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The Cryptostome Bryozoa from the Middle Ordovician Decorah Shale, Minnesota

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ABSTRACT

The Middle Ordovician Decorah Shale in Minnesota is a distinctive formation containing an abundant diversified fauna; this study is concerned with the cryptostome Bryozoa, a group that constitutes a large part of the fauna.

I have used a new approach in the interpretation of cryptostome zoarial structures emphasizing the dark boundary zones and their spatial arrangement in zoaria as distinct morphological features in genera of the families Rhinidictyidae, Stictoporellidae, and Ptilodictyidae. The dark boundary zones are formed by abutting or adjoining laminae and, when present, they outline zooecia or other structural segments of zoaria. In thin sections the boundaries appear as dark lines representing the edge views of planar to curved zones between zooecia and extend for different lengths throughout zoaria.

Sixteen species distributed among six genera are described and illustrated. One species, *Stictopora lita*, is new. On the basis of the boundary zones in association with other morphological features two new genera, *Astreptodictya*, type species *Pachydictya acuta* (Hall), and *Athrophragma*, type species *Pachydictya foliata* Ulrich, are proposed. Emended generic definitions are presented for *Stictopora, Escharopora* and *Graptodictya*. The wall structure of each genus is described in detail and, where the material permits, previously described Ordovician species are reassigned to new genera.

The informal stictoporid and escharoporid groups of Ross (Phillips, 1960) are redefined and three additional informal groups are proposed: "stictoporellid," athrophragmid, and astreptodictyid. The genera are reassigned to these groups as appropriate.

The stictoporid group is defined as having zoaria with approximately linear zooecial ranges in which adjacent zooecia are separated by range boundaries laterally and zooecial boundaries longitudinally. In the "stictoporellids" the zooecial boundaries are polygonal in tangential views and the range boundaries are lacking. The escharoporid group is characterized by having well-defined wall laminae that are continuous between adjacent zooecia. There are no boundary zones in the exozone of zoaria. In the athrophragmids the zooecial boundaries describe a cylindrical form in the exozone and appear approximately oval in tangential views. The walls between adjacent zooecia in the exozone may contain numerous intermittent dark zones, but there are no range boundaries. The astreptodictyid group is distinguished in having range partitions between adjacent zooecial ranges in exozone that extend throughout zoaria and are at about right angles to the zoarial surface. The zooecial boundaries are like those in the athrophragmids and the range boundaries, similar to those in the stictoporids, are located along the median of the range partitions.

Geographic and stratigraphic distribution of species permits the division of the Decorah Shale into three zones from bottom to top: 1. *Stictoporella angularis* zone, with three restricted species, 2. *Stictopora mutabilis* zone, with one restricted species, and 3. *Stictopora minima* zone, with two restricted species. One of the remaining species, *Stictopora lita*, occurs primarily in the *Stictoporella angularis* zone, but ranges into lower part of *Stictopora mutabilis* zone; seven species occur primarily in the *S. mutabilis* zone, but range into *S. minima* zone, and two were found throughout the section at all seven localities. Cryptostomata are abundant throughout the Decorah Shale except in the lower part of the *Stictopora mutabilis* zone. The three cryptostome zones approximately coincide with ostracode zones suggested by Swain and others in 1961.

On the basis of present knowledge, the *Stictoporella angularis* zone is the approximate biostratigraphic equivalent of the Spechts Ferry Shale Member of the Decorah Formation in Illinois, Wisconsin, and Iowa. Evaluation at the species level suggests that the cryptostomes of the Decorah Shale are more closely related to those of the Trenton Group of New York than to those of the Black River Group of New York.

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INTRODUCTION

The Decorah Shale is a distinctive unit in the Champlainian (Middle Ordovician) strata of the upper Mississippi Valley in Minnesota. In the upper Mississippi Valley zinc-lead district of Illinois, Iowa, and Wisconsin, the Decorah Shale is called the Decorah Formation. The Decorah fauna is noted for its abundance and diversity although the preservation of the faunal elements varies in quality. The Decorah bryozoan faunule includes representatives of five Paleozoic orders of the phylum.

This report deals with some so-called bifoliate forms of the order Cryptostomata. The purpose of the study was to evaluate the morphology of Decorah bifoliates and its bearing on taxonomy, and to investigate the geographic and stratigraphic distribution and zonational value of the species.

Previous studies of the Cryptostomata in Minnesota were those of Ulrich (1886, 1895) and Sardeson (1892a,b, 1897a,b, 1935a,b,c, 1936a,b,c,d,e, 1937a,b,c,d). The classical zonation of the Minnesota sequence (Sardeson, 1897a) has been widely used. Two of the zones were based by Sardeson on the vertical and lateral distribution of the bifoliates *Stictoporella* Ulrich and *Rhinidictya* Ulrich, the latter a junior synonym of *Stictopora* Hall.

Significant papers dealing with the stratigraphic aspects of the Decorah Shale and adjacent strata are by Kay (1929), Stauffer and Thiel (1941) Agnew (1955), and Weiss (1957). Templeton and Willman (1963) summarized the history of the study of Middle Ordovician in Illinois, described new rock-stratigraphic units and suggested major changes in commonly accepted correlations. However, a formal biostratigraphic classification was not attempted.

Swain and others (1961) inaugurated a study of Ostracoda from the Decorah Shale in Minnesota. They found that it may be possible to zone the Decorah Shale on the basis of the ostracodes and suggested the probable relationship of the zones to the member subdivisions. This study is of particular interest because the ostracode zones appear to coincide with those described here based on the cryptostome bryozoans.

Papers dealing with the bryozoans including the Cryptostomata from strata of Middle Ordovician outside of Minnesota are those by Hall (1847), Bassler (1911), Coryell (1921) and Fritz (1957). In a more recent publication Perry (1962) described in detail the bryozoans from the Spechts Ferry Shale Member of the Decorah Formation of Illinois, Wisconsin, and Iowa. He found that *Hallopora* Bassler, a trepostome, and *Stictoporella* Ulrich, of which one species is common in Minnesota (see p. 66), dominated the fauna. Ross (1964a) restudied the Cryptostomata from strata of the type region of the Black River and Trenton Groups in New York.

Methods of Study

Field work for this study was done during the summers of 1960 and 1961. The material studied was collected by the writer from the exposures of the Decorah Shale at Wangs, Roscoe, Rochester, Chatfield, and Spring Grove in Minnesota. The material from St. Paul, Minnesota, was collected by D. L. Hansen in 1951 for the study of the distribution of the Ostracoda.

Collections were made at two-foot intervals at each locality. Approximately three pounds of the collection obtained from each two-foot interval was air-dried, soaked for several hours in a cleansing liquid (white gasoline or Varsol) and then in water. The clay size fraction of the sample was discarded and the residue was picked for bryozoan fragments. Almost every sample contained a large number of bryozoan fragments (see far right column, fig. 11). The picked fragments were examined externally, sorted into groups and several fragments from each group were thin-sectioned. The technique for sectioning bryozoan fragments is described by Ross and Ross (1965, p. 41). The size of the fragments ranged from less than 1 mm to several centimeters in length and width, and from a fraction of a millimeter to several millimeters in depth. Fragments as small as 0.3 mm or even less in depth and approximately 1 mm in length yielded adequate thin sections for identification provided the internal features were reasonably well preserved.

In estimating the relative abundances of bryozoan fragments assigned to each species the following arbitrarily selected figures are used: 1-4 as rare, 5-9 as common, 10-24 as abundant and 25 or more as very abundant. These estimates are given in the section entitled "Occurrence" following each species description.

The approximate number of fragments assigned to each species from each three-pound channel sample of a collection representing a two-foot vertical interval of strata, and the ranges of the species are plotted in figure 11. The total number of bryozoan fragments in each sample is indicated in the column at the far right of figure 11.

The faunal zones are chosen on the basis of total ranges as far as they can be determined and on abundance and absence of the fragments of the various species in the samples.

Altogether 152 collections were obtained from seven localities, yielding approximately 14,500 bryozoan fragments from which about 1,400 thin sections have been made. In addition, the material in the type collections of the U. S. National Museum (USNM) was studied.

Localities and Register of Thin Sections

The cryptostome fragments described here, apart from those made available by the National Museum (USNM), were obtained from seven measured sections. These sections are shown graphically in figure 1, (modified from Swain and others, 1961, text fig. 1). The lithologic characters of the measured sections were summarized by Swain and others (1961, p. 346, 348).

St. Paul Section. – Upper part of Platteville Limestone, Decorah Shale, and lower part of Galena Dolomite in the quarry of Twin City Brick and Tile Plant, Cherokee Heights, St. Paul, Minnesota; adapted from Stauffer and Thiel (1941), Hansen (1951) Cornell (1956) and Swain and others (1961).

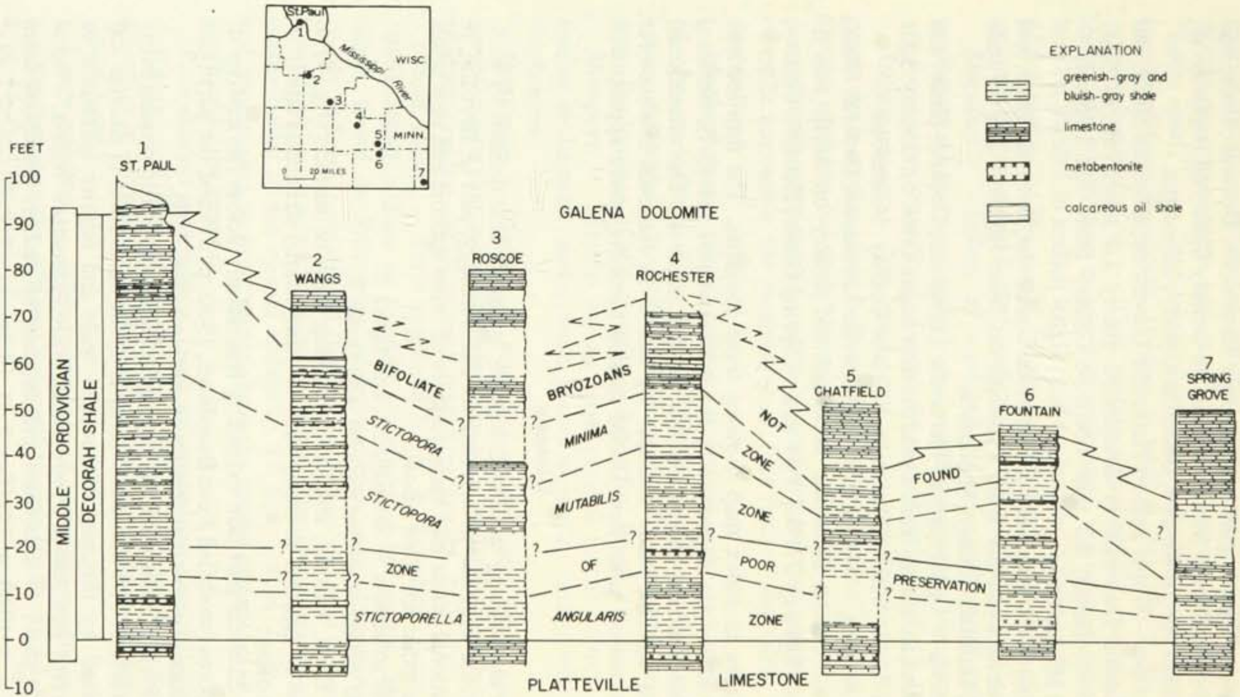

Figure 1 — Generalized stratigraphic sections of the Decorah Shale in Minnesota (modified from Swain and others, 1961, text fig. 1) showing cryptostome bryozoan zones; index map shows location of the collecting localities.

Wangs Section. – Upper part of Platteville Limestone, Decorah Shale, and lower part of Galena Dolomite from a roadcut on State Highway 56, 0.5 mile to 1 mile northwest of Wangs, Goodhue County, Minn.

Roscoe Section. – Upper part of Platteville Limestone, Decorah Shale, and lower part of Galena Dolomite from a roadcut on County State Aid Highway 11, 2.0 miles to 2.5 miles east of Roscoe, Goodhue County, Minnesota.

Rochester Section. – Upper part of Platteville Limestone, Decorah Shale, and lower part of Galena Dolomite in abandoned quarry 1.5 miles east of State Hospital, east of Rochester, 0.3 mile north of County State Aid Highway 9, Olmsted County, Minnesota.

Chatfield Section. – Upper part of Platteville Limestone, Decorah Shale, and lower part of Galena Dolomite from a roadcut on State Highway 30, 0.7 mile east of Chatfield, Olmsted County, Minnesota.

Fountain Section. – Upper part of Platteville Limestone, Decorah Shale, and lower part of Galena Dolomite from a roadcut near Sugar Creek on County State Aid Highway 8, 1.5 mile west of Fountain, Fillmore County, Minnesota.

Spring Grove Section. – Upper part of Platteville Limestone, Decorah Shale, and lower part of Galena Dolomite in abandoned quarry on north side of County State Aid Highway 27, 0.5 mile east of Spring Grove, Houston County, Minnesota.

Figure 1 includes an index map showing these localities. The thin sections obtained by the writer are deposited in the collections of the U. S. National Museum in Washington and assigned USNM catalog numbers. The unsectioned material and thin sections made available by the U. S. National Museum for study or illustrations are given new USNM catalog numbers where appropriate.

Glossary

The bryozoan terminology used in this paper is largely that defined by R. S. Bassler (1953) in the Treatise on Invertebrate Paleontology, part G, Bryozoa, p. G7 to G16. Additional terms and variant usages of other authors and new terms introduced in this paper are given below.

Astreptodictyid structure. – See page 26, and figure 8.

Athrophragmid structure. – See page 24, and figure 7.

Boundary. – Dark, narrow, straight to curving zone or surface (fig. 4) in which the laminae of adjacent zooecial walls or other zoarial structures adjoin or abut against each other.

Diaphragm. – Skeletal partition extending transversely across the cavities of zooecia or mesopores (modified from Boardman, 1960, p. 21) and the partitions of the vesicular tissues (interstitial vesicles of authors) (figs. 7, 8).

Endozone. – Part of individual and colony too undeveloped to possess many morphologic characters. The endozone consists of the basal parts of zooecia and zoaria, characterized by thinness of zooecial walls and relative sparseness or absence of transverse structures. Synonymous with "immature region," "axial region," or "inner part" of zooecium and zoarium of authors (modified from Boardman, 1959, p. 2; 1960, p. 22) (figs. 2,3).

Escharoporid structure. – Term introduced by Ross (Phillips, 1960, text fig. 1, p. 17; Ross, 1964a, pl. 1, figs. 3, 9; 1964b, p. 941). See page 21 and figure 6.

Exozone. – Part of individual and colony possessing most of the morphologic structures. The exozone consists of the outer parts of zooecia and zoaria characterized by thickened zooecial walls, and if present, by vesicular tissues, diaphragms, mesopores and mural tubuli. Synonymous with "mature region," "outer part," or "peripheral part" of zooecium and zoarium of authors (modified from Boardman, 1959, p. 2; 1960, p. 21) (figs. 2, 3).

Longitudinal view. – Thin section exposing the zooecia parallel to their length. In a bifoliate zoarium the plane of the section is in the center of a branch, parallel to branch length, and preferably at right angles to the mid-region of the surface of the zoarial branch and to the general plane of the mesotheca in the interior (modified from Boardman, 1960, p. 22) (fig. 2).

Maculae. – Clusters of modified zooecia and mural tubuli in different combinations that are regularly or irregularly spaced throughout a zoarium, and appear as areas generally flush with the zoarial surface (pl. 13, fig. 2).

Measurements. – The number of zoaria included in the tables of measurements for a species commonly are fewer than the total number of zoaria of that species available for study. In species in which few zoaria were available, these discrepancies were caused mostly by preservation that was bad enough to affect or make impossible the measurements. (See figure 2 and tables following species description.)

Median tubuli. – Small, tubelike structures in the dark zone along the middle of the mesotheca. The median tubule is filled with translucent calcite, apparently without structure, that is separated by a dark, narrow wall-like zone from the laminae of the mesotheca (pl.3, fig. 3a; pl. 10, fig. 1a; pl. 14, fig. 5a).

Mesopore. – Skeletal sac or tube, parallel to the zooecia but appreciably smaller in diameter, and in most genera limited to the exozone; with or without diaphragms.

Monticule. – Clusters of modified zooecia and mural tubuli in different combinations that are spaced regularly or irregularly throughout a zoarium and appearing on the surface as small protuberances (pl. 2, fig. 1c).

Mural tubuli. – Term suggested by R. S. Boardman (oral communication, 1966). Small, rodlike or tubelike structures in the zoaria. The type of mural tubuli found in *Stictopora, Astreptodictya,* and *Athrophragma* consists of poorly defined, cone-shaped flexures in the zooecial wall laminae, convex to the zoarial surface, or in the boundary zones. The mural tubuli are oriented about perpendicular to the zoarial surface (p. 17; figs. 3, 4; pl. 2, fig. 3d; pl. 5, fig. 2c), and may project as small spines above the zoarial surface (pl. 4, fig. 3). They are confined to the exozone.

Pachydictyid structure. – Term introduced by Ross (Phillips, 1960, p. 13).

Range. – Linear or curved series of zooecia, parallel or oblique with the direction of growth of a zoarial branch (modified from Phillips, 1960, p. 5). See figure 3 and 8.

Range partition. – A linear segment of laminated calcite in the exozone of a zoarium between the adjacent ranges of zooecia (fig. 8; pl. 10, figs. 1a, 1c, 2, 3a, 4; pl. 11, figs. 3b, 4; pl. 12, fig. 6).

"Stictoporellid" structure. – See page 19, and figure 5.

Stictoporid structure. – Term introduced by Ross (Phillips, 1960, p. 6; Ross, 1964b, p. 942). See page12, and figure 3 and 4.

Tangential view. – Thin section showing the view parallel to and under the surface of a zoarium (modified from Boardman, 1960, p. 22).

Transverse view. – Thin section showing the view at right angles to the branch of a zoarium, and to the general direction of growth (modified from Boardman, 1960, p. 22).

Vesicular tissue. – Part of zooecial wall with straight to curved diaphragms, single or overlapping in series between adjacent zooecia in endozone and exozone. Interstitial vesicles, tabulate interspaces of authors. Figure 7; plate 13, figure 1b, 1c; plate 14, figure 4.

Zoarial ratio. – Ratio of the depth of the exozone to the depth of the zooecia or to the perpendicular distance from the mesotheca to the zoarial surface (modified from Phillips, 1960, p. 8). Figure 2.

Zoarium. – The collective skeletal parts of a bryozoan colony (Boardman, 1960, p. 22).

Zooecial angle. – The angle between the mesotheca and the zooecial walls in the exozone; measured in longitudinal view. Figure 2.

Zooecial bend. – The bend in the zooecium generally located either between the endozone and exozone or in the early exozone (modified from Boardman, 1960, p. 22).

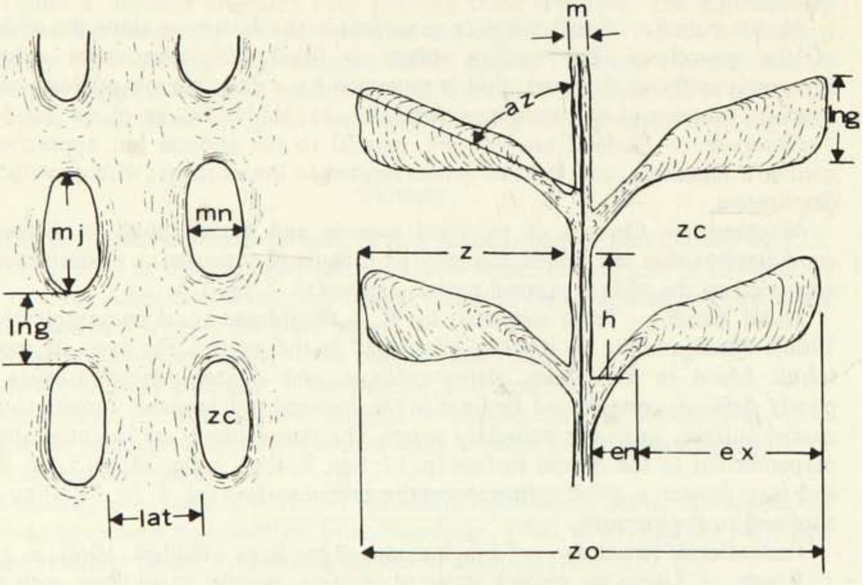

Figure 2 – Diagrams illustrating measurements: az, zooecial angle; en, endozone, depth of; ex, exozone, depth of; h, height of zooecial cavity in endozone; lat, wall width laterally; lng, wall width longitudinally; m, mesotheca, depth of; mj, major axis of a zooecial cavity; mn, minor axis of a zooecial cavity; z, zooecium, depth of; zc, zooecial cavity; zo, zoarium, depth of.

Zooecial cavity. – Space that contained the soft parts (polypide) of the whole animal or zooid. Figure 2-8.

Zooecium. – Zooecial cavity and the adjacent wall.

Previous Work

The monograph by Ulrich (1890) on the Paleozoic Bryozoa is considered by Boardman (1960, p. 25) to be the most important single work on the Order Trepostomata. The treatment of the Order Cryptostomata in the 1890 work was sketchy. Concerning the ptilodictyids, rhinidictyids, and stictoporellids, the wall structures were inadequately described although various morphological features such as median tubuli, hemisepta, acanthopore-like structures, vesicular tissue, and diaphragms were observed (Ulrich, 1890b, p. 298-322 and p. 344-349).

Ulrich's (1895) monograph on the Paleozoic Bryozoa from Minnesota contains what is probably the single most important work on the family Rhinidictyidae and the genus *Stictoporella.* In this work he described in considerable detail the zoarial structures in *Rhinidictya* (junior synonym of *Stictopora), Eurydictya, Phyllodictya,* and *Pachydictya* (Ulrich, 1895, p. 124-161). Ulrich's (1895) thoughts concerning the classification of the stictoporids, and especially the pachydictyids, although vague, still have an important bearing on understanding these generic groups. On the basis of his work the families Ptilodictyidae, Rhinidictyidae, and Stictoporellidae (Nickles and Bassler, 1900; Bassler; 1953) have remained essentially unchanged to the present. External zoarial variations were used as a fundamental criterion for the family grouping of the genera although the internal structures were relatively well known even at that time.

In 1960, Mrs. Ross (nee Phillips) recognized the need for revision of the generic and suprageneric classification of some bryozoan groups was long overdue and inaugurated a series of publications dealing with some of the bifoliate cryptostome genera (Phillips, 1960, Ross, 1960a,b,c, 1961, 1963, 1964a,b).

Ross (Phillips, 1960) established three informal taxonomic categories: stictoporid, pachydictyid, and escharoporid. These categories were distinguished from each other by distinctive laminate zooecial wall structures, mode of growth of the zooecium from the mesothecal plane, and occurrence of mesopores, acanthopores, and transverse structures in the zooecial cavities. At a later date Ross (1964b) established the escharoporid, pachydictyid, and stictoporid lineages.

Her escharoporid lineage (Ross, 1964b, p. 941, table 2) was characterized by having several zoarial forms, imperforate mesotheca, and escharoporid wall structure. In the same publication Ross (1964b) described the previously established stictoporid group (Phillips 1960, pl. 1, figs. 3, 5, 9, 11; Ross, 1963, pl. 7, figs. 1, 2, 4-8, 11) as a lineage (Ross, 1964b, p. 935, 943, fig. 8D) with escharoporid wall structure (Phillips, 1960, pl. 6, figs. 1-11; Ross, 1963, pl. 7, figs. 3, 9, 10; 1964a, pl. 1, figs. 1-9, especially figs. 3, 9; 1964b, p. 935, 942, fig. 8A), but with perforate mesotheca. Furthermore, Ross described pachydictyid wall structure (1964b figs. 8B, C) as a modification of escharoporid wall structure (Ross, 1964b, fig. 8A) and included the pachydictyid group in the pachydictyid lineage (1964b, p. 942).

STRUCTURES IN THE RHINIDICTYIDAE, STICTOPORELLIDAE, AND PTILODICTYIDAE

A study of the Middle Ordovician forms of the stictoporids, stictoporellids, escharoporids, and pachydictyids indicates that there are several problems in the interpretation of the zoarial or zooecial wall structures. Because of these problems in interpretation, the generic redefinitions of Ross (Phillips, 1960, Ross 1960a, b, c; 1961; 1963; 1964a, b) are not readily applicable to the Middle Ordovician forms from the Decorah Shale of Minnesota. Consequently, the genera do not fit into the suprageneric categories as established by Ross.

Because of these differences, I have studied the type suites of the genera and species found in the Decorah Shale and those of the other related species that are available in the U. S. National Museum. In addition a partial survey of published material was made in order to obtain an approximation of the number of valid species described. The material published in the Russian literature was examined in part, but could not be evaluated properly without examination of at least some of the thin sections that were used to figure the forms.

To the genus *Stictopora* there have been assigned about 50 species as indicated in the literature (Ross, 1966, p. 1400). Of these, Ross redescribed the type species *S. fenestrata* Hall (Phillips, 1960, p. 7; 1963, p. 591), another species (Ross, 1964a, p. 24, 25), and erected one new species (Ross, 1964a, p. 26). On file at the USNM are two or more thin sections of varying quality from 14 species of which *S. nicholsoni* Ulrich has also been redescribed by Ross (Phillips, 1960, p. 9). Of the remaining 13 species five are figured and described and one species is newly erected here in. The thin sections of the remaining seven species have been used for study, but the species are not discussed at this time.

In addition, thin sections of two species assigned to *Phyllodictya* Ulrich and three species of *Eurydictya* Ulrich have been studied because these two genera have many morphological features in common with those of the species assigned to *Stictopora*. However, *Phyllodictya* and *Eurydictya* are not discussed at this time.

A survey of the literature indicates that there are about 60 species that have been assigned to *Pachydictya* Ulrich. Of these about 30 species are reported in publications in English, mostly in North American literature. On file at the USNM are thin sections of 25 species of *Pachydictya* and for 17 of these there are three or more thin sections of varying quality. Of these 17 species, four have been described and figured in detail by Ross (Phillips, 1960; Ross, 1961, 1963), and five others are described and figured here in. In addition, two genera *Eopachydictya* Ross (1963, p. 591) with one species, and *Trigonodictya* Ulrich (1895, p. 160) appear to be closely related to *Pachydictya*. The proper taxonomic position of *Trigonodictya* (see also Coryell, 1921, p. 303; Phillips, 1960, p. 16) must still be evaluated when additional material becomes available.

To *Escharopora* there have been assigned at least 11 species. Ross (Phillips, 1960, p. 17; Ross, 1964a, p. 17) redescribed the type species *E. recta* Hall. One species is redescribed in this paper. Thin sections for the remaining nine species are available at the USNM and have been used in my study of escharoporid wall structure.

Based on the literature, about nine species have been assigned to *Graptodictya* Ulrich and *Arthropora* Ulrich. Ross (Phillips, 1960, p. 19) redescribed the type species of *Graptodictya, G. perelegans* (Ulrich). At a later date Ross (1960, p. 859) re-evaluated the type species of *Arthropora, A. shafferi,* (Meek), and assigned *A. shafferi* to *Graptodictya.* The thin sections of the remaining seven species are on the file at the USNM and have been used in the study of wall structure. However, only one species, *Graptodictya simplex* (Ulrich) is discussed and described in this paper.

In the literature eight species have been assigned to *Stictoporella* Ulrich. Ross (Phillips, 1960, p. 23) redescribed the type species, *S. interstincta* Ulrich and also *S. excellens* (Ross, 1960c, p. 1072). Three species are redescribed in this paper and the thin sections of another species, on file at the USNM, have been used in this study.

This study is by no means complete and the writer may have overlooked some European, especially Russian publications. No attempt has been made here to search for additional sectioned or unsectioned material of the known species at various North American universities and museums, except at the Department of Geology and Geophysics, University of Minnesota and at the U.S. National Museum. However, the writer feels that he has examined a sufficient amount of material to adequately arrange morphologically comparable species into genera and arrange the genera in tentative informal suprageneric groups.

The names that were established by Ross (Phillips, 1960) for these morphologic groups have been retained in the following discussion as far as possible. However, the morphological features of the walls are differently interpreted for recognizing these groups, except for those in the escharoporids. Because of the revised interpretation of the wall structures it was necessary to erect two new genera.

The name *Astreptodictya* is introduced for the pachydictyid forms of Ross that have the zoarial structure observed in *Pachydictya acuta* (Hall) and this species is the type species of the genus. Another name, *Athrophragma,* is introduced for those forms that have the structure of *Pachydictya foliata* Ulrich which is the type species of this second new genus.

The name "stictoporellid" is used tentatively for purposes of discussing the structure observed in the three *Stictoporella* species of the Decorah Shale. The taxonomic position of *Stictoporella* is reviewed briefly on page 64.

The concept of boundary zones is emphasized in grouping the genera. Ulrich recognized that some bryozoans secrete zoaria of laminated calcite (1890b, p. 310; 1895, p. 126). He also noted that the laminate zooecial walls contain structures that appear to be linelike; these are dark zones similar to the acanthopore-like features (Ulrich, 1895, p. 139, 143) illustrated by Ulrich (1895, pl. 5, figs. 18, 24, 25; pl. 6, figs. 3, 5, 6, 7a, 9, 11, 20; pl. 9, figs. 8, 10, 12). However, he did not recognize the dark zones as the boundaries of zooecia or ranges.

These boundaries (fig. 4) when viewed in three dimensions appear to separate the laminate zoaria into well-defined segments. Some of the boundaries are associated with the individual zooecia but others are zoarial features. These two kinds of the boundaries taken together indicate a pattern of zoarial secretion which is common to the genera in one group, as in the stictoporids (fig. 4) or to a number of species in one genus, as in *Astreptodictya* (fig. 8).

Stictoporid Structure

Present interpretation. The zooecial wall structure in the stictoporids is characterized by two boundary zones, one of which demarcates the zooecia and the other their ranges. Both boundaries are similar in their structure but differ in their relationships to the zooecia of a zoarium. One of these boundaries is located between the longitudinally adjacent zooecia and it is here defined as the zooecial boundary (figs. 3 and 4). The other boundary separates the laterally adjacent zooecia. However, this boundary in general is continuous throughout the entire length of a zoarial branch or a lobelike expansion between the areas of bifurcation, or it may diverge and curve into the adjoining branches. Furthermore, this boundary demarcates the zooecial ranges and therefore it is here defined as the range boundary (figs. 3 and 4). These two sets of boundaries form a pattern that characterizes the genera of the stictoporid group.

The zooecial boundary. Boardman (1960, p. 28), in a discussion of the wall structures in some Devonian trepostomes, suggested that a polypide contributes the inner half (relative to the polypide) of the deposits in the wall surrounding the polypide and the adjacent polypide contributes the material for the other half of the wall. The extent of the deposits formed by one polypide is indicated by the zooecial boundary.

In *Stictopora* the laminae are poorly defined in the thin zooecial walls of the endozone. Junctions between the zooecial walls and the mesotheca appear as hairlike, somewhat jagged, dark zones along which the zooecial wall laminae intertongue or adjoin with the mesothecal laminae (pl. 3, fig. 4; pl. 4, fig. 3; pl. 6, fig. 1b).

The zooecial boundary between adjacent walls in *Stictopora* is poorly marked in the endozone (pl. 2, fig. 2b; pl. 5, fig. 1b; pl. 7, figs. 5b, 6) but is very distinct in the exozone as seen in longitudinal view (pl. 1, fig. 4c; pl. 2, fig. 3c; pl. 4, fig. 2d; pl. 5, fig. 1a). This boundary is shown diagrammatically in figures 3 and 4.

In *Stictopora* the zooecial boundary begins at the mesotheca, as seen in longitudinal view, continues through the endozone and is well marked in the exozone. Along this zone the laminae which are deposited by the epithelium of the adjacent polypides either abut or adjoin. Why the boundary zone is more distinct between the zooecial walls in the exozone than in the endozone. is not clear.

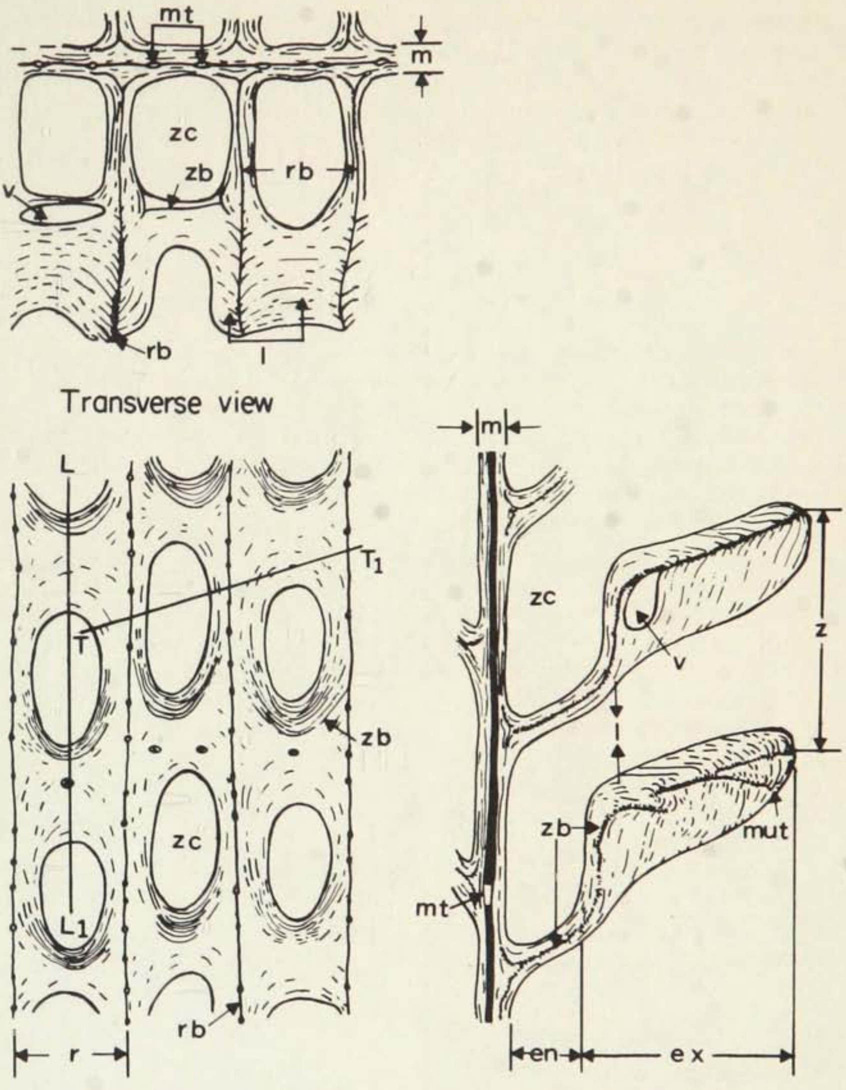

Figure 3 – Idealized diagrams of *Stictopora* Hall: en, endozone; ex, exozone; l, laminae; m, mesotheca; mt, median tubule; mut, mural tubule; r, range; rb, range boundary; v, vesicular tissue; z, zooecium; zb, zooecial boundary; zc, zooecial cavity; L-L_1, line showing the approximate position of the plane of the longitudinal section in the tangential view; T-T_1, line showing the approximate position of the plane of the transverse section in the tangential view.

