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THE CORALS OF THE BRASSFIELD FORMATION (MIDDLE LLANDOVERY) IN THE CINCINNATI ARCH REGION

A dissertation submitted to the

Division of Graduate Studies
of the University of Cincinnati

in partial fulfillment of the
requirements for the degree of

DOCTOR OF PHILOSOPHY

in the Department of Geological Sciences
of the Graduate School of Arts and Science

1976

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UNIVERSITY OF CINCINNATI

20 April 19 76

I hereby recommend that the thesis prepared under my supervision by RICHARD S. LAUB

entitled The corals of the Brassfield formation (Middle Llandovery) in the Cincinnati Arch region

be accepted as fulfilling this part of the requirements for the degree of Doctor of Philosophy

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Form 668—Grad. School—1M—12-69

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ABBREVIATIONS OF INSTITUTION NAMES

The names of scientific institutions have usually been abbreviated in this work, especially as the prefix to a catalogue number. Following are the full names:

AMNH: American Museum of Natural History

Cambridge: University of Cambridge Geological Museum

GS: Geological Survey of Great Britain

GSC: Geological Survey of Canada

MCZ: Museum of Comparative Zoology, Harvard University

PIN: Paleontological Institute of Novosibirsk

ROM: Royal Ontario Museum, Toronto

SNIIGGIMS: Sibirskii Nauchno-Issledovatelskii Institut Geologii, Geofiziki i Mineralnogo Syrya

UCGM: University of Cincinnati Geological Museum

UM: Paleontological Institution, University of Uppsala

UMMP: University of Michigan Museum of Paleontology

USNM: National Museum of Natural History, Smithsonian Institution

YPM: Yale Peabody Museum, Yale University

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ABSTRACT

Fifty-four species of corals (29 rugose, 19 tabulate, 6 heliolitid) have so far been identified from the Brassfield Formation (Middle Llandovery limestone, dolomite and clay) of the Cincinnati Arch. Coral assemblages of largely different character are concentrated in the north and southeast of the area, apparently controlled by environment.

This coral fauna appears to have been largely restricted to the present Cincinnati Arch area during Middle Llandovery time, with closest affinities on the species level to the corals of Anticosti Island and the Baltic region. Eight to twelve species pre-date Brassfield deposition in the area, some existing as early as the Late Ordovician. These oldest members of the Brassfield coral fauna were found in a number of areas throughout the world, rather than in a single ancestral homeland. At least half of the coral species survived the end of the Middle Llandovery, and spread into a large portion of the submerged continental areas of the world.

Some observations are made on aspects of form displayed by these corals, and on the character and possible environment of the Brassfield lithosome.

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INTRODUCTION

The end of Ordovician time saw a considerable change in the character of the world coral fauna. It is possible that this global change was tied to eustatic sea-level variations during a Late Ordovician ice age (see Sheehan, 1973 for the argument that the Ordovician-Silurian changeover in the North American brachiopod fauna was due to this same factor). Among the Rugosa, the dissepimentarium came into prominence (Hill, 1959a, p. 151, 152) and several evolutionary bursts occurred (Hill, 1956, p. 254) during the Silurian. Among the Tabulata, the auloporids increased in importance, as did the halysitids. Favosites, with mural pores on the wall faces, became dominant over Paleofavosites, with pores in the corners, and Halysites, with interstitial tubes, outpaced Catenipora, which lacked these structures. Among the Heliolitida , the coenosteal tubes developed solid walls. Beyond all this, the first-known true coral bioherms are found in Silurian rocks.

To now, nearly all our knowledge of Silurian corals is restricted to the Upper Llandovery, Wenlock and Ludlow, which are well-represented by deposits in the Baltic region (especially Gotland, the British Isles, the Falls-of-the-Ohio (Kentucky and Indiana), etc. The main virtue of the Brassfield coral fauna is that it bridges the gap between the Late Ordovician and this later Silurian record with a large, diverse fauna in which several important Silurian species

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make their first appearance, but from which the Ordovician flavor has not yet faded.

ACKNOWLEDGEMENTS

Numerous persons and organizations have made invaluable contributions to this study. While it would be impractical to make a complete list of those to whom I am indebted, the following deserve special thanks: Professor Kenneth E. Caster of the Geology Department, University of Cincinnati, was my principal advisor during this work. He, along with Professors Wayne A. Pryor and William Dreyer (respectively, Departments of Geology and of Biology at the University of Cincinnati) reviewed the manuscript, and offered valuable criticism. Much technical help and advice was given by Dr. William B. Harrison (Department of Geology, University of Western Michigan), and by Dr. William A. Oliver, Jr. (United States Geological Survey, Washington, D.C.). Thin-sectioning of some important types was done by Mr. William Pinckney of the U.S. Geological Survey, Washington, D.C. The large surveys of the scientific literature required by this study were made possible by the diligent cooperation of the staffs of the libraries of the University of Cincinnati Geology Department, the U.S. Geological Survey (Washington, D.C.), and the Buffalo Museum of Science. Grants from the Society of the Sigma Xi, and the University of Cincinnati Geology Department helped finance field work for this study.

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LOCALITIES OF BRASSFIELD EXPOSURES VISITED FOR THIS STUDY

1. Type locality of Brassfield Formation, along abandoned cut of Louisville and Atlantic Railroad, stretching between Panola and Brassfield, Madison County, Kentucky, starting from about .25 mile west of right-angle bend in State Route 499 at Panola; also, exposure on north side side of Route 499 about .5 mile east of this right-angle bend of the road at Panola, and a third exposure, about .4 mile further east, in Drowning Creek and along the road (Rt. 499) going uphill east of the Creek. Virtually all specimens came from the second site. Panola Quadrangle; 39°30'25"N, 84°06'30"W.

2. About 6 miles north of Manchester, Adams County, Ohio, on east side of Route 136. Manchester Quadrangle; 38°44'00"N, 83°36'45"W.

5. Exposure on north side of Route 52 in Adams County, Ohio, 10 miles east of Manchester, Ohio. Concord Quadrangle; 38°41'10"N, 83°27'45"W.

7. Exposures in quarries belonging to Southwest Portland Cement Company and to Atlas Steel Company along Route 235, about 1 mile east of the offices of the former company, near the juncture with Trebein Road, southeast of Fairborn, Greene County, Ohio. Yellow Springs Quadrangle; 39°48'45"N, 83°59'30"W.

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7a. In vicinity of locality 7, largest working quarry of Southwest Portland Cement Company (as of 1972), about 3.5 miles (18,000 feet) south of the main quarry office, along the quarry road. Yellow Springs Quadrangle; 39°46'30"N, 83°57'45"W.

9. Mine and quarry of Marble Cliff Company, near Lewisburg, Preble County, Ohio, .85 mile west of juncture between Ohio Route 503 and Euphemia-Castine Road. Lewisburg Quadrangle; 39°51'45"N, 84°33'15"W.

11. Series of three outcrops on NW side of Route 41, from 2.5 to 3.0 miles NE of West Union, Adams County, Ohio. West Union Quadrangle; 38°49'00"N, 83°30'30"W.

12. Route 41, where it crosses Ohio Brush Creek in Adams County, Ohio, 1.4 miles SW of Jacksonville, Ohio. Peebles Quadrangle; 38°53'40"N, 82°27'10"W.

13. Todd Fork Creek, NE of Wilmington, Clinton County, Ohio. Top of section is about 350 yards downstream from Route 68; base and best exposure of section is in stream-cut and abandoned quarry further downstream, about 400 yards upstream from Center Road. Wilmington Quadrangle; upstream exposure is 39°28'45"N, 83°50'45"W; downstream exposure is 39°28'50"N, 83°51'20"W.

14. Aramco Steel Company quarry, Piqua, Miami County, Ohio. Piqua East and Troy Quadrangles; 40°07'30"N, 84°14'00"W.

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15. Route 571, west of Interstate Route 75, and .3 mile east of West Milton, Miami County, Ohio. West Milton Quadrangle; 39°57'55"N, 84°19'15"W.

16. Base of Wright Brothers Memorial, Dayton, Greene County, Ohio, at crest of bluff overlooking Route 444 and the Huffman Dam, immediately below U.S.G.S. benchmark. Fairborn Quadrangle; 39°47'45"N, 84°05'25"W.

19. Two miles NE of Bryantsburg, Indiana, on Route 1150N, about 1.5 miles from Route 421, near border between Ripley and Jefferson Counties, Indiana. This is the Brassfield pinch-out. Rexville Quadrangle;

20. South of Bellvue, Jefferson County, Indiana, on Route 250, 2.5 miles from junction with Route 421.

21. Tri-County Stone Company quarry, 4 miles south of Cross Plains, Switzerland County, Indiana. Cross Plains Quadrangle; 38°53'45"N, 85°11'40"W.

22. Hanging Rock, 1 mile north of Madison, Jefferson County, Indiana, along Route 7. Clifty Falls Quadrangle; 38°45'05"N, 85°23'45"W.

23. Stream-cut and outcrop at border between Highland and Adams Counties, Ohio, on Ohio Route 247. Belfast Quadrangle; 39°01'30"N, 83°35'15"W.

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26. Top of Elkhorn Falls, just downstream from Indiana Toute 227, about 2 miles south of Richmond, Indiana town line, Wayne County, and just before Route 227 reaches Wolfe Road. New Paris Quadrangle; 39°46'40"N, 84°51'50"W.

28. Oldham County, Kentucky, near top of Ohio River Bluff at "Y" junction of private roads to house and to river, north of Dunbar Hollow, on property of George Eggers. LaGrange Quadrangle; 38°27'40"N, 85°29'00"W.

29. Exposure of west side of Brownsboro Road, .35 mile south of bridge over South Fork Harrod's Creek, Oldham County, Kentucky. Anchorage Quadrangle; 38°20'50"N, 85°33'40"W.

30. Road-cut on north side of Seatonville Road (Kentucky Route 1819), just above abandoned quarry on bluff of Floyd's Fork Creek, about 1 mile west of Seatonville, Jefferson County, Kentucky. Jeffersontown Quadrangle; 38°08'10"N, 85°32'00"W.

31. Road-cut on east side of U.S. Route 31E, about 1.6 miles SE of junction with Kentucky Route 44 in Mt. Washington, Bullitt County, Kentucky. Mt. Washington Quadrangle; 38°02'00"N, 85°32'00"W.

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32. Abandoned quarry on south edge of Bardstown, Nelson County, Kentucky, .6 mile south of U.S. Route 31E on extension of 4th Street. Bardstown Quadrangle; 37°48'00"N, 85°28'10"W. (Possibly not Brassfield)

33. Small abandoned quarry on north side of Route 52, about .3 mile north of north edge of New Hope, Nelson County, Kentucky. New Haven Quadrangle; 37°38'50"N, 85°32'10"W. (Possibly not Brassfield)

34. Road-cut on east side of Kentucky Route 527, on north edge of Raywick, Marion County, Kentucky. Raywick Quadrangle; 37°33'45"N, 85°25'50"W.

35. West bluff and east bank of stream in Webb Hollow tributary to Scrubgrass Creek, about 3.4 miles southwest of Mitchellsburg, Boyle County, Kentucky. Parksville Quadrangle; 37°34'15"N, 84°59'30"W. (Possibly not Brassfield)

36. South bank of Neals Creek, just east of bridge and about 275 yards downstream from church, in Lincoln County, Kentucky. (This is locality 1 CO-NE of Foerste, 1906, p. 147-148.) Halls Gap Quadrangle; 37°29'30"N, 84°39'15"W.

37. Abandoned quarry southwest of road junction at Sharpsville, Highland County, Ohio. Martinsville Quadrangle; 39°15'20"N, 83°45'05"W.

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38. Natural exposure on northwest bank of a creek .7 mile southwest of Belfast, Highland County, Ohio, where Ohio Route 485 crosses Rock Lick Creek, Belfast Quadrangle; 39°03'10"N, 83°32'30"W.

39. Natural exposure (near top) on south side of Ohio Route 73, 1.6 miles west of Louden, Adams County, Ohio, where the highway crosses Flat Run. Sinking Spring Quadrangle; 39°01'50"N, 83°28'45"W.

40. Route 150, 3 miles NW of Crab Orchard, Lincoln County, Kentucky, where road crosses Cedar Creek. Crab Orchard Quadrangle; 37°28'45"N, 84°33'10"W.

41. East side of of Route 25, 1.6 miles north of Berea, Madison County, Kentucky, where road crosses Silver Creek. Berea Quadrangle; 37°35'45"N, 84°16'55"W.

42. Interstate Route 75, 500 feet north of intersection (on overpass) with Route 595, about 3 miles northwest of Berea, Madison County, Kentucky. Berea Quadrangle; 37°36'00"N, 84°18'50"W.

43. Farristown, Madison County, Kentucky, where Route 1983 crosses Louisville & Nashville Railroad tracks. Berea Quadrangle; 37°37'25"N, 84°18'05"W. (Possibly not Brassfield)

45. Route 52 at Muddy Creek, .5 mile west of Waco, Madison County, Kentucky. Moberly Quadrangle; 37°44'25"N, 84°09'15"W.

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46. Type locality of Noland Member Brassfield Formation, about 2 miles east of College Hill intersection, on private road of the Armstrong Farm (as of 1972), where road ends in a gully after making a left and a right-hand turn, in Madison County, Kentucky. Palmer Quadrangle; 37°47'45"N, 84°05'30"W.

47. South Bluff of Red River on east side of Route 89, Estill County, Kentucky. Palmer Quadrangle; 37°49'00"N, 84°04'00"W.

48. Bluff on Steppingstone Road at Sugar Grove Church, just south of Interstate Route 64, southwest of Owingsville, Bath County, Kentucky. Preston Quadrangle; 38°06'10"N, 83°49'40"W.

49. Route 60, 1.6 miles east of Owingsville, Bath County, Kentucky. Colfax Quadrangle; 38°08'45"N, 83°44'25"W.

50. South bluff of river valley and adjacent road-cut, along road about .6 mile north of Colfax, Fleming County, Kentucky. Colfax Quadrangle; 38°13'20"N, 83°38'00"W.

51. Route 32, about 2 miles NW of Goddard, Fleming County, Kentucky. Flemingsburg Quadrangle; 38°22'45"N, 83°38'40"W.

52. Lumberton, Clinton County, Ohio, at abandoned quarry on Wilkins property (as of 1973), about 1000 feet east of McKay Road, and .2 mile south of where McKay Road crosses Anderson

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Fork Creek. Port William Quadrangle; 39°32'40"N, 83°50'20"W.

53. Kentucky Route 89, east side of road, about .3 mile north of Estill Springs, Estill County, Kentucky, on the north outskirts of Irvine, Kentucky. (Estill Springs is no longer a town, but its site is marked by an historical marker on the west side of the road.) Irvine Quadrangle; 37°42'30"N, 83°58'40"W.

53a. Kentucky Route 89, west side of road, about 1 mile north of Estill Springs (see comment under locality 53), on north outskirts of Irvine, Estill County, Kentucky. Irvine Quadrangle; 37°43'10"N, 83°58'55"W.

54. Outcrop on Kentucky Route 10, about 2.5 miles east of Kentucky Route 57 in Tollesboro, Lewis County, Kentucky. Tollesboro Quadrangle; 38°34'00"N, 83°32'30"W.

55. Ludlow Crush-Stone Quarry, about 1 mile west of Ludlow Falls, Miami County, Ohio. West Milton Quadrangle; 39°59'30"N, 84°21'15"W.

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TEXT-FIGURE 1

Map of study area, showing locations of Brassfield Formation outcrops studied: County outlines are indicated. North-south extent of map is 200 miles; east-west extent is 140 miles.

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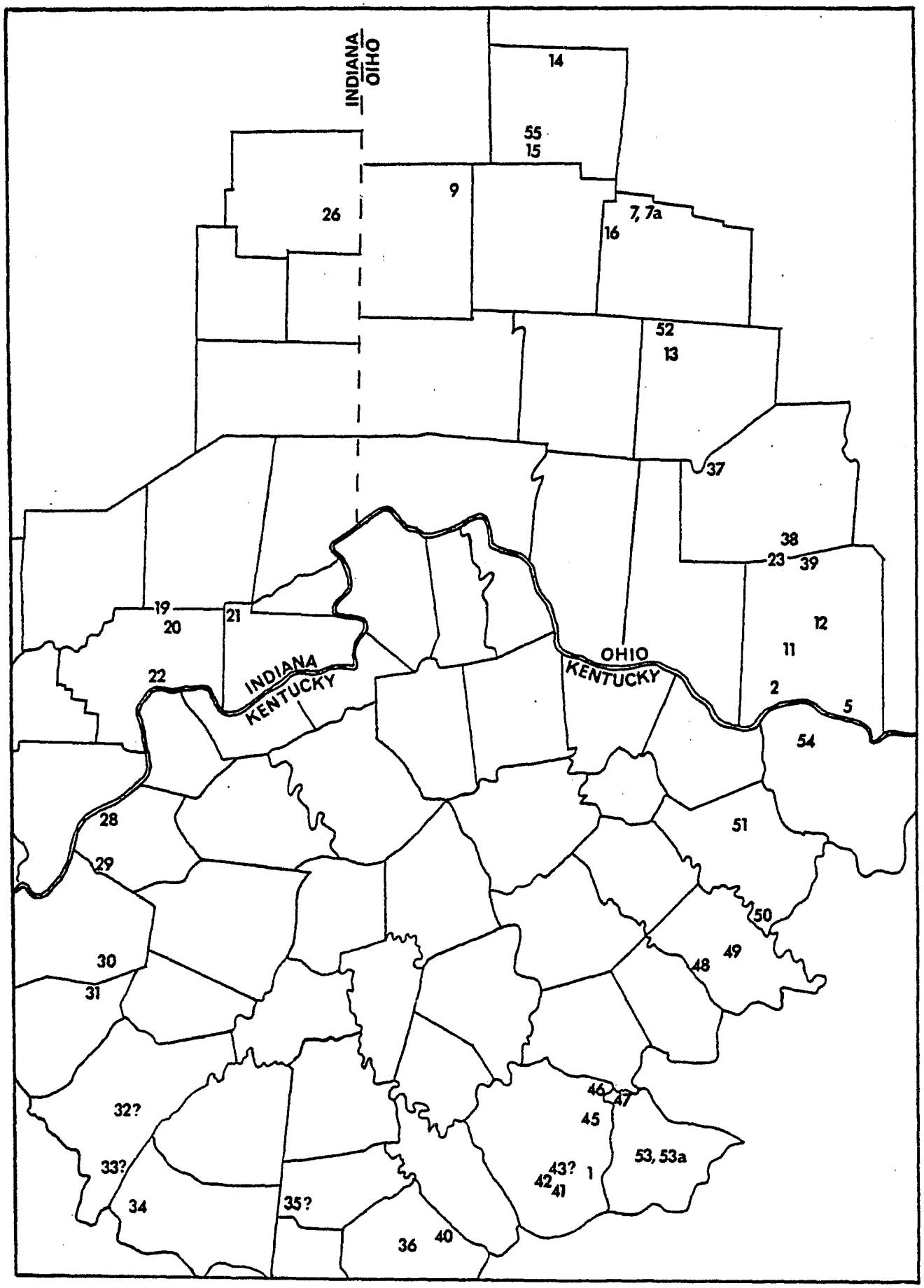

11b

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THE BRASSFIELD LITHOSOME

The rocks of the Brassfield Formation have been recognized as distinct for nearly a century-and-a-half. In his geological report on southwestern Ohio, Locke (1838, p. 239) referred to the "Flinty limestone" (a descriptive, not nomenclatural term) in Adams County, a name apparently pointing to the layers of chert common in the Brassfield here. The presence of ferrous oölite in the Brassfield caused earlier workers to refer it to the Clinton of New York (Owen, 1857, fide O'Donnell, 1967, p. 16; Orton, 1871, p. 145).

Foerste (1896) wrote that the differences between the fossil assemblages of the "Clinton" in Ohio and New York inclined him to regard the two as separate, and he suggested that the Ohio unit be called Montgomery Formation for "its typical development in Montgomery county, in Ohio" (p. 189). Later he found that this name was preoccupied, and discontinued its use (fide O'Donnell, 1967, p. 17). In 1904, Foerste reported that several species found in the New York Clinton do not appear in the vicinity of the Cincinnati Arch until the post-Brassfield Osgood bed, further confirming his contention of the non-equivalency of the two "Clintons".

The term "Brassfield" for the unit being dealt with here was introduced in 1906 by Foerste (p. 10, 27). The typical exposure is along the now-abandoned cut of the Louisville and Atlantic Railroad running between Brassfield and Panola in Madison County, Kentucky. The lower part, consisting of

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a few thick beds of "limestone" (actually, dolomite), is best seen near Panola, while the middle and upper portions, consisting of numerous thinner beds of dolomite, often interlayered with thin clay, is best seen near Brassfield.

The "type" Brassfield consists of these dolomites studied by Foerste along the railroad cut. Above them in this area lie interbedded dolomite and clay, which Foerste (1906, p. 10, 27) labelled (in ascending order) Plum Creek Clay, Oldham Limestone, Lulbegrud Clay, Waco Limestone and Estill Clay. He referred these five units to the "Crab Orchard division of Silurian" (p. 27), and wrote later (1935, p. 127) that it was W.M. Linney who in 1882 first used this term with Group status in a report on the geology of Lincoln County, published by the Kentucky Geological Survey. Rexroad et al. (1965) assigned the lower four units, the Plum Creek, Oldham, Lulbegrud and Waco, to their Noland Formation, based upon the exposure at College Hill, Kentucky (locality 46 of this study).

O'Donnell (1967, p. 38, 46) chose to regard the Noland as a member of the Brassfield Formation. Without making a judgement on the validity of this view, it has proven convenient to follow his usage in studying the Brassfield corals. Henceforth, then, when the term "Brassfield Formation" is used in this study, it includes as a member the Noland Formation of Rexroad et al. (1965).

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Geometry of the Brassfield lithosome in the Cincinnati Arch region - The Brassfield Formation outcrops around the Cincinnati Arch in a narrow horse-shoe pattern, elongate north-to-south, and opening southward. The north-south limits are approximately from twenty miles north of Dayton, Ohio to twenty miles south of Richmond, Kentucky. The east-west limits are approximately from eastern Adams County, Ohio to western Jefferson County, Indiana. The area of this study, then, extends through southwest Ohio, southeast Indiana, and north-central Kentucky. Beyond this region, the Brassfield is reported over a wide area, including Tennessee, Alabama and Illinois (Berry & Boucot, 1970; Swartz et al., 1942). Most reports of the Brassfield outside of the Cincinnati Arch area seem tentative, and probably these cases should be closely scrutinized before their true relationship to the type Brassfield is understood.

It is likely that the Brassfield deposits originally extended over the Cincinnati Arch. This is suggested by isolated occurrences of Brassfield beds as inliers on the portion of the Arch circumscribed by the main outcrop. Foerste (1935, p. 125, 169) reports such occurrences at Jeptha Knob near Shelbyville, and at Scrubgrass Creek near Mitchellsburg, both in Kentucky. Besides these inliers, distribution patterns of the corals in this unit reinforce the contention that Brassfield sediments originally covered the Cincinnati Arch (see section on coral distribution in

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the Brassfield Formation and accompanying figures).

In this region, the Brassfield attains its greatest thickness (up to fifteen meters) on the east side of the Arch between the latitudes of Cincinnati in the north and Lexington, Kentucky in the south. It is considerably thinner on the west side of the Arch, especially in Indiana and northern Kentucky (with the exception of a thick outcrop near Cross Plains, Indiana, locality 21). The outcrops in this area are commonly less than a meter thick and in certain localities the Brassfield pinches out completely (in western Ripley and adjacent parts of Jennings and Decatur Counties, Indiana, according to Foerste, 1904, p. 326). This pinch-out may be seen at locality 19 of this study. O'Donnell (1967, fig. 6) shows the Brassfield thickening slightly eastward from this "Ripley Island pinch-out", and also to the west into the sub-surface. While it is uncertain to what degree the westward thinning of the Brassfield reflects primary topography, as opposed to subsequent uplift of the Arch area, the reported thickening of this unit both east and west of the "Ripley Island" area suggests that the sea floor shoaled to the north and west, a conclusion also pointed to by the coral and lithofacies distributions.

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Facies distribution - No attempt has been made to systematically sample the Brassfield Formation in order to analyze its lithology, or to study it petrographically in the course of this research. O'Donnell (1967) has done such work, and should be referred to for details. Nonetheless, based upon field observations and the study of some thin-sections, it is possible to make some statements concerning the broad features of Brassfield sediments and their distribution.

Four general lithofacies constitute the Brassfield lithosome. These include:

1. a dolomitic mudstone and wackestone facies
2. a pelmatozoan packstone and grainstone facies
3. a ferruginous pelletal or oölitic packstone and grainstone facies
4. a terrigenous(?) clastic facies of silty clay

The terminology used here is that of Dunham (1962). Glauconite is common at certain horizons in the Brassfield, and might reasonably be included as a lithofacies, but insufficient information was gathered concerning its occurrence to warrant its inclusion.

Dolomite is nearly ubiquitous throughout the Brassfield in the area studied. It is uncertain to what extent it is primary, as opposed to being a replacement product of micrite. Evidence for both possibilities was observed: In at least one instance (locality 47) shell fragments appear to

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be altering to dolomite around their peripheries. On the other hand, a frequent occurrence is solitary corals lying in a matrix of bioclastic limestone, their septocoels filled with dolomite rhombs. Even here, the question remains of the possibility that the in-filling dolomite was originally micrite. In only one case (see below) was a possible occurrence of micrite observed, so that if the dolomite is entirely secondary, replacement must have been quite complete.

The bioclastic limestone appears to consist mostly of echinodermal fragments. Many specimens that appear to be entirely limestone prove, on being thin-sectioned, to consist of dolomite with greater or lesser proportions of shell fragments.

The bioclastic limestone contains numerous evidences of erosion, often well-hidden, that indicate a greater period of deposition than the thickness of the deposit would imply. For example, at locality 7 (Fairborn, Ohio) a specimen of the colonial rugosan Petrozium pelagicum in a solid block of limestone proved, on close inspection, to have an erosional surface truncating several adjacent corallites, and covered by the same sort of sediment as that below the erosional surface.

The ferruginous layers of the Brassfield are similar to those of the New York Clinton. They consist of bioclastic limestone (packstone and grainstone) containing smooth, rounded pellets or oöids. These layers are generally red-

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dish, though not always markedly-so. In some instances, the lithofacies was recognized by the presence of the characteristic rounded grains in thin-sections of ordinary-looking limestone.

The terrigenous(?) clastic layers are not clearly understood. Their components have not been analyzed, but they have a clay-like consistency, are gritty to the bite, and effervesce in hydrochloric acid (though this could be due to contamination by the surrounding lime). Their color is grey-green. Superficially, at least, they resemble the sediments of the Richmondian Elkhorn Formation, which in many localities directly underlies the Brassfield.

Two possible explanations for the presence of this silty clay are (1) that it represents a recurrence of the conditions that produced the Richmondian shales, or (2) that it represents a reworking of sediments from eroded Richmondian units. A third possibility is that it is due in part to both these causes, and some bits of evidence seem to support this idea. On the one hand, the clastics are frequently associated with scouring channels, and with evidence of considerable turbulence (see below). On the other hand, no definitely Richmondian fossils have been identified from these clays, while they definitely <u>do</u> contain species

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found in other lithofacies of the Brassfield.

These, then, are the major lithofacies which make up the Brassfield Formation. Following are some observations on their distribution:

There is a general increase in the proportion of organic fragments (and thus, $CaCO_3$) at the expense of dolomite in the Brassfield in a northerly direction. Thus, while the southern localities in central Kentucky (e.g., in the type area) are nearly all fine-grained dolomite with only a thin fossiliferous layer at the top (in the Noland Member), the northernmost localities, in the vicinity of Dayton, Ohio, are nearly all limestone, with dolomite occurring mostly toward the base, and as scattered rhombs among the organic fragments of the limestone.

Because dolomite and limestone are frequently interlayered, and even blend into single beds at the localities, it is not possible to demark a precise boundary between localities on the basis of the dominance of one or the other. In general, however, a line extending between the areas of localities 31 and 32 in the southwest, and localities 37 and 38 in the northeast would reasonably separate the more limy regions to the north from the more dolomitic regions to the south. A second, more southerly line extending from the area of localities 50 and 51 to that of localities 36 and 40 roughly separates the almost entirely dolomitic regions to the southward from the somewhat more calcareous

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dolomites northward. (See Figure 2.)

With few exceptions, the terrigenous detritus facies occurs either at the top or the bottom of the Brassfield Formation. Where the occurrence is basal, it appears to represent interfingering between the upper Richmondian shales and the Brassfield carbonates. This may be clearly seen at localities 3 and 5 in Adams County, Ohio.

The terrigenous clastics of the upper Brassfield are well-exposed at localities 46 (College Hill, Kentucky, type locality of the Noland Member) and 1 (east of Panola, Kentucky.

O'Donnell (1967, fig. 9) presents a fence-diagram based largely on sub-surface data, showing the shales as thickest toward the south and east areas of the Arch, and pinching out to the north and west. The sporadic development of this facies in the Brassfield of the Cincinnati Arch apparently reflects the situation of this area being on the border between the terrigenous clastic, and the carbonate domains.

In northern localities (7a, 15, 55) the terrigenous facies of the upper Brassfield is of considerable interest for several reasons. First, it occurs often in what seem to be scouring channels or large-trough cross-beds near the top of the formation. One of these structures may be seen at locality 15 (West Milton, Ohio) on the south side of Route 571, where it appears in longitudinal profile, run-

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TEXT-FIGURE 2

Lithofacies map of the Brassfield Formation in the study area: Boundaries are approximate; dots mark localities visited in this study.

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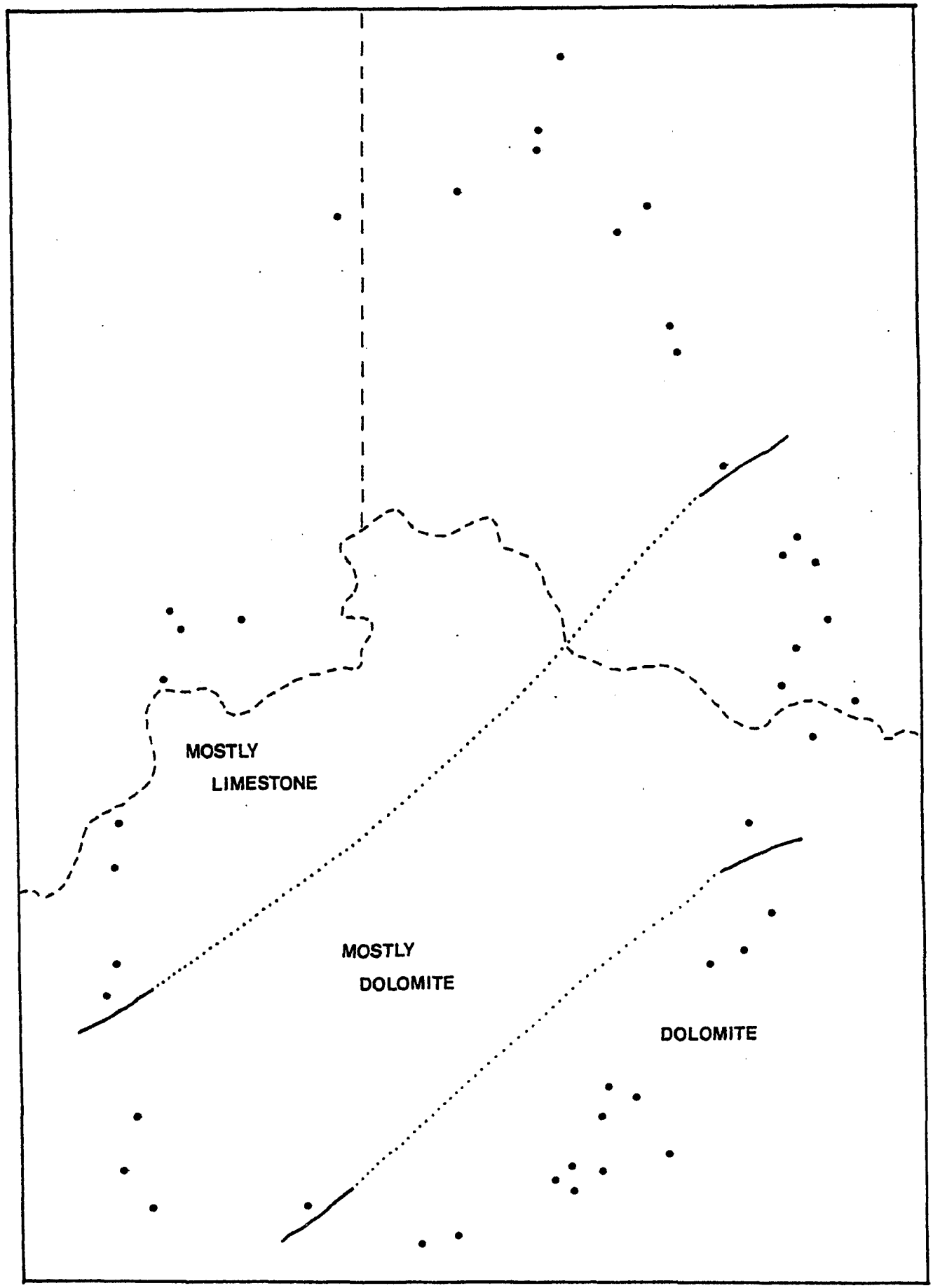

20b

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ning east-west.

The northern occurrences of this facies are noteworthy also for the great richness of the fossil coral assemblages they contain (in contrast with the relatively barren southern clastics). Most of these corals occur also in the carbonate facies of the northern Brassfield, but a small number have been observed only in the shales.

A clue as to the nature of this facies is given by a striking layer found at locality 7a (Fairborn, Ohio) by Dr. William B. Harrison III (presently, University of Western Michigan, Kalamazoo) during this study. Here is one of the few localities found in the north where the clastics are concentrated toward the middle, rather than the top of the Brassfield Formation. The bed in question is two feet thick at its center, extending laterally (in outcrop) for some two-hundred feet before pinching out, and consisting of hundreds of colonial corals packed together like loaves of bread on a baker's shelf, with clay in the interstices. In addition to these, there are two species of solitary corals (one of which has been found only in this bed). The colonies are worn, some apparently having been broken and eroded so that the cyclical spacing of the tabulae is manifested in parallel ridges on the truncated surfaces. A large number of the colonies lay upside-down in the bed, and the evidence of considerable turbulence, enough to transport and wear colonies as much as .4 meter in diameter

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as sedimentary cobbles, is unmistakeable. Most of the colonial corals found in this bed are also found in the carbonates of the Brassfield outcropping in this region, and even occur immediately above the clastic bed in the same outcrop. Interestingly, a possible present-day homologue may have been found for this feature, and will be discussed in the following section.

The ferruginous facies of the Brassfield appears to be associated with a packstone and grainstone lithology. It is characterized, aside from its often striking red color, by the presence of smooth, rounded pellets or oöids. These particles sometimes appear in thin-sections even in the absence of the red color, and probably represent the same environment as do their redder counterparts. The red color is most clearly seen in the northeastern localities (7a, Fairborn; 13, Todd Fork; 5, east of Manchester); but the presence of ooids or pellets in thin-sections from localities 37 (Sharpsville, Ohio), 21 (Cross Plains, Indiana), and 31 (Mt. Washington, Kentucky) suggest that the depositional environment of the ferruginous facies occurred there also, though the sediments are not red. Besidesthe presence of oöids or pellets, this facies is characterized by the omnipresence of calcareous organic fragments and macrofossils, especially echinodermal fragments, bryozoa, solitary corals and orthocone cephalopods.

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Geography of the Brassfield Sea - Studies of dolomite and dolomitization in recent years point to the fact that this process is associated with shallow, intertidal, and even supratidal regions of the littoral (Murray & Pray, 1965, p. 2; Shinn, Ginsburg & Lloyd, 1965). Penecontemporaneous dolomite may be seen today on Sugar Loaf Key in the Florida Keys.

O'Donnell (1967, fig. 11) traces the lithology of the Brassfield Formation for some distance away from the Cincinnati Arch, and shows that the dolomitic rocks characteristic of the southern half of this area also occupy the entire region to the west of the Arch. If dolomite is characteristically associated with an environment near the shoreline, this should indicate that the shore ran west of the present Arch down to about the Ohio River, where it turned eastward across the Arch to reappear in the eastern outcrops. The dolomitic deposits of the southern area, tnen, would represent an environment at or near sea-level with an embayment of shallow sea producing lime sediments.

Unfortunately, this montage is confused by the findings of Deffeyes, Lucia & Weyl (1965), who report dolomitization of Plio-Pleistocene sediments today by "refluxing" of magnesium-rich waters down through the permeable sediments of later years. Further, Murray & Lucia (1969) suggest similar secondary dolomitization, controlled by the sediment texture, in Mississippian beds of Alberta. What this means

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in terms of the above hypothetical geography, is that we cannot be certain if the Brassfield dolomite represents near-shore conditions, or if it represents an area of finer carbonate sediment which was subsequently uplifted to near sea-level, and dolomitized at this later date.

This being the case, it seems wiser to use other criteria for clues as to the topography of the Brassfield sea-floor. Following are some observations that may provide useful information:

1. In the north and northwest, there is a sharp break between the Brassfield Formation and the underlying Richmondian beds. At several localities, pebbles from the underlying beds occur in the base of the Brassfield (localities 14 and 21), and in at least one instance (at locality 21) there appears to be an angular unconformity below the Brassfield. Further south, on the eastern side of the Arch (localities 3, 5, etc.) the transition from Richmondian to Brassfield beds appearsmore gradual, represented by a zone of interfingering Brassfield-like dolomite and Richmond-like shale. Gray & Boucot (1972) studied the fossil spores found in this transition zone and in the base of the Brassfield in this region (at locality 12), and concluded there was a paraconformity, recording a trend from near sea-level environment (with intermingling terrigenous and marine conditions), to a more constantly marine environment higher in the section.

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2. The three coral biofacies detected in this study appear to occur in zones elongate in a northeast-southwest direction (Figure 3), which conforms to the pattern shown in (1) above, of a gradient in profoundness-of-unconformity along a northwesterly line. That is to say, the coral biofacies may roughly parallel the contours of the sea-floor.

3. The Brassfield is thickest to the east and south, and generally thinnest to the northwest, especially in southeast Indiana and northern Kentucky on the west side of the Arch. An actual pinch-out of the Brassfield may be seen at locality 19, near Bryantsburg, Indiana. O'Donnell (1967, fig. 6) shows these relationships in the form of an isopach map. He has used subsurface data to extend the area over which the Brassfield's thickness is indicated, and he shows that this unit again thickens to the west of its area of minimum thickness, in southeast Indiana. The presence of Brassfield deposits between "Ripley Island", the region of zero thickness, and the crest of the Arch, suggests that the "island" was indeed a topographically-positive area, affecting Brassfield sedimentation as stated by Rexroad (1967, p. 1). As the entire Arch area was uplifted subsequent to Brassfield deposition (O'Donnell, 1967, p. 121, says "There is no relationship between the lithosomes [of the Brassfield] and the present Cincinnati Arch."), it is difficult to be certain to what extent the isopachs reflect original sea-floor topography.

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TEXT-FIGURE 3

Coral biofacies map of the Brassfield Formation in the study area: Boundary lines of the biofacies are approximate; dots represent localities visited in this study. See Table 3 for detailed analysis of species occurrence at each locality.

