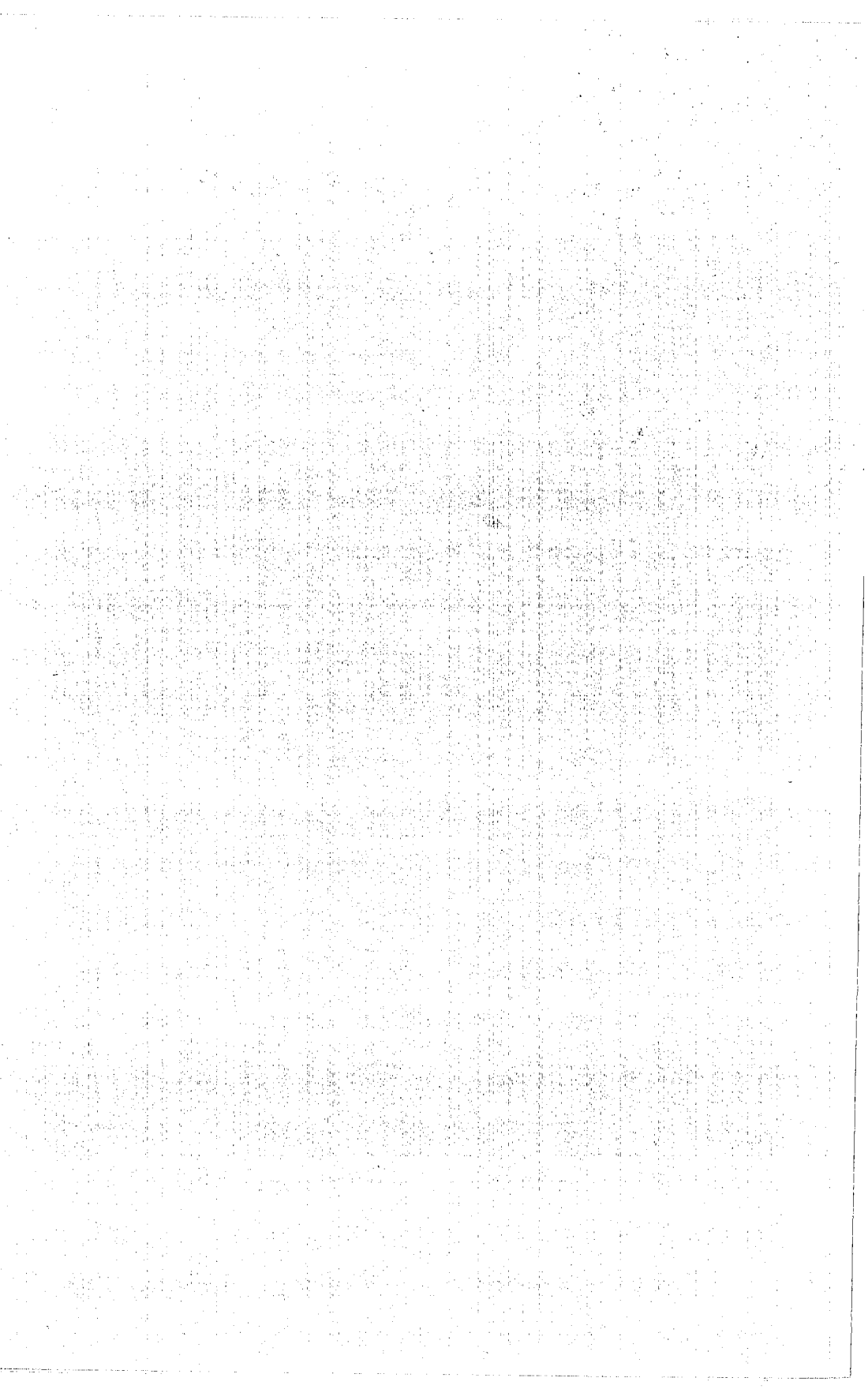


GEOLOGY STUDIES

Volume 17 Part 1 May 1970

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Brigham Young University Geology Studies

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Ordovician Bryozoa from the Pogonip Group of Millard County, Western Utah

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American Museum of Natural History, New York City, New York.

ABSTRACT.—Six species of bryozoans are recognized and described from the Pogonip Group of western Utah. All are new, but due to scarcity and poor preservation, only two new species are formally erected: *Dianulites utahensis* and *Phyllodictya crystalaria*. The other species belong to the following genera: *Batostoma*, *Eridotrypa*, *Amplexopora*?, and *Nicholsonella*.

Cryptostome bryozoans are restricted to the upper half of the Lehman Formation. The only trepostome whose range extends into the Lehman Formation is *Dianulites utahensis*. *Nicholsonella* sp. A occurs in the lower Kanosh Shale, and is the oldest species found in the region.

Some batostomids, eridotryids, and amplexoporids occur with young growth stages only, and, with the exception of one probable *Amplexopora*, were not described.

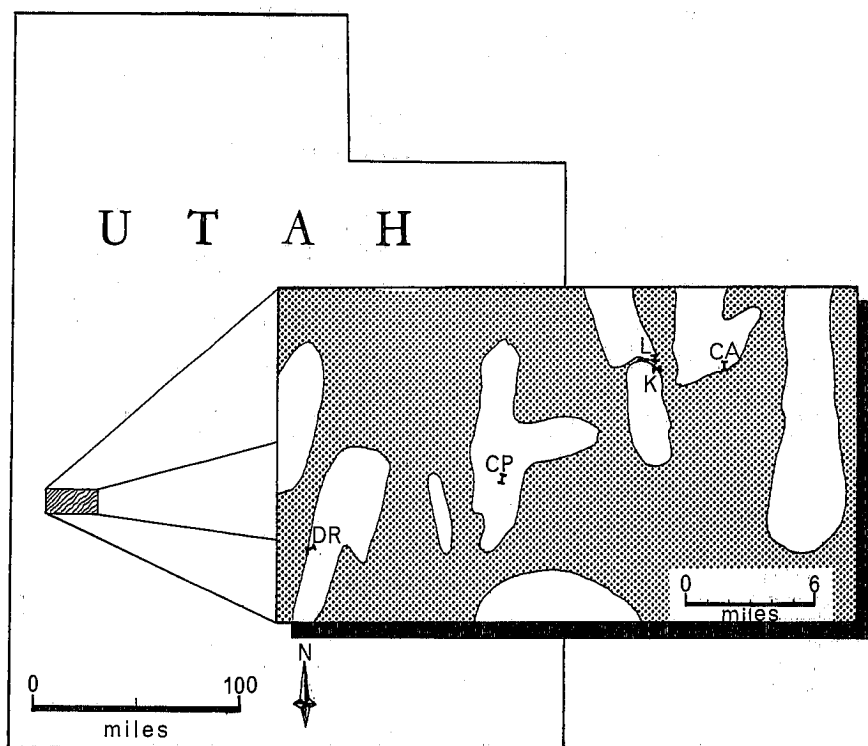
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INTRODUCTION

A study of bryozoans from Millard County, Utah, was undertaken as part of a faunal study of the lower and middle Ordovician System. Several horizons in the Pogonip Group were sampled, and only the middle Ordovician Kanosh Shale and Lehman Formation yielded bryozoans. Bryozoans are only sparsely represented in these two formations. The lowest occurrence is at Fossil Mountain, section K (Text-fig. 1), where the most complete continuous section of the upper Pogonip Group is exposed. In the Lehman Formation, bryozoans were not found at section K, but they were relatively abundant near Crystal Peak and the Desert Range experiment station, sections CP and DR respectively.