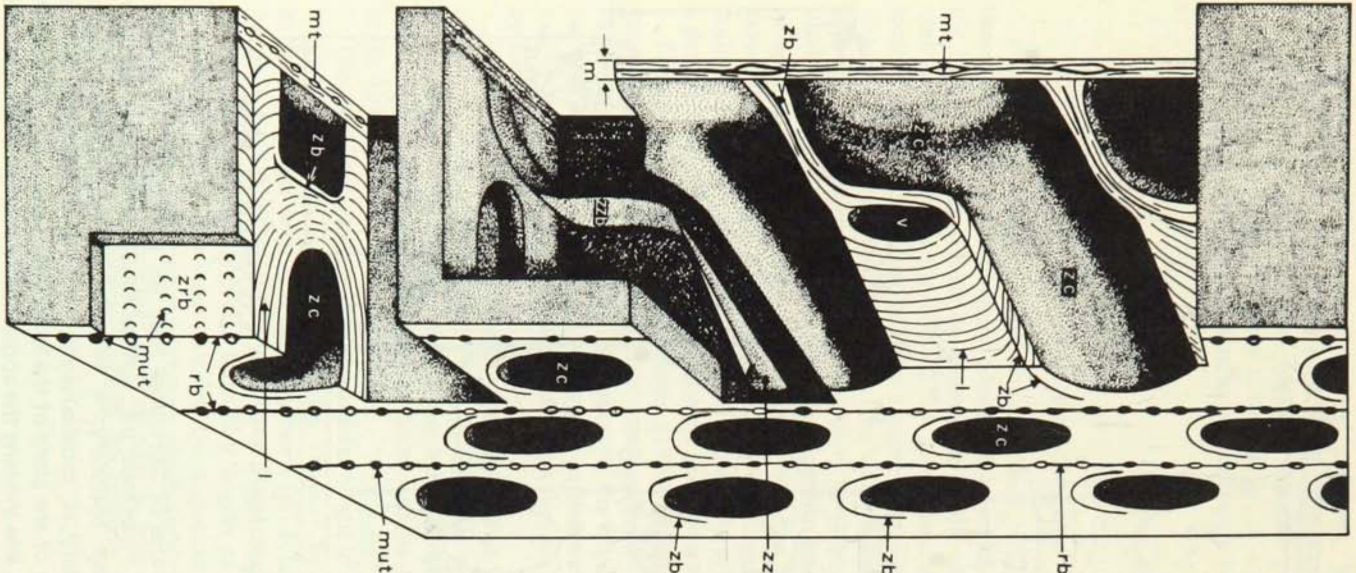

Figure 4 – Idealized drawing of *Stictopora* Hall. l, laminae; m, mesotheca; mt, median tubule; mut, mural tubule; rb, range boundary; v, vesicular tissue; zb, zooecial boundary; zc, zooecial cavity; zrb, part of the dark zone that is described by the range boundary (rb). Some mural tubuli (mut) begin within this zone in the inner exozone; zzb, slightly curved zone that is described by the zooecial boundary (zb). In this part of the drawing the laminate walls of the adjacent zooecia are removed in order to indicate the approximate position and the three dimensional aspect of the zone that is described by the zooecial boundary (zb). The zooecial and the range boundaries, zb and rb respectively, appear as dark, linelike zones in the edge views in the thin sections.

As indicated in the longitudinal section (fig. 3), the zooecial wall laminae approximately parallel the boundary zone in the endozone. It is postulated that the calcite secreted by the epithelium of the adjoining zooecia form laminae which are in close contact, like cards in a deck, and approximately parallel the zooecial boundary for some distance before trending toward it. Therefore it seems likely that the boundary zones in the endozone are hardly more visible than the contact zones between adjacent laminae. At a later growth stage, for example, during the formation of the exozone, the calcite crystals in the epithelium apparently are reoriented as to form the curved laminae. The tips of the distal edges of these laminae abut or adjoin and thus form the more distinct zooecial boundary zone in the exozone.

The zooecial boundaries in *Stictopora* subdivide the walls between the longitudinally adjacent cavities within a range in two unequal parts as observed in the lonitudinal (fig. 3, pl. 1, fig. 4c; pl. 2, fig. 3c; pl. 6, fig. 1a) and tangential views (fig. 3). In Stictopora in particular and in the *stictoporids* in general, the zooids contribute more material to the distal than to the proximal zooecial wall. Thus the zooecial boundaries are located approximately in the upper third of the walls in the exozone between the longitudinally adjacent zooecial cavities.

The laminae are broadly curved in the distal and proximal zooecial walls. Generally the laminae trend obliquely to the growth direction of the zooecia for some distance before curving into the zooecial boundaries. The zooecial boundary zones are well defined by relatively straight lines that are much darker than the adjoining wall laminae. Ulrich (1895, p. 139, 143; pl. 6, figs. 3, 5, 8, 11, 12, 15, 17, 20) noted the presence of the zones in the longitudinal views, but did not recognize them in the tangential views.

The same boundary zone is not readily visible in tangential views for the following reason: if the laminae terminate, adjoin or bend sharply and are parallel to the plane of the tangential section only at the junction of the zooecia, the zooecial boundary zones appear in the tangential views as lines or narrow light-shaded hyaline areas differentiated from the typical laminated structure on either side of the boundary (Boardman, 1960, p. 28).

In *Stictopora* the zooecial wall laminae are characteristically indistinct and the laminae of the adjacent zooecia curve broadly toward each other. Since the zooecial walls form an acute angle of 40° to 60° with the zoarial surface, the thin section plane cuts the zooecial wall laminae obliquely and their adjoining of abutting junction. Therefore in tangential views the zooecial walls commonly do not show their laminate structure nor the boundary zone between the longitudinal portions of adjacent zooecia. Occasionally, however, the boundary zones might appear as crescent-shaped areas (pl. 2, fig. 3a; pl. 4, fig. 1a; pl. 5, fig. 2b; pl. 6, fig. 1c) proximal of each zooecial cavity. This area merges imperceptibly with the lateral walls on each side of the zooecial cavities but does not enclose them.

The zooecial boundary, as seen in the longitudinal views, was not recognized as such in the restudy of the *Stictopora* by Ross (Phillips, 1960, p. 7). It appears, however, that this boundary has been commonly regarded as an acanthopore-like feature (Phillips, 1960, text-fig. 2; p. 5). This is improbable for the following reasons:

1. The zooecial boundary is observable, depending on the preservation, in the

upper third of each wall between the longitudinally adjacent zooecial cavities and it approximately parallels the zooecial cavity. Any longitudinal thin section plane is only approximately perpendicular to the zoarial surface, and this position will be rarely maintained in a single longitudinal range of zooecial cavities and the adjoining proximal and distal walls for a long distance. Because the thin section plane cuts obliquely, however slightly, across a zooecial range, the plane will only rarely pass through an acanthopore having a diameter of 0.01 mm or even less in the longitudinal walls within a zooecial range at exactly the same position.

2. In addition, the tangential views show that there are only a few acanthopores which are spaced randomly in the walls within a range, and they are not aligned longitudinally.
3. Even if the acanthopores were aligned in perfect longitudinal rows distally and proximally of each zooecial cavity, it would be practically impossible to maintain the plane of a thin section in such a single row of perfectly aligned acanthopores, 0.01 mm or even less in diameter, for a long distance.

This means that the dark boundary zone present in the upper third of the longitudinally adjacent walls is really an edge view of a curving zone or surface, convex proximally, along which the wall laminae of the adjacent zooecial walls adjoin (fig. 4, zzb).

The mural tubuli (acanthopores of authors) appear to arise from these boundary zones or originate close to them in the inner exozone and reach the zoarial surface approximately at right angles to it, whereas the zooecial boundaries, it is recalled, parallel the zooecial cavities (pl. 6, fig. 1a). Because the mural tubuli are at right angles to the zoarial surface, they are observed in the tangential views as small, circular dots in the distal zooecial walls.

In a transverse view showing the walls between the longitudinally adjacent zooecial cavities, the same boundary is not generally visible because the thin section cuts approximately parallel to the plane of it. However, this boundary is observable in those parts of the transverse view where the plane of the thin section passes through about the middle of the zooecial bends and at right angles to them near the base of the exozone (figs. 3, 4; pl. 3, fig. 4). In these transverse views the boundary appears again as a dark, narrow zone that approximately parallels the mesotheca and is at right angles to the range boundary (discussed below). Just before reaching it, the boundary turns about 90° or more and now trends obliquely toward the zoarial surface before passing out of the plane of the thin section cut (pl. 3, fig. 4; pl. 5, fig. 2a; pl. 8, fig. 2a). These dark, hairlike zones are different edge views of the same curving boundary zone that appears in the edge view in the longitudinal views.

The range boundary. Along the middle of the laterally adjacent zooecial walls, as seen in transverse and tangential views another dark, narrow zone extends through the entire depth of the endozone and the exozone at right angles to the zoarial surface. This zone is here defined as the range boundary. The range boundary extends longitudinally throughout a zoarial branch or a lobe between the areas of bifurcation. It may divide dichotomously or curve through the areas of bifurcation into the adjoining branch.

The range boundaries begin at the mesotheca where they intertongue with the mesothecal laminae (pl. 2, figs. 2c, 3b; pl. 3, fig. 4; pl. 5, fig. 2a; pl. 6, fig. 1b). These boundaries are relatively indistinct in the endozone where the laminae in the adjacent zooecial walls apparently are parallel to them, but they become more prominent in the exozone. In the exozone the laminae of the adjacent walls curve toward the range boundary, and they abut or adjoin along it.

In the shallow tangential views the range boundaries appear as distinct, linear, dark linelike zones separating the laterally adjacent, longitudinally aligned zooecia. The range boundaries commonly bear closely spaced mural tubuli in rows (pl. 1, fig. 4d; pl. 2, figs. 2a, 3a; pl. 3, fig. 3a; pl. 5, fig. 2b). The boundaries may widen slightly in the inner exozone where the mural tubuli apparently start to develop.

The laminated nature of the laterally adjacent walls is best observed in the transverse view, because in this view the thin section plane passes through the structure at right angles to it.

Structure of the mesotheca. The laminated structure of the mesotheca is best seen in transverse (pl. 1, fig. 4a; pl. 3, fig. 4; pl. 5, fig. 2a) and longitudinal views (pl. 2, figs. 3c, 3d; pl. 4, fig. 3; pl. 5, figs. 1a, 2c), where the plane of the thin section cuts the skeletal material at right angles to the plane of the laminae. It is also indicated diagramatically in figures 3 and 4. A dark zone along the median part of the mesotheca contains the median tubuli. In the transverse and the longitudinal thin sections this median zone appears in the side views as a dark line. Apparently the dark median zone results from very many closely spaced parallel laminae coming into close contact at the beginning of the secretion of the mesotheca.

The median tubuli in the dark zone have distinct cores of translucent calcite and appear generally ovate in cross section as seen in the transverse views (pl. 3, fig. 4; pl. 8, fig. 2a). In longitudinal view these translucent cores of the median tubuli are observed when the thin section is in the plane of a tubule, and the dark zone is visible when the plane of the section passes through the space between two adjacent median tubuli (pl. 1, fig. 8). Because the interval between the two adjacent median tubuli is larger than the diameter of a tubule, the dark zone is more prominent (pl. 2, fig. 3e) than the segments of the translucent cores in longitudinal views. The translucent cores, Ulrich's (1895, p. 126, 150) parallel and colorless lines, appear structureless and with poorly defined walls (pl. 3, fig. 3a). In those tangential views where the thin section plane is about parallel to the mesotheca in the zoarial margins, the median tubuli appear to curve or diverge slightly within the dark median zone toward to the zoarial edges (pl. 3, fig. 3a) and probably open to the exterior along the edges. These tubuli can be observed occasionally as oblique striae on the surface of the zoarial margins.

Structure of the mural tubuli. The acanthopore-like features in *Stictopora* and in related genera begin within the inner region of the exozone. They are not observed to a rise from the mesotheca. Herein these features are described as the mural tubuli.

Although in transverse views the mural tubuli are difficult to discern within the range boundary, they are observable in longitudinal views, where the thin section cuts within the zone of the range boundary (pl. 2, fig. 3d; pl. 4, fig. 3; pl. 5, fig. 2c; pl. 6, fig. 1d). The mural tubuli are relatively short, solid, rodlike structures at right angles to the zoarial surfaces at terminal portions. They are laminate and appear as small bulges or flexures in the wall laminae, convex to the zoarial surface. The laminae in these bulges appear to be more closely spaced than elsewhere. In general, no translucent cores, like those in the median tubuli, have been observed in the mural tubuli. In a shallow tangential section, the distal ends of the mural tubuli appear dotlike and are enclosed occasionally by thin dark rims which probably indicate sharp bends in the otherwise broadly curving zooecial wall laminae (pl. 1, fig. 7; pl. 2, fig. 3a; pl. 5, fig. 2b; pl. 6, fig. 1c).

The mural tubuli in the zooecial walls between the longitudinally adjacent cavities are generally not as common as those within the range boundaries (pl. 1, fig. 4d; pl. 2, fig. 3a; pl. 5, fig. 2b; pl. 6, fig. 1c; pl. 9, figs. 1d, 1e). They are structurally the same and are generally limited to the distal zooecial wall. They appear to rise from the zooecial boundary zones and reach the zoarial surface at right angles to it, whereas the zooecial boundaries parallel the zooecial cavities (pl. 6, fig. 1a; pl. 8, fig. 1b). In well-preserved specimens the mural tubuli of the range boundaries project as small, short solid spines above the zoarial surface (pl. 4, fig. 3).

Ulrich (1895, p. 126, 134, 149, 150, 161; pl. 11, fig. 12) assumed, although he could not demonstrate it adequately that the median tubuli or the horizontal tubuli (these terms were interchangeably used) are connected with the "minute tubes" (mural tubuli) in the zooecial walls.

According to Ross (Phillips, 1960, p. 5), the median tubuli form connections with the acanthopores (mural tubuli) of the zooecial walls in the exozone:

> "From the mesothecal plane they (median tubuli) extend outward through the zooecial walls to the periphery, and maintain growth approximately parallel to the direction of growth of the zooecia (pl. 5, figs. 2, 3)."

As interpreted in this paper, the mural tubuli differ from the median tubuli (p. 17) in structure. Furthermore, they do not appear to be interconnected, because the mesothecal laminae which form the basal zooecial walls in the endozone do not appear pierced or otherwise disturbed in longitudinal and transverse views. There seems to be little evidence of the mural tubuli or other morphological features similar to them in deep tangential views, except for the zooecial or range boundaries. The mural tubuli originate in the inner exozone within the zones of the range boundaries or those of the zooecia. The median tubuli, it is recalled, are contained within the dark zone along the median of the mesotheca. There is no evidence that the median tubuli breach the mesotheca at the base of the zooecia.

Diaphragms, vesicular tissue, superior hemisepta. Diaphragms (pl. 2, figs. 3c-3e) are thin, planar or slightly curved skeletal partitions that cross the zooecial cavities. They appear to consist of fine calcite laminae. In *Stictopora* and in the other genera of the stictoporid group the diaphragms abut or adjoin with the zooecial walls.

In some species there are irregular cavities (pl. 5; figs. 1a, 2c) in the zooecial walls near the base of the exozone (interstitial tissue, tabulate interspaces of authors) that may be partitioned occasionally by diaphragms similar to those in the zooecial cavities. This type of structure is here described as vesicular tissue.

Superior hemisepta are the laminate plates or hooklike extensions of the proximal zooecial walls that are observed in some species among the stictoporids. They extend about half way into the zooecial cavities of the endozone (pl. 3, fig. 3c).

Stictoporid group. In addition to *Stictopora,* the stictoporid structure is observed also in *Phyllodictya* and probably *Eurydictya* Ulrich. At present these three genera make up the stictoporid group. See also Phillips, 1960, figure 2, page 6, and Ross, 1964b, page 942.

"Stictoporellid" Structure

Present interpretation. Those Decorah species that are assigned tentatively to the genus *Stictoporella* Ulrich (see p.64) show another type of zoarial structure. This type of structure is here named "stictoporellid". The structure in the Decorah "stictoporellids" differs from that found in the type species of the genus, *S. interstincta* Ulrich 1882. Ross (Phillips, 1960, p. 23, pl. 10, figs. 1-7) redescribed *S. interstincta* and included it in the escharoporid group whose structure is reviewed briefly on p. 21.

In the stictoporids discussed in the preceding section the laminae of the zooecial walls were poorly defined. The laminae in the "stictoporellids" are much more distinct and are well defined in the exozone where they are accentuated commonly by dark streaks. These streaks appear to be more abundant in the areas adjacent to the zooecial cavities (pl. 16, figs. 1c, le). The laminae arch broadly away from the cavities toward the middle of the adjacent wall and form distinct boundaries in the exozone (pl. 16, figs. 1b, 1c).

At the zooecial boundaries the laminae of the adjacent walls adjoin or about at varying angles of less than 90°. The dark boundaries between the adjacent zooecia and the mesopores are readily discernible in all views showing the internal structure (fig. 5, pls. 15, 16) of the exozone, because these dark zones are the edge views of those surfaces along which the laminae of the adjacent zooecia or mesopores abut. However, if the plane of the thin section parallels or is slightly oblique to the laminae and the boundaries, they may not be observable. In the endozone the boundaries between the adjacent zooecia appear to be intermittent and they are less distinct. Likewise, the laminae appear to be poorly defined in the endozone.

The walls of the mesopores and those of the zooecia and the boundaries between the mesopores and the zooecia are constructed similarly. No diaphragms have been observed in the mesopores. However, the mesopores are filled commonly by the laminate skeletal material (pl. 16, figs. 1a, 1b, 1e) or they are closed near the zoarial surface (pl. 12, fig. 3).

The laminae in the mesotheca are poorly defined. Along the middle of the mesotheca is a dark, thin, commonly intermittent zone (pl. 15, fig. 3) along which the laminae of the opposing sides of the mesotheca adjoin. No median tubuli have been observed within this zone in the stictoporellids. Unlike the escharoporids, the mesotheca of "stictoporellids" does not thicken appreciably in the marginal areas of the zoaria.

In comparing "stictoporellids" with stictoporids the following differences are indicated by the boundaries in the zoaria. In "stictoporellid" species the zooecia are randomly distributed in the zoaria, that is, they are not aligned in distinct linear ranges as are those in the stictoporids. Consequently, there are no range boundaries in the "stictoporellids."

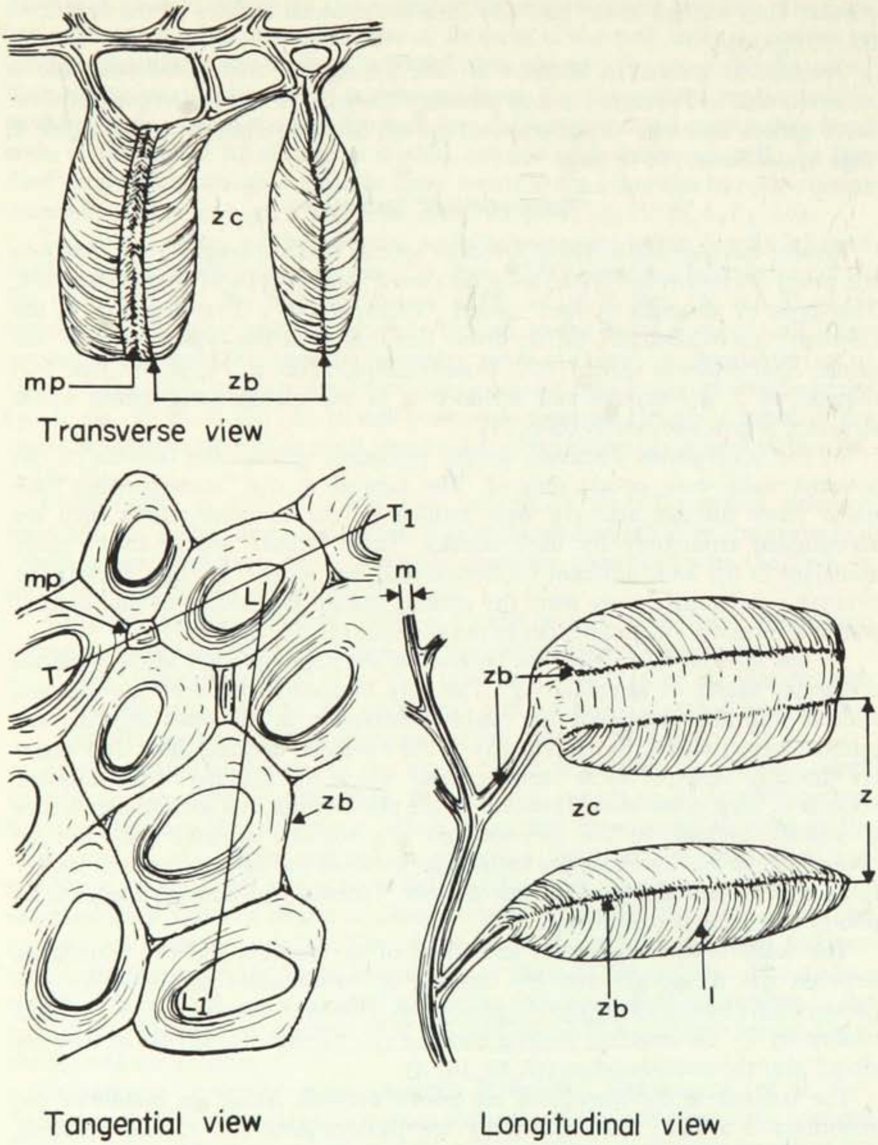

Figure 5 – Idealized diagrams of a "stictoporellid." l, laminae; m, mesotheca; mp, mesopore; z, zooecium; zb, zooecial boundary; zc, zooecial cavity; L-L_1, line showing the approximate position of the plane of the longitudinal section in the tagential view; T-T_1, line showing the approximate position of the plane of the transverse section in the tangential view.

The zooecial boundaries divide the walls between the adjacent cavities in two parts that are approximately equal in the "stictoporellids," but not in the stictoporids. Thus, each polypide of a "stictoporellid" secretes on each side of itself about an equal quantity of calcite during the formation of the walls. Furthermore, the zooecia appear to be approximately hexagonal, or polygonal as demarcated by the zooecial boundaries. Each boundary segment is relatively straight and it is shared by two adjacent zooecia or a zooecium and a mesopore.

In the stictoporids there are the range boundaries (p.16) that demarcate the ranges while separating the laterally adjacent zooecia, and the zooecial boundaries which are between the longitudinally adjacent zooecia within the ranges. The former are absent in the "stictoporellids" but the latter are similar to a segment of the polygonal boundary in the "stictoporellids" (fig. 5).

Perry (1962) recognized the boundary zones in *Stictoporella frondifera* Ulrich. He observed (p. 33) that:

> "The divisional line between adjoining zooecia may be observed throughout the entire tangential section of some specimens, as is depicted by Ulrich (1895, pl. 11, fig. 16), but in other specimens this line is prominent locally although obscure or not observed in other areas. I felt that the prominence of development of this divisional line may be related to depth of sectioning; tangential sections, however, prepared at different levels or depth within the zoarium, indicated such is not the case."

Escharoporid Structure

The zoaria of the forms discussed in the preceding sections have shown well-developed boundary zones demarcating the laminate structural segments.

In another large group of the cryptostome bifoliates the zooecial walls are constructed by apparently continuous laminae between the adjacent cavities. Furthermore, the boundary zones in the zooecial walls have not been observed in the exozones of the forms to be discussed below. The representatives of this group in the Decorah Shale are the species of *Escharopora* and *Graptodictya.*

The zooecial wall structures in *Escharopora* and *Graptodictya* have been redescribed by Ross (Phillips, 1960, Ross, 1960a, b, and 1964b), who named it escharoporid structure (Phillips, 1960). In general the agreement is good between the zooecial wall structures as described by her from the Middle Ordovician of the northeastern regions of North America and those observed in the forms from the Decorah Shale. In order to compare escharoporid structure with that of the other bifoliate genera it is described in the succeeding paragraphs.

Present interpretation. The zooecial wall laminae are continuous from cavity to cavity and no boundary zones are observed in the exozone of *Escharopora.* However, a thin, dark boundarylike zone appears to separate the adjacent zooecial walls in the endozone (pl. 17, figs. 3a, 3b). This zone begins at the mesotheca and merges with zooecial wall laminae at the base of the exozone.

As shown in the longitudinal section (fig. 6) the laminae forming the zooecial walls in the endozone may not be as distinct as those in the exozone. In the exozone the wall laminae trend for a short distance along a zooecial cavity and then turn in broad curves toward the adjacent cavity. These laminae are relatively long and are approximately transverse to the longitudinal direction of the zooecia through the greater part of their length. In longitudinal view zooecial laminae are not so well defined as in other views because the plane of the thin section is approximately parallel to the laminae (pl. 17, figs. 3c, 3d).

The sinuous configuration of the wall laminae, approximately M-shaped, is most observable in thin sections showing the transverse views (pl. 17, figs. 3a, 3b; pl. 18, figs. 1, 2, 5a) of the exozone. As the laminae curve broadly from one cavity to the next, they form rounded crests adjacent to each cavity and convex to the zoarial surface. Another crest is formed at about the middle of the zooecial wall between the adjacent caivities (fig. 6). This crest is convex to the endozone. Dark material is commonly concentrated among the curving laminae. Externally the crests of laminae may make ridges on the zoarial surfaces and they usually have been described as striae. In the tangential views where the plane of the thin section is approximately parallel to the laminae that form the rounded crests, the apexes of these crests appear as sinuous bandlike zones which may be somewhat lighter in color than the other areas of the walls (pl. 17, figs. 1a, 1b). These bandlike zones that enclose the zooecial cavities have been referred to as peristomes (Phillips, 1960, p. 18). The bands indicate the positions of the relatively broad apexes of the curved laminae.

In general, the curves of the sinuous laminae in *Escharopora* have relatively broad crests. However, in *Graptodictya* the curves of the laminae appear to be more V-shaped with relatively sharp crests (pl. 18, figs. 5a, 5b). In addition, there is a third V-shaped crest introduced in the zooecial walls between the longitudinally adjacent cavities (pl. 18, fig. 5a). Externally the crests of the laminae appear, like in *Escharopora,* as slightly raised ridges (peristomes, or striae of authors) around and between the zooecial cavities, thus giving the zoarial surface an ornate appearance. The so-called pustules are probably due to the irregularities in the crests of the laminae or they might be caused by the thin-sectioning process during which the apexes of the crests have been cut off.

The laminated structure of the mesotheca is best seen in transverse views (pl. 17, fig. 3b; pl. 18, fig. 1). Along the median of the mesotheca is a thin, intermittent zone in the midpart of a zoarium. In the undifferentiated marginal areas of the zoarium this zone merges with the broadly curved laminae. In *Graptodictya* the mesotheca is commonly zigzag in shape (pl. 18, fig. 5a).

Superior hemisepta are present (pl. 18, fig. 5b), mesopores are nontabulate and diaphragms are rare in the zoecial cavities. No mesopores have been observed in *Graptodictya.* Median tubuli and mural tubuli are absent in the escharoporids.

Escharoporid group. In addition to *Escharopora* Hall and *Graptodictya* Ulrich, Ross includes in this group the following genera: *Ptilodictya* Lonsdale, *Clathropora* Hall, *Phaenopora* Hall, *Phaenoporella* Nekhoroshev, *Chazydictya* Ross, *Championodictya* Ross, *Oanduella* Männil, and *Stictoporella interstincta* Ulrich (Phillips, 1960, p. 17, 23; Ross, 1960a, b; 1960c, p. 1963; 1963, p. 587; 1964b, p. 941).

The writer excludes from this group the genus *Stictopora* Hall and the three *Stictoporella* species described here in (but see Phillips, 1960, p. 7, 23: Ross, 1963c, p. 1072; 1964b, p. 942).

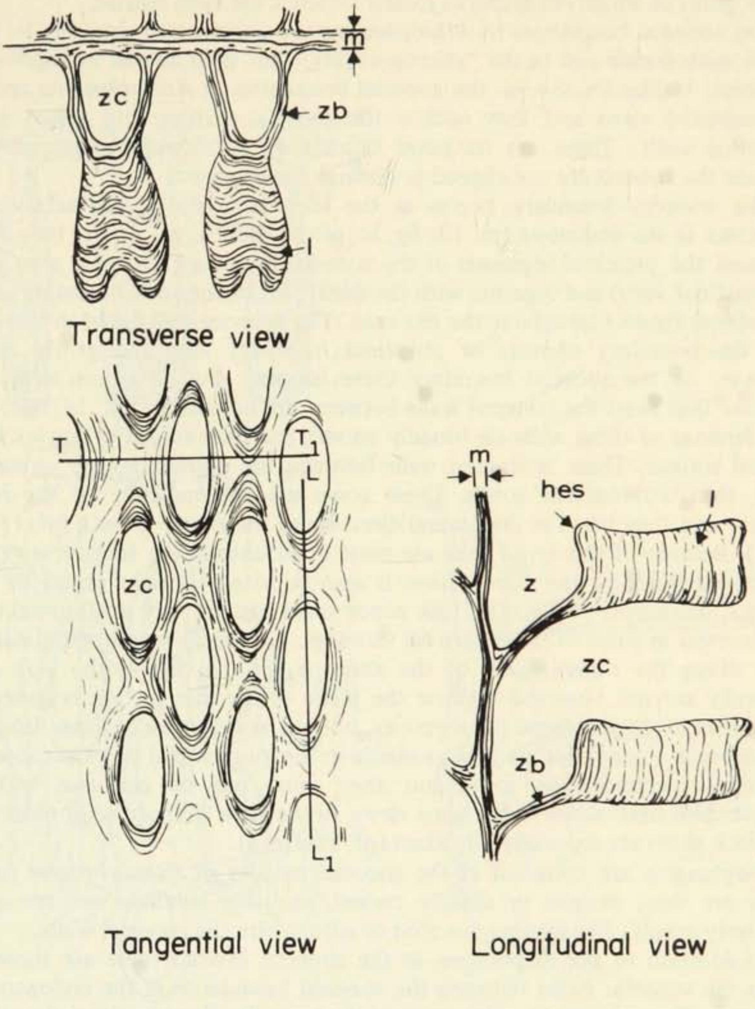

Figure 6 – Idealized diagrams of *Escharopora* Hall. hes, superior hemiseptum; l, laminae; m, mesotheca; zb, zooecial boundary; zc, zooecial cavity; $L\text{-}L_1$, line showing the approximate position of the plane of the longitudinal section in the tangential view; $T\text{-}T_1$, line showing the approximate position of the plane of the transverse section in the tangential view.

Athrophragmid Structure

A fourth type of the zoarial structure (fig. 7) occurs in *Athrophragma,* a new genus of which *Pachydictya foliata* Ulrich is the type species.

The zooecial boundaries in *Athrophragma* are constructed similarly to those in the stictoporids and in the "stictoporellids," but their zoarial arrangement is different. Unlike *Stictopora* the zooecial boundaries in *Athrophragma* are oval in tangential views and they enclose the zooecial cavities with a part of the adjoining walls. There are no range boundaries in *Athrophragma,* probably because the zooecia are not aligned in distinct linear ranges.

The zooecial boundary begins at the mesotheca and is characteristically indistinct in the endozone (pl. 13, fig. lc; pl. 14, figs. 4, 6). At the base of the exozone the proximal segments of the zooecial boundary curve (as seen in the longitudinal view) and together with the distal part of the same boundary form a cylindrical figure throughout the exozone. The zooecial wall between the cavity and the boundary consists of indistinct, relatively long and gently curving laminae. At the zooecial boundary these laminae abut or adjoin with those laminae that form the zooecial walls between the boundaries (pl. 14, figs. 1, 6). The laminae of these walls are broadly curved, and they are about convex to the zoarial surface. These laminated walls between the boundaries are crossed by dark, thin, intermittent zones. These zones are perpendicular to the zoarial surface and they trend in the general direction of the zoarial growth (pl. 13, figs. la, 2). Because of this trend they are most observable in the transverse views in which the plane of the thin section is approximately at right angles to them (pl. 13, fig. lb; pl. 14, fig. 3). These zones might contain very small mural tubuli as observed in some of the tangential views (pl. 13, fig. 2). In a longitudinal view that shows the outer region of the exozone (pl. 14, fig. 4) the dark zones generally are not observed because the plane of the thin section is commonly parallel or slightly oblique to the zones, but not in the plane of them. However, the zooecial boundaries are always visible in the longitudinal views because they describe a cylinder-like form, but they must not be confused with the intermittent dark zones in the same views. In the areas of maculae or monticules the dark zones are especially abundant (pl. 13, fig. 2).

Diaphragms are common in the zooecial cavities of *Athrophragma foliata.* They are thin, straight or slightly curved, probably laminate and are spaced relatively evenly. The diaphragms abut or adjoin with the zooecial walls.

In addition to the diaphragms in the zooecial cavities there are those that form the vesicular tissue between the zooecial boundaries in the endozone and exozone. The extensive development of the vesicular tissue in the endozone is a characteristic feature of *Athrophragma.* These diaphragms commonly begin at the mesotheca and may extend almost to the zoarial surface before merging with the laminate zooecial walls between the zooecial boundaries. In the endozone the vesicular diaphragms commonly envelop the zooecia. They are more closely spaced and more strongly curved, and more convex to the zoarial surface, than the diaphragms in the zooecial cavities. The diaphragms of the vesicular tissues abut or adjoin with the zooecial boundaries but do not cross them. They are best observed in longitudinal (pl. 13, fig. lc) and transverse views (pl. 13, fig. lb), but can also be seen in tangential views (pl. 13, fig. la) which show the endozone or inner exozone.

The mesotheca in the athrophragmids is constructed similarly to that in the stictoporids. It differs from that in the "stictoporellids" and escharoporids in having the median tubuli.

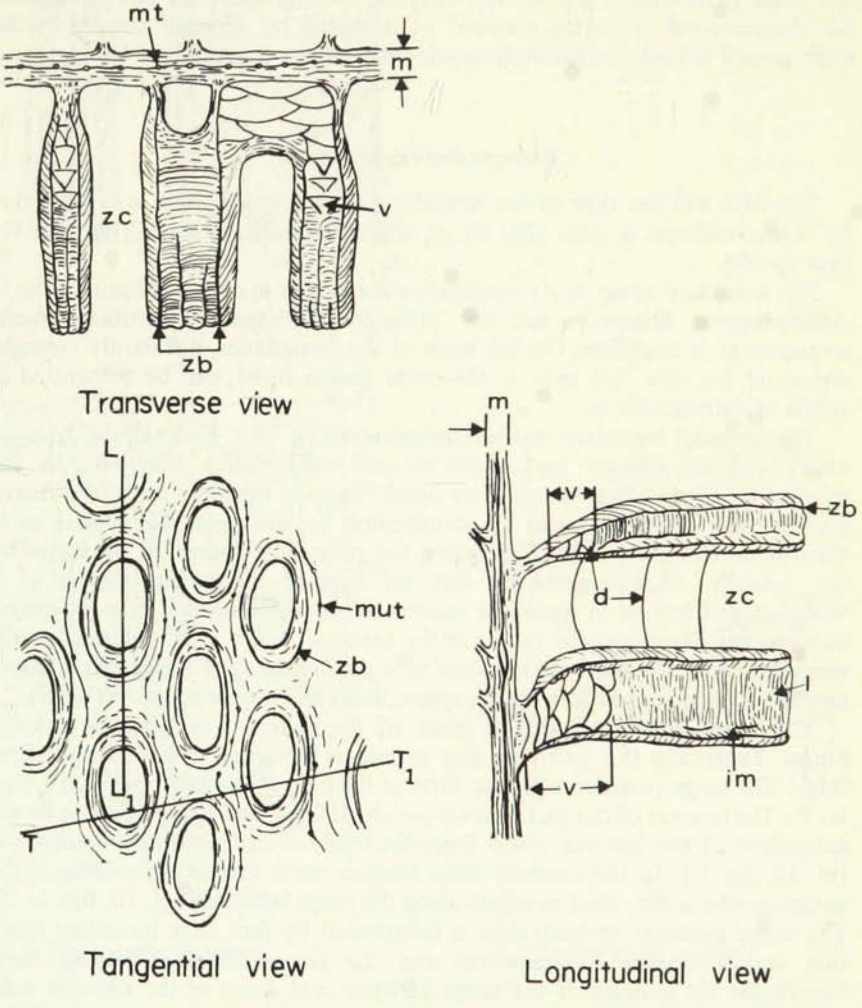

Figure 7 – Idealized diagrams of *Athrophragma.* n. gen. d, diaphragm; im, dark, intermittent zone; l, laminae (highly exaggerated); m, mesotheca; mt, median tubule; mut, mural tubule; v, vesicular tissue; zb, zooecial boundary; zc, zooecial cavity; L-L_1, line showing the approximate position of the plane of the longitudinal section in the tangential view; T-T_1, line showing the approximate position of the plane of the transverse section in the tangential view.

