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NORTH AMERICAN CYCLOCRINITID ALGAE

MATTHEW H. NITECKI

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NOVEMBER 16, 1970

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To my wife, Doris V. Nitecki

The patient proofreader, the steadfast collector, the merry campfellow, and a cause for great thanks.

"Even among living objects, where we may see individuals of all ages, and under every variety of external influences, the exact definition of a 'Species' is perhaps impracticable, except in the instances where the circle of analogies, in which most forms and structures are bound, is broken; how seldom then ought we to affirm confidently in regard to fossils, from a few individuals of unknown age and circumstances of life, what are the natural limits of the species."

—John Phillips, 1841, p. IX.

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Abstract

Cyclocrinitids are marine dasycladaceous algae of Ordovician and Silurian age. Their skeletal elements consist of a seldom calcified main axis on which lateral branches are borne in whorls. Calcified heads commonly form at the termini of the laterals. In North America cyclocrinitids are represented by three genera: *Anomaloides, Cyclocrinites,* and *Lepidolites. Anomaloides* (=*Anomalospongia*) possesses laterals calcified throughout their extent. They expand gently outward, and no heads form. Three secondary laterals form threadlike projections at the terminus of each lateral.

Cyclocrinites (=*Cyclocrinus, Lunulites, Cerionites, Pasceolus, Mastopora,* and *Nidulites*) with a globose thallus is the most diversified genus. The laterals expand at the termini and form generally six-sided heads. In one species the laterals branch to the second degree. The lateral heads are in some species supported by four to six ribs. In at least one species the laterals constrict twice and form two layers of heads, one above the other. The main axis is generally short, and attachment is by means of a pedicle that is, however, frequently not preserved. Calcification generally occurs above and below the lateral heads. One new species, *Cyclocrinites welleri,* is described.

Lepidolites consists of one species only and is the most modified of all cyclocrinitids. The laterals are short, small, and calcified; their ends are modified and form overlapping plates.

The cyclocrinitids have been variously assigned by many authors to many groups, particularly as an appendix to the sponges. They are here considered a basal receptaculitid stock that possesses the simplest structures. They fill an important gap in the fossil record of Paleozoic algae.

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Acknowledgments

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FIG. 1. Map of North America showing the geographic distribution of cyclocrinitids.

Part I

Introduction

Cyclocrinitids include a group of small problematic fossils of general receptaculitid type that range from Lower Middle Ordovician to Upper Middle Silurian. They are relatively common fossils in North America and are very widespread in Quebec, in the Midwest (particularly around Cincinnati, Ohio, and in Eastern Iowa), and in the Appalachian region (fig. 1). There are few groups of fossils that have been moved from taxon to taxon more than the cyclocrinitids. They have been placed among protozoans, sponges, corals, bryozoans, molluscs, algae, and problematica. The question as to whether they are plants or animals has been asked many times; however, most invertebrate paleontologists consider them to be animals of an unknown phylum. Many of the cyclocrinitid genera have been placed as an appendix to Porifera in the American *Treatise on Invertebrate Paleontology,* volume E, Porifera (Laubenfels, 1955), and in the Soviet *Osnovy Paleontologii* (volume on sponges, Sushkin, 1962). Recently, isolated papers have been published that have considered the nature of individual specimens of cyclocrinitids and have assigned them to the algae.

The present study of the American cyclocrinitids reveals that they are, as here defined, algae, and that the Paleozoic fossils are so similar to certain species of modern calcareous algae that they can be easily included together in the family Dasycladaceae. Cyclocrinitids share many common characters with receptaculitids. The two groups differ mainly in the structure and calcification of the heads of the lateral branches.

The cyclocrinitid thallus is globular, sometimes elongated, often spherical and commonly button-shaped. Certain forms appear cup-shaped because they were incompletely calcified. In many individuals no attachment to the substrate is observed, in others "distinct" rhizomes are found.

The early Paleozoic record of plants is very poor. However, by comparison with the recent distribution of plants and animals, and by the requirement of food and oxygen the plants must have been relatively as abundant in the Paleozoic time as they are today. Vinogradov (1953, p. 17), estimates that "the total quantity of algae is estimated to be around n $\times$ 10^{15}g, excluding the phytoplankton . . . and including only those which become attached to different substrata in the sea . . . On the average, then, there are from 1 to 5 kg of algae in each square meter of such of the bottom surface as is occupied by these plants, and the total area they occupy is not smaller than n $\times$ 10^{11}m^2." The record of fossil invertebrates requires a vast abundance of plant material from the beginning of the Paleozoic Era.

Durham (1967) emphasizes that the incompleteness of the fossil record is due to the incompleteness of our knowledge of this record. The present paper presents a part of the record of fossil plants in the otherwise poorly known Lower Paleozoic, and thus fills in the great gap in the fossil record.

I. DISTRIBUTION

1. *Stratigraphy.* The stratigraphic distribution of cyclocrinitids is shown in Figure 2. The Cincinnatian genera *Lepidolites* and *Anomaloides* are known from single localities only and are thus stratigraphically restricted to Upper Ordovician. *Lepidolites* is from Eden (Southgate) and *Anomaloides* is from Maysville (Mt. Hope). The genus *Cyclocrinites,* however, has a wide stratigraphic range that extends from the Lower Middle Ordovician to the Upper Middle Silurian, a time span of approximately 80 million years. The oldest cyclocrinitid is *Cyclocrinites welleri* from the Lower Champlainian Mazourka Formation. *C. pyriformis* extends almost through the entire middle Champlainian series. It is reported from Lenoir Limestone, Holston Limestone, Ottosee Shale, and Chambersburg Limestone where it is used as an index fossil. *C. globosus* is found in the Upper Champlainian Ottawa Formation, and is common in Cobourg beds. Cincinnatian species are *C. darwini* from Maysville and Richmond groups (particularly Arnheim and Bellevue Shales), *C. spaskii* from Fremont, and *C. halli* from Ellis Bay Formations. *C. halli* may possibly extend into Becscie Formation. The Silurian species are *C. gregarius* and *C. dactioloides. C. gregarius* is found in Becscie and Gun River Formations, and thus in the entire Albion Series. *C. dactioloides* is exclusively Niagaran. However, the Niagaran stratigraphy is not adequately correlated from locality to locality, and therefore, often formations are not recognized. *C. dactioloides* has been reported from Hopkinton Dolomite and from Thorn Group, however, the Museum catalogs are generally labelled only Niagaran. When more collections of cyclocrinitids are available for study their range may possibly be extended. In the Soviet *Osnovy Paleontologii* (volume on algae, 1963) references are made to Carboniferous and post-Paleozoic cyclocrinitids.

2. *Geographic distribution.* The geographic distribution of cyclocrinitids in North America can be grouped approximately into five arbitrary assemblages (fig. 1). The first unit is represented by three localities of one species each, *C. welleri* from Inyo Mountains in

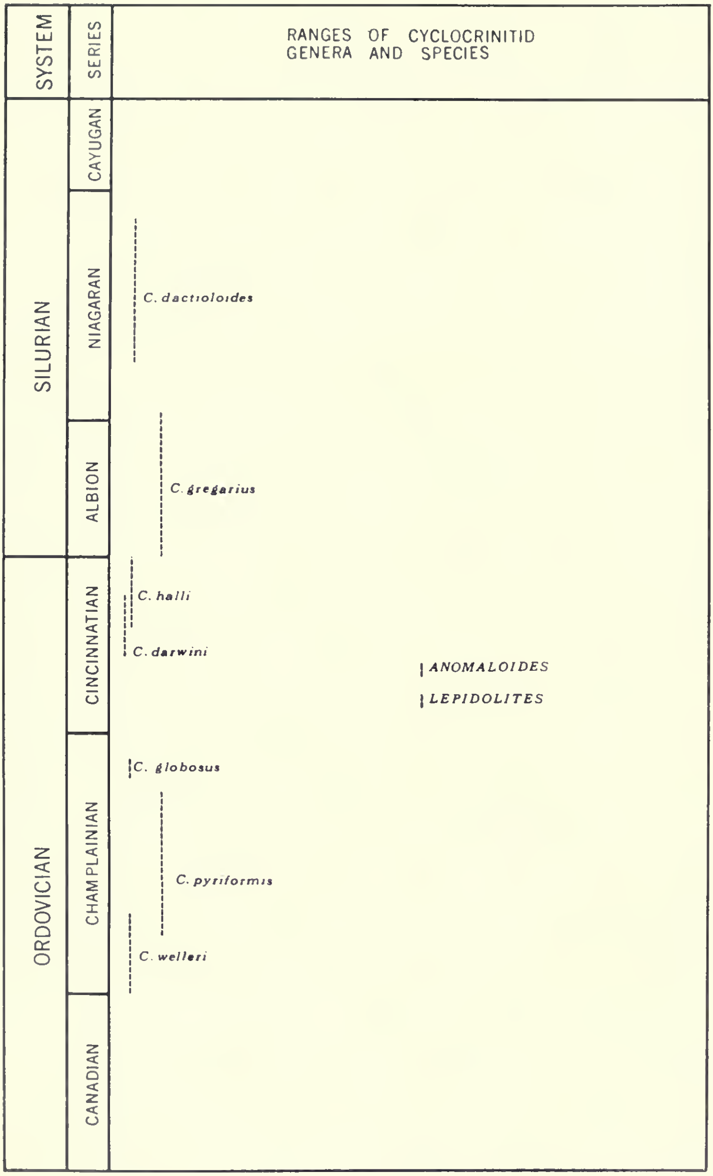

FIG. 2. Chart of stratigraphic distribution of North American cyclocrinitids.

California, *C. spaskii* from Canon City, Colorado, and undetermined *Cyclocrinites* from Bighorn Dolomite in Wyoming. The second assemblage consists of numerous Niagaran localities in the tri-state region of Illinois, Iowa, and Wisconsin and contains a single species *C. dactioloides*. The third group, the most abundant U. S. collecting site, consists of all three genera *Lepidolites, Anomaloides,* and *Cyclocrinites darwini* and the area is clustered around Cincinnati, Ohio. The fourth group consists of *C. pyriformis* which is found in a wide range along the entire geographic extent of Chambersburg Limestone from Pennsylvania to Alabama. The last assemblage comprises the wide spatial distribution of Canadian localities of *C. globosus, halli,* and *gregarius*. These fossils are found in Anticosti Island, in and around Ottawa City and on the shores of Lake Winnipeg, scattered around Lake Nipissing in Central Canada and in the Arctic on Southhampton Island.

II. CLASSIFICATION

1. *Receptaculitids.* Thirty-eight genera at various times have been assigned to receptaculitids. However, systematic study reveals that many of these are not receptaculitids and only 22 are considered a coherent taxonomic group. However, this number of genera Nitecki (1967) reassigned to the following six: *Anomaloides, Lepidolites, Cyclocrinites, Calathium, Ischadites,* and *Receptaculites.*

The number of species that have been assigned in the past to each genus is equally large. This proliferation of names is caused by the lack of detailed systematic study, and by the practice of basing descriptions of new species upon single specimens without comparative material. Thus in North America, 36 species have been assigned to the genus *Receptaculites* alone. The so-called species are mostly morphologic variants that were defined by difference of body shape and skeletal elements; however, the body shape and the skeletal dissimilarities are probably environmentally controlled. The individual species may have occupied more than one environment and thus morphologic variations resulted. In addition, the extent of preservation is dependent upon the degree of calcification of the skeleton. The calcification was variable, was probably seasonal and thus produced in the fossil populations numerous departures from a "typical" form. This further complicates their systematic interpretation.

Receptaculitids are here restricted to a taxon of marine, calcareous organisms that ranged from Lower Ordovician to Lower Middle Devonian. They are generally found in carbonate rocks, and are often associated with coral reefs; however, they were not true reef builders. One genus, *Calathium,* is associated with extensive bioherms of which it constitutes a main part.

By analogy with modern calcareous algae a main axis must have been present in most fossil species; however, it is very rarely preserved, presumably because it was seldom calcified; where present it is often short and robust, rarely branched. In larger species the main axis appears to have been absent. In most species the lateral branches are regularly arranged and borne in spirals on the main axis. They are of uniform size within the "whorl." In some species the laterals are completely calcified; however, in the majority only the termini of laterals are calcified. The termini of laterals are often modified into simple heads, or complicated structures which form an exterior wall.

The receptaculitids are easily divisible into two groups that are differentiated by the degree of calcification and by the complexity of lateral branches. Intermediate forms are present in both groups and give morphologic coherence to the receptaculitid taxon. The first group consists of the genus *Cyclocrinites* and its allies. The second group consists of *Calathium, Ischadites,* and *Receptaculites,* in which the calcification is very extensive and the laterals evolve complex supporting structures. The main axis may become reduced, and has disappeared altogether in certain larger species. *Calathium* is usually not completely calcified and thus forms cup-shaped thalli. Some calcified globular species are also found. The lateral head is rhombic and the number of supporting ribs is four. The tops of heads are calcified to form the exterior wall of the thallus. The main axis is short. *Ischadites* differs from *Calathium* in the length of the main axis, and in the complete calcification of the thallus. *Receptaculites* possesses the most complex skeleton. The lateral head is highly modified and the ribs supporting it are considerably increased in number. The main axis is reduced or absent. Certain North American receptaculitids reached a size of over one foot across, were hollow, and were probably filled with sea water.

2. *Cyclocrinitids.* Cyclocrinitids are characterized by simple lateral branches, by poor calcification of the thallus and by uncomplicated supporting structures of lateral heads. The morphological characters of the group are summarized in the key to the genera and in the key to the species of *Cyclocrinites* (Table 1). More species of cyclocrinitids have been named than is necessary. It is feared that in the present paper the number of species is also excessive, and that further reduction in names may be necessary. It seems that only three "good" easily definable taxa are present, namely, *Anomaloides, Cyclocrinites,* and *Lepidolites,* and that the so-called species of *Cyclocrinites* are but "morphospecies." The difficulties of classification of *Cyclocrinites* species are due to the variation of shapes of individual thalli that may be ecological, to the poor preservation, and to the uneven degree of calcification that differs even on the same specimen. Thus the criteria used, mainly the presence or absence of anatomical entities, may be in turn controlled by the above factors. For ex-

Table 1.—Key to genera of cyclocrinitids and species of *Cyclocrinites*. The key to the species is very theoretical.

Key to Genera

1.	Entire lateral calcified, without head	*Anomaloides*
1.	Lateral head forms	2
2.	Lateral head globular, regular	*Cyclocrinites*
2.	Lateral head modified, overlapping	*Lepidolites*

Key to the Species of *Cyclocrinites*

1.	Laterals branched	*welleri*
1.	Laterals unbranched	2
2.	Double lateral head	*dactioloides*
2.	Single lateral head	3
3.	Stellate structure present	*darwini*
3.	Stellate structure absent	4
4.	Calcification below and above lateral heads	*globosus*
4.	Generally only one calcified layer	5
5.	Entire main axis weakly calcified	*pyriformis*
5.	Entire main axis not calcified	6
6.	Distal end of lateral weakly calcified	*gregarius*
6.	Distal end of lateral not calcified	7
7.	Mucilaginous membrane, ornament hair and terminal orifice present	*halli*
7.	Only ornament present	*spaskii*

ample, the stellate structures may have been present but are not preserved in *C. globosus* and in *C. gregarius;* the same may hold true for branchings of laterals, and presence or absence of second layer of lateral heads. It seems possible that in North America *Cyclocrinites* may be, in reality, represented by one or two species only.

Previous Major Publications

I. EUROPEAN

The first cyclocrinitid was described by Eichwald in 1840 under the name *Cyclocrinites spaskii.* The specimens apparently came from Ordovician rocks near Tallinn, Estonia. The systematic position of *Cyclocrinites spaskii* and other related genera was uncertain until the publication of Stolley's (1896) monograph on *Coelosphaeridium, Cyclocrinus, Mastopora,* and *Apidium.* Stolley described these genera in detail and placed them among algae. Stolley did not study but only listed the American representatives of the group; however, he considered *Pasceolus* a synonym of *Cyclocrinus,* and *Nidulites* a synonym of *Mastopora.* It is a puzzle why this work remained virtually unknown to American paleontologists.

The most influential paper on fossil algae is that of Pia (1927) who placed a number of fossil genera in the Dasycladaceae (Siphoneae verticillatae). The fossils that are revised in the present work Pia had arranged in the tribe Cyclocrineae, in which he included *Coelosphaeridium, Mizzia, Cyclocrinus, Mastopora, Apidium,* and *Epimastopora.* Pia followed Stolley in considering *Pasceolus* a synonym of *Cyclocrinites,* and *Nidulites* a synonym of *Mastopora.*

Wood (1943) assigned the Carboniferous *Koninckopora* to the Cyclocrineae as a sub-family.

Currie and Edwards (1943) described Ordovician *Mastopora parva* and Silurian *Mastopora fava* as dasycladaceous algae from Girvan district of Scotland. They briefly compared *Cyclocrinites* with other algal genera.

The most recent foreign works are two volumes of the Russian treatise on paleontology, *Osnovy paleontologii,* Korde (1963) on algae, and Sushkin (1962) on receptaculitids (in volume on sponges). In the algal volume the general outline of classification of Pia is followed. The tribe Cyclocrineae includes the following genera: *Cyclocrinus, Coelosphaeridium, Mastopora, Mizzia, Kopetdagaria, Ovulites, Koninckopora, Epimastopora,* and *Unjaella. Nodulites* [sic] is considered a synonym of *Mastopora*. However, in the Soviet volume on sponges *Cerionites, Lepidolites, Nidulites, Anomaloides,* and *Pasceolus* are included as non-Russian genera in the family Receptaculitidae, which in turn is placed in the class Squamiferida. Squamiferida are considered *incertae sedis* of phylum Porifera.

Little discussion of American species is available in foreign literature.

II. NORTH AMERICAN

This is the first monograph on American cyclocrinitids. Over 100 titles exist that deal with some aspect of North American cyclocrinitids. These, however, are mostly stratigraphic or faunal lists, or summary reports. The paleontological papers concerned with cyclocrinitids, with few exceptions, either summarize previous work or consider cyclocrinitids to be invertebrate animals.

The first American cyclocrinitid from the midwest Niagaran series in Eastern Iowa was described and illustrated by D. D. Owen in 1844 as *Lunulites dactioloides.* No assignment to any group was made; however the fossil was illustrated on a plate containing corals only. The genus *Pasceolus* was first described by Billings (1857) and two species, *halli* and *globosus,* were illustrated. These were considered to be perhaps tunicates. Meek and Worthen (1868) named a new genus *Cerionites* to include *Lunulites dactioloides.* A great number of short papers followed in which either new species of *Pasceolus* were named, or occurrences were listed from various Canadian and American localities. Most of the authors of these papers were not certain of the taxonomic position of fossils and included them as *incertae sedis* among sponges or protozoans.

Twenhofel (1928) was the first North American author who referred to Stolley's (1896) work, and who considered *Pasceolus* an alga identical with *Cyclocrinites.* Twenhofel's recognition of the nature of cyclocrinitids went unnoticed until Elias (1947) published a paper on Late Permian algae from Texas which he compared with *Mastopora (Nidulites) pyriformis* Bassler, an Ordovician fossil from Appalachia.

In Laubenfels' *The Treatise on Invertebrate Paleontology* (1955), the volume on sponges, however, cyclocrinitids are treated as receptaculitids of an uncertain group, and are placed as an appendix to sponges. Unfortunately, in this volume certain dates of publication, stratigraphic, and geographic position, spelling of names, synonyms, interpretation of anatomy, references, and illustrations are erroneous.

Osgood and Fischer (1960) are the only American authors who deal exclusively with Ordovician cyclocrinitids; they consider them algae. *Mastopora pyriformis* is figured as dasycladaceous alga, and a central vesicle and supposed gametocysts are illustrated.

Griefe and Langenheim (1963) placed a specimen of *Mastopora* among the Dasycladacea. However, most other authors during this period did not consider them algae. The detailed history of numerous papers dealing with American cyclocrinitids is given in the annotated bibliography at the end of this paper, and selected more important descriptions are included in Part III.

Morphology

I. DESCRIPTION

1. *Terminology.* No consensus of opinion exists with respect to the anatomical terms applied to these organisms. When cyclocrinitids are placed among Porifera then the calcified parts are considered spicular and the terms are those of sponges. When, on the other hand, the taxon is referred to algae the botanical terminology is used. Unfortunately, no uniform botanical terminology exists; for example, the main axis is often referred to as central vesicle, central axis, or central body. The terminology is even more confusing when descriptions of calcified parts are made. The terminology of anatomical terms used in the present paper is a modification of that of Taylor (1960) and Fritsch (1948). Only one term is used for each individual morphological character. Taylor's axial cell and branchlets are here called main axis and laterals.

2. *Thallus.* In all cases the thallus is simple and unbranched. It is impossible to say whether it is unicellular, multicellular, or coenocytic. The thallus is differentiated only into upper, apical, and lower, basal, parts. Little differentiation into a root is present. The shape of the thallus varies from species to species and even within species. Different shapes of thalli are represented in Figure 3. It appears that certain of these shapes are genetically controlled, but many appear to be ecological variations. The fossils are of three basic shapes, pyriform (fig. 3A), globular (fig. 3E), and cushion-like (fig. 3D). The variations of these are an elongate shape (fig. 3H), club shape (fig. 3G), and miscellaneous shapes (fig. 3B, C, F). The pyriform specimens may have been attached by the narrow end, the cushion-shaped generally have flattish bottoms, and the globular forms may or may not have an attachment pedicle.

3. *Main axis.* The main axis is only rarely preserved in cyclocrinitids. Its preservation is dependent upon unusual circumstances of deposition, upon early diagenetic replacement, and upon the rare probability of calcification. Examination of a large number of cut

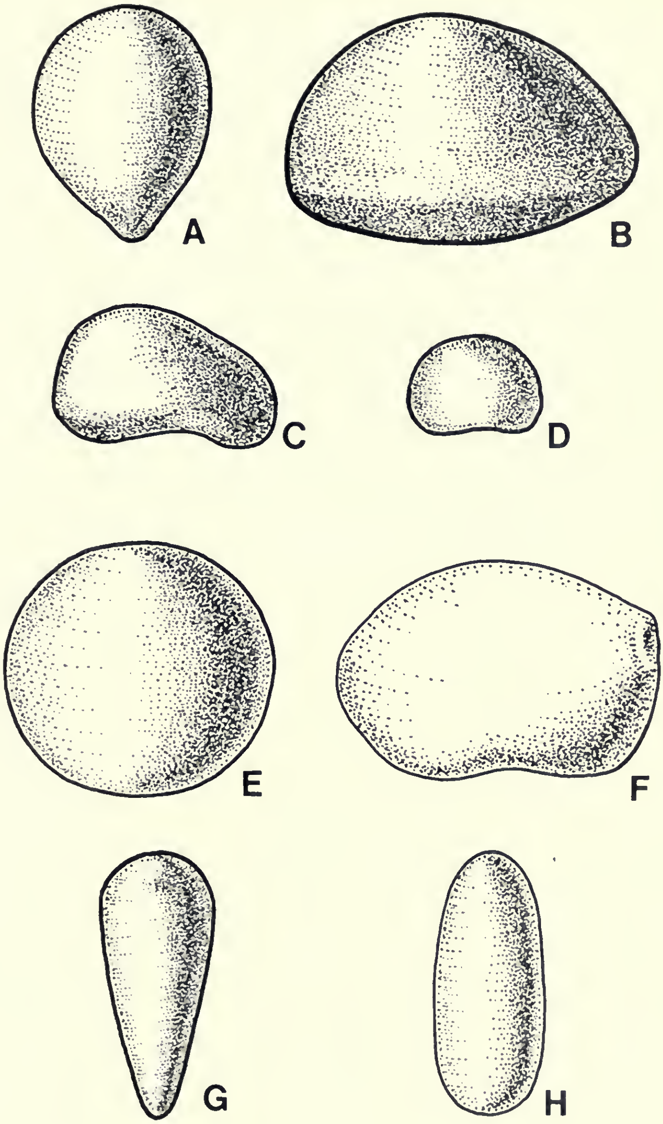

FIG. 3. Diagrammatic representation of the shapes of eight different thalli of cyclocrinitids. A, *Cyclocrinites halli* × 1; B, *C. globosus* × 1; C and D, *C. gregarius* × 1; E, *C. spaskii* × 2 and *C. dactioloides* × 1; F, *C. darwini* × 2; G, *C. pyriformis* × 1 and H, *Lepidolites dickhauti* × 2. All illustrations based on actual specimens.

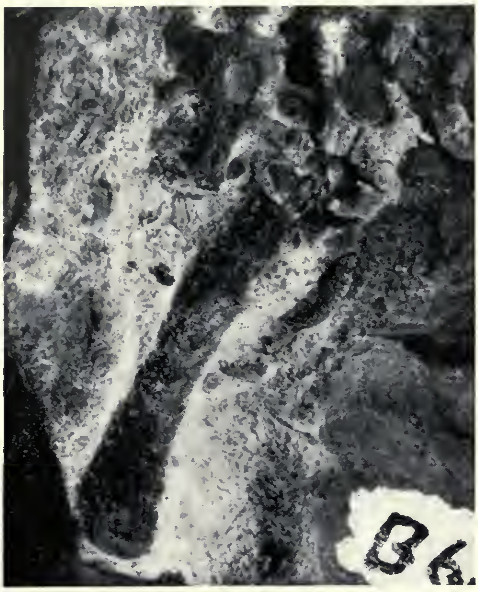

FIG. 4. *Cyclocrinites welleri* n. sp. Holotype. Univ. Calif. Mus. Paleont. 30720. Mazourka Formation, Independence Quadrangle, California. Elongated stem and scars of laterals are preserved. × 2.8.

and polished surfaces of cyclocrinitid specimens revealed very few central structures. The microprobe analysis of one specimen of *Cyclocrinites darwini* from Maysville, Kentucky, revealed a small central core. In only two lots of specimens are the main axes preserved. One is a single specimen of *Cyclocrinites welleri* from the Mazourka Formation of California, and the other is *Cyclocrinites pyriformis* from the Appalachian region. These reveal that the main axis is a rod-like, apically expanding, unbranched structure. The main axis of *Cyclocrinites welleri* is shown in Figures 4 and 5. In this species the laterals branched, and the primary branches are preserved in the form of short rods that are clustered in whorls.

In *Cyclocrinites pyriformis* the main axis is elongated, straight, and unbranched (fig. 6). It is assumed that the main axis was bulging at the end. Cross-sections of the thallus show remnants of the tubular, weakly calcified main axis.

However, no general description of the main axis can be given that would satisfy all cyclocrinitids. It is possible, for example, that *Anomaloides* was a hollow plant in the manner of the recent *Codium mamillosum* which lacks the main axis altogether.

4. *Laterals.* Laterals, or lateral branches, are the first set of structures arising from the main axis. In all but two species, *Anomaloides reticulatus* and *Cyclocrinites welleri,* the laterals are unbranched, and thus of the first order only. The interpretation of small, thin structures at the ends of laterals is difficult to make. Thus the threads in *Anomaloides* are considered second-degree branching, although they are thin rib-like projections. On the other hand, the stellate structures supporting the lateral heads of *Cyclocrinites darwini* are not considered secondary branches, because they form at the bases of lateral heads.

The laterals in *Anomaloides reticulatus* and *Cyclocrinites welleri* branch into the second order. In *Anomaloides* three secondary laterals are formed, while in *Cyclocrinites welleri* only two. The diversity of laterals is shown in Figure 7. In only two examples is the attachment of laterals to the main axis known, namely, in *Cyclocrinites welleri* and *C. pyriformis.* Only in one species, *Anomaloides reticulatus,* are the laterals observed in their entire length. It is assumed that in most cyclocrinitids the laterals are similar

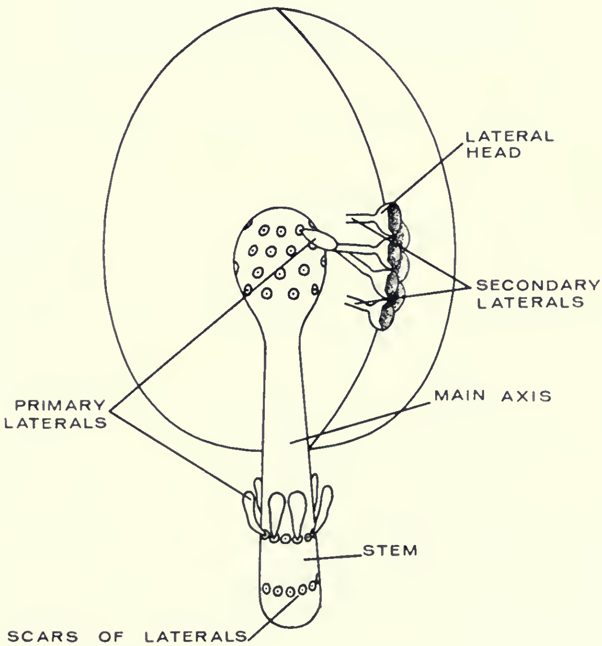

FIG. 5. Diagrammatic reconstruction of the thallus of *Cyclocrinites welleri* n. sp. The number of laterals is greatly reduced for the sake of clarity.

to those of *C. pyriformis* (fig. 8). The preserved laterals and their scars upon the main axis leave no doubt that laterals were arranged in whorls, and were not randomly distributed as was assumed by Pia (1927).

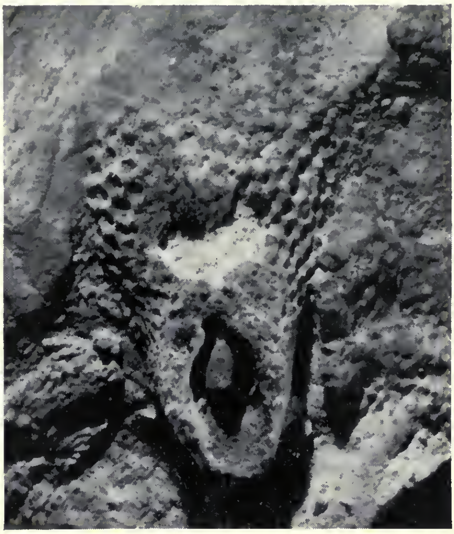

FIG. 6. *Cyclocrinites pyriformis* (Bassler). USNM 111806. Ward Cove, Staffordsville, Giles Co., Va. Elongated, straight main axis is preserved. × 3.

The laterals are numerous, and their termini are calcified, therefore the calcified lateral heads constitute the main characters used in the systematic revision. Each head lies against alternate heads in the adjoining rows and forms a pattern of lines upon the surface of the thallus strongly suggesting that the laterals, although borne in whorls, are also arranged in a helix.

All laterals within the whorl are of the same size; they are however shorter toward the apex and the base of the thallus. The older laterals are probably shed away as is noted in one species, *Cyclocrinites welleri*. The lateral heads are generally calcified below, and often above, and thus form a continuous cortex around the thallus. This calcified zone limits the communication of the plant with the outside, and forms an external calcified layer.

5. *Facet*. The facet is a thin polygonal calcified structure. In the genus *Cyclocrinites* the term facet is restricted to the smooth, generally very concave area of the base of the lateral head (figs. 9, 10). It is generally circumscribed by six walls, and is often

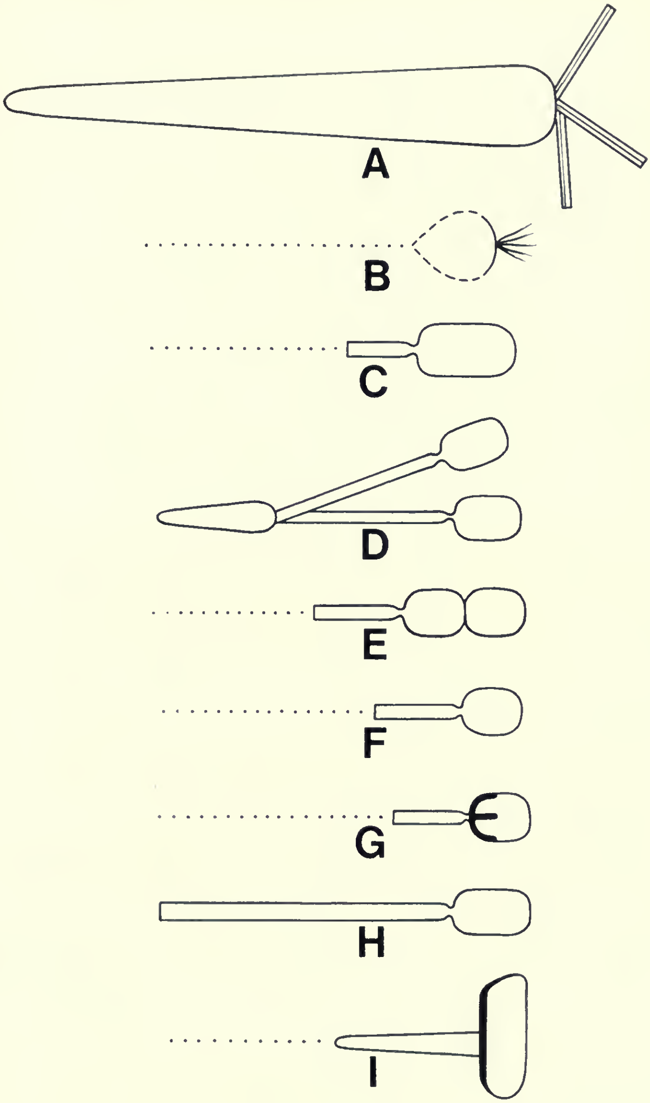

FIG. 7. Diagrammatic representation of nine different lateral branches of cyclocrinitids. Not to scale. A, *Anomaloides reticulatus* Ulrich; B, *Cyclocrinites halli* (Billings); C, *C. globosus* (Billings); D, *C. welleri* n. sp.; E, *C. dactioloides* (Owen); F, *C. spaskii* Eichwald; G, *C. darwini* (Miller); H, *C. pyriformis* (Bassler); I, *Lepidolites dickhauti* Ulrich.

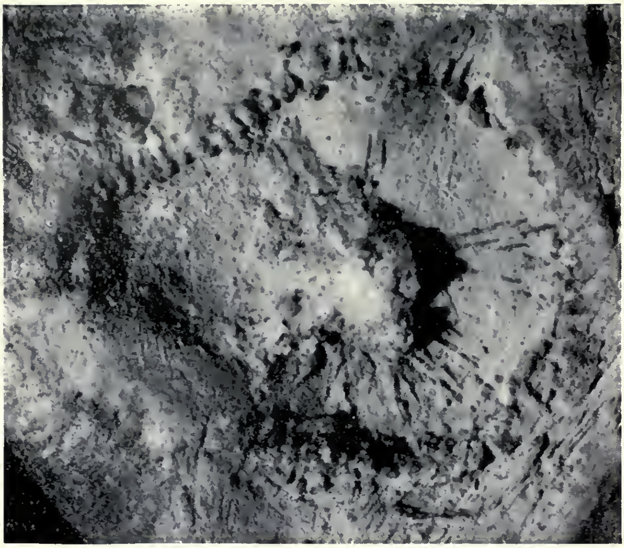

FIG. 8. *Cyclocrinites pyriformis* (Bassler) USNM 111806. Ward Cove. Staffordsville, Giles Co., Va. Lateral branches and lateral heads are preserved. × 2.5.

perforated in the middle for attachment to the lateral. The facets are the most calcified area of the plant, and commonly form a continuous calcareous envelope around the thallus.

6. *Lateral heads.* The term "head of the branch" is analogous to *cortical cell* of recent algae. However, the term "head" is here preferred because it does not imply or refer to the cellularity of organs. The lateral head is formed by the terminal dilation of a lateral, and is present in all cyclocrinitids with the exception of *Anomaloides reticulatus* (fig. 7A).

In the genus *Cyclocrinites* it is a globular body, sometimes supported by ribs (*C. darwini*); generally, however, without supporting structures. In *C. dactioloides* two heads form one above the other. In *Lepidolites* the heads are modified to form an imbricating plate-like structure (fig. 11).

7. *Attachment.* The attachment in the majority of cyclocrinitids is not preserved. In the instances where the attachment organs are preserved, as in *Cyclocrinites darwini, C. spaskii, C. welleri,* and *Lepidolites dickhauti,* they consist of an extension of the main axis and its modification into a stem. In *C. darwini, C. spaskii,* and *Lepidolites dickhauti* they probably consist of a short pedicle (figs.

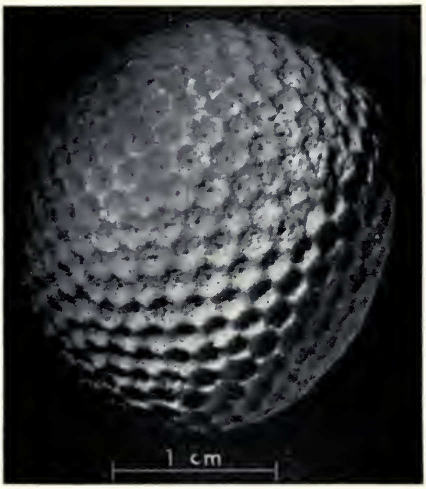

FIG. 9. *Cyclocrinites dactioloides* (Owen). FMNH P11020. Niagaran, Clinton, Iowa. Apical view showing facets and central perforations representing the lateral branches. × 3.

12–15), while in *C. welleri,* which has the only known well-preserved attachment structure, it is a relatively elongated stem (figs. 4, 5).

Thalli of such forms as *C. halli, C. pyriformis,* and *Anomaloides reticulatus* gently taper toward the base and are approximately club-shaped. Their attachment is assumed to have been similar to the rhizoid stems present in some recent forms. The cushion-shaped specimens may have been modified to the habit of "just sitting down" on the substrate, and hence probably possessed a rudimentary stem or no stem at all. It is possible that they had a mucous membrane that allowed for adherence to the substrate.

In the spherical forms the attachment was "a point" attachment, or no attachment at all. Some of these forms could roll gently in the manner of recent algae, only to be in some instances fastened down by a short pedicle as present in *C. spaskii.*

8. *Stellate structure.* A stellate structure occurs in one species only, *Cyclocrinites darwini* (figs. 7g, 16, 17). It consists of four, five, or six ribs that support and hold the lateral head. They are now preserved as radiating grooves on the facets. The ribs originate in the point of dilation of the branch, and radiate away from the lateral toward the corners of the facet, thus presenting a very regular pattern. The stellate structures are observed on few facets, but when present are very distinct features.

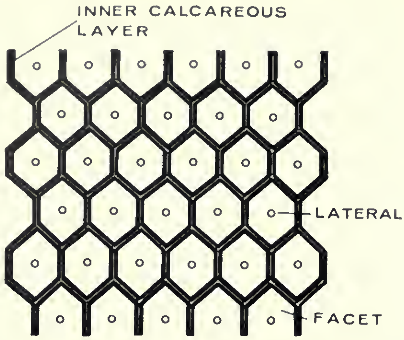

FIG. 10. Diagrammatic representation of the faceted surface of *Cyclocrinites dactioloides* (Owen).

The commonest arrangement of the stellate structure consists of one rib connecting with each corner of a facet. Since the most common facet is six-sided, the stellate structure with six ribs predominates. However, four-ribbed structures are noted in six-sided, as well as in four-sided facets. Rarely are five-ribbed structures found.

9. *Rosette.* In general, each lateral is in contact with six other laterals. This arrangement causes regular packing of lateral heads and of facets. Thus most surfaces exhibit a regular arrangement of six-sided facets whose walls produce regular intersecting lines upon the surface of the thallus. However, irregularity of distribution of laterals causes irregularity of distribution of lateral heads. This irregularity disrupts the common pattern of six-sided laterals and the resulting facets are in contact with four, five, seven, or eight other laterals. When eight laterals thus surround a single lateral

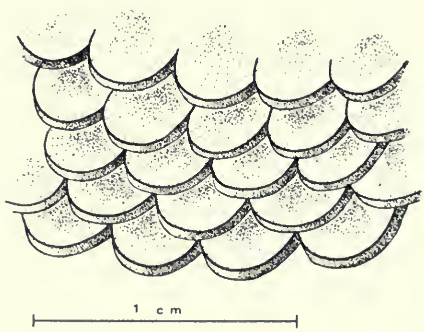

FIG. 11. Diagrammatic representation of the overlapping character of "plates" in *Lepidolites dickhauti* Ulrich. The plates are considered a modification of cyclocrinitid lateral head.

FIG. 12. *Cyclocrinites darwini* (Miller) FMNH UC 44909K. Maysville, Maysville, Ky. Scar of pedicle attachment is preserved. × 2.

FIG. 13. *Cyclocrinites spaskii* Eichwald. Univ. Mich. Mus. Paleontol. 21104. Fremont Fm., Canon City, Colo. Scar of pedicle attachment is preserved. × 3.

FIG. 14. *Lepidolites dickhauti* Ulrich (=holotype of *L. elongatus* Ulrich). USNM 46533, Eden, Covington, Ky. Scar of pedicle attachments is preserved.

a rosette forms (fig. 18). This rosette is not an area of attachment of the plant, neither does it have any anatomical significance except that it manifests the irregularity of distribution of laterals. Paradoxically, only when very regular surfaces are observed are these rosettes found.

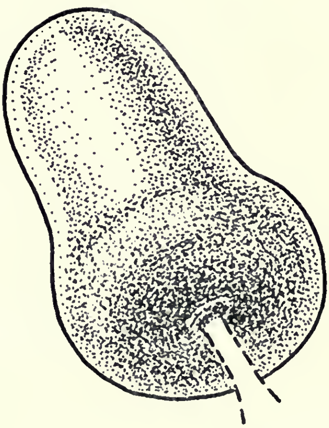

FIG. 15. Diagrammatic reconstruction of the thallus of *Lepidolites dickhauti* Ulrich. The basal part shows the assumed attachment mechanism.

FIG. 16. Reproduction of Foerste's (1914) figure of "*Pasceolus globosus*," showing stellate structures. This species is now referred to *Cyclocrinites darwini* (Miller).

10. *Membrane.* The membrane is very rarely preserved. It has been seen in *Anomaloides reticulatus* and in *Cyclocrinites halli*. The membrane of recent forms is mucous, thin, transparent, and relatively tough. The holotype of *Anomaloides reticulatus* appears to be covered with a thin membrane. It is impossible to say at the present time what is the nature of this membrane. It does appear as a somewhat shrunken vitreous "skin" and may have been formed by a calcification among the laterals of the second order, or it may

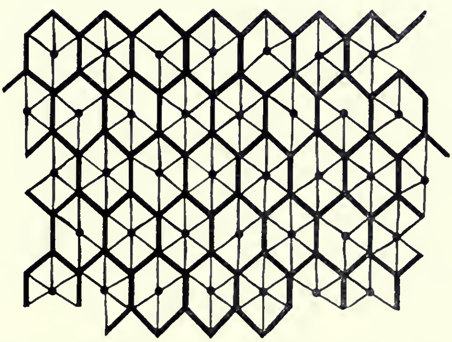

FIG. 17. Diagrammatic reproduction of stellate structures of *Cyclocrinites darwini* (Miller).

FIG. 18. *Cyclocrinites dactioloides* (Owen). FMNH UC 23760. Niagaran, Clinton, Iowa. The lateral head, rosette, and thickness of calcified zone is preserved. The rosette is outlined in ink.

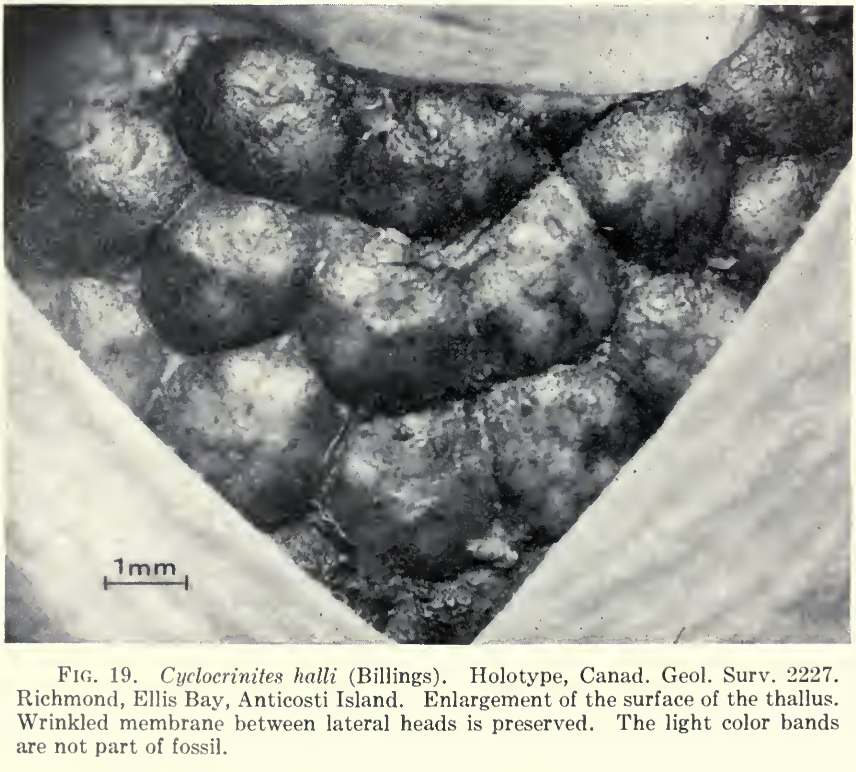

FIG. 19. *Cyclocrinites halli* (Billings). Holotype, Canad. Geol. Surv. 2227. Richmond, Ellis Bay, Anticosti Island. Enlargement of the surface of the thallus. Wrinkled membrane between lateral heads is preserved. The light color bands are not part of fossil.

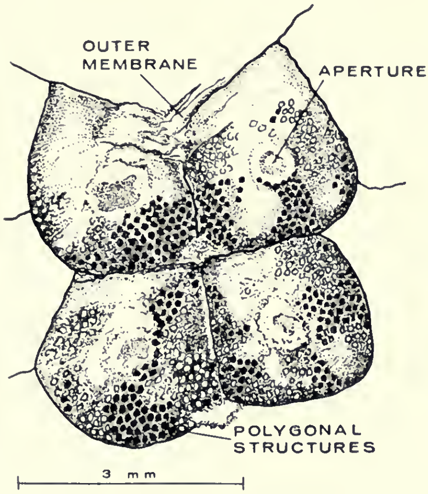

FIG. 20. Diagrammatic representation of four lateral heads of *Cyclocrinites halli* (Billings) shown in Figure 19, and the relation of polygonal structures, outer membrane, and aperture is shown.

represent a mucilaginous membrane, such as that of the recent *Codium mamillosum*.

In the holotype of *Cyclocrinites halli* the mucous membrane is better preserved than in other specimens of this species and is a very thin, almost net-like calcareous translucent layer (figs. 19, 20). It appears that the membrane forms a complete envelope around the thallus. It is wrinkled in places, particularly between the edges of the lateral heads where it is considerably thicker. The membrane is transparent, of waxy texture, and of horny color. It contains a large number of small inclusions (on one facet more than 100 were counted). The inclusions are generally very dark, almost black; however, a few are of a lighter color than the surrounding light brown membrane. The inclusions are oriented in a regular manner, forming lines that intersect each other. The orientation seemed to have originated from the central area of the facets.

The chemical nature of the membrane is unknown. It has the appearance of a mucilage that is common throughout the plant kingdom, and that often occurs among algae. Its function is assumed to have been the prevention of the diffusion of body substances into the outside. It may also have served as a means of attachment for the alga, a common behavior among recent forms.

