered as synonymous.

Another specimen illustrated by Schulz at the same time (fig. 17b) has a elongated oval basal body ring which was erroneously referred to recently as *N. iberica* by Bachmann (1970a, Abb. 1, fig. c. d. f.).

Dimensions. — Length of basal body ring, 36-52 μ; width, 24-30 μ; radial spine, 6-8 μ.

Known geologic range. — Miocene.

Occurrence. — Only from Mediterranean Italian outcrop samples, WRE 67-78 to -76, the *Calocycletta costata* radiolarian Zone (Sanfilippo, 1971) are the present species recovered.

Naviculopsis regularis (Carnevale) Pl. 31, figs. 3-5

Dictyocha regularis Carnevale, 1908, R. Inst. Veneto, Sci. Lett. Arti, Mem., vol. 28, No. 3, p. 35, pl. 4, fig. 28.

Dictyocha ausonia var. *regularis* Carnevale, Deflandre, 1950a, Microscopie, vol. 2, pp. 68/82-69/82, fig. 198 (only).

Remarks. — This lenticular-shaped species possesses relatively longer radial spines, and the size seems to agree with the middle Miocene form originally described by Carnevale from Bergonzano, Reggio Emilia, Italy.

Deflandre considered the present species as within the range of variation for his *Dictyocha ausonia,* but as discussed earlier, it is hard to conceive that two radial spines on the major axis can become longer, while the other two on the minor axis diminish (compare Pl. 31, figs. 3-5 with Pl. 25, figs. 1-8).

The present species also resembles the preceding species, *N. lata,* by showing some constriction at the middle of the basal body ring, but is generally smaller in size, and has a slender basal body ring and no small lateral windows as found in the *N. lata.*

Dimensions. — Length of basal body ring, 33-38 μ; width, 19-24 μ; radial spines, 14-22 μ.

Known geologic range. — Miocene.

Occurrence. — *N. regularis* is found from the Italian samples whose age has been identified as *Calocycletta virginis* and *C. costata* Zones (Sanfilippo, 1971).

Naviculopsis sp. Pl. 31, fig. 6

Naviculopsis navicula Stradner, 1961 (not Ehrenberg), Erdöl u. Kohle, vol. 14, No. 2, p. 89, fig. 46 (only).

Naviculopsis navicula Bachmann and Papp, 1968 (not Ehrenberg), Giorn. di Geol., ser. 2, vol. 35, fasc. 2, pl. 3, fig. 5.

Naviculopsis navicula Bachmann, 1970a (not Ehrenberg), Verh. Geol. B.-A., Jahrg. 1970, No. 2, abb. 2, figs. a, c-f (not b).

Remarks. — Although the present species is similar structurally to *N. navicula,* because it possesses the "Endflächen" (Stradner, 1961), it differs in that the apices on the major axis are sharply truncated, and it has two short spines at both corners of the plate. The specimen illustrated here is from Ernstbrunn, Austria, the possible type locality of Stradner's specimen for comparison.

Dimensions. — No complete specimen was observed.

Known geologic range. — Miocene (early).

Occurrence. — The specimen assignable to the present taxon is found only from Ernstbrunn, Austria, and has not been found in the deep-sea sediments.

Naviculopsis trispinosa (Schulz) Pl. 31, figs. 7, 8

Dictyocha navicula var. *trispinosa* Schulz, 1928, Bot. Archiv., vol. 21, No. 2, pp. 246-247, fig. 23a, b.
Dictyocha navicula var. *trispinosa* Schulz, Gemeinhardt, 1930, *in* Kryptogamen-Flora, vol. 10, pt. 2, p. 40, fig. 27.
Dictyocha navicula var. *trispinosa* Schulz, Deflandre, 1932a, Soc. France, Microsc., Bull., vol. 1, No. 1, fig. 24.
Naviculopsis biapiculata fa. *trispinosa* Schulz, Frenguelli, 1940, Rev. Mus., La Plata, n.s., vol. 2, Paleont., No. 7, fig. 11e.
Dictyocha navicula var. *trispinosa* Schulz, Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, p. 46, pl. 8, figs. 4-6.
Naviculopsis trispinosa (Schulz), Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, pp. 258-259, pl. 17, fig. 7.

Remarks. — Apparently the present species occurs rarely, and during the present study, no specimen was found. The specimen here illustrated is for reference purpose and particularly to present the lateral view.

Dimensions. — Length of basal body ring, 24 μ; of radial spines, 25 μ.

Known geologic range. — Eocene.

Occurrence. — No specimen belonging to *N. trispinosa* has been found in the present study. The representative specimen presented here is from a reference sample, S136/966, Bain's Farm section, Oamaru Diatomite, New Zealand.

Genus PARADICTYOCHA Frenguelli, 1940

Paradictyocha polyactis (Ehrenberg) Pl. 31, figs. 9-11

Dictyocha polyactis Ehrenberg, 1839, K. Akad. Wiss. Berlin, Abh., Jahrg. 1838, p. 129.
Dictyocha polyactis Ehrenberg, Ehrenberg, 1844a, Verh. K. Preuss. Akad. Wiss. Berlin, Ber., Jahrg. 1844, p. 80.
Dictyocha polyactis Ehrenberg, Ehrenberg, 1854, Mikrogeologie, pl. 22, fig. 50.
Distephanus speculum var. *octonaria* fa. *polyactis* (Ehrenberg), Jorgensen, 1899, Bergens Mus. Aarbog 1899, No. 6, pt. 2, p. 50.
Distephanus speculum var. *polyactis* (Ehrenberg), Lemmermann, 1901b (part), Deutsch. Bot. Ges., Ber., vol. 19, pp. 265-266, pl. 11, fig. 17.
Distephanus speculum var. *polyactis* (Ehrenberg), Lemmermann, 1903, *in* Nordisches Plankton, Bot., pt. 21, p. 31, fig. 106.
Not *Distephanus speculum* var. *polyactis* (Ehrenberg), Gemeinhardt, 1931b, Deutsche Südpolar-Exped., vol. 20 (Zool. vol. 12), p. 241, pl. 42, fig. 7.
Distephanus polyactis Deflandre, 1932c, Soc. Bot. France, Bull., vol. 79, Nos. 5-6, pp. 501-502, fig. 40 (only).
Distephanus speculum var. *polyactis* fa. *decagona* Zanon, 1934, Acta Pont. Acad. Sci. Nov. Lincei, vol. 87, p. 71, pl. n, fig. 47.
Distephanus speculum var. *polyactis* fa. *dodecagona* Zanon, 1934, Acta Pont. Acad. Sci. Nov. Lincei, vol. 87, p. 71, pl. n, fig. 48.
Paradictyocha polyactis (Ehrenberg), Frenguelli, 1940, Rev. Mus., La Plata, n.s., vol. 2, Paleont, No. 7, p. 52, fig. 7f, g (?); p. 54, fig. 8a (only).

Paradictyocha polyactis fa. *polyactis* Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 277, pl. 24, figs. 7-11.
Paradictyocha polyactis (Ehrenberg), Mandra, 1968 (part), California Acad. Sci., Proc., ser. 4, vol. 36, No. 9, p. 264.

Remarks. — The examination of related forms such as *Mesocena circulus* var. *apiculata* from various localities convinced the author that: (a) the present species actually occurs only rarely; (b) so far no intermediate forms have been found during the present study demonstrating the morphologic variation of the gradual disappearance of the apical structure as indicated by Frenguelli (1940) or the gradual enlargement of the apical ring to fuse with the basal body ring indicated by Deflandre (1950a); and (c) the diameter of the specimen is relatively larger than those of related forms frequently referred to as *Distephanus speculum.*

As shown previously (Lemmermann, 1901b; Ling, 1971), in lateral view, *Mesocena circulus* var. *apiculata* has two series of divergent radial spines on the exterior side of the basal body ring. Thus, should the disappearance of the apical ring as claimed by Frenguelli or fusion of the apical ring according to Deflandre actually be the case, at least one series of the radial spines should point either inwardly or perpendicular to the basal body ring on apical view, and so far this is definitely not the case. Thus perhaps it is advisable to limit the present species to the form that is close to Ehrenberg's original figure or only to the complete specimen of Frenguelli (1940, fig. 8a). It is possible that Mandra found the present species during his California study, but his figures are not like the present species and, therefore, they are excluded.

Lemmermann (1901b, 1903) illustrated a form, but without mentioning whether it is a fossil or modern form. Jorgensen (1899) recorded the present species from plankton samples of the west coast of Norway but without illustration. Gemeinhardt (1931b) referred to a single specimen from the Atlantic Ocean (0°18′N, 16°19′W), but as the basal diameter is approximately only 25 μ, (less than one-half that of the specimen found during the present study — about 60 μ here), and as Gemeinhardt himself illustrated in the same paper that there are wide variations in the number of spines of *Distephanus speculum* in the Atlantic, it is concluded that Gemeinhardt's specimen is related closely to *Distephanus speculum;* therefore it is excluded from the present species.

Dimensions. — Diameter of basal body ring, 60-66 μ; of radial spine, 4-8 μ.

Known geologic range. — Miocene. Glezer (1966, p. 277) described the Russian occurrence as Neogene.

Occurrence. — *P. polyactis* thus recognized is found, during the present study, only in one sample, EM 8-15, 36-37 cm, which is Luisian, according to Parker (1964), Bandy and Ingle (1970) or Helvetian according to Martini and Bramlette (1963).

Genus **ROCELLA** Hanna, 1930

Remarks. — The present genus was proposed by Hanna (1930) with *Rocella gemma* as the type by monotypy, and until recently, this unusual siliceous microfossil has not been recovered.

The exact nature or affinity of these remains is still uncertain. Hanna (1930) indicated that he was in favor of placing them within or closely related to silicoflagellates over the wheel-like plate of holothuridae, radiolarians, sponges, and diatoms, or the possibility of calcite replaced by amorphous silica. Recently Lipps (1970, p. 981) suggested that they were small valves of a diatom from which the silica had been dissolved from the "pores." The present author has studied deep-sea sediments from various parts of the world including the equatorial Pacific, but until now diatoms indicating such a possibility have never been encountered.

Therefore, despite the nature of the genus still remaining unknown, there is a good possibility of its being considered a biostratigraphic index for deep-sea sediments, and thus it is included in the present study.

Rocella gemma Hanna Pl. 31, figs. 12-15

Rocella gemma Hanna, 1930, Jour. Paleont., vol. 4, No. 4, pp. 415-416, pl. 40, figs. 8-18.

Remarks. — The specimens found during the present study agree with the original description and illustration given by Hanna from the San Gregorio Formation (possible Helvetian) near Purrissima, California, which Loeblich, III (*et al.*, 1968) regarded as Baja California, Mexico.

The present species was recovered from Core 17 of the DSDP Hole 34 at Lat. 39°28.21′N.; Long. 127°16.54′W., and its age is considered as "*Coccolithus bisectus* — *Triquetrorhabdulus carinatus* Subzone;" but whether the sample is autochthonous is questioned (McManus, *et al.,* 1970, pp. 114-115). Core 16 sample from the same hole, which is regarded as the same age as that of Core 17, was identified by Bukry and Bramlette (1970, p. 490) as upper Oligocene to lower Miocene from its nannofossil assemblage.

Dimensions. — Diameter, 50-70 μ.

Known geologic range. — Miocene.

Occurrence. — The present species is found abundantly in samples of MSN 149P, 294-296 cm, and rarely in JYN V 16P, 231-233 cm, and these samples are considered here as the base of the Miocene agreeing with the above observation. Therefore, it is considered that the above DSDP specimens are likely not reworked.

Genus **SEPTAMESOCENA** Bachmann, 1970b

Septamesocena apiculata (Deflandre) Pl. 29, figs. 11-15

Not *Mesocena oamaruensis* var. *apiculata* Schulz, 1928, Bot. Archiv., vol. 21, No. 2, p. 240, fig. 11.

Mesocena polymorpha var. *triangula* Lemmermann, Gemeinhardt, 1930 (part), *in* Kryptogamen-Flora, vol. 10, pt. 2, p. 28.

Mesocena polymorpha var. *triangula* fa. *glabra* Gemeinhardt, 1930 (not Schulz), *in* Kryptogamen-Flora, vol. 10, pt. 2, p. 28, fig. 12b (only).

Not *Mesocena apiculata* (Schulz), Hanna, 1931, Mining in California, vol. 27, No. 2, p. 198, pl. D, fig. 3 (?).

Mesocena apiculata (Schulz), Deflandre, 1932c, Soc. Bot. France, Bull., vol. 79, Nos. 5-6, p. 499, figs. 34 (?), 35.

Mesocena apiculata (Schulz), Tynan, 1957, Micropaleont., vol. 3, No. 2, p. 134, pl. 1, fig. 10.

Mesocena apiculata (Schulz), Stradner, 1961, Erdöl u. Kohle, vol. 14, No. 2, p. 89, figs. 28, 29, 32.

Mesocena apiculata (Schulz), Bachmann, 1962, Verh. Geol. B.-A., Jahrg. 1962, No. 2, p. 379, figs. 10, 11.

Mesocena apiculat (Schulz), Bachmann, 1963, *in* Bachmann, *et al.,* Geol., Ges. Wien, Mitt., vol. 56, No. 1, p. 152, pl. 19, figs. 60-62.

Mesocena oamaruensis Schulz, Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, p. 42, pl. 7, fig. 2; pl. 21, fig. 12.

Mesocena apiculata (Schulz), Bachmann, *in* Ichikawa, *et al.,* 1964, Kanazawa Univ., Sci. Rept., vol. 9, No. 1, p. 107, pl. 4, fig. 36.

Mesocena oamaruensis Schulz, Bachmann, *in* Ichikawa, *et al.,* 1964, Kanazawa Univ., Sci. Rept., vol. 9, No. 1, pp. 107-108, pl. 4, fig. 37.

Mesocena aff. *apiculata* (Schulz), Glezer, 1966, *in* Cryptogamic plants of the U.S.S.R., vol. 7, p. 282, pl. 28, fig. 5 (?); pl. 29, fig. 9.

Mesocena apiculata (Schulz), Bachmann and Papp, 1968, Giorn. di Geol., ser. 2, vol. 35, pl. 3, figs. 1, 2.

Mesocena apiculata (Schulz), Hajos, 1968, Geol. Hungarica, ser. Paleont., fasc. 37, p. 67, pl. 4, fig. 3.

Mesocena apiculata (Schulz), Bachmann, 1970a, Verh. Geol. B.-A., Jahrg. 1970, No. 2, pp. 280, 282, 284, pl. 5, figs. 10-16; pl. 6, figs. 1-5.

Septamesocena apiculata (Schulz), Bachmann, 1970b, *in* Cat. Fossil. Austriae, No. 1b, pp. 13-14.

Remarks. — In 1928, Schulz, recognized a silicoflagellate form with a smooth basal body ring but without septa from Hungarian sediments and established a *M. polymorpha* var. *triangula* fa. *glabra.* Gemeinhardt (1930) found the Schulz's *forma* unnecessary, but in his figure 12 b, he illustrated the presence of septa. The above synonymy is prepared after close examination of the figures illustrated by previous students of silicoflagellates. The new genus, *Septamesocena,* was proposed by Bachmann for the *Mesocena* with a septal structure. Stradner (1961) referred the present species to the form described originally by Schulz as *Mesocena oamaruensis* var. *apiculata* from Oamaru, New Zealand, and such practice was followed by Deflandre, Hanna, and others and until as recently as the early part of 1970 by Bachmann. The samples from the Oamaru Diatomite are currently under detailed examination; however, as already shown here (Pl. 28, figs. 2-4) for comparison, so far specimens from Oamaru which correspond with Schulz's original figure, have no septa.

Glezer recorded specimens ranging from early Paleocene to late Eocene in Russia. The early Paleocene specimen from the eastern slope of the Urals has no septal structure (pl. 28, fig. 5); the late Eocene form (pl. 29, fig. 9) from the Ural-Caspian area possess discontinuous lumen and can be interpreted as being due to septal structure, but it has a dentate basal body ring.

Dimensions. — Length of basal body ring, 42-58 μ; of radial spines, 2-3 μ.

Known geologic range. — Eocene (late) to Miocene.

Occurrence. — The present species is found only in DSDP 13-3-1, 120-121 cm and Italian outcrop samples. Examination of more Tertiary California samples is required before worldwide distribution of the present species can be discussed in more detail.

Genus **VALLACERTA** Hanna, 1928

Vallacerta hortoni Hanna Pl. 32, figs. 1, 2

Vallacerta hortoni Hanna, 1928, Jour. Paleont., vol. 1, No. 4, pp. 262-263, pl. 41, figs. 7-11.

Dictyocha siderea Schulz, 1928, Bot. Archiv., vol. 21, No. 2, p. 284, fig. 81a, b.

Dictyocha siderea Schulz, Gemeinhardt, 1930, *in* Krytogamen-Flora, vol. 10, pt. 2, p. 56, fig. 47.

Vallacerta hortoni Hanna, Deflandre, 1940a, Acad. Sci. Paris, C. R., vol. 211, No. 19, p. 446, figs. 1, 5.

Vallacerta hortoni Hanna, Deflandre, 1940c, Acad. Sci. Paris, C. R., vol. 211, No. 23, p. 598, fig. 1.
Vallacerta hortoni Hanna, Deflandre, 1950a, Microscopie, vol. 2, pp. 57/82-58/82, figs. 144-149.
Dictyocha siderea Schulz, Tsumura, 1959, Yokohama Munic. Univ., Bull., vol. 11, Nat. Sci., vol. 1, p. 66, pl. 4, fig. 52 (*fide* Tsumura, 1963).
Dictyocha siderea Schulz, Tsumura, 1963, Yokohama Munic. Univ., Jour., ser. C-45, No. 146, p. 59, pl. 11, fig. 12.
Vallacerta hortoni Hanna, Glezer, 1966, *in* Crytogamic plants of the U.S.S.R., vol. 7, p. 219, pl. 1, fig. 1; pl. 31, fig. 1.
Vallacerta hortoni Hanna, Mandra, 1968, California Acad. Sci., Proc., ser. 4, vol. 36, No. 9, p. 267, figs. 11, 12, 19.

Remarks. — A literature survey reveals that Hanna's article was published in January, while Schulz's article was dated in June of the same year; Hanna's name, therefore, has priority.

Although Schulz (1928) also proposed a quadrangular form as *Dictyocha siderea* var. *quadrata* from Prussia, no such *variety* is found in the topotypic sample, CAS 1144, from California.

Dimensions. — Diameter of pentagonal plate, 35-45 μ; length of spines, 5-8 μ.

Known geologic range. — Cretaceous (late) to Paleocene (early). The Paleocene occurrence is reported from Russia by Glezer (1966).

Occurrence. — The present species is recovered only from the topotypic material from California. Mandra (1968, p. 242) indicated that the present species (together with *Lyramula furcala*) is found only from Upper Cretaceous.

Ebridians

Terminology. — Morphologic terms used herein are those commonly employed and summarized by Deflandre (1951) and are shown in Text-figure 6.

Order STEREOTESTALES Lemmermann, 1901a

Genus **AMMODOCHIUM** Hovasse, 1932

Ammodochium rectangulare (Schulz) Pl. 32, figs. 3-5

Remarks. — For the synonymy, refer to Ling (1971).

Known geologic range. — Paleocene to Miocene.

Dimensions. — Length, 18-24 μ.

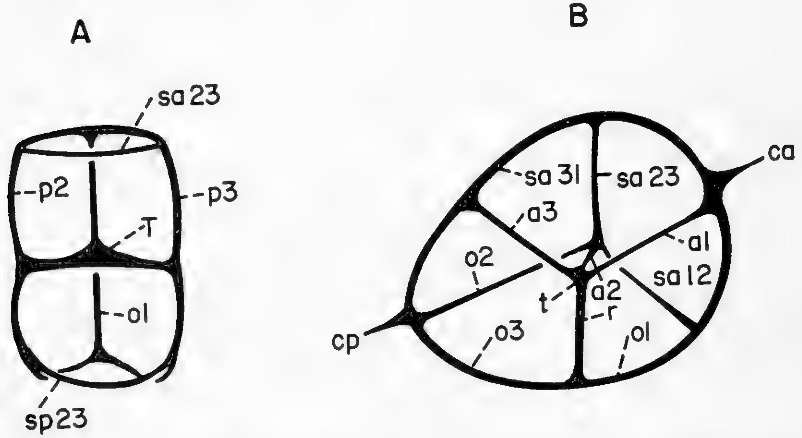
Occurrence. — From the samples studied, this species is found from WR TR 11, Low (Bo. 202), *Dorcadosypris alata* radiolarian

Zone (Riedel and Sanfilippo, 1970) to EM 6-2, 10-11 cm, late Miocene.

Genus **EBRIOPSIS** Hovasse, 1932a

Ebriopsis antiqua (Schulz) Pl. 32, figs. 6-12

Remarks. — For the synonymy of the present species, also refer to Ling (1971). Since the present species was first reported by Schulz, wide range of variation has been recognized by earlier investigators: surface ornamentation of skeletal elements is smooth or crenulate; with or without anterior and posterior axial spines, "corne axiale anterieure" and "corne axiale posterieure" of Deflandre (1951) (see Text-figure 6B).



Text-figure 6. — Terminology of ebridian skeleton. A. *Ammodochium rectangulare.* B. *Ebriopsis antiqua;* a = actine, ca = anterior axial spine, cp = posterior axial spine, o = opisthoclade, p = proclade, r = rhabde, sa = anterior synclade, sp = posterior synclade, t = triaene, T = triode (Modified after Deflandre, 1951).

Deflandre (1950b) noticed that in Paleocene *Ebriopsis valida,* both the rhabde and one of the opisthoclades are on the same plane of symmetry, but in Eocene form, *E. mesnili (=E. crenulata* in this paper, see below), there is an angle between the two skeletal elements, beginning from 12° to between 35° to 50° in the late Eocene (not Oligocene) Oamaru samples from New Zealand. At the time of Miocene form, *E. antiqua,* the opisthoclade 02 is approximately on the same plane with one of the actines, Deflandre, therefore, proposed the phylogenic lineage of *E. valida - E. mesnili - E. antiqua.*

Although no samples nor specimens from Paleocene sediments are available for the present study to confirm Deflandre's observation, lineage between *E. crenulata - E. antiqua* seems agreeable. In addition to his observation, the following are obvious from the present investigation:

1. Surface ornamentation is strongly coarse and crenulate in the middle Eocene specimens of *E. crenulata,* and also the skeletal elements are generally broader than those from the higher horizon.
2. A gradual size increase is noticed from specimens of middle Eocene to Miocene form.
3. Although forms without anterior and posterior axial spines are found from middle Eocene samples, the specimens with these spines occur mostly throughout Miocene and also possibly late Eocene, but the specimens with such well-developed spines are rather commonly found in Miocene samples and are also reported from various parts of the world.

Dimensions. — Diameter, 28-40 μ.

Known geologic range. — Paleocene to Miocene.

Occurrence. — The earliest occurrence of this species in the present study is from DSDP 6-6-2, 1-2 cm, and the latest is found in EM 6-2, 10-11 cm which is considered upper Miocene by Martini and Bramlette (1963) or Delmontian by Bandy and Ingle (1970).

Ebriopsis crenulata Hovasse Pl. 32, figs. 13-18

Podamphora mesnili Deflandre, 1932b, Acad. Sci. Paris, C. R., vol. 194, No. 24, p. 2172, figs. 6, 7. *nom. nud.*

Ebriopsis crenulata Hovasse, 1932b, Soc. Zool. France, Bull., vol. 57, No. 4, p. 281, fig. 4 I, II.

Podamphora mesnili Deflandre, Deflandre, 1933, Soc. Zool. France, Bull., vol. 57, No. 6, pp. 516, 519, 522, figs. 12, 13.

Ebriopsis mesnili (Deflandre), Deflandre, 1950b, Acad. Sci. Paris, C. R., vol. 230, No. 19, p. 1684, figs. 3-7.

Ebriopsis mesnili (Deflandre), Deflandre, 1951, Biol. France, Belgique., Bull., vol. 85, fasc. 1, p. 64, figs. 23-29, 50-54.

Ebriopsis mesnili (Deflandre), Hajos, 1968, Geol. Hungarica, ser. Paleont., fasc. 37, p. 71, pl. 6, fig. 12.

Remarks. — As clearly discussed by Loeblich, III *(et al.,* 1968, p. 51), the name *Podamphora mesnili* appeared in 1932b, but was a *nomen nudum* and only validated by a later article dated December 13 of the same year, but actual date of publication for the particular issue was February 15, 1933. However, Hovasse in the meantime published *Ebriopsis crenulata* on June 14, 1932, and, therefore, has priority over Deflandre's name.

The specimen of this species is characterized by a smaller size than the preceding species, coarsely crenulated surface ornamentation and broader skeletal parts. No anterior or posterior axial spines are found.

Dimensions. — Diameter, 24-32 μ

Known geologic range. — Eocene.

Occurrence. — Hovasse described the present species from Oamaru, New Zealand, and one specimen with a lorica. A specimen from Jackson's Paddock section, S136/914, of the Oamaru Diatomite, New Zealand, is here illustrated as a reference (Pl. 32, figs. 13, 14).

Genus **PARATHRANIUM** Hovasse, 1932c

Remarks. — The present genus was proposed by Hovasse (1932c, p. 465) with *P. tenuipes* as the type species. Loeblich, III (1965, p. 189) discussed *Dicladia* (Ehrenberg, 1844a, p. 73), and designated *D. ? clathrata* (Ehrenberg, 1944a, pp. 70, 79; 1854, pl. 18, fig. 100) as the type, and by so doing indicated that *Dicladia* has priority over *Parathranium.* This is later followed by Loeblich, III (*et al.*, 1968, pp. 32, 62). Recently, Deflandre (1971) rejected these opinions.

It should be pointed out here, however, that Ehrenberg's specimen from Richmond, Virginia, illustrated by him shows only two opisthoclades instead of three, and furthermore the exact nature for the portion of the proclades is not clear. Further study, particularly from the sample in the vicinity of Richmond, Virginia, is necessary in order to recognize the characters of *Dicladia ? clathrata;* thus at the present time *Parathranium* Hovasse is used.

Parathranium tenuipes (Hovasse) Pl. 32, figs. 19-21

Thranium tenuipes Hovasse, 1932a, Soc. Zool. France, Bull., vol. 57, No. 2, p. 123, fig. 5.

Thranium tenuipes Hovasse, Deflandre, 1932d, Soc. Zool. France, Bull., vol. 57, No. 4, pp. 309-311, figs. 31-33.

Parathranium tenuipes (Hovasse), Hovasse, 1932c, Soc. Zool. France, Bull., vol. 57, No. 2, pp. 465-466.

Parathranium clathratum Deflandre, 1951 (not Ehrenberg), Biol. France, Belgique., Bull., vol. 85, fasc. 1, p. 77, figs. 5, 172.

Parathranium clathratum Deflandre (not Ehrenberg), Hajos, 1968, Geol. Hungarica, ser. Paleont., fasc. 37, p. 72, pl. 6, figs. 16, 17.

Remarks. — The Californian specimens agree well with the previous records.

Dimensions. — Length of opisthoclade, 18-22 μ.

Known geologic range. — Miocene.

Occurrence. — The present species was recovered only from Mohole samples during the present study and ranges from EM 7-1, 14-15 cm, N.12 planktonic foraminiferal Zone (Riedel and Sanfilippo, 1970) to EM 8-9, 148-149 cm; thus it encompasses most of the Luisian and all the Mohnian stages by Parker (1964), Bandy and Ingle (1970), and Kanaya (1971).

DISCUSSION

(a) General

Having examined in detail the numerous silicoflagellates and ebridian taxa, it is now possible to investigate from the samples studied, their occurrences since Maestrichtian time.

The stratigraphic occurrences of the taxa are shown in Text-figures 2, 3, and 4 with the inclusion of the 28 experimental Mohole samples. The sample coverage throughout the Neogene section is considered adequate, strongly contrasting to the Paleogene interval, where available samples examined during the present study were clustered in a few stratigraphic age intervals and hence are admittedly inadequate for establishing a definite zonation. However, the following general statement can be made in ascending order:

Lyramula furcula - *Vallacerta hortoni* assemblage: At least a part of the Maestrichtian or uppermost Cretaceous section represented by sample CAS 1144 is characterized by these unique silicoflagellates. DSDP samples 4-4-1, 13A-2-1, 13A-4-1 and 13A-5-1 are of Cretaceous age (Ewing, *et al.*, 1969; Maxwell, *et al.*, 1970) but were unfortunately barren of these siliceous microfossils. Neither the lower nor upper limit of this assemblage, therefore, can be determined from the present study.

Naviculopsis foliacea assemblage: The middle Eocene interval, particularly its lower part, is characterized by the presence of various forms of *Naviculopsis* and *Corbisema* species. Occurrence of

Ebriopsis crenulata is also limited in this assemblage in the present study. Although the upper and lower limit of these taxa found in this interval cannot be decided at this time, preliminary examination of Oamaru Diatomite (Runangan Stage, NP.17 - NP.18 of calcareous nannoplankton Zones) and Kellogg Shale and Sidney Shale samples indicate that they would extend their occurrences to the upper Eocene and, therefore, sample WR TR 39F (1068), which is considered slightly below the Oligo-Eocene boundary, may indicate the highest occurrence for these forms. There is a good possibility that the interval could be subdivided in the future.

Rocella horizon: Occurrence of *Rocella gemma* at the base of the Miocene, in this paper, or possibly the top of the Oligocene, according to others, may be a good time marker.

As discussed earlier, it was only last year that *R. gemma* was found for the second time since the species was proposed, and for the first time it was found from deep-sea sediments, Core 17 of the Deep Sea Drilling Project Hole 34 near California. The sample was interpreted as upper Oligocene to lower Miocene. However, whether the sample was of autochthonous origin was questioned at that time. The present finding from samples JYN V, 16 P, 231-233 cm, and MSN 149 P, 294-296 cm, agrees with the above stratigraphic occurrence, and, therefore, this species may be a reliable time indicator.

From this horizon to the next assemblage, several known but long-range silicoflagellates make their first appearance, such as *Distephanus crux, D. speculum,* and *Dictyocha ausonia,* but further investigation is needed to establish the assemblage.

Dictyocha fibula var. *octagona* assemblage: The interval is defined by the range of *D. f.* var. *octagona.* The initial appearance of so-called *Mesocena elliptica, Cannopilus hemisphaericus,* and *Ammodochium rectangulare* is slightly below the base of assemblage, while the top of assemblage is marked by the latest occurrence of *Distephanus crux* var. *octacanthus.* Within this interval *Dictyocha* sp., *Ebriopsis antiqua* (with spine form), and *Mesocena circulus* var. *apiculata* appear.

From the upper part of this assemblage to the uppermost Miocene, numerous experimental Mohole samples were studied as shown in Text-figure 4. *Dictyocha fibula* and *Parathranium tenuipes* show initial appearance at the top of this assemblage. As indicated earlier, judging from the relationship with other microfossils, particularly with the radiolarians, this is the interval that Martini (1971a, b) recognized as his *Dictyocha octacantha* (*Distephanus crux* var. *octacanthus* in this paper) horizon from Deep Sea Drilling Project Leg VII of the western equatorial Pacific.

Cannopilus sphaericus assemblage: The top of the underlying *Dictyocha fibula* var. *octagona* assemblage to the latest occurrence of *Cannopilus sphaericus* defines the assemblage. The base of the assemblage is also marked by the earliest occurrence of *Distephanus crux* var. *longispina*, so-called "*Mesocena diodon*", and also coincides with the initial occurrence of the radiolarian species, *Cannartus (?) petterssoni*, according to Sanfilippo and Riedel (1970). The top of the assemblage is also the highest occurrence of *Corbisema triacantha, C. t.* var. *minor;* therefore, it is conceivable that the upper limit of *Corbisema triacantha* Zone of Martini is here. Occurrence of *Paradictyocha polyactis* also falls within this assemblage.

The boundary between this and overlying assemblages seems to agree well with the Helvetian? — Tortonian? boundary of Martini and Bramlette (1963), and the Luisian — Mohnian boundary of Parker (1964) and Bandy and Ingle (1970).

Distephanus crux var. *longispina* assemblage: The interval from above the underlying *Cannopilus sphaericus* assemblage to the last appearance of *Distephanus crux* var. *longispina* is considered as the present assemblage. The top thus defined coincides also with the latest occurrence of *Cannopilus hemisphaericus* and likely also with that of *Mesocena circulus*. The limited appearance of *Distephanus speculum* var. *pentagonus*, and the highest stratigraphic occurrence of "*Mesocena elliptica*" in Mohole samples are also found within this assemblage. The top of this assemblage coincides with the top of middle Miocene of Martini and Bramlette (1963) and is approximately in agreement with the top of the Mohnian stage of Parker (1964) and the lower and upper Mohnian boundary of Bandy and Ingle (1970).

Distephanus speculum var. *pseudofibula* assemblage: The assemblage is defined by the range of *Distephanus speculum* var. *pseudofibula* in the Mohole section which also coincides with the interval from the top of the underlying previous assemblage to the highest occurrence of the silicoflagellates and ebridians in the experimental Mohole samples. Within this interval, limited occurrence of *Distephanus speculum* var. *pseudocrux,* last occurrence of *Dictyocha ausonia, Ammodochium rectangulare, "Mesocena diodon"*, and *Parathranium tenuipes* are observed, and they may mark the Mohnian-Delmontian boundary according to the study made by Bandy and Ingle (1970), and Kanaya (1971).

The highest sample bearing silicoflagellates and ebridians from Mohole, EM 6-2, 10-11 cm, is recognized as Delmontian by Bandy and Ingle (*op. cit.*), and Kanaya (*op. cit.*) and is apparently in agreement with late Miocene age of Martini and Bramlette (1963). It is likely that the present assemblage is correlative with the *Dictyocha pseudofibula* horizon of Martini (1971a, b) from the western equatorial Pacific.

Above this assemblage, throughout the Pliocene to part of the Pleistocene interval, silicoflagellates are found sporadically during the present study, and no distinct assemblage can be recognized until the next and the last assemblage.

Dictyocha fibula var. *aculeata* assemblage: The beginning of modern forms, such as *Dictyocha fibula* var. *aculeata, D. fibula* var. *messanensis* provides the last and the latest assemblage recognized during the present study.

Within this assemblage, one horizon can be recognized by the recurrence of *Mesocena* cf. *elliptica,* which brackets the Jaramillo Event of Matuyama Reversed Epoch, about 0.79 million years in the eastern equatorial Pacific (Hays, *et al.*, 1969); a similar occurrence is recognized by Jousé (1969) and Muhina (1969). Ling (1970) also observed such an occurrence from the central north Pacific sediments and also added that the latest occurrence of *Dictyocha subarctios* and *D.* cf. *ausonia* is found at the same horizon.

(b) Mediterranean (Italy) region

The investigation thus far carried out on silicoflagellates and ebridians from deep-sea sediments of the Pacific and Atlantic oceans and some land outcrops demonstrates that there are much diversified taxa showing limited geological occurrence since late Cretaceous time in the low-latitude area. Reports from the midlatitude of the western Pacific (Ling, 1971) and the central north Pacific bottom sediments (Ling, 1970) also agree with such findings.

Previously, workers such as Ehrenberg, Zanon, and Deflandre recorded the occurrence of these siliceous microfossils from the Mediterranean region, but stratigraphic information about these samples was often vague, and the exact range of the taxa cannot be deduced from the existing data.

Samples from Italian localities were here examined in order to seek the stratigraphic occurrence of taxa in Italy, to compare the results with those from the present deep-sea sediments of low latitude, and at the same time to cross-correlate with the radiolarian zones from these samples recognized by Riedel and Sanfilippo (1971) and Sanfilippo (1971).

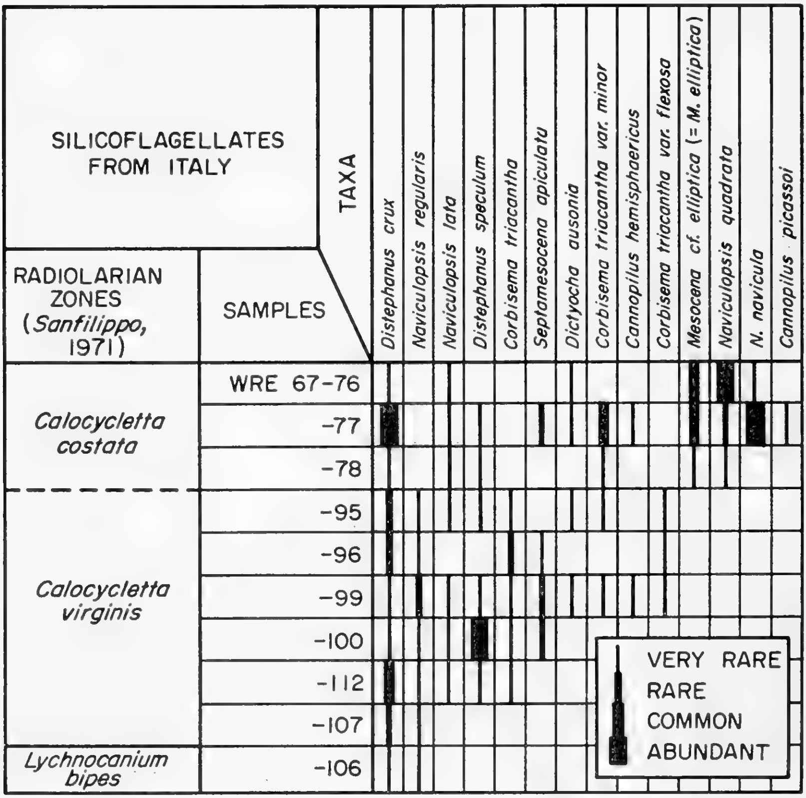
The results of the present stratigraphic occurrence are summarized in Text-figure 7, and the following microfloral boundaries are noted in ascending order:

1. The earliest occurrence of *Naviculopsis lata,* together with that of *Distephanus speculum* and *Corbisema triacantha,* marks the boundary between samples WRE 67- (in the following discussion the prefix WRE 67- will not be repeated) 107 and 112. The boundary of radiolarian zones, *Lychnocanium bipes* below and *Calocycletta virginis* above, is drawn between 106 and 107 and thus is slightly below the present silicoflagellate boundary.

2. The first appearance of *Mesocena* cf. *elliptica* and *Naviculopsis quadrata* occurs between samples 95 and 78. The boundary also marks the highest occurrence of *Naviculopsis regularis* and *Corbisema triacantha* and *C. triacantha* var. *flexuosa.* This boundary thus seems to agree with that of radiolarian zones, *Calocycletta virginis* below and *C. costata* above.

Although minor microfloral changes are recognized between the interval of samples 112 and 95, and of 78 and 76, the Italian samples thus can be grouped into three assemblages and thus boundaries are generally in agreement with the radiolarian results.

Perhaps the most interesting and significant phenomenon found in the Italian samples in comparison with the low- and midlatitudes of Pacific and Atlantic deep-sea sediments is the abundance of *Naviculopsis* specimens throughout the Italian samples here examined. Apparently some taxa are limited in their biogeographic distribution to the Mediterranean region and are within a part of the European continent only. However their value as a stratigraphic index is promising for the European Tertiary section.



Text-figure 7. — Distribution of silicoflagellates from Neogene Mediterranean (Italy) region. For detail study of the samples, see Sanfilippo (1971).