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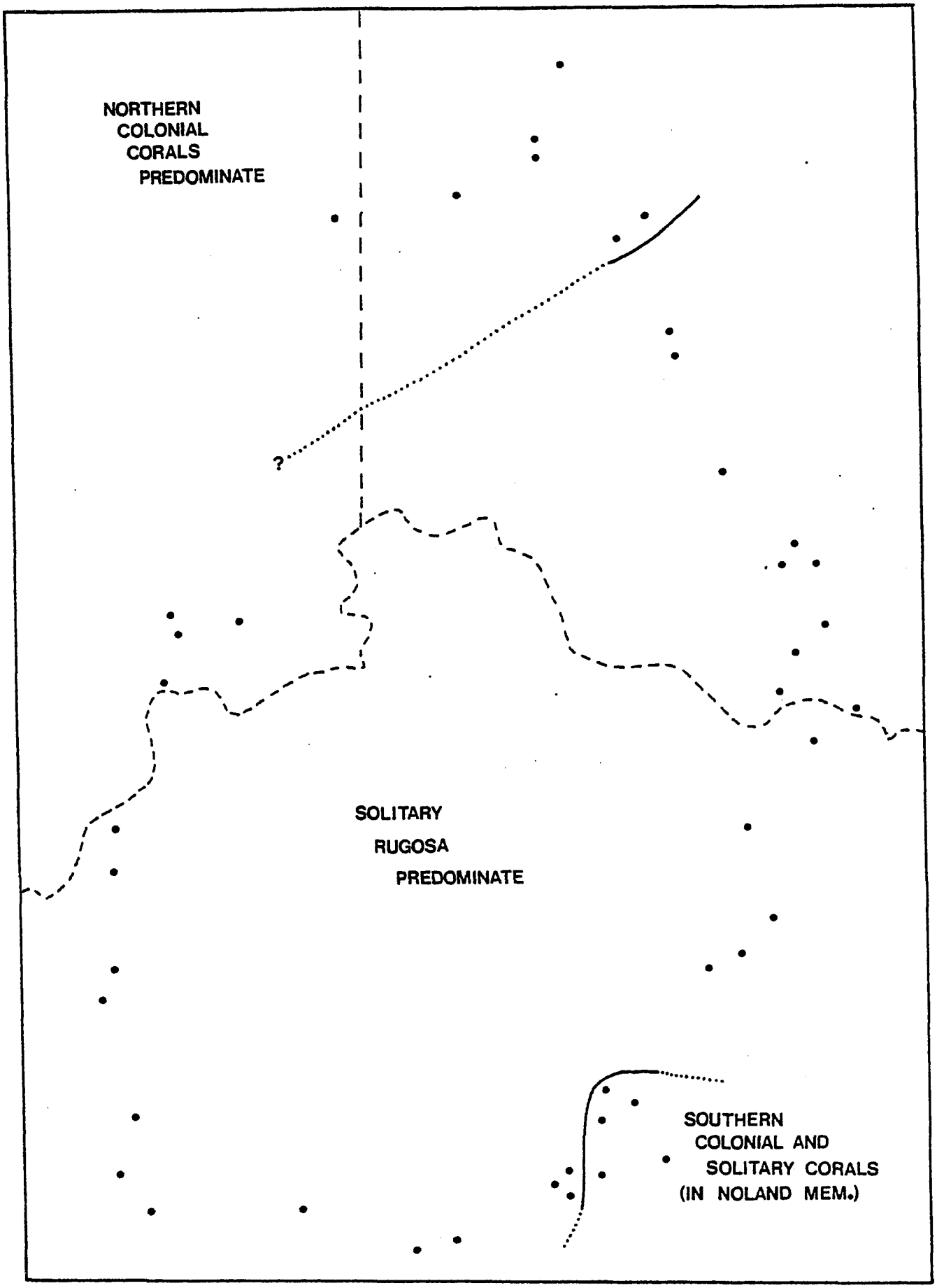

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4. The proportion of bioclastic material increases toward the north and west, resulting in coarse-grained limestone dominating the north, and grading southward into fine-grained dolomite without abundant shelly material. The contours of increasing liminess generally parallel the boundaries of the coral biofacies.

5. Evidences in the form of large, transported coral colonies (in the clay layer at locality 7a), and apparent scouring channels or large corss-bed troughs (localities 7 and 15) point to a high-energy environment in the northernmost area of the outcrop. This may indicate shallow water, though not necessarily so.

A possible modern homologue to the Brassfield sea may be found in the Florida Keys. Rodriguez Key consists of an accumulation of calcareous biological debris which formed in situ, the result of a high level of biotic activity locally. It overlies lime-mud, similar to that currently forming in the restricted carbonate environment of Florida Bay (Roger Swanson and Real J. Turmel, 1975, oral communication). It is suggested that this sequence formed as a result of the post-Pleistocene marine transgression northward in this area. At an earlier stage of the transgression, the site of present Rodriguez Key experienced very shallow, restricted marine conditions similar to Florida Bay today. As the water deepened, the increased circulation of an open-marine environment provided

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the food and oxygen necessary for the support of a large lime-producing community, whose remains have accumulated into Rodriguez Key. The same stratigraphic sequence occurs in the northern localities of the Brassfield, and is most clearly-seen at localities 7 and 7a (Fairborn). A deposit of fine material (here dolomite, rather than micrite) is overlain by a large deposit of coarse bioclastic limestone, containing many features indicative of a high energy environment. It seems quite likely that this sequence reflects the same events as occurred at the site of Rodriguez Key. The Brassfield is generally regarded as a transgressive sequence, and this view is supported both by the findings of Gray & Boucot (1972) and by field observations of this study. The dolomite of the lower Brassfield, then, would represent (either as dolomite, or as dolomitized lime mud) shallow, restricted marine conditions, which are succeeded (at least in the north) by more open-marine conditions suited to the support of a sufficiently-large benthic community to produce the large shell piles seen in the north.

Yet another feature of the northern Brassfield may have its modern homologue in the Florida Keys (and not far from Rodriguez Bank). The French Dry Rocks, south of the Keys, are a shoal consisting of an accumulation of large coral fragments, a storm-deposit. The pieces of coral, broken from the reef, have become tangled, forming a resistant structure. Perhaps this explains the origin of the layer of large,

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transported coral cobbles with interstitial clay at locality 7a (Fairborn). These coral colonies appear to have lived in the limestone environment, and were probably swept from other areas into their final resting-place. The interstitial clay extends no higher in the section than the exact top of the coral layer, suggesting that its presence there was controlled by the coral cobbles. In other words, the "storm-beach" accumulation of coral cobbles served as a sediment trap for the clay particles.

Until the matter of the origin of the Brassfield dolomite is better-understood, there seems little profit in speculating as to the location of the shore-line. If, however, we restrict ourselves to the question of energy in the water, all signs point to the northern localities as having experienced the most turgid conditions.

Current directions - At several localities, cross-beds were found, as well as fossils whose forms and orientations appeared to hold information on bottom-currents in the Brassfield Sea. The fossils included solitary corals and orthocone cephalopods, which might indicate the direction in which the current moved (experiments showed that the aperture would tend to point downstream), and bryozoan twigs, which might indicate the line along which the current moved, without showing the direction. The most meaningful readings, of course, were taken on groups of fossils lying in close

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proximity, and on about the same bedding-plane. In some instances, however, individual fossil orientations were measured, simply to see how they compared with the orientations of the assemblages.

All readings were made in the northeast quadrant of the outcrop area, stretching from the Ohio River northward in Ohio to the Dayton region. Most of the readings indicated a northerly direction of flow for the bottom currents. As, however, the orientation measurements were a by-product of this study, no attempt had been made at statistically-meaningful sampling, and the readings presented in Table 1, as well as their pictoralization in Figure 4, should only be regarded as data to be considered in future, carefully-designed studies of directional indicators in the Brassfield Formation.

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TABLE I

ORIENTATION READINGS IN THE BRASSFIELD

Locality	Source of data	Orientations
2.....	3 horn corals lying together, lower Brassfield; calices face:	N 30° E N N 45° E
5.....	6 horn corals 3" above base of Brassfield; calices face:	N 72° E S 80° E N 15° E N 40° E N 13° W S 80° E
	Cross-bed dips in upper Brassfield, above the upper chert layer (52" - 64" above chert)	N 80° E N 10° W N S 25° E
7.....	22 orthocone nautiloids together on bedding plane within an area of about 1 square yard at top of Brassfield; apertures face:	N 10° W, N 55° W N 25° E, N 50° E N 55° W, N N 15° E, N 55° W S 25° W, S 30° E S 35° W, S 30° E N 40° W, S N 40° W, S N 20° E, N 30° E N 25° E, N 85° W N 85° W, E

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TABLE I (continued)

Locality	Source of data	Orientations
13	3 horn corals in the ferruginous zone near top of Brassfield; calices face:	N 40° E N 10° E N 30° W
	3 orthocone nautiloids at same level; apertures face:	E E S 80° E
14	Horn coral, 106" above base of Brassfield; calice faces:	N 60° W
15	Horn coral, about 19 feet above Brassfield base, in channel; calice faces:	N 20° W
37	Numerous twig-like bryozoan fragments on single bedding plane, in middle Brassfield (c. 11 feet above quarry floor); elongation:	N 35° W - S 35° E

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TEXT-FIGURE 4

Rose diagrams showing orientations of fossils at some outcrops of the Brassfield Formation: Patterns are based upon the data recorded in Table 1, but do not include the cross-bed readings from locality 5. The plot at locality 37 is based upon the alignment of numerous small, slender twig-like fragments from bryozoan zoaria on a single bedding-plane, and so indicates only the line along which the current appears to have moved on the sea floor at that point. The other readings are of conical shells (orthocone cephalopods and solitary corals) whose broad apertures empirically orient facing down-current, and here the direction in which the bottom current moved is indicated.

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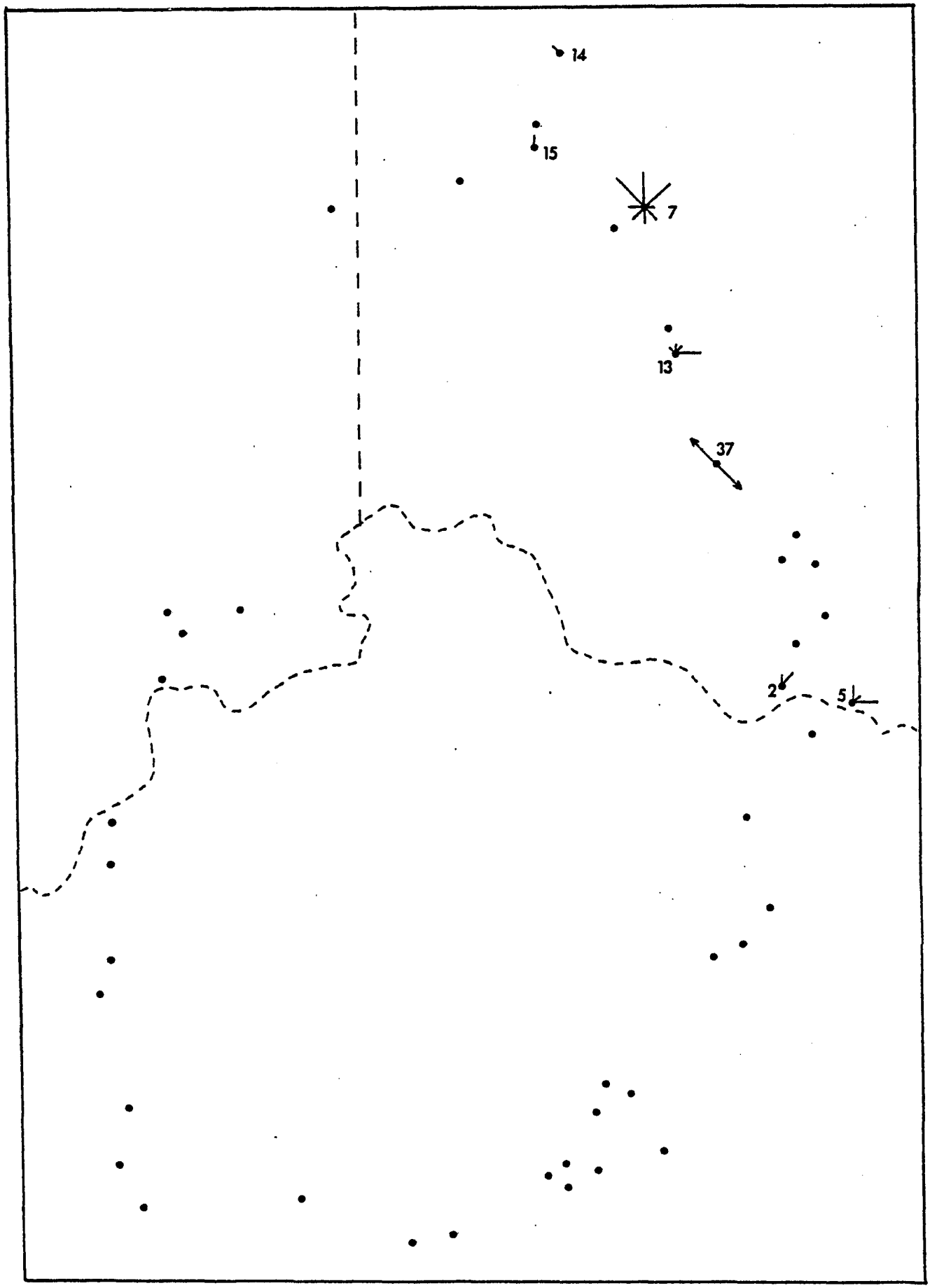

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Age of the Brassfield Formation - O'Donnell (1967) and Berry & Boucot (1970) summarize the evidence used to determine the age of the Brassfield. In general outline, it is as follows:

Brachiopods and conodonts have proven the most useful tools in age-correlation work. Berry & Boucot (ibid.) use the designations of Jones (1925) for subdividing the Llandovery, along with the work of Williams (1951) on brachiopods. These divide the early Llandovery into five divisions (A_1 - A_5), the middle Llandovery into three divisions (B_1 - B_3), and the late Llandovery into six divisions (C_1 - C_6). Two brachiopod genera, Platymerella and Microcardinalia, are regarded as good index fossils by Berry & Boucot (ibid., p. 127-128). The former has a range of "pre-C_1" according to these authors, while the latter is C_1 - C_2. They regard the type Brassfield in Madison County, Kentucky, as being in the Platymerella zone, though this genus is not found there, because northward, along strike, Platymerella occurs in Ohio beds assigned to the Brassfield, which are of pre-Microcardinalia age.

Microcardinalia occurs in the Oldham limestone bed of the Noland Member (O'Donnell, ibid., p. 75). Rexroad et al. (1965, p. 12) note that, while one species of this genus occurs in the Oldham in east-central Kentucky, another species of the same genus occurs at the top of the Brassfield beds immediately below the Noland at Dayton, Ohio (one of

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the most northerly localities). They interpret this (p. 13) as indicative of the Brassfield having transgressed northward.

Berry (1967) reported a new subspecies of the graptolite Climacograptus scalaris from the Noland Member near Colfax, Kentucky (locality 50 of this work). Berry & Boucot (ibid., p. 190-191) note that this graptolite belongs to a group which ranges from the early Late Ordovician into the early Late Llandovery, consistent with their estimate of a C_1 - C_2 age for the Noland in this area.

Rexroad (1967) studied the conodonts of the Brassfield, and concluded (p. 12-14) that the Brassfield, with the Noland Member, is entirely within the period of Walliser's Bereich I (pre-A_1 to B_3), and specifically that it is entirely within the upper half of that period. Walliser's work, in the 1950's and 1960's, was based on conodonts in the Carnic Alps of Europe. Rexroad goes on to say (p. 14) that graptolite work indicates that the Brassfield Formation (not including the Noland Member) falls within the European zones of Monograptus cyphus, M. gregarius, and M. convolutus (i.e., European graptolite zones 18 - 20, which include upper A_3 through B_3). This conclusion, of course, is based upon correlation of Rexroad's conodont zonation with the standard graptolite zonation.

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Rexroad's dating of the Brassfield and Noland based upon conodonts thus produces a somewhat greater age than does the brachiopod work reported by Berry & Boucot. These latter authors, however (p. 191), state that Rexroad, in an oral communication in 1967, informed them that he found celloni Zone conodonts (C_1 through mid-C_3) in the uppermost Waco bed (of the Noland Member). This better-reconciles the conodont and brachiopod data.

This summarizes the current thinking on the relative age of the Brassfield Formation. Hurley et al. (1960, p. 1804), using K-Ar and Rb-Sr methods of age-measurement on glauconite from the Brassfield Formation in Adams County, Ohio, obtained an absolute age of 410 million years for the unit.

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MORPHOLOGICAL TERMS USED IN THIS WORK

The terms used to describe coral morphology in this work are, with a few exceptions, based upon Hill (1936; 1956, p. 245-251). The latter is a glossary of terms used in reference to rugosans, tabulates, heliolitids and sclera-ctinians, while the earlier work deals specifically with rugosan morphology. Exceptions to Hill's usages are itemized below:

Rugosa - The word "septocoel" is here defined as the space between two adjacent major septa, extending axially to the imaginary plane connecting the axial edges of these septa. Thus, the cardinal fossula (as seen in transverse view in the top portions of Plate 15, figure 18, and Plate 16, figure 1) consists of two wide septocoels on either side of the cardinal septum.

Neuman (1969, p. 5) uses the term "septal lobe" to denote an extension of a septum into the axial region of the corallite, which is bent in a sharply-different direction from that of the main part of the septum. This is most clearly shown in Plate 21, figure 1. Hill (1956, p. 241) uses a similar term, "axial lobe", for a different concept, and these should not be confused.

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Tabulata - Hill (1956, p. 251, 311) uses the term "trabecula" to denote the rod-like element of the septum in rugosans, and the spinose projections found in tabulates and heliolitids. As such blanket use of the term might be suggestive of homology of these features (in what are now regarded as three quite-distinct groups), the more general term "spine" will be used in this work in the case of the tabulates and heliolitids, while Hill's usage will be retained for the rugosans.

In describing the halysitids, Hill & Stumm (1956, p. 469) use the term "microcorallite" for the sub-quadrate tubes located between the larger corallites in the chains of Halysites (see Plate 29, figures 3, 4; Plate 32, figure 2; Plate 38, figures 1, 2). As Etheridge (1904, p. 17) points out, other terms have been applied to these interstitial features. As it is not clear just what they represent, or even if they served a single purpose in various species, it seems best not to designate them as corallites at all, but to follow the usage of Etheridge (which he attributed to Nicholson) in calling them merely "interstitial tubes".

The term "balken" refers to rod-like elements that occur in the space between corallites of the Halysitidae, parallel to the corallite axes. The rods occur as two pairs, each pair at the border between a corallite tube and the interstitial area. Hamada (1959, p. 282-284) discusses and il-

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lustrates these features, and notes their potential as systematic tools.

Heliolitida - In describing the heliolitids, Hill & Stumm (1956, p. 458) use the term "tabularium" for the large, tabulated tubes of the corallum, and "coenenchyme" for the tubular or vesicular matrix, separating the tabularia. In this work, the word "corallite" is substituted for "tabularium", a practice found to be common in the literature. It is felt that the term "tabularium" as used by Hill & Stumm suggests an integral, rugosan-like relationship between these tubes and the intervening matrix of tubular or vesicular material, which has not been demonstrated. (The reference here is to the common occurrence of an axial tabularium and a peripheral marginarium [which when vesicular, is referred to as a "dissepimentarium"] in single rugosan corallites.)

Hill states (1956, p. 246) that "coenenchyme" refers collectively to the coenosteum (meaning "common hard-tissue") and the coenosarc (meaning "common soft-tissue"). As our fossils retain only the hard-parts of the original organisms, the term "coenosteum" is used in this work when referring to the intervening skeletal structure between the corallites of the heliolitids.

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MORPHOLOGICAL OBSERVATIONS

The corals of the Brassfield Formation display several morphological peculiarities worthy of closer attention:

Cnidarians are often referred to as possessing "radial" symmetry. This, of course, is merely superficial. The common elongation of the mouth, the presence of a siphonoglyph occasionally at one end of the mouth as in the Octocorallia (Bayer, 1956, p. 168), and the pattern of development of the mesenteries in Recent representatives of this group all clearly point to a fundamental bilateral symmetry in the Cnidaria, upon which radiality has been superimposed (as in the Echinodermata).

In the Rugosa, the symmetry is quite clearly bilateral, if a careful examination is made of the septal pattern. More especially, the presence of a cardinal fossula reinforces the bilaterality. This feature also serves to illustrate a second aspect of rugosan morphology, which might be called "directedness".

The solitary Brassfield rugosans which bear distinct cardinal fossulae generally have smooth exteriors, and are curved, with the fossula on the convex side of the corallite. This is probably related to the life position and feeding attitude of the animal. If the fossula may be presumed to mark an extension of the mouth or feeding apparatus, then probably the coral lay in the sediment on its convex side, with its oral disc oblique to, and touching the sea

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floor. This would bring the mouth region closer to the bottom and, presumably, to the principal source of the organism's food. Examples of this type of corallite may be seen in Plate 1, figures 9-11; Plate 2, figures 15-17; Plate 6, figures 6-9; and Plate 3, figures 9, 10.

In the other major types of Brassfield solitary corals, namely the scolecoid, patellate and talon-bearing forms, the life-position appears to have been different. The scolecoid forms (Plate 6, figures 16, 17) probably lay on the sediment under low-energy conditions, on their sides, changing position either as occasionally rolled by gentle currents, or more likely, as a result of changes in the location of their center of gravity due to axial growth. In any case, this radial change in life-position would seem to preclude the formation of a specialized organ in association with a specific radial position.

The patellate forms (Plate 4, figures 5-7; Plate 5, figure 1) were generally broader than high, with explanate peripheries which encrusted the sediment surface to produce a rather stable structure. The oral disc was directed upward, and was surrounded by the everted calice walls for an equal distance on all sides so that, again, the oral region was kept away from contact with the sediment surface, and no appreciable fossula formed.

The talon-bearing forms (Plate 4, figures 8, 9; Plate 5, figures 2, 3, and 6, 7) grew upward from the sediment,

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and were propped by lateral extensions of their basal portions (on the convex side when the corallite was curved). Probably, the oral disc was more-or-less horizontal, parallel to the sea floor, and was certainly not in contact with it. These may have depended for their food on quite different sources than did those forms with mouths closer to the bottom.

Logic dictates that there are three possible explanations of the relationship between curvature and radial position of the fossula in the first of these four types of corallites. (1) The position of the fossula may have been pre-determined genetically, with the result that the curvature of the corallite followed suit. (2) The curvature of the corallite may have been pre-determined genetically, so that the fossula was positioned to conform with the direction of curvature. (3) Both the orientation of the curvature and the position of the fossula may have been linked by some third factor. As this is a cardinal fossula, that is, one associated with the cardinal septum, it seems safe to eliminate the second possibility, since the cardinal septum is defined before the corallite is long enough for curvature to occur.

Minato (1961, Text-figures 20 and 22) shows the ontogenetic stages of Dalmanophyllum minimum (Ryder), a solitary rugosan from the Silurian of Gotland. Here, it is clear that curvature is convex on the cardinal side, but it is

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also seen that the strongest development of the cardinal fossula occurs at the point of greatest curvature of the corallite. This suggests that, while the cardinal septum surely pre-dates, and probably determines the curvature, there may be a close tie between the position of curvature and the radial location of the fossula, both with regard to position and time, and it is not yet possible to say which determines which.

The radial anisotropy of rugose corals, then, is clearly defined. There is, however, another sort of anisotropy that is not as well-known, and which further, appears to be of considerable taxonomic use. This is the presence of torsion of the axis, with the result that the septa do not take the shortest possible route (as seen in transverse sections) to the axis of the corallite. This phenomenon was noted in our Brassfield solitary rugosans (see Plate 12, figure 10; Plate 13, figure 6; Plate 14, figures 1-6; Plate 16, figures 1, 12) at an early stage of this study, and a literature search turned up only one reference to it, that of Voynovskiy-Krieger (1971). Presumably because this paper is in Russian, it does not appear to be generally known in the West, but its importance is considerable. This phenomenon of torsion is of particular interest because, in all instances so far encountered, the torsion is in a counter-clockwise direction (that is, looking down on the calice floor, the septal pattern has

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the aspect of a whirlpool in counter-clockwise rotation). Voynovskiy-Krieger described several distinct types of torsion, and gave an example of a coral showing each type. The torsion observed in the Brassfield corals (Rhegmaphyllum daytonensis, Dinophyllum stokesi, D. semilunum and D. hoskinsoni) is of types C and E as described in his work.

In all cases, these are solitary corals without dissepimentaria, generally classed among the streptelasmatids. This fact points to a high taxonomic importance for torsion. Torsion may be present at some stages, and not at others, but it always occurs in the same species (at least among those studied), and has only been observed to be counter-clockwise.

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DISTRIBUTION OF CORALS IN THE BRASSFIELD FORMATION

The fifty-four species described in this work (twenty-nine rugosans, nineteen tabulates, six heliolitids - see Table 2) represent the most prominent elements of the Brassfield coral fauna. Some more have been found but not yet analyzed, and many others doubtless await discovery.

The Brassfield dates from the Middle Llandovery, a time just before the abundant and diversified worldwide coral faunas characteristic of the later Silurian had developed, according to current lore. Taken in the light of this historical context, the respectability of this fauna is substantiated in comparing it with described coral faunas from the classic rock units of the later Silurian: For example, Stumm (1964, p. 10) reports sixty-seven species of corals from the Louisville Limestone (Late Wenlock and Early Ludlow) at the Falls of the Ohio near Louisville, Kentucky. Amsden (1949) describes a coral fauna of 41 species from the Brownsport Formation (Ludlovian) of western Tennessee.

Geographic distribution - The Brassfield Formation on the west side of the Cincinnati Arch is generally thin, with low coral diversity and abundance. Certain exceptions are encountered, as at localities 30 (Seatonville, Kentucky) and 17 (near Bunker Hill, Indiana, which is possibly not Brassfield at all). Apparently, the combination of true

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TABLE 2

List of rugosan, tabulate and heliolitid coral species in the Brassfield Formation of the Cincinnati Arch region

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RUGOSANS

Fam. Streptelasmatidae

Streptelasma scoleciforme sp. nov.

Dinophyllum stokesi (Milne-Edwards & Haime) 1851

Dinophyllum hoskinsoni (Foerste) 1890

Dinophyllum semilunum sp. nov.

Dalmanophyllum linguliferum (Foerste) 1906

Dalmanophyllum(?) obliquior (Foerste) 1890

Rhegmaphyllum daytonensis (Foerste) 1890

Schlotheimophyllum patellatum (Schlotheim) 1820

Schlotheimophyllum benedicti (Greene) 1900

Schlotheimophyllum ipomaea (Davis) 1887

Fam. Paliphyllidae

Paliphyllum primarium Soshkina, 1955

Paliphyllum suecicum Neuman, 1968 var. nov.

Paliphyllum regulare sp. nov.

Cyathactis typus Soshkina, 1955

Cyathactis sedentarius (Foerste) 1906

Protocyathactis cf. P. cybaeus Ivanovskiy, 1961

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Fam. Tryplasmatidae

Tryplasma radicula (Rominger) 1876

Tryplasma cylindrica (Wedekind) 1927

Tryplasma sp.

Fam. Calostylidae

Calostylis spongiosa Foerste, 1906

Calostylis lindstroemi Nicholson & Etheridge, 1878

Fam. Chonophyllidae

Strombodes socialis (Soshkina)1955

Fam. Arachnophyllidae

Arachnophyllum mamillare (Owen) 1844

Arachnophyllum granulosum Foerste, 1906

Petrozium pelagicum (Billings) 1862

Craterophyllum(?) solitarium (Foerste) 1906

Fam. Halliidae

Pycnactis tenuiseptatus sp. nov.

Schizophaulactis densiseptatus (Foerste) 1906

Fam. Cystiphyllidae

Cystiphyllum spinulosum Foerste, 1906

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TABULATES

Fam. Favositidae

Favosites favosus (Goldfuss) 1826

Favosites discoideus (Roemer) 1860

Favosites hisingeri Milne-Edwards & Haime, 1851

Favosites sp. A

Favosites densitabulatus sp. nov.

Paleofavosites prolificus (Billings) 1865b

Fam. Halysitidae

Halysites catenularius (Linnaeus) 1767

Halysites nitidus Lambe, 1899

Halysites(?) cf. H. meandrinus (Troost) 1840

Catenipora gotlandica (Yabe) 1915

Catenipora favositomima sp. nov.

Fam. Moniloporidae

Cladochonus sp. A

Cladochonus sp. B

Cladochonus sp. C

Fam. Syringoporidae

Syringopora reteformis Billings, 1858

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Fam. Syringolitidae

Syringolites sp. A

Fam. Alveolitidae

Alveolites labrosus (Milne-Edwards & Haime) 1851

Alveolites labechii Milne-Edwards & Haime, 1851

Fam. Pachyporidae

Striatopora flexuosa Hall, 1852

HELIOLITIDS

Fam. Proporidae

Propora conferta Milne-Edwards & Haime, 1851

Propora exigua (Billings) 1865b

Propora eminula (Foerste) 1906

Fam. Heliolitidae

Heliolites spongodes Lindstrom, 1899

Heliolites spongiosus Foerste, 1906

Fam. Palaeoporitidae

Palaeoporites sp.

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primary shoaling in the vicinity of Ripley Island (see discussion under "Brassfield Lithosome"), and erosion during uplift of the Cincinnati Arch cloud the stratigraphic and geographic patterns of coral distribution in this area. Nonetheless, the species here are those found elsewhere in the unit, as shown in Table 3.

On the eastern side of the Arch, the Ohio River provides a convenient line of reference. Twenty species have been found only north of the River, while twenty-four have been observed only southward of this latitude. Only ten species have, either definitely or questionably, been identified from both north and south of the River (Table 4).

Remarkable changes in diversity, as well as kind, of species occur along this north-south transsect. North of the Ohio River, expecially in the vicinity of Dayton, Ohio, there are many localities with rich coral assemblages (especially 14, 55, 15, 7, 7a, 13, 37, and 11 - see Figure 5). Scattered among these localities are others with lower diversities.

From just north of the Ohio River and southward to roughly the present latitude of Richmond, Kentucky, is a chain of localities which contains a monotonous fauna of very low diversity. In most cases, the only species likely to be found is the solitary rugosan, Rhegmaphyllum dayton-ensis (Foerste), though this single species may be extremely

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TABLE 3

Tabulation of the occurrence of coral species in the Brassfield Formation at the localities visited in this study. A dot indicates that the species has been collected and identified from that locality by the author during this study. An F indicates that Foerste reported the species from that locality, but that it was not collected by the author. A ? indicates that the identification by the author of that species from that locality is questionable.

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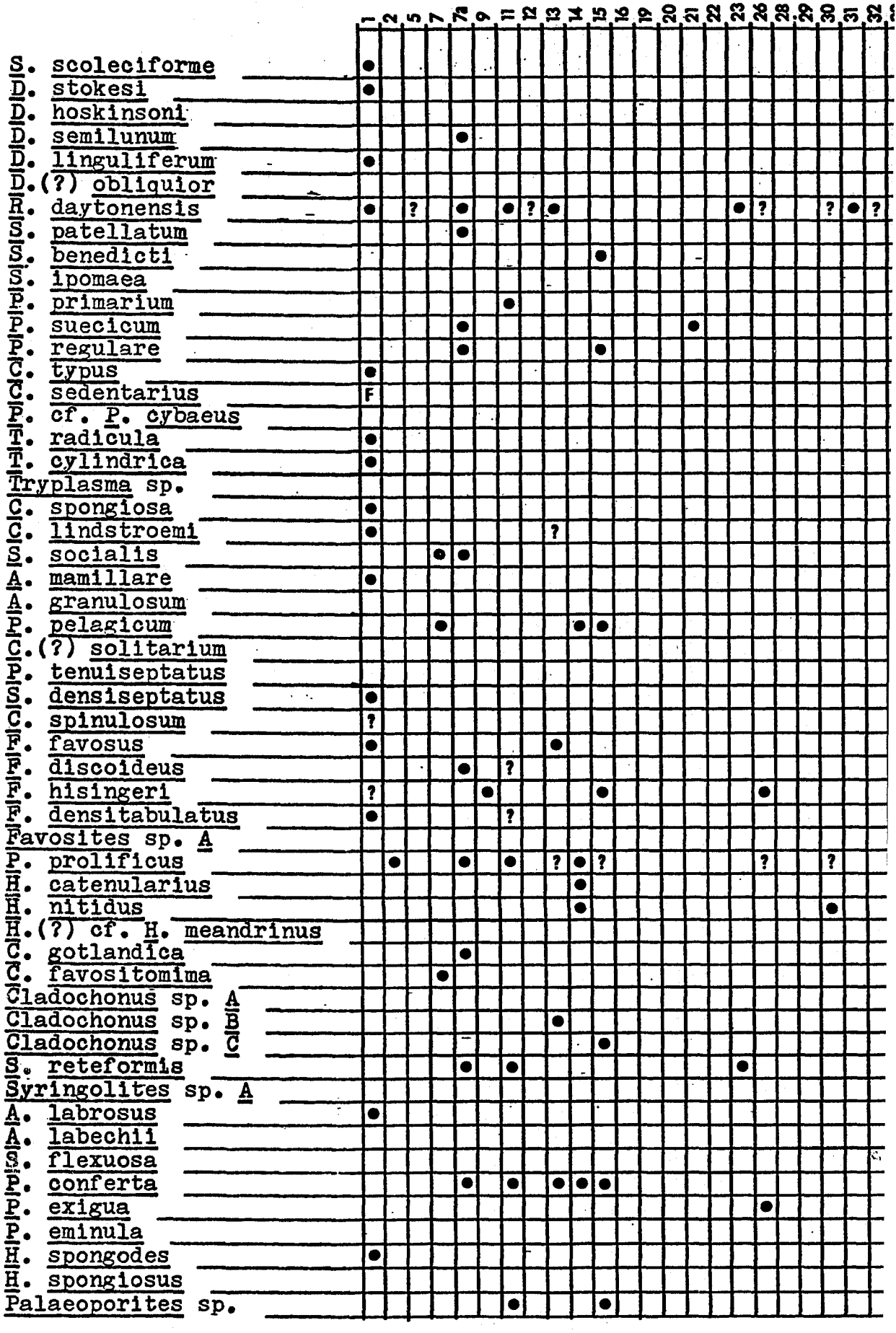

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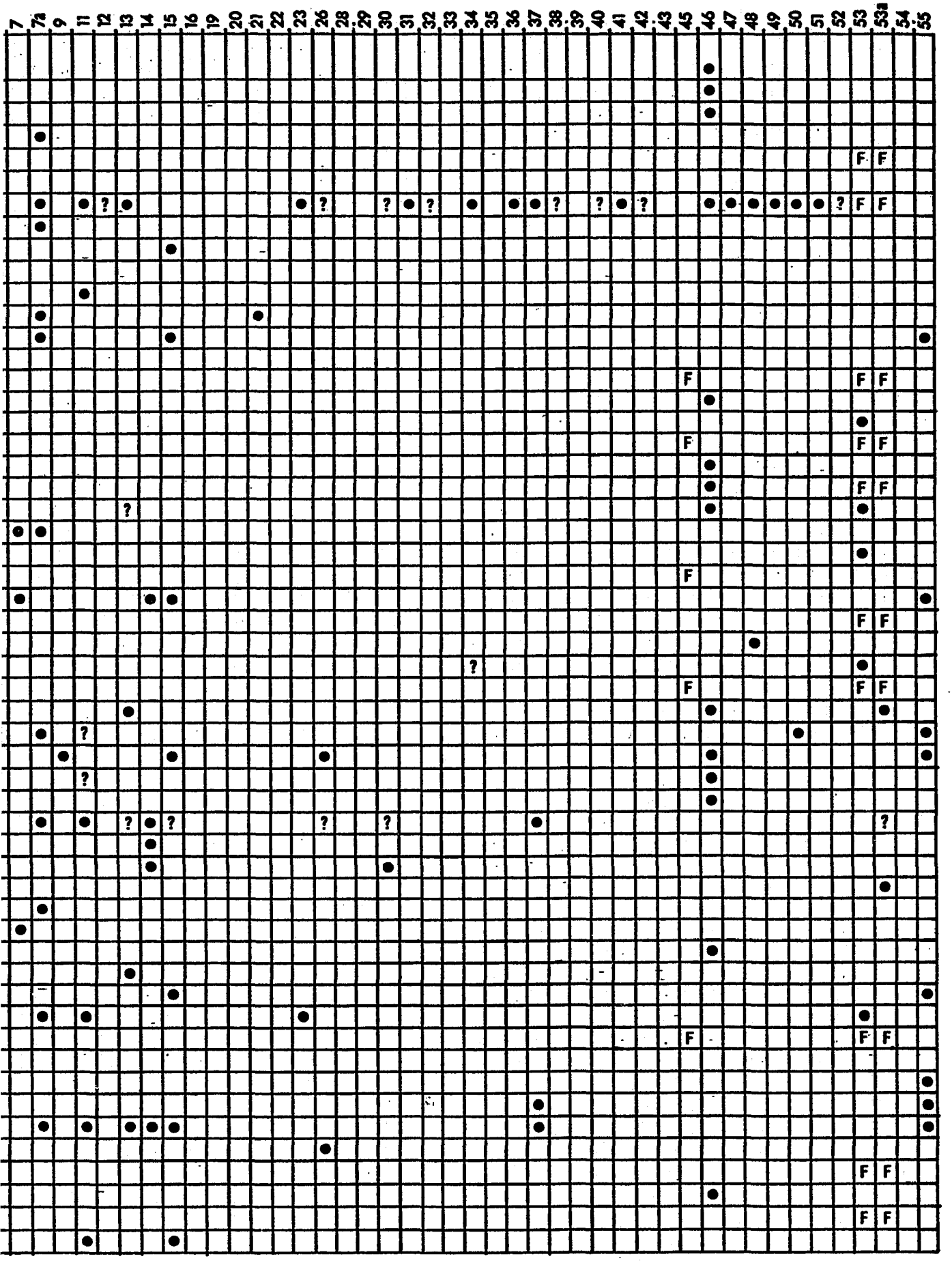

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TABLE 4

Categorization of the Brassfield coral species with regard to their occurrence north or south of the Ohio River, in the study area

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NORTH ONLY

Dinophyllum semilunum

Dalmanophyllum(?) obliquior

Schlotheimophyllum patellatum

S. benedicti

S. ipomaea

Paliphyllum primarium

P. suecicum

P. regulare

Strombodes socialis

Petrozium pelagicum

Halysites catenularius

Catenipora gotlandica

C. favositomima

Cladochonus sp. B

Cladochonus sp. C

Alveolites labechii

Striatopora flexuosa

Propora conferta

P. exigua

Palaeoporites sp.

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SOUTH ONLY

Streptelasma scoleciforme

Dinophyllum stokesi

Dalmanophyllum linguliferum

Cyathactis typus

C. sedentarius

Protocyathactis cf. P. cybaeus

Tryplasma radicula

T. cylindrica

Tryplasma sp.

Calostylis spongiosa

Arachnophyllum mamillare

A. granulosum

Craterophyllum(?) solitarium

Pycnactis tenuiseptatus

Schizophaulactis densiseptatus

Cystiphyllum spinulosum

Favosites sp. A

Halysites(?) cf. H. meandrinus

Cladochonus sp. A

Syringolites sp. A

Alveolites labrosus

Propora eminula

Heliolites spongodes

H. spongiosus

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NORTH & SOUTH

Dinophyllum hoskinsoni

Rhegmaphyllum daytonensis

Calostylis lindstroemi ?

Favosites favosus

F. discoideus

F. hisingeri

F. densitabulatus

Paleofavosites prolificus

Halysites nitidus

Syringopora reteformis

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TEXT-FIGURE 5a

Number of coral species occurring at each locality investigated, in the Brassfield Formation: Size of dot marking locality is proportional to number of species found there. In compiling this map, use was made of data from Foerste's work that was considered reliable. Also, several species questionably identified in this study from the field were included where it was probable that they represented a species other than those already identified from that locality. In this plot, rugosans, tabulates and heliolitids are considered together. In plots immediately following, each group is considered separately.