II. CALCIFICATION

1. *Chemical composition of skeleton.* The state of preservation of cyclocrinitids indicates that they possessed a rigid supporting skeleton. Chitin is a frequent skeletal tissue of many groups of invertebrate animals, but is absent in algae. Cellulose, on the other hand, together with pectin, is a common tissue among plants and forms covering layers of skeletal elements. Cellulose is rarely preserved in the fossil record though, and the cyclocrinitid skeleton most likely was inorganic. However, only a limited number of mineralogical forms can exist. Recent siliceous skeletons are of a highly dehydrated form of opal or quartz. Among plants these are found only in the skeletons of certain flagellates and diatoms, while other forms of silica are observed in bacteria, diatoms, and some representatives of pteridophytes and angiosperms (Vinogradov, 1953). Silicified cyclocrinitids are rare and no original siliceous material is observed. Vinogradov shows that many algae concentrate $MgCO_3$, but he states further that these Dasycladaceae that concentrate $CaCO_3$ contain little magnesium or only traces. It therefore appears that the skeleton of cyclocrinitids was not organic, siliceous, or magnesium carbonate. It must have been composed of $CaCO_3$, as is also strongly suggested by comparison with recent plants.

2. *Nature of calcium carbonate.* All organisms extract inorganic salts from their environments and concentrate them in their bodies. Calcium in the form of calcium carbonate is a common constituent of living organisms. However, it is not always concentrated in skeletal structures. In the majority of chemical analyses on recent algae no information on the nature of the mineralogy is readily available. Thus, it is difficult to find out whether dasycladaceous algae are calcitic or aragonitic. The X-ray analysis (Edward Olsen, personal communication) on one specimen of *Cymopolia barbata* from Dry Tortugas, Florida, indicates that it was aragonitic, and no trace of calcite was detected. No more analyses were run.

Vinogradov (1953, p. 67), who admits the incompleteness of the analyses of the recent Dasycladaceae, points out that the walls of *Acetabularia* are incrusted with $CaCO_3$. He further states that the microscopic studies indicate the presence of $Ca(COO)_2$ together with $CaCO_3$, P_2O_5, magnesium, iron, and manganese. Aragonite is concentrated in *Acetabularia mediterranea,* the only species studied in greater detail. No information is available in the literature as to whether dasycladaceous algae precipitate predominantly calcite or aragonite.

In the cyclocrinitid group only a few specimens of *Cyclocrinites halli,* and one specimen of *Anomaloides reticulatus,* are found that can be *definitely* considered to have been calcitic. Most other specimens of cyclocrinitids examined are either casts or molds. The nature of the original skeletal material cannot be determined with certainty; however, the absence of good preservation is suggestive of an aragonitic rather than a calcitic character. Calcitic skeletons, because of their more stable nature, are better preserved than the thermodynamically unstable aragonite. It is, of course, possible that $CACO_3$ was originally in an amorphous form.

3. *Comparison with recent forms.* In some recent forms (Vinogradov, 1953) the precipitation of calcium carbonate is seasonal, and its concentration varies during the year. If this condition was present in cyclocrinitids during the active period of precipitation the accident of mortality would have then produced better preserved specimens than when the burial occurred during the time of resorption of calcium carbonate. The uneven preservation of different specimens may be thus due to the seasonal differences that cause the varied degrees of calcification.

Church (1895), who discusses the calcification of *Neomeris dumetosa,* states that at first the apex does not calcify, but that the calcification begins below the growing point in the form of a fine precipitate of calcium carbonate. As the plant grows the calcification becomes more pronounced, and particularly the areas just under the dilated ends of the laterals form a continuous calcareous jacket. The main axis, the growing point and the filamentous parts of the laterals do not calcify.

Calcification in the cyclocrinitid group is very weak, possibly only a thin film or a somewhat thicker cortex. Preservation of the main axis, or of the attachment mechanism is rarely observed. Calcification concentrates in a few areas: (1) at the termini of lateral branches, (2) on the base and exterior of the lateral heads, and (3) in *Anomaloides* along the entire extent of lateral branches.

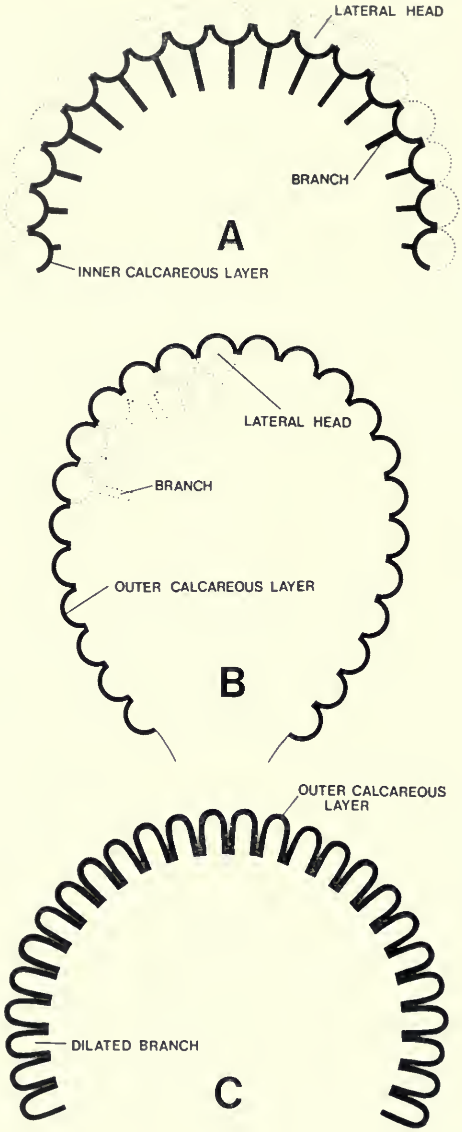

FIG. 21. Diagrammatic sagittal sections through thalli of different specimens of cyclocrinitids, reconstructing the manner of deposition of calcium carbonate. Dark, heavy lines represent the observed anatomical structures, the dotted lines the assumed or weak calcification, the shaded areas represent observed interlateral calcareous layer. A, Mode of calcification particularly common among *Cyclocrinites gregarius* (Billings), *C. darwini* (Miller), and in proximal heads of *C. dactioloides* (Owen); B, *Cyclocrinites halli* (Billings); C, *Cyclocrinites spaskii* Eichwald;

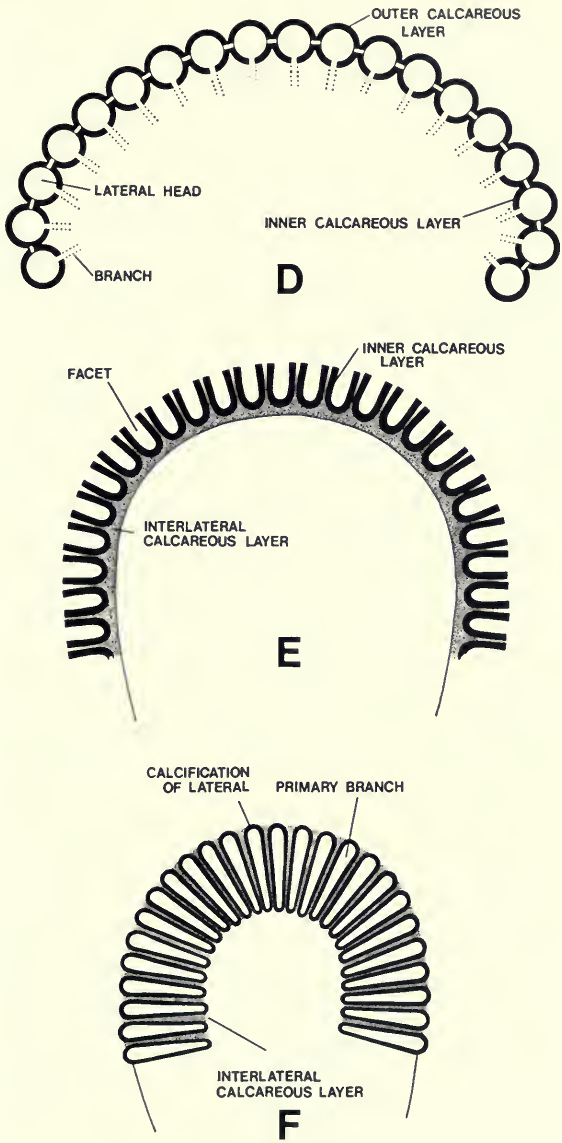

FIG. 21.—*Continued.* D, Calcification commonly found among *Cyclocrinites globosus* (Billings). There are two zones, upper and lower, that can detach easily and produce an effect of one; E, *Cyclocrinites pyriformis* (Bassler) and *C. welleri* n. sp. A heavy interlateral carbonate layer is laid down below the lateral head; F, *Anomaloides reticulatus* Ulrich. The entire primary branch is calcified in addition to the interlateral calcareous layer.

4. *Mode of calcification.* The common form of calcification is represented in Figure 21A where the calcification occurs at the termini of the lateral branches and at the bases of the lateral heads, along the facets. This preservation is very frequent, but not exclusive, among specimens preserved in Niagaran dolomite. In the past the remnants of the termini of lateral branches were referred to as "openings" or "pores" leading toward the interior of the organism. The concavities formed by the precipitation of carbonate on the interior of the facets, and left over after the removal of the dilated branches were referred to as "cells." In some forms the subsequent recrystallization produced a slight protuberance in the middle of the facet and thus further complicated the pattern of preservation and the interpretation of their nature. The dotted lines represent the reconstruction of the termini of the lateral branches. This reconstruction is based on comparison with specimens that exhibit the "filled in" facets. Thus, the specimens exist that probably had an additional calcification on the exterior. Such forms are rare, and generally only few "filled in" facets are found on any one thallus. The lateral branches are drawn only as long as are observed. In life, they probably extended much further to the interior. The main axis may have been very small.

Figure 21B depicts the condition of calcification where a thin film of $CaCO_3$ is deposited on the exterior of a thallus. This condition allows for the best preservation of most of the external structure; it is, however, very rare. Only one species, *Cyclocrinites halli*, is thus preserved.

Figure 21C represents a modification of the conditions shown in Figure 21B. However, the calcification along the edges of dilated lateral branches is more extensive, and includes the greater part of the heads of the branches. The specimens on which this illustration is based are almost all casts. The unusually elongated termini may be due to the post-depositional alterations. Nevertheless, all gradations in shapes and lengths of the dilated parts of the branches are observed. Figure 21C shows the conditions of very elongated lateral ends, however, in most species of *Cyclocrinites* these structures are much shorter. This group includes mostly spherical individuals and only a few cushion-like or flat bottom forms, and is best represented by *C. spaskii* from the Fremont Formation of Colorado.

Figure 21D shows schematically the condition of calcification on both the inner and outer walls of the lateral head. This calcification is seldom present on a large part of the thallus and generally only small portions of the plant are thus preserved. It is possible that this condition was more common during the life of the plant, but was not often preserved. In Figure 21E the calcification occurs along the outer parts of the lateral heads. The tops of the lateral heads are not calcified and hence the deep facets result. This condition is represented by *Cyclocrinites pyriformis* and *C. welleri*, where additional precipitation of carbonate occurs among the laterals below the heads. This method of calcification provides for more stable thalli, and a relatively thick calcareous layer is found under the lateral heads. Figure 21F represents the unusual calcification that occurs in one species, *Anomaloides reticulatus*; here the entire length of the primary branch is calcified. In addition, an interlateral calcareous layer is deposited among the laterals.

These six illustrations represent the six types of inferred calcification; it must be remembered, however, that gradation of calcification is very frequent, and that no one form is restricted exclusively to any one fossil population. An even more striking observation is that one individual may exhibit more than one type, or modification of it. In general, however, the spherical forms tend to be incrusted uniformly throughout the thallus, while cushion forms seem to have been calcified only on their convex upper surfaces. Nevertheless, some cushion forms are recognized in which calcification is present all around the body. Whether these were spherical forms later compacted cannot be determined.

The calcification begins on the strands of fine filaments (ribs or II degree laterals) at the termini of laterals, and along the ridges of the lateral heads, thus forming fine films, facets, and outer walls of lateral heads. Calcification was possibly a physiological adaptation that freed the plant from the mechanism of osmoregulation, or aided it in keeping the body sap and protoplasmic material on the inside.

Because the facets and associated calcification in the cushion forms are absent in the lower part of the thallus, it is assumed that carbonate was not deposited in that area. However, calcification may have occurred there but was subsequently resorbed or removed and this represents a process of aging. Such an explanation would alter the interpretation of ecology and perhaps systematics. It is still easier to assume that calcification and the formation of facets occurred only in an area in direct contact with water, and that parts resting on a substrate did not calcify.

III. GROWTH

1. *Main axis.* The lateral branches begin their growth on the main axis, and therefore the general shape of the plant and its growth are controlled by the shape and growth of the main axis. There is no indication among cyclocrinitids that the main axis ever branched; therefore its growth consisted only of an increase in length and diameter. The nucleation of growth by comparison with recent plants must have been apical.

2. *Growth pattern.* The growth pattern of cyclocrinitids is difficult to reconstruct, because of the generally incomplete and weak calcification. Variation within the group is noted; for example, some forms exhibit growth pattern apparently manifested by a regular increase in size, while other forms display a capricious pattern. Thus some young oval organisms when mature become pyriform, conical, rugged, and, in general, asymmetrical.

In *Cyclocrinites halli* new laterals may have formed at intervals along the tip of the main axis. As the growth increased the branches formed regularly. In *Anomaloides* the laterals are well oriented and the branches appear in distinct circlets or whorls that are parallel to each other. However, the base and apex of the plant are not preserved. In *Cyclocrinites dactioloides* the arrangement of facets form lines that are at about 45 degrees to the position of the main axis, and thus perhaps imply the growth pattern winding around the main axis.

3. *Arrangement of facets in C. dactioloides.* The regular and beautiful arrangement of cyclocrinitid facets has been noted by many authors, and has been compared to the "engine-turned ornament of a watch." This pattern is characteristic of all receptaculitids, and is particularly well developed in *Cyclocrinites dactioloides.* The facets form lines of incomplete spirals radiating from one to another central position of an organism, from the base to the top. The facets are closely packed, and it is their proximity that causes their shapes to be hexagonal or occasionally quadrangular. Each side of a facet forms a fraction of a line that when complete forms the

quasi spiral. Each line in turn, is parallel to another line formed by the joining of fractions made by contact of opposite side of the facet. This spiral arrangement of facets indicates that the addition of new facets (reflecting the addition of new branches) was also spiral. This means that a new branch was added at the top of the main axis in a position slightly up and to the side of the previous branch.

The spiral addition of new laterals and seeming arrangements of branches in whorls is seen as a compaction and packing of laterals into whorls, that in reality are but a compressed helix, which when interrupted forms circlets. Helix by definition winds around the cylinder, and the main axis can be considered a cylinder away from its initial growing point where it was probably a cone.

The size of facets in larger specimens is generally greater than in smaller fossils. Since the thallus and facets grew, so did the lateral branches. The growth, however, was uniform within the whorl, and the resulting shapes of facets are similar in all size ranges. Meek and Worthen (1868, p. 345) state that "on the upper . . . side these . . . are of uniform size . . . while those on the under side . . . .diminish in size from the periphery towards the center." This is rarely true as most specimens have facets of similar size on both upper and under sides. The growing tip in life is pointing up. The growing point was perhaps less calcified than the older parts, and therefore more subject to compaction. The resulting fossil has a flattish upper part, and convex lower side.

4. *Laterals.* The lateral heads and facets are largest at the greatest dimension of the plant. The greatest dimension is not always half-way across the thallus, but is generally higher. The size of facets and the thickness of the thallus decreases away from this "equatorial" region. Therefore, the length of lateral and the size of heads decrease in the same time. Since the addition of laterals occurs at the apex, the laterals at the base are the oldest, but not the largest; therefore the size of laterals was increasing with increased age of the plant.

The number of lateral branches within the whorl changes during the growth of the alga. The smaller specimens possess fewer facets than larger fossils, therefore, the laterals were added during the growth of the individual. This requires that in addition to the appearance of new laterals in the whorls at the apex, the lateral branches were either added to the already existing whorls, or the arrangement of laterals was really in helix and the laterals were pressed down during the growth.

The other possiblity is that the lateral branches divided more than is actually observed, and thus the number of facets represents the number of second or even third degree branching. Thus, the number of branches of the first order would remain the same. The main axis is generally not preserved; however, in the few instances when laterals are preserved (for example, in *Cyclocrinites pyriformis*) no indication of branching is evident in forms other than *C. welleri* and *Anomaloides reticulatus*.

The older, bottom part of the thallus cut away from illumination was probably dying away during the lifetime of the plant. In cushion-like forms, the lower facets are seldom preserved. Calcium carbonate may have been resorbed, and the branches died away.

Taxonomic Position

I. COMPARISON WITH OTHER TAXA

1. *Cyclocrinitids as animals.* In the past cyclocrinitids have been assigned to many invertebrate taxa and were even considered cystoids. In Shimer and Shrock (1944) *Cyclocrinites globosus* has been placed in a chapter of miscellaneous objects of probable organic origin and *Nidulites pyriformis* has been considered a sponge-like organism; however, no cyclocrinitid has been included among algae. Most workers considered the taxonomic position of cyclocrinitids difficult to ascertain, and hence cyclocrinitids have been commonly placed among receptaculitids as an addenda either to protozoa or to sponges.

In the past, taxonomic assignments to any group, except protozoans and sponges, were generally made only by title and without any discussion or argument. Therefore, no need exists to compare cyclocrinitids with any other invertebrate phyla except protozoans and sponges.

2. *Cyclocrinitids as protozoans.* The concept of protozoa has recently changed and protozoans are today regarded as an artificial assemblage, not as a coherent evolutionary taxon. They are unicellular, or acellular organisms mostly of microscopic size and seldom visible to the unaided eye. The large size protozoans are known only among sporozoans and mycetozoan plasmodia none of which have skeletal material. The cyclocrinitids with calcareous skeletons and their large size cannot be placed in any protozoan class.

There appears, however, to be a close link between phytoflagellate protozoans and algae, and perhaps an uninterrupted succession of the two can be established. However, no one has considered cyclocrinitids to be phytoflagellates, but the zoological affinity to protozoa has been stressed (Calvin, 1893). Commonly cyclocrinitids have been assumed to be sponges, which were assigned among protozoans or protistids.

3. *Cyclocrinitids as sponges.* Cyclocrinitids were considered either Calcispongea or an unknown class of Porifera. Calcareous sponges are known by the possession of one, three, or four-rayed calcareous spicules. No such spicules are found among cyclocrinitids, and, therefore, these forms cannot by definition be placed among calcareous sponges.

The concept of cyclocrinitids as a member of an "unknown" class of sponges is difficult to overthrow, particularly when cyclocrinitids are considered an "extinct unknown class." Nevertheless none of the fundamental unquestionably sponge-like anatomical parts, such as oscula and pores, are present in cyclocrinitids, and no spicular elements are observed. Therefore, the absence of these unmistakably poriferous morphological elements excludes cyclocrinitids from sponges.

4. *Cyclocrinitids as algae.* The similarity of cyclocrinitids with recent dasycladaceous algae has been demonstrated by Stolley (1896) and by Pia (1927). A number of other authors followed their lead and placed *Cyclocrinites, Pasceolus, Nidulites,* and *Mastopora* among algae either as a valid genus or as a synonym. *Anomaloides* and *Lepidolites,* however, have not been previously considered algae. The tubes or canals of earlier writers have been recognized as lateral branches, and the cells or cups are considered termini of branches. These are either referred to as cortical cells or, as in the present paper, lateral heads. The nature of the main axis and the mode of calcification has been recognized as characteristically algal in character.

The similarities with recent dasycladaceous algae are given in detail in a chapter on morphology of living representatives. It suffices to say here that the morphological variation among recent plants is much greater than among the fossils. Cyclocrinitids are a well-knit group readily differentiated into three genera but difficult to separate into species. Thus, the greatest difference between the fossils and recent forms rests in the presence of plasticity of recent plants and its absence among cyclocrinitids. The conspicuous variable elements among recent forms are shapes of thalli and branches, and shapes of main axes, and distribution, shape, and branching of laterals. The absence of this variability among cyclocrinitids may however, be only apparent and may be due to the imperfections of the fossil record.

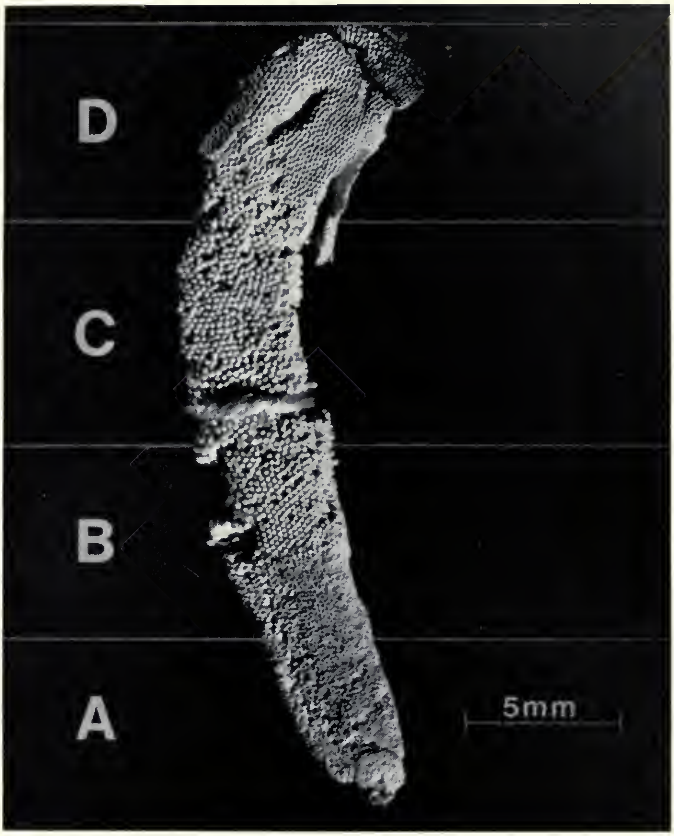

FIG. 22. *Neomeris dumetosa* Lamouroux. FMNH 952047, Recent, Oahu, Hawaii.

II. MORPHOLOGY OF SELECTED LIVING REPRESENTATIVES OF DASYCLADACEOUS ALGAE

1. *Characteristics.* The order Siphonocladiales includes plants heavily incrusted with calcium carbonate, in many of which septa form. Commonly a central vacuole is filled with sap, and is surrounded by a thick protoplasmic lining which in turn is surrounded by a wall. Most of the representatives of the order live in tropical seas.

In the family Dasycladaceae the main axis is generally rod-like. The lower end of the main axis is commonly devoid of laterals. Laterals are borne on the upper part where they are generally packed in whorls, and often branch.

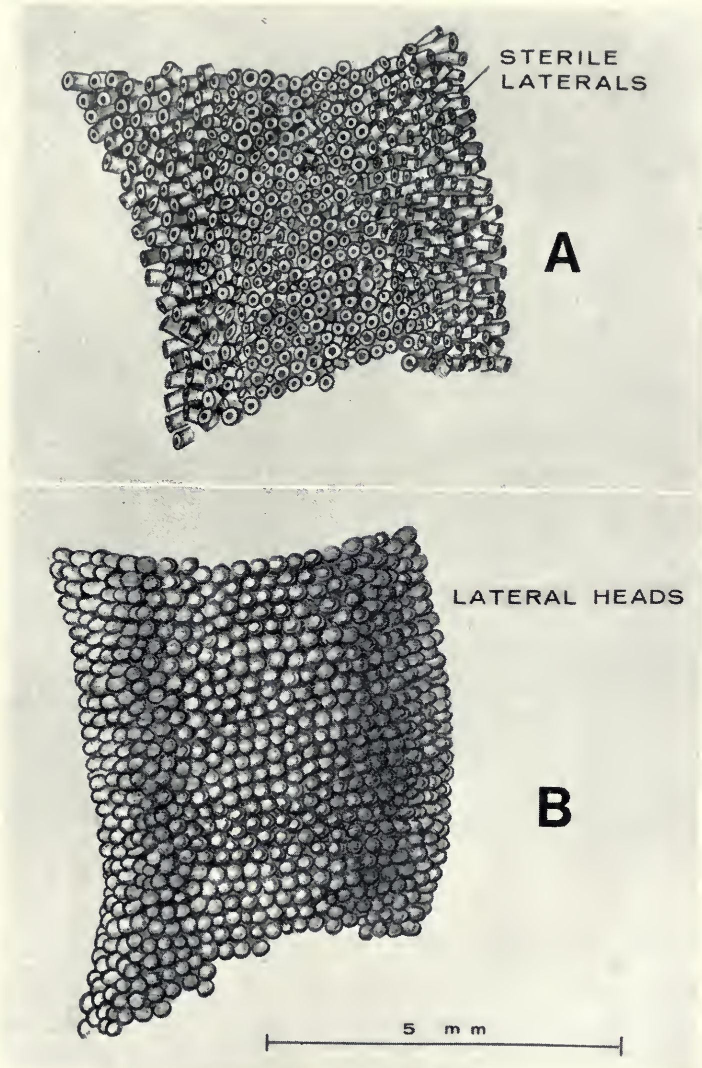

FIG. 23. Diagrammatic sketch of *Neomeris dumetosa* Lamouroux. Section A—the thallus with sterile laterals; section B—the lateral heads.

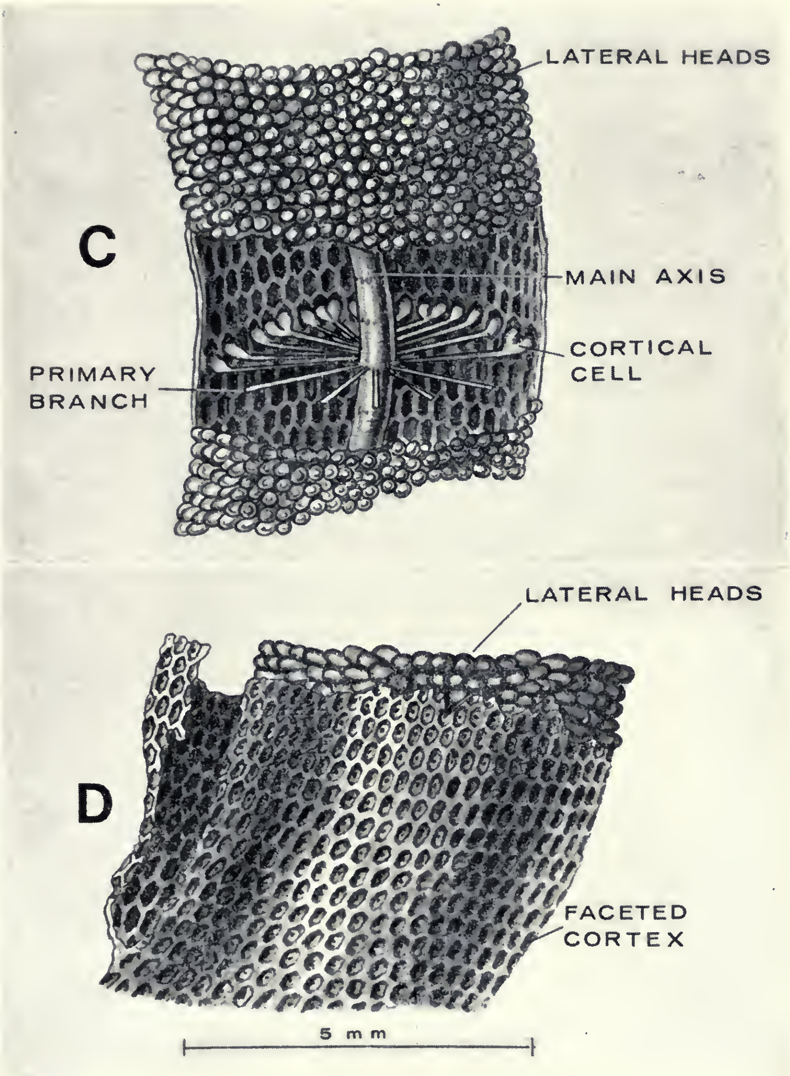

FIG. 23.—*Continued.* Section C—the exposed, uncalcified main axis, uncalcified laterals, and the sometimes branched lateral heads (=botanical cortical cell). The number of laterals within the whorl is reduced for the sake of clarity; section D—the relation of faceted cortex to the lateral heads.

A search of the Cryptogamic Herbarium in Field Museum of Natural History revealed two recent dasycladaceous algae that are very similar to the fossil cyclocrinitids. The two are labelled *Neomeris dumetosa* Lamouroux and *Bornetella oligospora* Solms-Laubach. A thorough search of the literature disclosed *Codium mamillosum* Harvey, a non-calcified form which is also very similar to our fossils. No adequate description of recent forms is available in paleontological literature. The discussion of these forms is for the purpose of comparison with the fossil specimens. The comparison is of necessity restricted to single plants without reference to their developmental stages.

2. *Neomeris dumetosa* Lamouroux (figs. 22–24). Only one dried specimen, Field Museum Natural History, no. 952047, from Oahu, Hawaii, is available for study. No attempt is made here to redescribe the species fully. Only those morphological structures that could be preserved as fossils are discussed. Detailed anatomical descriptions of this species are available (Howe, 1909).

The thallus (figs. 22, 23) is elongate, slender, unconstricted, unbranched, subcylindrical, and about 2.5 cm. long. The specimen is somewhat curved. The apex is rounded and the attachment is by means of a rhizoidal base. The main axis (fig. 23C) is slender, elongate, unbranched, and is weakly calcified. Laterals are arranged in whorls of about 30 branchlets. Calcification on lower ends of laterals is weak and is easily removed, but increasingly complete further away from their bases. The interior of a lateral branch consists of a fine "mucilaginous" thread. Laterals are short relative to the length of the body and are loosely cemented to each other by a thin deposit of calcium carbonate. This cementation occurs below the expanded distal ends, and the laterals are in clusters, and often, observed free.

Branches bifurcate into the second order and two lateral heads form. However, there are many laterals that do not branch into two heads. This is particularly true in the younger (upper) parts of the thallus, where single unbranched laterals predominate. Whether this is due to loss of one of the secondary branches or to absence of bifurcation is impossible to determine. Thus exists an unusual situation of dividing branches together with single branches on the same alga. In the dried specimen the majority of branches preserved are single. The termini of laterals rapidly dilate, form one or two, seldom three lateral heads, and are heavily calcified. These form a heavily calcified, faceted, continuous cortex (figs. 22, 23D, 24).

FIG. 24. *Neomeris dumetosa* Lamouroux. FMNH 952047. Recent, Oahu, Hawaii. Termini of laterals and calcareous cortex are shown.

Within the facets are small openings for attachment of rarely preserved, thin, and uniform short hair. The cortex is formed by deposition of calcium carbonate on the area immediately external to the laterals; cortical facets correspond to the position of the lateral heads. They are crowded together, in polygonal figures, mostly six-sided, but often irregular. These facets appear more numerous than the branches of the second order and tend to be aligned both transversely and obliquely as in the manner of a "machine-turned ornament of a watch."

Gelatinous "mucilage" is present and forms the core of the branches and the lining of the dilated termini of the laterals. It is heavily concentrated on the cortex, just below and just above the deposit of calcium carbonate.

Gametangia are heavily calcified in the mature portion of the plant and correspond in number to the branches of the first order. They are borne at the termini of laterals of the first order, and are surrounded by laterals of the second order.

FIG. 25. *Bornetella oligospora* Solms-Laubach. FMNH 979552, Recent, Philippines.

Neomeris, and possibly other genera as well, undergo a number of considerable and significant changes during their development. Church (1895, p. 582) guesses that *Neomeris* "recapitulates in its ontogeny . . . the phylogeny . . . of the whole group of the Dasycladaceae. . . ." The growth pattern that he studied shows a great variation of form, structure, and calcification and on the basis of that he has divided it into five stages. He has shown that these organisms undergo a remarkable process of ontogenetic development varying from a simple filamentous type to the complex mature plant. In the young, uncalcified individuals the main axis may branch; however in mature, calcified organisms the branching of the main axis occurs only as an anomaly. At first as the main axis becomes more tubular and wider, and as the wall thickens, the internodes between

FIG. 26. Diagrammatic representation of *Bornetella oligospora* Solms-Laubach. The faceted cortex, uncalcified main axis, and uncalcified laterals are shown. The number of laterals in the whorl, and the number of the gametangia are reduced for the sake of clarity.

whorls are relatively shortened, and old scars are pulled down and eventually disappear. As the size of the plant increases the number of appendages in individual whorls increases, and each lateral appendage becomes more complex and further subdivided.

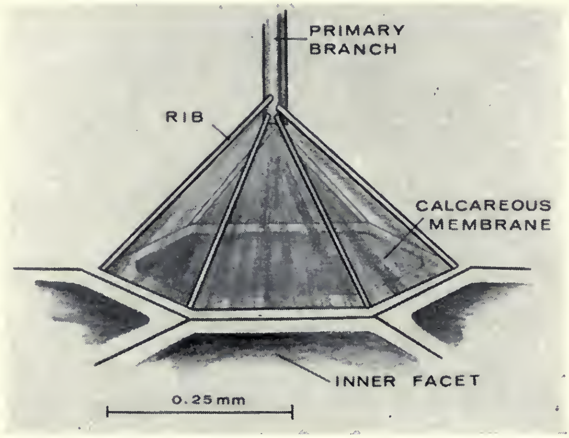

FIG. 27. Diagrammatic representation of the terminus of lateral branch of *Bornetella oligospora* Solms-Laubach. Calcareous membrane forms among the six ribs. The shape of facet is controlled by number of ribs.

These plants are very fragile and very small, and generally much smaller than their fossil counterparts. This, however, may be due to a bias in collecting fossils, since few fossils of small size are found in collections. The dry specimens of *Neomeris* examined are now flattened in the same manner that the fossil *Anomaloides* is flattened, in that the once continuous cylinder of calcified thallus presents the appearance of a flat, two dimensional plant.

3. *Bornetella oligospora* Solms-Laubach (figs. 25–27). Three dried specimens (FMNH no. 979552) from the Philippines are available for study. These differ from *N. dumetosa* in the manner of branching of laterals, in the degree of calcification, in the mode of formation of facets, and in the location of gametangia within the plant.

Laterals branch into a number of ribs (fig. 27) among which on top of a thin gelatinous mucilage a film of calcium carbonate is deposited. It is only here upon the surface of the thallus that calcification occurs and the well-developed facets form. Laterals and main axis do not calcify, hence the plant collapses and flattens upon drying.

Superficially, the facets in *Neomeris* are similar to those of *Bornetella;* however, the process of formation of the facets and the supporting structures is different. In *Neomeris* the $CaCO_3$ is deposited around the termini of branches, and later on top of and in between the lateral heads. In *Bornetella* calcium carbonate is deposited on a

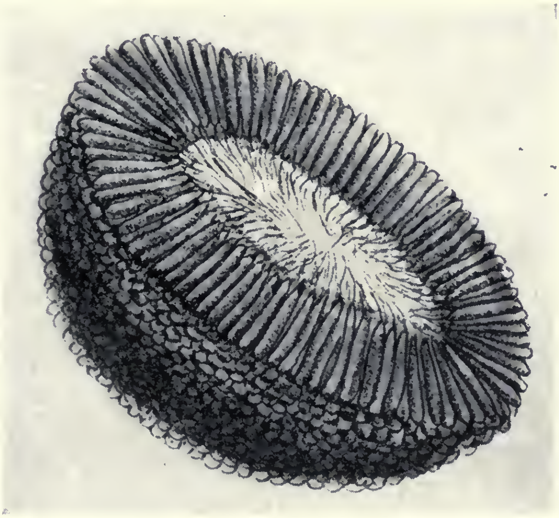

Fig. 28. Reproduction of Harvey's (1863) figure of *Codium mamillosum* Harvey from Western Australia. The illustration represents a cross-section view.

mucilage *between the ribs*. Since the resulting facets are superficially very similar, the method of their formation could be determined only from the internal morphology. In the fossil specimens the recognition of the type of formation of facets would depend upon the nature of preservation of the lateral branches.

Gametangia are borne scattered around the primary branches and are clustered (figs. 25, 26). No extensive calcification of gametangia is noted.

In fossil algae commonly only the facets are preserved, and for this reason the comparison with laterals of recent plants is significant. The external aspect of facets is strikingly similar in both recent and fossil plants. The approximation to a six-sided pattern, due to crowding and the number of ribs, the thickened ridge between facets, and the presence of an opening of the terminus of the branch are remarkably identical in the fossil and in the recent form.

The manner of formation of facets in the fossils preserved in dolomites in the Mississippi Valley region is highly suggestive of the pattern of formation of facets in the living *Bornetella* Calcified.

branches in the living *Neomeris* are like the branches in the fossil *Anomaloides*. The manner of dilation of the termini of laterals is also similar in fossil and in recent specimens. Mucilage, an important component of recent plants, is rarely known in fossil algae. The fine threads, or hair-like projections, or ribs, that may or may not be higher degree laterals, are also observed in fossil *Anomaloides* and *Cyclocrinites*.

Other fossil dasycladaceous algae, for example, receptaculitids, exhibit similarities in other anatomical parts. The comparison of this group with recent algae will be discussed elsewhere.

4. *Codium mamillosum* Harvey (fig. 28). No specimen of *Codium mamillosum* is available for study, and this discussion is based only upon Harvey's (1863) publication (see Part III). The recent *Codium mamillosum* is included in the present paper for the purpose of comparison with the Ordovician *Anomaloides reticulatus*. The illustrated specimen (fig. 28) differs from *Anomaloides*, but it also displays great similarities. The differences are in the absence of calcification in *Codium*, in its spherical shape, and in its consequent mode of attachment. However, there are important similarities between these two forms. The ramuli of *Codium* are almost identical with the laterals of *Anomaloides;* they are both elongated rods slightly tapering towards the center. The relative length and number of these are also very similar. In addition, both forms possess outer membranes that appear similar. In the fossil specimen it seems to be vitreous, a character of membrane ascribed to *Codium*. In the recent plant it is very tough and fine; apparently in the fossil it also must have been tough or else the fossil would not have been so well preserved.

III. PRESERVATION

The effects of calcification upon the preservation of anatomical details of cyclocrinitids is discussed in the section on calcification (p. 30). The influence of enclosing rocks is, however, difficult to evaluate. The specimens collected from dolomite are often, but not always, preserved as well as, or better than those obtained from limestones. Not all limestone specimens produce equal quality of morphologic preservation. Many of these fossils, particularly from the Cincinnati limestones are of concretionary nature and are harder than surrounding rock. A number of specimens are marked with slickenside grooves, suggestive of solution and pressure phenomena.

It seems that they became resistant to the weathering effects early in their diagenetic history and are altered to a more stable form than their original skeletal material. Few specimens are present that can with certainty be considered flattened by compaction. In those instances where flattening is suspected, an associated distortion of the facets around the periphery of the thallus is observed.

The preservation of the thallus is of great importance in taxonomic consideration. Certain species, and even genera, for example, *Mastopora, Nidulites,* and *Cerionites,* have been in the past differentiated on the basis of the differences of preservation. Unfortunately, this practice is still followed in the present paper; for example, presence or absence of stellate structures is here considered specific, although it may be only an accident of preservation.

The preservation of cyclocrinitids varies in a complicated way from specimen to specimen, and from collecting site to collecting site. The different patterns of preservation are diagrammatically represented in Figure 29. The illustration consists of four vertical and six horizontal sets. The vertical set A represents fossils as they are found weathered out from the rock, that is, they are common "filled in" specimens. Set B is a less common form with the interior hollow, and with the detailed anatomy preserved in the surrounding matrix. These forms are found in the Niagaran dolomites. The set C represents the external mold of the specimens shown in set A. This preservation is caused by formation of a cast either by filling in of empty space, or by preservation of "filled in" matrix. This is the commonest form of preservation of cyclocrinitids. The matrix is preserved after the destruction of the skeleton. The set D is the cast of the external mold or a replica of the cyclocrinitid itself. This preservation embodies filling in of the hollow mold (set C).

In set A it cannot be determined whether the lateral heads and facets were removed before or after deposition in some preferential diagenetic process; however, no process that would remove only one layer of lateral heads is known. The heads could, of course, have been removed in subaerial weathering, or in mechanical wear of the fossil, for example, in the moving water. In A1 both heads are preserved; however, if the fossil is preserved without any damage to the outer layer of lateral heads it cannot be determined whether one or two sets are present. In A2 certain heads but no outer facets are removed. In A3 all outer heads are gone, but none of the facets. The condition A3, judged only from the outer surface of the thallus, cannot be differentiated from A6. In A4 all outer facets are gone

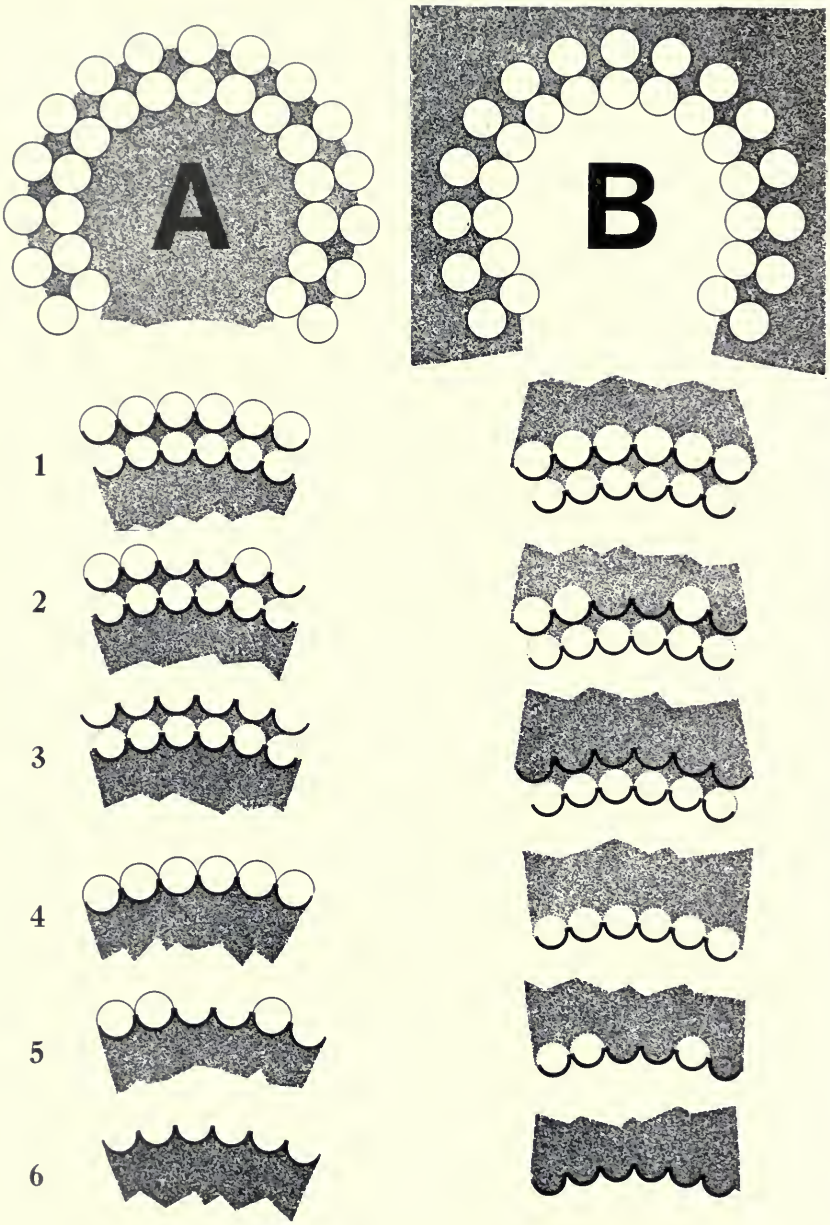

FIG. 29. Diagrammatic representation of preservation of *Cyclocrinites dactioloides* (Owen). Shaded areas represent matrix, thick heavy lines are calcified cortex formed along the facet, and thinner lines represent weaker calcification of lateral heads. Explanation in text (pp. 47, 50).

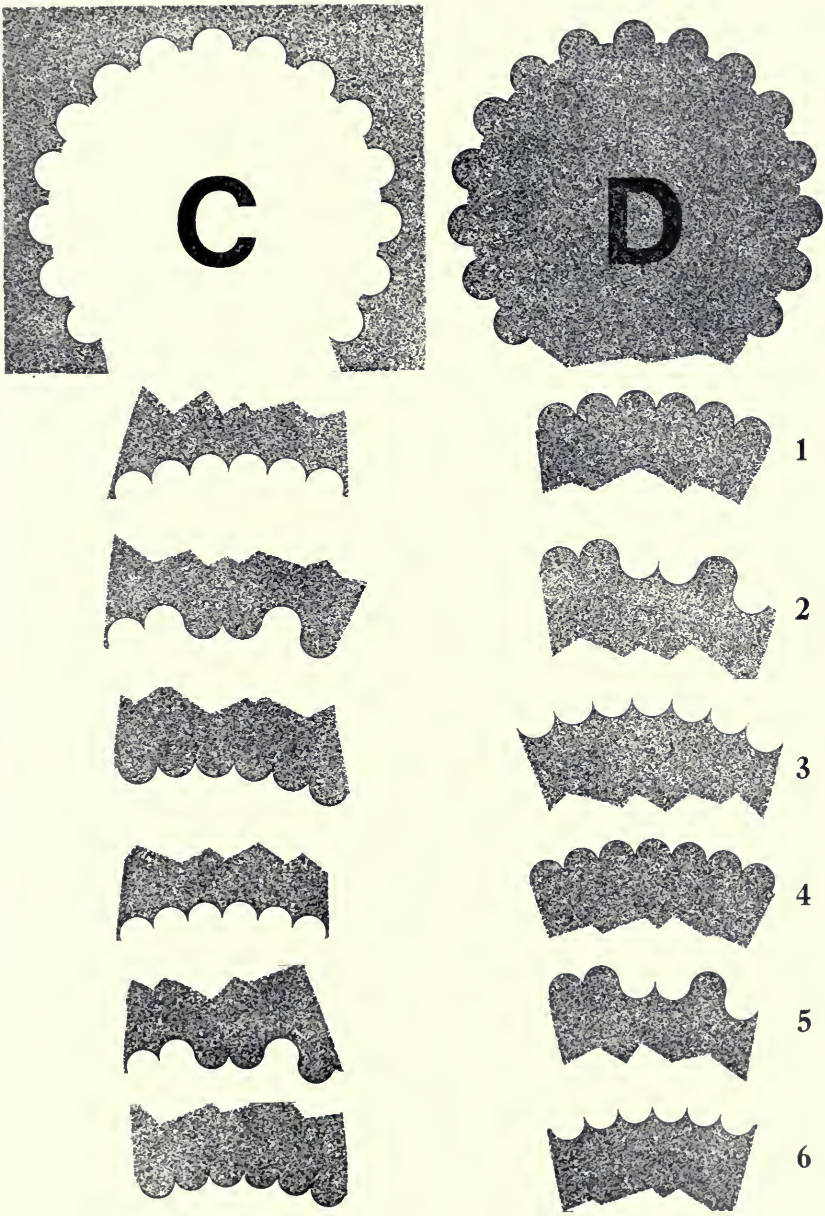

Fig. 29.—*Continued.*

and only the inner heads are preserved. This condition is externally similar to A1, from which it could only be differentiated by sectioning. In A5 some of the inner heads are gone, a condition again externally similar to A2. Finally, in A6 only inner facets remain.

The vertical set B represents the preservation of the specimen in its predepositional conditions. Figure B1 represents an alga that was buried, and is fossilized, with two layers of heads and facets. In Figure B2 the burial occurred after certain outer heads were detached, but before any of the outer facets were lost. In Figure B3 outer heads are lost but none of the outer facets. Figures B4 to B6 represent subsequent stages of removal of heads and facets. In these sections the various stages of preservation can sometimes be determined by cutting across the fossil and matrix. The rarest preservations are the first three horizontal sets.

The vertical series C represents the external mold of specimens, such as shown in set A. C1 is identical with C4, and C2 with C5; and C3 is the same as C6.

Series D represents preservation of fossils in the form of casts or replicas of external molds. In this series the replicas are the "negatives" of the condition shown in series C. The first, second, and third horizontal rows are identical with the fourth, fifth, and sixth rows respectively. No way of differentiating between these two sets of rows exists.

