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SMITHSONIAN MISCELLANEOUS COLLECTIONS
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Charles D. and Mary Vaux Walcott
Research Fund

A REVISION OF THE ORDOVICIAN
BRYOZOAN GENERA BATOSTOMA,
ANAPHRAGMA, AND AMPLEXOPORA

(WITH SEVEN PLATES)

By
RICHARD S. BOARDMAN
Associate Curator of Geology
United States National Museum
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A REVISION OF THE ORDOVICIAN BRYOZOAN
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INTRODUCTION

The genera *Batostoma* Ulrich, 1882, *Anaphragma* Ulrich and Bassler, 1904, and *Amplexopora* Ulrich, 1882, all belong to the order Trepostomata of the Bryozoa. The three genera are here grouped together merely as a convenience in discussing their mutual problems. The grouping does not necessarily imply close taxonomic relationships among the genera.

The genera *Batostoma* and *Anaphragma* are placed in the family Trematoporidae Ulrich in Miller, 1889 (Bassler, 1953, p. G113). *Batostoma* is a fairly common genus in Middle and Upper Ordovician rocks of North America. *Anaphragma* is known only from rocks of Richmond age in North America and highest Middle and Upper Ordovician rocks in Estonia. *Anaphragma* was described originally as, "agreeing in all essential respects with *Batostoma* Ulrich, except that both the zoecial tubes and mesopores are entirely devoid of diaphragms" (Ulrich and Bassler, 1904, p. 49). Based on the study of newly made thin sections of types, all internal characters of generic value are interpreted here to be dissimilar in the two genera (see p. 12).

The genus *Amplexopora* is the type genus of family Amplexoporidae Ulrich in Miller, 1889. Restudy of the primary types in the U. S. National Museum collection resulted in approximately half of the species previously placed in *Batostoma* being reassigned to *Amplexopora*, and this in turn doubled the number of species of *Amplexopora* in the collection. If these reassignments prove to be valid,

the resulting picture of morphologic trends and hypothesized lineages discussed below suggest that species of *Amplexopora* will prove extremely useful in stratigraphic paleontology.

The genus *Stromatotrypa* Ulrich, 1893, was investigated in connection with *Batostoma*, and study of new sections of the type species, *S. ovata* Ulrich, 1893, resulted in *Stromatotrypa* being considered a junior subjective synonym of *Batostoma*. (See p. 6 and pl. 7, figs. 2-4.)

The genus *Acanthotrypella* Vinassa de Regny, 1920, was considered to be a junior subjective synonym of *Batostoma* by Bassler (1935a, p. 54). Study of new sections of the type species, *B. variable* Ulrich, 1890, resulted in *Acanthotrypella* being considered a junior subjective synonym of *Amplexopora*. (See p. 19 and pl. 7, fig. 1.)

The manuscript was critically read by June Phillips, Yale University, N. Spjeldnaes, University of Oslo, and R. Cifelli and P. M. Kier, U. S. National Museum, and many of their suggestions have been incorporated in the final draft. Thin sections were prepared by T. M. Robison of the U. S. Geological Survey. Photography was done by J. Scott of the U. S. National Museum.

Wall structure and ontogeny of Anaphragma.—The thin zooecial walls in the endozones (immature or axial region of authors) of most trepostomes are either granular or longitudinally laminated and give no indication of whether their deposition took place from one or both sides of the walls. The zooecial walls in the endozones of the type species of *Anaphragma*, *A. mirabile* Ulrich and Bassler, 1904, are laminated and contain a dark median line that is connected distally to zooecial boundaries in the exozones (mature or cortical region of authors). These median lines are interpreted as zooecial boundaries in the endozones and are considered to indicate that the walls are transversely laminated and that deposition of the walls took place from both sides (Boardman, 1959, p. 2). Thus, the structure of the walls in the endozones of *A. mirabile* is thought to support the logical assumption that the walls result from deposition by tissue of immediately adjacent zooecia.

The microstructure and resulting appearance of zooecia, mesopores, and acanthopores of *A. mirabile* show progressive changes of remarkable magnitude through a thick-walled exozone. The zooecia are assumed to have grown by the addition of skeletal laminae on the surfaces at their distalmost ends, thus adding to the width of the exozone. The width of the exozone in a segment of a fossil zoarium

then is assumed to be approximately proportional to the ontogenetic growth stage or stages attained by the individual asexual zooids at their death. In the Trepostomata, a progressive decrease in the width of the exozone and number of zooecial diaphragms is generally observable from bottom to top of essentially complete zoaria of appreciable vertical extent such as ramose, frondescent, or bifoliate growth habits. The ontogenetic stage attained by the oldest zooids at the base of a colony then provides a measure of the astogenetic stage of the colony as a whole, and the progressive decrease in exozone width and number of diaphragms up through the colony to the growing tips indicate subsequent addition of progressively younger zooids.

A significant change in microstructure of zooecia as individuals within a colony grew distally is not common in exozones of the Trepostomata, so an estimate of ontogenetic stage is not generally possible in tangential sections that cut zooecia and acanthopores transversely. In *A. mirabile*, however, zooecial walls change from an integrate appearance with sharply defined zooecial boundaries to broadly amalgamate with obscure boundaries. Also, wall laminae change from a V-shaped to broadly U-shaped configuration in most zooecia, and acanthopores start with very small diameters and become progressively larger until they dominate cross-sectional shapes of mesopores and some zooecia (pl. 4). The variation is unusually large and a reasonably large number of specimens is necessary to demonstrate intermediate forms and to correlate variation with stage of development of individual zooecia.

Stratigraphic occurrence of offset acanthopores in Amplexopora.—The species restudied and included in *Amplexopora* in this paper occur in the Middle and Upper Ordovician series. All these species have acanthopores that extend through the exozones and are concentrated in zooecial corners, very similar to conservative acanthopores occurring throughout the order Trepostomata. In addition, the type species and most of the other Upper Ordovician species contain a second, more distinctive type of acanthopore that extends through only a part of the exozone width, is concentrated between zooecial corners, and is offset from the zooecial boundaries toward the voids of the zooecia resulting in inflection of the zooecial walls (see pl. 5, fig. 2). In extreme development, such inflection gives a petaloid or septate appearance to zooecia as seen in cross section in tangential thin sections. The superficial likeness of the offset acanthopores to radially arranged septa led Ulrich to term these acanthopores "pseudo-

septa" in the original description of the type species, *A. septosa* (Ulrich, 1879, p. 125). (For further description of offset acanthopores see pp. 19, 21.)

Of the approximately 18 Middle Ordovician species of *Amplexopora*, described and undescribed, in the U. S. National Museum collections, offset acanthopores causing inflection of zooecial walls are limited to a single undescribed species from the Cannon limestone near the top of the Trenton, Pulaski, Giles County, Tenn.

Of the approximately 14 Upper Ordovician species of *Amplexopora*, described and undescribed, in the U. S. National Museum collections, offset acanthopores causing inflection of zooecial walls were found in all but one species, *A. variable* (Ulrich), 1890, from the top of the Richmond group, Osgood, Ind.

Most of the Middle and Upper Ordovician species of *Amplexopora* referred to above have been described or differentiated on one to several sectioned specimens and are therefore necessarily typological in taxonomic approach. Despite the theoretical limitations of typologically defined species, enough specimens are available to indicate that offset acanthopores are characteristic of *Amplexopora* in the Upper Ordovician rocks of the Ohio and Mississippi River valleys.

Within the present concept of *Amplexopora* at least three inferred lineages appear concurrently in rocks of Middle and Upper Ordovician age in North America. One lineage is characterized morphologically by *A. conferta* (Coryell) of Black River age, *A. cylindracea* Ulrich and Bassler of Trenton age, and *A. columbiana* Ulrich and Bassler, of Maysville age, and seems to be geographically centered in the Central Basin region of Tennessee. The Upper Ordovician species in this first lineage develop offset acanthopores but not as strongly as those occurring in a second lineage characterized by the type species, *A. septosa* (Ulrich). This second lineage seems to be centered in the Ohio, Indiana, and northern Kentucky region, but this impression is no doubt partly due to the predominance of collections from that area in the Museum's Upper Ordovician material.

A third lineage is suggested by species such as *A. winchelli* Ulrich from the Decorah shale in the Upper Mississippi Valley and *A. cingulata* Ulrich and *A. robusta* Ulrich in formations of the Maysville group in the Ohio, Indiana, and northern Kentucky region. In this third lineage, the Upper Ordovician species develop offset acanthopores, which are so small in diameter that they rarely produce an extreme petaloid or "pseudo-septal" appearance in tangential sections.

SYSTEMATIC DESCRIPTIONS

Genus **BATOSTOMA** Ulrich

1882. *Batostoma* Ulrich, Journ. Cincinnati Soc. Nat. Hist., vol. 5, pt. 1, p. 154; pt. 2, p. 256.

1890. *Batostoma* Ulrich, Illinois Geol. Survey, vol. 8, pp. 379, 459.

1893. *Batostoma* Ulrich, Geology of Minnesota, vol. 3, pt. 1, pp. 288-290.

1893. *Stromatotrypa* Ulrich, Geology of Minnesota, vol. 3, pt. 1, pp. 301, 302.

Type species.—*Monticulipora (Heterotrypa) implicatum* Nicholson, 1881, by monotypy.