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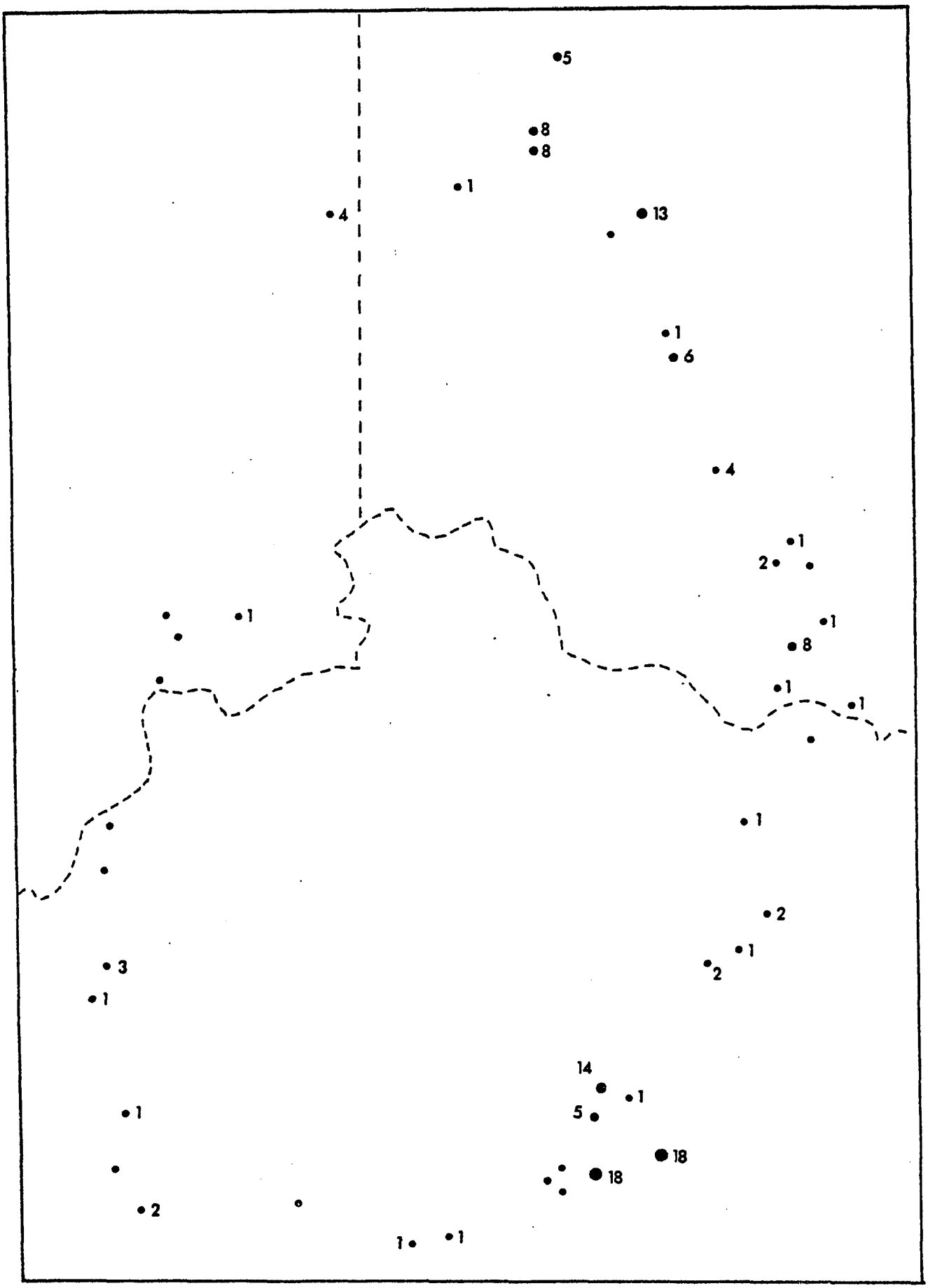

42h

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TEXT-FIGURE 5b

Number of species of rugose corals at each locality of the Brassfield Formation visited in this study

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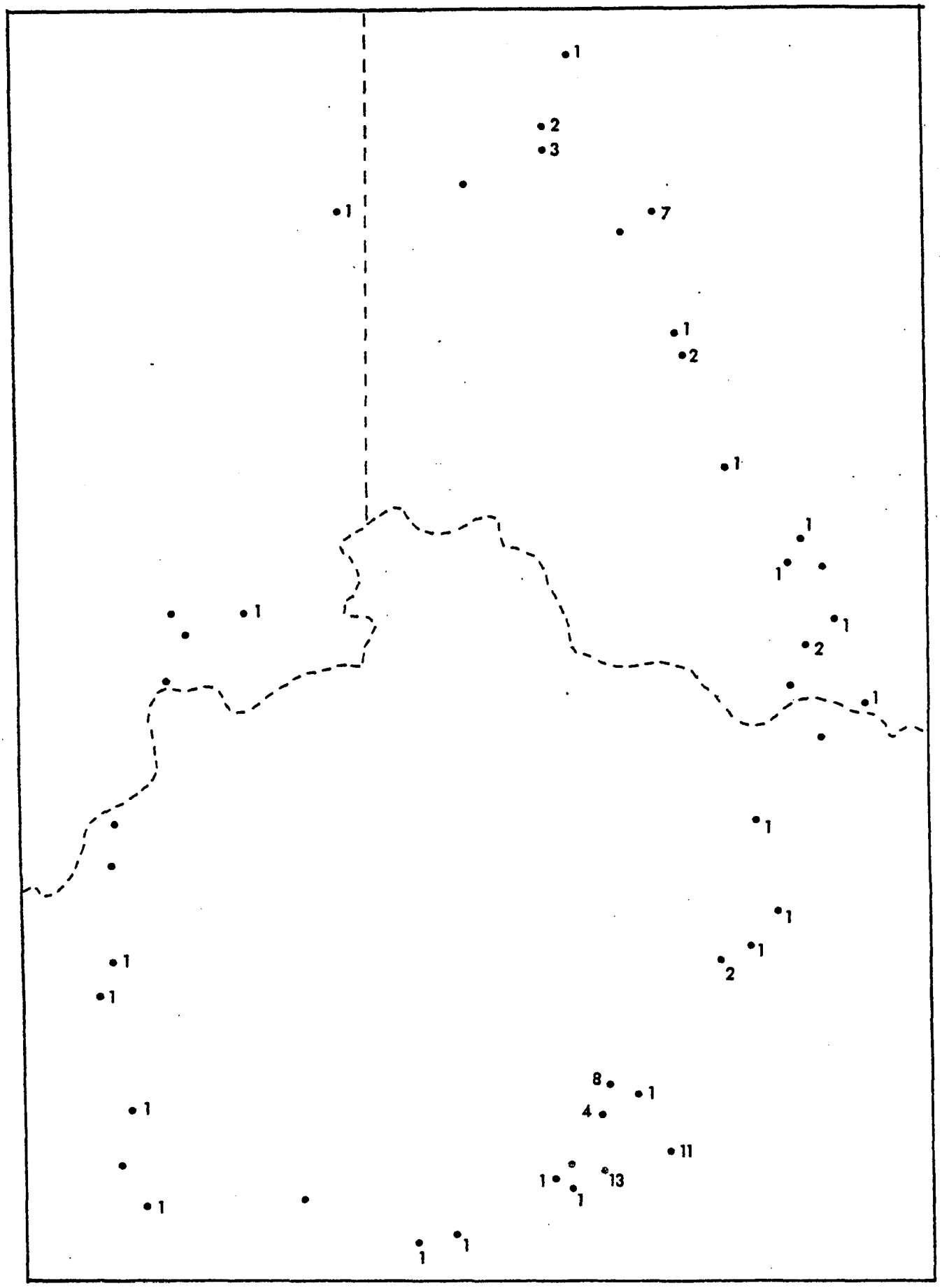

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TEXT-FIGURE 5c

Number of species of tabulate corals at each locality of the Brassfield Formation visited in this study

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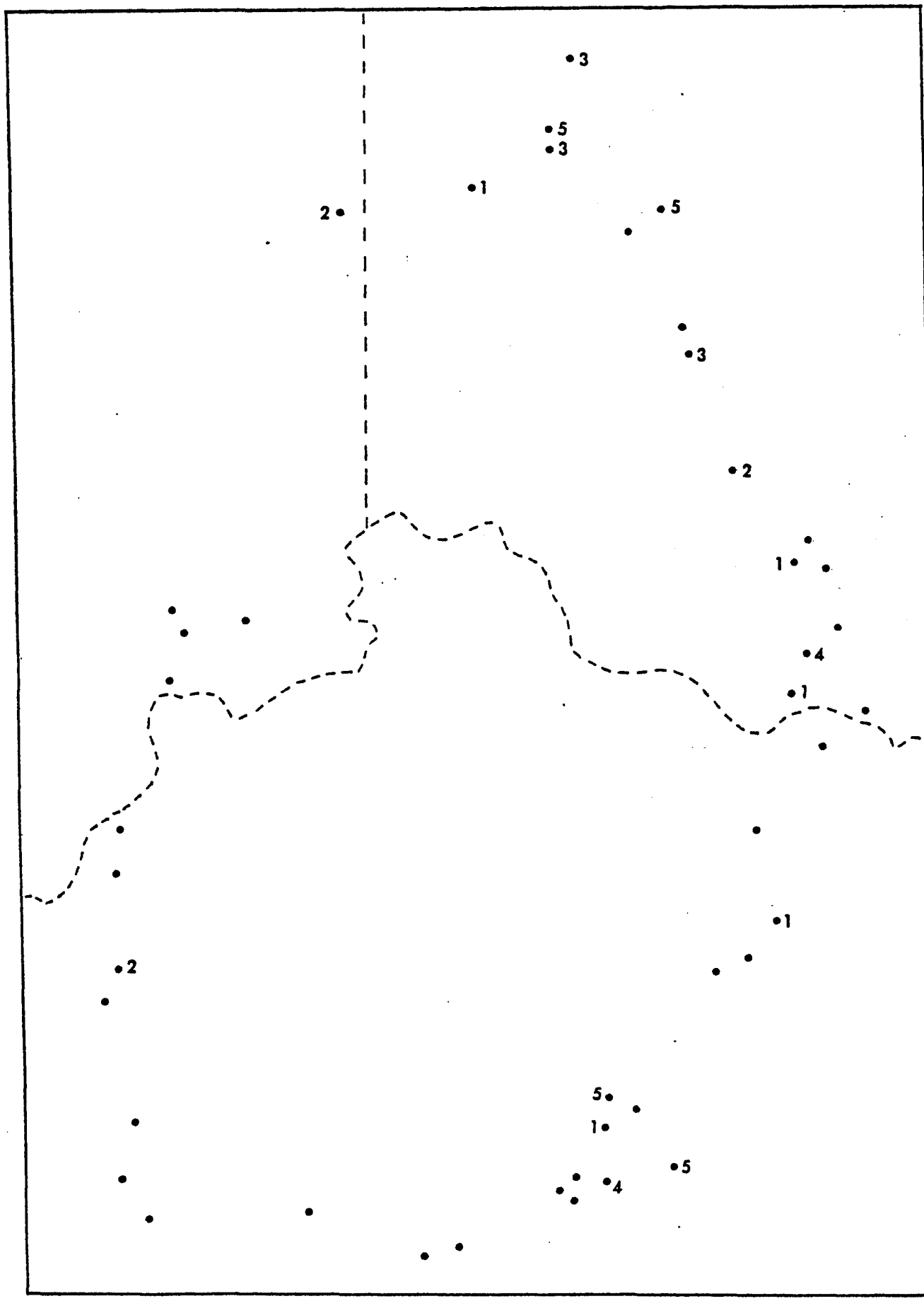

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TEXT-FIGURE 5d

Number of species of heliolitid corals at each locality of the Brassfield Formation visited in this study

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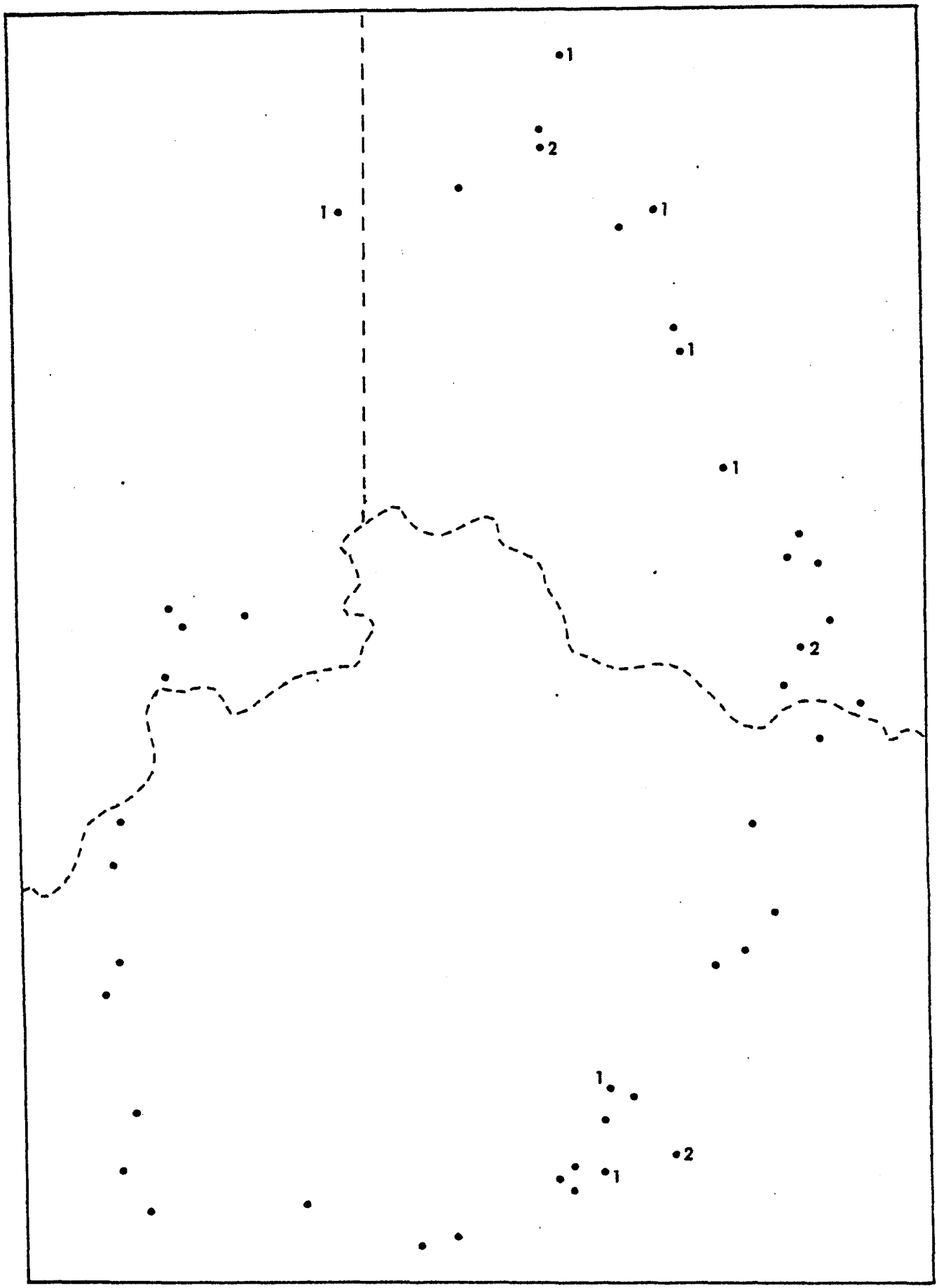

42n

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TEXT-FIGURE 5e

Brassfield Formation localities visited in this study, at which the solitary rugose coral Rhegmaphyllum daytonensis (Foerste) 1890 was found: These localities are marked by the larger dots. R. daytonensis is the most widely-occurring coral species of the Brassfield in the study area (see Table 3).

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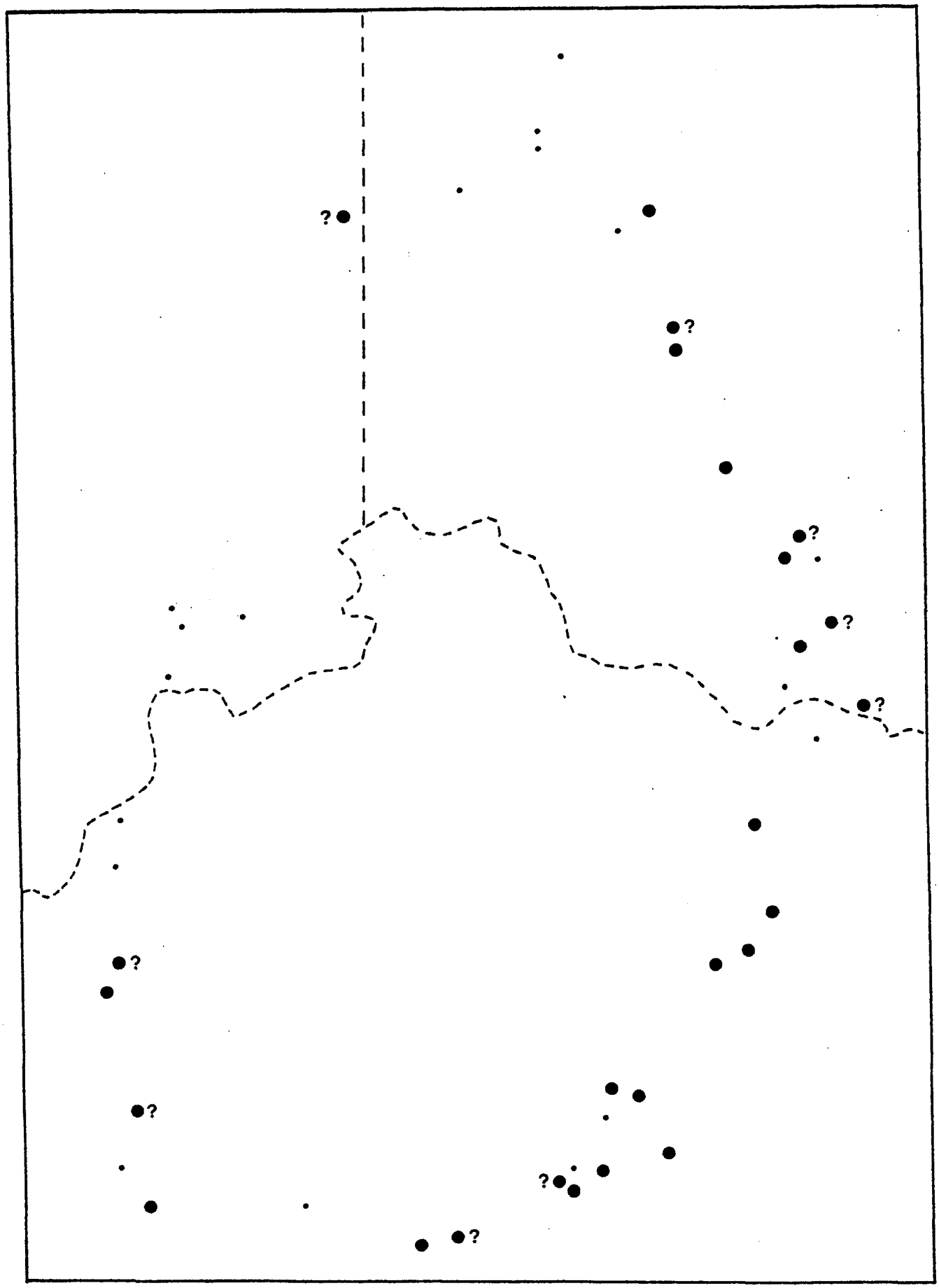

42p

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abundant at some of these localities.

South of this chain of localities is a small area containing sites of almost totally-barren Brassfield, in which the very top of the sections bear a coral fauna of even greater diversity than that encountered in the north. Again, as in the north, these sites are surrounded by localities with relatively few corals and low diversity.

There is much work that needs to be done before we can truly understand the distribution of Brassfield corals, and the environments in which they lived. Nonetheless, by analyzing the association of corals with general types of sediments, and by using a possible modern homologue as a model for the Brassfield Sea and its history, we can obtain what is at least a plausible hypothesis. Such a possible homologue has been found, in the form of Rodriguez Bank in the Florida Keys (see discussion under "Brassfield Lithosome" and below).

Coral-sediment associations - Table 5 shows the distribution of corals with respect to general type of sediment. All three sediment types contain rugosans, tabulates and heliolitids in roughly comparable proportions.

The fine-grained dolomite contains the most diverse assemblage, with twenty-nine species found only in this rock-type. Seventeen species occur only in the coarse-grained limestone (though three of these have been questionably iden-

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TABLE 5

Categorization of the Brassfield coral species with regard to the type of sediment with which they are associated

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DOLOMITE ONLY

Streptelasma scoleciforme

Dinophyllum stokesi

Dalmanophyllum linguliferum

Paliphyllum primarium

Cyathactis typus

C. sedentarius

Protocyathactis cf. P. cybaeus

Tryplasma radicula

T. cylindrica

Tryplasma sp.

Calostylis spongiosa

C. lindstroemi

Arachnophyllum mamillare

A. granulosum

Craterophyllum(?) solitarium

Pycnactis tenuiseptatus

Schizophaulactis densiseptatus

Cystiphyllum spinulosum

Favosites densitabulatus

Favosites sp. A

Halysites(?) cf. H. meandrinus

Cladochonus sp. A

Cladochonus sp. B

Syringolites sp. A

Alveolites labrosus

A. labechii

Propora eminula

Heliolites spongodes

H. spongiosus

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LIMESTONE ONLY

Dinophyllum semilunum

Dalmanophyllum(?) obliquior

Schlotheimophyllum patellatum

S. ipomaea

Paliphyllum suecicum

P. regulare

Strombodes socialis

Petrozium pelagicum

Favosites discoideus

Paleofavosites prolificus

Halysites catenularius

H. nitidus

Catenipora gotlandica

C. favositomima

Striatopora flexuosa

Propora conferta

P. exigua

Palaeoporites sp.

SHALE ONLY

Schlotheimophyllum benedicti

Cladochonus sp. C

DOLOMITE & LIMESTONE

Dinophyllum hoskinsoni

Rhegmaphyllum daytonensis

Favosites hisingeri

Syringopora reteformis

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tified from dolomite as well). Only five species can be confidently said to occur in both the dolomite and limestone. Besides these, two species have so-far been found only in the clay.

Examination of the distribution of corals from the standpoint of sediment type (Table 5) and geography (Table 4) shows a close correlation. In effect, the species that are characteristic of the southern area are so mostly due to the dominance of fine-grained dolomite in that region, while the northern species are apparently controlled by the restriction of coarse-grained limestone largely to that area. Of course, it need not be the sediments themselves for which the corals are specific, but more likely the environments they represent.

Comparable with Rodriguez Bank, the fine-grained dolomite of most of the Brassfield is thought to represent a restricted, near-shore environment, similar to Florida Bay today. It is possible that these consisted originally of lime-muds (micrites), and were subsequently dolomitized, but no definite pronouncements are yet warranted by the information available. As the Brassfield Sea transgressed in a northerly direction, this facies supported a small number of coral species, virtually all of them solitary rugosans, and few of which have been identified and described in this study. They generally appear to be streptelasmatids, corals whose lack of a dissepimentarium makes them more akin to the

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Ordovician forms than to those of the later Silurian.

In places, as the water deepened during transgression and more open-marine conditions prevailed, the resulting improved circulation supported an increased population of benthos, especially including bryozoa, corals and pelmatozoan echinoderms. The skeletons of these organisms accumulated into "shell piles" similar to Rodriguez Key.

Clay found its way into the environment, and was sometimes stabilized, perhaps by cystoid roots and algae, into mounds such as those seen at locality 7 near Fairborn, Ohio (Kissling, 1973, p. 49; oral communication, 1974). The sources of this clay are uncertain, but may have been the Richmondian shales to the north and west.

In these "banks" or "shell piles", coral life was abundant. Limestone bedding planes are covered with Favosites forbesi and Paleofavosites prolificus, as well as less-abundant species. Here colonial forms dominated the fauna. Few if any seem to have cemented themselves to firm substrates (except presumably to shell fragments in the earliest stages of skeletal development), so that they were subject to transport by strong currents. Most of the massive forms maintained a low physical profile, offering a small cross-sectional area to the currents. Kissling (1973) has shown this lack of firm attachment, and even current-inspired vagrancy, in the case of F. discoideus at Fairborn, Ohio (which he calls

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F. favosus), and has compared its probable mode-of-life with that of the modern scleractinian coral, Siderastrea radians in the Florida Keys.

The remarkable "clay-coral" bed lies in the midst of these supposed "bank" sediments at locality 7a (Fairborn). It consists of a bed of mostly large colonial corals, a large proportion of them overturned and showing signs of considerable wear. These corals (Paleofavosites prolificus, Catenipora gotlandica, Propora conferta, Strombodes socialis, Favosites discoideus, and the solitary rugosans Paliphyllum cf. P. suecicum and Dinophyllum semilunum) lie in a matrix of clay, and are stacked one above the other. The entire bed extends laterally for some sixty meters, and is about .6 meter in maximum thickness. These corals, and nearly all other species found in the clay at other localities occur also in the coarse-grained limestone, and the possibility that this stratigraphic feature represents a storm-beach of corals swept from the bottom and piled into a wave-resistant structure, comparable to the French Dry Rocks off of Tavernier Key, Florida Keys, has been discussed in the section on "Brassfield Lithosome".

The clay beds of the northern localities do not always contain such large and abundant specimens as found in the bed just described, but they do contain a much more concentrated assemblage of corals (especially at localities 15 and 55) than does the adjacent and surrounding limestone.

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In the southern region, especially at localities 1 (Panola), 46 (College Hill) and 53-53a (Irvine region), the top of the Brassfield (Noland Member) contains abundant shell material in dolomite. Here is found the greatest diversity of coral species of the entire Arch, all in the uppermost few inches of the outcrops. A low-energy environment is attested to by several factors: Delicate fenestrate bryozoans are abundant; many of the solitary rugosans (e.g., Tryplasma cylindrica and Streptelasma scoleciforme) are scolecoid and must have lain free on their sides; finally, several species (e.g., Calostylis lindstroemi and Protocyathactis cf. P. cybaeus had small talons at their extreme bases for attachment, which probably would not have supported them in rough water. (One specimen of C. lindstroemi, Plate 6, figures 16, 17, has such a tiny talon, but it is so long and scolecoid that it must have been attached only in its very early stages.)

As mentioned in the previous section the Noland Member of the southern Brassfield is regarded as about coeval with the northern Brassfield in the vicinity of Dayton. In this case, diverse southern fauna would about correspond in age with that of the north. In support of this contention, some elements of the southern fauna have been found near the top of the Brassfield in the north. Specifically, a single slab (UCGM 41859) from the upper Brassfield at locality 13 (Todd Fork near Wilmington, Ohio)

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contains Favosites favosus and Calostylis lindstroemi. This suggests some comingling of the restricted, quiet environment inhabited by these species, with the more open-marine environment of the northern fauna. As to why this southern fauna of the dolomites did not appear in the earlier transgressive sequence in the south, but is restricted to the very top, this is uncertain, though it may in part be due to its not yet having evolved.

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THE ANCESTRY, GEOGRAPHICAL EXTENT, AND FATE OF THE BRASSFIELD CORAL FAUNA

Having determined the major components (species) of the Brassfield coral fauna, several questions immediately presented themselves:

1) Where did the corals come from? Did this fauna have an ancestral homeland, or did its components immigrate from a number of places? Also, how many species were in existence prior to the start of Brassfield deposition?

2) Over what area did the Brassfield coral fauna extend as a recognizeable entity?

3) What ultimately became of these corals after the termination of Brassfield deposition in the Cincinnati Arch area?

In quest of answers to these questions, an extensive search was made of the literature on Late Ordovician through Wenlockian (and some Ludlovian) corals of the world. In all, some two hundred references were consulted, with the object of gaining information from as many parts of the world as possible (Figure 6). These references are listed on Table 6. All consisted of descriptions and figures (or, in the absence of figures, of descriptions sufficiently-detailed to give reasonable confidence of identification). Where possible, the specimens themselves were examined, but these represent a small minority of the cases. In no instance was a faunal list, or the mere mention of an occurrence used as data in

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TEXT-FIGURE 6

Map showing continent distributions during the Silurian and Early Devonian (after Briden et al., 1973, p. 127): Localities for which coral data were obtained for purposes of analyzing the history of the Brassfield coral fauna before, during and after Brassfield time, are marked by numbers which indicate the approximate number of references covering each region. Numerous other references (see Table 6) did not apply to one specific area, and are not included in this map. The longitudinal scale is in 30° intervals.

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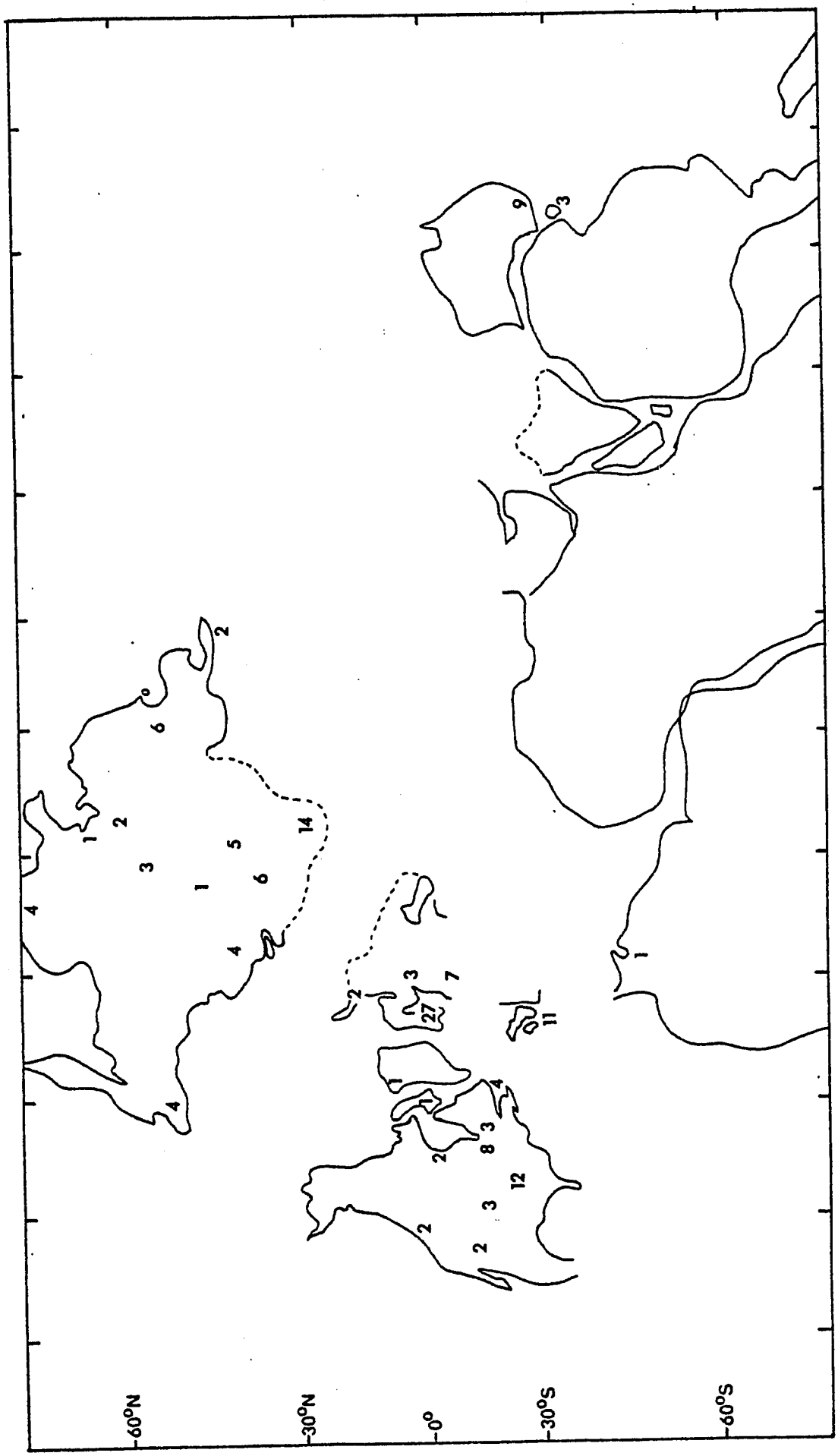

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TABLE 6

References used in analysis of the world-wide distribution of the Brassfield coral species before, during and after the time represented by the Brassfield Formation in the study area

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NORTH AMERICA

Western Tennessee: Amsden (1949), Roemer (1860) - Sil.

Northern Great Lakes: Bolton & Copeland (1972a) - Sil.; Rominger (1876) - Sil.; Hume (1925) - Sil.; Bolton (1957, 1966, 1968) - Sil.; Stumm (1963) - Ord.; Williams (1919) - Sil.; Sinclair (1955) - Ord.

Eastern Great Basin: Budge (Thesis) - Ord., Sil.

Southwest U.S.: Flower (1961), Hill (1959b) - Ord.

Northwest Ohio: Floyd et al. (1972) - Sil.

Ohio, Indiana, Kentucky: Laub (this study) - Sil.; Stumm (1964) - Sil.; Davis (1887) - Sil.; Kissling (1970, 1973) - Sil.

Canadian Maritimes: Northrop (1939) - Sil.; Twenhofel (1928) - Sil.; Shrock & Twenhofel (1939) - Sil.; Bolton (1972) - Ord. & Sil.

Canadian Cordillera: Norford (1962) - Ord., Sil.; Wilson (1926) - Ord.

Maine, Quebec: Oliver (1962, 1962a) - Sil.; Stumm (1962)

Iowa: Philcox (1970) - Sil.

Illinois & Missouri: Savage (1913) - Sil.

Oklahoma: Sutherland (1965) - Sil.

Manitoba: Okulitch (1943), Nelson (1963), Sinclair (1955) - Ord.

Canadian Arctic: Teichert (1937) - Ord, Sil.; Cox (1937)

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Greenland: Troedsson (1928) - Ord., Sil.

New York State: Hall (1847) - Ord.; Hall (1852) - Sil.; Oliver (1963) - Sil.

SOUTH AMERICA

Merida Andes, Venezuela: Scrutton (1971) - Sil.

EUROPE

Gotland: Tripp (1933) - Ord., Sil.; Lindstrom (1868, 1882, 1896) - Sil. (possibly some Ord.); Jones (in part; 1936) - Sil.

Ireland: Kal'o & Klaamann (1965) - Ord.

Norway: Spjeldnaes (1964) - Ord.; Stasínska (1967) - Ord., Sil.; Kiär (1899) - Sil.; Scheffer (1933) - Sil.; Klaamann (1971) - Sil.?; Spjeldnaes (1961) - Ord.

Sweden: Thorslund (1948) - Sil.; Stasínska (1967) - Ord., Sil.; Hisinger (1837); Neuman (1968) - Ord.

Czechoslovakia: Prantl (1940) - Sil.; Počta (1902) - Sil.; Prantl (1957) - Sil.; Galle (1968, 1973) - Sil.

Podolia: Bulvanker (1952) - Sil.; Różkowska (1946) - Sil.; Sytova (1968) - Sil.

Girvan, Scotland: Nicholson & Etheridge (1878, 1880) - Ord., Sil.; Wang (1948) - Ord., Sil.

Leningrad region: Cherkesov (1936) - Sil.

Germany: Weissermel (1894) - Sil.

Eastern Alps: Flügel (1956)

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Estonia: Klaamann (1959, 1961) - Sil.; Klaamann (1961a) - Ord.; Klaamann (1964) - Ord., Sil.; Kal'o (1956, 1958a, 1961) - Ord.; Kal'o (1957, 1958b) - Ord., Sil.

England: Smith (1930a) - Sil.; Tomes (1887) - Sil.?; Alexander (1947) - Sil.; Colter (1956) - Sil.; Butler (1937) - Sil.; Jones (1936) - Sil.; Lonsdale (1839) - Sil.; Milne-Edwards & Haime (1850-1854) - Sil.; Sutton (1966) - Sil.

Miscellaneous Europe - Lindström (1882b) - Russia; Neuman (1969) - Ord. of Scandinavia; Stasínska (1967) northern Europe; Dybowski (1873, 1874) - Baltic region; Milne-Edwards & Haime (1851);

AFRICA

Kenya coast: Gregory (1938) - age uncertain

ASIA

Kazakhstan: Poltavtseva (1965) - Sil.; Sharkova (1964) - Sil.; Sultanbekova (1971) - Ord.

Lushan, Kueichow: Chen (1959) - Sil.; Tsin (1956) - Sil.

Northwest Korea: Shimizu et al. (1934) - Sil.

Yunnan: Wang (1944) - Sil.; Wang (1947) - Sil.; Grabau (1926) - Sil.; Fontaine (1964)

Inner Mongolia: Wu (1958) - Sil.

Kansu: Yu (1956) - Sil.; Chi (1935) - possibly Devonian

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Afghanistan: Desparmet (1969) - Sil.; Lafuste & Desparmet (1970) - Sil.

East Iran: Flügel & Saleh (1970) - Sil.; Flügel (1962) - Sil.; Saleh (1969) - Sil.

Himalayas: Sahni & Gupta (1968) - Sil.; Cowper-Reed (1912) - Ord. & Sil.

Malaysia: Thomas (1963) - Sil.; Thomas & Scrutton (1969) - Sil.

Choltagh, Tuva, Mongolia: Chernyshev (1937b)- Sil.; Regnell (1941, 1961) - Sil.

Taimyr region, Norilsk: Chernyshev (1941a, 1941b) - Sil.; Ivanovskiy (1963) - Ord., Sil.; Zhizhina (1968) - Sil.; Zhizhina & Smirnova (1957) - Sil.

Uzbekstan: Dzyubo (1971) - Sil.; Lavrusevich (1971a) - Ord.; Lavrusevich (1971b) - Sil.

Siberian Platform (primarily the basins of the Podkamennaya Tunguska, and the Sukhaya Tunguska Rivers): Iskyul (1957) - Sil.; Ivanovskiy (1959a) - Sil.; Ivanovskiy (1960, 1962) - Sil.; Ivanovskiy (1961) - Ord.; Ivanovskiy (1959b, 1963) - Ord., Sil.; Soshkina (1955) - Ord., Sil.

Chukchee Penin., Kolyma River Basin: Kiryushina et al. (1939) - Sil.; Preobrazhenskiy (1964, 1968) - Ord.; Rukhin (1938) - Sil.

Sayan region, Siberia: Naumenko (1970) - Sil.

Novaya Zemlya and region to south: Zhizhina (1969) - Ord.; Chernyshev (1938a) - Sil.

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Salair Mts. and Gornogo Altay: Dzyubo (1960, 1962) - Ord.; Zheltonogova (1968) - Sil.; Cherepnina (1962) - Ord.; Cherepnina (1965) - Sil.

Tadzhikstan - Leleshus (1972) - Sil.; Lavrusevich (1965) - Sil.

Miscellaneous Asia: Orlov (1930) - Sil. of Ferghana; Yu (1960) - Ord. of China; Chernyshev (1938b) - U. Sil. of Letney River Basin

OCEANIA

New South Wales, Australia: Hill (1957) - Ord.; Hill (1940, 1954) - Sil.; Ross (1961) - Sil.; Webby (1971) - Ord.; Strusz (1961) - U. Ord., or L. Sil.; Webby & Semeniuk (1969) - Ord.; Webby (1972) - Ord.; Jones (1944)

Tasmania: Hill (1955) - Ord.; Hill (1942) - U. Ord.?, Sil.; Hill & Edwards (1941) - Ord.

Japan: Sugiyama (1940) - Sil.; Hamada (1956) - Sil.; Hamada (1958) - Ord., Sil.

New Guinea: Musper (1938) - Sil.?

Miscellaneous Oceania: Etheridge (1904, 1907) - Australia; Jones (1937) - Australian Favosites; Jones & Hill (1940) - Australian heliolitids

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WORLD (MISCELLANEOUS LOCALITIES)

Lindström (1899) - heliolitids of world

Tesakov (1965) - Silurian corals of USSR

Ivanovskiy (1969) - U. Ord. to Dev., world-wide (*Tryplasmatidae* and *Cyathophylloididae*)

Yabe (1915) - *Halysitidae*, world-wide

Jones (1936) - *Favosites* of various regions

Hill & Jell (1970) - tabulates of various regions

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this compilation.

Works by Berry & Boucot (1970, 1972), Hamada (1958), Gignoux (1950) and Manten (1971) made it possible to define the ages of almost all occurrences sufficiently to give meaningful information on the history of these species before, during and after Brassfield sedimentation (Tables 7 and 8). These results are presented here, using the most up-to-date map currently available (Briden et al., 1973).

Pre-Brassfield Distribution (Figure 7) - Eight of the species appear to have existed prior to Brassfield time. Three more may also predate the Brassfield, but this is uncertain. A twelfth species, belonging to the genus Protocyathactis, has not itself been reported in pre-Brassfield beds, but a very similar, and possibly ancestral species, P. cybaeus, has. Of this total of twelve species, eight range back to the Late Ordovician, while the remainder first appear in the Early Llandovery.

No single region appears to have been the homeland of these earliest Brassfield species, as they are found in North America, Europe, Asia, and possibly South America, with the Canadian Maritime Provinces and the Baltic area containing the greatest numbers.

Of interest is the fact that none of the rugose species have been found in the pre-Brassfield rocks of North America. They occur in the Baltic area and the Siberian Platform, with a possible additional occurrence in Venezuela. On the other

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TEXT-FIGURE 7

Same base-map as that used in Text-figure 6, showing parts of the world in which Brassfield coral species occurred before the deposition of the Brassfield Formation (before the Middle Llandovery): The numbers indicate the number of species of Brassfield corals in each region.

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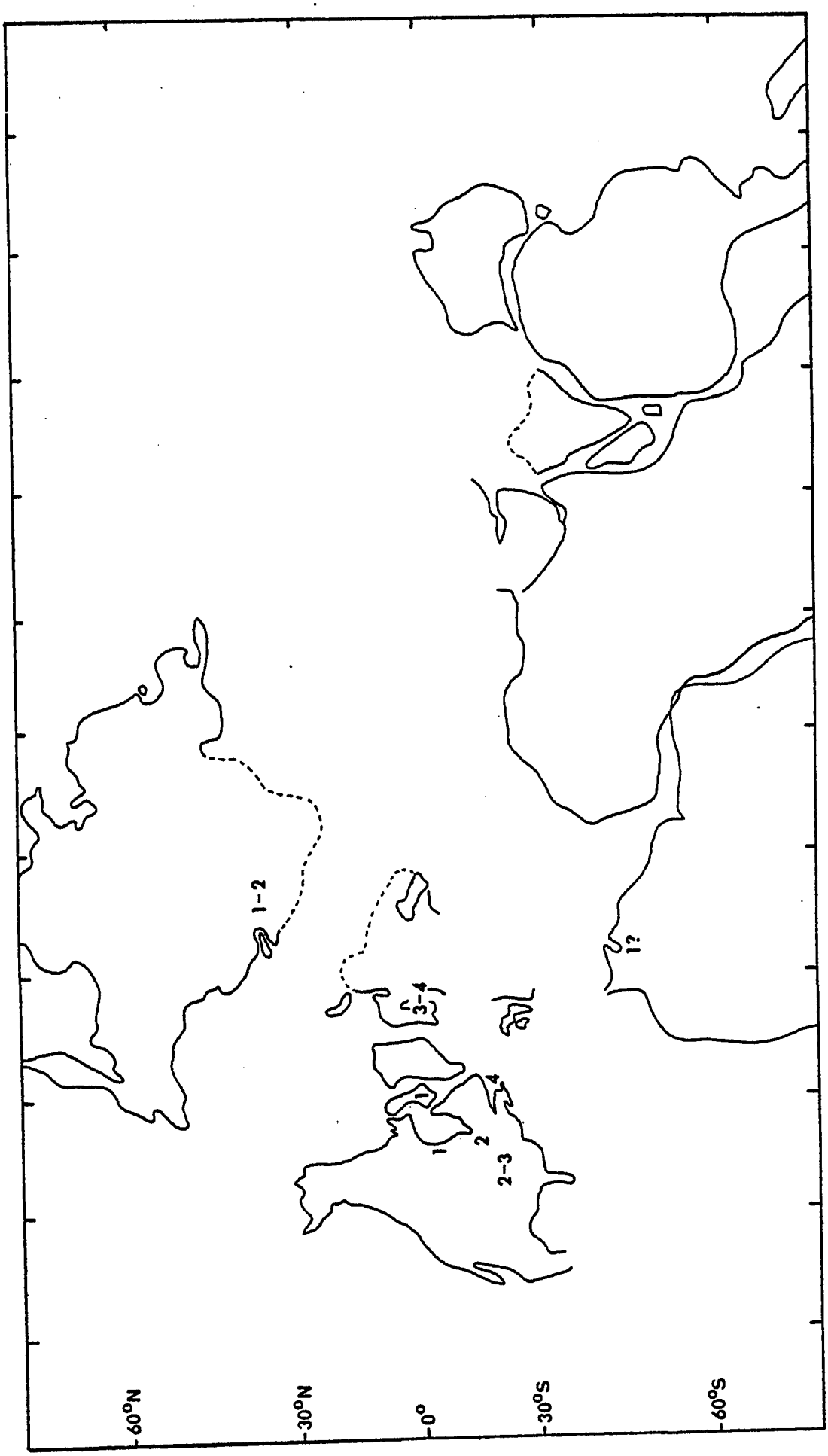

50b

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hand, except for occurrences in the Baltic region, the tabulates and heliolitids that later helped populate the Brassfield Sea, are found only on the North American continent.