Representatives of the Order Trepostomata were found in both the Kanosh Shale and Lehman Formation. The oldest form is *Nicholsonella* sp. A, found in the lowest limestone ledges of the Kanosh Shale. All the other trepostome species make their appearance in the middle or upper parts of the Kanosh Shale.



TEXT-FIGURE 1.—Generalized index map. Collected sections are labeled DR, CP, L, K, and CA. Stippled pattern represents intermontane valleys. For a more detailed map, see Hintze, 1951, Text-fig. 2.

These include *Batostoma* sp. A, *Eridotrypa* sp. A, *Amplexopora*? sp. A, and *Dianulites utabensis* n. sp., which is the only trepostome also found in the Lehman Formation.

Cryptostomes occur in the Lehman Formation, and are represented by *Phyllodictya crystalaria* n. sp., and possible fragments of stictopodid group representatives as defined by Phillips (1960).

With the exception of *Dianulites utabensis*, nearly all specimens were collected in place. Most of the *D. utabensis* specimens were collected as float and could have traveled downslope several feet from their original site of fossilization. This would artificially extend their stratigraphic range at the lower end. Vertical control of collections was derived from measurements of stratigraphic sections, either using a steel tape and Brunton compass, or a Jacobs staff and clinometer.

Specimens were prepared using standard techniques of thin-sectioning. Acetate peels were not useful in studying most of the bryozoans due to generally poor preservation.

I wish to express appreciation to Dr. J. Keith Rigby and Dr. Lehi F. Hintze of Brigham Young University who suggested the problem and provided field and laboratory guidance. In addition Dr. Hintze provided financial assistance

for the field study as part of his investigation of the Ordovician rocks of western Utah, sponsored by National Science Foundation Grant GB 3154. I am grateful to Dr. Richard S. Boardman of the National Museum of Natural History for our discussions of trepostome systematics, and for allowing me to examine specimens from the Simpson Group of Oklahoma. Discussions with Dr. Olger L. Karklins of the U. S. Geological Survey relating to problems of cryptostome systematics were most helpful. Facilities of Brigham Young University, the National Museum of Natural History, the American Museum of Natural History, and Columbia University were used in the preparation of the study of the Utah material. Types and reference collections of the National Museum of Natural History were made available for morphologic comparisons.

STRATIGRAPHY

This paper does not include detailed stratigraphic descriptions; for these the reader is referred to Hintze, 1951. Text-fig. 2 correlates the occurrence of bryozoans with sections measured during the course of this study and those measured by Hintze (1951). Correlation with Hintze's published sections was made on the basis of lithic similarity, using as reference horizons the boundary between the Kanosh Shale and the Lehman Formation at sections L, K, and CP (Text-fig. 2), and the boundary between the "Swan Peak" quartzite and the Lehman Formation at section DR (Text-fig. 2). This procedure is particularly useful, inasmuch as these boundaries are fairly easily distinguished in their respective sections.

CORRELATION

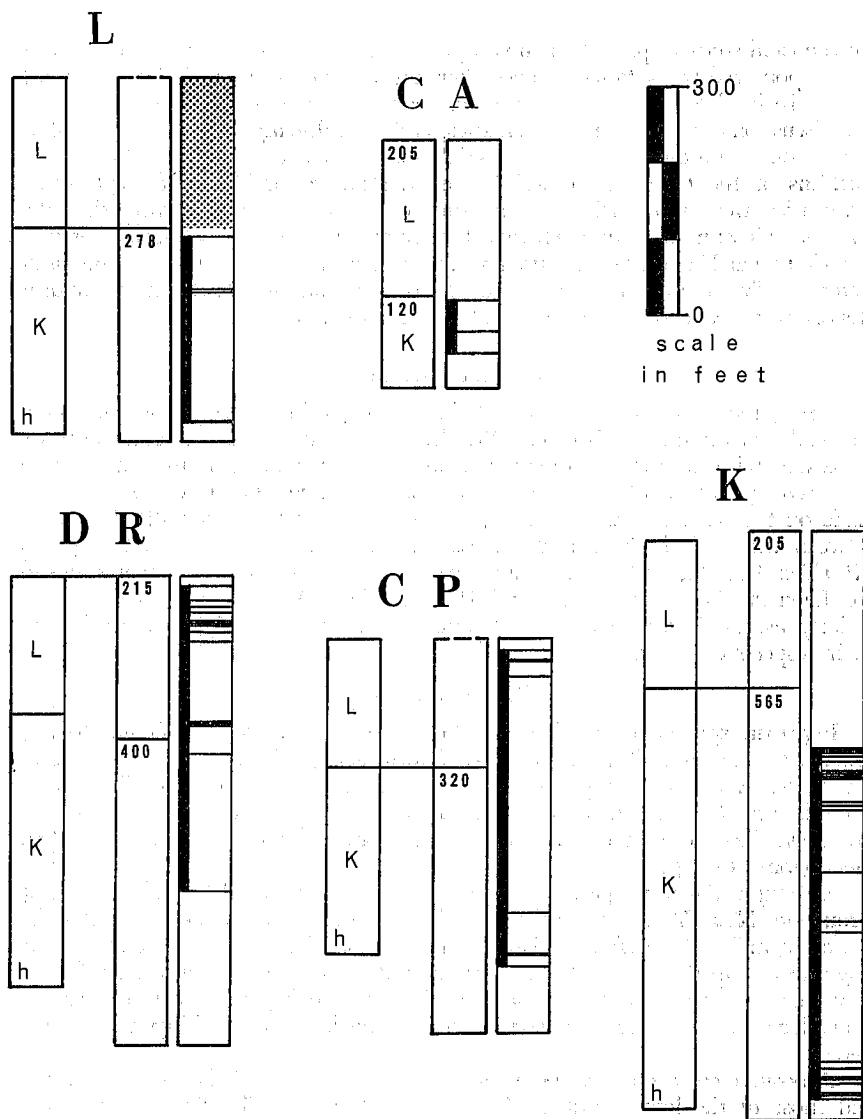
Bryozoan species of the Pogonip Group are not strikingly similar to any previously published Ordovician fauna. *Batostoma* sp. A superficially resembles *Batostoma suberassum* Coryell of the lower Stones River Group of Tennessee, but microstructural details of the lamellar walls of these two forms differ considerably. No species and few genera of the Stones River Group are found in the Pogonip Group.

Although Pogonip species are similarly unrelated to those of the Chazy Group in New York and Vermont, the degree of morphologic complexity is not significantly different. The number of species is much smaller in the Pogonip Group than in the Chazy Group, and differences between these faunas may represent facies or provincial variation, as the bryozoan-bearing Pogonip strata have been assigned a Chazyan age on the basis of brachiopods (Jensen, 1967).

A positive correlation can be made between the faunas of the Pogonip Group and those of the lower Simpson Group in Oklahoma. The Kanosh Shale and Lehman Formation species appear congeneric, and possibly conspecific, with many forms from the Oil Creek and McLish Formations respectively. This comparison is based on a cursory examination of the Simpson Group fauna, and any conclusions must be considered tenuous at the present. Nevertheless, the Pogonip bryozoans appear to be more closely related to the Simpson fauna than to any previously published North American fauna.