Emended definition.—Zoaria are ramose or incrusting and moniticules are generally low. Zoecial walls in the endozones are thin, dark, and granular and are connected directly with the well-defined, dark, granular, slightly serrated zoecial-mesopore boundaries of the exozones. In the exozones, zoecia are generally oval in cross section and contain thin, laminated, irregularly spaced diaphragms. As seen in longitudinal sections, the laminae of adjacent zoecial walls lie nearly parallel to the zoecial boundaries, then curve distally just before intersecting the boundaries to form a V-shaped pattern that has extremely long, convexly curved limbs. In tangential sections, walls of adjacent zoecia are generally integrate in appearance.

Mesopores are polygonal in cross section, filling the spaces between zoecia. Laminated wall material on the mesopore sides of boundaries is generally thinner than on zoecial sides, and is lacking entirely in earlier growth stages of several species. Mesopores contain closely spaced diaphragms that generally are curved convexly outward. Larger mesopores have more than one longitudinal row of curved diaphragms that together form a flattened cystose pattern. Mesopore diaphragms are generally thicker than those in zoecia and consist of a thin, dark, granular layer on proximal sides and a thicker laminated layer on distal sides. Acanthopores are variable in size and abundance, and in a few species are very rare.

Discussion.—Based on an examination of thin sections of primary types of species now assigned to *Batostoma* in the U. S. National Museum collections, the following species are considered to belong to that genus:

B. cumingsi Loeblich, 1942, Bromide formation, Middle Ordovician, Oklahoma.

B. fertilis Ulrich, 1886, lower half of the Trenton shales, Middle Ordovician, Minnesota.

B. fertile var. *circulare* Ulrich, 1893, lower third of the Trenton shales, Middle Ordovician, Minnesota.

B. manitobense Ulrich, 1889, Stony Mountain formation, Upper Ordovician, Manitoba.

- B. maysvillense* Nickles, 1905, Mount Hope shale member of the Fairview formation, Upper Ordovician, Maysville, Ky.
B. prosseri Cumings and Galloway, 1912, Waynesville and Liberty formations, Upper Ordovician, Ind.
B. varium Ulrich, 1893, middle third of Trenton shales, Middle Ordovician, Minneapolis, Minn.

The holotype sections of *B. inutilis* Coryell, 1921, and *B. ramosa* Coryell, 1921, both from the Pierce limestone of Tennessee, and *B. humile* Ulrich, 1893, from the Galena shales, Minnesota, were made from fragments of zoaria that contained early stages of development, and generic affinities are not clearly demonstrated. These species are retained in the genus until additional material can be studied.

The primary types of *Batostoma magnopora* Ulrich, 1893, are silicified and structures are insufficiently preserved to identify the specimens generically.

For a list of species originally placed in *Batostoma* that compare closely with the genus *Amplexopora* and are here reassigned to that genus, see page 18.

The type species of *Stromatotrypa* is *S. ovata* Ulrich, 1893, by original designation. The primary types of *S. ovata* (U.S.N.M. 43614) are from the *Rhinidictya* beds (approximately the middle third) of the Decorah shale, Minneapolis, Minn. Sections of previously unsectioned cotypes agree with the two cotypes that had been sectioned, and all are considered to be thin-walled incrusting forms of the genus *Batostoma* (pl. 7, figs. 3, 4). Reexamination of sections of the type species of *Batostoma*, *B. implicatum* revealed a short section of conspecific overgrowth having walls comparable in thickness (pl. 7, fig. 2) with those of *S. ovata*. All qualitative generic characters of *Batostoma* are present in *S. ovata*, including comparable wall structure, arrangement and shape of zooecia and mesopores, and the convexly curved diaphragms in mesopores. Perhaps most significant are the notched acanthopores with structureless cores that are found in *S. ovata* (pl. 7, fig. 3b), the type species of *Batostoma*, and most, but not all, of the other species of *Batostoma*. This type of acanthopore is very rare in the Trepostomata, occurring in one other genus of the order as now understood.

Also of importance, but only suggestive of the real nature of *S. ovata*, is one of the newly sectioned cotypes consisting of a complicated incrusting growth on the branch of a specimen of *B. varium* Ulrich, the primary types of which are also from the Middle Decorah shales

of Minneapolis. All the incrusting growth included in the thin section appears to be overgrowth conspecific with the supporting branch of *B. varium*. Species characters of incrusting forms and overgrowths are generally extremely variable, owing at least in part to compensations made necessary in covering rough, irregular surfaces. It is possible to say only that the overgrowth on the specimen of *B. varium* could be within the morphologic range of the other primary types of *S. ovata*. The other primary types of *S. ovata* incrust other genera of Bryozoa and so are true incrusting growths. A detailed study of many topotypes is necessary to clarify the relationships between the two species. On the basis of comparison of presumed generic characters, however, *Stromatotrypa* is here considered to be a junior subjective synonym of *Batostoma*, and *S. ovata* is reassigned to *Batostoma*.

Two other species in the National Museum collections have been assigned to *Stromatotrypa*. The primary types of *S. globularis* Ulrich and Bassler, 1913, Keyser limestone member of the Helderberg limestone, West Virginia and Maryland, are badly silicified and resectioning of the types has not revealed sufficient characters to reassign the species. *S. frondosa* Loeblich, 1942, from the Bromide formation, Oklahoma, is closely comparable with *B. prosseri* Cumings and Galloway, 1912, and both species are placed in *Batostoma* with some uncertainty.

BATOSTOMA IMPLICATUM (Nicholson)

Pl. 1, figs. 1-5; pl. 2, figs. 1-4; pl. 7, fig. 2

1881. *Monticulipora (Heterotrypa) implicatum* Nicholson, The genus *Monticulipora*, p. 147, pl. 2, figs. 7-7e, text fig. 27.
1882. *Batostoma implicatum* (Nicholson), Ulrich, Journ. Cincinnati Soc. Nat. Hist., vol. 5, pt. 2, p. 256.
1908. *Batostoma implicatum* (Nicholson), Cumings, Indiana Dept. Geol. and Nat. Res. 32d Ann. Rep., p. 774, pl. 7, fig. 7; pl. 8, fig. 2.

Type data.—The species was first named in a faunal list by Ulrich (1880, p. 12) but no indication, definition, or description was included. The list dealt with the fauna about Cincinnati, and Ulrich reported the species from the 100- to 200-foot interval above the low-water mark of the Ohio River. This interval now forms the greater part of the Southgate member of the Latonia shale of the Eden group (Bassler, 1906, p. 8; 100 to 220 feet above the low-water mark). In 1881, Nicholson published a description of the species based on specimens received from J. M. Nickles of Cincinnati, a close associate of UL-

rich. The locality was given by Nicholson as "Cincinnati Group, Ohio," and the depository of the primary types is unknown.

Material studied.—The assumption is made here that the primary types came from the Southgate member in the Cincinnati region. The description below is based on specimens from that member identified as *B. implicatum* in the U. S. National Museum collections, plus specimens collected by the author, as follows:

U.S.N.M. 2994: Southgate member, Chesapeake and Ohio Railroad cut on northeast slope of Bald Knob on west side of Mill Creek, Cincinnati, Ohio, collected by R. Boardman. Sections from 9 fragmentary zoaria studied.

U.S.N.M. 2995: Southgate member, 150 feet above river, head of Monmouth Street, Newport, Ky. Collector unknown. Sections from 9 fragmentary zoaria were studied.

U.S.N.M. 2999: Southgate member, Shadwell Street, Cincinnati, Ohio. Collector unknown. Sections from 10 fragmentary zoaria were studied.

U.S.N.M. catalog numbers of illustrated specimens are 138266-138272.

Description.—Zoaria are ramose, incrusting, or a combination of these two growth habits. Branches are circular to elliptical in cross section. Secondary overgrowth is characteristically well developed on ramose zoaria, as many as four layers occurring on older branches. Irregular development of overgrowths, especially their ramose extensions beyond primary branches, produces anastomosing branches that display erratic and confused zooecial growth at surfaces where branches are joined. Lateral branches arising from overgrowths are commonly discordantly small in diameter and random in arrangement. Local patches of more extended zooecial growth or abrupt changes in direction and diameter of secondary branches beyond the ends of primary branches produce localized swellings on the branches that are characteristic of the species.

Monticules are generally flush with the surface of the zoarium and the monticular zooecia are little different from intermonticular zooecia.

In the endozone, zooecial walls are thin, dark, and somewhat granular in appearance. The zooecia are extremely variable in width and irregular in direction, bending in and out of the planes of longitudinal thin sections. Partitions transverse to the zooecia are common but irregularly distributed and are planar or curved. Many zooecia seem

to originate at transverse partitions, either one large zooecium becoming two at the partition, or two zooecia becoming one.

In the exozone, the species is characterized by an irregularity of gross structures and poorly defined microstructure that is uncommon in trepostomes. Walls between adjacent zooecia or adjacent zooecia and mesopores are delimited by boundaries that in longitudinal sections are well defined, dark, granular, slightly serrated lines or zones. The boundaries are located at the points at which laminae from adjacent walls abut. Laminae of zooecia and mesopores are generally difficult to distinguish and intersect the boundaries at angles of less than 90 degrees to form the V-shaped pattern characteristic of the genus. Diaphragms in the zooecia are generally thin, laminated, slightly curved to planar, and widely and irregularly spaced. Cystoidal diaphragms are few.