The zoarial structure of the athrophragmids differs from that in the stictoporids in having the oval zooecial boundaries (tangential view) in the exozone and in the irregular alignment of the zooecia. The nonlinear growth of the zooecia in the zoaria of the athrophragmids probably precludes the development of the range boundaries that are observed in the stictoporids and the range partitions of the astreptodictyids. Furthermore, the athrophragmids are characterized in having zooecial walls shared by adjacent zooecia in the exozone and in having extensively developed vesicular tissues.

Astreptodictyid Structure

The fifth and last type of the zoarial structure described here in is illustrated by *Astreptodictya* n. gen. (fig. 8) of which *Pachydictya acuta* (Hall), is the type species.

The boundary zones in *Astreptodictya* are similar in construction to those in *Athrophragma, Stictopora* and the "stictoporellid" species, but their zoarial arrangement is modified. On the basis of the boundaries, differently arranged structural features, not seen in the other genera listed, can be recognized in zoaria of *Astreptodictya*.

The zooecial boundary, as in *Athrophragma* (p. 24), encloses the zooecial cavity with the adjacent part of the zooecial walls. Unlike *Athrophragma,* the zooecia are aligned in approximately linear ranges in the direction of the zoarial growth. The zooecial ranges are demarcated by the range boundaries as in *Stictopora*. However, unlike *Stictopora,* the range boundaries are not shared by the laterally adjacent zooecia, but are formed along the middle of a wedge-shaped feature in transverse section. The wedge-shaped feature is secreted between the linear zooecial ranges in the exozone, and it is here defined as the range partition. As shown in transverse view the beginning of the range partitions can be regarded conveniently as the approximate base of the exozone (fig. 8).

The range partition occupies most of the zoarial area between zooecial ranges. Externally this partition may appear as a slightly elevated longitudinal ridge. The range partition starts to form at the base of the exozone (pl. 10, figs. la, 2). The laminae of the partition are poorly defined, and they appear to be the extensions of the laminae which form the thin zooecial walls in the endozone (pl. 10, fig. la). In the exozone these laminae curve toward the middle of the partition where they abut or adjoin along the range boundary (pl. 10, figs. la, 2). The range partition on both sides is demarcated by thin, dark boundary zones that appear linelike in transverse and the tangential views. Along these boundaries the laminae of the range partition and those of the zooecial walls adjoin or abut and the apexes of these adjoining laminae point toward the endozone (pl. 10, figs. la, 2; pl. 11, fig. 3b).

The relationships between the range partition and the structures of the zooecial walls are seen best in the thin section showing the transverse views (pl. 10, figs. la, 2; pl. 11, figs. la, 2a, 3b). In these views of the exozone, five dark and distinct boundaries can be discerned which are the edge views of the zones that are cut perpendicularly by the thin section (fig. 8). These boundary zones outline the several parts of an astreptodictyid zoarium.

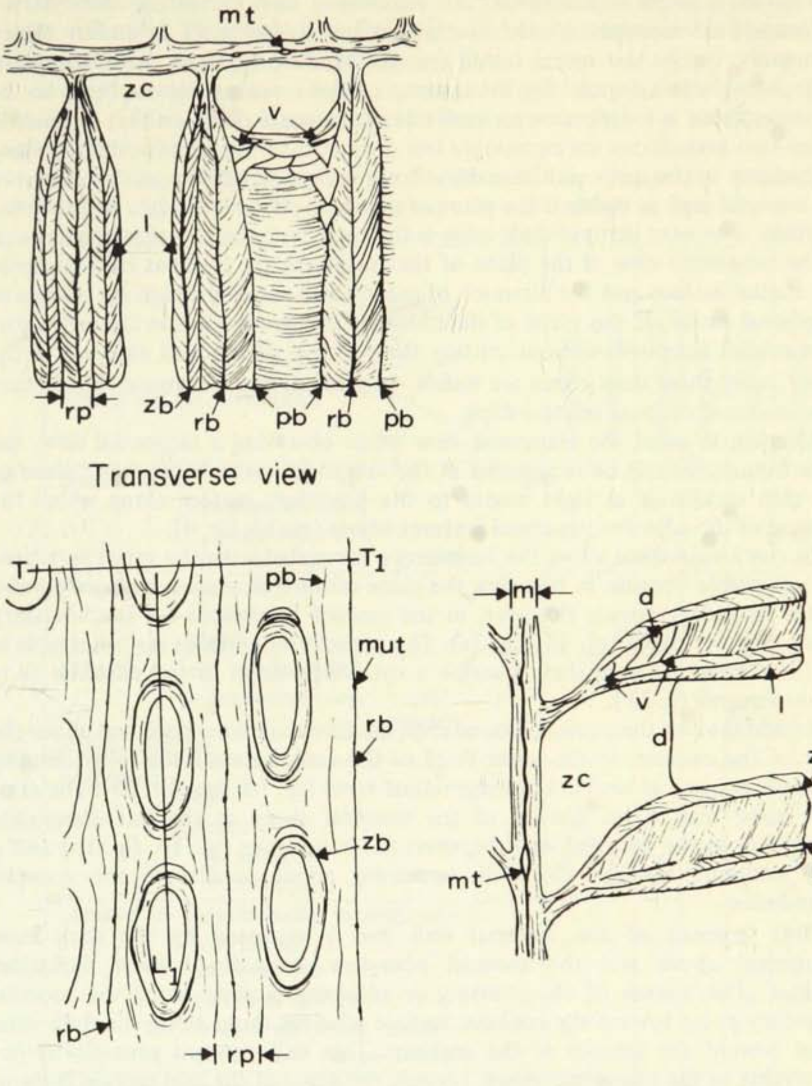

Figure 8 — Idealized diagrams of *Astreptodictya* n. gen. d, diaphragm; im, dark, intermittent zone; l, laminae (highly exaggerated); m, mesotheca; mt, median tubule; mut, mural tubule; pb, range partition boundary; rb, range boundary; rp, range partition; v, vesicular tissue; zb, zooecial boundary; zc, zooecial cavity; $L\text{-}L_1$, line showing the approximate position of the plane of the longitudinal section in the tangential view; $T\text{-}T_1$, line showing the approximate position of the plane of the transverse section in the tangential view.

The dark zone beginning at the mesotheca and extending through the endozone and exozone to the zoarial surface is the range boundary which commonly carries the mural tubuli (pl. 10, figs. la, 2), as in *Stictopora.* The range boundary is formed by the laminae of the range partitions. Next, in the exozone, there is a dark zone on each side of the range partition that outlines it. These two boundaries are commonly less distinct than the range boundary along the median of the range partition. Next to the range partition a small segment of the zooecial wall is visible if the plane of the thin section is at right angles to the zoarium. The next distinct dark zone is the zooecial boundary that appears oval in the tangential view, if the plane of the transverse cut is still at right angles to the zoarial surface and the direction of growth and passes through the middle of a zooecial cavity. If the plane of the tranverse thin section passes through a part of a zoarial fragment without cutting the segment of the wall adjacent to the cavity, only three dark zones are visible. In general, any transverse thin section view shows all of these relationships.

Keeping in mind the transverse view while observing a tangential view, the same boundaries can be recognized in the tangential views because the plane of the thin section is at right angles to the boundary surface along which the laminae of the adjacent structural features adjoin (pl. 11, fig. 4).

In the longitudinal views the boundaries associated with the range partitions are not visible because in this view the plane of the thin section is about parallel to the boundary zones. However, in the case of an oblique cut the boundary zones may be visible (pl. 11, fig. 3a). The zooecial boundaries are observable in all three views because they describe a cylindrical form in the exozone as in *Athrophragma* (p. 24).

In addition to the zooecial boundaries, another dark zone begins at about the base of the exozone in the lower third of the walls between the longitudinally adjacent zooecia as seen in the longitudinal views (pl. 10, figs. 1b, 3b). The same dark zone may begin distally of the vesicular tissue at the last discernible diaphragm in the zooecial walls between the boundaries (pl. 10, fig. 1b) and it may continue through the wall, remaining about parallel to the zooecial boundaries.

This segment of the zooecial wall that is enclosed by the dark zone mentioned above and the zooecial boundary, consists of short, indistinct laminae. The apexes of the abutting or adjoining laminae along the zooecial boundary point toward the zooecial surface whereas those along the dark zone point toward the interior of the zoarium. This wall segment generally is not observable in the transverse views, because the plane of the thin section is about parallel to it. In a tangential section the end view of the same segment might appear as a crescent shaped area just distal to the zooecial boundaries within a zooecial range (pl. 10, figs. 1c, 4; pl. 11, fig. 4). The segment apparently merges laterally with the laminae of the zooecial walls or the range partitions.

The boundaries in the zoaria of the astreptodictyids are often obscured by impurities in the zooecial walls or by mural tubuli. However, by keeping in mind the three-dimensional aspect of the boundary zones and that of the mural tubuli, these morphological features can be readily distinguished.

The vesicular tissues between the adjacent zooecia are not as common as those in *Athrophragma.* In *Astreptodictya* they appear to lie within the zooecial walls between the zooecial boundaries and those of the range partitions in the inner exozone. The general configuration and the arrangement of the vesicular tissue is similar to that in *Athrophragma.*

Astreptodictyid group. Besides *Astreptodictya* n. gen., the genera *Trigonodictya* Ulrich and *Eopachydictya* Ross are tentatively included in the astreptodictyid group.

The distinguishing morphologic features of the six genera used in the established and proposed structural groups are summarized in figure 9.

Morphologic features \ Genera	*Escharopora*	*Graptodictya*	"stictoporellid"	*Stictopora*	*Athrophragma*	*Astreptodictya*
Zoarial habits:						
ramose, branching	V	X	V	X		V
tapering stem	X					
explanate, lobelike expansions			V		X	V
Ranges of zooecia in exozone:						
linear			V	X		X
nonlinear	X	X	V		X	
Mesotheca with median tubuli						
in transverse view: ovate				X		
circular					X	X
Range partition						X
Boundaries:						
range				X		X
zooecial						
in endozone	X	X	X	X	X	X
in exozone			X	X	X	X
Laminae of zooecial walls in exozone –						
well defined	X	X	X			
poorly defined				X	X	X
curved or arched			X	X	X	X
sinuous with broad crests	X					
sinuous with narrow crests		X				
Mesopores, without diaphragms	X					
Vesicular tissue						
begins commonly in inner exozone				V		X
begins commonly at mesotheca					X	
Mural tubuli begin within inner exozone				X	X	X
Hemisepta, superior	X	X		V		

Figure 9 – Summary of distinguishing features in the species of the six genera studied. Five of the genera are used to define tentative informal suprageneric groups. *Graptodictya* has the escharoporid structure. X, observed in all available species; V, observed in some species.

GEOGRAPHIC AND STRATIGRAPHIC DISTRIBUTION OF CRYPTOSTOME BRYOZOA FROM THE DECORAH SHALE IN MINNESOTA

Based on the distribution of cryptostome Bryozoa, the Decorah Shale can be divided into three biostratigraphic units (figs. 1, 10, 11). These are from oldest to youngest: the *Stictoporella angularis* zone, *Stictopora mutabilis* zone (including a zone of poor preservation in the lower part), and *Stictopora minima* zone.

In general the thickness of each of the zones diminishes to the southeast, the zones occurring over thicker intervals at St. Paul than at Spring Grove, Minn., just a few miles north of the Iowa border (figs. 1, 10; Winchell and Ulrich, 1897, p. lxxxviii). The *Stictoporella angularis* (fig. 10) zone is the approximate equivalent of the upper two-thirds of Sardeson's *Stictoporella* bed (Sardeson, 1897a, p. 27; Winchell and Ulrich, 1897, p. lxxxviii). The *Stictopora mutabilis* zone appears to include the *Ctenodonta, Phylloporina,* and part of the fucoid bed of Winchell and Ulrich (1897, p. lxxxviii) beside the *Stictopora* bed and parts of the fucoid bed of Sardeson (1897a, p. 28) and Winchell and Ulrich (1897, p. lxxxviii). The *Stictopora minima* zone is probably the approximate equivalent of parts of the fucoid bed and the *Orthisina* (*Vellamo*) bed of Sardeson (1897a, p. 28, 29) and the fucoid and *Clitambonites* beds of Winchell and Ulrich (1897, p. lxxxviii).

Weiss (1957, fig. 1) provided a graphic summary of both the earlier and present day terminology of subdivision of the Decorah Shale in Minnesota.

On the basis of present knowledge, it appears that the *Stictoporella angularis* zone is also the approximate equivalent of the *Eurychilina subradiata* zone of Cornell (in Swain and others, 1961, p. 349) and is somewhat more extensive vertically than the upper part of the Spechts Ferry Member of the Platteville Formation of Stauffer and Thiel (1941, p. 79). The *Stictopora mutabilis* zone is probably the equivalent of the *Byrsolopsina planilateralis* zone of Cornell (in Swain and others, 1961, p. 349) and corresponds to most of the Guttenberg Submember of the Decorah Shale Member of the Galena Formation of Stauffer and Thiel (1941, p. 81) in Minnesota. This zone also represents the main Decora Shale fauna. The *Stictopora minima* zone appears to be the approximate equivalent of the *Bollia simplex* zone of Cornell (*in* Swain and others, 1961, p. 349) and of the Ion Submember of the Decorah Shale Member of the Galena Formation of Stauffer and Thiel (1941, p. 81) in Minnesota.

The suggested cryptostome bryozoan zones and the published ostracode zones are compared with the earlier subdivision of the Decorah Shale in Figure 10.

1	2	3	4	5	6	7
Sardeson, 1892a, 1897a (some units too thin)	Winchell & Ulrich, 1895, 1897	Stauffer & Thiel, 1941	Weiss, 1957	Cornell in Swain, and others 1961	This report	Heyl and others 1959
Beds 7 - 9	Trenton — Galena Limestone	Galena Formation — Stewartville Member	Galena Formation — Stewartville, Prosser Members	Galena Formation	Galena Dolomite	Galena Formation — Stewartville Member
6 *Orthisina* bed *(Vellamo)*	Trenton — Shales — Upper Galena Shale; Basal Beds	Galena Formation — Prosser Member	Galena Formation — Cummingsville Member			Galena Formation — Prosser Member
5 Fucoid bed	Black River — Shales — Upper 3rd	Galena Formation — Decorah Member — Ion Submember	Decorah Formation	Decorah Formation — *Bollia simplex* zone	Decorah Shale — *Stictopora minima* zone	Decorah Formation — Ion Member
4 *Stictopora* bed *(Rhinidictya)*	Black River — Shales — Middle 3rd	Galena Formation — Decorah Member — Guttenberg Submember		*Byrsolopsina planilateralis* zone; *Eurychilina subradiata* zone	*Stictopora mutabilis* zone; *Stictoporella angularis* zone	Guttenberg Member; Spechts Ferry Mbr.
3 *Stictoporella* bed	Stones River — Shales — Lower 3rd	Platteville Formation — Spechts Ferry Member	Platteville Formation — Carimona Member	Platteville Formation	Platteville Limestone	Platteville Formation — Quimbys Mill Mbr.
2 *Bellerophon* bed	Stones River — Shaly limestone	Platteville Formation — McGregor Member	Platteville Formation — McGregor Member			Mc Gregor Member
1 Buff limestone bed	Stones River — Building layers		Pecatonica Member			Pecatonica Member

Figure 10 — Nomenclature applied to stratigraphic units exposed in southeastern Minnesota (column 1-6), and to Middle Ordovician rocks of the Upper Mississippi Valley zinc-lead district (column 7). Columns 1-4 are modified from Weiss (1957, fig. 1). Column 5 is a tentative summary of the ostracode zones as suggested by Swain and others (1961, p. 349, text fig. 1). The cryptostome bryozoan zones of this report are shown in column 6. Column 7 is modified from Heyl and others (1959, p. 11, fig. 3).

Stictoporella angularis Zone

The base of the *Stictoporella angularis* zone is placed at the 0-foot datum from which the stratigraphic section is measured at each locality. The lower limit of the zone may be subject to change after an investigation of the bryozoan fauna in the Platteville Limestone. The top of the zone is placed at the highest occurrence of *Stictoporella angularis* Ulrich in the collections.

The *Stictoporella angularis* zone is characterized by an abundance of cryptostome fragments in the lower part while near the top the number of fragments decreases considerably (fig. 11). Other stratigraphically restricted species in this zone are *Stictopora exigua* (Ulrich), *Athrophragma foliata* (Ulrich), and possibly *Stictopora lita* n. sp.

Stictoporella angularis is abundant at St. Paul, Rochester, Chatfield, and Spring Grove, sparingly present at Roscoe and Fountain and was not found at Wangs where part of the stratigraphic interval is covered. *S. angularis* extends about 14 feet above the datum plane at St. Paul and Rochester. At Spring Grove the species apparently does not range higher in the section than 6 feet above the datum. The same range is observed at Roscoe where the collections contained no bryozoan fragments from 6 to 12 feet above the datum. It appears that the zone thins southeastward from St. Paul and from Rochester.

Stictoporella frondifera Ulrich ranges from the *S. angularis* zone into the *Stictopora mutabilis* zone. It is sparingly present at St. Paul, Wangs, Rochester, Chatfield and Fountain. At Spring Grove, however, many specimens are present in the middle and upper parts of the *Stictoporella angularis* zone, and a few fragments are found also in the higher zone of *Stictopora mutabilis*. Perry (1962, p. 34) found *S. frondifera* in 9 out of 10 localities of the Spechts Ferry Shale Member of the Decorah Formation in Illinois, Wisconsin, and Iowa. He also reported that the thickness of the Spechts Ferry Shale Member (Perry, 1962, p. 3) is invariably less than 10 feet which is about the same as the thickness of the *S. angularis* zone at Spring Grove. At St. Paul and Rochester, it should be recalled, the thickness of this zone is approximately 14 feet.

Stictopora exigua and *S. lita* are found in large numbers at all localities except at Wangs where part of the stratigraphic interval is covered. Both species are for the most part restricted to the *Stictoporella angularis* zone. However, at St. Paul and Rochester, *S. lita* extends into the lower part of the *Stictopora mutabilis* zone. As in the previously discussed species, the ranges of *S. exigua* and *S. lita* become progressively shorter southeast of Rochester and St. Paul.

Athrophragma foliata, a species with a distinct form and probably of considerable stratigraphic importance occurs in large numbers in the middle part of the *Stictoporella angularis* zone at St. Paul. A few specimens are found also at Wangs, but none is present in the collections from any of the other localities.

Escharopora subrecta and *Graptodictya simplex* are present in varying numbers throughout the section at all the localities. In general *E. subrecta* is more abundant than *G. simplex.* It appears that *E. subrecta* is more abundant in the *Stictopora mutabilis* zone than below or above this zone.

Stictopora mutabilis Zone

The base of the *Stictopora mutabilis* zone is placed at the highest occurrence of *Stictoporella angularis* Ulrich. The lower two to six feet of the zone is characterized by poor preservation or total absence of bryozoans as well as all other fossil material. The highest occurrence of *S. mutabilis* was used to define the top of the zone.

Stictopora mutabilis is abundant at St. Paul, Rochester, Chatfield, Fountain, and Spring Grove. Just a few fragments were found in the collections from Wangs and none at Roscoe, where the stratigraphic interval is covered or badly slumped. The vertical extent of *Stictopora mutabilis* decreases from Rochester, and at Spring Grove this species is found only in interval of about two feet.

Stictopora paupera Ulrich, a species closely related to *S. mutabilis* appears in the collections from about the middle of the *S. mutabilis* zone at St. Paul and Wangs. At Rochester, Chatfield, Fountain, and Spring Grove *S. paupera* appears just above the zone of poor preservation. With the exception of the sections at Roscoe, *S. paupera* extends into the lower part of the *Stictopora minima* zone. In that zone the number of specimens in the collections decreased considerably.

Stictopora cf. *S. neglecta* (Ulrich) is found in the upper part of the *Stictopora mutabilis* zone in the section at Rochester and Spring Grove. In all the other section *S. cf. S. neglecta* appears restricted to the *S. minima* zone.

Astreptodictya acuta (Hall), *A. fimbriata* (Ulrich), and *A. elegans* (Ulrich) are present in relatively small numbers. These forms begin to appear in the collections from the middle part of the *Stictopora mutabilis* zone and range into the lower part of the *Stictopora minima* zone. None has been found in the collections from the section at Spring Grove. The presence of these species of *Astreptodictya* may be of some stratigraphic significance. Ross (1964a, text fig. 2) reports that *Pachydictya acuta acuta* (*Astreptodictya* in this paper) of the *Pachydictya acuta* subspecies complex begins to appear at the base of Trenton Group in the type region of the New York.

Stictoporella dumosa is found in the upper part of the *Stictopora mutabilis* zone at St. Paul and in the lower part of the *Stictopora minima* zone at Wangs. It has not been recognized in collections from the other localities.

Stictopora minima Zone

The base of the *Stictopora minima* zone is placed at the highest occurrence of *S. mutabilis*. The top of the zone is placed at the highest occurrence of *S. minima* in the collections and may be subject to change because the bryozoan fauna of the Galena Dolomite has not yet been investigated in detail.

Although *Stictopora minima* does not appear abundantly in any of the collections, the number of fragments assigned to this species is somewhat larger in the collections from St. Paul and Wangs than from the other localities. The vertical extent of the species decreases southeast from St. Paul and Rochester as in the case with the other species.

The only other species which appears to be restricted to this zone is *Astreptodictya pumila* (Ulrich). It is found in the collections from St. Paul, Wangs, Rochester, and Fountain, but apparently is not present at Roscoe, Chatfield, and Spring Grove. Nekhoroshev (1961) reported the species from the

Middle Ordovician of the Siberian Platform; his use of this name for Siberian bryozoans may need to be revised.

Regional Correlation of the Decorah Shale

Weiss (1957, p. 1027, 1043) concluded on the basis of the study of macrofossils that the ages Black River and Trenton based on the Middle Ordovician rocks of New York could not be meaningfully applied to Minnesota Ordovician rocks. Perry (1962, p. 3) summarized the history of the age determination of the Spechts Ferry Shale Member of the Decorah Formation in Illinois, Wisconsin, and Iowa, and concluded that because of lack of knowledge concerning bryozoan faunas of the Middle Ordovician, the age of the Spechts Ferry could not be established definitely as either Black River or Trenton. Templeton and Willman (1963, p. 95) raised the Decorah Shale to the stratigraphic rank of a subgroup and the Spechts Ferry Shale Member to the rank of a formation in Illinois and correlated their Spechts Ferry Shale with the Selby Member, the basal member of the Rockland Formation of Kay (1937) of the type Trenton in New York. Bergström and Sweet (1966, p. 298), correlated the Decorah Shale with the Rockland Formation of New York using the relative-abundance curves of some conodont species.

On the basis of the bryozoans the *Stictoporella angularis* zone of the Decorah Shale in Minnesota appears to be the biostratigraphic equivalent of the Spechts Ferry Shale Member of the Decorah Formation in Illinois, Wisconsin, and Iowa. Although Ross (1964a) investigated the cryptostome bryozoans of the Black River and Trenton Groups in New York and found that certain species (Ross, 1964a, text fig. 2) may have restricted stratigraphic distributions, the detailed correlation with the Minnesota sequence is still uncertain. Clearly, an investigation of the bryozoan faunule from the underlying Platteville Limestone and the re-evaluation of the trepostome faunule from the Decorah Shale would be of value in settling the problem of the correlation of the Middle Ordovician rocks of Minnesota with the standard Ordovician sequence in New York state. Nevertheless, it does appear that the cryptostomes in the Decorah Shale, *Stictopora exigua, S. lita, S. mutabilis, S. paupera, Escharopora subrecta, Astreptodictya acuta,* and *A. elegans,* are more closely related to the forms of the Trenton Group than to the Black River Group species of New York. However, Swain and others (1961, p. 349) found that the ostracodes in the Spechts Ferry Member of the Platteville Formation of Stauffer and Thiel (1941, p. 79) of Minnesota are generically somewhat more closely related to the Platteville, which is considered Black River in age, than to the overlying main portion of the Decorah.

SYSTEMATIC DESCRIPTIONS

Genus Stictopora Hall, 1847

Stictopora Hall, 1847, p. 73; Phillips, 1960, p. 7; Ross, 1966, p. 1400-1401.
Sulcopora d'Orbigny, 1849, p. 499-501;
Rhinidictya Ulrich, 1882, p. 152; Bassler, 1915, p. 1106; Bassler, 1934, p. 190; Bassler, 1953, p. G140; Coryell, 1921, p. 300, Nekhoroshev, 1961, p. 142; Astrova, 1965, p. 279.

Type species: *Stictopora fenestrata* Hall (1847, p. 16), designated by Ulrich (1886, p. 67), redescribed by Ross (Phillips, 1960, p. 7).

Definition: Zoarium ramose with relatively straight, ribbon-shaped branches having zooecia in linear ranges demarcated by range boundaries. Zoarial attachments in some species formed by encrusting expansion having few, randomly spaced, irregular zooecia.

Zooecia rectangular, with straight to slightly curved walls in endozone, about ovate cavities in exozone in tangential views, form an approximate ogee-shaped curve from mesotheca to zoarial surface in longitudinal view. Zooecia in ranges adjacent to margin at an angle with growth direction of branch, strongly elongate occasionally.

Zooecial walls thicken gradually in some species, abruptly in others with change in direction of zooecial growth at base of exozone; walls occasionally elevated laterally and proximally to cavities at surface.

Laminae of mesotheca poorly defined, form intermittent junctions with zooecial wall laminae of endozone, merge or continue without apparent break with laminae of zoarial margins. Laminae of zooecia poorly defined, irregularly U-shaped, convex to zoarial surface, inclined to cavities, being somewhat longer in distal than proximal zooecial walls in exozone.

Boundary zones, formed by abutting or adjoining laminae of adjacent walls, begin at mesotheca. Range boundaries relatively straight along median between laterally adjacent ranges, continue longitudinally throughout zoarium, probably bifurcate near margins and in areas of branching. Zooecial boundaries form slightly curved zones between longitudinally adjacent zooecia within ranges.

Median tubuli of mesotheca well defined, ovate in cross section in transverse view. Mural tubuli poorly to well defined, small, formed by irregular cone shaped flexures of zooecial wall laminae at right angles to zoarial surface, begin within boundaries of ranges, zooecia or apparently rise at random in distal zooecial walls in inner exozone; commonly more abundant in areas of branching, margins of some species.

Vesicular tissue, formed in distal zooecial walls at base of exozone in some species, extend for varying distances within exozone. Diaphragms planar, thin, randomly spaced in cavities, abut or merge with wall laminae; few in some species, absent in others. Superior hemisepta thin, hooklike, formed by laminar extensions of proximal zooecial walls at base of exozone; well defined in some species, poorly defined or absent in others; inferior hemisepta rare.

Monticules, macules rare, randomly spaced, consist of irregular zooecia. Maculae more common in species having wide zoarial branches.

Stictopora exigua (Ulrich)

Plate 1

Rhinidictya exigua Ulrich, 1890a, p. 184, fig. 9; Bassler, 1915, p. 1107; Shrock and Raasch, 1937, p. 540.

Type material: Lectotype here designated from syntype suite USNM 43708, thin section USNM 162871; specimen probably illustrated by Ulrich, 1890a, page 184, figure 9c, d; Ulrich, 1895, plate 8, figure 9, 10. Paralectotypes: thin section USNM 162872, 162873; two unsectioned specimens USNM 162874, 162875 from suite USNM 43708 illustrated by Ulrich, 1895, plate 8, figure 6, 7 and 8 respectively; one unsectioned specimen USNM 162876 from syntype suite USNM 43708. Locality: Decorah Shale, *Stictoporella* bed, Minneapolis, Minn. One unsectioned specimen USNM 162877 from syntype suite USNM 43708 from Fountain, Minn.

Additional material from Minnesota: Thin sections USNM 162878-162897 from Rochester; USNM 162898-162912 from Roscoe. Approximate count of unsectioned zoarial fragments: St. Paul 320; Wangs 20; Rochester 470; Roscoe 100; Chatfield 39; Fountain 32; Spring Grove 35.

Description: *External features* – Zoarium small, branching dichotomously at intervals of 3 to 5 mm; margins of branches narrow with edges rounded proximally, becoming sharper distally; zooecial cavities ovate to subovate, oblique to zoarial surface, separated by slightly raised laterally adjacent walls; commonly five to nine ranges per branch, including one, rarely two ranges adjacent to margins; zoarium subcylindrical proximally, attachment explanate or tubelike encrusting expansion.

Internal features – Zooecia subquadrate to rectangular with straight laterally adjacent, slightly curved longitudinally adjacent walls in endozone (pl. 1, fig. 6); zooecial cavities ovate to subcircular in exozone (pl. 1, figs. 4d, 6, 7), being somewhat narrower in inner exozone (pl. 1, figs, 4b, 4c) and more elongate, oblique to growth direction of zoarium, in one to two marginal ranges (pl. 1, fig. 6).

Zooecial walls in exozone in general form small angle with mesotheca, thicken smoothly in zooecial bends. (pl. 1, figs. 5, 8). Range boundaries relatively straight, becoming somewhat flexuous in areas of branching (pl. 1 figs. 4a, 6); zooecial boundaries poorly defined in endozone, well defined in exozone (pl. 1, figs. 5, 6).

Mesotheca with closely spaced median tubuli (pl. 1, fig. 2b), approximately 0.01 to 0.02 mm thick. Mural tubuli within range boundaries in single rows (pl. 1, fig. 7); few, randomly spaced poorly defined in zooecial walls in exozone, more abundant in areas of branching, margins (pl. 1, fig. 4d).

Table 1.* – Quantitative data, *Stictopora exigua* (Ulrich)

	Ns	Nm	Range	Mean	s	V	95% C.I.
Branch depth.	30	41	0.33-1.60	0.501	0.1971	39.3	0.44-0.56
Branch width.	28	34	0.71-2.00	1.149	0.3295	28.7	1.03-1.26
Cav. axis: mj.	12	12	0.13-0.29	0.192	0.0508	26.5	0.16-0.22
Cav. axis: mn.	12	12	0.06-0.13	0.950	0.0239	25.2	0.08-0.11
Depth: endo.	31	32	0.07-0.15	0.101	0.0214	21.2	0.09-0.11
Depth: exo.	31	33	0.06-0.20	0.108	0.0333	30.8	0.10-0.12
Depth: zoo.	30	31	0.14-0.29	0.212	0.0356	16.8	0.20-0.23
Zoo. angle.	27	29	2°(?)-70°(?)	25.7°	15.97°	–	20°-31°
H. cav. endo.	20	20	0.24-0.38	0.300	0.0370	12.3	0.28-0.32
Wall w: lng.	13	15	0.08-0.24	0.135	0.0427	31.6	0.11-0.16
Wall w: lat.	13	13	0.03-0.19	0.079	0.0407	51.4	0.05-0.10
Cav./2 mm lng.	10	10	5-8	6.9	0.99	14.4	6-8
Cav./2 mm lat.	9	9	10-13	11.2	1.09	9.7	10-12
Cav./1 mm^2.	5	5	15-18	16.6	1.14	6.9	15-18
Zoarial ratio.	26	26	0.32-0.76	0.509	0.1009	19.8	0.47-0.55

*All measurements are in mm, except for zooecial angles. All measurements and counts are made in middle areas of zoarial fragments and between monticules or maculae.

ABBREVIATIONS

Ns, number of fragments measured
Nm, number of measurements
Mean, arithmetic
s, standard deviation
V, coefficient of variation
95% C.I., confidence interval of mean

Cav. axis: mj and mn, major and minor axis of zooecial cavity
Depth: endo., exo. and zoo., depth of endozone, exozone, and zooecium in zoarium
Zoo. angle: zooecial angle
H. cav. endo., height of zooecial cavity in endozone in longitudinal view
Wall w: lng. and lat., wall width longitudinally and laterally between adjacent zooecia in tangential view
Cav./2 mm lng. and lat., number of zooecial cavities per 2 mm longitudinally and laterally in tangential view
Cav./1mm^2, number of zooecial cavities per one mm^2 in tangential view
Msp/1mm^2, number of mesopores per 1mm^2 in tangential view

Remarks: *Stictopora exigua* belongs to a group of bifoliate bryozoans that are characterized by small zoaria. In external appearance *S. exigua* is similar to *S. paupera, S. lita, S.* cf. *S. neglecta,* smaller fragments of *S. mutabilis, S. minima,* and *Astreptodictya pumila.*

Internally the angle between the mesotheca and the zooecial walls in the exozone is smaller in *S. exigua* than in the species mentioned above. The exozone is generally narrower in *S. exigua* and no diaphragms, hemisepta, or vesicular tissue have been observed in *S. exigua. S. exigua* is closely related to *S. lita* but differs in the shape and size of the zooecial walls, their average angle with the mesotheca and thus in the shape and size of the cavities. Zoaria are generally smaller in *S. exigua* than in *S. lita.* Zoarial branches in *S. exigua* are narrower but the walls in tangential views are generally wider than those in *S. paupera.* S. *exigua* has much smaller zoarium then *S. mutabilis.* Zoaria in *S.* cf. *S. neglecta* are about of the same size or slightly larger but with thicker zooecial walls in the exozone than in *S. exigua.* The presence of hemisepta distinguishes *S. minima* from *S. exigua. Astreptodictya pumila* has the astreptodictyd wall structure and thus differs from *S. exigua* although the zoaria are approximately the same in size.

In describing *Stictopora exigua,* Ulrich (1890a, p.184; 1895, p. 131) vaguely indicated the nature of the internal structure but did not figure it. In the syntype collection USNM 43708 there are zoarial fragments that were probably used for illustrations by Ulrich (1895, pl. 8, figs. 6-10). Because of the scarcity of fragments in the collection, only one was chosen for thin sectioning. This fragment shown in pl. 1, fig. 1a is thought to be the same as that figured by Ulrich, 1895, pl. 8, figs. 9, 10 and probably in 1890a, p. 184, fig. 9c. The poorly preserved internal structure of this specimens is shown in pl. 1, figs. lb, 1c. This and the other views obtained from recently collected material are the first illustration of the internal wall structures in *S. exigua.*

Occurrence: Decorah Shale, Minnesota. (See figs. 1 and 11; feet indicate distance above base of the formation). St. Paul, very abundant 0-7 ft, rare to abundant 7-12 ft; Wangs, rare to abundant 6-13 ft; Roscoe, very abundant 0-2 ft, rare 4-6 ft; Rochester, very abundant 0-7 ft, rare to abundant 8-10 ft; Chatfield, very abundant 0-2 ft, common 2-3 ft; Fountain, rare 0-2 ft, rare to very abundant 4-8 ft; Spring Grove, very abundant 0-2 ft.

Bassler (1915, p. 1107) reported the species from Decorah Shale, Minneapolis and Fountain, Minnesota. Other occurrences are reported in the literature, but are in need of verification. Rare in Means quarry, Kentland, Indiana, Middle Ordovician: Div. 8, unit 15 (Shrock and Raasch, 1937, p. 540); Bromide Formation, Ordovician, Rock Crossing, Criner Hills, Oklahoma (Decker and Merritt, 1931, p. 48); Platteville Limestone, Dixon quadrangle, Illinois (Knappen, 1926, p. 59); Decorah Formation *Glyptorthis bellarugosa* faunule, lower part of Ion Dolomite Member, Iowa (Kay, 1929, p. 660).