Distribution During Brassfield Time (Figure 8) - The current data indicate that about forty of the fifty-three Brassfield coral species first entered the fossil record during Brassfield time. The fauna appears to have been rather restricted geographically, with only six species (and two others questionably) having been found elsewhere during this time: in the northern Great Lakes area, Manitoba, the Canadian Maritime Provinces, and the Baltic area. Of these, the fauna of the Maritimes unquestionably shows the greatest similarity to the Brassfield fauna.

Post-Brassfield Distribution (Figure 9) - At least twenty-seven, and possibly as many as thirty-two, coral species survived the termination of Brassfield conditions in the Cincinnati Arch region. These went on to populate a large portion of the epicontinental sea area in later Silurian time, uniting with other species to form the well-known post-Brassfield coral faunas of Gotland, Britain, Bohemia, the Siberian Platform, the Far East, and eastern North America.

Several species reappeared in the general vicinity of what had been the Brassfield Sea. When the Louisville Limestone (Late Wenlockian and Early Ludlovian) was being

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TEXT-FIGURE 8

Same base-map as that used in Text-figure 6, showing parts of the world in which Brassfield coral species occurred during the deposition of the Brassfield Formation (during the Middle Llandovery): The numbers indicate the number of Brassfield species in each region.

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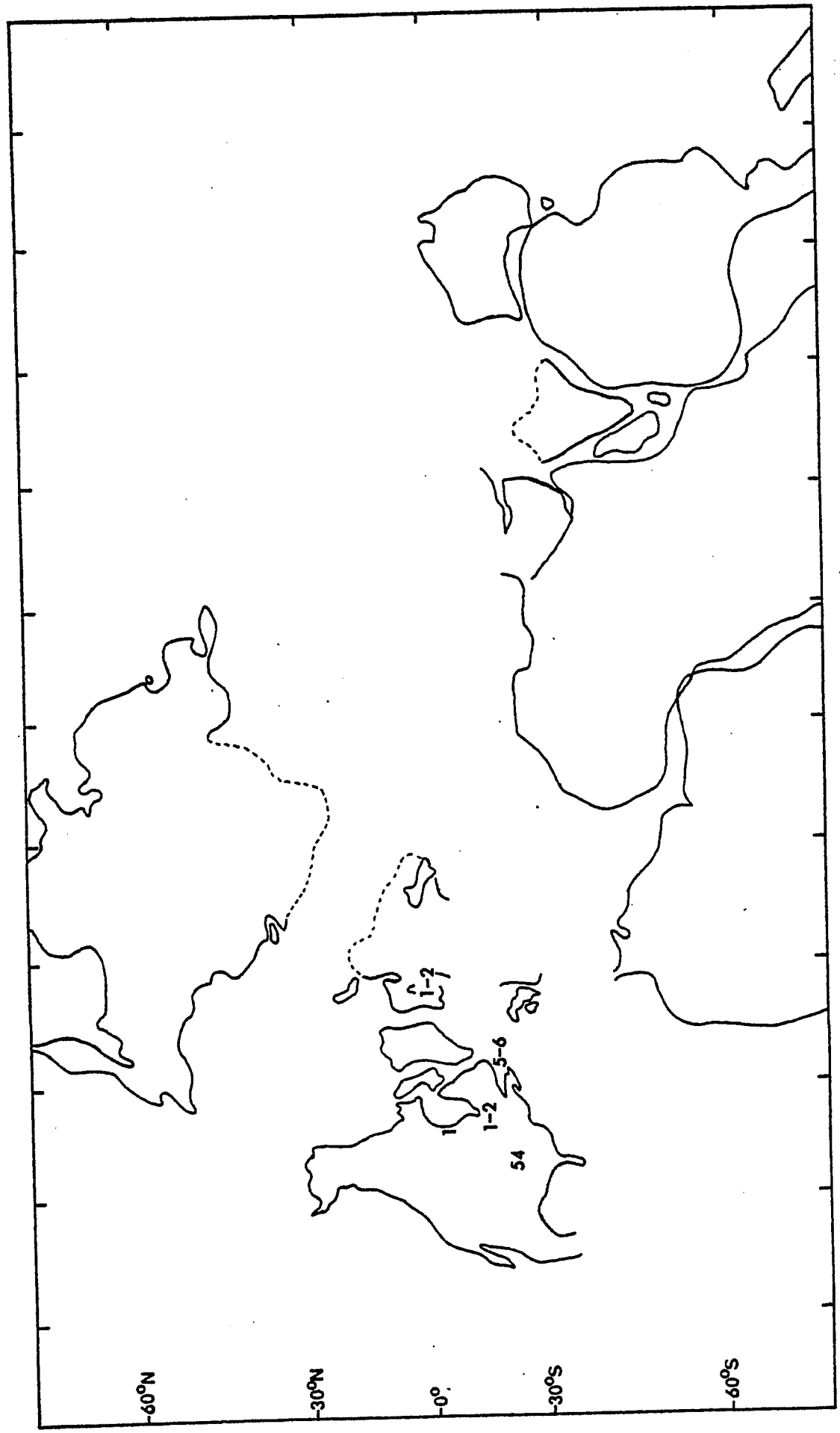

51b

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TEXT-FIGURE 9

Same base-map as that used in Text-figure 6, showing parts of the world in which Brassfield coral species occurred after the deposition of the Brassfield Formation (after the Middle Llandovery): The numbers indicate the number of species of Brassfield corals in each region.

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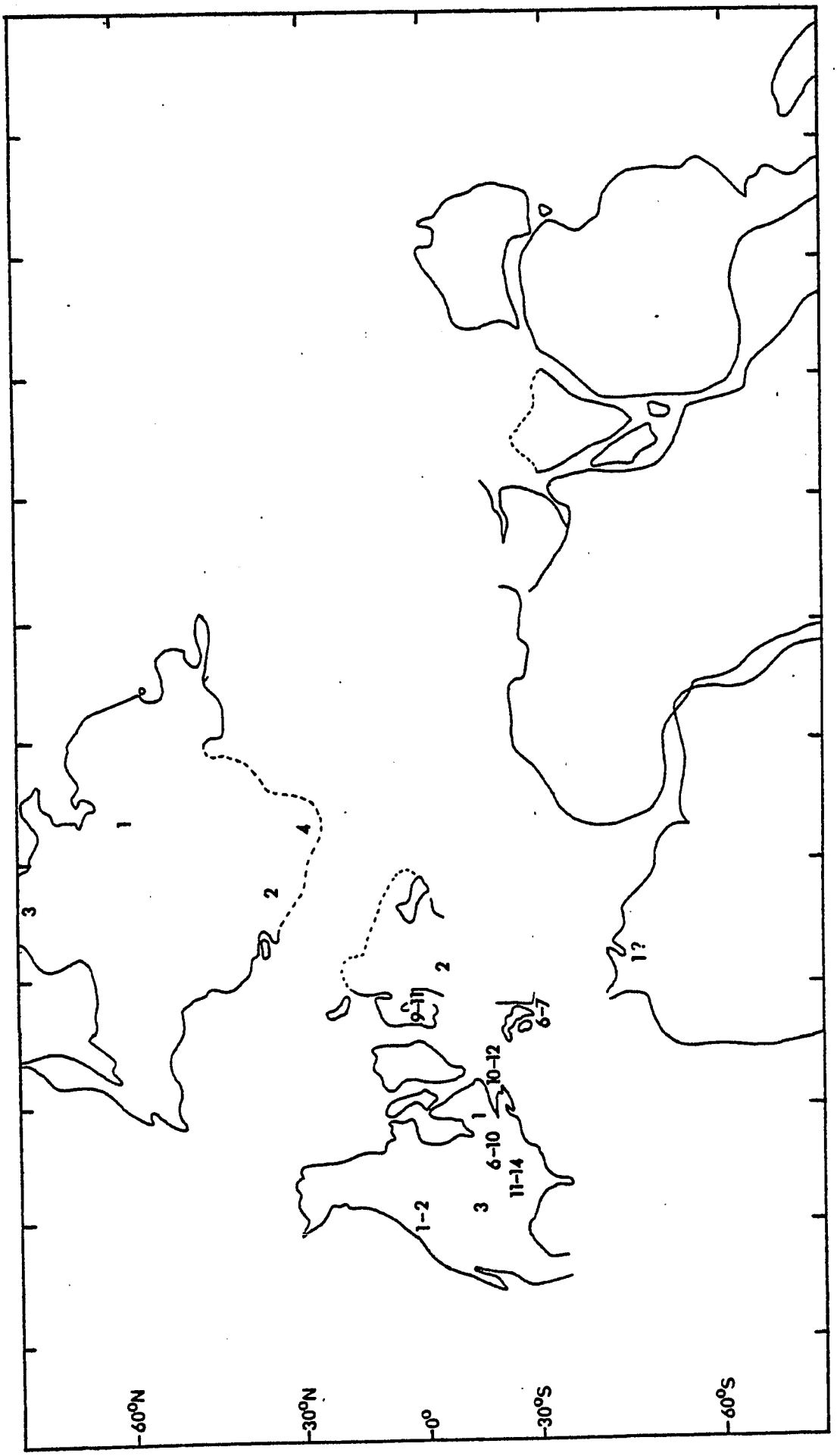

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deposited at Louisville, Kentucky, seven or eight Brassfield species were present (Schlotheimophyllum benedicti, Halysites nitidus, Arachnophyllum mamillare, Heliolites spongodes, Favosites discoideus, F. hisingeri, Schlotheimophyllum ipomaea, and possibly Dinophyllum linguliferum). Later in the Early Ludlovian, the Brownsport Formation of western Tennessee was deposited in a sea inhabited by Favosites discoideus, Favosites sp. A, Halysites(?) cf. H. meandrinus, and possibly Tryplasma radicula.

Our present knowledge of the Ordovician and Silurian corals of western North America and South America is very limited. The presence of Brassfield species in the former, and possibly in the latter area marks them as promising regions for future investigations into the history of this fauna.

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TABLE 7

Chronologic ranges of the Brassfield coral species: The presence of a species anywhere in the world before the time of the Brassfield Formation is denoted by an X in column A. The O and S associated with these notations indicates that the species occurs, respectively, in the Late Ordovician, or the Early Llandovery (pre-Brassfield Silurian).

Column B records the presence of a Brassfield species during Brassfield time (Middle Llandovery) anywhere in the world except in the study area.

Column C records the presence of a Brassfield species anywhere in the world after Brassfield time.

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	A	B	C
RUGOSANS			
Fam. Streptelasmatidae			
Streptelasma scoleciforme sp. nov.			
Dinophyllum stokesi (Milne-Edwards & Haime) 1851			X
Dinophyllum hoskinsoni (Foerste) 1890			
Dinophyllum semilunum sp. nov.			
Dalmanophyllum linguliferum (Foerste) 1906	X? (O)?		X?
Dalmanophyllum(?) obliquior (Foerste) 1890			
Rhegmaphyllum daytonensis (Foerste) 1890	X? (S)	X?	X?
Schlotheimophyllum patellatum (Schlotheim) 1820			X
Schlotheimophyllum benedicti (Greene) 1900			X
Schlotheimophyllum ipomaea (Davis) 1887			X
Fam. Paliphyllidae			
Paliphyllum primarium Soshkina, 1955	X (O)		
Paliphyllum suecicum Neuman, 1968 var. nov.	X (O)		

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	A	B	C
Paliphyllum regulare sp. nov.			
Cyathactis typus Soshkina 1955			X
Cyathactis sedentarius (Foerste) 1906			
Protocyathactis cf. P. cybaeus Ivanovskiy, 1961	X? (O)		
Fam. Tryplasmatidae			
Tryplasma radicula (Rominger) 1876			X
Tryplasma cylindrica (Wedekind) 1927			X
Tryplasma sp.			
Fam. Calostylidae			
Calostylis spongiosa Foerste, 1906			X
Calostylis lindstroemi Nicholson & Etheridge, 1878			X
Fam. Chonophyllidae			
Strombodes socialis (Soshkina) 1955		X	X
Fam. Arachnophyllidae			
Arachnophyllum mamillare (Owen) 1844			X

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	A	B	C
Arachnophyllum granulosum Foerste, 1906			
Petrozium pelagicum (Billings) 1862		X	
Craterophyllum(?) solitarium (Foerste) 1906			
Fam. Halliidae			
Pycnactis tenuiseptatus sp. nov.			
Schizophaulactis densiseptatus (Foerste) 1906			
Fam. Cystiphyllidae			
Cystiphyllum spinulosum Foerste, 1906			
TABULATES			
Fam. Favositidae			
Favosites favosus (Goldfuss) 1826		X?	X
Favosites discoideus (Roemer) 1860	X (S)	X	X
Favosites hisingeri Milne-Edwards & Haime, 1851		X	X
Favosites sp. A			X
Favosites densitabulatus sp. nov.			

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	A	B	C
Paleofavosites prolificus (Billings) 1865b	X (O)	X	X
Fam. Halysitidae			
Halysites catenularius (Linnaeus) 1767			X
Halysites nitidus Lambe, 1899			X
Halysites(?) cf. H. meandrinus (Troost) 1840			X(?)
Catenipora gotlandica (Yabe) 1915	X (S)		X
Catenipora favositomima sp. nov.			
Fam. Moniloporidae			
Cladochonus sp. A			
Cladochonus sp. B			
Cladochonus sp. C	X (O)		
Fam. Syringoporidae			
Syringopora reteformis Billings, 1858			X
Fam. Syringolitidae			
Syringolites sp. A			

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	A	B	C
Fam. Alveolitidae			
Alveolites labrosus (Milne-Edwards & Haime) 1851			X
Alveolites labechii Milne-Edwards & Haime, 1851	X? (O)		X
Fam. Pachyporidae			
Striatopora flexuosa Hall, 1852			X
HELIOLITIDS			
Fam. Proporidae			
Propora conferta Milne-Edwards & Haime, 1851	X (O)	X	X
Propora exigua (Billings) 1865b	X (S)		X
Propora eminula (Foerste) 1906			X?
Fam. Heliolitidae			
Heliolites spongodes Lindstrom, 1899			X
Heliolites spongiosus Foerste, 1906			X?
Fam. Palaeoporitidae			
Palaeoporites sp.			

TABLE 8

Lists of Brassfield coral species arranged geographically and chronologically: The middle column consists of occurrences in strata coeval with the Brassfield Formation (Middle Llandovery) in areas other than the study area.

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PRE-BRASSFIELD	COEVAL WITH BRASSFIELD	POST-BRASSFIELD
(Eastern United States)		
P. conferta		A. mamillare
Cladochonus sp. C		C. spongiosa
A. labechii ?		S. benedicti
		S. ipomaea
		D. linguliferum ?
		T. radicula ?
		H. nitidus
		H. (?) cf. H. meandrinus ?
		F. discoideus
		F. hisingeri
		Favosites sp. A
		A. labrosus
		S. flexuosa
		H. spongodes

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(Northern Great Lakes)

P. conferta
P. prolificus

S. socialis
F. favosus ?

T. radicula
A. mamillare
D. stokesi
F. favosus ?
F. hisingeri
P. prolificus
A. labrosus ?
A. labechii ?
S. reteformis
P. eminula ?

(Canadian Maritimes)

P. conferta
P. exigua
P. prolificus
F. discoideus

P. pelagicum
F. favosus ?
F. discoideus
F. hisingeri
P. prolificus
P. conferta

A. mamillare
D. stokesi
F. favosus ?
F. discoideus
F. hisingeri
P. prolificus
H. nitidus
A. labechii
S. flexuosa
P. conferta
P. exigua
P. eminula ?

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(Baltic)

P. conferta

C. gotlandica

P. suecicum

D. linguliferum ?

P. pelagicum

R. daytonensis ?

T. cylindrica

S. patellatum

R. daytonensis ?

F. discoideus

F. hisingeri

P. prolificus

H. catenularius

C. gotlandica

P. exigua

H. spongodes

H. spongiosus ?

(Britain)

S. benedicti

C. lindstroemi

D. linguliferum ?

F. discoideus

F. hisingeri

A. labrosus

A. labechii

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(Siberian Platform)

P. primarium

P. cf. P. cybaeus

(ancestral to ours ?)

S. socialis

C. typus

(SW Siberia & Iran)

S. patellatum

S. socialis

H. catenularius

C. gotlandica

(Far East)

P. prolificus

(Japan)

H. catenularius

(Japan)

P. conferta

(Japan)

H. spongodes

(Kansu Prov., China)

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(Miscellaneous localities)

P. conferta

(NE Canadian Arctic)

P. prolificus

(Manitoba)

R. daytonensis ?

(Venezuela)

P. conferta

(Manitoba)

T. radicula

(Oklahoma)

A. mamillare

(Iowa)

S. socialis

(Lake Timiskaming in Canada)

F. favosus

(Iowa & Brit. Columbia)

F. hisingeri

(Bohemia)

H. nitidus ?

(Brit. Columbia & Venezuela)

H. spongodes

(Bohemia)

H. catenularius of undetermined age, in Australia

P. conferta in Sil. of Korea, and Sil. of Siberian Platform

F. discoideus in Silurian of Korea

T. radicula in Sil. of Great Basin (western U.S.)

Favosites sp. A in Silurian of Baffin Island (Canadian Arctic)

F. hisingeri in Llandovery of Southampton Island (Canadian Arctic)

A. labrosus in Silurian of Canadian Maritimes

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ORDER RUGOSA

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Family Streptelasmatidae Nicholson in Nicholson & Lydekker, 1889

nom. correct. Wedekind, 1927 (pro Streptelasmidae Nicholson in Nicholson & Lydekker, 1889)

Rugosa, consisting of solitary and fasciculate corals lacking a dissepimentarium; theca a septal stereozone; minor septa short; major septa dilated to varying degrees in early stages, meeting axially, but thinning and withdrawing from axis through ontogeny; in ephebic stage, major septa may intertwine in axis to form various types of axial structures, usually with stereomal deposits ; tabulae usually domed axially, both complete and incomplete; cardinal side convex in almost all solitary species.

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Streptelasma Hall, 1847

1847 Streptoplasma Hall, p. 17

1847 Streptelasma Hall, page facing p. 339

1876 Zaphrentis Rafinesque, Rominger, p. 140-142 (partim)

1927 Dybowskia Wedekind, p. 18 (non Dall, 1876, p. 46)

1940 Brachyelasma Lang, Smith & Thomas, p. 28, 55 (pro Dybowskia Wedekind, 1927, non Dall, 1876)

Type species - Streptelasma corniculum Hall, 1847, p. 69 (SD C.F. Roemer, 1861, p. 19)

Type locality and horizon - Lower Trenton Limestone (Upper Middle Ordovician) at Middleville, New York State

DIAGNOSIS - Solitary corals lacking a dissepimentarium; theca a septal stereozone; cardinal side convex; septocoels open throughout ontogeny; in early neanic stage, septa in contact distally, drawing apart through ontogeny to leave open axial area in ephebic stage which contains only a few septal lobes; tabulae often incomplete.

DESCRIPTION - These are solitary corals, of trochoid or cylindrical, and sometimes scolecoid form. In some species (though not the type species) basal-attachment or supportive structures may be present. The theca is a septal stereozone.

The cardinal septum is on the convex side of curved corallites, and the cardinal fossula, when present, is weakly-developed.

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In the earliest stages, the septa are in axial contact. From at least the early neanic phase onward, the septocoels are open. As the corallite grows, the axial ends of the septa draw apart, as each septum comes to occupy a proportionally smaller part of the radius than in earlier stages. At this point, the axis of the corallite contains only a few septal lobes, winding irregularly. No axial structure is developed, contrary to common belief. The minor septa are generally rather short, less than half the length of the radius.

There is no dissepimentarium. The tabulae are often incomplete, and are usually convex (though sometimes concave) in the axis.

DISCUSSION - In his original description of this genus, Hall (1847, p. 17) used the name Streptoplasma, designating thereby the axial twisting of the septa as one of the most distinctive features of the form. In this same work ("Corrections", facing p. 338), Hall corrected the generic name, with apparent propriety, to Streptelasma, the name currently used. In so modifying the name, he noted that the error had occurred "in changing the generic name from Streptophyllum, which was the original name in MS."

In this work, Hall described several species of Streptelasma (one of which, S. expansa, sic, is based upon a paratoid plate, according to its catalogue card at the American Museum of Natural History). S. corniculum, from the

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original species suite, was designated the type species by C.F. Roemer (1861, p. 19). Hall & Simpson (1887, p. xi) belatedly, and so, invalidly, selected S. expansum for this honor. Thus, Roemer's timeliness preserved Streptelasma a cnidarian appelation, rather than echinodermal.

Rominger (1876) treated Streptelasma as a subgenus of Zaphrenthis Rafinesque & Clifford, 1820. He noted (p. 141) that undue attention had been paid by Milne-Edwards to the cardinal fossula, in assigning species to Zaphrenthis. Rominger felt that Streptelasma should be accommodated under the roof of Zaphrenthis (as a subgenus), considering it to differ from the latter solely in having a less-prominent fossula and in the axial twisting and "entanglement" of its septa, giving rise to a "spongiose-cellulose pseudo-columella".

Rominger did not consider the presence of a dissepimentarium in Zaphrenthis, as distinct from its absence in Streptelasma, in determining the identity of these two genera. Also, his characterization of the axial structure as spongy suggests that he was including species of Grewingkia Dybowski (1873) in his suite of Streptelasma species. Indeed, his plates seem to support this idea. The axial mutual-involvement of the major septa of Streptelasma is much-less developed than in Grewingkia, where it is complex and "spongy". This is clearly seen in Neuman's excellent treatment of Scandinavian streptelasmatids of the Upper Ordovician (1969),

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in which he figured and described and described the internal features of the holotype of S. corniculum, together with numerous other species of Streptelasma, and of Grewingkia. Streptelasma's axial structure consists of only a few elongate septal lobes, whereas Grewingkia's is far more intricate, and includes many more lobes. In addition, while Grewingkia's neanic septal dilation tends to be great, often excluding the septocoels, that of Streptelasma is characteristically weak. Streptelasma rusticum (Billings), the famous Richmondian solitary coral of the Cincinnati Arch area is, in reality, a Grewingkia.

Wedekind (1927) introduced the genus Dybowskia from the Upper Ordovician of Norway, selecting his new species, D. prima, as the type species. Lang et al. (1940, p. 55) later noted that the generic name was preoccupied, and renamed the genus Brachyelasma. Wedekind's figures consist of a transverse view (apparently of the ephebic stage), and a longitudinal view. Taken alone, these sections make this species (and thus, the genus) a candidate for Streptelasma Hall. Neuman (1969, p. 11-17) discusses D. prima, and illustrates internal views of several specimens from Norway's Upper Ordovician, providing convincing evidence that Brachyelasma is indeed identical to Streptelasma.

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Streptelasma scoleciforme sp. nov.

Plate 1, fig. 1-8; Plate 12, fig. 1-8

Type material - Holotype: UCGM 41942 (Plate 1, fig. 1-3; Plate 12, fig. 1-4); Paratype: UCGM 41953 (Plate 12, fig. 5-8)

Type locality and horizon - Locality 1, the top of the Noland Member, Brassfield Formation, near Panola, Kentucky

Number of specimens studied - 22

DIAGNOSIS - Solitary, characteristically scolecoid Streptelasma with contratingency of septa.

DESCRIPTION - This species is characteristically scolecoid in form, with many changes in calice orientation and, sometimes, diameter with growth, making it reminiscent of Calostylis lindstroemi (q.v.). Some corallites, however, appear less scolecoid than trochoid, but it is rare that either irregular expansions of the diameter or changes of calice orientation do not occur. Specimens have been found as long as 23 mm, but most are rather smaller. Often, a specimen is somewhat compressed laterally, such that its diameter is noticeably greater in one direction than at right angles to it.

The internal structure is similar to that found in most species of Streptelasma (see Neuman, 1969 for examples). The theca is a septal stereozone, about 0.5 mm thick. The

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septa in earlier stages are fairly straight, and reach to the axis where their tips may become fused. These septa have an axially-tapering central core which is less dense optically than the rest of the septum. At this stage, the septa have a maximum width of .3 mm at the wall, and taper axially. The cardinal septum may be recognized in some cases by the fact that the septa immediately adjacent to it on both sides maintain a fairly constant lateral distance from it. As the corallite grows, the diameter increases at a greater rate than does the length of the septa, such that they seem to withdraw from the axial area. Their proximal ends retain about the same thickness as in earlier stages, but the distal ends are now much more attenuated. at no stage does a complex axial structure of intertwined septal ends (as in Grewingkia) develop. The minor septa are extremely short, usually no more than 1/5 the length of the major septa. In one specimen they are absent in a diameter of about 5 mm, but present at 7 mm. (see Plate 12, fig. 6, 7).

Perhaps the most distinctive feature of this species is the presence of contratingency among the major septa. In general this occurs between a shorter septum and the major septum on its counter side. The appearance is similar to that seen in Schizophaulactis densiseptatus (Foerste) (q.v.) which is associated with the present species in the field, but it is unclear if the major septa of S. scoleciforme

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form in the same manner as do those of the other species. The minor septa are seldom, if ever, contratingent.

There is no dissepimentarium within the corallite; only a complex pattern of complete and incomplete tabulae (Plate 12, fig. 3, 4). The former may be horizontal, concave or convex. The curved topography of the tabular surfaces often intersects the plane of a transverse section to give the appearance of dissepiments between the septa.

Distribution - Kentucky: Middle Llandovery (Brassfield Formation, Noland Member)

Brassfield occurrence - Localities 1 (near Panola) and 46 (near College Hill) in central Kentucky

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Dinophyllum Lindström, 1882

1882 Dinophyllum Lindström, p. 21

1900 Scenophyllum Simpson, p. 210

Type species - Dinophyllum involutum Lindström (1882, p. 21), by monotypy (=Clisiophyllum hisingeri Milne-Edwards & Haime, 1851). A more detailed description, with figures, is given by Lindström in a later paper (1896, p. 38).

Type locality and horizon - Silurian of Olenek, Siberian Platform.

DIAGNOSIS - Solitary corals lacking a dissepimentarium; theca a septal stereozone; cardinal side convex (when corallite is curved); minor septa very short; in ephebic stage, major septa reach axis with counter-clockwise whorl; tabulae axially convex, sometimes steeply conical.

DESCRIPTION - This genus consists of solitary corals which vary in form from the curved, rapidly-expanding corallite of D. stokesi Milne-Edwards & Haime (Plate 1, fig. 9-11) to a more nearly conical, straight corallite of slimmer proportions (D. hoskinsoni [Foerste], Plate 2, fig. 2, 4). Some species have a cylindrical form (D. involutum Lindström, as shown by Lindström, 1896, p. 39). The theca is a septal stereozone, and its outer surface is marked with a series of longitudinal grooves, corresponding to the positions of the septa.

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In the early stages of ontogeny, the septa show varying degrees of thickening by stereomal deposits, but a calice level, the septa are unthickened. Also in later stages, the septa undergo counter-clockwise torsion, typical of many streptelasmatids. This torsion usually affects the cardinal fossula as well, which is typically present in later stages. At this point, the fossula is well-developed, and may be straight-sided (D. semilunum sp. nov.), or have distinctly bowed lateral borders, giving it an elliptical shape (D. stokesi Milne-Edwards & Haime).

The major septa reach the axis in the ephebic stage, either singly or in distally-joined groups. The minor septa, in contrast, are short, less than half the length of the major septa.

The tabulae are mostly incomplete, and are oriented in such a manner as to slope fairly steeply from the axis down toward the periphery of the calice. The resulting axial convexity of the tabulae, and the twisting of the distal ends of the major septa around this convexity (see Lindström, 1896, fig. 88, 95) is regarded as characteristic of this genus. A similar pattern is seen in Clisiophyllum Dana (1846), a genus often confused with Dinophyllum, but containing a dissepimentarium, lacking in Lindström's genus.

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DISCUSSION - Simpson's (1900) Scenophyllum agrees in all respects with Lindstrom's concept of Dinophyllum, and is generally regarded as a junior synonym of the latter. Simpson's genus is based upon Zaphrenthis conigera Rominger (1876), a Devonian form from Michigan.

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Dinophyllum hoskinsoni (Foerste)

Plate 2, fig. 1-4; Plate 12, fig. 9, 10; Plate 13, fig. 4-6

cf. 1882b Dinophyllum involutum Lindström, p. 21-22

1890 Streptelasma hoskinsoni Foerste, p. 344-345, Plate IX, fig. 1-4; perhaps fig. 5, 6

cf. 1896 Dinophyllum involutum Lindström, p. 38-42, Plate VII, fig. 87-98

Type material - Lectotype (here chosen): USNM 84783, the original of Foerste's Plate IX, fig. 2 (see Plate 2, fig. 2 and Plate 12, fig. 9, 10 of the present work). Paratype: USNM 84783, the original of Foerste's Plate IX, fig. 1 (see Plate 2, fig. 1 of the present work).

Type locality and horizon - "Brown's Quarry", west of New Carlisle, Ohio, probably from the Brassfield Formation (Middle Llandovery).

Number of specimens studied - 3

DIAGNOSIS - Dinophyllum with little or no curvature of the corallite axis; rugose swellings common; no talon or other attachment structure at base; cardinal fossula prominent; tabulae present distinctive bilaterally-symmetrical aspect in longitudinal section, like dishes and bowls of different sizes and concavities stacked upside-down; septa not sufficiently-dilated to constrict septocoels.

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DESCRIPTION - The paratype of this species (USNM 84783) shows very slight curvature of the axis. Vertically it stands 3.3 cm high, and the length of its convex side is 3.6 cm. The specimen is longitudinally-striated with narrow grooves, separated by much-broader ridges. There are three distinct growth discontinuities (though not demonstrably rejuvenescence) occurring at distances of 1.5, 2.25 and 2.95 mm above the base (measured along the convex side). The diameters at these points are 7.0 mm, 15.0 mm, and 18.5 mm.

The lectotype also shows little curvature. Its vertical height is 2.0 cm, and its diameter at the top is 1.3 cm. It is rugose, and the surface pattern of its theca is as in the paratype.

In a transverse section through the lectotype taken at a level with a diameter of 8 mm (Plate 12, fig. 10), the theca is a septal stereozone, about 1 mm thick. The septa The septa are of two orders. There are 20 major septa (including the cardinal septum), of which all but the cardinal septum reach the axis, where they are affected by a counter-clockwise whorl. The cardinal septum is about 1/4 the length of the major septa, and is distinguished only by its shortness. In the axis, a sort of fusion of the septal ends appears to be brought about by sparse patches of stereom. The minor septa of this level are virtually restricted to the theca.

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In a lower transverse section of the lectotype, the diameter is 5 mm. There are 19 major septa, reaching to the axis, but with no obvious whorl. The theca is .3 mm thick at this level.

A vertical section of the lectotype (Plate 12, fig. 9) shows one of the most characteristic features of this species. The tabulae are convex, with flattened tops and down-bowed sides. They are arranged like dishes and bowls of differing depth and diameter piled upside-down, one atop the other. The result is a remarkable bilateral symmetry of the interior of the corallite. In this specimen there is one particularly high-domed, narrow-based tabula whose edges rest upon the underlying tabula. The lower tabulae are spaced about 3 in 1.5 mm vertically. The fuller one on top stands 1.5 mm high. In transverse section (Plate 12, fig. 10) these tabulae appear as lines in the septocoels, generally concave towards the theca.

One specimen of this species was found in the field, at locality 46 (near College Hill, Kentucky). The corallite is fairly straight, about 2.5 cm long (Plate 2, fig. 4), and is broadest at the top (2.3 cm at the level of the calice floor). There are localized rugose swellings that give the impression of a stick of bamboo.

In a transverse section made near the top (at a diameter of 1.6 cm) the theca is a septal stereozone, about 1 mm thick. The 29 major septa appear to reach the vicinity

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of the axis (the central portion of the section is destroyed), where they are affected by a counter-clockwise whorl. The minor septa are about 1/6 to 1/7 the length of the majors at this level. The cardinal fossula is oblong, with the cardinal septum running its full length (about 5 mm) and not reaching the axis. It runs directly along the midline of the fossula, and is stopped by the juncture of the bounding septa and a rise of a tabula. A darkish core runs along the centers of the major and minor septa, tapering to a sharp point where they enter the stereozone. It should be noted that in the floor of the calice of the whole specimen, the cardinal fossula is more elliptical, and nearly pointed at its axial end. (See Plate 13, fig. 5.)

A lower transverse section, with a diameter of 9.5 mm in the greatest direction and 7.0 mm in the shortest, is elliptical (Plate 13, fig. 6). Here the theca is .2 to .25 mm thick, and it is clear thea the longitudinal grooves on the theca reflect the positions of the septa, and that the ridges mark the septocoels. The length proportions between the major and minor septa are the same at this level as in the upper section, but the majors extend only about halfway to the axis. The abundance of sediment in the cavity suggests this may be due to breakage, but we cannot be certain.

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In longitudinal section (Plate 13, fig. 4) the lower, cylindrical portion of the corallite (seen in the cardinal-counter plane) displays the striking bilateral symmetry of the tabulae discussed above. In one case, a tabula appears to have been depressed axially so that its upper surface corresponds to that of the tabula on which it rests. Where the rim of a narrower tabula abuts the surface of the tabula just beneath it, the lamellae of the former merge smoothly with those of the latter, such that the zone of lamellar merging is no thicker than either of the tabulae individually. The spacing of each of the five main complete tabulae in the axis is as follows: the bottom two are 2.0 mm apart, the third from the bottom is .5 mm above the second, the fourth is .7 mm above the third, and the fifth is 2.0 mm above the fourth. At the top of the section, where the diameter of the corallite swells, the axial tabulae grow higher and narrower, while maintaining bilateral symmetry. In the space between their sides and the theca are found large, incomplete tabulae not particularly contributing to the symmetrical appearance. In transverse section, as noted in the lectotype. the tabulae appear as lines in the septocoels, concave toward the theca.

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DISCUSSION - Foerste (1890) noted the characteristic transverse annulations of this species, and the fact that usually only the lower portion of the corallite is curved. The calices, he reported, are at least 8 mm deep, with steep sides. (This latter feature he must have obtained from specimens other than the two in the type suite, as the calices are not exposed in them.) Foerste was unable to provide information on the internal structure, except that the septa vary in number from 40 to 55.

To better understand this species, it would be well to compare it with Dinophyllum involutum Lindström (1882b), the type species of this genus. Lindström's specimens came from the Silurian of Gotland (probably the Högklint beds of Early Wenlock age), though he also reported the species from the Silurian of the Olenek River basin in northern Siberia. In his original description, Lindström described the coral as solitary, and either straight or slightly curved. The epithecal ridges are distinct. The major septa are 55 to 60 in number. The cardinal septum extends to the center where it joins with the counter septum. The other major septa also reach the axial region, where they undergo torsion (apparently counter-clockwise), and form an axially-convex "columella" of axially-upraised incomplete tabulae. Between the theca and the incomplete tabulae, occupying the septocoels, is a "long strip of a loose, spongy mass, which sometimes fills the entire septocoel". No figures accompany this

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description, but Lindstrom gives the dimensions of the specimen as 41 mm long and 31 mm wide.

In 1896, Lindström gave a more detailed, and illustrated description of his species. To his earlier description he added the fact that the corallite is distinctly rugose. In the shallow cup are present two orders of septa, with up to 60 major septa. (The figures show the minor septa as virtually restricted to the stereozone.) A cardinal fossula(?) contains 3 to 4 small septa. The corallite growth is not accompanied by particularly rapid increase of septal number: In a diameter of 25 mm (about 10 mm above the base) there are 40 major septa; higher, at a diameter of 34 mm, there are found 50 major septa, and this number remains constant until a diameter of 37 mm is reached, at which point the maximum number, 54 septa, are found. The entire length of this sectioned specimen is 58 mm.

In this article, Lindström delved somewhat into the early ontogeny of the species. This need not concern us here, except to say that the steromal filling of the septocoels on the cardinal side during the neanic stage (as seen in D. semilunum sp. nov., discussed elsewhere in this text) does not appear to occur in D. involutum.

The major septa approach the axis, where they undergo counter-clockwise torsion as they rise up the axial slope of the "columella". The tabulae present a confused pattern, but appear generally to be incomplete, rising from the theca

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toward the elevated axis. There is no dissepimentarium. The septa seemed to Lindström to have perforations, which he was at a loss to explain, suggesting that they may have been parasitic in origin. No mention is made in this description of the spongy deposits in the septocoels, noted by Lindström in his earlier paper (1882b). The largest specimen he measured was 12.0 cm long and 4.5 cm in diameter.

Lindström figured several varieties of his form, possibly representing more than one species. For example, fig. 87 shows the septa undergoing torsion as they ascend the axial prominence, while fig. 89 shows them going straight to the axis. Fig. 94-98 suggest an axial boss elongate in the cardinal-counter plane (as also described by Ryder, 1926, p. 394-395, Plate XII, fig. 7-9). Apparently no specimen has yet been designated the holotype of D. involutum, so that it is difficult to judge which of these forms should be regarded as typical.

D. hoskinsoni (Foerste) differs from D. involutum Lindström in the bilateral symmetry of its tabulae, and the prominence of its cardinal fossula.

Distribution - Ohio, Kentucky: Middle Llandovery (Brassfield Formation)

Brassfield occurrence - Type suite from near New Carlisle, southwestern Ohio, probably Brassfield Formation (based on lithology and Foerste's data); also found at locality

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46, Noland Member, Brassfield Formation near College Hill, central Kentucky.

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Dinophyllum stokesi (Milne-Edwards & Haime)

Plate 1, fig. 9-15; Plate 12, fig. 11, 12; Plate 13, fig. 1-3

1851 Zaphrentis stokesi Milne-Edwards & Haime, p. 330, Plate 3, fig. 9

1876 Zaphrentis stockesii Rominger, p. 145, Plate LI, lower tier

1876 Zaphrentis umbonata Rominger, p. 146, Plate LI, lower tier

cf. 1882b Dinophyllum involutum Lindström, p. 21-22

cf. 1896 Dinophyllum involutum Lindström, p. 38-42, Plate VII, fig. 87-98

1906 Zaphrentis intertexta Foerste, p. 307-308, Plate 7, fig. 1A, B

? 1906 Zaphrentis intertexta, varieties or young, Foerste, p. 308-310, Plate 7, fig. 5A-E

1919 Zaphrentis stokesi Williams, p. 65, Plate XIV, fig. 1, 2

1928 Zaphrentis stokesi Twenhofel, p. 116

? 1960 Dinophyllum breviseptatum Ivanovskiy, p. 92-93, Plate IX, fig. 1

1966 Dinophyllum(?) umbonata Bolton, p. 16, Plate V, fig. 9

1968 Dinophyllum(?) umbonata Bolton, p. 48, Plate 13, fig. 30.

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Type material - Possibly in Museum of Natural History, Paris.

Type locality and horizon - Silurian (probably Llandovery or Wenlock) of Drummond Island, Lake Huron.

Number of specimens studied - 19

DIAGNOSIS - Curved, trochoid Dinophyllum with rapidly- increasing diameter, widest perpendicular to the cardinal-counter plane; cardinal fossula prominent, elliptical in outline, and located on convex side of corallite; septa in mature stages thick, resulting in narrow septocoels; tabulae do not display the bilateral symmetry found in D. hoskinsoni (Foerste); basal attachment scars and stereomal deposits on the cardinal side found in D. semilunum sp. nov., are absent from this species.

DESCRIPTION - This species includes some of the largest solitary corallites found in the Brassfield Formation. The largest specimen studied (Plate 1, fig. 9-11) has the following dimensions:

length (straight line from base to highest point) = 6.5 cm

length along convex side (curvature) = 8.5 cm

diameter in cardinal-counter plane (at level of calice floor) = 4.4 cm

diameter in plane perpendicular to latter = 4.9 cm

The proportions remain fairly constant throughout the growth of an individual, and show little variation from one corallite to another. All specimens are curved in the cardinal-

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counter plane with the cardinal side convex, and in all specimens studied the elliptical cross-section is narrowest in the cardinal-counter plane. Corallites increase in diameter rather rapidly, maintaining an apical angle of about 65° (though occasionally somewhat less). The corallite is weakly-rugose, the surficial wrinkles never being so prominent as to detract from the regularity of the corallite's expansion with age. The theca is invested with narrow longitudinal grooves, separated by much broader ridges of low convexity. These ridges near the top of the largest specimen attain a width of about 1.3 mm, while the grooves are no wider than a pencil-line. No attachment scars are evident on the surface.