Mesopores are common between zooecia although they rarely surround the zooecia completely. The mesopores contain thick, closely spaced diaphragms that are generally curved convexly outward. Larger mesopores have more than one longitudinal row of diaphragms; the rows are separated by the diaphragms themselves curving back proximally through 90 degrees to form an irregular, flattened, cystose pattern. The proximal sides of mesopore diaphragms display a dark granular layer of material similar in appearance to the material of the zooecial walls in the endozones and the zooecial boundaries in the exozones. This dark layer is connected directly to the boundaries between the mesopores and adjacent zooecia in many mesopores. The distal sides of the mesopore diaphragms are thicker than the proximal dark layer and are composed of laminated material similar in appearance to that of the zooecial walls. The laminated material thins rapidly as it bends either proximally with the diaphragms in the center of a mesopore, or distally along the wall of a mesopore. Thus, the laminated material on the mesopore side of the wall is either lacking or much thinner than the laminated deposit of relatively constant thickness on the zooecial side of the boundary.

Acanthopores are conspicuous in longitudinal sections and characteristically display a large core of structureless, transparent calcite. The cores have sharply notched sides caused by the unequal extensions of laminae into them from the surrounding laminated material of the zooecial walls. A few acanthopores appear to have very short lateral branches.

In tangential sections, younger ontogenetic stages of development,

as seen in young branches or in deep tangential sections of older branches, have a different appearance than older stages of development, as seen in shallow sections of older branches. In younger stages, the dark, granular, zooecial-mesopore boundaries are easily visible and in tangential sections appear as straight lines between zooecia and straight or curved lines between zooecia and adjacent mesopores. The curved boundaries are convex toward the mesopores, producing irregular, compressed, subpolygonal cross sections in the mesopores and subpolygonal to subcircular boundaries in the zooecia. In these younger stages the mesopores are open, having little or no laminated tissue on the mesopore walls inside the boundaries. The mesopores appear to be merely open spaces between the zooecia. The zooecia contain a thick laminated deposit inside the boundaries that smooth out the polygonal configurations of the boundaries and produce generally oval zooecial voids.

In tangential sections older growth stages are characterized by a general thickening of skeletal material in zooecia and mesopores. The dark zooecial-mesopore boundaries are largely obscured, zooecial walls are thickened, reducing the diameters of zooecial voids, and mesopores are generally filled with skeletal material originating either from the mesopore walls or a combination of walls and diaphragms. The filling of mesopores makes their numbers obscure in tangential sections in older growth stages.

Acanthopores in tangential sections are randomly arranged on the zooecial boundaries. Many appear transparent and structureless, a few show the concentric laminae more typical of the Trepostomata. Acanthopores are extremely variable in number and diameter from zoarium to zoarium, and within a few zoaria are extremely variable in diameter. Many acanthopores, regardless of diameter, cause inflection of zooecial walls. There seems to be little correlation between zooecial wall thickness and acanthopore diameter, the tangential sections through older growth stages with thick walls can have either large, small, or variable acanthopores. This variability in diameter of acanthopores is at least partly controlled by the notched character seen in longitudinal sections.

Monticules in tangential sections are either concentrations of several filled mesopores or zooecia that are slightly larger in diameter than intermonticular zooecia.

Quantitative data.—The following tables are based on sections from 25 fragmentary zoaria that are thought to be topotypes of Nicholson's original specimens. All measurements are in millimeters.

The axial ratio is the ratio of the diameter of the endozone to the corresponding branch diameter.

TABLE 1.—*General measurements*

	Maximum	Minimum
Diameter of zoarium.....	9.1	4.4
Diameter of endozone.....	5.1	2.5
No. zooecia in 2 mm. (longitudinal direction).....	6½	5
Average major axis of zooecial void per fragment...	0.30	0.23
Acanthopores per zooecium.....	3.5	0.6

TABLE 2.—*Ontogeny*

Average No. diaphragms in zooecium	Width of exozone	Axial ratio
1-2	1.2-1.6	0.64-0.74
3	2.3	0.60
5	2.2-2.5	0.56-0.67
6	2.6-2.8	0.49-0.56
8	3.3	0.57
9	4.4	0.52
12	4.8	0.44

Genus ANAPHRAGMA Ulrich and Bassler

1904. *Anaphragma* Ulrich and Bassler, Smithsonian Misc. Coll., vol. 47, No. 1470, p. 49.
1911. *Anaphragma* Ulrich and Bassler, Bassler, U. S. Nat. Mus. Bull. 77, p. 297.
1920. *Batostoma* (*Anaphragma*) Ulrich and Bassler, Vinassa de Regny, Atti Soc. Ital. Sci. Nat., vol. 59, p. 226.
- 1935a. *Anaphragma* Ulrich and Bassler, Bassler, Fossilium Catalogus, I: Animalia, pars 67, p. 46.

Type species.—*Anaphragma mirabile* Ulrich and Bassler, 1904, by original designation.

Emended definition.—Zoaria are ramose. Zooecial walls in endozones range from straight to crenulated, are laminated, and generally display dark zooecial boundaries. In the exozone, laminae of zooecial walls generally form a U-shaped pattern in longitudinal sections, but a V-shaped pattern is common in walls of early exozones and occurs throughout the length of zooecia in some zoaria. Thin, complete diaphragms are sparsely distributed, one to several in a very few zooecia; most zooecia completely lack diaphragms.

In tangential sections, zooecial walls are generally amalgamate, but can be integrate in appearance. Laminated acanthopores are common; their size can be extremely variable within a species.

Mesopores are common, have walls comparable in thickness with zooecia, and are generally without diaphragms.

Discussion.—*Anaphragma* is described in the literature as agreeing in all essential respects with *Batostoma*, except for very few diaphragms in zooecia and mesopores and crenulated zooecial walls in the endozone. The phyletic histories of *Anaphragma* and *Batostoma* are not known at present, so the relationships between the two genera

TABLE 3.—*Summary of generic characters distinguishing Anaphragma and Batostoma*

<i>Structures in common</i>	<i>Batostoma</i>	<i>Anaphragma</i>
Endozone	Uniformly thin and granular	Variable in thickness, laminated with visible zooecial boundaries
Exozone wall laminae ..	V-shaped pattern	U-shaped, rarely V-shaped pattern in older growth stages
Zooecial boundaries	Well defined throughout	Obscured in older growth stages
Zooecial walls in tangential view	Integrate	Amalgamate, except in a few zooecia in youngest growth stages
Mesopore walls	Laminated material lacking in earlier growth stages, generally thinner than that of adjacent zooecia in later stages	Laminated material comparable in thickness with zooecia throughout
Acanthopores	Generally filled with transparent calcite and in many species sides are notched. Diameter not greatly controlled by growth stage	Laminated and obscure in longitudinal sections. Diameter largely controlled by growth stage in type species

must be evaluated on morphologic comparisons alone. Further sectioning of the cotype suite and topotypes of *A. mirabile* indicate that the only comparable character the two genera share, as the genera are presently understood, is a distressing external homeomorphy, as witnessed by five previously unsectioned specimens of *Batostoma* sp. in the cotype suite of *A. mirabile*. Table 3 summarizes the generic descriptions of structures that the two genera have in common. It is not impossible, of course, for one of the generic stocks to have developed from the other, but on the basis of our limited data the external homeomorphy seems fortuitous and there is no evi-

dence for a phyletic or descriptive relationship between the genera.

The collection of the U. S. National Museum also includes a species of *Anaphragma* identified as *A. mirabile* from the Fernvale formation near Pulaski, Tenn., and two other forms of *Anaphragma* identified as *A. mirabile* Bassler, 1911 (p. 298) and *A. mirabile cognata* Bassler, 1911 (p. 299), from the highest Middle and Upper Ordovician of Esthonia. Sections were made of some of the specimens identified as *A. mirabile* from Delafield and Iron Ridge, Wis., in the original description of the species, but the internal structure is completely gone and no identification can be made.

ANAPHRAGMA MIRABILE Ulrich and Bassler

Pl. 3, figs. 1-4; pl. 4, figs. 1-4

1904. *Anaphragma mirabile* Ulrich and Bassler, Smithsonian Misc. Coll., vol. 47, No. 1470, p. 49, pl. 13, figs. 9-11.

Material studied.—The cotype suite, U.S.N.M. 43218, from the Richmond group, Wilmington, Ill., includes a sectioned specimen here designated the lectotype, six specimens that are considered conspecific with the lectotype after sectioning, and five specimens of an undescribed species of *Batostoma* that is a close external homeomorph of *A. mirabile* but is quite different internally.

In addition, 21 topotype specimens were studied from the following collections:

U.S.N.M. 2996: Richmond group (approximately 10 feet of beds exposed) on west bank of Kankakee River, just north of U. S. 66A bridge, Wilmington, Illinois. Collected by A. R. Loeblich, Jr.

U.S.N.M. 2997: Richmond group, Wilmington, Illinois. Collected by E. O. Ulrich.

New U.S.N.M. catalog numbers 138273 to 138280 are assigned to individual primary types and topotypes; the lectotype is 138275.

Description.—Zoaria are ramose; branches are generally circular in cross section. Conspecific overgrowth is poorly developed, occurring on three specimens in very thin patches. Monticules are low and difficult to distinguish externally.

In the endozone, zoecial walls range from straight to irregularly undulated and display a considerable variation in thickness. The zoecial walls are laminated and adjacent zoecia are separated by dark zoecial boundaries running down the centers of the walls. These boundaries merge distally into the zoecial boundaries of the early exozone.

In the early exozone as seen in longitudinal sections, zoecial

boundaries are well-defined dark lines or narrow serrated zones and the wall laminae that intersect the boundaries form either a V-shaped or sharply U-shaped pattern. As the walls are followed distally in the early exozone, the V-shaped pattern is generally lost and the U-shaped pattern broadens so that the zone of curved laminae makes up an increasing proportion of total wall thickness. Also, as seen in longitudinal sections, zooecial boundaries are commonly marked by a dark granular zone of appreciable width that can alternate at irregular intervals along a zooecial wall with the more common boundary formed by abutting laminae. As the broadening of the U-shaped laminae progresses distally, the zooecial boundaries become more obscure, until the boundaries are completely lost in later growth stages.