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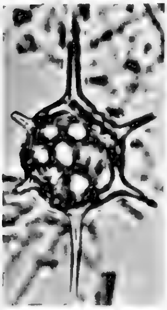
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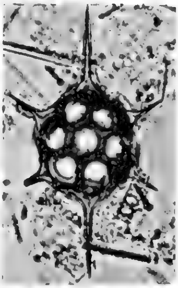
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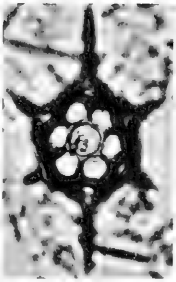
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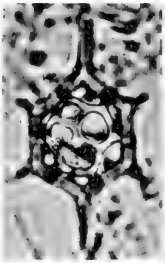
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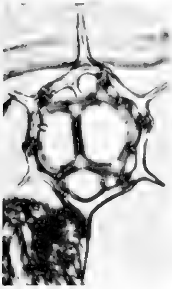
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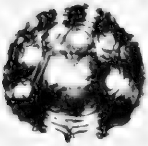
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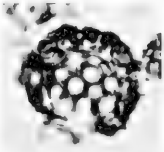
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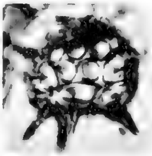

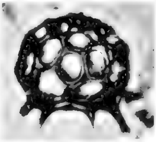
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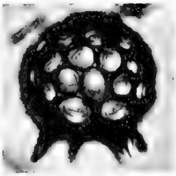
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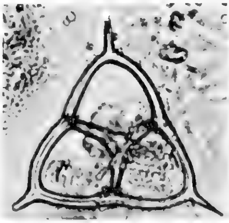
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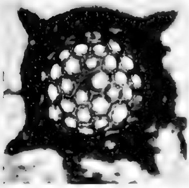
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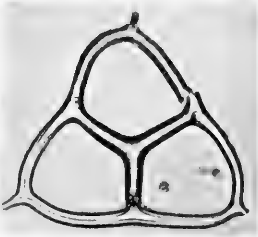
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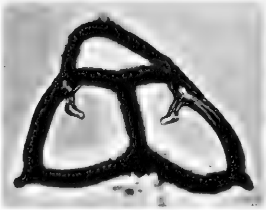
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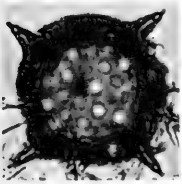
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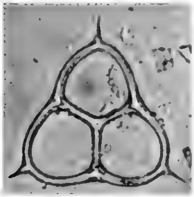
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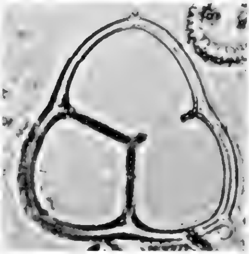
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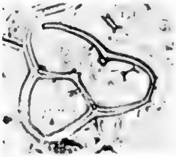
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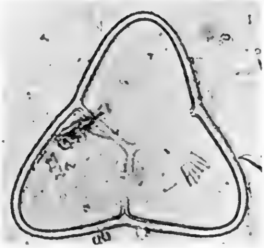
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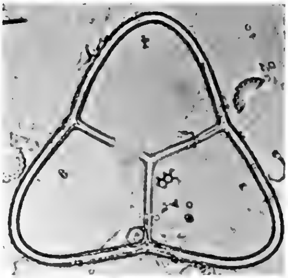
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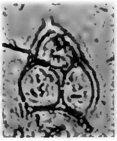
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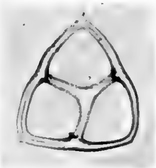
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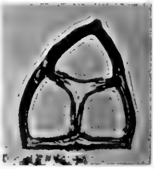

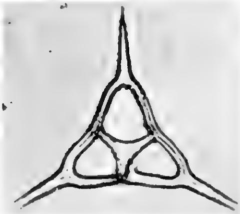
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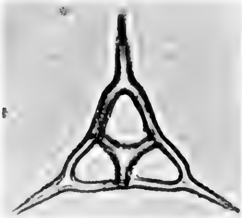
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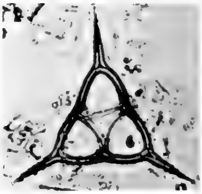
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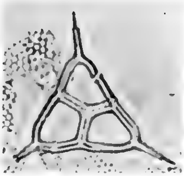
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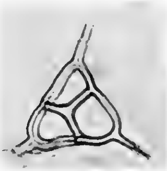
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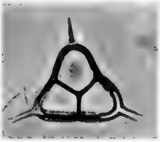
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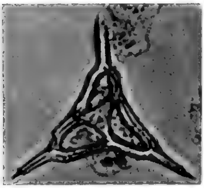
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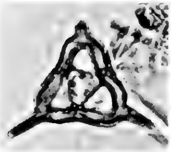
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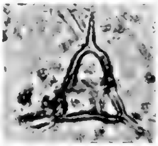
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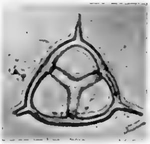
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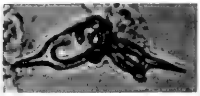
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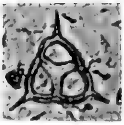
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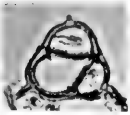
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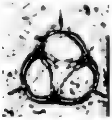
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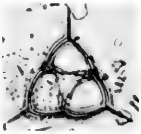
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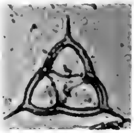

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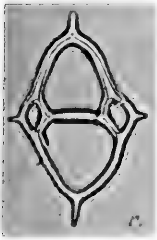
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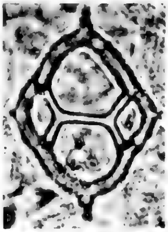
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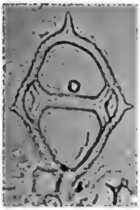
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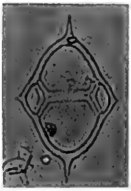
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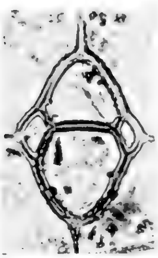
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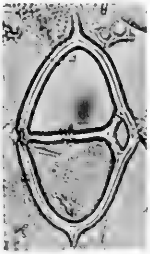
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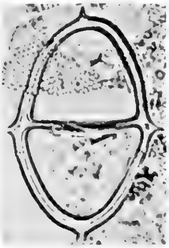
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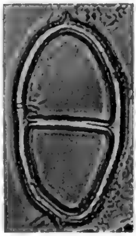
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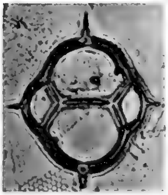
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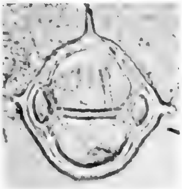
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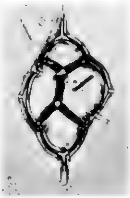
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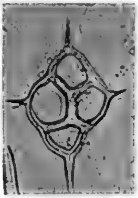
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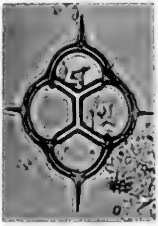
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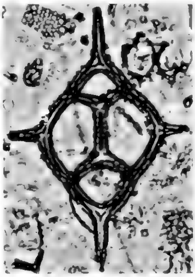
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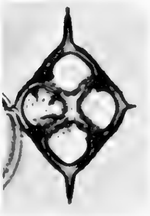
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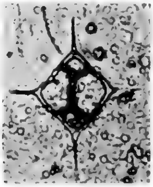
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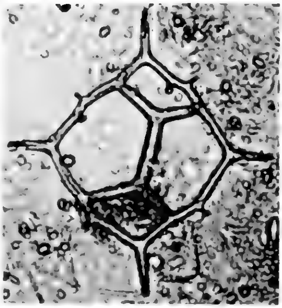
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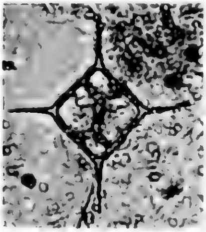
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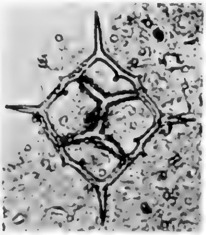
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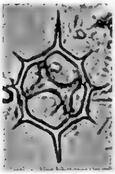
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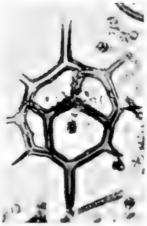
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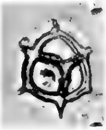
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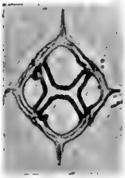
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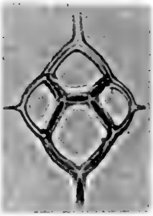
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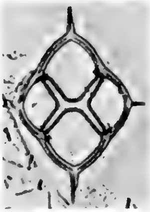
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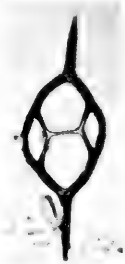
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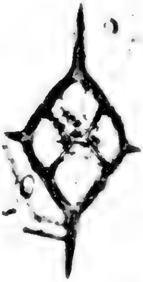
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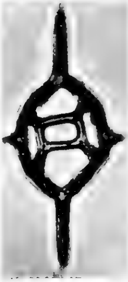
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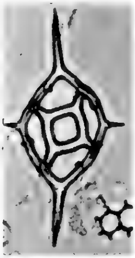
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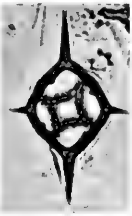
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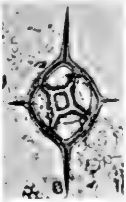
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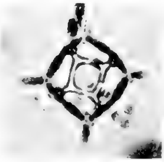
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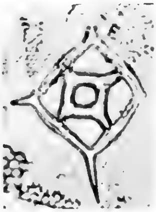
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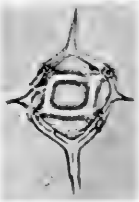
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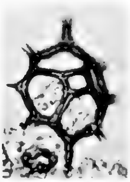
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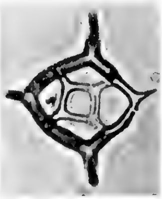
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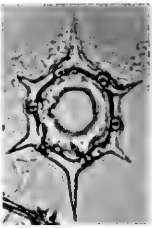
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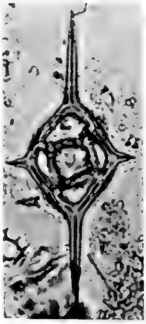
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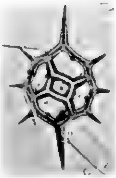

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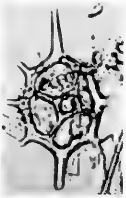

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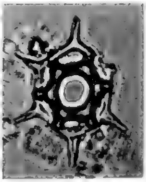

EXPLANATION OF PLATE 26

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EXPLANATION OF PLATE 27

All figures ×500 unless otherwise indicated.

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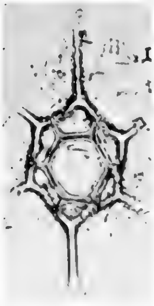
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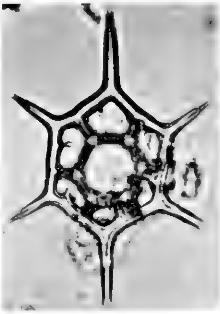
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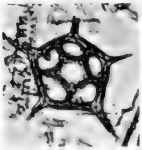
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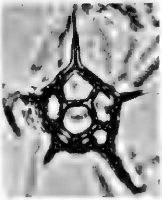
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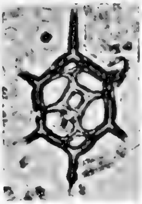
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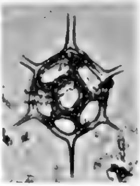
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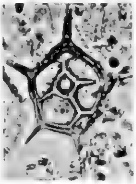
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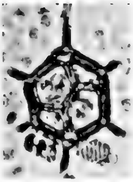
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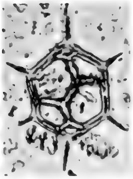
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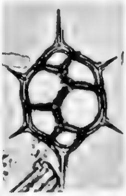
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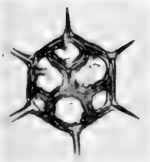
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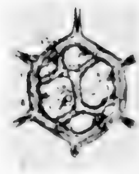
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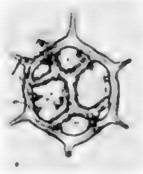
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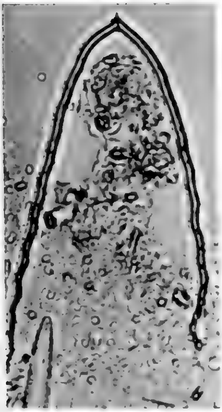
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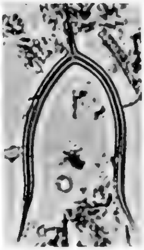
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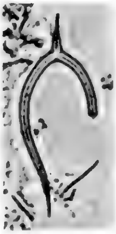
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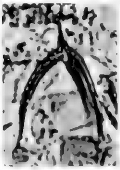
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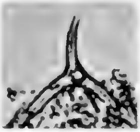
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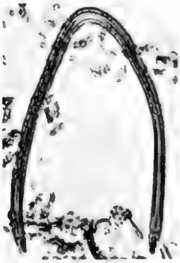
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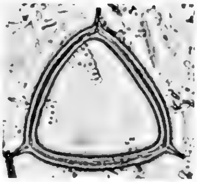
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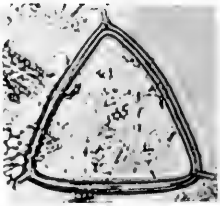
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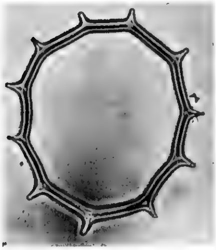
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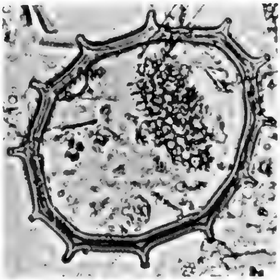
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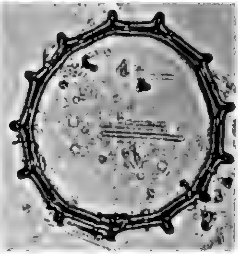

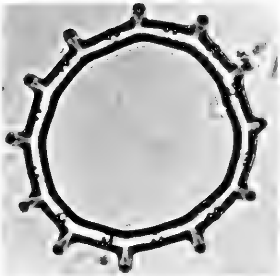
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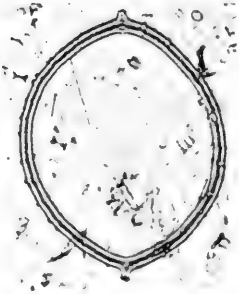
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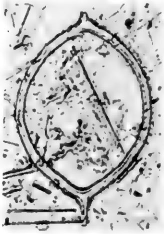

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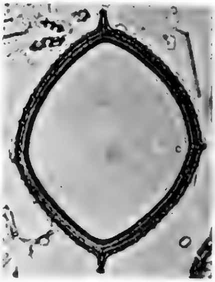

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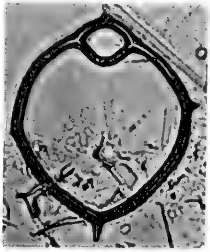

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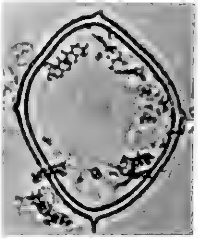

EXPLANATION OF PLATE 28

All figures ×500 unless otherwise indicated.

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1. **Lyramula simplex** Hanna 172
1. CAS 1144, L-2 (Q36/4).

2-4. **Mesocena apiculata** (Schulz) 173
2. S136/966, L-2 (L13/0); 3. the same specimen of figure 2 under the phase contrast photomicrograph; 4 S136/880, L-2 (R5/4).

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EXPLANATION OF PLATE 29

All figures ×500 unless otherwise indicated.

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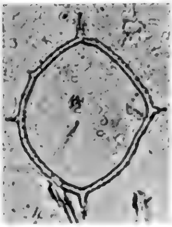
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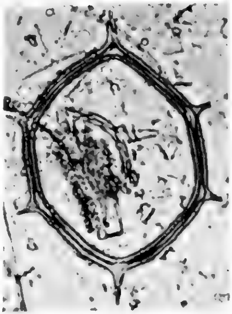
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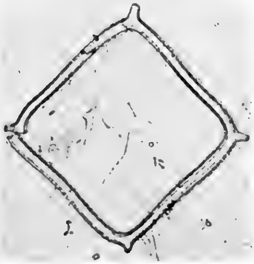
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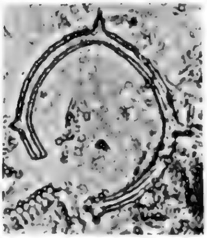
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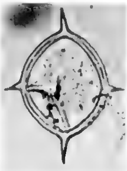
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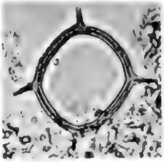
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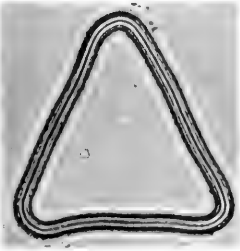
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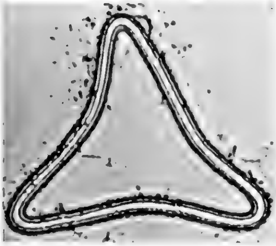
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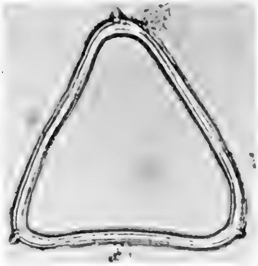
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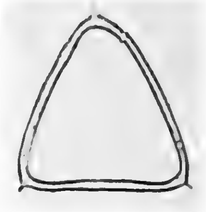
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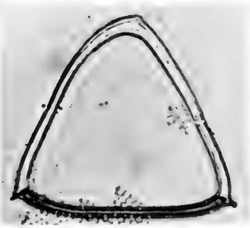
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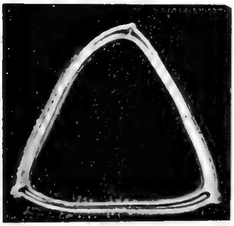
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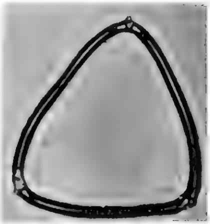
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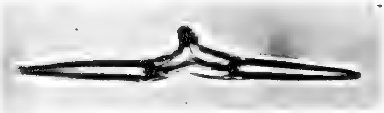
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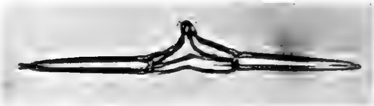
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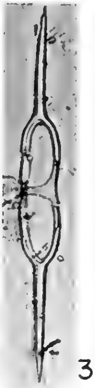
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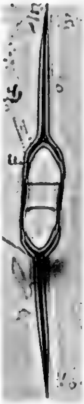
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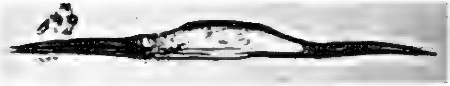
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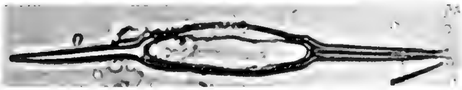
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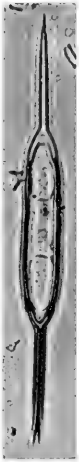
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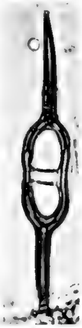
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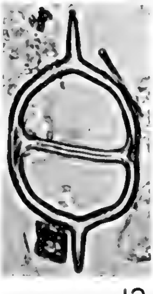
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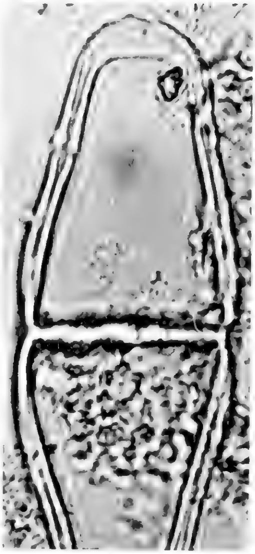
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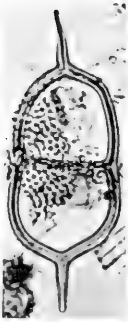
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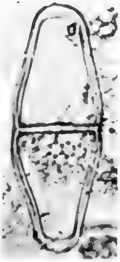
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EXPLANATION OF PLATE 30

All figures ×500 unless otherwise indicated.

Figure Page

1-4. **Naviculopsis biapiculata** (Lemmermann) 181

1, 2. Different focus levels, lateral view, S136/914, L-2 (R31/4); 3. DSDP 6-6-2, 1-2 cm, L-3 (Q17/0); 4. WR TR 39F (J.S.1068), L-3 (R40/1).

5-8. **Naviculopsis constricta** (Schulz) 183

5. S136/878, L-2 (N48/0); 6. Lateral view, S136/1096, L-2 (C23/0); 7. KEL 9, R-1 (E46/3); 8. DSDP 6-6-2, 1-2 cm, R-2 (W46/0).

9-11. **Naviculopsis foliacea** Deflandre 184

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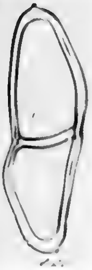
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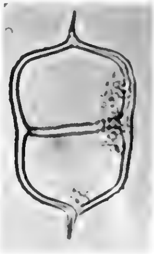
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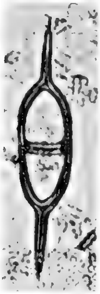
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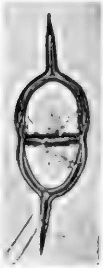
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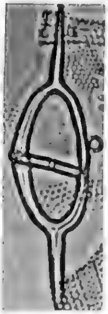
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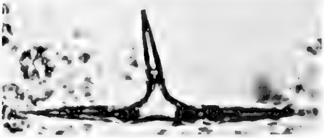
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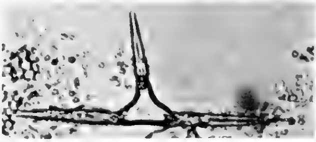
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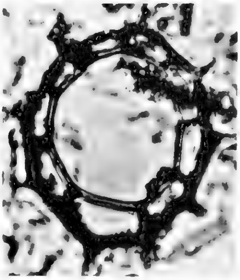
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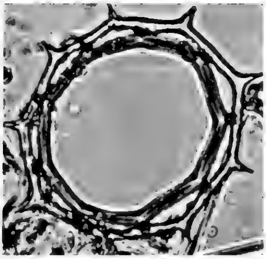
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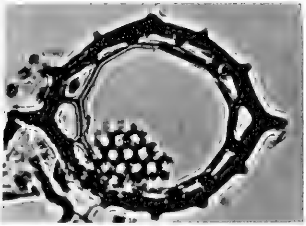
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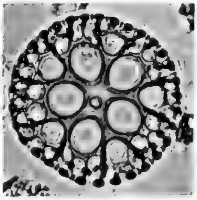
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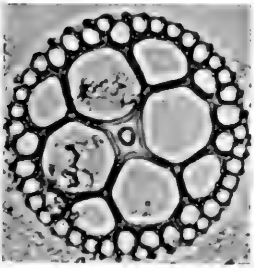

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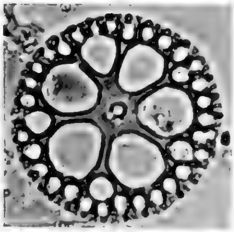

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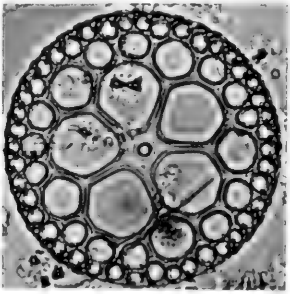


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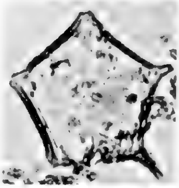
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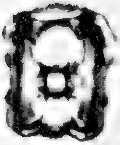
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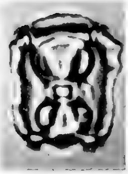
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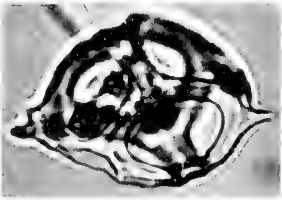
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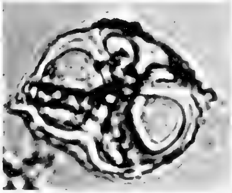
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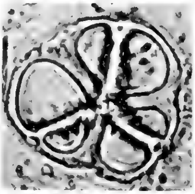
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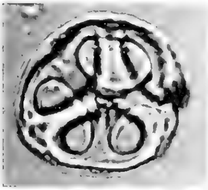
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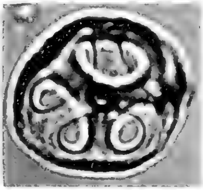
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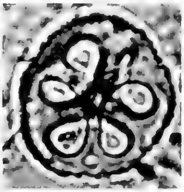
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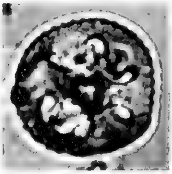
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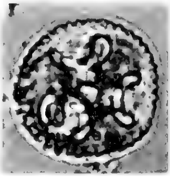
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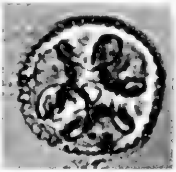
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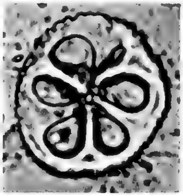
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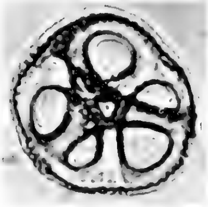
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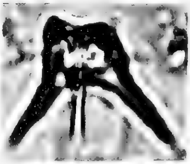
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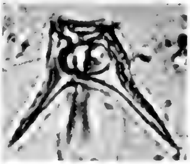
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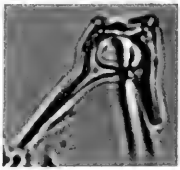
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SILURO-DEVONIAN MICROFAUNAL BIOSTRATIGRAPHY IN NEVADA

By

W. A. McClellan

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W. A. McClellan

ABSTRACT

From a regional microfossil study of Silurian and Lower Devonian strata in central Nevada, a large and diversified fauna of Foraminiferida and Ostracoda is described in detail for the first time. The foraminifers consist of 22 genera and 45 species. Two of the genera, *Anictosphaera* and *Atelikamara,* and the following species are new: *Anictosphaera progressa, Aschemonella bastillensis, Atelikamara incomposita, Haplophragmoides antiquus, Hemisphaerammina bipatella, Sorosphaera compacta, Sorosphaera inflata, Storthosphaera malloryi.* Recognition of *Haplophragmoides antiquus* in the Lower Devonian of central Nevada is the earliest record of the family Lituolidae. The ostracode fauna contains 29 genera and 20 identifiable species. Of these, *Longiscapha* is a new genus, and *Aechmina cortezensis, Longiscapha nevadensis, Rudderina mutaspina, Thlipsura bispinosa, Ulrichia obesita,* and *Winchellatia fragilis* are new species.

The Foraminiferida recorded here have been combined with previously known Silurian species from the Midwest to establish a tentative series of assemblage zones for the Silurian and Lower Devonian of North America, which are based on dominance of the different subfamilies. The Nevada fauna represents the Upper Silurian, characterized by the Psammosphaerinae, and the Lower Devonian, characterized by the Astrorhizinae and Hemisphaeramminae. The Lower and Middle Silurian assemblages, best known in the Midwest, have been divided into the following three zones: 1) Albion — Hippocrepininae, Rhizammininae, Ammodiscinae; 2) lower Niagaran — Saccammininae, Ammodiscinae; 3) middle Niagaran — Hippocrepininae, Psammosphaerinae, Hemisphaeramminae. In general, there is not sufficient evidence for widespread correlations on the basis of the ostracodes recognized here, though several genera and species of the Nevada fauna compare closely with those known from Appalachian strata of uppermost Silurian and Lower Devonian age.

The physical environment shows local variances with time which are recognized regionally as lithosomes. Association of the foraminifers with the several lithosomes suggests overall similarity to associations in other parts of North America. Associations between ostracodes and the various lithosomes remain uncertain due to their sporadic and limited occurrence.

ACKNOWLEDGMENTS

The writer wishes to especially thank Dr. V. S. Mallory for his critical review and suggestions on several important points in this study. Dr. John Kepper also assisted in many ways. The Atlantic Richfield Company generously contributed field expenses and research facilities. Additional contributions for field expenses were made by Humble Oil and Refining Company. The University of Nevada, Las Vegas, provided research funds for scanning electron microscopy. The Paleontological Museum of the University of Cincinnati in Cincinnati, Ohio, provided type specimens for study.

INTRODUCTION

Paleontological studies of Silurian and Lower Devonian rocks in the Cordilleran region have been mostly centered around the brachiopod faunas. Detailed microfossil reports have dealt exclusively with conodonts, though recent progress has been made with chitinozoans. Analysis of the combined brachiopod, conodont, and graptolite faunas has made possible the faunal subdivision of these strata, and certain of the elements have proven useful for interregional correlations.

Foraminiferal studies of Middle Paleozoic rocks have never been made west of Oklahoma. The work of Ireland (1939) from that area is the only detailed study of the Upper Silurian and Lower Devonian. The only report of ostracodes from these strata in Nevada is that of Berdan in Gilluly and Masursky (1965). Foraminiferida and Ostracoda are reported here in detail for the first time from Nevada.

In addition to the systematic description of species, the fauna has been applied as a biostratigraphic tool, and the age relationships of the formations, previously established on macrofossils or other bases, are re-examined in a regional framework throughout central Nevada, (Text-fig. 1). At this time the microfauna cannot be applied biostratigraphically in as refined a manner as the brachiopods and graptolites.

The physical stratigraphic record is represented by a series of lithologically distinct bodies (lithosomes) which persisted, or were recurrent, over an area for a considerable time. Lithosomes are recognized and presented here for two reasons. First, they demonstrate the changing depositional patterns across the region, an understanding of which is necessary to correctly interpret and correlate the various formational units. Second, they represent the environment which must be related to the biota for ecologic interpretations.

All microfossils which are figured or otherwise recognized as identified material have been deposited in the micropaleontology collections of the Geology and Paleontology Division, Thomas Burke Memorial Washington State Museum, at the University of Washington in Seattle. Locality numbers are designated by the prefix UWA, and a description of each locality is given in the Locality Register.

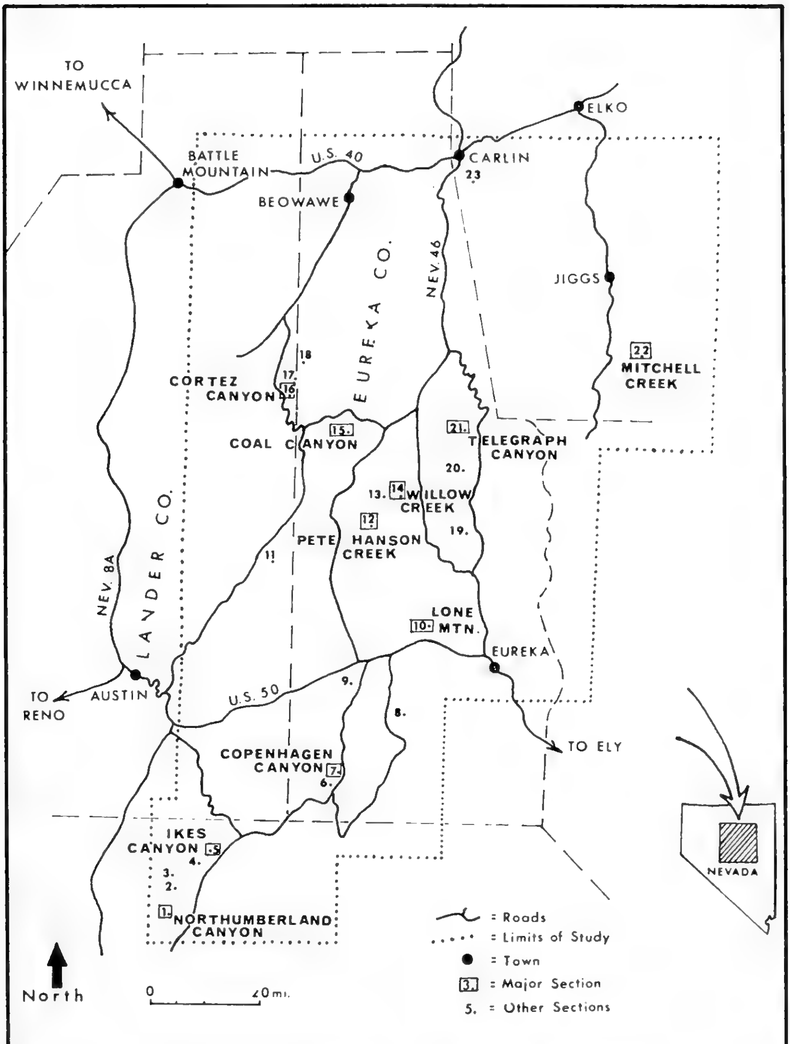


Fig. 1: INDEX MAP OF CENTRAL NEVADA

STRATIGRAPHY

Silurian and Lower Devonian rock units in Nevada comprise the major part of the Tippecanoe Sequence as demonstrated by Smith (1966) in his study of this sequence throughout western North America. Within the boundaries of the present study (Text-fig. 1) these rocks have been preserved in considerable thicknesses beneath the Wallbridge Discontinuity (Wheeler, 1963). They present a complete lateral series of marine rock types, from back-reef dolomites to reefoid units, fore-reef carbonates and shales, and finally the eugeosynclinal cherts, black shales, and quartzites. The various formational units (Text-fig. 2) are briefly outlined here and then considered, as applicable, in a presentation (Text-fig. 3) of the lithosomal units. The lithosomes more accurately illustrate the important lithic variables of the physical environment, which may be then related to the biological variables in the discussion of paleoecology. Previous workers have discussed the formations, and the purpose here is to develop an integrated picture of the Silurian and Lower Devonian environment. Correlations (Text-fig. 2) are based primarily on this integrated picture and the Foraminiferida and Ostracoda.

FORMATIONS AND AGES

The first recognition of rocks of Silurian age was by Hague (1892) who included all carbonates in the region ranging from Upper Ordovician through Silurian time as the Lone Mountain Limestone. He referred to those rocks, believed to be Devonian in age, as the Nevada Limestone. Subsequent work has resulted in several restrictions of these units as originally defined, as well as nomenclatural additions. In recent years relative agreement has been reached on the nomenclature by most workers. Merriam (1940) restricted the name Lone Mountain to a massive dolomite unit representing Late Silurian and possibly earliest Devonian sedimentation. To the east, outside of this area, the Lone Mountain Dolomite, thus restricted, merges with several other dolomite formations which have different lithologic characteristics. The Lone Mountain Dolomite has been demonstrated by Winterer and Murphy (1960) to be a dolomitized reefoid complex cropping out in a band striking north-northeast through east-central Nevada. The reef grew in a westerly direction during Silurian time and persisted into the early Devonian.

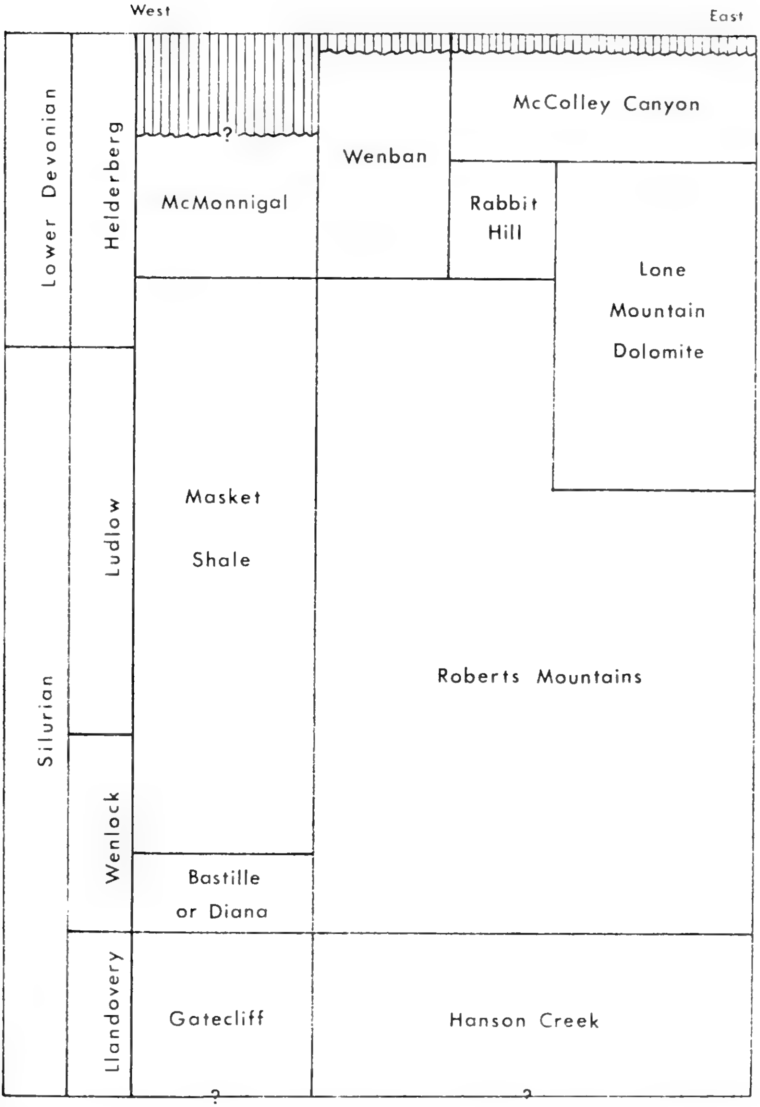


Fig. 2: STRATIGRAPHIC RELATIONSHIPS OF SILURIAN AND LOWER DEVONIAN FORMATIONS IN CENTRAL NEVADA

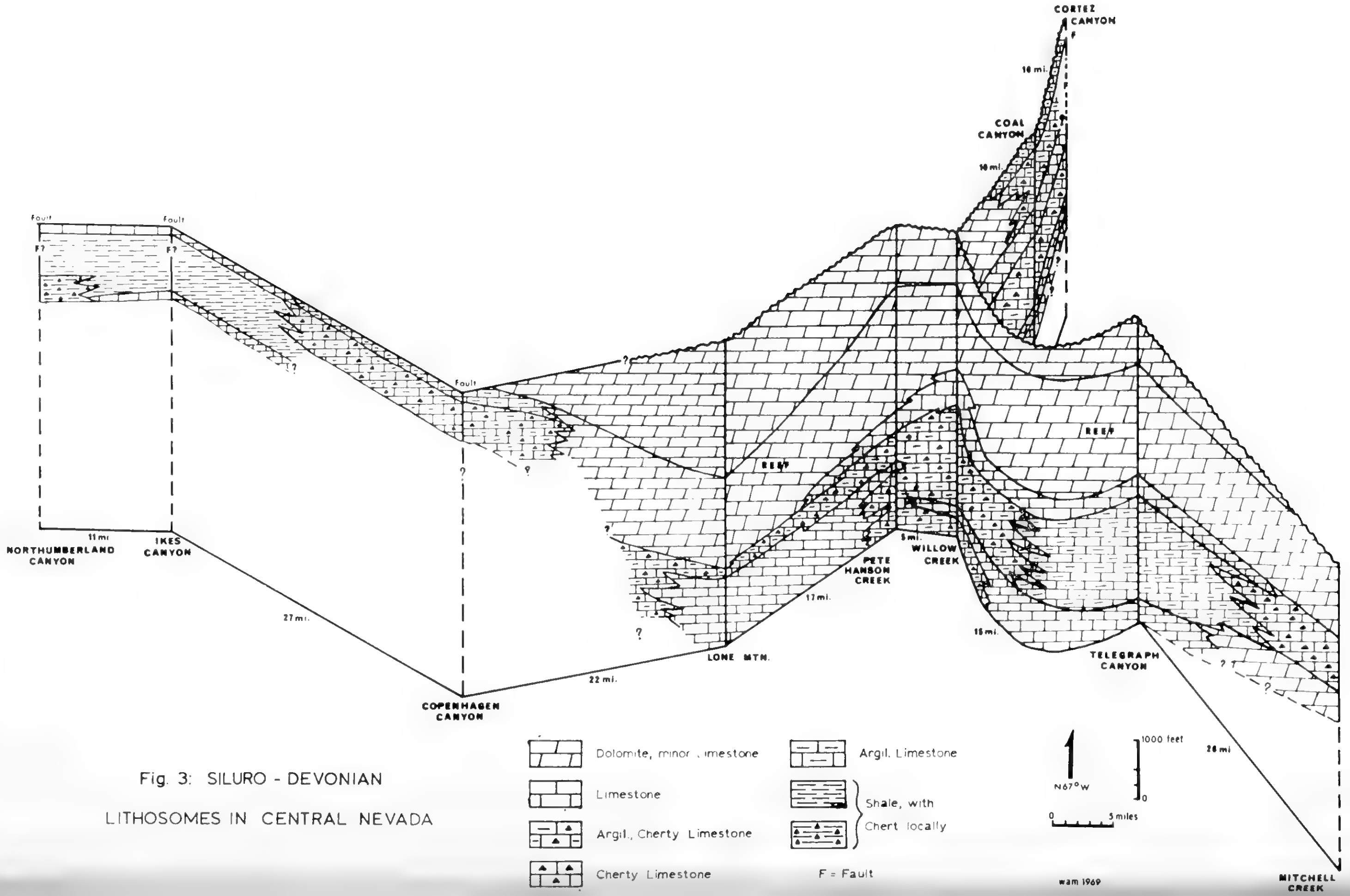


Fig. 3: SILURO - DEVONIAN

LITHOSOMES IN CENTRAL NEVADA

Underlying the Lone Mountain Dolomite is the Roberts Mountains Formation, the upper part of which is a lateral fore-reef equivalent of the former. In the type area, the formation (described by Merriam, 1940) lies beneath the Lone Mountain Dolomite with a gradational contact between them. Approximately five miles north of this locality, at Kelly Creek, the upper Roberts Mountains Formation grades laterally into the dolomite. These upper beds are mostly medium-bedded, dark gray limestones with some shale interbeds and occasional chert. The lower units of the formation are composed typically of thin-bedded limestones and calcareous shales, with chert common as irregular masses and laminae, or bedded in the lowermost units. The base of the Roberts Mountains Formation is recognized by the common occurrence of chert which is not present in the immediate underlying beds of the Hanson Creek Formation. Although the formation becomes somewhat modified in lithology as one progresses to adjacent areas, there are certain features which may be consistently recognized. Westward from the type area, the formation becomes increasingly argillaceous, platy in appearance, and characteristically weathers to shades of light gray, buff, and pinkish lavender. Eastward it becomes more thickly bedded and locally dolomitic until indistinguishable from the Laketown Dolomite in eastern Nevada. The unifying characteristic remains, however, as the presence of well-bedded limestones and chert, though the latter may be sporadic. Text-figure 2 shows the stratigraphic position of the Roberts Mountains Formation and its relationship to the Lone Mountain Dolomite.

Basinward of the carbonates is the stratigraphically equivalent Masket Shale described by Kay (1960). It is dominantly a calcareous, silty, gray-black, platy shale which weathers to shades of buff and pinkish lavender. Subordinate interbeds are composed of dark gray limestone, locally fossiliferous, which appear very similar to beds of the Roberts Mountains Formation. The Masket Shale becomes siliceous in places, with some black chert interbeds. Interpretations of these lithic variations are shown on Text-fig. 3. Kay and Crawford (1964) dated the Masket Shale as Middle Silurian on the basis of graptolites.

Two limestone units composing the basal Masket Shale have been designated the Bastille Limestone Member and Diana Limestone Formation by Kay and Crawford (1964). The latter is recognized only locally by them and its absence elsewhere explained as being due to lenticularity of the unit. Throughout the region carbonates were deposited immediately prior to deposition of the dark shales, and it is probable that both the Bastille Limestone and Diana Limestone (Text-fig. 2) are equivalent representatives of this earlier carbonate unit. They should probably both be considered as units of formational rank, preceding the Masket Shale Formation. Biostratigraphic evidence, presented subsequently, suggests their equivalence with lower units of the Roberts Mountains Formation. It is suggested here that the local absence of these limestones, as reported by Kay and Crawford (p. 439), is most probably due to faulting. Because every section of the Masket Shale is part of a thrust sheet and shows local structural complications, it is likely that the formation is nowhere recognizably complete. The overlying Lower Devonian carbonates can be well correlated throughout the area on the basis of their ostracode fauna, which compares favorably with Helderbergian faunas in eastern North America (see discussion of biostratigraphy). Therefore, the upper limit of the Masket Shale can be placed near the Silurian-Devonian boundary. Within the formation more refined age determinations are not possible with the meager faunas presently known from it.

Johnson (1965) proposed the name Windmill Formation for thick-bedded, dark gray limestones containing minor interbeds of calcareous shale which crop out of Coal Canyon (Text-fig. 1) in the northern Simpson Park Range. Some of the beds are limestone breccias representing fore-reef talus of the Lone Mountain reef dolomite (Winterer and Murphy, 1960). Similar thick bedding is present at Willow Creek, Telegraph Canyon (Text-fig. 1) and Kelly Creek where it has been considered as upper Roberts Mountains Formation. The Windmill Formation is considered here to be only a member of the Roberts Mountains Formation, characterized by well-bedded limestones with subordinate shale and little chert. In contrast, the lower part of the formation is usually thin, platy limestones with abundant chert and calcareous shale interbeds.