Stictopora lita, n. sp.

Plate 2

Plate 3, Figures 1, 2, 4

Rhinidictya trentonensis (Ulrich), Ulrich, 1895, p. 135, pl. 6, figs. 14-18; pl. 7, figs. 6-9.

Type material: Holotype: thin section USNM 162918 from Rochester. Paratypes: thin sections USNM 162919-162927 from Rochester; USNM 162928-162932 from Roscoe; USNM 162933, 162934 from Fountain.

Hypotype suite USNM 43607: some specimens probably figured by Ulrich, 1895, pl. 7, figs. 6-9; two thin sections USNM 162935 and 162936 figured by Ulrich, 1895, plate 6, figure 14, 15, and 16-18 respectively; thin section USNM 162937. Locality: Decorah Shale, *Stictoporella* bed, Minneapolis, Minn.

Additional material from Minnesota: Thin sections USNM 162938-162948 from Rochester; USNM 162949-162951 from Roscoe; USNM 162952-162954 from Fountain. Approximate count of unsectioned zoarial fragments: St. Paul 700; Wangs 30; Roscoe 50; Rochester 570; Chatfield 170, Fountain 105, Spring Grove 360.

Description: *External Features* – Zoarium small, branching dichotomously at intervals of 6 to 8 mm; branches with narrow margins, having commonly rounded, rarely sharp edges; zooecial cavities ovate to subquadrate, oblique to zoarial surface, ranges separated by slightly elevated laterally adjacent walls; commonly eight to twelve ranges per branch, including one to two near margins with elongate zooecial cavities, oblique to growth direction of zoarium; zoarium probably attached by encrusting, irregular expansion.

Internal features – Zooecia subquadrate to rectangular with straight laterally adjacent, slightly curved longitudinally adjacent walls in endozone (pl. 3, fig. 2a); zooecial cavities ovate in exozone (pl. 2, figs. 1b, 2a, 3a).

Zooecial walls in exozone commonly form medium angle with the mesotheca (pl. 2, figs. 3c, 3e; pl. 3, figs. 1b, 2b). Range boundaries straight (pl. 2, figs. 2a, 3a) to slightly flexuous (pl. 2, fig. 1b). Zooecial boundaries poorly defined in endozone (pl. 2, fig. 3a), well defined in exozone (pl. 2, figs. 3b, 3c).

Mesotheca with closely spaced median tubuli (pl. 3, fig. 4), about 0.01-0.02 mm thick. Mural tubuli within range boundaries in single rows (pl. 2, figs. 2a, 3a, 3d; pl. 3, fig. 4); those in zooecial walls in exozone randomly spaced, few to common, more abundant near zoarial margins (pl. 2, fig. 3a), areas of branching, may diverge from zooecial boudaries.

Diaphragms thin, planar to slightly curved, about one per cavity of some zooecia, lacking in others (pl. 2, fig. 3). Vesicular tissue poorly defined in inner exozone of some zooecia (pl. 2, fig. 2b), absent in others.

Table 2. – Quantitative data, *Stictopora lita*, n. sp.*

	Ns	Nm	Range	Mean	s	V	95% C.I.
Branch depth.	29	48	0.47-1.32	0.726	0.1619	22.3	0.68-0.77
Branch width.	30	38	1.00-4.07	1.838	0.5892	32.1	1.64-2.03
Cav. axis: mj.	16	16	0.14-0.24	0.175	0.0273	15.6	0.16-0.19
Cav. axis: mn.	15	15	0.05-0.14	0.086	0.0241	28.1	0.07-0.10
Depth: endo.	25	25	0.07-0.17	0.109	0.0229	21.0	0.10-0.12
Depth: exo.	25	26	0.14-0.44	0.254	0.0871	34.3	0.22-0.29
Depth: zoo.	25	25	0.23-0.54	0.360	0.0916	25.5	0.32-0.40
Zoo. angle.	25	26	34°-62°	43.1°	7.10°	16.4	40°-46°
H. cav. endo.	21	21	0.22-0.35	0.289	0.0310	10.7	0.27-0.30
Wall w: lng.	17	17	0.08-0.20	0.134	0.0355	26.6	0.12-0.15
Wall w: lat.	16	16	0.05-0.12	0.077	0.0185	24.1	0.07-0.09
Cav./2 mm lng.	16	16	5-8	6.6	0.72	10.8	6-7
Cav./2 mm lat.	16	16	10-14	11.2	0.98	8.8	10-12
Cav./1 mm.^{2}	14	14	13-24	17.5	2.53	14.5	16-19
Zoarial ratio	25	25	0.55-0.82	0.684	0.0812	11.9	0.65-0.72

*Explanation of abreviations follows Table 1.

Remarks: In general, the zoarium of *Stictopora lita* is larger than that of *S. exigua, S.* cf. *S. neglecta* and is similar in size to that in *S. paupera.* However, the zoarial branches in *S. paupera* are thinner and wider than those in *S. lita* in which the zooecial walls in the exozone are better defined. The zooecial walls in the exozone form a larger angle with the mesotheca in *S. lita* than in *S. exigua* (pl. 1, fig. 4b; pl. 2, fig. 3e). The zoarium in general is smaller in *S. lita* than in *S. mutabilis.* In the former the zooecial walls, forming a shallower exozone, increase gradually in the thickness in the zooecial bends while in the latter the change in the thickness is more abrupt in the bends. The laminae forming the distal zooecial walls appear relatively longer and less curving in *S. lita* than those in *S. mutabilis* and *S.* cf. *S. neglecta.*

In search for the type material of *S. trentonensis* (Ulrich), the holotype of *S. trentonensis* was found in the type collection USNM 43707. The collection consists of one, relatively well preserved, zoarial fragment from Lebanon Limestone of the Stones River Group, Lebanon, Tenn. A branch of this zoarium is illustrated on plate 3, figure 3b, and the internal views in figure 3a, 3c.

The label on this collection, USNM 43707, indicates that the zoarium was identified at first, probably by Ulrich, as *Dicranopora trentonensis* Ulrich (Ulrich, 1882, p. 167). The zoarium, however, does not appear to be the one figured by Ulrich (1882, pl. 6, figs. 15, 15a).

Hypotype collection USNM 43607 contains few zoarial fragments from the Decorah Shale of Minnesota identified as *Stictopora trentonensis* (Ulrich). Some of the zoarial fragments from this collection apparently have been figured by Ulrich (1895, pl. 7, figs. 6-9). A thin section, USNM 162936, probably obtained from a zoarial fragment in the same hypotype collection, was used for figure 16-18 on plate 6 (Ulrich, 1895).

Since Ulrich (1882, p. 167) did not discuss or show the internal morphological features of *S. trentonensis,* the holotype of the species was thin sectioned and is figured on plate 3, figure 3a-c. Similarly, zoarial fragments from the hypotype collection USNM 43607 were also thin sectioned. Although the internal structure in the zoarial fragments from the collection USNM 43607 is poorly preserved, three views of one zoarial branch are shown on plate 2, figures 1a-c (USNM 162937).

Note in *S. trentonensis* the shapes of the zooecial cavities, walls, the vesicular tissue, and the well-defined, curving superior hemisepta projecting into some of the zooecial cavities and joining the mesotheca in one cavity (pl. 3, figs. 3a, 3c). In *S. lita* (pl. 2; pl. 3, figs. 1, 4) note the differently shaped zooecial cavities the gradual thickening of the zooecial walls in the zooecial bends and the absence of the superior hemisepta and the well-defined vesicular tissues. The internal morphological features shown by the holotype of *S. trentonensis* have not been observed in the stictoporid species collected recently from the Decorah Shale in Minnesota.

Occurrence: Decorah Shale, Minnesota. (See figs. 1 and 11; feet indicate distance above base of the formation). St. Paul, very abundant 0-9 ft, rare to abundant 9-17 ft; Wangs, rare 6-8 ft, very abundant 8-10 ft; Roscoe, very abundant 0-2 ft; Rochester, very abundant 1-8 ft, abundant to very abundant 8-18 ft; Chatfield, very abundant 0-3 ft; Fountain, abundant to very abundant 0-7 ft; Spring Grove, abundant to very abundant 0-8 ft.

Stictopora mutabilis Ulrich

Plate 4, Figures 1, 2

Plates 5, 6

Stictopora mutabilis Ulrich (part), 1886, p. 66

Rhinidictya mutabilis (Ulrich), Bassler, 1915, p. 1108; Ockerman, 1926, p. 117; Shrock and Raasch, 1937, p. 540; Shimer and Shrock, 1944, p. 269, pl. 102, figs. 6, 7; Moore, Lalicker, and Fisher, 1952, p. 165.

Type material: Lectotype USNM 162955 here designated from syntype suite USNM 43812, probably figured by Ulrich, 1895, plate 7, figure 14. Paralectotypes: unsectioned specimen USNM 162956, probably figured by Ulrich, 1895, plate 7, figure 19-21; USNM 162957, probably figured by Ulrich, 1895, plate 7 figure 12; three unfigured specimens USNM 162958; one specimen USNM 162959, probably figured by Ulrich, 1895, plate 7, figure 13; thin section USNM 162960 (not figured); thin section USNM 162961, figured by Ulrich, 1895, plate 6, figures 4, 5; thin sections USNM 162962, 162963, probably used by Ulrich, 1895, to figure some specimens on plate 6; thin sections USNM 162965 (not figured). Locality: Decorah Shale, *Rhinidictya* bed, Minneapolis and St. Paul, Minn.

Additional material from Minnesota: Thin sections: USNM 162913-162917, 162966-162995 from Rochester. Approximate count of unsectioned zoarial fragments: St. Paul 660, Rochester 340, Chatfield 27, Fountain 410, Spring Grove 80.

Description: *External features* – Zoarium small to medium, commonly branching at intervals of 4 to 12 mm; branches somewhat narrower proximally, wider distally with narrow margins having round to sharp edges; zooecial cavities ovate, slightly oblique to zoarial surface, somewhat constricted in central ranges, more elongate, directed outward in marginal ranges; commonly 10 to 18 ranges per branch, including two to four ranges next to each margin; ranges demarcated by slightly elevated, laterally adjacent walls; longitudinally adjacent walls slightly elevated proximally of cavities; maculae irregular in size, poorly defined, consist of zooecia with unusually wide walls with many mural tubuli. Maculae occasionally aligned along middle of branches in more robust zoaria, otherwise randomly spaced, lacking in smaller zoaria.

Internal features – Zooecia subquadrate to rectangular with straight laterally adjacent, slightly curved longitudinally adjacent walls in endozone (pl. 5, fig. 1b; pl. 6, fig. 1b); cavities ovate in exozone (pl. 4, fig. 2c; pl. 5, fig. 2b).

Zooecial walls of exozone commonly form medium angle with mesotheca (pl. 4, figs. 1b, 2d). Range boundaries straight (pl. 4, fig. 2c; pl. 5, fig. 1b) to slightly flexuous (pl. 4, fig. 2a); zooecial boundaries poorly defined in endozone (pl. 4, fig. 1b; pl. 5, fig. 1b), well defined in zooecial bends, (pl. 6, fig. 1b), exozone (pl. 4, figs. 1a, 2d), occasionally intermittent (pl. 6, fig. 1a).

Mesotheca with closely spaced median tubuli, straight to flexuous at irregular intervals (pl. 4, fig. 2d). Mural tubuli within range boundaries in single, rarely double rows, (pl. 5, figs. 2b, 2c); those in zooecial walls in exozone randomly spaced, few to abundant, commonly rise from zooecial boundaries (pl. 4, figs. 1a, 1b, 2d; pl. 5, fig. 2b).

Diaphragms thin, planar to slightly curved, rare, about one per cavity of some zooecia, absent in others. Vesicular tissue occasionally well defined in inner exozone in some zooecia (pl. 6, fig. 1d) absent in others. Superior hemisepta poorly defined, rare.

Table 3. – Quantitative data, ***Stictopora mutabilis*** **Ulrich***

	Ns	Nm	Range	Mean	s	V	95% C.I.
Branch depth.	25	46	0.45-1.80	1.019	0.3326	32.6	0.92-1.11
Branch width.	29	42	1.31-8.0	2.593	1.1769	45.3	2.22-2.95
Cav. axis: mj.	23	24	0.11-0.18	0.142	0.0191	13.4	0.13-0.15
Cav. axis: mn.	23	23	0.04-0.08	0.065	0.0165	25.2	0.06-0.07
Depth: endo.	25	25	0.07-0.15	0.114	0.0178	51.6	0.11-0.12
Depth: exo.	25	26	0.13-0.75	0.370	0.1686	44.3	0.31-0.45
Depth: zoo.	25	28	0.23-0.87	0.506	0.1766	34.9	0.44-0.57
Zoo. angle.	25	30	46°-70°	57.5°	6.13°	10.7	55°-60°
H. cav. endo.	25	25	0.22-0.34	0.271	0.0383	14.1	0.25-0.29
Wall w: lng.	23	23	0.07-0.16	0.131	0.0212	16.1	0.12-0.14
Wall w: lat.	23	24	0.05-0.14	0.087	0.0224	25.7	0.08-0.10
Cav./2 mm lng.	23	23	6-8	7.4	0.66	8.9	7-8
Cav./2 mm lat.	22	22	7-14	12.2	1.58	12.3	12-13
Cav./1 mm^2.	18	18	19-28	22.4	2.31	10.3	21-24
Zoarial ratio.	25	25	0.52-0.91	0.738	0.0992	13.4	0.70-0.78

*Explanation of abbreviations follows Table 1.

Remarks: *Stictopora mutabilis* is closely related and similar to *S. lita.* The zoaria of *S. mutabilis* are usually more robust than those of *S. lita,* and in general they have somewhat thicker mesotheca, about 0.02-0.03 mm, and deeper exozone. The zooecial walls in the zooecial bends thicken more abruptly and form a larger angle with the mesotheca in the exozone of *S. mutabilis* than in that of *S. lita.* In the latter the walls are generally smooth and slender in the zooecial bends. The vesicular tissues, rare in *S. lita,* are common and better defined in *S. mutabilis.* The superior hemisepta may occur in *S. mutabilis* but are not observed in *S. lita.*

The zoaria of *S. mutabilis* are much larger than those of *S. exigua* or *S.* cf. *S. neglecta. S. mutabilis* is closely related to *S. paupera* in which the zoaria are generally smaller and less robust with narrower zooecial walls.

Ulrich (1895, p. 125) described and illustrated *S. mutabilis* extensively. Recently collected zoarial fragments are in good agreement with Ulrich's description and the measurements fall within the limits given by Ulrich (1895, p. 125). It might be noted that the walls forming the zooecial bends at the base of the exozone are commonly rounded and do not show sharp angularity. The angularity of the zooecial bends, if present, is probably due to a broken off superior hemiseptum that occasionally occurs at the base of the exozone.

Ulrich (1895, p. 126) assumed, but could not show it adequately that in *S. mutabilis* the median tubuli were connected directly with the mural tubuli of the range boundaries and thus opened to the external environment. In the zoarial fragments described here, such a connection is not observed. It seems, however, to be more likely that the median tubuli open to the external environment along the edges of the zoarial margins.

Occurrence: Decorah Shale, Minnesota. (See figs. 1 and 11; feet indicate distance above base of the formation.) St. Paul, abundant to very abundant 19-29 ft, abundant 29-35 ft, abundant to very abundant 35-45 ft, rare to very abundant 45-59 ft; Rochester, common to very abundant 18-33 ft, rare to common 33-44 ft; Chatfield, rare to common 20-29 ft; Fountain, rare to very abundant 10-29 ft; Spring Grove, very abundant 8-10 ft.

Occurrences reported in the literature: Common in the Decorah Shale and the Galena Dolomite, Prosser Member, at Cannon Falls, Lanesboro, Fountain, Preston and other localities in southern Minnesota (Ulrich, 1895, p. 128; Bassler, 1915, p. 1108); reported from Ordovician (Wassalem) of Uxnorm, Estonia (Bassler, 1915, p. 1108); fairly abundant in Galena Dolomite near Appleton, Wisconsin (Ockerman, 1926, p. 117); not very common in Kentland, Indiana, McKee quarry, Middle Ordovician: Div. 8, unit 17-18, and Means quarry, Middle Ordovician: Div. 8, unit 15 (Shrock and Raasch, 1937, p. 540); Bromide Formation, Rock Crossing, Criner Hills, Oklahoma (Decker and Merritt, 1931, p. 48); Platteville Limestone, Dixon quadrangle, Ill., (Knappen, 1926, p. 59); Leray Member, Ottawa Formation, Middle Ordovician, Canada (Fritz, 1957, Table 2); Decorah Formation, upper part of Spechts Ferry Shale Member, near Patch Grove, Wisconsin (Kay, 1929, p. 658); abundant in Decorah Formation, *Glyptorthis bellarugosa* faunule, lower part of Ion Dolomite Member near Ion, Iowa (Kay, 1929, p. 660); common in Decorah Formation, *Prasopora* faunule, upper part of Ion Dolomite Member, Church, Iowa (Kay, 1929, p. 661); very abundant in type section of Glenburnie Member of the Chaumont

Formation, Middle Ordovician, north of Kingston, Ontario (Kay, 1929, p. 665); common in Decorah Formation, Guttenberg Limestone Member, near Salena, Ill. (Kay, 1929, p. 659); Chambersburg Limestone, Ordovician, Appalachian Valley, Virginia (Butts, 1940, pt. 1, p. 199). Most of these reported occurrences need to be verified.

Stictopora paupera Ulrich

Plate 7

Stictopora paupera Ulrich (part), 1886, p. 69
Rhinidictya paupera (Ulrich), Bassler, 1915, p. 1109.

Type material: Lectotype USNM 162996 here designated from syntype suite USNM 43602, figured by Ulrich (1895, pl. 5, fig. 19) thin section figured here on plate 7, figure 1. Paralectotypes: unsectioned specimen USNM 162997 figured by Ulrich (1895, pl. 5, figs., 20, 21); thin sections USNM 162998-163001 (not figured). Locality: Decorah Shale, *Phylloporina* bed, St. Paul, Minn.

Additional Material from Minnesota: Thin sections: USNM 163002-163014 from Rochester, USNM 163015-163020 from Wangs. Approximate count of unsection zoarial fragments: St. Paul 520; Wangs 40(?), Rochester 730; Chatfield 570; Fountain 710; Spring Grove 35.

Description: *External features* – Zoarium small to medium, branching at intervals of 3-5 mm; branches with narrow margins having sharp to round edges; zooecial cavities ovate to subquadrate, oblique to zoarial surface, more elongate, directed outward in marginal ranges; commonly seven to eleven ranges per branch, about 15 in areas of branching; ranges demarcated by slightly elevated, relatively narrow, laterally adjacent walls; proximal part of zoarium commonly subcylindrical; attachment commonly formed by irregular, encrusting expansion.

Internal features – Zooecia rectangular with straight laterally adjacent, slightly curved longitudinally adjacent walls in endozone (pl. 7, fig. 6); cavities ovate in exozone (pl. 7, fig. 1b, 5 b.).

Zooecial walls in exozone relatively thin, form median angle with mesotheca (pl. 7, figs. 2a, 5a). Range boundaries poorly to well defined (pl. 7, figs. 1b, 2a); zooecial boundaries poorly defined, occasionally intermittent (pl. 7, fig. 5a).

Mesotheca with closely spaced median tubuli straight to flexuous at irregular intervals. Mural tubuli within range boundaries poorly defined, relatively small, in single rows, occasionally absent (pl. 7, fig. 6), those in zooecial walls of exozone randomly spaced, rare or absent.

Diaphragms thin, slightly curved, rare, about one per cavity of some zooecia, lacking in others (pl. 7, fig. 3a). Vesicular tissue poorly defined in inner exozone, rare (pl. 7, fig. 2b).

Table 4. – Quantitative data, *Stictopora paupera* Ulrich*

	Ns	Nm	Range	Mean	s	V	95% C.I.
Branch depth	23	34	0.37-0.08	0.570	0.1063	18.6	0.53-0.61
Branch width	20	25	1.00-2.68	1.511	0.4479	29.6	1.32-1.70
Cav. axis: mj.	5	5	0.13-0.19	0.174	0.0251	14.4	0.14-0.20
Cav. axis: mn.	5	5	0.06-0.10	0.090	0.0173	19.2	0.07-0.11
Depth: endo.	22	22	0.06-0.14	0.110	0.0173	15.8	0.10-0.12
Depth: exo.	22	22	0.06-0.26	0.157	0.0501	31.9	0.13-0.18
Depth: zoo.	22	22	0.15-0.38	0.268	0.0529	19.7	0.24-0.29
Zoo. angle.	21	21	43°-75°	62.8°	9.06°	14.4	59°-67°
H. cav. endo.	19	19	0.22-0.31	0.264	0.0283	10.7	0.25-0.27
Wall w: lng.	10	10	0.05-0.15	0.087	0.0359	41.3	0.06-0.11
Wall w: lat.	10	10	0.03-0.17	0.053	0.0125	23.6	0.04-0.06
Cav./2 mm lng.	4	4	7-8	7.5	0.5773	7.7	7-8
Cav./2 mm lat.	4	4	12-14	12.6	0.9574	7.5	11-14
Cav./1 mm^2.	3	5	17-23	19.4	2.30	11.9	17-22
Zoarial ratio.	22	22	0.40-0.76	0.57	0.0846	14.7	0.53-0.61

*Explanation of abbreviations follows Table 1

Remarks: In *Stictopora paupera* the zoaria are generally larger than those in *S. exigua* or *S.* cf. *S. neglecta.* The vesicular tissues are occasionally observed in *S. paupera* but not in *S. exigua.* In zoaria of *S. paupera* the branches are thinner and wider with well defined margins but with narrower zooecial walls than in *S. lita.*

In *S. mutabilis* the zoarial branches are generally wider and thicker with wider zooecial walls than in *S. paupera.* The vesicular tissue is more common in *S. mutabilis* than in *S. paupera.* No superior hemisepta are observed in *S. paupera.*

Ulrich (1886, p. 69) described the external features of *S. paupera* without figuring them. In a subsequent publication Ulrich (1895, p. 129, pl. 5, figs. 19-21) figured the species and indicated the nature of the internal structure without illustrating it.

In the syntype suite USNM 43602 there are slabs with zoaria of *S. paupera,* one of which, according to marking, was used for illustrating figure 19, plate 5 of Ulrich, 1895. The external view of the same zoarium is figured here on plate 7 figure 1d and the internal views of one branch from the same zoarium, thin section USNM 162996, is figured on plate 7 figure 1a-c. These and the other views (pl. 7, figs. 2-6) are the first figures showing the internal structure of *S. paupera.*

Occurrence: Decorah Shale, Minnesota. (See figs. 1 and 11; feet indicate distance above base of the formation.) St. Paul, rare to very abundant 33-65 ft, rare to abundant 69-71 ft; Wangs, rare 41-45 ft; Rochester, abundant to very abundant 21-39 ft, rare to common 39-51 ft; Chatfield, abundant to very abundant 16-32 ft; Fountain, rare to abundant 8-14 ft, abundant to very abundant 14-30 ft; Spring Grove, rare to abundant 8-14 ft.

Reported from Decorah Shale, Cannon Falls, Minnesota, and Decorah, Iowa (Bassler, 1915, p. 1109); common in the Decorah Formation, Guttenberg Limestone Member, south of Waukon, Iowa (Kay, 1929, p. 660).

Stictopora cf. *S. neglecta* (Ulrich) 1895

Plate 8

Material from Minnesota: Thin sections: USNM 163021-163039 from Wangs; USNM 163040-163042 from Rochester; USNM 163043 from Roscoe. Approximate count of unsectioned zoarial fragments: St. Paul 110(?), Wangs 40 Roscoe 15, Rochester 12, Chatfield 10, Fountain 12, Spring Grove 45.

Description: *External features* – Zoarium small, branching dichotomously; branches with marginal edges commonly rounded; zooecial cavities ovate, oblique to zoarial surface, with somewhat larger cavities, directed outward, in marginal ranges; approximately 4 to 10 ranges per branch; ranges demarcated by relatively wide, slightly elevated laterally adjacent walls; zoarial attachment apparently formed by an encrusting irregular basal expansion.

Internal features – Zooecia probably rectangular with straight to curved walls in endozone; cavities ovate to subcircular in exozone (pl. 8, fig. 2c).

Zooecial walls in exozone relatively thick with smooth to angular zooecial bends at base of exozone, form medium to large angle with mesotheca. Range boundaries straight to flexuous (pl. 8, figs. 1a, 2a, 2c); zooecial boundaries poorly to well defined (pl. 8, figs. 2b, 2c).

Mural tubuli within range boundaries well defined in closely spaced single rows (pl. 8, fig. 2c); those in zooecial walls of exozone randomly spaced, rare of absent. Median tubuli closely spaced in mesotheca. Diaphragms thin, rare; vesicular tissue rare, poorly defined.

Table 5. – Quantitative data, ***Stictopora*** **cf.** ***S. neglecta*** **(Ulrich).***

	Ns	Nm	Range	Mean	s	V	95% C.I.
Branch depth.	15	19	0.39-0.68	0.546	0.0753	13.9	0.51-0.58
Branch width.	10	10	0.55-1.90	1.096	0.4050	37.0	0.81-1.38
Cav. axis: mj.	2	2	0.13-0.16	0.145			
Cav. axis: mn.	2	2	0.07-0.09	0.080			
Depth: endo.	14	14	0.07-0.14	0.100	0.0204	20.3	0.08-0.11
Depth: exo.	13	13	0.09-0.20	0.143	0.0366	25.6	0.12-0.17
Depth: zoo.	13	13	0.16-0.29	0.246	0.0393	16.0	0.22-0.27
Zoo. angle.	9	9	45°-76°	64.9°	8.870	13.7	58°-72°
H. cav. endo.	5	5	0.22-0.33	0.272	0.0409	15.0	0.22-0.32
Wall w: lng.	3	3	0.12-0.18	0.143			
Wall w: lat.	3	4	0.04-0.07	0.052			
Cav./1 mm^2.	2	2	21-25	23.0			
Zoarial ratio.	13	13	0.39-0.69	0.580	0.1036	17.9	0.51-0.64

*Explanation of abbreviations follows Table 1.

Remarks: *Stictopora* cf. *S. neglecta* is closely related to *S. paupera, S. mutabilis, S. lita,* and *S. exigua* from Minnesota and to *S. neglecta* (Ulrich) from Kentucky. The zoarium appears to be smaller in *S.* cf. *S. neglecta* than in *S. paupera* although the zooecial walls seem to be wider in *S.* cf. *S. neglecta.* The shape of the zooecial cavities and that of the walls is similar to those in *S. mutabilis* in which the zooecial bends are also commonly angular. However, the superior hemisepta are not observed in *S.* cf. *S. neglecta.* Zoarium of *S.* cf. *S. neglecta* compares in size with that of *S. exigua* and *S. minima.* In *S. exigua* the angles are smaller between the zooecial walls and the mesotheca in the exozone and *S. minima* has well-defined superior hemisepta. Zoarium in *S.* cf. *S. neglecta* is generally smaller than that in *S. lita.* The zooecial walls thicken more abruptly and form larger angles with mesotheca in the exozone in *S.* cf. *S. neglecta* than in *S. lita* and thus the zooecial cavities are shaped differently in both species.

Occurrence: Decorah Shale, Minnesota. (See figs. 1 and 11; feet indicate distance above base of the formation.) St. Paul, abundant to veiy abundant (?) 73-85 ft, common 85-89 tt; Wangs, rare 46-59 ft; Roscoe, common 35-38 ft; Rochester, rare 36-43 ft, rare 46-51 ft; Chatfield, rare 32-35 ft; Fountain, rare 33-34 ft; Spring Grove, very abundant 10-16 ft.

Occurrences reported in literature: *Stictopora neglecta* (Ulrich) has been reported from Middle Ordovician, Frankfort, Boyle, and Mercer Counties, Kentucky; Nashville, Tennessee; St. Paul, Minnesota (Bassler, 1915, p. 1108); *S.* cf. *S. neglecta* reported from Ignertog, Melville Peninsula, Arctic Canada (Teichert, 1937, p. 34, 58); Bromide Formation, Oklahoma (Loeblich, 1942); Eggleston Formation, lower Middle Ordovician, Tazewell County, Virginia (Cooper and Prouty, 1943, p. 881). Most of these occurrences need to be verified.

Stictopora minima (Ulrich)

Plate 9

Rhinidictya minima Ulrich, 1890a, p. 183, fig. 8; Bassler, 1915, p. 1108.

Type material: From syntype suite USNM 43709, thin sections 43709-1-5, 7, specimen USNM 163044 figured here on plate 9, figure 1, The same specimen was illustrated by Ulrich (1890a, p. 183, figs. 8b, c; 1895, pl. 5, figs. 14, 15). Thin section USNM 163045 figured by Ulrich (1895, pl. 5, fig. 18). From syntype suite, USNM 43610, thin section USNM 163046. Locality: Decorah Shale, Cannon Falls, Minnesota.

Additional material from Minnesota: Thin sections USNM 163047-163052 from Wangs; USNM 163053-163058 from Roscoe. Approximate count of unsectioned zoarial fragments. St. Paul 50, Wangs 70, Roscoe 30, Rochester 10, Chatfield 20, Fountain 15, Spring Grove 20.

Description: *External features* – Zoarium small, branching dichotomously; branches with narrow margins, about 0.01 mm wide, occasionally crenulated; zooecial cavities ovate, more elongate, directed outward in ranges near margins; commonly 7-9 ranges per branch, including one, rarely two marginal ranges;

zooecial walls relatively wide; laterally adjacent walls slightly elevated, demarcate ranges; longitudinally adjacent walls occasionally rise proximally of cavities; maculose areas irregular, randomly spaced; zoarium apparently attached by irregular encrusting expansion.

Internal features – Zooecia rectangular in endozone, with straight walls; cavities ovate to subcircular in exozone; occasionally restricted in maculose areas (pl. 9, fig. 1e).

Zooecial walls thicken abruptly, form angular bends at base of exozone, medium to large angle with mesotheca in exozone; laminae of walls, adjacent to cavities, occasionally darkened (pl. 9, figs. 1c, 1d). Range boundaries straight to flexuous, zooecial boundaries indistinct, might be absent in exozone of some zooecia (pl. 9, fig. 1c).

Median tubuli closely spaced in mesotheca. Mural tubuli within range boundaries poorly defined; those in zooecial walls of exozone usually well defined, common, randomly spaced or aligned in intermittent rows. Hemisepta common, short, hook-like. Maculose areas with abundant mural tubuli, few zooecial cavities, merge into zoarial margins.

Table 6. – Quantitative data, *Stictopora minima* **(Ulrich)***

	Ns	Nm	Range	Mean	s	V	95% C.I.
Branch depth.	25	34	0.27-1.00	0.580	0.1966	33.8	0.51-0.65
Branch width	22	28	0.59-2.50	1.296	0.5733	44.3	1.07-1.52
Cav. axis: mj.	6	7	0.12-0.22	0.164	0.0360	22.0	0.13-0.20
Cav. axis: mn.	6	7	0.06-0.09	0.077	0.0113	14.4	0.07-0.09
Depth: endo.	22	22	0.08-0.22	0.122	0.0354	29.1	0.11-0.14
Depth: exo.	22	22	0.03-0.28	0.130	0.0637	48.9	0.10-0.16
Depth: zoo.	22	22	0.14-0.42	0.257	0.0801	31.1	0.22-0.29
Zoo. angle.	13	13	52°-85°	69.3°	10.34°	14.9	63°-76°
H. cav. endo.	11	11	0.24-0.35	0.293	0.0352	12.0	0.27-0.32
Wall w: lng.	5	6	0.09-0.22	0.155	0.0521	33.6	0.10-0.21
Wall w: lat.	5	6	0.05-0.10	0.080	0.0167	21.0	0.06-0.10
Cav./2 mm: lng.	4	4	3-7	5.5	1.73	31.4	3-8
Cav./2 mm: lat.	4	4	13-14	13.5	0.58	42.8	12-14
Zoarial ratio.	19	19	0.21-0.70	0.48	0.134	27.8	0.42-0.54

*Explanation of abbreviations follows Table 1.

Remarks: Zoaria of *Stictopora minima* is similar in size and in general appearance to those in *S. exigua* and *Astreptodictya pumila* (Ulrich). The regular presence of the superior hemisepta, abrupt thickening of the zooecial walls, angularity of the zooecial bends and the relatively large zooecial angle distinguishes *S. minima* from *S. exigua*. The general configuration of the laminae in the slightly differently shaped zooecial walls in the exozone distinguishes *S. minima* from all the other *Stictopora* species. *Astreptodictya pumila* differs from *S. minima* in having the astreptodictyid structure.

Ulrich (1890a, p. 183) named and described *S. minima* on external appearance of zoarium. In a subsequent publication Ulrich (1895, p. 132) commented on the internal morphology of the species and figured a shallow tangential thin section (Ulrich, 1895, pl. 5. fig. 18), from syntype suite USNM 43709. Another fragment of zoarium was used by Ulrich to illustrate figure 8b, c (Ulrich, 1890a, p. 183) and again figure 14 and 15 on plate 5 (Ulrich, 1895). The same specimen from syntype suite USNM 43709 is figured here on plate 9, figure 1 a-g. These and other views on plate 9, show parts of internal structure in *S. minima* for the first time.

Occurrence: Decorah Shale, Minnesota. (See figs. 1 and 11; feet indicate distance above base of formation.) St. Paul, rare 69-81 ft, rare to abundant 81-89 ft; Wangs, rare to common 46-60 ft; Roscoe, abundant 35-38 ft; Rochester, common 51-52 ft; Chatfield, abundant 34-36 ft; Fountain, abundant 33-34 ft; Spring Grove, rare to common 14-16 ft.

Bassler (1915, p. 1108) reported *S. minima* from the Galena Dolomite, Prosser Member, Cannon Falls, Minnesota.

Genus Astreptodictya n. gen.

Table 7

Type species: *Pachydictya acuta* (Hall) 1847; redescribed by Ross, 1964a, p. 21-22, pl. 3, figs. 2-6, 8-11; designated here.

Definition: Zoarium ramose or explanate; zoarial branches relatively straight to slightly curved, ribbon shaped in ramose, lobelike in explanate forms; both with well-defined to indistinct, striated, wavy, crenulated margins in some species. Ranges of zooecia linear, demarcated by range partitions.

Mesotheca straight or partly zigzag in some species; laminae of mesotheca poorly defined, form intermittent junctions with zooecial wall laminae of endozone, merge or continue without apparent break with laminae in zoarial margins.

Range partitions in exozone linear to flexuous, formed by broadly V-shaped laminae, extend throughout exozone of zoarium, apparently bifurcate near margins, areas of branching; slightly elevated at surface, with range boundary along median of partitions.

Zooecia rectangular to approximately rhombic with straight to slightly curved walls in endozone, ovate to circular cavities in exozone in tangential views; form an approximate ogee shaped curve from mesotheca to zoarial surface in longitudinal views. Zooecia in ranges adjacent to margins at an angle with growth direction of branch, strongly elongate occasionally. Zooecial walls thicken gradually at base of exozone, commonly elevated adjacent to cavities at surface. Laminae of zooecial walls poorly defined, irregulary W-shaped, inclined to cavities.

Boundary zones dark, well defined, formed by abutting or adjoining laminae. Range boundaries begin at mesotheca, continue along middle of range partitions throughout zoarium, apparently bifurcate near margins, areas of branching. Boundaries of range partitions begin at base of exozone, continue throughout zoarium, occasionally merge with zooecial boundaries. Zooecial boundaries begin at mesotheca, enclose part of zooecial wall with cavity, form ovate to circular zones in tangential view of exozone.