There is a general increase in zooecial wall thickness distally in the early exozone as the zone of curved laminae broadens. Zooecial wall thickness is markedly variable, however, from zoarium to zoarium and also can vary irregularly along the length of a zooecium in the outer part of the exozone. The thickness of a limited segment of a zooecial wall in the outer exozone can decrease to thicknesses common in the early exozone, but the zone of curved laminae remains relatively broad and the zooecial boundary obscure, indicating that wall thickness alone does not determine the nature of the curved laminae and the zooecial boundary. The pattern of laminae is V-shaped and the zooecial boundaries well defined throughout the length of a few zooecia in two of the specimens sectioned.

The general aspect of tangential sections varies considerably with zooecial wall thickness from zoarium to zoarium and also seems to be controlled, at least in part, by stage of ontogenetic development within a zoarium. In the five sections containing exozones of 3 mm. or less in width, the corresponding tangential sections display relatively small acanthopores that cause little or no inflection of zooecial walls, and the zooecial walls range from integrate to broadly amalgamate. In the 10 sections containing exozones ranging from 3 to 5 mm. in width, acanthopores range in size from small, to medium—recognized by noticeable inflection of zooecial walls, to large—recognized by acanthopores controlling cross-sectional shapes of mesopores and zooecia by strongly inflecting their walls. Zooecial walls range from narrowly amalgamate to broadly amalgamate in the 3- to 5-mm. interval. Also within this interval, the three sections showing medium-sized acanthopores are all amalgamate, and the one section that has large acanthopores is broadly amalgamate. In the five sections having exozone widths greater than 5 mm., corresponding tangential sections

all contained large acanthopores and the walls were broadly amalgamate.

Acanthopores are confined to zooecial corners, except in advanced growth stages in which acanthopores are large and have a generally irregular appearance and distribution. Central canals of acanthopores are very small or filled. Mesopores are arranged in an apparently

TABLE 4.—General measurements

	Lectotype	Paratypes and topotypes	
		Minimum	Maximum
Diameter of zoarium.....	6.1	5.4	13.9
Diameter of endozone.....	2.2	2.9	5.3
Average diameter of zooecial void per fragment (longitudinal direction).....	0.27	0.26	0.35
Acanthopores per zooecium	2.7	1.4	4.3
Mesopores per zooecium.....	1.0	0.53	1.6

TABLE 5.—Ontogeny

	Width of exozone	Axial ratio	Tangential aspect
	1.8	0.75	Acanthopores small,
	2.0	—	zooecial walls integrate
	2.5-2.9	0.54-0.65	to broadly amalgamate
	3.1	0.58-0.62	Acanthopores small to
	3.8-3.9	0.48-0.54	large, zooecial walls
Lectotype.....	3.9	0.35	narrowly amalgamate to
	4.0-4.4	0.45-0.47	broadly amalgamate
	4.6	0.46	
	5.4	0.41	Acanthopores large,
	5.7	0.35	zooecial walls broadly
	8.1	0.32	amalgamate
	9.2	0.34	
	9.7	0.26	
	10.6	0.21	

random pattern between zooecia and have walls comparable in structure and nearly comparable in thickness with walls of adjoining zooecia. Some of the smaller mesopores have noticeably thinner walls than adjoining zooecia. No diaphragms were seen in mesopores.

Monticules were not distinguished in all tangential sections, and are generally marked by slight increases in zooecial wall thickness and zooecial and acanthopore diameters.

Quantitative data.—Tables 4 and 5 above are based on sections of fragments from the lectotype and 20 paratype and topotype zoaria. All measurements are in millimeters. The axial ratio is the ratio of the diameter of the endozone to the corresponding branch diameter.

Discussion.—A direct relation exists between the progressive broadening of the U-shaped pattern of the zooecial wall laminae and the amalgamated appearance of the walls in tangential sections. In the early part of the exozone the laminae are V- or sharply U-shaped and the resulting appearance of walls in the tangential view is integrate or narrowly amalgamate. As the zooecia become older and grow distally, the ends of the laminae at the bottom of the U lie in the plane of a tangential section to form the amalgamate band of structureless or granular-appearing skeletal material in the tangential section. Thus, as that U-shaped configuration broadens and takes up an increasing proportion of the wall thickness as the zooid grows older, the amalgamate band becomes broader and shallow tangential sections of older zooecia are broadly amalgamate.

Genus AMPLEXOPORA Ulrich

1882. *Amplexopora* Ulrich, Journ. Cincinnati Soc. Nat. Hist., vol. 5, pt. 1, p. 154; pt. 2, p. 254.
 1890. *Amplexopora* Ulrich, Illinois Geol. Survey, vol. 8, pp. 377, 450.
 1904. *Amplexopora* Ulrich, Ulrich and Bassler, Smithsonian Misc. Coll., vol. 47, No. 1470, p. 41.
 1908. *Amplexopora* Ulrich, Cumings, Indiana Dept. Geol. and Nat. Res., 32d Ann. Rep., p. 739.
 1920. *Acanthotrypella* Vinassa de Regny, Atti Soc. Ital. Sci. Nat., vol. 59, p. 221.
 1935a. *Acanthotrypella* Vinassa de Regny, Bassler, Fossilium catalogus, I: Animalia, pars 67, p. 41. (Considered a junior subjective synonym of *Batostoma*.)

Type species.—*Atactopora septosa* Ulrich, 1879, by subsequent designation herein. E. O. Ulrich published a paper entitled "American Paleozoic Bryozoa" in parts in the Journal of the Cincinnati Society of Natural History. The first part is dated October 1882, the second part December 1882. In part 1, Ulrich established the genus *Amplexopora* with a brief definition (p. 154). In part 2 (p. 254) Ulrich described "*Amplexopora cingulata*, n. gen. et sp. (Plate XI, figs. 5-5b) Generic char., ante p. 154." In remarks following the description of *A. cingulata* Ulrich states, "The species above described I regard as the type of the genus, *Amplexopora*, proposed by me in the last number of the Journal, p. 154."

In part 1, Ulrich preceded his taxonomic section with a discussion of morphology in which he cited four names of species of *Amplexopora*. Two of the names are here considered to have been *nomina nuda*, and two valid, as follows:

One of the *nomina nuda*, "*Amplexopora variabilis*, Ulrich" (1882,

p. 124), has never been validated. The species Ulrich might have been referring to is *Batostoma variabile* Ulrich, 1890.

"*Amplexopora cingulata* Ulrich" is mentioned on page 126 of the October publication but was not described and figured until the December number. Therefore, *A. cingulata* is considered not to have been available as the type species of *Amplexopora*.

One of the two valid species, "*Amplexopora discoidea*, James" (Ulrich, 1882, p. 123), should have been cited as *A. discoidea* (Nicholson). James first listed the name in 1871 without indication, definition, or description. Nicholson borrowed James's types and described them as *Chaetetes discoideus* James (Nicholson, 1874, p. 511, pl. 30, figs. 4-4d) thereby making himself the author of the species. The whereabouts of the primary types is unknown.

"*Amplexopora septosa* Ulrich" is the second valid species mentioned in the October number (p. 128). This citation is in error, lacking the parentheses around the author's name, as the species was originally placed in *Atactopora* (Ulrich, 1879, p. 125). However, Ulrich removed any doubt as to the species referred to by stating that *Atactopora septosa* belonged to *Amplexopora* (1882, pt. 2, p. 255). *Atactopora septosa* Ulrich, 1879, is here designated the type species of *Amplexopora*.

Emended definition.—Zoaria are ramose, frondescent, incrusting, or massive, and monticules are generally well developed. In the exozone, wall structure commonly appears integrate, but can be amalgamate. Laminae from adjacent zooecia intersect a sharply defined zooecial boundary at angles of less than 90 degrees to form a V-shaped pattern pointing distally. Distinct zooecial linings are present in several species. Laminae of the diaphragms are continuous distally with the laminae of these zooecial linings, or in other species, with the zooecial wall laminae. Diaphragms are extremely variable in thickness, curvature, parallelism, and spacing, with compound and cystoidal diaphragms and cystiphragms common in many species.

Mesopores are lacking to few: early chambers are beaded and later diaphragms are regularly and closely spaced. Acanthopores are generally abundant and are of two types: those that are concentrated in zooecial corners and extend throughout the width of the exozone, occurring in all species; and additional acanthopores that are concentrated between zooecial corners and extend through a part of the exozone width, occurring in some species. These additional

acanthopores are generally offset from zooecial boundaries toward zooecial voids causing inflection of zooecial walls.

Discussion.—Based on an examination of thin sections of primary types of species previously assigned to *Amplexopora* now in the U. S. National Museum collections, the following species are considered correctly assigned to that genus:

- A. ampla* Ulrich and Bassler, 1904, Leipers limestone, Upper Ordovician Nashville, Tenn.
A. cingulata Ulrich, 1882, Fairmount limestone member of Fairview formation, Upper Ordovician, McKinney's Station, Ky.
A. columbiana Ulrich and Bassler, 1904, Leipers limestone, Upper Ordovician, Columbia, Tenn.
A. convoluta Bassler, 1935b, Hermitage formation, Middle Ordovician, Harts-ville, Tenn.
A. cylindracea Ulrich and Bassler, 1904, Catheys limestone, Middle Ordovician, Nashville, Tenn.
A. persimilis Nickles, 1905, Economy member of the Latonia shale, Upper Ordovician, West Covington, Ky.
A. pustulosa Ulrich, 1890, Waynesville shale, Upper Ordovician, Hanover, Ohio.
A. robusta Ulrich, 1883, Bellevue limestone member of the McMillan formation, Cincinnati, Ohio.
A. septosa (Ulrich), 1879, Mount Hope shale member of the Fairview formation, Upper Ordovician, Covington, Ky.