The calice is typical of Dinophyllum, with the distal ends of the septa affected by a counter-clockwise whorl, and raised to form a low axial boss. The minor septa do not participate in forming the boss, and extend only about 1/3 the distance to the axis. The upper surface of the highest tabula is visible in the septocoels, and is raised in the axis along with the septal ends.

The cardinal fossula is similar to that of D. hoskinsoni (Foerste), being prominent, elliptical in outline due to the lateral flexing of the two major septa forming its boundaries. Often it is nearly as wide as long, to the extent that it reaches the axis, to be caught up in the axial whorl. The fossula is deepest in the middle, or towards the

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proximal end (closest to the theca), shallowing distally against the axially-rising tabula as the bounding septa come together. The cardinal septum is depressed in the fossula, with a wide space between it and the neighboring septa.

All specimens studied had been subject to recrystallization, so that in only one instance was the internal structure sufficiently preserved to allow meaningful investigation (Plate 1, fig. 12-15; Plate 12, fig. 12; Plate 13, fig. 1-3). The theca is a septal stereozone. In a transverse section measuring 1.6 cm X 1.9 cm (Plate 13, fig. 2) its thickness is 1.5 mm.

The septa in levels ranging in diameter from 1.8 X 1.5 cm to 2.5 X 2.2 cm were thick, leaving septocoels consistently narrower than the septa. An exception was on the counter side of the highest section (Plate 13, fig. 1), where the septocoel width about equals that of the septa.

In these sections the minor septa are nearly restricted to the stereozone, and the majors appear to be split along their axial planes. The significance of this is unclear. Possibly it reflects the dissolution of a central zone of different structure from the outer layers of the septum. This idea is supported by the presence of a zone of optically less-dense material in the central portions of well-preserved septa, with a darker zone to either side, possibly representing secondary deposits. In some instances it appeared that

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the darker deposits covered only the more proximal portions of the septum, the distal portions consisting of the lighter core-material. Axially the major septa flex generally to their right, each contacting the distal end of its neighbor. Those on the cardinal side attenuate distally someshat more than the other septa, and approach the axis more closely, though they are somewhat sinuous.

So far as can be determined, the tabulae are complete, close-spaced (often less than 1 mm apart), and are distinctly convex upward. Some are smoothly-rounded, while others appear to be more sharply-peaked axially.

DISCUSSION - D. stokesi was first reported by Milne-Edwards & Haime (1851, p. 330) from the Silurian of Drummond Island, Lake Huron. The specimen they described is trochoid, without prominent rugae. Its straight longitudinal length is given as 8 cm, the calice diameter (maximum?, minimum?) as 4 cm, and the calice depth as nearly 2 cm, indicating a corallite slightly longer and narrower than our own largest specimen.

These authors describe the corallite as "...légèrement comprimé dans le sens opposé à la courbure." This is translated as "gently compressed in a direction opposed to the curvature", a phrase of uncertain meaning. Their figure (Plate III, fig. 9) suggests the coral's cross-sectional diameter is slightly greater in the cardinal-counter plane than in any other direction. Our specimens, where elliptical, were widest perpendicular to this direction. The cardinal

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fossula is located on the convex side of the corallite. There is no indication in the description or figure that it is elliptical in plan. The illustration, in fact, suggests that the sides are fairly parallel.

Milne-Edwards & Haime's specimen has 64 major septa (compared with about 44 in our largest specimen). These are slightly thickened at the wall-juncture, and reach the axis in a rather flexuous manner, where they join in an elevation of the calice floor. The proximal portions of these septa are described as composed of a pair of lamellae, possibly corresponding to the paired pattern noted in our thin-sections (in which case they would be the remnant secondary deposits after solution of the original septal core. Very short secondary septa, apparently nearly restricted to the thecal region, occur between the major septa.

The major differences between Milne-Edwards & Haime's specimen, and those of the Brassfield, are the lack of ellipticity in the fossula of the former, and the apparent absence of compression in this specimen. In this sense, the Drummond Island coral would seem to have more in common with the specimen figured by Bolton (1966, 1968), and identified as Dinophyllum(?) umbonata (Rominger). This specimen (GSC 20521) is from the Fossil Hill Formation (Late Llandovery through Middle Wenlock) of Manitoulin Island, and thus corresponds closely with the Drummond Island specimen in both location and age.

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Nonetheless, both the Drummond Island specimen, and the Manitoulin Island specimen do show some degree of lateral flexing of the septa bounding the fossula, such that this character, and the apparent lack of compression might be regarded as of sub-specific importance. Consequently, our specimens, and Bolton's, are regarded as conspecific with Milne-Edwards & Haime's species.

Rominger (1876) described specimens of this species from the Manistique Formation (Middle Llandovery through Middle Wenlock) of Point Detour, northern Michigan. These are trochoid corallites with broad, elliptical calices, apparently narrowest in the cardinal-counter plane. The size-range corresponds well with that of the Brassfield form. There are reportedly up to 60 to 65 major septa, attaining the axis where they are affected by a counter-clockwise whorl, which is slightly elevated above the more peripheral portions of the calice floor. (The whorl in Rominger's figure appears to be clockwise because his figures were all reversed in the printing process.) Between each pair of major septa is found a short minor septum, reaching about half-way to the axis. A large, elliptical fossula occurs on the convex side of the corallite. There seems little doubt that the specimens figured by Rominger (UMMP 8615) are conspecific with our own.

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In the same work, Rominger described what he considered to be a new species, Zaphrenthis umbonata. These corals (UMMP 8614) come from the same region and unit as "Zaphrentis stockesii", and Rominger noted the close similarity of the two forms. It is unclear why he chose to set these corals apart from Milne-Edwards & Haime's species, and in fact, stated that their relationships were open to question. Z. umbonata has all the morphic features characteristic of D. stokesi: the sizes and shapes are the same, have an elliptical fossula on the convex side of the corallite, similar septal arrangement, and an axial prominence where the distal ends of the septa join. The septa of the larger figured specimen of Z. umbonata go directly to the axis without whorling, however, but this seems acceptable in light of the variation shown by the specimens studied.

Foerste (1906) reported this species, under the new name of "Zaphrentis intertexta", from the Brassfield Formation on the eastern side of the Cincinnati Arch in central Kentucky. His specimens are of the same general size as our larger ones, with the characteristic stout trochoid form, and compressed cross-section (narrowest in the cardinal-counter plane).

The peripheral portion of the calicular area is better-preserved than in our specimens. Foerste's Plate 7, fig. 1A shows a broad marginal area accounting for about one-half of the radius, sloping down to the calice floor. The point of contact between these two regions is the deepest portion

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of the calice, forming a sort of peripheral moat around the central floor. Axially, the floor rises into a broad boss. A prominent cardinal fossula which appears to be elliptical is located on the convex side of the corallite, and reaches to the axis. The major septa attain the axis, where they are affected by a counter-clockwise axial whorl. The minor septa appear to be restricted to the high peripheral zone of the calice. Foerste stresses the fact that the distal ends of the major septa cross one-another, producing a reticulate pattern in the axis. This is seen in some, but not all of our specimens, and is not considered a character of specific rank.

Foerste regarded his specimens as differing from that of Milne-Edwards & Haime by virtue of a more rapid expansion from the base, having fewer septa, and having a reticulate pattern in the axis. Our assemblage, however, indicates that none of these are sufficient grounds for a separate species.

In the same paper, Foerste described and figured specimens which he believed (probably correctly) to be young individuals of his species, Z. intertexta (D. stokesi). In some of these, the cardinal septum appears to fuse axially with what may be the counter septum, dividing the calice into two halves. This condition is approached in some of our specimens, and appears to result in a decrease of the of the axial whorl. It is possible that this state noted by Foerste is a normal phase of the ontogeny, prior to develop-

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ment of the axial whorl, but the material at hand is insufficient to provide the necessary evidence.

Williams reported this species in 1919 from the "Lockport" (actually Fossil Hill) Formation of Manitoulin Island and Cabot Head, Lake Huron (Late Llandovery through Middle Wenlock). His figures show two specimens, the smaller (GSC 4688) with a large cardinal fossula and little or no axial whorl, and the larger (GSC 4694) also with a prominent fossula and a well-developed counter-clockwise axial whorl. These specimens agree well in all respects with our concept of this species.

Twenhofel (1928) reported this species from the Jupiter and Chicotte Formations (Late Llandovery to Early Wenlock) of Anticosti Island. The description given agrees very well with our own material, except for Twenhofel's remark that the tabulae are commonly depressed in the center. It seems likely that the Anticosti material can be regarded as conspecific with the Brassfield specimens.

Ivanovskiy (1960) reported a new species, Dinophyllum breviseptatum, from the Upper Llandovery beds 66 km upstream from the mouth of the Borgiyachin River in the Siberian Platform. The corallite is trochoid, with a maximum diameter of 40 mm and a length (to the rim) of 25 mm on the concave, and 55 mm on the convex side.

The figures indicate a form much like our own in general proportions. It should be noted that Ivanovskiy's diameter

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measurement was made at the calice rim, while ours was made at the level of the calice floor. The cardinal septum lies on the convex side of the corallite, and occupies an elliptical fossula characterized as indistinct by Ivanovskiy (p. 92), but appearing comparable to ours in Plate IX, fig. 1a of Ivanovskiy. Proximally, stereom thickens the ends of the septa to form a stereotheca.

About half-way to the axis, the septa twist to one side. Many do not reach the axis, but unite distally with their neighbors. Ivanovskiy's transverse section suggests that the septa on the counter side are less-thickened than those of the cardinal side, a situation opposite that seen in our specimens. The cardinal septum is long, and bends before reaching the axis, a feature also found in the Brassfield specimens. The counter and lateral septa of the Russian form, as well as our own, are indistinct.

Ivanovskiy was unable to detect clear alternation between major and minor septa in his specimens. This was the case in our thin-sections (Plate 12, fig. 11; Plate 13, fig. 1-3) and often in whole specimens from the Brassfield. In other specimens, however (Plate 1, fig. 10) the two orders are more distinct. The discrepancies seem related to the waviness of the septa, and to preservation.

The tabulae in the Russian form are complete, and rise axially from the stereozone to assume a "cupola-like" aspect. They are spaced about .75 mm apart, a figure consistent with

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our specimens. There is no dissepimentarium.

Ivanovskiy's figure 1a shows the septa affected by a clockwise axial whorl. If this is a faithful illustration, then we have here a significant difference between the Russian coral and our form, not to mention all other specimens of the genus Dinophyllum encountered. Thus far, illustrations of clockwise whorls in this genus have been due to reversal of the figure in printing (as in the case of Rominger, cited above) or of mounting transverse sections upside-down. If this is not the case with Ivanovskiy's species, then this form should be closely studied in an effort to understand axial torsion.

D. breviseptatum appears to differ from our form primarily in the pattern of septal thickening, which appears greatest, and seems to extend farther, along the septa of the cardinal side. This is opposite of the pattern found in the Brassfield specimens of D. stokesi. It should be noted, however, that Ivanovskiy's section is of greater diameter than that obtained from our specimen. As he indicates (p. 93) that he has no information on the ontogeny of his species, and as only one of our specimens produced useful sections, it is possible that this difference will ultimately prove less-important than it is now considered, in which case the Brassfield form might well be conspecific with the Russian species. Until further study is possible, it seems best to leave the relationship between these forms

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open to question.

D. involutum (Lindström), the type species of Dinophyllum Lindström, has been discussed in connection with D. hoskinsoni (Foerste) of the Brassfield Formation (q. v.). It differs from the Brassfield form of D. stokesi primarily in being more elongate and thin, with a round cross-section (Lindstrom, 1896, figure on p. 39), in having incomplete tabulae, and in apparently lacking a well-developed fossula. These differences are not so striking as to preclude the possibility that these two forms represent subspecies of a single species, but present information makes it best to regard them as distinct species.

Distribution - Drummond Island: Silurian; Manitoulin Island: Late Llandovery through Middle Wenlock; Point Detour, northern Michigan: Middle Llandovery through Middle Wenlock; Kentucky: Middle Llandovery (Brassfield Formation); Anticosti Island: Late Llandovery to early Wenlock. (Possible occurrence - Siberian Platform: Late Llandovery).

Brassfield occurrence - Localities 1 (near Panola) and 46 (near College Hill) in central Kentucky. Large numbers of specimens have been collected by other workers in this vicinity, in the southwest corner of the Panola Quadrangle.

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Dinophyllum semilunum sp. nov.

Plate 1, fig. 16-19; Plate 13, fig. 7; Plate 14, fig. 1-7

cf. 1928 Zaphrentis hannah Twenhofel, p. 115,
Plate II, fig. 8, 9

cf. 1949 Ptychophyllum(?) cliftonense Amsden, p. 112-113,
Plate XXX, fig. 1-7

Type material - Holotype: UCGM 41924 (see Plate 1, fig. 18, 19, and Plate 14, fig. 1-7 of the present work).

Type locality and horizon - Locality 7a, near Fairborn, Ohio, in the clay-coral bed described under "Brassfield Lithosome" in the Brassfield Formation (Middle Llandovery).

DIAGNOSIS - Dinophyllum in which the septocoels of the cardinal side are filled with stereom in the neanic stage, gradually diminishing into the ephebic stage; cardinal fossula becomes discernible as stereom decreases, with somewhat bulbous end distally and parallel sides proximally; major septa and fossula affected by counter-clockwise axial whorl; carinae absent.

DESCRIPTION - The solitary corallite is usually trumpet-shaped, being fairly narrow through most of its length, and flaring strongly at the calice (Plate 1, fig. 16, 19). In most specimens found, the original length appears to have been about 3 to 4 cm. The outer surface is usually worn, and has a pattern of longitudinal alternating light and dark lines,

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the latter representing the septa, and the former representing the septocoels. These lines are of about the same breadth. In one specimen with a well-preserved calice, the depth of the calice was at least 1.3 cm, its lip-to-lip diameter at least 3.5 cm., and the width of the floor about 2 cm. It should be noted, however, that while the calice is strongly-flared, it is definitely not reflexed, as in Ptychophyllum Milne-Edwards & Haime.

The corallite cross-section tends to be elliptical, with greatest diameter in the cardinal-counter plane. No strong curvature has been noted, and while there is no clear evidence of talons or rootlets, the basal region seems to have attachment scars (Plate 1, fig. 16), suggestive of an erect growth-habit.

The theca is a septal stereozone, its thickness measuring about 1 mm near mid-height. The septa may be traced proximally into this stereozone, and emerge from it distally through the sharp diminishing of the interseptal deposits.

The septa are of two distinct orders, the minors attaining no more than 1/4 to 1/3 the length of the majors. The latter extend to the center from the neanic stage into the ephebic stage. In the axis, their ends fuse with those of adjacent septa, or even with septa entering from 90° or 180° away.

A distinctive cardinal fossula is present from the late neanic stage, continuing into the ephebic stage. Character-

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istically, its sides are parallel, except for the distal-most end, which tends to be slightly bulbous. The cardinal septum runs through the entire length of the fossula, and commonly bends to the right at its distal end, to abut against the side of the septum forming the border of the fossula. From here it fuses with that septum and continues with it to the axis (Plate 14, fig. 1, 2).

The axis of the corallite is affected by a counter-clockwise whorl, involving the cardinal fossula as well as the major septa. The distal bending of the cardinal septum mentioned above is in the same sense as the axial whorl.

Perhaps the most distinctive feature of this species is the presence of stereom filling the septocoels of the cardinal side. Slightly less than half of all the septo-coels are thus affected, and the diminishing of these depos-its marks the gradual transition from neanic to ephebic stage, for our purposes. The cardinal fossula usually first becomes evident as a split in this in-filled zone (Plate 14, fig. 1-7).

In longitudinal sections (Plate 13, fig. 7) the absence of a dissepimenatrium is noted. The interior is replete with incomplete tabulae forming a convexity of the axis. It is when they down-bow peripherally, passing through the plane of a transverse section, that they may be mistaken for vesic-ular dissepiments of a dissepimentarium, in the septocoels.

Within the septocoels, there seems to be a pattern to the orientation of the incomplete tabulae: As the calice

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floor is encountered in transverse section, in-filling sediment first appears in the deeper, peripheral zones of the septocoels. These pockets of sediment are bounded distally by what must be the surface of a down-bowed incomplete tabula, which links the sides of the two septa forming the lateral boundaries of the pocket. The distal boundaries of the pockets lie not at right angles to the bounding septa, but rather with an oblique orientation. It always seems to contact the septum on the cardinal side of the pocket more distally than it does the septum on the counter side. The result is that the cardinal-counter plane forms the axis of symmetry in which the shape of these sediment pockets on one side is the mirror-image of those on the other side. This has been clearly seen in one specimen, and is suggested in other, less-complete specimens.

DISCUSSION - There are a number of species which, though clearly distinct from D. semilunum, yet share similarities with it deserving of notice:

Twenhofel (1928) described Zaphrentis (sic) hannah from the Becscie and Gun River Formations (Middle Llandovery) of Anticosti Island. The holotype (from the latter unit) has a septal pattern in its later stages quite similar to that of D. semilunum. The cardinal fossula is of the same type, the minor septa are short, and the major septa reach the axis, where they are affected by a rather weak counter-clockwise whorl. The theca is a septal stereozone, and no

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dissepimentarium appears to be present. The earliest stage studied (diameter = 6 mm) shows the septa dilated, and completely closing the septocoels. This has never been observed in our species, but the lowest level studied in D. semilunum is about 1 cm in diameter, and the equivalent stage may not have been reached. The absence, however, of stereomal filling of the septocoels on the cardinal side during the earlier stages of Z. hannah, indicates that we are dealing with a different species from (though one possibly congeneric with) our own.

Ptychophyllum(?) cliftonense Amsden from the Brownsport Formation (Early Ludlow) of western Tennessee superficially resembles our species, but the presence of a well-developed dissepimentarium indicates that it is a quite distinct form, probably belonging to Ptychophyllum Milne-Edwards & Haime. The presence of some stereomal in-filling of the septocoels on one side of the paratype (YPM 17691) seems related to the presence of basal support structures in Amsden's species, which is probably not the case in our own. Also, the spinose carinae on the sides of the septa in Amsden's species are absent from D. semilunum. These carinae are similar to those seen in many of Sutherland's (1965) corals from Oklahoma's Henryhouse Formation, of equivalent age to the Brownsport.

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Distribution - Ohio: Middle Llandovery (Brassfield Formation).

Brassfield occurrence - Locality 7a, near Fairborn, Ohio.

The species occurs in the clay-coral bed, described in section on the "Brassfield Lithosome" in this work.

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Dalmanophyllum Lang & Smith, 1939

1933 Tyria Scheffen, p. 33 (non Huebner, 1819, p. 166, a lepidopteron; nec Fitzinger, 1826, p. 29, 60, a reptile)

1939 Dalmanophyllum Lang & Smith, p. 153 (pro Tyria Scheffen, 1933)

Type species - Cyathaxonia dalmani Milne-Edwards & Haime (1851, p. 322).

Type locality and horizon - Upper Silurian of Gotland

DIAGNOSIS - Solitary and compound corals lacking dissepimentarium; theca a septal stereozone; cardinal side convex; minor septa very short; major septa reach close to axis, sometimes contacting linguoid axial structure formed in ephebic stage by juncture of cardinal and presumably counter septa; interior mostly filled with stereome.

DESCRIPTION - This genus consists of solitary corals (with a possible exception mentioned in the "Discussion"), which are trochoid, and are convex on the cardinal side. The corallites appear to have been unattached to the substrate, except for D. minimum (Ryder) 1926, which often has an apparent attachment scar at its apex (Ryder, 1926, p. 396, Plate XII, fig. 2). The theca, a septal stereozone, bears grooves on its external surface, marking the positions of the internal septa.

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The septa are of two orders, the majors reaching the axis, but the secondaries barely protruding from the stereozone. The most characteristic feature of this genus is its columella, a linguoid process that protrudes sharply from the base of the deep calice. This structure is elliptical in the horizontal cross-section, and smoothly curved in the vertical section along its plane of symmetry. It is elongate in the cardinal-counter plane. The columella differentiates in the later stages of the coral's ontogeny, and is the result of juncture of the cardinal septum axially with one of the septa on the opposite side of the calice, presumably the counter septum.

In the earliest ontogenetic stages observed in this study, the septa all meet in the axis, and the septocoels are filled by the stereom thickening the septa. As the corallite grows, the septa withdraw from the axis, in typical streptelasmatid fashion, and the septocoels gradually become vacant. At this stage the major septa often join in groups of two or three by uniting their distal ends. At this time, the axial juncture between the cardinal and counter septa becomes thickened by stereome, such that in transverse section it has the shape of a football in profile.

The stereomal thickening of the septa usually restricts the development of tabulae, such that they are virtually always absent. There is no dissepimentarium.

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DISCUSSION - Lang & Smith (1939) erected Dalmanophyllum for Cyathaxonia dalmani Milne-Edwards & Haime (1851) from the Silurian of Gotland, when they determined that this species was not congeneric with C. cornu Michelin, the type species of Cyathaxonia Michelin (1847). Lang & Smith suggested that Dalmanophyllum dalmani was related generically to Tyria insertum Scheffen (1933), type species of his Tyria (by subsequent designation of Lang & Smith, 1939). As Tyria was a pre-occupied name, however, Lang & Smith proposed their new generic name, Dalmanophyllum, in its stead.

Tyria insertum is from the 5b Zone (Porkuny, variously regarded as Late Ordovician and basal Llandovery - see Hill, 1959, p. 151; Manten, 1971, p. 17) in the vicinity of Oslo, Norway, and appears to be a compound coral. If so, this would be the only such form known to the genus Dalmanophyllum.

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Dalmanophyllum(?) obliquior (Foerste)

Plate 2, fig. 5, 10, 11; Plate 15, fig. 1, 2

1890 Streptelasma obliquior Foerste, p. 345, Plate IX, fig. 14, 15

1893 Streptelasma obliquins (sic) Foerste, p. 601, Plate XXXIV, fig. 14, 15 (figures labelled Streptelasma? obliquius)

Type material - Holotype: USNM 84794 (fig. 14 of Foerste, 1890), specimen shown on Plate 2 and 15; Paratype: USNM 84785 (fig. 14 of Foerste, 1890).

Type locality and horizon - Hanover, Indiana, from the Clinton beds (Brassfield Formation).

Number of specimens studied - Only holotype and paratype studied. No specimens found in field.

DIAGNOSIS - The specimens studied give too little information on this species to allow a meaningful diagnosis to be formulated. Consequently, the description of the species will concern itself with merely describing the holotype and paratype of Foerste's species. Clearly, more material is needed to give a fuller picture of this form.

DESCRIPTION - The two specimens of the type suite show little structure on the outside. The paratype shows weak longitudinal striation and rugosity. The only external features shared by these specimens is the fact that they are solitary

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corals, apparently without attaching structures, and their apertures seem more oblique than is usual in horn corals.

As shown in Foerste's figures, they are of quite different sizes: The length of the paratype, measured in a straight line from the base to the higher calice margin is about 28 mm, with a diameter of 16 mm, and the length of the holotype is about 19 mm, with a diameter of about 7 mm. Both corallites are gently curved.

The holotype was sectioned transversely at two levels. The lower level (Plate 15, fig. 2) has a diameter of 5 mm, with a circular outline. The theca is a septal stereozone, just under 1 mm in thickness. The minor septa are almost entirely restricted to the stereozone at this level, but 22 major septa are present. One of these, probably the cardinal, extends through the axis and contacts what may be the counter septum. The cardinal septum is of about constant width, and has a dark, discontinuous midline, as have the other septa. The septa immediately to either side of the cardinal are short, and diverted away from it, such that they terminate against the sides of the septa to their respective counter sides. The rest of the septa, all majors, extend axially, without quite reaching the center of the section. Most join distally with a neighboring septum and terminate without contacting the cardinal septum.

In the higher section (Plate 15, fig. 1) the outline is elliptical, 7 X 6 mm in diameter. The cardinal septum ex-

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tends along the shorter diameter. As in the lower section, the cardinal septum reaches into the axis to contact the counter septum, but now the axial portion of these united septa is somewhat swollen. The two septa to either side of the cardinal are still bent outward, contacting their neighbors to the counter side. At this stage there is a total of 24 major septa, and the minors protrude but slightly from the stereozone in places. The septa are mostly shorter now, not coming as close to the axis as before, and not fusing their ends together. This, however, may be due to recrystallization of the specimen. At this level, the theca is 1 mm thick.

There do not appear to be vesicular dissepiments in the septocoels, and nothing is known of the tabulae or other features ordinarily seen in longitudinal section.

DISCUSSION - Foerste's original description, unfortunately, has nothing to add to our knowledge of this species, and his later (1893) reference merely recorded its presence in the "Clinton beds" of Hanover, Indiana, while repeating his earlier figures.

In general form, this species seems to fit most readily in the genus Dalmanophyllum, in view of the presence of a swollen, elongate axial structure formed by the extended cardinal septum, the short secondary septa, the presence of a septal stereozone, and the apparent absence of a dissepimentarium. Its relationship to the other species of this

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genus, predominantly found in the southern region of the Cincinnati Arch in Kentucky, cannot be determined at this time.

Distribution - Indiana: Middle Llandovery (Brassfield Formation).

Brassfield occurrence -Hanover, Indiana.

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Dalmanophyllum linguliferum (Foerste)

Plate 2, fig. 6-9, 12-17, 20-23; Plate 15, fig. 3-12

? 1878 *Lindströmia laevis* Nicholson & Etheridge, p. 90-92, Plate VI, fig. 4, 4a-e

? 1887 *Cyathophyllum gainesi* Davis, Plate 104, fig. 1-6

1906 *Lindstroemia lingulifera* Foerste, p. 311-312, Plate 5, fig. 2A-F

cf. 1926 *Dinophyllum minimum* Ryder, p. 395-397, Plate XII, fig. 2-6; Text-fig. 3

? 1933 *Lindströmia laevis* Scheffen, p. 31, Plate V, fig. 1

? 1933 *Tyria insertum* Scheffen, p. 33, Plate V, fig. 2, 3

cf. 1961 *Dalmanophyllum minimum* Minato, p. 81-85, Plate XI, fig. 1a, 2a, 3a, 5, 7-9, 12, 13, 16; Text-fig. 20-22

? 1964 *Dalmanophyllum gainesi* Stumm, p. 17, Plate 6, fig. 31, 32

Type material - Lectotype (here chosen) - USNM 87175, the original of Foerste's (1906) Plate 5, fig. 2C (shown on Plate 2, fig. 6, 7, 12-14 of this work). Also under this catalogue number are the originals of figures 2D, 2E and F, paratypes of the species.

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Type locality and horizon - "Along the road north of Estill Springs, north of Irvine" in central Kentucky (locality 53-53a of this study).

Number of specimens studied - 10 (including the type suite plus 7 specimens collected in the field).

DIAGNOSIS - Dalmanophyllum with diameter about equal to length, and cardinal fossula present on convex side in later stages; major septa bear elongate carinae; in earliest stage, septocoels are entirely closed by stereome; no attachment scars present.

DESCRIPTION - The type material, described and figured by Foerste (1906) will be described in the "Discussion" section for this species.

Seven specimens of Dalmanophyllum, all of which seem to be conspecific, were found at locality 1 (near Panola, Kentucky). These are curved, solitary corals with the cardinal side convex. There is a tendency for the diameter in the cardinal-counter plane to be somewhat shorter than that in other directions (though this is not universally true), which with the sense of axial curvature, results in a cuneate, calceoliform (rhizophylloform) corallite. It seems likely that specimens of this sort lay on their cardinal (convex) side on the sediment, unattached, with the oral disc directed obliquely.

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The theca is rugose, and fine longitudinal grooves reflect the positions of the major and minor septa inside. In most of the specimens collected there is little evidence of wear, rather unusual in the Brassfield. Several have virtually perfect basal points.

The following measurements, taken from the largest and smallest of the specimens found in the field, give some indication of the size-range involved:

perpendicular height from base to calice floor	7 mm	14 mm
perpend. height from base to convex calice lip	17	22
max. diameter across calice floor	7	7
max. diameter across calice lip	12	17

Three of the field specimens were studied in thin section. These will be described in turn as to external and internal features:

The first specimen (Plate 2, fig. 15-17; Plate 15, fig. 9, 10) has an extremely well-preserved calice, free of sediment. The diameter across the rim of the calice is 14.5 mm, and at the level of the floor, about 10.0 mm. In this specimen the cross-section is more circular than in the others. The upper edges of the major septa (27 in number) are flat and parallel to the calice floor, extending about 1.5 to 2.0 mm from the theca. From here they drop nearly vertically to the calice floor, a distance of about 4.5 mm.

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The higher transverse section is circular in cross-section, with a diameter of 11 mm (Plate 15, fig. 10). The theca is a septal stereozone, slightly over 1 mm thick. The minor septa are almost entirely restricted to the stereozone, with only the smallest point occasionally projecting into the septocoels. The major septa are thickened proximally by stereome just distal to the stereozone, and number 26 at this level. The cardinal septum lies in a fossula, and the two major septa to either side of it join their axial ends to the sides of the major septum to the counter side of each. The other major septa join their axial ends together in groups of two and three, and these connections are cemented by secondary deposits of stereome. One septum is somewhat thinner than the others, and doesn't reach as far axially as most, but bends toward the counter side, contacting its neighbor. The cardinal and presumed counter septa are connected across the axis to form a diametric line. In the axis, for a length of 3.5 mm, this line is thickened by secondary stereome, in the midst of which may be seen the thinner material of the septa proper. This is the mode of formation of the linguoid columella. Only a very few of the septa are in contact with the columella at this stage.

In longitudinal section (Plate 15, fig. 9), no tabulae or dissepiments were discerned...only twisted masses of stereome. This presumably reflects the section plane inter-

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secting septa and the stereome of the axis. The deposits of the more axial region are perforate in places.

The calice of the second specimen (UCGM 41946) is not so-well preserved as that of the first. The diameter across the rim of the calice is 11 X 12 mm (the shorter direction being in the plane of the cardinal-counter line). The base of the calice is about 6.5 mm in diameter, and the length of the axial columella is about 2.5 mm. There are 25 major septa present, their axial ends approaching and sometimes contacting the base of the columella. The major septa do not have the distinct upper shelf seen in the previous specimen, though it is unclear if this is an artifact of the poorer state of preservation. There appears to be a cardinal fossula, though it is largely obscured by encrustations in this region. The minor septa are not as prominent as in the previous specimen. Two possible minors appear on either side of the cardinal septum, though these could be weakly-developed major septa. Again, the septa bear faint ridges, similar to those mentioned above.

One transverse section (Plate 15, fig. 11) was taken just below the calice floor, and a longitudinal section (Plate 15, fig. 12) was also taken. The former has a circular cross-section, 7.5 mm in diameter. On one side, the perimeter of the circle has been slightly depressed, as a natural consequence during growth. Twenty-one major septa appear in the section, though no minor septa are present. The septa are secondarily thickened by stereome, and this

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thickening increases peripherally, the stereome extending into the stereotheca to give the portions of the septa in the stereotheca a bulbous appearance. This pattern was seem in the previous specimen, though not so clearly. The septa join axially in groups of two, three and (in one case) four. The presumed cardinal and counter septa join across the axis (the counter septum approaching somewhat indirectly to the columella), to form a diametric lamella which is only slightly thickened in the axis, the thickened portion measuring about 1.5 mm in length. There is no clear symmetry of the septa around the presumed cardinal septum as seen in the previous specimen, but this may be due to the narrower diameter (earlier stage) represented. The theca is about .7 mm thick.

The longitudinal section is identical to that of the previous specimen, with copious stereomal deposits, particularly in the axis. No tabulae or dissepiments appear to be present. Perforations occur in some areas of the axial stereome, and in the base of the corallite are what seem to be the axial ends of the early septa.

A third specimen (Plate2, fig. 20-23; Plate 15, fig. 5-8) was studied in transverse section only. The diameter at the calice rim is 17 X 15 mm (the latter in the cardinal-counter plane). The calice, unfortunately, was filled-in.

Four transverse sections were taken. The lowest (Plate 15, fig. 8) is 4 X 3.5 mm in diameter, slightly broader in the cardinal-counter plane. The septocoels are

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completely closed by stereome. There appear to be about 21 septa present, with no clear distinction of orders. The cardinal septum lies on the convex side, and to either side of it the neighboring septa parallel the cardinal such that they abut against the side of the septa to their counter side. This forms a sort of fossula, clearly marking the cardinal. The cardinal septum extends into the axial area, and is the longest septum present. It doesn't appear to be in direct contact with the counter septum at this stage. In the peripheral zone, wedges appear between the septa, possibly representing incipient septa.

The next-highest section (Plate 15, fig. 7) has a diameter of 6.5 mm. Here there are 24 major septa, two of which are being inserted about 90° from the cardinal septum. Now the two septa neighboring the cardinal to either side are distinctly curved axially toward their respective counter sides, contacting the sides of their neighboring septa. No minor septa are yet present. Some of the septa have bulbous peripheral ends where they enter the stereozone. The septocoels are now becoming open. The axial area is obscured by dolomitization.

The third section, higher-still in the corallite (Plate 15, fig. 6) has a diameter of 9 mm. There are 24 septa present now, all majors. One of them is only a large stub in a septocoel. It was first believed that this was a septum in the process of being inserted. As, however, it

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corresponds in position with a fully-developed septum of the lower transverse section, it seems more likely that this is a septum which has been aborted by crowding. Despite the nearly 50% increase in the diameter of this stage over its predecessor, this septum is only slightly shorter than the one corresponding to its position in the preceding section. The septa of this level are proportionately shorter than those of the previous level. The latter reached nearly to the axis, while the former leave an axial space fully 1/3 the total diameter. From a septum on the counter side (but not directly opposite the cardinal) there extends a thin band of skeletal material connecting it with a small feature that appears to be the remnant of a nearly-destroyed axial structure.

In the fourth and highest section (Plate 15, fig. 5) the diameter is 7 X 6 mm, shorter in the cardinal-counter plane. There are 27 major septa, with dilated proximal ends, and minors represented by small bumps in the septocoels. The theca is 1 mm thick. The septa at this level are more slender than at lower levels. The cardinal septum is not so clearly-marked as below. A columella extends along the cardinal-counter plane, presumably connecting these two septa, and measuring 4 mm in length, and 1.5 mm at its greatest breadth. The septa are joined axially in twos and threes, but only in a few cases do the axial ends contact the columella.

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DISCUSSION - Nicholson & Etheridge (1878) described Lindstroemia laevis from the greenish mudstones of Penkill, near Girvan, Scotland. They regarded these beds as Late Llandovery in age, and the latest estimates (Ziegler et al., 1974) are in agreement with this.

These solitary corals are curved, with the diameter equal to or slightly greater than the length. The figures give no impression of foreshortening of the cardinal-counter diameter, a feature commonly seen in our form. The calice is oblique, and was filled with sediment in all specimens studied by these authors. All that could be determined is that the calice is deep, expanding abruptly, and the septa are quite short near its lip. At various levels, from 15 to 23 major septa were found, which join axially into a columella projecting up into the calice. Minor septa were not clearly observed. Presumed arched tabulae appear in the base (see Plate VI, fig. 4b of Nicholson & Etheridge), but dissepiments are absent.

The columella is elongate in horizontal plane, just as seen in our specimens, and presumably lies in the cardinal-counter plane. Considerable stereome is involved in its formation. The proximal ends of the septa expand where they enter the stereozone. In a transverse section, supposed to be 6 mm in diameter, the columella is 2.4 mm long, with a maximum width of about .6 mm. In this stage (fig. 4e of Nicholson & Etheridge), the septa have nearly all lost contact with the columella, but have not joined distally in

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groups.

The corallites are apparently smaller than ours, averaging "three lines" (about 6.5 mm) in length, and "3.5 lines" in greatest diameter. Large specimens reach a length of "6 lines" (about 13 mm) and a diameter of 6 to 7 lines. Thus, the largest Penkill specimens are comparable in size to our smallest. As the authors indicate that they find up to 23 major septa (presumably in their larger specimens), it is likely that they were simply dealing with small individuals of a species that could attain dimensions similar to ours.

No mention is made of a cardinal fossula in these specimens (though in a previous description, of L. subduplicata, these authors specifically noted the absence of such a feature), and no mention is made of ridges on the septa (as the septa were observed only in thin-section). The two transverse sections they show (of different specimens) do not clearly show the symmetry about the cardinal septum so commonly seen in the Brassfield specimens.

The over-all similarities between the Girvan form and our own are so strong as to make it likely they are conspecific. In the absence of definitive information on the presence of a fossula in the former, however, it is best to regard their conspecificity as questionable, pending further investigation, and to not apply Nicholson & Etheridge's trivial name to the Brassfield species.

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Davis (1887) figured the species Cyathophyllum gainesi from the Louisville Formation (Late Wenlock and Earliest Ludlow) near Louisville, Kentucky. Later, Stumm (1964) refigured two of the specimens and described the species. He gave their locality as Brunerstown, 12 miles east of Louisville.

The corals are trochoid, curved, with a length of 1.0 to 1.5 cm and a maximum diameter of 0.5 to 1.5 cm (comparable in size with our specimens). The calices are funnel- or cup-shaped, similar in depth to ours. Some specimens have a peripheral platform on top of the septa, as seen in the first of the three Brassfield specimens described above. Stumm reports about 50 septa (apparently referring to the total of both orders), and a blade-like columella formed by the junction of the cardinal and counter septa. The major septa extend to the base of this columella. The minor septa are very short, largely restricted to the periphery, as in our specimens. The figures and description do not make it clear if there is a fossula, or if the septa bear ridges.

The syntypes of Davis' species (MCZ 7551-7556) were not available for study, so that it is best to treat this form as probably conspecific with our own, due to the many features they share, but to withold a final decision pending further study.

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The earliest reference in the literature to a form unquestionably conspecific with our own is that of Foerste's (1906) Lindstroemia lingulifera from the Waco bed, Noland Member of the Brassfield Formation near Panola, Kentucky (locality 1 of this study), and from the same horizon north of Estill Springs, Kentucky (vicinity of locality 53-53a). The type assemblage consists of three specimens (USNM 87175), which are the originals of Foerste's Plate 5, fig. 2C-F.

The calice areas of these specimens are poorly-preserved, the walls being destroyed, leaving only the calice floor. The exterior of the theca is as found in our specimens. The calice shows a cardinal fossula on the convex side, and a linguiform columella of the same form and orientation as in the Brassfield specimens. In a diameter of 11.5 mm, the specimen of fig. 2D shows 28 septa (major). The minors are apparently restricted to the stereozone. This specimen presents what is essentially a cross-section, as the calice walls are gone, and the ratio of septa-to-diameter is in good agreement with that found in our own specimens.

The specimens shown in Foerste's fig. 2E and F was sectioned (Plate 15, fig. 3, 4). This specimen was about 17 mm in length (measured straight, from the base to the highest part of the convex side), and about 11.5 mm in diameter. Note, however, that these dimensions are of the specimen without the calice wall.

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The transverse section is 9.5 mm in diameter. There appear to be about 25 major septa, all peripherally-thickened (secondary alteration somewhat obscures the exact number). The columella connects the presumed cardinal and counter septa, and measures 3.5 mm in length, with a maximum breadth just under 0.5 mm. Clearly, this structure is the result of stereomal thickening of the cardinal-counter lamella in the axis. The septum presumed to be the cardinal is curiously-bent, and slightly out-of-line with the columella. The septum to one side of it aborts against the side of its neighbor toward the counter side, but this does not happen in the case of the septum on the other side of the presumed cardinal. The stereotheca is slightly over 1 mm thick, and no minor septa appear in it. The major septa join axially in groups of two and three, and in some cases, these groups seem to be joined by stereomal deposits to the side of the columella.

The longitudinal section is similar to those of our field specimens. The axial area is filled with a perforated mass of stereome. Between this mass and the theca, there are a few axially-convex tabulae, separated from one-another by distances of about 0.4 to 0.6 mm.

Ryder (1926) reports a species from the Wenlock of Gotland, Dinophyllum minimum, which clearly belongs to the genus Dalmanophyllum Lang & Smith. It is a trochoid coral, reaching a maximum length of 26 mm, and diameter of 12 mm.

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The calice is fairly deep, with a small linguoid columella projecting from the floor, often united with the cardinal septum. The ratio of coral diameter to number of major septa appears to be comparable to that of our specimens. A depression or flattening, interpreted as an attachment-scar, often appears on the lower convex side (Plate 2, fig. 19), a feature not found in our Brassfield specimens. Ryder reports two forms of this coral,one "short, squat, and turbinate" and the other "elongated, this latter with the calyx usually set oblique to the axis of growth". It seems likely that he was dealing with two separate species. The cardinal and counter septa are united by the columella, and the axial ends of the other major septa unite in groups of from two to four. The septa appear to be thickened slightly peripherally, and development of minor septa is feeble.