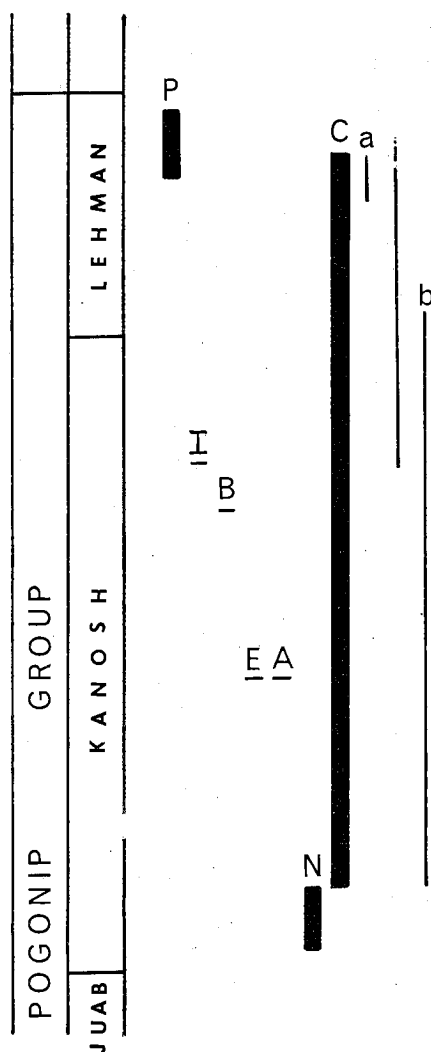
ECOLOGY

A detailed environmental study was not undertaken, but correlation of zoarial habits with lithic types is evident. Ramose forms are found in rocks



TEXT-FIGURE 2.—Correlation of measured sections with those of Hintze (1951), and bryozoan collection zones. Hintze's sections are designated by the letter *h*. *K* and *L* refer to the Kanosh Shale and Lehman Formation respectively. Sections used by the author were measured in the summer, 1965, by L. F. Hintze and the author. These columns have figures of total exposed thickness of each formation in its respective section. Lines connecting these columns with those of Hintze (1951) are based on lithic control as judged by the author.

The far-right column for each section shows sampling coverage. Zones that yielded bryozoans are indicated by horizontal lines, and black vertical bars show the total range of bryozoan occurrences in each section. Strata that were not collected are indicated by a stippled pattern.



TEXT-FIGURE 3.—Ranges of studied specimens. Abbreviations: P, *Phyllodictya crystalaria* n. sp. Hinds; I, indeterminable eridotrypids? and batostomids?; B, *Batostoma* sp. A; E, *Eridotrypa* sp. A; A, *Amplexopora*? sp. A; N, *Nicholsonella* sp. A; C, *Dianulites utabensis* n. sp. Hinds; a, variety a of *D. utabensis*; b, variety b of *D. utabensis*.

with silty to coarse arenitic textures of bioclastic debris and sub-rounded to rounded quartz grains. Bedding planes occasionally have abundant ramose bryozoans on them. This bedding plane orientation is particularly noticeable of eridotrypids, batostomids, and amplexoporids? at section CP, and nicholsonellids at section K. *Batostoma* sp. A was found in a 1½ to 2-foot thick bed of quartzose calcisiltite, and many of them were oriented at an angle to the bedding plane as if in growth position. The bifoliate *Phyllodictya crystalaria* n. sp. was

found in the fine bioclastic limestones of the Lehman Formation at sections CP and DR, occurring both parallel to and at angles to the bedding planes. *Dianulites utahensis* specimens are associated with all lithologies of the Kanosh Shale and Lehman Formation except the fine shales. All specimens collected in place were in silty to shaly partings between limestones, and were oriented with the convex side of the colony up, which apparently is the stable attitude for living and death assemblages.

Many zones contain ramose specimens in earlier growth stages, and some species are known only from younger growth stages. Positive generic identification was not feasible in most of these colonies. This paucity of older growth stages may be a result of abrasion in a high energy environment, or possibly selective transporation. The apparent lack of physical wear makes the former unlikely, and the latter, if it occurred, cannot be harmonized with size and shape distribution of the other faunal elements. Recent bryozoans do not produce gametes until they have reached a certain stage of ontogenetic and astogenetic maturity. If this is also true of these Ordovician forms, then the problem can best be explained by assuming that living conditions were harsh, and that the few zoaria that attained sexual maturity gave rise to a progeny most of which died at various levels of immaturity. This conclusion is not in disagreement with the sparse numbers of ramose bryozoans in the Kanosh Shale. Another possible explanation that cannot be entirely dismissed is that these forms became sexually mature before developing skeletal features that are commonly associated with older growth stages. This last idea, however, is not in agreement with what little is known about the reproductive cycle of extant bryozoans.

MORPHOLOGY

Because the cross-sectional shape of both the zooecium and the zooecial-void are interpreted as important taxonomic characters, their attributes and relationships are briefly discussed. The shape of the zooecium is a function of packing of contiguous zooecia and polymorphic individuals, and is the shape which represents the initial surface of secretion by the zooids. The zooecial shape may change during ontogeny due to changes in zooecial attitude, variations in zoarial form, and development of polymorphic individuals or zooids during astogeny. The zooecial-void shape is influenced not only by the shape of the zooecium, but also by the thickness and distribution of wall laminae. Although the range of individual and ontogenetic variation in the configuration of the zooecial-void appears species dependent, it is usually a circular to ovate cylinder in zones of thick lamellar deposits. In the endozone the shape of the two are similar and nearly congruous in most cases, so much so that separate descriptions are redundant. Size and shape differences between them may be quite pronounced in the exozone, and should be adequately demonstrated in systematic studies.

EXPLANATION OF TABLES FOUND IN THE SYSTEMATIC DESCRIPTIONS

The following abbreviations are used in tables showing measurements and statistical compilations: MZvD, maximum zooecial-void dimension (in millimeters) as measured in tangential section; MMvD, maximum mesopore-void dimension (in millimeters) as measured in tangential section; MAD, maximum "acanthopore" dimension (diameter, in millimeters) as measured in tangential section; d/mm, number of diaphragms per millimeter length of zooecium as

measured in longitudinal section; WZv/mm^2 , number of whole zooecial-voids per square millimeter as measured in tangential section; WA/mm^2 , number of whole "acanthopores" per square millimeter as measured in tangential section; Sx , standard deviation; Nm , number of measurements made; Nz , number of zoaria measured. All numbers in parentheses were calculated from zoarial means.

Several new species were not given formal names because of lack of sufficient material for an adequate population study. Nevertheless, some measurements and statistical compilations are given for most of these so that they may be available for future comparisons.

SYSTEMATIC PALEONTOLOGY

Genus *BATOSTOMA* Ulrich, 1882*BATOSTOMA* sp. A

Plate 1, figs. 1-3; Plate 2, figs. 1-2.

Description.—Zoaria are ramose. The growing tip of the colony has very thin zooecial walls, few to no diaphragms, and is a distal expression of axial region. Exozone width increases only gradually in a proximal direction away from the growing tip.

The zooecial-void is an irregularly ovoid cylinder. The zooecium is very nearly the same shape, as the corners between three or more zooecia are occupied by acanthopores, or occasionally by mesopores.

Diaphragms in the zooecia are, with rare exceptions, restricted to the outer endozone and the exozone. Although they are more closely spaced in the exozone, they do not exhibit consistent spacing patterns. Many of them abut against a previously formed diaphragm, and are in part tangentially appressed to the older diaphragm.

Zooecial walls in the endozone are smooth to moderately crinkly, and usually more crinkly at the base of the exozone.