The following species originally placed in the genus *Batostoma* (p. 5) are here reassigned to *Amplexopora*. These species lack the distinctive mesopores of the type species of *Batostoma* and in other characters compare with the type species of *Amplexopora*.

- Batostoma billingsi* Bassler, 1927, English Head and Vaureal formations, Upper Ordovician, Anticosti Island. (Types show mesopores in early exozone that are crowded out in later stages to form typical amplexoporid appearance.)
B. chapparsi Loeblich, 1942, Bromide formation, Middle Ordovician, Oklahoma.
B. conferta Coryell, 1921, Pierce limestone, Middle Ordovician, Murfreesboro, Tenn.
B.? *decepiens* Ulrich, 1893, Decorah shale (*Rhimidictya* beds), Middle Ordovician, Minneapolis, Minn.
B. elongata Caley, 1936, Wekwemikongsing formation, Upper Ordovician, Manitoulin Island, Ontario.
B. minnesotense Ulrich, 1893, Decorah shale (*Rhimidictya* beds), Minneapolis, Minn.
B. variabile Ulrich, 1890, top of the Richmond group, Osgood, Indiana. (Type species of *Acanthotrypella* Vinassa de Regny, 1920.)
B. winchelli var. *spinulosum* Ulrich, 1893, middle third of Trenton shales, Middle Ordovician, Minneapolis, Minn.

Amplexopora winchelli Ulrich, 1886, from the Decorah shale (*Rhimidictya* beds) Minneapolis, Minn., was reassigned to *Batostoma*

(Ulrich, 1893, p. 295) and is here reassigned to *Amplexopora*, the original genus.

The available evidence strongly indicates that two types of acanthopores are present in the type species and in most of the other Upper Ordovician species of *Amplexopora*. In the type species, the shorter, offset acanthopores generally are concentrated in early and middle parts of exozones and largely between zoecial corners, in contrast to the long acanthopores extending throughout the exozones and centered in zoecial corners. In tangential sections, the total number of acanthopores in areas containing offset acanthopores is approximately twice that of areas without offset acanthopores.

Some of the short offset acanthopores appear almost spinelike. In tangential sections acanthopores are cut transversely and offset acanthopores always have an extension of skeletal material connecting the acanthopores and zoecial walls. Thus, regardless of the first impression given in plate 5, figure 2e, offset acanthopores in three dimensions are not spines supported only at their bases and projecting freely into the zoecial voids, but "spines" supported continuously along their lengths by a ridge of skeletal material connected to zoecial walls.

A distinction is made between inflection of zoecial walls by offset acanthopores and inflection of zoecial walls by acanthopores relatively large in diameter and centered on zoecial boundaries. Examples of inflection by large, centered acanthopores are found in *Amplexopora conferta* (Coryell) and *A. winchelli* var. *spinulosum* (Ulrich), both Middle Ordovician forms.

The taxonomic significance of the offset acanthopores cannot be estimated until much more is known of the distribution of related species and their morphologic variation. Offset acanthopores are not now considered a necessary attribute for the genus *Amplexopora*, or a basis for erection of subgenera within the genus.

The genus *Acanthotrypella* Vinassa de Regny was described merely as a thick-walled *Acanthotrypa* and the originally designated type species is *Batostoma variable* Ulrich, 1890. The cotypes of *B. variable* are in the U. S. National Museum collections and consist of four partly silicified specimens from the top of the Richmond group, Osgood, Ind. The cotype originally figured by Ulrich (1890, pl. 35, fig. 5) is here designated the lectotype (U.S.N.M. 43820) and sections are illustrated on plate 7, figure 1. The specimen does not seem to differ significantly from *Amplexopora septosa*, except for the lack of offset acanthopores that inflect zoecial walls. The species is here

placed in *Amplexopora* and *Acanthotrypella* is considered a junior subjective synonym of *Amplexopora*.

AMPLEXOPORA SEPTOSA (Ulrich)

Pl. 5, figs. 1-2; pl. 6, figs. 1-3

1879. *Atactopora septosa* Ulrich, Journ. Cincinnati Soc. Nat. Hist., vol. 2, p. 125, pl. 12, figs. 7-7c.
1882. *Amplexopora septosa* (Ulrich), Journ. Cincinnati Soc. Nat. Hist., vol. 5, pt. 1, p. 128; pt. 2, p. 255.

Material studied.—The cotype suite of *A. septosa*, U.S.N.M. 43621, contained a tangential thin section and a number of unsectioned specimens. After sectioning, seven of the cotypes compared closely with the original thin section and description of the species and are considered to be conspecific. The remainder of those sectioned belong to other genera. The new U.S.N.M. catalog number of the lectotype is 138281; paratypes and topotype are 138282 to 138288. The primary types are from the Mount Hope shale member of the Fairview formation, Maysville group, of the Upper Ordovician at Covington, Ky.

In addition, sections were made from topotype suites, U.S.N.M. 44912 and 44913, collected by E. O. Ulrich.

Description.—Zoaria are ramose; branches are circular to elliptical in cross section. Conspecific overgrowth is common. Monticules are high and nearly conical in outline. The inflection of zooecial walls by acanthopores that characterizes the species can generally be seen on exteriors of well-preserved specimens and seems to occur in randomly arranged groups of zooecia.

In the endozone, zooecial walls are extremely thin and are finely crenulated to nearly straight. Diaphragms are generally sparse and are concentrated in dome-shaped zones extending across the endozones and in the outer regions of the endozones just preceding the exozones.

In the exozone, walls are relatively straight and moderate and constant in thickness for the genus. In a few zooecia, short lengths of wall vary in thickness. Zooecial boundaries in longitudinal view are generally well-defined, dark, serrated lines or zones between abutting laminae from adjacent zooecia. Laminae of adjacent zooecia generally intersect the boundaries at angles much less than 90 degrees to form a V-shaped pattern. A thin zooecial lining is common, and tends to vary proportionally in thickness to the thickness of the diaphragm immediately connected with the lining.

Diaphragms vary considerably from zoarium to zoarium in spacing, parallelism, thickness, and curvature. They range from parallel and widely and evenly spaced to cystoidal, compound, and closely and irregularly spaced. If present, marked thickening or closeness of spacing of a few diaphragms in a zooecium occurs in similar positions in most of the zooecia of a section.

In longitudinal view, the acanthopores that are offset and inflect zooecial walls are visible within zooecial voids for short intervals in areas of the section that happen to be immediately adjacent and running generally parallel to the zooecial walls. The offset acanthopores arise from zooecial walls and are attached to the walls along their entire length by ridges of skeletal material. In thicker sections and polished sections these offset acanthopores appear to vary in length, unlike most acanthopores that are within zooecial walls and run throughout the width of the exozone. The offset acanthopores begin at the inception of the exozone in some zoaria or well within the exozone in other zoaria. The offset acanthopores may end well within the exozone, or may continue to the distal ends of the zooecia. Commonly, the offset acanthopores end at the outermost diaphragm and thus are not seen on the exterior in many areas of a zoarium.

Mesopores are very rare. Early mesopore chambers are beaded. Distally the beading is lost and mesopore diaphragms are thick and closely and regularly spaced. Laminae of diaphragms in mesopores and zooecia are continuous distally with laminae of surrounding walls.

In tangential sections, zooecial walls appear integrate or amalgamate. The amalgamate appearance is generally more pronounced in areas of a thin section that contain offset acanthopores. In zooecia appearing amalgamate in tangential section, the amalgamate band appears granular and its margins merge gradually into the laminated appearance of the inner part of the walls. Zooecial linings are easily distinguishable by a darker shade and sharp contact with the remainder of the zooecial wall.

In areas of tangential sections that do not contain offset acanthopores, acanthopores are dark and are concentrated in zooecial corners. A few occur between corners and are centered on zooecial boundaries. In areas of tangential sections that contain pronounced inflecting of zooecial walls by offset acanthopores, these offset acanthopores are generally between zooecial corners, and the numerical concentration of all acanthopores is nearly twice that of areas without inflection. Offset acanthopores always have an extension of skeletal material connecting the acanthopores and zooecial walls.

TABLE 6.—General measurements (in mm.)

	Original section 43621	Lectotype 138281	Paratypes					
			138282	138283	138284	138285	138286	138287
Diameter of zoarium.....	—	9.5	—	—	7.3	9.1	11.9	7.1
Diameter of endozone.....	—	5.1	—	—	4.1	5.8	9.4	5.3
Average major axis of zooecial void.....	0.21	0.22	0.23	0.20	0.21	0.21	0.21	0.20
Acanthopores per zooecium:								
Zooecial walls inflected.....	5.1	3.9	—	—	3.8	3.3	—	3.8
Walls not inflected.....	—	2.4	1.4	2.2	2.0	1.8	2.2	2.0
Ontogenetic characters:								
No. diaphragms in zooecium.....	—	12	15	12	16	11	6	4
Width of exozone.....	—	4.4	4.1	3.5	3.2	3.3	2.5	1.8
Axial ratio	—	0.54	—	—	0.56	0.64	0.79	0.75

In monticules, zooecia can have enlarged diameters and walls are generally thickened. Monticular mesopores are common and are either randomly or centrally located in the monticules. (See explanation of plate 5 for further discussion of monticules.)