In the earliest stages (diameter = 2 mm) the axial lamella is present, with the ends of the other septa united with it. This structure thickens in later stages. The trasnverse sections suggest a fossula or pseudofossula containing the cardinal septum, but no specific mention is made of this in the text. (Nonetheless, Minato [1961] in an ontogenetic survey of specimens from Gotland which he considered to be D. minimum, reports a cardinal fossula.) The figures also indicate that in the earliest stages (diameter = 2 mm) the septocoels are open. Minato's fig. 22 substantiates this. This fact, and the presence of basal attachment-scars makes it best to regard Ryder's species as distinct from ours.

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Scheffen (1933) describes two forms that resemble the present species, from the Ringerike area near Oslo, Norway. These come from Zone 5b, which Neuman (1969, p. 2) assigns to the Porkuny Stage. Neuman considers this stage to be Upper Ordovician, while Manten (1971) regards is as Lowermost Llandovery in age. In either case, it is considered pre-Brassfield in age.

The first of these species is Lindstroemia laevis Nicholson & Etheridge, 1878, which is discussed above. This has a simple columella, arising from the union of the septa. It is free-standing in the ephebic stage, and joins the cardinal and counter septa. The major septa are single, or united axially into groups, and are peripherally-thickened. Minor septa are weakly-developed. The corallite diameter is from 5 to 10 mm. In a diameter of 6.5 mm are found 21 major septa, similar to the ratio found in the Brassfield specimens. The stereotheca is about 0.5 mm thick. There is no sign of tabulae.

The information on this species given by Scheffen is too incomplete for any conclusions to be safely drawn. The figure shows only a portion of a transverse section, with a free-standing columella about 2 mm long and 0.7 mm at its greatest breadth. It is not possible to determine if a fossula is present. Further information on the external features, especially the length and nature of the base, would make it easier to determine the relationship between the Norwegian and Brassfield forms. From what may be seen, it

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is likely that they would prove to be conspecific.

The second form described by Scheffen, Tyria insertum, has a simple columella, easily recognized even before separation from most of the septa. In the stereotheca, the proximal ends of the septa stand out clearly. Stereome fills the interior of the corallite in early stages. The septa reportedly withdraw evenly from the axial columella. Though the characters of this species described by Scheffen agree with those of D. linguliferum (Foerste), there is too little information available to draw conclusions on the relationships between the two forms.

Distribution - Kentucky: Middle Llandovery (Brassfield Formation).

There are forms similar to our own occurring in northwest Europe. In no instance can they be confidently said to be conspecific with the present species. In some instances, such as D. minimum (Ryder) morphologic features preclude conspecificity. In others, such as L. laevis Nicholson & Etheridge , L. laevis N. & E. of Scheffen, C. gainesi Davis, D. gainesi (Davis) of Stumm, and T. insertum Scheffen, details are lacking in the descriptions to make conspecificity conclusive. In any case, it seems likely that we may look for the ancestry of D. linguliferum (Foerste) to the Late Ordovician or Early Llandovery of Scandinavia or western Europe.

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Brassfield occurrence - Locality 1 (near Panola, central Kentucky); Foerste's specimens included some from north of Estill Springs, central Kentucky (vicinity of locality 53-53a of this work).

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Rhegmaphyllum Wedekind, 1927

1927 Rhegmaphyllum Wedekind, p. 14.

1927 Regmaphyllum Wedekind, p. 74

1937 Regmaphyllum Soshkina, p. 85

1940 Rhegmatophyllum Lang, Smith & Thomas, p. 114
(nom. van. pro Rhegmaphyllum Wedekind, 1927)

? 1960 Briantelasma Oliver, p. 89

Type species - (SD Soshkina, 1937, p. 85) Turbinolia turbinata Hisinger (1837); = Zaphrentis(?) (sic) conulus Lindström (1868, p. 428). Lang, Smith & Thomas mistakenly imply (1940, p. 114) that the type species is Wedekind's (1927, p. 74) R. turbinatum (Hisinger).

Type locality and horizon - Silurian of Gotland. Lang, Smith & Thomas say the species is "very abundant at the Slite Marls at Slite and at Visby. Widely distributed in Gotland and ranges from Wenlock to Ludlow."

DIAGNOSIS - Solitary corals lacking dissepimentarium; theca a septal stereozone; minor septa very short; major septa reach axis, sometimes with counter-clockwise whorl; well-marked cardinal fossula on convex side of corallite, with parallel sides; interior mostly filled with stereome.

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DESCRIPTION - These are solitary, non-dissepimentariate rugose corals. Their form varies from straight-conical to ceratoid. No basal attachment structures are known in this genus, the lower portion of the cone simply coming to a smooth point. The theca, a septal stereozone, is thick.

The major septa reach to the axis. The minor septa, however, are characteristically short, often barely protruding from the theca.

A straight-sided cardinal fossula appears to be ubiquitous. Within it is a cardinal septum depressed below the level of the calice floor, but reaching the axis. The septa forming the walls of the fossula often distally truncate the septa between them and the cardinal septum.

The axis of Rhegmaphyllum species is very commonly affected by a counter-clockwise axial whorl: Plate 16, fig. 1, 12.

The interior of the corallite is mostly filled with stereome. This serves to thicken the septa in the earlier stages of growth, filling the septocoels and leaving only sutures between the septa. In later stages, incomplete tabulae are sometimes present, sloping from the axis downward toward the theca: Plate 15, fig. 19

The septal trabeculae may thicken to form elongate carinae, which project upward toward the axis from the periphery. On worn specimens, these may be manifest on the surface as a pattern of diamond shapes in the planes of the septa: Plate 3, fig. 8

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DISCUSSION - Soshkina (1937, p. 85) designated Rhegmaphyllum turbinatum (Hisinger) 1837 as type species of this genus. In his earliest usage of the trivial name, Hisinger (1831, p. 128) attributed it to Lamarck, who had considered it a Madrepora. Lang et al. (1940, p. 114) incorrectly considered Soshkina's selection to have been Wedekind's (1927) Turbinolia turbinata Hisinger, 1831.

Lang et al. (ibid.) believed Wedekind's (and Hisinger's) R. turbinatum to be identical to Zaphrentis(?)(sic) conulus Lindström (1868), and opined that the correct name of the type species is R. conulus, though the reason for this is unclear. Seemingly, the only rationale would be that these authors did not regard Hisinger's specimen as belonging to Lamarck's species, but no mention is made of Lamarck in their discussion of Rhegmaphyllum.

Another possibility, and the more likely one, is that Lang et al. consider Wedekind's concept of the species, as revealed in his description, to better fit Z. conulus than Hisinger's species. Wedekind's specimens share with Z. conulus the possession of a fairly straight axis, rather than curved as in Hisinger's figure (1837). On the other hand, Wedekind reports the absence (or at least, the lack of observation) of a cardinal fossula, an element which is distinct in Lindstrom's figures of Z. conulus.

It seems, then, that the matter of the type species of Rhegmaphyllum Wedekind must await further study of the type

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specimens involved, a view apparently shared by Hill (1956, p. 269) in the Treatise on Invertebrate Paleontology.

Before describing Rhegmaphyllum on page 74 of his work, Wedekind (1927) listed the genus in a systematic array (p. 14). In this list, the spelling was "Rhegmaphyllum". Later, on p. 74, Wedekind (whether by design or typographical error) spelled the name as"Regmaphyllum" without further comment. This latter spelling was used by Soshkina (1937). As the first spelling of the generic name is "Rhegmaphyllum", a name apparently properly in keeping with the rules of nomenclature, and as Wedekind gives no indication that he has intentionally changed his mind in altering the spelling on the later page, it seems that "Rhegmaphyllum" must be regarded as the correct name. Lang et al. (1940, p. 114) emended the spelling to Rhegmatophyllum, a modification also regarded as invalid.

Briantelasma Oliver (1960) is a solitary rugose genus from the Silurian and Lower Devonian of North America, whose characters mark it as closely-related to Rhegmaphyllum. The two forms share the general radiality of the septa, which in the case of the majors, extend to the axis without forming an axial structure. The septocoels are largely filled with the stereome of dilated septa in both genera. In addition, both Briantelasma and Rhegmaphyllum have a cardinal fossula. On the other hand, the minor septa of Briantelasma tend to be rather longer (1/3 to 2/3 the length of the majors)

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than is usual in Rhegmaphyllum, and its tabulae are reportedly complete. More study is necessary on the type material before the relationships between Briantelasma and the present genus can be ascertained.

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Rhegmaphyllum daytonensis (Foerste)

Plate 2, fig. 25-28; Plate 3, fig. 1-17; Plate 15, fig. 15-19; Plate 16, fig. 1-12

cf. 1868 Zaphrentis conulus Lindström, Text-fig. on p. 428; Plate VI, fig. 8

cf. 1882 Zaphrentis conulus Lindström, p. 16, 20-21

1890 Cyathophyllum celator daytonensis Foerste, p. 339-340, Plate IX, fig. 9-11 (non Zaphrentis celator Hall, 1877)

1893 Cyathophyllum celator, Hall, var. Daytonensa Foerste, p. 601, Plate XXXIV, fig. 9-11

? 1894 Zaphrentis vortex Weissermel, p. 630, Plate L, fig. 3, 4

cf. 1896 Zaphrentis conulus Lindström, p. 32-34, Plate VI, fig. 65-68

? 1896 Zaphrenthis vortex Lindström, p. 34-35, Plate VI, fig. 69-73

1906 Zaphrentis charaxata Foerste, p. 310-311, Plate 7, fig. 4A-E

? 1933 Lindströmia torsa Scheffen, p. 31-32, Plate V, fig. 6, 7

? 1962 Briantelasma sp. Oliver, p. 27, Plate 14, fig. 8-12

? 1971 Leolasma kaljoi Scrutton, p. 211-212, Plate 2, fig. 13; Plate 3, fig. 1-8; Text-fig. 7

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Type material - Holotype: USNM 84796, the original of Foerste's (1893) Plate XXXIV, fig. 10 (identical to Foerste's (1890) Plate IX, fig. 10), figured on Plate 2, fig. 27, and Plate 16, fig. 1, 2 of this work. Paratypes: USNM 84796, possibly the originals of Foerste's (1893) Plate XXXIV, fig. 9, 11 (identical to Foerste's [1890] Plate IX, fig. 9, 11), shown on Plate 2, fig. 28 and 26 of this work, respectively); and USNM 93518 (shown on Plate 2, fig. 25 of this work).

In the museum box with USNM 93518 is a card bearing no catalogue number, designating as type of the species the original of Foerste's (1893) Plate XXXIV, fig. 10. This figure bears no resemblance to the specimen in the box. In the box with specimens catalogued as USNM 84796, on the other hand, is another card with the number 84796 on it, again designating fig. 10 as the type. Both labels appear to be in Foerste's handwriting. In neither his 1890 description, nor that of 1893 did Foerste indicate which figure represented the type of the species, though he did refer to a type specimen. Consequently, the museum label is our only source of information as to which specimen he regarded as the type. It appears that the card in the box with USNM 93518 was placed there by mistake, and that the true type, as intended by Foerste, is is the one of three specimens included under USNM 84796 that best agrees with Foerste's fig. 10. The other two

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specimens, all labelled as cotypes on their museum cards, should be regarded as paratypes.

Type locality and horizon - Dayton, Ohio, site of the Veterans' Hospital (called Soldiers' Home by Foerste), from the Brassfield Formation (Middle Llandovery).

Number of specimens studied - Over 100

DIAGNOSIS - Trochoid or turbinate Rhegmaphyllum with counter septum lengthening through ontogeny as cardinal shortens; cardinal and counter septa in contact, or nearly so, at all levels below floor of the fossula; axial structure solid (no axial tube), often whorled counter-clockwise; septa ridged in later growth-stages; major septa rhopaloid.

DESCRIPTION - This is one of the most remarkable species found in the Brassfield. It is by far the most widespread (Table 3, Text-fig. 5e), occurring definitely at 18 localities, and possibly at 9 others. Locally its abundance can be quite striking, as at localities 5, 37 and others. More significant is the fact that it is often abundant where other species are almost totally lacking (locality 5). Its plasticity of form makes it difficult to pin down a definite description of this species universally applicable. Certain distinct features found in the R. daytonensis group seem to occur together in various combinations, but none are so closely-correlated as to allow confident splitting of this form into more than one species.

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The corallite may be trochoid or turbinate, varying widely in the width-to-length ratio. It is always curved, with a convex cardinal side. The outer surface may be smooth (perhaps due to wear) or distinctly longitudinally-striate. Rugosity occurs, but is not particularly pronounced. Foerste (1906, p. 310) noted that the longitudinal striae, especially on weathered specimens, appear as "zig-zag lines dividing the surface into small polygonal facets arranged in more or less quincuncial order." As will be shown below, this pattern reflects peculiarities of the septal structure, brought to the surface by wearing of the theca.

The calice is distinctive, dominated by a distinct, deep cardinal fossula, parallel-sided or narrowly wedge-shaped, and reaching the axis. The fossula borders are formed by two major septa. The cardinal septum lies in the axis of the fossula, dipping deep below the level of the calice floor before reaching the axis, but reappearing distally to rise closer to the axis. Also in the fossula, on either side of the cardinal septum, is a major septum which abuts the side of the major septum forming the border of the fossula on its side. This is due to the fact that these abutting lie parallel to the cardinal septum, while the bounding septa (like all the other septa) are radially-disposed relative to the axis. This pattern of the cardinal region is sometimes encountered in Dalmanophyllum (q. v.).

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In many specimens, the septa bear ridges (elongate carinae) sub-parallel to the calice floor, and slightly higher axially than peripherally. These are the same features as were recognized in Dalmanophyllum linguliferum (Foerste) (q.v.), occurring on both sides of a septum, and are arranged both oppositely and alternately, even on a single septum (Plate 3, fig. 14). The ridges appear to be absent in early stages. In three specimens in the collection of Ohio State University, they appear at the following elevations above the base: 12 mm (OSU 22598), 12 mm (OSU 22603), and 17 mm (OSU 22597). It is presumably the intersection of these carinae with the weathered corallite surface that produces the zig-zag lineations mentioned above (Plate 3, fig. 8). This relationship is shown especially-well in Plate 3, fig. 11. The carinae are presumed to be due to unusual thickening of trabeculae at intervals along the septum.

The minor septa do not extend so far axially as do the majors, but they bear ridges when these features are present on the major septa.

Axially the major septa unite, and their juncture may or may not be affected by a whorl. Invariably, the sense of the whorl is counter-clockwise. In the absence of a whorl, the counter septum extends to, and apparently across, the axis. From the depths of the cardinal fossula, a septum arises, in the axis, and joins with the counter septum.

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It has not been determined if it is the axial end of the cardinal septum rising from the fossula, or the axial end of the counter septum extending into the fossula. Actual juncture between the two cannot be seen in the fossula due to in-filling sediment. When the axial ends of the septa are whorled, juncture between the counter and cardinal septa is ruptured.

Usually, a broad, flat-topped convexity occupies the calice, separated by a fairly narrow moat from the calice wall. This convexity appears to be due to whorling of the septal ends, accompanied by stereomal deposits between them. The fossula extends into the boss, and is usually affected by the whorl. The moat contains a series of radially-disposed marginal pits in most cases, which are the septocoels restricted to the periphery by axial deposits of stereome. (Plate 3, fig. 15).

Occasionally, there is septal abortion among the major septa, where one or more appear to be crowded out from the axis by their neighbors, such that they reach only mid-way between the ends of the major and minor septa. In at least one case (Plate 3, fig. 9) there is a certain symmetry to this: Two septa are aborted, one being the seventh to one side of the cardinal septum, the other being the eighth to the other side.

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As may be surmised, there is considerable variation in the configuration of the calice floor, depending upon whether or not there is an axial whorl or boss. In a specimen with a boss (Plate 3, fig. 15-17), the calice diameter (at the rim) is about 2.0 cm, with a depth (to the top of the boss) of about 7 mm. The boss diameter is 8.5 mm. The specimen itself measures 2.1 cm along its convex side, and 1.2 cm along its concave side.

A second specimen, without a whorl and boss (Plate 3, fig. 9, 10) has a rim diameter of 1.7 cm, with an approximate depth of 3.5 mm. The vertical profile of the calice is a segment of a circle. The length, measured along the convex side, is 2.1 cm, and along the concave side, 1.1 cm.

A third specimen (Plate 3, fig. 12-14) has a slight axial prominence, but no whorl. The rim diameter is 2.1 cm, about equal to that of the previous specimen, but its convex and concave sides measure, respectively, 3.5 cm and 1.8 cm, making it more elongate than either of the two specimens described above. Yet, its septal pattern is identical to that of the previous specimen, being without a whorl, with a continuous septum running from the counter across to the cardinal side. On the other hand, this specimen has very prominent carinae, while these are absent in the previous specimen.

A series of nine transverse, oriented sections were taken from a single specimen (Plate 16, fig. 3-11):

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The lowest section is 2 mm in diameter. All that can be determined is that the approximately 10 septa present fill the entire cross-section.

The next level is 5 mm in diameter. Here the fewer-than-20 septa still fill the entire cross-section, and are all of one order.

The third section is 7 mm in diameter. About 21 septa are present, with well-developed incipient septa wedged between them. Again, the entire cross-section is filled.

The fourth level is 9 mm in diameter, with approximately 27 septa. It becomes difficult to count the septa now, for while some are fully-inserted, reaching the axis, others are not yet of full length, and reach only about half-way to the axis. So far, all are of the major order. The marginal pits (discussed above) are beginning to form. The cardinal septum is one of the longest, reaching directly to the axis with the other septa abutting against it. From the opposite direction, a second septum (presumably the counter) does the same, but does not contact the cardinal. At this level the counter-clockwise axial whorl forst becomes apparent. The fossula opens to either side of the cardinal septum as two short spaces, midway between periphery and axis.

The fifth level has a diameter of about 11.5 mm, with about 31 or 32 septa. The axial space, which was a pin-point in the previous section, is broader now, with only a few septal ends intruding (noteably that of the counter, and pos-

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sibly, to a lesser degree, the cardinal). This trend of the shortening of the cardinal septum, concurrent with lengthening of the counter, is one of the distinctive features of this species. The marginal pits are now more elongate, approximating full septocoels. The axial whorl is less-obvious here than in the previous section. The cardinal reagion appears to have suffered somewhat from diagenesis, but it seems that the cardinal septum touches the end of the counter septum, though these two are not colinear, nor are they readily differentiated.

In the sixth section, the outline is more elliptical than below, measuring about 13.5 X 11.5 mm in diameter. The shortest diameter lies at about 45° to the cardinal-counter plane. The counter septum reaches and crosses the axial area, but a small gap appears to separate it from the cardinal. The cardinal fossula is larger here, but alteration obscures its true nature. There are about 31 or 32 major septa present. What may be incipient minor septa appear in the stereozone, but do not yet protrude into the septocoels. The thickness of the stereotheca is about 2 mm. Stereome deposits give the axial ends of the septocoels a rounded aspect, and restrict the marginal pits peripherally, as well as adding to the solidarity of the axial structure. A gap remains between one side of the counter septum in the axis, and the axial ends of the approaching septa. Otherwise, the axial structure is solid.

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The seventh level measures 15.0 X 13.5 mm across, compressed as the last section. The cardinal fossula here nearly reaches the axis. About 36 major septa are present. The marginal pits are longer here, shaped more like ordinary septocoels. Stereome is still present in the axis, but the axial structure is more loose here. The axial whorl is well-defined, and there is no connection between the counter and cardinal septa. The minor septa do not yet protrude from the stereozone, which has about the same thickness as in the above section.

The eighth level measures 16.0 X 15.0 mm across, compressed as below. There are 35 major septa present. The axial whorl, though recognizeable, is weak. The presumed counter septum crosses the axis, but does not contact the cardinal septum. The distal ends of the major septa in the axis are still slightly-thickened by stereome, but not to the degree encountered in lower sections. The axial structure has become more open. The minor septa do not yet protrude from the stereozone. The cardinal fossula reaches the axis and is slightly affected by the whorl. The septocoels are now largely free of stereome, and in them may be seen the first signs of tabulae.

The nineth, and highest level is incomplete. It appears to have been compressed as below, with a maximum diameter of 17.5 mm. The stereozone is 2 mm thick. The septa do not reach the axis, as this section is just above the

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calice floor. As a consequence of this, the cardinal fossula is parallel-sided (whereas below, the sides bowed outward slightly), and opens axially. The cardinal septum is considerably shorter than in lower sections. The theca at the cardinal area is about half the thickness found elsewhere at this level, and the cardinal septum hardly extends beyond the inner edge of the adjacent stereozone. The minor septa now protrude as short points in the septocoels, though the base of the protruding portion is much narrower than the segment of wall from which it emerges.

Other specimens show the same features in transverse section as this specimen. In some cases, the sutures between the septa in the stereozone are zog-zagged, reflecting the intersection of the septal carinae with the plane of the transverse section. The axial whorl may occur at one level, but not at another. In one specimen (Plate 3, fig. 12-14), for example, the calice floor does not have an axial whorl, and the cardinal and counter septa appear to be continuous, and in contact. A transverse section just below the calice level, however (Plate 15, fig. 18), shows a small whorl, with one of the septal ends blocking contact between the cardinal and counter septa.

Longitudinal sections of this species (Plate 15, fig. 19; Plate 16, fig. 2) show a corallite filled basally with stereome, but becoming more spaceous distally. Strongly-convex incomplete tabulae may be seen between the theca and the

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axial structure. The section on Plate 15 shows the septal carinae, visible as short bars nearly perpendicular to the corallite's outer surface, such that they are slightly higher axially than peripherally.

DISCUSSION - In a series of papers (1868, 1882, 1896), Lindström discussed his species, Zaphrenthis conulus, from the Baltic area and the Siberian Platform. The first reference (1868) consists of two transverse views of the corallite, showing 25 major septa (including the cardinal) with an equal number of minor septa, at most 1/3 the length of the majors. The cardinal septum, along with two other short septa on either side of it, lies in a parallel-sided fossula, which extends to the axis. The axis is vacant, the void occupying about 1/7 the total diameter of the corallite. This axial space, connected with the fossula, has the combined appearence of a key-hole. The septa and fossula are affected by a counter-clockwise axial whorl. The specimen is from Gotland, but neither its size nor its horizon are given.

In his 1882 paper, Lindström refers to occurrences of his species in the Silurian (probably Early or Middle) of the Middle (Podkamennaya?) Tunguska River Basin of the Siberian Platform. These are specimens considerably larger than the average, reaching 40 mm long and 23 mm broad at the calice rim. The largest examples are more expansive distally and not so elongatedly conical. Also, they are somewhat

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curved. Lindström asserts that, in thin-section, they are in agreement with the Gotland specimens.

In the same paper, he refers to specimens of this species from near the Olenek River, of Silurian age. These are regularly-conical and straight. The cross-section near the calice is elliptical to circular. The calice is funnel-shaped, deepened at the innermost end (axial) of the cardinal fossula. The axis is whorled. There are 34 to 35 major septa, and an equal number of minors. The cardinal fossula is very large, and key-hole-shaped. The tabulae are frequently incomplete, and arched against the axis.

Lindström's 1896 reference is more detailed, and deals with the Gotland form. The corallite is simple, straight, regularly-conical, seldom curved (and then only slightly). The theca is weakly-rugose. There are no signs of attachment devices. The calice is circular to slightly elliptical, its depth extending for 1/5 the total corallite length. A corallite 55 mm long has a calice 12 mm deep, and about 30 major septa, alternating with as many minor septa which project but slightly from the wall. Two or three septa, including the cardinal, occur in the fossula. The major septa extend to the axis and meet along a circular rim which bounds the axial space. The septa bear ridges and grooves, as found in the Brassfield specimens. In thin-section, the major septa appear as twisted cords rimmed by dark stereome. The axial edges of the major septa are irregular, such that when

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they meet and grow together, a spongy mass forms in the axial area. The sparse tabulae are strongly convex axially.

This species bears a general resemblance to ours. The form of the cardinal fossula is similar, as is the ridging of the septa. In details, however, differences are evident. The two septa neighboring the cardinal in the fossula abut against the sides of their neighbors, the major septa forming the fossula walls. This character, found in the Brassfield form, does not appear in Z. conulus. Also, while something approaching an axial void is on rare occasions seen in our specimens (e.g., Plate 3, fig. 15), it is never so well-developed as in Lindström's form. Finally, R. daytonensis is invariably curved, while Z. conulus is generally straight. The conclusion drawn is that, while Z. conulus is surely congeneric with R. daytonensis, the two forms are distinct species.

Foerste (1890) introduced a new form, Cyathophyllum celator daytonensis from the Brassfield Formation at Dayton, Ohio. He regarded it as a new subspecies of Hall's (1877) Zaphrenthis celator. Examination of the type of Hall's species (AMNH 1888) shows that these two forms are not conspecific. Foerste's type suite consists of the holotype (USNM 84796) and three paratypes (two catalogued as USNM 84796 and one as USNM 93518). The holotype is shown on Plate 2, fig. 27, and Plate 16, fig. 1, 2 of this work. The paratypes are shown on Plate 2, fig. 25, 26, 28.

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All the specimens are trochoid, and bear rugosity and longitudinal striae on their outer surfaces. On the surface of the holotype (see figure), the pattern of septal insertion makes it clear that the convex side (shown in the figure) is the location of the cardinal septum.

The holotype was studied in transverse and longitudinal sections (Plate 16, fig. 1, 2, respectively). The transverse section has a diameter of 2 cm, and shows about 38 major septa, including the cardinal. The minor septa are represented by extremely short points barely protruding from the stereozone (which is 3 mm thick, with zig-zagged sutures between the proximal ends of the septa). The structure of the cardinal fossula is somewhat obscured by fragmentation. The major septa and the axial end of the fossula are affected by a counter-clockwise axial whorl, and the axial ends of the major septa have stereomal deposits between them, making the axial structure more solid. There is no appreciable axial void.

The longitudinal section shows the meaning of the zig-zagged sutures in the stereozone: The septa bear carinal ridges on their sides, which rise axially. The ridges are spaced about 3 per mm, and are more strongly-developed in the stereozone than on the sides of the free septa. Very steep tabulae, some incomplete, occur in the space between the stereozone and the axial complex. This form is undoubtedly a species of Rhegmaphyllum Wedekind, and is identified

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with the Brassfield form. (In 1893, Foerste recorded the presence of this species at Dayton, Ohio, in the"Clinton", and repeated the same figures of the 1890 paper, without a description.)

In 1896, Lindström presented a detailed description and figures of a species, Zaphrentis vortex, for which he had previously (1885, 1888) given only the name, with no description or figures. The specimens are from Gotland, in the oldest marls in the area of Visby (Upper Llandovery or Lower Wenlock, according to Manten [1971, p. 43 and geologic map]). This coral is conical, generally curved, short and expands rapidly distally. The rugae are coarse. The sutures of the septa in the stereozone are undulose, as in the Brassfield form. The calice is quite deep, about 17 mm in a corallite 25 mm long. The septa bear sub-horizontal ridges, as found in the Brassfield specimens. The cardinal fossula is prominent, deepest axially, and has a key-hole-like form. It is often affected by an axial whorl whose direction cannot, however, be determined from the figures. The axial region is thickened by stereome. Where not obscured by stereomal deposits, a few tabulae may be seen, apparently arching upward axially.

Lindström's figure 71 suggests the counter septum goes into the axial end of the cardinal fossula, a feature distinctive of our form. If this does in fact occur, then it is likely that the two are conspecific, possibly represent-

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ing two varieties of the same species. Pending further study, we must regard the Brassfield and Gotland forms as only possibly conspecific.

Weissermel (1894) described what he regarded as specimens of Zaphrenthis vortex from Königsberg, Trömpau and Bergenthal in Prussia. He gave a general description of what were apparently fragmentary examples.

The corallite is short, conical, rapidly expanding distally, straight or weakly-curved. The thecal striae are pinnately-arranged against three principal striae. The cardinal fossula is wide and long, reaching the axis, and remaining about constant in width. It contains the short cardinal septum, and what Weissermel regarded as two minor septa. The cardinal fossula is bounded by two major septa, parallel to the cardinal. In the rest of the calice, the septa are radially-arranged. Besides the cardinal septum, there are 25 to 43 major septa, alternating with an equal number of minors. When the corallite is curved, the fossula lies on the convex side.

Where the interior is not filled with stereome, tabulae may be seen, horizontal in the axis, and sloping steeply peripherally. There is no dissepimentarium.

Weissermel's description is too sketchy to allow confident identification of his form with our own, though there are clearly similarities. No mention is made of ridged septa, nor of the fate of the counter septum on reaching the

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axis. Also, the lack of strong curvature is more reminiscent of Rhegmaphyllum conulus (Lindstrom) than of R. daytonensis (Foerste).

Foerste (1906) described what he regarded as a new species, Zaphrenthis charaxata from the Waco bed of the Noland Member, Brassfield Formation, north of Irvine, Kentucky (locality 53-53a of this study). The type suite (USNM 87178, of which the lectotype here chosen is shown on Plate 3, fig. 1-5) consists of four specimens, labelled as cotypes, from among the total of twenty-nine specimens included under this catalogue number. In all specimens, the calice walls have been destroyed, leaving only the calice floor, with occasional fragments of the wall, and the lower portions of the corallites. Most of the specimens are around 1 cm in diameter, trochoid, ranging from 1.83 to 0.82 cm in length (measured in a straight line from the base of the corallite to the calice floor on the convex side). In all but one instance, the corallites are curved, and in all but two instances (or possibly three) the cardinal fossula is on the convex side of the corallite. Of the thirteen specimens in which the axis was clearly visible, all but two have a counter-clockwise axial whorl. The number of major septa range from 27 to 32. In some cases the axial ends of the major septa, where they meet in the axial complex, are dilated (Plate 3, fig. 1), almost forming small separate knobs. The peripheral ends of the septa are also thick-

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ened. The sides of the cardinal fossula are generally parallel, and the fossula reaches the axis. Quincunx could clearly be seen on the surfaces of twenty-two of the specimens. In two of the largest specimens (including the original of Foerste's fig. 4A) the sides of the septa are ridged, though this was not always obvious, due to wearing of the specimen. In transverse section (Plate 15, fig. 15, 16) the proximal thickening, and the parallelism of the sides of the fossula are most obvious. Without question, this form is conspecific with R. daytonensis (Foerste).

Lindstroemia torsa Scheffen (1933) from Stage 6 (probably Llandovery) in the Oslo area of Norway, bears some resemblance to our form. The major septa are fused together axially, where they and the cardinal fossula are affected by a counter-clockwise whorl. This torsion, visible even in the more-compact younger stages, is considered typical of the species by Scheffen. The whorl rises as an axial convexity in the floor of the calice. The minor septa are but weakly developed. Tabulae cross the plane of section in the septocoels, sloping downward from the axis. The corallite diameter is about 15 mm, and the septa seem to have lateral spacing similar to that seen in our own specimens. From the little that can be seen in Scheffen's figures, and discerned from his description, it seems possible that this form will prove conspecific with our own, judging from the septal arrangement, features of the fossula, and the stereome-thickened axial structure. Lack of information, however, on the

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experiences of the counter septum, and on the presence or absence of septal carinae, make it wisest to reserve judgement.

From the Sayabec Formation (Wenlock in age) in the Lake Matapedia region of Quebec, Oliver (1962) described Briantelasma sp., a form with much in common with our own. As Oliver's description is readily-available, we will deal here only with a consideration of the similarities and differences between these species.

Oliver's measurements of 60 mm and about 30 mm as the lengths of his two specimens, and 13 mm and 12 mm as the corresponding maximum diameters, indicate corallites rather more elongate than ours. The number of major septa in a given diameter (29 in 12 mm, 20 in 7 mm, for example) indicate ratios similar to those found in the Brassfield specimens. The septa are often rhopaloid (dilated distally), as is common in our own, and the axis is affected by a counterclockwise whorl. There doesn't appear to be a void in the axial structure. The stereozone is about 1 mm thick at the level of a corallite diameter of 1.2 cm.

The minor septa project only a very short distance from the stereozone, reaching no more than 1/4 the length of the majors. The fossula is not clearly shown in the figures, but generally seems similar to our own. Marginal pits appear in one cross-section that is just over 1 cm in diameter, and so far as can be determined, the interior is filled

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There is no indication from lower sections of the progressive shortening of the cardinal septum, and coincident lengthening of the counter septum found in our form, nor is there mention of septal carinae. These two factors are sufficiently important to require a suspension of judgement on the affinities of the Quebec and Brassfield forms pending further study, but the available information indicates the likelihood of a close relationship.

Scrutton (1971) described a new species, Leolasma kaljoi, from Rio Caparo near the Paso Caparo in the Merida andes of Venezuela. This is the only reference encountered during this study of a Silurian coral from South America. Scrutton assigns an Early Llandovery age to his material.

These are straight, conical corallites, reaching at least 30 mm in length, with steep-sided calices about 10 mm deep. The early stages are free of septocoels, the septa occupying the entire cross-section. Incipient septa appear as wedges between the proximal ends of the septa. In some instances, an axial vortex twists the septal ends in a counter-clockwise manner. A cardinal fossula appears to be the first space to form in the cross-section, followed by an axial thinning of the major septa. With this axial thinning, the dilated axial ends of the major septa remain to fill out the axial complex. From the time of axial separation of the major septa, the cardinal septum shortens rapidly, and the rhopaloid ends of the septa in the axial complex break apart,

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causing disintegration of the complex. As noted in one of our specimens (Plate 15, fig. 18), the cardinal fossula extends proximally into the stereozone, making the thecal area thinner at this point than elsewhere. The corallite diameter ranges up to 17 mm, with 38 major septa present in this case. Tabulae were observed in only one longitudinal section, and seem similar to those present in the Brassfield specimens.

It is in its straight, conical form that L. kaljoi most clearly differs from the Brassfield form. This, plus the absence of evidence that the counter septum extends axially at the expense of the cardinal septum, and the lack of mention in the description of septal carinae make it best to not conclude that these forms are conspecific. Further study may, however, show that they are of the same species, as there remain many similarities.

Distribution - Ohio and Kentucky: Middle Llandovery (Brassfield Formation).

Possibly conspecific forms occur in the following localities: Gotland: Upper Llandovery or Lower Wenlock; Norway: Llandovery?; Quebec: Wenlock; Venezuela: Early Llandovery.

Brassfield occurrence - Localities 1, 5?, 7a, 11, 12?, 13, 23, 26?, 30?, 31, 32?, 34, 36, 37, 38?, 40?, 41, 42?, 46, 47, 48, 49, 50, 51, 52?

Specimens collected by Foerste (reported 1890) in Dayton, Ohio; (reported 1906) north of Irvine, Kentucky (vicinity of localities 53-53a of this study).

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Schlotheimophyllum Smith, 1945

1945 Schlotheimophyllum Smith, p. 18

Type species - Fungites patellatus Schlotheim, 1820, p. 347, partim

Type locality and horizon - Silurian of Gotland.

DIAGNOSIS - Solitary or compound corals, lacking dissepimentarium; theca a septal stereozone; corallite patellate, with reflexed calice walls; septa of both orders dilated, in mutual contact laterally along sutures, with no septocoels remaining; minor septa indistinguishable from majors in outer portion of calice wall, both orders of nearly equal length; major septa reach axis, sometimes forming axial structure; calice wall has fibrous microstructure, without dissepiments.

DESCRIPTION - This genus contains corals of solitary and compound form, which often grow to unusually large size, and beautiful countenance. The calices are broad and explanate, such that the corallite often appears like the modern Fungia, a possible ecologic analogue. The calice walls form a broad horizontal surface which appears to have encrusted the sediment surface, and the more central portion of the corallite is similar in position to the stalk of a mushroom. The septa of both orders are dilated throughout almost their entire length, so that the septocoels are reduced to sutures over

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all the horizontal platform formed by the outer calice walls. It is only in the central region that they differentiate visibly into major and minor septa. Here, the minors stop abruptly, their axial ends describing an ellipse or circle around the corallite axis. The major septa continue axially, often first having their upper edges depressed below the level of the outer parts of the calice, to form a calicular pit. In the axis, the ends of the major septa, in some species, intertwine to form a ropy axial structure which may protrude to form an axial boss.

The internal structure of this genus is striking. There are no vesicular dissepiments in the marginarium. Rather, this portion of the corallite consists of layers of trabecular sclerenchyme representing the septal microstructure, with no interlayered dissepiments. The surfaces of these layers are oriented in such a way as to slope downward toward the corallite axis (that is, in the same direction as would be expected were they layers of dissepiments in a dissepimentarium).

Tabulae are restricted to the narrow calicular pit, and tend to be incomplete.

DISCUSSION - Schlotheimophyllum, Mucophyllum, Chonophyllum, and Craterophyllum are four rugosan genera all sharing the basic characters of a wide, reflexed calice wall with dilated dissepiments meeting along sutures, and a patellate form. For this reason, they have often been confused, one

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for the other. Their basic differences lie in combinations of two characters: calice walls with a trabecular or dissepimental structure, and axial ends of the major septa either entering or not entering the calicular pit area. Following is a cross-tabulated table to show the relationships of these genera, all of which, it might be noted, are Silurian forms:

	Structure of calice wall: Trabecular	Structure of calice wall: Dissepimental
Septa enter calice pit	Schlotheimophyllum	Chonophyllum
Septa do not enter calice pit	Mucophyllum	Craterophyllum

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Schlotheimophyllum patellatum (Schlotheim)

Plate 5, fig. 1; Plate 20, fig. 1, 2

1820 Fungites patellatus Schlotheim, p. 347 (partim)

1837 Fungites patellatus Hisinger, p. 99, Plate XXVIII, fig. 3

non 1854 Ptychophyllum patellatum Milne-Edwards & Haime, p. 291, Plate LXVII, fig. 4, 4a

cf. 1865 Ptychophyllum canadense Billings, p. 107.

cf. 1901 Chonophyllum canadense Lambe, p. 185-186, Plate XVII, fig. 1, 1a-c, 2, 3, 3a, 3b, 4

cf. 1901 Chonophyllum belli Lambe (partim), p. 186-187, Plate XVI, fig. 6 (non fig. 5; non Billings, 1865)

1926 Chonophyllum patellatum Lang, Plate XXX, fig. 4-6

1927 Chonophyllum planum Wedekind, p. 41-42, Plate 7, fig. 2, 3

1927 Chonophyllum patellatum Wedekind, p. 42, Plate 7, fig. 1

1945 Schlotheimophyllum patellatum Smith, p. 18-19, Plate 32, fig. 1

1970 Schlotheimophyllum patelloides Flügel & Saleh, p. 276, Plate 4, fig. 4

1971 Schlotheimophyllum patellatum Lavrusevich, p. 66-67, Text-fig. 15

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Type material - Lectotype of Smith (1945, p. 19): " a specimen from Gotland bearing Schlotheim's original label, in the Schlotheim Collection, Geologisch-paläontologisches Institut und Museum (Naturkunde Museum) der Friedrich-Wilhelms Universität, Berlin."

Type locality and horizon - Silurian of Gotland

Number of specimens studied - 1

DIAGNOSIS - Schlotheimophyllum in which the early stage is trochoid, but which develops a broad, reflexed calice wall, forming a horizontal platform in later stages; septa of this platform are broad, flattened, and laterally-contiguous along sutures; in the axis is a calicular pit, containing a convex axial structure which may be circular or elliptical in horizontal section, formed by axially-contorted major septa and tabulae.

DESCRIPTION - The specimen is a solitary corallite, of which about 1/3 is missing. Assuming the corallite was originally symmetrical, it was elliptical in the horizontal plane, measuring about 5 X 4 cm in diameter and 1.25 cm high. In its earlier stages it was trochoid, or perhaps turbinate in form. In later stages, its width increased at a far-greater rate than its height, and the calice walls became reflexed, such that they they formed horizontal extensions of a broad upper platform. In general appearance, then, it was similar to Fungia (the "mushroom coral"), a Recent scleractinian. In

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In the center of this platform is the elliptical calicular pit, measuring 2.2 X 1.1 cm in diameter, and elongate in the same direction as the corallite's upper surface.

The septa are wedge-shaped in surface aspect, dilating proximally to a maximum width of 1.25 mm at the periphery of the horizontal calice platform. Throughout most of this horizontal region, the minor septa are not morphologically-distinct from the major septa, and all septa are laterally-contiguous along straight suture-lines. Proximally (about 1.4 cm from the periphery of the corallite) the septa all thin to a blade-like edge, and plunge toward the floor of the calicular pit. The minor septa extend no further towards the axis than the rim of this pit. The major septa, however, continue across the floor of the depression, and their axial ends twist and fuse into an elevated, elliptical axial structure. This structure has a relief of about .25 cm, and is elongate, with basal diameters of 1.5 X .5 cm. The texture of this structure is ropy, and its elongation is in the same direction asthat of the calicular pit.

In vertical section, the corallite's broad platform has a fibrous structure (Plate 20, fig. 2), characteristic of the genus. These fibers represent the trabecular elements of the septa. The septocoels are closed, leaving no room for dissepiments. The calicular pit (Plate 20, fig. 1) contains the contorted elements of the axial structure, consisting of twisted septal ends and incomplete tabulae. Be-

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tween this structure and the walls of the pit arch several incomplete tabulae, separated vertically by about 1 mm.

At one point, during its reflexed stage (Plate 20, fig. 1) the corallite decreased in radius at one edge by about .5 cm, and then expanded by about .35 cm, just prior to the polyp's death. A similar feature may be seen in Wedekind's Chonophyllum planum, in his Plate 7, fig. 3.