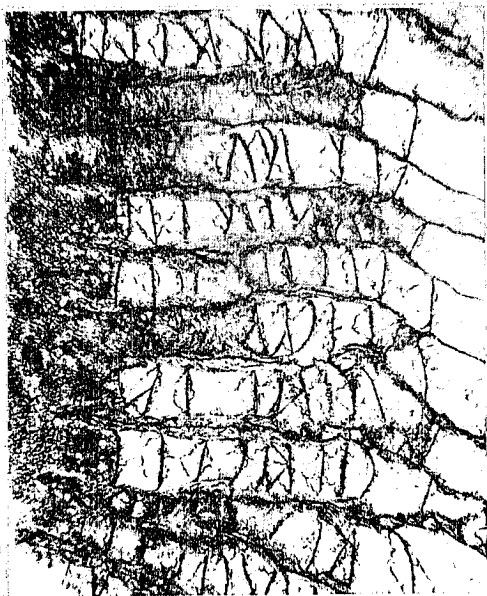
TABLE I
Measurements of *Batostoma* sp. A

Measurements*	Range	Mean	Mode	Sx	Nm	Nz
MZvD, intermonticular	.20-.30 (.24-.27)	.25 (.25)	.25 (-)	.02 (.02)	25	3
MZvD, monticular	.30-.45	.33	.35, .40	.18	10	1
WZv/mm ² , intermonticular	7-9 (7-8.5)	8 (7.8)	8 (-)	.7 (.8)	7	3
width of zoarial branch	6-7 mm 4-5 mm	(old growth stages) (young growth stages)			3 4	1 1

*For explanation of abbreviations and units, see page 24-25.

Discussion.—This species has all the characteristics of the genus *Batostoma* as redefined by Boardman (1960). It has few mesopores for the genus, but those that are present have typical batostomid microstructures. Acanthopores are usually inconspicuous due to their small size and the preservation of the colony.

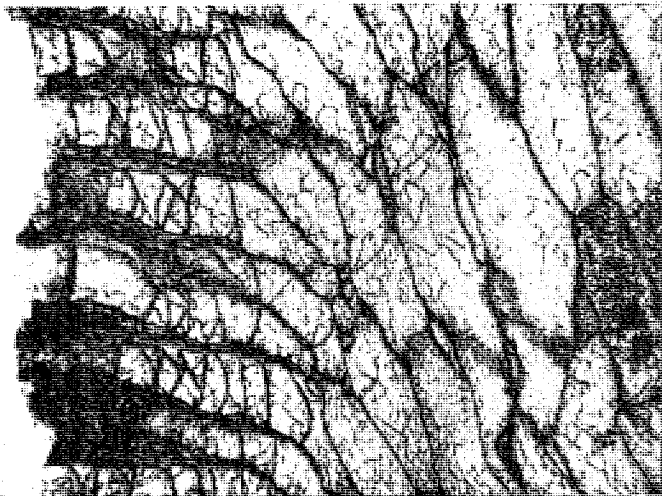
Occurrence.—It occurs in a 1½ to 2-foot thick, light brown-weathering ledge of quartzose calcisiltite to fine calcarenite, 410 feet above the base of the Kanosh Shale at section K. Specimens are quite rare.



1



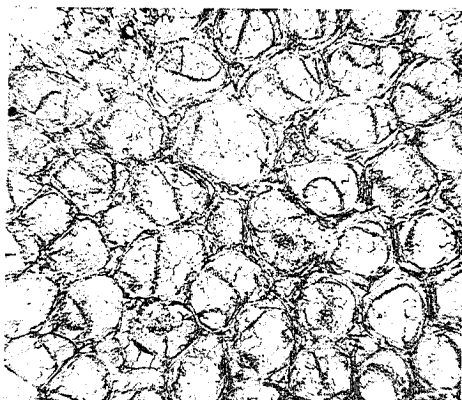
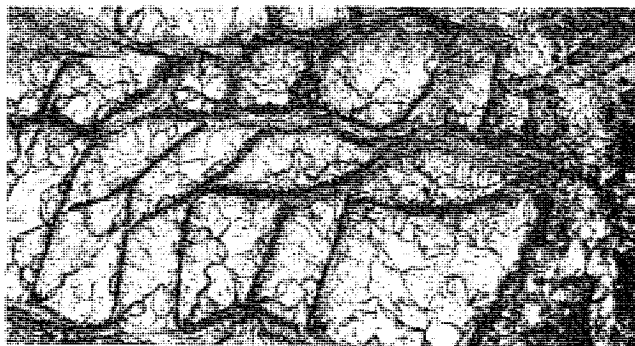
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EXPLANATION OF PLATE 1.
BATOSTOMA of the Kanosh Shale

FIGS. 1-3.—*Batostoma* sp. A, X30. 1. longitudinal view of the exozone showing zooecia in older growth stages, BYU 1500. 2. longitudinal view of the exozone showing zooecia in younger growth stages, BYU 1500. 3. longitudinal view showing typical appearance of the endozone and exozone of a zoarium, BYU 1500.

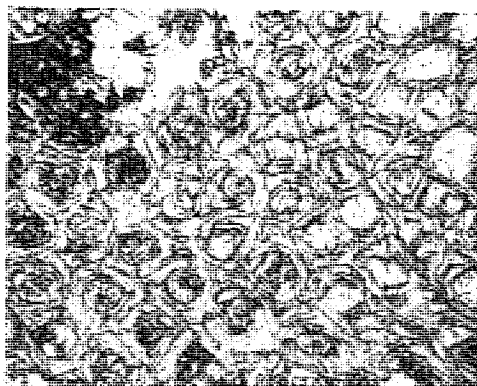


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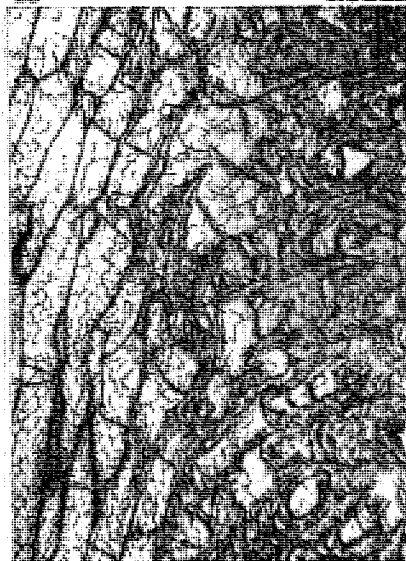
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3

EXPLANATION OF PLATE 2.
BATOSTOMA and *ERIDOTRYPA* of the Kanosh Shale

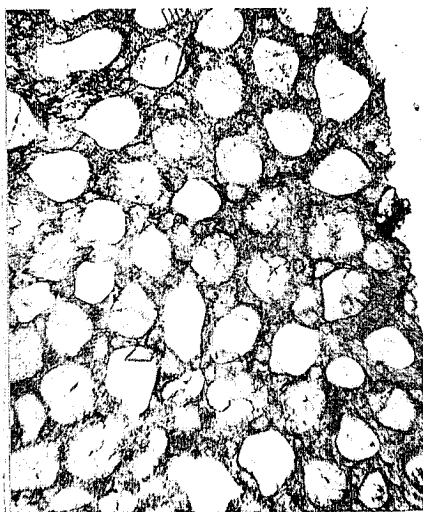
- FIGS. 1-2.—*Batostoma* sp. A, fig. 1, X100, fig. 2, X30. 1. longitudinal view of zoecium with diaphragms, and a typical batostomid mesopore, BYU 1500. 2. tangential view, BYU 1500.
- FIGS. 3-4.—*Eridotrypa* sp. A, X30. 3. tangential view, BYU 1501. 4. longitudinal view most typical of this species, BYU 1501.