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EXPLANATION OF PLATES

PLATE I

Batostoma implicatum (Nicholson)

- Fig. 1. Longitudinal view of identified specimen, U.S.N.M. 138266, $\times 50$, showing acanthopores with lateral branches or nodes. U.S.N.M. collection 2999.
- Fig. 2. Transverse view of identified specimen, U.S.N.M. 138267, $\times 50$, illustrating the continuity of the zooecial wall of the endozone and the zooecial boundary in the exozone. Note also the typical configuration of the laminae in the exozone. U.S.N.M. collection 2999.
- Fig. 3a. Longitudinal view of identified specimen, U.S.N.M. 138268, $\times 50$, showing several notched acanthopores and continuity between the zooecial-mesopore boundary and the dark, granular, proximal layer of the mesopore diaphragms. U.S.N.M. collection 2995.
- Fig. 3b. Longitudinal view of the overgrowth of same zoarium, $\times 100$, showing wall structure that is typical of the species.
- Fig. 4. Longitudinal view of identified specimen, U.S.N.M. 138269, $\times 5$, showing irregular zooecial growth of anastomosing branches. U.S.N.M. collection 2995.

- Fig. 5. Longitudinal view of identified specimen, U.S.N.M. 138270, $\times 10$, showing configuration of zooecial walls of the endozone. U.S.N.M. collection 2995.

PLATE 2

Batostoma implicatum (Nicholson)

- Fig. 1. Tangential view of identified specimen, U.S.N.M. 138270, $\times 50$, illustrating the passage from the thicker walled growth stage to the younger, thin-walled stage. Note variation in diameters of acanthopores. U.S.N.M. collection 2995.
- Fig. 2. Tangential view of identified specimen, U.S.N.M. 138271, $\times 50$, showing an extreme thickening of zooecial walls and no laminated development of mesopore walls in a relatively young growth stage. U.S.N.M. collection 2994.
- Fig. 3a. Transverse view of identified specimen, U.S.N.M. 138268, $\times 10$, showing transverse shape of zooecia in the endozone and a secondary overgrowth incrusting the primary branch. U.S.N.M. collection 2995.
- Fig. 3b. Tangential view from same zoarium, $\times 50$, illustrating an older growth stage characterized by mesopores largely filled with skeletal material.
- Fig. 3c. Longitudinal view from same zoarium, $\times 50$, showing the thin widely spaced diaphragms of the zooecia, the typical notched acanthopore, and the thick, distally curved diaphragms of the mesopores.
- Fig. 4. Longitudinal view of identified specimen, U.S.N.M. 138272, $\times 50$, illustrating a younger growth stage than that shown in figure 3c. U.S.N.M. collection 2994.

PLATE 3

Anaphragma mirabile Ulrich and Bassler

- Fig. 1. Longitudinal view of topotype, U.S.N.M. 138273, $\times 50$, showing the progressive broadening of the zone of curved laminae and obscuring of the dark, irregular zooecial boundary as growth proceeded from right to left in figure. Distortion into V-shaped laminae in lower zooecial wall is probably caused by proximity of an acanthopore running along zooecial boundary. U.S.N.M. collection 2996.
- Fig. 2. Longitudinal view of paratype, U.S.N.M. 138274, $\times 20$, displaying extremely thin zooecial walls. U.S.N.M. cotype suite 43218.
- Fig. 3a. Deep tangential section of lectotype, U.S.N.M. 138275, $\times 50$, showing a young growth stage in a zoarium with exceptionally thick zooecial and mesopore walls. Note narrowly amalgamate appearance (dark zones between tubes), and small, almost undistinguishable acanthopores in a few zooecial corners. U.S.N.M. cotype suite 43218.
- Fig. 3b. Longitudinal section of lectotype, $\times 20$, showing thick zooecial walls and two diaphragms.
- Fig. 3c. Longitudinal section of lectotype, $\times 50$, showing a diaphragm and dark, granular zooecial boundary zone in middle segment of centered zooecial wall.
- Fig. 4. Longitudinal section of branch of topotype zoarium, U.S.N.M. 138276, $\times 5$, showing thin zooecial walls, and general lack of diaphragms. U.S.N.M. collection 2996.

PLATE 4

Anaphragma mirabile Ulrich and Bassler

- Fig. 1a. Longitudinal section of topotype, U.S.N.M. 138277, $\times 50$, showing moderately thick-walled zooecia that developed broad zones of curved laminae. Note center channel of acanthopore in lower left corner of figure. U.S.N.M. collection 2996.
- Fig. 1b. Longitudinal view from same section, $\times 50$, showing strongly V-shaped laminae and well-defined zooecial boundary in exozone. Note center channels of acanthopores in two zooecial walls at bottom of figure.
- Fig. 2. Tangential section of topotype, U.S.N.M. 138278, $\times 50$, illustrating appearance of advanced growth stages in a thick-walled zoarium. Note the very large acanthopores irregularly inflecting zooecia and mesopores, and the broadly amalgamate appearance of the walls. U.S.N.M. collection 2996.
- Fig. 3a. Deep tangential section of topotype, U.S.N.M. 138279, $\times 50$, illustrating an intermediate growth stage in a thin-walled zoarium. Note the inflection of zooecial walls by the acanthopores and the enlarged zooecium and acanthopore in the monticule in lower right of figure. U.S.N.M. collection 2996.
- Fig. 3b. Longitudinal section of same zoarium, $\times 50$, showing variation in zooecial wall thicknesses and generally U-shaped wall laminae of intermediate and possibly advanced growth stages.
- Fig. 4. Tangential section of topotype, U.S.N.M. 138280, $\times 50$, illustrating young growth stage in a thin-walled zoarium. Note integrate appearance and small acanthopores. U.S.N.M. collection 2996.

PLATE 5

Amplexopora septosa (Ulrich)

- Fig. 1. Transverse view of paratype, U.S.N.M. 138282, $\times 10$, showing transverse shape of zooecial tubes in endozone. Note slight outward displacement of exozone in monticule at extreme left of figure, relative to intermonticular exozone in remainder of view.
- Fig. 2a. Tangential view of lectotype, U.S.N.M. 138281, $\times 30$, showing a monticule with a cluster of mesopores and apparently very few offset acanthopores, surrounded by an intermonticular area containing abundant offset acanthopores. Because of the outward displacement of the exozone in the monticule, the section passes proximal to the zone of offset acanthopores in the monticule, but through the offset acanthopores in the intermonticular area.
- Fig. 2b. Tangential view of lectotype, $\times 50$, showing amalgamate appearance of zooecial walls and offset acanthopores generally concentrated between zooecial corners.
- Fig. 2c. Longitudinal view of lectotype, $\times 50$, illustrating the origin of an offset acanthopore and its spinelike appearance. The apparent distal termination of the acanthopore (distal direction to the right) can be merely the passing of the acanthopore out of the plane of the section.
- Fig. 2d. Shallow tangential section of lectotype, $\times 20$, showing mud-filled living chambers of intermonticular zooecia cut distally to the zone of offset

acanthopores, and monticules in lower right and middle left of figure that are convex enough to project the offset acanthopores into the plane of the section.

Fig. 2e. Longitudinal section of lectotype, $\times 20$, showing a well-developed zonation of offset acanthopores through the middle of the exozone.

PLATE 6

Amplexopora septosa (Ulrich)

Fig. 1a. Longitudinal view of paratype, U.S.N.M. 138284, $\times 100$, showing zooecial wall structure with thin zooecial lining connected directly to the thicker diaphragms. Extreme proximal (left side of figure) diaphragms in both zooecia are compound.

Fig. 1b. Longitudinal view of same specimen, $\times 20$, showing an extreme development of irregularly and closely spaced cystoidal and compound diaphragms. Note offsetting of exozone of monticule in left center of figure.

Fig. 1c. Tangential view of same variant specimen, $\times 50$, showing acanthopores between zooecial corners that cause little offset and inflection of zooecial walls. Other zooecia in the section show the stronger, more typical inflection.

Fig. 2. Longitudinal view of topotype, U.S.N.M. 138288, $\times 50$, showing appearance of a moderate development of offset acanthopores. From topotype suite of U.S.N.M. 44913.

Fig. 3a. Longitudinal view of paratype, U.S.N.M. 138287, $\times 50$, showing a young growth stage indicated by few zooecial diaphragms and mesopore with early chambers beaded.

Fig. 3b. Longitudinal view of same specimen, $\times 100$, showing zooecial wall structure with sharply defined zooecial boundaries of abutting laminae.

Fig. 3c. Tangential view of same specimen, $\times 50$, showing severe inflection of zooecial walls by spinelike acanthopores equal in development to those shown in longitudinal view in plate 5, figure 2c.

PLATE 7

Fig. 1. *Amplexopora variabile* (Ulrich)

Fig. 1a. Longitudinal view of lectotype, U.S.N.M. 43820, $\times 20$, from the top of the Richmond group, Osgood, Ind.

Fig. 1b. Tangential view of same specimen, $\times 20$, showing small acanthopores confined to zooecial corners.

Fig. 2. *Batostoma implicatum* (Nicholson)

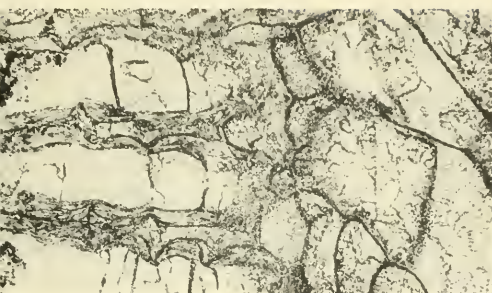
Longitudinal view of identified specimen, U.S.N.M. 138269, $\times 50$, showing the appearance of a thin-walled essentially incrusting growth, comparable in dimensions to longitudinal views of *B. ovata*. Note location of incrusting growth in larger view of section, plate 1, figure 4. U.S.N.M. collection 2995.