Median tubuli of mesotheca circular in cross section in transverse views. Mural tubuli poorly defined, small, apparently formed by irregular, cone shaped flexures of wall laminae, begin within range, probably zooecial boundaries, or rise at random within walls between zooecia in inner exozone, more abundant in areas of branching, margins, maculae; common in some species, few or absent in others.

Vesicular tissue formed in walls between zooecia at base of exozone, rarely in endozone, may extend for varying distances within walls of exozone; diaphragms of vesicular tissue slightly curved, convex to zoarial surface, merge with wall laminae, inflect or abut with boundaries of range partitions, zooecia. Diaphragms of zooecial cavities planar, thin, unevenly spaced, few to common in some species, absent in others.

Monticules, maculae rare, randomly spaced; consist of few irregular zooecia with mural tubuli.

Remarks: The genus *Astreptodictya* differs from *Stictopora* in having the ramose and explanate zoarial growth forms, well defined zooecial boundaries that are ovate to circular in tangential views of exozone and in having the range partitions. In general, the pattern of the boundary zones in *Astreptodictya* is distinctly different from that in *Stictopora.*

The laminae forming the walls are characteristically poorly defined in both genera. However, the laminae appear to be more W-shaped and they may intersect the boundary zones along the apexes of the W's at smaller and more acute angles in *Astreptodictya* than in *Stictopora.* The change in the growth direction of the zooecia is less marked in *Astreptodictya* than in *Stictopora.* The thickening of the zooecial walls is commonly more abrupt in *Stictopora* than in *Astreptodictya.*

The zooecial cavities in the endozone are similar in shape although the rectangularity of the cavities appear to be better defined in *Stictopora* than in *Astreptodictya.* In the exozone the zooecial cavities are more circular in tangential views in *Astreptodictya* than in *Stictopora.* In both genera the zooecia are in linear ranges, but the range boundaries in *Astreptodictya* are formed along the middle of range partitions which lack in *Stictopora.*

The median and the mural tubuli appear to be structurally the same in *Astreptodictya* and in *Stictopora.* However, the median tubuli are circular in cross section as seen in the transverse views of species assigned to *Astreptodictya* while those in *Stictopora* are ovate in cross section. The vesicular tissue in the walls and the diaphragms in the zooecial cavities are more common in *Astrepto-dictya.* The boundary zones and the mesotheca are similarly formed in both genera. Hemisepta have not been observed in Astreptodictya.

The genus *Pachydictya* differs from *Astreptodictya* in having the pachy-dictyid wall structures described by Ross (Phillips, 1960, p. 13-16).

Table 7. – List of species, subspecies and a variant now assigned to *Astreptodictya*, n. gen.

Name	Lithic unit	Age and Locality	Reference
Pachydictya acuta (Hall) 1847	See p. 55	See p. 56	See p. 55
P. acuta acuta (Hall)	Rockland, Kirkfield, and Shoreham Formations, as used by Ross.	Middle Ordovician; New York.	Ross, 1964a, p. 21
P. acuta minor Ross 1964	Shoreham and Denmark Formations, as used by Ross	Middle Ordovician; New York.	Ross, 1964a, p. 22
P. acuta tabulata Ross 1964	Chaumont, Rockland, Kirkfield, and Shoreham and Denmark Formations, as used by Ross	Middle Ordocivian; New York.	Ross, 1964a, p. 22
P. acuta tristolone Ross 1964	Chaumont, Rockland, Kirkfield, and Shoreham Formations, as used by Ross	Middle Ordovician; New York.	Ross, 1964a, p. 23
P. acuta var. manniensis Ross 1964	Shoreham Formation, as used by Ross	Middle Ordovician; New York.	Ross, 1964a, p. 23
P. ambigua Ross 1961	Ellis Bay Formation, as used by Ross	Late Ordovician to Silurian; Anticosti Island, Canada.	Ross, 1961, p. 339
P. bifurcata (Hall) 1883	Brassfield Limestone	Silurian; Ohio, Kentucky	Bassler, 1915, p. 928

(continued on next page)

Table 7 (continued)

P. elegans Ulrich 1895	See p. 57	See p. 58	See p. 57
P. fenestelliformis (Nicholson) 1875		Late Ordovician; Ohio, Illinois	Bassler, 1915, p. 928
P. fimbriata Ulrich 1886	See p. 53	See p. 54	See p. 53
P. gigantea Ulrich 1895		Late Ordovician; Illinois	Ulrich, 1890b, p. 524
P. occidentalis Ulrich 1895	Decorah Shale	Middle Ordovician; Minnesota	Ulrich, 1895 p. 151
P. pumila Ulrich 1890	See p. 59	See p. 60	See p. 59
The following species are assigned tentatively:			
P. crassa (Hall) 1852		Ordovician and Silurian; Canada, New York, Ohio, Indiana, Kentucky.	Ulrich, 1895, p. 147; Ross, 1961, p. 337
P. obesa Foerste 1887	Brassfield Limestone	Early Silurian; Ohio	Bassler, 1915, p. 930
P. triseralis Ulrich 1890	Trenton Limestone as used by Ulrich	Ordovician; Montreal, Canada	Ulrich, 1895, p. 159;
P. turgida Foerste 1887	Brassfield Limestone	Early Silurian; Ohio	Bassler, 1915, p. 930

Astreptodictya fimbriata (Ulrich)

Plate 10, Figures 3, 4

Pachydictya fimbriata Ulrich, 1886, p. 75; Bassler, 1915, p. 930; Shimer and Shrock, 1944, p. 270, pl. 102, figs. 1, 2.

Type material: Specimen USNM 163059 from syntype suite, USNM 43581, probably illustrated by Ulrich, 1895, plate 8, figure 31, 32; another specimen, USNM 163060, illustrated by Ulrich, 1895, plate 8, figure 33, 34; thin section USNM 163061 illustrated by Ulrich, 1895, plate 9, figure 13, 14; thin sections USNM 43581-1, 3-5. Locality: Decorah Shale, *Rhinidictya* bed, St. Paul, Minnesota.

Additional material from Minnesota: Thin sections: USNM 163062-163069 from Wangs; USNM 163070-163072 from Roscoe. Approximate count of unsectioned zoarial fragments: St. Paul 120; Wangs 160; Roscoe 30; Rochester 20; Chatfield 5.

Description: *External features* – Zoarium medium, slender, branching dichotomously at irregular intervals; branch margins wavy, obliquely striated, with sharp edges, commonly 0.40 mm in width; about 11 ranges per branch including one to two near margins with larger zooecial cavities; about 14 ranges in areas of branching; zooecial walls relatively wide, range partitions slightly elevated in some zoaria; maculae rare, small, unevenly spaced; monticules rare, irregular ridge or knoblike.

Internal features – Mesotheca generally straight, about 0.02-0.03 mm in thickness, with median tubuli closely spaced.

Range partitions generally straight with poorly defined boundaries that merge occasionally with those of zooecia in inner exozone. Zooecial cavities ovate in tangential view of exozone. Mural tubuli small, indistinct, rare in range boundaries; randomly spaced, common in zooecial walls. Vesicular tissue in inner exozone indistinct, rare in some, absent in other zoaria.

Diaphragms thin, few, randomly spaced in cavities of some zoaria; straight to slightly curved, indistinct in vesicular tissues. Boundarylike dark zone parallels zooecial boundaries distally or proximally of cavities in longitudinal views. Maculae, monticules formed of wide zooecial walls with abundant mural tubuli, few or no zooecial cavities.

Table 8. – Quantitative data, *Astreptodictya fimbriata* **(Ulrich).***

	Ns	Nm	Range	Mean	s	V	95% C.I.
Branch depth.	11	15	0.40-1.05	0.648	0.1786	27.6	0.55-0.75
Branch width	10	12	1.50-4.20	2.904	0.8771	30.2	2.35-3.46
Cav. axis: mj.	7	11	0.18-0.28	0.218	0.293	13.4	0.20-0.24
Cav. axis: mn.	8	11	0.08-0.14	0.119	0.0164	13.8	0.11-0.13
Depth: endo.	9	9	0.07-0.15	0.097	0.0229	23.7	0.08-0.11
Depth: exo.	9	11	0.14-0.33	0.211	0.0596	28.2	0.17-0.25
Depth: zoo.	9	10	0.22-0.43	0.317	0.0702	22.2	0.27-0.37
Zoo. angle.	7	10	52°-82°	67.2°	10.41°	15.5	59°-.75°
H. cav. endo.	4	7	0.26-0.43	0.366	0.0728	19.9	0.29-0.43
Wall w: lng.	8	12	0.10-0.17	0.134	0.0193	14.4	0.12-0.15
Wall w: lat.	7	13	0.07-0.14	0.099	0.0253	25.5	0.08-0.11
Cav./2 mm lng.	6	8	5-6	5.8	0.46	8.1	5-6
Cav./1 mm^2	2	3	9-13	10.7	2.08	19.5	5-16
Zoarial ratio.	9	11	0.55-0.77	0.662	0.0685	10.4	0.62-0.71

*Explanation of abbreviations follows Table 1.

Remarks: *Astreptodictya fimbriata* differs from *A. acuta* in having well-defined, relatively wide and wavy zoarial branch margins with sharp edges. In general the zoarial branches are thinner but the zooecial walls are somewhat wider with more mural tubuli in *A. fimbriata* than in *A. acuta.* The vesicular tissues are rarely observed in *A. fimbriata,* but are common in *A. acuta.* The zigzag pattern of mesotheca has not been observed in *A. fimbriata.*

The zoarial fragments of *A. fimbriata* from the Decorah Shale in Minnesota agree with Ulrich's (1895, pl. 8, figs. 28-34) descriptions. Ulrich figured the external features (1895, pl. 8, figs. 28-34) of *A. fimbriata* and illustrated two tangential views (1895, pl. 9, figs. 13, 14). The longitudinal and the transverse views are figured here (pl. 10, figs. 3a, b) for the first time.

Occurrence: Decorah Shale, Minnesota. (See figs. 1 and 11; feet indicate distance above the base of the formation.) St. Paul, very abundant 29-33 ft, rare to very abundant 40-51 ft; Wangs, rare to abundant 42-57 ft; Roscoe, abundant 35-38 ft; Rochester, rare 35-37 ft, 42-44 ft; Chatfield, rare 26-30 ft.

Occurrences reported in the literature: Reported from the Decorah Shale, Minneapolis and St. Paul, Minnesota (Bassler, 1915, p. 930); common in Decorah Formation, *Glyptorthis bellarugosa* faunule (lower part of Ion Dolomite Member), Iowa (Kay, 1929, p. 660); common in type section of Glenburnie Member of the Chaumont Formation, north of Kingston, Ontario (Kay, 1929, p. 665); *Pachydictya* cf. *P. fimbriata* reported from Pierce Limestone, Stones River Group, Tennessee (Coryell, 1921, p. 269). Some of the indicated occurrences need to be verified.

Astreptodictya acuta (Hall)

Plate 10, Figures 1, 2

Stictopora? acuta Hall, 1847, p. 74.

Pachydictya acuta (Hall), Bassler, 1915, p. 928; Sardeson 1937a, p. 19-30 99-107; Shimer and Shrock, 1944, p. 270, pl. 102, figs. 3, 4; Ross, 1964a, p. 21-22, pl. 3, figs. 2-6, 8-11.

Type material: Hypotypes: USNM 43721, probably figured by Ulrich (1895, pl. 8, figs. 11, 12); Trenton Falls, New York; USNM 44099 figured by Ulrich (1895, pl. 9, fig. 7); Cannon Falls, Minn.

Additional material from Minnesota: Thin section: USNM 163073-163074 from Rochester; USNM 163075-163083 from Wangs; USNM 163084-163087 from Roscoe. Approximate count of unsectioned zoarial fragments: St. Paul 100; Wangs 20; Roscoe 30; Rochester 30; Chatfield 20; Fountain 15.

Description: *External features* – Zoarium small to medium, slender, branching dichotomously; branch margins usually distinct, faintly striated with sharp to rounded edges; zooecial cavities ovate, slightly oblique to zoarial surface, aligned in relatively straight ranges; commonly eight ranges per branch including one to two marginal ranges having more elongate cavities, slightly directed outward; zooecial walls relatively wide; range partitions commonly elevated; occasional small maculae randomly spaced near areas of branching, margins or along zoaria.

Internal features – Mesotheca 0.02 to 0.04 mm thick, commonly zigzag in shape in central part of some zoaria; median tubuli closely spaced.

Range partitions straight to flexuous; their boundaries occasionally merge with those of zooecia. Zooecial cavities ovate in tangential view of exozone. Mural tubuli small, poorly defined, commonly absent in range boundaries; rare, randomly spaced or lacking in walls between zooecia. Vesicular tissue common in zooecia of some zoaria, begin in inner exozone, may extend about half way through walls in exozone. Diaphragms thin, one to two per cavity of some zoaria, absent in others; straight to curved, common in vesicular tissue, about 0.03 to 0.05 mm apart. Boundarylike dark zone parallels zooecial boundaries distally of cavities, vesicular tissues in longitudinal views.

Table 9. – Quantitative data, *Astreptodictya acuta* **(Hall)***

	Ns	Nm	Range	Mean	s	V	95% C.I.
Branch depth.	11	15	0.40-1.30	0.883	0.2204	25.0	0.76-1.00
Branch width.	11	11	1.10-4.00	2.682	1.1764	43.9	1.89-3.47
Cav. axis: mj.	8	8	0.22-0.32	2.537	0.0329	13.0	0.23-0.28
Cav. axis: mn.	8	8	0.11-0.18	0.132	0.0271	20.5	0.11-0.16
Depth: endo.	12	16	0.07-0.22	0.123	0.0361	29.3	0.10-0.14
Depth: exo.	12	16	0.10-0.50	0.282	0.1067	37.9	0.22-0.34
Depth: zoo.	11	15	0.21-0.66	0.420	0.1114	26.5	0.36-0.48
Zoo. angle.	8	9	58°-70°	63.2°	3.42°	5.4	60°-66°
H. cav. endo.	6	7	0.36-0.40	0.387	0.0170	4.4	0.37-0.40
Wall w: lng.	8	9	0.05-0.15	0.108	0.0303	28.1	0.08-0.13
Wall w: lat.	8	10	0.06-0.11	0.076	0.0165	21.7	0.06-0.09
Cav./2 mm lng.	7	8	5-6	5.5	0.53	9.7	5-6
Cav./2 mm lat.	8	9	8-10	8.6	0.70	8.2	8-9
Cav./1 mm^2	5	7	10-15	11.6	1.61	14.0	10-13
Zoarial ratio.	12	17	0.25-0.83	0.659	0.1364	20.7	0.59-0.73

*Explanation of abbreviations follows Table 1.

Remarks: *Astreptodictya acuta* resembles *A. ambigua,* a recently described new species (Ross 1961, p. 339, pl. 44, figs. 1-6; pl. 45, figs. 6, 9) from the Ellis Bay Formation, Ordovician, Anticosti Island, Canada. Fragments from the zoaria of both species appear to be similar in size, branch width and depth. There appears to be fewer zooecia with wider walls per two mm laterally and longitudinally in *A. ambigua* than in *A. acuta.* The mesotheca seems to be somewhat thicker in *A. ambigua* than in *A. acuta* but in spacing and size the median tubuli are about the same in both species as seen in the transverse view. These views also show (pl. 10, fig. 1a) that the boundary zones, which are well defined in *A. acuta* are observable also in *A. ambigua* (Ross, 1961, pl. 44, figs. 2, 3). The walls adjacent to the cavities are well defined in *A. acuta* (pl. 10, figs. 1b 1c) (Ross, 1964a, pl. 3, figs. 3, 4, 6, 10) and in *A. ambigua* (Ross, 1961, pl. 44, figs. 1, 5). The vesicular tissues in the walls appear better developed in *A. acuta* than in *A. ambigua.* Diaphragms in the zooecial cavities are rare in both species.

The zoarial fragments from the Decorah Shale in Minnesota agree with Ulrich's (1895, p. 135) general description in regard to the external zoarial features. The nature of the internal morphology was vaguely indicated by Ulrich (1895, p. 157) without illustration at that time. The zoarial fragments from Minnesota showing internal features are figured here.

Ross (1964a, p. 21-22, pl. 3, figs. 2-6, 8-11) redescribed and showed the internal features of the holotype of *Pachydictya acuta* for the first time.

Occurrence: Decorah Shale, Minnesota. (See figs. 1 and 11; feet indicate distance above base of the formation.) St. Paul, common 43-47 ft, rare to abundant 55-63 ft, common to very abundant 65-71 ft; Wangs, rare to abundant 41-54 ft; Roscoe, very abundant 35-38 ft; Rochester, rare to common 35-51 ft; Fountain, rare to common 25-27 ft.

Ross (1964a, p. 22) reports that *A. acuta acuta* (Hall): " . . . is found in the Trentonian at Canajoharie Creek . . . , at Middleville . . . , at Newport . . . , at Sugar River . . . , at Roaring Brook . . . and it apparently ranged from the Rockland Formation into the Shoreham Formation."

Bassler (1915, p. 928) indicated the occurrence of *A. acuta* in Iowa, Kentucky, Ontario, and Manitoba. Fritz (1957, table 2) found *A. acuta* in the Leray and Rockland Members of the Ottawa Formation (as used by Fritz) in Canada. Knappen (1926, p. 59) reported it from the Platteville Limestone in Dixon quadrangle, Illinois. Decker and Merritt (1931, p. 38) listed *A. acuta* as occurring in the Tulip Creek Formation of the Simpson Group in Oklahoma. Some of the occurrences given above are in need of verification.

Astreptodictya elegans (Ulrich)

Plate 11

Pachydictya elegans Ulrich, 1895, p. 154, pl. 8, figs. 18, 19; pl. 9, figs. 8, 9. Bassler, 1915, p. 929; Toots, 1952, p. 130, pl. 8, fig. 4.

Type material: One fragment USNM 163088, from the syntype suite USNM 43583, figured by Ulrich 1895, plate 8, figure 18, 19. Hypotypes: thin sections USNM 34976-1, 2, 4 and USNM 163089. Thin section USNM 163090 is figured here on plate 11, figure 4. Locality: Decorah Shale and Galena Dolomite, *Clitambonites* bed, St. Paul, Minnesota. Thin sections: USNM 34876-1, 2 from four miles south of Cannon Falls, Minn.; USNM 55165-1-3 from 3 miles southeast of Cannon Falls, Minn.

Additional material from Minnesota: Thin sections: USNM 163091-163093 from Rochester; USNM 163094 from Wangs. Approximate count of unsectioned zoarial fragments: St. Paul 20; Rochester 5; Chatfield 1.

Description: *External features* – Zoarium medium, branching commonly; branch margins obliquely striated with sharp to rounded edges, about 0.28 mm wide; zooecial cavities ovate in straight ranges; range partitions slightly elevated, approximately 12 zooecial ranges per branch, about 24 in areas of branching including one or two marginal ranges with larger cavities; zooecial walls relatively wide, especially in areas of branching, near margins; zoarium apparently grows from basal encrusting expansion with regularly aligned zooecia having abundantly striated walls; erect part of zoarium connects with basal expansion by short, neck-like zoarial segment with abundant striations, no zooecial cavities.

Internal features – Mesotheca about 0.02-0.05 mm thick, may zigzag unevenly in central parts of some zoaria; median tubuli closely spaced.

Range partitions straight to flexuous, occasionally with intermittent boundaries that may merge with those of zooecia. Zooecial cavities ovate in tangential view of exozone. Mural tubuli within range boundaries indistinct, occasionally occur in zooecial boundaries, walls, more abundant in marginal areas, commonly aligned in dark, intermittent zones diverging from boundaries.

Vesicular tissue well defined, common, begin near base of exozone, may extend about half way through walls rarely reach zoarial surface. Diaphragms thin, distinct; commonly two to three per zooecial cavity, about 0.10 to 0.16 mm apart; straight to curved in vesicular tissue, about 0.03 to 0.06 mm apart; dark boundary-like zone, commonly intermittent, parallels zooecial boundaries distally and proximally of cavities in longitudinal views.

Table 10. – Quantitative data, *Astreptodictya elegans* **(Ulrich)***

	Ns	Nm	Range	Mean	s	V	95% C.I.
Branch depth.	9	12	0.60-2.10	1.326	0.4551	30.4	1.04-1.61
Branch width.	8	10	2.40-5.00	3.570	0.9764	27.4	2.87-4.27
Cav. axis: mj.	6	9	0.19-0.27	0.222	0.0273	12.3	0.20-0.24
Cav. axis: mn.	6	9	0.10-0.15	0.117	0.0173	14.8	0.10-0.13
Depth endo.	10	11	0.07-0.12	0.100	0.0148	14.8	0.09-0.11
Depth: exo.	10	10	0.23-0.85	0.508	0.2121	41.7	0.35-0.66
Depth: zoo.	10	10	0.35-0.95	0.616	0.1992	32.3	0.47-0.76
Zoo. angle.	9	10	53°-82°	67.3°	7.96°	11.8	61°-73°
H. cav. endo.	8	9	0.30-0.50	0.392	0.0710	18.1	0.34-0.45
Wall w: lng.	7	9	0.12-0.21	0.146	0.0317	21.8	0.12-0.17
Wall w: lat.	7	9	0.09-0.15	0.126	0.0200	16.0	0.11-0.14
Cav./2 mm lng.	6	6	5-6	5.2	0.40	7.9	5-6
Cav./2 mm lat.	6	7	7-9	8.3	0.76	9.1	8-9
Cav./1 mm^2.	5	7	10-13	11.3	1.11	9.8	10-12
Zoarial ratio.	10	10	0.62-0.94	0.800	0.0929	11.6	0.73-0.87

*Explanation of abbreviations follows Table 1.

Remarks: *Astreptodictya elegans* differs from *A. acuta* and *A. fimbriata* in having larger zoaria with wider branches and more extensively developed vesicular tissues. The vesibular tissues are usually lacking in *A. fimbriata.* The mural tubuli in the zooecial walls of *A. elegans* are aligned commonly in short, intermittent dark zones which may diverge from the boundaries. In *A. acuta* and *A. fimbriata* the mural tubuli in general do not show a preferred alignment except for those in the boundaries.

Ulrich illustrated (1895, pl. 8, figs. 18, 19) the external appearance of zoarium in *A. elegans* and figured the internal structure in a tangential view (Ulrich, 1895, pl. 9, figs. 8, 9). The longitudinal and the transverse views of the zooecial structure are given herein. (pl. 11, figs, 1a, b; 2a, b; 3a, b).

Occurrence: Decorah Shale, Minnesota. (See figs. 1 and 11; feet indicate distance above base of the formation.) St. Paul, common 57-59 ft. 67-69 ft; Rochester, rare 35-43 ft; Chatfield, rare 28-30 ft.

Bassler (1915, p. 929) indicated the occurrence of *A. elegans* in Galena Dolomite, Prosser Member, in St. Paul, Minnesota; in rocks of Middle Ordovician age in Wesenberg, Estonia. Toots (1952, p. 130) reports *A. elegans* from Kuckersit C_2-C_3 Ordovician, Kava, Estonia. Some of the occurrence and locality data are in need of verification.

Astreptodictya pumila (Ulrich)

Plate 12, Figures 4-6

Pachydictya pumila Ulrich, 1890a, p. 186, fig. 11; Bassler, 1915, p. 931.
Rhinidictya humilis Ulrich, 1890a, p. 185, fig. 10.
?Pachydictya pumila Ulrich, Nekhoroshev, 1961, p. 157, pl. 35, figs. 8-10.

Type material: Specimens from syntype suite USNM 43702: specimen USNM 163095 figured by Ulrich, 1890a, p. 185, figure 10a, b; 1895, plate 8, figure 5; specimen USNM 163096 figured by Ulrich, 1890a, p. 185, figure 10a; 1895, plate 8, figure 4; specimen USNM 163097 figured by Ulrich, 1890a, p. 186, figure 11b; 1895, plate 10, figure 4; specimen USNM 163098 figured by Ulrich, 1890a, p. 186, figure 11a; 1895, plate 10, figure 1; specimen USNM 163099 figured by Ulrich, 1890a, p. 186, figure 11a; 1895, plate 10, fig. 1; specimen USNM 163100 figured by Ulrich, 1890a, p. 186, figure 11a; 1895 plate 10, figure 1; thin sections USNM 43702-1 to 8. Locality: Cannon Falls, Minn.

Additional material from Minnesota: Thin sections: USNM 163101-163110 from Rochester. Approximate count of unsectioned zoarial fragments: St. Paul 40; Wangs 80; Roscoe 5; Rochester 20; Fountain 10 (?).

Description: *External features* – Zoarium small, branching commonly at irregular intervals; branch margins with sharp to rounded edges distally, about 0.15 mm wide, occasionally absent proximally; zooecial cavities ovate in relatively straight ranges; range partitions slightly elevated, commonly five ranges per branch including one marginal with more elongate cavities; ranges indistinct in proximal areas of zoarium; zooecial walls narrow, may widen in areas of branching, near margins. Monticules, maculae rare, unevely spaced; zoarium probably attached by encrusting expansion with randomly spaced, irregular zooecia.

Internal features – Mesotheca straight to slightly flexuous with poorly defined median zone having closely spaced somewhat larger median tubuli, about 0.02 mm in diameter.

Range partitions with indistinct boundaries. Zooecial cavities ovate in tangential view of exozone; mural tubuli small, indistinct within range boundaries; few, randomly spaced, or lacking in zooecial walls.

Vesicular tissue near base of exozone in some zooecia, absent in others may extend about half way through exozone. Diaphragms thin, indistinct, rare; usually occur near base of exozone of some zooecia, slightly curved in vesicular tissues, about 0.03 to 0.04 mm apart.

Table 11. – **Quantitative data,** *Astreptodictya pumila* **(Ulrich)***

	Ns	Nm	Range	Mean	s	V	95%C.I.
Branch depth.	14	16	0.50-0.90	0.647	0.0981	15.2	0.59-0.70
Branch width.	14	15	0.70-2.30	1.229	0.4303	35.0	0.99-1.47
Cav. axis: mj.	5	5	0.18-0.24	0.216	0.0230	10.6	0.19-0.24
Cav. axis: mn.	5	6	0.10-0.14	0.120	0.0141	11.8	0.11-0.13
Depth: endo.	10	13	0.05-0.12	0.092	0.0196	21.2	0.08-0.10
Depth: exo.	10	10	0.12-0.32	0.209	0.0656	31.3	0.16-0.26
Depth: zoo.	10	10	0.22-0.42	0.305	0.0570	18.7	0.26-0.34
Zoo. angle.	6	6	62°-80°	71.7°	7.09°	9.9	64°-79°
H. cav. endo.	7	7	0.30-0.40	0.368	0.0362	9.8	0.34-0.40
Wall w: lng.	5	6	0.07-0.13	0.105	0.0207	19.7	0.08-0.13
Wall w: lat.	5	6	0.05-0.13	0.083	0.0320	38.4	0.05-0.12
Cav./2 mm lng.	4	4	5-6	5.5	0.58	10.5	5-6
Cav./2 mm lat.	4	4	7-10	8.5	1.30	15.2	6-11
Cav./1 mm^2.	2	2	10-12	11.0	1.41		
Zoarial ratio.	10	10	0.52-0.86	0.67	0.1081	16.0	0.60-0.75

*Explanation of abbreviations follows Table 1.

Remarks: The zoarium in *Astreptodictya pumila* is characteristically small and similar in size to zoaria in *Stictopora exigua, S. minima,* and smaller specimens of *S. lita.* The zoarium in *A. pumila* is the smallest among astreptodictyid species discussed in this paper.

Apart from the difference in the size of zoaria, *A. pumila* differs from *A. acuta* in having thicker mesotheca with somewhat larger median tubuli in transverse views and relatively thick zooecial walls in endozone. The vesicular tissues are less extensive in *A. pumila* than in *A. acuta.* In regard to the extent of the development of these tissues, *A. pumila* is in an intermediate position between *A. ambigua, A. fimbriata,* and *A. acuta,* and *A. elegans.* In the former two species the vesicular tissues are absent or rarely observed and in the latter two they are common.

Ulrich (1890a, p. 185, 186; 1895, p. 157) described and figured the external appearance of *A. pumila.* Nekhoroshev (1961, p. 157, pl. 35, figs. 8-10) figured the internal features of zoarial fragments which were assigned to *A. pumila* from Ordovician strata in the Siberian platform, in tangential and tranverse views.

A longitudinal view of *A. pumila* is figured here (pl. 12, fig. 5) in addition to the transverse and tangential views (pl. 12, figs. 4, 6). *A. pumila* from the Decorah Shale, like some of the other forms, is characteristically poorly preserved.

Occurrence: Decorah Shale, Minnesota. (See figs. 1 and 11; feet indicate distance above base of the formation.) St. Paul, rare to very abundant 61-67 ft, rare 81-87 ft; Wangs, common to very abundant 51-60 ft; Roscoe, rare 35-38 ft; Rochester, rare to abundant 46-52 ft; Fountain, rare to common 32-33 ft.

Bassler (1915, p. 931) indicated the presence of *A. pumila* in Middle Ordovician rocks near Cannon Falls, Minnesota, and at Trenton Falls, New York. Nekhoroshev (1961, p. 157) reports *A. pumila* from the lower Middle Ordovician strata in Tas-Urah, Siberia.

Genus Athrophragma n. gen.

Type species: *Pachydictya foliata* Ulrich 1886, p. 73; 1895, p. 149, pl. 9, figs. 1-5; pl. 10, figs. 5-10; designated here.

Definition: Zoarium explanate, branching unevenly into lobelike expansions with obliquely striated margins; ranges of zooecia oblique to indistinctly linear. Mesotheca straight to slightly flexuous with poorly defined laminae forming intermittent junctions with zooecial wall laminae of endozone, merge or continue without apparent break with laminae of zoarial margins.

Zooecia irregularly ovate, elongate in endozone with ovate to circular cavities in exozone in tangential views, form relatively smooth curve from mesotheca to zoarial surface. Zooecial walls thicken gradually with change in direction of growth at base of exozone, commonly elevated adjacent to cavities at surface. Laminae of zooecial walls poorly defined, irregularly, broadly U-shaped in exozone, convex to surface, inclined to cavities. Zooecial boundaries dark, well defined, begin at mesotheca, formed by abutting or adjoining laminae, enclose part of zooecial wall with cavity, form ovate to circular zones in tangential view of exozone. Dark, distinct zones, intermittent, straight to slightly flexuous, align in approximate growth direction of zoarium, rise at random within zooecial walls or diverge from zooecial boundaries in exozone, abundant in areas of maculae, near margins. Median tubuli of mesotheca circular in cross section in transverse views. Mural tubuli small, commonly align within dark zones, rarely within zooecial boundaries. Vesicular tissue commonly formed at mesotheca, occasionally encloses zooecial cavities with part of wall in endozone, near base of exozone, may reach zoarial surface in areas of maculae.

Diaphragms planar to slightly curved, about evenly spaced in zooecial cavities; curved, convex to zooecial surface, commonly in overlapping series in vesicular areas, merge with zooecial wall laminae in exozone, abut or adjoin with zooecial boundaries.

Maculae common, about evenly spaced, with dark, intermittent zones, occasionally with mural tubuli, commonly without zooecial cavities. Monticules with few zooecia, randomly spaced.

Remarks: *Athrophragma* differs from *Astreptodictya* in having an explanate growth form with lobelike, uneven zoarial expansions, and indistinct alignment of zooecial cavities in somewhat oblique ranges but without range partitions between them. The laminae forming the zooecial walls are characteristically poorly defined in both genera. Configuration of laminae in *Athrophragma* differs from that in *Astreptodictya* in being more U-shaped. However, the poor preservation of the available specimens makes the description of the configuration of laminae somewhat tentative. The zooecial cavities in the endozone are slightly differently shaped in *Athrophragma* than those in *Astreptodictya*. Similarly in the exozone, where the zooecial cavities are less ovate and more circular in *Athrophragma* than in *Astreptodictya*. The vesicular tissues are more extensive in *Athrophragma* than in *Astreptodictya*. In the former the vesicular tissues commonly begin at the mesotheca and occasionally enclose the zooecial cavities near the base of exozone. The diaphragms of vesicular tissues appear better developed in *Athrophragma* than in *Astreptodictya*.

The median tubuli and the mural tubuli which are small and poorly defined, appear to be similarly formed in *Athrophragma* and in *Astreptodictya*. However, in *Athrophragma* the mural tubuli in the zooecial walls are commonly aligned in the short, dark, flexuous zones and they are rarely positioned individually. The well defined range boundaries of *Stictopora* and *Astreptodictya* are not observed in *Athrophragma*.

The maculae and the monticulas are common, evenly spaced and may be aligned in longitudinal, alternate pattern on the zoarial surface in *Athrophragma*. In *Astreptodictya* the maculae are observed rarely.

Stictopora differs from *Athrophragma* in having the stictoporid wall structure (fig. 3). *Pachydictya* differs from *Athrophragma* in having the pachydictyid wall structures as defined by Ross (Phillips, 1960, p. 13-16).

The following species are assigned now to *Athrophragma*, n. gen.: *Pachydictya foliata* Ulrich 1886, see below; *P. magnipora* Ulrich 1889, Middle Ordovician, Trenton age, St. Andrews, Manitoba (Ulrich, 1889, p. 43).

Athrophragma foliata (Ulrich)

Plates 13,14

Pachydictya foliata Ulrich, 1886, p. 73; Bassler, 1915, p. 930; Sardeson, 1937a, p. 19-30, 99-107.

? *Pachydictya* cf. *P. foliata*, Wilson, 1949, p. 43, pl. 4, figs. 1, 2; Astrova, 1965, p. 281, pl. 76, Fig. 2.

Type material: Lectotype USNM 163111 here designated from syntype suite USNM 43584, figured by Ulrich, 1895, plate 10, figure 8; thin section figured here, plate 13, figure 1. Paralectotypes: USNM 163112, figured by Ulrich, 1895, plate 10, figure 5; USNM 163113, figured by Ulrich, 1895, plate 10, figure 6; USNM 163114, figured by Ulrich, 1895, plate 10, figure 7; USNM 163115, 36 unsectioned specimens; thin sections USNM 163116-163122. Locality: Decorah Shale, *Stictoporella* bed, St. Paul, Minnesota. Thin sections USNM 163123-163125 from syntype suite USNM 34911; locality: Decorah Shale, Minneapolis, Minnesota.

Additional material from Minnesota: USNM 163126-163129 from St. Paul; USNM 163130 from Wangs. Approximate count of unsectioned zoarial fragments: St. Paul 130; Wangs 4.

Description: *External features* – Zoarium dividing unevenly; margins obliquely striated with sharp to rounded edges; zooecial cavities ovate to subcircular, more elongate near maculae, monticules and zoarial margins, aligned in oblique, slightly curved, indistinct ranges; zooecial walls relatively wide, occasionally striated; maculae commonly striated, about 1.00 mm in diameter, aligned in indistinct alternate rows, approximately 3 to 4 mm apart; monticules rare, unevely spaced, consist of few zooecia with wide walls.

Internal features – Mesotheca straight to slightly curved, about 0.04 mm thick, with median tubuli closely spaced. Zooecial cavities ovate to subcircular in tangential view of exozone. Mural tubuli poorly defined, commonly aligned in dark, intermittent zones in walls between zooecia, occasionally obscuring zooecial boundaries, more abundant in maculae, monticules, near margins, commonly appear as striations on zoarial surface. Vesicular tissue extensively developed, begins at mesotheca, may extend throughout exozone between cavities, occasionally closing them near surface, may form maculae. Diaphragms thin, straight to curved, about three to five or more per zooecium, 0.12 to 0.30 mm apart, appear more widely spaced in inner than outer exozone. Diaphragms of vesicular tissue curved, about 0.03 to 0.06 mm apart.