1



2



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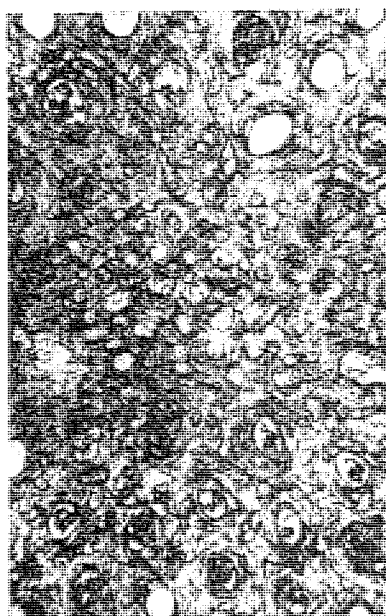


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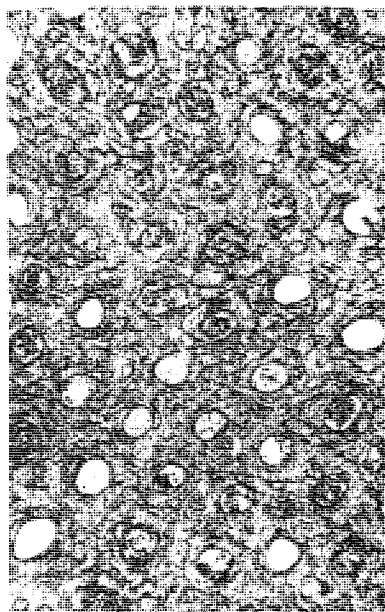
EXPLANATION OF PLATE 3.

ERIDOTRYPA and *NICHOLSONELLA* of the Kanosh Shale

- FIGS. 1-2.—*Eridotrypa* sp. A, X30. 1. longitudinal view showing exozone with "cystose" structure, BYU 1501. 2. longitudinal view at a branching point in the zoarium, showing reduced thickness of exozone walls and more distant spacing of diaphragms typical of slightly younger zooecia, BYU 1501.
- FIGS. 3-4.—*Nicholsonella* sp. A, X30. 3. tangential view of youthful colony showing zooecia, mesopores, and acanthopores. This is similar to a very deep tangential section in an older colony, BYU 1502. 4. longitudinal view of youthful colony showing mesopores with thick tabulae, BYU 1502.



1



2



3

EXPLANATION OF PLATE 4.
NICHOLSONELLA of the Kanosh Shale

FIGS. 1-3.—*Nicholsonella* sp. A, X30. 1. tangential view of a monticulus, BYU 1503. 2. tangential view of an intermonticular area, BYU 1503. 3. longitudinal view of the exozone, showing zooecia and a monticular area, BYU 1504.

Material studied.—Eight thin-sections of four zoaria: BYU 1500 (3)**, KN341-1 (1), KN341-2 (3), KN341-3 (1).

Repository.—Brigham Young University. Figured specimen BYU 1500 [KS410f]***.

Genus ERIDOTRYPA Ulrich, 1893

ERIDOTRYPA sp. A

Plate 2, figs. 3-4; Plate 3, figs. 1-2.

Description.—In the endozone, zooecia are polygonal with straight to slightly curved walls that are weakly undulatory in the longitudinal direction. Walls are dark and granular, occasionally exhibiting structures that appear as micro-tubules. These structures are located at the interface between the walls secreted by contiguous zooids. Diaphragms are scarce in the axial region. They are distally convex to flat, erratically spaced, and often approach the zooecial wall at angles other than ninety degrees.

The proximal portion of the exozone is marked by thickened laminar deposits of the zooid and regularly occurring diaphragms. Zooecia in the exozone are subpolygonal to polygonal, the zooecial-voids being subpolygonal to circular. Lamellar buildup of the thick exozonal walls constricts the zooecial-void diameters up to one-half to one-third the size of the zooecial-void diameters of the endozone. As in the endozone, minute tubules occur at the zooecial boundaries. Wall laminae abut against a very thin, dark, zooecial boundary which is continuous with the thin, dark, endozonal boundaries. Wall laminae approach the zooecial boundary at a low angle. As a result, the zooecia appear weakly integrate in tangential section.

Diaphragms are flat to weakly convex or concave distally, and either perpendicular or slightly angled to the length of the zooecium. Generally they are thin, dark, and granular, but some have a thin laminate layer on their distal side. Thickness of this layer correlates with ontogenic development, as the thickening usually becomes more pronounced distally within any given zooecium. Diaphragms vary in spacing from one and three-quarters to one-third the zooecial-void diameter apart. Spacing trend of diaphragms in a zooecium only approximates a consistent decrease distally, for many exceptions occur in a zooecium.

Mesopores form in the endozone as cystose structures, often arising from the distal side of a zooecium. They extend through the exozone, but may be obscured in tangential section due to the thick overgrowth of laminae. Mesopore walls consist of a dark layer with thick laminated calcareous layers on their distal side. The calcareous laminate layer is continuous with the mesopore wall.

Occurrence.—It is found in the Kanosh Shale at section K, 260 feet above the base of the formation.

Material Studied.—Eight zoaria from three thin-sections: BYU 1501, KS260-3K, and KS260-5K.

Repository.—Brigham Young University. Figured specimen BYU 1501 [KS260].

**Numbers in parentheses following section numbers represent the total number of thin-sections with that number.

***For purposes of cross reference, locality collection-numbers are included in brackets for all types and figured specimens.

TABLE II
Measurements of *Eridotrypa* sp. A.

Measurements	Range	Mean	Mode	Sx	Nm	Nz
MZvD, exozone	.08-.18 (.13-.14)	.13	.13	.025	30	2
MZvD, endozone	.21-.40 (.26-.27)	.26	(-)	.05 (-)	20	2
WZv/mm ²	10-12	—	—	—	3	1

Genus NICHOLSONELLA Ulrich, 1889

NICHOLSONELLA sp. A

Plate 3, figs. 3-4; Plate 4, figs. 1-3.

Description.—Zoaria are ramose, and occasionally have overgrowths. Monticules (or maculae?) are common, and lack zooecia. They are composed of lamellar tissue and acanthopores.

Zooecial walls of the endozone vary slightly in thickness, and are curved or wavy. Diaphragms sporadically occur throughout the endozone. The zooecial tubes bend gradually outward in the endozone, and the angle increases rapidly at the base of the exozone which is marked by a pronounced thickening of the zooecial walls. The exozone becomes very wide in astogenetically older colonies.

The exozone consists of thickly laminated zooecial walls with abundant solid acanthopores and small to large diameter mesopores which usually form a thickened skeletal zone between adjacent zooecia. Mesopores occasionally have very thick diaphragms, and the spaces between the diaphragms are spherical to ellipsoidal. Zooecia have very thin diaphragms spaced as close as one-fourth to one and one-half zooecial-void diameters apart. Zooecial-voids in the exozone are ovate cylinders which become constricted in older zooecia due to excessive lamellar deposits. Zooecia, which are ovate cylinders with highly irregular outer surfaces, intersect the zoarial surface at a right angle with only slight random divergence in attitude. Zooecia immediately surrounding the monticules have slightly larger diameter zooecial-voids than those midway between the monticules, and a relatively consistent size gradient between the two exists. Monticules consist of enlarged mesopores? and no zooecia.

TABLE III
Measurements of *Nicholsonella* sp. A.

Measurements	Range	Mean	Mode	Sx	Nm	Nz
MZvD, intermonticular	.08-.28 (.15-.20)	.18 (.17)	.15, .19 (.17)	.04 (.06)	100	5
WZv/mm ² , intermonticular	7-15 (9-13)	10 (10.5)	10 (10)	1.8 (1.1)	73	16

Remarks.—Poor preservation obscures and very likely obliterates many zooecial diaphragms. Some specimens show very erratic spacing of diaphragms, with those of the exozone only slightly closer together than those of the endozone. Some specimens appear to entirely lack diaphragms. It is not possible to tell how much of the variation is or is not due to preservation.

This species appears closely related to *Nicholsonella pulchra*.

Occurrence.—Specimens were found in the lower Kanosh Shale in thin limestone interbeds from 20 to 74 feet above the base of the formation.