Fig. 3. *Batostoma ovata* (Ulrich)

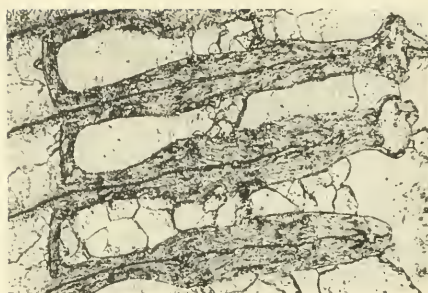
Fig. 3a. Longitudinal view of lectotype, U.S.N.M. 138289, $\times 50$, showing thin, remote zooecial diaphragms, a sharply defined zooecial boundary, and

thicker, convexly curved mesopore diaphragms forming a cystose pattern.

- Fig. 3b. Longitudinal view of lectotype, $\times 100$, showing notched acanthopore, typical of those found in most species of *Batostoma*.
- Fig. 3c. Tangential section of lectotype, $\times 50$, showing polygonal mesopores, oval, thin-walled zooecia, and acanthopores with structureless cores.
- Fig. 4. One of two original longitudinal sections of paratype, $\times 50$, showing convexity of diaphragms in mesopores. U.S.N.M. 43614.



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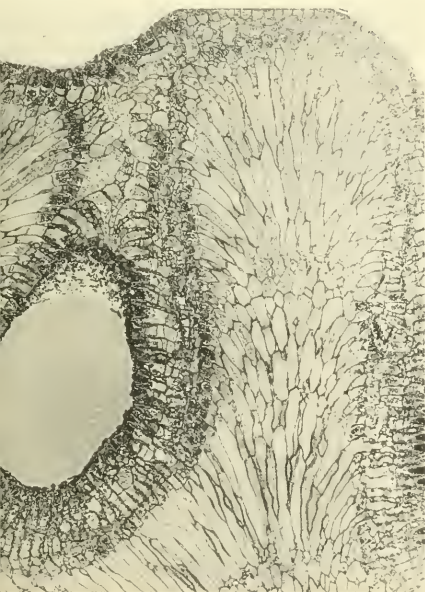
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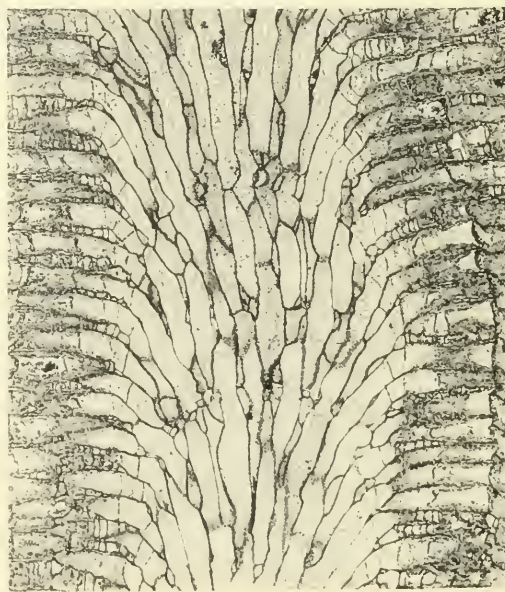
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3b

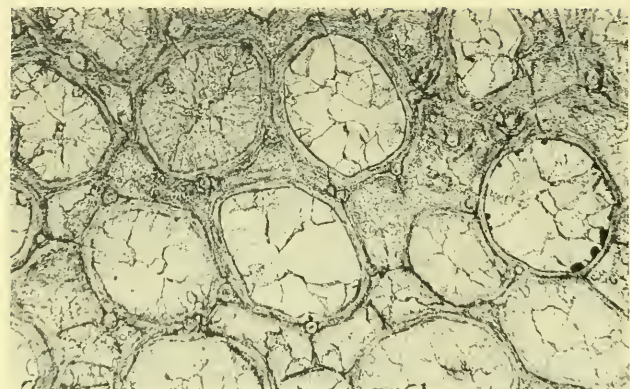


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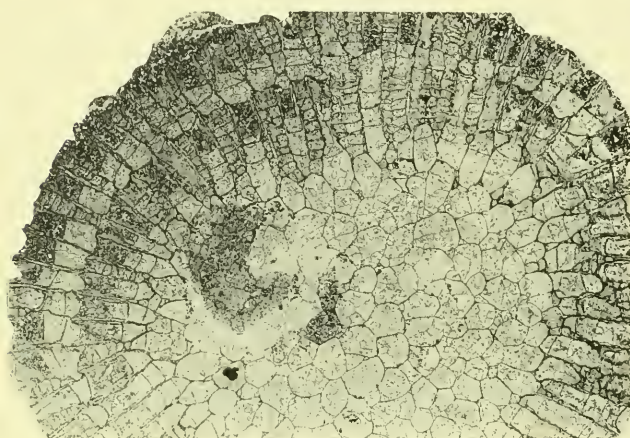


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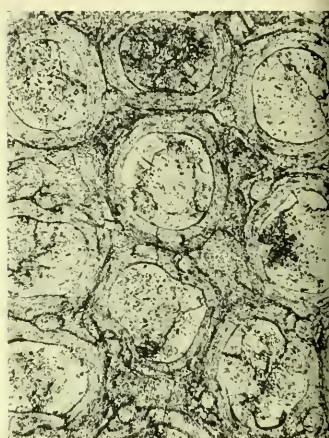
BATOSTOMA IMPLICATUM (NICHOLSON)
(SEE EXPLANATION OF PLATES AT END OF TEXT.)



1



3a



3c



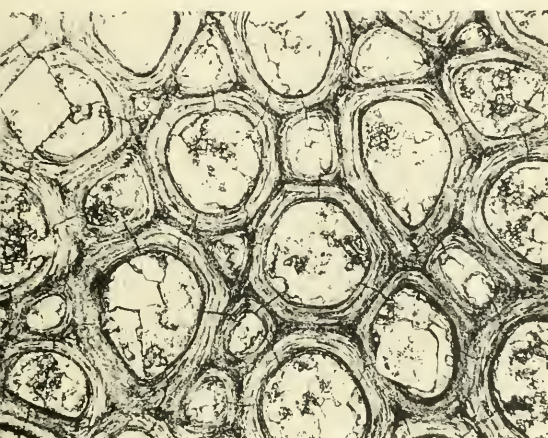
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(SEE EXPLANATION OF PLATES AT END OF TEXT.)



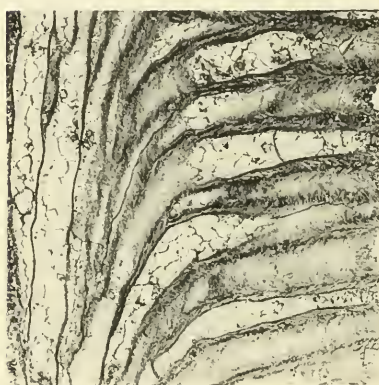
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2



3a



3b



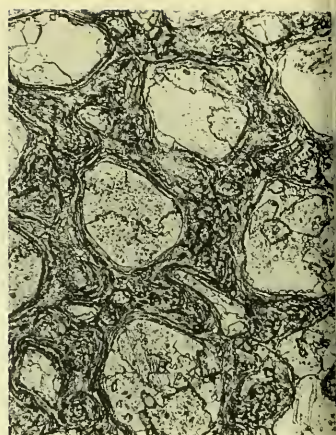
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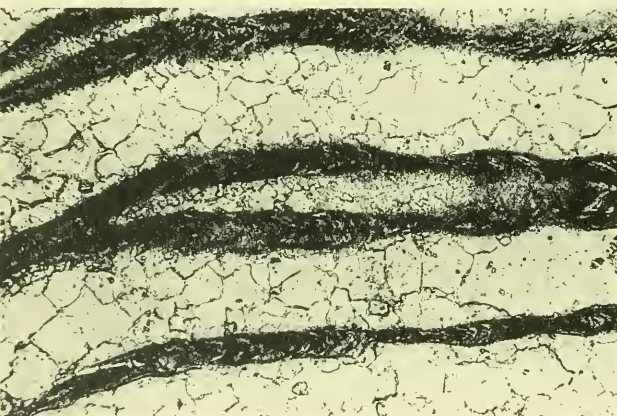
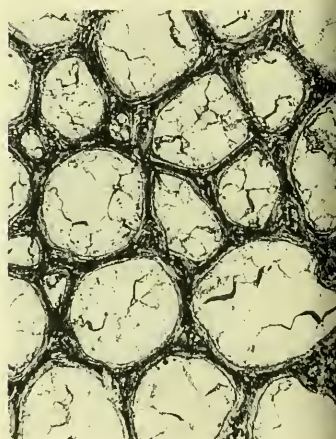
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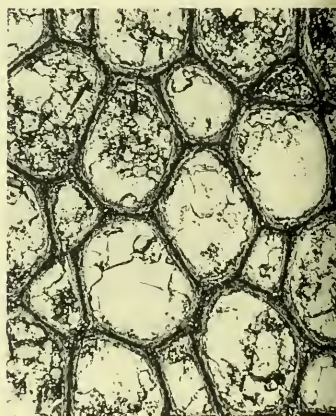
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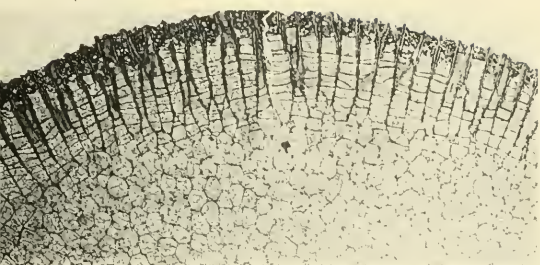
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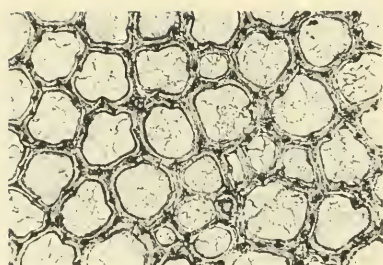
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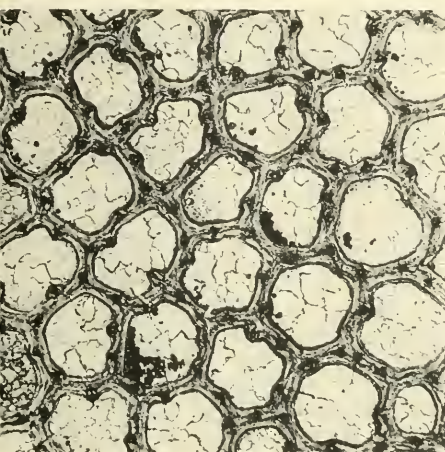
ANAPHRAGMA MIRABILE ULRICH AND BASSLER
(SEE EXPLANATION OF PLATES AT END OF TEXT.)