The above diagrams are incomplete because there are many modifications associated with partial removal of different zones, and the effects of dolomitization are unknown. It appears, from the examination of collections of *Cyclocrinites dactioloides,* that the removal of lateral heads and of calcified zone was commonly accomplished by jumps and the entire layer disappeared at once. Very seldom is partial preservation observed; mostly all heads are either present or absent and the double layer of heads is rarely noticed.

Ecology

The geographic distribution of collecting sites indicates an aerial spread that implies a relatively wide range of ecologic conditions such as distributions and kinds of shores, depth, seasons, temperature, and so on. Thus no uniformity of fauna would be expected from such a large geographic range. Cyclocrinitids, particularly the genus *Cyclocrinites*, consist of species that are remarkably alike in spite of the great geographic distance separating the individual collecting sites. The explanation of this range lies perhaps in an equally large stratigraphic extent. The age of the genus, about 80 million years, is long enough for the similar ecological conditions to be repeated many times in different geographic areas.

I. DEPTH

The habitat of the recent calcareous algae extends into great depth, perhaps as much as 400 m. (Vinogradov, 1953). In Bermuda the green calcareous algae flourish and are well represented up to the depth of 90 m. Taylor (1960, p. 30) states that it is very notable that at a depth of 90 m., or lower, almost all of the algae of the Chlorophyceae belong to Siphonales. Thus, by comparison it is assumed that cyclocrinitids grew from tide level to comparatively deep waters. The light requirements limits the depth distribution of algae. It seems that pyriform organisms were living in less disturbed, probably deeper water or in sheltered areas.

II. SALINITY

All organisms reflect the medium in which they live; thus, for the plant that extracts calcium carbonate from the sea and maintains it, the Ca^{++} and CO_3^{--}, ions must be available. The calcareous algae of today, therefore, live in an environment of normal marine salinity of around 3.8 percent. The cyclocrinitids also lived in an environment of normal marine salinity, probably away from the mouth of large rivers that would dilute the salinity and introduce large quantities of mud. They are all associated with good marine faunas

III. SHORE LINE

The recent calcareous algae are distributed in the littoral zone, particularly in the Northern Hemisphere, where the shore line is considerably longer. By analogy, it is assumed that fossil forms must have also been restricted to the littoral zone controlled by extensive shore line.

IV. TEMPERATURE

Dasyclads that extract calcium carbonate from the sea inhabit warm water only and are absent from cold seas. These are either the tropics, or the temperate zones that are supplied by relatively strong warm currents such as the Gulf Stream. Therefore, the cyclocrinitids were growing either in tropical seas or in waters influenced by tropical currents. It appears that the areas where they are found today must have been considerably warmer during the early Paleozoic time.

V. REEFS

Lowenstam (1957) states that the family of receptaculitids, which he considers sponges and in which he includes "*Cerionites*," are widespread in all types of inter-reef habitats and are even present on the wave-swept reef surfaces. The specimens of *Cyclocrinites dactioloides* collected from Iowa appear to be from the inter-reef regimen. The few specimens of the same species collected in and around Chicago are associated with reef localities, and appear on top of the reef proper. None are known to have been collected within the reef itself. Thus, although the Niagaran cyclocrinitids are associated with reefs, none are definite reef builders. No other cyclocrinitids are known to have been associated with reef deposits.

VI. WATER ACTION

The calcareous skeletons of cyclocrinitids are weakly calcified, therefore, the plants could not tolerate strong wave action. The plants must have lived below the influence of the force of strong waves, and probably below the zone of tidal waves. Certain organisms could live in this zone, if they were sheltered, however, such protection would require structures that surely could be detected from the sedimentary regimen. No such structures are observed.

The pyriform specimens have an elongation suggestive of attachment which implies growth in relatively undisturbed water allowing for a straight upward growth. These were most likely lithophytic, and possibly epiphytic. The cushion-shape organisms were probably sitting on the bottom in a gently moving water. There is no indication that these forms were diagenetically disturbed or altered, and all the termini of branches are of the same size. Were these fossils flattened, or in any way altered, the preservation of facets should reflect the change. The globular specimens may represent the higher energy environment and were possibly moved gently about the bottom.

VII. BOTTOM CONDITIONS

Recent calcareous algae do not tolerate sandy or muddy environments. Taylor (1960, p. 7) points out that the shores consisting of extensive flats or muds, as, for example, the areas extending from New Jersey to Central Florida, are devoid of algae, because of the inabilities of these plants to find a suitable natural attachment. By analogy, it is assumed that cyclocrinitids also needed a firm non-sandy, non-muddy bottom, for the attached forms and for those that rolled gently about the bottom. If the interpretation of the shape of thalli is correct then the substrate was the firmest in the case of the globular forms, and less rigid in the cushion forms. The cushion forms due to their relatively large bottom surface could support themselves on less firm substrate.

VIII. SYMBIOSIS

The term symbiosis is here understood in the same sense as used by Allee *et al.* (1949, p. 243); that is, including all relations between partners, commensalism: a one-sided benefit without harm to the host, and parasitism: a one-sided benefit with harmful effects upon the host organism. Among algae the relation can exist between it and another plant, or between it and an animal. Both of these are preserved in cyclocrinitids. The growth of a plant upon the exterior of another plant, in which no harm is done to the host is termed epiphytic growth. The attachment of an animal to another or to a plant in a similar union is termed commensalism. In both cases at least one party benefits from the relation.

An epiphytic growth appears on a specimen of *C. halli* (holotype Canada Geol. Surv. 2227). It was interpreted by Billings (1857)

FIG. 30. *Cyclocrinites halli* (Billings). Holotype Canad. Geol. Surv. 2227. Ellis Bay Formation, Anticosti Island. Epiphytic growth is seen in center of thallus.

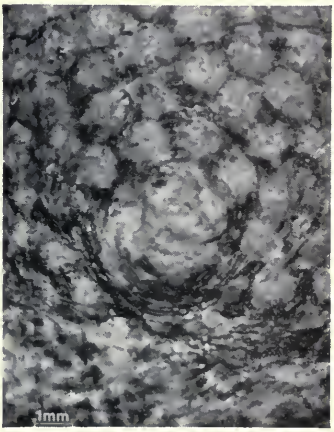

FIG. 31. Enlargement of Figure 30, showing details of the surface and nature of the overgrowth.

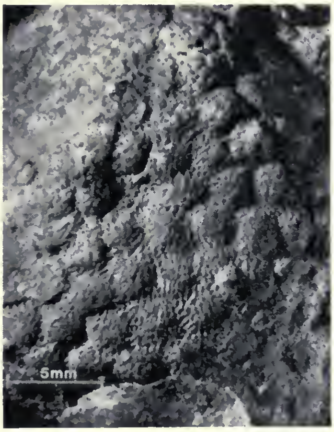

FIG. 32. *Cyclocrinites globosus* (Billings) Canad. Geol. Surv. 9333, Ottawa Formation, Ottawa, Ontario. Commensal bryozoan is preserved.

as an orifice; however, Twenhofel (1927) considered it to serve some other purpose, and suggested that it may even have been the attachment place of a commensal organism like a *Crania.* In the specimen described by Billings and Twenhofel three of these structures are present. Their radii are 0.98, 0.71, and 0.15 cm., respectively. In all three cases these are projections above the surface of the thallus. The greatest projection is 0.05 cm. Figure 30 shows the complete thallus with a centrally placed organism. A larger magnification of this structure is shown in Figure 31. It appears that the "overgrowth" consists of fine carbonate ridges that are arranged in a regular circular manner. There are three "overgrowths" of which two overlap as if one organism grew upon the other. In one, the fine ridges are more crowded at one end and considerably further apart at the opposite end, suggestive of the shell of a *Crania*-like brachiopod. The other two overgrowths do not manifest such an arrangement, and their ridges are more regularly placed around the central area. The organism that left its impression is unknown. The first may belong to a brachiopod of the super-family Craniacea; the other two are not identical, and because they overlap it appears that these are epiphytic algae. In the Herbarium in Field Museum's Department of Botany are calcareous algae that correspond to these structures. For example, a circular alga from Hawaii, *Valonia forbesii,* shows the circular arrangement of fine strands (our ridges) arranged in a manner similar to the overgrowth on *Cyclocrinites halli.* Only when *Valonia* is allowed to dry, can the strands be observed, and these are indistinguishable from our fossil structures. Thus, although it cannot be identified with certainty it seems best to interpret these structures as epiphytic growths. In another specimen of *Cyclocrinites globosus* (Canada Geol. Surv. 9333) a well-developed overgrowth is also seen (fig. 32). It is an invertebrate commensal, either a bryozoan or a coral. Both the host and the symbiont, however, are poorly preserved. Suggestion of a much smaller, unknown organism, somewhat similar in pattern to the structure found on the surface of the holotype of *Cyclocrinites halli,* is found in one very small area of the same fossil. It is larger than the structure on *C. halli* and appears extraneous. Another specimen of *C. globosus* (Canada Geol. Surv. 1376d) possesses a similar "overgrowth" but on one facet only. The three occurrences are unmistakably organic; the pattern of growth is away from their centers.

Two specimens of *Cyclocrinites halli* from Anticosti Island in the collection of Museum of Comparative Zoology, no. 2748, show encrusting bryozoans. However, the bryozoan appears to have been attached upon only one specimen during the life of the alga. Two specimens in the collection of University of Cincinnati Museum, nos. 34431 and 34432, show a trepostomatid bryozoan colony well preserved upon a fragment of a thallus of *Cyclocrinites darwini.* The actual fossil of the alga is absent, but the preserved bryozoan growing on the plant delineates the shape of facets of that portion of the thallus. It appears that the skeleton of the cyclocrinitid was less resistant to removal (probably by solution) than the bryozoan skeleton. It also appears that the plant was relatively rigid in order to support the growing bryozoan colony.

In the collection of the Department of Geology, Miami University, there are specimens almost completely overgrown with *Homotrypella* sp.; one is a specimen of *Cyclocrinites darwini* (no. H 91.1) from Waynesville, near Hamilton, Ohio, and two are unnumbered specimens from unknown horizon and locality.

Part II

Systematic Descriptions

SIPHONOCLADIALES

Definition:—"Plants uni- or multicellular, simple or branched, the branching irregular, or lateral from a primary axis, or organized in two or three planes into specialized thallus structures; cells generally multinucleate, with a net-like chromatophore or many disk-like chromatophores; pyrenoids usually present." (Taylor, 1960, pp. 96–97).

Family DASYCLADACEAE Kützing, 1843

Definition:—"Plants each composed of a long axial cell attached to the sub-stratum at the base by rhizoidal outgrowths, and bearing regular whorls of simple or forked branchlets of limited growth; reproduction by aplanospores or cysts, which in turn produce gametes." (Taylor, 1960, p. 97).

Discussion:—Main axis is always tubular. The lower end of main axis is commonly devoid of laterals. Laterals are borne on upper part where they are always packed in whorls. Laterals often branch.

Tribe CYCLOCRINITEAE Pia, 1920

Definition:—Small, solitary, dasycladaceous, marine alga; shape of thallus probably ecologically controlled; main axis unbranched; laterals arranged in whorls, about 50 in the central area; all branches within whorl develop to the same length; laterals commonly constricted terminally then dilated to form heads; facets form at termini of laterals, or precipitation of calcium carbonate between ribs of stellate structures; constriction and dilation of laterals, when present, causes formation of a wall which when laterals are in contact forms the faceted face; outer surfaces generally compact; communication with outside generally restricted; almost complete incrustation with calcium carbonate; carbonate precipitation generally along base of lateral head; younger plants probably not calcareous; when attached then basally; reproduction and sex organs unknown; Ordovician and Silurian.

Discussion:—The tribe, as here defined, differs from Pia's (1927) definition in the inclusion of other genera and in the interpretation of the position of laterals on the main axis.

The American representatives of the tribe include three genera: *Anomaloides* Ulrich, 1878, *Cyclocrinites* Eichwald, 1840, and *Lepidolites* Ulrich, 1879. The examination of the small collection of recent dasycladaceous algae in the Field Museum Herbarium reveals that the family includes forms that greatly vary anatomically from each other. Genera, as defined in phycological literature, are also very broad taxa that comprise diversified organisms. The three genera here included together in one tribe comprise a coherent group that when better known may be considered a subfamily.

Anomaloides Ulrich, 1878

1878. *Anomaloides*
*Ulrich, Jour. Cincinnati Soc. Nat. Hist., **1**, no. 2, p. 92 (also p. 6 in separate).

1883. *Anomaloides* Ulrich, 1878
Miller, Amer. Palaeo. fossils, 2nd ed., p. 280.

1885. *Anomaloides* Ulrich, 1878
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **8**, no. 3, pp. 165–166.

1885. *Receptaculites* Defrance, 1827 (in part)
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **8**, no. 3, p. 165.

1887. *Anomaloides* Ulrich, 1878
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, pp. 249–250.

1887. *Receptaculites* De France, 1827
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, pp. 246, 249–250.

1888. *Anomaloides* Ulrich
Ulrich, Amer. Geol., **1**, p. 324.

1889. *Anomaloides* Ulrich, 1878
Miller, North Amer. Geol. Palaeontol., p. 224.

1891. *Receptaculites* De France, 1827 (in part)
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **14**, no. 1, pp. 61, 62.

1891. *Anomaloides* Ulrich, 1878
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **14**, no. 1, p. 61.

1895. *Anomaloides* Ulrich
Ulrich, Geol. Minnesota, **3**, pt. 1, pp. 68–74.

* Asterisks identify more important descriptive papers. This and subsequent synonymy lists also include citations regarding occurrences, stratigraphy, and additional references.

1895. *Anomalospongia* (Ulrich)
*Ulrich, Geol. Minnesota, **3**, pt. 1, pp. 68–74.

1897. *Anomalospongia* Ulrich, 1893
Miller, North Amer. Geol. Palaeontol., 2nd appendix, p. 722.

1915. *Anomaloides* Ulrich
Bassler, Bull. U. S. Nat. Mus., no. 92, p. 49.

1955. *Anomaloides* Ulrich, 1878
Laubenfels, Treatise Inv. Paleontol., p. E110.

1962. *Anomaloides* Ulrich, 1878
Sushkin, Osnovy paleontol., p. 83.

1968. *Anomaloides*
Nitecki, Geol. Soc. Amer. Ann. Mtg., p. 35.

Definition:—Thallus small, elongated, laterals branched into second degree; first degree straight in densely packed whorls, constricted at termini where trifurcating into second order; second order laterals thin and double; facets weak and formed by secondary laterals; no cortex; mucilaginous membrane suggested; calcification of laterals only, primary laterals heavily, secondary weakly calcified; environment of low energy, or protected niche.

Anomaloides reticulatus Ulrich, 1878

Figures 7a, 21f, 33–36

1878. *Anomaloides reticulatus*
*Ulrich, Jour. Cincinnati Soc. Nat. Hist., **1**, pp. 92–93, pl. 4, figs. 6, 6a–b (also pp. 6–7 in separate).

1880. *Anomaloides reticulatus* Ulrich
Ulrich, Cat. fossils, p. 30.

1881. *Anomaloides reticulatus* Ulrich
James, J. F., Cat. fossils Cincinnati Group, p. 26.

1883. *Anomaloides reticulatus* Ulrich, 1878
Miller, Amer. Palaeo. fossils, 2nd ed., p. 280.

1885. *Anomaloides reticulatus* Ulrich
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **8**, no. 3, p. 166.

1885. *Receptaculites reticulatus* (Ulrich)
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **8**, no. 3, p. 166.

1887. *Anomaloides reticulatus* Ulrich, 1878
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, pp. 249–250.

1887. *Receptaculites reticulatus* (Ulrich)
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, pp. 249–250.

1889. *Anomaloides reticulatus* Ulrich, 1878
Miller, North Amer. Geol. Palaeontol., p. 224.

1891. *Receptaculites reticulatus* Ulrich, 1878
James, Jour. Cincinnati Soc. Nat. Hist., **14**, no. 1, p. 62, text-figs. 4b, c.

FIG. 33. *Anomaloides reticulatus* Ulrich. Holotype FMNH UC 8820. Maysville, Covington, Ky. The specimen is incomplete at both ends. Fragment of thallus is reconstructed with plaster of Paris.

1895. *Anomaloides reticulatus* Ulrich
Ulrich, Geol. Minnesota, **3**, pt. 1, pp. 68–74, text-fig. 1a, pl. F, figs. 13–15.

1895. *Anomalospongia reticulata* (Ulrich)
*Ulrich, Geol. Minnesota, **3**, pt. 1, pp. 68–74, text-fig. 1a, pl. F, figs. 13–15.

1902. *Anomalospongia reticulata* Ulrich
Nickles, Jour. Cincinnati Soc. Nat. Hist., **20**, no. 2, p. 77.

1905. *Anomaloides reticulatus* Ulrich
Schuchert *et al.*, Bull. U. S. Nat. Mus., no. 53, p. 50.

1905. *Anomalospongia reticulata* (Ulrich)
Schuchert *et al.*, Bull. U. S. Nat. Mus., no. 53, p. 50.

1915. *Anomaloides reticulatus* Ulrich
Bassler, Bull. U. S. Nat. Mus., 92, p. 50.

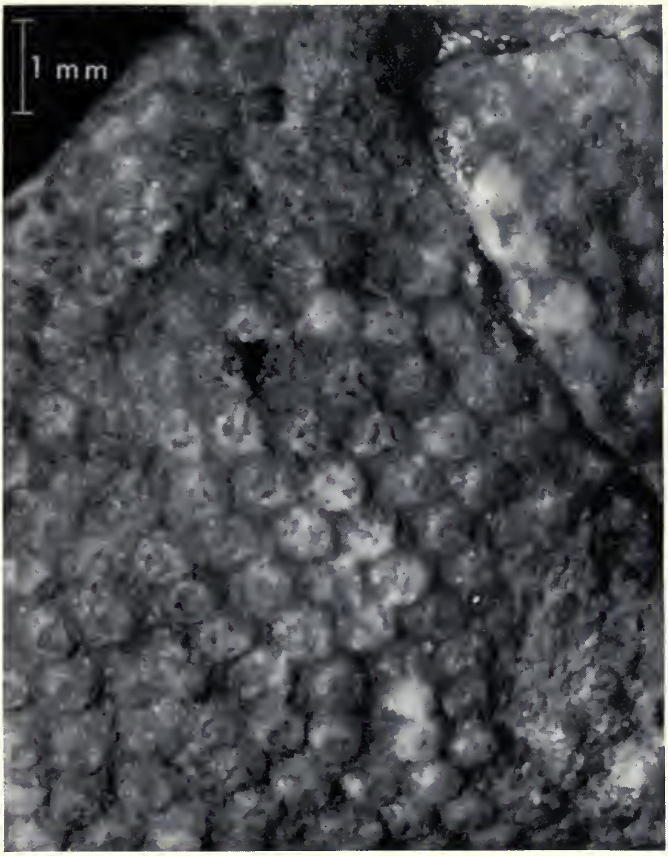

FIG. 34. Enlargement of Figure 33, showing the rarely preserved secondary branches on top of the laterals.

1948. *Anomaloides rcticulata* Ulrich
Dalvé, Fossil fauna Ord. Cincinnati region, p. 15.

1955. *Anomaloides reticulatus*
Laubenfels, Treatise Inv. Paleontol., p. E110.

Definition:—Same as genus.

Description:—The holotype, in the collection of Field Museum, consists of a specimen broken into five pieces. It appears that it was the most complete and the largest specimen that Ulrich had, and that it was already broken when Ulrich studied it; it is possible that some other of his "specimens" belong to the holotype. The fossil is now glued together (fig. 33). The specimen has been very much flattened in such a manner that proximal ends of the laterals are in contact. The fossil is calcareous.

THALLUS. Thallus is unbranched and consists probably of a non-calcified elongated main axis and of calcified laterals. Thallus is narrow at the lower end, expanding rapidly to twice that width. Except in the damaged area this width is maintained. There appears to be a slight curvature to the otherwise erect body. The lower end is broken and no attachment mechanism is observed. The general body shape is thus elongated and relatively erect. This may imply growth in an environment of low energy, or in a protective niche.

The thickness of the main axis is guessed from the degree of compaction of the body and from the distance between the proximal termini of the laterals. It is assumed that the main axis was an elongated tube, or that there was no main axis, and that the area was occupied by interwoven filaments in the manner of the recent *Codium mamillosum*.

PRIMARY LATERALS. Only laterals are now preserved. Laterals of the second degree are very thin and fragmentary and are only locally preserved (fig. 34). Thus, the first degree laterals are all that is initially observed (fig. 33). It was the primary laterals that Ulrich described in his original definition of the species. His "spines" are secondary laterals.

Primaries are thin, elongated, almost club-shaped and arranged parallel to each other; their proximal ends are pointed, the distal ends are rounded and gently expanding (figs. 7a, 35). A slight narrowing of the lateral just below its broadening (not shown in the figures) is present. In other cyclocrinitids a very pronounced expansion is referred to as a lateral head. A few of the laterals possess an almost polygonal surface, but no distinct hexagons are observed.

The distal end when weathered out presents a ring-like structure, an indication that the laterals consisted of a central non-calcified area and a calcareous wall. The thickness of the wall of the lateral is thus judged to be about one-third of the thickness of the branch. This thickness is assumed to be a minimum thickness of calcium carbonate precipitation upon the laterals.

The smallest, oldest laterals are found in the lower, narrower end of the thallus, and their length and thickness increase slightly toward the younger, upper end of the organism.

The laterals are packed very closely together, are parallel to each other, are heavily calcified, and are cemented together by a thin

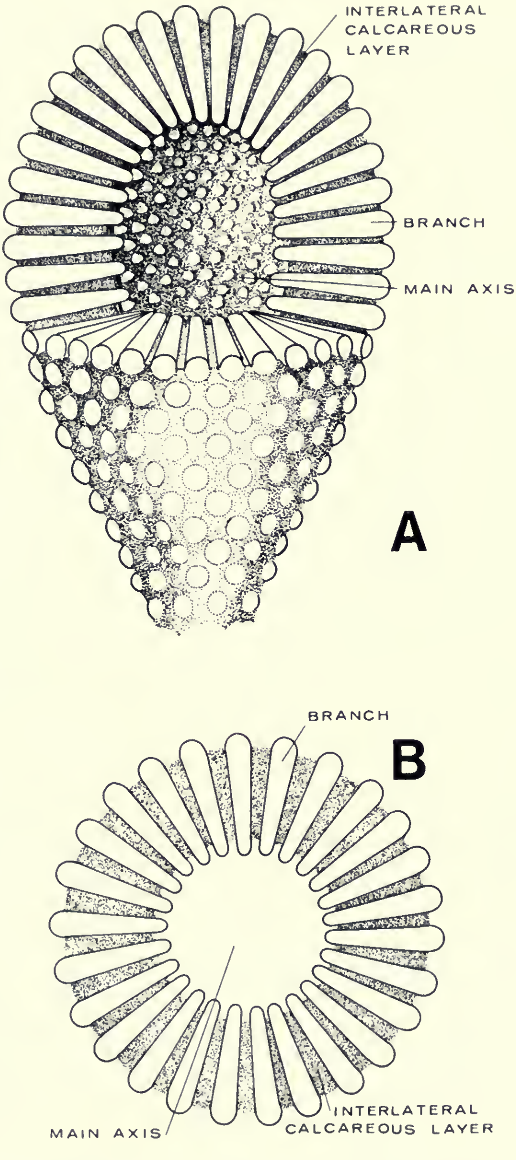

FIG. 35. Diagrammatic reconstruction of *Anomaloides reticulatus* Ulrich. Secondary branches not shown; number of laterals decreased for sake of clarity; the main axis may have been absent. A, Representation of the upper portion of the thallus; B, Cross-section of the thallus.

deposit of calcium carbonate among the laterals. Each lateral is generally in contact with six other laterals, but there are exceptions, and the contact may be with a smaller number. The distal ends of the laterals form distinct and very well delineated horizontal lines at right angles to the main axis. Vertical lines are also formed, but these are short, and can be traced only over a short distance. The laterals are arranged in whorls, which are spaced closely together. The number of laterals in a whorl varies from about 30 at the lower end to about 76 at the upper end.

SECONDARY BRANCHES. On the outer end of the primary branches there is a set of three reticulating, fine, double secondary laterals (figs. 7a, 34). These are not preserved everywhere on the thallus, are limited in distribution, are often broken, and frequently consist of fewer than three double branchlets. When present intact they form a fine meshwork of facets (fig. 36). Ulrich in his later work (1895) considered *Anomaloides* a sponge, and therefore concluded that these were spicules.

In the better preserved examples the center of trifurcation is in the middle of the top of the primary branches. However, frequently this position has been misplaced, and the branchlets can be found radiating from a point that is anywhere among the termini of the primaries. They must have detached easily, but still retained their general reticulating pattern. The calcified facets thus formed were strong enough to allow for the misplacement without breakage. When so misplaced, they are found preserved interlocking in a number of orientations. Nowhere, however, was an orientation found that would correspond to the close packing suggested by Ulrich's (1895) drawing. When not broken, the figuration of second-

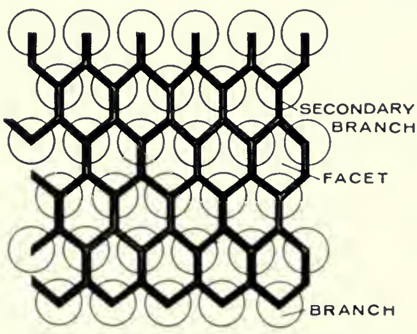

FIG. 36. Diagrammatic representation of the surface of *Anomaloides reticulatus* Ulrich. The termini of lateral branches and the branches of the second order forming facets are shown.

ary branches is such that each branchlet is in contact with two other branchlets (fig. 36) and the reticulate pattern of facets forms, similar to *Cyclocrinites,* and many receptaculitids. The angle that the branchlets form with the primaries is not perpendicular but differs from one position on the thallus to the other in such a way as to suggest that the branchlets were pressed down upon the termini of the primaries.

THE SURFICIAL MEMBRANE. The surface of the fossil appears to have been covered with a thin membrane resembling the membrane covering *Cyclocrinites halli.*

Reconstruction:—In the lower end of the thallus the laterals point *up* toward the interior. In the broader upper end they point *down* toward the center. This orientation may be misleading, since the fossil is badly squeezed. However, since there is no deformation along the longest axis of the plant, and because both ends of the thallus are broken, this orientation suggests that the plant was not conical as suggested by Ulrich. It is assumed here that the plant was rather club-like as shown in Figure 35A. It is very possible that the general shape was more elongated, and that the attachment was rhizoid. The alga possessed a central non-calcareous main axis from which the laterals projected in densely packed whorls. The laterals, in turn, branched, and formed somewhat elevated and weakly calcified facets. The thallus could have been branching, in a manner suggested by Ulrich's second illustration; however, no evidence for a branching main axis is at the present available. The reason a complete thallus is not preserved and the conical shape is produced may be that the upper, younger part of the body, and the lowermost rhizoid portions did not calcify, or calcified weakly.

Relationship:—The general shape and the manner of calcification of laterals is very similar to recent forms, particularly *Neomeris.* The facet arrangement is characteristically cyclocrinitid. The suggestion of a membrane and the poorly developed facets place *Anomaloides reticulatus* close to *Cyclocrinites halli.* The branching of laterals into double trifurcating branchlets is, however, unique for this genus.

Ulrich pointed out the similarity of *Anomalospongia* to *Amphispongia* Salter, 1861. *Amphispongia* is a Silurian (Ludlow) organism preserved as impressions only, and consisting of "tubes" about 3 mm. long, arranged so that their round ends form an outer surface, while the pointed ends reach a central axis. The upper end of the organism possesses some spicular material that can be interpreted as secondary laterals. The basal part of *Amphispongia* as described by Hinde (1888, pp. 130–132) agrees well with our *Anomaloides*. The upper part, however, is very poorly known and the fossil appears to be composed of slender four- and five-ray "spicules," not fused with one another, but arranged in an anomalous way, along the longest axis of the specimen. From Hinde's figure the nature of the "spicules" is not as clear a matter as his discussion makes it. According to his illustration (Hinde, 1888, pl. 3, figs. 3, 3a-f), these are so arranged that only three rays can be recognized. It is easy to conclude that Hinde has interpreted more perhaps than the specimen shows. Unfortunately the specimens of *Amphispongia* are not available for examination and comparison. Until these are studied no decision on the relationship of *Amphispongia* to *Anomaloides* can be made. However, at this time a suggestion of a close relationship is seen.

Measurements:—Although the specimen is badly squashed it is possible to measure three dimensions—the height, the width, and the compressed width of the thallus. The height represents a measurement of a broken individual.

Height	5.05 cm.
Larger width at the apex	2.01 cm.
Compressed width at the apex	0.46 cm.

The dimensions of the laterals are difficult to measure and are therefore approximate.

Largest lateral at the apex	0.28 cm. long
Shortest lateral at the lower end	0.19 cm. long

Material:—Holotype, Faber Collection, Walker Museum of Paleontology of the University of Chicago, now in the Field Museum of Natural History, UC8820.

Stratigraphy and locality:—Upper Ordovician, Cincinnatian, Maysville (Mt. Hope) about 275 feet above nineteenth century low watermark in the Ohio River, at Covington, Kentucky.

Cyclocrinites Eichwald, 1840

1840. *Cyclocrinites*
*Eichwald, Ueber Silur. Schicht. Esthland, p. 192.

1850. *Cyclocrinites* Eichwald
Milne-Edwards and Haime, Paleontol. Soc., vol. 48, p. LXXIV.

1851. *Nidulites*
Salter, Quart. Jour. Geol. Soc. London, 7, p. 174.

1857. *Pasceolus* Billings
*Billings, Geol. Surv. Canada. Rept. Prog., 1853–54–55–56, p. 342.

1860. *Cyclocrinus* Eichwald
*Eichwald, Leth. Ross. Paleontol. Russie, **1**, pp. 637–638.

1860. *Cyclocrinites*
Milne-Edwards, Hist. Nat. Corall., **3**, pp. 452–453.

1865. *Pasceolus* Billings
*Billings, Palaeozoic fossils, **1**, Geol. Surv. Canada, pp. 390–392.

1865. *Cyclocrinus* Eichwald
Billings, Palaeozoic fossils, **1**, Geol. Surv. Canada, p. 392.

1865. *Cyclocrinites* Eichwald
Niles, Proc. Boston Soc. Nat. Hist., **10**, pp. 19, 20.

1865. *Cyclocrinus* Eichwald
Billings, Canad. Nat., **2**, pp. 197, 198.

1865. *Pasceolus* Billings
Billings, Canad. Nat., **2**, pp. 195–198.

1866. *Cyclocrinites*
Billings, Cat. Sil. Fossils, Anticosti, Geol. Surv. Canada, p. 70.

1866. *Cyclocrinus* Eichwald
Billings, Cat. Sil. Fossils, Anticosti, Geol. Surv. Canada, pp. 70, 71.

1866. *Nidulites* Salter
Billings, Cat. Sil. Fossils, Anticosti, Geol. Surv. Canada, p. 71.

1866. *Pasceolus* Billings
Billings, Cat. Sil. Fossils, Anticosti, Geol. Surv. Canada, pp. 69, 70, 71, 72.

1868. *Cyclocrinus* Eichwald, 1859
Bigsby, Thesaurus Siluricus, p. 19.

1868. *Mastopora* Eichwald, 1859
Bigsby, Thesaurus Siluricus, p. 85.

1868. *Nidulites* Salter, 1851
Bigsby, Thesaurus Siluricus, p. 4.

1868. *Pasceolus* Billings, 1857
Bigsby, Thesaurus Siluricus, p. 192.

1868. *Cyclocrinites* Eichwald
Meek and Worthen, Geol. Surv. Ill., **3**, p. 346.

1868. *Cerionites* Meek and Worthen
Meek and Worthen, Geol. Surv. Ill., **3**, p. 346.

1868. *Pasceolus* Billings
*Meek and Worthen, Geol. Surv. Ill., **3**, p. 346.

1874. *Pasceolus* Billings
Miller, S. A., Cincinnati Quart. Jour. Sci., **1**, no. 1, pp. 4, 5, 6.

1875. *Cyclocrinus* Eichwald
Kayser, Zeits. Deut. Geol. Gesell., **27**, pp. 776, 780.

1875. *Pasceolus* Billings
Kayser, Zeits. Deut. Geol. Gesell., **27**, pp. 776, 777, 778, 779–783.

1875. *Pasceolus* Billings
James, U. P., Cat. Lower Sil. fossils, p. 8.

1876. *Cyclocrinus* Eichwald, 1840
*Roemer, Lethaea palaeo., I Theil., pp. 286, 292–294, 295.

1876. *Nidulites* Salter
Roemer, Leth. palaeo., I Theil, p. 294.

1876. *Pasceolus* Billings, 1857
Roemer, Leth. palaeo., I Theil, pp. 295, 297.

1877. *Pasceolus* Billings, 1857
Miller, American Palaeo. fossils, p. 43.

1878. *Astylospongia* Roemer (in part)
Mickleborough and Wetherby. Classified list Lower Sil. fossils, p. 81 (pamphlet p. 21).

1878. *Pasceolus* Billings
Mickleborough and Wetherby. Classified list Lower Sil. fossils, pp. 81, 86 (pp. 21, 26 pamphlet).

1878. *Cyclocrinites* Eichwald
*Nicholson and Etheridge, Monogr. Sil. fossils, Girvan Dist., pp. 13, 14, 15.

1878. *Cyclocrinus* Eichwald
Nicholson and Etheridge, Monogr. Sil. fossils, Girvan Dist., pp. 15, 16, 17.

1878. *Nidulites* Salter, 1851
Nicholson and Etheridge, Monogr. Sil. fossils, Girvan Dist., pp. 10–11, 12, 15, 16, 17.

1878. *Pasceolus* Billings
Nicholson and Etheridge, Monogr. Sil. fossils, Girvan Dist., pp. 12, 13, 14, 15, 16, 17, 18.

1879. *Pasceolus* Billings, 1857
Miller, 10th Ann. Rept. Geol. Surv. Indiana, p. 29 (p. 8 in pamphlet).

1880. *Cyclocrinus* Eichwald
Zittel, Handb. Palaeontol., **1**, pp. 84, 425, 728, not 391.

1880. *Mastopora* Eichwald
Zittel, Handb. Palaeontol., **1**, p. 84.

1880. *Nidulites* Salter
Zittel, Handb. Palaeontol., **1**, p. 728.

1880. *Pasceolus* Billings
Zittel, Handb. Palaeontol., **1**, pp. 84, 425, 728.

1883. *Cerionites* Meek and Worthen
Whitfield, Wisc. Geol. Surv., **4**, pp. 268, 269.

1883. *Pasceolus* Billings
Whitfield, Wisc. Geol. Surv., **4**, p. 268.

1884. *Cyclocrinus* Eichwald
Hinde, Quart. Jour. Geol. Soc. London, **40**, pp. 802, 803, 834.

1884. *Cyclocrinus* Eichwald (=*Nidulites* Salter)
Hinde, Quart. Jour. Geol. Soc. London, **40**, p. 834.

1884. *Mastopora* Eichwald
Hinde, Quart. Jour. Geol. Soc. London, **40**, pp. 798, 834.

1884. *Pasceolus* Billings
Hinde, Quart. Jour. Geol. Soc. London, **40**, pp. 802, 803, 818, 834, 835, *not* 816.

1885. *Pasceolus*
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **8**, no. 3, p. 164.

1887. *Pasceolus* Billings
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, pp. 246, 248.

1887. *Astylospongia* Roemer, 1860 (in part)
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, pp. 246, 247.

1888. *Cyclocrinus* Eichwald
Roemer, Neu. Jahr. Min. Geol. Pal., Band 1, pp. 74, 75.

1888. *Pasceolus* Billings
Roemer, Neu. Jahr. Min. Geol. Pal., Band 1, p. 74.

1889. *Cyclocrinus* Eichwald
*Nicholson and Lydekker, Manual Paleontol., **1**, pp. 186–188; **2**, p. 1564.

1889. *Mastopora* (*Nidulites*)
Nicholson and Lydekker, Manual Paleontcl., **2**, p. 1564.

1889. *Nidulites*
Nicholson and Lydekker, Manual Paleontol., **1**, pp. 186, 187, 188.

1889. *Nidulites* (*Mastopora*)
Nicholson and Lydekker, Manual Paleontol., **1**, p. 188, figs. 74a–c.

1889. *Pasceolus* Billings
Nicholson and Lydekker, Manual Paleontol., **1**, p. 186.

1889. *Cerionites* Meek and Worthen, 1868
Miller, North Amer. Geol. Palaeontol., pp. 153, 156.

1889. *Pasceolus* Billings, 1857
Miller, North Amer. Geol. Palaeontol., pp. 153, 156, 162.

1891. *Pasceolus* Billings, 1857
James, Jour. Cincinnati Soc. Nat. Hist., **14**, no. 1, pp. 53, 54, 58.

1891. *Cyclocrinus*
James, Jour. Cincinnati Soc. Nat. Hist., **14**, no. 1, p. 58.

1893. *Cerionites*
Calvin, Amer. Geol., **12**, pp. 54, 55, 56, 57.

1893. *Pasceolus*
Calvin, Amer. Geol., **12**, p. 54.

1893. *Cerionites*
Calvin, Proc. Iowa Acad. Sci., **1**, part 3, pp. 13, 14, 15.

1893. *Pasceolus*
Calvin, Proc. Iowa Acad. Sci., **1**, part 3, p. 14.

1894. *Cyclocrinus* Eichwald
Ami, Ottawa Nat., **8**, p. 83.

1894. *Nidulites*
Ami, Ottawa Nat., **8**, pp. 83, 84.

1894. *Pasceolus* Billings
Ami, Ottawa Nat., **8**, p. 83.

1895. *Pasceolus*
Dana, Manual Geol., p. 515.

1895. *Cerionites* Meek and Worthen
Winchell and Schuchert, Geol. Minnesota, **3**, pt. 1, p. 67.

1895. *Pasceolus* Billings, 1857
Winchell and Schuchert, Geol. Minnesota, **3**, pt. 1, p. 68.

1895. *Cyclocrinus*
Head, Palaeo. sponges, p. 12.

1895. *Mastopora* Eichwald, 1852.
Head, Palaeo. sponges, p. 11.

1895. *Nidulites*
Head, Palaeo. sponges, p. 12.

1896. *Cyclocrinus*
*Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, pp. 177, 179, 180, 181, 185, 187, 188, 189–218, 219, 220, 225–226, 227, 228, 229, 230, 231, 232, 236, 237, 239, 241–258, 259, 265–266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276–277, 278, 279.

1896. *Cyclocrinus* (*Pasceolus*)
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, pp. 225, 239.

1896. *Mastopora*
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, pp. 177, 181, 191, 204, 208, 209, 210, 212, 214, 215, 218–234, 236, 237, 238, 259–261, 262, 265, 267, 268, 270, 272, 273, 274, 275, 276, 277, 278, 279.

1896. *Nidulites*
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, pp. 201, 204, 205, 206, 208, 209, 210, 214, 215, 218, 220, 223, 224, 225, 227, 228, 229, 230, 231, 232, 233.

1896. *Nidulites* (*Mastopora*)
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, pp. 225, 227.

1896. *Pasceolus*
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, pp. 177, 189, 190, 200, 201, 202, 203, 204, 205, 206, 208, 209, 210, 212, 213, 214, 215, 216, 225, 227, 228, 229, 230, 239, 264.

1896. *Pasceolus* (*Cyclocrinus*)
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, pp. 215, 225.

1910. *Pasceolus*
*Foerste. Bull. Sci. Lab., Denison Univ., **16**, p. 86.

1915. *Cerionites* Meek and Worthen
Bassler, Bull. U. S. Nat. Mus., no. 92, p. 204.

1915. *Cyclocrinites* Eichwald
Bassler, Bull. U. S. Nat. Mus., no. 92, pp. 327–328.

1915. *Nidulites* Salter
Bassler, Bull. U. S. Nat. Mus., no. 92, p. 855.

1915. *Pasceolus* Billings
Bassler, Bull. U. S. Nat. Mus., no. 92, p. 946

1916. *Pasceolus*
*Foerste, Bull. Sci. Lab., Denison Univ., **18**, pp. 289, 290.

1919. *Cerionites*
Bassler, Md. Geol. Surv., Cambrian and Ordovician, p. 194.

1919. *Nidulites*
Bassler, Md. Geol. Surv., Cambrian and Ordovician, p. 194.

1927. *Cerionites* Meek and Worthen
Pia, Handb. Paläobot., p. 64.

1927. *Cyclocrinus* Eichwald
*Pia, Handb. Paläobot., pp. 64, 66.

1927. *Mastopora* Eichwald
*Pia, Handb. Paläobot., p. 66.

1927. *Nidulites* Salter
*Pia, Handb. Paläobot., p. 66.

1927. *Pasceolus* Billings
Pia, Handb. Paläobot., p. 64.

1928. *Cyclocrinites* Eichwald emend. Stolley
*Twenhofel, Geol. Surv. Canada, Mem., 154, pp. 100–101.

1928. *Mastopora* Eichwald
Twenhofel, Geol. Surv. Canada, Mem. 154, pp. 100–101.

1928. *Nidulites*
Twenhofel, Geol. Surv. Canada, Mem. 154, p. 101.

1928. *Pasceolus* Billings
Twenhofel, Geol. Surv. Canada, Mem. 154, p. 100.

1943. *Cerionites* Meek and Worthen
Howell, Wagner Free Inst. Sci. Bull., **18**, no. 4, p. 40.

1943. *Cyclocrinus*
Howell, Wagner Free Inst. Sci. Bull., **18**, no. 4, p. 40.

1943. *Pasceolus* Billings
Howell, Wagner Free Inst. Sci. Bull., **18**, no. 4, p. 40.

1943. *Mastopora* (=*Nidulites* Salter)
*Wood, Quart. Jour. Geol. Soc. London, **98**, pp. 210, 211, 213.

1943. *Cyclocrinites* Eichwald
*Currie and Edwards, Quart. Jour. Geol. Soc. London, **98**, pp. 235, 238.

1943. *Cyclocrinus* Eichwald
Currie and Edwards, Quart. Jour. Geol. Soc. London, **98**, p. 238.

1943. *Mastopora* Eichwald, 1840
*Currie and Edwards, Quart. Jour. Geol. Soc. London, **98**, pp. 235, 236, 238, 239.

1943. *Nidulites* Salter, 1851
Currie and Edwards, Quart. Jour. Geol. Soc. London, **98**, p. 235.

1943. *Pasceolus* Billings
Currie and Edwards, Quart. Jour. Geol. Soc. London, **98**, p. 238.

1944. *Cyclocrinites* Eichwald, 1840
Shimer and Shrock, Index Fossils of North Amer., p. 719.

1944. *Nidulites* Salter, 1851
Shimer and Shrock, Index Fossils of North Amer., p. 57.

1948. *Pasceolus* Billings
Wilson, Geol. Surv. Canada, Bull., no. 11, pp. 24, 27.

1948. *Cyclocrinus* Eichwald
Wilson, Geol. Surv. Canada, Bull., no. 11, p. 27.

1952. *Nidulites* Salter
Moore *et al.*, Invertebrate fossils, pp. 87, 97.

1952. *Cyclocrinus* Eichwald
Johnson, Quart. Colo. School Mines, **47**, no. 2, pp. 38, 40.

1952. *Mastopora* Eichwald
Johnson, Quart. Colo. School Mines, **47**, no. 2, pp. 38, 44.

1952. *Nidulites* Salter
Johnson, Quart. Colo. School Mines, **47**, no. 2, p. 44.

1952. *Pasceolus*
Johnson, Quart. Colo. School Mines, **47**, no. 2, p. 40.

1954. *Nidulites*
Twenhofel, *et al.*, Bull. Gecl. Soc. Amer., **65**, pl. 1.

1954. *Cyclocrinus* Eichwald
Johnson, Quart. Cclo. School Mines, **49**, no. 2, pp. 70, 71.

1954. *Mastopora* Eichwald
Johnson, Quart. Colo. School Mines, **49**, no. 2, p. 71.

1955. *Cyclocrinites* Eichwald, 1842
Laubenfels, Treatise Inv. Paleontol., p. E110.

1955. *Cerionites* Meek and Worthen, 1868
Laubenfels, Treatise Inv. Paleontol., p. E110.

1955. *Nidulites* Salter, 1851
Laubenfels, Treatise Inv. Paleontol., p. E110.

1955. *Pasceolus* Billings, 1857
Laubenfels, Treatise Inv. Paleontol., p. E110.

1957. *Pasceolus*
Wilson, Canad. Field Nat., **70**, no. 1, p. 49.

1959. *Cyclocrinus*
Johnson and Konishi, Quart. Colo. School Mines, **54**, no. 1, p. 11.

1959. *Mastopora* Eichwald, 1840
Johnson and Konishi, Quart. Colo. School Mines, **54**, no. 1, pp. 28, 47, 48, 51.

1959. *Nidulites* Salter, 1851
Johnson and Konishi, Quart. Colo. School Mines, **54**, no. 1, p. 51.

1960. *Cyclocrinus* Eichwald
Osgood and Fischer, Jour. Paleontol., **34**, pp. 896, 897, 899.

1960. *Mastopora* Eichwald
*Osgood and Fischer, Jour. Paleontol., **34**, pp. 896, 897, 899, 900, 901.

1960. *Nidulites* Salter
Osgood and Fischer, Jour. Paleontol., **34**, pp. 896, 897.

1960. *Pasceolus* Billings
Osgood and Fischer, Jour. Paleontol., **34**, p. 896.

1962. *Cerionites* Meek and Worthen, 1868
Sushkin, Osnovy paleontol., p. 83.

1962. *Nidulites* Salter, 1851
Sushkin, Osnovy paleontol., p. 83.

1962. *Pasceolus* Billings, 1857
Sushkin, Osnovy paleontol., p. 83.

1963. *Cyclocrinus*
Korde, Osnovy paleontol., p. 212.

1963. *Mastopora*
Korde, Osnovy paleontol., p. 212.

1963. *Mastopora* Eichwald, 1840
Griefe and Langenheim, Jour. Paleontol., **37**, p. 567.

1963. *Nidulites*
Griefe and Langenheim, Jour. Paleontol., **37**, p. 567.

1967. *Cyclocrinites*
Nitecki, Geol. Soc. Amer., Ann. Mtg., p. 165.

1967. *Cerionites* Meek and Worthen
Finks, Jour. Paleontol., **41**, no. 3, p. 805.

1967. *Pasceolus* Billings
Finks, Jour. Paleontol., **41**, no. 3, p. 805.

1968. *Cyclocrinites*
Nitecki, Geol. Soc. Amer., Ann. Mtg., p. 35.

Definition:—Thallus spherical, pyriform, cushion-like, button-like, claviform or otherwise elongated; shape generally ecologically controlled; basally attached by rhizoid extension of main axis or by point attachment, or attachment mechanism absent; when attachment mechanism is absent a "sitting down" habit develops. Main axis, often robust, generally expanding; laterals generally unbranched, numerous, regularly arranged in whorls, of uniform size within whorl; laterals dilate once, sometimes twice; lateral heads sometimes supported by ribs; facets generally six-sided, mostly regular; calcification below or above, or below and above lateral heads.

Synonyms:—The following generic names used in North America are here considered junior synonyms of *Cyclocrinites: Mastopora* Eichwald, 1840; *Cyclocrinus* Bronn, 1848; *Nidulites* Salter, 1851; *Pasceolus* Billings, 1857; *Cerionites* Meek and Worthen, 1868.