Overlying the Roberts Mountains Formation is the Rabbit Hill Limestone, a stratigraphic and fore-reef equivalent of the upper

Lone Mountain Dolomite. The Rabbit Hill Limestone, named by Merriam (1963) from exposures one mile south of the Copenhagen Canyon locality (Text-fig. 1), is a sequence of dark gray limestones and calcareous shales, with rare chert, which weather light gray to buff. These beds are weak and incompetent, with minor drag folds which are related to the thrusting that has caused Lower Ordovician limestones to override these Siluro-Devonian limestones in the area of Copenhagen Canyon. The Rabbit Hill contains a large invertebrate fauna with several taxa closely related to Appalachian species of Helderbergian age. In addition to this age documentation (Merriam, *ibid.,* p. 43), there is evidence shown by the ostracode fauna described herein. Elsewhere the formation commonly contains abundant tentaculitids and a similar ostracode assemblage. At the type locality Merriam suggested that the underlying Roberts Mountains Formation may be disconformable or possibly in fault contact. The latter case appears to be likely in view of the known local structural complications. It may also be possible that there is more Roberts Mountains Formation present in the area, but it is not exposed. Additional consideration of this possibility is given below in the context of the Hanson Creek Formation.

The McMonnigal Limestone (Kay, 1960) is a dark gray, well-bedded biosparite with a large diversified fauna indicating a Helderbergian age. It overlies the Masket Shale with gradational contact in the type area of Ikes Canyon. The invertebrate fauna correlates fairly well with that of the Rabbit Hill Limestone, and the ostracodes and foraminifers are similar, the same characteristic species being dominant.

The lower Wenban Limestone of Gilluly and Masursky (1965) is lithologically similar to the McMonnigal Limestone except for a scarcity of invertebrate fossils. Gilluly and Masursky considered that this lower part of their formation may be disconformable with thicker bedded, blocky limestone beds of Middle Devonian age above. The abundant foraminiferal and ostracode fauna recovered here suggests the same conclusion, as it correlates closely with that of the McMonnigal Formation and Rabbit Hill Formation and points strongly to a Helderbergian age. Upper Wenban ostracodes were identified by Berdan (*in* Gilluly and Masursky) as Middle to Upper Devonian, different from those identified by the writer.

Hence, there appears to be strong biostratigraphic evidence for an unconformity within the Wenban Limestone representing the Wallbridge Discontinuity.

The lower Wenban Limestone, McMonnigal Limestone, and Rabbit Hill Limestone are all shown as equivalent to the uppermost Lone Mountain Dolomite in Text-fig. 2.

SUBJACENT AND SUPERJACENT FORMATIONS

The only formation conformably overlying the previously discussed units and not included in this study is the McColley Canyon Formation of Johnson (1962). This Lower Devonian formation was the basal unit of Hague's Nevada Limestone (1892) and was first named, as a member, by Carlisle (*et al,* 1957). Within this region the McColley Canyon has only been preserved in areas of maximum reef development (Text-fig. 3). Here it is dominantly a dolomitic limestone, with local variations in the amount of dolomitization. Wherever the formation is not conformably overlying Helderbergian beds the upper contact of the latter rocks is a present erosion surface or fault contact. At some localities Middle Devonian rocks rest unconformably on Lone Mountain Dolomite or McColley Canyon.

Subjacent rock units are also dependent in several cases on local structure. At March Spring the Masket Shale is in fault contact with the Lower Ordovician Antelope Valley Limestone, and at Mitchell Creek (Text-fig. 1) underlying rocks are Upper Cambrian limestones. At all other localities where the contact is exposed the rocks are carbonates in conformable contact. In the west the Gatecliff Dolomite is directly beneath the basal limestone member of the Masket Shale.

Eastward, the Hanson Creek Formation, a dolomitic limestone, precedes the basal cherty beds of the Roberts Mountains Formation. The Hanson Creek is reportedly present (Merriam, 1963) at Copenhagen Canyon, but the beds appear very much like the Roberts Mountains lithology, including abundant laminae of chert. If these beds are in fact Hanson Creek then the Roberts Mountains is reduced to only 600 feet beneath the Rabbit Hill Limestone, or less than one-half its normal thickness elsewhere when it has the same lithology. It is believed that the dolomitic limestone beds mapped as

Hanson Creek by Merriam (1963) are only a dolomitic extension of the Roberts Mountains lithology seen at Lone Mountain only 22 miles away.

LITHOSOMES

The lithic patterns are best revealed when viewed as three-dimensional bodies, which maintain relative continuity within the study area and mutually intertongue with each other. These lithosomes, being a physical product of the environment through time, can be directly applied to the biostratigraphy and paleoecology. Text-figure 3 shows the six different lithosomes recognized in the Silurian and Lower Devonian rocks of central Nevada.

The easternmost lithosome is one of pure carbonate represented by reef dolomites and back-reef dolomites. The major part of this body is formed by the Lone Mountain reef here representing an environment of high energy conditions with a reef biota of tabulate corals, brachiopods, and echinoderms. East of this massive reef dolomite are back-reef units, which are thick-bedded, generally devoid of fossils, and represent quieter, lagoonal conditions. This lithosome rests on and intertongues to the west with several limestone lithosomes.

A lithosome of relatively pure limestone underlies the dolomite over much of the area. To the northwest, between Willow Creek and Coal Canyon, the two intertongue as lateral equivalents. Winterer and Murphy (1960) demonstrated a local gradation from reef dolomite to fore-reef limestone in the vicinity of Willow Creek in the northern Roberts Mountains. Ten miles away, in Coal Canyon (Text-fig. 1) thick-bedded limestones with reef breccia occupy a stratigraphic position equivalent to the reef dolomite. A lateral intertonguing of the two lithosomes has been interpreted to have occurred between these two local outcrops. To the south and east, the pure limestone becomes increasingly dolomitic. Because there is considerable local variation in the amount of dolomitization, it has not been possible to separate, with certainty, these beds from those containing little dolomite.

The cherty limestone lithosome is only developed in the eastern part of the studied area. Here it follows a dolomite, is in turn succeeded by another dolomite, and intertongues to the west with argillaceous limestones. It does not appear to be an extensive body and may be only a local variation of the pure limestone lithosome.

The argillaceous and cherty limestone lithosome is widespread and has an irregular configuration. In some directions it intertongues with argillaceous limestones, in others with more nearly pure carbonate. In the central part of the area these beds intertongue with dolomitic limestones. Westerly, the unit becomes increasingly argillaceous until changing to a calcareous shale which is locally siliceous. This latter lithology typifies the Masket Shale. Within the unit the amount of chert is variable, though generally more abundant in the lowest beds. This is the characteristic lithology of the Roberts Mountains Formation.

In two separated areas are rocks which represent an argillaceous limestone lithosome. An eastern unit lies between the cherty limestones and argillaceous, cherty limestones, and it is vertically bounded by pure limestone. To the west, the unit is present as a fore-reef equivalent of the dolomites in latest Silurian and early Devonian time. Here, it succeeds argillaceous and cherty, or nearly pure, limestones, and contains a much larger amount of detrital material than in the east. Beds equivalent to this lithosome in the westernmost parts of the area are well-bedded, fossiliferous, limestones. The physical conditions necessary for deposition of these beds, apparently basinward of the lower energy argillaceous limestones, are not evident at present.

A calcareous, and locally siliceous, shale lithosome represents a transition to the basinal conditions evident in strata west of the area studied here. This body is vertically bounded by medium-bedded, pure limestones and intertongues with the argillaceous and cherty limestone lithosome to the east. It represents the Masket Shale from Ikes Canyon to Northumberland Canyon (Text-fig. 1) in the Toquima Range. Fossils are extremely rare in these dark shales which are suggestive of a quiet water, euxinic environment.

PALEONTOLOGY

Silurian and Lower Devonian ages for the strata studied here have been based primarily on the graptolite and brachiopod faunas. Additional dating has been made by comparison of Nevada conodont faunas with their correlatives in Europe.

The first zonation of these rocks was made by Merriam (1940), who established several informal zones in the Roberts Mountains, Lone Mountain, and immediately overlying unnamed formations. These zones have undergone modification and refinement by recent workers. Johnson and Boucot (1968, p. 69) recognized 20 zones, or subzones, for the Lower Devonian rocks alone in this region. The Silurian has not been so refined biostratigraphically. Following Merriam (1940) most of the Silurian has been assigned to an upper Llandovery and younger age by comparisons with Appalachian brachiopod faunas.

Graptolite studies (Kay and Crawford 1964; and Johnson, 1965, p. 368) suggested age assignments similar to those based on brachiopods. The lower Masket Shale contains graptolites of Zone 26, early Wenlockian age (Kay and Crawford, 1964, p. 438). Other species reported by them from the Gatecliff Formation, immediately below the Bastille Limestone, are Zone 20, of middle Llandovery age. Identifications have been made of graptolites occurring in the Roberts Mountains Formation (correlative with the Masket Shale) where it crops out in the Coal Canyon area of the Simpson Park Range. These suggest a range from latest Llandovery age to early Devonian (Johnson, 1965, p. 368).

Integration of the graptolites and brachiopods provides reasonably accurate age assignment for other formations which are also part of this Silurian and Lower Devonian sequence in central Nevada. Accordingly, the generally recognized stratigraphic positions of all formations included within this study are outlined in Text-fig. 2. The foraminifers and ostracodes, discussed here subsequently, substantiate the ages previously assigned. The lower Wenban Limestone, tentatively placed partially in the Lower Devonian by Gilluly and Masursky (1965), has been correlated with well-known Helderbergian beds on the basis of comparative microfaunas.

Studies of conodonts in these rocks have been somewhat successful in the same usage as the invertebrates. Clark and Ethington (1966, p. 666) suggested somewhat younger ages for the Roberts Mountains Formation and Lone Mountain Formation on the basis of conodonts alone. Their conclusions resulted from direct comparisons to European faunas. However, such long range correlations with no geographic intermediary faunas are tenuous, especially in view of the revisions currently being done in Europe on the Lower Devonian conodonts there (*e.g.* Carls and Gandl, 1969). Conodont faunas reported by Klapper (1969, p. 72) from the Roberts Mountains Formation have indicated ages comparable to those assigned to Merriam's (1940) zones discussed above.

FORAMINIFERIDA

Reports of Middle Paleozoic foraminifers have been made by several authors from rocks geographically situated from Kansas to Ohio. In most cases these have been limited to a general description of species and some tentative suggestions on biostratigraphic relations. Mound (1961) and McClellan (1966), in their studies of Lower and Middle Silurian faunas in southern Indiana, considered the relative abundance of the different species and the dominance of particular families and subfamilies. McClellan (pp. 454, 455) recognized characteristic species and subfamilies in the Waldron Shale (lower Wenlockian) which separated that unit from Lower Silurian formations in Indiana. Biostratigraphic comparisons with these Indiana faunas are presented in another section.

Foraminiferal faunal comparisons, distributions, and ranges of this Nevada material are only possible with faunas from the above areas, from which the foraminifers are adequately known. The stratigraphic ranges within the Silurian have been referred to the European stages to be compatible with graptolite and brachiopod zonations previously established for the rocks in central Nevada. European stages for the Lower Devonian have not been used here because of the lack of graptolites and present uncertainty regarding interregional extent of brachiopod zones. Accordingly, the more inclusive North American stage name, Helderbergian, has been used here.

Among the genera of Middle Paleozoic arenaceous Foraminiferida recorded previously, nearly all are represented in the rocks of central Nevada. Many of the species are the same as those from the midwest, and others are here reported for the first time. Table 1 lists the genera whose previous geographic distribution has been extended to the Cordilleran region.

Table 1

Extended Geographic Distribution of Known Silurian Genera

Glomospira
Hemisphaerammina
Hyperammina
Marsipella
Metamorphina
Psammosphaera
Raibosammina
Rhabdammina
Sorosphaera
Sorostomasphaera
Stegnammina
Thurammina
Tolypammina
Webbinelloidea

Other genera considered to be common in Silurian strata elsewhere but significantly missing from Table 1, are *Saccammina* Sars (1869), *Lagenammina* Rhumbler (1911), *Ammodiscus* Reuss (1862), *Lituotuba* Rhumbler (1895), and *Turritellella* Rhumbler (1904). Except for *Lagenammina* all of these genera are rare in strata younger than Lower Silurian which probably explains their absence in Nevada. Dunn (1942, p. 319) reported *Lagenammina* as a common constituent of Middle Silurian faunas in Illinois. Perhaps this represents a local abundance for the genus is rare in Indiana (McClellan, 1966, p. 456).

Several species of the genera listed in Table 1 occur here in strata of different age than previously reported. This is also the case of the genera *Nanicella* Henbest (1935), *Sorostomasphaera* McClellan (1966), and *Stomasphaera* Mound (1961). Previously and presently known ranges of these species are given in Table 2.

Two new genera, *Anictosphaera* and *Atelikamara,* and eight new species are named herein. The species are *Anictosphaera progressa, Aschemonella bastillensis, Atelikamara incomposita, Haplophragmoides antiquus, Hemisphaerammina bipatella, Sorosphaera compacta, Sorosphaera inflata,* and *Storthosphaera malloryi.* This is the first record of *Haplophragmoides* from rocks older than Mississippian, and *Storthosphaera* has previously been known only from the Recent.

Table 2

Extended Stratigraphic Range of Known Species

	Previous	Present
Hemisphaerammina coronata	M. Sil.	M. - U. Sil.
Marsipella torta	L. Sil.	Sil. - L. Dev.
Nanicella dainae?	L. Carb.	L. Dev. - L. Carb.
Raibosammina aspera	U. Ord.	U. Ord. - L. Dev.

Rhabdammina bifurcata	L. Sil.	Sil. - L. Dev.
R. major	Recent	U. Sil, Rec.
Sorostomasphaera waldronensis	M. Sil.	M. - U. Sil.
Stegnammina contorta	M. Sil.	M. Sil. - L. Dev.
S. hebesta?	M. Sil.	M. Sil. - L. Dev.
S. moremani	L. Sil.	Sil. - L. Dev.
S. quadrangularis	L. Sil.	Sil. - L. Dev.
Stomasphaera brassfieldensis	L. - M. Sil.	Silurian
Thurammina arcuata	L. - M. Sil.	Sil. - L. Dev.
Tolypammina tortuosa	L. Sil.	Sil. - L. Dev.
Webbinelloidea hattini	M. Sil.	M. Sil. - L. Dev.
W. ventriquetra	M. Sil.	M. - U. Sil.

OSTRACODA

The ostracodes in this region are more local in occurrence than the foraminifers. They are rare in the Silurian strata, but in Lower Devonian rocks they are excellent tools for correlation. The only previous study of Middle Paleozoic ostracodes in central Nevada was by Berdan (*in* Gilluly and Masursky, 1965), who listed a number of genera found in the Devonian Wenban Limestone. Although many of these genera were reported by Berdan from the upper Wenban (younger than any rocks studied here), those from the lower Wenban Limestone, at a locality only a few miles from Cortez Canyon, contain eight genera found by the writer at the same stratigraphic level elsewhere.

Lower Devonian reports on Ostracoda by Coryell and Cuskley, (1934), Swartz and Whitmore (1956) and Copeland (1962) contain faunal elements comparable to those in Nevada. The work of Coryell and Cuskley on the Haragan Shale in Oklahoma is the nearest, geographically, of the three. Two Haragan genera, *Parahealdia* Coryell and Cuskley, 1934 and *Aechmina* Jones and Holl, 1869, are represented by similar species at probably the same horizon in central Nevada. Swartz and Whitmore (1956) made a detailed study of uppermost Silurian and lowest Devonian ostracodes in eastern New York. The following genera and species from Nevada are common to those from New York and are of nearly the same age.

Bolbiprimitia teresaccula
Bythocypris sp.
Kloedenia aparchoides
Limbinaria sp.

Myomphalus? sp.
Saccarchites saccularis
Velibeyrichia? sp.
Welleriopsis jerseyensis

The Lower Devonian of Nevada contains several other genera and species, which also have been found in the Dalhousie beds of northern New Brunswick, Canada (Copeland, 1962, pp. 18-48). While not precisely correlative with the Nevada rocks, the Dalhousie beds were considered Helderbergian in age by Copeland (p. 23). The following species compare closely to Dalhousie species, and *Phlyctiscapha keslingi* Copeland is common to both areas.

Aechmina equilateralis
Bythocypris aff. *B. alcocki*
Eukloedenella aff. *E. dalhousiensis*
Phlyctiscapha keslingi
Tubulibairdia cf. *T. chaleurensis*

The ostracodes described here represent a diversified fauna, but individuals are often rare in occurrence and poorly preserved. Therefore many specimens have been identified only to genus. In addition, many species are apparently smaller than normal, which might be caused by ecological factors and are considered in the paleoecology discussion. With these limitations phylogenetic relationships and species comparisons can only be evaluated superficially. All families and subfamilies, however, are those which normally dominate ostracode faunas of the Middle Paleozoic. The family Quasillitidae, represented here by *Quasillites* sp., is usually more characteristic of the later Devonian. A closely related family, the Ropolonellidae, is represented by species of *Rudderina* Coryell and Malkin (1936) which previously have been reported only from the Middle Devonian. *Winchellatia fragilis* is the first member of the family Sigmoopsidae to be definitely recognized in the Upper Silurian, all other representatives being limited to the Ordovician.

One new genus, *Longiscapha*, and six new species are recognized here. The species are *Aechmina cortezensis*, *Longiscapha nevadensis*, *Rudderina mutaspina*, *Thlipsura bispinosa*, *Ulrichia obesita*, and *Winchellatia fragilis*.

OTHER MICROFOSSILS

The foraminifers and ostracodes strongly dominate the microfauna of the rocks studied here, but certain other groups occur with regularity at several localities. Conodonts were found in some quantity in a few sections. Detailed systematic descriptions of a fauna recovered from the same stratigraphic sections have been published by Clark and Ethington (1966). Species recognized here are listed in Table 3 with the numbers of the localities at which they occur.

Additional microfossils include sponge spicules, radiolarians, and tentaculitids. The first are almost exclusively six-rayed types, with little variety of form. The radiolarians, apparently also only a few varieties, have been pyritized in every case. Tentaculitids were found at a few localities within the Lower Devonian. They are especially abundant at locality UWA 5973 in the Rabbit Hill Formation where they are readily recognized on the surfaces of rock samples.

Table 3: Conodonts

Species	Localities (UWA)
Belodella triangularis	5976
Distacodus? sp.	5993
Hindeodella sp.	5985, 5986, 5976
Icriodus curvatus	6010, 6012
I. expansus	5986, 5994
I. latericresens	5993
I. symmetricus	6012
I. spp.	5993, 6012
Ozarkodina? aff. *O. media*	5974, 5985, 5994
Panderodus cf. *P. simplex*	6028, 6012, 5989
P. unicostatus	5986, 5981, 6028, 5974, 5993, 6007
Prionodina sp.	5974
Spathognathus bipennatus?	5986
S. canadensis	5976, 5985, 5986, 6027
S. fundamentatus	6028
S. spp.	5985
Synprioniodina sp.	5985
Trichonodella inconstans	5976, 5985
Trichonodella cf. *T. inconstans*	5986
Distacodontidae ? genus	6028

PALEOECOLOGY

The lithology of the Silurian and Lower Devonian strata in this region varies considerably both laterally and vertically. The major pattern of environment is that of shallow, warm, well-aerated, marine waters in the east, and westward deepening with subsequent quieter bottom conditions in which fine detrital material was deposited. Within the basic pattern there are six readily definable physical environments persisting in the area. Placed in a three dimensional framework, they are represented as lithosomes (Text-fig. 3) whose physical development has been previously discussed. The following discussion relates the lithosomes, which represent the physical environment, to the foraminifer and ostracode biota.

DOLOMITE AND REEF LITHOSOME

This environment represents the shallowest and at times, most active water conditions. The easternmost thickly bedded dolomites contain a meager invertebrate fauna and foraminifers and ostracodes are lacking. Deposition was in back-reef and probable lagoonal areas. The bedded dolomite deposition advanced westward in time, following the advancement of a linear reef trend being developed before them. The reef is recognized by massive dolomites which contain colonial corals and a variety of other invertebrate organisms, especially brachiopods and crinoids. Actual reef growth appears to have been sometimes sporadic and local in extent. Still, this was an environment of relatively shallow water with substantial turbulence and oxidation. Under such high energy conditions microfossils which inhabited the area could easily have been removed after death. Ostracodes are rare in this environment, and those found are preserved as undiagnostic casts. *Psammosphaera cava, Stegnammina quadrangularis,* and *Sorosphaera compacta* were the only foraminifers recurring in samples taken from reef dolomites, and none of these species is restricted to a reef environment. More frequently foraminifers were found in the back-reef dolomites, especially where there was a substantial percentage of calcite in the rock. These occurrences probably are due to more favorable preservation. *Rhabdammina bifurcata* was found only in these dolomites but is known from silty limestones (Osgood Formation) in Indiana.

LIMESTONE LITHOSOME

The relatively pure limestones represent two environments; one of fore-reef conditions, and one of shallow carbonate bank conditions. The latter represent widespread, well-bedded, blanket type deposition of lime under conditions highly favorable to organic development in many places. The invertebrate fauna is diversified and dominated by brachiopods. This environment, as seen in Text-figure 3, was widespread immediately prior to development of the Lone

Mountain reef. It is also represented in part by the McColley Canyon Formation which overlies the reef dolomite. At this time, however, local restriction and dolomitization is evident. Foraminifers and ostracodes, often mutually abundant, occur widely in the limestone, most frequently associated with larger invertebrates. Though the ostracodes were common in this lithosome, their distribution, especially of individual species, appears to be highly localized and controlled by factors not presently recognized.

The foraminifers are common to both environments represented by the limestone lithosome. They are less common in the fore-reef areas, because deposits there often consist of limestone breccias containing abundant rugose corals and large crinoidal fragments which indicate highly turbulent conditions where microfossils would be readily washed away. The species listed below were found only in rocks representing these two environments of carbonate deposition which suggests their preference for high energy conditions.

Hyperammina constricta
Stegnammina hebesta?
Stegnammina moremani
Thurammina arcuata
Thurammina tubulata
Tolypammina tortuosa
Aschemonella bastillensis

In addition there are several species which occur most commonly in these environments, though not restricted to them: *Anictosphaera progressa, Sorosphaera compacta,* and *Storthosphaera malloryi.*

CHERTY LIMESTONE LITHOSOME

The environment represented here is developed only to a limited extent in the area studied. The carbonate is fine-grained, thickly bedded, and fossils are rarely present. The presence of chert in the sediment suggests that the bottom was a lime mud with a poorly defined interface (Dapples, 1959, p. 42), in which an essentially closed chemical system evolved during diagenesis favoring concentration of silica. Such conditions were apparently unfavorable for a biota which would have left a fossil record.

ARGILLACEOUS, CHERTY LIMESTONE LITHOSOME

Conditions responsible for development of this lithosome were often widespread during much of the Silurian and persisted into the early Devonian in the region of fore-reef deposition. The sediments in this environment are thin-bedded, argillaceous carbonates with nodular, laminated, and bedded chert. The abundance of fine detritals suggests quiet bottom conditions with little current activity. Macrofossils occur sporadically, usually in cleaner limestone beds, and consist mostly of brachiopods, small echinoderm fragments, and small rugose corals. The abundant chert here may be controlled by temperature. Dapples (1967, pp. 325, 326) showed that precipitation of dissolved silica can be induced by lowering the temperature only, under normal marine pH conditions. With low circulation, muddy waters, and resultant reduction in light penetration the temperature of the bottom might be sufficiently lower than that of near surface waters to cause precipitation of silica from a delicately balanced equilibrium system. The dissolved silica involved in this formation of chert would have originated from material containing amorphous silica. Crystalline quartz is much less soluble (Krauskopf, 1959, p. 7) and would not take part. Hence, the arenaceous foraminifers would not be affected by these processes. Depth may also have been a factor in the temperature. The fact that nearly pure limestones succeed these rocks, and are in turn succeeded by reef deposits, suggests a shallowing trend subsequent to deposition of the argillaceous, cherty limestones.

The foraminiferal fauna in this environment contains a larger number of species than any other. The following species were recovered only from samples representing this environment.

Rhabdammina major
Hyperammina casteri
Psammosphaera laevigata
Ceratammina cf. *C. cornucopia*
Sorostomasphaera waldronensis
Hemisphaerammina bipatella
Metamorphina tholus
Webbinelloidea ventriquetra

Hemisphaerammina bradyi was found commonly here, but it was also present in argillaceous limestone. *Atelikamara incomposita* occurs commonly here and also at one locality in the pure carbonate lithosome.

ARGILLACEOUS LIMESTONE LITHOSOME

Thin-bedded, platy, argillaceous limestones succeed other limestone types throughout the region westward of the dolomites.

At Telegraph Canyon in the Sulphur Springs Range rocks of this lithology occur much lower stratigraphically and in apparent equivalence to cherty limestones in adjacent areas. The high percentage of fine detrital material and dark color of these strata suggests an environment with low energy conditions, a quiet benthos, not well oxygenated, with abundant organic matter, and much suspended material. The invertebrate fauna is small and dominated by brachiopods. Much of the fauna consists of allochthonous broken fragments periodically dumped by currents to form discontinuous layers or lenses. Many foraminifers are present in rocks of this lithosome, *Rhabdammina cylindrica* being a particularly common species. Only a few species were apparently restricted to this environment, and the habitat of none of these is adequately known in other regions. These species are:

Marsipella sp.
Hemisphaerammina discoidea?
Haplophragmoides antiquus

SHALE LITHOSOME

The dark, calcareous beds which constitute, for the most part, the Masket Shale represent deeper water, basinal conditions with slow deposition, and contain rare indigenous fossils. The following foraminifers were found in these rocks but were not restricted to them:

Psammosphaera cava
Raibosammina aspera
Stegnammina contorta
Nanicella dainae?

Distribution of ostracodes in the various physical environments represented by the lithosomes follows no demonstrable pattern. The mixing of species with all types of carapaces gives no indication of which are characteristic bottom dwellers, burrowers, or swimmers. The ecologic controls which have limited these organisms are not now evident. Light has generally been considered important in arthropod distribution, but some of the largest faunules represent muddy environments indicative of marginal photic conditions.

The ostracode fauna overall appears to be composed of smaller than average representatives in species which could be compared to other regions. This was possibly due in part to a majority of juveniles in some species, but in others, recognizable adult instars were smaller than as known elsewhere. Several possible factors might be responsible locally: lack of nutrients, intensive competition, catastrophic death of a young population, or movement of the more easily transportable smaller shells of juveniles. However, none of these factors seem adequate to explain the small size and localized occurrence of the same ostracodes through a large span of geologic time across an entire region.

BIOSTRATIGRAPHY

Previous work containing biostratigraphy of primitive arenaceous foraminifers has been concerned with faunas in Lower and Middle Silurian strata. Mound (1961, p. 14) noted that the Brassfield Limestone fauna of the Lower Silurian in southeastern Indiana was characterized by the dominance of the family Ammodiscidae, especially the genera *Ammodiscus* Reuss (1862), *Lituotuba* Rhumbler (1895), and *Turritellella* Rhumbler (1904). The slightly younger Osgood Formation in the same area, reported by Browne and Schott (1963), contains a large fauna characterized by the subfamily Saccammininae (McClellan, 1966, p. 455). The Middle Silurian Waldron Shale, also in southeastern Indiana, differs faunally from the Osgood in being dominated by many hemisphaeramminids. McClellan further differentiated the two formations on characteristic genera, stating (p. 455) that the Waldron contained few specimens of *Ammodiscus* and *Lituotuba* species, but *Sorosphaera* Brady (1879) was common. The opposite case characterizes the Osgood fauna.

It is apparent that the Lower and Middle Silurian strata of Indiana can be divided into assemblage zones of arenaceous foraminifers. A similar approach to the younger Silurian and Lower Devonian rocks in central Nevada shows many similarities to the Waldron Shale in dominance of particular groups and species. In Tables 4-8 the relative abundance and stratigraphic range for the entire area has been plotted for the species of each of the families and subfamilies representing the fauna. The subfamily Psammosphaerinae, as seen on Table 4, dominates the fauna. The several species of *Sorosphaera* are characteristic of Ludlovian rocks. *Steg-*

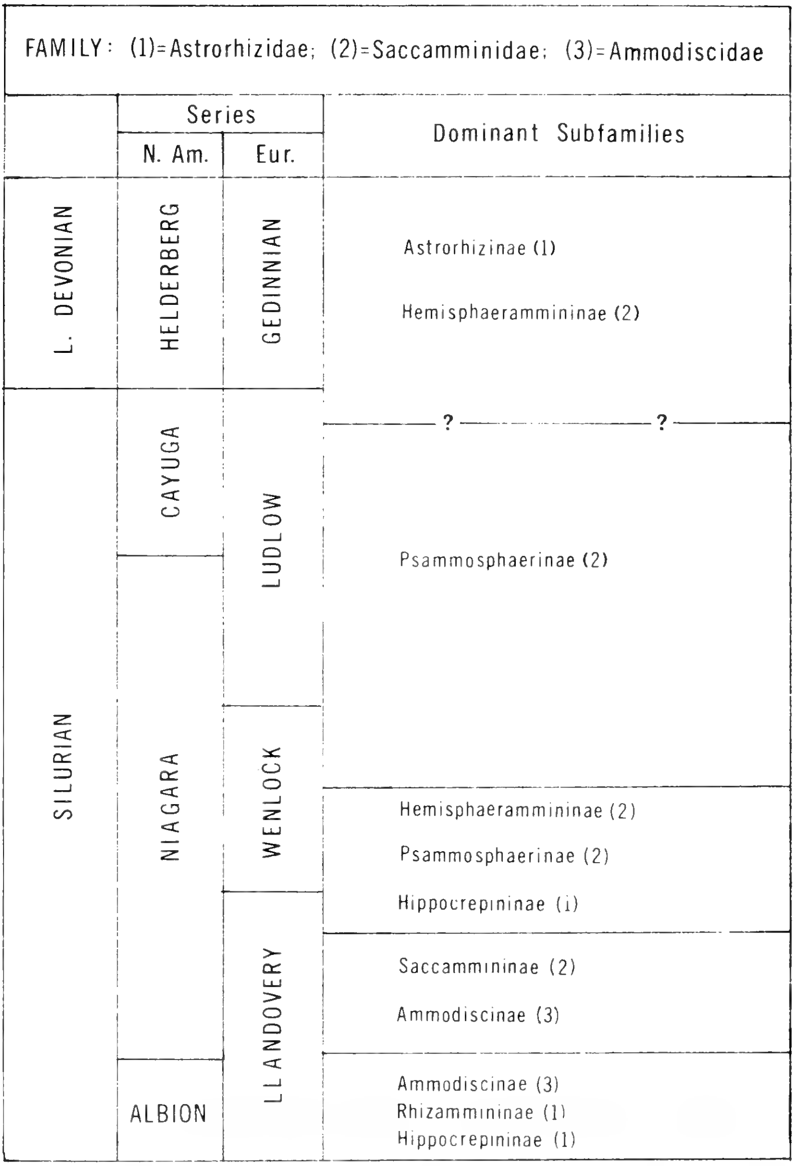
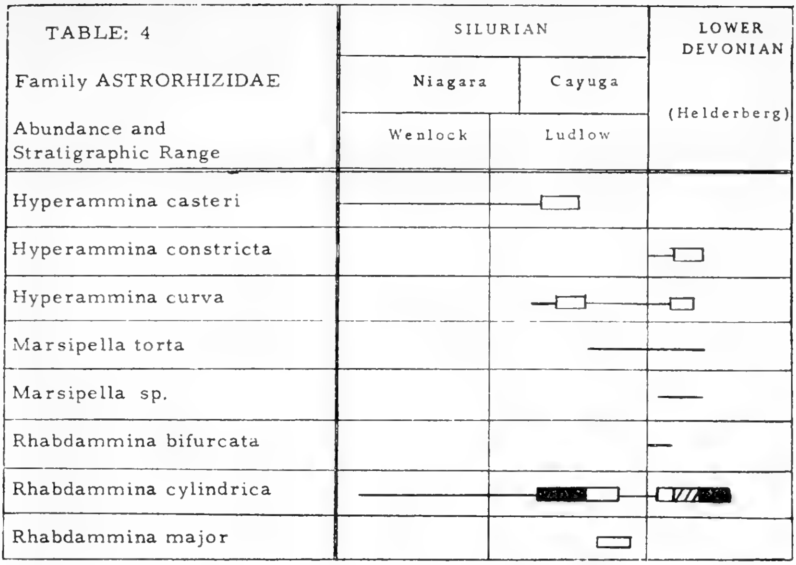


Fig. 4: **FORAMINIFERAL ASSEMBLAGE ZONES**

TABLE: 4

Family ASTRORHIZIDAE

Abundance and Stratigraphic Range



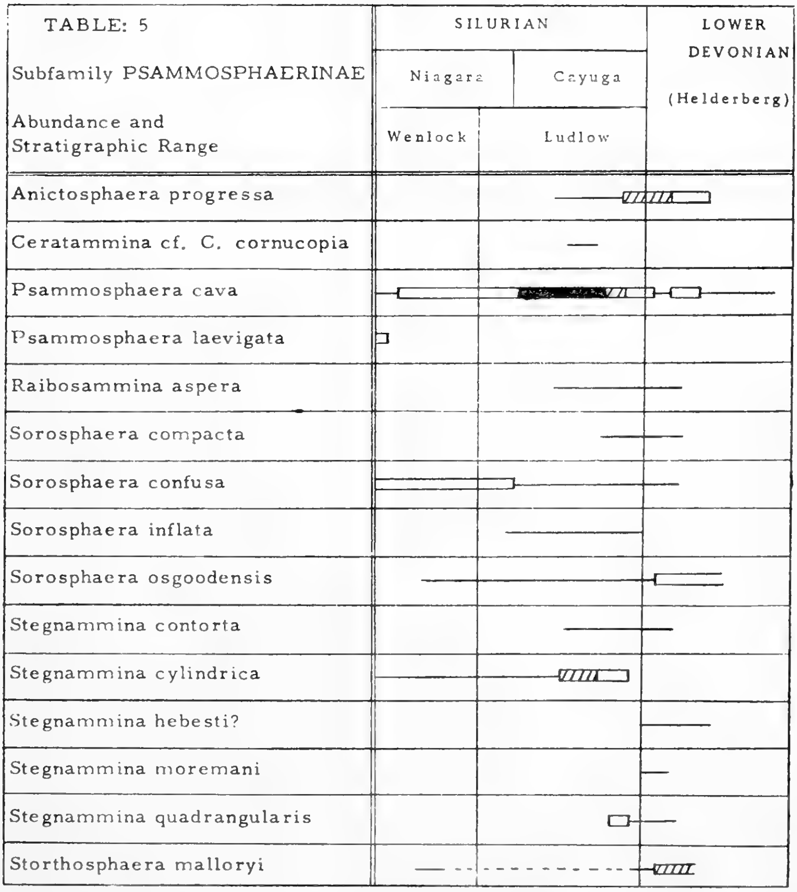
Rare: 1-2 (——) Common: 6-10 (▨)

Uncommon: 3-5 (▭) Abundant: over 10 (■)

TABLE: 5

Subfamily PSAMMOSPHAERINAE

Abundance and Stratigraphic Range



Rare: 1-2 (——) Common: 6-10 (▨)

Uncommon: 3-5 (▭) Abundant: over 10 (■)

TABLE: 6 Subfamily SACCAMMININAE Abundance and Stratigraphic Range	SILURIAN		LOWER DEVONIAN (Helderberg)
	Niagara	Cayuga	
	Wenlock	Ludlow	
Sorostomasphaera waldronensis		—	
Stomasphaera brassfieldensis	– – – – –	– – – – – —	
Thurammina arcuata			—▭
Thurammina quadritubulata?		—	
Thurammina trituba	—		
Thurammina tubulata		—	

Rare: 1-2 (—) Common: 6-10 (▨)

Uncommon: 3-5 (▭) Abundant: over 10 (■)

TABLE: 7 Subfam. HEMISPHAERAMMININAE Abundance and Stratigraphic Range	SILURIAN		LOWER DEVONIAN (Helderberg)
	Niagara	Cayuga	
	Wenlock	Ludlow	
Atelikamara incomposita		—▨	
Hemisphaerammina bipatella	—		
Hemisphaerammina bradyi	—	—▭■—	—▭
Hemisphaerammina cf H. bradyi	—	—	
Hemisphaerammina coronata		—	
Hemisphaerammina discoidea?		—	—
Metamorphina gibbosa	—		
Metamorphina tholus		—	
Webbinelloidea hattini		—	—▭
Webbinelloidea hemispherica		—	▨
Webbinelloidea aff W. nodosa			—
Webbinelloidea ventriquetra		—	

Rare: 1-2 (—) Common: 6-10 (▨)

Uncommon: 3-5 (▭) Abundant: over 10 (■)

nammina Moreman (1930) species and *Anictosphaera progressa* characterize the very latest Ludlovian strata and Helderbergian strata. The Hemisphaeramminae appear to be much more important in the Lower Devonian, especially *Webbinelloidea* Stewart and Lampe (1947). An exception to this is *Hemisphaerammina bradyi* which is most common in the Upper Silurian. Though not as clearly defined as the Hemisphaeramminae, the family Astrorhizidae is also better represented in the Lower Devonian. However, nearly all of the astrorhizid species are known elsewhere from all levels within the Silurian.

Pursuant to the above discussion, an informal zonation of the Silurian and Lower Devonian in central Nevada is shown on Text-fig. 4. The assemblage zones defined here are combined with those characteristic of Llandovery strata to lower Wenlock strata in southern Indiana. Further studies on the Upper Silurian in other areas may provide a refinement of the assemblages evident in Nevada.

Little work has been done on Devonian foraminifers, making it difficult to establish any consistent relationship patterns. Ireland (1939) reported several Silurian species from the Lower Devonian Haragan Shale of Oklahoma. In addition he considered *Ceratammina cornucopia, Metamorphina bipartita,* and *Psammonyx maxwelli* as restricted to the Lower Devonian. Other species, similarly restricted, have since been found in the Silurian. *Ceratammina* cf. *C. cornucopia* was found in Nevada in the latest Silurian; the other species were not encountered. The Haragan foraminifers, and those from Helderbergian beds here, have many characteristic Silurian species. It appears that a gradual transition occurs, with introduction of more and more Devonian species. The subfamily Hemisphaeramminae is the dominant group.

Middle Devonian foraminifers are well known only in Ohio (Stewart and Lampe, 1947; Summerson, 1958). Two widely ranging Silurian species, *Psammosphaera cava* Moreman and *Sorosphaera osgoodensis* Stewart and Priddy occur commonly in these beds. *Hemisphaerammina* Loeblich and Tappan (1964) and *Webbinelloidea* Stewart and Lampe (1947) are the dominant genera however. The Devonian species *Hemisphaerammina discoidea* (Summerson) has been reported in the Silurian Waldron Shale by Mc-

Clellan (1966, p. 487) and questionably recognized here in the Rabbit Hill (Table 13). *Webbinelloidea hemispherica* Stewart and Lampe, also known in the Silurian is more common in the Devonian. Table 7 shows the increasing abundance and number of species of these two genera in the younger strata of this study. There is still a more marked difference between the Lower Devonian species of Nevada and the Middle Devonian of Ohio than between any rocks in the Silurian. Perhaps the most characteristic feature of the foraminiferal fauna is the stratigraphic limitation of *Stegnammina* Moreman (1930) and *Fairliella* Summerson (1958). As presently known, the several species of *Stegnammina* are restricted to strata no younger than Lower Devonian, and those of *Fairliella* occur only in the Middle Devonian.

Because the earliest Silurian sediments studied here are Wenlock in age and the Waldron Shale in Indiana is lower Wenlockian, there is only a small overlap between the two areas. There are several species which characterize the overlap. *Sorosphaera confusa* Brady which occurs sporadically throughout the Silurian, is present in similar quantities in both Indiana and Nevada. *Psammosphaera laevigata* White is common in the Lower Silurian and only present in the lowest strata in Nevada. Similarly, *Glomospira* Rzehak (1885), characteristic of the Lower Silurian, is represented in Nevada by *G. siluriana* which occurs rarely in the same units as *Psammosphaera laevigata* White. The only Silurian records of *Aschemonella* Brady (1879) are an unnamed species found in the Waldron Shale (Hattin, 1960, p. 2016) and *A. bastillensis* McClellan found here in the Bastille Limestone of early Wenlockian age.

The total stratigraphic range of the ostracodes is shown on Table 9 and Table 10, each representing one of the two orders to which the species belong. Most of the species were found only in strata of Helderbergian age. One of the most commonly occurring species *Phlyctiscapha keslingi* Copeland has a greater stratigraphic range than previously known. It is likely that many other species would also prove to be more long lived if additional material were studied in detail. The restricted ranges in Table 9 and Table 10 should be used with caution for that reason. *Winchellatia fragilis* McClellan is the youngest known species of the Sigmoopsidae, an Ordovician family, and its uppermost Silurian occurrence here may

TABLE: 8 Additional Families Abundance and Stratigraphic Range	SILURIAN		LOWER DEVONIAN (Helderberg)
	Niagara	Cayuga	
	Wenlock	Ludlow	
Ammodiscidae Glomospira siluriana	—		
Toloypammina tortuosa			—
Hormosinidae Aschemonella bastillensis	—		
Lituolidae Haplophragmoides antiquus			—
Endothyridae Nanicella dainae?			—

Rare: 1-2 (—)

Uncommon: 3-5 (▭)

Common: 6-10 (▨)

Abundant: over 10 (▬)

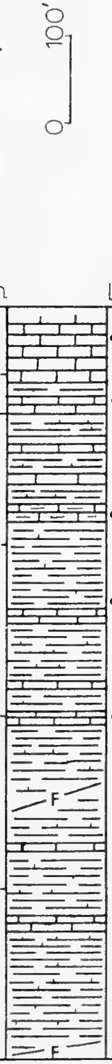
be stratigraphically useful. *Limbinaria* Swartz *in* Swartz and Whitmore, 1956 is restricted to upper Ludlow and lower Helderberg strata in eastern North America and has a similar occurrence here.