DISCUSSION - In examining descriptions and figures of specimens assigned to S. patellatum, it was tempting to consider the Brassfield specimen, with its elongate calicular pit and axial structure, as distinct from other specimens of the species, in which these features were more circular in outline. It appears preferable, however, to mold the concept of Schlotheim's species to include this range of variation. The length:width ratio of the Brassfield specimen's calicular pit is 2. In comparison, a specimen from Gotland, consisting of four laterally-fused corallites of this species (no 4814 in the collection of the University of Cincinnati Geological Museum), has three corallites in which this ratio is 1.5, and a fourth with a partially-broken pit region that appears to have been nearly circular.

Smith (1945, p. 19) designated as lectotype of this species the single specimen remaining of Schlotheim's six syntypes. Unfortunately, he did not figure the specimen, and gives a rather general description: "Although a somewhat worn specimen it admirably typifies the species, as inter-

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preted by Hisinger, Edwards and Haime, and others. It is a flat, oval specimen of the usual mushroom shape 20 mm high and 70 mm wide through its longer diameter."

Hisinger (1837) mentions the occurrence of S. patellatum on Gotland, and his figure (Plate XXVIII, fig. 3), though showing nothing of the interior of the calicular pit, is in good agreement with our concept of the species. He notes its lamellar structure, round outline, and flattened surface.

Milne-Edwards & Haime (1854) describe and figure a specimen identified as Ptychophyllum patellatum. They thereby synonymize with Schlotheim's species one described by Lonsdale (1839), Strombodes plicatum (see synonymy and discussion under Schlotheimophyllum benedicti). In fact, Land & Smith (1927, p. 482) note that Milne-Edwards & Haime's figures are of the same specimen (G.S. 6569) as was illustrated by Lonsdale (fig. 4b, c). This specimen is not here considered as conspecific with Schlotheim's species, but rather, is assigned to S. benedicti (which see, for explanation).

Lambe's (1901) illustration of the type of Ptychophyllum canadense Billings from Anticosti Island appears to be a different form from S. patellatum. The broad, reflexed calice is present, and the dilated septa are contiguous laterally along sutures. The central pit, however, is enclosed in a steep-sloped, relatively-narrow mound, rather more narrowly conical than is usual in this species. More important,

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while Billings mentions the septa entering the calicular pit, the major septa meeting in the axis with a whorl, the type figured by Lambe (Plate XVII, fig. 1, 1a-c) appears to be without septa in the central pit. Rather, it appears more like Craterophyllum Foerste, with septa extending only to the margin of the pit, and only tabulae present within the axis. Further, Lambe's figure gives no evidence of a convex axial structure, here considered typical of S. patellatum. In fig. 3b, however, Lambe shows the calice of another specimen in which the septa do clearly reach the axis of the calicular pit (though there is no convex axial structure indicated). It will be necessary to study the type material of P. canadense first-hand before its relationships can be understood.

In the same publication, Lambe redescribed Billings' (1865) Chonophyllum belli. He figured two specimens, one of which (Plate XVI, fig. 6; non fig. 5, the lectotype) bears a strong resemblance to S. patellatum from the Brassfield. However, examination of this specimen (GSC 2624a) revealed what appear to be vesicular dissepiments in the reflexed calice wall, suggesting that this does indeed belong to Chonophyllum, as does the lectotype. These specimens are from the Silurian of Grand Manitoulin Island, Lake Huron.

Lang (1926) figures sections of what appear to be S. patellatum. One figure (Plate XXX, fig. 4) is from "horizon c of Lindström, Häftings Klint (North Gotland)",

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probably of early Ludlow age. The second specimen (fig. 5, 6) is reportedly from beds of Wenlock age on Gotland. These figures show the trabecular structure of the corallite, and the nature of the axial structure (which is somewhat elongate in fig. 4).

Wedekind (1927) describes and figures a new species, Chonophyllum planum, from Skovengen, Tyrifjord, Norway. No age is given for the specimens on which the description is based. In the same paper, Wedekind described and figured Chonophyllum patellatum from the coast near Visby, Gotland, in the Dinophyllum-Chonophyllum horizon (Högklint beds, of Early Wenlock age). Both forms are figured as silhouettes, but it is clear, through comparison with his other figures, that Wedekind intended to show that these are not vesiculose. The difference between these two species, according to the author, is the presence of rejuvenescence, and apparently, the sharper break at the calice rim between the near-horizontal upper surface and the descending wall. Examination of specimens and published figures, however, indicates that these differences are all accommodated within S. patellatum.

From the Silurian Niur Formation of eastern Iran, Flügel & Saleh (1970) describe Schlotheimophyllum patelloides, which appears in no significant way different from Schlotheim's species. The form is patellate, with reflexed calice walls, and a central circular calicular pit containing a convex axial structure of twisting, fused major septal ends

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and tabulae. The trabecular nature of the corallite deposits, and absence of vesicular dissepiments is clear from the figure. The septa dilate peripherally, and are in lateral contact along sutures.

Finally, Lavrusevich (1971) reports Schlotheimophyllum patellatum from the Late Llandovery of the Zeravshan-Gissar Mountain region of Uzbekstan. The specimen is patellate, reflexed, 16 mm high and 50 mm wide. The central pit has a width of 7 mm, and a depth of 5 mm. The apical angle, typically obtuse in this species, is about 100°. Within the calicular pit is a convex axial structure formed by septal ends and domed tabulae. The septa dilate peripherally, leaving no septocoels. The reflexed calice is thickest around the calicular pit (10 mm), gradually thinning to 2 mm near the periphery.

Distribution - Gotland: Early Wenlock - Early Ludlow; Norway: Silurian(?); Iran: Silurian; Uzbekstan: Late Llandovery; Ohio: Llandovery (Brassfield Formation); Anticosti Island(?): Silurian.

Brassfield occurrence - Locality 7a, in southwest Ohio (Fairborn).

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Schlotheimophyllum benedicti (Greene)

Plate 3, fig. 18-20; Plate 4, fig. 1-4; Plate 17, fig. 1-5

1839 *Strombodes plicatum* Lonsdale, p. 691-692, Plate 16 *bis*, fig. 4b, c (*non* fig. 4, 4a; *non Cyathophyllum plicatum* Goldfuss, 1826, p. 59)

1854 *Ptychophyllum patellatum* Milne-Edwards & Haime, p. 291, Plate LXVII, fig. 4, 4a (*non Fungites patellatus* Schlotheim, 1820, p. 247)

1887 *Omphyma verrucosa* Davis, Plate 105, fig. 11 (*non* Rafinesque & Clifford, 1820, p. 235; *nec* Milne-Edwards & Haime, 1851, p. 403; *nec* Rominger, 1876, p. 118)

1900 *Ptychophyllum benedicti* Greene, p. 28, Plate 12, fig. 4-6

1927 *Chonophyllum*(?) *patellatum* Lang & Smith, p. 482 (*partim*); (*non Fungites patellatus* Schlotheim, 1820, p. 247)

Type material - Lectotype (of Stumm, 1964, p. 25): AMNH 23505, original of Greene's fig. 5 (figured here in Plate 4, fig. 1-4, Plate 17, fig. 3-5); Paratypes: AMNH 23504, 23506.

Type locality and horizon - Louisville Formation (Late Wenlock and Early Ludlow) near Louisville, Kentucky (Bear-grass Creek quarries).

Number of specimens studied - 1

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DIAGNOSIS - Schlotheimophyllum in which the septa are not fused along a suture in the more horizontal outer portion of the calice, but retain a narrow valley between themselves; septa "feathery" in texture; axial boss absent; septa meet in axis, and are affected by counter-clockwise whorl.

DESCRIPTION - The specimen collected from the Brassfield is broadly-turbinate, but the configuration of what remains of the base suggests that the corallite was trochoid in its earlier stages. The walls display several episodes of sharp change in their profile, shifting from near-horizontal to near-vertical (Plate 3, fig. 19). This produces a "stepped" or "shelfed" profile, apparently common in this species. The theca has very broad ribs (Plate 3, fig. 20), separated by somewhat-narrower troughs. Near the base of the corallite, these ribs are about 0.3 mm across (measuring from trough axis to trough axis) and broaden upward to about 1.3 mm near the top.

The specimen's axial length is 2.2 cm to the level of the calice rim, and the calice is 0.9 cm deep. In addition, an estimated 0.4 cm has been lost from the base of the corallite. The calice reaches its maximum diameter of 4.7 cm at an estimated height of 2.3 cm above the original base (the minimum diameter at this level is 3.5 cm). At this point, rejuvenescence occurred, the calice contracting, and the growing area shifting to a segment of the calice constituting about 40% of the septocoels. From this region, a new calice

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developed, while the rest of the old calice filled in with sediment. The new calice grew with one side contingent with the nearest wall of the old calice, and at the time that growth ceased, had attained a lip-to-lip diameter of 3.5 X 2.5 cm.

The calice wall consists of two zones: the upper half lies at an angle of about 25° to the horizontal, while the lower half is steeper, about 35°. The result is a central steep-walled area with an outer region of more nearly-horizontal wall. The boundary between these two regions is gentle, but distinct, and the hollow it encloses is about 2.0 X 1.3 cm in diameter at its upper limit. The calice floor itself is concave.

The upper, rejuvenated calice has approximately 30 major septa, with what appear to be minor septa between some, but not all of them. All the septa are broad and flattened in the outer, more horizontal portion of the calice, and separated by grooves less than half as wide as the septa themselves. The septa taper downward and, in the deeper portion of the calice, are as narrow as, or narrower than the grooves separating them. It seems that only the major septa cross the calice floor to meet in the axis, but as the majors and minors are not readily-distinguishable, it is safest to say that some of the septa stop short of the axis, going no farther than the lower portion of the steep central wall. The rest of the septa cross the calice floor and meet in the

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axis, though many join their ends with those of their neighbors just before the axis, closing their septocoels. The axis is affected by a weak, narrow, counter-clockwise whorl.

A transverse section of the specimen just below the calice floor (Plate 17, fig. 2), where the diameter is 1.8 cm, reveals clearly the major and minor septa. The minors lie between each pair of majors, and extend from the periphery about half-way to the axis.

Perhaps the most distinctive feature of this specimen is the "feathery" texture of its septa. This may be seen in both superficial examination of the specimen, and in thin-section, and is most obvious in the outer portion of the calice, where the septa are widest. It appears to be due to pitting of the septal surfaces, and the presence of very short splinter-like branches diverging from the axis of each septum towards the periphery of the calice.

In vertical section, the calice walls appear to consist of distinct layers, each having trabeculae projecting about 0.5 mm normal to its surface (Plate 17, fig. 1). The septa, as seen in this section, are undulatory. No tabulae or vesicular dissepiments were noted in vertical section, though what may be very thin-walled dissepiments appear in the septocoels as seen in transverse section.

There is no evidence of basal attachment-structures on this specimen.

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DISCUSSION - The first appearance of this species in the literature is in Lonsdale's section in Murchison's Silurian System (1839). In his brief description, the only feature Lonsdale firmly refers to is the axial spiral contortion of the septa. His figure 4b shows the whorling as counter-clockwise, which, if accurate, would be the only coral with its axis whorled in this direction encountered in this study, from the Lower Paleozoic. It seems more likely that the figure has been somehow reversed, a not uncommon occurrence (e.g., Rominger's 1876 coral plates). Lonsdale seems to have tried to communicate to the reader the idea of a roughened surficial texture on the septa, here interpreted as the "featheriness" noted in our specimen. Also, in his figure 4b, the septa in the more-horizontal outer portion of the calice, while flattened, yet remain separated by spaces too broad to be termed "sutures". Figure 4c shows the broad ribbing and stepped nature of the theca. Lonsdale's figures 4 and 4a may represent worn examples of this species, but they cannot confidently be identified with our species. The specimens described by Lonsdale are from the Wenlock Limestone (Late Wenlock in age, according to Gignoux, 1955) on the western slopes of the Malvern Hills, England.

Lang & Smith (1927), in their critical revision of Lonsdale's rugose corals, give the following information on the specimen (GS 6569) on which Lonsdale's fig. 4b and c is based: The diameter is 4.5 cm, and the height less than 2 cm (with

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part of the base missing). The calice has a wide, moderately deep central pit, and a reflexed margin, which succeeds an earlier, broader calice. The axial whorl of the septal ends rises as a boss from the calice floor. The lower surface of the corallite is slightly concave, with a stout central cone representing the early, pre-expansion portion of the specimen. Lonsdale's figures suggest that the axial whorl does not rise in a particularly-pronounced boss, though there does appear to be a small convexity. In any case, this feature is not considered sufficient to preclude the conspecificity of Lonsdale's specimen and our own.

Lonsdale identified his specimens as Strombodes plicatum, referring the species to Goldfuss (1826, p. 59). Goldfuss' figure (Plate XVIII, fig. 5) however, shows the septa of the outer theca as broad and flat, bordering each other laterally along sharp sutures. This is distinct from our specimen, and from Lonsdale's figures. Lonsdale's synonymy also includes Strombodes plicatum of Ehrenberg (1831, p. 312), a reference to which I have not had access, so that it is not possible at this time to determine the relationship between Ehrenberg's coral and our own. Lonsdale's final entry in his synonymy is Milne-Edwards' description of Cyathophyllum plicatum in the second edition (1836) of Lamarck's Histoire Naturelle des Animaux sans Vertebres (vol II, p. 431). Milne-Edwards' reference is clearly to Goldfuss' description and figure of a specimen from the limestones of Sweden, and

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so is no more related to Brassfield specimens of the present species than was Goldfuss' material.

Milne-Edwards & Haime (1954) describe and figure a specimen under the name Ptychophyllum patellatum. According to Lang & Smith (1927, p. 482) this is the same specimen as was shown by Lonsdale (1839) in his fig. 4b, c, and is thus regarded as conspecific with the Brassfield form.

Davis (1887, Plate 105, fig. 11) figured a calice-view of a specimen from the "Upper Niagara white clay, near Louisville" in Kentucky, probably of Late Wenlock or Early Ludlow age, and either from, or associated with the Louisville Limestone. While the general form of this solitary coral cannot be discerned due to the limited view provided by the figure, the calice is clearly similar to that of our specimen. The septa are broad in the outer, more-horizontal portion of the calice, and taper towards the axis, which lies in the central, steeper-walled region. Here the major septa (the only ones to cross the calice floor) are affected by a weak counter-clockwise axial whorl. The septa in the outer portion of the calice are not sutured laterally, but are separated by valleys, apparently broader than are found in the Brassfield specimen, relative to the septal width. In places the septa do appear undulose, perhaps feathery.

Davis identified his specimen as Omphyma verrucosa. Stumm, however (1964, p. 47) notes that this name, originally used by Rafinesque & Clifford (1820, p. 235) apparently

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referred to specimens of Early Mississippian age from Kentucky, and considers the description too indefinite. Milne-Edwards & Haime (1851, p. 403) described a specimen from the Silurian of Drummond Island in Lake Huron, figured by Bigsby (1824, Plate XXIX, fig. 1, 2a, b) which is clearly not comparable to our specimen, nor apparently, to Davis'. Rominger's Omphyma verrucosa has rootlet talons and a prominently-convex calice floor, separated from the wall by a distinct moat. Davis' specimen is thus distinct from Omphyma verrucosa, probably as this name had originally been used, and certainly as it has subsequently been used, so that this name cannot be applied to our Brassfield specimen.

Ptychophyllum benedicti Greene (1900) from the Beargrass Creek quarries near Louisville, Kentucky (Louisville Limestone, Late Wenlock and Early Ludlow in age) seems to be in good agreement with the Brassfield specimen in most features (Plate 4, fig. 1-4; Plate 17, fig. 3-5). The outer surface is "stepped" and broadly-ribbed. The general dimensions of the lectotype (figured here) are quite close to those of our specimen: axial height is 2.3 cm (with one edge of the upper surface slightly higher); diameter is about 3.9 cm; the calice depth is about 8 mm. There are 41 major septa crossing the calicular pit, reaching close to the axis (with a possible void between them), and the minor septa do not extend beyond the calice wall, at the base of the pit. The axial ends of the major septa are

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affected by a narrow counter-clockwise axial whorl, most clearly seen in transverse section, and appear to contain some patches of stereome in this region. Though the specimen is silicified, the trabecular nature of the walls is preserved, and the septa in the outer walls, though dilated, yet have valleys, not sutures, separating them from one another. In these outer portions of the calice, the septa have a somewhat roughened texture, though if this is the "featheriness" observed in the Brassfield form, or merely an artifact of silicification, is uncertain.

The differences between these two corals lie mainly in the more narrow and regular calicular pit in Greene's specimen, and its greater number of septa in a corallite of about equivalent size to our own. In light of the variation seen in similar forms, however, it seems reasonable to consider our specimen conspecific with Greene's.

Incidentally, if Greene's figure 4 is conspecific with with his other specimens, this would indicate that this species can occur in compound, as well as solitary form.

Distribution - Ohio: Middle Llandovery (Brassfield Formation); England: Late Wenlock; Kentucky: Late Wenlock or Early Ludlow.

Brassfield occurrence - Locality 15, in a clay pocket near the top of the unit, at West Milton, Ohio.

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Schlotheimophyllum ipomaea (Davis)

Plate 4, fig. 5-7

1887 Ptychophyllum ipomaea Davis, Plate 104, fig. 7; Plate 105, fig. 9 (non fig. 10)

1890 Ptychophyllum ipomaea Foerste, p. 342-343

1964 Schlotheimophyllum ipomaea Stumm, p. 25-26, Plate 25, fig. 1, 2

Type material - Lectotype (chosen by Stumm, 1964, p. 25): MCZ 8164, the specimen figured by Davis (1887) in his Plate 104, fig. 7 and Plate 105, fig. 9; shown in present work on Plate 4, fig. 5-7.

Type locality and horizon - Louisville Formation (Late Wenlock and Early Ludlow) at Louisville, Kentucky.

Number of specimens studied - None found in the field. Only the lectotype was studied.

DESCRIPTION - The only indication of this species in the Brassfield Formation is Foerste's (1890) description of the best of several specimens he collected from the former quarry in the Brassfield Formation east of Centreville, Ohio. Unfortunately, no illustration accompanies this description. Foerste's account of the specimen, however, is in such good agreement with the lectotype of S. ipomaea (Davis) that it was decided to include this species in the list of corals occurring in the Brassfield. Foerste's description is here given in toto:

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"The specimens here described are from the upper layers of the Clinton Group at Allen's Quarry, east of Centreville, Ohio. The calyx of the best preserved specimen has a diameter of 56 mm. and is composed of ninety-seven septa, which have an average width of 2 mm. near the border of the calyx, where they are contiguous; they gradually narrow towards the centre of the calyx, becoming separated; at a distance of 6 mm. from the centre they are separated to the extent of about .5 to .8 mm. At the centre the lamellar septa of our specimens are not visible but are presumed to be more or less twisted as is common in the genus. At the border of the calyx the tops of the septa are broad and flattish, very moderately convex, and maintain this character for a greater or less degree for about 10 or 12 mm. where they gradually assume the lamellar form. The calyx is broad and flat or but moderately concave for about three-fifths the distance from the border to the centre of the calyx, after which the septa rapidly descend forming a central cup about two-fifths of the width of the calyx in diameter, and <u>at least</u> 5 mm. deep, although on account of the partial filling up of this central depression exact measurements cannot be given. Towards the border the margin of the calyx is usually slightly elevated, thus adding to the suggestiveness of the specific name. The septa as a rule are almost straight in the flattened portion of the calyx, although sometimes slightly curved, yet never as much so as in the Niagara specimen figured from Louisville,

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Kentucky. The vertical height of the specimen is about 33 mm. The external surface of the specimen is vertically marked by the septal furrows, which are in many places rather indistinct, and by concentric quite strong wrinkles with very few concentric striae; the preservation of the exterior of the specimen is such as to suggest that fine striae, even if originally present, have probably not been preserved. Various pits and markings on one side of the specimen may indicate the bases of former rootlets, but of this no certainty is felt. A section at the base of the specimen shows transverse dissepiments when the septa are not contiguous."

DISCUSSION - Foerste referred to this species in the heading to the fore-going description as "Ptychophyllum ipomea sp. nov., a puzzling fact, since he did mention the "Niagara specimen figured from Louisville, Kentucky". Clearly, this must be an error in the text, and it is not considered here that Foerste regarded his specimens as representing a species which he was describing for the first time.

Stumm (1964) gave a description of the specimen figured (but not described) by Davis. This specimen is shown in the present work (Plate 4, fig. 6, 7) from side, top and bottom. Although Foerste included no figure, his description is sufficiently detailed to allow meaningful comparison between his specimen from the Brassfield, and the lectotype.

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The lectotype (shown here natural size) is broader than Foerste's specimen (64 mm vs. 56), but has fewer septa (70 vs. 97). In both specimens, the septa reach a maximum breadth at the periphery of similar proportions (2 to 2.5 mm in the lectotype, 2 mm in Foerste's). The septa in Foerste's specimen behave the same as in the lectotype on approaching the calice pit, becoming separate and narrower. Unfortunately, the axial behavior of the septa is obscured by partial in-filling of the pit in the Brassfield specimen. The depth of this pit is similar in the two specimens. Foerste refers to a slight elevation of the marginal platform of the calice near the border (of the pit?) which is also found in the lectotype. The height of the lectotype (excluding a strange fold of one portion of the periphery) is about 28 mm, compared with 33 mm in Foerste's specimen. Some features possibly identical with the "pits and markings" that Foerste saw on the exterior of his specimen, and which he felt might mark the bases of attachment rootlets, appear on the lectotype. Finally, Foerste's final remark, concerning "transverse dissepiments" seen in a basal section where the septa are not contiguous is difficult to interpret. "Transverse dissepiments" usually refer to tabulae, and he may be speaking of tabulae in the axial area. Unfortunately, no sections were made of the lectotype so that the two specimens cannot be compared in this important manner.

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A feature noted in the lectotype, and unfortunately not mentioned by Foerste, is the fact that, in the peripheral portions of the calice platform, where the septa are most strongly-dilated, there is an alternating widening and narrowing of the septa. When the septa are traced axially, it is found that the broader septa are almost invariably the minors, alternating with the narrower but slightly-longer major septa.

S. ipomaea differs from S. patellatum, one of the two other species of this genus in the Brassfield, in lacking a convex axial structure, and in the alternating of broadness between the dilated major and minor septa.

From the other Brassfield species of this genus, S. benedicti, it differs in lacking the "feathery" texture of the septa, and in having sutures, rather than narrow vallies between the peripheral dilated septa.

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Family Paliphyllidae Soshkina, 1955

Solitary rugosans with dissepimentarium, typically with well-developed talon for basal support; septa thin, with no dilation; tabulae generally incomplete, forming flattened domes; tabularium may contain septal lobes, lamellae, and pali, but these do not inter-twine to form a dense axial structure.

Soshkina and Kabakovich (in Sokolov, 1962) include both Paliphyllum and Cyathactis in the family Cyathactidae. In her original description of these two genera, however, Soshkina (1955) placed Paliphyllum in her new family Paliphyllidae (p. 121), and Cyathactis in her new family Cyathactidae (p. 122). Thus, if these two genera are to be considered co-familial (and in this it seems that Soshkina and Kabakovich are justified), Paliphyllidae clearly is the name to be used, by virtue of its priority over Cyathactidae.

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Paliphyllum Soshkina, 1955

1955 Paliphyllum Soshkina, p. 121-122

? 1956 Sclerophyllum V.M. Reiman, p. 37-38

Type species - Paliphyllum primarium Soshkina, 1955, p. 122.

Type locality and horizon - Siberian Platform, basin of the Podkamennaya Tunguska River, from the upper level of the Stol'bov Suite (Upper Ordovician; Upper Caradocian)

DIAGNOSIS - Solitary rugose corals with dissepimentarium; basal talon commonly present; septocoels open in all stages observed; minor septa long (1/3 to 1/2 the length of major septa); septa in contact axially in early stages, drawing apart as growth progresses, but leaving septal lamellae and pali in axial space; median septum may be located in axial space during neanic and ephebic stages; tabulae generally convex, often incomplete; theca a septal stereozone.

ORIGINAL DESCRIPTION - "Corals solitary, conical, weakly-curved. On outer surface are visible fine longitudinal striae and attachment scars. On the calice floor is a small cupola-like boss. Septa of two orders of length, weakly thickened peripherally, gradually thinning axially. The cardinal and counter septa are joined, and together with disjunct axial ends (pali) of the rest of the septa, form the axial elevation. Tabulae convex marginally, and a

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broad zone of dissepiments is developed peripherally."

DISCUSSION - Neuman (1968, p. 231) expressed the belief that the differences between Paliphyllum Soshkina and Sclerophyllum Reiman (Porkuny Stage, Upper Ordovician or Lower Llandovery of Estonia) are not significant at the generic level. In this he shared the opinion of Kal'o (1958) and Ivanovskiy (1963). The opinion of these authors that intermediate species or varieties link these two genera forming a single genus is difficult to assess at this point. Certainly, the differences in structure of the axial complexes is distinct between Paliphyllum and Sclerophyllum. (In the latter a transverse section reveals a reticulate pattern in the axial complex, apparently without a median lamella or pali.)

These authors have not presented material that convincingly shows synonymy of these genera, so that it is best to reserve judgement on the matter.

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Paliphyllum primarium Soshkina

Plate 18, fig. 1-3

1955 Paliphyllum primarium Soshkina, p. 122, Plate X, fig. 3a, b

cf. 1956b Sclerophyllum sokolovi Reiman (in Kal'o), p. 38-39, Plate X, fig. 5-9; Text-fig. 4

cf. 1958b Paliphyllum soshkinae soshkinae Kal'o, p. 109-110, Plate II, fig. 10-14

cf. 1958b Paliphyllum soshkinae karinuense Kal'o, p. 110-111, Plate III, fig. 1-9

1961 Paliphyllum primarium Ivanovskiy, p. 204-205, Plate III, fig. 2a, b

cf. 1968 Paliphyllum suecicum Neuman, p. 231-237, Text-fig. 1-3

Type material - Holotype: PIN 587/3057 (Paleontological Institute of Novosibirsk), the specimen figured by Soshkina (1955).

Type locality and horizon - Upper Caradocian (upper levels of the Stolbov Group), at the lower course of the Podkamennaya Tunguska River, above the Stolbov River, in the Siberian Platform.

Number of specimens studied - 1

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DIAGNOSIS - Paliphyllum with long, straight major septa, and a relatively narrow axial space (about 5 mm across in a corallite diameter of 2.75 cm); septa relatively numerous proportional to diameter (e.g., 71 of each order in a diameter of 2.75 cm); septa not markedly-thickened peripherally.

DESCRIPTION - A single specimen has been collected, encased entirely in rock, so that its external features and dimensions are unknown. Two transverse, and one longitudinal section were made. Apparently the coral was curved, and the absence of the theca, as well as irregularities of the margins, indicate that the specimen had been subject to considerable wear prior to final burial.

The lower transverse section (Plate 18, fig. 3) was originally about 2.5 cm in diameter, though chunks had been broken from the periphery. The septa are quite abundant, considering the diameter, there being 64 major septa, and nearly as many minors (not all of the latter being yet present at this stage). The major septa are fairly straight, extending for about 11 mm of the 12.5 mm radius, so that there is a rather narrow space in the axis, free of septa. The major septa are broadest at their proximal ends, reaching a width of about 0.6 to 0.7 mm. About 4 mm toward the axis they are thinnest, a hairline, and beyond this they broaden and retain a width of about 0.2 to 0.3 mm, with only the slightest tapering as the axis is approached.

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None of the septa appear to have a mid-line.

The minor septa at this level are perhaps 2/3 the length of the majors. There is an imaginary line through the axis, presumably representing the cardinal-counter plane. The minor septa are contratingent on the side of the major septum to their left on one side of the line, while those on the other side are contratingent on the right. This orientation carries through the entire periphery of the coral. That septum of the two within this imaginary line, from which the axial ends of the minor septa diverge, is here considered the cardinal, by comparison with the pattern in other corals. This presumed cardinal septum is not clearly seen, but one which is in about that position is elongate, its end entering the axial space as a snaking, thickened line. This is accompanied by other such septal elements in the axial space which, however, are disjoined from the septa from which they arise, thus forming the pali so characteristic of Paliphyllum. There appears to me a median lamella at this stage, but it does not lie in the presumed cardinal-counter plane, and it is unclear if it connects these two septa.

Rejuvenescence at this stage is suggested by discontinuity of the minor septa (but not the majors) in one area, and an accompanying infilling of sediment.

The surfaces of the tabulae and the dissepiments intersect the plane of the section in the septocoels. Those nearest the axis are concave toward the periphery, while those

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closer to the periphery are concave toward the axis.

The higher transverse section (Plate 18, fig. 2) has a diameter of 2.75 cm, with 71 major septa and an equal number of minors. The latter are only about 1/2 the length of the former, and are contratingent in the same manner as in the earlier phase. Again, the major septa reach fairly straight towards (but not quite to) the axis, leaving a central gap of about 5 mm. Several septa do, however, continue for a greater distance into the space, and judging by the disposition of the minor septa, by their position relative to the septa of the earlier stage, and by the fact that they are at opposite sides of the coral, two are believed to be the cardinal and counter septa. These extenare somewhat thicker than the more proximal parts of the septa, and usually are not quite colinear with them.

The major septa are thickest at the periphery, about 4 mm wide at most, and appear to be narrowest at a point just proximal to the distal end of the adjacent minor septa. Beyond this point they widen almost imperceptibly, and continue with little change in width to the axis. In some cases, the septal structures of the axis are apparently disjunct from the rest of the septa, forming pali. Most, however, appear to be conjunct.

As in the lower section, the tabulae and dissepimental projections in the septocoels are concave outward in the axial area, and concave inward in the peripheral area.

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There is a zone between these two sets of plates in which very few such plates appear, and this is taken to signify a moat-like depression between the tabularium and the dissepimentarium.

The longitudinal section (Plate 18, fig. 1) was not well-oriented, and missed the narrow axial area. It shows the straight distal ends of the major septa with plates (probably of the tabularium) lying generally at right angles to the septa, in the septocoels. These plates, and those of the dissepimentarium, are 1/3 to 1/2 the thickness of the septa. The dissepiments of the dissepimentarium are about 1.5 to 2.5 mm long (in the axial plane of the coral) and slope down axially at an angle of about 60° from the horizontal, to the corallite axis. The tabularium is about 1.5 cm across near the highest preserved portion of the specimen, and probably consists of incomplete, peripherally-inclined tabulae (as found in most species of this genus). Rejuvenescence is suggested by two sharp outward-directed lips of the dissepimentarium, spaced 12 mm apart.

Of interest is the fact that the close-spacing of the septa near the axis, especially in the upper section, results in some septa being crowded out from the center, so that they remain shorter than the others.

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DISCUSSION - Soshkina described Paliphyllum primarium as solitary corals, adhering one-to-the-other, broadly-conical, weakly-curved, bearing fine longitudinal ribbing on the outer surface, and well-developed attachment-scars. The cup is shallow, with a rounded edge and a broadly-raised axial structure. The major septa are thick at the periphery and not fused in this area, but rather, fully-isolated (presumably meaning they form a stereozone), and thin gradually toward the axis. Their axial ends again thicken, and small oval pali form a rather dense axial structure. The cardinal and counter septa unite in the axis, crossing the axial structure. The cardinal septum lies in a long, narrow, open fossula, located on the convex side of the corallite. The minor septa are about 1/2 radius in length, somewhat thickened, and gradually taper toward the axis. At the confluence of their axial ends and the thickened major septa is formed a sort of inner wall (i.e., the region of the axis within this confluence is visually separate). In a diameter of 24 mm are found 56 septa of each order. The tabulae are convex peripherally, while in the center they intersect the axial structure. It is unclear from Soshkina's figures if the tabulae are complete.

Our specimen agrees sufficiently with P. primarium to be regarded as conspecific with that form. The general features of Soshkina's transverse section are seen in our own, namely the rather narrow axial space, with numerous

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septa (56 major septa in the Siberian form, as compared with 64 in the portion of the Brassfield form with similar diameter). The median septum (axial lamella) in our form is rather less regular (not so straight or symmetrical in the axial space) than that of Soshkina's specimen, but considering the variability of corals, this might be regarded more as a sub-specific, than a specific, difference.

Reiman (in Kal'o, 1956b) described what he considered a new genus and species, Sclerophyllum sokolovi, from the Porkuny Stage (Borkholmian) of the Upper Ordovician or Lower Llandovery at Porkuny, Estonia. Neuman (1968) and Kal'o (1958) regard Sclerophyllum as a junior synonym of Paliphyllum, and so it is appropriate to examine this species in comparison with the Brassfield representatives of the genus.

According to Reiman, S. sokolovi (based upon one incomplete, but well-preserved specimen) is long (reaching 11.0 cm) with a maximum diameter (at a level of rejuvenescence) of 3.5 cm, and a minimum diameter of only 1.6 cm. The corallite is cylindrical throughout. The distance between rejuvenescent levels, as well as the sharpness of rejuvenescence, is unequal. The minimum distance between these levels is 20 mm. Very fine transverse "ornamentation" (rugae?) are present, as well as distinct longitudinal furrows, up to 14 occurring in a width of 1 cm. The relationship between furrows and septa has not been determined.

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The septa in transverse section are thin, and broadened peripherally, where their ends fuse to form a stereotheca. The major septa reach the axial complex, their ends uniting in groups of two and three. The minor septa are over 1/2 the length of the majors. Peripherally, the septa of both orders are identical. The minor septa bend axially toward an adjacent major septum, as a rule affecting contratingency. Judging from Reiman's transverse sections, the contratingency is of the same pattern as seen in our specimen. Reiman described this bending of the minor septa as "changing", with"groups of united septa bending to one side, but septa of other groups, adjacent along the periphery, to the other side". He regards this pattern as related to the arrangement of the quadrants with regard to protosepta. Reiman's Plate X, fig. 7 shows a transverse section 3.2 cm in diameter, with 65 septa of each order.

The axial complex in transverse view has the appearance of a net with cells of different sizes. The thickness of the separate elements of the complex is not greater than that of the septa. In transverse view, the complex occupies 1/4 the coral's diameter.

The convex tabularium consists of incomplete tabulae, spaced with 12 to 13 disposed vertically in 1 cm, but of varying convexity. There are supplementary plates between the tabularium and dissepimentarium. The dissepimentarium, according to Reiman, is "highly primitive", consisting of

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large dissepiments of "unequal development" (convexity?). In areas immediately above levels of rejuvenescence, where the diameter of the corallite is minimal, the tabulae nearly reach the wall of the corallite, and dissepiments have very steep, curved plates. In areas of maximal diameter, dissepiments tend to be elongate. The dissepiments average 5 mm in length, and are inclined axially, with an angle of less than 40° to the corallite wall. Some dissepiments apparently don't rest upon other dissepiments, but rather, lap onto the tabulae.

The resemblance between Reiman's species and our Brassfield specimen are strong. In both cases, there are abundant septa, with the minors of comparable length, and contratingent in apparently the same manner to the majors. The axial structure, in both cases, is quite narrow, and lies in the midst of the rather straight, radiating major septa. The Estonian specimen's tabularium appears to be typical of those found in Paliphyllum, and is therefore of the sort we would expect in our own specimen. The two cannot be compared as to external form, as too little information was obtainable from the Brassfield specimen. Rejuvenescence is a prominent feature of S. sokolovi, and its presence in our specimen is suggested by distinct marginal projections seen in longitudinal section, and by apparent interruption of the minor septa in the lower transverse section. The two lips of rejuvenescence ween in our own longitudinal section are

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12 mm apart, while Reiman reports the minimum interval in his specimen as 20 mm.

The differences are as great as the similarities between these forms. The septa of the Estonian coral appear to be rather thinner than our own. Further, the mature of the axial structure is quite different. The Brassfield specimen has definite pali, and at least in the lower section, a feature that might pass for a median septum. Reiman mentions neither of these features in his coral, and his figures bear out his description of the axial structure as being reticulate. It seems unlikely, then, that these two forms are conspecific, though they may be fairly-closely related.

Kal'o (1958b) described two varieties of a new species, Paliphyllum soshkinae, from the eastern Baltic. The first, P. soshkinae soshkinae, is from the Llandoverian Juurusian Stage, at the Vakhtrepa Canal in the island of Khiyumaa. The corallites are sub-cylindrical, 50 to 60 mm high, with a maximum diameter of 20 to 25 mm. The floor of the shallow calice is convex, and the calice margin is rounded. The epitheca is thin, with a finely-furrowed outer surface, often destroyed.

The major septa are long, gradually-thinning, with thickened axial ends. The septa are weakly-wavy, partially unequal in thickness. The axial complex is generally fairly dense, with coarse elements, granular in appearance (pali?), but in some specimens, later stages of growth have thinner

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elements. The number of septa in a given diameter is as follows: At 19 mm, 33 and 34 septa of each order (two specimens; at 18 mm, 36 septa; at 16 mm, 37 septa; and at 15 mm, 33 and 35 septa.

The minor septa of very young stages are short. The tabulae are convex, and especially in the peripheral parts, are "split" (incomplete?). The dissepimentarium consists of 5 to 6 rows of principally small vesicles. Elongate dissepiments are found among short, highly-convex ones.

This form differs from our own in having apparently finer axial elements, lacking a median septum, in the thickening of the axial ends of the major septa, in having a narrower maximum diameter. In view of these facts, it seems clear that these are different species.

Kal'o's second variety, P. soshkinae karinuense, is from the Raykkyulaskian Stage (Llandovery) of Karinu. The corallite is cylindrical, reaching a height of 60 mm, with a maximum diameter of 30 mm. It displays parricidal budding. The epitheca is finely-striated, and the calice floor is nearly flat.

The septa of both orders are long (the minor septa are over half the length of the majors), and generally thin axially. In five specimens, studied at different levels, the number of septa of each order ranged from 33 to 43, in diameters ranging from 13 to 29 mm.

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In the proximal portion of the corallite, the axial ends of the septa of the first order are thickened, and the axial complex is best-developed. In the middle stage, the minor septa are longer, reaching about 3/4 the length of the majors, and the axial thickening of the major septa has decreased. In late stages, the axial thickening has nearly disappeared, and the axial complex contains separate, oval, coarse fragments (pali).

The tabulae are convex, incomplete. The dissepiments in most cases are small and convex, with interspersed larger ones, which are elongate.

This variety, too, is not conspecific with ours, having far fewer septa in a given diameter, and having thickened septal ends. Also, the Baltic form has proportionally longer minor septa than does the Brassfield form.

Ivanovskiy (1961) described specimens which he assigned to P. primarium, from the Upper Ordovician Dolborsk Stage in the basin of the Podkamennaya Tunguska River in the Siberian Platform. These are solitary corallites, broadly-conical, or shaped like curved horns, relatively small (the height of the best-preserved specimen is not over 30 mm, with a maximum diameter of 18 mm).

The major septa are equal, thickened with layers of stereome. They thin gradually as they reach the axis. Their axial ends are slightly thickened and isolated, forming a dense axial structure of pali. The minor septa are thin,

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and about 1/2 the length of the majors. Their axial ends are often contratingent on the sides of the adjacent major septa, though whether of not the pattern of contratingency is as found in our specimen cannot be determined from the figures or description. In diameters varying between 16 and 24 mm, the number of septa of each order generally varies within the limits of 37 to 56. This higher figure is in good agreement with Soshkina's specimen, and slightly lower than that found in our lower transverse section (25 mm with 64 septa of each order).

The tabulae are incomplete in Ivanovskiy's figure (though in his description he says they are complete), and are slightly convex axially. The tabulae are close-spaced, with an average spacing of 0.5 mm. The marginarium consists of 5 to 9 rows of rather large, strongly-swollen dissepiments.

In the earliest-known stages, the septa are short, and but slightly thickened, with slightly-widened peripheral ends forming a narrow stereozone. Ivanovskiy states that there are no dissepiments, and offers as evidence his Plate III, fig. 2b, a transverse section about 6 mm in diameter. We cannot, however, be certain that the dissepiments have not been subject to wear. Ivanovskiy's longitudinal section goes down to the level from which his small, transverse section must have been cut. It shows a narrow, but definite dissepimentarium at this stage, which widens distally.

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The interior of different specimens shows considerable variation. Variability is seen in the septal thickness, the length of the minor septa (1/3 to 1/2 the corallite radius), the density of the axial complex, and the number of rows of dissepiments (5 to 9), as well as the form of the dissepiments. Not all stages of a single specimen will show the same degree of contratingency of minor on major septa.

The data shows that Ivanovskiy's specimens are close to ours, if not actually conspecific. The straightness of the septa, the narrowness of the axial structure with its pali, the large number of septa relative to the diameter all speak of P. primarium. The absence of a distinct median septum cannot be weighed too-heavily if we are to consider the Brassfield form conspecific with Soshkina's, as our median septum is not so distinct as hers. It seems that, for the time being, Ivanovskiy's specimens may be regarded as conspecific with our own and Soshkina's.