Table 12. – Quantitative data, ***Athrophragma foliata*** **(Ulrich)***

	Ns	Nm	Range	Mean	s	V	95% C.I.
Branch depth.	7	10	1.20-2.60	2.012	0.5638	28.0	1.60-2.42
Cav. axis: mj.	5	8	0.24-0.31	0.28	0.0300	10.6	0.26-0.31
Cav. axis: mn.	5	9	0.15-0.20	0.178	0.0156	8.7	0.16-0.19
Depth: endo.	4	4	0.07-0.09	0.077	0.0096	12.4	0.06-0.09
Depth: exo.	4	4	0.62-1.10	0.980	0.2400	24.5	0.60-1.36
Depth: zoo.	4	4	0.70-1.30	1.100	0.2708	24.6	0.67-1.53
Zoo. angle.	4	5	60°-81°	70.2°	8.23°	11.7	60°-80°
H. cav. endo.	4	4	0.40-0.47	0.430	0.0360	8.3	0.37-0.49
Wall w: lng.	4	7	0.11-0.33	0.207	0.0844	40.7	0.13-0.28
Wall w: lat.	5	9	0.07-0.22	0.136	0.0472	34.8	0.10-0.17
Cav./2 mm lng.	4	8	4-6	5.1	0.83	16.2	4-6
Cav./2 mm lat.	5	8	5-8	6.4	0.91	14.4	6-7
Cav./1 mm^2.	5	8	9-11	9.3	0.74	7.9	9-10
Zoarial ratio.	4	4	0.85-0.92	0.895	0.0332	3.7	0.84-0.95

*Explanation of abbreviations follows Table 1.

Remarks: The specimens of *A. foliata* collected in Minnesota agree with Ulrich's (1886, p. 73; 1895, p. 149, pl. 9, figs. 1-5) earlier description. The taxonimic postion of *A. foliata* (Ulrich) in regard to *A. magnipora* (Ulrich) (Ulrich, 1889, p. 43) needs to be evaluated.

A. foliata also appear to be closely related to *Trigonodictya irregularis* Coryell, (Coryell, 1921, p. 303; pl. 13, figs. 8, 9), from which additional material needs to be collected and evaluated.

Occurrence: Decorah Shale, Minnesota. (See figs. 1 and 11; feet indicate distance above base of the formation.) St. Paul, rare to very abundant 1-5 ft, very abundant 5-7 ft, rare to common 7-11 ft; Wangs, rare 6-8 ft.

Bassler (1915, p. 930) indicated the presence of *A. foliata* (Ulrich) in Minneapolis, St. Paul, and Cannon Falls, Minnesota. Wilson (1949, p. 34, 38, 43) reports *A.* cf. *foliata* from the Pierce, Ridley, and Lebanon Limestones of central Tennessee, and Astrova (1965, p. 281) reports it from the Middle Ordovician on the Island Vaigasch in the Passage of the Karsh Sea, Western Arctic province. These occurrences need to be verified.

Genus *Stictoporella* Ulrich 1882

Remarks: Nekhoroshev (1956, p. 48) erected the genus *Stictoporellina* and named *Stictoporella cribrosa* Ulrich 1895 (p. 184) as the type species. It appears that *Stictoporellina* Nekhoroshev was erected on the basis of the external appearance of the zoarium without the description of the configuration of the laminae in the walls of the zooecia and mesopores.

Until the type material of both genera, *Stictoporella* Ulrich (Phillips 1960, p. 23) and *Stictoporellina* Nekhoroshev, is reinvestigated bearing in mind the three dimensional aspects of the internal zoarial structure, the taxonomic assignment of the *Stictoporella* species discussed in this paper is provisional.

Stictoporella angularis Ulrich

Plate 15

Stictoporella angularis Ulrich, 1886, p. 71; Bassler, 1915, p. 1191.

Type material: From syntype suite USNM 43470: specimen USNM 163131, figured by Ulrich, 1895, plate 11, fig. 1; specimen USNM 163132, figured by Ulrich, 1895, plate 11, fig. 2. Two thin sections, USNM 163133, 163134, probably figured by Ulrich, 1895, plate 11, figure 8-11. Locality: Decorah Shale, *Stictoporella* bed, Minneapolis, Minnesota.

Additional material from Minnesota: Thin sections USNM 163135-163141 from Rochester. Approximate count of unsectioned zoarial fragments: St. Paul 140; Rochester 420; Chatfield 230; Fountain 9; Spring Grove 60.

Description: *External features* – Zoarium small, branching dichotomously at uneven intervals; branches ribbon like to subrounded with narrow margins having sharp to rounded edges; zooecia with ovate cavities, relatively wide walls sloping toward cavities; zooecial boundaries occasionally ridgelike; mesopores polygonal to circular, few, small, commonly closed, randomly spaced.

Internal features – Mesotheca straight to flexuous, approximately 0.02 to 0.04 mm thick. Zooecia elongate, aligned in indistinctly linear ranges in endozone, irregularly hexagonal to polygonal in tangential view of exozone; wall laminae occasionally dark streaked boundaries between zooecia, mesopores well defined, occasionally with pustulelike dots. Diaphragms thin, rare in zooecia, lacking in mesopores.

Table 13. – Quantitative data, *Stictoporella angularis* Ulrich*

	Ns	Nm	Range	Mean	s	V	95% C.I.
Branch depth.	14	25	0.35-1.90	1.125	0.4411	39.2	0.94-1.31
Branch width.	4	4	1.50-2.70	2.025	0.5123	25.3	1.21-2.84
Cav. axis: mj.	16	42	0.12-0.25	0.180	0.0300	16.7	0.17-0.19
Cav. axis: mn.	16	45	0.07-0.18	0.112	0.0252	22.6	0.10-0.12
Depth: endo.	15	31	0.08-0.20	0.120	0.0239	20.0	0.11-0.13
Depth: exo.	15	31	0.12-0.76	0.381	0.1908	50.1	0.31-0.45
Depth: zoo.	15	25	0.30-0.90	0.540	0.1736	32.2	0.47-0.61
Zoo. angle.	14	17	70°-90°	82.3°	5.30°	6.4	80°-85°
H. cav. endo.	9	13	0.30-0.65	0.405	0.1047	25.8	0.34-0.47
Wall w: lng.	15	42	0.08-0.30	0.198	0.0584	29.5	0.18-0.22
Wall w: lat.	15	47	0.06-0.23	0.125	0.0308	24.6	0.12-0.13
Cav./2 mm lng.	12	16	3-7	5.1	1.12	22.2	4-6
Cav./2 mm lat.	12	16	6-9	7.5	0.70	9.2	7-8
Cav./1 mm^2.	15	30	8-16	11.4	1.89	16.5	10-12
Msp/1 mm^2.	11	17	0-8	3.8	2.19	57.1	3-5
Zoarial ratio.	14	14	0.47-0.55	0.704	0.1097	15.6	0.64-0.77

*Explanation of abbreviations follows Table 1.

Remarks: *Stictoporella angularis* differs from the type species, *S. interstincta* Ulrich, in having unevenly spaced mesopores, dark, well-defined boundaries between the zooecia or mesopores and the indistinct alignment of zooecia in the exozone. In the endozone the zooecia appear aligned in somewhat linear ranges in both species. The diameters of the ovate zooecial cavities in exozone are similar in both species. The hemisepta are absent in *S. angularis* and does not appear to be present in *S. interstincta* but see Ross (Phillips, 1960, p. 23).

S. angularis is closely related to *S. frondifera* Ulrich and *S. dumosa* Ulrich. The morphological resemblance is indicated in the remarks of the respective species.

Occurrence: Decorah Shale, Minnesota. (See figs. 1 and 11; feet indicate distance above base of the formation.) St. Paul, rare 0-3 ft, very abundant 3-7 ft, rare to common 7-13 ft; Rochester, common to very abundant 0-8 ft, rare 8-14 ft; Chatfield very abundant 0-3 ft; Fountain, rare 0-6 ft; Spring Grove, very abundant 0-2 ft, rare 2-6 ft.

Bassler (1915, p. 1191) indicated the occurrence of *S. angularis* in Minneapolis, St. Paul and in Goodhue and Fillmore counties, Minnesota.

Stictoporella frondifera Ulrich

Plate 16

Stictoporella frondifera Ulrich, 1886, p. 72; Bassler, 1915, p. 1192; Perry, 1962, p. 31, pl. 7, figs. 1-9.

Type material: From syntype suite USNM 43472: specimens USNM 163142-163144 figured by Ulrich, 1895, plate 11, figure 12-14 repectively; thin sections USNM 163145-163147, probably figured by Ulrich, 1895, plate 11, figures 16-19; Decorah Shale, *Stictoporella* bed, Minneapolis, Minn.

Additional material from Minnesota: Thin sections: USNM 163148 from Wangs; USNM 163149, 163150 from Fountain; USNM 163151-163153 from Spring Grove. Approximate count of unsectioned zoarial fragments: St. Paul 35; Wangs 1; Rochester 2; Chatfield 20 (?); Fountain 28; Spring Grove 260.

Description: *External features* – Zoarium explanate, branching unevenly in lobelike expansions with subrounded margins; zooecia polygonal to subcircular, aligned in slightly curving, diagonally intersecting ranges; zooecial cavities broadly ovate; walls relatively wide; mesopores polygonal to subcircular, common, occur singly, in pairs of two or in aggregates of many in maculae; maculae common, unevenly spaced, commonly 2 to 5 mm apart, consist of zooecia with wide walls, mesopores; some incomplete zoaria about 56 mm in length, 22 mm in width.

Internal features – Mesotheca straight to slightly flexuous, about 0.02 to 0.03 mm thick. Zooecia elongate, aligned in indistinctly linear ranges in endozone, irregularly hexagonal to polygonal in oblique ranges in tangential view of exozone; wall laminae occasionally dark streaked boundaries between zooecia, mesopores well defined, commonly with pustulelike dots. Mesopores begin near base of exozone, commonly filled with laminated calcite. Diaphragms thin, rare in zooecial cavities, absent in mesopores.

Table 14. – Quantitative data, *Stictoporella frondifera* (Ulrich)*

	Ns	Nm	Range	Mean	s	V	95% C.I.
Branch depth.	10	16	1.00-1.80	1.340	0.2417	18.0	1.21-1.46
Cav. axis: mj.	11	35	0.12-0.22	0.183	0.0250	13.6	0.17-0.19
Cav. axis: mn.	11	34	0.08-0.23	0.128	0.0336	26.1	0.12-0.14
Depth: endo.	10	14	0.08-0.15	0.116	0.0234	20.1	0.10-0.13
Depth: exo.	10	17	0.35-0.70	0.565	0.1011	18.0	0.51-0.62
Depth: zoo.	10	15	0.45-0.85	0.705	0.1102	15.6	0.64-0.77
Zoo. angle.	5	6	72°-85°	79.7°	5.16°	6.5	74°-85°
Wall w: lng.	11	34	0.07-0.37	0.186	0.0891	47.8	0.16-0.22
Wall w: lat.	11	33	0.08-0.28	0.137	0.0389	28.3	0.12-0.15
Cav./2 mm lng.	12	22	4-8	6-4	1.09	17.2	6-7
Cav./2 mm lat.	4	5	7-8	7.6	0.55	7.2	7-8
Cav./1 mm^2	12	28	4-17	10.4	1.61	15.6	10-11
Msp./1 mm^2.	6	24	4-15	8.0	3.46	43.3	6-9
Zoarial ratio.	10	10	0.75-0.92	0.818	0.494	6.0	0.78-0.85

*Explanation of abbreviations follows Table 1.

Remarks: *S. frondifera* Ulrich differs from the type species *S. interstincta* Ulrich in having explanate zoarium, well-defined boundary zones, larger zoarial ratios, wider angles between the zooecial walls in endozone and in exozone, and in the distribution and kind of the maculae.

S. frondifera differs from *S. angularis* in having larger and explanate zoarium, abundant mesopores, distinct maculae and larger zoarial ratios.

Perry (1962, p. 31, pl. 7, figs. 1-9) reports *S. frondifera* from the Spechts Ferry Shale Member of the Decorah Formation in Iowa and Wisconsin. The zoarial fragments from Minnesota agree closely with the specimens described by Perry (1962, p. 31) except for the thickness of the zooecial walls that appear to be thicker in the fragments from Minnesota.

Occurrence: Decorah Shale, Minnesota. (See figs. 1 and 11; feet indicate distance above base of the formation.) St. Paul, rare 3-11 ft, 29-31 ft; Wangs, rare 10-12 ft; Rochester, rare 12-14 ft; Chatfield, rare 24-28 ft; Fountain, very abundant 6-8 ft, rare 12-14 ft; 26-28 ft; Spring Grove, very abundant 4-8 ft; common 8-10 ft.

Bassler (1915, p. 1192) indicated the occurrence of *S. frondifera* in the Decorah Shale at Minneapolis, St. Paul, Preston and Fountain, Minnesota. Perry (1962, p. 34) reports *S. frondifera* from the Spechts Ferry Shale Member of the Decorah Formation at two localities in Iowa, five in Wisconsin, and two in Illinois.

Stictoporella dumosa Ulrich

Plate 12, Figures 1-3

Stictoporella dumosa Ulrich, 1895, p. 181; Bassler, 1915, p. 1191.

Type material: Specimens from syntype suite USNM 43613: thin sections USNM 163154-163156. Locality: Decorah Shale, *Phylloporina* bed, St. Paul, Minn.

Additional material from Minnesota: Thin sections USNM 163157-163164 from Wangs. Approximate count of unsectioned zoarial fragments: St. Paul 6; Wangs 110.

Description: *External features* – Zoarium small, ribbon-like, slender, branching unevenly; branches with subrounded margins; zooecial cavities broadly ovate, with relatively narrow walls; mesopores abundant, occur singly or align in short rows between zooecia.

Internal features – Mesotheca slightly flexuous, approximately 0.01 to 0.03 mm thick. Zooecia elongate, aligned in indistinctly linear ranges in endozone, polygonal to circular in oblique ranges in tangential view of exozone. Laminae of walls occasionally dark streaked. Boundaries between zooecia, mesopores somewhat flexuous. Mesopores common, begin near base of exozone, occur singly, in pairs of two or more, align in short rows. Diaphragms thin, rare in zooecia, absent in mesopores.

Table 15. – Quantitative data, ***Stictoporella dumosa*** **Ulrich***

	Ns	Nm	Range	Mean	s	V	95% C.I.
Branch depth.	7	10	0.70-1.10	0.858	0.1598	18.6	0.74-0.97
Branch width.	2	2	1.70-2.20	1.950			
Cav. axis: mj.	5	12	0.14-0.26	0.186	0.0320	17.2	0.16-0.21
Cav. axis: mn.	5	12	0.06-0.10	0.080	0.0153	19.2	0.07-0.09
Depth: endo.	7	4	0.10-0.20	0.144	0.0274	19.0	0.13-0.16
Depth: exo.	7	13	0.20-0.35	0.261	0.0554	21.3	0.23-0.29
Depth: zoo.	7	12	0.30-0.50	0.407	0.0590	14.5	0.37-0.44
Zoo. angle.	6	7	61°-86°	78.6°	8.28°	10.5	71°-86°
H. cav. endo.	4	4	0.40-0.48	0.437	0.0350	8.0	0.38-0.49
Wall w: lng.	4	8	0.14-0.31	0.239	0.0572	24.0	0.19-0.28
Wall w: lat.	5	13	0.09-0.20	0.131	0.0377	28.9	0.11-0.15
Cav./1 mm^2.	5	5	10-13	11.8	1.30	11.0	10-13
Msp./1 mm^2.	5	8	3-12	8.2	3.45	41.9	5-11
Zoarial ratio.	7	7	0.55-0.73	0.630	0.0676	10.7	0.57-0.70

*Explanation of abbreviations follows Table 1.

Remarks: *Stictoporella dumosa* is related closely to *S. angularis*. Both species have slender, relatively thin, ribbonlike branches, and similar zoarial ratios. *S. dumosa* differs from *S. angularis* in having more mesopores per sq. mm. There is at least one mesopore or more per each zooecium. The mesopores in *S. dumosa* seem to be less commonly filled with the laminated calcite than in *S. angularis*. The zooecia are more rounded than polygonal and their alignment is more linear in *S. dumosa* than in *S. angularis*. The dark and well defined boundary zones appear more flexuous in *S. dumosa* than in *S. angularis* as seen in the longitudinal and transverse views.

S. dumosa differs from *S. frondifera* in the size of the zoarium, zoarial growth habit, in the shape of the zooecial walls and cavities as seen in the longitudinal views and in the zoarial ratios.

Zoarial fragments assigned to *S. dumosa* agree in general with Ulrich's (1895, p. 181) original description. The internal appearance of zoaria is figured here for the first time.

Occurrence: Decorah Shale, Minnesota. (See figs. 1 and 11; feet indicate distance above base of the formation.) St. Paul, rare 41-51 ft, Wangs, rare 47-49 ft, very abundant 49-51 ft.

Bassler (1915, p. 1191) also reported *S. dumosa* from St. Paul, Minnesota.

Genus Escharopora Hall 1847

Escharopora Hall, 1847, p. 73; Bassler, 1915, p. 498,; 1953, p. G137; Ross, 1964a, p. 17.

Type species: *Escharopora recta* Hall, 1847, p. 73, by monotypy; redescribed by Ross (Phillips, 1960, p. 17).

Definition: Zoarium ribbonlike, relatively straight, tapering proximally, rarely ramose; zoarial margins well-defined distally in some species.

Mesotheca straight to slightly flexuous; laminae poorly defined in midregion of zoarium, apparently continuous or merge with laminae of zooecial walls in endozone; laminae well-defined, curved, convex to zoarial edges, merge or continue without break with laminae of zoarial margins.

Zooecia narrowly ovate, elongate, aligned in approximately linear ranges in endozone; cavities ovate to polygonal in oblique or diagonal ranges in tangential view of exozone, form approximately J-shaped curve from mesotheca to surface in longitudinal view. Zooecial walls thicken abruptly with change in direction of zooecial growth at base of exozone.

Laminae of zooecial walls, mesopore-like depressions in exozone well defined, approximately M-shaped in transverse view, broadly curved with rounded apexes forming sinuous, slightly elevated, interweaving ridges at surface in some species; laminae continuous between zooecial cavities in exozone.

Zooecial boundaries intermittent, poorly defined, probably formed by contiguous laminae in endozone, absent in exozone.

Monticules formed by aggregation of zooecia with somewhat larger cavities in some species. Superior hemisepta, poorly to well defined, formed by extension of laminae of zooecial walls at base of exozone.

Remarks: *Escharopora* is characterized by the tapering zoarium that rarely branches, by the distinct diagonal alignment of zooecia, and by the continuity of the laminae between the adjacent zooecial cavities in the exozone in which no boundary zones have been observed.

Escharopora differs from *Stictopora, Astreptodictya, Athrophragma,* and *Stictoporella* in having the escharoporid wall structure. It is similar to *Graptodictya,* and the differences between the two genera are discussed on page 72.

Escharopora subrecta (Ulrich)

Plate 17; Plate 18, Figures 1-3

Ptilodictya subrecta Ulrich, 1886, p. 63
Escharopora subrecta (Ulrich), Bassler, 1915, p. 501

Type material: Specimens USNM 163165-163171 from syntype suite USNM 43818, figured by Ulrich, 1895, plate 12, figures 5, 7, 8, 10-12 and 14 respectively; from USNM 43819 specimen USNM 163172 figured by Ulrich, 1895, plate 12, figure 17, 24. Syntype collection USNM 43818 from the Decorah Shale, Minneapolis; USNM 43819 from the Decorah Shale, Fountain, Minnesota.

Additional material from Minnesota: Thin sections USNM 163173-163196 from Rochester. Approximate count of unsectioned zoarial fragments: St. Paul

860; Wangs 50; Roscoe 10; Rochester 550; Chatfield 230; Fountain 450; Spring Grove 220.

Description: *External features* – Zoarium small to medium, slender straight to slightly curved; basal extremity subrounded, with linear striations; zoarium widens and thickens approximately 1 to 2 mm distally of basal extremity where zooecial cavities appear between striae. Zooecia elongate with ovate cavities in proximal region of zoarium, hexagonal to polygonal near zoarial margins, in distal or wider areas of zoarium; cavities aligned in distinct diagonal pattern. Zoarial margins narrow, become distinct short distance distally of the subrounded proximal zoarial region. Monticules few, unevenly spaced consist of irregular zooecia, generally absent in wider areas of zoarium.

Internal features – Mesotheca straight to slight flexuous. Zooecia ovate in proximal midarea of zoarium in tangential view of exozone, hexagonal to polygonal along zoarial margins or in distal areas of larger zoaria. Walls of zooecia with dark streaked laminae adjacent to cavities, occasionally with pustulelike dots in tangential view. Hemisepta hooklike, common, extend obliquely into zooecial cavities at base of exozone.

Table 16. – Quantitative data, *Escharopora subrecta* (Ulrich)*

	Ns	Nm	Range	Mean	s	V	95% C.I.
Branch depth.	33	52	0.30-2.40	0.884	0.4398	49.8	0.76-1.00
Branch width.	22	25	1.20-4.90	3.00	1.2468	41.5	2.48-3.52
Cav. axis: mj.	21	40	0.18-0.25	0.211	0.0261	12.4	0.20-0.22
Cav. axis: mn.	21	38	0.07-0.12	0.101	0.0158	15.6	0.10-0.11
Depth: endo.	21	33	0.08-0.20	0.105	0.0274	26.0	0.10-0.12
Depth: exo.	23	41	0.12-0.80	0.259	0.1289	49.8	0.22-0.30
Depth: zoo.	22	39	0.20-0.90	0.373	0.1316	35.3	0.33-0.42
Zoo. angle.	21	28	57°-85°	69.7°	7.84°	11.2	67°-72°
H. cav. endo.	12	15	0.38-0.50	0.439	0.0375	8.5	0.42-0.46
Wall w: lng.	21	44	0.05-0.30	0.224	0.0353	15.8	0.21-0.23
Wall w: lat.	21	60	0.01-0.24	0.066	0.0415	63.0	0.06-0.08
Cav./2 mm lng.	21	21	0.06-0.09	8.0	0.92	11.6	7-8
Cav./2 mm lat.	21	21	0.10-0.14	11.5	0.98	8.5	11-12
Cav./1 mm^2.	21	28	0.14-0.27	20.8	3.01	14.4	20-22
Zoarial ratio.	22	22	0.29-0.81	0.68	0.126	18.5	0.62-0.74

*Explanation of abbreviations follows Table 1.

Remarks: *Escharopora subrecta* (Ulrich) is related closely to the type species *E. recta* Hall and differs from it in having thinner, more slender zoaria with smaller diameters of zooecial cavities and narrower walls. The mesopores are found in *E. recta* (Phillips, 1960, p. 19) but have not been observed in *E. subrecta.* The tapering basal extremities of the zoaria in *E. subrecta* seem to indicate that the proximal zoarial tips may have articulated with some sort of basal attachments. However, the mode of attachment has not been observed. The specimens assigned to *E. subrecta* agree with the forms described by Ulrich (1895, p. 168).

Occurrence: Decorah Shale, Minnesota. (See figs. 1 and 11; feet indicate distance above base of the formation.) St. Paul, very abundant 1-7 ft, common 11-13 ft, 15-19 ft, very abundant 21-25 ft, common to very abundant 25-43 ft, rare to common 45-51 ft, common 57-59 ft, rare 75-79 ft; Wangs, rare to abundant 6-16 ft, rare 34-41 ft; Roscoe, rare 0-2 ft, common 4-6 ft; Rochester, rare to common 0-14, rare 16-20 ft, very abundant 20-33 ft; abundant to very abundant 33-40 ft; rare to common 40-49 ft; Chatfield, rare to very abundant 15-28 ft; rare to common 28-32 ft; Fountain, rare 0-2 ft; 10-12 ft; common to very abundant 12-30 ft; Spring Grove, rare 4-10 ft, common to very abundant 10-16 ft.

Bassler (1915, p. 501) indicated the presence of *E. subrecta* in the Middle Ordovician strata in Minneapolis, Minn.; Decorah, Iowa; Beloit, Wisconsin; Lake Nipissing, Ontario, Canada; and from Ordovician at Uxnorm, Estonia. Most of these occurrences need to be verified.

Genus Graptodictya Ulrich, 1882

Graptodictya Ulrich, 1882, p. 152; Bassler, 1915, p. 567; Bassler 1953, p. G137; Ross, 1964a, p. 20; Astrova, 1965, p. 251.
Arthropora Ulrich, 1882, p. 167; Ross, 1960b, p. 859.

Type species: *Ptilodictya perelegans* Ulrich, 1878, p. 94, pl. 4, figs. 16, 16a; designated by Ulrich, 1882, p. 165; redescribed by Ross (Phillips, 1960, p. 19).

Definition: Zoarium small, ramose with relatively straight to curved branches having generally distinct margins, commonly with ridges.

Mesotheca straight or flexuous to zigzag; laminae poorly defined, apparently continuous or merge without break with laminae of zooecial walls in endozone, zoarial margins.

Zooecia rhomboid to ovate in approximately linear ranges in endozone, cavities ovate to circular in oblique ranges in tangential view of exozone, form approximately J-shaped curve from mesotheca to surface in longitudinal view. Zooecial walls thicken abruptly with change in direction of zooecial growth at base of exozone.

Laminae of zooecial walls well defined in exozone, about M-shaped or with three relatively sharp apexes toward zoarial surface in transverse view of some species, may form pustulelike dots in tangential view, sinuous, slightly elevated ridges at surface.

Zooecial boundaries intermittent, poorly defined, formed by apparently contiguous laminae in endozone, probably merge with wall laminae at base of exozone, absent in exozone.

Superior hemisepta poorly to well developed, formed by extension of laminae of zooecial walls at base of exozone. Diaphragms planar, thin, rare in zooecia of some species, absent in others.

Remarks: *Graptodictya* is characterized by the small zoaria with the oblique alignment of the zooecia, interweaving ridges between the cavities and by the continuity of the laminae between the adjacent zooecial cavities in the exozone. In *Graptodictya* the boundary zones have not been observed in the zooecial walls in the exozone.

Graptodictya differs from *Escharopora* in having branching zoaria with strongly ridged surface, slightly different configuration of the wall laminae in the exozone, rhomboid to ovate zooecial cavities in the endozone and in the absence of the mesopore-like structures. Both genera have the escharoporid wall structure.

Graptodictya simplex (Ulrich)

Plate 18, Figures 4-6

Arthropora simplex Ulrich, 1886, p. 65; Bassler, 1915, p. 72.

Type material: Specimens USNM 163197, 163198 from syntype suite USNM 43503, figured by Ulrich, 1895, plate 14, figure 14, 15; one thin section, USNM 163199 probably figured by Ulrich, 1895, plate 14, figure 20, 21. Locality: Decorah Shale, *Rhinidictya* bed, St. Paul and Minneapolis, Minnesota.

Additional material from Minnesota: Thin sections: USNM 163200-163218 from Rochester; USNM 163219 from Wangs. Approximate count of unsectioned zoarial fragments: St. Paul 400; Wangs 30; Roscoe 5; Rochester 670; Chatfield 100; Fountain 300; Spring Grove 30.

Description: *External features* – Zoarium small, slender, ribbonlike to subrounded, branching at uneven intervals; branches commonly with well-defined, sharply edged margins having oblique ridges. Zooecial cavities ovate, occasionally enclosed by ridges, aligned in diagonally intersecting ranges; zooecial walls with one to three ridges or more in areas of branching, margins.

Internal features – Mesotheca straight to flexuous or zigzag in some zoaria. Zooecia rhomboid to elongate in tangential view, aligned in somewhat linear ranges in endozone; cavities ovate in tangential view of exozone. Walls of zooecia commonly with pustulelike dots in lightly sinuous rows in tangential view, dark streaked laminae in exozone. Superior hemispeta short, hooklike, thin, extend obliquely into each cavity at base of exozone.

Table 17. – Quantitative data, ***Graptodictya simplex*** **(Ulrich)***

	Ns	Nm	Range	Mean	s	V	95% C.I.
Branch depth.	26	37	0.23-0.70	0.503	0.1285	25.5	0.46-0.54
Branch width.	16	16	0.76-1.60	1.256	0.2358	18.8	1.13-1.38
Cav. axis: mj.	13	23	0.11-0.21	0.147	0.0226	15.4	0.14-0.16
Cav. axis: mn.	14	21	0.04-0.10	0.072	0.0144	20.0	0.06-0.08
Depth: endo.	21	30	0.07-0.15	0.107	0.0177	16.6	0.10-0.11
Depth: exo.	21	28	0.05-0.23	0.124	0.0411	33.3	0.11-0.14
Depth: zoo.	21	27	0.14-0.28	0.228	0.0412	18.0	0.21-0.24
Zoo. angle.	18	19	60°-90°	85.3°	9.78°	11.5	80°-90°
H. cav. end.	2	2	0.40-0.45	0.425			
Wall w: lng.	13	18	0.17-0.27	0.240	0.0325	13.6	0.22-0.26
Wall w: lat.	13	23	0.06-0.13	0.103	0.0189	18.4	0.09-0.11
Cav./2 mm lng.	8	8	5-6	5-8	0.46	8.0	5-6
Cav./2 mm lat.	6	6	10-13	11.2	1.33	12.0	10-13
Zoarial ratio.	18	18	0.40-0.68	0.534	0.0862	16.2	0.49-0.58

*Explanation of abbreviation follows Table 1.

Remarks: *Graptodictya simplex* Ulrich differs from the type species, *G. perelegans* (Ulrich), in having small, slender zoaria with fewer and thinner branches, more zooecial cavities per 2 mm longitudinally and laterally, smaller zoarial ratios, and with larger angles between zooecial walls and the mesotheca in the endozone.

Ulrich (1882, p. 167) erected *Arthropora* and designated *Ptilodictya (Stictopora) shafferi* Meek 1872 as the type species. Ross (1960b, p. 859) restudied the type material and assigned *Arthropora shafferi* (Meek) to *Graptodictya* Ulrich (Phillips, 1960, p. 19; Ross, 1960b, p. 859).

G. simplex appears more closely related to *G. shafferi* than to *G. perelegans* and differs from the former in having larger zoarial ratios, fewer and thicker zoarial branches and well-defined superior hemisepta.

Ulrich (1895, p. 177) indicated that the fragments of zoarial branches are jointed in *G. simplex*. The jointed zoarial fragments have not been observed in the recent collections. However, lack of complete zoaria leaves the description inadequate and therefore does not exclude the possiblity that zoaria might be jointed.

Occurrence: Decorah Shale, Minnesota. (See figs. 1 and 11; feet indicate distance above base of the formation.) St. Paul, very abundant 0-5 ft, rare to common 17-21 ft, common to very abundant 21-37 ft, common to abundant 39-43 ft, 47-53 ft, rare to very abundant 53-63 ft, common 67-71 ft, rare to common 75-79 ft; Wangs, rare 6-13 ft, 31-34 ft, 46-56 ft; Roscoe, rare 0-2 ft; Rochester, rare to common 0-8 ft, 10-20 ft, very abundant 20-24 ft, common 24-27 ft, very abundant 27-36 ft, common 36-38 ft, rare 40-52 ft; Chatfield, common 16-20 ft, common to very abundant 20-26 ft, rare 26-32 ft; Fountain, common 0-8 ft, rare to common 10-18 ft, common to very abundant 18-30 ft; Spring Grove, rare 0-2 ft, 8-10 ft, rare to abundant 12-16 ft.

Bassler (1915, p. 72) indicated the presence of *G. simplex* in Decorah Shale at Minneapolis and St. Paul, Minn., and Decorah, Iowa.