Local stratigraphic distribution of the foraminifers and ostracodes is shown on Tables 11-22, including columnar sections and sample localities. From these distributions the previously discussed composite range charts were compiled. It is evident that the occurrences are locally discontinuous for the most part. This may be due in part to transportation of dead specimens, with the resultant faunule thus representing a thanatocoenose for most of the species. This is possible for some of the sample localities in the Willow Creek Section (Table 19). The ostracodes are even more locally restricted which clearly limits their biostratigraphic use without detailed study.

TABLE: 9 Order PALEOCOPIDA	SILURIAN		DEVONIAN
Stratigraphic Range	Wenlock	Ludlow	Helderberg
BEYRICHICOPINA			
Aechmina cortezensis			—
Aechmina equilateralis			—
Aechmina longior			—
Aechmina aff. A. phantastica			—
Bolbiprimitia teressaccula		—	—
Hollinella sp.		—	
Kloedenia aparchoides		—	
Limbinaria sp.		—	
Myomphalus? sp.			—
Phlyctiscapha keslingi		—	—
Phlyctiscapha sp.			—
Saccarchites saccularis		—	
Ulrichia obesita			—
Ulrichia sp.			—
Velibeyrichia? sp.			—
Welleriopsis jerseyensis			—
Winchellatia fragilis		—	
KLOEDENELLOCOPINA			
Eukloedenella aff. E. dalhousiensis			—
Neokloedenella? sp.			—
Parahealdia aff. P. pecorella			—
Paraparchites sp.		—	—
Pseudoleperditia? sp.		—	

TABLE: 10 Order PODOCOPIDA	SILURIAN		DEVONIAN
Stratigraphic Range	Wenlock	Ludlow	Helderberg
PODOCOPINA			
Acanthoscapha aff. A. navicula			—
Bairdia sp.		—	
Berounella sp.		—	
Bythocypris aff. B. alcocki		—	—
Bythocypris? sp.			—
Longiscapha nevadensis		—	
METACOPINA			
Birdsallella sp.			—
Healdia? sp.			—
Phanassymetria sp.			—
Quasillites sp.			—
Rudderina mutaspina			—
Rudderina spp.		—	
Thlipsura bispinosa			—
Tubulibairdia cf. T. chaleurensis		—	—
T. aff. T. chaleurensis			—
Tubulibairdia sp.			—

March Spring

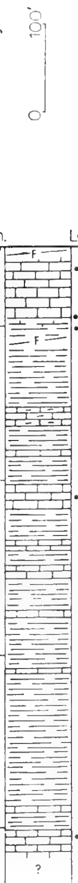


Age	Fm.	Locality	Foraminiferida								Ostracoda		
			Hyperammina curva	*Psammosphaera cava*	*Raibosammina aspera*	*Rhabdammina cylindrica*	*Stegnammina contorta*	*Stegnammina quadrangularis*	*Storthosphaera malloryi*	*Webbinelloidea hemispherica*	*Bythocypris* aff. *B. alcocki*	*Myomphalus*? sp.	*Phlyctiscapha keslingi*
Helderberg	McMon	5993	–	–	–	R	–	–	–	–	–	–	X
		5994	–	–	–	–	–	–	–	–	–	X	X
	Masket	5995	–	U	–	R	–	R	R	R	X	–	–
		5996	–	–	R	–	R	–	–	–	–	–	–
Ludlow		5997	R	R	–	U	–	–	–	–	–	–	–

R = rare, U = uncommon

Table 11: STRATIGRAPHIC OCCURRENCE OF SPECIES AT MARCH SPRING

Ikes Canyon



Age	Fm.	Locality	Foraminiferida															Ostracoda								
			Hemisphaerammina bradyi	Hyperammina constricta	Psammosphaera cava	Raibosammina aspera	Rhabdammina cylindrica	Sorosphaera confusa	Sorosphaera inflata	Sorosphaera sp.	Stegnammina contorta	Stegnammina cylindrica	Stegnammina hebesta?	Stegnammina mormani	Storthosphaera mallory i	Thurammina arcuata	Webbinelloidea hemisphaerica		Bythocypris aff. B. alcocki	Bythocypris? sp.	Eukloedenella aff. E. dalhousiensis	Phlyctiscapha keslingi	Quasillites sp.	Rudderina mutaspina	Tubulibairdia aff. T. chaleurensis	Ulrichia obesita	Velibeyrichia? sp.
Helderberg	McMon.	5986	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		X	X	–	X	–	–	–	X	–
		5985	R	R	C	R	C	R	–	R	–	–	R	R	C	R	R		X	–	X	X	X	X	X	X	X
		5984	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		X	–	–	X	–	X	–	–	–
Ludlow	Masket	5987	–	–	U	–	–	–	F	–	R	R	–	–	–	-	–		–	X	-	X	–	–	–	–	–
Wenlock	Diana	5988	–	–	R	–	R	–	–	–	–	–	–	–	–	–	-		–	–	–	–	–	–	–	–	–

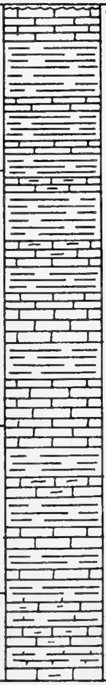
R=rare, U=uncommon, C=common

Table 12: **STRATIGRAPHIC OCCURRENCE OF SPECIES AT IKES CANYON**

Rabbit Hill

0 100′

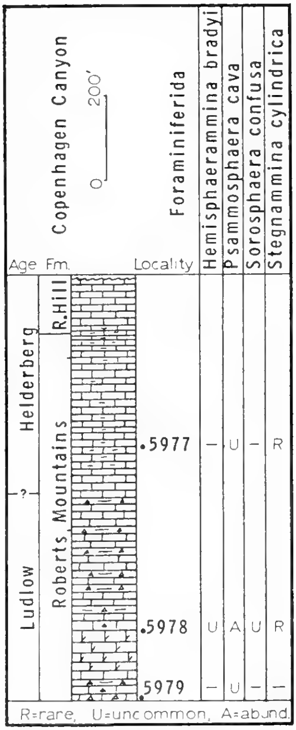
Foraminiferida



Age	Fm.	Locality	Anictosphaera progressa	Haplophragmoides antiquus	Hemisphaerammina bradyi	Hemisphaerammina discoidea?	Hyperammina curva	Metamorphina tholus	Nanicella dainae?	Psammosphaera cava	Rhabdammina cylindrica	Sorosphaera osgoodensis	Stegnammina contorta	Storthosphaera malloryi	Webbinelloidea hattini	Webbinelloidea hemispherica	Webbinelloidea aff. W. nodosa
Helderberg	Rabbit Hill	•6009	U	–	–	–	R	–	–	U	–	–	–	–	U	–	–
		•6010	R	R	R	R	–	R	–	A	R	U	R	U	–	C	R
		•6011	–	–	–	–	–	–	–	–	C	–	–	–	–	–	–
	R. Mt.	•6012	–	–	–	–	–	–	–	–	–	U	–	–	–	–	–
		•6013	–	–	–	–	–	–	R	R	–	–	–	–	–	–	–

R=rare, U=uncommon, C=common, A=abundant

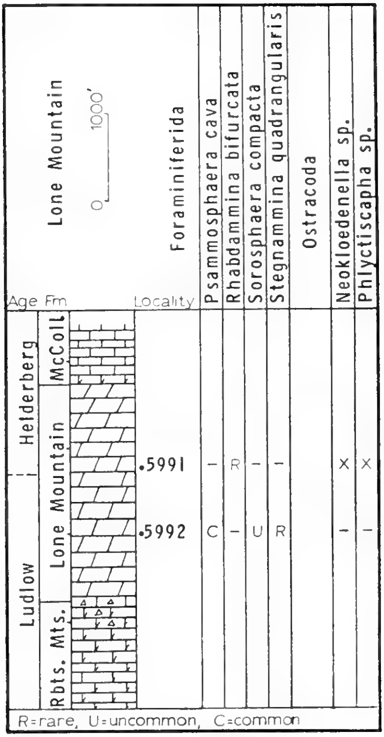
Table 13: STRATIGRAPHIC OCCURRENCE OF SPECIES AT RABBIT HILL



Locality	Hemisphaerammina bradyi	Psammosphaera cava	Sorosphaera confusa	Stegnammina cylindrica
5977	–	U	–	R
5978	U	A	U	R
5979	–	U	–	–

R=rare, U=uncommon, A=abund.

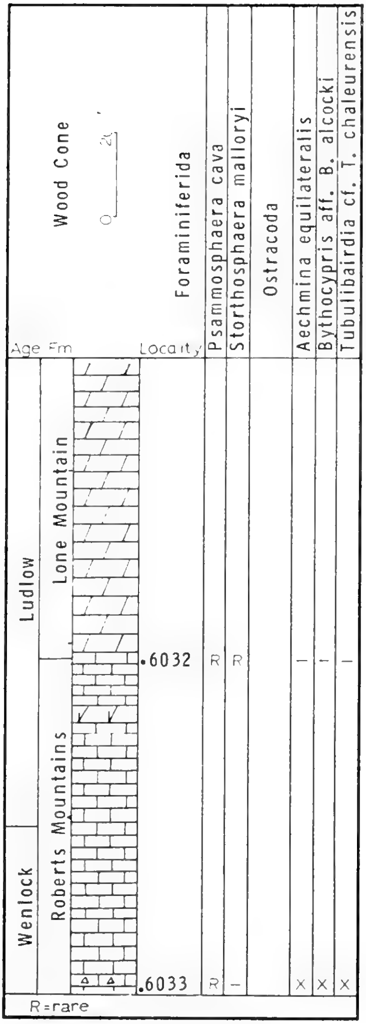
Table 14: STRATIGRAPHIC OCCURRENCE OF SPECIES AT COPENHAGEN CANYON



Locality	Foraminiferida: Psammosphaera cava	Rhabdammina bifurcata	Sorosphaera compacta	Stegnammina quadrangularis	Ostracoda: Neokloedenella sp.	Phlyctiscapha sp.
5991	–	R	–	–	X	X
5992	C	–	U	R	–	–

R=rare, U=uncommon, C=common

Table 15: STRATIGRAPHIC OCCURRENCE OF SPECIES AT LONE MOUNTAIN

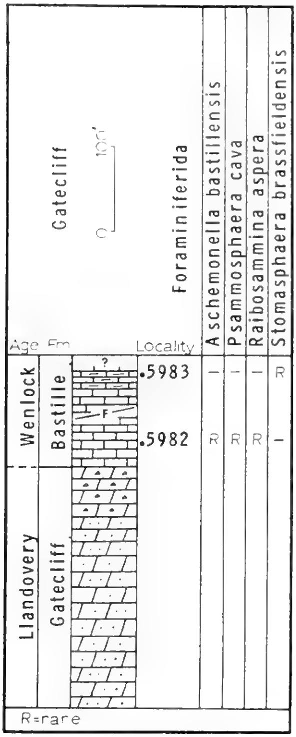


Wood Cone

Age	Fm	Locality	Foraminiferida		Ostracoda		
			Psammosphaera cava	Storthosphaera malloryi	Aechmina equilateralis	Bythocypris aff. B. alcocki	Tubulibairdia cf. T. chaleurensis
Ludlow	Lone Mountain						
Ludlow	Roberts Mountains	.6032	R	R	–	–	–
Wenlock	Roberts Mountains	.6033	R	–	X	X	X

R=rare

Table 16: STRATIGRAPHIC OCCURRENCE OF SPECIES AT WOOD CONE

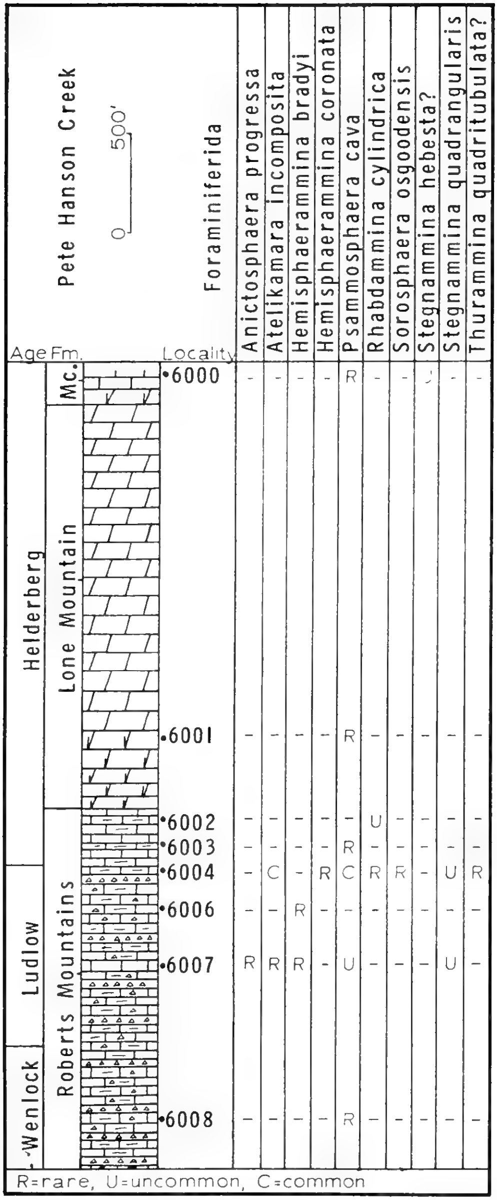


Gatecliff

Age	Fm	Locality	Foraminiferida			
			Aschemonella bastillensis	Psammosphaera cava	Raibosammina aspera	Stomasphaera brassfieldensis
Wenlock	Bastille	.5983	–	–	–	R
Wenlock	Bastille	.5982	R	R	R	–
Llandovery	Gatecliff					

R=rare

Table 17: STRATIGRAPHIC OCCURRENCE OF SPECIES AT GATECLIFF



Age	Fm.	Locality	Anictosphaera progressa	Atelikamara incomposita	Hemisphaerammina bradyi	Hemisphaerammina coronata	Psammosphaera cava	Rhabdammina cylindrica	Sorosphaera osgoodensis	Stegnammina hebesta?	Stegnammina quadrangularis	Thurammina quadritubulata?
Helderberg	Mc.	•6000	-	-	-	-	R	-	-	U	-	-
	Lone Mountain	•6001	-	-	-	-	R	-	-	-	-	-
	Roberts Mountains	•6002	-	-	-	-	-	U	-	-	-	-
		•6003	-	-	-	-	R	-	-	-	-	-
Ludlow		•6004	-	C	-	R	C	R	R	-	U	R
		•6006	-	-	R	-	-	-	-	-	-	-
		•6007	R	R	R	-	U	-	-	-	U	-
Wenlock		•6008	-	-	-	-	R	-	-	-	-	-

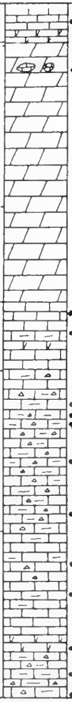
Foraminiferida

R=rare, U=uncommon, C=common

Table 18: STRATIGRAPHIC OCCURRENCE OF SPECIES AT PETE HANSON CREEK

Willow Creek

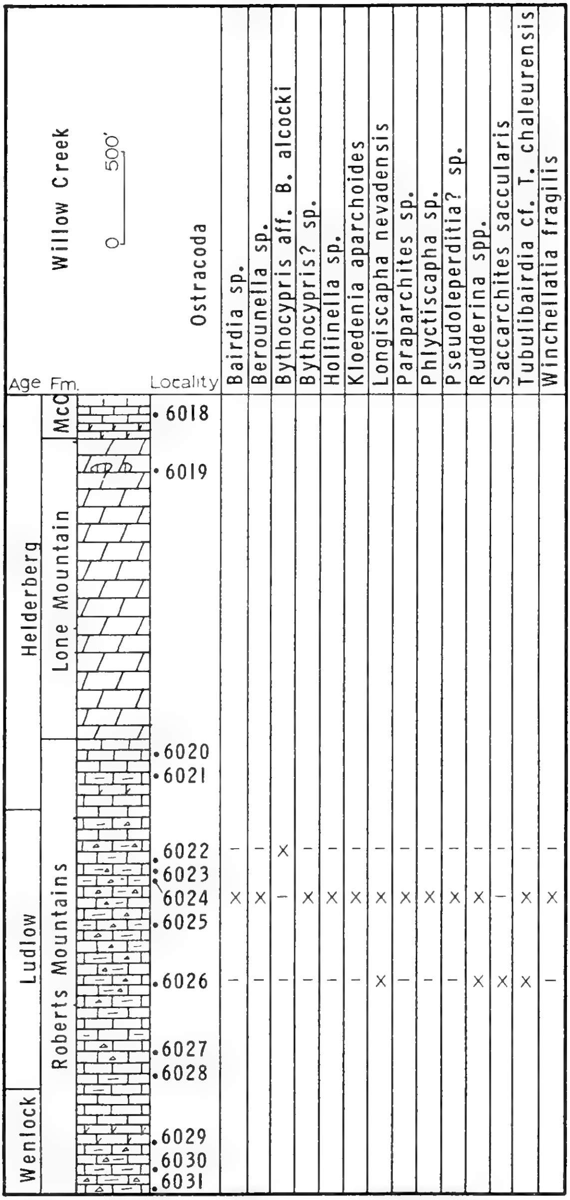
0 500'



Age	Fm	Locality	Anictosphaera progressa	Atelikamara incomposita	Glomospira siluriana	Hemisphaerammina bradyi	Hemisphaerammina? cf. H. bradyi	Hyperammina curva	Hyperammina casteri	Marsipella torta	Metamorphina gibbosa	Psammosphaera cava	Psammosphaera laevigata	Rhabdammina cylindrica	Rhabdammina major	Sorosphaera compacta	Sorosphaera confusa	Sorosphaera osgoodensis	Sorostomasphaera waldronensis	Stegnammina contorta	Stegnammina cylindrica	Stegnammina quadrangularis	Stomasphaera brassfieldensis	Storthosphaera malloryi	Thurammina arcuata	Tolypammina tortuosa	Webbinelloidea hattini	Webbinelloidea hemispherica	Webbinelloidea aff. W. nodosa	Webbinelloidea ventriquetra
Helderberg	McC	•6018	–	–	–	U	–	–	–	–	–	U	–	U	–	–	–	U	–	–	–	–	–	–	U	R	–	U	R	–
	Lone Mountain	•6019	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	R	–	–	–	–	–	–	–	–
	Roberts Mountains	•6020	C	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	C	–	–
		•6021	–	–	–	–	–	–	–	–	–	R	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ludlow		•6022	R	C	–	–	–	–	–	U	–	A	–	R	U	R	R	–	–	–	U	–	R	R	–	–	–	R	–	–
		•6023	–	–	–	–	–	–	–	–	–	R	–	–	–	–	–	–	R	–	–	–	–	–	–	–	–	–	–	–
		•6024	–	–	–	A	–	U	U	–	–	A	–	A	–	–	–	–	–	R	C	–	–	–	–	–	–	–	–	R
		•6025	R	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	R	–	–	–
		•6026	–	–	–	–	–	–	–	–	–	–	–	R	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		•6027	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	R	–	–
		•6028	–	–	–	U	R	–	–	–	–	–	–	–	–	–	–	–	R	–	–	–	–	–	–	–	–	–	–	–
Wenlock		•6029	–	–	–	–	–	–	–	–	–	–	–	U	–	–	–	R	–	–	–	–	–	–	–	–	–	–	–	–
		•6030	–	–	R	R	–	–	–	–	R	R	–	–	–	–	U	–	–	–	–	–	–	R	–	–	–	–	–	–
		•6031	–	–	–	–	–	–	–	–	–	–	U	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

R=rare, U=uncommon, C=common, A=abundant

Table 19: STRATIGRAPHIC OCCURRENCE OF FORAMINIFERS AT WILLOW CREEK

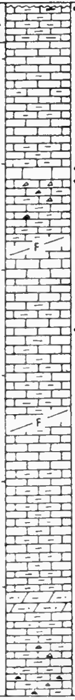


Age	Fm.	Locality	Bairdia sp.	Berounella sp.	Bythocypris aff. B. alcocki	Bythocypris? sp.	Hollinella sp.	Kloedenia aparchoides	Longiscapha nevadensis	Paraparchites sp.	Phlyctiscapha sp.	Pseudoleperditia? sp.	Rudderina spp.	Saccarchites saccularis	Tubulibairdia cf. T. chaleurensis	Winchellatia fragilis
Helderberg	McC	6018														
	Lone Mountain	6019														
	Roberts Mountains	6020														
		6021														
Ludlow		6022	–	–	X	–	–	–	–	–	–	–	–	–	–	–
		6023														
		6024	X	X	–	X	X	X	X	X	X	X	X	–	X	X
		6025														
		6026	–	–	–	–	–	–	X	–	–	–	X	X	X	–
		6027														
		6028														
Wenlock		6029														
		6030														
		6031														

Table 20: STRATIGRAPHIC OCCURRENCE OF OSTRACODES AT WILLOW CREEK

Coal Canyon

0 500'

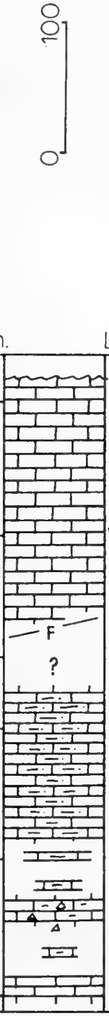


Age	Fm	Locality	Foraminiferida										Ostracoda															
			Hyperammina constricta	Hyperammina curva	Marsipella torta	Marsipella sp.	Nanicella dainae?	Psammosphaera cava	Rhabdammina cylindrica	Sorosphaera compacta	Sorosphaera inflata	Storthosphaera mallory	Aechmina equilateralis	Aechmina longior	Aechmina aff. A. phantastica	Bolbiprimitia teresaccula	Bythocypris aff. B. alcocki	Bythocypris? sp.	Limbinaria sp.	Paraparchites sp.	Phlyctiscapha keslingi	Rudderina mutaspina	Thlipsura bispinosa	Tubulibairdia cf. T. chaleurensis	Tubulibairdia sp.	Ulrichia sp.	Welleriopsis jerseyensis
Helderberg	R. H.	•5973	–	U	R	R	U	–	A	–	–	–	X	X	X	–	X	X	–	–	–	–	X	–	X	X	X
	Roberts Mountains	•5975	–	–	–	–	–	R	–	–	–	–	–	–	–	X	–	X	–	–	–	X	–	X	–	–	–
		•5974	R	–	–	–	–	–	–	R	–	–	–	–	–	X	X	X	X	X	X		–	–	–	–	–
Ludlow		•5976	–	–	–	–	–	R	R	–	R	R	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Wenlock																											

R=rare, U=uncommon, C=common, A=abundant

Table 21: STRATIGRAPHIC OCCURRENCE OF SPECIES AT COAL CANYON

Cortez Canyon



Age	Fm.	Locality	Foraminiferida		Ostracoda										
			Psammosphaera cava	Rhabdammina cylindrica	Acanthoscapha aff. A. navicula	Aechmina cortezensis	Birdsallella sp.	Bythocypris aff. B. alcocki	Healdia? sp.	Myomphalus? sp.	Parahealdia aff. P. pecorella	Phanassymetria sp.	Phlyctiscapha keslingi	Thlipsura bispinosa	Tubulibairdia aff. T. chaleurensis
Helderberg	Wenban	•5980	R	–	–	X	X	–	–	–	X	X	–	X	X
		•5981	–	U	X	X	–	X	X	X	X	–	X	X	–
Ludlow	Roberts Mountains														

R=rare, U=uncommon

Table 22: STRATIGRAPHIC OCCURRENCE OF SPECIES AT CORTEZ CANYON

SYSTEMATIC PALEONTOLOGY

Order FORAMINIFERIDA Eichwald, 1830

Suborder TEXTULARIINA Delage and Herouard, 1896

Superfamily **AMMODISCACEA** Reuss, 1862

Family **ASTRORHIZIDAE** Brady, 1881

Subfamily **ASTRORHIZINAE** Brady, 1881

Genus **RHABDAMMINA** M. Sars *in* Carpenter, 1868

1869. *Rhabdammina* M. Sars *in* Carpenter, Royal Soc. London, Proc., vol. 18 (1868), No. 114, p. 61.

Type species. — *Rhabdammina abyssorum* M. Sars (1869, *ibid.*, p. 61).

Description. — Test free, tubular, straight or branching with elongate arms, wall agglutinated, usually well cemented, apertures at open ends of tubular arms.

This primitive genus, whose species are straight or branching tubes, is similar to several other genera. The most closely related is *Astrorhiza* Sandahl (1858) which also branches but differs in possessing a central chamber. Linear species of *Rhabdammina,* such as *R. linearis* Brady or *R. cylindrica* Glaessner, have often been misidentified, usually as *Bathysiphon* Sars (1872) species. This is especially true in studies of Paleozoic foraminifers because of poor test preservation. *Bathysiphon* should be partly defined, however, on the basis of a wall structure consisting of an inner layer of cemented sponge spicules covered by an outer layer of sand grains, or other mineral matter, with calcareous or siliceous cement. This wall structure was well illustrated by Cushman (1910, p. 32) in his discussion of Recent species of *Bathysiphon.* The wall structure of *Rhabdammina* is clearly shown by the scanning electron micrographs on Plate 33. A related third genus, *Marsipella,* uses sponge spicules, sand grains, or other foraminifer tests indiscriminantly in forming its tests. In contrast, *Rhabdammina* exclusively employs mineral grains, such as quartz, in the construction of its test. It is, therefore, probable that many identifications of *Bathysiphon,* based on completely arenaceous structured material, should be referred to *Rhabdammina.*

Rhabdammina bifurcata Browne and Schott Pl. 33, figs. 8, 9; Pl. 39, fig. 4

1963. *Rhabdammina bifurcata* Browne and Schott, Bull. Amer. Paleont., vol. 46, No. 209, p. 198, pl. 48, figs. 4, 5.

Description. — Test free, consisting of three nearly straight, branching, tubular arms united in a single plane to form a Y-shaped test, lower arm of the Y normally being longer than the other two; wall finely arenaceous and well cemented; apertures at open ends of tubes.

Measurements. — Dimensions of figured hypotypes as follows:

	Test Length	Diameter	Short Arm	Long Arm
34682	0.22 mm	0.07 mm	0.11 mm	0.18 mm
34683	indet.	0.11 mm	0.21 mm	indet.

Occurrence. — This species was found only at locality UWA 5991, where it is a rare element of the fauna. Its only other known occurrence is in the Osgood Formation of Indiana of Llandovery, or lowest Niagaran age, and its presence in Nevada extends the range of the species to the lowest Devonian.

Rhabdammina cylindrica Glaessner Pl. 33, figs. 10, 11; Pl. 40, fig. 4

1937. *Rhabdammina cylindrica* Glaessner, Moscow Univ. Lab. Paleont., Prob. Paleont., vol. 2-3, p. 354.
1941. *Bathysiphon exiguus* Moreman, Stewart and Priddy, Jour. Paleont., vol. 15, No. 4, p. 370, pl. 54, fig. 7.
1942. *Bathysiphon exiguus* Moreman, Dunn, Jour. Paleont., vol. 16, No. 3, p. 322, pl. 42, fig. 27.
1961. *Bathysiphon exiguus* Moreman (in part), Mound, Indiana Dept. Conserv., Geol. Sur., Bull. No. 23, p. 36, pl. 3, figs. 17-20.
1963. *Bathysiphon exiguus* Moreman (in part), Browne and Schott, Bull. Amer. Paleont., vol. 46, No. 209, p. 232, pl. 52, fig. 7, 8.
1966. *Bathysiphon exiguus* Moreman, McClellan, Bull. Amer. Paleont., vol. 50, No. 230, p. 462, pl. 36, figs. 1-5; pl. 40, figs. 1-5.

Description. — Test apparently free, straight cylindrical tube; wall finely arenaceous, poorly to well cemented; aperture at open ends of tubular test.

Measurements. — Hypotype 34684 diameter 0.09 mm, length 0.84 mm; 34685 diameter 0.11 mm, length 0.67 mm.

Occurrence. — Widespread throughout the area; present in varying degrees of abundance at all stratigraphic horizons within the several limestone formations. Figured specimens from UWA 5973.

Discussion. — The species *Bathysiphon exiguus* Moreman

(1930) has frequently been applied to specimens having a straight, cylindrical or tubular test consisting of apparently arenaceous material. Moreman's description (p. 46) of this species mentioned the character of a slightly tapering test. Possibly Moreman's specimens should also be referred to the genus *Rhabdammina* on the basis of wall material. If so, they would be distinct from the species *R. cylindrica* Glaessner (1937) by virtue of the slight taper of the test. The species named by Glaessner is limited to cylindrical, nontapering forms. Subsequent authors have identified material, which is cylindrical and nontapering, as *Bathysiphon exiguus.* Mound (1961) and Browne and Schott (1963) included a variety of forms under the latter species, some of which can be referred to the former *R. cylindrica.* McClellan's (1966) material contained one specimen (U.C. 37783) which is properly a *Bathysiphon* but should be assigned to another species due to the constrictions present on the test.

Rhabdammina major de Folin Pl. 33, fig. 1

1887. *Rhabdammina major* de Folin, Naturaliste, Paris, vol. 9, No. 2, p. 127 (*fetae*).

Description. — Test free, large, cylindrical, twisted, branching tube; wall composed of single layer of fine to medium sand grains with moderate cement; apertures at open ends of branching tubes.

Measurements. — Hypotype 34686 length 1.63 mm, diameter 0.33 mm, branch length 0.37 mm.

Occurrence. — This species is present only at locality UWA 6022 in shaly limestones. It has not previously been reported from the Silurian.

Discussion. — The Y pattern of branching in *Rhabdammina bifurcata* is distinctive from the type of branching in *R. major*, and the twisted nature of most specimens of the latter is also a distinctive characteristic. Previously, *R. major* has been recorded as a Recent species, but it is found here in rocks of Middle Ludlow age.

Subfamily **RHIZAMMININAE** Rhumbler, 1895

Genus **MARSIPELLA** Norman, 1878

1878. *Marsipella* Norman, Ann. Mag. Nat. Hist., ser. 5, vol. 1, p. 281.

Type species. — *Marsipella elongata* Norman (1878, *ibid.*, pl. 16).

Loeblich and Tappan (1964, p. 186) redescribed the genus as follows:

> Test free, consisting of undivided tubular, cylindrical, or elongate-fusiform chamber, which may be slightly twisted; wall of agglutinated sand, sponge spicules, or tests of other foraminifers; apertures at open ends of tube.

The above description is more in keeping with modern generic concepts than the original of Norman which appears to be restricted to the type species. An important feature is the variety of wall material allowable in this primitive foraminifer. While *Marsipella elongata* used sand grains and sponge spicules, several species, including those in the Paleozoic, used only the sand grains. This suggests a close relationship to *Rhizammina* Brady (1879) which uses the same materials in two layers, but whose test is not commonly twisted and fusiform. *Bathysiphon* Sars (1872) shows more specialization, consistently having an inner layer with spicules and an outer one of sand grains.

Marsipella torta Stewart and Priddy Pl. 33, fig. 7

1941. *Marsipella*? *torta* Stewart and Priddy, Jour. Paleont., vol. 15, No. 4, p. 370, pl. 54, fig. 4.

Description. — Test free, cylindrical, twisted tube, tapering toward apertural end; wall thin, medium to finely arenaceous, moderately cemented; aperture terminal at end of tube, additional apertures not presently known from incomplete specimens.

Measurements. — Length of the figured hypotype 34673 is 1.16 mm; larger diameter 0.30 mm, smaller, apertural diameter 0.18 mm.

Occurrence. — This species occurs rarely at two localities representing a time span from middle Ludlow to Helderberg age. It has previously been reported from the Osgood Formation of Indiana, which is earliest Niagaran, or middle Llandovery. Hypotype from locality UWA 6022.

Discussion. — Stewart and Priddy, in discussion of the generic position of this species, believed that it was more twisted than normal for the genus, and that it lacked sponge spicules in the test. Because the wall structure is known to be variable, their generic classification seems correct. Specimens recovered from the Nevada material are somewhat damaged so that no example adequately demonstrates the complete variability of the species. The tapering test is characteristic and serves to separate specimens from unbranched examples of *Rhabdammina major.*

Marsipella sp. Pl. 33, fig. 3

Description. — Test free, subcylindrical, moderately contorted, tubular; wall fine to medium sand grains poorly cemented; apertures at ends of tube though poorly defined due to damaged tests. One end with narrow lip at aperture.

Measurements. — Length of figured specimen 34674 is 1.09 mm, diameter of undamaged portion 0.12 mm.

Occurrence. — Rarely present at locality UWA 5973 in strata of Helderbergian age. Similar individuals referred to this genus have been reported from the Middle Silurian Waldron Shale in Indiana by Hattin (abstract, 1960, p. 2016).

Discussion. — The two specimens recovered here both have one end of the test flattened, apparently by external forces, so that the original form is indeterminate. The test is less contorted than that of *M. torta,* the wall composition less consistent, and there is little cement. What appears to be minute openings of the test surface may be due to the poor cementation.

Subfamily **HIPPOCREPININAE** Rhumbler, 1895

Genus **HYPERAMMINA** Brady, 1878, emend. Conkin, 1961

1878. *Hyperammina* Brady, Ann. Mag. Nat. Hist., ser. 5, vol. 1, pp. 433-434.

Type species. — *Hyperammina elongata* Brady (1878, *ibid.*, pl. 20, fig. 2a,b).

The generic concept of *Hyperammina* that Conkin first discussed (1954, pp. 167-168) and later (1961, p. 254) proposed as an emended description is that which is followed herein.

Description. — Test free, arenaceous; with an elongate tubular, singular or branching second chamber, which may be nontapering, may taper toward the proloculus, or in a few species taper toward both the aperture and proloculus; aperture open or constricted slightly to strongly; interior smooth; exterior rough, may be marked by transverse constrictions of varying strength.

Hyperammina casteri Conkin Pl. 33, figs. 2, 6

1961. *Hyperammina casteri* Conkin, Bull. Amer. Paleont., vol. 43, No. 196, p. 260, figs. 6, 7; pl. 20, figs 1-18; pl. 26, figs. 7, 8.

Description. — Test free, proloculus shape variable, usually oblate to spherical, followed by straight second chamber which expands gradually from constriction near proloculus to diameter greater than the proloculus; wall thin to thick, finely arenaceous, well cemented; aperture terminal on second chamber. Microspheric forms have a small, pointed proloculus and rapidly expanding second chamber giving the test the appearance of an elongated cone.

Measurements. — Microspheric specimen 34670 has a test length of 0.58 mm, proloculus diameter of 0.06 mm, apertural end diameter of 0.16 mm. Specimen 34669 has broken second chamber and indeterminate length, but proloculus diameter is 0.18 mm.

Occurrence. — This species is poorly represented here in Middle Silurian strata at only two localities in the northern Roberts Mountains (UWA 5989, UWA 6024).

Discussion. — Megalospheric forms of *H. casteri* are similar to those of *H. glabra* Cushman and Waters (1927), but the proloculus diameter is larger in relation to the second chamber than in the latter species. Conkin (1961, pp. 261-263) presented a thorough discussion of the affinities of *H. casteri* to other species with which the writer is in agreement. This species was first reported from earliest Mississippian strata where it is abundant in dark shales, silts, and calcareous shales. McClellan (1966, p. 460) found it to be dominant in lower energy environments of the Waldron Shale. In the present material it occurs in argillaceous and cherty limestone beds.

Hyperammina constricta Gutschick and Treckman Pl. 33. fig. 4

1959. *Hyperammina constricta* Gutschick and Treckman, Jour. Paleont., vol. 33, No. 2, p. 237, pl. 34, figs. 17-19, text fig. 1m,n.

Description. — Test free, proloculus spherical; second chamber long, straight or slightly curved, bearing regularly spaced, slight constrictions; wall thin, finely arenaceous, well cemented; aperture terminal opening on second chamber. Microspheric stage not present in this material.

Measurements. — Figured hypotype 34671 has length of 0.76 mm, maximum diameter 0.13 mm, minimum diameter 0.10 mm at constrictions.

Occurrence. — Present only in rocks of lowest Devonian age at localities UWA 5974 and UWA 5985.

Discussion. — Previously this species has been known only locally from Silurian and Mississippian rocks in Indiana. Its presence in Nevada indicates a wider geographic occurrence. In every case it is found in relatively clean limestones indicative of a preference for higher energy conditions than those of some hyperamminids, such as *H. casteri* which preferred a quiet, muddy environment, and *H. rockfordensis* (Conkin, 1961, pp. 270-272).

Hyperammina curva (Moreman) Pl. 33, fig. 5

1930. ***Bathysiphon curvus*** Moreman, Jour. Paleont., vol. 4, No. 1, p. 45, pl. 5, figs. 9, 10.

1961. ***Hyperammina curva*** (Moreman), Mound, Indiana Dept. Conserv., Geol. Sur., Bull. No. 23, p. 35, pl. 3, figs. 13-16.

Description. — Test free, with megalospheric proloculus small and bluntly rounded, microspheric pointed; second chamber long, gently tapering, and slightly curved with no constrictions; wall thin, finely arenaceous, well cemented; terminal opening of second chamber serves for an aperture.

Measurements. — Specimen 34672 has a broken second chamber; remaining length is 0.44 mm, diameter 0.15 mm.

Occurrence. — This is the most common *Hyperammina* species known from these rocks in Nevada. It was recovered from several horizons, indicating a presence throughout the entire sequence of strata studied here. The stratigraphic range of *H. curva* is here extended at least into the lowest Devonian by its occurrence in the Rabbit Hill Limestone. Figured specimen from locality UWA 6024.

Discussion. — The original type specimens have the proloculus missing, hence Moreman's mistaken identification as a species of *Bathysiphon.* However, they are well tapered as in Hyperammina. Mound (1961, p. 35) recovered a large number of specimens from the Brassfield Limestone of Indiana which compared closely with Moreman's types and also possessed proloculi.

Both of these collections are from rocks of Llandovery age in which the species is more abundant than in the younger rocks of central Nevada. Ecologically the Brassfield is probably similar to the silty limestone and argillaceous limestone of the Roberts Mountains Formation and Rabbit Hill Formation. Other occurrences of

H. curva (Ireland 1939; Dunn, 1942), in the Illinois Basin, are in more pure carbonates, but the abundance of the foraminifer is not stated in these instances.

Family **SACCAMMINIDAE** Brady, 1884

Subfamily **PSAMMOSPHAERINAE** Haeckel, 1894

Genus **PSAMMOSPHAERA** Schulze, 1875

1875. *Psammosphaera* Schulze, Komm. Untersuch. deutsch. Meere in Kiel, Jahresber., vol. 1872-73, p. 113 (*fetae*).

Type species.—*Psammosphaera fusca* Schulze (1875, *ibid.*). Cushman's (1918, p. 34) redescription is given below:

> Test free or attached, single chambered, usually spherical, no definite aperture, the pseudopodia making their way out through the interstitial openings between the elements of the test; wall of sand grains, mica flakes, sponge spicules, or other foraminiferal tests firmly cemented.

This genus, with its simple, nonspecialized form, is one of the most primitive foraminifers known and is a common constituent of arenaceous foraminiferal faunas from the Middle Ordovician to Recent. It is found in almost every environment which agglutinated foraminifers have inhabited. In the Silurian and Lower Devonian of Nevada *Psammosphaera* has been found in rocks with lithologies varying from calcareous, dark, organic shales to reefoid dolomites. In several instances it is the only foraminiferal genus represented. This situation may be incurred by specimen transport into a thanatocoenose, but tubular and polythalmous, spherical genera would also be subject to the same transportation if such were the case. It appears more likely that *Psammosphaera* was more primitive and able to tolerate a greater variety of ecologic conditions. At the same time, the genus is often the most abundant one in a well-developed, diversified faunule. A possible explanation for this situation may be a lack of intensive competition among the foraminifers due to the small number of individuals present.

Psammosphaera cava Moreman Pl. 34, fig. 21

1930. *Psammosphaera cava* Moreman, Jour. Paleont., vol. 4, No. 1, p. 48, pl. 6, fig. 12.

Description.—Test free, spherical; wall thick to thin, outer layer of medium to coarse sand grains and inner pseudochitinous layer, well cemented but not an excess on the surface; no apparent aperture.

Measurements. — Hypotype 34679 has a diameter of 0.25 mm.

Occurrence. — Widespread, generally abundant relative to other foraminifers in these rocks. Specimen 34679 at locality UWA 6010.

Discussion. — Spherical test shapes with a single arenaceous layer over an inner pseudochitinous one, such as *P. cava,* are prone to deformation after death of the animal. Therefore, a wide range of variation in shape may result, all of which represent the same species. Several new species have been erected by authors for these shapes. McClellan (1966, pp. 468-470) reviewed the synonymies which are referable to *Psammosphaera cava.*

Psammosphaera laevigata White Pl. 34, fig. 26; Pl. 39, fig. 1

1928. *Psammosphaera laevigata* White, Jour. Paleont., vol. 2, No. 3, p. 183, pl. 27, figs. 1a,b.

Description. — Test free, spherical, wall finely arenaceous with abundant cement, surface appearing smooth and silky; no aperture apparent, other than small, interstitial pseudopodia openings.

Measurements. — The diameter of the figured specimen is 0.24 mm.

Occurrence. — This species has been recorded as a minor faunal element from the Lower Silurian of Indiana and is similarly present here in the lower part of the Roberts Mountains Formation at locality UWA 6031.

Discussion. — White's type material appears to have been flattened. This flattening is not uncommon with Paleozoic species of *Psammosphaera,* but the examples here do not show similar distortion. The fine wall texture and abundant cement makes them readily distinguishable from specimens of *P. cava.*

Genus **ANICTOSPHAERA** McClellan, n. gen.

Type species. — *Anictosphaera progressa* McClellan, n. sp.

Description. — Test free, multilocular, globular to spherical chambers closely appressed to loosely joined, broad openings between chambers; wall consists of single layer of agglutinated sand grains, well cemented; no definite aperture.

The most important feature of this genus is the presence of broad internal openings between the chambers, hence the origin of the name (Greek, *anictos* = open). The test has several chambers and no aperture, features which characterize many Psammosphaerinae. Other members of the subfamily which are polythalmous have no visible openings between the chambers. There is some indication of multilocular development in *Storthosphaera* Schulze (1875) indicated by the outward projections from the central chamber, which give the appearance of incipient chambers formed by an infolding of the test wall. Such "pseudochambers" are not evident on *Anictosphaera;* instead, well-developed chambers bearing recognizable sutures are readily observable.