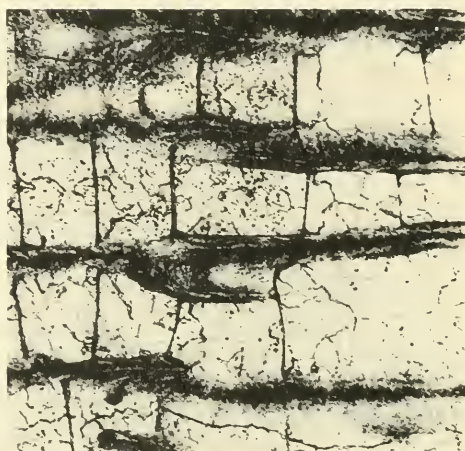
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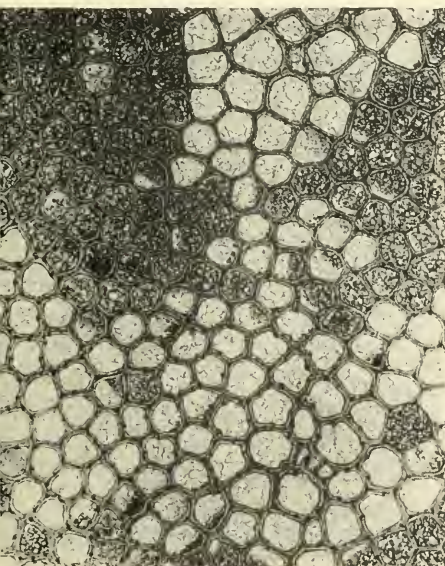
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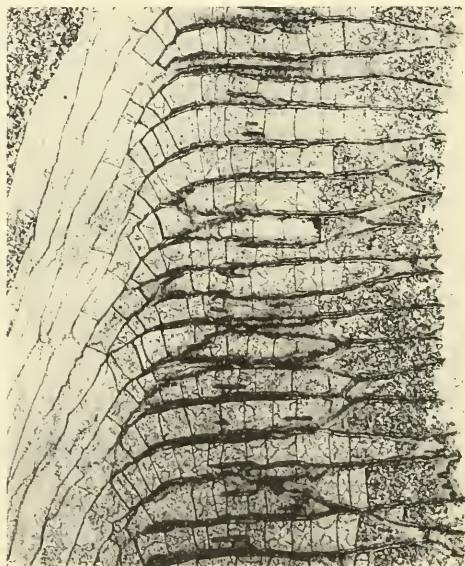
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2c



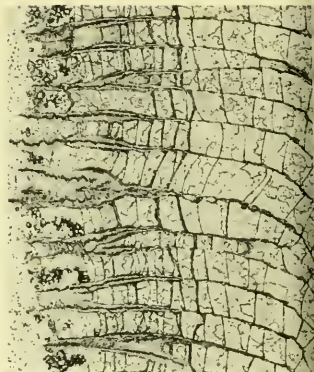
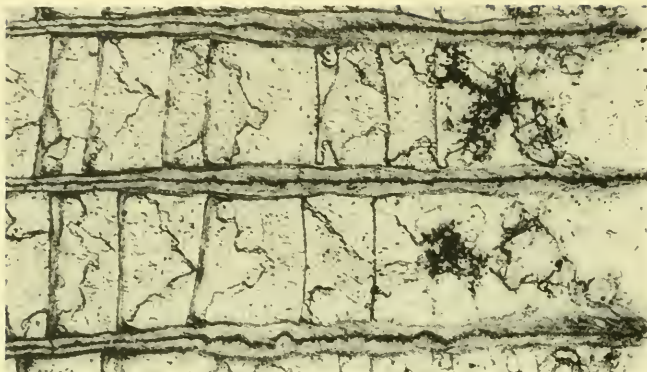
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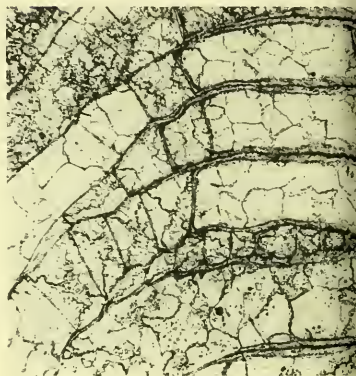
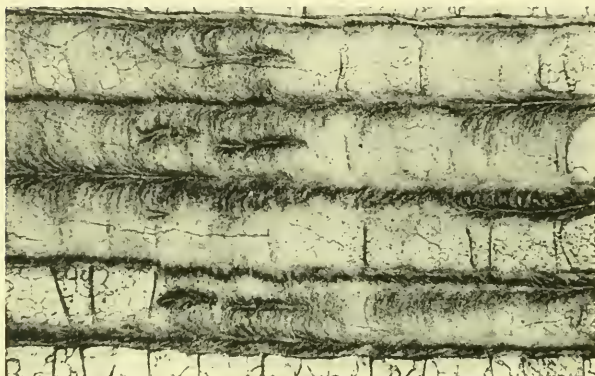
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AMPLEXOPORA SEPTOSA (ULRICH)

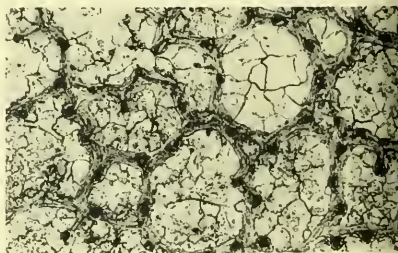
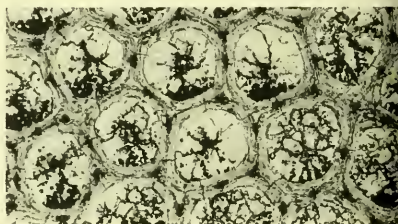
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1a



2



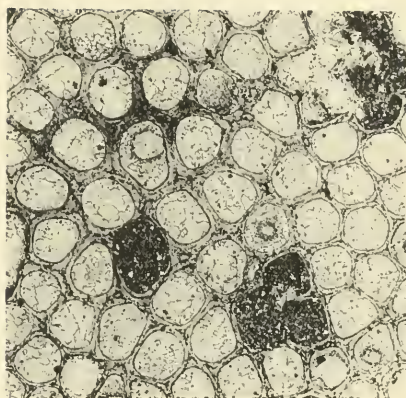
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AMPLEXOPORA SEPTOSA (ULRICH)

(SEE EXPLANATION OF PLATES AT END OF TEXT.)



1a



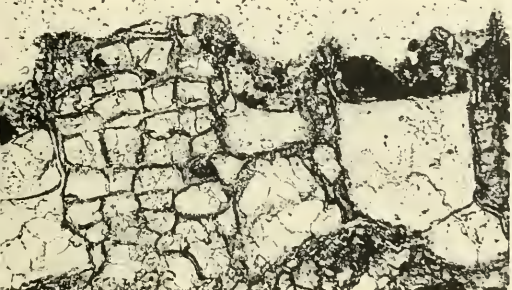
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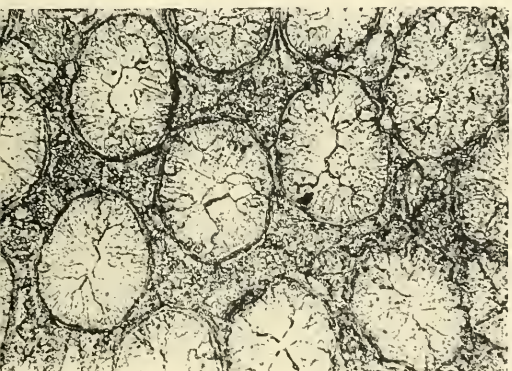
3b



3a



4



3c

AMPLEXOPORA MIRABILE (ULRICH), BATOSTOMA IMPLICATUM (NICHOLSON),
B. OVATA (ULRICH)

(SEE EXPLANATION OF PLATES AT END OF TEXT.)