Eichwald (1840) described the new genus *Mastopora* with one species, *concava*. No separate descriptions were given, therefore, the description of the species is the same as that of the genus. Eichwald's description is without illustrations and is inadequate. Pia (1927) redefines *Mastopora* and erects the subtribe *Mastoporinae* for the reception of three genera: *Mastopora* Eichwald (=*Nidulites* Salter), *Apidium* Stolley, and *Epimastopora* Pia. *Apidium* and *Epimastopora* are not known from North America. The most recent definition of the genus is that of Korde et al. (1963) in the Soviet *Osnovy paleontologii*. The translation of the Russian text is given in Part III. It appears from the translation that *Mastopora* differs from *Cyclocrinites* in the absence of "covering plates" or "membrane," in the size of the thallus, in the degree of calcification, and possibly in the branching of laterals. No European specimens are available for study, however, the published descriptions and illustrations of European material show algae that cannot be distinguished from the American specimens described as *Mastopora*. The examination of American fossils reveals that these are only slightly different (perhaps on the specific level) from species of *Cyclocrinites*. The presence or absence of "plates" is only a matter of preservation; the size of the thallus varies within species and no separation of species can be based on the size; the degree of calcification is highly variable within a single collecting lot; and finally no evidence for branching of laterals exists.

The name *Cyclocrinus* was first introduced by Bronn in 1848 [reference not seen]. This change of spelling of the name *Cyclocrinites* was accepted by Eichwald in 1860 (pp. 637–638) because of the suggested relationship to echinoderms, among which he placed his fossils at that time. This alternative spelling was preferred and used by most subsequent workers (see the synonymy list). However, the name *Cyclocrinus* is, according to the nomenclatural rules, invalid and is here rejected as a synonym.

The genus *Nidulites*, with a single species *favus*, was described by Salter (1851). Since no separate description exists, the definition of genus and species is identical (see Part III). *Nidulites* is considered by most workers identical with *Mastopora* and this view is entirely accepted here. The detailed discussion of the few American species referred in the past to *Nidulites* and *Mastopora* and the comparison with European species is given under the heading of *Cyclocrinites pyriformis* (pp. 127).

The genus *Pasceolus* was originally proposed by Billings (1857) for the reception of two species, *P. halli* and *P. globosus*. Additional species were later assigned to it. The holotype of *P. halli* is a very unusual specimen because it possesses a mucilaginous membrane covering the lateral heads. The type specimens of *P. globosus* represent fossils of a common form preserved without lateral heads. There are other minor differences between the species. On the basis of these two sets of types two different species can be recognized. However, jointly the two species possess characters that by definition place them in the genus *Cyclocrinites*, mainly the presence of the outer "covering" of the lateral heads and the presence of "cells" or facets. Neither of these two species possesses characters that would permit separating one or both of these from the earlier defined genus *Cyclocrinites*. They are, however, different specifically from *C. spaskii*.

Meek and Worthen (1868, pp. 345–346, pl. 5, figs. 2a–c) described and illustrated a single specimen of *C. dactioloides* provisionally under the generic name *Pasceolus* ? *dactylioides* [sic]. They were convinced of the correctness of their specific identification; however, they had doubts about the generic assignment. The specimen was compared with *Pasceolus, Cyclocrinites,* and *Receptaculites,* and found to be different from these. Although they did not formally propose a new name, they concluded that their specimen belonged to a new genus, *Cerionites.* The similarities that they noted were as follows: with *Pasceolus,* the same general appearance, and the possibilities of presence of hexagonal "plates" should the fossil be a cast of the interior; with *Receptaculites,* the tendency of "cells" on the underside to arrange themselves in curved lines. The differences that they observed were as follows: with *Pasceolus,* the surface is covered with hexagonal pits; "plates" on the underside diminish in size toward the center and form curved lines; Billings in a letter to the authors considered it to belong to a genus intermediate between *Pasceolus* and *Receptaculites*—a suggestion the authors agreed with. Differences with *Cyclocrinites* are absence of plates, absence of "cystidian openings," and absence of any other openings except those in the middle of the "cell." Differences with *Receptaculites* are hexagonal "pits" instead of quadrangular or rhombic, the internal character is probably different, and those cited in Billings' letter.

The similarities that Meek and Worthen observed to *Pasceolus* and *Receptaculites* are correct, but the dissimilarities they noted are due to three factors: Meek and Worthen did not examine either *Cyclocrinites* or *Pasceolus* specimens; they accepted the interpretation, prevailing at the time, that cyclocrinitids are cystoids and they studied only one, cushion-shaped specimen, on which only facets were preserved. Later Billings (1866, p. 72) himself described two "good" cyclocrinitid species, *Pasceolus gregarius* and *P. intermedius.* Types of these species (figs. 38–40) are barely distinguishable from the Meek and Worthen specimen of *C. dactioloides* (fig. 45).

Cyclocrinites halli (Billings, 1857)

Figures 3A, 7B, 19, 20, 21B, 30, 31

1857. *Pasceolus halli* Billings
*Billings, Geol. Surv. Canada, Rept. Prog., 1853–54–55–56, pp. 342–343.

1863. *Pasceolus Halli* Billings
Billings *in* Logan, Geol. Surv. Canada, Rept. Prog. to 1863, fig. 312, p. 309.

1865. *Pasceolus Halli* Billings
*Billings, Palaeo. fossils, **1**, Geol. Surv. Canada, pp. 390–392, text-fig. 366

1865. *Pasceolus Halli* Billings
Verrill, Proc. Boston Soc. Nat. Hist., **10**, p. 19.

1865. *Pasceolus Halli* Billings
Niles, Proc. Boston Soc. Nat. Hist., **10**, pp. 19–20.

1865. *Pasceolus Halli* Billings
Billings, Canad. Nat., **2**, pp. 195, 196, 197, text-fig. 13.

1866. *Pasceolus Halli* Billings
Billings, Cat. Sil. Foss. Anticosti, Geol. Surv. Canada, pp. 69, 70, 71, 72.

1868. *Cyclocrinus Halli* Billings
Bigsby, Thesaurus Siluricus, p. 19.

1868. *Pasceolus Halli* Billings
Bigsby, Thesaurus Siluricus, p. 192.

1874. *Pasceolus Halli* Billings
Miller, Cincinnati Quart. Jour. Sci., **1**, no. 1, pp. 4, 5.

1875. *Pasceolus Halli* Billings
Kayser, Zeits. Deut. Geol. Gesell., **27**, pp. 779, 780.

1876. *Pasceolus Halli* Billings
Roemer, Lethaea palaeo., I Theil, p. 295.

1877. *Pasceolus halli* Billings, 1857
Miller, American Palaeo. fossils, p. 43.

1878. *Pasceolus Halli* Billings
*Nicholson and Etheridge, Monogr. Sil. fossils, Girvan Dist., text-fig. 1a, pp. 14, 15.

1880. *Pasceolus Halli* Billings
Zittel, Handb. Palaeontol., **1**, p. 728.

1884. *Pasceolus Halli* Billings
Hinde, Quart. Jour. Geol. Soc. London, **40**, p. 835.

1889. *Pasceolus Halli* Billings
*Nicholson and Lydekker, Manual Paleontol., **1**, fig. 73a.

1889. *Pasceolus halli* Billings, 1857
Miller, North Amer. Geol. Palaeontol., p. 162, text-fig. 117.

1889. *Pasceolus halli*
Lesley, Geol. Surv. Penn., Rept. P4, **2**, p. 603, text-fig.

1895. *Pasceolus Halli* Billings, 1865
Head, Palaeoz. sponges, p. 12.

1896. *Cyclocrinus Halli* Billings
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, Heft 2, pp. 200, 201, 206, 213, 214, 215, 216, 217, 218.

1896. *Cyclocrinus* (*Pasceolus*) *Halli* Billings
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, p. 215.

1910. *Pasceolus halli*
*Foerste, Bull. Sci. Lab. Denison Univ., **16**, p. 86.

1910. *Pasceolus halli*
Schuchert and Twenhofel, Bull. Geol. Soc. Amer., **21**, p. 703.

1914. *Cyclocrinites halli*
Twenhofel, Geol. Surv. Canada, Mus. Bull., no. 3, pp. 9, 12.

1915. *Pasceolus halli* Billings
Bassler, Bull. U. S. Nat. Mus., no. 92, p. 947.

1916. *Pasceolus halli* Billings
*Foerste, Bull. Sci. Lab. Denison Univ., **18**, pp. 289–290.

1927. *Cyclocrinus Halli* Billings
Pia, Handb. Paläobot., p. 66.

1928. *Cyclocrinites halli* (Billings)
*Twenhofel, Geol. Surv. Canada, Mem., 154, pp. 83, 100, 101, 102.

1948. *Pasceolus halli* Billings
*Wilson, Canada Geol. Surv. Bull., no. 11, pp. 27, 28, pl. 13, fig. 6, pl. 14, fig. 7.

1955. *Pasceolus halli* SD Hinde, 1844
Laubenfels, Treatise Inv. Paleontol., p. E110.

1959. *Pasceolus halli* Billings, 1866
Johnson and Konishi, Quart. Colo. School Mines, **54**, no. 1, p. 11.

1966. *Pasceolus halli* Billings
Bolton, Cat. types, **3**, p. 143.

Definition:—Thallus small, pyriform; elongated and probably attached; mucilage present; calcification above the heads of laterals but below membrane; laterals unbranched, in whorls; lateral heads polygonal, numerous, and well packed; terminal hair probably present; either tuft of hair or apertures on lateral head in apical region; environment probably protected or deeper water.

Description:—It appears from his description that Billings had more than one specimen. Bolton (1966) suggests also that more than one specimen was originally present. However, only the holotype is available in the collection of the Canadian Geological Survey, and there are 13 specimens from the Museum of Comparative Zoology.

The holotype (fig. 30) is a very well preserved specimen. The rock of which it is composed is calcilutite. The calcification is on the exterior of facets only. The specimen cannot be a cast as was suggested by Billings because of the presence of the organic "overgrowth" (fig. 31) and the presence of mucilage (figs. 19, 20). It is impossible to see how the "overgrowth" and the external mucilaginous membrane could be preserved on a cast. The fossil is not flattened or deformed, nor are any solution effects noted. Only the lower, elongated end is broken. The general body shape is pyriform, the basal end is narrower.

THALLUS. The thallus is unbranched, and the main axis is therefore considered also unbranched. The laterals are most certainly in whorls. Thickness and length of main axis and of laterals are unknown. No circular aperture such as Billings noted is present. Billings' orifice is a portion of an unidentified attached organism (fig. 31). The elongated end is assumed to be a modification for attachment.

Laterals. "Plates" are not present; however, on the termini of the lateral branches, lateral heads are observed. From fossils that are slightly broken and damaged it appears that the branches dilated rapidly and formed heads. These were pressed together, calcified, and formed an external wall or cortex. The "ornamentation" is noted on the faceted outer surface. The lateral heads are packed closely together with little apparent linear regularity and leave no empty space between. Maximum number of laterals at the narrower end is 12; across the maximum diameter of the thallus approximately 50. The outline of individual facets varies from circular to polygonal. Polygonal facets vary from four-sided to eight-sided. The most common is six-sided, however very few are true polygonals. Irregularly shaped lateral heads are common and include drop-shape and pyriform. The edges of heads form continuous lines that can be traced only over a very short distance, commonly not longer than the length of six lateral heads.

A few lateral heads on the apex of the thallus possess slightly elevated rings suggestive of openings (figs. 19, 20). These are here interpreted either as scars of constrictions of individual branches, or as apertures. If these are scars, then the plant possessed apical tufts; if, however, these were apertures without any protruding elements, then the plant was unusual in having orifices on the apical facets. The specimen no. 2749 in the collection of the Museum of Comparative Zoology possesses structures highly suggestive of a second set of lateral heads. This structure is similar to the second layer of heads observed in *Cyclocrinites dactioloides*. The preservation of this fossil is rather poor, nevertheless, it is possible that the second layer of heads was indeed present in this species. Should this prove to be the case, the apertures would be interpreted as constrictions of laterals between two sets of lateral heads. Because of the presence of a mucilaginous membrane it is, however, not likely that a second set of lateral heads was present.

Polygonal structures. A regular pattern of minute polygonal structures, perhaps equivalent to the ornament on Stolley's European material, is observed on many facets on the holotype (figs. 19, 20). These are arranged in a fairly regular pattern of lines and could have served for attachment for the threads of hair that, when present, formed a dense tuft perhaps on the entire surface, similar to certain recent algae. They follow and to some extent are modified by the pattern of the overlying "overgrowth." They are now a black residue, suggestive of organic matter. They possess a definite polygonal

TABLE 2.—Measurements in centimeters of 14 specimens of *Cyclocrinites halli* (Billings) from Ellis Bay Formation, Anticosti Island.

Specimen no. CGS 2227 is from the Canadian Geological Survey, all other specimens are from the Museum of Comparative Zoology.

Specimen no.	CGS 2227	Unnumbered					MCZ 2748					MCZ 2749		
Height	3.57	4.20	3.66	2.84	2.93	5.86	3.20	4.99	....	....	....	2.84	....	4.17
Width	2.73	3.17	2.92	2.71	2.29	2.98	2.84	3.25	3.86	2.93	2.18	2.53	2.59	....

pattern and are surrounded by whiter matter. Each polygon is of an order of dimension of about .01 mm. These structures thus appear organic, and appear to be imbedded in the mucous membrane.

MUCOUS MEMBRANE. The mucous membrane is on the exterior of the thallus and is present on a number of specimens. It is very suggestive of the mucilaginous layer of recent algae. If it is the same, then the calcification occurred in a manner suggestive of the *Neomeris* pattern, mainly below the membrane. It, however, differs from *Neomeris'* calcification in lacking an outer calcified zone.

Relationship:—This species, with the exception of the genus *Anomaloides,* is the only cyclocrinitid that has a strong suggestion of a mucilaginous membrane. This sets it apart from all other species of *Cyclocrinites.* Whether other *Cyclocrinites* possess the mucilage, and whether their calcification occurred in the same manner is unknown. For this reason, it seems best to retain the species *C. halli* for the retention of the organisms that possess the membrane. Should later study reveal the presence of a mucilage in the European material, then the species might be rejected as a synonym of some other European *Cyclocrinites.* Until such time, however, the presence of the mucilage is considered a specific character, whether or not its absence in other forms is due to their biology—a question that cannot be solved at the present time. It is recognized that the presence of the mucilage could be, however, an accident of preservation, and if this could be shown then the taxonomic position of this species would likewise have to be changed. The regular, elongated, pyriform shape of the plant is suggestive of a habitat in greater depth, or in a protected sea without much motion, stir, or agitation, and may very well have been ecologically controlled.

In the size of thallus and in the shape and dimensions of lateral heads the species is not distinguishable from other species of *Cyclocrinites.* The mucilage and facets are however, distinctly different and are like those of recent dasycladaceous algae.

Material and measurements:—Holotype no. 2227 in the collection of the Geological Survey of Canada, Ottawa, Canada. Size of lateral head at lower end, 0.09 cm.; size of lateral head through the middle, 0.14 cm.; size of lateral head at apex, 0.20 cm. Thirteen specimens in the Museum of Comparative Zoology; their measurements are given in Table 2.

Stratigraphic position and locality:—Upper Ordovician, Ellis Bay Formation; White Cliff, Ellis Bay, Anticosti Island, Quebec, Canada.

Cyclocrinites globosus (Billings, 1857)

Figures 3B, 7C, 21D, 32, 37

1857. *Pasceolus globosus* Billings
*Billings, Geol. Surv. Canada, Rept. Prog. 1853–54–55–56, p. 343.

1863. *Pasceolus globosus* Billings
Billings *in* Logan, Geol. Surv. Canada, Rept. Prog. to 1863, p. 954.

1865. *Pasceolus globosus* Billings
*Billings, Palaeozoic fossils, **1**, Geol. Surv. Canada, pp. 390–391, text-fig. 367.

1865. *Pasceolus globosus* Billings
Billings, Canad. Nat., **2**, pp. 195, 196, 197, text-fig. 14.

1866. *Pasceolus globosus* Billings
Billings, Cat. Sil. Fossils Anticosti, Geol. Surv. Canada, p. 70.

1868. *Cyclocrinus globosus* Billings
Bigsby, Thesaurus Siluricus, p. 19.

1868. *Pasceolus globosus* Billings
Bigsby, Thesaurus Siluricus, p. 192.

1874. *Pasceolus Globosus* Billings
Miller, Cincinnati Quart. Jour. Sci., **1**, no. 1, p. 4.

1875. *Pasceolus globosus* Billings
Kayser, Zeits. Deut. Geol. Gesell., **27**, pp. 777, 779, 780.

1876. *Pasceolus globosus* Billings
Roemer, Lethaea palaeoz. I Theil, p. 296.

1877. *Pasceolus globosus* Billings, 1857
Miller, Amer. Palaeo. fossils, p. 43.

1878. *Pasceolus globosus* Billings
*Nicholson and Etheridge, Monogr. Sil. fossils Girvan Dist., text-fig. 1b.

1889. *Pasceolus globosus* Billings
*Nicholson and Lydekker, Manual Paleontol., **1**, fig. 73b.

1889. *Pasceolus globosus* Billings, 1857
Miller, North Amer. Geol. Palaeontol., p. 162.

1895. *Pasceolus globosus* Billings, 1865
Head, Palaeoz. sponges, p. 12.

1896. *Pasceolus globosus* Billings
Ami, Trans. Roy. Soc. Canada, ser. 2, **2**, sec. 4, p. 154.

1896. *Cyclocrinus globosus* Billings
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, Heft 2, pp. 200, 201, 206, 213.

1896. *Cyclocrinus* (*Pasceolus*) *globosus* Billings
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, p. 215.

1899. *Pasceolus globosus* Billings
Ami, Geol. Surv. Canada, Ann. Rept., new ser., **10**, p. 300 I.

1902. *Pasceolus globosus* Billings
Ami, Geol. Surv. Canada, Ann. Rept., new ser., **12**, p. 64G.

1910. *Pasceolus globosus*
*Foerste, Bull. Sci. Lab. Denison Univ., **16**, p. 86.

1913. *Pasccolus (Cyclocrinus) spaskii* ? Eichwald
McInnes, Geol. Surv., Canada Mem. 30, p. 61.

1915. *Pasceolus globosus* Billings
Bassler, Bull. U. S. Nat. Mus., no. 92, p. 947.

1916. *Pasceolus globosus* Billings
Foerste, Bull. Sci. Lab. Denison Univ., **18**, p. 290.

1927. *Cyclocrinus globosus* Billings
Pia, Handb. Paläobot. p. 66.

1937. *Pasceolus globosus* Billings
Kay, Bull. Geol. Soc. Amer., **48**, pp. 263, 278, pl. 10.

1944. *Cyclocrinites globosus* (Billings)
Shimer and Shrock, Index Fossils of North Amer., p. 719, pl. 303, fig. 22.

1948. *Pasceolus globosus* Billings
*Wilson, Bull. Canada Geol. Surv., no. 11, pp. 4, 27, 28, pl. 14, figs. 4–6.

1952. *Cyclocrinus globosus* Billings
Johnson, Quart. Colo. School Mines, **47**, no. 2, p. 40.

1966. *Pasceolus globosus* Billings
Bolton, Cat. types, **3**, p. 143.

Definition:—Thallus large, mostly cushion-like, can approach sphericity; shape probably ecologically controlled; main axis perpendicular to substrate; laterals in whorls, not branched; laterals dilate and form heads; calcification on lower and on upper parts of heads; attachment mechanism unknown; base flat, seldom concave.

Description:—The description is based on a number of specimens including original fossils of Billings.

THALLUS. These are relatively large cyclocrinitids reaching over 5 cm. in diameter. Their commonest body shape is cushion-like, with relatively flat bases (fig. 3B). Specimens with slightly or very convex bases, and others tilted, and some almost spherical are also found. The distribution of facets is relatively regular, an indication that the main axis was perpendicular to the substrate. This is further supported by the general shape of the thallus, with almost always a flat lower part at a right angle to the rest of the body. Microscopic observation of a section cut across the thallus shows that the fossil is now filled with organic debris. The older branches at the lower end that form the base were probably not exposed to light. It is very likely that these were dead, and the resting platform consisted of their calcareous walls only.

Laterals:—There is no evidence that laterals branch. The laterals dilate, form lateral heads, and thus form an outer wall. The thin section shows small rings approximately 0.005 mm. in diameter. These are believed to be cross-sections of laterals. They may rep-

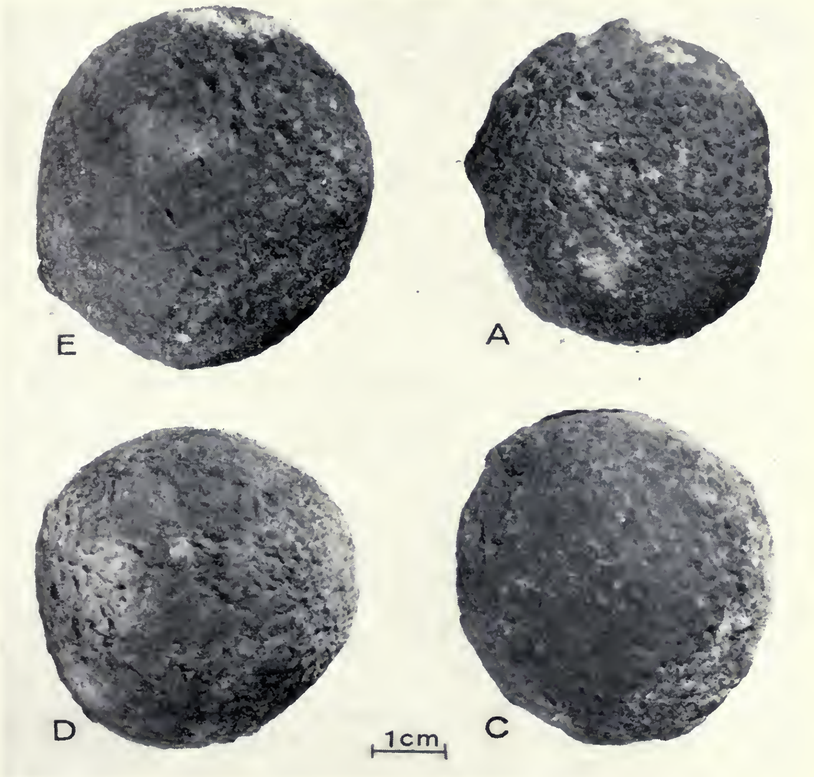

FIG. 37. *Cyclocrinites globosus* (Billings). Canada Geol. Surv. 1376 a, c–e. Cobourg? beds, Ottawa, Ontario. Holotype probably specimen 1376 a. All apical view.

resent sporangia, but this is unlikely. The facets are 0.25 cm. across. If the rings are indeed uncalcified laterals, then their expansion into lateral heads was considerable.

No facets are observed on the base, but calcification was persistent in that area. In the growing and expanding thallus the younger laterals may have pushed the older down toward the base where, due to lack of light, they died. Thus, as already stated, the laterals were probably absent from the lower part of the plant. The distribution of facets indicates that laterals were borne on whorls.

FACETS. Facets are concave and form by precipitation of carbonate under the lateral heads. Each facet communicates commonly with six others, less frequently with a smaller or a larger number. The facets are rounded, sometimes polygonal, very rarely six-sided.

Some facets have a distinct shallow rim, indicating that the calcification below the lateral head was shallow. The borders of facets (in effect, contacts of individual laterals) form parallel lines. Two sets of these are present and are approximately at right angles to each other. The lines are diagonal to the main axis. Facets are generally very poorly preserved, and are never found at the bottom of the plant.

Membrane. A suggestion of a mucilaginous membrane is seen in the form of a "wrinkled" facet. But this is restricted to one facet of one specimen (Canada Geol. Surv., 1376e) and, therefore, remains a puzzle.

Attachment. No attachment mechanism is observed. Possibly, these forms were attached loosely by a mucilaginous membrane or its modification on the base, or they simply rested on the substrate without any anchorage (fig. 3B).

Calcification. None of the cross sections through thalli shows any evidence of calcification other than in the termini of laterals. Since both facets and lateral heads are preserved, calcification occurred in a double layer around the body (fig. 21D). Whether it was double at the base of the plant is not known. Calcification, however, must have been strong enough to resist compaction, since no flattened specimens are found. This calcification below and above the lateral head is similar to that of the recent algae.

Since no small individuals have been observed, it is assumed that they did not calcify while in the immature, small stage.

Preservation:—The fossils examined include characteristically poorly preserved specimens. Details of anatomy are not preserved. This inferior preservation implies poor calcification, or mineralogy of the skeleton different from the associated well-calcified and well-preserved invertebrates. The skeletons were probably aragonitic. During diagenesis these fossils acted as hard bodies and slickensided surfaces are common.

Ecology:—The shape of the body of a recent alga is a strong ecological indicator (Fritsch, 1948). It is believed that *C. globosus* was just resting upon the bottom. There is a distinct vertical orientation of the thallus, and most forms are cushion-shaped. It is these cushion-shaped organisms that are considered as definitely resting on the surface. Those that were more spherical have no facets preserved on their bases, hence these also were probably resting on bottom. The specimens that are now concave at their lower end

TABLE 3.—Measurements in centimeters of 36 specimens of *Cyclocrinites globosus* (Billings). CGS=Canad. Geol. Surv. specimens from Cobourg beds in and around Ottawa, Ontario; UC=Univ. Chicago (FMNH) from "Trenton," Rochesterville, Ottawa; CM=University of Cincinnati Mus.: 37467 from Erindale Fm., Cooksville, Ontario and other CM specimens are from "Trenton," Ottawa; MU=Miami Univ. from Ottawa, Ontario.

Specimen number	CM 388	CM 388	CM 388	CM 388	MU	MU
Height	1.60	1.02	1.66	1.10	1.10	1.11
Width	5.03	4.27	4.35	4.59	4.15	3.28

Specimen number	CGS 9333	CGS 1376	CGS 1376a	CGS 1376b	CGS 1376c	CGS 1376d	CGS 1376e	UC 3700	UC 3700	UC 3700
Height	3.02	2.46	1.87	3.36	2.64	2.93	3.21	2.19	1.85	1.20
Width	3.81	4.30	4.71	5.39	5.00	4.94	5.42	4.43	3.06	2.43

Specimen number	CM 37467	CM 38828	CM 38828	CM 882	CM 882	CM 882	CM 882	CM 882	CM 882	CM 882
Height	1.12	2.44	.079	1.71	1.40	1.45	1.51	1.31	1.38	1.39
Width	2.15	4.76	....	4.82	4.28	3.86	3.40	4.64	3.46	3.55

Specimen number	CM 882	CM 882	CM 882	CM 882	CM 882	CM 882	CM 882	CM 388	CM 388	CM 388
Height	1.21	1.27	1.15	1.17	0.98	0.75	0.54	2.62	1.55	1.11
Width	3.28	3.13	3.26	2.82	3.26	3.26	2.67	4.93	4.50	....

were probably resting on an uneven surface. The individuals with tilted thalli were possibly growing against a gentle water current. Many specimens are found with impressed, small, broken fossils upon their bases. The substrate upon which these grew consisted of broken organic debris.

There is no indication that any of these organisms were rolled along the bottom of the sea. Neither is there any evidence for assuming a condition of motionless water to allow for the growth of elongated thalli. It is possible that young forms were better attached, but were not calcified. With calcification and increased weight the resting habit may have developed in older plants.

Whether these fossils represent thanatocoenosis or biocoenosis is impossible to say.

Relationship:—C. globosus is a "typical" cyclocrinitid. It is very similar to other species of the genus, and differs from them by its relatively large size, its poor preservation, the presence of a double layer of calcification above and below the dilated termini of the laterals, and in its apparent lack of ribs and second layer of lateral heads. Most of the characters used for its definition may, however, be ecologic and not specific. Further studies involving larger collections may solve this problem. The narrow concept of this species could in the future be enlarged to include other morphological types.

Material and measurements:—Holotype probably specimen 1376a in Canada Geological Survey Collection; other "syntypes," "hypotypes," and slides in Canada Geological Survey nos. 1376, b-e, 9333; five specimens in Field Museum (Univ. Chgo. Collection); two specimens in collections of Miami University; 24 specimens in the University of Cincinnati Museum. Measurements are given in Table 3.

Stratigraphic position and localities:—Middle Ordovician: Ottawa Formation, Cobourg beds; "Trenton"; Erindale Formation. In and around Ottawa, Rochesterville, and Cooksville, Ontario, Canada.

Cyclocrinites gregarius (Billings, 1866)

Figures 3C–D, 21A, 38–40

1866. *Pasceolus gregarius* Billings
*Billings, Cat. Sil. Fossils Anticosti. Geol. Surv. Canada, 1866, p. 72.

1866. *Pasceolus intermedius* Billings
*Billings, Cat. Sil. Fossils Anticosti. Geol. Surv. Canada, p. 72.

1868. *Pasceolus gregarius* Billings
Bigsby, Thesaurus Siluricus, p. 192.

1868. *Pasceolus intermedius* Billings
Bigsby, Thesaurus Siluricus, p. 192.

1875. *Pasceolus gregarius* Billings
Kayser, Zeits. Deut. Geol. Gesell., **27**, p. 780.

1875. *Pasceolus intermedius* Billings
Kayser, Zeits. Deut. Geol. Gesell., **27**, p. 780.

1876. *Pasceolus gregarius* Billings
Roemer, Lethaea palaeoz., I Theil, p. 296.

1876. *Pasceolus intermedius* Billings
Roemer, Lethaea palaeoz., I Theil, p. 296.

1877. *Pasceolus gregarius* Billings, 1866
Miller, Amer. Palaeo. fossils, p. 43.

1877. *Pasceolus intermedius* Billings, 1866
Miller, Amer. Palaeo. fossils, p. 43.

1889. *Pasceolus gregarius* Billings, 1866
Miller, North Amer. Geol. Palaeontol., p. 162.

1889. *Pasceolus intermedius* Billings, 1866
Miller, North Amer. Geol. Palaeontol., p. 162.

1894. *Nidulites favus* Salter, var.
Ami, Ottawa Nat., **8**, pp. 83–84, 89.

1895. *Pasceolus gregarius* Billings, 1865
Head, Palaeoz. sponges, p. 12.

1895. *Pasceolus intermedius* Billings, 1865
Head, Palaeoz. sponges, p. 12.

1896. *Cyclocrinus* (*Pasceolus*) *gregarius* Billings
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, p. 215.

1896. *Cyclocrinus* (*Pasceolus*) *intermedius* Billings
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, p. 215.

1897. *Pasceolus gregarius* ? Billings
*Whiteaves, Palaeoz. fossils, **3**, part 3, pp. 144–145.

1901. *Pasceolus gregarius* Billings
Dowling, Geol. Surv. Canada. Ann. Rept. (new ser.) **11**, (for 1898) Rept. F, pp. 38, 48, 69, 73, 76, 78, 86.

1909. *Pasceolus intermedius* Billings
Foerste, Bull. Sci. Lab. Denison Univ., **14**, p. 304.

1910. *Pasceolus gregarius*
Foerste, Bull. Sci. Lab. Denison Univ., **16**, p. 86.

1910. *Pasceolus intermedius*
Foerste, Bull. Sci. Lab. Denison Univ., **16**, p. 86.

1914. *Cyclocrinites gregarius*
Twenhofel, Bull. Canada Geol. Surv. Mus., no. 3, p. 13.

1914. *Cyclocrinites intermedius*
Twenhofel, Bull. Canada Geol. Surv. Mus., no. 3, p. 13.

1915. *Nidulites gregarius* (Billings)
Bassler, Bull. U. S. Nat. Mus., no. 92, p. 855.

1915. *Nidulites intermedius* (Billings)
Bassler, Bull. U. S. Nat. Mus., no. 92, p. 855.

1916. *Pasceolus gregarius* Billings
Foerste, Bull. Sci. Lab. Denison Univ., **18**, p. 289.

1927. *Cyclocrinus gregarius* Billings
Pia, Handb. Paläobot. p. 66.

1927. *Cyclocrinus intermedius* Billings
Pia, Handb. Paläobot. p. 66.

1928. *Cyclocrinites gregarius* (Billings)
*Twenhofel, Geol. Surv. Canada Mem., no. 154, pp. 56, 83, 102.

1928. *Cyclocrinites intermedius* (Billings)
*Twenhofel, Geol. Surv. Canada Mem., no. 154, pp. 55, 58, 83, 101, 102, pl. 1, fig. 10.

1929. *Pasceolus gregarius*
Foerste, Bull. Sci. Lab. Denison Univ., **24**, p. 131.

1941. *Nidulites gregarius* (Billings)
Roy, Field Mus. Mem., **2**, pp. 193, 195.

1941. *Cyclocrinites intermedius* (Billings)
Dresser and Denis, Quebec Bur. Mines Geol. Rept. 20, **2**, pl. 39, fig. 8.

1966. *Pasceolus gregarius* Billings
Bolton, Cat. types, **3**, p. 143.

1966. *Cyclocrinites intermedius* (Billings)
Bolton, Cat. types, **3**, p. 142.

1966. *Pasceolus intermedius* Billings
Bolton, Cat. types, **3**, p. 143.

Definition:—Thallus small, cushion-like, generally concave, sometimes flat at base, apically convex; main axis uncalcified, perpendicular to base; laterals regularly arranged in whorls, constricted below lateral heads; portion of lateral below constriction calcified; heads closely packed; facets deep, forming regular lines; constriction of laterals at base of lateral heads preserved as orifice; base without facets poorly preserved; weak calcification below lateral heads; mucilaginous membrane suggested.

Description:—The description is based upon Billings' original material.

THALLUS. These fossils are somewhat smaller than *Cyclocrinites globosus,* but are comparable in size with *C. dactioloides.* They are all, as far as can be determined, cushion-shaped or nearly so (figs. 3C-D, 38, 39). Their bases are either flat or concave, the latter more common. The surfaces of bases are uneven, irregular, and changing from specimen to specimen. The bases are poorly preserved, are free of facets, and are assumed to have been poorly calcified.

The apex of the thallus is convex, thus giving an appearance of a semi-dome (fig. 39). These shapes are not distorted and a regularity of shapes is a rule.

FIG. 38. *Cyclocrinites gregarius* (Billings). Canada Geol. Surv. 2230e. About 50 specimens from Becscie Formation, Anticosti Island, Quebec.

FIG. 39. *Cyclocrinites gregarius* (Billings). Canada Geol. Surv. 2230, probable holotype from Becscie Formation, Anticosti Island, Quebec.

MAIN AXIS. Little of the shape of the main axis can be reconstructed from the general shape of the thallus and from the distribution of facets. It appears that the plant had a straight non-calcareous main axis perpendicular to its base. The thickness of the main axis, however, cannot be determined; it could have been a thin rod, a hollow robust cylinder, or a short spherical body.

LATERALS. There is no indication that the laterals divided, and it is assumed that only primaries existed. These are borne on the main axis in whorls, with the maximum number of about 50 in a whorl at the greatest dimension of the thallus. The proximal portions of the laterals did not calcify. There is a slight suggestion of the presence of laterals in a cross-section of the thallus, but this, however, is not certain. The constricted distal ends of laterals dilate rapidly and form lateral heads. The constriction is represented by an orifice in the facet; the base of the lateral head is represented by the facet (fig. 39). The lateral heads are packed closely together, and are pressed into polygonal structures. The precipitation of calcium carbonate occurs on the inner side of the lateral heads. At the base of the thallus the laterals probably died in a manner common to all cushion-shaped forms.

A cross-section of the laterals below the constriction is sometimes preserved. The calcification of the laterals is never longer than twice the depth of the facet. It thus appears that calcification occurs below the facets and along the laterals.

FACETS. Facets are formed by the precipitation of calcium carbonate upon the inner surfaces of lateral heads. It is these surfaces that are now preserved and form deep commonly rounded cup-shaped facets (figs. 39, 40). The shape of the facet, which in some cases is polygonal, varies from four to seven sides. The six-sided facets predominate, in which case each facet contacts six others. The regularity of the walls of the facets depends upon the degree of packing, the closer packed laterals producing more regular polygons.

On bases of many facets a small orifice consisting of darker colored calcite is found. This calcite on occasion forms a protuberance rather than an opening, a condition dependent upon preservation. The orifice represents the cross-section through the lateral at the point of its constriction.

The walls of facets form intersecting lines that cross each other at right angles (figs. 39, 40). These lines are inclined with respect to the main axis. The length of lines depends upon the preservation of the fossil, the better preserved having longer lines. The maximum distance traced extends over 15 facets.

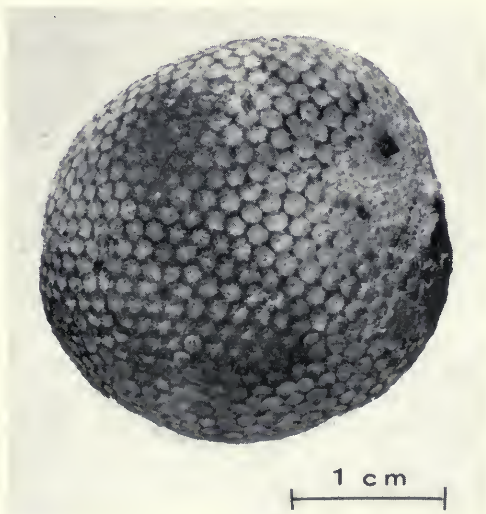

FIG. 40. *Cyclocrinites gregarius* (Billings). Canada Geol. Surv. 8131. Gun River Formation, Anticosti Island, Quebec. This specimen was originally described as *C. intermedius* (Billings) (Twenhofel, 1928).

The irregularity of facets is noted in the formation of rosettes. The rosettes are present only in the specimens that possess regularly formed facets, and when the resulting intersecting lines are long.

CALCIFICATION. Only one layer of lime precipitated under the heads of laterals (fig. 21A). No evidence for the exterior layer exists. The general degree of calcification is poor, and only in a few instances are facets well preserved. The calcification is generally poorer than in other cyclocrinitids and is certainly weaker than the calcification of the associated brachiopods. Only the area away from the base contains facets, and it is this part that is better calcified. Weak calcification is also noted on laterals just below the lateral heads.

ATTACHMENT. The shape of the thallus is indicative of a sitting position, characteristic of all cushion-shaped forms. At the base of certain specimens there is a slit-like structure that could be an indentation for the reception of an attachment pedicle. However, the slit may have been caused by some post-mortem, or diagenetic change unrelated to the original organization of the plant. The "just sitting on the substrate" habit is here favored, particularly since many individuals have bases with irregular surfaces on which impressions of invertebrate fossils are seen. No such impressions are found elsewhere on the thallus, and therefore they are interpreted as representatives of the debris accumulated at the bottom of the sea.

Preservation:—Preservation is generally very poor and the fossils consist of coarsely crystalline calcite. The external appearance of the plant is "dirty." This aspect is due to the presence of fine-grained, shaly matrix that fills in the facets and obstructs the view of the already poorly preserved thallus. An unusual aspect of "shrinkage" is found on a slab of rock with many specimens (fig. 38). The fossils are smaller than the concavity in which they are located. The impression of the fossil is seen in the walls of the cavity. The empty space between the fossil and the matrix represents the amount of shrinkage and is in order of 0.10 cm. The largest space measured is 0.11 cm. The average diameter of the fossils in this slab is 1.87 cm. The measurement of the smallest gap is meaningless because there are specimens that apparently did not shrink, and all gradation of the distances exist. No effect of solution was noted, therefore, these spaces cannot be considered solution effects. They can only be interpreted as shrinkage. No explanation for this underwater shrinkage exists. Whether it is related to a change in mineralogy cannot be known, unless the original mineralogical composition is understood. The change from aragonite to calcite causes expansion, not shrinkage, in volume, hence it cannot be responsible for this phenomenon.

The associated organisms are better preserved than *C. gregarius*, an example of a relatively poor preservation of cyclocrinitids. The unanswered question is whether *C. gregarius* was less resistant to changes than were, for example, brachiopods. And, if so, what were the changes and why did the preferential preservation occur?

Relationship:—The species is a "good" cyclocrinitid, and is very similar to *C. globosus* and *C. darwini*. It is also closely related to the casts of specimens of *C. dactioloides* described from the Mississippi Valley, from which it is practically indistinguishable. It is possible that it may be a synonym of any one of these three species.

It possesses a number of similarities to recent forms, mainly the formation and structure of the termini of the laterals, the heads of the laterals and the resulting facets.

Ecology:—A very weak overgrowth similar to the mucilaginous membrane of *C. halli* is noted. Since only the inner calcification is observed, this structure cannot be an integral part of the plant, and must be considered foreign. This overgrowth is under the heads of laterals, and it originated after the death of the plant, and hence implies the post-mortem rigidity of the skeleton.

On bases of certain specimens there are impressions of fragments of fossils. Since the impressions are, as in other cyclocrinitids, only on the bases, their presence is interpreted as an indication of the conditions of the substrate. The substrate consisted of broken-up debris of skeletal material.

All associated brachiopods are found on the reverse side of the slab containing *C. gregarius*. The brachiopods are well preserved casts, mostly disarticulated, sorted, and oriented with the same side up. The sorting of size and the orientation implies a current; however, because one articulated shell is present it is believed little transportation occurred. *C. gregarius* are concentrated in a zone above (or below; the orientation of slab in the field is unknown) and are sorted and oriented. The condition of deposition must have been similar to conditions existing for the deposition of the brachiopods, or the current could have been weaker, if these plants were lighter than invertebrates.

A pattern on the surface of one specimen appears as grooves caused by a burrowing organism.

Synonym:—Pasceolus intermedius Billings, 1866.

TABLE 4.—Measurements in centimeters of 29 specimens of *Cyclocrinites gregarius* (Billings). Only better preserved specimens were measured.

All specimens are from the Canada Geological Survey and carry a prefix CGS.

Specimen number	2338d	2338c	2338b	2338a	2338f	2338g	2338	8131
Width	2.77	2.77	2.96	2.81	2.67	2.87	2.53	3.46
Height	....	1.69	1.90	1.86	1.42	1.81	1.62	2.01
Specimen number	2230c	2230	2230a	2230e	2230e	2230e	2230e	2230e
Width	2.19	1.93	2.11	1.76	2.05	1.75	2.08	1.58
Height	1.18	1.36	1.41	....	....	....	....	....
Specimen number	2230e	2230e	2230e	2230e	2230e	2230e	2230e	2230e
Width	1.42	1.82	2.10	1.90	2.07	1.26	1.94	2.16
Height	....	....	....	....	....	....	....	....
Specimen number	2230e	2230e	2230e	2230e	2230e			
Width	1.78	2.13	2.37	1.57	1.98			
Height	....	....	....	....	....			

Material and Measurements:—Holotype probably 2230; about 54 specimens 2230 a-d; 8131; seven specimens 2338. All from Canada Geological Survey Collection. Measurements are given in Table 4.

Stratigraphy and location:—Lower Silurian, Becscie Formation, Reef Point, Anticosti Island, Quebec, Canada, and Middle Silurian, Gun River Formation: Cape MacGilvray and three miles west of Jupiter River, Anticosti Island, Quebec.

Cyclocrinites welleri n. sp.

Figures 4, 5, 7D, 21E and 41

1963. *Mastopora* (?) sp.
Griefe and Langenheim, Jour. Paleontol., **37**, pp. 566, 567, pl. 63, fig. 4.

Definition:—Thallus large, probably globular; laterals in whorls almost regularly placed; laterals branched into two secondaries; main axis continues into stem; stem weakly calcified approximately one-fifth of body length; facets large, generally in contact with six others; calcification below lateral heads.

Description:—NAME. The species *welleri* is named for J. Marvin Weller, a tolerant teacher and a gentle friend, who patiently over the years, schooled the author in the practice of paleontology.

THALLUS. The thallus is probably globular; however, the preservation of the fossil does not allow for an exact definition of body shape (fig. 41). The thallus occupies a flat area, one side of which dips into the rock and disappears. The other side, however, grades into an impression of the fossil. The impression of the fossil upon the rock surface indicates that the organism was at least 5.39 cm. across. The dimensions of the preserved parts are 4.68 cm. by 3.27 cm. The specimen is broken into three parts that are now glued together. From Griefe and Langenheim's (1963) description, as well as from the observation of the broken surface, it appears that no internal structures are preserved.

MAIN AXIS. Part of the main axis is preserved (figs. 4, 41). The main axis forms a continuous structure, part of which constitutes the stem. The upper end of the main axis disappears under the preserved zone of facets and is not observed. It probably bulged in the manner suggested in Figure 5. The bulging of the main axis is believed to account for the globular body shape. In the more elongate specimens of other cyclocrinitids, the main axis was probably longer and thinner.

FIG. 41. *Cyclocrinites welleri* n. sp. Holotype, Univ. Calif. Mus. Paleontol. 30720. Mazourka Formation, Independence Quad., California. × 2.

The length of the exposed main axis is 1.79 cm. However, the remnants of the facets cover part of it, and only 1.11 cm. is exposed, in the form of the stem. The width of the main axis varies from 0.28 to 0.35 cm.

The scars of laterals are preserved on the main axis in the form of short rods. The rods are about 0.08 cm. long and less than 0.05 cm. across. They are arranged in whorls. They are difficult to measure and to count, but it appears that around 25 are present on the base.

STEM. The stem is the exposed part of the main axis and is therefore its prolongation. It is gently curved and expands at the base (fig. 4). The stem, as well as the entire main axis, appears to have been weakly calcified. The scars of laterals are preserved on the exposed length of the main axis, hence it appears that during the growth of the plant the older laterals died and were shed. The thallus subsequently moved up along the main axis as younger laterals were added and the older part of the main axis was exposed in the form of a stem with the preserved scars of the laterals.

LATERALS. The number of the secondary laterals corresponds to the number of facets. In addition to the silicified facets there are impressions of facets upon the rock. Thus the organism was larger than the area covered by the silicified facets. It is difficult to count the facets exactly, therefore, an arbitrary line across the specimen was drawn along which they were counted. Their number varies depending upon the position of the line, but no less than 20 facets were counted. Since the preserved part represents one side of the thallus, the total number of laterals must have been twice this amount. It cannot be determined exactly how much of the organism is missing, but it seems not much; therefore it is believed that the total number of laterals did not exceed 50. This number is twice the number of scars upon the stem. Therefore the scars and remnants of laterals upon the stem represent the primary branches, and the preserved facets represent the secondary laterals. There are about 25 short remnants of laterals upon the main axis. These indicate that the primaries are weakly calcified and are short. From these extend two longer secondary branches that are uncalcified and that terminate in calcified lateral heads. This relationship is shown diagrammatically in Figure 5.

Facets. Most facets are silicified, somewhat distorted, and in contact with six others. Walls of the facets are thick, occasionally up to 0.07 cm. They form lines that are less regular than lines formed in other cyclocrinitids. The flattening of the specimen may have disrupted the otherwise regular pattern. The facets are large and vary in size from 0.27 to 0.46 cm.

No lateral heads are preserved.

Relationship:—This species differs from all other cyclocrinitids examined in the presence of an unusual, long, well-preserved stem, and in the branching of the laterals. In size of thallus and distribution of laterals it is very similar to the *Cyclocrinites globosus* group.

Preservation:—The specimen is silicified, except for the main axis which is calcareous. The thallus appears flattened. The matrix is a dark colored limestone.

Stratigraphic position and locality:—Middle Ordovician, Mazourka Formation. "Limestone approximately 250 feet stratigraphically below top of Mazourka Formation on the south-facing slope in the first canyon south of the canyon containing Lead Canyon Trail" (Griefe and Langenheim, 1963, p. 573). Independence Quadrangle, California.

Material:—One specimen UCMP 30720 described by Griefe and Langenheim, 1963, p. 567, in the collection of University of California Museum of Paleontology, Berkeley, California.

Cyclocrinites dactioloides (Owen, 1844)

Figures 3E, 7E, 9, 10, 18, 21A, 29, 42–45

1844. *Lunulites ? dactioloides*
*Owen, Geol. Rep. Iowa, Wisconsin, Illinois, p. 69, [406], pl. 13, fig. 4.

1868. *Cerionites dactylioides* (Owen)
*Meek and Worthen, Geol. Surv. Illinois, **3**, pp. 345–346, pl. 5, figs. 2a–c.