Arenosphaera Shchedrina (1939) appears similar to the type species *Anictosphaera progressa,* but close inspection reveals the multiple apertures between the agglutinated grains of the wall. Thus, Shchedrina's genus belongs in the subfamily Saccammininae. All other characters of the two genera point to a close phylogenetic relationship.

Anictosphaera progressa McClellan, n. sp. Pl. 34, figs. 1-5

Description. — Test free, multilocular, subspherical chambers tightly appressed with rectilinear boundary bearing a generally deep suture; presently known only as bilocular forms which have one chamber larger than the other; internal opening between chambers wide and circular; wall thin, medium to finely arenaceous, well cemented; no aperture known.

Measurements. — Diameters of the smaller chamber varies from 0.08 mm to 0.19 mm. Larger chamber diameter ranges from 0.22 mm to 0.27 mm. The ratio of diameters between the chambers is most often approximately 2:1. Wall thickness is fairly constant at 0.02 mm.

Pl. 34	Spec. Number	Small Chamber	Larger Chamber
Fig. 1	34651 paratype	0.19 mm	0.27 mm
Fig. 2	34652 paratype	0.08 mm	0.17 mm
Fig. 3	34653 paratype	0.14 mm	0.27 mm
Fig. 4	34654 holotype	0.10 mm	0.24 mm
Fig. 5	34655 paratype	0.11 mm	0.22 mm

Occurrence. — This species is present in rocks from the middle Roberts Mountains Formation to Rabbit Hill Formation. This represents a range of middle Upper Silurian (Ludlow) to lowest Devonian age. Specimen 34651 from locality UWA 6020; 34652 and 34653 from UWA 6010; 34654, and 34655 from UWA 6009.

Discussion. — The 2:1 ratio between the two chambers occurs commonly but might represent microspheric individuals. The paratype 34651, has a ratio of 3:2 that may indicate a megalospheric form. It is believed that this represents a particularly robust individual, and there is insufficient material available to seriously consider the possibilty of dimorphism. No. 34653 does not have a strong suture between the chambers, but this is most probably only an individual variant in this respect, though it was first believed to be a dimorphic form.

The most common occurrence of *Anictosphaera progressa* is in thin-bedded argillaceous limestones, but it is also present in the more nearly pure carbonates as well. From the known occurrences and associations it does not appear that any significant ecologic interpretations can be made.

Genus **CERATAMMINA** Ireland, 1939

1939. *Ceratammina* Ireland, Jour. Paleont., vol. 13, No. 2, p. 194.

Type species. — *Ceratammina cornucopia* Ireland (1939, *ibid.*, p. 196, figs. A-31, 32).

The description given by Ireland (p. 194) is as follows:

> Test free, horn-shaped; wall composed of fine sand grains; surface smooth; aperture not apparent.

Ceratammina cf. **C. cornucopia** Ireland Pl. 34, fig. 25

Description. — Test free, near horn-shaped but only slightly curved, apparent constriction near larger end of horn; wall thin, finely arenaceous, well cemented; no apparent aperture.

Measurements. — Length of figured specimen is 0.26 mm, larger diameter 0.17 mm, smaller diameter 0.11 mm.

Occurrence. — This species is rarely present at locality UWA 6017 of uncertain stratigraphic position in the Upper Silurian. Ireland (1939, p. 196) reported it as a distinctive Lower Devonian form.

Discussion. — The referred specimen is not well preserved, showing a fracture along one side of the test. The constriction near the larger end may be externally induced, and also be partly responsible for the indistinctness of the horn shape. Because of this damage the specimen cannot be definitely determined as a *Ceratammina cornucopia.*

Genus **Raibosammina** Moreman, 1930

1930. *Raibosammina* Moreman, Jour. Paleont., vol. 4, No. 1, p. 50.

Type species. — *Raibosammina aspera* Moreman (1930, *ibid.*, pl. 6, figs. 13-15), designated lectotype.

The genus, as originally designated, included forms which have subsequently been considered as species of *Stegnammina* Moreman (1930), including the original type *R. mica* Moreman. Loeblich and Tappan (1964, p. 196) included all *Raibosammina* species within *Stegnammina.* McClellan (1966, p. 474) discussed the relationships of these genera and suggested that *Raibosammina aspera* might well be better considered as generically separate from other *Stegnammina* species. It is, therefore, necessary to emend the original description of Moreman which did not restrict the genus to only branching forms. The following emendation is considered necessary:

> Test free, subcylindrical, chamber may be crooked, irregularly branching; wall of variable thickness, arenaceous, poorly to well cemented, no aperture apparent.

As thus described the genus is monotypic and *Raibosammina aspera* is, therefore, designated as typical.

Raibosammina is closely related to *Stegnammina* which has several similar subcylindrical species, but it differs from the latter in having a branching test. The only other species previously identified as a *Raibosammina* is *Stegnammina mica* (Moreman), a subcylindrical, nonbranching, monothalmous form.

Raibosammina aspera Moreman Pl. 33, fig. 12; Pl. 39, fig. 3

1930. *Raibosammina aspera* Moreman, Jour. Paleont., vol. 4, No. 1, p. 50, figs. 13-15.

1964. *Stegnammina aspera* (Moreman), Loeblich and Tappan, Treat. Invert. Paleont., Pt. C, Protista 2, vol. 1, p. 196

Description. — Test free, subcylindrical and branching, ends bluntly terminated; wall of poorly sorted sand grains, moderately cemented; no apparent aperture, numerous pseudopodia openings on surface.

Measurements. — Figured hypotype 34681 has diameter of 0.29 mm and length of 0.71 mm.

Occurrence. — Uncommon at localities UWA 5985 and UWA 5996.

Discussion. — This species has been recognized in rocks from Upper Ordovician to Lower Devonian age. It does not appear to have obvious habitat preferences nor to occur in abundance at any time during its known geologic range. It has a fairly wide geographic distribution, being present in faunas from Indiana, Oklahoma, and Nevada.

Genus **SOROSPHAERA** Brady, 1879

1879. *Sorosphaera* Brady, Quart, Jour. Micr. Sci., vol. 19, new ser., pp. 28-29.

Type species. — *Sorosphaera confusa* Brady (1879, *ibid.,* pl. 4, figs. 18, 19).

Brady's original description follows:

> Test free, irregular; consisting of a number of convex or spheroidal chambers, either discrete or more or less embracing, irregularly crowded together. Walls thin, loosely arenaceous in texture. General aperture, none. Long diameter of large specimens, 1/6 inch (4.5 mm.)

Several species of this genus have been erected on the basis of differing number of chambers. It can readily be demonstrated that these species are all within the expected range of variation of a single species. The difference in number of chambers may be due to breakage and separation, or ontogeny. Grubbs (1939, p. 544) suggested the former and Hattin (personal communication) found a complete ontogenetic sequence of the genus which suggests the latter, in the Waldron Shale. The writer concurs with these opinions and has here considered two and three chambered forms as fragments or neanic individuals of species having a greater number of chambers. In the case of an isolated chamber it is impossible to recognize *Sorosphaera* from *Psammosphaera cava* unless a fragment of a second chamber is present.

Sorosphaera confusa Brady — Pl. 34, fig. 24

1879. *Sorosphaera confusa* Brady, Quart. Jour. Micr. Sci., vol. 19, new ser., pp. 28, 29, pl. 4, figs. 18, 19.

Description. — Test free, multilocular, consisting of a variable number of subspherical chambers connected closely in a random manner with adjoining walls somewhat appressed, entire test having a massive appearance; wall thin, usually finely arenaceous, well cemented; no apparent aperture.

Measurements. — Chamber diameters of the hypotype 34687 are 0.29 mm, 0.43 mm.

Occurrence. — Infrequently present at several localities and stratigraphic levels. Hypotype from locality UWA 6030.

Discussion. — *Sorosphaera confusa* has been previously recognized throughout strata of Silurian age, and here is found in rocks of lowest Devonian age. None of these occurrences are in abundance. Though typically occurring in argillaceous or silty limestones, it has also been found in dolomitic limestones.

Sorosphaera osgoodensis Stewart and Priddy
Pl. 34, figs. 15, 16; Pl. 39, fig. 6

1930. *Sorosphaera tricella* Moreman, Jour. Paleont., vol. 4, No. 1, p. 49, pl. 5, figs. 12, 14.
1932. *Sorosphaera tricella* Moreman, Croneis, *et al.*, Science, vol. 75, No. 1935, pl. 138.
1941. *Sorosphaera osgoodensis* Stewart and Priddy, Jour. Paleont., vol. 15, No. 4, p. 371, pl. 54, fig. 11.
1942. *Sorosphaera bicella* Dunn, Jour. Paleont., vol. 16, No. 3, p. 325, pl. 42, figs. 17, 18.
1942. *Sorosphaera multicella* Dunn, *ibid.*, p. 325, pl. 42, figs. 19a, b.
1942. *Sorosphaera tricella* Moreman, Dunn, *ibid.*, p. 324, pl. 42, fig. 15.
1947. *Sorosphaera bicelloidea* Stewart and Lampe, Jour. Paleont., vol. 21, No. 6, p. 534, pl. 78, fig. 6.
1958. *Sorosphaera bicella*? Dunn, Summerson, Jour. Paleont., vol. 32, No. 3, p. 551, pl. 81, fig. 13.
1958. *Sorosphaera bicelloidea* Stewart and Lampe, Summerson, *ibid.*, p. 81, fig. 14.
1961. *Sorosphaera bicella* Dunn, Mound, Indiana Dept. Conserv., Geol. Sur., Bull. No. 23, p. 33, pl. 3, figs. 4-6.
1961. *Sorosphaera tricella* Moreman, Mound, *ibid,* p. 34, pl. 3, figs. 7-10.
1963. *Sorosphaera bicella* Dunn, Browne and Schott, Bull. Amer. Paleont., vol. 46, No. 209, p. 211, pl. 49, fig. 16.
1963. *Sorosphaera tricella* Moreman, Browne and Schott, *ibid.*, p. 212, pl. 49, fig. 15.
1966. *Sorosphaera bicella* Dunn, McClellan, Bull. Amer. Paleont., vol. 50, No. 230, p. 472, pl. 37, 41, figs. 7-9.
1966. *Sorosphaera tricella* Moreman, McClellan, *ibid.*, pl. 37, 41, fig. 10.

Description. — Test free, multilocular, consisting of any number of spherical to subspherical chambers, usually joined and always in a single plane which may be somewhat distorted; wall thin, fine to coarsely arenaceous, moderately cemented; no apertures apparent, infrequent minute and poorly defined pseudopodia openings present.

Measurements. — Four-chambered figured specimen 34688 has chamber diameters of 0.15 mm, 0.15 mm, 0.16 mm, 0.13 mm. Specimen 34790 has diameters of 0.15 mm, and 0.13 mm.

Occurrence. — This species, though not widespread or abundant in Nevada, is present at several horizons. In Silurian rocks and Devonian rocks of other areas from which it has been reported, it also occurs in modest numbers. Hypotypes from locality UWA 6018.

Discussion. — The several synonymous species listed above consist of individuals described as having two or three chambers and are here considered invalid. The figured specimens show that breakage readily occurs by separation between chambers. Specimen 34688 has four complete chambers and a large part of a fifth preserved. Specimen 34790 has only a small part of a third chamber remaining. The writer concludes that such accidental breakage is responsible for the several species names applied by previous authors.

The inclusion of two-chambered and three-chambered forms in the species S. *osgoodensis* is sometimes difficult to accomplish because the chambers are attached in a single plane. This is especially true with two-chambered specimens when there are few individuals in a sample. S. *osgoodensis* specimens having only two chambers may be confused with S. *irregularis* Grubbs (1939) or S. *subconfusa* Dunn (1942). There presently is some doubt as to the validity of the latter two species, and they may well be S. *osgoodensis*. The chart below illustrates their relationships.

S. *osgoodensis*	S. *irregularis*	S. *subconfusa*
1) Loosely joined, spherical chambers	Chambers closely joined, spherical	Closely joined, subspherical chambers
2) Growth-planar	Growth-irregular	Massive, irregular appearance
3) Well cemented	Very well cemented	Well cemented

(this feature has questionable specific validity)

Sorosphaera inflata McClellan, n. sp. Pl. 34, figs. 11, 12; Pl. 40, fig. 1

Description. — Test free, multilocular, chambers subspherical, presently known only as bilocular with one chamber two or three times larger than the other, chamber wall appressed where closely joined, with external suture moderate to deep, no openings between chambers; wall thin, medium to finely arenaceous, poor to well cemented; no aperture known.

Measurements. — Paratype 34689 has smaller chamber diameter 0.15 mm, larger chamber 0.30 mm, and wall thickness 0.05 mm. Holotype 34690 with smaller chamber diameter 0.08 mm, larger chamber 0.27 mm, wall thickness 0.02 mm.

Occurrence. — This species is rare, occurring at locality UWA 5976 and locality UWA 5987. Both localities are probably of latest Ludlovian age.

Discussion. — The distinctive feature of *Sorosphaera inflata* is the pronounced inequality of size between the two chambers with subequal diameters. Loeblich and Tappan (1964, p. 196) included *Arenosphaera perforata* Shchedrina (1939) as a species of *Sorosphaera.* This, then, would appear to be a closely related species because it has similar inequality in chamber size. However, *A. perforata* has an opening between chambers and multiple openings in the test wall, and thus actually should be considered a genus in the Saccammininae. If this is true, *S. inflata,* which has no recognizable openings between chambers or in the exterior wall, would have no known close relatives.

Only two-chambered forms are currently known, but it is likely that specimens with more chambers may be found in the future.

Although ecologic considerations of this new species must of necessity be limited by the quantity of material and its limited geographic extent, the two occurrences are in medium-bedded, fine-grained limestones. One of these bears common crinoidal fragments. The lack of argillaceous material might suggest somewhat higher energy conditions.

Sorosphaera compacta McClellan, n. sp. Pl. 34, figs. 13, 14; Pl. 40, fig. 2

Description. — Test free, massive, multilocular, subrounded to subangular, chambers closely packed in an irregular mass and nearly indistinct externally, adjoining chambers tightly appressed with linear sutures faint to nonexistent; wall thin, medium to finely arenaceous, moderately cemented; no apparent apertures.

Measurements. — Holotype 34691 has chamber diameters of 0.18 mm, 0.19 mm, 0.14 mm. Paratype 34692 has diameters of 0.11 mm, 0.13 mm, 0.17 mm.

Occurrence. — This species is present in the Lone Mountain Formation and Roberts Mountains Formation, with a stratigraphic range through the Upper Ludlow. Holotype 34691 from locality UWA 5974 and 34692 from locality UWA 5992.

Discussion. — *Sorosphaera confusa* is the most closely related species to S. *compacta,* but the latter is more massive in appearance and has more closely joined chambers. In the holotype, chambers can only be recognized because of the broken test. The figured paratype has a slightly depressed suture separating one of the three chambers. The chambers can also be externally recognized on an unfigured paratype, 346791 which has two partially damaged chambers.

Sorosphaera compacta was recovered from samples without silt or mud. This would seem to indicate a preference for relatively higher energy conditions. Associated invertebrates include brachiopods, Bryozoa, corals and crinoids in abundance. The microfauna is usually quite diversified and includes ostracodes, conodonts and, in one instance, tentaculitids. This fauna has been preserved in limestones and limey dolomites suggestive of well aerated waters having bottom currents.

Sorosphaera sp. Pl. 34, fig. 20

Description. — Test apparently free, multilocular, chambers subspherical where not badly damaged, overall test configuration indeterminate; wall thin, composed of fine sand grains well cemented; aperture unknown.

Measurements. — Diameter of measurable chamber 0.11 mm, other chamber diameter is indeterminate.

Occurrence. — Present only at locality UWA 5985.

Discussion. — Though the specimen is partially broken and one chamber much distorted, this species is not referable to S. *confusa* which also occurs at the same locality, for the well-developed chamber is more nearly spherical and discrete than those of that species.

S. confusa and this species are the only sorosphaerids present in the McMonnigal Limestone.

Genus **STEGNAMMINA** Moreman, 1930, emend. McClellan, 1966

1930. *Stegnammina* Moreman, Jour. Paleont., vol. 4, No. 1, p. 49.

Type species. — *Stegnammina cylindrica* Moreman (1930, *ibid.*, p. 49, pl. 7, fig. 12).

The emended description of McClellan (1966, p. 475) is given below.

> Test free, monothalmous, cylindrical to angular, straight to curved; wall thin to thick, agglutinated, poorly to well cemented; aperture not apparent.

Stegnammina contorta McClellan Pl. 34, fig. 22

1966. *Stegnammina contorta* McClellan, Bull. Amer. Paleont., vol. 50, No. 230, p. 476, pls. 36, 40, figs. 17, 18a, b.

Description. — Test free, monothalmous, cylindrical and twisted, ends rounded, chamber tubular and narrow; wall thick, fine to medium arenaceous grains, poorly cemented; no aperture apparent.

Measurements. — Length of figured hypotype 34696 is 0.57 mm and diameter 0.12 mm.

Occurrence. — Present in small numbers at several localities representing a general Ludlow age. Specimens at locality UWA 6010, which is very near the probable Silurian-Devonian boundary, are the latest known occurrence for the species. Hypotype 34696 is from locality UWA 6024.

Discussion. — *Stegnammina contorta* evidently has no strong preference for a particular energy level of its habitat. It has most frequently been recovered from sediment consisting of mixed argillaceous and calcareous material. The species is also present in limestones with little argillaceous material, though there is some indication that this is not the preferred environment.

Stegnammina cylindrica Moreman Pl. 34, fig. 18

1930. *Stegnammina cylindrica* Moreman, Jour. Paleont., vol. 4, No. 1, p. 49, pl. 7, fig. 12.
1942. *Stegnammina cylindrica brevis* Dunn, Jour. Paleont., vol. 16, No. 3, 1. 325, pl. 42, fig. 25.

Description. — Test free, monothalmous, cylindrical, ends flattened; wall thin, finely arenaceous, well cemented; no definite aperture, but small pseudopodia openings present on test surface.

Measurements. — Figured specimen 34697 measures 0.22 mm in length and 0.13 mm in diameter.

Occurrence. — This species was found at several localities in the middle Roberts Mountains Formation, or its equivalent, representing middle Ludlow time. Though well known elsewhere from older Silurian strata it has not been recognized in the older units within this area. Presence of this species at locality UWA 5978 lends paleontological support to the assignment of these beds to the Roberts Mountains Formation rather than to the Hanson Creek, as suggested in the stratigraphic discussion previously. The figured hypotype is from locality UWA 6017.

Discussion. — The length of *Stegnammina cylindrica* has been shown by Mound (1961, p. 25) to range from 0.17 mm to 0.50 mm. The subspecies, *S. cylindrica brevis* Dunn supposedly varies from Moreman's type in being only half as long. However, it is still well within the range determined by Mound for *S. cylindrica* specimens.

The occurrence noted above is the youngest yet known for the species *sensu stricto.* Mound (1961, p. 25) and Browne and Schott (1963, p. 210) considered *Stegnammina elongata* Ireland (1939) as synonymous with *S. cylindrica.* The writer believes that *S. elongata* presently is not well enough known to be so placed taxonomically. The main reason concerns the use of length-width ratios in the two species. McClellan (1966, p. 475) suggested the likelihood of a fairly constant 2:1 ratio between these dimensions for *S. cylindrica.* Measurements made on specimens recovered here agree with that ratio. The ratio in *S. elongata,* if similarly constant, would be much greater, but no measurements have been made for a comparison. The only reported occurrence of *Stegnammina cylindrica* in the Devonian is that by Mound (1961) and Browne and Schott (1963). Following the above discussion of that species and *S. elongata,* as considered herein the specimens at locality UWA 6010 represent the youngest occurrence of *S. cylindrica.*

Stegnammina hebesta? Moreman Pl. 34, fig. 19

1930. *Stegnammina hebesta* Moreman, Jour. Paleont., vol. 4, No. 1, p. 50, pl. 7, fig. 13.

Description. — Test free, subcylindrical, robust, ends rounded, diameter about two-thirds the length; wall thin, finely arenaceous and well cemented; no apparent aperture.

Measurements. — Length of the figured specimen is 0.21 mm and diameter 0.14 mm.

Occurrence. — Hypotype 34698 is from the McMonnigal Limestone at locality UWA 5985. Forms referred to this species are also present at locality UWA 6000. Both localities are of Helderbergian age.

Discussion. — The type specimen of Moreman is more robust than any of those in the present material, having a diameter about three-fourths the length. This feature is one of the main reasons for separating *S. hebesta* from the less robust species *S. cylindrica.* The material at hand is poorly preserved for the most part, and the thin test walls are fragile, making measurement of the length-diameter ratio difficult. The figured specimen, though slightly deformed, seems typical, however, and has a ratio of 3:2 which is between *S. cylindrica* and *S. hebesta.* The consistency found within examples of the former species precludes the identification of this material with them. Therefore, it has been referred to *S. hebesta* with some question.

Ecologically this species had a preference for a higher energy environment as indicated by its occurrence in nearly pure carbonate rocks. In contrast, *Stegnammina cylindrica* was found in rocks indicative of quieter conditions as well as consistently occurring at lower stratigraphic horizons.

Stegnammina moremani (Dunn) Pl. 34, fig. 17; Pl. 39, fig. 2

1942. *Thekammina moremani* Dunn, Jour. Paleont., vol. 16, No. 3, p. 326, pl. 42, fig. 22.
1961. *Thekammina moremani* Dunn, Mound, Indiana Dept. Conserv., Geol. Sur., Bull. No. 23, p. 26, pl. 1, fig. 29.
1964. *Stegnammina moremani* (Dunn), Loeblich and Tappan, Treat. Invert. Paleont., Pt. C, Protista 2, vol. 1, p. 196.

Description. — Test free, triangular in outline, slightly depressed; wall thin, finely arenaceous, well cemented; no aperture apparent, except minute openings on test surface.

Measurements. — Length of hypotype 34699, measured from triangle apex to opposite side is 0.21 mm for each side.

Occurrence. — This is a rare species, present only at locality UWA 5985 in the McMonnigal Limestone. The only previous report of *S. moremani* is from the Lower Silurian Brassfield Limestone in Missouri and Indiana.

Discussion. — Loeblich and Tappan (1964 p. 196) included species of *Raibosammina* Moreman (1930) and *Thekammina* Dunn (1942) within the generic limits of *Stegnammina* stating that "modifications of chamber shape are not regarded as generic in importance". Because *Thekammina* had been erected on the basis of its angular test shape it falls within the species limits set by them.

Stegnammina quadrangularis (Dunn) Pl. 34, figs. 23, 27

1942. *Thekammina quadrangularis* Dunn, Jour. Paleont., vol. 16, No. 3, p. 326, pl. 42, fig. 23.
1961. *Thekammina quadrangularis* Dunn, Mound, Indiana Dept. Conserv., Geol. Sur., Bull. No. 23, p. 25, pl. 1, fig. 28.
1963. *Thekammina quadrangularis* Dunn, Browne and Schott, Bull. Amer. Paleont., vol. 46, No. 209, p. 210, pl. 49, figs. 13, 14.
1964. *Stegnammina quadrangularis* (Dunn), Loeblich and Tappan, Treat. Invert. Paleont., Pt. C, Protista 2, vol. 1, p. 196.

Description. — Test free, boxlike with planar sides; wall thin, fine to coarsely arenaceous, poor to moderately cemented; no aperture apparent.

Measurements. — Hypotype 34700 has length 0.44 mm and width 0.42 mm. Hypotype 34701 has length 0.64 mm and width 0.31 mm.

Occurrence. — Specimen 34700 is from locality UWA 5992 and 34701 from locality UWA 6019, both in the Lone Mountain Dolomite. The species is also uncommonly to rarely present at several other localities from Ludlow to Lower Helderberg age.

Discussion. — For the same reasons as those presented in the discussion of *S. moremani,* this species belongs within the limits of *Stegnammina* and the generic name *Thekammina* should be suppressed as a junior synonym.

The test shape of *S. quadrangularis* varies substantially from nearly square to elongate, always with the boxlike form. Most specimens here were nearly square. The height of the test is usually indeterminate because the thin, fragile wall is so easily damaged and distorted.

This species occurs most frequently in silty and shaly limestones indicating a probable preference for quieter water. However, the two hypotypes are from a distinctly different environment, the reefoid conditions in the Lone Mountain Dolomite. It is one of the few foraminifers found in this environment, and its presence here is the only known occurrence in such conditions as well as its youngest stratigraphic position.

Genus **STORTHOSPHAERA** Schulze, 1875

1875. *Storthosphaera* Schulze, Komm. Untersuch. deutsch. Meere *in* Kiel, Jahresber, vol. 1872-73, p. 113.

Type species. — *Storthosphaera albida* Schulze (1875, *ibid.*, pl. 2).

Description. — Test free, monothalmous, irregular chamber, wall finely arenaceous, poorly to well cemented, aperture indefinite.

The surface of the test wall may be irregular with protuberances of various configurations but not possessing any aperture. The interior, despite the irregularities of the test which suggest incipient chambers, lacks a definite indication of subdivision that might suggest *Sorosphaera.*

Storthosphaera malloryi McClellan, n. sp.
Pl. 34, figs. 6-10; Pl. 40, fig. 3

Description. — Test free, irregular, globular chamber appears lumpy on exterior; wall thin, very finely arenaceous, well cemented; no aperture apparent.

Measurements. — Maximum test size for the figured specimens averages 0.26 mm.

Pl. 34	Spec. Number	Test Size
Fig. 6	34703 holotype	0.29 mm
Fig. 7	34704 paratype	0.19 mm
Fig. 8	34705 paratype	0.22 mm
Fig. 9	34706 paratype	0.26 mm
Fig. 10	34707 paratype	0.33 mm

Occurrence. — Present throughout the stratigraphic interval at several localities. Holotype 34703 from locality UWA 5985; paratypes 34704, 34705 at UWA 5985; 34706 at UWA 5976; and 34707 at UWA 6010.

Discussion. — This species varies considerably from the type, *S. albida,* which has an irregular wall thickness and heterogeneous development of ridges and protuberances on the surface. In contrast, *S. malloryi* has a thin wall and a lumpy, or globular, surface appearance. The lumpy nature actually resembles chambers but smaller lumps make up most of the surface of these pseudochambers. Interiorly there is no indication of subdivision into a multilocular growth, hence this is regarded as a species of *Storthosphaera.*

Previously *Storthosphaera* has been known only from the Recent and generally from cold waters. In the present material it ranges from the Middle Silurian to Lower Devonian. There seems not to be any preference for a particular environment other than not being found in the high energy condition of the reefoid dolomites.

Subfamily **SACCAMMININAE** Brady, 1884

Genus **SOROSTOMASPHAERA** McClellan, 1966

1966. *Sorostomasphaera* McClellan, Bull. Amer. Paleont., vol. 50, No. 230, pp. 478, 479.

Type species. — *Sorostomasphaera waldronensis* McClellan, (1966, *ibid.*, pls. 37, 41, figs. 1-5).

The original description of McClellan (1966, p. 478) is as follows:

> Test free, multilocular, consisting of a variable number of globular to spherical chambers irregularly attached to each other; chambers may be loosely connected or appressed where adjoined; wall thin, finely arenaceous, well cemented; single, rounded aperture on each chamber, no openings between chambers.

Sorostomasphaera differs from *Sorosphaera* Brady (1879) in possessing apertures, and from *Saccamminoides* Geroch (1955) in having consistent chamber diameters each with an aperature.

Sorostomasphaera waldronensis McClellan Pl. 35, figs. 7, 8

1966. *Sorostomasphaera waldronensis* McClellan, Bull. Amer. Paleont., vol. 50, No. 230, pp. 479-80, pl. 37, 41, figs. 1-5.

Description. — Test free, multilocular, variable number of chambers which are subspherical, chambers loosely or firmly joined, wall thin, very finely arenaceous, well cemented; single circular aperture on each chamber.

Measurements. — Diameter of single chamber is 0.30 mm on hypotype 34694. Diameter of 34695 is 0.29 mm. These measurements compare closely with the original types (McClellan, 1966, p. 480).

Occurrence. — Rarely present at two localities, UWA 6028 (hypotypes) and UWA 6025 in the Willow Creek section. The stratigraphic interval is Wenlockian to lower Ludovian, in the lower and middle Roberts Mountains Formation.

Discussion. — The presence of this species here extends its stratigraphic range, but it is significantly absent from localities in younger strata which indicate quite similar physical environment conditions. McClellan (1966, p. 379) stated that the genus was not particularly specialized ecologically, and its occurrence in Nevada is similar to that discussed by him. Thus it is possible that *Sorostomasphaera waldronensis* is biostratigraphically a useful species restricted to rocks of middle and upper Niagaran age.

Genus **STOMASPHAERA** Mound, 1961

1961. *Stomasphaera* Mound, Indiana Dept. Conserv., Geol. Sur., Bull. No. 23, p. 28.

Type species. — *Stomasphaera brassfieldensis* Mound (1961, *ibid.*, pl. 2, figs. 9-13, text fig. 3).

Mound's (p. 28) generic diagnosis is as follows:

> Wall rough, thick to thin, medium to coarsely arenaceous, grains poorly to well cemented; test free, subangular to spherical, most commonly subspherical or spherical; aperture single, round or oval.

This is a common Lower Silurian genus in Indiana but rare from younger rocks. It occurs rarely in central Nevada no higher than lower Ludlovian, or uppermost Niagaran.

Stomasphaera brassfieldensis Mound Pl. 36, fig. 7

1961. *Stomasphaera brassfieldensis* Mound, Indiana Dept. Conserv., Geol. Sur., Bull. No. 23, p. 28, pl. 2, figs. 9-13, text fig 3.

Description. — Test free, monothalmous, subspherical, slightly produced around aperture; wall thin, medium to finely arenaceous, well cemented; single, round aperture.

Measurements. — Hypotype 34702 diameter is 0.62 mm and aperture 0.14 mm.

Occurrence. — The figured specimen is from locality UWA 6022 in the Roberts Mountains. The species is also present at locality UWA 5983 in the Bastille Limestone. Rare at both localities.

Discussion. — The similarity between *S. brassfieldensis* and *Saccammina* Sars (1869) species is close except for the aperture. *Saccammina* species have the aperture at the end of a short neck which is lacking on the well-preserved *Stomasphaera brassfieldensis* in the Bastille strata and Roberts Mountains strata. *Sorostomasphaera waldronensis* also has affinities with *Stomasphaera brassfieldensis*, but is consistently more nearly spherical, has no modification of the test in the apertural area, and has a thinner and more finely arenaceous wall. These features allow identification even of isolated chambers.

Genus **THURAMMINA** Brady, 1879

1879. *Thurammina* Brady, Quart. Jour. Micro. Sci. new ser., vol. 19, pp. 45-47.

Type species. — *Thurammina papillata* Brady (1879, *ibid.*, p. 45) subsequently designated, Cushman, 1910, p. 57.

Brady (1879) failed to provide a generic diagnosis and Cushman (1910, p. 57) subsequently described the genus and designated the type species.

> Test typically free, usually nearly spherical, but in some species compressed, chamber single and undivided in typical species; wall thin, composed of fine sand with more or less chitin; apertures several to many at the end of nipple-like protuberances of the surface, occasionally wanting.

There are a number of lower Paleozoic species of *Thurammina* but seldom is any one of them abundant. The material studied herein has each of the species sparsely present at only one or two localities. McClellan (1966, p. 481) did not find the genus to be generally useful as an environmental indicator. Certain species may nonetheless be ecologically restricted in the Siluro-Devonian sediments of central Nevada.

Thurammina arcuata Moreman Pl. 35, fig. 18

1930. *Thurammina arcuata* Moreman, Jour. Paleont., vol. 4, No. 1, p. 54, pl. 6, figs. 2, 3.

Description. — Test free, monothalmous, arcuate, inflated polygonal outline; wall thin, finely arenaceous, well cemented; apertures several, at ends of short, broad protuberances.

Measurements. — Width of hypotype 34708 is 0.37 mm. Aperture neck length 0.04 mm.

Occurrence. — Uncommon, figured specimen from locality UWA 6018, in the McColley Canyon Formation. Also present in the McMonnigal Limestone at locality UWA 5985. Both formations are of Lower Devonian age.

Discussion. — The specimens recovered here are more robust than Moreman's figured types, and the short nodes bearing the apertures are better developed. The polygonal and arcuate outline is consistent with both Moreman's (1930) specimens and those of Browne and Schott (1963).

Thurammina arcuata has previously been recorded from Lower and Middle Silurian argillaceous limestone strata. McClellan (1966, p. 460) listed this species as one limited to lower energy environments in the Waldron Shale of Indiana. The specimens from central Nevada were found in less argillaceous carbonates, suggestive of higher energy conditions.

Thurammina quadritubulata? Dunn Pl. 35. fig. 20

1942. *Thurammina quadritubulata* Dunn, Jour. Paleont., vol. 16, No. 3, p. 334, pl. 43, fig. 22.

Description. — Test free, monothalmous, spherical; wall thin, composed of medium-sized sand grains, moderately cemented; four apertures at ends of short, broad tubules arranged in pairs on different planes.

Measurements. — Diameter of hypotype 34709 is 0.51 mm; aperture necks 0.035 mm.

Occurrence. — This species is rarely present at locality UWA 6004 in the Roberts Mountains Formation.

Discussion. — The apertures of the specimens studied herein show a variation in arrangement from that described by Dunn as normal for the species. He described the apertures (p. 334) as:

> four blunt tubular necks arranged in opposite pairs, the horizontal plane of one pair cutting the vertical pair of the other at right angles. Viewed from above, however, the four tubes do not lie in vertical planes through the center of the sphere but are offset on opposite sides of perpendicular vertical central planes.

These specimens have one pair of apertures arranged at opposite poles. The other pair does not form a plane normal to the first pair, because one aperture is at an angle of less than 90 degrees. It is believed that the above arrangement only represents a variation, though positive identification of the specimens as *T. quadritubulata* was not possible because comparison with the holotype could not be made.

Thurammina trituba Dunn Pl. 35, fig. 17

1942. *Thurammina tributa* [*sic*] Dunn, Jour. Paleont., vol. 16, No. 3, p. 334, pl. 43, fig. 26.

Description. — Test free, monothalmous, triangular outline slightly inflated; wall thin, finely arenaceous, well cemented; apertures number three, at ends of short nodes forming corners of triangular test outline.

Measurements. — Lengths of the three sides from aperture to aperture are 0.30 mm, 0.30 mm, 0.35 mm on figured hypotype 34710.

Occurrence. — Rarely present in the Gatecliff Dolomite at locality UWA 5998.

Discussion. — The specimen described here is slightly more robust than characteristic for the species. Its occurrence in the Gatecliff Dolomite compares well stratigraphically with the occurrence in the Osgood Limestone reported by Dunn (1942, p. 334). Kay and Crawford (1964, p. 438) suggested a Llandovery age for the Gatecliff on the basis of the graptolite fauna and the Osgood is in nearly the same stratigraphic interval. Because the species is only rarely present and has been reported only from Missouri and central Nevada, too much importance should not be placed on its biostratigraphic occurrence.

Thurammina tubulata Moreman Pl. 35, fig. 19

1930. *Thurammina tubulata* Moreman, Jour. Paleont., vol. 4, No. 1, p. 52, pl. 5, fig. 8.

Description. — Test free, monothalmous, spherical, wall thin, finely arenaceous, abundant cement; apertures at ends of variously positioned tubes.

Measurements. — Diameter of figured specimen 34711 is 0.22 mm and aperture neck is 0.04 mm long.

Occurrence. — This species occurs rarely at locality UWA 6015 only.

Discussion. — The single specimen recovered here has several of the tubules mostly broken off leaving only the bases. Those which are intact are long and definitely indicate the specimen to be a *T. tubulata* rather than *T. papillata* which has shorter, nodular projections.

Subfamily **HEMISPHAERAMMININAE** Loeblich and Tappan, 1961

Genus **HEMISPHAERAMMINA** Loeblich and Tappan, 1957

1904. *Webbinella* Rhumbler, Archiv. Protistentkunden, vol. 3, pt. 1, p. 228.
1957. *Hemisphaerammina* Loeblich and Tappan, U.S. Nat. Mus., Bull. 215, pp. 223, 224.
1958. *Fairliella* (in part) Summerson, Jour. Paleont., vol. 32, No. 3, pp. 555, 556.

Type species. — *Hemisphaerammina batalleri* Loeblich and Tappan (1957, *ibid.* p. 224, pl. 72, fig. 3).

The redescription given by Loeblich and Tappan (1964, p. 202) is as follows:

> Test attached, consisting of single hemispherical chamber; may have bordering flange; wall agglutinated, with considerable cement; no apparent aperture.

This genus was established by Loeblich and Tappan (1957) for those agglutinated species of *Webbinella* Rhumbler (1901) which were excluded when the type *W. hemispherica* was recognized as a polymorphinid. Certain species of *Fairliella* Summerson (1958) can also be allotted to *Hemisphaerammina. F. dicantha* Summerson and *F. clitellata* Summerson are retained in that genus as distinctly different from *Hemisphaerammina,* following the decision of McClellan (1966, pp. 484, 485).

Hemisphaerammina bradyi Loeblich and Tappan
Pl. 35, fig. 1; Pl. 36, fig. 6

1957. *Hemisphaerammina bradyi* Loeblich and Tappan, U.S. Nat. Mus., Bull. 215, p. 224, pl. 72, fig. 3.

Description. — Test attached, monothalmous, hemispherical, highly convex with side wall forming a sharp angle at junction with base; dorsal wall thickness greater than the ventral, finely arenaceous, well cemented; no apparent aperture.

Measurements. — Figured hypotype 34663 has diameter of 0.31 mm and height of 0.28 mm.

Occurrence. — The hypotype is from locality UWA 6018. The species is common at all stratigraphic intervals in the area.

Discussion. — The most favorable environment for *H. bradyi* appears to have been that in which well-bedded limestones were deposited from waters bearing little argillaceous material. It is commonly found in samples with a diversified foraminiferal and invertebrate faunule, that implies relatively higher energy conditions. The only previous Paleozoic record of this species is in the Waldron Shale of Indiana (McClellan, 1966, p. 485) where it is in calcareous shales, but again, is associated with a diversified faunule of a type similar to that of central Nevada.

Hemisphaerammina? cf. **H. bradyi** Loeblich and Tappan Pl. 35, fig. 2

Description. — Test attached, monothalmous, hemispherical, moderately convex; wall thin, finely arenaceous, base thinner than convex dorsal wall, well cemented; no apparent aperture.

Measurements. — Specimen 34664 has diameter of 0.28 mm and height of 0.13 mm.

Occurrence. — Present at locality UWA 6028 associated with typical specimens of *Hemisphaerammina bradyi.*

Discussion. — *Hemisphaerammina bradyi* is typically hemispherical and highly convex, the test being nearly as high as it is broad. Variants with partially collapsed tests can usually be readily recognized. This form is questionably referred to the genus *Hemisphaerammina* because of the abnormally low convexity which seems not to be caused by collapse. A closely related genus, *Webbinelloidea* Stewart and Lampe (1947), has several species which also have low convexity but differ from *Hemisphaerammina* in the manner of junction between the dorsal and ventral walls (see generic discussion of *Webbinelloidea*).

Hemisphaerammina coronata (Ireland) Pl. 35, fig. 4; Pl. 38, fig. 4

1939. *Webbinella coronata* Ireland, Jour. Paleont., vol. 13, No. 2, p. 198, fig. B-11.

Description. — Test attached, monothalmous, elongate hemispherical, broad flange with projecting spines; wall thin, finely arenaceous, well cemented; no aperture apparent.

Measurements. — Test length of figured specimen 34665 is 0.15 mm, width 0.13 mm, height 0.11 mm, wall thickness 0.01 mm, width of flange 0.02 mm.

Occurrence. — Only a single specimen was recovered from locality UWA 6004 in the midlde Roberts Mountains Formation.

Discussion. — This specimen is much smaller than Ireland's holotype, whose length is 0.87 mm, and probably represents a neanic individual. A scanning electron micrograph shows the dorsal wall having the grains arranged in concentric layers, a pattern not previously recognized in other specimens. Only a small part of the diagnostic basal flange is preserved but *Hemisphaerammina casteri* McClellan (1966), the only other species with a broad flange, has a very thick flange with no spines, and, therefore, cannot be confused with *H. coronata.*

Hemisphaerammina discoidea? (Summerson) Pl. 35, fig. 3

1958. *Fairliella discoidea* Summerson, Jour. Paleont., vol. 32, No. 3, p. 557, pl. 82, fig. 20, text figs. 6a, b.

1966. *Hemisphaerammina discoidea* (Summerson), McClellan, Bull. Amer. Paleont., vol. 50, No. 230, p. 486, pls. 38, 42, figs. 2a, b, 3.

Description. — Test attached, monothalmous, slightly ovoid, strongly biconvex, dorsal and ventral surface joined along highly sinuous line which is sharply defined with thickened test wall; flange questionably present as wedge edge of sinuous junction line; wall thin to thick, medium to coarsely arenaceous, poorly cemented; no apparent aperture.

Measurements. — Width of figured specimen is 0.26 mm and height is 0.22 mm.

Occurrence. — Rarely present only at locality UWA 6010, of earliest Devonian age.

Discussion. — This species has previously been reported from the Columbus Limestone (M. Devonian) of Ohio, and Waldron Shale (M. Silurian) of Indiana. The specimen here differs from those of earlier reports in the configuration of the junction line between the dorsal and ventral surfaces. The Devonian forms (Summerson, 1958, p. 557) possess a straight to slightly sinuous junction line, while those from the Silurian (McClellan, 1966, p. 486.) show more variation. Specimens from both of these occurrences have a definite wedge-shaped flange. Specimen 34666 has a much more highly sinuous junction line and may be lacking the wedge-shaped flange. Unfortunately the flange is difficult to recognize and for this reason identification of the species was questioned.

The actual configuration of the junction line probably is not constant for the species. The varying curvature of the line could readily be a function of the attaching surface. Those specimens with a highly sinuous line have correspondingly highly convex ventral and dorsal walls.