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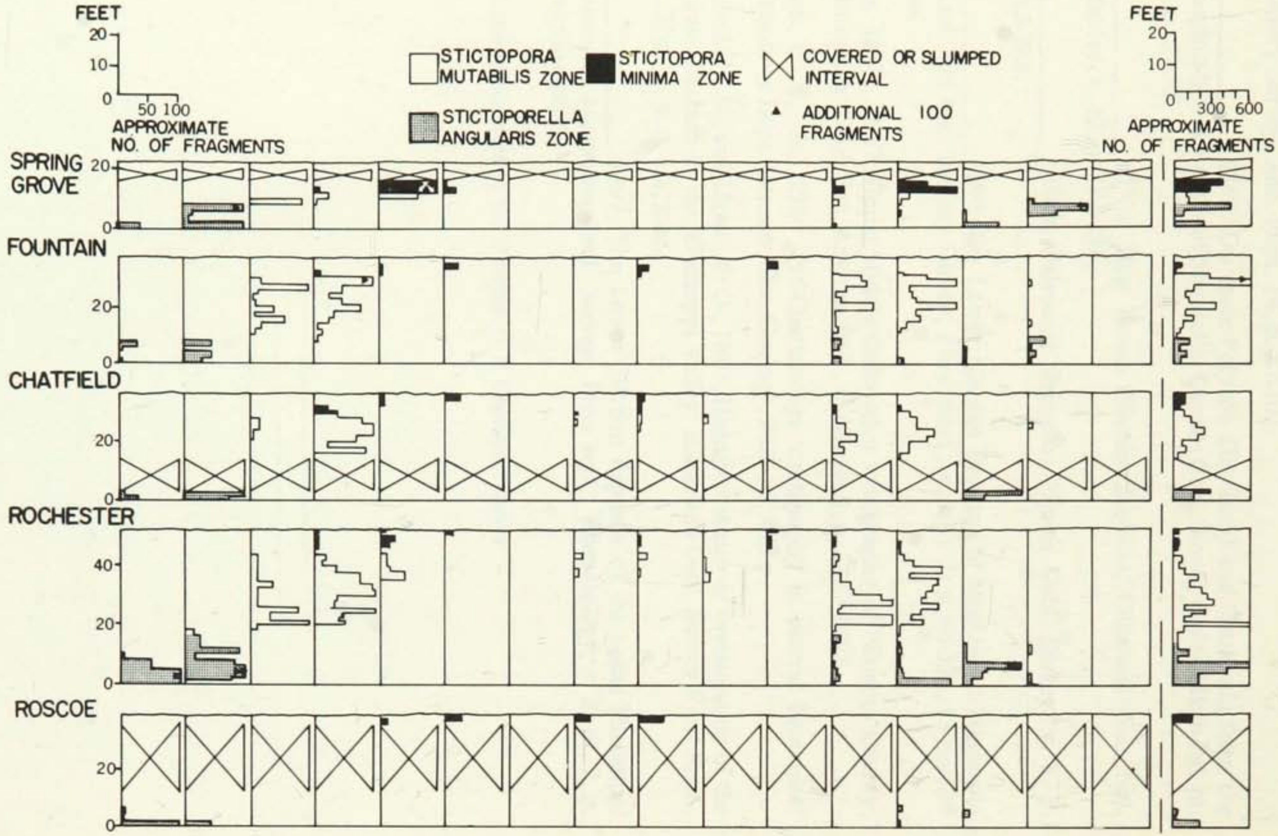
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ANGULARIS ZONE
ADDITIONAL 100
FRAGMENTS
FEET
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NO. OF FRAGMENTS
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GROVE
FOUNTAIN
CHATFIELD
ROCHESTER
ROSCOE
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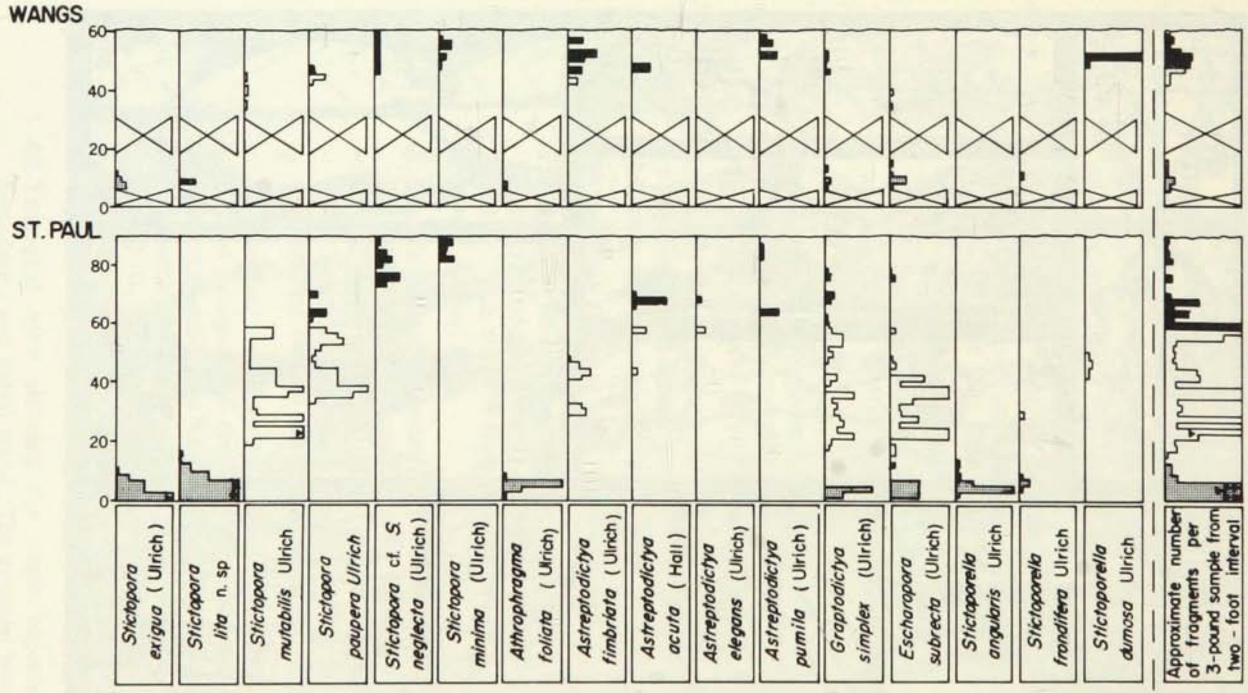
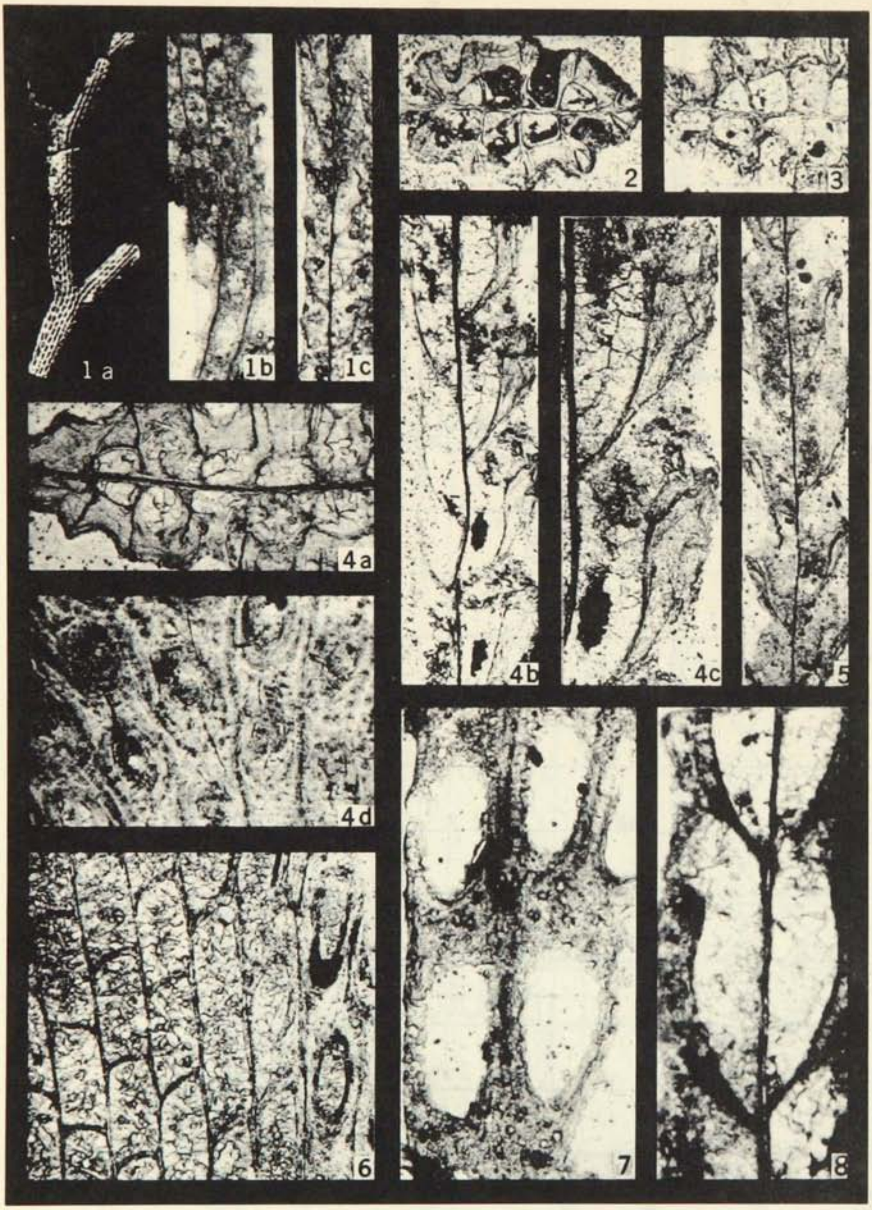


Figure 11 – Stratigraphic distribution of cryptostome Bryozoa in the Decorah Shale in Minnesota.



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1c
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3
4a
4b
4c
5
4d
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7
8

Plate 1

Figures

Stictopora exigua **(Ulrich) (p. 36).**

1. Decorah Shale, *Stictoporella* bed; Minneapolis. Lectotype. USNM 162871. This specimen probably was illustrated by Ulrich, 1890a, page 184, figure 9c, 9d; 1895, plate 8, figure 9, 10.
   1a. External view of zoarium showing the branching pattern commonly found in the stictoporids. Note the alignment of zooecia in distinct longitudinal ranges; X3.4.
   1b. Tangential view showing zooecial walls in the exozone (lower part of the figure) and in the endozone (upper part of the figure). Note the thin, dark range boundary between the laterally adjacent zooecial walls (lower part of figure); X26.
   1c. Longitudinal view showing the general shape of the zooecial walls and cavities in the endozone and exozone. Specimen poorly preserved; X26.
2. Decorah Shale, 0-3 ft. above base; Roscoe, USNM 162905. Transverse view of characteristically small specimen showing the laminate zooecial walls with the obscured range boundaries: X43.
3. Decorah Shale, 0-3 ft. above base; Roscoe, USNM 162902. Transverse view showing the indistinct laminae in the zooecial walls, the range boundaries, and the shape of the zooecial cavities; X43.
4. Decorah Shale, 6-8 ft. above base; Rochester, USNM 162896.
   4a. Transverse view showing the mesotheca with thin, dark zone along the middle containing median tubuli that are ovate in cross section. Note that the range boundaries are at right angles to the zoarial surface; X43.
   4b. Longitudinal view showing the mesotheca, zooecial walls, and the shape of the zooecial cavities. Note that the zooecial boundaries parallel the general direction of the zooecial cavities. The mural tubuli appear as irregularities in the laminae of the distal zooecial walls and are formed at right angles to the zoarial surface; X43.
   4c. Longitudinal view showing a detail of figure 4b. Note the poorly defined laminae and the dark zooecial boundary between the adjacent zooecia. The beginning of the zooecial boundary at the mesotheca and its termination at the zoarial surface is obscured. The short, translucent segments in the mesotheca indicate the places where the plane of the thin section passes through a median tubule; X85.
   4d. Tangential view showing the ovate zooecial cavities, range boundaries and mural tubuli. The zooecial boundaries appear as faint, somewhat darker zones proximal of the zooecial cavities; X43.

5. Decorah Shale, 6-8 ft. above base; Rochester, USNM 162894. Longitudinal view showing thin zooecial walls in the exozone. Note the relatively small angle formed between the zooecial walls in exozone and the mesotheca; X43.

6. Decorah Shale, 0-3 ft. above base; Roscoe, USNM 162901. Endozone and part of the exozone in the tangential view. Note the rectangular shape of the cavities and the slightly curved walls, convex distally, between longitudinally adjacent zooecia in the endozone. The walls between the laterally adjacent zooecia show the range boundaries without mural tubuli in the endozone. The mural tubuli begin to appear in the range boundaries in the exozone along the right part of the figure; X43.

7. Decorah Shale, 0-3 ft. above base; Roscoe, USNM 162904. Tangential view showing poorly defined mural tubuli within the range boundary. A few mural tubuli might be present in the zooecial walls, but these are obscured by foreign material on the zoarial surface as are the zooecial boundaries; X85.

8. Decorah Shale, 0-3 ft. above base; Roscoe, USNM 162906. Longitudinal view showing thin zooecial walls and the shape of the zooecial cavities. Note the narrow angle between the zooecial walls in the exozone and the mesotheca. The zooecial boundaries cannot be discerned because of poor preservation; X85.

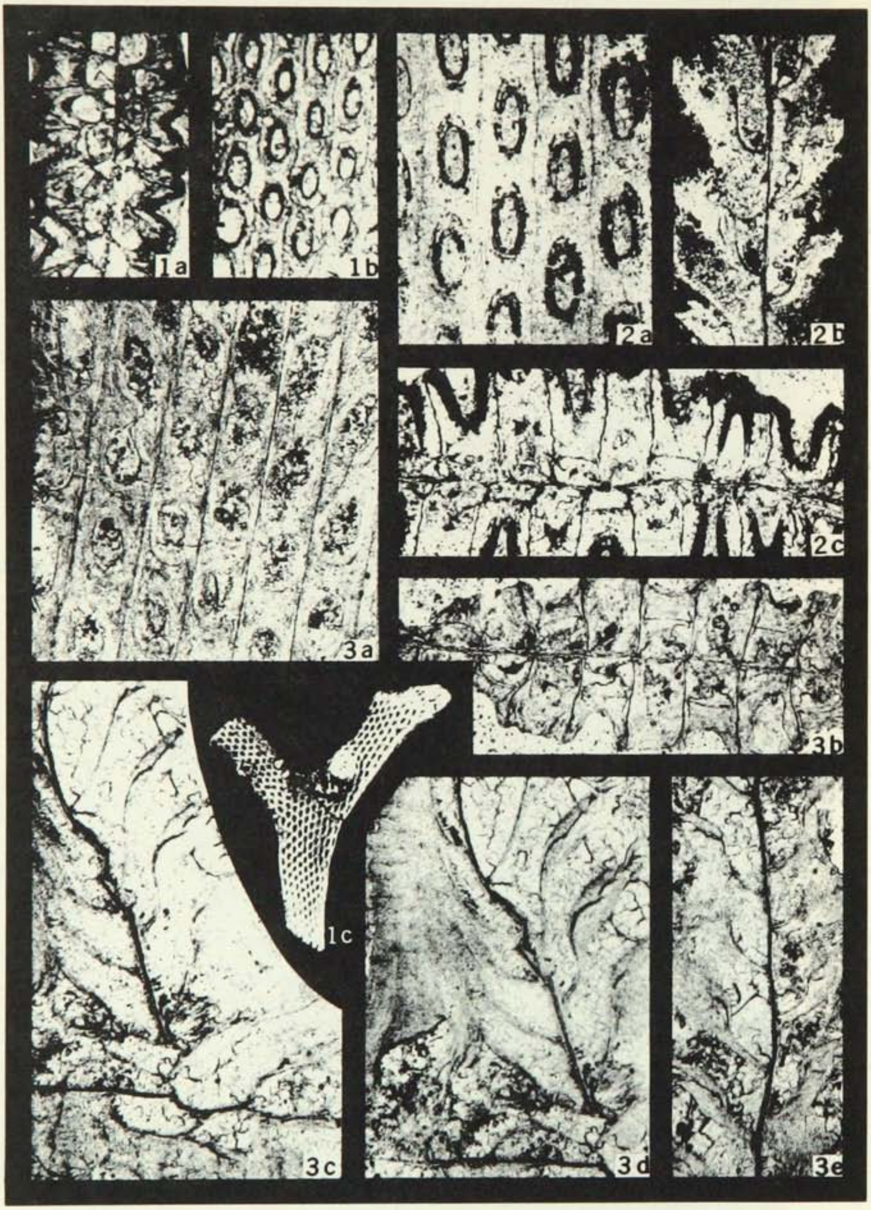

1a
1b
2a
2b
3a
2c
3b
1c
3c
3d
3e

Plate 2

Figures

Stictopora lita **n. sp. (p. 39).**

1. Decorah Shale, *Stictoporella* bed; Minneapolis. USNM 162937 from hypotype suite of *Rhinidictya trentonensis* Ulrich.

   1a. Transverse view of characteristically poorly preserved specimen showing the relatively wide exozone and the shape of the zooecial cavities; X26.

   1b. Tangential view showing the alignment of the zooecia and shape of the cavities in the outer exozone. Note the range boundaries with some mural tubuli. The zooecial boundaries are poorly defined; X26.

   1c. External view showing the width and branching pattern of the zoarium. Note a monticule on the right branch; X3.4.

2. Decorah Shale, 0-2 ft. above base; Fountain. USNM 162934.

   2a. Tangential view showing the alignment of the zooecia and the faint range and zooecial boundaries; X43.

   2b. Longitudinal view showing the general shape of the zooecial walls and cavities; X43.

   2c. Transverse view showing distinct range boundaries and parts of zooecial boundaries in the exozone. The laminae are characteristically poorly defined in the zooecial walls; X43.

3. Decorah Shale, 5-7 ft. above base; Rochester. Holotype, USNM 162918.

   3a. Tangential view of the outer exozone showing the alignment of the zooecia, range and the zooecial boundaries. The latter appear as indistinct, dark hairlike curved zones proximally of the zooecial cavities. Other views of the same boundaries in the exozone are shown in the figures 3c, 3e and at the base of the exozone in figure 3b. Note some mural tubuli in the upper left of figure; X43.

   3b. Transverse view showing the laminate zooecial walls, range and zooecial boundaries, and the median tubuli. The range boundaries begin at the mesotheca and terminate at the zoarial surface. Note a thin, dark zone in some of the zooecial walls at the base of the exozone that is at right angles to the range boundaries. This zone is a segment of the zooecial boundary between the longitudinally adjacent zooecia as shown in the longitudinal views (figs. 3c, 3e); X43.

   3c. Longitudinal view showing part of the basal zoarial attachment and the erect part of the zoarium. Note the horizontally lying segment of the mesotheca and the poorly defined zooecial walls and cavities in the basal part of the zoarium. The junction, if there is one, between the mesothecas is indefinitely shown (lower part of figure). In the erect part of the zoarium note the shape of the zooecial walls and the cavities with one to two diaphragms; X43.

3d. Longitudinal view showing mural tubuli within a range boundary in the exozone, part of which is not shown in figure 3c. Note the thin, hairlike zones at right angles to the zoarial surface in upper left of figure; these are the mural tubuli within a range boundary. In this part of the zoarium the plane of the thin section is approximately within the plane of a range boundary shown in figures 3a, 3b; X43.

3e. Longitudinal view showing distal part of the zoarium shown in figures 3c, 3d. Note the shape of the zooecial walls and that of the cavities with some poorly defined diaphragms; X43.


1a
1b
2a
3b
3a
3c
2b
4

Plate 3

Figures

Stictopora lita **n. sp. (p. 39).**

1. Decorah Shale, 2-4 ft. above base; Rochester, USNM 162920.
   - 1a. Transverse view showing the range boundaries. The laminae of the zooecial walls are obscured somewhat by the recrystallization of the skeletal material; X43.
   - 1b. Longitudinal view showing slightly different shapes of the zooecial walls and cavities. Despite the poor preservation the zooecial boundaries are shown in the endozone and exozone; X43.
2. Decorah Shale, 0-3 ft. above base; Roscoe, USNM 162929.
   - 2a. Tangential view showing the general shape of the zooecia in the endozone (upper right part of figure) and in the exozone (lower left part of figure). Note the curved walls, convex distally, between the longitudinally adjacent zooecia in the endozone. The wall structure is obscured by an opaque mineral; X43.
   - 2b. Longitudinal view of a characteristically poorly preserved zoarium. The zooecial boundaries are hardly visible. Note the shape of the zooecial walls in the exozone; X43.

Stictopora trentonensis **(Ulrich).**

3. Stones River Group, Lebanon Limestone, Lebanon, Tenn. Holotype, USNM 43707. (See remarks, p.40)
   - 3a. Tangential view showing part of the endozone and the exozone. Note the shape of the zooecial walls and that of the cavities. The median tubuli are shown in the left part of the figure. These tubuli may appear as striations on the zoarial margins in the external views; X26.
   - 3b. External view showing the only available zoarial fragment in the type collection; X3.4.
   - 3c. Longitudinal view showing the shape of the zooecial walls, cavities, hemisepta, and the vesicular tissues in the inner exozone; X26.

Stictopora lita **n. sp. (p. 39).**

4. Decorah Shale, 0-2 ft. above base; Fountain, USNM 162953.

   Transverse view showing in detail the boundaries in the laminae zooecial walls, mesotheca, and the shape of the zooecial cavities in the endozone. Note how the laminae of the adjacent zooecial walls abut or adjoin along the range boundaries. Note also that a hairlike, jagged zone separates the laminae of the mesotheca from the laminae of the zooecial walls in the endozone. It is observable at several junctions between the mesotheca and the zooecial walls that this jagged zone merges with the range boundary in the endozone; X85.


1a
1b
2a
2b
2c
2d
3

Plate 4

Figures

Stictopora mutabilis **Ulrich (p.41).**

1. Decorah Shale, 21-23 ft. above base; Rochester, USNM 162971.

   1a. Tangential view showing the alignment of the zooecia, shape of the cavities, zooecial and range boundaries, and mural tubuli; X43.

   1b. Longitudinal view showing the shape of the zooecial walls, cavities and the zooecial boundaries; X43.

2. Decorah Shale, 20-21 ft. above base; Rochester, USNM 162966.

   2a. Tangential view showing part of zoarium in an area of branching; X43.

   2b. Transverse view showing the poorly defined laminae of the zooecial walls and the range boundaries; X43.

   2c. Tangential view showing the alignment of the zooecia and the shape of the zooecial cavities; X43.

   2d. Longitudinal view showing the shapes of the zooecial walls and cavities. Note the relatively wide angle formed between the mesotheca and the zooecial walls in the exozone. Note the disruptions in the zooecial boundaries between the adjacent zooecial walls; X43.

Unknown stictoporid species

3. Longitudinal view.

   The purpose of this figure is to show the well-developed mural tubuli in a range boundary. In the upper left of the figure note how the mural tubuli begin in the exozone and project as short spines above the zoarial surface. These tubuli are aligned in a row and are formed by short curving segments of the wall laminae. In the lower right of the figure note the poorly defined laminae of the zooecial walls and the zooecial boundary along which the laminae abut or adjoin; X85. Encrusted by *Homotrypella instabilis* Ulrich, Echinosphaerites C-1 layer, Ordovician, 4 miles east of Tallin, Estonia. USNM 57277-1.

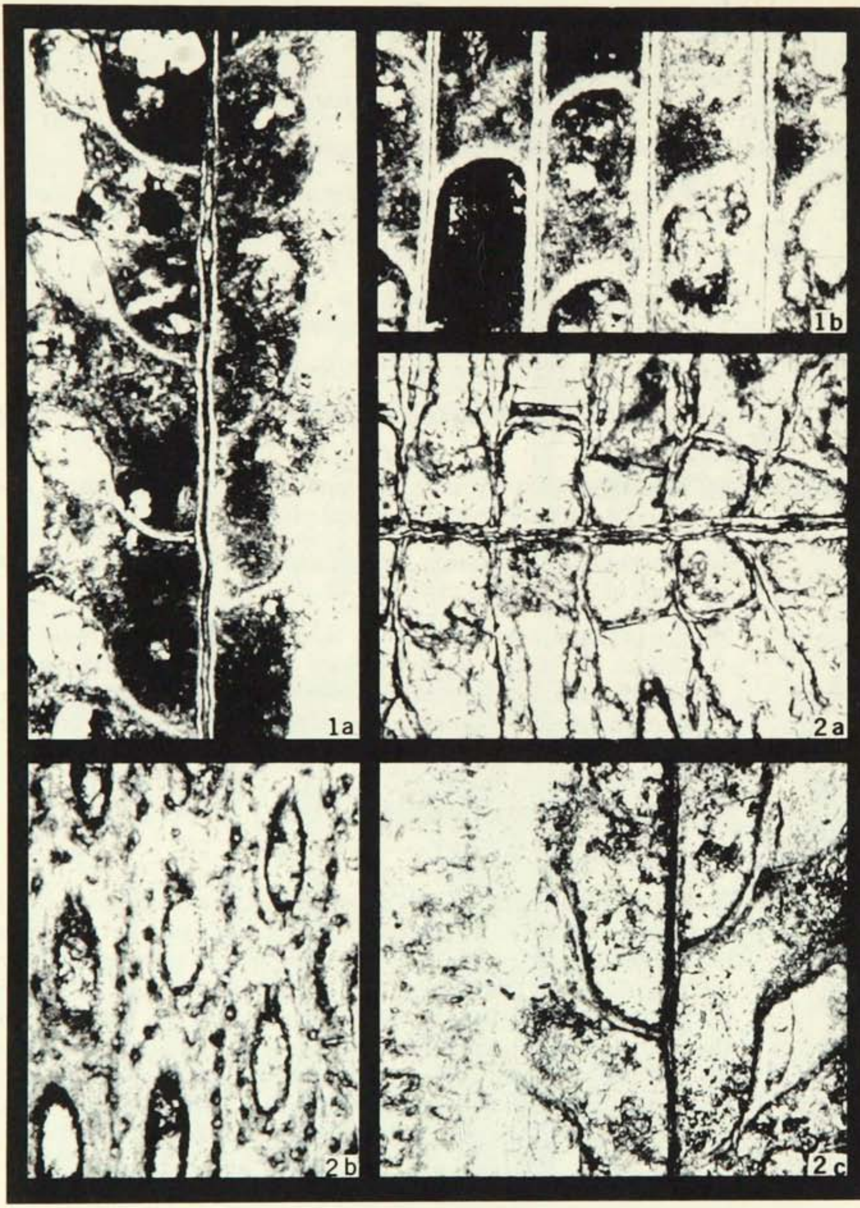

1a
1b
2a
2b
2c

Plate 5

Figures

Stictopora mutabilis **Ulrich (p.41).**

1. Decorah Shale, 21-23 ft. above base; Rochester, USNM 162975.

   1a. Longitudinal view of a young zoarium. Note the vesicular tissue in the distal zooecial walls near the base of the exozone, just below the zooecial boundaries. Segments of the median tubuli in the mesotheca, showing the translucent cores, are observable in the upper part of the figure; X85.

   1b. Tangential view showing the endozone. Note the well defined range boundaries. The zooecial boundaries are rather indistinct; X85.

2. Decorah Shale, 20-21 ft. above base; Rochester, USNM 162916.

   2a. Transverse view showing the mesotheca, laminate zooecial walls, range and zooecial boundaries, and the shape of the zooecial cavities; X85.

   2b. Tangential view showing mural tubuli and the shape of the zooecial cavities. Some of the mural tubuli are on the range and the zooecial boundaries; X85.

   2c. Longitudinal view showing the mural tubuli within a range boundary (in the left of figure) and the vesicular tissues. The thin section plane passes obliquely from the longitudinally adjacent (lower right of the figure) into the laterally adjacent zooecial walls (left part of the figure); X85.


1a
1b
1c
1d

Plate 6

Figures

Stictopora mutabilis **Ulrich (p.41).**

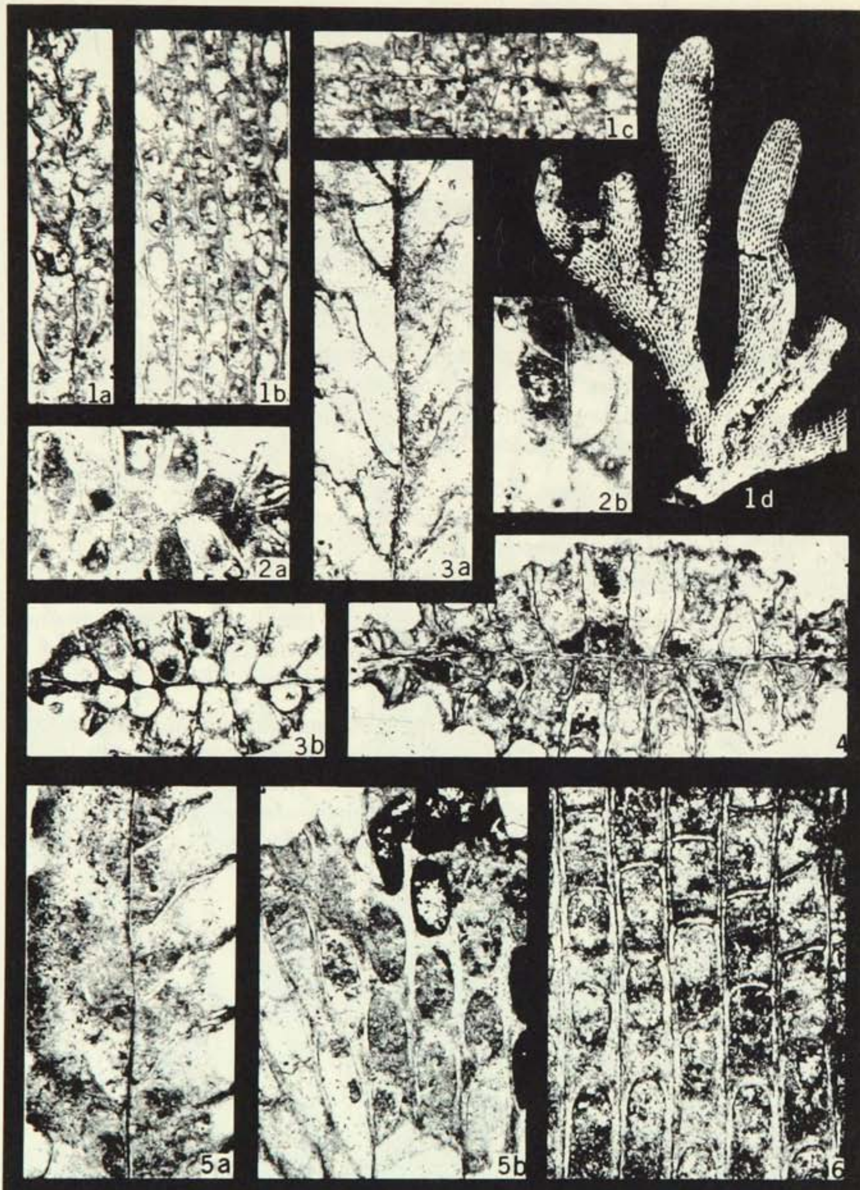
1. Decorah Shale, 23-25 ft. above base; Rochester, USNM 162973.

   1a. Longitudinal view showing the shapes of the zooecial walls and the cavities. Note the zooecial boundaries and the vesicular tissues below them in the inner exozone. The cavities are filled by an opaque mineral; X85.

   1b. Transverse view showing the zooecial walls, the shape of the zooecial cavities in the endozone, and the vesicular tissues. The laminate structure of the zooecial walls is obliterated, but the range and zooecial boundaries are well defined; X85.

   1c. Tangential view showing the mural tubuli on the range boundaries and in the zooecial walls. The zooecial boundaries appear as faint zones proximal of the zooecial cavities; X85.

   1d. Longitudinal view showing the oblique plane of the thin section passing through the longitudinally adjacent zooecial walls in the inner exozone (note the vesicular tissues) into the laterally adjacent walls in the outer exozone (note the mural tubuli in the plane of a range boundary at right angles to the zoarial surface); X85.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2b
3a
3b
4
5a
5b
6

Plate 7

Figures

Stictopora paupera **Ulrich (p.44).**

1. Decorah Shale, *Phylloporina* bed; St. Paul. From syntype suite USNM 43602. Lectotype, thin section USNM 162996.

   The external view of this specimen was illustrated by Ulrich (1895, pl. 5, fig. 19).

   1a. Longitudinal view showing the slightly zigzag mesotheca. The shape of the zooecial cavities and walls are obscured by impurities; X26.

   1b. Tangential view showing the alignment of the zooecia with the relatively narrow walls and the range boundaries; X26.

   1c. Transverse view showing the range t_undaries and the mesotheca; X26.

   1d. External view of the zoarium showing the branching pattern; X3.4.

2. Decorah Shale, 31-33 ft. above base; Rochester, USNM 163013.

   2a. Transverse view of a characteristically thin zoarium showing the zooecial walls and the range boundaries; X43.

   2b. Longitudinal view showing thin zooecial walls in the exozone with poorly defined vesicular tissues; X43.

3. Decorah Shale, 21-23 ft. above base; Rochester, USNM 163011.

   3a. Longitudinal view showing the shapes of the zooecial walls and cavities. There appears to be some overgrowth on the zoarium. Note poorly defined diaphragms in the zooecial cavities; X43.

   3b. Transverse view showing the narrow zooecial walls and range boundaries; X43.

4. Decorah Shale, 29-31 ft. above base; Rochester, USNM 163006. Transverse view showing the narrow zooecial walls, range boundaries, mesotheca, and the shape of the zooecial cavities in the endozone; X43.

5. Decorah Shale, 23-25 ft. above base; Rochester, USNM 163004.

   5a. Longitudinal view showing the shape of the zooecial walls and cavities; X43.

   5b. Tangential view showing narrow zooecial walls in the endozone and exozone; X43.

6. Decorah Shale, 23-25 ft. above base; Rochester, USNM 163008. Tangential view showing the range boundaries in the endozone; X43.


1a
2a
1b
2b
2c

Plate 8

Figures

Stictopora **cf.** *S. neglecta* **(Ulrich) (p.46).**

1. Decorah Shale, 55-57 ft. above base; Wangs, USNM 163027.

   1a. Transverse view showing the laminate zooecial walls, range and zooecial boundaries, the shape of the zooecial cavities in the endozone, and the mesotheca. Segments of mural tubuli are visible in some zooecial walls; X85.

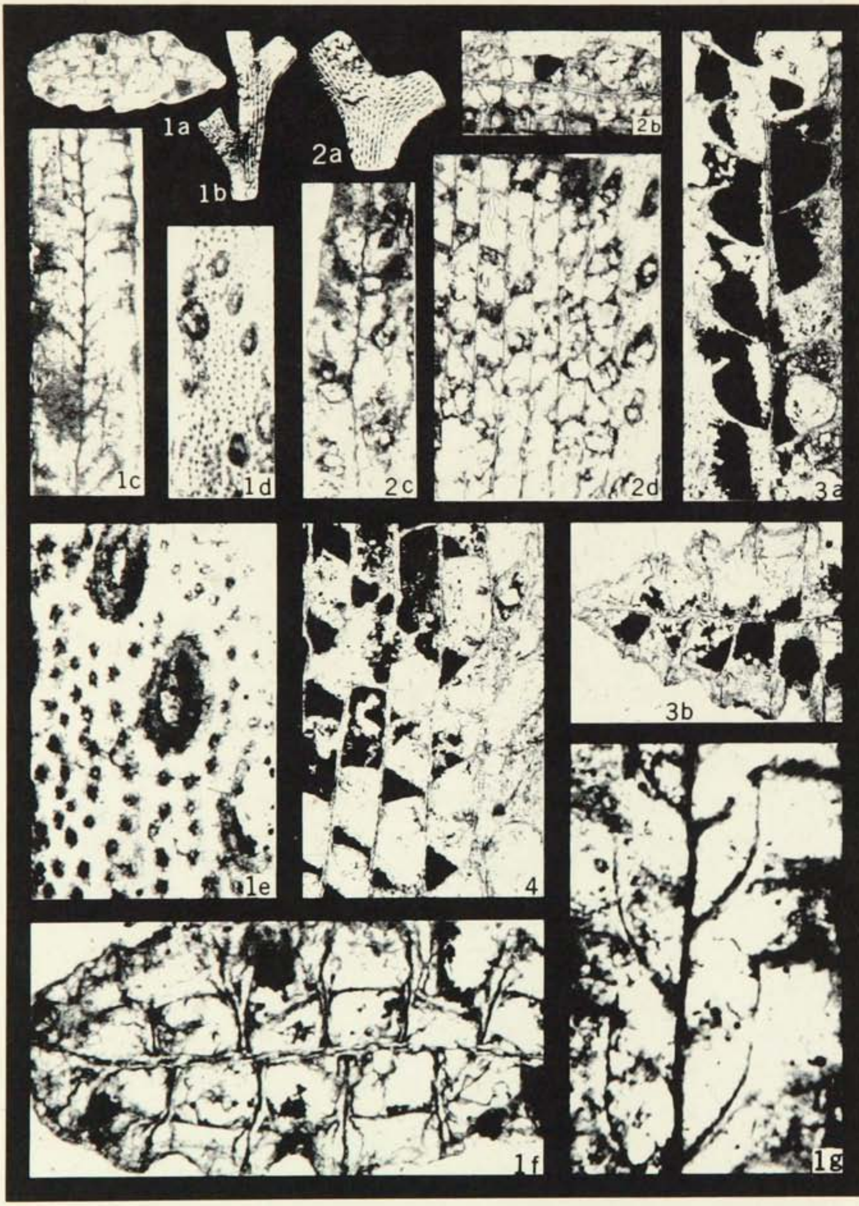
   1b. Longitudinal view showing the general shape of the zooecia. The zooecial boundaries and the laminae in the walls are poorly defined; X85.

2. Decorah Shale, 32-34 ft. above base; Roscoe, USNM 163043.

   2a. Transverse view showing the laminate zooecial walls, range and zooecial boundaries and the shape of the cavities in the endozone; X85.

   2b. Longitudinal view showing poorly defined laminae in the zooecial walls and the zooecial boundaries; X85.