1868. *Pasceolus ? dactylioides* (Owen)
Meek and Worthen, Geol. Surv. Illinois, **3**, pp. 345–346, pl. 5, figs. 2a–c.

1868. *Lunulites ? dactioloides* Owen
Meek and Worthen, Geol. Surv. Illinois, **3**, pp. 345, 346.

1874. *Lunulites* (?) *dactioloides* Owen
Miller, Cincinnati Quart. Jour. Sci., **1**, no. 1, p. 5.

1875. *Lunulites dactylioides* Owen
Kayser, Zeits. Deut. Geol. Gesell., **27**, p. 780.

1876. *Receptaculites dactyloides*
Roemer, Lethaea palaeoz., I Theil, p. 289.

1877. *Lunulites*(?) *dactioloides*
Miller, Amer. Palaeo. fossils, p. 43.

1877. *Receptaculites dactioloides* Owen, 1840
Miller, Amer. Palaeo. fossils, p. 43.

1883. *Cerionites dactyloides* (Owen)
*Whitfield, Wisc. Geol. Surv., **4**, pp. 267–269, 350, pl. 13, figs. 1–3.

1884. *Lunulites dactioloides*
Hinde, Quart. Jour. Geol. Soc. London, **40**, p. 846.

1884. *Receptaculites dactioloides* Owen
Hinde, Quart. Jour. Geol. Soc. London, **40**, p. 798.

1888. *Pasceolus Billingsi*
*Roemer, Neu. Jahr. Min. Geol. Pal., Band 1, pp. 74–75.

1889. *Cerionites dactyloides* Owen, 1844
Miller, North Amer. Geol. Palaeontol., p. 156, text-fig. 97.

1889. *Lunulites ? dactyloides*
Miller, North Amer. Geol. Palaeontol., p. 161.

1893. *Cerionites dactiloides*
Calvin, Amer. Geol., **12**, p. 54.

1893. *Cerionites dactyloides*
Calvin, Amer. Geol., **12**, p. 54.

1893. *Cerionites dactylioides* (Owen)
*Calvin, Amer. Geol., **12**, pp. 53–57, text-fig.

1893. *Lunulites ? dactioloides*
Calvin, Amer. Geol., **12**, p. 54.

1893. *Pasceolus ? dactylioides*
Calvin, Amer. Geol., **12**, p. 54.

1893. *Cerionites dactiloides*
Calvin, Proc. Iowa Acad. Sci., **1**, pt. 3, p. 13.

1893. *Cerionites dactyloides* Owen
Calvin, Proc. Iowa Acad. Sci., **1**, pt. 3, p. 13.

1893. *Cerionites dactylioides* (Owen)
*Calvin, Proc. Iowa Acad. Sci., **1**, pt. 3, pp. 13–15, text-fig.

1893. *Lunulites ? dactioloides*
Calvin, Proc. Iowa Acad. Sci., **1**, pt. 3, p. 13.

1893. *Pasceolus ? dactylioides*
Calvin, Proc. Iowa Acad. Sci., **1**, pt. 3, p. 13.

1895. *Cerionites dactylioides* (Owen)
Winchell and Schuchert, Geol. Minn. **3**, pt. 1, pp. 60, 67.

1895. *Cerionites dactiloides* Whitfield, 1882
Head, Palaeoz. sponges, p. 6.

1895. *Lunulites dactioloides* D. D. Owen, 1844
Head, Palaeoz. sponges, p. 6.

1895. *Pasceolus ? dactylioides* Meek and Worthen, 1868
Head, Palaeoz. sponges, p. 6.

1895. *Receptaculites dactioloides* S. A. Miller, 1877
Head, Palaeoz. sponges, p. 6.

1895. *Cerionites dactylioides* Owen
Wilson, Amer. Geol., **16**, pp. 278, 279.

1896. *Cyclocrinus dactylioides* Owen
*Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, p. 279, figs. 30, 31.

1896. *Cyclocrinus (Pasceolus) dactylioides* Owen
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, p. 215.

1896. *Pasceolus dactylioides* Owen
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, pp. 212, 213, 216.

1896. *Cyclocrinus (Pasceolus) Billingsii*
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, p. 215.

1896. *Pasceolus Billingsii*
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, p. 205. 212, 213, 216, 228.

1898. *Cerionites dactylioides*
Calvin, Iowa Geol. Surv., **8**, p. 149.

1898. *Cerionites*
Calvin, Iowa Geol. Surv., **8**, p. 150.

1899. *Cerionites dactyloides* (Owen)
Whitfield, Ann. N. Y. Acad. Sci., **12**, no. 8, p. 145.

1900. *Cerionites dactylioides*
Calvin and Bain, Iowa Geol. Surv., **10**, p. 454.

1900. *Cerionites*
Calvin and Bain, Iowa Geol. Surv., **10**, pp. 445, 454, 455, 456, 459.

1915. *Cerionites dactyloides* (Owen)
Bassler, Bull. U. S. Nat. Mus., 92, p. 204.

1923. *Cerionites dactylioides* (Owen)
Thomas, Proc. Iowa Acad. Sci., **29**, p. 85.

1927. *Cyclocrinus dactylioides* Owen
Pia, Handb. Paläobot., p. 66.

1927. *Cyclocrinus Billingsii* Roemer
Pia, Handb. Paläobot., p. 66.

1943. *Cerionites dactioloides* (Owen)
*Howell, Wagner Free Inst. Sci. Bull., **18**, no. 4, pp. 35, 39–41, figs. 4, 8, 9.

1944. *Cerionites*
Greacean and Ball, Trans. Wisc. Acad. Sci., **36**, p. 418.

1946. *Cerionites dactyloides* Owen, 1884
Ball and Greacean, Chicago Acad. Sci., Spec. Publ. 7, p. 15.

1946. *Cerionites dactyloides* (Owen)
Greacean and Ball, Sil. Inv. Greene Mem. Mus., p. 11.

1952. *Cyclocrinus billingsi* Roemer
Johnson, Quart. Colo. School Mines, **47**, no. 2, p. 40.

1954. *Cerionites dactyloides* Owen
Peck and McFarland, Jour. Paleontol., **28**, no. 3, p. 298.

1955. *Cerionites dactylioides*
Laubenfels, Treatise Inv. Paleont., p. E110.

1957. *Cerionites*
Lowenstam, Geol. Soc. Amer. Mem. 67, pp. 241, 245.

1959. *Sphaerospongia*
Collinson, Guide for Beginning Fossil Hunters, pl. 1, 2 figs.

1960. *Cerionites*
Brown and Whitlow, Bull. U. S. Geol. Surv., 1123-A, p. 33.

1967. *Paceolus* ? [sic] *dactylioides* (Owen)
Hansman and Scott, J. Paleontol., **41**, p. 1023.

Possible Synonym: **Cyclocrinites favus** (Salter)

1851. *Nidulites favus* Salter
*Salter, Quart. Jour. Geol. Soc. London, **7**, p. 174, pl. 9, figs. 16, 17.

1868. *Nidulites favus* Salter
Bigsby, Thesaurus Siluricus, p. 4.

1876. *Nidulites favus*
Roemer, Lethaea palaeoz., I Theil, p. 294.

1878. *Nidulites favus* Salter
*Nicholson and Etheridge, Mongr. Sil. fossils, Girvan Dist., pp. 11–13, 18–19, pl. 9, figs. 15–22; text-fig. 1i.

1889. *Cyclocrinus* (*Nidulites*) *favus*
*Nicholson and Lydekker, Man. Paleontol., **1**, fig. 73 i.

1895. *Nidulites favus* Salter
Head, Palaeoz. sponges, pp. 5, 12.

1915. *Nidulites favus* (Salter)
Bassler, Bull. U. S. Nat. Mus., 92, p. 855.

1916. *Nidulites favus*
Raymond, Bull. Mus. Comp. Zool., **56**, no. 3, p. 238.

1916. *Nidulites favus* (Salter)
Grabau, Bull. Geol. Soc. Amer., **27**, p. 577.

1928. *Nidulites favus*
Twenhofel, Geol. Surv. Canada, Mem. 154, p. 101.

1943. *Mastopora fava* (Salter)
*Currie and Edwards, Quart. Jour. Geol. Soc. London, **98**, pp. 235, 237–238, 239, pl. 11, figs. 1–3.

1944. *Nidulites favus*
Shimer and Shrock, Index Fossils of North Amer., p. 57.

1952. *Mastopora fava* Salter
Johnson, Quart. Colo. School Mines, **47**, no. 2, p. 44.

1955. *Nidulites favus*
Laubenfels, Treatise Inv. Paleontol., p. E110.

1959. *Mastopora fava* (Salter)
*Johnson and Konishi, Quart. Colo. School Mines, **54**, no. 1, pp. 13, 14, 15, 26, 46, 51, pl. 6, figs. 1–4.

1960. *Mastopora favosa* (Salter)
Osgood and Fischer, Jour. Paleontol., **34**, pp. 896, 897, 899, 901.

Definition:—Thallus unbranched, spherical or discoid, most commonly button or cushion shaped; shape ecologically controlled; main axis uncalcified, possibly thick and short; laterals constrict and dilate twice; laterals in whorls; lateral heads in two well-formed layers one above another; facets generally regular, perforated and hexagonal; walls of facets form intersecting lines; heavy calcification below, and light above and around lateral heads; attachment unknown.

Description:—THALLUS. The shape of the thallus varies (fig. 3E, 42–45). Basically it is a modified sphere. Specimens that are almost perfect spheres are found, although these are not common. It is possible that the scarcity of the spherical shape is due to the nature of the preservation that seldom allows for non-compressed specimens to be found. Thus it is likely that many specimens now compressed were originally spherical. In spherical forms neither orientation nor attachment position is observed.

Three basic patterns of departure from sphericity are recognized: the first appears as general flattening of the body; second, flattening of one part of the thallus only; and third, assorted irregular shapes. In the first type the form varies from a sphere to a flat disc. All gradations are found, and facets are generally preserved all over the surface of the fossil. The presence of facets throughout the flattened specimens indicates that they were compacted after death.

The second type of shape is the plant with only one side flattened. In this group specimens are included that appear to have a small piece cut off at the bottom, fossils that appear as half-spheres, and specimens that are very thin and flat-bottomed. The fossils flattened on only one side probably represent the original shape, since

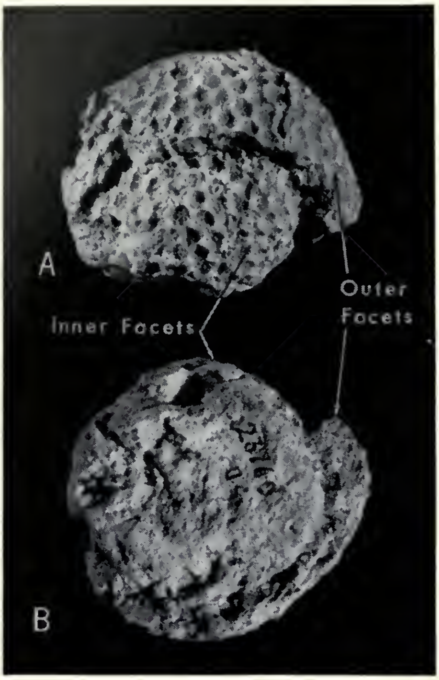

FIG. 42. *Cyclocrinites dactioloides* (Owen) FMNH UC 23760F, Niagaran, Clinton, Iowa. A, Lateral view; B, Basal view. Two layers of facets are shown. × 2.

no facets are found on these even "bottoms." This type of shape is very characteristic of the habit of growth of the cushion-shape cyclocrinitid. Cushion-shaped forms can have flat or concave bottoms.

The third group includes specimens whose thalli cannot be placed in either category and which are unevenly compressed individuals. These shapes could have resulted from post-mortem compaction, or from the growth pattern. Rounded and angular wedge-shaped thalli may represent actual growth conditions.

In addition to these groups, specimens are found that appear possibly damaged and subsequently healed. This, of course, cannot be proven, but small fractures as if by injury are observed.

MAIN AXIS. The main axis is not preserved, therefore was probably not calcified. It can be concluded from the general body shape and from the arrangement of laterals that the main axis was straight and at a right angle to the substrate. The thin and flattened speci-

FIG. 43. *Cyclocrinites dactioloides* (Owen) FMNH P 11020. Niagaran, Clinton, Iowa. Lateral view. × 3.

mens suggest that the axis was short. It is believed that it was probably relatively inflated.

LATERALS. The regular distribution of facets indicates that laterals on the main axis are borne in whorls. The proximal ends of laterals did not calcify. However, very short extensions from the facets toward the main axis are observed. The calcified distal end dilates twice and forms lateral heads in two layers one above the other (fig. 42). The number of laterals in the whorl in equatorial position is about 50.

Rosettes (fig. 18) are common only when the pattern of distribution of laterals is very regular. In *dactioloides* occasionally the great

FIG. 44. *Cyclocrinites dactioloides* (Owen) Chicago Acad. Sci. 7988. Jones County, Iowa. Thickness of calcified layer is preserved. × 3.

regularity of arrangement of laterals is disrupted, and the unusual configuration results. This may be sometimes caused by an addition of a new lateral. When the pattern of distribution of laterals is less orderly and the surface is irregular as in certain other cyclocrinitids, then the rosettes are not detected.

LATERAL HEADS. The lateral heads of *dactioloides*, as of other cyclocrinitids, are very similar to those of the recent alga *Neomeris dumetosa*. This similarity lies in their shape, relative size, and distribution on the surface. In *N. dumetosa* the laterals are of unequal length and therefore the heads are not all at the same level. *C. dactioloides* differs from *N. dumetosa* in having two different layers (fig. 7E) of lateral heads distributed very uniformly, so as to form two distinct layers, one exactly above the other. This is the only cyclocrinitid, with the possible exception of *C. halli*, that has this pattern. In all other American cyclocrinitids the laterals dilate only once and hence only one layer of heads forms. The lateral above the first head forms a perforated septum that is identical to the basal calcified area below the first head. Thus the second head of the same branch is formed, and is of equal symmetry and regularity as the first one. The second head easily detaches, and then the specimen is not distinguishable from the one-layered thallus.

Generally, only the impression of the first head is found in the form of a facet impressed upon the surface. Frequently, however, the upper, second lateral head is also preserved. The size and shape of the head varies not only within the collecting sample, but also on a single specimen.

The most common shape of the head is a short column with six sides which are a prolongation of the walls of a facet. However, tall and angular columns as well as rounded columns, tall or short without distinct angularity, are also noted. The elongated columns are rarer. Heads slightly constricted at their termini are observed.

An average width of head is 0.25 cm., while the longest measured is 0.37 cm. long; the average height is 0.23 cm. Thus they are somewhat shortened polygons, as few are observed with height that equals width. The tallest head noted is 0.32 cm. long. The elongated ends are unusual and are associated with irregularities of the surface such as rosettes. Generally, each facet touches six other facets; sometimes four, five or seven. When this number changes, an irregularity of shape results.

The first heads are preserved more often than the second; they also tend to be more polygonal, generally hexagonal.

FACETS. The calcification of the under sides of lateral heads forms facets (figs. 9, 10). These are unusually regular, hexagonal, often perforated, mostly concave structures. Rarely four-sided facets are lined up to form squares consisting of four facets. Each perforation represents a point on the lateral, just below dilation. The walls of facets form regular intersecting lines occasionally interrupted by introduction of new facets. It is these additional facets that mark the addition of a new lateral on a whorl. The dimensions of the facets, just as those of the lateral heads, vary from specimen to specimen and sometimes even on one individual. The sizes of facets correspond to those of lateral heads. Exceptions to the regularity of arrangement of facets are found. Thus, specimens are observed with facets of irregular shapes that do not produce intersecting lines.

CALCIFICATION. Calcification occurs continuously around the lateral heads (fig. 21A). The lateral heads are heavily calcified and the thickness of the calcareous layer is about 0.04 cm. (fig. 18). When heads are detached their impressions are preserved in the form of facets. The exclusive preservation of the second (upper) head alone is not observed. The laterals are only calcified for a short distance below the lateral heads.

In spherical and in flattened forms the calcification is continuous around the thallus. In forms with only one side flattened the calcification is discontinuous, and occurs upon the upper spherical part of the thallus only. It appears that the basal part of the plant in contact with the substrate was either not calcified or was calcified to a lesser degree.

ATTACHMENT. No attachment mechanism is observed in spherical forms. The shape of the cushion-like specimens with flat or somewhat concave bases is suggestive of the resting on the bottom position. It is probable that mucous membrane served the function of attachment.

Ecology:—The rocks in which these fossils are found are high purity dolomites. The associated invertebrates are disarticulated, but not broken, indicating a condition of gentle water action. The accompanying pelecypods are so well preserved that their growth lines are observed. It appears that cushion-shaped cyclocrinitids grew upon the debris consisting of these disarticulated shells. The spherical forms that do not show any attachment mechanism may have rolled gently on the bottom. Whether the flattened specimens were compacted or whether they grew this way is difficult to know. The sphericity of the cyclocrinitid body shape, and the disarticulated nature of the associated invertebrates indicates the degree of motion of water. The strength of water was sufficient to disarticulate or to transport the clams, but in undamaged condition.

Aging effects:—The oldest part of the plant is the lowest, hence the least exposed to light. It often differs from the rest of the thallus in being more compacted and in its facets and heads being deformed. These are preserved as fused and squashed ends of laterals. This fusing possibly gave rigidity and support to the organism. The aging effect is found only on these cushion-shaped specimens that are without facets on their basal parts, and therefore probably not compacted. This condition is comparable to the pronounced aging of thalli of *Ischadites* and *Receptaculites.* In most specimens generally the upper facets are more regularly hexagonal and appear larger than the lower facets.

Relationships:—The unique feature of this species is the formation of two sets of lateral heads. Whether this condition is present or absent in other species is difficult to determine because the outer layer appears easily lost. However, Salter (1851, p. 174; see p. 158 this paper) in his description of *Nidulites favus* observed and illustrated two layers. He was, however, uncertain of the nature of the fossil and considered it to be either an egg case of gastropod or a bryozoan. It is possible that his species is identical with *C. dactioloides,* particularly since Currie and Edwards' (1943, pp. 237–238, pl. 11, figs. 1–3) description and figure of *Mastopora fava* is indistinguishable from *C. dactioloides.* No decision, however, can be reached until the British specimens are examined.

Preservations:—All specimens examined are in dolomite. The fossils from the environs of Chicago are of a light gray color. The specimens from Iowa are of darker, almost tan or brown color.

The degree of preservation of morphological parts varies (fig. 29). Casts and molds of outer and inner lateral heads, as well as of facets are common. The uncommon two-layered thalli are found. The upper (apical) part of the thallus is generally better preserved than the lower (basal) part. In general, little compaction occurs and spherical forms are abundant. Certain pre- and post-depositional damage is present. Horizontal and vertical flattening is observed. In some small disc-shaped specimens a collapsed top similar to the

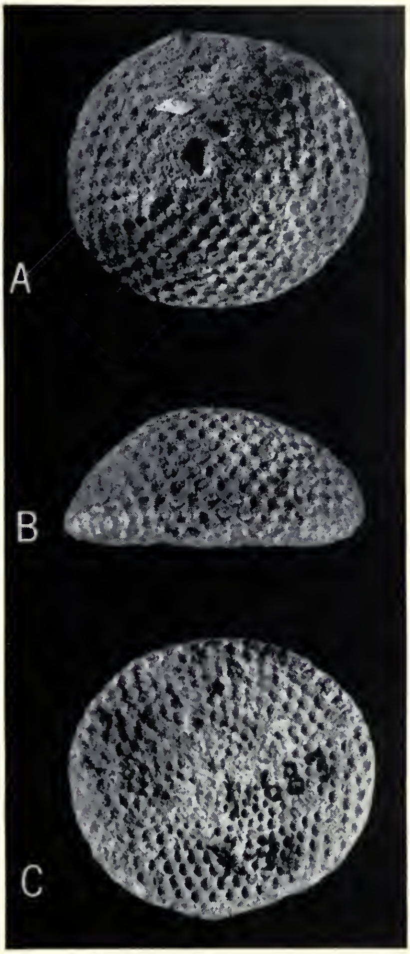

FIG. 45. *Cyclocrinites dactioloides* (Owen). Univ. Illinois UIX 31. Niagaran, Carroll County, Illinois. A, Apical view; B, Lateral view; C, Basal view. This is the type of "*Cerionites dactylioides*" of Meek and Worthen. × 2.

breakage in *Ischadites* is observed. Certain specimens acted as hard bodies, and stylolites and slickensides are observed on their surfaces. In these concretionary forms the facets are deepened by solution.

Discussion of synonyms:—Cerionites dactylioides of Meek and Worthen. Meek and Worthen (1868, p. 346) tentatively assigned *dactioloides* to the new genus *Cerionites*. They based the discussion upon one single specimen, and changed the spelling of Owen's *dactioloides* to *dactylioides*. This change of spelling is not valid. The

TABLE 5.—Measurements in centimeters of 103 specimens of *Cyclocrinites dactioloides* (Owen). (P=Field Mus.; UC=Univ. Chgo. in Field Mus.; CAS=Chgo. Acad. Sci.; UIX=Univ. Illinois, Urbana; MCZ=Mus. Comp. Zool.; SUI=State Univ. Iowa.)

Specimen number						All SUI					
Height	2.78	2.05	2.10	2.16	2.17	2.11	0.99	1.30	1.60	1.85	1.62
Width	3.08	3.04	2.54	3.04	2.33	2.49	2.56	1.98	2.99	2.65	2.25
Height	1.68	1.65	1.13	....	1.39	1.50	2.98	....	2.04	....	2.55
Width	2.07	2.67	2.41	2.19	1.83	1.97	3.58	2.48	3.03	3.04	3.01
Height	1.53	2.00	2.44	1.73	1.54	1.55	1.62	1.31	1.34		
Width	2.07	2.95	2.89	2.16	2.47	2.25	2.80	1.85	1.87		

Specimen number	P11020P	P11020Q	P11020K	P11020A	P11020H	P11020M	P11020G	P11020T	P11020C	P11020D
Height	2.51	1.65	1.37	1.61	1.88	1.72	1.65	1.69	1.87	1.17
Width	3.27	2.70	2.39	2.53	3.26	2.82	3.66	2.44	3.19	2.33

Specimen number	P11020E	P11020F	P11020B	P11020I	P5750	UC 51854	P5749	UC 10801Q	UC 10801R	UC 10801S
Height	1.29	1.82	2.13	1.72	3.17	2.87	1.86	1.66	1.28	1.34
Width	2.36	2.45	3.50	1.93	3.39	3.16	2.21	2.77	2.12	2.51

Specimen number	UC 10801U	P9207	P16791W	P16791X	UC 23760Z	UC 23760A	UC 10801B	UC 10801C	UC 10801D	UC 23760E
Height	1.57	2.15	2.29	2.25	1.15	1.74	1.22	1.79	2.10	2.10
Width	2.97	2.97	2.59	2.83	2.67	2.53	2.38	3.00	3.67	2.27

TABLE 5.—Measurements in centimeters of 103 specimens of *Cyclocrinites dactioloides* (Owen). (P=Field Mus.; UC=Univ. Chgo. in Field Mus.; CAS=Chgo. Acad. Sci.; UIX=Univ. Illinois, Urbana; MCA=Mus. Comp. Zool.; SUI=State Univ. Iowa)—*Continued.*

Specimen number	UC 23760F	UC 23760G	UC 23760H	UC 23760I	UC 23760J	P11020K	P11020L	P11020M	CAS7988	CAS7988	
Height	2.30	3.84	1.93	1.88	1.59	2.13	1.50	1.65	2.47	1.22	
Width	3.62	4.03	2.55	2.02	3.06	3.17	2.01	2.18	4.19	2.59	
Specimen number	UC 3760H	UC 3760G	P11020J	P11020Y	P11020R	UC4600	UC 44394	UIX31	MCZ7462	MCZ	
Height	1.94	2.66	2.06	1.53	1.51	3.01	....	1.32	2.83	1.59	
Width	3.16	3.24	3.21	2.21	....	3.01	3.21	2.95	2.91	2.12	
Specimen number						All SUI					
Height	1.28	1.06	2.03	1.83	2.02	2.73	2.36	2.19	1.04	1.78	2.10
Width	2.97	2.05	3.24	2.08	2.71	3.26	2.86	2.52	2.40	2.26	2.80
Height	2.11	1.23	1.76	2.93	1.88	1.50	2.06	2.78	2.62	1.87	2.14
Width	3.02	2.67	2.26	2.36	3.70	2.62	2.30	3.63	3.37	2.99	2.80

thallus of the specimen used by them is small and cushion-shaped (fig. 45). The lower, basal part is uneven, flattish with small concavities. The facets on the base appear to converge towards the middle; however the central area into which they converge is obscure, and cannot be determined. The upper part is convex, more regular than the base with facets not converging toward any central point. On both the upper and lower side the facets form intersecting lines, however, they are more pronounced on the top. The facets are somewhat larger on the upper side, where they are perforated. On the basal part their preservation is poorer and hence no perforation is observed. The facets tend to decrease in size toward the middle of the base. The preservation of the specimen is not as good as indicated in Meek and Worthen figures.

Cyclocrinites billingsii of Roemer, 1888. *Cyclocrinites dactioloides* from Clinton, Iowa, has been referred to *Pasceolus Billingsii* by Ferd. Roemer (1888). Roemer briefly compared the specimens from Iowa to *C. spaskii,* and found these to differ only in the size of facets. He refers to *billingsii* as a known species, the fossils of which he received from America, probably with the erroneous name already attached. He was likewise misinformed about stratigraphy as he considered *billingsii* to be also Ordovician (Lower Silurian of Roemer). The authorship of the name *billingsii* was attributed to Roemer by later workers. The name *billingsii* is here rejected and suppressed because it is a synonym.

Stratigraphic position and locality:—All specimens examined are Niagaran. They came from around Clinton, Monmouth, Maquoketa, and Monticello in Iowa; from Bridgeport Quarry in Chicago, Illinois, from Carroll County, Illinois, and from localities in Jones and Linn Counties, Iowa.

Material and measurements:—Sixty-two specimens in Field Museum of Natural History; 90 specimens in State University of Iowa; two specimens in Chicago Academy of Science; one specimen in University of Illinois, Urbana; two specimens in Museum of Comparative Zoology; numerous specimens in University of Wisconsin in Milwaukee. The measurements are given in Table 5.

Cyclocrinites spaskii Eichwald, 1840

Figures 3E, 7F, 13, 21C, 46, 47

1840. *Cyclocrinites Spaskii*
*Eichwald, Ueber Silur. Schicht. Esthland, pp. 192–193 (or 78–79 in extract).

1860. *Cyclocrinus Spaskii* Eichwald
*Eichwald, Leth. Ross. Pal. Russie, **1**, pp. 638–640, pl. 32, figs. 21a–d [figures not seen].

1860. *Cyclocrinites Spaski*
Milne-Edwards, Hist. nat. Corall. **3**, p. 453.

1865. *Cyclocrinus Spaskii* Eichwald
Billings, Palaeoz. fossils, **1**, Geol. Surv. Canada, p. 392.

1865. *Cyclocrinus Spaskii* Eichwald
Billings, Canad. Nat., **2**, p. 197.

1868. *Cyclocrinus Sparki* [sic] Eichwald
Bigsby, Thesaurus Siluricus, p. 19.

1874. *Cyclocrinus Spaskii* Eichwald
Miller, Cincinnati Quart. Jour. Sci., **1**, no. 1, p. 4.

1876. *Cyclocrinus Spaskii* Eichwald
*Roemer, Lethaea palaeoz. I Theil., pp. 291, 293, 294–295, pl. 3, figs. 21a–e.

1878. *Cyclocrinus Spaskii* Eichwald
*Nicholson and Etheridge, Monogr. Sil. fossils, Girvan Dist., text-figs. e–h.

1880. *Cyclocrinus Spaskii* Eichwald
Zittel, Handb. Palaeontol., **1**, p. 728.

1884. *Cyclocrinus Spaskii* Eichwald
Hinde, Quart. Jour. Geol. Soc. London, **40**, p. 834.

1888. *Cyclocrinus Spaskii* Eichwald
Roemer, Neu. Jahr. Min. Geol. Pal., Band 1, p. 74.

1889. *Cyclocrinus Spaskii*
*Nicholson and Lydekker, Man. Paleontol., **1**, figs. 73e–h.

1895. *Cyclocrinus Spaskii* Eichwald, 1852
Head, Palaeoz. sponges, pp. 5, 10.

1897. *Cyclocrinus Spaskii*
Whiteaves, Palaeoz. sponges, **3**, part 3, pp. 144, 145.

1915. *Cyclocrinites spaskii* Eichwald
Bassler, Bull. U. S. Nat. Mus., 92, p. 328.

1916. *Cyclocrinites spasskii* [sic]
Raymond, Bull. Mus. Comp. Zool., **56**, no. 3, pp. 200, 201, 204, 205, 244.

1916. *Cyclocrinites spasski* [sic]
Twenhofel, Bull. Mus. Comp. Zool., **56**, no. 4, p. 305.

1927. *Cyclocrinus Spaskii* Eichwald
*Pia, Handb. Paläobot., p. 66.

1928. *Cyclocrinites spaskii*
Twenhofel, Geol. Surv. Canada, Mem. 154, p. 100.

1944. *Cyclocrinites spaskii*
Shimer and Shrock, Index Fossils of North Amer., p. 719.

1952. *Cyclocrinus spaskii* Eichwald
Johnson, Quart. Colo. School Mines, **47**, no. 2, p. 40.

1955. *Cyclocrinites sparkii* [sic]
Laubenfels, Treatise Inv. Paleontol., p. E110.

Definition:—Thallus small, unbranched, globular; attachment mechanism present; unbranched laterals in whorls; height of lateral heads variable; weak calcification above and below the lateral heads; possible ornaments on outer calcified layer of heads.

FIG. 46. *Cyclocrinites spaskii* Eichwald. U. S. Nat. Mus. 26870. Ordovician, Kegel, Estonia.

Description:—This is the species upon which Eichwald originally based the definition of the genus. The only European specimens that were located are housed with the collections of the Smithsonian Institution. These were studied and compared with Eichwald's (1860) description and with the American representatives of the species.

Discussion of Eichwald description:—The common shape of Eichwald's fossils appears to have been globular, and only occasionally elongated. North American representatives are also globular; the suggestion of attachment is comparable in the two groups, and in both cases an elongated end is considered an attachment area.

The "little stars" of Eichwald were not observed on the European material; however, the stellate structures are common among *C. darwini*, and among "higher" receptaculitids, particularly in the *Ischadites* from the Niagaran dolomites. The hollow prominences in the middle of the star indicate the termini of lateral branches at the point of expansion. The calcification of Eichwald's specimens must have varied considerably within his numerous localities, and even among collections made on the same site. The preservation that in turn depends greatly upon calcification must have also varied. No "mouth" has been observed, neither any convincing confirmation of its existence can be found in the literature.

THALLUS. Thalli are very small, spherical, sometimes globular or ovoid (figs. 3E, 13, 46). The surfaces of European fossils appear uneven, possibly caused by careless cleaning with a metal instrument.

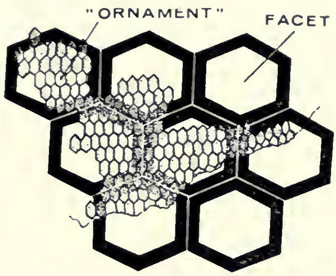

FIG. 47. Diagrammatic representation of the ornament of *Cyclocrinites spaskii* Eichwald. Based on USNM 26870.

The thalli are very uniform, and are not compressed. The main axis must have been short, and was probably expanding.

ATTACHMENT. There are areas on the thalli that can be interpreted as indications of attachment; these are of two kinds, one a somewhat elongated end of the thallus and, second, a small concavity at the base for probable pedicle insertion. In the American fossils, the lower end of the main axis is abruptly terminated (fig. 13).

LATERALS. Laterals are not observed, only facets and lateral heads are preserved (figs. 13, 46). The walls of facets form a pattern of regular lines that are, however, in European fossils less pronounced than in American fossils. From this arrangement of facets distribution of laterals on the main axis is deduced to have been in whorls. The American species possess up to 60 facets around the largest diameter.

Lateral heads:—In American fossils lateral heads are unusually deep. Thus, the variation of the height of lateral heads possibly exists within this species.

Ornaments:—Ornament on the exterior of the European fossils is present and is illustrated in Figure 47. It is preserved in small patches in a reticulate pattern and is composed of pigmented material of iron oxide controlled by brown, fine spots. The little polygonals are smaller than one-sixth of a facet.

The ornament may be a part of the plant because the ornaments correspond with the centers of the lateral heads and the ornament is sometimes impressed upon the walls of laterals in a way that is sug-

TABLE 6.—Measurements in centimeters of 14 specimens of *Cyclocrinites spaskii* Eichwald. All specimens from University of Michigan, Museum of Paleontology no. 21104.

Width	1.50	1.18	1.53	1.58	1.65	1.17	1.36
Height	....	1.12	....	1.62	....	....	....
Width	1.59	1.47	1.07	1.79	1.65	1.48	1.70
Height	....	1.38	1.05	1.57	....	1.36	1.69

gestive of common contemporaneous growth of the lateral head and its ornament. The indications, however, that these may be extraneous are as follows: (a) When present on thallus that part of the body surface is well preserved. (b) Most of the ornament seems superimposed. (c) Most, although not all, of the ornament transgresses the walls of the laterals, and continues from one to another. (d) The ornament is present on lateral heads and facets, therefore above and under the heads. This can be only explained as a commensal growing upon the plant that has lost a few of its lateral heads. (e) When ornament is absent, it is absent from lateral heads and from facets. (f) The reticulate pattern of ornament is highly suggestive of the secretion of adhesive organs of an organism that grew attached on the plant.

Thus, there is no certainty that the ornament is part of the plant. However, since European writers (Stolley and Pia) accepted the ornament as an integral part of the organism, and since the present author examined only few European fossils, the conclusion of an ornament as an integral part of the thallus is here provisionally accepted.

CALCIFICATION. Calcification appears very weak. Because facets and lateral heads are present, the calcification was above and below the heads of laterals.

Preservation:—The European fossils consist of calcite. Small partially pyritous bodies are present. The general preservation is very poor. The American specimens are in dolomitic limestones.

Material, Stratigraphic Position, and Measurements:—Two specimens in the collection of the U. S. National Museum, USNM 26870. Larger specimen poorly preserved, spherical with no ornaments, but with damaged exterior. Smaller specimen better preserved. *Stratigraphic position:* Ordovician, Kegel, Estonia. *Measurements:* Largest dimensions: 1.83 cm. and 1.08 cm. One specimen was originally in the collection of the Museum of the Mining School in St. Petersburg, Russia.

American representatives: 14 specimens UMMP 21104, from Fremont Limestone, Canon City, Colorado. Measurements of American specimens are given in Table 6.

Cyclocrinites darwini (Miller, 1874)

Figures 3F, 7G, 12, 16, 17, 21A, 48

1874. *Pasceolus Darwini*
*Miller, Cincinnati Quart. Jour. Sci., **1**, no. 1, pp. 5–6, text-figs. 1 and 2.

1874. *Pasceolus Claudei*
*Miller, Cincinnati Quart. Jour. Sci., **1**, no. 1, pp. 6–7, text-fig. 3.

1875. *Pasceolus darwini* S. A. Miller
James, U. P., Cat. Lower Sil. fossils, p. 8.

1875. *Pasceolus claudei* S. A. Miller
James, U. P., Cat. Lower Sil. fossils, p. 8.

1876. *Pasceolus Darwinii* S. A. Miller
Roemer, Lethaea palaeoz., I Theil, p. 296.

1876. *Pasceolus Claudii* S. A. Miller
Roemer, Lethaea palaeoz. I Theil, p. 296.

1877. *Pasceolus darwini* S. A. Miller, 1874
Miller, Amer. Palaeo. fossils, p. 43.

1877. *Pasceolus claudii* S. A. Miller, 1874
Miller, Amer. Palaeo. fossils, p. 43.

1878. *Astylospongia tumidus* James
James, U. P., Paleontologist, no. 1, p. 1.

1878. *Pasceolus Darwini* S. A. Miller
Mickleborough and Wetherby, Classified list Lower Sil. fossils, p. 81 (pamphlet p. 21).

1878. *Pasceolus Claudei* S. A. Miller
Mickleborough and Wetherby, Classified list Lower Sil. fossils, p. 81 (pamphlet p. 21).

1878. *Astylospongia tumida* James
Mickleborough and Wetherby, Classified list Lower Sil. fossils, p. 81 (pamphlet p. 21).

1879. *Pasceolus darwini* S. A. Miller, 1874
Miller, 10th Ann. Rept. Geol. Surv. Indiana, p. 29 (p. 8 in pamphlet).

1879. *Pasceolus claudei* S. A. Miller, 1874
Miller, 10th Ann. Rept. Geol. Surv. Indiana, p. 29 (p. 8 in pamphlet).

1879. *Astylospongia tumidus* James
James, U. P., Paleontologist, no. 4, p. 29.

1880. *Pasceolus darwini* S. A. Miller
Ulrich, Cat. fossils, p. 30.

1880. *Pasceolus claudi* S. A. Miller
Ulrich, Cat. fossils, p. 30.

1880. *Astylospongia tumida* James
Ulrich, Cat. fossils, p. 3.

1880. *Pasceolus globosus* Billings
Ulrich, Cat. fossils, p. 30.

1881. *Pasceolus darwini*, S. A. Miller
James, Cat. fossils Cincinnati Group, p. 27.

1881. *Pasceolus claudi* S. A. M.
James, Cat. fossils Cincinnati Group, p. 27.

1881. *Astylospongia tumida* James
James, Cat. fossils Cincinnati Group, p. 6.

1887. *Pasceolus darwini* S. A. Miller, 1874
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, pp. 248–249.

1887. *Pasceolus claudii* S. A. Miller, 1874
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, pp. 248–249.

1887. *Pasceolus globosus* Billings
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, p. 248.

1887. *Astylospongia tumida* U. P. James
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, p. 247.

1889. *Pasceolus darwini* S. A. Miller
Miller, North Amer. Geol. Palaeontol., p. 162, text-figs. 115, 116.

1889. *Pasceolus claudii* S. A. Miller
Miller, North Amer. Geol. Palaeontol., p. 162, text-fig. 114.

1891. *Pasceolus darwinii* Miller, 1874
James, Jour. Cincinnati Soc. Nat. Hist., **14**, no. 1, p. 59.

1891. *Pasceolus claudii* Miller, 1874
James, Jour. Cincinnati Soc. Nat. Hist., **14**, no. 1, p. 59.

1891. *Pasceolus globosus* Billings, 1857
James, Jour. Cincinnati Soc. Nat. Hist., **14**, no. 1, pp. 58, 59.

1891. *Astylospongia tumidus* James
James, Jour. Cincinnati Soc. Nat. Hist., **14**, no. 1, pp. 54, 60.

1891. *Pasceolus* (?) *tumidus* U. P. James, 1878
James, Jour. Cincinnati Soc. Nat. Hist., **14**, no. 1, pp. 54, 59–60, text-fig. 3.

1895. *Astylospongia tumida* James
Head, Palaeo. sponges, p. 9.

1896. *Cyclocrinus* (*Pasceolus*) *Darwinii* Miller
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, p. 215.

1896. *Cyclocrinus* (*Pasceolus*) *Claudii* Miller
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, part 2, p. 215.

1902. *Pasceolus globosus* Billings
Nickles, Jour. Cincinnati Soc. Nat. Hist., **20**, no. 2, pp. 66, 69, 76, 90.

1909. *Pasceolus darwini* Miller
*Foerste, Bull. Sci. Lab. Denison Univ., **14**, pp. 303–305, pl. 8, figs. 1A and B.

1909. *Astylospongia tumidus* James
Foerste, Bull. Sci. Lab. Denison Univ., **14**, p. 304.

1910. *Pasceolus darwini*
*Foerste, Bull. Sci. Lab. Denison Univ., **16**, p. 86.

1910. *Pasceolus claudei*
Foerste, Bull. Sci. Lab. Denison Univ., **16**, p. 86.

1914. *Pasceolus globosus* Billings
*Foerste, Bull. Sci. Lab. Denison Univ., **17**, p. 336, pl. 4, fig. 4.

1915. *Pasceolus darwini* Miller
Bassler, Bull. U. S. Nat. Mus., 92, p. 947.

1915. *Pasceolus claudei* Miller
Bassler, Bull. U. S. Nat. Mus., 92, p. 946.

1916. *Pasceolus darwini* Miller
*Foerste, Bull. Sci. Lab. Denison Univ., **18**, pp. 287, 288, 289, 290.

1916. *Pasceolus claudei* Miller
*Foerste, Bull. Sci. Lab. Denison Univ., **18**, pp. 285, 287, 288, pl. 3, fig. 2.

1916. *Pasceolus tumidus* James
*Foerste, Bull. Sci. Lab. Denison Univ., **18**, pp. 285, 287–290, pl. 3, fig. 1.

1927. *Cyclocrinus Darwini* Miller
Pia, Handb. Paläobot., p. 66.

1927. *Cyclocrinus Claudei* Miller
Pia, Handb. Paläobot., p. 66.

1936. *Pasceolus claudei* Miller
Chappars, Ohio Jour. Sci., **36**, p. 32.

1936. *Pasceolus darwini* Miller
Chappars, Ohio Jour. Sci., **36**, p. 32.

1948. *Pasceolus darwini* Miller
Dalvé, Fossil fauna Ord. Cincinnati region, p. 26.

1948. *Pasceolus claudei* Miller
Dalvé, Fossil fauna Ord. Cincinnati region, p. 26.

1952. *Cyclocrinus darwini* Miller
Johnson, Quart. Colo. School Mines, **47**, no. 2, p. 40.

1952. *Cyclocrinus claudei* Miller
Johnson, Quart. Colo. School Mines, **47**, no. 2, p. 40.

1965. *Pasceolus Darwini* Miller
Nitecki, Fieldiana: Geol., **13**, p. 502.

1965. *Pasceolus Claudei* Miller
Nitecki, Fieldiana: Geol., **13**, p. 502.

1965. *Pasceolus globosus* Billings
Nitecki, Fieldiana: Geol., **13**, p. 502.

1965. *Astylospongia tumidus* James
Nitecki, Fieldiana: Geol., **13**, p. 500.

Definition:—Thallus small, shape gently flattened sphere; concavity for pedicle attachment present; main axis, possibly short; laterals regularly placed in whorls; heads formed by dilation of laterals, supported by ribs; ribs form stellate structure; weak calcification below lateral heads, weaker above; facets predominantly six-sided, generally form regular intersecting lines.

Discussion of Miller's description:—The thalli of type specimens are depressed, but the depression is very small and insignificant, except for one specimen where it is pronounced. The facets are pentagonal or hexagonal, however, six-sided facets are commonest, and irregular shapes are also frequent. Five-sided facets are relatively rare. No bryozoans are observed, but small fragments of invertebrates are noted attached to the surface of the thalli, and appear to have been cemented in the diagenetic process. The perforation mentioned by Miller is a rosette.

Description:—THALLUS. The shape of the thallus (fig. 3F) varies from a slightly flattened sphere to an almost cushioned shape. Shapes of irregular globes are also present.

A

B

FIG. 48. *Cyclocrinites darwini* (Miller). Holotype FMNH UC 8838. Maysville, Maysville, Ky. A, Apical view; B, Basal view. × 2.

MAIN AXIS. The main axis is rarely preserved, and therefore was not calcified; it was probably short, and may have been inflated. One specimen from Maysville, Kentucky possesses a small central core.

ATTACHMENT MECHANISM. Three out of five original specimens described by Miller (1874) possess a distinct circular depression on a somewhat flattened bottom side. The depressions are interpreted as areas for the retention of a stalk (figs. 12, 48B). The nature of the stalk is unknown, its length is assumed to have been short. These depressions have been somewhat altered by digging out with tools, nevertheless they appear distinct and natural features.

LATERALS. The regular distribution of facets indicates that laterals are regularly placed in whorls. In the greatest dimension of the thallus over 50 facets were counted. Because of the poor preservation the exact number of laterals is difficult to determine. Laterals were not calcified, hence are not preserved. The laterals dilate and form lateral heads, supported by ribs (figs. 16, 17).

LATERAL HEADS. Heads form in the regular cyclocinitid habit, however, are so poorly preserved that their exact shape or size cannot be determined. They are generally six-sided, sometimes irregular, and appear short. They detach easily, and very few are preserved.

STELLATE STRUCTURES. The unique characteristic of this species is the presence of stellate structures. These structures are very similar to the ribs in recent alga (fig. 27) and are comparable to similar, although commonly four-sided, structures in *Ischadites*. In some species of *Receptaculites* the ribs are much more numerous and form complicated structures.

There are some stellate structures that consist of only five ribs. These, however, are rare. It appears that the number of ribs is partially responsible for the number of sides of facets. Thus, six ribs cause six-sided facets; however, the number of sides of the facets is probably also controlled by the compression (packing) of the lateral heads. Individual head is surrounded by a number of other heads, and the number of sides (walls) of the facet is determined to a great extent by the number of contacts that it makes with other laterals. In this way the lateral head is compressed to the geometric figure, whose number of sides corresponds to the number of contacts it makes with other laterals. This condition is present in those cyclocrinitids that do not possess the stellate structures.

FACETS. Facets are very regular, six-sided structures (fig. 16, 48A). However, five or four-sided facets as well as irregular shapes are common. The facets form interesting lines upon the top of the thallus. In the lower part of the body they seem to converge toward the central attachment area and appear to be somewhat smaller in size.

Both facets and lateral heads are present. Facets are better delineated, and are more common, thus indicate stronger calcification. The walls of facets in many specimens are deformed by compaction and are thus irregular.

CALCIFICATION. The continuous calcified layer is present at the base of lateral heads. The calcification was apparently weak. The upper proximities of heads were also calcified, but to a much lesser extent. Thus, two zones of calcification were present, but these were probably not connected.

Preservation:—Preservation of the body shape is good, however the preservation of heads and of facets is exceedingly poor. Although such delicate structures as stellate ribs are preserved, most of the facets are missing, and parts of the surface are undetermined. Preservation of the anatomical details is so poor that often it is impossible to say whether the facet or lateral head is present.

Internal structure:—Polished cross-section does not indicate any internal structure.

Relationship:—Two species, *C. globosus* and *C. darwini*, overlap each other morphologically. *C. darwini* from the environment of Cincinnati, Ohio, is characterized by the presence of stellate structures. *C. globosus* from Eastern Canada is of a larger size. The absence of stellate structures on *C. globosus* may be real, or it may be due to preservation, or the failure of detection. In the Cincinnati region large specimens of the *C. globosus* size are found that also lack stellate structures. However, most *C. darwini* do not have stellate structures preserved. It, thus, seems that the definition of species based on the presence or absence of these structures is beset with difficulties. Either only one species is present that includes specimens whose lateral heads are either supported or unsupported by stellate structures, or two distinct species exist. In the latter case the morphological overlap exists. Until more work with larger numbers of specimens is done, the two distinct, but overlapping species are here recognized.

Discussion of synonyms:—Cyclocrinites claudei (Miller). Except for size the types of *C. claudei* are not distinguishable from *Cyclocrinites darwini*. If *C. claudei* were just smaller organisms, the total

TABLE 7.—Measurements in centimeters of 164 specimens of *Cyclocrinites dWrwini* (Miller). UC, P and PE=Field Mus.; MCZ=Mus. Comp. Zool.; MU=Miami Univ.; CM=Univ. Cincinnati Mus. specimens.