Hemisphaerammina bipatella McClellan, n. sp.
Pl. 35, figs. 5, 6; Pl. 38, figs. 3a,b

Description. — Test attached, monothalmous, dorsal side moderately convex and elliptical, ventral side slightly convex and hemispherical; heavy flange at contact of upper and lower surfaces is wide adjacent to long axis of the dorsal ellipse of the chamber and narrow to absent along short axis giving overall test a circular outline, flange merges gently into chamber surface without suture and is indistinct from ventral portion of chamber; wall thick, medium to finely arenaceous, grains may be arranged in concentric layers; poorly to moderately cemented; no aperture apparent.

Measurements. — Holotype 34668 has chamber length 0.30 mm, width 0.18 mm, total diameter 0.31 mm, height 0.15 mm; flange width 0.05 mm, thickness 0.04 mm. Paratype 34667 chamber length is 0.20 mm, width 0.12 mm, total diameter 0.20 mm, height 0.11 mm; flange width 0.04 mm, thickness 0.03 mm.

Occurrence. — Present only at locality UWA 5990 in the basal beds of the Roberts Mountains Formation.

Discussion. — *Hemisphaerammina bipatella* is most closely related to *H. casteri* McClellan (1966), both species characterized by a broad, thick marginal flange. It is also closely related to *H. coronata* (Ireland, 1939) in showing a tendency to develop the test with concentric layers of sand grains, but the latter species has a much thinner flange. *H. discoidea* (Summerson, 1958) has a biconvex test much like *H. bipatella,* but a narrower flange and more variable shape. All the specimens recovered here closely resemble the holotype though some are less well preserved.

Isolated chambers of the multilocular *Metamorphina imbricata* McClellan (1966) look somewhat similar to *H. bipatella* in their thick, broad flange and moderate convexity. The chamber is hemispherical, the bordering flange shows a constant width around it, and the ventral surface is planar rather than convex. *H. bipatella* cannot be a *Metamorphina* species because that genus is only known to have a planar surface of attachment, is multilocular, and is not known to have wall material arranged in an orderly manner. None of the specimens here show any evidence of multilocularity.

Interpretations of ecology must remain inconclusive until the species has been recognized more widely. It was found as a common constituent of a limited foraminiferal faunule, lacking associated invertebrates. It occurs in an argillaceous, cherty limestone, suggesting a rather quiet bottom habitat with low circulation.

Genus **ATELIKAMARA** McClellan, n. gen.

Type species. — *Atelikamara incomposita* McClellan, n. sp.

Description. — Test attached, inflated dorsally, ventral surface planar to angular; interior incompletely divided into incipient chambers by walls which may be slightly developed to semicomplete; wall thin to thick, composed of poorly sorted sand grains, well cemented; aperture indefinite.

The distinguishing feature of this genus is the incipiently developed chambers, hence the origin of the name: Greek *atelis* = incomplete, *kamara* = chamber. *Storthosphaera* Schulze (1875) resembles *Atelikamara* externally in the irregular shape, but the latter differs in being attached, and, therefore, belongs in the Hemisphaeramminae. The same difference separates this new genus from *Anictosphaera* n. gen. which has incomplete walls dividing the chambers of a free test.

Atelikamara does not have definite chambers like multilocular genera in the same subfamily. In comparison with unilocular genera, none of them has any suggestion of division into chambers. Thus, *Atelikamara* is distinct in its character of the partial test subdivision. The degree to which subdivision takes place is apparently quite variable, as partially developed walls may be present as well as only very slightly developed partitions on the same specimen. Often the partial chambers are separated by a depression in the exterior test wall, such that they present the appearance of nodes on the surface of the test.

Atelikamara incomposita McClellan, n. sp.
Pl. 36, figs. 1-3, 6; Pl. 40, figs. 5a,b

Description. — Test attached, irregular outline, conical to irregularly inflated dorsally, ventral surface usually planar, may be angular; interior subdivisions incomplete to nearly lacking; exterior surface may have nodular appearance with slight depressions corresponding to interior subdivisions; wall thin to thick, basal wall unknown, composed of poorly sorted sand grains, abundant cement; no apparent aperture, scattered pseudopodial openings between grains on dorsal surface.

Measurements. — Dimensions of the type specimens suggest two distinct sizes, but the differences are caused by grain sizes in the wall construction.

Pl. 36	Specimen	Length	Height	Wall
Fig. 1	34658 holotype	0.63mm	0.38mm	0.04mm
Fig. 2	34793 paratype	0.67mm	0.45mm	0.04mm
Fig. 3	34657 paratype	0.34mm	0.15mm	0.015mm
Fig. 6	34659 paratype	0.37mm	0.14mm	0.015mm

Occurrence. — Holotype 34658 and paratype 34793 are from locality UWA 6022 where the species is common. Paratype 34657 is from locality UWA 6004, and paratype 34659 from locality 6007. All localities are in the middle and upper parts of the Roberts Mountains Formation.

Discussion. — The external form of this species is distinctive by its irregularity. In the holotype the lumpy appearance only moderately suggests the internal form. The paratypes have a more globulose surface suggesting corresponding internal partial subdivision but actually have little development of the partial chamber walls. Several unfigured specimens from the type locality lack surface expression of the incipient chamber development inside. The basal surface is completely lacking in every specimen and likely contained no agglutinated material, and, therefore, it has not been preserved. It is apparent from specimen 34793 that the surface of attachment was variable and partially responsible for the form of the entire test. This individual was attached in a narrow crevice, evidenced by the sharp angularity of the base, and was, therefore, restricted in growth to a less spreading habit than specimens attached to a flat surface.

There are two distinct sizes suggested in the measurements of the figured specimens. Other foraminifers from locality UWA 6022 have utilized coarser grains than normal in constructing their tests. The large size and thick wall of *Atelikamara incomposita* specimens at this locality has resulted from use of coarse sand grains in the test wall. Examples from other localities all used finer grains resulting in a thin wall and smaller test size. Since all the foraminifers recovered from locality UWA 6022 have used larger grains than normal, it is clear that the grain size was determined by the coarseness of available material rather than a preference of the organism. For this reason the size differences of *A. incomposita* do not represent two species, because grain size alone, in a primitive foraminifer, is not of specific value.

Atelikamara incomposita occurs commonly only in the uppermost beds representing the argillaceous and cherty limestone lithosome. It occurs rarely in thick-bedded limestones slightly lower stratigraphically. All these occurrences are in the Roberts Mountains Formation where it is approximately uppermost Niagaran age. The argillaceous and cherty limestones suggest a preference by the organism for low energy, quiet water conditions.

Genus **METAMORPHINA** Browne, 1963

1963. *Metamorphina* Browne, *in* Browne and Schott, Bull. Amer. Paleont., vol. 46, No. 209, p. 223.

Type species. — *Webbinella tholus* Moreman (1933, Jour. Paleont., vol. 7, No. 4, p. 395, pl. 47, figs. 8, 10).

Following is the generic diagnosis given by Browne *in* Browne and Schott (1963, p. 223):

> Test attached, plano-convex, varying in outline from circular to oval to linear; often surrounded by a marginal flange; single chambered to multichambered; wall of fine sand grains, smooth to roughly finished with the basal wall thin and frequently missing; aperture not apparent.

This genus is characterized by its thin basal wall and marginal flange. *Hemisphaerammina* differs from *Metamorphina* in being single chambered often having an orderly arranged wall material, and having higher dorsal convexity. The type species *M. tholus* (Moreman) was formerly considered a *Webbinella* until Loeblich and Tappan (1957, p. 224) reevaluated the latter genus (see generic discussion of *Hemisphaerammina*). *Metamorphina* was erected for those arenaceous, multilocular forms of *Webbinella*, subsequently.

Metamorphina tholus (Moreman) **Pl. 35, fig. 13; Pl. 39, fig. 5**

1933. *Webbinella tholus* Moreman, Jour. Paleont., vol. 7, No. 4, p. 395, pl. 47, figs. 8, 10.
1963. *Metamorphina tholsus* (*sic*) (Moreman), Brown and Schott, Bull. Amer. Paleont., vol. 46, No. 209, p. 225, pl. 51, figs. 1-9.

Description. — Test attached, plano-convex with low convexity widening to the basal plane, may have marginal flange; number of chambers variable, closely appressed with rectilinear contact and well-developed suture; wall of fine or poorly sorted sand grains, well-cemented, basal wall thin and often missing; aperture not apparent.

Measurements. — Hypotype 34676 has test length of 0.35 mm and width of 0.22 mm. Chambers are each 0.18 mm long and small, third chamber length is 0.07 mm.

Occurrence. — Rare, only at locality UWA 6010.

Discussion. —*M. tholus* is a common species of the Lower Silurian but has not been reported from younger rocks except in the Mississippian Lodgepole Limestone of Montana (Gutschick, Weiner and Young, 1961, p. 1205). In Nevada it presently is known only at one locality, but further study, especially in the argillaceous limestones in which it most often occurs in other areas, should reveal a more widespread occurrence in this region. The specimen figured here has less well sorted wall material than is customary for the species. In addition, the wall dividing the two chambers does not extend to the base as is normal, (best seen on Pl. 39, fig. 5). An interesting feature of the specimen is the small third chamber which apparently was only partially developed.

Metamorphina gibbosa (Ireland) Pl. 35, fig. 16

1939. *Webbinella gibbosa* Ireland, Jour. Paleont., vol. 13, No. 2, p. 198, figs. B-23, 24.
1963. *Metamorphina gibbosa* (Ireland), Browne and Schott, Bull. Amer. Paleont., vol. 46, No. 209, p. 224, unfigured.
1966. *Metamorphina gibbosa* (Ireland), McClellan, Bull. Amer. Paleont., vol. 50, No. 230, p. 490, pl. 38, figs. 4a, b, 5; pl. 42, figs. 4a, b, 5.

Description. — Test attached, polythalmous, plano-convex, marginal flange narrow, may be incomplete, chambers closely joined with faint suture defining contact plane; wall thin, basal wall very thin and commonly absent, finely arenaceous, well cemented; no aperture apparent.

Measurements. — Hypotype 34675 has test length of 0.44 mm, chambers 0.24 mm, 0.18 mm, and 0.13 mm; test height 0.18 mm.

Occurrence. — Present in rare numbers only at locality UWA 6030 in the lower Roberts Mountains Formation of Wenlockian age.

Discussion. — The diagnostic features of this species are the very narrow marginal flange and faint, slightly depressed, dorsal sutures between chambers. *M. tholus* (Moreman) may also have only a narrow flange, but its sutures are more prominent and depressed. An additional feature, which appears with relative consistency, is the high convexity of *M. gibbosa* compared to other species, such as *M. tholus* and *M. imbricata*.

McClellan (1966, p. 492) considered these three species to represent a phylogenetic lineage with *M. gibbosa* the most primitive and *M. imbricata* the most advanced. The former species has been recorded from the Lower and Middle Silurian of several areas, while the latter is known only from the Middle Silurian of Indiana.

If *M. gibbosa* is more primitive and characteristic of the Lower Silurian, then its stratigraphic position in central Nevada may be significant. The one locality at which it occurs has a foraminiferal faunule quite similar to that found in the Waldron Shale of southeastern Indiana (McClellan, 1966). These comparative faunal elements from the Waldron are species commonly found in Lower Silurian rocks elsewhere. This evidence suggests correlation between the Waldron Shale and basal units of the Roberts Mountains Formation based on the foraminifers. *M. gibbosa* and *Glomospira siluriana* (see discussion of that species) are probably the most diagnostic species.

Genus **WEBBINELLOIDEA** Stewart and Lampe, 1947

1947. *Sorosphaeroidea* Stewart and Lampe, Jour. Paleont., vol. 21, No. 6, p. 534.
1947. *Webbinelloidea* Stewart and Lampe, *ibid.*, pp. 534, 535.

Type species. — *Webbinelloidea similis* Stewart and Lampe, (1947, *ibid.*, p. 535, pl. 78, fig. 8).

Description. — Test attached, multilocular, usually plano-convex, chambers hemispherical, globular, to subangular and usually highly convex; junction of base and sides forms an obtuse angle; wall thick to thin, well cemented, finely to coarsely arenaceous; no apparent aperture.

This genus resembles *Metamorphina* Browne (1963) in general form and habit but lacks the marginal flange and thin basal wall of that genus. Single chambered specimens differ from *Hemisphaerammina* Loeblich and Tappan (1957) on three counts: firstly, many examples of the latter species have a marginal flange like that of *Metamorphina;* secondly, *Webbinelloidea* joins the basal, or ventral, wall to the dorsal with a contact that forms a rounded, bluntly obtuse angle often greater than 90 degrees. A comparable feature on *Hemisphaerammina* forms a sharp, V-shaped angle of not more than 90 degrees. Thirdly, several species of *Hemisphaerammina* have test wall material oriented in a regular, layered manner, while species of *Webbinelloidea* have yet been found to only randomly place grains in the test wall.

Sorosphaeroidea Stewart and Lampe (1947) differs only in the polygonal outline of the chambers. This genus, therefore, differs in traits which seem to be only of specific character. A more detailed discussion has been presented by Conkin and Conkin (1970, p. 4).

The material here recovered and referred to *Webbinelloidea* is so placed in accordance with the generic description of Stewart and Lampe (1947) and Summerson (1958). Recently Conkin and Conkin (1970) have restudied the type material of the former authors plus new material from the Devonian of Ohio. As a result they have revised the genus and emended the description, providing four morphological groups all within the type species *W. similis.* They also have demonstrated that *Webbinelloidea* contains an aperture on the dorsal surface. Hence the genus would properly be in the subfamily Saccammininae. Of the Nevada species, only *W. hemispherica* has been revised by Conkin and Conkin, the others not being included in their study. The material recovered here does not show any evidence of an aperture even under scanning electron microscopy (Pl. 38, figs. 1, 2). Therefore the original generic concept of *Webbinelloidea* is followed here, though it is recognized that more, well-preserved material may necessitate future revision. In view of Conkin and Conkin's discoveries (1970) the entire relationship of *Webbinelloidea, Metamorphina,* and *Hemisphaerammina* should be closely studied for probable phyletic revisions.

Webbinelloidea hattini McClellan Pl. 35, fig. 12

1966. *Webbinelloidea hattini* McClellan, Bull. Amer. Paleont., vol. 50, No. 230, p. 495, pls. 38, 42, figs. 10, 11.

Description. — Test attached, one- or two-chambered forms known, plano-convex with high conical convexity of upper surface, junction of basal surface forms rounded angle, suture between chambers deep, rectilinear; wall thin to thick, fine to coarsely arenaceous, moderately cemented; no apparent aperture.

Measurements. — Hypotype 34713 has diameter of 0.31 mm and height of 0.26 mm.

Occurrence. — The figured specimen is from locality UWA 6025. Also present at locality UWA 6009, which gives a range of upper Wenlock to lower Helderbergian age in Nevada.

Discussion. — The high conical convexity of the dorsal surface is characteristic for the species. Multilocular specimens are further characterized by the deep, rectilinear suture between chambers. *Webbinelloidea similis* Stewart and Lampe (1947) is similarly multilocular but has a less conical form and the chambers are more loosely connected.

Webbinelloidea hemispherica Stewart and Lampe
Pl. 35, figs. 9, 10; Pl. 38, fig. 1

1947. *Webbinelloidea hemispherica* Stewart and Lampe, Jour. Paleont., vol. 21, No. 6, p. 535, pl. 79, figs. 1a, b.

Description. — Test attached, apparently monothalmous, chamber hemispherical and strongly convex, basal edge slightly rounded; wall thick, moderately to coarsely arenaceous, well cemented; no apparent aperture.

Measurements. — Hypotype 34714 has a diameter of 0.21 mm and height of 0.11 mm. Hypotype 34715 diameter is 0.25 mm and height 0.16 mm.

Occurrence. — Hypotype 34714 is from locality UWA 5990 and 34715 from locality UWA 6010, also present at several other localities and stratigraphic horizons.

Discussion. — This species differs from *W. hattini* on its lesser convexity. Stewart and Lampe (1947, p. 535) separated this species from *W. similis* on the basis of its unilocularity, and in the possession of a thicker basal wall and higher convexity. The first character was probably due to an insufficient number of specimens. None of the material studied here shows any definite evidence of being other than single chambered, and, therefore, is all referable to *W. hemispherica. W. similis* presently is only known from the Middle Devonian of Ohio, whereas *W. hemispherica* is known at horizons ranging from Middle Silurian to Middle Devonian. *W. hemispherica* specimens recognized here do not compare adequately with those of Conkin and Conkin (1970) to be similarly considered a *W. similis* as revised by them.

Webbinelloidea aff. **W. nodosa** Summerson
Pl. 35, figs. 11, 15; Pl. 38, fig. 2

1958. *Webbinelloidea nodosa* Summerson, Jour. Paleont., vol. 32, No. 3, p. 555, pl. 82, fig. 12.

Description. — Test attached, apparently monothalmous, square outline, ventral surface planar, dorsal surface highly convex with vertical sides; upper surface divided into subequal quadrants by rectilinear sutures and each quadrant is convex forming a node;

junction between dorsal and ventral surfaces forms rounded right angle; wall thin to medium, composed of sand grains, well cemented; no apparent aperture.

Measurements. — Figured specimen 34716 has length of 0.26 mm, nodes 0.13-0.14 mm, height 0.19 mm, wall thickness 0.015 mm. Specimen 34717 has length 0.30 mm, nodes of 0.15 mm, height of 0.22 mm, and wall thickness 0.01 mm.

Occurrence. — Specimen 34716 from locality UWA 6018; 34717 from locality UWA 6010, both rare in occurrence.

Discussion. — Summerson (1958 p. 555) characterized *Webbinelloidea nodosa* by its two rows of nodes on the upper surface and its rectangular outline. He further described the species to be roughly hemispherical in section, and to have a slight peripheral lip where the basal surface joins the upper. The Nevada specimens are more nearly rectangular in section, the sides being vertical, however, they possess the nodes and similar outline. They also differ in the junction of the upper and lower surfaces, appearing as a rounded angle instead of a peripheral lip. Because of the several similar features, as well as the obvious differences also present, the material herein is deemed to have affinities for *W. nodosa.* Criteria for erecting a new species are considered insufficient, though perhaps these specimens, in view of the generic revision of *Webbinelloidea* by Conkin and Conkin (1970), should be considered a species of *Atelikamara,* n. gen. There is a similarity in development of incipient chambers and no apparent apertures.

Webbinelloidea ventriquetra McClellan Pl. 35, fig. 14

1966. *Webbinelloidea ventriquetra* McClellan, Bull. Amer. Paleont., vol. 50, No. 230, p. 496, pls. 38, 42, figs. 6, 7a, b.

Description. — Test attached, bilocular, high dorsal convexity, ventral surface formed by two planar surfaces separated by an acute angle which bisects the longitudinal axis of the test; chambers closely joined with a rectilinear boundary and deep dorsal suture; wall of medium thickness, finely arenaceous, moderate amount of cement; no aperture apparent.

Measurements. — Specimen 34718 has an overall length of 0.56 mm, individual chambers are 0.30 mm and 0.26 mm, and height is 0.31 mm.

Occurrence. — Rare, present only at locality UWA 6024 in the Roberts Mountains Formation.

Discussion. — This species bears a much sharper angle at the junction of the dorsal and ventral walls than is characteristic for the genus. In this respect it is more like species of *Hemisphaerammina,* but that genus is restricted to unilocular forms. The only other species of *Webbinelloidea* which does not have a planar basal surface of attachment is *W. globulosa* McClellan (1966) which has a concave ventral wall. Such a configuration suggests a more exposed living position for the animal in contrast to *W. ventriquetra,* whose test is probably indicative of habitation in protected places, such as in a crack or small crevice.

Family **AMMODISCIDAE** Reuss, 1862

Subfamily **AMMODISCINAE** Reuss, 1862

Genus **GLOMOSPIRA** Rzehak, 1885

1860. *Trochammina* [in part] Jones and Parker, Quart. Jour., Geol. Soc. London, vol. 16, p. 304.
1885. *Glomospira* Rzehak, Naturforsch. Vereins Brünn, Verhandl., vol. 23 (1884), p. 126.

Type species. — *Trochammina gordialis* Jones and Parker, (1860, *ibid.,* p. 304).

Following is Cushman's (1959, p. 96) redescription of the genus.

> Test free, with a proloculum and long, tubular, undivided, second chamber winding about its earlier coils in various coils in various planes; wall arenaceous with much cement; aperture at end of the tube.

This genus frequently occurs in Lower Silurian rocks, but is poorly known from Middle Silurian through Devonian time.

Glomospira siluriana Ireland Pl. 36, fig. 5

1939. *Glomospira siluriana* Ireland, Jour. Paleont., vol. 13, No. 2, p. 201, figs. B-27, 28.

Description. — Test free, proloculus followed by tubular second chamber coiled in varying planes around it with four or five revolutions, tube inflated; wall thin, finely arenaceous, well cemented; aperture at end of tube which is slightly uncoiled.

Measurements. — Specimen 34661 has minimum diameter of 0.37 mm and maximum diameter 0.53 mm.

Occurrence. — This species is rare; present only at locality UWA 6030 in the basal beds of the Roberts Mountains Formation.

Discussion. — *Glomospira siluriana* is a common species in Lower Silurian rocks from other regions. Its occurrence in the basal Roberts Mountains Formation of Nevada is the youngest yet recorded. In combination with *Metamorphina gibbosa,* it may be useful in correlating the lowest Roberts Mountains beds with Middle Silurian rocks of Indiana. Further discussion of its stratigraphic implications is presented in the section on biostratigraphy.

Subfamily **TOLYPAMMININAE** Cushman, 1928

Genus **TOLYPAMMINA** Rhumbler, 1895

1879. *Hyperammina* [in part] Brady, Quart. Jour. Micr. Sci., new ser., vol. 19, pt. 1, p. 33.

1895. *Tolypammina* Rhumbler, Kongl. Gesell. Wiss. Göttingen, Nachr, p. 83.

Type species. — *Hyperammina vagan* Brady (1879, *ibid.,* p. 33, pl. 24, figs. 1-5).

The generic redescription of Cushman (1959, p. 98) is as follows:

> Test attached, with proloculus and long, tubular, undivided, second chamber, earliest portion sometimes coiled, later irregular; wall arenaceous with much cement; aperture at the end of the tube.

Lituotuba Rhumbler (1895) has a similar habit of irregular growth in the second chamber. In comparing these two genera Loeblich and Tappan (1964, p. 213) considered that Tolypammina "differs from *Lituotuba* in lacking the early streptospiral coil."

Tolypammina tortuosa Dunn Pl. 36, fig. 4

1942. *Tolypammina tortuosa* Dunn, Jour. Paleont., vol. 16, No. 3, p. 341, p. 44, figs. 19-21, 32.

Description. — Test attached, proloculus spherical, followed by long tubular second chamber which commonly coils around proloculus in early stages, later portion irregularly winding; wall thin, finely arenaceous, well cemented; aperture at end of tubular second chamber.

Measurements. — Hypotype 34712 tube diameter is 0.18 mm.

Occurrence. — This species is rare and present only at locality UWA 6018 in rocks of lower Helderbergian age.

Discussion. — This is a well-known species in Lower Silurian rocks and has also been widely reported from the Lower Mississippian. While its occurrence in Nevada is Devonian and fills a gap in the record, it is rare and only present locally.

Conkin (1961, p. 305) considered all species of *Tolypammina*, including *T. tortuosa*, which occur in Lower Mississippian rocks, to be characteristic in shallow, warm, near shore, calcium rich sediments. He found that often the genus is common in environments which lack other organisms. *T. tortuosa* occurs here in the fine-grained basal beds of the McColley Canyon Limestone as part of a large microfauna. These limestone beds immediately overlie massive reef units of the Lone Mountain Dolomite. They indicate shallow, warm, alkaline conditions during deposition, which should have been quite favorable to species of *Tolypammina*.

Superfamily **LITUOLACEA** de Blainville, 1825

Family **HORMOSINIDAE** Haeckel, 1894

Subfamily **ASCHEMONELLINAE** Eimer and Fickert, 1899

Genus **ASCHEMONELLA** Brady, 1879

1879. *Aschemonella* Brady, Quart. Jour. Micr. Sci., new ser., vol. 19, pt. 1, p. 44.

Type species. — *Aschemonella scabra* Brady (1879, *ibid.*, p. 44, pl. 27, figs. 1, 2, 4-11).

Loeblich and Tappan (1964, p. 214) redescribed the genus as given below:

> Test free, consisting of tubular or inflated chambers in single or commonly branching series; wall thin, finely to coarsely agglutinated, firmly cemented; apertures several, rounded, at ends of tubular necks.

Described species of this genus are known from the Cretaceous to Recent. Cushman (1959, p. 90) mentioned that somewhat similar, partially divided, tubular forms are known as far back as the Silurian, but he did not document his statement. The only Paleozoic occurrence, of which the writer is aware, is that listed by Hattin (1960, p. 2016) from the Middle Silurian Waldron Shale in southeastern Indiana.

Aschemonella bastillensis McClellan, n. sp. Pl. 36, fig. 8

Description. — Test free, with tubular chambers inflated on apertural side, constricting ring divides chambers from tubes which connect them, tubes slightly expanding in direction of chamber addition; wall thin, finely arenaceous, well cemented; apertures round and single for each chamber, at end of short neck on inflated side of chamber.

Measurements. — Holotype 34656 has the following dimensions: maximum chamber diameter 0.11 mm, connecting tube minimum diameter 0.04 mm and maximum indeterminate (distorted), length of apertural neck 0.04 mm, and aperture diameter 0.055 mm.

Occurrence. — Rare, present only at locality UWA 5982 in the Bastille Limestone of Wenlockian age.

Discussion. — The presence of this genus in the Silurian is the first occurrence of the superfamily Lituolacea, indicating considerable evolutionary development of Foraminifera early in their history. The reported occurrence of the genus in the Waldron Shale (Hattin, 1960, p. 2016) appears correlative with that in the Bastille Limestone, and substantiates other biostratigraphic evidence of the probable age equivalence of these two units.

The lower beds of the Bastille Limestone, from which *Aschemonella bastillensis* was recovered, are a thick-bedded, coarse-grained, biosparite. Residues obtained from samples treated with dilute hydrochloric acid contained abundant crinoidal fragments and common well sorted and rounded, frosted, medium-sized quartz grains. These components suggest the sediment was deposited under conditions of relatively high energy.

Family **LITUOLIDAE** de Blainville, 1825

Subfamily **HAPLOPHRAGMOIDINAE** Maync, 1952

Genus **HAPLOPHRAGMOIDES** Cushman, 1910

1910. *Haplophragmoides* Cushman, U.S. Nat. Mus., Bull. 71, pt. 1, p. 99.

Type species. — *Nonionina canariensis* d'Orbigny (1839, *in* Barker-Webb and Berthelot, Hist. Nat. Iles Canaries, vol. 2, pt. 2, p. 128, pl. 2, figs. 33, 34).

Following is the redescription of Cushman (1959, p. 102):

> Test free, planispiral, of several coils, usually not completely involute; chambers simple; wall single, arenaceous or with sponge spicules, firmly cemented, amount of cement varying greatly in different species; aperture simple, at the base of apertural face of the chamber.

This well-known and common genus is here reported for the first time from strata older than Carboniferous, in beds of lowest Devonian age.

Haplophragmoides antiquus McClellan, n. sp. Pl. 37, figs. 1-2

Description. — Test free, planispiral and involutely coiled, seven chambers in last whorl; chambers slightly inflated, narrowly arcuate in section; sutures radiate and partially indistinct; prominent, broad, umbilical plug present; wall finely arenaceous, grains aligned along trace of sutures, moderately cemented; aperture a thin interiomarginal slit, small accessory apertures near basal-lateral surface of chambers in last whorl.

Measurements. — Maximum diameter of holotype 34792 is 0.31 mm and axial diameter is 0.11 mm.

Occurrence. — Rare, only found at locality UWA 6010 in the Rabbit Hill Formation of lowest Helderbergian age.

Discussion. — The two most distinctive features of *Haplophragmoides antiquus* are the broad umbilical plug and pinpoint accessory apertures. The latter are only recognizable on electron micrographs. The presence of these apertures has not previously been noted on any known species of *Haplophragmoides.* There is the possibility that *H. antiquus* is generically distinct, but until the type species of *Haplophragmoides* is studied by electron microscopy for presence of similar apertures, such distinction cannot be made. Other characters of the species appear to be rather conservative when compared to the various complexities which have been added in many of the other species of the genus (*i.e.* the strongly lobate chambers of *H. canariensis*). This new species compares most nearly to *H. pusillum* Höglund (1947) from the Recent. The latter species has similar sutures and manner of growth but lacks the umbilical plug and is more robust.

Suborder **FUSULININA** Wedekind, 1937

Superfamily **ENDOTHYRACEA** Brady, 1884

Family **ENDOTHYRIDAE** Brady, 1884

Subfamily **LOEBLICHIINAE** Cummings, 1955

Genus **NANICELLA** Henbest, 1935

1935. *Nanicella* Henbest, Washington Acad. Sci., Jour., vol. 25, p. 34.

Type species. — *Endothyra gallowayi* Thomas (1931, Jour. Paleont., vol. 5, No. 1, p. 40, pl. 7).

Description. — Test free, planispirally coiled, mostly evolute, numerous low chambers; wall finely granular calcareous, two layers which may be similar or the outer one darker and thinner; aperture interiomarginal equatorial slit.

Thomas (1931, p. 40) originally defined the type species as belonging to the genus *Endothyra* Phillips (1846). Henbest (1935, p. 34) considered the species to be generically different from other *Endothyra* species. His considerations were based on the less inflated chambers, more regular coiling, and the distinct boundary between the spiral and septal walls possessed by the *E. gallowayi*, which he then placed as the type species for *Nanicella.*

This genus has been previously recorded from rocks no older than Devonian in Iowa and the USSR. Its presence in Nevada extends its range to very earliest Devonian time (lower Helderberg).

Nanicella dainae? Chernysheva Pl. 36, figs. 9, 10

1940. *Nanicella dainae* Chernysheva, Soc. Nat. Moscow Bull., new ser., tome 48 (Sect. geol. tome 18), No. 5-6, p. 127.

Description. — Test free, discoid, planispirally coiled, evolute, laterally compressed; chambers slightly inflated, almost of equal height in each whorl, number 12-14 in last whorl; sutures irregularly radial, shallow; wall finely granular, two layers unrecognizable; aperture interiomarginal slit.

Measurements. — Diameter of 34677 is 0.70 mm and thickness 0.18 mm. Specimen 34678 has a diameter of 0.52 mm and thickness 0.15 mm.

Occurrence. — The figured specimens were found at locality UWA 6013 in the upper Roberts Mountains Formation of lowest Helderbergian age. Also present at locality UWA 5973 in the Rabbit Hill Formation, slightly younger in age.

Discussion. — The specimens studied here possess all the features of *Nanicella dainae,* with the possible exception of the narrow, irregularly radial sutures. Preservation is inadequate to positively recognize the sutures, hence the questioned identification. Comparisons with other *Nanicella* species shows *N. dainae* to be most closely related to the type *N. gallowayi.* Chernysheva (1940, p. 127) considered *N. dainae* to have a somewhat more robust test with a rounded, rather than acute, periphery, and less distinct sutures. In addition, the chambers of *N. gallowayi* are more rapidly expanding in each whorl and have a much greater height.

Nanicella dainae has previously been recorded only from Lower Carboniferous (lower Visean) rocks in the southern Ural Mountains of the USSR.

Subclass **OSTRACODA** Latreille, 1806

Order **PALAEOCOPIDA,** Henningsmoen, 1953

Suborder **BEYRICHICOPINA** Scott, 1961

Superfamily **BEYRICHIACEA** Matthew, 1886

Family **BEYRICHIIDAE** Matthew, 1886

Genus **BOLBIPRIMITIA** Kay, 1940

Type species. — *Halliella fissurella* Ulrich and Bassler, 1923.

Bolbiprimitia teresaccula Swartz and Whitmore Pl. 41, figs. 1-3

1956. *Bolbiprimitia teresaccula* Swartz and Whitmore, Jour. Paleont., vol. 30, No. 5, p. 1082, pl. 104, fig. 18.

Description. — Carapace subovate; straight hinge extending for nine-tenths of entire length; anterior cardinal angle obtuse, posterior a right, or slightly acute angle; valve strongly convex, anterior margin broadly rounded; flattened border extends along margins, with velate ridge in male valves; S_2 forms a small rounded depression slightly anterior of midpoint.

Measurements. — Figured specimens, all male valves, have the following dimensions:

Pl. IX	Spec. Number	Length	Height
Fig. 1	34731	1.04mm	0.67mm
Fig. 2	34732	0.64mm	0.44mm
Fig. 3	34733	0.72mm	0.52mm

Occurrence. — The hypotypes were all found at locality UWA 5974; also present at locality UWA 5975. Both occurrences are in the upper Roberts Mountains Formation.

Discussion. — The original type for this species is a female valve. All the specimens found here are male valves, which compare closely in all characters of the shell, and in addition have a velate ridge. The elongate dimorphic pouch occupies the position of the velgate ridge in female valves. The small rounded S_2 on these specimens is distinctive from the elongate cleft of *Bolbiprimitia limbata.* Otherwise the species is similar.

B. teresaccula has previously been known from the Manlius Limestone of uppermost Silurian age in New York. Its presence in the upper beds of the Roberts Mountains Formation in central Nevada, appears to represent approximately the same stratigraphic position.

Genus **KLOEDENIA** Jones and Holl, 1886

Type species. — *Beyrichia wilckensiana* Jones, 1855.

Kloedenia aparchoides Swartz and Whitmore Pl. 41, fig. 7

1956. *Kloedenia aparchoides* Swartz and Whitmore, Jour. Paleont., vol. 30, No. 5, p. 1067, pl. 103, figs. 11-14.

Description. — Carapace subovate, dorsally truncated, anterior cardinal angle obtuse, posterior nearly a right angle; hinge line long, straight; convex anterior margin; valve moderately convex, slightly trilobate; S_2 slightly posterior to middle, S_1 halfway from S_2 to margin; flattened border along margin.

Measurements. — Specimen 34744, not mature, has a length of 0.70 mm and height of 0.42 mm.

Occurrence. — Present only at locality UWA 6024 in the Roberts Mountains Formation.

Discussion. — This rarely occurring species is represented here by an immature individual which does not have the border as well developed as in the types of Swartz and Whitmore (1956). In addition, the lobation and sulci are barely recognizable, which is also probably due to the immaturity of the specimen.

Genus **MYOMPHALUS** Swartz and Whitmore, 1956

Type species. — *Myomphalus dorsinodus* Swartz and Whitmore, 1956.

Myomphalus ? sp. Pl. 41, fig. 13

Description. — Carapace nearly subrectangular, only slightly ovoid and dorsally truncated; hinge straight, three-quarters of length of shell, cardinal angles obtuse; shell moderately convex, S_1 and S_2 shallow, elongate, poorly developed; exterior and posterior margins convex, marginal border distinct and narrow.

Measurements. — The figured specimen has a length of 0.74 mm and height of 0.44 mm.

Occurrence. — Specimen 34750 is from locality UWA 5981 in the lower Wenban Limestone. Also present in the McMonnigal Limestone at locality UWA 5994. Both formations are of Helderbergian age.

Discussion. — The genus *Myomphalus* is described as being subovoid, with a weak S_2 and bordering rounded knobs. On the specimens found here, the median sulcus is bordered by two raised areas, but there is also an indication of an elongate S_1. The shell outline varies from the characteristic subovoid form, being nearly rectangular with convex anterior and posterior margins. The shell outline may appear subrectangular because of an elongate dimorphic pouch which is ill-defined. The material recovered here is insufficient and not adequately preserved to be specifically identified, or even definitely recognized as belonging to the genus *Myomphalus.*

Genus **PHLYCTISCAPHA** Kesling, 1953

Type species. — *Phlyctiscapha rockportensis* Kesling, 1953.

Phlyctiscapha keslingi Copeland Pl. 41, figs. 5, 6

1962. *Phylctiscapha keslingi* Copeland, Geol. Sur. Canada, Bull. 91, p. 36, pl. IX, figs. 20-24.

Description. — Carapace subovate, dorsally truncate; hinge straight, about two-thirds total length, dorsal corners rounded, cardinal angles obtuse; shell strongly convex, greatest width in female is median and in male is posteromedian; anterior and posterior margins convex, entire margin and narrow border separated from lateral shell surface by a furrow; left valve overlaps right valve, especially along ventral margin.

Measurements. — The length of 34756 is 0.68 mm and height 0.38 mm. Specimen 34757 has length 0.56 mm and height 0.44 mm.

Occurrence. — The figured hypotypes are from locality UWA 5985 in the Lower Devonian McMonnigal Limestone, where the species is abundant. It has been found widely distributed throughout the area in rocks no older than upper Ludlow in age.

Discussion. — One of the most abundant ostracode species in central Nevada, *Phlyctiscapha keslingi* is restricted to rocks of latest Silurian and early Devonian age. In every case it occurs in fore-reef carbonates or calcareous shales. The figured specimens appear to be representative adults in size but are less than one-half the size of Copeland's types. Perhaps the Nevada specimens are dwarfed, though their abundance would suggest that they were quite satisfied in the environment represented here. If they are not dwarfs, then Copeland's specimens may be abnormally large individuals.

Phlyctiscapha sp. Pl. 41, fig. 4

Description. — Carapace elongate subovoid, dorsally truncate; hinge straight, about two-thirds total length, dorsal corners rounded, cardinal angles obtuse; shell strongly convex, greatest width is median; anterior and posterior margins strongly convex, entire margin with narrow border separated from lateral surface of valve by shallow furrow.

Measurements. — Figured specimen 34758, a female valve, has a length of 0.41 mm and height 0.27 mm.

Occurrence. — Specimen 34758 is from locality UWA 5991 in the lower McColley Canyon Formation which is Helderbergian in age. Also present in the Roberts Mountains Formation at locality UWA 6024.

Discussion. — This form is quite similar to *P. keslingi* in most of its characteristics. It differs in being more elongate in outline and has a more broadly convex posterior margin. A further consideration is the occurrence. *Phlyctiscapha* sp. was found in dolomite and argillaceous, cherty limestone samples, which represent much different environments than the fore-reef carbonates and calcareous shales in which *P. keslingi* was found.

Genus **SACCARCHITES** Swartz and Whitmore, 1956

Type species. — *Saccarchites saccularis* Swartz and Whitmore, 1956.

Saccarchites saccularis Swartz and Whitmore Pl. 41, fig. 12

1956. *Saccarchites saccularis* Swartz and Whitmore, Jour. Paleont., vol. 30, No. 5, p. 1080, pl. 103, figs. 18, 19.

Description. — Carapace subovate in outline, truncate dorsally; hinge straight, about four-fifths of length, cardinal angles obtuse and subequal; shell moderately convex, greatest width is median; anterior margin more convex than posterior, narrow submarginal border at both ends but lacking on ventral margin.

Measurements. — Length is 0.37 mm and height 0.26 mm on specimen 34772.

Occurrence. — Rare; at locality UWA 6026 in the Roberts Mountains Formation.

Discussion. — The specimen figured here appears to be an immature instar in which the lobation and sulcus are not recognizable. Adult specimens from the uppermost Silurian Manlius Limestone of New York are about five times larger (Swartz and Whitmore, 1956, p. 1080). The Manlius examples also are somewhat younger than those of central Nevada, which are still within the Upper Silurian.

Genus **VELIBEYRICHIA** Henningsmoen, 1954

Type species. — *Beyrichia moodeyi* Ulrich and Bassler, 1908.

Velibeyrichia? sp. Pl. 41, fig. 10

Description. — Carapace subovoid, elongate; hinge straight, nearly equal to shell length, cardinal angles both near right angles; margins of valve with well-developed, striated frill, which is at a sharp angle to the plane of contact between valves; greatest width is apparently slightly postero-median, median sulcus is a shallow groove extending to midpoint of height, poorly developed lobes border this sulcus.

Measurements. — Figured specimen 34785 has a length of 0.93 mm and indeterminate height about ½ of length.

Occurrence. — Present only at locality UWA 5985 in the McMonnigal Limestone.

Discussion. — All the specimens recovered here are poorly preserved and none adequately exhibit all the features of the genus. The lobation is less distinct than normal for the genus, but the frill is usually mostly preserved and the general shape is that of *Velibeyrichia.* The figured specimen appears to be a male left valve with only the anterior portion of the frill preserved.

Genus **WELLERIOPSIS** Swartz and Whitmore, 1956

Type species. — *Welleriopsis diplocystulis* Swartz and Whitmore, 1956.

Welleriopsis jerseyensis (Weller) Pl. 41, figs. 8, 9

1903. *Beyrichia jerseyensis* Weller, Geol. Sur. New Jersey, vol. 3, p. 255, pl. 23, fig. 5.

1956. *Welleriopsis jerseyensis* (Weller), Swartz and Whitmore, Jour. Paleont., vol. 30, No. 5, p. 1075, pl. 105, figs. 14-16.

Description. — Carapace subovate, dorsally truncated by straight hinge line for three-fourths of length; anterior cardinal angle bluntly obtuse, posterior angle more sharply obtuse; anterior margin convex with greatest point anteroventral, posterior margin straight in upper part, curving gently into ventral margin, low marginal ridge is most prominently developed anteriorly; lateral surface moderately convex, median sulcus as narrow moderately deep furrow extending from hinge to two-thirds the distance to margin, L_2 well developed, broad, L_3 slightly produced dorsally.

Measurements. — Specimen 34786 length is 0.74 mm and height 0.48 mm; 34787 measures 0.67 mm and 0.41 mm.

Occurrence. — Uncommon, found only in locality UWA 5973 in the Rabbit Hill Formation.

Discussion. — The two specimens figured here appear to be immature and do not have the marginal ridge well developed ventrally. The occurrence of this species in Nevada is in strata of Helderbergian age, younger than the uppermost Silurian occurrence recorded to date in eastern North America.

Beyrichiidae ? genus Pl. 41, fig. 16

Description. — Carapace broadly oval in outline, dorsally truncated; hinge gently concave dorsally, two-thirds of length; cardinal angles obtuse, anterior one more bluntly so; anterior margin moderately convex, posterior slightly convex, maximum height from mid-ventral point, narrow marginal border bounded by small furrow; surface strongly convex, abundant small spines and few large spines, S_2 a long, deep furrow slightly anterior of midpoint and reaching three-fourths of height toward ventral margin, S_3 shallow, curving around posterior of prominent median L_2, L_1 is broad, less prominent; dimorphic pouch enlarged anteroventrally, merging dorsally with L_1 extends ventrally to point directly below L_2.