Material studied.—60 thin-sections of 39 zoaria:

BYU 1500	(2)	KS52-11K	(2)	R31-3	(1)	W68-3	(1)
BYU 1503	(2)	KS52-12K	(1)	H1-2	(1)	W68-4	(2)
KS52-1K	(2)	KS56-1K	(2)	H5-5	(1)	W68-5	(2)
KS52-2K	(3)	KS56-2K	(4)	W32-1	(1)	W68-6	(1)
KS52-3K	(1)	KS56-3K	(3)	W57-2	(1)	W68-7	(1)
KS52-4K	(1)	KS56-4K	(2)	W57-3	(1)	W72-1	(1)
KS52-6K	(1)	KS56-7K	(2)	W57-4	(1)	W72-2	(1)
KS52-7K	(2)	R20-1	(1)	W57-5	(1)	W74-1	(1)
KS52-8K	(2)	R30-1	(3)	W57-6	(1)	W74-2	(1)
KS52-9K	(2)	R30-5	(1)	W57-7	(1)		

Repository.—Brigham Young University. Figured specimens BYU 1502 [KS52] and BYU 1503 [R30].

Genus DIANULITES Eichwald, 1829

DIANULITES UTAHENSIS n. sp. Hinds

Plate 5, figs. 1-4.

Description.—Zoaria are hemispherical to irregularly massive, varying in height and diameter up to 40mm and 70mm respectively. Lamellar growth occurs, but is not common. New basal laminae and zooecia grow peripherally over silted-in portions of the zoarium, tending to maintain the shape and symmetry of the colony.

Monticules consist of clusters of larger and smaller diameter zooecia with slightly thicker walls than the intermonticular zooecia. Zooecia are polygonal in cross-section, usually five or six sided, and contain numerous parallel to sub-parallel diaphragms. Rarely, zooecia in a monticule are irregularly ovoid or petaloid shaped in cross-section. Zooecial walls are straight to wavy, non-laminated, and hyaline or granular.

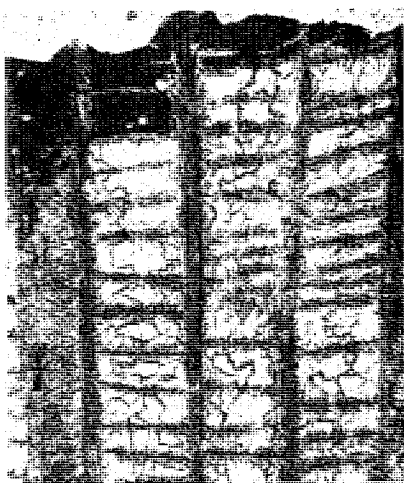
Diaphragms are flat, slightly convex proximally or distally; occasionally they are extremely convex distally. Usually they are perpendicular to the zooecial wall, but some form obliquely to the wall. Spacing of the diaphragms in the zooecia of larger zoaria indicates synchronous, cyclic periods of rapid and slow growth. At the proximal end of the zooecia of some zoaria, diaphragms are less closely spaced than in other specimens. When present, this region varies in length from 0.5 to 3.0 mm.

"Acanthopores" are abundant and located at most junction corners of the zooecia, and often between the corners. The diameter of "acanthopores" is usually greatest at the junction corners of the zooecia. These "acanthopores" are solid, cylindrical structures that do not show typical acanthopore microstructure.

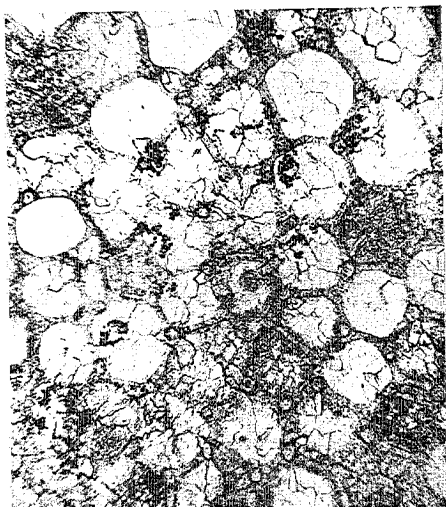
Remarks.—Spacing of diaphragms which is alternately far apart and close together is probably due to rapid and slow growth periods. That small zoaria do not usually show this cyclicity suggests a positive correlation with astogenetic development. If the maximum life span of one of these colonies was just a few years, as it is in many living bryozoans, then the cyclic spacing of diaphragms could result from the external effects of physical or chemical fluctuations in the environment, possibly associated with seasonal changes.



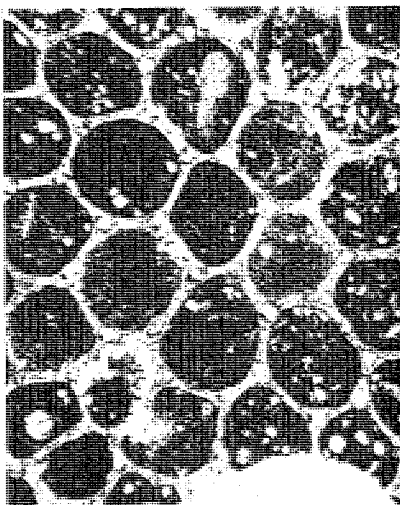
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EXPLANATION OF PLATE 5.
DIANULITES of the Kanosh Shale and Lehman Formation

- FIGS. 1-4—*Dianulites utabensis* n. sp. Hinds, X30. 1. longitudinal view of holotype showing diaphragms spaced far apart in a Kanosh form, BYU 1505. 2. longitudinal view showing close spacing of diaphragms in a Lehman form, BYU 1506. 3. tangential view of holotype centered on an intermontic area, BYU 1505. 4. tangential view of a Lehman form showing a monticular area, BYU 1507.

TABLE IV
Measurements of *Dianulites utahensis* n. sp.

Measurements	Range	Mean	Mode	Sx	Nm	Nz
WZv/mm ²	2-14 (4.3-8.0)	5.8 (5.5)	6 (6)	2.1 (0.8)	198	36
WA/mm ²	10-28 (15.5-25)	17.8 (19.2)	17 (17,19)	3.8 (2.3)	82	25
MZvD, intermonticular	.23-.41 (.28-.35)	.32 (.32)	.30 (.31)	.03 (.02)	310	31
MZvD, monticular	.37-.82 (.42-.65)	.49 (.48)	.45 (.48)	.07 (.05)	316	34
d/mm	1-10 (3.0-8.3)	5.4 (5.2)	6 (5)	1.5 (1.1)	330	38
MAD	.03-.12 (.06-.07)	.07 (.07)	.06, .07 (.07)	.01 (.005)	300	15

An endozone and exozone cannot be differentiated in this species either on the basis of diaphragm spacing or wall structure, and the entire zoarium above the basal lamina is best called the exozone.

Varieties of this species are recognizable on the basis of diaphragm spacing and zoarial dimensions. It is stratigraphically useful to distinguish two varieties. In variety *a* the bulk of a zoarium has a maximum spacing density of three to four diaphragms per zoecial-void diameter length (longitudinally), and a minimum spacing density of two diaphragms per zoecial-void diameter length. Variety *b* includes forms in which the diaphragms are spaced farther apart with a maximum of two to three and a minimum of less than one to one diaphragm per zoecial-void diameter length. Variety *b* often occurs as larger colonies than variety *a*, and some colonies of variety *b* have smaller diameter intermonticular zoecia than variety *a*. Variety *a* is found only in the Lehman Formation, most abundantly at section DR. Variety *b* is not restricted to a particular formation, but is rare in the upper part of the Lehman Formation, and is most abundant in the upper part of the Kanosh Shale at section K. Morphologic differences between the two are interpreted as changes in growth rates in response to varying ecologic factors in time and space. The degree of morphologic variation is not considered significant enough to warrant sub-species designation, although within the limits of the area studied, recognition of these two varieties may be useful as a stratigraphic tool.