Specimen number	UC52003A	UC52003B	UC10814A	UC10814B	UC10814C	UC44399A	UC44399B	UC44399C	UC44399D
Height	1.78	0.80	1.58	1.81	1.69	1.62	1.42	0.90	1.70
Width	3.57	2.55	2.22	2.77	2.73	3.10	3.11	2.70	2.86
Specimen number	UC44399E	UC44399F	UC44399G	UC44377A	UC44377B	UC44378	UC44909B	UC44909L	UC44909E
Height	1.41	1.27	0.98	1.22	1.68	0.75	2.26	1.43	1.84
Width	2.51	3.05	2.05	2.96	2.87	1.45	3.25	2.57	2.42
Specimen number	UC44909H	UC44909K	UC44909D	UC44909A	UC44909F	UC44909C	UC44909G	UC44909M	UC44916K
Height	1.07	1.50	1.46	1.93	1.24	....	2.13	1.63	1.54
Width	2.35	2.67	2.30	2.47	1.62	2.24	2.78	2.36	2.63
Specimen number	UC44916A	UC44916D	UC44916H	UC44916L	UC44916B	UC44916M	UC44916J	UC44916N	UC44916E
Height	1.96	1.76	1.66	1.78	0.76	1.53	1.89	1.64	1.04
Width	2.60	2.49	2.73	2.54	1.59	1.81	2.61	2.14	1.66
Specimen number	UC44916C	UC44916P	UC44916F	UC44916G	UC1222A	UC1222C	UC1222B	UC1222E	UC1222G
Height	1.31	0.93	1.01	0.83	1.77	1.44	1.29	1.21	....
Width	1.68	1.59	1.54	1.49	2.34	2.10	2.13	2.14	1.90

TABLE 7.—Measurements in centimeters of 164 specimens of *Cyclocrinites darwini* (Miller). UC, P and PE=Field Mus.; MCZ=Mus. Comp. Zool.; MU=Miami Univ.; CM=Univ. Cincinnati Mus. specimens—*Continued.*

Specimen number	UC1222F	PE5820F	PE5820B	PE5820A	PE5820C	PE5820G	PE5820E	PE5820D	PE5820H
Height	1.23	2.12	2.11	0.96	0.97	1.11	1.00	0.85	2.01
Width	1.68	3.38	2.75	2.45	1.94	1.55	1.83	1.59	2.85
Specimen number	UC44393A	UC44393B	UC44393C	UC8837A	UC8837C	UC8837D	UC8837B	UC44382	UC44382
Height	1.55	1.92	1.40	1.35	1.17	0.70	1.22	0.82	0.60
Width	2.26	2.70	2.34	1.52	1.54	1.47	2.14	1.37	1.53
Specimen number	UC44382	UC44382	UC44382	UC44382	UC52002A	UC52002B	UC44383A	UC44383B (fragment)	UC44383C
Height	0.80	0.88	0.96	0.65	1.74	1.34	2.00	0.84	2.38
Width	1.36	1.32	1.18	1.05	2.29	2.25	4.17	4.76	4.30
Specimen number	UC8838E	UC8838A	UC8838B	UC8838C	UC8838D	UC44390A	UC44390C	UC44390B	UC44383D
Height	1.82	2.29	1.79	1.67	....	1.00	1.71	2.49	1.39
Width	2.76	3.09	2.71	2.12	2.36	3.99	4.62	4.27	5.71
Specimen number	MCZ735	MCZ735	MCZ735	MCZ	MCZ	MCZ	MCZ1553		
Height	1.93	....	1.75	....	1.25	1.12	2.53		
Width	2.68	3.44	1.69	4.62	2.84	3.32	3.52		

TABLE 7.—Measurements in centimeterz of 164 specimens of *Cyclocrinites darwini* (Miller). UC, P and PE=Field Mus.; MCZ=Mus. Comp. Zool.; MU=Miami Univ.; CM=Univ. Cincinnati Mus. specimens—*Continued.*

Specimen number	MU DE784	MU DE785	MU DE786	MU DE787	MU602	MU DE788	MU602	MU602	MU602
Height	....	2.61	2.81	1.83	1.23	1.63	1.05	1.09	1.18
Width	3.97	4.17	5.78	2.85	2.30	2.29	1.84	2.05	2.12
Specimen number	MU349L	MU DE789	CM28360	CM28360	CM28360	CM28360			
Height	2.03	0.98	1.72	1.28	2.18	0.78			
Width	2.89	1.40	2.75	2.76	2.50	2.16			
Specimen number	CM3310	CM3310	CM3310	CM3310	CM3310	CM38827	CM28360	CM28360	CM28360
Height	1.95	2.14	1.89	1.74	2.16	0.79	1.47	1.96	1.59
Width	3.05	3.87	3.01	2.48	3.10	1.44	2.14	3.00	3.07
Specimen number	All number CM28360								
Height	0.96	1.09	1.18	1.16	1.24	0.91	1.60	1.11	0.81
Width	2.60	2.79	2.83	2.94	1.78	2.40	2.04	1.67	1.94
Specimen number	All number CM28360								
Height	0.57	1.16	1.05	1.86	1.60				
Width	....	1.53	2.00	2.29	2.66				

Table 7.—Measurements in centimeters of 164 specimens of *Cyclocrinites darwini* (Miller). UC, P and PE=Field Mus.; MCZ=Mus. Comp. Zool.; MU=Miami Univ.; CM=Univ. Cincinnati Mus. specimens—*Continued.*

Specimen number	All number CM7129								
Height	2.00	1.50	1.34	1.47	1.49	1.56	1.09	1.70	0.85
Width	2.71	3.32	2.94	2.39	1.99	2.70	2.42	2.43	2.32
Specimen number	All number CM7129								
Height	1.37	0.96	1.13	1.62	1.43	1.14	1.19	1.66	1.28
Width	2.58	2.02	2.35	2.09	2.28	2.06	2.30	2.77	2.50
Specimen number	All number CM7129								
Height	0.93	1.48	1.77	1.80	1.07	1.39	2.15	1.35	2.06
Width	2.80	2.29	2.60	2.37	2.15	3.04	2.42	2.01	3.08
Specimen number	All number CM7129								
Height	1.14	1.90	1.45	1.55	1.14	1.72	1.34	2.00	1.83
Width	1.57	2.03	2.50	2.31	1.87	2.90	1.70	2.72	2.18
Specimen number	CM7129	CM7129							
Height	1.62	1.70							
Width	3.50	2.93							

number of facets would be the same as in *C. darwini.* If, on the other hand, they were younger organisms, then the total number would depend upon the habit of growth and upon addition of new branches. Since the growth pattern of these plants is not known, the difference in number of facets in a given area is difficult to evaluate. The situation is even more complicated because the number of facets per given area within a single fossil depends upon the area counted. There appears a great difference in density of these within single organisms. For example, the number of facets within a single lot including the holotype also shows discrepancy; almost twice the number are counted from one specimen to the other. Miller's (1874) observation that these forms lack the depression for the attachment of the pedicle is also not certain. Most of these have some resemblance to the pedicle, or were artificially dug out. Calcification is identical to *Cyclocrinites darwini.* The interior and the exterior of the lateral heads are calcified. However, the most common occurrence is that of the interior calcification. This mode of calcification is characteristic of other cyclocrinitids. In general, most *Cyclocrinites* from around the Cincinnati region are more deformed than those from other regions. However, because a somewhat shaly matrix is associated with these fossils, the deformation may be diagenetic rather than representative of the original degree of calcification.

Cyclocrinites tumidus (U. P. James) (=*Astylospongia tumidus* U. P. James, 1878). J. F. James (1887) summarized the original U. P. James description and later (1891) assigned the species to *Pasceolus,* and illustrated "plates with depressed lines running from the center to the six corners." Foerste (1916) illustrated the holotype and noted that "distinct grooves extend from the angles toward the center, toward which they widen and at which they coalesce." He further observed that these stellate markings are also present on the type specimen of *Pasceolus darwini.* He concluded that *P. darwini, claudei,* and *tumidus* are all one species. Nitecki (1965, p. 500) states that "very poor nature of the specimens does not warrant assignment of these forms to either of the two (*Astylospongia* or *Pasceolus*) genera. These objects cannot be identified." It is agreed here that these fossils are very poorly preserved specimens, however, Nitecki (1965) did not observe the stellate markings, and consequently missed their significance. Foerste (1916, pl. 3, fig. 2) illustrated these structures. His photograph was probably retouched, because the examination of the holotype and of other specimens fails to recognize the structures as illustrated by Foerste.

The stellate structures are present, but are poorly preserved, are less common, and differ from those shown by Foerste. The number of ribs varies from four to six; six-ribbed are the most common, and five-ribbed are the rarest. The specimens used by James (1878) to describe the species *tumidus* are indistinguishable from the type specimens of *Cyclocrinites darwini*. Therefore, *Cyclocrinites tumidus* (James, 1878) is considered a synonym of *Cyclocrinites darwini* (Miller, 1874).

Material and measurements:—Holotype UC8838A (now in Field Museum); 104 specimens in Field Museum; 70 specimens in University of Cincinnati Museum; 13 specimens in Miami University Collection; 41 specimens in Museum of Comparative Zoology. Measurements are given in Table 7.

Stratigraphic position and locality:—Middle Cincinnatian. Cincinnati, Ohio and environs in Kentucky and Indiana.

Cyclocrinites pyriformis (Bassler, 1915 *not* Stolley, 1896)

Figures 3G, 6, 7H, 8, 21E, 49–51

1896. Not *Cyclocrinus pyriformis*
Stolley, Archiv. Anthropol. Geol. Schleswig-Holsteins, **1**, parr 2, pp. 254–256, 258, text-figs. 76–81, 20–27.

1909. *Nidulites* cf. *favus*
Bassler, Va. Geol. Surv. Bull. II-A, p. 59.

1909. *Nidulites*
Bassler, Va. Geol. Surv. Bull. II-A, pl. 7, fig. 11, p. 59.

1909. *Nidulites favus*
Stose, U. S. Geol. Surv. Atlas no. 170, p. 9.

1909. *Nidulites*
Stose, U. S. Geol. Surv. Atlas no. 170, pp. 8, 9, 10.

1911. *Nidulites favus*
Ulrich, Bull. Geol. Soc. Amer., **22**, pp. 327, 329, 515.

1911. *Nidulites* sp.
Ulrich, Bull. Geol. Soc. Amer., **22**, pp. 322, 324, 325, 326, 327, 328.

1915. *Nidulites pyriformis* Bassler
Bassler, Bull. U. S. Nat. Mus., 92, p. 855.

1919. *Nidulites pyriformis* Bassler
*Bassler, Md. Geol. Surv. Cambrian and Ordovician, pp. 141, 174, 175, 193–194, 220, pl. 46, figs. 1–5.

1919. *Nidulites*
Bassler, Md. Geol. Surv. Cambrian and Ordovician, pp. 132, 133, 140, 141, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154.

1919. *Nidulites favus*
Field, Amer. Jour. Sci., ser. 4, **48**, p. 424.

1919. *Nidulites*
Field, Amer. Jour. Sci., ser. 4, **48**, p. 425.

1926. *Nidulites* cf. *favus*
Butts, Geol. Alabama, Sp. Rept. 14, p. 102, pl. 19, figs. 13, 14.

1926. *Nidulites* sp.
Butts, Geol. Alabama, Sp. Rept. 14, p. 114.

1927. *Nidulites*
Giles, Jour. Geol., **35**, p. 44.

1927. *Mastopora pyriformis* Bassler
*Pia, Handb. Paläobot., p. 66, fig. 44.

1927. Not *Cyclocrinus pyriformis* Stolley
Pia, Handb. Paläobot., p. 66.

1940. *Nidulites pyriformis* Bassler
Butts, Bull. Va. Geol. Surv., 52, part 1, pp. 197, 199, 200.

1940. *Nidulites* cf. *N. pyriformis*
Butts, Bull. Va. Geol. Surv., 52, part 1, pp. 144, 171, 184.

1940. *Nidulites ovoides*
Butts, Bull. Va. Geol. Surv., 52, part 1, p. 142.

1940. *Nidulites* sp.
Butts, Bull. Va. Geol. Surv., 52, part 1, pp. 171, 198.

1941. *Nidulites pyriformis* Bassler
*Butts, Bull. Va. Geol. Surv., 52, part 2, p. 110, pl. 95, figs. 35–38.

1941. *Nidulites ovoides* Butts
*Butts, Bull. Va. Geol. Surv., 52, part 2, p. 53, pl. 76, figs. 8–10.

1943. *Nidulites pyriformis* Bassler
Cooper and Prouty, Bull. Geol. Soc. Amer., **54**, pp. 829, 830, 856, 866, 883.

1943. *Nidulites*
Cooper and Prouty, Bull. Geol. Soc. Amer., **54**, pp. 819, 829, 830, 832, 833, 850, 853, 856, 858, 863, 864, 868, 884.

1943. *Mastopora pyriformis* (Bassler)
Currie and Edwards, Quart. Jour. Geol. Soc. London, **98**, p. 239.

1943. [?] *Mastopora parva* (Nicholson and Etheridge)
*Currie and Edwards, Quart. Jour. Geol. Soc. London, **98**, pp. 235, 236–237, 238, 239, pl. 11, figs. 5–9, 1 text-fig.

1944. *Nidulites pyriformis* Bassler
Shimer and Shrock, Index fossils North Amer., p. 57, pl. 17, fig. 21.

1944. *Nidulites pyriformis* Bassler
Cooper, Bull. Va. Geol. Surv., 60, pp. 44, 70 and listed on pls. 8 and 5.

1944. *Nidulites*
Cooper, Bull. Va. Geol. Surv., 60, pp. 45, 48, 50, 52, 53, 55, 70, 71.

1945. *Nidulites*
Huffman, Jour. Geol., **53**, p. 153.

1946. *Nidulites pyriformis* Bassler
Cooper and Cooper, Bull. Geol. Soc. Amer., **57**, pp. 42, 44, 59, 60, 61, 62, 63, 66, 71, 80, 82, 85, 89, 91, 92, pl. 2, figs. 3 and 4.

1946. *Nidulites* cf. *N. pyriformis* Bassler
Cooper and Cooper, Bull. Geol. Soc. Amer., **57**, p. 42.

1946. *Nidulites ovoides* Butts
Cooper and Cooper, Bull. Geol. Soc. Amer., **57**, pp. 59, 77, 80, 82, 84, 85, 89, 91, 98.

1946. *Nidulites*
Cooper and Cooper, Bull. Geol. Soc. Amer., **57**, pp. 40, 41, 42, 44, 45, 46, 47, 48, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 68, 71, 78, 81, 82, 83, 86, 88, 92, 93, 94, 95, 96, 107, 109.

1947. *Mastopora* (*Nidulites*) *pyriformis* (Bassler)
*Elias, Jour. Paleontol., **21**, no. 1, pl. 18, figs. 12–14.

1947. *Nidulites.*
Elias, Jour. Paleontol., **21**, no. 1, p. 55.

1952. *Nidulites pyriformis* Bassler
*Moore et al., Invertebrate fossils, p. 87, fig. 3.5 (4).

1952. Not *Cyclocrinus pyriformis* Stolley
Johnson, Quart. Colo. School Mines, **47**, no. 2, pp. 39, 40, pl. 4, fig. 6.

1952. *Mastopora pyriformis* Bassler
Johnson, Quart. Colo. School Mines, **47**, no. 2, p. 44.

1952. *Mastophora* [sic] *pyriformis* Bassler
Johnson, Quart. Colo. School Mines, **47**, no. 2, p. 52, pl. 12, figs. 1–4.

1952. *Nidulites*
Johnson, Quart. Colo. School Mines, **47**, no. 2, p. 53, pl. 12, fig. 5.

1954. *Nidulites pyriformis*
Twenhofel et al., Bull. Geol. Soc. Amer., **65**, p. 286.

1954. *Mastopora pyriformis* Bassler
Johnson, Quart. Colo. School Mines, **49**, pl. 34, figs. 1–5.

1957. *Nidulites pyriformis* Bassler
Vokes, Maryland Geol. Mines. Bull. 19, p. 78, pl. 2, figs. 7, 8.

1959. *Mastopora parva*
Johnson and Konishi, Quart. Colo. School Mines, **54**, no. 1, pl. 6, figs. 5–9.

1960. *Mastopora pyriformis* (Bassler)
*Osgood and Fischer, Jour. Paleontol., **34**, pp. 896–902, pls. 117–118, 2 text-figs.

1963. *Mastopora pyriformis* (Bassler)
Griefe and Langenheim, Jour. Paleontol., **37**, p. 567.

1963. *Mastopora ovoides* (Butts)
Griefe and Langenheim, Jour. Paleontol., **37**, p. 567.

Name:—Bassler's (1909) caption to Figure 11 on plate 7 reads only *Nidulites*. In his list of fossils on p. 59 he refers it to *Nidulites* cf. *favus*. Bassler (1915, p. 855) in the *Bibliographic Index of American Ordovician and Silurian Fossils* refers his previous figure to "*Nidulites pyriformis* Bassler (new species)." Thus the name is founded on illustration without description (Bassler, 1909) and supplemented by name without description (Bassler, 1915). Later, Bassler (1919) described the species fully and illustrated the holotype and a number of additional specimens.

Stolley (1896, pp. 254–256, text-figs. 20–27) described and illustrated *Cyclocrinus pyriformis* from Sylt in Schleswig-Holstein

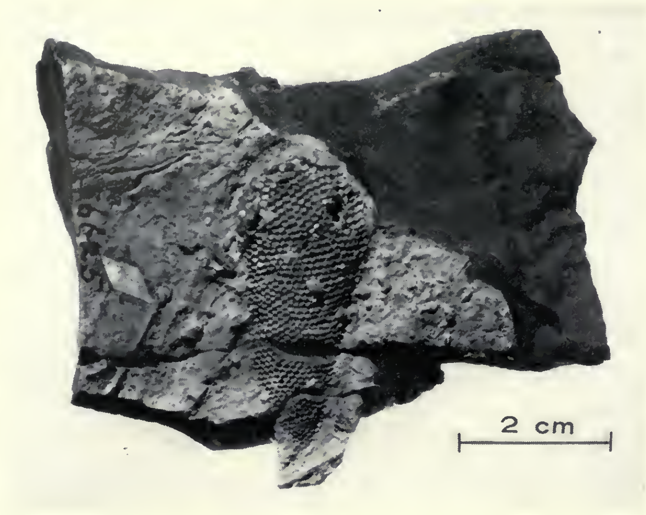

FIG. 49. *Cyclocrinites pyriformis* (Bassler). Holotype USNM 56625. Chambersburg Limestone, Strasburg, Virginia.

(Northern Germany). At the present time, without study of Stolley's specimens, no comments on this species can be made. The name *Cyclocrinites pyriformis* (Bassler), therefore, is provisionally retained until the European material is available for examination.

Definition:—Thallus claviform, or nearly so, gently tapering toward the base, generally circular in cross-section; attachment basal; main axis elongated, weakly calcified, apically expanding; laterals spirally added arranged in whorls; laterals dilate from lateral heads; calcification continuous and heavy under lateral heads, weak along main axis and laterals; facets deep, generally six-sided or round; habit probably erect in quiet waters.

Description.—THALLUS: Thallus is claviform when well preserved, nearly claviform when only partially preserved (fig. 49), and only rarely ovoid (figs. 50, 51). It is broader at the top, and is gently tapering toward the base. Cross-section through the thallus is usually circular. This is observed on a number of specimens and on different positions of the plant and is common particularly in fossils collected from Chambersburg Formation in Virginia. The shapes of thalli are thus generally regular. Actual attachment mechanism is not preserved, but the shape of the body requires that the thallus is basally attached, and that the stem, if present, is just a short prolongation of the main axis. The smallest thallus

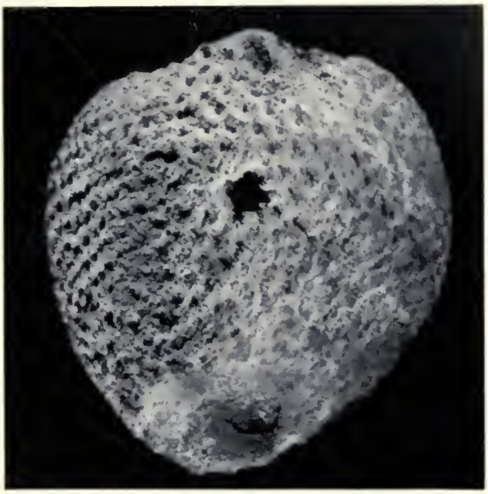

Fig. 50. *Cyclocrinites pyriformis* (Bassler). USNM 71474. Little Oak Limestone, Pelham. Shelby County, Alabama. × 3.

Fig. 51. *Cyclocrinites pyriformis* (Bassler). USNM 97372–3. Lenoir, Blacksburg, Virginia. Cross-section through thallus showing distribution of laterals. (Laterals marked with ink.) × 3.

measured is 0.26 cm. long and 0.08 cm. across. Smaller specimens are observed, but are not measured. The longest specimen is 3.99 cm. long and the widest is 2.03 cm. across.

MAIN AXIS. The elongated, straight, unbranched, and apically expanding main axis is present. The bulging of the main axis is required by the pyriform shape of the thallus, and is interpreted from the distribution of laterals (fig. 8). The lower end of the main axis is a tubular structure less than 0.1 cm. across. It is devoid of scars and is shown on Figure 6. Some specimens are present that possess a main axis partially preserved; none, however, are found with the entire length preserved. Therefore, it is assumed that the main axis was weakly calcified.

LATERALS. Laterals are unbranched, concentrated on the upper part of the main axis, and their maximum thickness is 0.02 cm. (fig. 8). They are rarely preserved, therefore were weakly calcified. The laterals are added spirally, are subsequently compressed, and thus appear to have been in whorls. The whorl, then, is in actuality a compressed spiral. The largest number of laterals within a whorl at the greatest dimension of the thallus is almost 50. The number of laterals at the base cannot be exactly determined, because the very end of the base is not preserved; however, as few as 15 have been counted. The end of the lateral expands and forms the lateral head. The calcification along the head is heavy.

The laterals are observed in sections of USNM 97372 cut parallel to the main axis (fig. 51). They are small openings filled with calcite. Under high magnification the lateral in cross-section consists of two parts, the inner core and the outer envelope. The outer envelope is the weakly calcified part. The inner part expands rapidly toward the end where the lateral head forms. In other sections (not shown in illustration) cut across thalli the number of laterals is considerably greater than in the section shown in Figure 51. The arrangement of laterals clearly reflects the arrangement of facets upon the surface, mainly two intersecting lines are formed. Thus, the growth of laterals appears to have been in spirals, and laterals are not randomly positioned.

LATERAL HEADS. Very few heads are preserved. Their bases are heavily calcified; however, the distal parts are weakly calcified or calcification is absent. From the preserved depth of facets it appears that the heads are relatively deep.

FACETS. Facets are generally very regular, six-sided polygons. The largest are up to 0.13 cm. across, and are relatively deep. The interior of the facet is generally round, however, their walls are polygonal, and form regular lines upon the surface of the thallus. Small openings, representing the termini of laterals are observed on bottoms of facets.

Facets in USNM 97372 form relatively shallow cups, arranged in criss-crossing lines. The walls of facets are not well delineated, appear fused or worn out, and many are filled with unknown ring-like structures.

FACETAL STRUCTURES. Inside the facets of specimens USNM 97372 are obscure bodies consisting of coarse, very dark color calcite. They appear a part of the specimen because they are within the calcite structure of the thallus. They seem ring-like, but in actuality may be fillings in the whole of the cavity of the facet. Under the magnification the structures consist of darker color calcite, and are not black as they appear to the unaided eye. No explanation is available for this structure except that it consists of coarse calcite, almost as if vuggy.

CALCIFICATION. Calcification of the thallus (fig. 21E) is heavy and occurs mainly in bases of lateral heads, where it forms a continuous interlateral wall. The thalli are rarely bent, or deformed, therefore the calcified layer withstood well the pressure of the overburden. The calcified zone varies in thickness from 0.099 to 0.17 cm. The average thickness of the calcified zone is 0.1 cm., which is relatively thick. The main axis, the laterals, and the end of laterals are rarely calcified.

OVERGROWTH. The holotype has an organism, probably a bryozoan growing on the apex of the thallus.

Preservation:—The preservation is generally very good. Thalli are not collapsed and are seldom deformed. However, the preservation is fragmentary, and no complete specimen is found. The interior of many specimens is filled with crystals of calcite. The unusual preservation of laterals and facetal structures is noted; however, certain facets are "smoothed" as if the specimens were rolled, or were subject to solution.

Relationship:—This species appears the same as the illustration and description of *Mastopora parva* (Nicholson and Etheridge) of Currie and Edwards, 1942, pl. 11, figs. 5-9. However, there is a discrepancy between descriptions of Currie and Edwards (1942) and of Nicholson and Etheridge (1878). The latter workers state that their specimen is considerably smaller than their *Mastopora fava.* Currie and Edwards, on the other hand, describe a considerably larger specimen. In both descriptions the size appears the only differentiating factor. Without the examination of the English material, no taxonomic decision can be made at the present time. *Cyclocrinites pyriformis* (Bassler) appears similar to *Mastopora parva,* and *C. dactioloides* appears identical with *M. fava.*

Butts (1926) illustrated a cyclocrinitid from Little Oak Limestone in Alabama under the name of *Nidulites* cf. *favus.* This and one other specimen are incomplete and not well preserved. The base and apex are missing on both specimens, therefore the actual shape may have been different from the preserved shape which is vase-like. The thalli are somewhat laterally compressed. The facets are small, regularly arranged in rows, generally six- often seven-sided and are commonly perforated in the middle. The end of the lateral just below the facet is often calcified. These specimens are not *C. favus* which is similar or even perhaps identical with *C. dactioloides.* No characters are present that would suggest that these are *dactioloides.* These specimens are tentatively placed with *C. pyriformis* because the arrangement of facets is similar and, in addition, their geographic and stratigraphic positions are close. Examination of more specimens is needed before their specific position is certain.

Discussion of synonym:—Nidulites [now *Cyclocrinites*] *ovoides* Butts, 1941—The name of this species was first listed only by Butts (1940, p. 142) in a table of fossils from the Lenoir Limestone. Because the name was neither accompanied by description nor by illustration it was an "empty" name. In 1941, however, Butts illustrated the species and in his caption to figures he briefly compared it with *Nidulites pyriformis.* This comparison constitutes the description and validates the name. These specimens differ from other *Cyclocrinites pyriformis* in the presence of the facetal structures and in the lack of the preservation of the lower end. However, the calcification of laterals, which is very rare in the genus and the almost entire absence of calcification of lateral heads is the same. The bases in these specimens are missing. When reconstruction of the lower part is attempted, the shape of the thallus changes and a more elongated form results. The shape could have been, of course, pyriform. Thus *ovoides* is here considered a synonym of *pyriformis.*

TABLE 8.—Measurements in centimeters of 30 specimens of *Cyclocrinites pyriformis* (Bassler). All specimens are from U. S. National Museum and carry a USNM prefix. Often more than one specimen is assigned to a single number. USNM 71474 are strongly elongated along a plane perpendicular to the main axis, therefore two measurements are given; their height is not complete.

Specimen number	56625	111789	111789	97551b	97551a	97551a	97551a	97551a	97551a
Height	3.85	3.28	1.80	3.09	2.98	3.33	2.27	2.73	2.92
Width	1.81	1.37	1.20	1.47	1.25	1.43	1.36	1.23	1.76
Specimen number	97551a	97551d	11806	11806	8410	8410	8410	8410	8410
Height	2.90	3.38	3.34	....	0.26	2.55	2.26	3.42	2.36
Width	1.83	1.68	2.03	1.99	0.08	1.50	1.20	1.05	1.18
Specimen number	333F4	333F4	333F4	333F4	333F4	333F4	71474	71474	97372
Height	3.29	3.99	2.88+	3.15+	2.55+	2.84+	2.25+	2.33+	1.88
Width	1.58	1.18	1.14	1.64	1.43	1.26	2.34–2.08	2.26–2.08	1.34
Specimen number	97372	97372	97372						
Height	1.64	1.81	1.29						
Width	1.45	1.22	1.02						

Stratigraphic position and location:—Middle Ordovician through nearly complete thickness of Chambersburg Limestone throughout its entire geographic extent from Pennsylvania through Maryland to Draper Mountain, Virginia; at base of the Ottcsee Limestone in Virginia; Little Oak Limestone, three miles northeast of Pelham, Shelby County, Alabama; Lenoir Limestone, along North Fork of Roanoke River, three miles southeast of Blacksburg, Montgomery County, Virginia.

Material and measurements:—(1) Holotype (fig. 49) here selected, the specimen USNM 56625 illustrated by Bassler, 1909, pl. 7, fig. 11; Bassler, 1919, pl. 46, figs. 1 and 2. (2) Eleven specimens on block USNM 333F4; illustrated by Bassler, 1919, pl. 46, fig. 3. (3) Two blocks of limestone USNM 8410 consisting of five and ten specimens each illustrated by Bassler, 1919, pl. 46, figs. 4 and 5. (4) USNM 97551-a—97551-d. 97551-a consists of numerous specimens, many incomplete, illustrated by Butts, 1941, pl. 95, fig. 35; 97551-b consists of one specimen in matrix, illustrated by Butts, 1941, pl. 95, fig. 36; 97551-c consists of one cross-section imbedded in limestone, illustrated by Butts, 1941, pl. 96, fig. 37; 97551-d consists of a single specimen weathered out from the rock, illustrated by Butts, 1941, pl. 95, fig. 38. (5) Block of limestone USNM 111789 consisting of three specimens, the largest illustrated by Cooper and Cooper, 1946, pl. 2, fig. 3. (6) Two small pieces of limestone USNM 111806 (figs. 8 and 6). The other specimen figured by Cooper and Cooper, 1946, pl. 2, fig. 4, also a number of fragmentary specimens. (7) Two specimens USNM 71474. (8) Four specimens of "*Nidulites ovoides*" Butts, 1941, two nearly complete and two cut parallel to the main axis and partially polished; from the U. S. National Museum, marked co-types two numbers 97372 and 395V. Measurements are given in Table 8.

Cyclocrinites sp.

1863. *Pasceolus*
Billings *in* Logan, Geol. Surv. Canada, Rept. Prog. to 1863, p. 308.

1868. *Pasceolus* sp. ind.
Bigsby, Thesaurus Siluricus, p. 192.

1871. *Cyclocrinites* (?)
James, U. P., Cat. Lower Sil. fossils, p. 6.

1873. *Pasceolus* (sp. undetermined)
James, U. P., Additions Cat. Lower Sil. fossils, p. 2 (or 16).

1875. *Pasceolus* sp.
James, U. P., Cat. Lower Sil. fossils, p. 8.

1881. *Pasceolus gibbosus* Billings
James, Cat. fossils Cincinnati Group, p. 27.

1882. *Pasceolus*
Miller, Jour. Cincinnati Soc. Nat. Hist., **4**, p. 284 (also in pamphlet p. 18).

1910. *Pasceolus camdenensis* Foerste
*Foerste, Bull. Sci. Lab. Denison Univ., **16**, pp. 85–86, pl. 2, fig. 6.

1910. *Pasceolus*
Foerste, Bull. Sci. Lab. Denison Univ., **16**, p. 86.

1910. *Pasceolus*
Schuchert and Twenhofel, Bull. Geol. Soc. Amer., **21**, pp. 702, 709, 710.

1912. *Nidulites* sp. ind.
Raymond, Geol. Surv. Canada Summary Rept. for 1911, p. 356.

1915. *Pasceolus camdenensis* Foerste
Bassler, Bull. U. S. Nat. Mus., 92, p. 946.

1916. *Cyclocrinites*
Raymond, Bull. Mus. Comp. Zool., **56**, no. 3, pp. 205–245.

1916. *Nidulites*
Raymond, Bull. Mus. Comp. Zool., **56**, no. 3, pp. 252, 272.

1919. *Cerionites* sp.
Savage and Van Tuyl, Bull. Geol. Soc. Amer., **30**, p. 350.

1927. *Cyclocrinus camdensis* [sic] Foerste
Pia, Handb. Paläobot., p. 66.

1930. *Cyclocrinites* aff. *C. gregarius* Billings
Miller, Amer. Jour. Sci., **20**, p. 198.

1937. *Pasceolus globosus* Billings
Kay, Bull. Geol. Soc. Amer., **48**, pp. 263, 278, pl. 10.

1946. *Cerionites* sp.
Greacean and Ball, Sil. Inv. Greene Memorial Mus., p. 11.

1947. *Cerionites*
Elias, Jour. Paleontol., **21**, no. 1, p. 55.

1947. *Pasciolus* [sic]
Elias, Jour. Paleontol., **21**, no. 1, p. 55.

1948. *Pasceolus camdenensis* Foerste
Dalvé, Fossil fauna Ord. Cincinnati region, pp. 37, 46, 52, 55.

1952. *Cyclocrinus hospitalis* Salter
Johnson, Quart. Colo. School Mines, **47**, no. 2, p. 40.

1952. *Cyclocrinus mellifluus* Salter
Johnson, Quart. Colo. School Mines, **47**, no. 2, p. 40.

1952. *Mastopora concava* Eichwald
Johnson, Quart. Colo. School Mines, **47**, no. 2, p. 44.

1952. *Mastopora parva* Nicholson and Etheridge
Johnson, Quart. Colo. School Mines, **47**, no. 2, p. 44.

1968. *Cyclocrinites* sp.
Kerr, Geol. Survey Canada, Paper 67-27, p. 55.

(1) Six specimens PE2097. Two are cut and polished. These bodies are globular, somewhat flattened, poorly preserved, and with

little detailed anatomy observed. They are all casts, and hence no internal structure can be seen. There appear to be cyclocrinitid facets present that form intersecting curved lines. These facets are small and in order of 0.01 cm. across. Their number can be counted only very approximately and appears to be around 50 across the equator. The height of the thallus can be measured on only two specimens and varies from 1.48 to 2.35 cm. The smallest width is 1.88, the largest 3.00 cm. Ordovician. Arctic Canada, Southampton Island. S. K. Roy, Collector. No assignment to species can be made.

(2) Three specimens UC 52004. James Hall collection, labelled in the Museum catalog as *Cyclocrinites* sp. These are very poorly preserved globular specimens and their preservation does not allow for the taxonomic assignment. The measurements of the largest specimen are height 2.36 cm. and width 3.05 cm. The smallest specimen is 1.25 cm. high and 1.68 cm. wide. The fossils may be either *Cyclocrinites* sp. or other unrelated organisms. The specimens carry James Hall's rectangular, orange-red ticket numbered 677. Hall's original catalog lists it as Lower Helderbergian, two miles north of Clarksville, New York. If these specimens are cyclocrinitids the range of cyclocrinitids should be extended to the Lower Devonian.

(3) *Pasceolus camdenensis* Foerste, 1910. This species appears to have been based on one specimen only. It cannot be located now, and the search of the collection of type specimens in the American Museum of Natural History failed to produce the type. (Batten, personal communication). Therefore, the discussion is based on the Foerste, 1910, description and illustration only. The illustration of the specimen closely resembles the holotype of *C. halli*. The shape of thallus, slightly pointed basally, and the shape and distribution of lateral heads appear very similar in both specimens. The stratigraphic position of *camdenensis* is just below the stratigraphic position of *halli*. The dissimilarities are in the geographic distribution of the two species and in the size of the thallus; *camdenensis* appears almost half the size of the *halli*. The size, however, cannot be a differentiating factor when only one specimen is known. Except for the geographic location, the convexity of the "plate" was the sole character used by Foerste to differentiate *camdenensis* from *globosus*. *C. globosus*, however, is found with both concave and convex "plates," a preservation apparently unknown to Foerste. *C. globosus* from Ontario, except for the presence of stellate structures, is indistinguishable from *C. darwini* from the Cincinnati region. *C. camdenensis*

Foerste is placed among uncertain *Cyclocrinites* until the holotype is located.

Lepidolites Ulrich, 1879

1879. *Lepidolites*
 *Ulrich, Jour. Cincinnati Soc. Nat. Hist., **2**, no. 1, pp. 20–21.

1879. *Lepidolites* (Ulrich)
 James, U. P., Paleontologist, no. 4, p. 32.

1883. *Lepidolites* Ulrich, 1879
 Miller, Amer. Palaeo. fossils, 2nd ed., p. 261.

1885. *Lepidolites* Ulrich
 James, J. F., Jour. Cincinnati Soc. Nat. Hist., 8, no. 3, pp. 163–165.

1885. *Ischadites* Murchison, 1839
 James, J. F., Jour. Cincinnati Soc. Nat. Hist., **8**, no. 3, p. 163.

1887. *Lepidolites* Ulrich, 1879
 James, J. F., Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, p. 249.

1887. *Ischadites* Murchison, 1839
 James, J. F., Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, pp. 246, 249.

1888. *Lepidolites* Ulrich
 Ulrich, Amer. Geol., **1**, p. 324.

1889. *Lepidolites* Ulrich, 1879
 Miller, North Amer. Geol. Palaeontol., pp. 153, 160.

1890. *Lepidolites* Ulrich, 1879
 Ulrich, Geol. Surv. Ill., **8**, pp. 217, 239.

1891. *Receptaculites* De France, 1827 (in part)
 James, Jour. Cincinnati Soc. Nat. Hist., **14**, no. 1, pp. 61, 62.

1891. *Lepidolites* Ulrich, 1878
 James, Jour. Cincinnati Soc. Nat. Hist., **14**, no. 1, pp. 61, 62.

1892. *Lepidolites*
 Rauff, Abhandl. K. bayer, Akad. Wiss., p. 649.

1895. *Lepidolites* Ulrich
 Winchell and Schuchert, Geol. Minn., **3**, pt. 1, p. 67.

1915. *Lepidolites* Ulrich
 Bassler, Bull. U. S. Nat. Mus., 92, p. 707.

1955. *Lepidolites* Ulrich, 1889
 Laubenfels, Treatise Inv. Paleontol., p. E110.

1962. *Lepidolites* Ulrich, 1889
 Sushkin, Osnovy paleontol., p. 83.

1968. *Lepidolites*
 Nitecki, Geol. Soc. Amer. Ann. Meet., p. 35.

Definition:—Thallus small, globular to elongate; main axis non-calcified; basal indentation for reception of attachment mechanism; laterals in whorls; elongated termini of laterals thickened and calcified; lateral heads modified into scale-like calcified, imbricating plates.

Lepidolites dickhauti Ulrich, 1879

Figures 3H, 7I, 11, 14, 15, 52, 53

1879. *Lepidolites dickhauti*
*Ulrich, Jour. Cincinnati Soc. Nat. Hist., **2**, no. 1, pp. 21–22; pl. 7, figs. 17, 17a, 17b.

1879. *Lepidolites elongatus*
*Ulrich, Jour. Cincinnati Soc. Nat. Hist., **2**, no. 1, p. 22, pl. 7, fig. 16.

1879. *Lepidolites dickhauti* Ulrich
James, U. P., Paleontologist, no. 4, p. 32.

1879. *Lepidolites elongatus* Ulrich
James, U. P., Paleontologist, no. 4, p. 32.

1880. *Lepidolites dickhauti* Ulrich
Ulrich, Cat. fossils, p. 30.

1880. *Lepidolites elongatus* Ulrich
Ulrich, Cat. fossils, p. 30.

1881. *Lepidolites dickhauti* Ulrich
James, Cat. fossils Cincinnati Group, p. 26.

1881. *Lepidolites elongatus* Ulrich
James, Cat. fossils Cincinnati Group, p. 26.

1883. *Lepidolites dickhauti* Ulrich, 1879
Miller, Amer. Palaeo. fossils, 2nd ed., p. 261.

1883. *Lepidolites elongatus* Ulrich, 1879
Miller, Amer. Palaeo. fossils, 2nd ed., p. 261.

1885. *Lepidolites dickhauti* Ulrich
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **8**, no. 3, pp. 163–164.

1885. *Ischadites dickhauti* Ulrich
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **8**, no. 3, p. 165.

1885. *Lepidolites elongatus* Ulrich
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **8**, no. 3, p. 164.

1885. *Ischadites elongatus* Ulrich
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **8**, no. 3, p. 165.

1887. *Lepidolites dickhauti* Ulrich, 1879
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, p. 249.

1887. *Ischadites dickhauti* (Ulrich)
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, p. 249.

1887. *Lepidolites elongatus* Ulrich, 1879
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, p. 249.

1887. *Ischadites elongatus* (Ulrich)
James, J. F., Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, p. 249.

1889. *Lepidolites dickhauti* Ulrich, 1879
Miller, North Amer. Geol. Palaeontol., p. 160.

1889. *Lepidolites elongatus* Ulrich, 1879
Miller, North Amer. Geol. Palaeontol., p. 160.

1890. *Lepidolites dickhauti* Ulrich
Ulrich, Geol. Surv. Ill., **8**, p. 239.

1890. *Lepidolites elongatus* Ulrich
Ulrich, Geol. Surv. Ill., **8**, p. 239.

1891. *Receptaculites dickhauti* Ulrich, 1879
James, Jour. Cincinnati Soc. Nat. Hist., **14**, no. 1, p. 63.

1892. *Lepidolites dickhauti* Ulrich
Rauff, Abhandl. K. bayer. Akad. Wiss., p. 649.

1895. *Lepidolites dickhauti* Ulrich
*Winchell and Schuchert, Geol. Minn., **3**, pt. 1, p. 67, pl. F, figs. 11, 12

1895. *Lepidolites Dickhauti* Ulrich, 1879
Head, Palaeoz. sponges, pp. 5, 7, 11.

1895. *Lepidolites elongatus* Ulrich, 1879
Head, Palaeoz. sponges, pp. 7, 11.

1895. *Ischadites dickhauti* Rauff, 1892
Head, Palaeoz. sponges, p. 5.

1902. *Lepidolites dickhauti* Ulrich
Nickles, Jour. Cincinnati Soc. Nat. Hist., **20**, no. 2, p. 70.

1905. *Lepidolites dickhauti* Ulrich
Schuchert et al., Bull. U. S. Nat. Mus., no. 53, p. 350.

1905. *Lepidolites elongatus* Ulrich
Schuchert et al., Bull. U. S. Nat. Mus., no. 53, p. 350.

1915. *Lepidolites dickhauti* Ulrich
Bassler, Bull. U. S. Nat. Mus., 92, p. 707.

1948. ? *Lepidolites dickhauti* Ulrich
Dalvé, Fossil fauna Ord. Cincin. Region, p. 9.

1954. Not *Lepidolites* aff. *L. dickhauti* Ulrich.
Miller, Geol. Soc. Amer. memoir 62, p. 10, pl. 6, figs. 1–4.

1955. *Lepidolites dickhanti* [sic] S. D. Miller
Laubenfels, Treatise Inv. Paleontol., p. E110.

Definition:—The definition of *L. dickhauti* is the same as that of the genus.

Discussion:—Ulrich originally named and described two species of *Lepidolites, dickhauti* and *elongatus,* and designated the former as the type species. The difference between these two was based on size and shape of the body. The examination of Ulrich's original material reveals that gradations of size and shape between these two species exist. Therefore only one species, *L. dickhauti,* is here recognized, and *L. elongatus* is placed in the synonymy.

Description:—THALLUS. Thallus is simple and relatively erect; its shape varies from elongate to a robust saclike (figs. 3H, 14, 15, 52). The longest specimen appears to have a ratio of length to width of 5–1. In the shortest example this ratio is 4–3. Most fossils are broken and, therefore, the reconstruction of general shape (fig. 15) is based on a few more or less complete specimens. The commonest shape is slightly pyriform; thallus at the base is rounded, rapidly expanding, reaching the maximum dimension approximately one-

FIG. 52. *Lepidolites dickhauti* Ulrich. Holotype USNM 46533, Eden, Covington, Kentucky.

third of the way up and then gradually tapering to a blunt end. The thallus is very poorly preserved, and small holes on the surface are noted.

MAIN AXIS. Main axis is straight and non-calcified. Since the calcified parts of laterals are of uniform size, it is supposed that entire laterals are also of uniform length, and thus the main axis in a general way reflects the pattern of the thallus, but is somewhat shorter.

LATERALS. The heavily calcified termini of laterals (fig. 53) are found on two specimens only. These are short, pointed, straight, unbranched, of reasonably uniform size, and arranged parallel to each other. The total length of laterals is unknown and is dependent upon the thickness of the main axis. It is not known whether laterals are of the first or the second order. By comparison with other cyclocrinitids, it is assumed that the calcified ends represent ends of primaries. The possibility exists that these calcified fragments are structures comparable to the weakly calcified short primaries of *Cyclocrinites welleri*. Should this be the case, *Lepidolites*

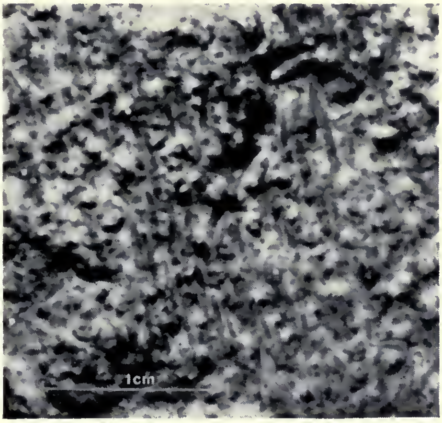

FIG. 53. *Lepidolites dickhauti* Ulrich. USNM 46533. Eden, Covington, Kentucky. Lateral branches are preserved.

possesses branched laterals. The regular arrangement of plates indicates that laterals are borne in whorls.

PLATES. The ends of laterals are modified and form plates (fig. 11). These are small, oval to circular in outline, sometimes polygonal, mostly of irregular shape, fragmentary, and poorly preserved. When badly preserved they may appear as pimples, or irregular projections upon the surface; frequently they are absent. It is assumed that the original shape of plates was circular or oval, and that other forms are due to the post-mortem or diagenetic modification. The plates are of uniform thickness, are scale-like, and overlap like shingles on a roof. The regularity in the arrangement of plates forms horizontal and diagonal lines. In addition, there are vertical lines formed by the alternate position of plates from one horizontal row to another.

The largest plates are in the center of the thallus, the smallest are in the bottom. The number of plates increases rapidly from the base. No differentiation of the calcification of plates is noted. On a few plates a radiating stellate structure, analogous to structures in other cyclocrinitids, is present. These structures, barely visible, are found on six- and four-sided plates and possess a ventral depression and four branchlets radiating from it.

ATTACHMENT. The basal part of the thallus is very well preserved, and shows a deep indentation that appears as an attachment scar (figs. 14, 15, 52). The attachment was probably a pedicle that may have consisted of basal hair or tufts of hair.

CALCIFICATION. Because of flattening and breakage it is assumed that calcification was not continuous. The termini of laterals are well calcified. Plates are the only other elements on which the deposition of calcium carbonate occurrs.

MUCILAGE. Mucilaginous membrane is not observed. What Ulrich called "integument" is not noted, only a finely compressed clay surface is present.

Faunal association:—The associated fauna consists of marine invertebrates and includes fragments of trilobites, bryozoans, brachiopods, crinoid stems, and perhaps ostracods and graptolites. None of these, however, are pyritized. Only the plates of *Lepidolites* are preserved as sulphides. No reason for this selective mineralization is apparent.

Affinities:—The genus is related to other cyclocrinitids in possession of unbranched thallus and main axis, and the presence of calcareous, simple laterals. It differs from the generalized cyclocrinitids in the presence of overlapping plates that are assumed to be a modification of cyclocrinitid lateral head.

Material:—The material available consists of two almost complete specimens, including a holotype, and 24 fragments. All are from the United States National Museum, and all bear one number—USNM 46533.

Stratigraphic position and locality:—Upper Ordovician, Eden (Southgate), Covington, Covington Creek and about 150 feet above low water mark in the Ohio River, Kentucky.

Measurements (in centimeters):—

a. Holotype: height 1.25; width 1.06
b. Referred specimen (holotype of *L. elongatus*): height 1.86; width 0.78
c. Other fragments vary from 0.23–2.32
d. Laterals: length up to 0.4; width 0.11–0.15
e. Plates: average 0.3; largest 0.38

Part III

Original Definitions and Descriptions of Other Authors

This section consists of original and emended definitions of various authors. Quotations from rare publications, translations from foreign literature, and selected more important descriptions are included. They are arranged in alphabetical order of the original designations and are cross-indexed.