Measurements. — Length of 34789 is 0.30 mm and height 0.75 mm.

Occurrence. — Rarely present at locality UWA 6024 in the middle Roberts Mountains Formation.

Discussion. — The lobation and dimorphic pouch suggest that this form belongs in the Beyrichiidae. The figured specimen, to which the description refers, is believed to be a female right valve. Another specimen, which has been broken, apparently lacks the anteroventral dimorphic pouch and is probably a male. The two specimens are not sufficiently well preserved to compare closely with any particular beyrichiid genera, and may represent a new genus.

Superfamily **DREPANELLACEA** Ulrich and Bassler, 1923

Family **AECHMINIDAE** Boucek, 1936

Genus **AECHMINA** Jones and Holl, 1869

Type species. — *Aechmina cuspidata* Jones and Holl, 1869.

Aechmina equilateralis Bassler Pl. 41, figs. 18, 19

1941. *Aechmina equilateralis* Bassler, Washington Acad. Sci., Jour., vol. 31, No. 1, p. 24, fig. 14.

Description. —Carapace nearly equilateral, greatest height one-third of length from anterior; hinge straight, long; cardinal angles equally obtuse; anterior and posterior margins convex, anterior slightly more so, ventral margin has maximum convexity in anteroventral area, entire margin denticulate; lateral surface greatest convexity anteroventral, stout mid-dorsal spine with broad base is directed slightly posteriorly.

Measurements. — Specimen 34721 has a length of 0.69 mm and height 0.37 mm. Specimen 34722 length is 0.74 mm and height 0.44 mm.

Occurrence. — This is a commonly occurring species at locality UWA 5973 in the Rabbit Hill Formation. Fragments found at locality UWA 6024 have questionably been referred to this species.

Discussion. — No mention was made by Bassler (1941, p. 24) of dimorphism in this species. The figured hypotype 34772 appears slightly more enlarged in the anteroventral region of the valve, thereby distorting the equilateral outline. This enlargement may possibly be the representation of a dimorphic pouch.

Aechmina longior Bassler Pl. 41, fig. 14

1941. *Aechmina longior* Bassler, Washington Acad. Sci., Jour., vol. 31, No. 1, p. 24, fig. 13.

Description. — Carapace subequilateral, greatest height at midpoint; hinge straight, long, cardinal angles equally bluntly obtuse; anterior and posterior margins convex, entire margin denticulate; lateral surface has greatest convexity slightly anterior of midpoint, mid-dorsal spine is very long, slender, directed posteriorly.

Measurements. — Dimensions of hypotype 34723 are length 0.59 mm and height 0.35 mm.

Occurrence. — Present in the Rabbit Hill Formation only at locality UWA 5973.

Discussion. — This species is similar to *Aechmina equilateralis* except for the dorsal spine. *A. longior* is distinguished by the very long and slender dorsal spine, which is quite distinct from that of *A. equilateralis.* Both species are present at the same locality; the latter occurring in greater numbers.

Aechmina aff. **A. phantastica** Kesling Pl. 41, fig. 17

1953. *Aechmina phantastica* Kesling, Mich. Univ., Mus. Paleont. Contr., vol. 11, p. 3, pl. 1, figs. 1-5.

Description. — Carapace subrectangular, dorsally truncate; hinge straight, about three-fourths of length; cardinal angles obtuse, subequal, posterior margins moderately convex, ventral margin slightly convex; dorsally directed, slender curved spines at point of cardinal angles; lateral surface moderately convex, broad based, stout, mid-dorsal spine directed perpendicular to commissure plane and slightly posteriorly, and spine is bluntly terminated.

Measurements. — Length of specimen 34724 is 0.71 mm and height is 0.50 mm.

Occurrence. — Rare, present only at locality UWA 5973 in the Rabbit Hill Formation.

Discussion. — The form and position of the prominent mid-dorsal spine on this specimen is identical to that of *Aechmina phantastica.* Overall dimensions are also quite similar. This form differs in possessing long, slender, curved spines arising from the ends of the hinge line. It also has a less semicircular outline, greater width, and the major spine is not granuloreticulate as in *A. phantastica.* The extra dorsal spines (posterior one is broken at base) are the most significant characteristics of this form. Coupled with the other differences from *A. phantastica,* it probably represents a separate, new species, but the single ?LV found here is believed to be insufficient for establishment of a species.

Aechmina cortezensis McClellan, n. sp. Pl. 41, figs. 11, 15

Description. — Carapace ovoid to subellipsoidal, partially truncated dorsally; hinge straight, about two-thirds length, gradually merging with margin at ends; anterior and posterior cardinal angles subequal, broadly obtuse; anterior margin and posterior are equally stongly convex, ventral margin moderately convex; lateral surface moderately convex with greatest width median to slightly anteromedian; dorsal median spine broad based, long, directed outward at angle of 40-60 degrees from commissure plane, distal half may curve slightly posteriorly.

Measurements. — Holotype 34725 has length of 0.57 mm, height 0.30 mm, and length of spine 0.41 mm. Paratype 34726, a RV, has length 0.55 mm and height 0.29 mm.

Occurrence. — The type specimens are present at locality UWA 5980 in the lower Wenban Limestone.

Discussion. — *Aechmina cortezensis* is most similar to *A. longior* Bassler (1941) which is present in probable correlative beds of the Rabbit Hill Formation. The dorsal median spine and shell size of *A. cortezensis* are similar to *A. longior.* This species differs, however, in having more strongly convex anterior and posterior margins, broader cardinal angles, shorter hinge line, and lacks the denticles on the margin.

There is some variability in the shape of the valves in this new species, the most typical being subellipsoidal, but they may also be nearly ovate. In addition there is an indication of lateral swelling in the anteroventral area, as on figured specimen 34726, that may be distortion or possibly indicate a dimorphic pouch.

Family **BOLLIIDAE** Boucek, 1936

Genus **ULRICHIA** Jones, 1890

Type species. — *Ulrichia conradi* Jones, 1890.

Ulrichia obesita McClellan, n. sp. Pl. 42, figs. 1-3

Description. — Carapace subrectangular to ovoid; hinge long, straight; cardinal angles obtuse, subequal; anterior and posterior margins equally convex, marginal rim distinct, forming sharply defined, narrow shelf; lateral surface strongly convex, finely reticulate in concentric pattern in adult, marginal rim more coarsely reticulate; anterior dorsomedian node round, posterior node forms narrow, strongly developed ridge with dorsal end more posterior than ventral end, S_2 forms a narrow short, deep groove between nodes.

Measurements. — Dimensions of the figured specimens are as follows:

Pl. 42	Spec. Number	Length	Height
Fig. 1	34780 holotype	0.67mm	0.43mm
Fig. 2	34782 paratype	0.44mm	0.30mm
Fig. 3	34783 paratype	0.37mm	0.26mm

Occurrence. — The type specimens were present at locality UWA 5985 in the McMonnigal Limestone. Also present at locality UWA 5986 in the same area and formation.

Discussion. — This species differs from others within the genus in the shape of the dorsomedian nodes, the posterior one being a ridge rather than the characteristic subcircular form. It is also much more highly convex laterally, than is customary for species of *Ulrichia.* The reticulate surface pattern is recognizable only on adult forms, such as the holotype. The reticulation continues, more coarsely, on the narrow, marginal rim, which is not the usual pattern for the genus.

Ulrichia sp. Pl. 42, figs. 4, 7

Description. — Carapace subrectangular, truncate dorsally; hinge long and straight; cardinal angles subequal; margin convex, narrow, well-defined rim; lateral surface moderately elongated, sharply defined, posterior node smaller, subcircular, S_2 shallow, broad, extending down to midpoint.

Measurements. — Specimen 34783 length is 0.92 mm and height 0.61 mm. Dimensions of 34784 are 0.78 mm and 0.48 mm.

Occurrence. — Present only at locality UWA 5973 in the Rabbit Hill Formation.

Discussion. — This form differs from *Ulrichia spinosa* in the shape of the nodes but otherwise has many similarities. It also resembles *U. acricula* in the position and form of the nodes. However, the marginal rim is narrower and the shell is more robust than the lowly convex shell of *U. acricula.*

Bolliidae ? genus Pl. 43, figs. 16, 17

Description. — Carapace subquadrate, dorsally truncated; hinge long, straight, nine-tenths of length; cardinal angles equal, obtuse, nearly right angles; anterior margin gently convex, posterior slightly convex, marginal rim very narrow and sharply defined; lateral surface strongly convex, greatest width at midpoint; anterior node slightly elongate, sharply elevated, positioned just anterior of midpoint; posterior node forms linear, prominent, knifelike ridge beginning at dorsal margin and merging posteroventral of midpoint into a lower, well-defined ridge that curves ventrally around anterior node and continues up and around until terminating at dorsal margin directly above anterior node; S_1 forms shallow, arcuate depression between anterior median node and curving ridge, S_2 is deep, linear groove slightly posterior of midpoint.

Measurements. — The length of 34734 is 0.38 mm and height 0.29 mm. Specimen 34735 has been broken but dimensions are approximately 0.45 mm and 0.35 mm.

Occurrence. — The figured specimens are from locality UWA 5985. Also present at UWA 5994 and UWA 5975 in strata of latest Silurian to early Devonian age.

Discussion. — This form has affinities for both *Ulrichia* Jones (1890) and *Bollia* Jones and Holl (1886). The separate anterior dorsomedian node is similar to that of *Ulrichia.* The posterior node and ventral ridge extending from it are suggestive of *Bollia.* The ridge in *Bollia* connects with an anterior lobe, whereas the ventral ridge on this form extends instead in an arcuate line around the anterior node to the dorsal margin. This last feature is distinctive from other bolliids, thus a generic placement cannot be made. There is neither sufficient, nor adequately preserved material to be described.

Superfamily **HOLLINACEA** Swartz, 1936

Family **HOLLINIDAE** Swartz, 1936

Genus **HOLLINELLA** Coryell, 1928

Type species. — *Hollinella dentata* Coryell, 1928.

Hollinella sp. Pl. 42, fig. 6

Description. — Carapace ovoid, truncated dorsally; hinge line long, straight; cardinal angles obtuse, anterior more broadly so; anterior margin strongly convex, posterior tapers smoothly into ventral margin, well developed, broad striate frill extends along entire margin; lateral surface strongly convex, L_2 well developed, rounded node, L_3 low, broad, and indistinct; median sulcus between lobes is shallow, short, extending only in curving pattern along posterior side of L_2.

Measurements. — Dimensions of 34743 are length 0.76 mm, height 0.51 mm and width of frill 0.15 mm.

Occurrence. — Present only at locality UWA 6024 in the Roberts Mountains Formation.

Discussion. — Well-preserved specimens of this form are rare, and, therefore, specific identification could not be made. The median sulcus is not as broad as normal for most species of the genus, and the L_3 is poorly developed.

Family **SIGMOOPSIDAE** Henningsmoen, 1953

Genus **WINCHELLATIA** Kay, 1940

Type species. — *Winchellatia longispina* Kay, 1940.

Winchellatia fragilis McClellan, n. sp. Pl. 42, fig. 5

Description. — Carapace ovate, dorsally truncate; hinge line long, straight; anterior cardinal angle barely obtuse, posterior is a right angle; anterior margin gently convex, ventral nearly straight, curving evenly into posterior margin which is straight; lateral surface has greatest width posteroventral of midpoint; S_1 very shallow, narrow groove, S_2 deep, beginning at midpoint and widening from a narrow groove upward to near dorsal margin where it bends slightly forward; L_2 forms rounded low node outlined by S_1 and S_2, L_3 an indistinctly raised area with greatest height posteroventral; histial ridge fine and sharply defined extends from near anterior cardinal angle around ventral part of valve, ending posteroventrally where posterior margin begins; ventromedian based spine extends laterally from broad base, with thickened posterior margin, otherwise very thin and flat, appears winglike with backward directed tip.

Measurements. — The holotype male, 34788, has length of 0.42 mm and height 0.34 mm.

Occurrence. — Present only at locality UWA 6024, where it is rare in Roberts Mountains beds of Upper Silurian age.

Discussion. — The fragile winglike spine on each valve is distinctive from similarly placed nodes on other species in the genus. In other characters this new species resembles *Winchellatia minnesotensis* Kay (1940) which has an acute posterior cardinal angle, while that of the former is a right angle.

Previously the genus has been reported only from Middle Ordovician strata.

Superfamily **PRIMITIOPSACEA** Swartz, 1936

Family **PRIMITIOPSIDAE** Swartz, 1936

Subfamily **PRIMITIOPSINAE** Swartz, 1936

Genus **LIMBINARIA** Swartz, 1956

Type species. — *Limbinaria multipunctata* Swartz, 1956.

Limbinaria sp. Pl. 42, figs. 8, 9

Description. — Carapace subrectangular, dorsally truncate; hinge long and straight; cardinal angles obtuse, subequal; anterior and posterior margins lowly convex, ventral margin nearly straight; lateral surface has large, slightly elevated medial area with subrounded median pit; continuous narrow ridge parallels margins, separating them from medial area, is discontinuous dorsally; surface of valve coarsely punctate.

Measurements. — Specimen 34746 length is 0.92 mm and height indeterminate.

mm. Specimen 34746 length is 0.92 mm and height indeterminate.

Occurrence. — Rare, only present at locality UWA 6024 in the Roberts Mountains Formation.

Discussion. — The presently known specimens of this form are not well enough preserved to be specifically identified. They are similar to *Limbinaria multipuncta* Swartz (1956), except in having a subrectangular outline. The dorsal marginal area appears to vary somewhat also with a different configuration of the ridge that borders the medial area.

Suborder **KLOEDENELLOCOPINA** Scott, 1961

Superfamily **KLOEDENELLACEA** Ulrich and Bassler, 1908

Family **KLOEDENELLIDAE** Ulrich and Bassler, 1908

Genus **EUKLOEDENELLA** Ulrich and Bassler, 1923

Type species. — *Eukloedenella umbilicata* Ulrich and Bassler, 1923.

Eukloedenella aff. **E. dalhousiensis** Copeland Pl. 42, figs. 10, 11

1962. *Eukloedenella dalhousiensis* Copeland, Geol. Sur. Canada, Bull. 91, p. 42, p. X, figs. 1-6.

Description. — Carapace elongate, ovate; hinge straight posteriorly, right valve hinge slightly angulated over left valve at midpoint; posterior margin convex, ventral nearly straight, anterior margin has greatest convexity anteroventrally; greatest width posteromedial, valves lanceolate in dorsal view; median sulcus faint to indistinguishable.

Measurement. — Specimen 34740 measures 0.45 mm in length and 0.22 mm in height. Specimen 34741 is 0.37 mm in length and 0.19 mm in height.

Occurrence. — Present only at locality UWA 5985 in the Lower Devonian McMonnigal Limestone.

Discussion. — The specimens described here compare well to *Eukloedenella dalhousiensis* Copeland (1962) in most characters. A notable exception is the lack of the distinct median sulcus of that species. Since *E. dalhousiensis* adults are typically about twice the size of the specimens here, it is possible that this material either represents early instars in which the sulcus is not recognizable, or if such instars should exhibit the sulcus, the use of open nomenclature is justified until more detailed information is available.

E. dalhousiensis has been recorded in the upper Dalhousie beds of New Brunswick, Canada, which have been called Helderbergian in age (Copeland, 1962, p. 23). The age of the McMonnigal Limestone, from which these specimens were taken, has also been considered Helderbergian on the basis of its megafauna (Kay and Crawford, 1964, p. 440).

Genus **NEOKLOEDENELLA** Croneis and Funkhouser, 1939

Type species. — *Neokloedenella prima* Croneis and Funkhouser, 1939.

Neokloedenella ? sp. Pl. 42, fig. 12

Description. — Carapace subrectangular, lanceolate in dorsal view; hinge straight, overlap indeterminate; anterior cardinal angle very bluntly obtuse, posterior angle also obtuse; anterior margin strongly convex, posterior moderately so, ventral margin nearly straight; lateral surface highly convex, median sulcus unrecognizable, greatest width in posterior third of valve.

Measurements. — Specimen 34751 has length of 0.56 mm and height 0.29 mm.

Occurrence. — Present at locality UWA 5991 in the lower McColley Canyon Formation.

Discussion. — The poorly preserved male RV figured here resembles the *Neokloedenella* sp. reported by Stover (1956, p. 1111) from the Middle Devonian Windom Shale of western New York.

Family **GEISINIDAE** Sohn, 1961

Genus **PSEUDOLEPERDITIA** Schneyder, 1956

Type species. — *Pseudoleperditia tuberculifera* Schneyder, 1956.

Pseudoleperditia ? sp. Pl. 42, fig. 13

Description. — Carapace subquadrate, dorsally truncated; hinge straight, long; anterior cardinal angle obtuse, posterior forms a right angle; anterior margin nearly straight, ventral margin curves into slightly convex posterior; lateral surface strongly convex, greatest width ventromedian, L_2 forms a small, rounded node with median sulcus directly adjacent, forming shallow, elongate depression; prominent, broad, short spines directed upward from lateral surface of valve at points of the cardinal angles; margin lacks border but has short denticles anteriorly and ventrally.

Measurements. — Length of 34759 is 0.45 mm and height 0.30 mm.

Occurrence. — Rarely present only at locality UWA 6024 in the middle Roberts Mountains Formation.

Discussion. — This specimen has been questionably referred to *Pseudoleperditia* Schneyder (1956), which is monotypic, on the basis of the similarity in the lobation and cardinal spines. It seems to differ in lacking the marginal border of *P. tuberculifera,* having denticles instead, in a straighter hinge line, less anterior convexity, and in having the greatest width ventromedianly. The last character may be caused by an elongate brood pouch in this position. The type of hingement is indeterminate which further hinders positive identification, as it is an important character of the genus.

Superfamily **LEPERDITELLACEA** Ulrich and Bassler, 1906

Family **LEPERDITELLIDAE** Ulrich and Bassler, 1906

Genus **PARAHEALDIA** Coryell and Cuskley, 1934

Type species. — *Parahealdia pecorella* Coryell and Cuskley, 1934.

Parahealdia aff. **P. pecorella** Coryell and Cuskley Pl. 42, figs. 14, 16, 17

1934. *Parahealdia pecorella* Coryell and Cuskley, Amer. Mus. Nat. Hist., Nov. 748, text fig. 17.

Description. — Carapace elliptical, female shorter and more robust, more sharply convex in posterior margin than in anterior; hinge long, straight; margins smooth, dorsally slightly convex; lateral surface strongly convex, greatest width in posterior third where two short spines are directed posteriorly, upper spine at a low angle posterodorsally, bases of spines separated by narrow, flattened area; median sulcus very shallow and broad, extending down from dorsal margin for about one-third of height.

Measurements. — Specimen 34777, female RV, measures 0.46 mm by 0.33 mm.

Occurrence. — Abundant at locality UWA 5980. Also, questionable specimens present at locality UWA 5981; both in the lower Wenban Limestone.

Discussion. — These specimens differ from *Parahealdia pecorella* in being slightly convex dorsally, the spines are somewhat closer together, and the sulcus is broader and less distinct. In addition, female specimens are shorter and more rounded in outline.

Superfamily **PARAPARCHITACEA** Scott, 1959

Family **PARAPARCHITIDAE** Scott, 1959

Genus **PARAPARCHITES** Ulrich and Bassler, 1906

Type species. — *Paraparchites humerosus* Ulrich and Bassler, 1906.

Paraparchites sp. Pl. 42, fig. 15

Description. — Carapace broadly ovate, strongly convex; hinge about two-thirds of length, cardinal teeth indistinct; small, narrow, marginal ridge extends posteroventrally to anteroventrally, dorsal margin nearly straight; surface smooth, nonlobate, nonsulcate.

Measurements. — Length of 34754 is 0.64 mm and height 0.48 mm.

Occurrence. — Figured specimen from locality UWA 6024. Also occurs at locality UWA 5974. Both localities are in the upper two-thirds of the Roberts Mountains Formation.

Order PODOCOPIDA, Müller, 1894

Suborder **PODOCOPINA** Sars, 1866

Superfamily **BAIRDIACEA** Sars, 1888

Family **BAIRDIIDAE** Sars, 1888

Genus **BAIRDIA** McCoy, 1844

Type species. — *Bairdia curta* McCoy, 1844.

Bairdia sp. Pl. 43, figs. 1, 2

Description. — Carapace lanceolate in outline, acuminate anteriorly, maximum height one-fourth of length from posterior; LV with short, small spine at midpoint of posterior margin, RV with short, small spine forming anterior point, LV overlaps RV dorsally on margin between spines; lateral surfaces smooth, maximum width near midpoint, tapering gradually to acuminate anterior.

Measurements. — Specimen 34727 length is 0.55 mm plus spines (0.04 mm each) and height 0.29 mm.

Occurrence. — Present only at locality UWA 6024 in the middle Roberts Mountains Formation.

Discussion. — The genus *Bairdia* seems indicated by the manner in which the valves are joined as well as the form of the shell and presence of small spines. Positive identification and comparisons to other, possibly related, species could not be made because of a lack of material.

Genus **BYTHOCYPRIS** Brady, 1880

Type species. — *Bairdia bosquetiana* Brady, 1866.

Bythocypris aff. **B. alcocki** Copeland Pl. 43, figs. 3-5

1962. *Bythocypris alcocki* Copeland, Geol. Sur. Canada, Bull. 91, p. 46, pl. X, figs. 16-20.

Description. — Carapace elongate reniform, broadly ovate posteriorly; hinge straight, in anterior half; LV overlaps RV on entire margin; greatest height median to posterior, greatest width posteromedian; margin nearly straight ventrally, anterior margin with maximum point of convexity median to ventral; lateral surface moderately convex, smooth.

Measurements. — Specimen 34737 is 0.56 mm by 0.29 mm; 34736 measures 0.46 mm by 0.22 mm.

Occurrence. — Specimen 34737 from locality UWA 5974, and 34736 from locality UWA 6026. This form is widely distributed throughout the area in strata from Ludlovian to Helderbergian in age. It occurs most frequently in rocks of the latter age.

Discussion. — One of the more common constituents of the ostracode fauna in central Nevada, specimens referred to this species show a wide variation in shape. The shell outline varies from reniform to elliptical and the point of greatest width from posterior to anteromedian in position. *Bythocypris alcocki* Copeland (1962) is reniform and has a maximum width posteriorly. The left valve overlaps the right along the entire margin, in the same manner as shown by whole specimens from Nevada. *B. phaseolina* Ulrich and Bassler (1923) is similar to *B. alcocki* but more ellipsoidal and elongate. The specimens studied herein show some resemblance to *B. phaseolina* as well as apparent gradation from that species to *B. alcocki.*

Bythocypris ? sp. Pl. 43, figs. 6

Description. — Carapace subreniform, arcuate dorsally, laterally tumid; hinge straight, questionably anterior half; ventral margin straight to slightly concave, forming acute angles where joining anterior and posterior margins, dorsal margin strongly convex; lateral surface highly convex, greatest width median to ventromedian, maximum height at midpoint; valves dorsally depressed on median marginal area, may be depressed to form flattened area along ventral margin.

Measurements. — Dimensions of specimen 34739 are length 0.48 mm and height 0.29 mm.

Occurrence. — Figured specimen from locality UWA 5974. This form is present at several localities in beds ranging from Ludlow to Helderberg in age.

Discussion. — Species of *Bythocypris* are commonly reniform to ovate and not ventrally flattened as is this form. The dorsal depression of the valves along the hinge is suggestive of a similar structure present on *Newsomites* Morris and Hill (1952). However, it is believed that these specimens are generally more comparable in form to that of *Bythocypris.*

Family **BEECHERELLIDAE** Ulrich, 1894

Genus **ACANTHOSCAPHA** Ulrich and Bassler, 1923

Type species. — *Beecherella navicula* Ulrich, 1891.

Acanthoscapha aff. **A. navicula** (Ulrich) Pl. 43, figs. 7, 8

1891. *Beecherella navicula* Ulrich, Amer. Geol., vol. 8, No. 4, p. 203, pl. 2, figs. 8, 9.

Description. — Carapace elongate, spindle-shaped; hinge long, adont; flattened flange of margins greatly reduced; LV with very short dorsoposterior spine, anterior spine in contact with margin, RV with anterior end produced into short broad spine.

Measurements. — Specimen 34719, a RV, length is 0.74 mm and height 0.30 mm; 34720, a LV, length 0.57 mm and height 0.21 mm.

Occurrence. — Present only at locality UWA 5981 in the lower Wenban Limestone of Lower Devonian age.

Discussion. — These specimens differ from *Acanthoscapha navicula,* which occurs in Lower Devonian rocks of New York, in several respects. They are considerably smaller, the anterior and posterior spines are much shorter, the shell is less acuminate anteriorly, and the anterior spines contact the margin. The original types of *A. navicula* have a narrow marginal surface between the spine and margin.

Genus **LONGISCAPHA** McClellan, n. gen.

Type species. — *Longiscapha nevadensis* McClellan, n. sp.

Description. — Carapace elongate, scaphoid, middle third ventrally constricted, anterior spindle-shaped, posterior convex; hinge straight, long; lateral valve surfaces smooth, strongly convex with broad dorsum, compressed at ends, LV slightly overreaching RV; spines lacking, or reduced, on LV only.

The general scaphoid form and adont hinge place this genus definitely in the family Beecherellidae. The constriction of the median portion of the valves is similar to that of *Ulrichella* Boucek (1936), but is only represented as a height reduction, as the greatest width of the shell is in the same area. This genus is less acuminate than other genera within the family, and the spine is poorly developed.

Longiscapha nevadensis McClellan, n. sp. Pl. 43, figs. 9-11

Description. — Carapace scaphoid, anterior spindle-shaped; dorsal margin straight, anterior margin bluntly acuminate, ventral margin gently concave through medial third of shell, posterior strongly convex, anterior and posterior low marginal ridge defined by very shallow furrow; lateral surface of valve smooth, strongly convex, slightly convex dorsum, greatest height at end points of hinge; short, broad based, dorsal spine directed forward from anterodorsal position on LV.

Measurements. — Holotype 34747 length is 0.59 mm and height 0.22 mm. Paratype 34748 length is 0.53 mm and height 0.19 mm and paratype 34749 length is 0.64 mm and height 0.22 mm.

Occurrence. — This species was found only at localities UWA 6024 (type material) and UWA 6026 in the upper Roberts Mountains Formation at Willow Creek, which is of probable Ludlow age.

Discussion. — This species is characterized by the depressed anterior and posterior with the accompanying marginal border, and the greatest height being at the ends of the hinge line.

At both localities, from which *Longiscapha nevadensis* was recovered, the strata are cherty, argillaceous limestones. The bedding is very thin, with the shale and chert in laminae and stringers, suggestive of quiet bottom conditions and slow deposition. The microfauna is large and diversified here, but other invertebrate fossils are rare.

Superfamily **CYTHERACEA** Baird, 1850
Family **BEROUNELLIDAE** Sohn and Berdan, 1960
Genus **BEROUNELLA** Boucek, 1936

Type species. — *Berounella rostrata* Boucek, 1936.

Berounella sp. Pl. 43, fig. 13

Description. — Carapace subquadrate, with a long spine extending from posterior dorsal margin; anterior cardinal angle produced into long, thin spine directed dorsally and curving forward; lateral surface strongly convex, L_1 is anteromedian to ventral; deep, straight sulcus begins at dorsal margin above L_1 and extends to midpoint; ventral lobe leading from L_1 backward until merging with L_3, has long, delicate lateral spine curving posteriorly from posteroventral point; L_3 broad, rising from posterodorsal position to merge with ventral lobe; marginal flange developed only posteroventrally.

Measurements. — Length of specimen, exclusive of spine is 0.58 mm and height 0.29 mm.

Occurrence. — Only one specimen is known, from locality UWA 6024 in the Roberts Mountains Formation.

Suborder METACOPINA Sylvester-Bradley, 1961

Superfamily **HEALDIACEA** Harlton, 1933
Family **HEALDIIDAE** Harlton, 1933
Genus **HEALDIA** Roundy, 1926

Type species. — *Healdia simplex* Roundy, 1926.

Healdia ? sp. Pl. 43, fig. 12

Description. — Carapace ovate; dorsal and ventral margins moderately convex, anterior and posterior both rounded; lateral surface strongly convex, greatest width posterior, surface smooth with posterior shoulder bearing two very short and blunt spines.

Measurements. — Specimen 34742 length is 0.63 mm and height 0.39 mm.

Occurrence. — Found rarely, only at locality UWA 5981 in the lower Wenban Limestone.

Discussion. — This form is poorly represented in the area and specimens cannot be positively identified as having healdiid hingement and overlap of the valves. On the basis of shape and surface features it has been referred to the genus *Healdia*. The degree and direction of overlap could not be determined, so it is possible that the generic assignment is incorrect.

Family CAVELLINIDAE Egorov, 1950

Genus **BIRDSALLELLA** Coryell and Booth, 1933

Type species. — *Birdsallella simplex* Coryell and Booth, 1933.

Birdsallella sp. Pl. 43, fig. 14

Description. — Carapace elongate ellipsoidal, RV overreach of LV noticeable only on dorsal and ventral borders, dorsal view wedge-shaped; anterior margin convex, posterior nearly truncate, dorsal and ventral margins straight; lateral surface smooth, greatest width posterior; posterior swelling developed into strong ridge projecting backward to margin.

Measurements. — The figured specimen has a length of 0.74 mm and height of 0.45 mm.

Occurrence. — This genus occurs only at locality UWA 5980 in the lower Wenban Limestone.

Family **PACHYDOMELLIDAE** Berdan and Sohn, 1961

Genus **PHANASSYMETRIA** Roth, 1929

Type species. — *Phanassymetria triserrata* Roth, 1929.

Phanassymetria sp. Pl. 43, fig. 20

Description. — Carapace subovate, asymmetrical, angular in cross-section; dorsum convex, forming longitudinal shoulders with straight hinge in groove between, ventral margin straight; LV overlaps RV strongly on venter and is the larger valve; maximum width slightly posteroventral of midpoint; lateral surface coarsely punctate.

Measurements. — Length of figured specimen is 1.03 mm and height is 0.65 mm.

Occurrence. — Present at locality UWA 5980 in the lower Wenban Limestone, from which only one specimen was recovered.

Discussion. — This specimen differs from the known species of *Phanassymetria,* but it is not possible to establish a new species until additional material has been found.

Genus **TUBULIBAIRDIA** Swartz, 1936

Type species. — *Tubulibairdia tubulifera* Swartz, 1936.

Tubulibairdia cf. **T. chaleurensis** Copeland Pl. 43, figs. 15, 19

1962. *Tubulibairdia chaleurensis* Copeland, Geol. Sur. Canada, Bull. 91, p. 47, pl. X, figs. 32-36.

Description. — Carapace ovate, elongated; hinge straight, about half of total length; dorsal margin slightly convex, anterior and posterior strongly so, ventral margin straight; LV overlaps RV, most pronounced ventrally; lateral surface smooth, highly convex, greatest width posterior giving ovoid shape in dorsal view, maximum height slightly posterior of median.

Measurements. — Specimen 34776 length is 0.55 mm and height 0.29 mm.

Occurrence. — Specimen 34776 is from locality UWA 6024. This species is widely distributed in the area in strata ranging from Ludlovian to Helderbergian age.

Discussion. — *Tubulibairdia chaleurensis* has been previously recorded in the type area of New Brunswick, Canada, where it occurs in the Lower Devonian Dalhousie beds. The species described here occurs in strata of similar age. It differs from Copeland's types in being more elongate with a straight venter, and the maximum width is closer to median.

Tubulibairdia aff. **T. chaleurensis** Copeland Pl. 43, fig. 18

1962. *Tubulibairdia chaleurensis* Copeland, Geol. Sur. Canada, Bull. 91, p. 47 pl. X, figs. 32-36.

Description. — Carapace ovate; hinge straight, about half of total length; dorsal and ventral margins gently convex, anterior and posterior strongly convex; LV overlaps RV except dorsally; lateral surface smooth, robust with high convexity, greatest width at midpoint and tapering evenly to both ends, dorsum rises above hinge line.

Measurements. — Specimen 34778 has a length of 0.63 mm and height of 0.43 mm.

Occurrence. — This form was found only at locality UWA 5985 in the McMonnigal Limestone.

Discussion. — In general outline, viewed laterally, this form resembles *Tubulibairdia chaleurensis* more so than the preceding species. Differences are seen, however, in the median maximum width, and the valve overlap, which is continuous on the anterior border in contrast to Copeland's types. With these significant differences the present material has affinities for, but is distinct from, *T. chaleurensis*.

Tubulibairdia sp. Pl. 43, fig. 21

Description. — Carapace ovate; entire margin convex; overlap of valves indeterminate; lateral surface smooth, strongly convex, maximum width posterior.

Measurements. — Specimen 34779 length is 0.66 mm and height is 0.44 mm.

Occurrence. — Several specimens of single valves were found at locality UWA 5973 in the Rabbit Hill Formation of Lower Devonian age.

Discussion. — The single valves occurring at the above locality appear to belong to *Tubulibairdia,* although unrecognizable specifically. Their characters are more generalized than the previously described species which compare to *T. chaleurensis.*

Superfamily **QUASILLITACEA** Coryell and Malkin, 1936
Family **QUASILLITIDAE** Coryell and Malkin, 1936
Genus **QUASILLITES** Coryell and Malkin, 1936

Type species. — *Quasillites obliquus* Coryell and Malkin, 1936.

Quasillites sp. Pl. 44, figs. 1-3

Description. — Carapace subquadrate, ends rounded; LV overlaps RV except on dorsal margin; lateral surface moderately convex, greatest width median, ornamented with fine ridges and grooves; both valves have flattened dorsum with shoulders forming narrow ridges for entire length, LV may also have ventral groove setting off part of valve which overlaps RV; LV has anterior and posterior, short, blunt spines placed near ventral margin; RV may have similar matching pair, only one, or no spines.

Measurements. — The figured specimens have the following dimensions: specimen 34760 has length 0.48 mm and height 0.25 mm and specimen 34761 length is 0.44 mm, height 0.22 mm.

Occurrence. — Present only at locality UWA 5985 in the McMonnigal Limestone.

Discussion. — None of the known species of *Quasillites* adequately fits the description of these specimens, which are more equilateral than described species as well as having a distinctive development of the lateral spines. Stover (1956, p. 1124) discussed the problem of variability encountered in *Quasillites* species. In the present material considerable variation is suggested, such that it is deemed advisable not to erect a new species until more specimens are available for study.

Family **ROPOLONELLIDAE** Coryell and Malkin, 1936

Genus **RUDDERINA** Coryell and Malkin, 1936

Type species. — *Rudderina extensa* Coryell and Malkin, 1936.

Rudderina mutaspina McClellan, n. sp. Pl. 44, figs. 4-8

Description. — Carapace elongated subtriangular, triangle hypotenuse formed by central margin; hinge straight, extending for over 0.8 of greatest length; dorsal margin straight, anterior slightly convex, venter straight to convex rearward, posterior margin strongly convex; well developed, flattened marginal ridge anteriorly separated from lateral surface by narrow furrow, similar posterior ridge mostly indistinct; LV with convex medial portion of dorsal margin, lateral surface smooth, greatest height anterior, greattest width posteroventral; single, long, tapering, finely pointed spine arises from point of greatest width; the spine is directed anterolaterally in early instars, progressively changing to a posterolateral direction in adults.

Measurements. — Dimensions of the several instars figured are listed below:

Pl. 44	Spec. Number	Length	Height
Fig. 4	34763 paratype	0.47 mm	0.23 mm
Fig. 5	34764 paratype	0.47 mm	0.23 mm
Fig. 6	34765 paratype	0.65 mm	0.30 mm
Fig. 7	34766 paratype	0.65 mm	0.30 mm
Fig. 8	34767 holotype	0.76 mm	0.38 mm

Occurrence. — The type specimens are from locality UWA 5985 in the McMonnigal Limestone. Also present at locality UWA 5984 and UWA 5975. These occurrences range in age from upper Ludlovian to Helderbergian.

Discussion. — The single spine is distinctive for this species. Previously known species have two spines, one directed anteriorly and one posteriorly near the valve margins. The spine of *Rudderina mutaspina* is more nearly median though still near the ventral border. This single spine appears to change direction with growth of the individual (see Pl. 44, figs. 4-8), suggesting considerable variation within the species.

Rudderina spp. Pl. 44, figs. 9-12

Description. — Carapace subtriangular, greatest height anterior; long, slender, curving spine directed posterolaterally from median area at point of greatest width; some specimens also with small, curving, dorsal spines at ends of straight hinge line.

Occurrence. — Specimens figured here are from locality UWA 6024; also at UWA 6026. Both occurrences in the Roberts Mountains Formation.

Discussion. — Several different forms have been included here which appear to belong under the genus *Rudderina,* because of the general outline and spine development.

Superfamily **THLIPSURACEA** Ulrich, 1894

Family **THLIPSURIDAE** Ulrich, 1894

Genus **THLIPSURA** Jones and Holl, 1869

Type species. — *Thlipsura corpulenta* Jones and Holl, 1869.

Thlipsura bispinosa McClellan, n. sp. Pl. 44, figs. 13-15

Description. — Carapace subovate; dorsal margin convex, ventral straight, anterior and posterior strongly convex with maximum convexity of posterior below midline; lateral surface strongly convex, greatest width posterior, flat depressed area rises from posterior margin to form shoulder which leads from posteroventral margin to dorsal position at about one-third of distance to anterior of valve; two anteriorly directed furrows lead from shoulder, with small node representing maximum convexity point of valve and separating the furrows; marginal to the furrows are two short spines projecting from the shoulder, the ventral spine directed posteriorly and the dorsal one posterodorsally directed.

Measurements. — Following are the dimensions of the figured type specimens.

Pl. 44	Spec. Number	Length	Height
Fig. 13	34773 holotype	0.90 mm	0.52 mm
Fig. 14	34774 paratype	0.69 mm	0.41 mm
Fig. 15	34775 paratype	0.92 mm	0.56 mm

Occurrence. — Specimens 34773 and 34774 are from locality UWA 5980 in the lower Wenban Limestone. Specimen 34775 is from locality UWA 5973 in the Rabbit Hill Formation.

Discussion. — The most closely related species to *Thlipsura bispinosa* is *T. furca* Roth (1929), which has a similar outline and two furrows. The latter differs in lacking the spines and having a better defined central node separating the furrows.

This species is not widely distributed in the area and is known only from the Lower Devonian. Where it does occur, it is one of the more common constituents of the fauna.

LOCALITY REGISTER

Numbers in ( ) refer to location numbers given for the sections on the index map, Fig. 1.

Coal Canyon (15) — Long. 116°28′, Lat. 40°2′30″, Horse Creek Valley Quadrangle

UWA 5973 Located at top of hill on east side of Coal Canyon at elev. 6905′, NE 1/4, SE 1/4, SE 1/4 Sec. 17, T25N,

	R49E, north end of Simpson Park Range. Rabbit Hill Fm.
UWA 5974	Located west and 830′ down section from UWA 5973 at elev. 6440′. Roberts Mountains Fm.
UWA 5975	Located south of UWA 5974, at elev. 6310′, on south line 1300′ west of E corner Sec. 17. Roberts Mountains Fm.
UWA 5976	Located on slope on west side of Coal Canyon, at elev. 6440′, southeast of UWA 5975. Roberts Mountains Fm.
Copenhagen Canyon (7) — Long. 116°24′, Lat. 39°12′30″, Horse Heaven Mountain Quadrangle	
UWA 5977	Located at top of cliff on west side of road in Copenhagen Canyon at elev. 7100′; NW 1/4, SW 1/4, SW 1/4 Sec. 36, T16N, R49E. Roberts Mountains Fm.
UWA 5978	Located near base of cliff, east and down section 430′ from UWA 5977, at elev. 6970′. Roberts Mountains Fm.
UWA 5979	Located on west side of road, 350′ south and 180′ down section from UWA 5978, at elev. 6865′. Roberts Mountains Fm.
Cortez Canyon (16) — Long. 116°38′ Lat. 40°11′, Cortez Quadrangle	
UWA 5980	Located on north side near top of hill which forms east side of Cortez Canyon, at elev. 6000′, by claim monument located 13,025′ N19W of SW corner Sec. 6, T26N, R48E. Wenban Limestone
UWA 5981	Located north and 55′ down section from UWA 5980, at elev. 5900′. Wenban Limestone
Gatecliff (2) — Long. 116°47′30″, Lat. 39°00′, Wildcat Peak Quadrangle	
UWA 5982	Located 1/2 mile west of Caesar Canyon, on north side of Mill Canyon at elev. 7840′, 30′ above base of cliff where canyon is crossed by stock fence. Bastille Limestone
UWA 5983	Located on slope above and 220′ up section from UWA 5982, at elev. 7920′. Bastille Limestone

Ikes Canyon (5) — Long. 116°44′, Lat. 39°03′, Dianas Punch Bowl Quadrangle

UWA 5984 Located on west side of Copper Mt., overlooking Ikes Cabin, on north side of canyon, at elev. 8360′ and 6700′ S87W from NW corner Sec. 17, T14N, R46E, in the Toquima Mountains. Masket Shale

UWA 5985 Located north and 10′ up section from UWA 5984, in small saddle at elev. 8320′. Base of McMonnigal Limestone

UWA 5986 Located northwest and 45′ up section from UWA 5985, on north side of saddle at elev. 8290′. McMonnigal Limestone

UWA 5987 Located southwest of UWA 5986 on nose of hill 250′ above bottom of canyon, at elev. 8010′, 1/4 mile east of Ikes Cabin. Masket Shale

UWA 5988 Located south and 390′ down section from UWA 5987, at elev. 7790′. Masket Shale

Kelley Creek (13) — Long. 116°20′30″, Lat. 39°56′, Roberts Creek Mountain Quadrangle

UWA 5989 Located 6600′ due south of BM 6109 which is in NW 1/4 Sec. 21, T24N, R50E, on slope of ridge on east side of Kelley Creek at elev. 6880′, near mouth of canyon on north flank of Roberts Mountains. Roberts Mountains Fm.

UWA 5990 Located northwest and down section 135′ from UWA 5989, at elev. 6850′. Roberts Mountains Fm.