In order to understand the generic assignment of *D. utahensis*, the following points are germane.

While discussing the genus *Dianulites*, Bassler (1911, p. 229) makes the following morphologic observations:

"The massive zoarium of thin walled, angular zoecia, without acanthopores, occurs in a number of totally unrelated genera, but these features, in connection with the peculiar glassy-like internal structure, and the occurrence of numerous small granules or tubular structure in the walls, form a combination of characters duplicated in part in only one other group, namely the peculiar Ordovician genus *Nicholsonella*."

The wall structure, better described as a lack of well defined microstructural elements, is due to preservation, and may be related to the original structure or composition of the zoaria. This similarity may indicate close phyletic affinities between the genera *Nicholsonella* and *Dianulites*. As noted by Bassler (1911,

p. 229), *Dianulites* differs from *Nicholsonella* "in its prevailing massive zoarium, more simple zooecial structure, and in the absence of a calcareous deposit filling the mature portion of the mesopores." These distinctions are for the most part considered valid, but a question arises over the existence of mesopores in *Dianulites*.

That mesopores are present in the type species of the genus, *Dianulites fastigiatus*, is doubted. The disposition of the holotype specimen is unknown, and therefore unavailable at the present time. Text figures in Bassler (1911 and 1953) of specimens designated plesiotypes, and assumed to be conspecific with *D. fastigiatus*, show zooecia with no diaphragms surrounded by mesopores with diaphragms. Thin sections from which these figures were made show that nearly all the tubes contain diaphragms, and that all the tubes are of the same kind. These are considered herein to be zooecia, and mesopores are absent not only in the figured specimen, but also in other topotype specimens in the reference collection of the National Museum of Natural History.

Thin sections of *D. insueta* syntypes do not show mesopores. Some other species assigned to *Dianulites* do have mesopores, e.g. *D. petropolitana*. For species with so few skeletal features, presence or absence of mesopores can be considered generically significant. *Dianulites*, as currently defined in the literature, includes both species with and without mesopores, and should probably be redefined. Such redefinition is not within the scope of this paper. Nevertheless, if the specimen of *D. fastigiatus* figured by Bassler (1911 and 1953) is considered conspecific with the holotype specimen, absence of mesopores would become the normal or expected morphologic expression in species of *Dianulites*, *sensu stricto*, and those species differing primarily by the presence of mesopores would likely be assigned to a different supraspecific taxon.

D. fastigiatus figured by Bassler (1911 and 1953) lacks large "acanthopores," while in *D. insueta* they are very pronounced and abundant. Although this difference could be judged significant in terms of negating the congeneric relationship of the two species, on the basis of general morphology and wall structure, the statement by Bassler (1927, p. 151) that "... this species [*D. insueta*] is a typical *Dianulites*. . ." is accepted in this study.

D. utahensis differs from *D. insueta* in having a hemispherical growth habit, in lacking a noticeable endozone.

Two Russian species assigned by Astrova (1965) to the genus *Cyphotrypa* are similar to *D. utahensis*. *C. kojimensis* Astrova has thinner zooecial walls and fewer diaphragms than *D. utahensis*, and *C. kossjensis* Astrova has consistently larger diameter zooecia than *D. utahensis*.

Occurrence.—Specimens were found up to 50 feet below the top of the Lehman Formation at section DR, and sporadically in the Lehman Formation at section CP. They first appeared 74 feet above the base of the Kanosh Shale at section K, and became abundant about 380 feet above the base of the formation. Specimens were found in the upper Kanosh Shale at all localities, and although most of them were collected as float, many were found in place in section K.

Material studied.—82 thin-sections of 39 zoaria:

BYU 1505 (2)	CA75-2 (2)	DR419-1 (2)	DR565-1 (2)
BYU 1506 (2)	L-195-1 (2)	DR525f-1 (2)	CP120-1L (2)
BYU 1507 (2)	DR200-1 (2)	DR540f-1 (2)	KW-1 (3)

KN300f-1	(1)	W448-1	(2)	W475-4	(2)	W480-5	(2)
K11-7	(3)	W453-1	(2)	W475-8	(2)	W480-6	(2)
K14A-1	(3)	W456-1	(1)	W475-9	(3)	W480-7	(2)
K15C-1	(4)	W475-1	(2)	W480-1	(3)	W480-10	(2)
K15E-1	(3)	W475-2	(2)	W480-2	(2)	W481-1	(2)
K16-1	(3)	W475-2	(2)	W480-3	(1)	W484-1	(1)
W406-1	(1)	W475-3	(2)	W480-4	(2)	W485-1	(2)

Repository.—Brigham Young University. Holotype BYU 1505 [L197]; figured specimens BYU 1506 [DR550], and BYU 1507 [DR552].

Genus AMPLEXOPORA Ulrich, 1882

AMPLEXOPORA? sp. A

Plate 7, figs. 3-4

Description.—Zoarium is ramose. The zooecial shape is polygonal, and the zooecial void shape is subpolygonal to rounded in cross-section in the exozone. Zooecia have diaphragms only in the exozone, and are first found where the laminate walls begin to thicken. Mesopores are not common, and acanthopores are small and inconspicuous due to preservation. Zooecia approach the zoarial surface at an oblique angle.

TABLE V
Measurements on *Amplexopora?* sp. A

Measurements	Range	Mean	Mode	Sx	Nm	Nz
WZv/mm ²	6-10	8	7.9	1.2	10	1
MZvD, exozone	.22-.37	.27	.30	.04	20	1
MMvD, exozone	.05-.08	—	—	—	3	1
Width of zoarial branch	3 mm					

Remarks.—This description is based on one astogenetically immature specimen with young zooecia only. Other amplexoporids, eridotrypids, and batostomids occur in the Kanosh Shale with young zooecial features only. Only this species appears sufficiently different generically from the rest of the described fauna to warrant inclusion of a separate description.

Occurrence.—260 feet above the base of the Kanosh Shale at section K.

Material studied.—One specimen showing both longitudinal and tangential views on one thin-section: BYU 1576.

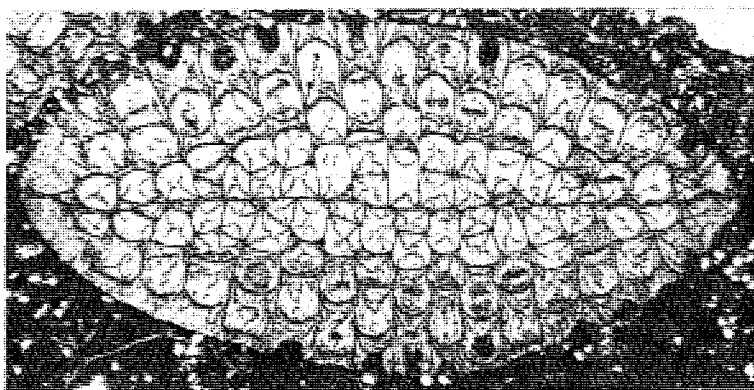
Repository.—Brigham Young University. Figured specimen BYU 1576 [KS260].

Genus PHYLLODICTYA Ulrich, 1882

PHYLLODICTYA CRYSTALARIA n. sp. Hinds

Plate 6, figs. 1-5; Plate 7, figs. 1-2.