Anomaloides Ulrich, 1878

"Incerta Sedes. *Anomaloides,* n. gen. The above generic name is proposed for the reception of certain hollow, compressed, conical bodies, having much of the form of the rays of the Asteroidea. Upon examination, however, they are found to have no surface which can be called either ventral or dorsal, since they are composed uniformly of elongated, cylindrical, spine like bodies, which are placed parallel with each other, and perpendicular to the surface.

"The fragments from which this description is taken are in all so peculiar, and so different from anything heretofore known, that it would be exceedingly difficult, and probably premature for me to attempt to point the affinities of the genus from the specimens at hand. At present, however, I believe they are to be looked for in the Echinodermata." (Ulrich, 1878, p. 92.)

Anomaloides reticulatus Ulrich, 1878

"The thirty-five fragments before me were found on a spot about two feet square, and it may be possible that they all belonged to one individual, but that seems scarcely probable. They are all hollow, and the envelope is composed of an aggregation of sub-cylindrical or rather club-shaped stems, which are placed parallel with each other, and perpendicular to the surface; their inner ends are acutely pointed, while that end which shows on the exterior surface is rounded, and with a minute pit on the top, for the articulation of two very fine and small spines. The distribution of these club-shaped plates is very regular, being arranged in curved or flexuous transverse, and diagonally intersecting lines; and on account of their cylindrical form, there are a great number of interstices, which may be referable to pores, analogous to those in the Asteroidea.

"Two of the specimens are compressed, conical in form; one is two inches in length, and the greatest breadth is three-fourths of an inch; its two edges run nearly parallel for about one and one-fourth of an inch, from where it tapers rapidly to a point. These specimens may represent rays. Another specimen appears to be part of a disk, and judging from its form it seems possible that it was supplied with three such rays, as those described. Two other fragments were observed, in which some small specimens of *Bellerophon bilobatus* were found within the envelope of plates." (Ulrich, 1878, pp. 92–93.)

Astylospongia tumidus U. P. James, 1878 [now *Cyclocrinites darwini* (Miller)]

"*Astylospongia tumidus*. (James.) Fossil subglobose, more or less depressed, with a shallow cavity on one side. Surface rough and generally covered with pit-like markings; sometimes quite distinctly lobed; examples examined not very satisfactory. Locality—Cincinnati." (U. P. James, 1878, p. 1.)

Bornetella Munier-Chalmas, 1877

"Thallus clavate, provided with a velum of 5–6 angled cells; the axis throughout the frond dorsally (always?) naked, cylindrical below, much wider above, subclavate and obtuse apically; verticils numerous, superposed, crowded below the obtuse apex, the lower [verticils] farther apart, with numerous, regularly 2–3 branched filaments. Basal articulations of the filaments all very long cylindric; branchlets beneath the obtuse dilated apex bearing 4 articulated secondary branchlets [these] little dilated, truncate at apex, in cortical velum; shorter filaments (perhaps alternating with the previous branchlets) aggregated in age, with shorter basal articulation and crowned with 4 obovate branches each fruit-bearing." (De-Toni, 1889, pp. 414–415; translated from Latin.)

Codium mamillosum Harvey

"Root a mere point of fixture. Frond spherical, egg-shaped or kidney-shaped, very dense and solid. When cut across, the central portion is seen to be formed of innumerable, very slender, branching, interwoven, thread-like filaments, set in and surrounded by a rather firm but slimy jelly; and the exterior portion, or peripheric stratum, of very thick, inflated, bright-green, bag-like ramuli, which rise from the slender internal filaments, and are continuous with them at the base. The center of the frond therefore may be regarded as composed of interwoven rootlets, of which the peripheric ramuli are the true fronds, the sphere being a compound body formed of a colony of unicellular Algae. The membrane is very tough and fine, and when dry has a vitreous or satiny lustre. The endochrome is bright-green, thickish, and fills the ramuli. No fruit has been observed. When dry the frond does not adhere to paper.

"This curious plant is in all essential characters a *Codium*, but the peripheric ramuli are of such large size, so much distended, and so glassy, that at first sight it might be taken for a *Valonia*. The centre is very gelatinous, the filaments inextricably interwoven, and the balls contain so much slime that they are a long time in drying. I once or twice found the frond attached, but usually there is no mark on the surface by which one point more than another can be recognized as base or apex. Probably after a time it becomes detached and floats freely in the sea as *Cladophora Aegagropila* does in freshwater lakes." (Harvey, 1863, caption to pl. 41.)

Cyclocrineae Pia, 1920

"The overall form of the thallus spherical to elongated egg-shaped. Branches randomly positioned. There they form a well-integrated (closed off) cortical layer. No sporangia present, the spores thus were probably formed in the stem cells. Paleozoic only." (Pia, 1927, p. 63, translated from German.)

Cyclocrinites Eichwald emend Stolley

"The systematic position of the problematical bodies to which the above generic names have been applied is not one upon which paleontologists are generally agreed, and there is hardly a single group of invertebrates of rank lower than the brachiopods to which they have not been assigned. Stolley, who has exhaustively studied these organisms, considers *Cyclocrinites* and *Pasceolus* identical, but distinct from *Nidulites* which he considers identical with *Mastopora* Eichwald, the latter having priority. He refers all of them to the Siphoneae, a group of algae whose cell substance is impregnated with calcium carbonate. The present writer makes the same reference.

"The Anticosti rocks contain three species of these organisms, of which all appear to belong to *Cyclocrinites*. Through the kindness of Doctor R. S. Bassler the writer was permitted to study a specimen in the United States National Museum, identified as *Cyclocrinus spaskii*, from the Ordovician of Reval, Russia. The specimen is a cast and differs from the Anticosti examples of *P. halli* in having a more spherical shape and in not being quite so well preserved. Later, scores of the species in excellent preservation were collected from the type localities of Eichwald's *Cyclocrinites*. Examination of these confirmed the reference. It may be that *P. gregarius* and *P. intermedius* should not be referred to *Cyclocrinites* (as was done by Stolley) since examination of hundreds of specimens of the latter species has shown none with dome-shaped elevations and in no instance were cell covers discovered, this being one of the chief characters relied on by Stolley to separate *Cyclocrinites* from *Mastopora*, or *Nidulites*. Supplementary evidence supporting this view is found in a statement by Hinde that *Nidulites favus* occurs on Anticosti. In all probability he was referring to *intermedius* as he is known to have been in the locality where that species is abundant. Except, however, for the fact that cell covers have never been found, all other characters agree with *Cyclocrinites*. "(Twenhofel, 1928, pp. 100–101.)

Cyclocrinites Eichwald, 1840
See: **Mastopora** Eichwald, 1840
Pasceolus Billings, 1857

Cyclocrinites concava (Eichwald)
See: **Mastopora concava** Eichwald, 1840

Cyclocrinites dactioloides (Owen)
See: **Lunulites dactioloides** Owen, 1844
Nidulites favus Salter, 1851
Pasceolus billingsii Roemer, 1888

Cyclocrinites darwini (Miller)
See: **Astylospongia tumidus** U. P. James, 1878
Pasceolus darwini Miller, 1874

Cyclocrinites globosus (Billings)
See: **Pasceolus globosus** Billings, 1857

Cyclocrinites gregarius (Billings)

"The specimens of these species have all the characters of *C. intermedius*, from which they differ only in the average size of the individuals and the size of the plates, there being from four to five plates in 5 mm. instead of about three to five. These differences and the fact that they occur in slightly lower strata should lead to the retention of the species until more is known concerning it . . ." (Twenhofel, 1928, p. 102.)

Cyclocrinites gregarius (Billings)

See: **Pasceolus gregarius** Billings, 1866

Cyclocrinites halli (Billings)

"The convex elevations which cover casts of the interior range in diameter from 1 to 2.25 mm. There is also considerable variation in the shape of the entire specimen, though this is probably largely the result of pressure. The holotype is pear-shaped with a height of 35 mm. and a diameter of 25 mm., almost a circle in section. The elevations supposed by Billings to be apertures probably serve some other purpose, since one specimen in the collections of the National Museum of Canada has three of these elevations of different sizes and heights and Billings mentions one having four. They are probably due to irregularities of growth and in some instances they may have been places of attachment of some commensal, perhaps a *Crania*. In many of the specimens a small bryozoan encrusts the supposed integument. This supposed integument resembles a thin, skin-like covering and may well have been present, since many marine organisms have a thin organic covering over the shell. Its presence in no way conflicts with the views of Stolley . . ." (Twenhofel, 1928, p. 101.)

Cyclocrinites halli (Billings)

See: **Pasceolus halli** Billings, 1857

Cyclocrinites intermedius (Billings) [now *Cyclocrinites gregarius* (Billings)]

"This species is somewhat larger than *C. gregarius* and has more plates for a given space, although the variation in this respect is not great. It is also larger than *C. halli*. The two species, as preserved, differ from *C. halli* in that no cover plates have been found, so that the surfaces present concave depressions instead of dome-like elevations. The shape is globular, about 24 mm. in diameter, and with three to five plates in 5 mm." (Twenhofel, 1928, p. 102.)

Cyclocrinites pyriformis (Bassler)
See: **Nidulites ovoides** Butts, 1941
Nidulites pyriformis Bassler, 1915

Cyclocrinites Spaskii Eichwald, 1840

"These graceful completely round spheres consist of small penta- or hexagonal little plates which have a diameter of a little more than one-third of a line, while the spheres are nine lines in diameter. The surface of the little plates has a radiating design; the rays are prominent above the surface in some well-preserved specimens and thus they are very similar to the *Heliocriniten*, though the areas in *Cyclocrinit* are much smaller and therefore also more numerous; they are absolutely smooth in the middle, without any rays. The latter, usually 15, show up only at some distance from the center and do not transcend the border of the little plates, which are therefore not formed by them as is the case in *Heliocrinit*. Since these spherical bodies are always grown into a firm stone one does not see anywhere their openings. This species was found in a dense limestone at Numelas, not far from Reval." (Eichwald, 1840, pp. 78–79; translated from German).

Cyclocrinites spaskii Eichwald, 1840
See: **Cyclocrinus Spaskii** Eichwald, 1840

Cyclocrinites welleri n. sp.
See: **Mastopora** sp.

Cyclocrinites sp.
See: **Pasceolus camdenensis** Foerste, 1910

Cyclocrinus [now *Cyclocrinites*] Eichwald, 1840

"Genus 26. *Cyclocrinus* m. first described as *Cyclocrinites* in Schichtensyst. von Esthland. page 192.

"The globular calyx, hollow inside with indistinct holes, is made up of numerous small rounded plates which form the whole surface. These plates are so close to each other that they become more or less angular; the middle of their surfaces is provided with a small hollow ? protuberance from which extend in all directions 15, 20 to 25 short rays which delimit each plate. It seems that the protuberances, in other better-preserved specimens, retain small tubes that stick out over the whole surface of the calyx. They are very close to each other and seem fused. Moreover, the plates are at an even and uninterrupted level, except for the opening of the mouth which shows up reasonably well on the mold of the interior cavity of the globe; these plates rest on a common calcareous base which passes between them and fills in their interspaces; the base seems to be provided with small pores of which the biggest arise from the hollow protuberance in continuation of the tubes; the smallest ones perhaps communicate with the convex basal parts of the plates, made up of the rays of the surface. Below the base common to the plates, there are it seems other semi-globular spheres, which also appear hollow inside and which in vertical section show small vertical canals; these may well be the continuation of the pores of the common base which come out there in the semi-globular cavities.

The pores and the canals have some similarities with the water vascular canals of the *Echinosphaerites* and *Heliocrines,* and the radiating ribs of the surface (have a resemblance) with the rays of their surfaces (*Echinosphaerites* and *Heliocrines*).

"A small rudimentary stem seems to have existed on the side opposite the hole of the mouth.

"The strange genus is found only in the *Orthoceratites* limestone, in the horizon which is called Cyclocrinites limestone." (Eichwald, 1860, pp. 637–638; translated from French.)

Cyclocrinus [now *Cyclocrinites*] Eichwald, 1840

"*Cyclocrinus* Eichwald (*Pasceolus, Cerionites*). Shape and general construction are very similar to the *Coelosphaeridium,* to which the genus is certainly closely related. Calcification is however very weak, the branches being clearly differentiated into a thin stem and a flat cortical cell, externally closed off with a limy membrane, that shows regularly arranged pores. I consider it correct to circumscribe the genus *Cyclocrinus* in the same sense as did Stolley, thus to include in it also *Pasceolus* and the other genera that he cited as synonyms. The European species have been extensively investigated by Stolley. However Kiesow has maintained that many of these genera are based only on the different mode of preservation. This question could be solved only if we were to investigate very extensive material, which so far has not been available to me. The American species are generally insufficiently known. Many of the specimens are probably not closely identifiable at all, because the outer membranes with their characteristic sculpture is missing. At the moment one can do nothing but to place the species names without further critical analysis." (Pia, 1927, pp. 64, 66; translated from German.)

Cyclocrinus [now *Cyclocrinites*] Eichwald, 1840

"*Cyclocrinus* Eichwald, 1840 (*Cyclocrinites* Eichwald, 1840). Type species *Cyclocrinites spaskii* Eichwald, 1840; horizon 'Rakvere' (formerly 'Vezenberskie bed') (Ordovician). Estonian Soviet Republic. Thallus spherical or oval with stalk-like leg in the lower part; overall diameter of the body from a few millimeters to a few centimeters (average 1–3 cm.). The central nucleus spherical. Lateral branches straight, on ends possessing mushroom-shaped expansions, their bulging ends in contact one with the other, forming a continuous covering. Calcification of thallus weak, originating mainly in the covering part of the body around the bulging ends of the lateral branches. Because of the precipitation of $CaCO_3$ on the interior of the covering layer, the limy film forms a cup-shaped depression, in which the bases of the bulging ends are placed, and on the outer surface of which calcareous plates originate, generally of six-sided form. Likewise the plates of the thin lime armor that form around the thallus come in contact. The degree and character of calcification of the plates, the presence on them of round, triangular, rectangular and other apertures are definite indicators of species assignments. Several species Ordovician-Carboniferous. Ordovician of Baltic and Kazahstan, Carboniferous of SSSR, Ordovician of Scandinavia. Redeposited Ordovician rocks of Northern Germany, Poland." (Korde, ed., 1963, p. 212; translated from Russian.)

Cyclocrinus Eichwald, 1840

See: **Cyclocrinites** Eichwald, 1840

Cyclocrinus [now *Cyclocrinites*] **Spaskii** Eichwald, 1840

"*Cyclocrinus Spaskii* . . . the globular calyx, sometimes elongated towards the withdrawn base where the little stem must have been fixed, is made of several hundreds of little plates a half-line in diameter with a slightly convex surface provided with several rays in in the form of a little star in the middle of which is a hollow prominence. The surface bristled with hollow spines or closely packed tubes. The polished calyx plates have on their surfaces little pores which seem to arise from their perforated base and pass through the common calcareous layer on which the plates are attached by their bases. Below this are some hemispherical bodies attached to each other, their convexity turned toward the internal cavity and serving perhaps to receive the openings of the tubes of the plates.

"*Habitat:*—Cyclocrinitid limestone of Mounalass in Estonia, but also in the orthoceratid limestone of Wesenberg and Nyby, on the islands of Odinsholm and Dagö, especially with *Megalaspis gigas* at Hohenholm and even in the vicinity of St. Petersbourg nearby Gatschina in the *Platystrophia lynx* dolomite.

"The size of the calyx is one inch, sometimes more, sometimes less, and is found in different conditions of preservation, the plates ordinarily retaining the stars and the central prominence. Sometimes, for example in the vicinity of Wesenberg, the plates are separated by interstices, since the walls which should be found between them are lacking, or as in the Isle of Dagö the tubes of the plates are well preserved and decorate like prickles the entire surface.

"It was in the cyclocrinitid limestone of the Isle of Dagö that I saw just as distinctly the mouth opening on the inner side of the calyx surrounded by very small confluent plates.

"In any case, this paradoxical body belongs to the class of radiating animals in the family of cystoids, and not in that of corals where Edwards and Haime (British fossil corals. Introduction 1, page LXXIV) placed it, since polyps never form hollow globes and are never built of little regular plates between which is the distinct orifice which could correspond to a mouth.

"Edwards and Haime called this body a star-shaped polyp with hexagonal calyxes where the vertical lamellae (septa) do not extend to the visceral chamber occupied by very small and thin platforms (small tabulae). The vertical lamellae are the little radiating ridges, and the visceral cavity is the hollow prominence that fixes the little tubes, of which the cavity is wrinkled transversely on the inside probably by growth layers, but I see nowhere any distinct platforms. The closest affinity of *Cyclocrinites* is with *Heliocrinites* whose surface is decorated with similar radiating ridges and many pores which pierce it in many places.

"The structures of this enigmatic body is in general too little known to permit placing it where it belongs among fossils." (Eichwald, 1860, pp. 638–640; translated from French.)

Lepidolites Ulrich, 1879

"This generic name is proposed for the reception of some very peculiar fossils, obtained by Mr. H. E. Dickhaut and the author, near

Covington, Kentucky, on and in the shale immediately surrounding some of the hard clay nodules, which frequently occur in the shales of the lower part of the Hudson River group. They consist of much flattened, calcareous bodies, which in their original state must have had, in the type species, a sub-spherical, and in the other species, a sub-cylindrical form. They are hollow, with a thin envelope of imbricating plates or scales. The lower (?) end has an outside indentation similar to that borne by an apple for the reception of the stem, while the corresponding part of the interior is raised into a small cone. The interior of the sack appears to be lined with a very thin and delicate integument, to the outer surface of which the scales are attached. No openings of any kind can be detected.

"Type: *L. dickhauti.*

"In the imbricating plates some resemblance is presented to such genera of the PALAECHINIDAE, as *Lepidesthes,* but these fossils can scarcely be referred to the ECHINODERMATA, on account of the entire absence of openings, and of any series of plates that might be termed ambulacra. The genus seems, in certain characters, to be related to *Pasceolus,* which by some authorities is considered to be a Cystidean, while others place the genus with the PROTISTA. On account of the unique characters of the specimens on which the genus is founded, I have though it advisable to describe them, provisionally, as fossils with uncertain affinities. However, I have no doubt, that when these characters are better understood, the genus will be the type of a new family, if not indeed of a new order." (Ulrich, 1879, pp. 20–21.)

Lepidolites dickhauti Ulrich, 1879

"All the specimens of this species examined are exceedingly flattened, but their original form undoubtedly was either sub-spherical or sub-pyriform, with the lower portion considerably indented. The envelope of scale-like plates is very thin, being little more than one-hundredth part of an inch in thickness, and appears to have been slightly flexible. The plates imbricate, with the exposed margin rounded, and arranged in concentric lines crossing each other in a quincuncial manner; they are much smaller about the indented portion, gradually becoming larger as the rows approach the upper portion. The appearance presented by a specimen that is flattened vertically, is very like that style of ornamental work on watchcases called "rose engine turning." In the largest plates observed, the exposed portion has a diameter that is not more than one thirtysecondth of an inch. Detached plates have a length that is equal to about three times the greatest breadth, and are somewhat cuneiform in outline, the widest end being that one which is exposed on the exterior of the sack. When the exceedingly delicate integument lining the interior of the sack, and to the outside of which the plates are attached is removed, the lower ends of the plates are exposed; this side of the plates is provided with a slightly defined, longitudinal furrow.

"Specimens of this species are usually coated with iron, which effectually destroys their minute characters. Fortunately the author found some fragments that were entirely free of that troublesome substance, and from these the details of the above description were obtained.

"Named in honor of the energetic collector, Mr. H. E. Dickhaut." (Ulrich, 1879, pp. 21-22.)

Lepidolites dickhauti Ulrich, 1879
See: **Lepidolites elongatus** Ulrich, 1879

Lepidolites elongatus [now *L. dickhauti*] Ulrich, 1879

"This species differs from the type of the genus mainly in its different form. The form of *L. dickhauti* is sub-spherical, while that of the species under consideration is sub-cylindrical, with the ends usually somewhat truncated. The length is generally equal to about three and a half times the diameter of transverse measurement. The specimens are coated with iron, and for that reason I was unable to ascertain whether the plates differ from those of the type species. Their arrangement is very much the same.

"This species seems to have attained a larger size than *L. dickhauti*. The largest specimen found, though defective at both ends, in its flattened condition is nearly two inches in length, by three-fourths of an inch in width.

"Formation, locality and collectors; same as the last." (Ulrich, 1879, p. 22.)

Lunulites [now *Cyclocrinites*] **dactioloides** Owen, 1844

Truncated spherical, with five or six sided cellular depressions in rows around the circumference, like those on a thimble, one inch and a quarter in circumference." (Owen, 1844, p. 69.)

Mastopora [now *Cyclocrinites?*] Eichwald, 1840

"*Mastopora* Eichwald (*Nidulites* Salter). Cortical cells are prismatic with slightly curved floor. Their side-walls show a well marked thickening very similar to the living *Bornetella*. Some species reach the size of a large apple. The form was mostly spherical or egg-shaped, in one case nearly club-shaped. All species so far known belong to the Ordovician. They are: *M. concava* Eich., *M. fava* Salt., *M. odini* Stoll., *M. parva* Nich. and Ether. spec., *M. pyriformis* Bassl. spec. It is a matter of investigation to determine whether some of the species assigned above to *Cyclocrinus*, do not belong to *Mastopora*." (Pia, 1927, p. 66; translated from German.)

Mastopora [now *Cyclocrinites?*] Eichwald, 1840

"*Mastopora* Eichwald, 1840 (*Nodulites* [sic] Salter, 1857). Type species—*Mastopora concava* Eichwald, 1840; "Ievskii" bed (Ordovician), Estonian SSSR. Thallus spherical or pyriform, big (exact size unknown because of incomplete preservation of fossils). Lateral branches, possibly in turn dividing into branching of the II order. Throughout their full length they remain thin, thickening in their ending only, acquiring the form of a cubic (hexahedral?) prism. These are tangent, jointly forming the enclosing part of the thallus. Calcification of thallus weak, only in the region of the enclosing part. $CaCO_3$ precipitated in the walls of the prismatic enlargements of the lateral branch, in which, in fossil specimens are high hollow [tubular] prismatic cells from 0.1 to 0.3 cm. in diameter; on the exterior they freely open (calcareous plates not detected), interior smoothly rounded, ending with small opening in the center. In the neighborhood of the opening on the inside of the cell, zones of thickening of $CaCO_3$ are visible in a few specimens. Several species. Ordovician of Baltic region; Ordovician and Silurian of England, Norway; Ordovician of America, redeposited Ordovician rocks of Poland, northern Germany and Holland." (Korde, ed., 1963, p. 212; translated from Russian.)

Mastopora [now *Cyclocrinites?*] **concava** Eichwald, 1840

"This very striking genus is very close to *Receptaculites*. Here likewise the colonial skeleton was plate-like, but sharply depressed, scarcely a line high; on the upper surface as well as deeper within one can detect a quantity of regular round tubercles, which are perforated through the middle; each opening leads to a hole, which likewise makes a short cylinder, though much broader than the opening;

these little tubes are very closely packed. The underside, mostly hidden in limestone, shows as it seems the lower openings of these tubes as hexagonal orifices, which are so close together that also this underside appears hexagonal. I know fragments of only one to one and a half zoll [zoll=2.61 cm.] from Odinsholm and from Estonia not far from Reval. You find it also as gravel around Potsdam: Mr. Klöden (F. Klöden, Versteinerungen der Mark Brandenburg, Berlin, 1834) shows a picture as *Cellepora hexagonalis* Münst. (s. Goldfuss l.c. Tab. 36, fig. 6) which however is very small and thin-walled, while our gigantic genus consists of obvious tubes." (Eichwald, 1840, pp. 90–91; translated from German.)

Mastopora sp. [now *Cyclocrinites welleri* n. sp.]

"*Mastopora* (?) sp. Oval plate approximately 45 mm. long and 30 mm. wide; honey-combed surficial pattern of hexagonal cups, largest cup approximately 3 mm. in diameter; reverse side not exposed but appears irregular, walls of cups form ridges." (Griefe and Langenheim, 1963, p. 567.)

Subtribe Mastoporinae Pia [now *Cyclocriniteae*, Pia, 1920]

"Subtribe Mastoporinae. Cortical cells are very small and numerous, laterals probably branched, external membrane mostly non-calcified, only occasionally uniformly calcified, but always without any ornament." (Pia, 1927, p. 66; translated from German.)

Neomeris Lamouroux, 1916

"Plants small, generally gregarious, spindle-shaped or subcylindrical, more or less calcified, with an erect elongate axis tipped with a small cluster of bright green filaments, in the mature portion bearing closely placed whorls of short compound branchlets, each branchlet consisting of a basal cell bearing one whorl of branchlet cells with greatly expanded distal ends, each of which bears one delicate uniseriate hair filament; sporangia solitary, terminal on the primary branchlet cells between the cells of the secondary whorl, each containing one large aplanospore." (Taylor, 1960, pp. 99–100.)

Neomeris dumetosa Lamouroux

"Plants subcylindrical, elongate, 20–40 mm. long, 1–2 mm. diam., acute or acuminate at the apex, the terminal hair tuft inconspicuous; whorled basal branchlet cells bearing 3–8 capitate cells of the second order which are easily shed when past maturity, but these cells when intact forming a continuous cortex of polyhedral facets 100–185μ diam.; sporangia calcified but free, 150–200μ long including stipe, above which they are nearly spherical, 135–160μ diam., soon deciduous." (Taylor, 1960, p. 101.)

Nidulites favus Salter, 1851 [now possibly *Cyclocrinites dactioloides* (Owen)]

"The fossil to which the above name is applied is a frequent one in the Llandeilo flags of Pembrokeshire; at Haverfordwest particularly so, where it occurs associated with fossils very much of the same character as those from the strata here described. It occurs as oval or roundish plates, about 2 inches broad, spreading out from a center (of attachment?) into a flattened irregularly wavy form; the entire surface of both upper and under sides covered with hexagonal cups, in our Scotch specimens a line wide, in the Welsh ones something less. These cups are about two-thirds their diameter deep, their edges smooth and even with the general surface, and their bases rounded and almost always with a central punctum or depressed point (which shows itself on the cast as a tubercle), and which is probably its point of attachment to the membrane or lamina forming the base for both series of cups. This membrane, whatever may have been its texture, is always absent in our specimens, a narrow space, as in fig. 17b, being left between the upper and under series of cups, though some traces of its presence are to be seen in some sharp wrinkles which are seen radiating from the center of the plate where one series is broken away. The lower surface of the cups themselves appears to have been a little wrinkled too towards their pedicle, as may be seen on the specimen fig. 17a, where one series of cups has been separated from the opposite one before being fossilized, and where we have consequently only the impression of their lower surface. Such an impression has been figured (from this locality) by my friend Prof. M'Coy, as a cast of his *Palaeopora favosa*.

"Were it not for the very large size of the cells, and the total absence of any diaphragm or covering to their wide mouths, it would have been natural to refer these double-sided cellular plates to the *Bryozoa*. I have to thank Prof. Milne-Edwards, however, for calling my attention to their analogy with the *Nidi* of Gasteropod Molluscs, the variety of arrangements among which are so striking. If they are of this nature, *Murchisonia* seems to be the only genus likely to produce them, as that genus is plentiful in both districts where they occur. The name *Nidulites* might perhaps stand, whether they belong to the *Mollusca* or otherwise.

"*Locality*. Mulloch Quarry, Dalquharran, in the shelly sandstones." (Salter, 1851, pp. 174–175.)

Nidulites ovoides Butts, 1941 [now *Cyclocrinites pyriformis* (Bassler)]

"*Nidulites ovoides* Butts, n. sp. [Figs.] 8, 9, exterior view of two specimens. [Fig.] 10 showing the form and size of the openings of the radial tubes. Differs from *Nidulites pyriformis* in its ovoid shape as contrasted with the pear shaped outline of *N. pyriformis*." (Butts, 1941, p. 53 caption to figures 8–10 in plate 76.)

Nidulites pyriformis Bassler, 1915 [now *Cyclocrinites pyriformis* (Bassler)]

"The body of this interesting organism, which is such an abundant fossil at certain horizons in the Chambersburg limestone of the Appalachian Valley, is pyriform and pedunculate, with an outer covering of hexagonal, cuplike plates fused or articulated by their edges. On the exterior each plate is deeply concave and marked off at the surface by a sharp wall. The plates are smallest at the narrow end of the organism, but increase in size in the more swollen part where an average diameter for them of one millimeter is the rule. The interior of the organism is hollow and is frequently filled with crystalline calcite. Specimens about 35 mm. in length are the rule, but some individuals attain a length of 50 mm. Small fragments of *Nidulites*, especially where partly imbedded in the rock, much resemble a massive bryozoan with large zooecia, but examination with a lens reveals the very different nature of the hexagonal plates or cups. The systematic position of *Nidulites* is still quite uncertain. These bodies were supposed by Salter to be the egg-ribbons of marine gastropods. Later paleontologists placed them among the Protozoa, but today prevalent opinion is that they are allied to *Receptaculites, Cerionites, Ischadites* and related genera, and are either sponges or calcareous algae." (Bassler, 1919, pp. 193–194.)

Pasceolus Billings, 1857 [now *Cyclocrinites* Eichwald, 1840]

"CLASS UNCERTAIN. *Genus* Pasceolus. The above generic name is proposed for certain ovate or sub-globular bodies resembling the *Ischadites Koenigi* of the Silurian system, but differing therefrom in the form of the plate-like markings of the casts of the interior, which in this genus are pentagonal or hexagonal instead of quadrangular. A specimen from Anticosti shews that the animal was enclosed in a thin leather-like sack, and attached to the bottom by a short tubular continuation of this external covering. Its affinities appear to be with those of the *Tunicata*." (Billings, 1857, p. 342.)

Pasceolus billingsii Roemer, 1888 [now *Cyclocrinites dactioloides* (Owen)]

"Only few German paleontologists got acquainted with the genus *Pasceolus* of Billings through authentic American specimens. I, myself, until a short time ago, knew it only through the descriptions of American authors, and I was uncertain about its systematic position, although I considered it for the time being related to *Receptaculites* and *Cyclocrinis* (Leth. palaeoz. p. 295). The long desired explanation I obtained through specimens of *Pasceolus Billingsii* from the Lower Silurian strata of Clinton, Iowa, for which I am thankful to Mr. P. J. Farnsworth of Clinton, Iowa. The specimens in question are walnut-size, sphere-shaped bodies without any recognizable place of attachment, which are covered on their whole surface with very regular, six-sided, sharply bordered fossae of two millimeter diameter. They are steinkerns and the enclosing rock as well as the mass of the body itself is a finely granulated, porous dolomite of yellow-gray color. These bodies are very much like the specimens of *Cyclocrinus Spaskii* Eich., found as steinkern in the diluvial gravel of the so-called "Backstein" Limestone. (compare Leth. palaeoz. Atlas, table 3, figure e). Only the six-sided fossae are larger than in the last mentioned [specimen], in which their diameter is only little more than one millimeter. The concave impressions of the exterior surface of the spheres behave exactly as in the above mentioned [specimen]. They are small concavities, which are covered with very regular, low six-sided prisms that are separated only by thin hollow septa. They are altogether very much like the pictures of the impressions of the outer surface called by Dr. Klöden *Cellepora hexagona* from the gravel of the Mark Brandenburg, or to be exact, similar to the thin covering of the spherical bodies, preserved as steinkern and consisting of six-sided prismatic cells. Only the diameter of these six-sided prisms is smaller than that of *Cyclocrinus Spaskii,* and is corresponding to the smaller diameter of the grooves of the convex surface of sphere. In one of the specimens at our disposal one can very clearly observe the relation of the concave planes to the convex planes in their position to each other. One can see here that each of the low six-sided prisms stands over one of the shallow grooves of the convex plane. In every respect this behavior is similar to that which one observes in the steinkerns of *Cyclocrinus Spaskii* in the diluvial gravels of the Backstein Limestone (compare Lethaea erratica, pp. 55, 56). Finally, one becomes convinced that *Pasceolus* is identical with *Cyclocrinus*. Both genera are constructed for free spherical bodies in which a relatively thin wall consisting of small cells surrounds a spherical cavity into which, with a small pore-shaped opening the cells empty while the exterior end of the cells possesses a lid-shaped closure with an unusual inner radial structure. The generic name *Cyclocrinus* has the priority because it is the older name; also, so far known species of the genus are Lower Silurian." (Roemer, 1888, pp. 74–75, translated from German.)

Pasceolus camdenensis Foerste, 1910 [now *Cyclocrinites* sp.]

"In the American Museum of Natural History, in New York City, there is a specimen of *Pasceolus* which is labelled as coming from Camden, Ohio. It is almost spherical, the vertical diameter being 30 mm., and the transverse diameter nearly 28 mm. Forty-five to fifty plates lie along a line encircling the specimen horizontally. The plates usually are hexagonal in outline, and are arranged in crossing diagonal rows, but locally the outline may be more nearly pentagonal and occasionally five plates may appear to meet at a central point. Five plates occur in a length of 10 mm. along the diagonal lines, varying to 7 in the same length where they are of smallest size. The exposed surfaces of the plates are convex. The nature of the impressions which would be left by these plates upon the matrix filling the cavity of the fossil is unknown. The specimen is not pointed at one end, as though for attachment to some object, as in case of the species *Pasceolus halli*.

"*Pasceolus halli* possesses convex plates bent so as to be slightly depressed towards the angles and elevated toward the sides. Fragments of an unknown species of *Pasceolus* from Anticosti, presenting the same form of plates, possess a series of minute granules visible only under a higher magnifier. These granules are arranged in diagonal series diverging on each of the radial elevations, just mentioned, toward the depressed angles of the plates. This ornamentation suggests that this division of *Pasceolus* may belong to Cystids.

"*Pasceolus globosus*, the type of the genus *Pasceolus*, belongs to the group of species characterized by the presence of somewhat concave plates, often marked by six stellate radiating lines of depression extending from the center of each plate toward the angles.

"It is not certain that the group typified by *Pasceolus halli* is congeneric with *Pasceolus globosus*. *Pasceolus darwini* and *Pasceolus claudei* belong to the *Pasceolus globosus* group. The plates of *Pasceolus gregarius* and *Pasceolus intermedius* have not been described." (Foerste, 1910, pp. 85-86.)

Pasceolus claudei Miller, 1874 [now *Cyclocrinites darwini* (Miller)]

"Body spherical, without any depression where the column or pedicle was attached. Entire surface marked by closely crowded pentagonal or hexagonal depression, about $^1/_{30}$th of an inch in diameter. Diameter, ½ to ¾ of an inch.

"It differs from *P. Darwini* in size, and in having no depression where the pedicle was attached. It is possible that it might be the young of *P. Darwini*, but at present I think it is a distinct species.

"Found associated with *P. Darwini*, about two miles south of Maysville, Kentucky, but not found at Cincinnati, nor elsewhere, so far as yet known to me." (Miller, 1874, pp. 6-7.)

Pasceolus [now *Cyclocrinites*] **darwini** Miller, 1874

"Upper half of body hemispherical; lower half slightly depressed from the hemispherical form, and having a central circular depression marking the place where the column or pedicle that supported the body was attached. In casts, the entire surface is marked by closely crowded pentagonal and hexagonal depressions, about a line in diameter, in specimens 1¼ inches in diameter.

"Usually compressed, so as to show a somewhat angular periphery, but good specimens show a round periphery, without change in the uniformity of the depression.

"It is sometimes found partly incrusted with a bryozoum, but it is generally clean, showing clearly the depressions, even in specimens very much compressed.

"The incrusting bryozoum also shows pentagonal depressions, which clearly proves that the pentagonal depressions in the *Pasceolus* were filled with plates that were a little convex on the outer surface. Some specimens show convex pentagonal elevations, but the material in the convex elevations does not appear to be different from other parts of the surface, no part of which shows any cellular structure.

The pentagonal concave depressions in the bryozoum appear perfectly smooth, thereby indicating that the plates of the *Pasceolus* were smooth.

"One specimen has a perforation about forty-five degrees from what appears to be the apex, but whether it marks an opening to the interior or not I am unable to say. If it does, however, it would seem strange that out of fifty other specimens, nearly as good, none of them show anything of it. I broke one specimen into two parts, and polished the surfaces, but discovered no cellular structure.

"Fragments and poor specimens are rare on the hills back of Cincinnati, at an elevation of about 400 feet above low water-mark. I found good specimens about two miles south of Maysville, Kentucky, in a railroad cut, that came out of a layer of marl, about two feet in thickness, between the harder stratified rocks. In the same excavation, I found *Glyptocrinus decadactylus, Orthis sinuata, Stellipora antheloidea,* large *Orthis lynx,* and other fossils that are found at Cincinnati, from 350 to 450 feet above low water-mark." (Miller, 1874, pp. 5–6.)

Pasceolus [now *Cyclocrinites*] **globosus** Billings, 1857

"Subglobular from one to two inches in diameter; surface markings principally hexagonal, and about two lines in diameter." (Billings, 1857, p. 343.)

Pasceolus [now *Cyclocrinites*] **gregarius** Billings, 1866

"This species is smaller than *P. halli,* and is always globular or nearly so. The individuals are from 6 to 12 lines in diameter, usually about 9 lines; there are from three to four plates ? in the width of 2 lines. Reef Point: Div. 1, A. G. J. Richardson. There are the remains of about fifty in a small slab of limestone 5 inches in width and 7 inches in length." (Billings, 1866, p. 72.)

Pasceolus [now *Cyclocrinites*] **halli** Billings, 1857

"Body ovate or balloon-shaped, being regularly rounded above and produced below into a short neck-like pedicle, which constitutes the organ of attachment; outer integument thin, its external surface covered with small irregular rounded wrinkles about ten in one line, distinctly visible to the naked eye; its interior reticulated with ridges corresponding to the divisions between the plate-like markings of the cast of the inside. The cast of the interior is completely covered with hexagonal or pentagonal divisions, presenting the appearance of *Sphaeronites* or *Favosites;* these spaces are each about a quarter of a line in diameter at the base of the fossil, but increase in size above, until at the summit they are one line in diameter. The spaces are convex in their centers, and the interior of the integument is fitted with concave depressions to correspond.

"One specimen was procured with the integument preserved; it extends below the base, and encloses the short pedicle as well as the body above. On one side of the cast there is a small elevation about half-way between the top and bottom, which appears to mark the position of an aperture in the side of the animal. I beg to dedicate this species to Professor Hall. Length of specimens one inch and a-half, greatest diameter about the middle, thirteen lines. *Locality and Formation.*—White Cliff, Gamache Bay, Middle Silurian. Collector.—J. Richardson. (Billings, 1857, pp. 342–343.)

Pasceolus intermedius Billings, 1866 [now *Cyclocrinites gregarius* (Billings)]

"Globular; about 12 lines in diameter; four concave plates ? in width of 3 lines." (Billings, 1866, p. 72.)

Annotated Bibliography

ALLEE, W. C., ALFRED E. EMERSON, ORLANDO PARK, THOMAS PARK, and KARL P. SCHMIDT

1949. Principles of Animal Ecology. W. B. Saunders Co., Philadelphia and London. 837 pp., 263 figs.

AMI, HENRY M.

1894. Notes on fossils from Quebec City, Canada. Ottawa Nat., 8, pp. 82–90 (=Trans. Ottawa Field-Naturalists' Club, vol. 10).

Notes the first occurrence of *Nidulites favus* Salter in Canada as an imperfect specimen collected from the Ordovician Quebec Group. *Nidulites* is considered a rhizopod and is compared with *Pasceolus* Billings, *Sphaerospongia* Salter, and *Cyclocrinus* Eichwald. This paper was also issued separately with different pagination.

1896. Note on some of the fossil organic remains comprised in the geological formations and outliers of the Ottawa Palaeozoic basin. Proc. Trans. Roy. Soc. Canada, ser. 2, **2**, sec. 4, pp. 151–158.

Notes the occurrence of *Pasceolus globosus* Billings, from the Trenton Limestone, from the Ottawa Valley.

1899. Appendix II. On some Cambro-Silurian and Silurian fossils from Lake Temiscaming, Lake Nipissing and Mattawa outliers. Ann. Rept. Geol. Surv. Canada, new ser., **10**, Rept. I for 1897, pp. 289–302.

Pasceolus globosus Billings is listed from the Black River beds at Lake Nipissing.

1902. Appendix. Lists of fossils to accompany report by Dr. R. W. Ells on the City of Ottawa Map. Ann. Rept. 1899, new ser., **12**, Geol. Surv. Canada, pp. 51G–77G.

Pasceolus globosus Billings is listed from the shore of Ottawa River in Ottawa City.

BALL, JOHN R. and KATHERINE F. GREACEAN

1946. Catalog of the Eagan Collection of Silurian invertebrate fossils at the Chicago Academy of Sciences. Chicago Acad. Sci. Spec. Publ. no. 7, 55 pp., 1 fig.

Two specimens of *Cerionites dactyloides* [sic] (Owen) from Iowa are housed in Chicago Academy of Science.

BASSLER, RAY S.

1909. The cement resources of Virginia West of the Blue Ridge. Va. Geol. Surv. Bull. II-A. 309 pp., 30 pls., 30 figs.

Nidulites sp. is illustrated; this specimen was later named *Nidulites pyriformis*. *Nidulites* cf. *favus* Salter occurs in northwestern Virginia, and the genus is prominent in the Chambersburg Formation.

1915. Bibliographic index of American Ordovician and Silurian fossils. Smithsonian Institution, Bull. U. S. Nat. Mus., 92, 2 vols., 1521 pp., 4 pls.

Most of the important literature on American cyclocrinitids up to 1915 is listed. New species *Nidulites pyriformis* Bassler is named.

1919. Maryland Geol. Surv. Cambrian and Ordovician, 424 pp., 58 pls., 27 text-figs., tables.

Nidulites pyriformis Bassler is illustrated and described for the first time, and placed with doubt in calcareous algae. Numerous localities of *N. pyriformis* are listed from Chambersburg Limestone from Virginia, Maryland and Pennsylvania.

Bigsby, John J.

1868. Thesaurus Siluricus. The flora and fauna of the Silurian Period. With addenda (from recent acquisitions). 214 pp., 1 map. J. Van Voorst, London.

This is a listing of all genera and species known at that time from the Silurian Period as it was defined in 1868. *Cyclocrinus globosus* and *C. halli* are listed as crinoids, and *Pasceolus* species are listed as *incertae sedis.*

Billings, Elkanah

1857. Report for the year 1856, of E. Billings, Esq., Palaeontologist, addressed to Sir William E. Logan, Provincial Geologist. Geol. Surv. Canada. Report of Progress for 1853–54–55–56, pp. 247–345.

This report contains a section: "New Species of Fossils from the Silurian Rocks of Canada, pp. 256–345." In this section genus *Pasceolus* and two species *P. halli* and *P. globosus* are described (pp. 342–343) for the first time. These are placed in class uncertain, allied to the Tunicata. The original description of the genus and of the species is quoted in the appendix.

P. halli is from White Cliff, Gamache Bay, and *P. globosus* from the Trenton Limestone at Ottawa. This is also published in French version.

1863. *In* Logan, William E., Geol. Surv. Canada. Report of progress from its commencement to 1863; illustrated by 498 wood cuts in the text, and accompanied by an atlas of maps and sections. 983 pp.

All fossil material in this volume is submitted by Billings. In addition, "Catalogue of Lower Silurian fossils," pp. 936–954 is introduced. This part is entirely by Billings. There are no descriptions of fossils in this volume, but figures are inserted with the text. *Pasceolus Halli* Billings is figured, and *P. globosus* Billings is listed.

1865. Palaeozoic fossils. Volume 1. Containing descriptions and figures of new or little known species of organic remains from the Silurian rocks. 1861–1865. Geol. Surv. Canada, 426 pp., 401 figs.

The several parts which appeared as one volume in 1865 were published separately. The part in which description and discussion of *Pasceolus* Billings is included was however issued only once in the complete work.

Pasceolus halli Billings and *P. globosus* Billings are described in detail and are figured. Comparison is made with *Receptaculites*, *Cyclocrinus*, *Sphoeronites*, *Sphoerospongia*, and *Zoantharia*, but no assignment into class is made. The genus *Pasceolus* is considered possibly congeneric with *Cyclocrinus*, or at least belonging to the same family.

1865. Notes on some of the more remarkable genera of Silurian and Devonian fossils. Canad. Nat., new ser., **2**, pp. 184–198, 14 text-figs.

The description and illustration of *Pasceolus* Billings is identical to description in Palaeozoic Fossils, vol. 1, 1865.

1866. Catalogues of the Silurian fossils of the Island of Anticosti, with descriptions of some new genera and species. Geol. Surv. Canada, Spec. Rept., 93 pp.

This report contains five papers of which the second is "Catalogue of the fossils of the Anticosti Group with descriptions of some of the species." Genus *Pasceolus* and species *halli* and *globosus* are redescribed, and Verrill and Niles discussion is given and commented on. Two new species *gregarius* and *intermedius* are described.

BOLTON, THOMAS E.

1966. Catalogue of type invertebrate fossils of the Geological Survey of Canada. Geol. Surv. Canada, Dept. Mines Tech. Surv., **3**, 203 pp.

The following types of fossils are listed as housed with the collection of Geological Survey of Canada in Ottawa: *Cyclocrinites intermedius* (Billings), *Pasceolus globosus* Billings, *P. gregarius* Billings, *P. halli* Billings, and *P. intermedius* Billings. These are listed as algae under the heading "Incertae sedis."

BROWN, C. ERVIN and JESSE W. WHITLOW

1960. Geology of the Dubuque South Quadrangle Iowa–Illinois. Bull. U. S. Geol. Surv., 1123-A, 93 pp., 1 pl., 18 text-figs.

Cerionites beds are 25 feet thick in Dubuque County and are in Hopkinton Dolomite.

BUTTS, CHARLES

1926. The Palaeozoic rocks. *In* Geology of Alabama. Geol. Surv. Alabama, Spec. Rept. no. 14, pp. 41–230, figs. 2–4, pls. 3–76.

Nidulites cf. *N. favus* from Little Oak Limestone in Shelby County, Alabama is figured; and *Nidulites* is listed from Lenoir Limestone.

1940. Geology of the Appalachian Valley in Virginia. Va. Geol. Surv. Bull. 52, Part 1. Geologic text and illustrations, 568 pp., 63 pls., 10 figs., 10 tables.

Nidulites pyriformis is listed from a number of localities, and a name *Nidulites ovoides* is introduced without illustration and without description.

1941. Geology of the Appalachian Valley in Virginia. Va. Geol. Surv. Bull. 52, Part 2, Fossil Plates and explanations, 271 pp., pls. 64–135.

Nidulites ovoides n. sp. is illustrated and described. *Nidulites pyriformis* is figured.

CALVIN, SAMUEL

1893. On the structure and probable affinities of *Cerionites dactylioides* Owen. Amer. Geol., **12**, pp. 53–57, 1 text-fig.

Cerionites dactylioides [sic] (Owen) is considered a gigantic protozoan. The spelling of the specific name is discussed. The specimens are from Niagaran near Maquoketa, Iowa.

1893. On the structure and probable affinities of *Cerionites dactylioides* [sic] Owen. Proc. Iowa Acad. Sci. for 1892, **1**, part 3, pp. 13–15.

This is the same paper as Calvin, 1893, Amer. Geol., **12**, pp. 53–57.

1898. Geology of Delaware County, pp. 119–199, 13 pls., 1 map. *In* Iowa Geol. Surv., 8, Ann. Rept. for 1897.

Cerionites dactylioides [sic] is listed from Delaware County, Iowa, as an index for bed no. 4. The presence of this fossil at this horizon is constant throughout the state.

CALVIN, SAMUEL and H. F. BAIN

1900. Geology of Dubuque County, pp. 379–651, text-figs. 45–102, pls. 4–11, 3 maps. *In* Iowa Geol. Surv., **10**, Ann. Rept. for 1899.