   2c. Tangential view showing part of the branching area of the zoarium and the range boundaries with mural tubuli; X85.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1d
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2d
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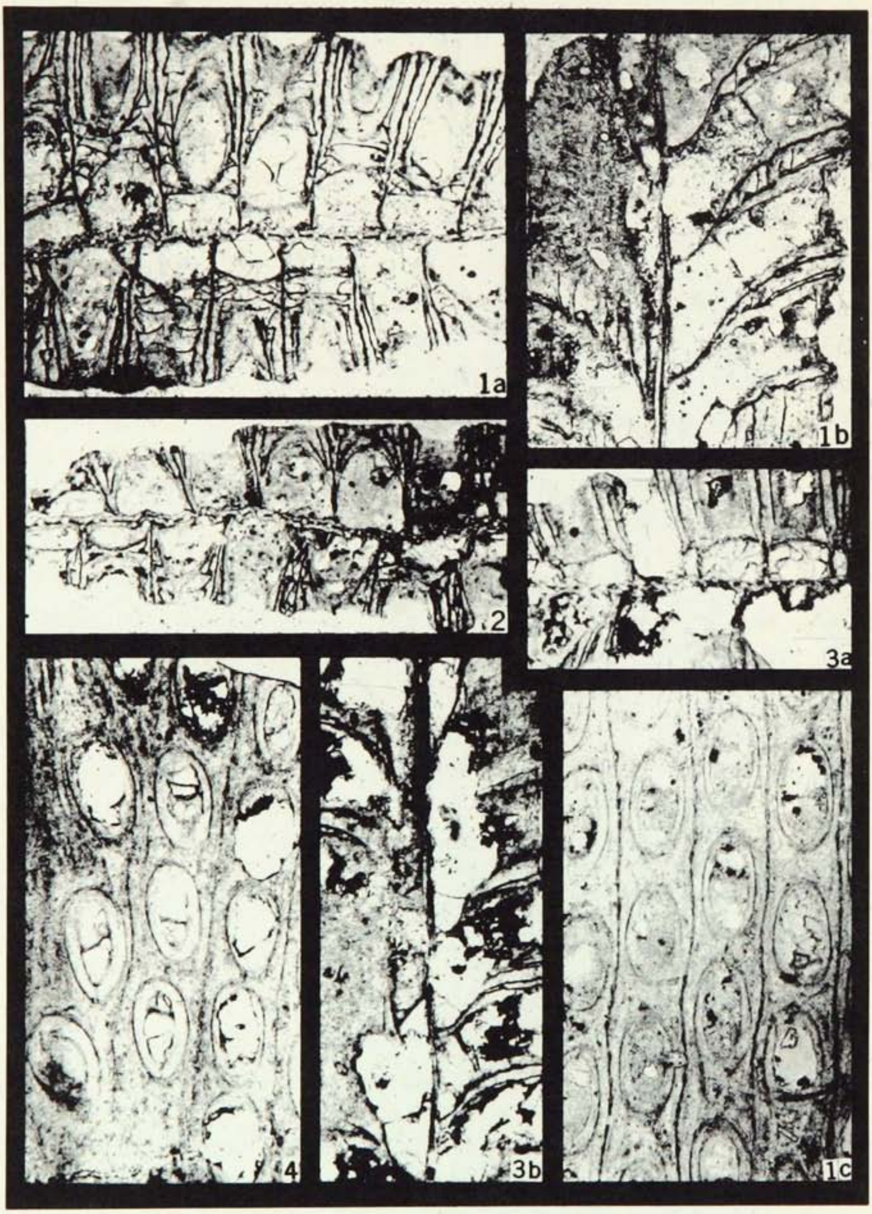
1f
1g

Plate 9

Figures

Stictopora minima **(Ulrich) (p.47).**

1. Decorah Shale, Cannon Falls; from syntype suite USNM 43709, thin section USNM 163044.
   Zoarial fragment of which the external view was probably illustrated by Ulrich, 1890a, page 183, figure 8b, and again 1895, plate 5, figures 14 and 15.
   - 1a. Transverse view showing the zooecial walls and the shape of the cavities in the endozone; X26.
   - 1b. External view showing the branching pattern and the alignment of the zooecia; X3.4.
   - 1c. Longitudinal view showing the general shape of the zooecia; X26.
   - 1d. Tangential view showing a maculose area with mural tubuli and somewhat irregular alignment of the zooecia. The zooecial cavities are enclosed by darker laminae and the boundaries are not defined; X26.
   - 1e. Tangential view showing a detail of figure 1d. The zooecial boundaries probably are lacking and the range boundaries are poorly defined. Note the mural tubuli; X85.
   - 1f. Transverse view showing a detail of figure 1a. The range boundaries are well defined. Note the shape of the zooecial cavities in the endozone; X85.
   - 1g. Longitudinal view showing a detail of figure 1c. Well-defined zooecial boundaries are lacking between adjacent zooecia in the exozone. Note the poorly defined hemisepta; X85.
2. Top of the Decorah Shale, Cannon Falls; from syntype suite USNM 43610, thin section USNM 163046.
   - 2a. External view showing the alignment of the zooecia; X3.4.
   - 2b. Transverse view showing the general shape of the zooecia and the range boundaries; X26.
   - 2c. Longitudinal view showing somewhat flexuous mesotheca. The zooecia are poorly defined; X26.
   - 2d. Tangential view showing the shape of the zooecial cavities and the range boundaries in the endozone; X26.
3. Decorah Shale, 59-61 ft. above base; Wangs, USNM 163049.
   - 3a. Longitudinal view showing well-defined hemisepta. The zooecial boundaries are not apparent; X43.
   - 3b. Transverse view showing the laminate zooecial walls and the range boundaries; X43.
4. Decorah Shale, 59-61 ft. above base, Wangs, USNM 163050.
   Tangential view showing the zooecia in the endozone. The range boundaries are distinguishable, but those of the zooecia might be lacking; X43.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3a
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3b
1c

Plate 10

Figures

Astreptodictya acuta **(Hall) (p. 55).**

1. Decorah Shale, 32-34 ft. above base; Roscoe, USNM 163085.

   1a. Transverse view showing the general relationships among the boundaries of the range partitions, zooecia and those of the zooecial ranges. Note the relatively thick, slightly zig-zag mesotheca with median tubuli, circular in cross section, within the dark zone. The laminae of the zooecial walls and those of the range partitions are poorly defined. The vesicular tissues appear in the inner exozone; X43.

   1b. Longitudinal view showing the shape of the zooecial walls and cavities, zooecial boundaries, and the vesicular tissues. Note the poorly defined diaphragms in the zooecial cavities; X43.

   1c. Tangential view showing the alignment of zooecia, shape of the cavities, zooecial boundaries, and the range boundaries with mural tubuli. The range partitions and their boundaries are poorly defined; X43.

2. Decorah Shale, 32-34 ft. above base; Roscoe, USNM 163084.
   Transverse view of a small zoarium. Note the boundaries and the shape of the mesotheca; X43.

Astreptodictya fimbriata **(Ulrich) (p. 53).**

3. Decorah Shale, 53-55 ft. above base; Wangs, USNM 163065.

   3a. Transverse view showing the poorly defined laminae of the zooecial walls and the boundaries. The vesicular tissues are poorly defined or lacking; X43.

   3b. Longitudinal view showing the shape of the zooecia and their boundaries; X43.

4. Decorah Shale, 53-55 ft. above base; Wangs, USNM 163066.
   Tangential view showing the alignment of the zooecia, the range and zooecial boundaries, and the shape of the zooecial cavities. The range partitions are hardly distinguishable. Note a maculose area in the lower left and median tubuli in the upper left of the figure; X43.


1a
2a
1b
2b
3a
4
3b

Plate 11

Figures

Astreptodictya elegans **(Ulrich) (p. 57).**

1. Decorah Shale, 41-43 ft. above base; Rochester, USNM 163093.

   1a. Transverse view showing the zooecia, range partitions, vesicular tissues, and the shape of the zooecial cavities in the endozone. The boundaries are obscured by additional dark zones with or without mural tubuli, X43.

   1b. Longitudinal view showing the shape of the zooecia and poorly defined diaphragms; X43.

2. Decorah Shale, 35-37 ft. above base; Rochester, USNM 163091.

   2a. Transverse view showing partially preserved zooecai. Note the vesicular tissues; X43.

   2b. Longitudinal view showing some vesicular tissues. The specimen is characteristically poorly preserved; X43.

3. Galena Dolomite, lower part(?), *Clitambonites* bed; St. Paul; from hypotype suite USNM 34976, thin section USNM 163090.

   3a. Longitudinal view showing the shape of the zooecia, their boundaries, and the vesicular tissues. Note some poorly defined diaphragms in the zooecial cavities; X26.

   3b. Transverse view showing the boundaries of the zooecia, ranges and those of the range partitions. These boundaries are obscured by additional dark zones, some with mural tubuli; X26.

4. Decorah Shale, 35-37 ft. above base; Rochester, USNM 163092.
   Tangential view showing the range and zooecial boundaries. The boundaries of the range partitions are indistinct; X43.


1a
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1c
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Plate 12

Figures

Stictoporella dumosa **Ulrich (p. 67).**

1. Decorah Shale, *Phylloporina* bed; St. Paul. From the syntype suite USNM 43613, thin section USNM 163155.
   - 1a. Longitudinal view showing the general shape of the zooecia, their boundaries, and the flexuous mesotheca; X26.
   - 1b. Transverse view showing the mesotheca and the shape of the zooecial cavities in the endozone; X26.
   - 1c. Tangential view showing the alignment and shape of the zooecia in the endozone and exozone and the distribution of the open and closed mesopores. Note the boundary zones; X26.
2. Decorah Shale, 53-55 ft. above base; Wangs, USNM 163161.
   Longitudinal view showing the shape of the zooecia and their cavities. Note the laminae of the walls and the zooecial boundaries; X43.
3. Decorah Shale, 51-53 ft. above base; Wangs, USNM 163164.
   Tangential view showing the alignment of the zooecia. Note the shape of the zooecia as outlined by their boundaries and the distribution of the open or closed mesopores; X43.

Astreptodictya pumila **(Ulrich) (p. 59).**

4. Decorah Shale, 51-52 ft. above base; Rochester, USNM 163103.
   Transverse view showing the width of a characteristically small zoarium. Note the shape of the zooecial cavities in the endozone and the relatively large median tubuli in the mesotheca. The boundaries are obscured by an opaque mineral; X43.
5. Decorah Shale, 51-52 ft. above base; Rochester, USNM 163101.
   Longitudinal view showing the relatively thick mesotheca, the shape of the zooecia, and the zooecial boundaries in the endozone; X43.
6. Decorah Shale, 51-52 ft. above base; Rochester, USNM 163102.
   Tangential view showing the alignment and shape of the zooecia. The zooecial and the range boundaries are well defined, those of the range partitions are indistinct; X43.

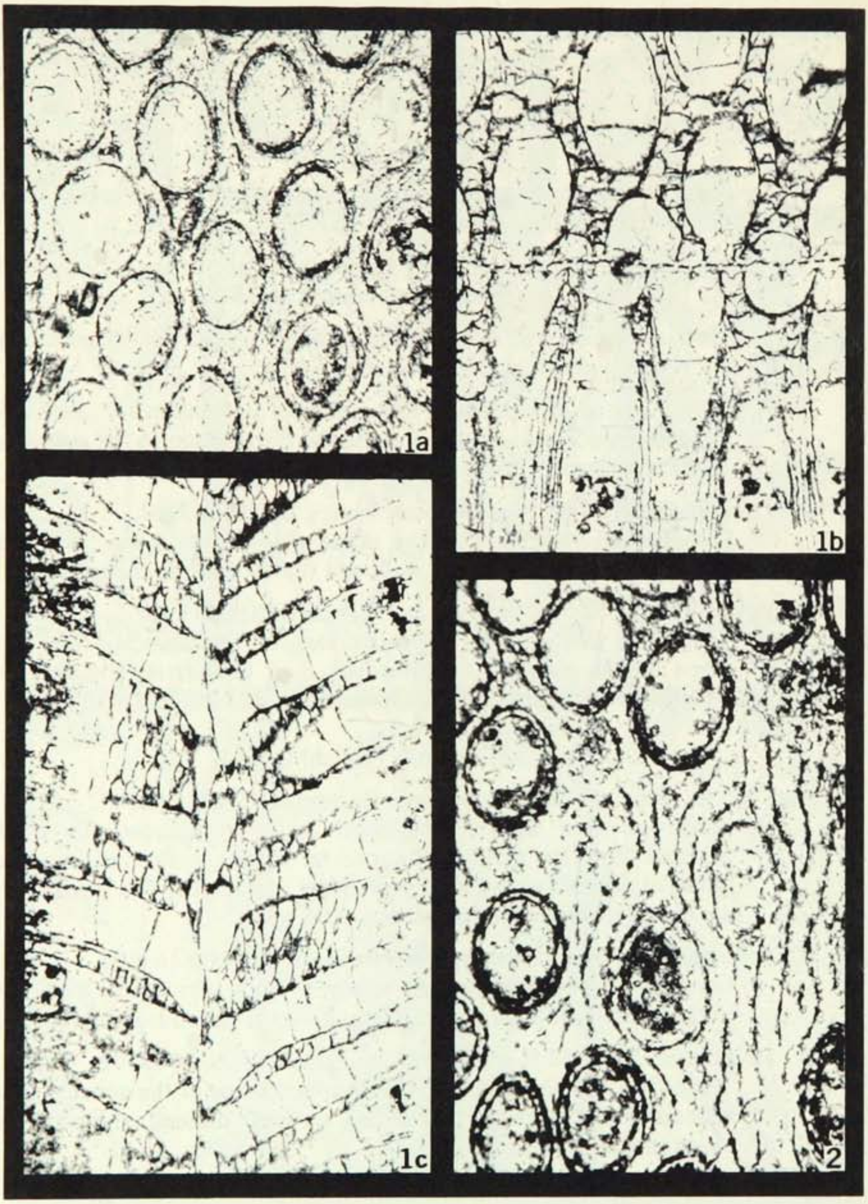
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Plate 13

Figures

Athrophragma foliata **(Ulrich) (p.62).**

1. Decorah Shale, *Stictoporella* bed; St. Paul. Lectotype, USNM 163111.
   Specimen figured by Ulrich, 1895, plate 10, figure 8.

   1a. Tangential view showing the alignment of the zooecia, their boundaries and the dark, intermittent zones between zooecia. Vesicular tissues are partly exposed in the lower left of figure; X43.

   1b. Transverse view showing the shape of the zooecial cavities in the endozone, the mesotheca with the median tubuli, the vesicular tissues, and many dark, intermittent zones in the zooecial walls that obscure their boundaries; X43.

   1c. Longitudinal view showing the mesotheca, shape of the zooecia, zooecial boundaries, and the vesicular tissues. Note the diaphragms in the zooecial cavities and the dark zones in the walls; X26.

2. Decorah Shale, *Stictoporella* bed; St. Paul, USNM 163119.
   Tangential view showing the shape of the zooecia, a maculose area and many dark zones with or without mural tubuli; X43.

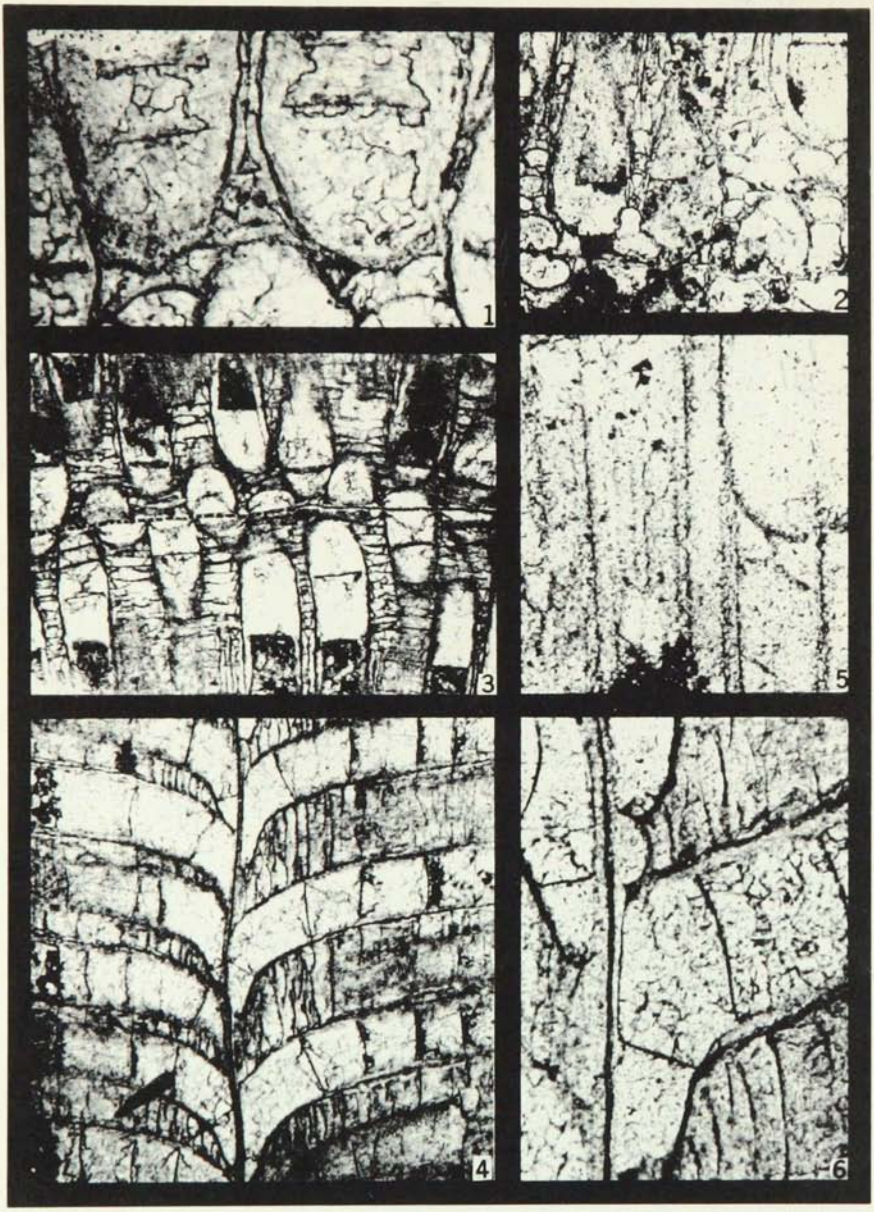
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Plate 14

Figures

Athrophragma foliata **(Ulrich) (p.62).**

1. Decorah Shale, *Stictoporella* bed; St. Paul, USNM 163122.
   Transverse view showing the indistinct laminae in the zooecial walls and the zooecial boundaries; X85.
2. Decorah Shale, 10-12 ft. above base; Wangs, USNM 163130.
   Transverse view of a poorly preserved specimen showing the vesicular tissues; X85.
3. Decorah Shale; Minneapolis, USNM 163123.
   Transverse view showing the mesotheca, vesicular tissues, zooecial boundaries and the dark zones between the zooecia. Note some diaphragms in the zooecial cavities; X27.
4. Decorah Shale; Minneapolis, USNM 163124.
   Longitudinal view showing the mesotheca, the shape of the zooecia, vesicular tissues, and the diaphragms in the zooecial cavities; X27.
5. Decorah Shale, 3-5 ft. above base; St. Paul, USNM 163126.
   Tangential view showing the median tubuli in the mesotheca and part of a zooecial cavity; X85.
6. Decorah Shale, *Stictoporella* bed; St. Paul, USNM 163127.
   Longitudinal view showing the mesotheca, vesicular tissues, zooecial boundaries and the diaphragms in the zooecial cavities; X85.

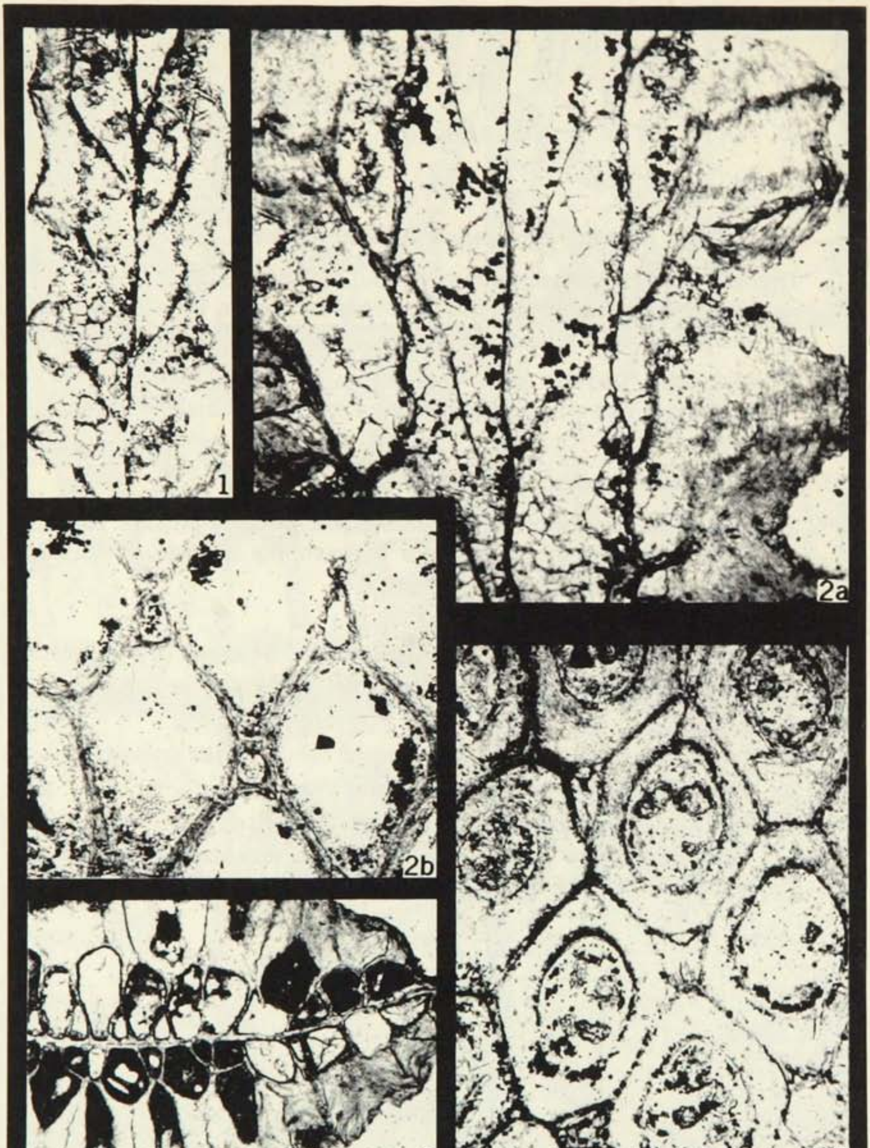
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Plate 15

Figures

Stictoporella angularis Ulrich **(p.64)**.

1. Decorah Shale, 2-4 ft. above base; Rochester, USNM 163139.
   Longitudinal view showing the laminate walls and the zooecial boundaries; X43.
2. Decorah Shale, 5-7 ft. above base; Rochester, USNM 163136.
   - 2a. Longitudinal view showing the shape of the zooecia, laminate walls and the zooecial boundaries. The plane of the thin section passes through an undulating zoarium; X85.
   - 2b. Tangential view showing the shape of the zooecia and mesopores near base of the exozone; X85.
3. Decorah Shale, 14-16 ft. above base; Rochester, USNM 163144.
   Transverse view showing the zooecia with laminate walls and the boundaries; X43.
4. Decorah Shale, 5-7 ft. above base; Rochester, USNM 163135.
   Tangential view showing the shapes of the zooecia as outlined by dark boundaries and that of the cavities. Note the closed mesopores; X85.

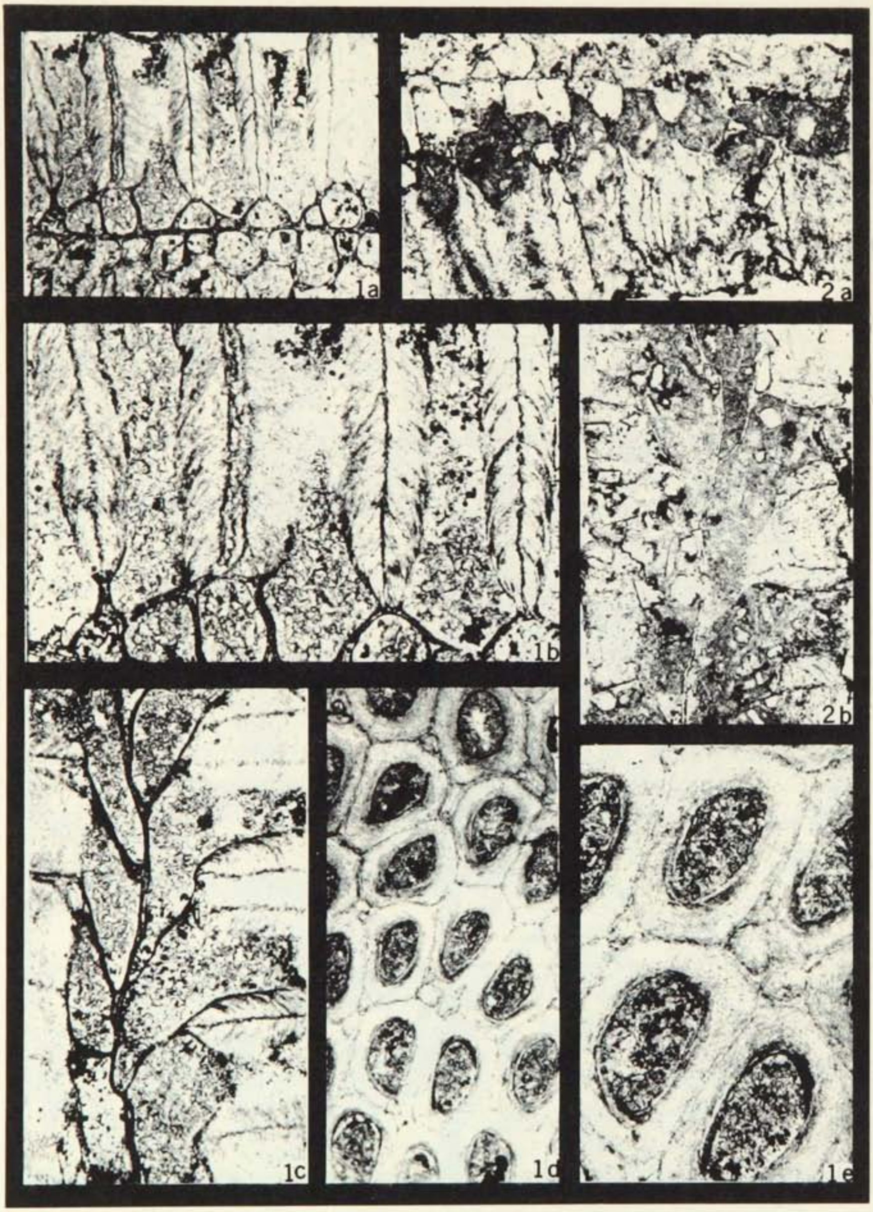
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Plate 16

Figures

Stictoporella frondifera **Ulrich (p.66).**

1. Decorah Shale, 0-2 ft. above base; Fountain, USNM 163150.

   1a. Transverse view showing the shape of the zooecia and the mesotheca; X43.

   1b. Transverse view showing a detail of figure 1a. Note the configuration of the laminae in the zooecial walls and the zooecial boundaries. A closed mesopore is shown between adjacent zooecia; X85.

   1c. Longitudinal view showing the shape of the mesotheca and the zooecia; X43.

   1d. Tangential view showing the arrangement of the zooecia, closed mesopores and their shapes. Note the well-defined zooecial boundaries; X43.

   1e. Tangential view showing in detail a part of figure 1d. Note the laminae and the boundaries of the zooecia and mesopores; X85.

2. Decorah Shale, 10-12 ft. above base; Wangs, USNM 163148.

   2a. Transverse view of a poorly preserved specimen showing the general shape of the zooecia; X43.

   2b. Longitudinal view showing partially preserved zooecia; X43.

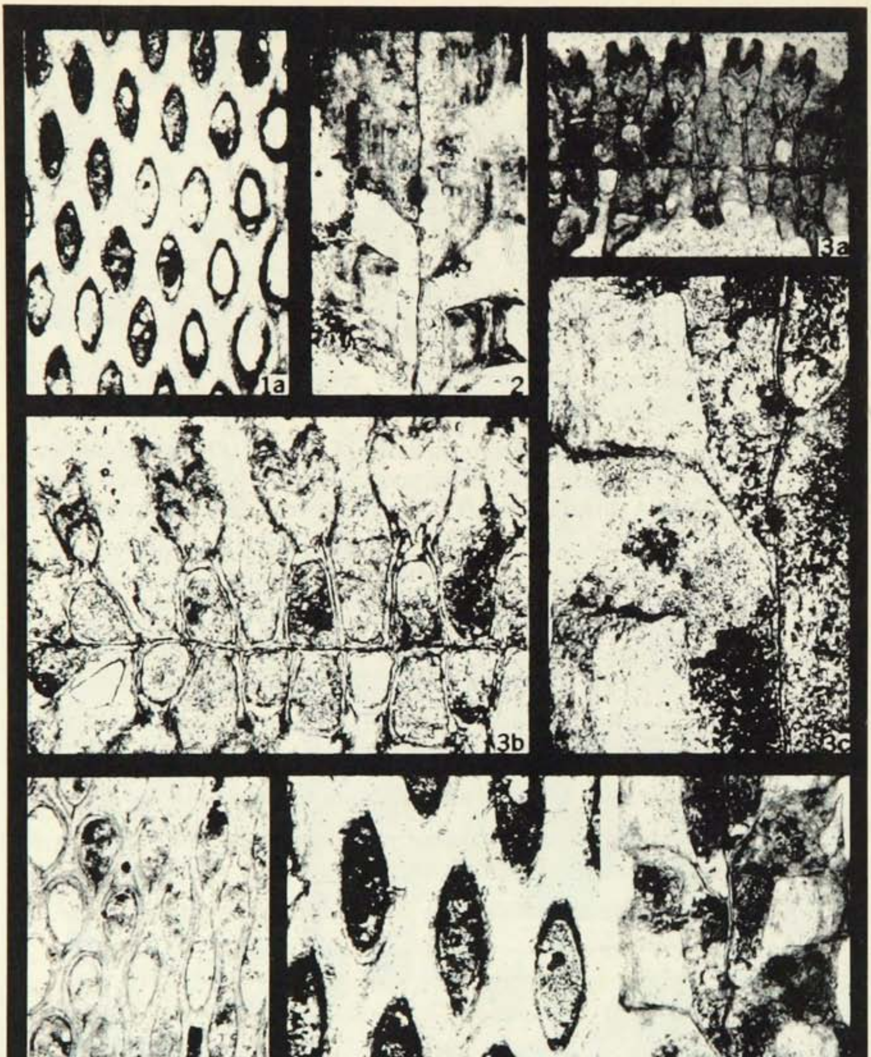
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Plate 17

Figures

Escharopora subrecta **(Ulrich) (p.69).**

1. Decorah Shale, 27-29 ft. above base; Rochester, USNM 163191.

    1a. Tangential view showing the alignment of the zooecia; X43.

    1b. Tangential view showing a detail of figure 1a. Note the darkening of the laminae adjacent to the cavities. Parts of the zooecial walls, lighter in shade, indicate the approximate position of the apexes of the curved laminae; X85.

2. Decorah Shale, 21-22 ft. above base; Rochester, USNM 163183. Longitudinal view showing the mesotheca and the shape of the zooecia. Note the apexes of the laminae that project above the zoarial surface adjacent to the cavities; X43.

3. Decorah Shale, 23-25 ft. above base; Rochester, USNM 163182.

    3a. Transverse view showing the general shape of the zooecia and the projecting apexes of the broadly curved laminae; X43.

    3b. Transverse view showing a detail of figure 3a. Note the configuration of the laminae in the exozone and the boundaries of the zooecia in the endozone only; X85.

    3c. Longitudinal view showing a detail of figure 3d. Note that the laminae are continuous between the adjacent zooecia; X85.

    3d. Longitudinal view showing the shape of the zooecia and stubby hemisepta; X43.

4. Decorah Shale, 27-29 ft. above base; Rochester, USNM 163179. Tangential view showing the zooecia in the endozone and exozone; X43.

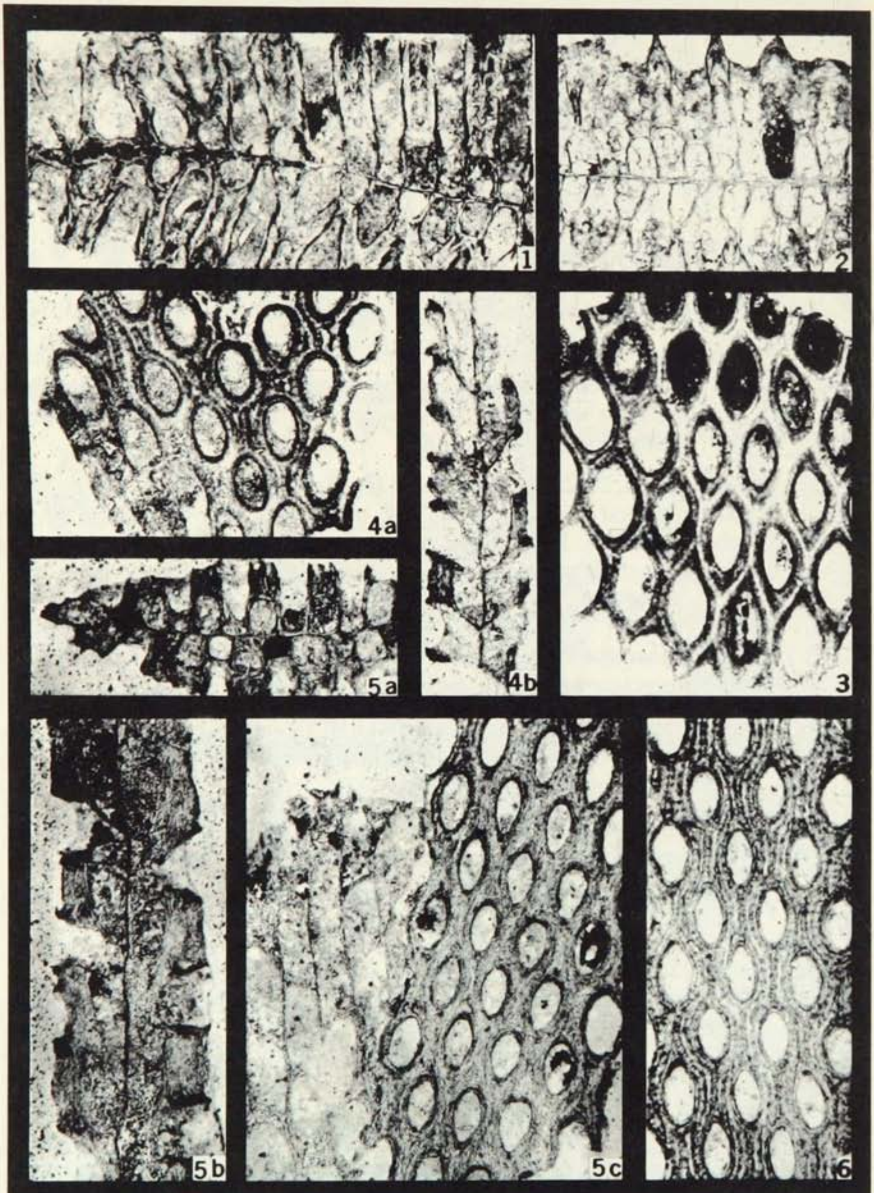
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Plate 18

Figures

Escharopora subrecta **(Ulrich) (p. 69).**

1. Decorah Shale, 21-22 ft. above base; Rochester, USNM 163184.
   Transverse view showing the shape of the zooecia and the curved laminae of the mesotheca in the marginal area of the zoarium; X43.
2. Decorah Shale, 31-33 ft. above base; Rochester, USNM 163195.
   Transverse view showing the mesotheca and the shape of the zooecia in the endozone; X43.
3. Decorah Shale, 29-31 ft. above base; Rochester, USNM 163194.
   Tangential view showing the lighter shaded areas along the zooecial walls. These areas indicate the approximate position of the apexes of the broadly curved laminae that may project above the zoarial surface; X43.

Graptodictya simplex **(Ulrich) (p. 72).**

4. Decorah Shale, 41-43 ft. above base; Rochester, USNM 163216.
   - 4a. Tangential view showing the shape of the zooecia and the arrangement of the pustules in the zooecial walls; X43.
   - 4b. Longitudinal view showing the general shape of the zooecia and the mesotheca; X43.
5. Decorah Shale, 23-25 ft. above base; Rochester, USNM 163215.
   - 5a. Transverse view showing the slightly zigzagging mesotheca, the shape of the zooecial cavities in the endozone and the finely laminated zooecial walls; X43.
   - 5b. Longitudinal view showing the general shape of the zooecia, the stubby hemisepta and the finely laminated walls; X43.
   - 5c. Tangential view showing the zooecia in the endozone and exozone; X43.
6. Decorah Shale, 23-25 ft. above base; Rochester, USNM 163214.
   Tangential view showing the alignment of the zooecia and that of the pustules in the zooecial walls; X43.

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