Lone Mountain (10) — Long. 116°16′, Lat. 39°35′, Bartine Ranch Quadrangle

UWA 5991 Located 12,000′ north and 6200′ east of the NE corner of Sec. 1, T19N, R50E, on southwest side and near top of Lone Mountain, at elev. 7200′. Lone Mountain Dolomite

UWA 5992 Located due south and 830′ down section from UWA 5991, at elev. 7040′. Lone Mountain Dolomite

March Spring (4) — Long. 116°44′, Lat. 39°02′45″, Dianas Punch Bowl Quadrangle

UWA 5993 Located 7550′ west of NW corner, Sec. 20, T14N, R47E on top of hill west of small spring and ½ mile south of Ikes Canyon, at elev. 8200′. McMonnigal Limestone

UWA 5994 Located east and 70′ down section from UWA 5993, on hillside at elev. 8160′. McMonnigal Limestone

UWA 5995 Located east and 130′ down section from UWA 5994, at elev. 8090′. Masket Shale

UWA 5996 Located east and 100′ down section from UWA 5995, at elev. 8050′. Masket Shale

UWA 5997 Located east and 130′ down section from UWA 5996, at elev. 7980′. Masket Shale

Mill Canyon (3) — Long. 116°48′, Lat. 39°01′, east side of Toquima Mts., Wildcat Peak Quadrangle

UWA 5998 Located at base of ridge on the west side of the north fork of Mill Canyon, 3600′ north of junction with the main canyon, at elev. 8280′. Gatecliff Dolomite

Northumberland Canyon (1) — Long. 116°50′, Lat. 38°54′, 7 miles south of Mill Canyon in Toquima Mts., unsurveyed

UWA 5999 Located at base of hill on north side of Northumberand Canyon, 100 yards west of the mouth of Perkins Canyon and approximately one mile west of national forest boundary, at elev. 7800′. Perkins Canyon Fm. (U. Ord?)

Pete Hanson Creek (12) — Long. 116°20′, Lat. 39°53′, Roberts Creek Mountain Quadrangle

UWA 6000 Located in high saddle on ridge separating two forks of Pete Hanson Creek, 2300′ north and 2800′ west of Roberts Creek Mountain, at elev. 9150′. McColley Canyon Fm.

UWA 6001 Located due west on side of hill and 1850′ down section from UWA 6000, at elev. 8680′. Lone Mountain Dolomite

UWA 6002 Located west and 405′ down section from UWA 6001, at elev. 8570′ in low saddle. Roberts Mountains Fm.

UWA 6003 Located west and down section 125′ from UWA 6002, in low saddle, at elev. 8570′. Roberts Mountains Fm.

UWA 6004 Located west and 170′ down section from UWA 6003, at elev. 8600′ on small nob at end of saddle. Roberts Mountains Fm.

UWA 6006 Located west and 170′ down section from UWA 6004, at elev. 8560′. Roberts Mountains Fm.

UWA 6007 Located west and 310′ down section from UWA 6006, at elev. 8500′. Roberts Mountains Fm.

UWA 6008 Located west and 740′ down section from UWA 6007, at elev. 8330′. Roberts Mountains Fm.

Rabbit Hill (6) — Long. 116°25′, Lat. 39°12′, Horse Heaven Mountain Quadrangle

UWA 6009 Located in middle of flat top of Rabbit Hill ¾ mile west of road on north side of Whiterock Canyon, at elev. 7200′. Rabbit Hill Fm.

UWA 6010 Located SSE and 400′ down section from UWA 6009, on edge of steep slope at elev. 7120′. Rabbit Hill Fm.

UWA 6011 Located east and 55′ down section from UWA 6010, at elev. 7070′. Roberts Mountains Fm.

UWA 6012 Located east and 25′ down section from UWA 6011, at elev. 7050′. Roberts Mountains Fm.

UWA 6013 Located east and 25′ down section from UWA 6012, base of the hill at elev. 7030′. Roberts Mountains Fm.

Telegraph Canyon (21) — Long. 116°04′, Lat. 40°06′, Mineral Hill Quadrangle

UWA 6014 Located on low ridge 3900′ west of BM 6912 at top of pass above Telegraph Canyon; SW 1/4, SW 1/4, NE 1/4, Sec. 36, T26N, R52E, at elev. 6850′. Roberts Mountains Fm.

UWA 6015 Located east and 2080′ up section from UWA 6014, on nose of hill at elev. 7040′. Roberts Mountains Fm.

Twin Springs Hills (9) — Long. 116°24′45″, Lat. 39°30′, Antelope Peak Quadrangle

UWA 6016 Located on low rise on east side of Twin Springs Hills in NW 1/4, NE 1/4, NW 1/4 Sec. 25, T19N, R49E, at elev. 6360′. Roberts Mountains Fm.

UWA 6017 Located southwest and 260′ up section from UWA 6016, at elev. 6380′. Roberts Mountains Fm.

Tyrone Gap (19) — Long. 116°04′30″, Lat. 39°49′, Garden Valley Quadrangle

UWA 6034 Located 250′ east of center of WL, Sec. 1, T22N, R52E at south end of hogback, at elev. 6000′. Lone Mountain Dolomite

Willow Creek (14) — Long. 116°19′, Lat. 39°57′, Roberts Creek Mountain Quadrangle

UWA 6018 Located 1150′ east and 3100′ south of SE corner Sec. 15, T24N, R50E, on point of ridge on east side of Willow Creek, at elev. 7100′. McColley Canyon Fm.

UWA 6019 Located northwest and 320′ down section from UWA 6018, at elev. 6950′. Lone Mountain Dolomite

UWA 6020 Located west and 1505′ down section from UWA 6019, at center EL Sec. 22, T24N, R50E, at elev. 6590′. Roberts Mountains Fm.

UWA 6021 Located NNW and 110′ down section from UWA 6020 at elev. 6550′ Roberts Mountains Fm.

UWA 6022 Located west and 435′ down section from UWA 6021, at elev. 6320′. Roberts Mountains Fm.

UWA 6023 Located south and 70′ down section from UWA 6022, at elev. 6310′. Roberts Mountains Fm.

UWA 6024 Located west and 50′ down section from UWA 6023, beside trail behind ranch house, at elev. 6280′. Roberts Mountains Fm.

UWA 6025 Located west and 230′ down section from UWA 6024, on hill on west side of Willow Creek, at elev. 6500′. Roberts Mountains Fm.

UWA 6026 Located southwest and 310′ down section from UWA 6025, at elev. 6540′. Roberts Mountains Fm.

UWA 6027 Located west and 355′ down section from UWA 6026, at elev. 6500′. Roberts Mountains Fm.

UWA 6028 Located southwest and 130′ down section from UWA 6027, on north flank of mountains at elev. 6610′. Roberts Mountains Fm.

UWA 6029 Located west and 330′ down section from UWA 6028, at elev. 6580′. Roberts Mountains Fm.

UWA 6030 Located north and 155′ down section from UWA 6029, on small northward projecting nose of hill, midway between Willow and Birch creeks, at elev. 6500′. Roberts Mountains Fm.

UWA 6031 Located NNW and 105′ down section from UWA 6030, at elev. 6455′ approximately 50′ above base of hill. Roberts Mountains Fm.

Wood Cone (8) — Long. 116°09′, Lat. 39°23′, Bellevue Peak Quadrangle

UWA 6032 Located 2700′ west and 1100′ north of BM 7201 by road north of Wood Cone Peak, on slope of small nob of hill, at elev. 7160′. Roberts Mountains Fm.

UWA 6033 Located southwest and 750′ down section from UWA 6032, at elev. 7080′. Roberts Mountains Fm.

The following sections were studied, but no microfossils were recovered from the samples:

Bailey Pass (20) — Long. 116°06′, Lat. 39°55′, Garden Valley Quadrangle, from top of pass down east side of Sulphur Spring Range

Cole Creek (23) — Long. 116°07′, Lat. 40°37′, Carlin Quadrangle, S 1/2 Sec. 34, T32N, R52E

Fourmile Canyon (18) — Long. 116°33′, Lat. 40°12′, Cortez Quadrangle, at mouth of canyon

Mill Canyon (17) — Long. 116°35′, Lat. 40°12′, Cortez Quadrangle, at boundary of Lander and Eureka counties

Mitchell Creek (22) — Long. 115°35′, Lat. 40°09′, Sherman Mountain Quadrangle, west side of southern Ruby Mountains

Sheep Corral Canyon (11) — Long. 116°34′, Lat. 39°56′, Walti Hot Springs Quadrangle, SW corner Sec. 14, T23N, R48E

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The University of Nevada provided the funds for the illustrations of this paper.

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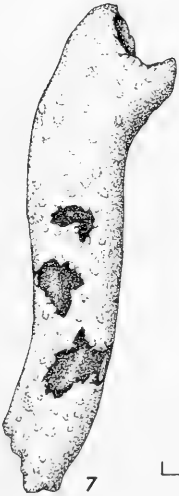
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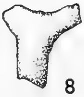
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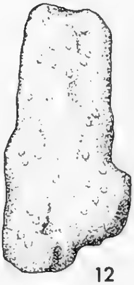

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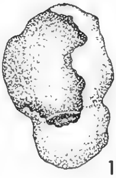
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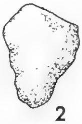
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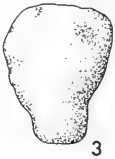
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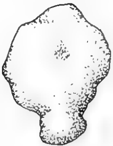
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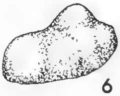
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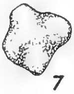
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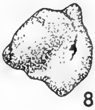
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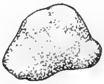
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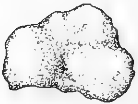
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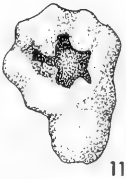
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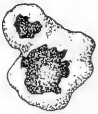
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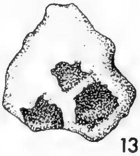
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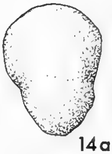
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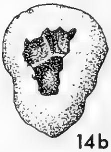
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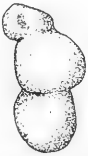
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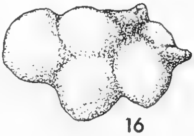
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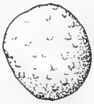
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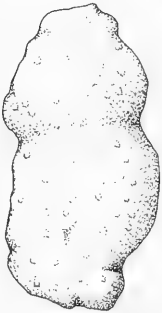
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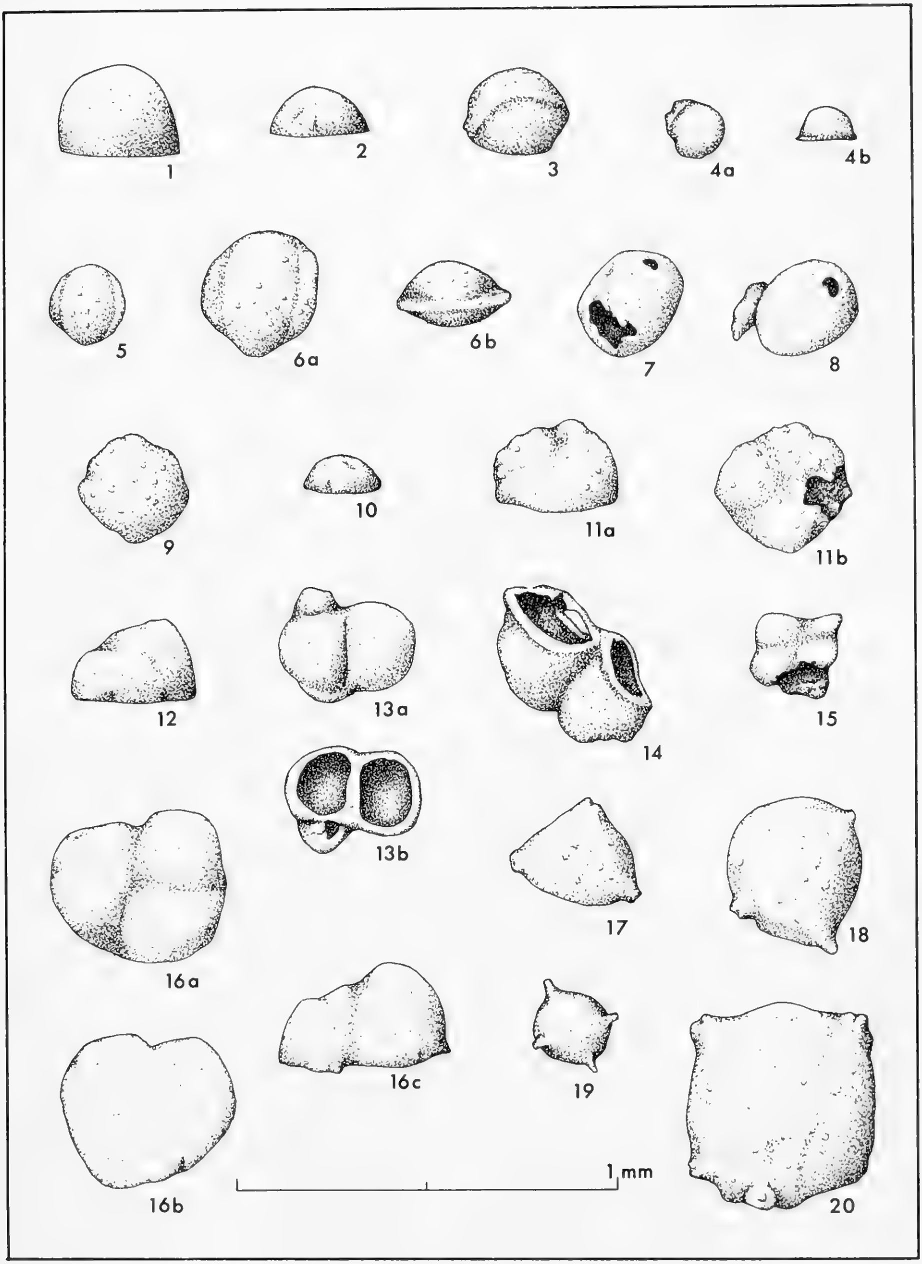
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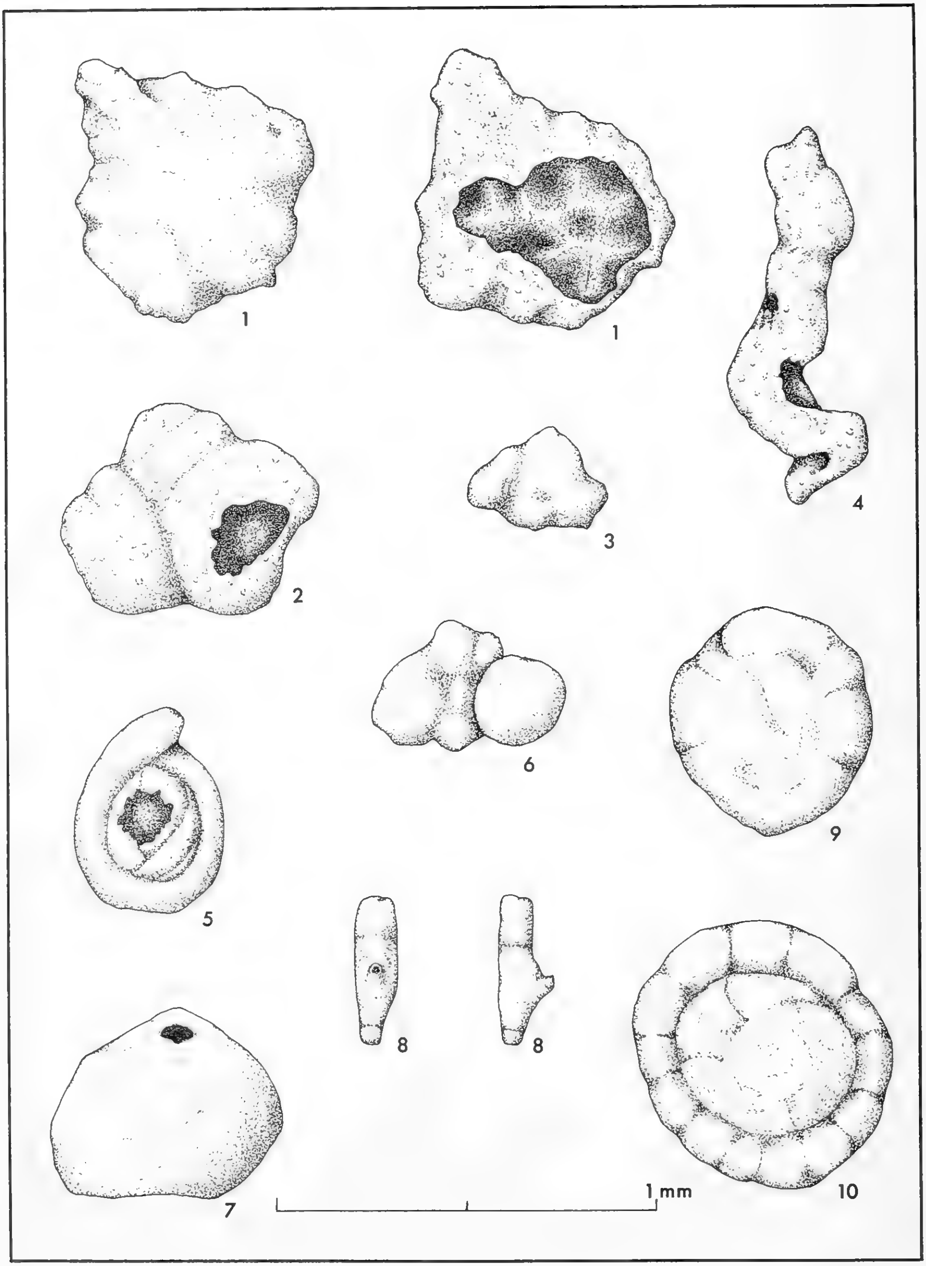
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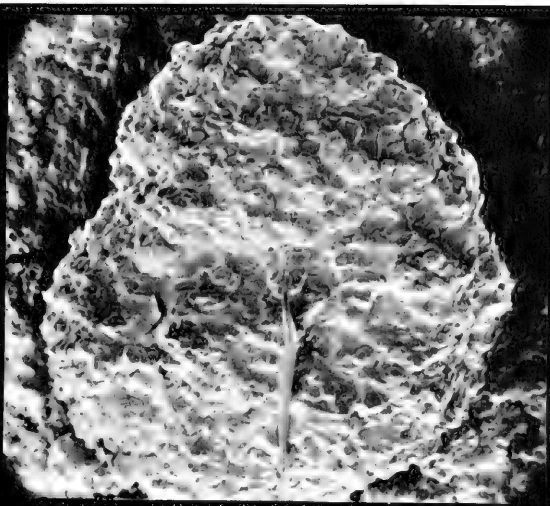

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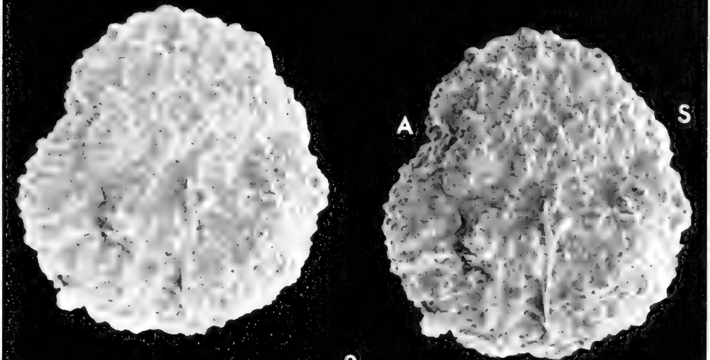

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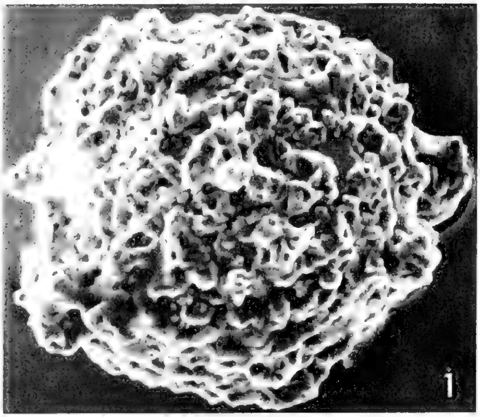
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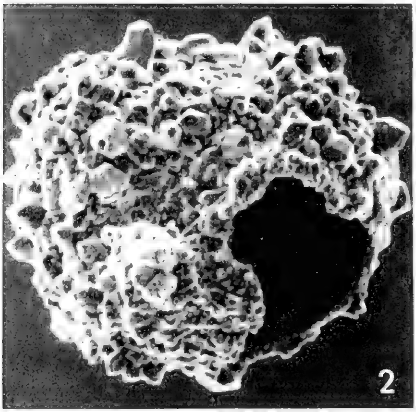
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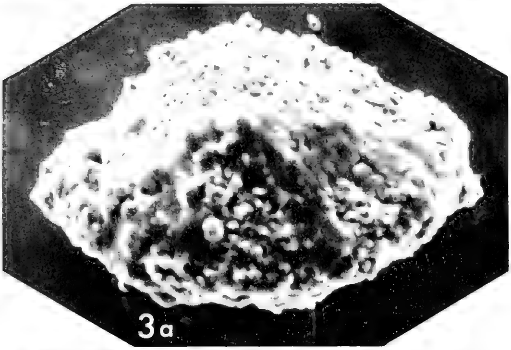
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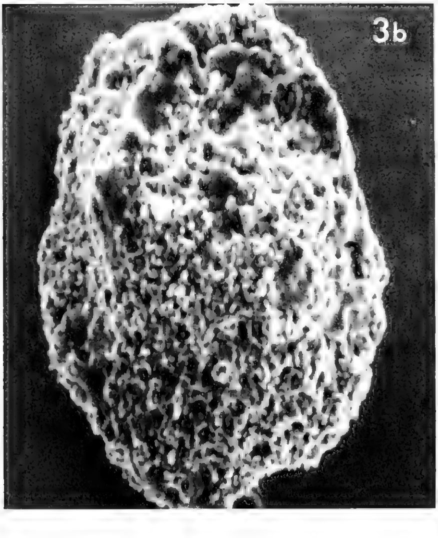
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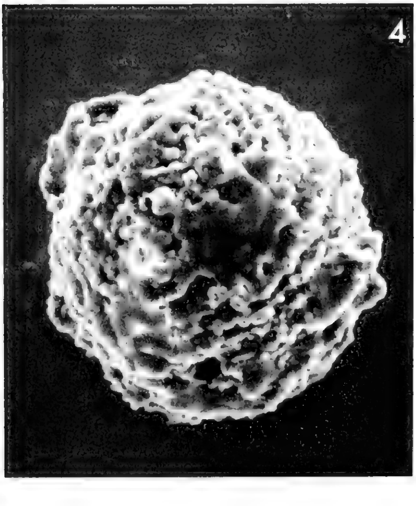
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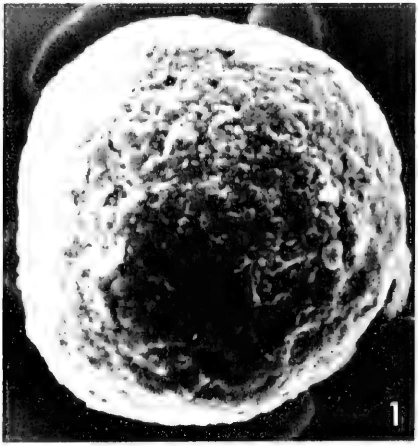
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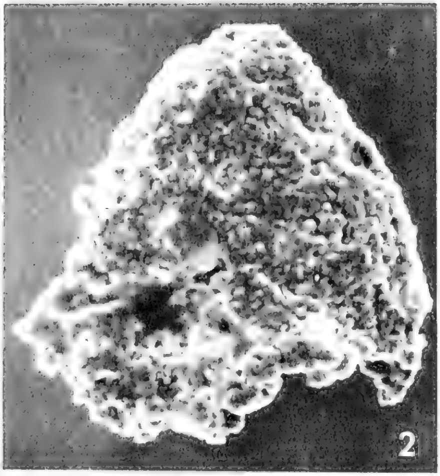
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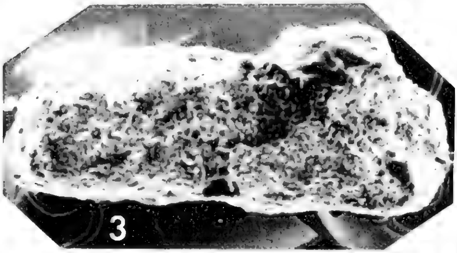
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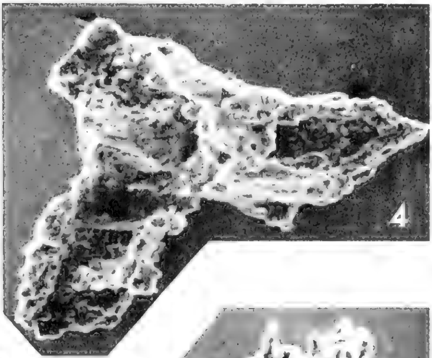
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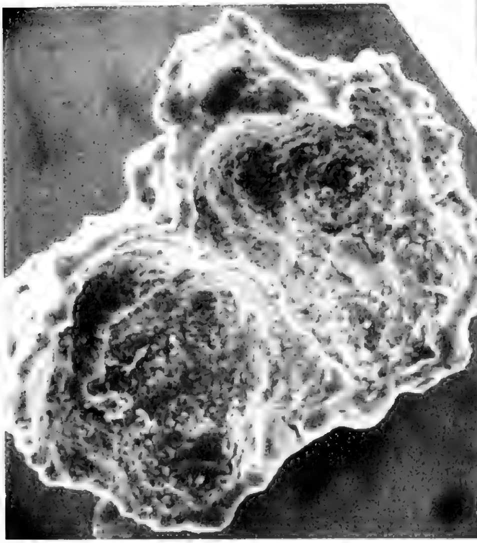
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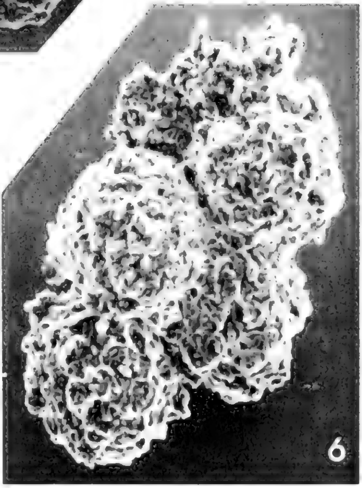
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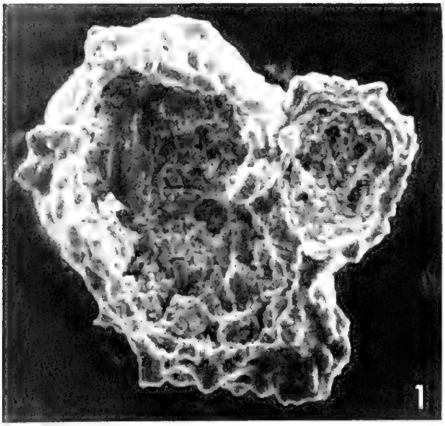
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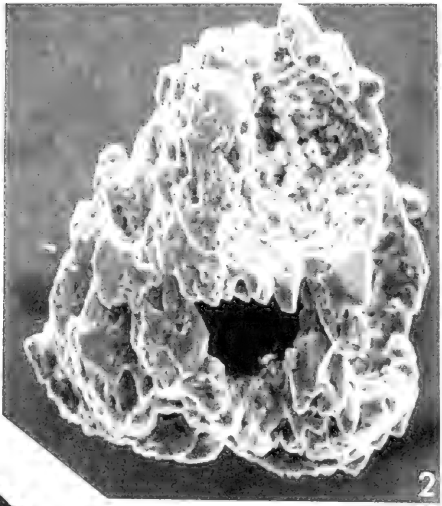
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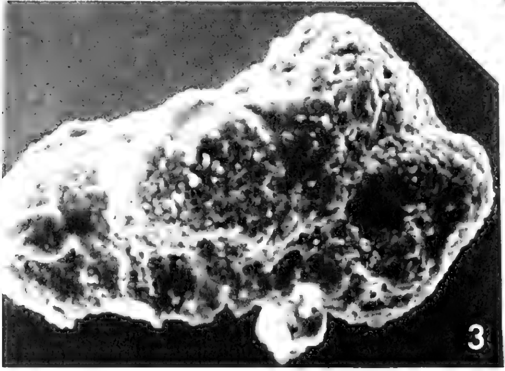
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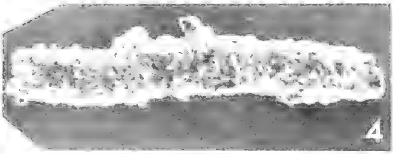
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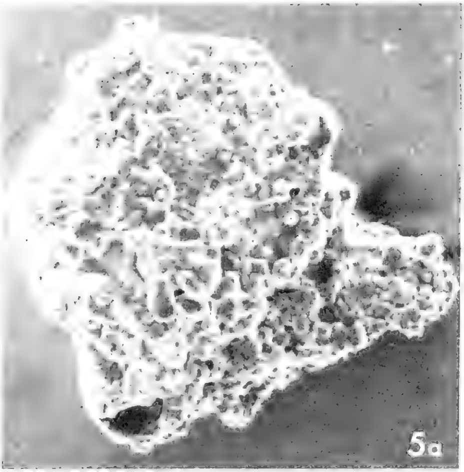
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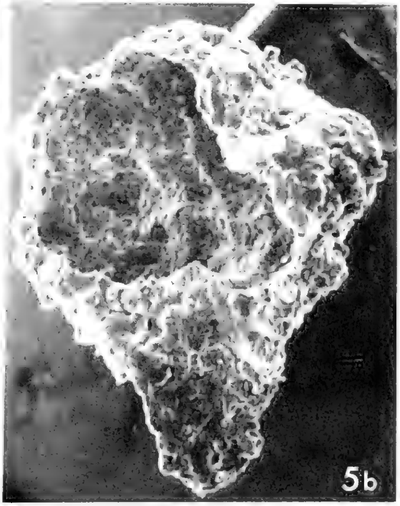
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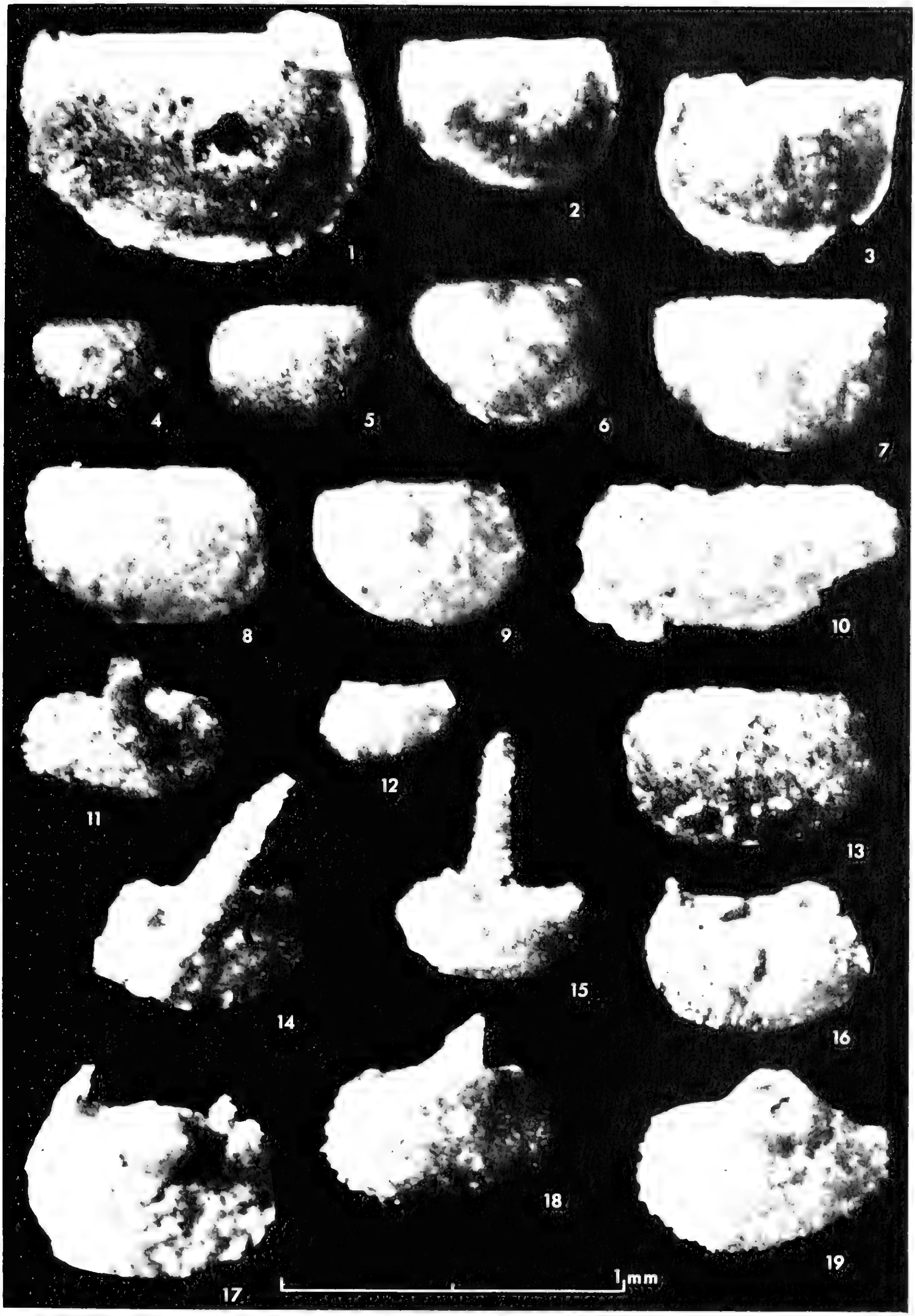
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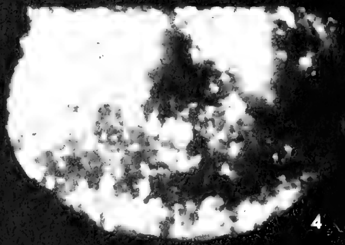
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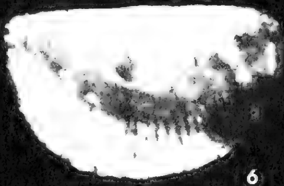
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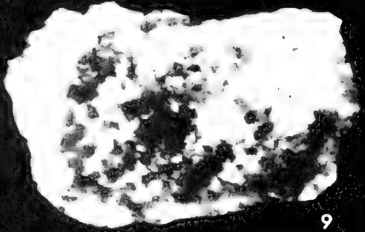
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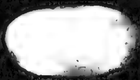
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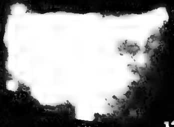
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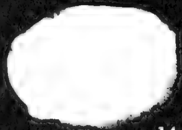
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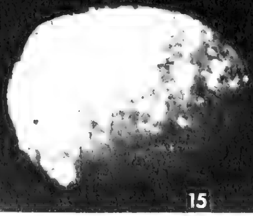
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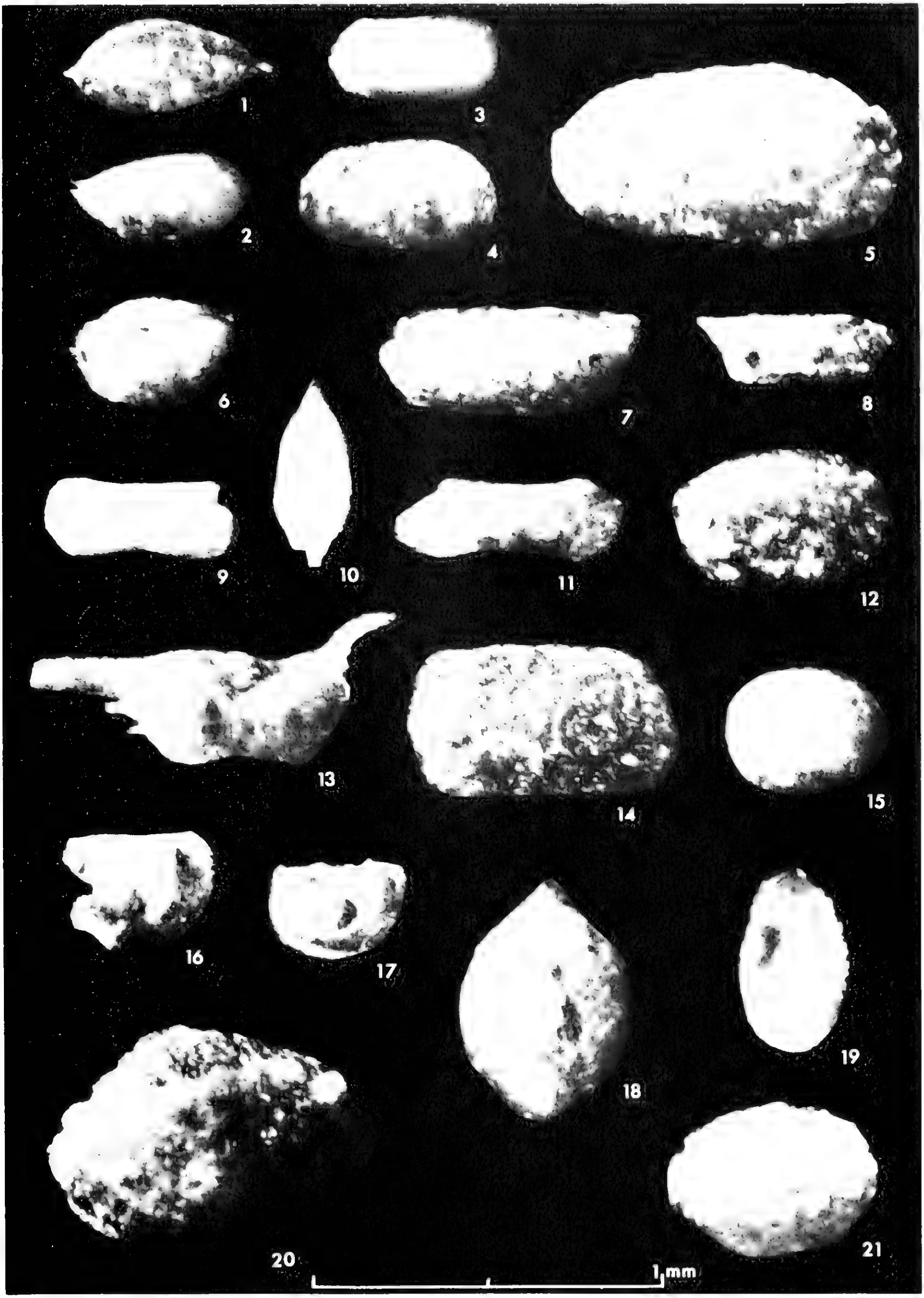
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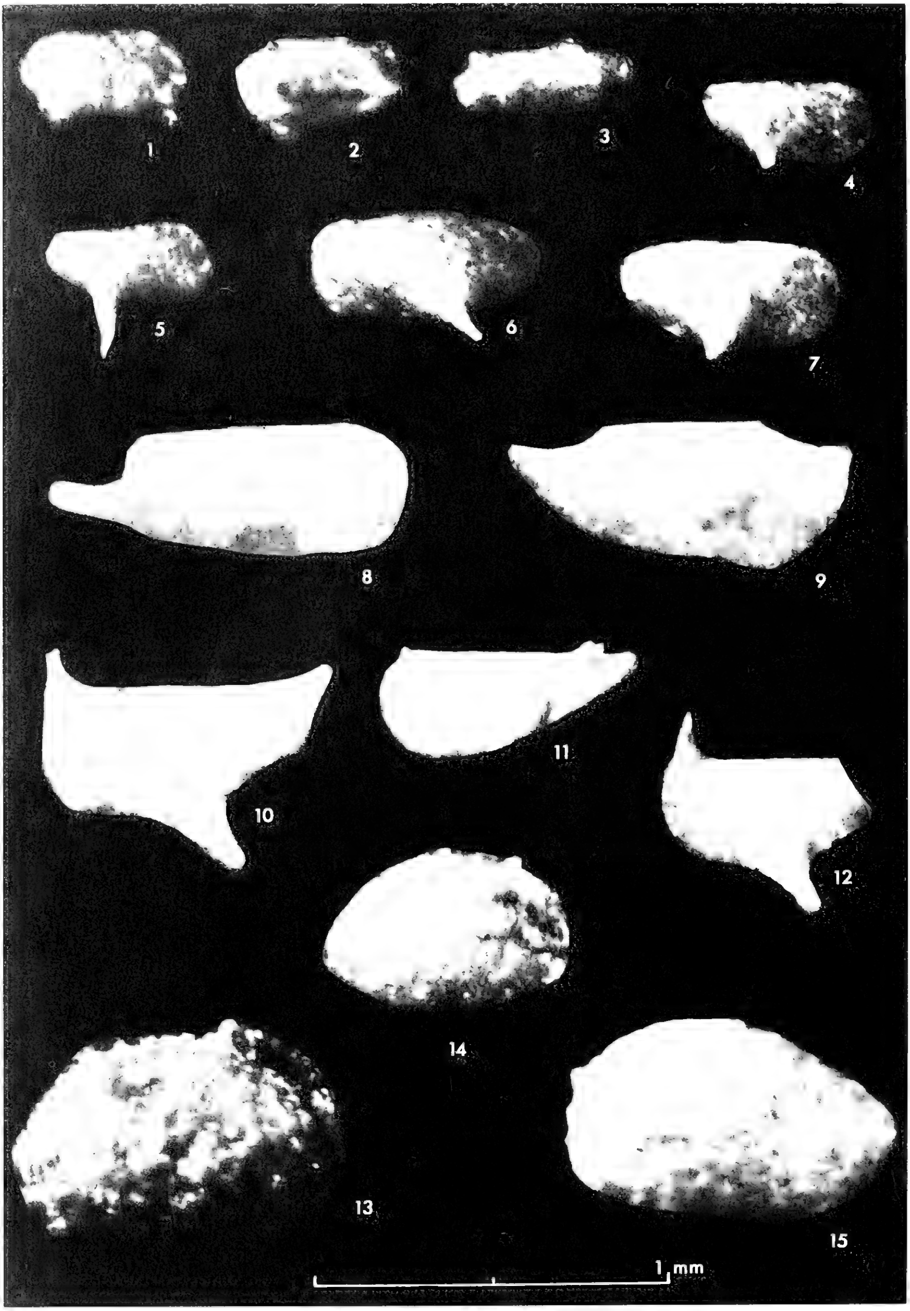
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