Cerionites dactylioides [sic] is a typical species of beds nos. 8, 9, and 10 of Niagaran in Dubuque County, Iowa. Particularly, it is a good index for the generalized Niagaran section where it is a sixth bed from seven recognized generalized beds.

CHAPPARS, MICHAEL STEPHEN

1936. Catalog of the type specimens of fossils in the University of Cincinnati Museum. Ohio Jour. Sci., **36**, pp. 1–45.

Ten cotypes of *Pasceolus claudei* Miller, and five cotypes ? of *Pasceolus darwini* Miller, are housed with the collections of the University of Cincinnati Museum.

Church, Arthur H.

1895. The structure of the thallus of *Neomeris dumetosa*, Lamour. Ann. Bot., **9**, no. 36, pp. 581–608, pls. 21–23.

Very detailed and well illustrated developmental stages of *Neomeris dumetosa*, a recent alga from Singapore, is given.

Collinson, C. W.

1959. Guide for beginning fossil hunters. Ill. State Geol. Surv., Educ. ser., **4**: 39 pp., illus.

Sphaerospongia sp. [=*Cyclocrinites dactioloides* (Owen)] from Illinois is illustrated.

Cooper, Byron N.

1944. Geology and mineral resources of the Burkes Garden Quadrangle, Virginia. Va. Geol. Surv. Bull. 60, 299 pp., 21 pls., 11 text-figs. and 5 pls.

Several localities of *Nidulites pyriformis* are listed from Middle Ordovician of the Burkes Garden Quadrangle, Virginia.

Cooper, Byron N. and G. Arthur Cooper

1946. Lower Middle Ordovician stratigraphy of the Shenandoah Valley, Virginia. Bull. Geol. Soc. Amer., **57**, pp. 35–114, 3 pls., 9 text-figs.

This is a very detailed paper on stratigraphy of Shenandoah Valley, Virginia. *Nidulites* sp., *Nidulites pyriformis* Bassler, and *N. ovoides* Butts, are listed from numerous localities. *Nidulites* is very important facies fossil and characterizes finely granular, thin-bedded Middle Ordovician limestones.

Cooper, Byron N. and Chilton E. Prouty

1943. Stratigraphy of the Lower Middle Ordovician of Tazewell County, Virginia. Bull. Geol. Soc. Amer., **54**, pp. 819–886, 5 pls., 3 figs.

The Lower Middle Ordovician succession of Tazewell County, Virginia, hitherto referred to Chazy and Black River is divisible into 29 faunal and lithologic zones. *Nidulites* beds are in Ward Cove Limestone Member of Cliffield Formation. *Nidulites pyriformis* Bassler, which have been considered indicative of the Ottosee Formation, have been found below beds containing the Murfreesboro fauna.

Currie, Ethel D. and Wilfred Norman Edwards

1943. Dasycladaceous algae from the Girvan area. Quart. Jour. Geol. Soc. London, **98**, pp. 235–240, pl. 11, 1 text-fig.

Two dasycladaceous algae are described and illustrated from the Girvan district, Great Britain. *Mastopora parva* (Nicholson and Etheridge) is Ordovician, and *M. fava* (Salter) is a Lower Silurian fossil. Brief discussion of *Cyclocrinites* Eichwald and comparison with other genera is made. *Cyclocrinus* Eichwald and *Pasceolus* Billings are synonyms of *Cyclocrinites* Eichwald.

Dalvé, Elizabeth

1948. The fossil fauna of the Ordovician in the Cincinnati region. Univ. Cincinnati, Cincinnati, Ohio. 56 pp.

Lists cyclocrinitids from the Cincinnati region.

Dana, James

1895. Manual of Geology-treating of the principles of the science with special reference to American Geological History, 4th ed. American Book Co., New York, 1087 pp., 1575 figs.

Pasceolus is mentioned as characteristic sponge of Utica and Hudson Epochs.

De-Toni, J. Bapt.

1889. Sylloge Algarum omnium hucusque cognitarum. Vol. 1. 531 pp.

Contains descriptions of published genera and species of recent algae up to date of publication. The text is in Latin.

Dowling, D. B.

1901. Report on the geology of the west shore and Islands of Lake Winnipeg. Canada Geol. Surv. Ann. Rept., n. ser., **11**, for 1898, rept. F, 100 pp., numerous figures.

This is a report on the geology of the west shore and islands of Lake Winnipeg. *Pasecolus gregarius* Billings is listed from a number of localities.

Dresser, John A. and T. C. Denis

1941. Geology of Quebec, vol. 2. Descriptive Geology, Quebec Bur. Mines Geol. Rept. 20, 544 pp., 44 pls., 41 text-figs., 3 maps.

Cyclocrinites intermedius (Billings) is figured from the Gun River Formation of Anticosti.

Durham, J. Wyatt

1967. The incompleteness of our knowledge of the fossil record. Jour. Paleontol., **41**, no. 3, pp. 559–565.

Eichwald, Carl Eduard von

1840. Ueber das silurische Schichten-system in Esthland, pp. 1–96 (in extract form or pp. 115–210 when bound with part 1). Nat. Heilk. Med.-chirur. Akad. St. Petersburg, Heft 2.

Cyclocrinites Spaskii is first described on pp. 78–79 (or 192–193), and *Mastopora concava* on pp. 90–91 (or 204–205). French edition of this work was not seen.

1860. Lethaea Rossica ou Paléontologie de la Russie. Vol. 1, Stuttgart, 1657 pp.

This is a greatly enlarged version of Eichwald's 1840 work on fossils from Russia. *Cyclocrinites* is defined and its name changed to *Cyclocrinus*. *Cyclocrinites Spaskii* is redescribed and illustrated. New species *C. exilis* is defined and figured. The atlas accompanying this volume was not seen.

Elias, Maxim K.

1947. *Permopora keenae*, a new Late Permian alga from Texas. Jour. Paleontol., **21**, no. 1, pp. 46–58, pl. 18, 8 text-figs.

Permopora keenae, a new Permian dasycladaceous alga from Texas, is described and illustrated. It is compared with recent algae and with *Mastopora* (*Nidulites*) *pyriformis*, which is figured.

Field, Richard M.

1919. The Middle Ordovician of Central and South Central Pennsylvania. Amer. Jour. Sci., ser. 4, **48**, art. 27, pp. 403–428, 3 text-figs.

Nidulites favus is listed from Chambersburg in Marion, Pennsylvania.

FINKS, ROBERT M.

1967. S. A. Miller's Paleozoic sponge families of 1889. Jour. Paleontol., **41**, no. 3, pp. 803–807.

FOERSTE, A. F.

1909. Preliminary notes on Cincinnatian and Lexington fossils. Bull. Sci. Lab. Denison Univ., **14**, pp. 289–324, pls. 7–11.

The type specimen of *Pasceolus darwini* Miller, now *Cyclocrinites darwini* from the base of the Bellevue bed, along the railroad two miles southeast of Maysville, Kentucky, is described and illustrated. *P. darwini* is compared with *P. tumidus* James and *P. intermedius* Billings.

1910. Preliminary notes on Cincinnatian and Lexington fossils of Ohio, Indiana, Kentucky and Tennessee. Bull. Sci. Lab. Denison Univ., **16**, pp. 17–87, 6 pls.

New species *Pasceolus camdenensis* Foerste, is described and illustrated from Camden, Ohio. The comparison with *P. halli, P. globosus, P. darwini, P. claudei, P. gregarius,* and *P. intermedius* is made.

1914. Notes on the Lorraine faunas of New York and the Province of Quebec. Bull. Sci. Lab. Denison Univ., **17**, pp. 247–340, 5 pls.

Pasceolus globosus Billings from Point Pleasant Limestone, Ohio is illustrated. The specimen shows stellate structures. It is now considered *Cyclocrinites darwini* (Miller).

1916. Notes on Cincinnatian fossil types. Bull. Sci. Lab. Denison Univ., **18**, pp. 285–355, 7 pls.

Pasceolus claudei and *P. tumidus* from the Cincinnati region are figured and described, and considered to be one species together with *P. darwini*. *P. globosus* is more closely related to *P. Halli* than to the *P. darwini* group of species; the name *P. globosus* is dropped from the list of Kentucky and Ohio species.

1929. The Cephalopods of the Red River Formation of Southern Manitoba. Bull. Sci. Lab. Denison Univ., **24**, pp. 129–235, pls. 11–39.

Pasceolus gregarius is listed from Southern Manitoba.

FRITSCH, F. E.

1948. The structure and reproduction of the algae, vol. 1. 791 pp., 245 figs. Cambridge Univ. Press.

GILES, ALBERT W.

1927. The geology of Little North Mountain in Northern Virginia and West Virginia. Jour. Geol., **35**, pp. 32–57, 5 text-figs.

Nidulites division 125–130 feet thick is a third zone of Chambersburg Limestone in Northern Virginia.

GRABAU, AMADEUS W.

1916. Comparison of American and European Lower Ordovicic Formations. Bull. Geol. Soc. Amer., **27**, pp. 555–622, 10 text-figs.

Nidulites favus (Salter) is listed from Baltic and Quebec.

GREACEAN, KATHERINE F. and JOHN R. BALL

1944. Studies of Silurian fossils in the Thomas A. Greene Collection at Milwaukee–Downer College. Trans. Wisc. Acad. Sci. Arts, Letters, **36**, pp. 415–419.

Cerionites is listed as a Niagaran sponge from Cook County, Illinois.

1946. Silurian invertebrate fossils from Illinois in the Thomas A. Greene Memorial Museum at Milwaukee-Downer College. Bull. Milwaukee-Downer Coll., 61 pp.

Cerionites dactyloides [sic] (Owen) and *Cerionites* sp. from Illinois are listed in collection of museum at Milwaukee.

GRIEFE, JOHN L. and R. L. LANGENHEIM, JR.

1963. Sponges and brachiopods from the Middle Ordovician Mazourka Formation, Independence Quadrangle, California. Jour. Paleontol., **37**, no. 3, pp. 564–574, pls. 63–65, 2 text-figs.

Mastopora (?) sp. [now *Cyclocrinites welleri*], from Mazourka Formation from California is described and figured. It is considered dasycladacean alga.

HANSMAN, ROBERT H. and HAROLD W. SCOTT

1967. Catalog of Worthen type and figured specimens at the University of Illinois. Jour. Paleontol., **41**, no. 4, pp. 1013–1028.

The specimen of *Paceolus*? *dactylioides* [sic] (Owen) described and illustrated by Meek and Worthen is listed as housed with the collections at the University of Illinois at Urbana.

HARVEY, WILLIAM HENRY

1863. Phycologia Australica; or a history of Australian seaweeds. Vol. 5, 59 pls. London.

Codium mamillosum is described and illustrated in this classic compilation on Australian recent marine alga.

HEAD, WILLIAM R.

1895. Palaeozoic sponges of North America. Published by the author. 14 pp.

This is a privately published list of "recognized, bad and doubtful" species of Paleozoic sponges. Cyclocrinitids are listed.

HINDE, GEORGE JENNINGS

1884. On the structure and affinities of the family of the Receptaculitidae, including therein the genera *Ischadites*, Murchison (=*Tetragonis*, Eichwald): *Sphaerospongia*, Pengelly; *Acanthochonia*, gen. nov.; and *Receptaculites*, Defrance. Quart. Jour. Geol. Soc. London, **40**, pp. 795–849, pls. 36–37.

In this classic paper on receptaculitids, the comparison is made with certain cyclocrinitid genera, which Hinde does not consider receptaculitids. The genera considered are *Mastopora*, *Nidulites* (=*Cyclocrinus*), and *Pasceolus*. *Cyclocrinus Spaskii* Eichwald and *Pasceolus Halli* Billings are discussed.

1887 and 1888. A monograph of the British fossil sponges, vol. 1. Sponges of Palaeozoic and Jurassic strata, parts 1 and 2, 188 pp., 9 pls., 2 tables and 7 text-figs. [Part 1 published 1887, and part 2 in 1888; these two parts with third part were found together in 1912 and constitute vol. 80 of the Palaeontographical Society.]

Amphispongia oblonga Salter is described and illustrated as a possible hexactinellid sponge. [This organism is here considered related to *Anomaloides reticulatus* Ulrich.]

HOWE, M. A.

1909. Phycological studies—IV. The genus *Neomeris* and notes on other Siphonales. Torr. Bot. Club Bull., **36**, pp. 75–104, pls. 1–8.

Detailed anatomical descriptions of the genus *Neomeris* and its six species is given. *Neomeris dumetosa* is well illustrated.

HOWELL, B. F.

1943. New records of Receptaculitidae from the Mississippi Valley. Bull. Wagner Free Inst. Sci., **18**, no. 4, pp. 35–42, 9 figs.

Cerionites dactioloides (Owen) is illustrated and briefly discussed.

HUFFMAN, GEORGE GARRETT

1945. Middle Ordovician limestones from Lee County Virginia to Central Kentucky. Jour. Geol., **53**, no. 3, pp. 145–174, 9 figs., 17 tables.

Nidulites is listed from the lower "Ottosee" of Lee County, Virginia.

JAMES, JOSEPH F.

1881. Catalogue of the fossils of the Cincinnati Group. James Barclay, Cincinnati, 27 pp.

Certain cyclocrinitids are listed under the heading *incerta sedes*.

1885. Remarks on the genera *Lepidolites, Anomaloides, Ischadites* and *Receptaculites*, from the Cincinnati Group. Jour. Cincinnati Soc. Nat. Hist., **8**, no. 3, pp. 163–166.

Lepidolites Ulrich and *Pasceolus* are proposed to belong to the receptaculitids of the sponges. The species of *Lepidolites* Ulrich are like *Ischadites* Murchison and should be included there. *Anomaloides* Ulrich is placed as a junior synonym of *Receptaculites* Defrance.

1887. Protozoa of the Cincinnati Group. Jour. Cincinnati Soc. Nat. Hist., **9**, no. 4, pp. 244–252.

Brief descriptions of the following organisms are included: *Astylospongia tumida* [now *Cyclocrinites darwini*], U. P. James, *Pasceolus globosus* Billings, *P. darwini* Miller, *Ischadites* [now *Lepidolites*] *dickhauti* Ulrich, and *Receptaculites* [now *Anomaloides*] *reticulatus* Ulrich. All are considered sponges.

1891. Manual of the paleontology of the Cincinnati group. Jour. Cincinnati Soc. Nat. Hist., **14**, no. 1, pp. 45–72, 6 text-figs.

The following organisms are described: *Astylospongia* [now *Cyclocrinites*] *tumidus* James, *Pasceolus globosus* Billings, *P. darwini* Miller, *P. claudii* Miller, *P.* (?) *tumidus* James.

The genera *Anomaloides, Lepidolites,* and *Pasceolus* are discussed. *Pasceolus* (?) *tumidus* U. P. James and *Anomaloides reticulatus* Ulrich are illustrated. Genera *Anomaloides* and *Lepidolites* are considered to belong to *Receptaculites* Defrance.

JAMES, U. P.

1871. Catalogue of the Lower Silurian fossils, Cincinnati group, found at Cincinnati and vicinity—within a range of forty or fifty miles. Paleontology, 14 pp.

Cyclocrinites (?) is listed from Cincinnati, Ohio.

1873. Additions to catalogue of Lower Silurian Fossils, Cincinnati Group. Paleontology, 4 pp.

Pasceolus sp. are added to the list of fossils collected from the Cincinnati rocks, published in 1871. This publication has been also issued later bound together with the first catalogue.

1875. Catalogue of Lower Silurian fossils of the Cincinnati Group. Found at Cincinnati and vicinity—within a circuit of 40 or 50 miles. New edition much enlarged. With descriptions of some new species of corals and polyzoa. Paleontology, 8 pp.

Pasceolus claudei S. A. Miller, *P. darwini* S. A. Miller, and *Pasceolus* sp. (?) are listed, from Cincinnati group.

1878. Descriptions of newly discovered species of fossils from the Lower Silurian formation.—Cincinnati Group. Paleontology, no. 1, pp. 1–7.

Astylospongia tumidus James [now *Cyclocrinites darwini* (Miller)] is described.

1879. Descriptions of newly discovered fossils—on geological nomenclature—and supplement to catalogue. Paleontologist, no. 4, pp. 25–32.

In the supplement to catalogue of Lower Silurian fossils *Astylospongia tumidus* James [now *Cyclocrinites darwini* (Miller)], *Lepidolites dickhauti* Ulrich, and *L. elongatus* Ulrich are listed.

JOHNSON, J. HARLAN

1943. Geologic importance of calcareous algae with annotated bibliography. Quart. Colorado School Mines, **38**, no. 1, 102 pp., 23 figs., 2 tables.

No references to cyclocrinitids are made. The bibliography of one paper dealing with cyclocrinitids ("Stolley 1896B") is given.

1951. An introduction to the study of organic limestones. Quart. Colorado School Mines, **46**, no. 2, 185 pp., 104 pls., 1 fig.

1952. Ordovician rock-building algae. Quart. Colorado School Mines, **47**, no. 2, pp. 29–56, 12 pls., 3 tables.

Translation of Pia's 1927 discussion on cyclocrinitids and reproduction of Pia's original illustration is given. *Pasceolus* species are placed in *Cyclocrinus* Eichwald and *Nidulites pyriformis* Bassler is included in *Mastopora*. Types of *Mastopora pyriformis* (Bassler) are shown in photograph.

1954. An introduction to the study of rock-building algae and algal limestones. Quart. Colorado School Mines, **49**, no. 2, 117 pp., 10 tables, 62 plates.

Family Dasycladaceae is briefly discussed, and illustrated from foreign literature. *Mastopora pyriformis* Bassler is figured.

JOHNSON, J. HARLAN and KENJI KONISHI

1959. A review of Silurian (Gotlandian) algae. Quart. Colorado School Mines, **54**, Part I, no. 1, 114 pp., 29 pls., 8 tables, 9 maps, 1 fig.

Currie and Edwards, 1943, pl. 11 of *Mastopora* is reproduced. The definition and discussion of the genus *Mastopora* is based on published material.

KAY, G. MARSHALL

1937. Stratigraphy of the Trenton Group. Bull. Geol. Soc. Amer., **48**, no. 2, pp. 233–302, pls. 1–10, 13 text-figs.

Pasceolus globosus Billings is noted as locally abundant at the base of the Cobourg Formation in northwest New York, and in the Hallowell member of the Cobourg Formation in Hallowell township, Prince Edward County, Ontario. It has been considered to mark the top of the Sherman Fall Limestone in Trenton Falls Gorge, New York.

KAYSER, EMANUEL

1875. Ueber die Billings'sche Gattung *Pasceolus* und ihre Verbreitung in paläozoischen Ablagerungen. Zeits. Deut. Geol. Gesell., **27**, pp. 776–783, pl. 20.

Two European species are illustrated as *Pasceolus tesselatus* and *Pasceolus Rothi*, and a general discussion on the genus *Pasceolus* is included. [These species are now assigned to "*Ischadites.*"]

Pasceolus globosus Billings is listed from "Upper Silurian" of Ottawa, and *P. halli*, *P. gregarius*, and *P. intermedius* are listed from the "Middle Silurian" of Anticosti.

KERR, J. WM.

1968. Stratigraphy of Central and Eastern Ellesmere Island, Arctic Canada. Geol. Surv. Canada, Paper 67–27, part 2, 92 pp., 5 pls., 2 tables, 10 text-figs.

Cyclocrinites sp. is listed from the Irene Bay Formation, Ordovician of Arctic Canada.

KORDE, K. B., ed.

1963. Tip Chlorophyta. Systematic part in *Osnovy Paleontologii*. Orlov, Y. A. ed., Vodorosli, Mohoobraznye, Isilofitovye, Plaunovidnye, Chlenistostevelnye, Paporotniki. Pp. 199–223, 60 text-figs. [in Russian].

The following genera are defined, illustrated and placed in tribe Cyclocrineae: *Cyclocrinus* Eichwald, 1840, *Coelosphaeridium* Roemer, 1885, *Mastopora* Eichwald, 1840, *Mizzia* Schubert, 1908, *Kopetdagaria* Maslov, 1960, *Ovulites* Lamark, 1816, *Koninckopora* Lee, 1912, *Epimastopora* Pia, 1922, and *Unjaella* Korde, 1951.

LAUBENFELS, M. W. DE

1955. Porifera, pp. E21–E112. *In* Moore, R. C., ed. Treatise on Invertebrate Paleontology, part E Archaeocyatha and Porifera.

This is a brief account of receptaculitids, as an uncertain group.

LESLEY, J. P.

1889. A dictionary of the fossils of Pennsylvania and neighboring states named in the reports and catalogues of the Survey. Geol. Surv. Penn., Rept. P. 4, **2**, pp. 439–914, numerous figures.

The reproduction of *Pasceolus halli* Billings, 1863, from the Anticosti Group in the Gulf of St. Lawrence is given.

LOWENSTAM, HEINZ A.

1957. Niagaran reefs in the Great Lakes Area. Geol. Soc. Amer. Mem. 67, pp. 215–248, 4 figs.

Cerionites are considered reef-dwelling sponges related to *Receptaculites*.

MCINNES, WILLIAM

1913. The basins of Nelson and Churchill Rivers. Canada Dept. Mines. Geol. Surv. Mem., no. 30, 146 pp., 19 pls., 1 map.

Pasceolus (*Cyclocrinus*) *spaskii* (?) Eichwald was collected in the vicinity of Cormorant Lake, near Lake Winnipeg. [It is now assigned to *C. globosus* (Billings)].

MEEK, F. B. and A. H. WORTHEN

1868. Part II. Palaeontology. Geol. Palaeontol., **3**, Geol. Surv. Illinois, pp. 291–574, 20 pls., numerous text-figs.

Pasceolus dactylioides [sic] (Owen) from Carroll County, Illinois is described and illustrated. New generic name *Cerionites* is proposed for this species. Comparison to *Cyclocrinites* Eichwald and *Receptaculites* is made.

MICKLEBOROUGH, J. and A. G. WEATHERBY

1878. A classified list of Lower Silurian fossils, Cincinnati Group. Jour. Cincinnati Soc. Nat. Hist., **1**, no. 2, pp. 61–86. Also printed separately in 1878 as a pamphlet containing 26 pp.

Astylospongia [now *Cyclocrinites*] *tumida* James, *Pasceolus claudei* S. A. Miller, and *Pasceolus Darwini* S. A. Miller are listed from the Cincinnati group.

MILLER, A. K.

1930. The age and correlation of the Bighorn formation of Northwestern United States. Amer. Jour. Sci., **20**, pp. 195–213.

Cyclocrinites aff. *gregarius* (Billings) is listed from Bighorn Formation, Wyoming.

MILLER, A. K., WALTER YOUNGQUIST, and CHARLES COLLINSON

1954. Ordovician cephalopod fauna of Baffin Island. Geol. Soc. Am. Mem. 62, 234 pp., 63 pls., 20 text-figs.

Supposed *Lepidolites* aff. *L. dickhauti* Ulrich is illustrated and listed from the Upper Ordovician Silliman's Fossil Mount, Baffin Island. These are now believed to be *Receptaculites* sp.

MILLER, S. A.

1874. Genus *Pasceolus* (Billings). Cincinnati Quart. Jour. Sci., **1**, no. 1, pp. 4–7, text-figs. 1–3.

Miller summarizes the generic characters of the genus and the original description of *Pasceolus* by Billings, and describes the new species *P. Darwini* from Ordovician rocks near Cincinnati, Ohio and Maysville, Kentucky and *P. Claudei* from the Ordovician rocks near Maysville, Kentucky.

1877. The American Palaeozoic fossils: a catalogue of the genera and species, with names of authors, dates, places of publication, groups of rocks in which found, and the etymology and signification of the words, and on introduction devoted to the stratigraphical geology of the Palaezoic rocks. 246 pp. Cincinnati, Ohio.

Pasceolus Billings is listed with six species as an *incertae sedis* among Porifera. *Lunulites* (?) *dactioloides* is referred to *Receptaculites dactioloides* (Owen) and placed among sponges.

1879. Catalogue of Fossils found in the Hudson River, Utica Slate and Trenton groups, as exposed in the southeast part of Indiana, southwest part of Ohio and northern part of Kentucky. Tenth Ann. Rept. Geol. Surv. Indiana, pp. 22–56 (also issued in pamphlet, 35 pp.).

Pasceolus claudei S. A. Miller and *P. darwini* S. A. Miller are listed as belonging to class Rhizopoda of sub-kingdom Protista.

1882. Observations on the unification of geological nomenclature, with special reference to the Silurian Formation of N. America. Jour. Cincinnati Soc. Nat. Hist., vol. 4, no. 4, pp. 267–293 (also in pamphlet, 27 pp.).

Lists *Pasceolus* from the Hudson River Group as a protist.

1883. The American Palaeozoic fossils: a catalogue of the genera and species, with names of authors, dates, places of publication, groups of rocks in which found and the etymology and signification of the words, and an introduction devoted to the stratigraphical geology of the Palaeozoic rocks. Second ed., January, 1883, pp. 241–334.

Lepidolites Ulrich, *L. dickhauti* Ulrich, and *L. elongatus* Ulrich are listed as supposed spongoids related to *Cyathophycus*. *Anomaloides* Ulrich and *A. reticulatus* Ulrich are listed as poorly understood echinoderms.

1889. North American geology and palaeontology for the use of amateurs, students and scientists. Cincinnati, Ohio, 664 pp.

Pasceolus Billings is placed in family Pasceolidae; *Cerionites* Meek and Worthen is placed in family Receptaculitidae; and *Lepidolites* Ulrich is placed in "family affinity uncertain"; all are considered sponges.

Cerionites dactyloides [sic] Owen, *P. claudii* S. A. Miller, *P. darwini* S. A. Miller, *P. halli* Billings are figured; *Pasceolus intermedius* Billings, *P. gregarius* Billings, *P. globosus* Billings, *Lepidolites dickhauti* Ulrich are listed. All the above taxa are considered sponges.

Anomaloides Ulrich and *A. reticulatus* Ulrich are considered echinoderms not well understood.

1897. Second appendix to North American geology and palaeontology, pp. 719–793, text-figs. 1266–1458.

Anomalospongia Ulrich is considered unrelated to sponges.

MILNE-EDWARDS, H.

1860. Histoire naturelle des coralliaires ou polypes proprement dits, vol. 3. Paris. 560 pp.

Genus *Cyclocrinites* and species *Cyclocrinites Spaski* [sic] are described in Appendix and are considered corals.

MILNE-EDWARDS, H. and JULES HAIME

1850. A monograph of the British Fossil Corals. Part 1. Introduction: Corals from the Tertiary and Cretaceous Formations. 71+LXXXV pp., 11 pls. Bound as Paleontographical Society, vol. 48.

Cyclocrinites Eichwald is described as Zoantharia *Incertae sedis.*

MOORE, RAYMOND C., CECIL G. LALICKER, and ALFRED G. FISCHER

1952. Invertebrate fossils. McGraw-Hill, New York. 766 pp., numerous figs.

Nidulites is listed with sponges, but is stated not to be a sponge but probably a calcareous alga. *Nidulites pyriformis* Bassler, Middle Ordovician from Pennsylvania is illustrated.

NICHOLSON, HENRY ALLEYNE and ROBERT ETHERIDGE, JR.

1878–1880. A monograph of the Silurian fossils of the Girvan District in Ayrshire with special reference to those contained in the "Gray collection," 3 parts in one vol., 11 text-figs., 24 pls., 1 table.

Genera *Pasceolus* Billings, *Cyclocrinus* Eichwald, *Sphaerospongia* Salter, and *Nidulites* Salter are assumed to be all perhaps congeneric and related to *Receptaculites* Defrance. However, more work is needed to ascertain their exact relation to each other and to lower invertebrates. Numerous specimens are figured.

NICHOLSON, HENRY ALLEYNE and RICHARD LYDEKKER

1889. A manual of palaeontology for the use of students with a general introduction on the principles of palaeontology, 3rd ed., 2 vols., 1624 pp., 1419 figs.

Pasceolus, *Cyclocrinus*, and *Nidulites* are described and illustrated. No definite taxonomic assignment is made, however, the resemblance to calcareous algae is noted. This is an abbreviated version of the Nicholson and Etheridge, 1878, discussion on Cyclocrinitids.

NICKLES, J. M.

1902. The geology of Cincinnati, Jour. Cincinnati Soc. Nat. Hist., **20**, no. 2, pp. 49–100, 1 pl.

Pasceolus globosus Billings is listed from the Cincinnati beds, the Utica, Lorraine, and Richmond Groups. *Lepidolites dickhauti* Ulrich is reported from Lower Utica beds, and *Anomalospongia reticulata* Ulrich from the Mt. Hope beds. *Anomalospongia* and *Lepidolites* are considered sponges. *Pasceolus* is considered of uncertain position.

NILES, A. E.

1865. Untitled minutes of the March 2, 1864 meeting. Proc. Boston Soc. Nat. Hist., **10**, pp. 19–20.

Specimens of *Pasceolus Halli* Billings were exhibited, and various authors concluded that this form should be included in Cystideans, in the family Sphaeronitidae. The fossils were collected at Ellis Bay, on Anticosti Island. *Pasceolus* Billings is considered the same as *Cyclocrinites* Eichwald.

NITECKI, MATTHEW H.

1965. Catalogue of type specimens in Chicago Natural History Museum. Porifera. Fieldiana: Geol., **13**, no. 6, pp. 477–509.

Type specimens of *Pasceolus Darwini* Miller, *P. claudei* Miller, and *Astylospongia tumidus* James are listed as housed in Field Museum of Natural History. All are considered *incertae sedis.*

1967. Systematic position of receptaculitids, Geol. Soc. Amer., 1967 Ann. Mtg., pp. 165–166.

Cyclocrinitids are considered a group of receptaculitids.

1968. Revision of North American cyclocrinitids. Geol. Soc. Amer., North-Central Sec., Ann. Mtg., p. 35.

This is an abstract of the present paper, presented at the Geol. Soc. Amer. North-Central Section Meetings.

OSGOOD, RICHARD G., JR. and ALFRED G. FISCHER

1960. Structure and preservation of *Mastopora pyriformis*, an Ordovician dasycladacean alga. Jour. Paleontol., **34**, no. 5, pp. 896–902, pls. 117–118, 2 text-figs.

Mastopora pyriformis (Bassler) is figured as dasycladaceous alga. Central vesicle is figured, as well as supposed gametocysts.

OWEN, D. D.

1844. "Report of a Geological Exploration of part of Iowa, Wisconsin, and Illinois, made under instructions from the Secretary of the Treasury of the United States, in the Autumn of the year 1839; with charts and illustrations. 28th Congr., 1st Session Senate document no. 407." Washington, 191 pp.

The first cyclocrinitid in North America *Lunulites dactioloides* is briefly described and illustrated.

PECK, JOSEPH H. and HERDIS B. MCFARLAND

1954. Whitfield collection types at the University of California. Jour. Paleontol., **28**, no. 3, pp. 297–309, pl. 29.

The depository of the type of *Cerionites dactyloides* [sic] Owen, was indicated by Whitfield (1899) to be the University of California, but was never sent to California.

PHILLIPS, JOHN

1841. Figures and descriptions of the Palaeozoic fossils of Cornwall, Devon, and West Somerset. [Great Britain and Ireland Geol. Surv. England and Wales. Topographical Memoirs.] Longman, Brown, Green, and Longmans, London. XII, 231 pp., 60 pls.

PIA, JULIUS

1927. Abteilung: Thallophyta. *In* Hirmer, Max. Handb. Paläobot., München, pp. 31–136, figs. 14–129.

This is the most cited work on cyclocrinitids. *Cyclocrinus* Eichwald together with *Mizzia* Schubert and *Coelosphaeridium* Roemer are placed in the subtribe Cyclocrininae, tribe Cyclocrineae. *Pasceolus* Billings and *Cerionites* Meek and Worthen are considered synonyms of *Cyclocrinus*. The American species of *Cyclocrinus* are listed only. The genera *Mastopora* Eichwald, *Apidium* Stolley, and *Epimastopora* Pia are placed in the subtribe Mastoporinae of the tribe Cyclocrineae. *Nidulites* Salter is considered synonym of *Mastopora*. *Mastopora pyriformis* (Bassler) is illustrated.

RAUFF, HERMAN

1892. Untersuchungen über die Organisation und systematische Stellung der Receptaculitiden. Abhandl. K. bayer. Akad. Wiss., II, **17**, Bd. 3, Abth., 78 pp. (pp. 645–722), 7 pls.

Lepidolites Ulrich belongs perhaps with *Ischadites* Murchison.

RAYMOND, PERCY E.

1912. Palaeontological Division, II. Invertebrate, pp. 351–357. *In* Canada Geol. Surv. Summary Rept. for 1911. Sessional paper no. 26.

Nidulites sp. ind., is reported from Quebec City Formation in Quebec. The fauna listed from Quebec is considered identical to the Chambersburg Limestone of eastern Pennsylvania.

1916. The correlation of the Ordovician strata of the Baltic Basin with those of Eastern North America. Bull. Mus. Comp. Zool., **56**, no. 3, pp. 177–286, 8 pls.

Certain cyclocrinitids are listed from European and American localities.

REED, F. R. COWPER

1912. Ordovician and Silurian fossils from the central Himalayas. Geol. Surv. India. Palaeontol. Indica. ser. 15, **7**, no. 2, 168 pp., 20 pls.

Pasceolus mellifluus (Salter), *Pasceolus*? *shianensis* sp. nov. and *Apidium indicum* sp. nov. are described and illustrated as *incertae sedis* from localities in central Himalayas.

REZAK, RICHARD

1959. New Silurian Dasycladaceae from the Southwestern United States, Part 2. Quart. Colorado School Mines, **54**, no. 1, pp. 115–129, 4 pls.

A new tribe Verticilloporeae is erected for two new dasycladaceous Silurian genera, *Verticillopora* Rezak and *Phragmoporella* Rezak.

ROEMER, FERD.

1888. Ueber die Gattungen *Pasceolus* und *Cyclocrinus*. Neues Jahrb. Mineral Geol. Palaeontol., Band 1 (1888), pp. 74–75.

Pasceolus Billings is considered identical with *Cyclocrinus* Eichwald; the latter name has the priority. *Pasceolus Billingsii* is considered very similar to *Cyclocrinus spaskii*. *P. Billingsii* is considered a well-known species.

1876, 1880, 1897. Lethaea geognostica. I. Theil. Lethaea palaeozoica. Text and Atlas, 324 pp., 61 text-figs., 62 pls.

Genera *Receptaculites*, *Cyclocrinus*, *Pasceolus*, *Tetragonis*, *Polygonosphaerites*, and *Archaeocyathus* are placed in the family "*Receptaculitiden*." Receptaculitids are considered foraminifers. Genus *Cyclocrinus* Eichwald, 1840, is discussed; *Cyclocrinus Spaskii* Eichwald is discussed and illustrated. *Pasceolus* Billings, 1857, is discussed and is considered distinct from *Cyclocrinus*. The following species are included in *Pasceolus*: *P. Halli* Billings, *P. globosus* Billings, *P. gregarius* Billings, *P. intermedius* Billings, *P. Darwinii* S. A. Miller, *P. Claudii* S. A. Miller, *P. Goughii* Salter, and *P. Sedgwicki* Salter. *Nidulites* Salter is considered identical to *Cyclocrinus*.

It appears that more than one edition of Lethaea was issued. I have an edition dated 1880, 1897, consisting of 688 pages.

Roy, S. K.

1941. The Upper Ordovician fauna of Frobischer Bay. Baffin land. Field Mus. Nat. Hist., Geol. Mem., **2**, 212 pp., 146 text-figs.

Nidulites gregarius (Billings) is listed from Red River Formation in southern Manitoba.

Salter, J. W.

1851. Descriptions of a few of the above fossils. Pp. 173–177, pls. 8–10. *In* Murchison, R. I., "On the Silurian rocks of the south of Scotland." Quart. Jour. Geol. Soc. London, **7**, pp. 139–178.

A new genus and species *Nidulites favus* is described and illustrated from "Llandeilo flags of Pembrokeshire."

Savage, T. E. and Francis M. Van Tuyl

1919. Geology and stratigraphy of the area of Paleozoic rocks in the vicinity of Hudson and James Bay. Bull. Geol. Soc. Amer., **30**, pp. 339–379, pls. 11–13.

Cerionites sp. is listed from the Shammattawa Limestone along the Shammattawa River.

Schuchert, Charles, W. H. Doll, T. W. Stanton, and R. S. Bassler

1905. Catalogue of the type specimens of fossil invertebrates in the Department of Geology. United States National Museum. Smithsonian Inst. Bull. U. S. Nat. Mus., no. 53. Part 1, Fossil Invertebrates, 704 pp.

The type specimens of *Anomaloides reticulatus* Ulrich, *Lepidolites dickhauti* Ulrich and *L. elongatus* Ulrich are deposited with the collections of the U. S. National Museum.

Schuchert, Charles and W. H. Twenhofel

1910. Ordovicic–Siluric section of the Mingan and Anticosti Islands, Gulf of Saint Lawrence. Bull. Geol. Soc. Amer., **21**, pp. 677–716.

Pasceolus halli Billings and *Pasceolus* sp. are reported from the Ellis Bay Formation.

Shimer, Hervey W. and Robert R. Shrock

1944. Index fossils of North America. John Wiley and Sons, New York. 837 pp., 303 pls.

In this well-known classic *Nidulites pyriformis* Bassler is illustrated and is placed among unrecognized class of sponges.

Cyclocrinites globosus (Billings) is figured and placed among "miscellaneous objects of probable organic origin."

Stolley, E.

1896. Untersuchungen über *Coelosphaeridium*, *Cyclocrinus*, *Mastopora* und verwandte Genera des Silur. Archiv für Anthropologie und Geologie Schleswig-Holsteins und der benachbarten Gebiete. Vol. 1, part 2, pp. 177–282 (1–106), 105 text-figs.

This is the first and only monograph on cyclocrinitids. The genera *Coelosphaeridium*, *Cyclocrinus*, *Mastopora*, and *Apidium* are described and placed among algae. The American representatives are only listed.

Stose, George W.

1909. Mercersburg–Chambersburg folio. U. S. Geol. Surv., Geol. Atlas no. 170, 19 pp., 1 table, 6 maps, 18 figs.

Nidulites favus is listed from Chambersburg quadrangle in south central Pennsylvania. *Nidulites* bed is a marker of Chambersburg Limestone. *Nidulites favus* has not been positively observed in the Mercersburg quadrangle.

Sushkin, M. A.

1962. Class Squamiferida (Receptaculida). *In* Orlov, Y. A., ed., Osnovy paleontologii, Gubki, Arheotsiaty, Kishechnopolostnye, Chervi, pp. 81–83, text-figs. 121–124, pl. 9, figs. 9–10 [in Russian].

The following genera are placed together in the order Receptaculitida, class Squamiferida, phylum Porifera: *Receptaculites* Defrance, 1827, *Ischadites* Murchison, 1839, *Acanthochonia* Hinde, 1884, *Sphaerospongia* Pengelly, 1861, *Cerionites* Meek and Worthen, 1868, *Dictyocrinus* Hall, 1859, *Lepidolites* Ulrich, 1889, *Nidulites* Salter, 1851, *Anomaloides* Ulrich, 1878, and *Pasceolus* Billings, 1857.

Taylor, William Randolph

1960. Marine algae of the eastern tropical and subtropical coasts of the Americas. University of Michigan Press, Ann Arbor, Michigan. 870 pp., 80 pls., 14 text-figs.

Thomas, A. O.

1923. Some new Paleozoic glass-sponges from Iowa. Proc. Iowa Acad. Sci., 1922, **29**, pp. 85–88, 1 pl.

Cerionites dactylioides [sic] (Owen) occurs in Silurian of Iowa.

Twenhofel, W. H.

1914. The Anticosti Island Faunas. Geol. Surv. Canada, Mus. Bull. no. 3, Geol. series no. 19, 38 pp., 1 pl.

This is a summary of Twenhofel's 1928 monograph on the Geology of Anticosti Island. Cyclocrinitids are listed.

1916. The Silurian and high Ordovician strata of Estonia, Russia, and their faunas. Bull. Mus. Comp. Zool., **56**, no. 4, pp. 287–340, 5 pls.

Cyclocrinites spasski [sic] is listed from Baltic.

1928. Geology of Anticosti Island. Geol. Surv. Canada Memoir no. 154, 481 pp., 60 pls., 1 text-fig.

This is an important description, with one figure, of the genus *Cyclocrinites*, and species *C. halli*, *C. gregarius*, and *C. intermedius*.

Twenhofel, W. H., chmn.

1954. Correlation of the Ordovician formations of North America. Bull. Geol. Soc. Amer., **65**, pp. 247–298, 2 text-figs., 1 pl.

The range of *Nidulites* is given as middle Champlainian, and is said to range from the Valcour Formation through the Black River Stage to the Rockland Formation. *Nidulites pyriformis* is listed from Ward Cove Limestone.

Ulrich, E. O.

1878. Descriptions of some new species of fossils from the Cincinnati Group. Jour. Cincinnati Soc. Nat. Hist., **1**, no. 2, pp. 92–100, pl. 4.

The new genus *Anomaloides* and its new species *A. recticulatus* are described from the Cincinnati group at Covington, Kentucky. This paper together with a paper on annelids was bound separately and issued with altered pagination. *Anomaloides reticulatus* is reprinted on pp. 6–7.

1879. Descriptions of new genera and species of fossils from the Lower Silurian about Cincinnati. Jour. Cincinnati Soc. Nat. Hist., **2**, pp. 8–30, pl. 7.

The genus *Lepidolites* and the species *L. dickhauti* and *L. elongatus* are described from the "Hudson River Group at Covington, Kentucky." This paper was reprinted unchanged, except for new pagination (22 pp.) and circulated as a separate.

1880. Catalogue of fossils occurring in the Cincinnati Group of Ohio, Indiana, and Kentucky. James Barclay, Cincinnati, Ohio, 31 pp.

Astylospongia [now *Cyclocrinites*] *tumida* James is listed among sponges. *Anomaloides reticulatus* Ulrich, *Lepidolites dickhauti* Ulrich, *L. elongatus* Ulrich, *Pasceolus claudei* Miller, *P. darwini* Miller, and *P. globosus* Billings are all classed as *incertae sedis* from around Cincinnati, Ohio.

1888. The palaeontological labors of Prof. Jos. F. James. Amer. Geol., **1**, pp. 323–327.

1890. American Palaeozoic Sponges. Geol. Surv. Illinois, **8**, Geol. Palaeontol., pp. 209–241.

Lepidolites Ulrich is considered to belong to receptaculitids.

1895. On the structure and systematic position of "*Anomaloides*," and a proposal to change the name to *Anomalospongia*. Minn. Geol. Surv. Final Rept., **3**, pt. 1, pp. 68–74, 1 text-fig.

The author recommends that *Anomaloides reticulatus* Ulrich be changed to *Anomalospongia reticulata* since following the first description the sponge nature of the specimens became apparent. The specimens are described in detail and the genus compared to various receptaculitids, with the suggestion that *Anomalospongia* and *Amphispongia* be included in a new, unnamed family or order separate from the receptaculitids.

1911. Revision of the Paleozoic Systems. Bull. Geol. Soc. Amer., **22**, pp. 281–680, pls. 25–29.

Nidulites favus is used as stratigraphic marker in *Nidulites* bed in the Appalachian region.

VERRILL, A. E.

1865. Untitled minutes of the March 2d, 1864 meeting. Proc. Boston Soc. Nat. Hist., **10**, p. 19.

Specimens of *Pasceolus Halli* Billings were exhibited, and various authors concluded that this form should be included in Cystideans. The fossils were collected at Ellis Bay, on Anticosti Island.

VINOGRADOV, A. P.

1953. The elementary chemical composition of marine organisms. Sears Found. Mar. Res., Yale Univ. Mem. 2, 647 pp., 327 tables.

VOKES, HAROLD E.

1957. Geography and Geology of Maryland. Bull. Maryland Dept. Geol. Mines Water Res., **19**, 243 pp., 28 pls., 12 tables, 32 figs.

Nidulites pyriformis Bassler is illustrated from Chambersburg limestone of Maryland.

WHITEAVES, J. F.

1897. The fossils of the Galena–Trenton and Black River formations of Lake Winnipeg and its vicinity. Geol. Surv. Canada, Palaeozoic fossils, **3**, part 3, pp. 129–242, pls. 16–22.

This is the third part of the third volume of "Palaeozoic fossils" and it deals with Ordovician fossils of Lake Winnipeg and its vicinity. Certain new fossils are described and illustrated. *Pasceolus gregarius* ? Billings is described and cannot be satisfactorily distinguished from *Cyclocrinus Spaskii* Eichwald.

WHITFIELD, R. P.

1882 [1883]. Palaeontology, pp. 161–363, 27 pls. *In* Geology of Wisconsin Survey of 1873–1879, vol. 4, part 3.

Cerionites dactyloides [sic] (Owen) from the Niagaran group at Waukesha, Wisconsin, is described and illustrated. The genus is compared to *Pasceolus* and *Receptaculites*. It is found to be very similar to *R. globulare* and *R. hemispherica*.

1899. List of fossil, types and figured specimens, used in the palaeontological work of R. P. Whitfield, showing where they are probably to be found at the present time. Ann. New York Acad. Sci., **12**, nc. 8, pp. 139–186.

The specimen of *Cerionites dactyloides* [sic], described and illustrated by Whitfield (1882) is housed in University of California. [Also see: Peck and McFarland, 1954.]

WILSON, ALICE E.

1948. Miscellaneous classes of fossils, Ottawa formation, Ottawa–St. Lawrence Valley. Bull. Geol. Surv. Canada, **11**, 116 pp., 28 pls., 4 text-figs.

Pasceolus globosus Billings is described and figured. Genus *Pasceolus* Billings is described and compared to *Cyclocrinus* Eichwald. *Pasceolus* is placed in "Appendix to the sponges."

1957. A guide to the geology of the Ottawa district. Canad. Field Nat., **70** for 1956, no. 1, pp. 1–68, 5 pls., 1 map, numerous text-figs.

Pasceolus is considered a "near sponge" and is found in Cobourg beds in Ottawa district.

WILSON, A. G.

1895. The Upper Silurian in Northeastern Iowa. Amer. Geol., **16**, pp. 275–281.

Cerionites dactyloides [sic] (Owen) is abundant in the upper "Pentamerous beds" within the state.

WINCHELL, N. H. and C. SCHUCHERT

1895. Chapter III. Sponges, Graptolites, and Corals from the Lower Silurian of Minnesota. Minn. Geol. Surv. Final Rept., **3**, pt. 1, pp. 55–95, pls. F, G, 7 text-figs.

Receptaculitids are extensively reviewed and current synonyms given for the American species. *Cerionites dactyloides* [sic] (Owen), *Lepidolites dickhauti* Ulrich and *Anomalospongia reticulata* (Ulrich) are described and figured.

WOOD, ALAN

1943. The algal nature of the genus *Koninckopora* Lee; its occurrence in Canada and western Europe. Quart. Jour. Geol. Soc. London, **98**, pp. 205–222, pls. 8–10, 3 text-figs.

A Mississippian genus *Koninckopora* Lee, originally described as a bryozoan is considered a dasycladaceous alga from Europe and Canada. The genus is placed in the Tribe Mastoporinae and sub-family Cyclocrineae.

ZITTEL, KARL A.

1878–1880. Handbuch der Palaeontologie, vol. 1. Protozoa. Coelenterata, Echinodermata, und Molluscoidea. Druck und Verlad Von R. Oldenbourg, Munchen und Leipzig. 765 pp., 558 text-figs.

Cyclocrinus Eichwald, *Mastopora* Eichwald, *Dictyocrinus* Hall, *Pasceolus* Billings, and *Sphaerospongia* Pengelly are considered problematic members of the family Dactyloporidae. *Nidulites* Salter is considered a synonym of *Cyclocrinus* Eichwald.

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