Description.—Zooecia occur in longitudinal ranges which are not always evenly opposed across the mesotheca. The longitudinal ranges are quite regular, but often in transverse view the lateral number of ranges is one or two less than the number of zooecia spaced along the mesotheca. The additional zooecia are proximal ends of more distal zooecia in between the existing ranges, and this increase distally along the mesotheca appears to be the method of lateral ex-



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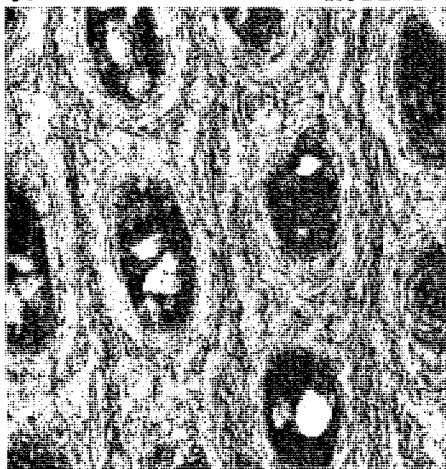
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EXPLANATION OF PLATE 6.
PHYLLODICTYA of the Lehman Formation

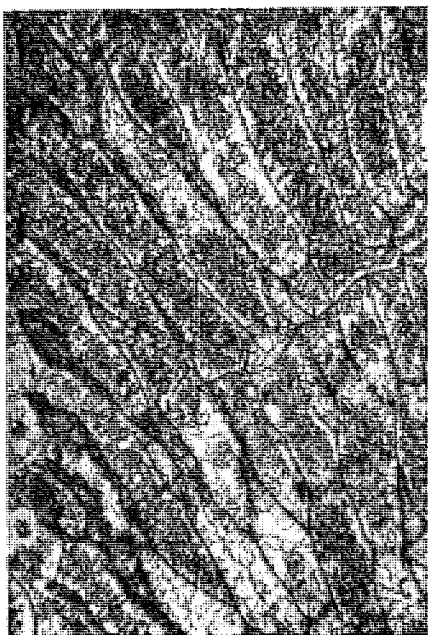
FIGS. 1-5.—*Phyllodictya crystalaria* n. sp. Hinds, X30. 1. transverse view of holotype, BYU 1508. 2. tangential view, BYU 1509. 3. longitudinal view of holotype, BYU 1508. 4. transverse view of a young colony, BYU 1510. 5. longitudinal view of a young colony, BYU 1510.



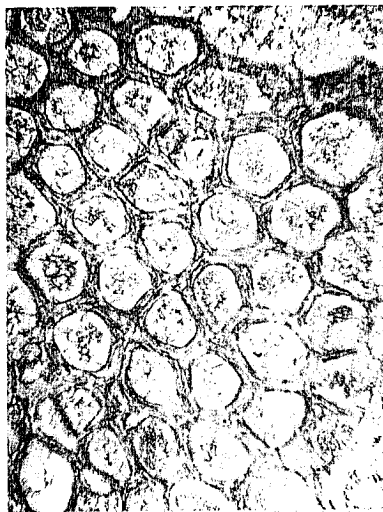
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EXPLANATION OF PLATE 7.
PHYLLODICTYA and *AMPLEXOPORA?*
 of the Lehman Formation and Kanosh Shale Respectively

- Figs. 1-2.—*Phyllodictya crystalaria* n. sp. Hinds, X100. 1. shallow tangential view showing minute tubules formed at the zooecial boundaries, BYU 1511. 2. transverse view of holotype showing tubuli of mesotheca varying in size marginally, BYU 1508.
- Figs. 3-4—*Amplexopora?* sp. A, X30. 3. longitudinal view showing distal growing tip. The faintly developed exozone has only one noticeable diaphragm. This specimen contains only young zooecia, BYU 1576. 4. tangential view, BYU 1576.

pansion of the colony. The frequency of addition of new ranges of zooecia is low, and the ribbon shape of the colony slowly expands in a distal direction.

Zooecia have thin, dark, granular boundaries that are slightly irregular to wavy. With the exception of the proximal ends, zooecial walls are thickened by calcareous laminae that parallel the zooecial boundary. These deposits are four to five times thicker on the distal side than on the proximal side of the zooecium, and the thickness changes evenly in a circumzooecial direction. The zooecial-void diameter has a slight decrease distally throughout the exozone due to the increasing thickness of the laminae. Frequently the distal side of the zooecium in the exozone is modified into imbricate chambers, both single and multiple (Plate 6, fig. 3), and their microstructure is typical of the genus. The total area occupied by these structures varies considerably, and the size of the zooecium changes proportionally, thus maintaining a fairly constant zooecial-void diameter from one zooecium to the next.

The zooecial-void is a slightly tapering cylindrical chamber in the exozone. The zooecium in the exozone is shaped like an ovate cylinder with a flat to usually convex side distally. Diaphragms are numerous in the exozone, up to ten per zooecium in the holotype, and are on the whole more closely spaced distally although the spacing is often irregular. The diaphragms are either perpendicular to the zooecium or slightly tilted. Orientation of tilted diaphragms shows no preferred trend. Diaphragms are flat to slightly convex either distally or proximally. Their microstructure is similar to the zooecial walls at the zooecial boundary, i.e., thin, dark, and apparently granular. No deposits of calcareous laminae are found on the diaphragms, even though the laminae of the zooecial walls and the imbricate chambers appear to arise from the margins of the diaphragms. Pores (tubuli?) between zooecia are small and occur infrequently. Median tubuli in the mesotheca are both circular and ovate in cross section. Major axes of cross sections of the median tubuli are parallel to the plane of the mesotheca. The tubuli exhibit a definitely erratic and rapid increase in size as they approach the exozonal laminae of the zoarial margins. Large diameter, solid, cylindrical rods are located in the zone of thick exozonal laminae of the zoarial margins along the extension of the mesothecal plane, and are interpreted as serial homologues of the median tubuli.

TABLE VI
Measurements of *Phyllodictya crystalaria* n. sp.

Measurements	Range	Mean	Mode	Sx	Nm	Nz
MZvD, exozone (some measurement from longitudinal section)	.06-.15 (.08-.11)	.10 (.10)	.10 (.10)	.015 (.008)	150	12
WZv/mm ²	10-17	12.8	14	2.1	10	4
length of major axis of tubuli, and serial homologues in microns: exozone	10-40	23.9	15	9.5	22	1*
endozone	5-30	13.9	10	4.5	57	1*

number of ranges of zooecia/mm along the mesotheca: 5-7.

ratio of maximum thickness of branch to width of branch: 1:2.0 to 1:4.3; 1:2.0 is of a section of a zoarium with zooecia in older growth stages; 1:4.3 is of a section of a zoarium with zooecia in younger growth stages.

*holotype as measured from a transverse section.

Remarks.—*P. crystalaria* differs from *P. varia* Ulrich and *P. frondosa* Ulrich in having more and closer spaced diaphragms. *P. frondosa* Ulrich is considerably different in growth habit from the ribbon-shaped *P. crystalaria*.

Occurrence.—Specimens were found from 140 to 200 feet above the base of the Lehman Formation at section CP and DR.

Material studied.—28 thin-sections of 25 zoaria.

BYU 1508	(3)	DR540f-2	(2)	DR540f-6	(1)	DR600-1	(2)
BYU 1509	(3)	DR540f-3	(3)	DR547-1	(1)	DR600-2	(3)
BYU 1510	(2)	DR540f-4	(3)	DR547-2	(1)		
BYU 1511	(1)	DR540f-5	(2)	DR547-3	(1)		

Repository: Brigham Young University. Holotype BYU 1508 [CP155L]; other figured specimens BYU 1509 [CP155L], BYU 1510 [CP155L], and BYU 1511 [DR547].

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