Neuman (1968) described a new species, Paliphyllum suecicum, from the Upper Ordovician Boda Limestone at Osmundsberg, Sweden. This is a ceratoid or cylindrical coral, 5 to 10 cm high, with corresponding diameters of 3.0 and 3.5 cm. The theca is a septal stereozone. A talon is present at the base of the convex side. Neuman noted the presence of very distinct growth-lines, similar to those seen in rejuvenescence, where the direction of growth is altered, but makes no

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definite statement about whether or not rejuvenescence actually occurs. Weak interseptal ridges occur on the theca. The calice is shallow, with a flat bottom. In the early neanic stage, the cardinal and counter septa are joined by a dilated median septum, with the axial ends of the other septa fused with it into an axial complex. With growth, the major septa loose contact with the median septum, and the minors grow to about 1/2 the length of the majors. The septa here are somewhat thicker than at later stages. The cardinal septum is in what Neuman regards as a fairly-distinct pseudofossula.

In later neanic stages, the counter septum loses contact with the median septum. The axial complex now consists of the median septum with some septal lobes, some of which are in contact with it. This is at a level where the diameter is about 13 mm, and the talon is still present in the section. The septa of both orders are now broader peripherally and narrower axially. At a higher level, where the diameter is about 2.2 X 2.0 cm, septal lamellae (pali) develop in the axis. The cardinal septum now detaches from the median septum.

In the ephebic stage, the dissepimentarium is lonsdaleoid, with the largest dissepiments in the most peripheral area. In later stages, there are 3 to 4 series of dissepiments. The theca remains a stereozone. The major septa are now about 2/3 the radius in length, and the minors are about

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3/4 the length of the majors, and contratingent as in the Brassfield form. There may be as many as 50 septa of each order at this stage. The axial structure, which has expanded at the expense of the major septa, now consists of round and elongate septal lamellae (pali) without the median lamella.

The tabularium consists of incomplete tabulae forming a floor generally flattened or weakly-convex, occasionally becoming weakly-concave in the very late stages. The borders are steep, resulting in a marginal moat, often invested with what Neuman calls supplementary plates: generally concave, small plates which are added to the moat to decrease its depth.

This form is clearly not conspecific with our own. The degree of septal thickening in all stages, the relatively small number of septa (46 in a diameter of about 3.0 cm), the waviness of the septa, and the relatively broad axial space are all features pointing to this fact.

Distribution - Ohio: Middle Llandovery (Brassfield Formation); Siberian Platform: Late Ordovician.

Brassfield occurrence - Locality 11, near West Union, Ohio, in the upper Brassfield.

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Paliphyllum regulare sp. nov.

Plate 20, fig. 3-5

cf. 1955 Paliphyllum primarium Soshkina, p. 122, Plate X, fig. 3a, b

cf. 1956b Sclerophyllum sokolovi Reiman (in Kal'o), p. 38-39, Plate X, fig. 5-9; Text-fig. 4

cf. 1958b Paliphyllum soshkinae soshkinae Kal'o, p. 109-110, Plate II, fig. 10-14

cf. 1958b Paliphyllum soshkinae karinuense Kal'o, p. 110-111, Plate III, fig. 1-9

cf. 1961 Paliphyllum primarium Ivanovskiy, p. 204-205, Plate III, fig. 1-9

cf. 1968 Paliphyllum suecicum Neuman, p. 231-237, Text-fig. 1-3

Type material - Holotype: UCGM 41969 , shown on Plate 20, fig. 3-5.

Type locality and horizon - From locality 7a, near Fairborn, Ohio, in the clay-coral layer in the middle Brassfield at this locality, immediately overlying the ferruginous bed.

Number of specimens studied - 3

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DIAGNOSIS - Paliphyllum with marked radial symmetry in ephebic stage; septa dilated proximally, tapering smoothly distally; minor septa contratingent in earlier stages (diameter = 1.0 cm), but only infrequently in later stages (diameter = 1.9 cm); axial structure relatively-broad (c. 6 mm across in total corallite diameter of 1.9 cm), and has long median septum and pali.

DESCRIPTION - Of the three Paliphyllum species found in the Brassfield, this is the regularly-radial in transverse section. The four specimens collected were too poorly-preserved to provide much information on the external features, such as presence or absence of talons.

The best specimen (UCGM 41969 , shown on Plate 20, fig. 3-5) has a diameter of 1.9 cm near its distal end, and a length of about 3 cm along its curved axis, as it has been preserved. About 1 cm is missing from the base. Two transverse, and one longitudinal section were made.

The lower transverse section (fig. 5) was taken just over 1 cm above the lowest preserved portion. The cut was made somewhat off the perpendicular to the axis of the corallite, and the original diameter was slightly over 1 cm. There are approximately 39 major septa at this level, and probably an equal number of minors. The latter appear to be 1/2 the length of the former, and are mostly contratingent upon them. On either side of an imaginary line through the center, the contratingency is to the left and to the right.

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The presumed cardinal septum (that from which the minor septa diverge) is thicker than the others, and appears to lie on the convex side. The presence of a fossula or pseudofossula could not be determined.

The septa of both orders are thickened peripherally, and taper smoothly toward the axis. They undergo only the slightest flexing on their way to the axis, most of the bending occurring at the axial end.

The theca is not preserved at this level. The axial space, with a diameter of about 0.3 cm, contains a loose array of septal lobes and lamellae, all showing considerable curvature. A number of the lobes and lamellae align in the axis, forming a median lamella roughly in the cardinal-counter plane. Any connections with the septa are obscure.

The tabular and dissepimental projections in the plane of the section are concave axially in the peripheral portions of the septocoels, and concave peripherally in the more axial areas.

The regularity of form is most obvious in the higher section (fig. 4), which is only slightly elongate in the cardinal-counter plane. The diameter is 1.9 cm, and 48 major septa, with the same number of minors, are present at this level. At this point, however, the minor septa are <u>not</u> contratingent. The minor septa are half or less the width of the majors (and about 1/3 to 1/2 their length) at a given distance from the periphery. All septa are distinctly thick-

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est peripherally, tapering smoothly toward the axis. Again, the cardinal septum is a bit thicker than the other majors, and the septa of both orders immediately to either side of it flex to either side (toward their counter side), but only at their most axial ends. A septum opposite the presumed cardinal is slightly thicker than the adjacent majors, and projects further axially. This is presumably the counter septum.

An axial space lies within the axial ends of the major septa, about 5.7 X 4.9 mm in diameter, elongate in the cardinal-counter plane. A long median septum extends the length of the space, and, while it is definitely colinear with the cardinal and counter septa, it is unclear if it actually contacts either. If not, the gap is quite narrow. To either side of this median septum, and radiating out toward the periphery, are long pali, up to 1.4 mm in length. Of all of the specimens of Paliphyllum studied, this has the longest, most symmetrically-disposed median lamella.

The projections of the tabulae and dissepiments in the septocoels are as in the lower transverse section. As in the other specimens of this genus studied from the Brassfield, the axial limit of the axially-concave plates is about coincident with the axial ends of the minor septa.

The theca is too poorly-preserved to allow analysis.

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In longitudinal section (fig. 3) the tabularium is convex, with a moat separating it from the dissepimentarium. At the distal end of the corallite, the tabularium is about 1.6 mm in diameter, and consists of broadly-convex, incomplete tabulae. In the moat area, the form of the tabulae is less-regular. Nearer the proximal end of the corallite, there is a suggestion that some of the tabulae are convex peripherally and depressed axially, but this is unclear. The dissepimentarium is very-poorly preserved, with only a few vesicles shown in this section. Those most axial appear to lie at an angle nearly parallel to the corallite axis, a pattern seen in the other two species of this genus in the Brassfield. The dissepimentarium seems to thin appreciably toward the base of the corallite, but this may simply reflect wear.

The axial edges of septa caught in the longitudinal section show that they are straight in the vertical plane.

Several other specimens of this species were studied, each from a different locality. UCGM 41999, from locality 55 (near Ludlow Falls, Ohio), has a maximum diameter of 2.5 cm, and contains 42 septa of each order at this level. The minor septa are 2/3, or rarely, 3/4 the length of the majors. The axial area is recrystallized beyond analysis, but the straightness of the septa, their smooth tapering, the absence at this stage of contratingency, and the radial regularity all point to the present species.

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In longitudinal section, this specimen is identical to the holotype. The tabularium, which consists of incomplete tabulae forming a flattened or slightly-depressed floor, is separated from the dissepimentarium by a moat, in which short vesicles constitute supplementary plates added to decrease the depth of the moat. The dissepiments are of variable length, but reach a maximum of 3 mm. The theca and outer surface are not preserved.

15-32 → Another specimen, UCGM 41772 , from locality 15 (West Milton, Ohio), was seen only in transverse section. In a diameter of 2 cm are 38 septa of each order, with the minor septa about 1/2 the length of the majors, and often contratingent upon them. The pattern of contratingency is unclear. The septa are somewhat more crooked than is usual for this species, but still are relatively straight in comparison with other species of the genus. They taper smoothly toward the axis. The axial structure is obscured by the irregular plane of the section.

Contratingency of the minor septa in this specimen, though accomplished by only a few of the minor septa, shows that lack of contratingency cannot be considered a hallmark of this species. Rather, it can be said that, compared with other species of Paliphyllum, such as P. suecicum Neuman, contratingency is relatively uncommon.

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This species is unlike any other described of this genus, and is clearly an entity unto itself. As the other species to which it will be compared have already been described in the "Discussion" section for P. primarium, only the features distinguishing the present species from these others will be given here.

The Brassfield form has less-crowded septa than P. primarium, with greater dilation of the septa peripherally. A greater proportion of the cross-section is occupied by the axial structure than in Soshkina's species.

From Sclerophyllum sokolovi, our form differs in having greater dilation of the proximal ends of the septa, and in lacking the reticulate axial structure of the Estonian specimens. Further, the septa seem to be less densely-packed in our species, but this is uncertain, as levels in the corallite comparable to ours are not shown in Reiman's transverse sections.

From Paliphyllum soshkinae soshkinae and P. soshkinae karinuense, our specimens differ in having a long, symmetrically-disposed median septum.

From Ivanovskiy's P. primarium, our form differs in the same features as from Soshkina's original material of that species.

From Paliphyllum suecicum, our form differs principally in having straighter, more radially-symmetrical septa, and a well-developed median septum with long, radiating pali. At

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this diameter in Neuman's specimens (see his figure 3B), the median septum is irregular, and the pali chaotic.

Distribution - Ohio: Middle Llandovery (Brassfield Formation.

Brassfield occurrence - Locality 7a, the clay-coral bed near Fairborn, Ohio. (See discussion of this bed in section on the "Brassfield Lithosome"); locality 15, near West Milton, Ohio; locality 55, near Ludlow Falls, Ohio, in the clay bed at the top of the Brassfield.

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Paliphyllum cf. P. suecicum Neuman

Plate 4, fig. 8, 9; Plate 19, fig. 1-5

cf. 1955 Paliphyllum primarium Soshkina, p. 122, Plate X, fig. 3a, b

cf. 1956b Sclerophyllum sokolovi Reiman (in Kal'o), p. 38-39, Plate X, fig. 5-9; Text-fig. 4

? 1958b Paliphyllum soshkinae soshkinae Kal'o, p. 109-110, Plate II, fig. 10-14

? 1958b Paliphyllum soshkinae karinuense Kal'o, p. 110-111, Plate III, fig. 1-9

cf. 1961 Paliphyllum primarium Ivanovskiy, p. 204-205, Plate III, fig. 2a, b

1968 Paliphyllum suecicum Neuman, p. 231-237, Text-fig. 1-3

Type material - Holotype: UM D 1305, in the collection of the Museum of the Institute of Palaeontology, University of Uppsala. (This is the holotype of P. suecicum Neuman.)

Type locality and horizon - Boda Limestone (Upper Ordovician) at Osmundsberg, NE quarry, Siljan District, Sweden.

Number of specimens studied - 3

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DIAGNOSIS - Paliphyllum with sinuous septa, surrounding a relatively-broad axial structure (1/4 to 1/3 the total corallite diameter) whose boundaries are ill-defined due to the uneven length of the major septa; from intermediate growth-stages, a short median septum (lamella) usually present, attached to cardinal septum; minor septa mostly contratingent on adjacent major septa.

DESCRIPTION - Three specimens were studied in thin-section, and confirmed as conspecific. Each will be described in turn:

The largest specimen (Plate 4, fig. 8, 9; Plate 19, fig. 1, 4, 5) is also the best-preserved. It comes from locality 7a, near Fairborn, Ohio. The corallite is 5.3 cm long (from base to calice rim), and attained a diameter of 3 cm. At its base is a talon for attachment. The basal cross-section is elliptical, with greatest diameter in the presumed cardinal-counter plane, while the more distal cross-section is more circular. The diameter across the calice rim is 3.9 X 2.8 cm.

Two transverse sections were studied, spaced about 17 mm apart. The lower is from the most worn portion of the specimen, but appears to have originally measured about 2 X 1.2 cm. It contains 36 major septa, and an equal number of minors. The major septa are of about the same thickness throughout, and are rather crooked (as compared with those

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of P. primarium). In many cases their distal ends unite. They are quite variable in length, such that there is no sharp border (as there was in P. primarium) separating the septal zone from the enclosed axial space. Septal ends intrude into, and occasionally cross, the axial space, generally undergoing sharp changes of direction from their more proximal ends. Many of these axial ends are disjunct, forming pali, which appear to radiate from the axis, and are mostly 2/3 to 1 mm long.

The minor septa are about 1/2 the length of the majors, and tend to be contratingent upon them. A. in P. primarium, an imaginary line (running along the greatest diameter of the corallite) divides those minor septa contratingent to the left from those contratingent to the right. Presumably, this is the cardinal-counter plane, along which the corallite is elongate. In comparison with other related species, in is assumed that the minor septa are contratingent in such a way as to diverge axially from the cardinal septum, and converge toward the counter septum. Nothing readily-recognizeable as a median septum is found in this section. The theca is preserved only in one area, where its thickness is about 0.4 mm. The nature of the theca is unclear. The small portion preserved suggests the slightly bulbous proximal end of a septum embedded in the wall, but it is quite possible that this is a stereozone. Thin projections of tabulae and dissepiments lie in the plane-of-section within the septocoels.

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The higher transverse section is about 3 cm in diameter, and fairly circular. There appear to be about 44 major septa, and an equal number of minors, though at this level, the greater length of the minors (often 2/3 to 3/4 the length of the majors) makes it hard to differentiate. The major septa are thickened proximally. No theca is preserved at this stage. The minor septa are contratingent in the manner described for the lower section.

As in the lower section, the axial ends of the septa project for varying distances into the axial space. One in particular extends more directly towards the axis than do the others, forming the closest thing to a median septum (lamella) seen in our specimen. It is uncertain if this is the cardinal or counter septum, though the direction of distal flexing displayed by some of the minor septa suggest that it is more likely the former than the latter. If this is the case, it would indicate a rotation of this septum through about 120° from its position in the lower section.

In the septocoels are projections of the tabulae and dissepiments. These are concave toward the periphery when nearer the axis, and concave toward the axis when nearer the periphery. Those closest to the periphery are so concave towards the axis as to have their sides nearly parallel to the septa, thus enhancing the appearance of thickening in this area.

In longitudinal section, the tabularium is 2.1 cm broad

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near the top of the specimen, and 1.4 cm broad 1.2 cm lower. It consists of incomplete tabulae forming an axially-convex of relatively-thin vesicles, sloping peripherally to a moat filled with coarser, more irregularly-shaped vesicles against the dissepimentarium. The vesicles of the dissepimentarium slope axially at 45° to 60° to the horizontal, and are generally 1 to 3 mm long. The septal ends which project into the plane of the section are straight in a vertical direction.

A second, smaller specimen (Plate 19, fig. 2, 3) from the same locality and horizon as the previous specimen is confidently assigned to this species. Aspreserved, its length is about 2.1 cm from the base to the calice rim, and 1.8 cm to the base of the calice. About 0.3 cm is missing from the base. Its maximum diameter is about 2 cm across the calice rim.

A single transverse section was made, just below the calice floor, measuring 1.6 X 1.3 cm in diameter. The theca is of the same sort described in the previous specimen, and reaches a maximum thickness of 0.6 mm. There are 32 major septa with an equal number of minors. The latter are 1/2 to 2/3 the length of the majors, and are mostly contratingent on them. Several of the major septa are in axial contact. Numerous pali are present in the axial space, as is a median septum. This latter is about 2 mm long, an extension of the cardinal septum, and is aligned with (though

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not touching) the counter septum. Both these septa are well-defined in this section by virtue of the pattern of contratingency, and lie along the shorter diameter of the corallite. The direction of concavity of the tabular and dissepimental projections in the septocoels is as was described for the previous specimen.

The longitudinal section shows a convex tabularium of low, incomplete tabulae, which is slightly less than 1 cm across the top. A deep moat separates this area from the dissepimentarium, which is identical to that in the previous specimen. The axial ends of the septa, in this section, are straight vertically.

A third specimen was poorly-preserved, but closely-resembles this species. It is from locality 21, near Cross Plains, Indiana. As it was entirely encased in rock, little is known of its external features except that the corallite was probably curved.

Two transverse sections were taken, one 1.3 cm and the other 1.7 cm in diameter. The number of septa of each order in the two sections is 36 and 37 respectively. In places the minor septa are very short, barely protruding from the theca, while in other areas they are longer, and appear to be contratingent on the major septa in the same manner as seen in the other specimens. The axial ends of the major septa are often fused, and a somewhat sinuous median septum, as well as several pali, occur in both sections. The theca

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is clearly a septal stereozone. The plates of the tabulae and dissepiments are poorly-preserved in these sections.

Little is discernible in the longitudinal section, but a tabularium and dissepimentarium of the sort described above seems to be present here.

DISCUSSION - The species to which this will be compared are all described under the discussion section of Paliphyllum primarium. Consequently, we will deal here only with the specific similarities and differences between them and the present species.

From P. primarium Soshkina , this species differs in having fewer septa in a given diameter, a greater proportion of the transverse area occupied by the axial complex, and more-sinuous septa.

From Sclerophyllum sokolovi, it differs in the structure of the axial complex (reticulate in S. sokolovi, in contrast to the paliferous Brassfield form), in having a proportionally-broader axial structure with more-sinuous septa, and in lacking the marked rejuvenescence of the Estonian form.

From P. soshkinae soshkinae, our form differs in having a median septum, and a more-sinuous septal apparatus. In all other important respects, the two forms are identical.

From P. soshkinae karinuense, it differs in the absence of parricidal budding, and in having more-sinuous septa. In other respects it is quite similar, and might ultimately

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prove to be a variety of P. soshkinae Kal'o.

Ivanovskiy's (1961) P. primarium differs from our form in the same ways as do Soshkina's specimens.

The Brassfield form most closely resembles Neuman's (1968) P. suecicum, from the Late Ordovician of Sweden. Our specimens show the presumed cardinal septum still in contact with the median septum at about the same level as in Neuman's specimens, after contact with the counter septum has been lost. The number of septa at given levels is similar in both forms, as is their sinuosity, and their proportional length (relative to the diameter). In both, the axial area occupies a relatively large area, as compared with P. primarium and S. sokolovi. The length of the minor septa relative to the majors is comparable in both. The flatness of the tabularium surface in the Swedish form is approximated in ours, though the occasional axial concavity of the tabulae in the former has not been seen in our specimens. Finally, the supplementary plates reported by Neuman in the moat of his specimen is present in ours.

There are, nonetheless, some differences. The proximal dilation of the septa seen in the earlier stages of the Swedish form is not matched in our own. Also missing is the lonsdaleoid aspect of the outer dissepimentarium reported by Neuman in his specimens. Neuman notes that in the ephebic stage, the median septum is gone, leaving only pali in the axis. The lamella forming the median septum is yet pre-

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sent at the fairly-advanced stage shown on Plate 19, fig. 2. It is, however, still in contact with the cardinal septum, a stage which Neuman indicates exists prior to the total isolation and ultimate disappearance of the median septum. In a rather wider stage of the first specimen described (Plate 19, fig. 1), the median septum has apparently become non-existent. More sections would be necessary to determine the extend to which the Brassfield form agrees with the Swedish in this respect.

In balance, it seems possible that the Brassfield specimens are conspecific with Neuman's material, though likely representing a different subspecies.

Distribution - Ohio: Middle Llandovery (Brassfield Formation)

There are strongly-similar forms in the Llandovery of Estonia (Juurusian and Raykkyulaskian Stages).

Brassfield occurrence - Locality 7a (near Fairborn, Ohio), in the coral-clay bed described under "Brassfield Lithosome"; locality 21 (near Cross Plains, Indiana).

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Cyathactis Soshkina, 1955

1955 Cyathactis Soshkina, p. 122-123

? 1961 Protocyathactis Ivanovskiy, p. 205

Type species - Cyathactis typus Soshkina (1955, p. 123)

Type locality and horizon - Upper Kochumdekskoy Group (Llandovery) of the Siberian Platform

DIAGNOSIS - Solitary rugose corals with dissepimentarium, and well-developed basal-attachment structures; minor septa long, about ½ the length of the major septa; septa thin, in axial contact in earliest stages, drawing apart from axis with upward growth of the corallite, such that in ephebic stage, only a few septal lobes remain in axial region; tabulae often axially-depressed, incomplete.

ORIGINAL DESCRIPTION - "Solitary corals with strong attachment structures. In cup are thin, long septa of both orders. Fossula at cardinal septum located on convex side of coral, cup somewhat displaced laterally. Primary septa numerous, thin, nearly discontinuous, more-or-less reaching axis. Secondary septa long; their length is about half the radius of the transverse section, often their axial ends contact the primary septa. The tabulae are marginally convex, sometimes depressed medially and incomplete. Vesicular zone quite broad, consisting of small swollen dissepiments. In early ontogeny, septa thin."

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DISCUSSION - The most important points in Soshkina's description are that this is a solitary, dissepimentariate coral, in which the major septa reach, or nearly reach, the axis, but do not become mutually-involved to form an axial structure. In this respect, it might be said that its non-dissepimentariate counterpart would be Streptelasma (rather than Grewingkia). Another point of importance, and one stressed by Soshkina in the portion of the generic discussion dealing with comparisons with other genera, is the fact that the septa remain thin (unthickened by stereome) throughout the coral's ontogeny. This thinness of the septa, even in the early growth stages is stressed in contrast to other Silurian dissepimentariates, such as Phaulactis, Mesactis, Lykophyllum, and Semaiophyllum.

Ivanovskiy (1961, p. 205) created the genus Protocyathactis for an Upper Ordovician coral of the Siberian Platform which agrees with Cyathactis Soshkina in all respects save the presence of thickening of the septa. The possibility that these two actually constitute a single genus (with priority belonging to the latter) is strong, but in the absence of sufficient information to allow a sound decision, they are treated in this work as separate genera.

Cyathactis strongly resembles Paliphyllum Soshkina (q.v.) except for the presence of a distinctive axial structure in the latter. Because of their similarity, they are here considered co-familial.

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Cyathactis typus Soshkina

Plate 5, fig. 6, 7; Plate 20, fig. 6-8

cf. 1906 Cyathophyllum sedentarium Foerste, p. 315-316, Plate 6, fig. 3A-C

1955 Cyathactis typus Soshkina, p. 123, Plate IX, fig. 2; Plate XI, fig. 1a, b

cf. 1955 Cyathactis tenuiseptatus Soshkina, p. 124, Plate XI, fig. 2a, b

Type material - PIN 587/759, at Paleontological Institute of Novosibirsk.

Type locality and horizon - Left bank of Podkamennaya Tunguska River, above Severnoy River in Siberian Platform; from level B-1-5 in the upper part of the Kochumdekskaya Group (G^{k3}), of Middle and Upper Llandovery.

Number of specimens studied - 1

DIAGNOSIS - Cyathactis with thin septa; minor septa about 1/2 the radius in length, often contratingent on majors; tabularium of incomplete tabulae, broadly concave axially, convex on periphery; dissepiments not small (as in C. tenuiseptatus); in early stages at least, cardinal septum short, in fossula that communicates directly with axial space, and counter septum long, extending to or beyond axis.

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DESCRIPTION - This species is represented in our collection by a single small corallite, presumably a young individual (Plate 5, fig. 6, 7). It measures 2.1 cm in vertical height (not along growth axis), with about .3 cm more missing from the base. The corallite apparently had grown to an axial height of about 12 mm with a diameter of about 13 mm, forming a broad cone. At this point, a talon of about 9 mm length extended about 45° down from the calice, in the plane of the corallite's greatext diameter. The corallite grew up about 5 mm more when a second, thicker talon, about 10 mm long, grew from the calice on the same side as the first. Now, possibly through rejuvenescence, the axial growth changed direction through about 40°, so that the calice was now inclined toward the talons, in the plane of greatest diameter. There are 8 mm more of axial growth preserved, and at this stage, a talon of about 10 mm length, and thicker than the last, extended in the same direction, as an elongation of the calice, and bearing septa along at least the proximal half of its upper surface.

The side of the corallite is a wrinkled, rugose surface, with relatively weak longitudinal striae. The calice shows thin septa approaching, but not quite reaching, the axis, so that a space about 3 mm in diameter occupies the axis of the corallite. The calice is fairly round, except for the elongation of the third talon, and is about 13 mm in diameter. It is too poorly-preserved to allow distinction of

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minor septa without benefit of thin-sections.

In transverse section, the thinness of the septa is striking, their width being at most 0.1 mm. Two transverse sections were studied, one near the base of the specimen, with a diameter of 8 mm, and one just below the base of the calice, with a diameter of about 11 mm, elongated by 10 mm by the uppermost talon, and possibly showing rejuvenescence.

In the lower section (Plate 20, fig. 8), 38 septa are present. If these include minor septa, they are not recognizeable as such. No midline is seen in any ot the septa of this specimen, though this may be due to the state of recrystallization. One septum in the lower section is longer than the others, and is the only one to reach the axis, and slightly beyond. The others come within 4/5 radius of the axis. The distal ends of the septa bend slightly to form four triangles, one with its apex at the axial end of the above-mentioned long septum, and the others at 90°, 180°, and 270° from this point. Opposite the long septum is a very short one, extending through only half the radius to the axis, and lying in a rather broad gap between the adjacent septa. This short septum is thinner than the others, and is presumed to be the cardinal septum, while the long one is likely the counter septum. It could not be determined whether the cardinal gap represents a true cardinal fossula, or a pseudofossula. If these septa have been cor-

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rectly identified, then the talons lie on the counter side of the corallite. Dissepiments occur in the peripheral portions of the septocoels, but their projections in the plane of section, and the projections of the tabulae, do not occur within half a radius of the axis. Those projections closest to the axis are concave peripherally, while those in the more peripheral portion of the septocoels are concave axially. At one part of the periphery is preserved what looks like a zone of broad dissepiments into which the proximal ends of the septa do not extend, rather like a lonsdaleoid pattern, but this is not fully clear.

In the higher transverse section (Plate 20, fig. 7) there are 48 major septa, but all the minor septa do not yet seem to be present. Those that are recognizeable as minors are all on the counter side of the corallite, and are less than 1/2 a radius in length. Most are contratingent (or nearly-so) on the side of an adjacent major septum. The radius is about 5.5 mm, and the axial gap has a diameter of nearly 2 mm. The major septa are gently or strongly curved in places, mostly closer to the axis, and are in some instances in mutual contact distally. However, the four triangles of the lower section are now gone. Further, co cardinal septum, counter septum, or fossula are recognizeable at this level.

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In this section there is the appearance of rejuvenescence, the new skeletal material lying on the side away from the talon. The presumably earlier septa of the talon extension are continuous with the major septa of the rejuvenated corallite on one side, but there appears to be no continuity between the minor septa of the two areas. (though they are aligned). Again, the plate projections in the septocoels closest to the axis are generally concave toward the periphery, while those in the peripheral portion of the septocoels, though irregular, seem generally concave axially.

In longitudinal section (Plate 20, fig. 6), the presence of the talon somewhat confuses the picture. The tabularium attains a maximum diameter of about 6 mm, and consists of mostly incomplete tabulae forming a broadly-concave axial region, and a sharply-convex periphery. The distance between the peripheral crests reaches 5 mm. The nature of the dissepimentarium is unclear, but it appears to consist of axially-sloping dissepiments more-or-less 1 mm long in the corallite's axial plane. The theca is poorly-preserved, but appears to be only slightly thicker than the major septa, by a factor of about 2. The talon is difficult to analyze from a structural standpoint, but appears to consist of dissepimental and thecal material.

DISCUSSION - Soshkina's description of this species gives the following information:

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This species consists of solitary corals, barrel-shaped, with sharp contractions of the diameter, and well-developed basal attachment-scars. The theca bears fine longitudinal ribbing. The calice is broad, with a somewhat reflexed rim. On the broad, flat base of the calice is a distinct cardinal fossula on the convex side of the corallite, which is also the side of the attachment-scar's occurrence. The major septa are thin and weakly-curved. From the periphery they extend not-quite to the axis. In places, their axial ends are disjunct. The counter septum projects somewhat into the vacant central space. The cardinal septum is sometimes weakly shortened and lies in a narrow fossula, which widens axially and opens broadly on the vacant axial space. The minor septa are about half a radius in length, and are contratingent on the neighboring major septa. In a diameter of 25 to 26 mm, there are 55 to 56 septa of each order. The tabulae, mostly incomplete, are broad, convex on the periphery, and weakly-concave in the center. The dissepimentarium consists of vesicles, strongly-convex, and inclined to the axis. In transverse section, the vesicles and the tabulae are convex in opposite directions.

Soshkina considered the distinguishing characters of this species to be the thin septa, narrow opening of the axial end of the fossula, and the axial concavity of the tabulae.

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If one makes allowances for the fact that the Brassfield specimen is younger than Soshkina's (based upon overall size and septal number), the similarity between these two specimens is indeed striking. In both cases the septa are thin, with contratingent minor septa of about equal proportional length. In both cases the tabulae are incomplete with broadly-concave axial portions and convex peripheries. In both cases the vesicular dissepiments are of about the same size (in contrast with the small dissepiments of C. tenuiseptatus Soshkina (1955)). Soshkina spoke of a distinct cardinal fossula in the calice, a feature not obvious in our somewhat recrystallized specimen. The shortened cardinal septum and the elongate counter septum reported by Soshkina are in the lower section of our specimen, but are not distinguishable in the upper section.

The cardinal fossula of the Brassfield specimen (if such it be) is of the sort reported by Soshkina, opening into the axial space (though not as broadly as she reports), rather than forming a pit where it enters the axial region, as is the case in C. tenuiseptatus. Soshkina notes that the "attachment scars" occur on the cardinal side of the corallite, whereas in our case, they occur on what is taken to be the counter side. This is not regarded as being significant enough to preclude a close relationship between these specimens, and it seems safe to regard them as sonspecific.

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Cyathactis typus is compared with C. sedentarius in the discussion section dealing with the latter.

From C. tenuiseptatus (which is described in the "discussion" section for C. sedentarius), the present species differs primarily in the round pit formed by the axial end of the fossula between the tabularium and dissepimentarium in the former, and in the former's more-abundant, and finer dissepiments. Further the tabularium of C. tenuiseptatus is convex, while that of C. typus is flat, or even concave, with convexity only at its margins. These are clearly two distinct species.

Distribution - Kentucky: Middle Llandovery (Brassfield Formation); Siberian Platform: Middle or Upper Llandovery.

Brassfield occurrence - Locality 1 (near Panola, central Kentucky).

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Cyathactis sedentarius (Foerste)

Plate 5, fig. 8-11; Plate 21, fig. 1-3

1906 Cyathophyllum sedentarium Foerste, p. 315-316, Plate 6, fig. 3A-C

cf. 1955 Cyathactis typus Soshkina, p. 123, Plate IX, fig. 2; Plate XI, fig. 1a, b

cf. 1955 Cyathactis tenuiseptatus Soshkina, p. 124, Plate XI, fig. 2a, b

Type material - Holotype (designated by Foerste on museum label): USNM 87177, the original of Foerste's (1906) Plate 6, fig. 3B. This specimen is figured in this work on Plate 5, fig. 9, 11. Several other specimens are included with the holotype under this number, but the two others figured in Foerste's plate are not among them.

Type locality - Waco bed, Noland Member of the Brassfield Formation, "...from along the road north of Estill Springs, north of Irvine, Kentucky". This is equivalent to our localities 53-53a.

Number of specimens studied - None found in field. Only the holotype and associated specimens were studied.

DIAGNOSIS - Cyathactis with broad septa (major septa slightly broader than septocoels), infrequent contratingency of septa, convex tabularium; dissepiments relatively large (compared with C. tenuiseptatus), being 1.0 to 2.5 mm long in longitud-

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inal section; proximal ends of septa are "feathered", though this may be diagenetic.

DESCRIPTION - As no specimens of this species were found in the field during this study, description and analysis must necessarily be based upon a set of specimens from a single locality, described and collected by Foerste, and preserved in the collection of the U.S. National Museum, no. 87177. Only one of these specimens was illustrated by Foerste, and he indicated on the museum label that this was the holotype (Plate 6, fig. 3B). As the type specimen was not sectioned, the internal features described below are of another specimen.

The assemblage consists of the holotype and twelve other specimens. Where the base is preserved, a well-developed talon occurs. In two instances the talon attaches to a bryozoan frond, representing apparently the same species in both cases. Rejuvenescence is common.

Most specimens show some degree of wear. Their form is quite variable, ranging from long, slender forms (6.5 cm long and 2.5 cm wide) to low, broad forms (3.5 cm long and 4.5 cm wide). All specimens are elliptical in cross-section, the talon lying generally along the greater diameter.

The calices, where well-preserved, are flaring (see Plate 5, fig. 9). The peripheral portion, in one example, lies at about 30° to the plane of the mouth, while the inner zone is steeper. There appear to be two orders of septa, the majors reaching the vicinity of the axis, and the minors

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apparently restricted to the wall of the calice.

Exterior of holotype (Plate 5, fig. 9, 11) - The axial height from the base to the calice floor is about 5 cm. The height to the highest calice lip is 7 cm. Maximum diameter across the rim of the calice is 4 cm, and the minimum diameter (reconstructed) is about 3 cm. The outer surface of the corallite is strongly-rugose. At an early growth-stage, the corallite apparently rejuvenesced, at the same time changing the direction of growth by about 90°. A second rejuvenescence occurred at about 3 cm from the base. The calice floor has a diameter of 1.75 X 1.25 cm. Judging by relief and width, there are two orders of septa. The minor septa appear to end near the base of the calice wall, but this is uncertain. There are approximately 60 septa of each order present.

Interior of another specimen (Plate 21, fig. 1-3) - Two transverse and one longitudinal section were made of the specimen shown on Plate 5, fig. 8, 10.

The lower transverse section is 17 X 11.5 mm in diameter. Both orders of septa are thickest at a point 1.5 mm from the periphery. The major septa extend to the axial region, where their twisting, anastomosing, sometimes-fusing ends form a loose axial structure. The minor septa are about half the length of the majors, and are not contratingent. The septocoels contain many plates of the tabulae and dissepiments. Those near the periphery are concave axially, for the most part, while those further toward the axis are con-

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cave peripherally. About 41 septa of each order are present at this level. The theca is not preserved.

The higher transverse section measures 29 X 23 mm in diameter, and was taken from a level about 1.5 cm above the lower section. Here (as in the lower section) the theca was not preserved. The minor septa are nearly as long as the majors, though the total number of septa appears to be the same. The peripheral (proximal) ends of the septa are "feathery", with what appear to be branches diverging toward the theca. This "featheriness" was not noted in the lower section, but this could be due to the greater degree of alteration in that level. As below, the septa are broadest somewhat inward from the periphery, and the orientation of the incomplete tabular, and dissepimental plates in the septocoels is as in the lower section. The nature of the axial structure, and the proportion of the axial structure's diameter to the length of the minor septa (about 2 : 1) remains about the same. There is no evidence of a cardinal fossula. The concavity of the plates in the more peripheral parts of the septocoels (probably representing the dissepimentarium) is much greater than that of the more axially-located plates (probably representing the tabularium).

In the longitudinal section the dissepimentarium near the top of the section is about 5 mm thick, with rather markedly-convex dissepiments. The tabularium at this level is about 1 cm wide, and consists of incomplete tabulae inclined downward toward the periphery, lying among the ends

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of the major septa. Between the tabularium and dissepimentarium is a zone, about 2 to 3 mm wide, of concave, often incomplete plates.

DISCUSSION - Foerste (1906) based his description of this species apparently on unsectioned specimens. In addition to the type locality, he reported specimens from the Waco bed of the Noland Member, Brassfield Formation east of Panola (locality 1 of this study) and from the same horizon "half a mile east of Waco, where the road to Cobb Ferry turns off from the pike to Irvine", in Kentucky.

Soshkina (1955) described Cyathactis typus, a new species from the Siberian Platform in the upper Kochumdekskaya Group (Middle and Upper Llandovery). See the "discussion" section of C. typus in the present work for the description of this species.

The present species differs from C. typus in having broader septa, with non-contratingent minor septa, a more generally-convex tabularium, and in having an intermediate narrow zone of concave, sometimes incomplete plates, between the tabularium and dissepimentarium. The "featheriness" of the peripheral portions of the septa in C. sedentarius are not reported in C. typus. Clearly, these are two distinct species.

Soshkina, in the same paper, described a second species of Cyathactis, C. tenuiseptatus, from the right bank of the Podkamennaya Tunguska River, above the mouth of the Stolbov

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River in the Siberian Platform. Stratigraphically, this species occurs lower than C. typus, in layer 2v (Soshkina uses the Russian letter B) of the middle Kochumdekskoy Group (G^{k2}). These are solitary corallites, as large as our sectioned specimen of C. sedentarius, somewhat conical or cylindro-conical in form. On the outer surface are fine longitudinal ribs, and sometimes, rugae. Strong attachment scars occur on the convex side of the corallite, as is the case with our species. The calice has a broad, flat bottom and gently-sloping walls.

The major septa don't quite reach the axis. They are thin, radial, and relatively-straight, as seen in C. typus. The minor septa are over half a radius in length, and are not contratingent. The somewhat-shortened cardinal septum lies in a fossula on the convex side of the corallite. The axial end of the fossula is a round pit at the border between the tabularium and dissepimentarium. Two lateral fossulae are less distinct. In a diameter of 25 mm there are 50 septa of each order, roughly the same as found in the sectioned specimen of the present species.

The tabulae are incomplete, and broadly-convex. The dissepimentarium consists of 30 to 40 rows of dissepiments, apparently zoned by size, and distinctly more numerous and smaller than those found in our form, and in C. typus. This is reflected in the distinctly abundant in-filling of the septocoels by the dissepimental plates as seen in transverse

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section. The dissepimental rows are all inclined axially. The dissepiments in the septocoel do not all extend completely across the septocoels, but rather, lap on one another, so that in transverse section is seen a pattern similar to that seen in Smith's (1945)figure of Ptychophyllum? whittakeri (Plate 10, fig. 1).

As in the current species, and in C. typus, the dissepiments are concave to the axis, while the incomplete tabulae are concave toward the periphery (when seen in transverse section). Throughout ontogeny, the septa are equally thin.

C. tenuiseptatus differs from C. sedentarius in having more abundant dissepiments and thinner septa. The similarities between these forms are several, but for now, they should be regarded as distinct species.

Distribution - Kentucky: Middle Llandovery (Brassfield Formation).

Brassfield occurrence - Vicinity of our localities 53 and 53a (north of Irvine, Kentucky); also reported from our locality 1 (1/2 mile east of Panola, Kentucky), and from 1/2 mile east of Waco, Kentucky; all in the Waco bed, Noland Member, Brassfield Formation.

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Protocyathactis Ivanovskiy, 1961

1961 Protocyathactis Ivanovskiy, p. 205

Type species - Protocyathactis cybaeus Ivanovskiy (1961, p. 206).

Type locality and horizon - Upper Ordovician of the Siberian Platform.

DIAGNOSIS - Identical to Cyathactis Soshkina (q.v.), except that in Protocyathactis, the septa are thickened by stereome in all stages of ontogeny.

ORIGINAL DIAGNOSIS - "Coral solitary, sub-cylindrical or ceratoid, with striated epitheca. Septa thickened stereoplasmally through their entire extend; in central space axial complex absent. Tabulae convex. In periphery is developed numerous small, swollen dissepiments."

DISCUSSION - See discussion under Cyathactis.

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Protocyathactis cf. P. cybaeus Ivanovskiy

Plate 5, fig. 2-5; Plate 18, fig. 4-8

cf. 1928 Cyathophyllum cormorantense Twenhofel, p. 118-119, Plate III, fig. 2-4

? 1961 Protocyathactis cybaeus Ivanovskiy, p. 206, Plate III, fig. 3a, b

Type material - Ivanovskiy's holotype of P. cybaeus is no. 517/4, SNIIGGIMS Collection.

Type locality - (of P. cybaeus): Late Ordovician (Upper Caradocian) Dolborskiy Stage, 4 km upstream from the mouth of the Nizhnyaya Chunku River, in the basin of the Podkamennaya Tunguska River, Siberian Platform.

Number of specimens studied - 2

DIAGNOSIS - Protocyathactis with talons restricted to the base, and exhibiting rejuvenescence.

DESCRIPTION - The specimens studied are solitary, compressed laterally, and have little distinct curvature. Both specimens display rejuvenescence, and have small basal talons. Because of the rejuvenescence, the maximum diameter is not at the top of the corallite, but at the point just below the rejuvenescent contraction. Following are some measurements:

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	Max. length	Elev. of max. diameter	Max. diameter
larger specimen	2.5 cm	1.8 cm	1.45 X 1.25 cm
smaller specimen	1.5 cm	1.1 cm	1.0 X 1.2 cm

The calice of the larger specimen is well-preserved in a rejuvenated outgrowth of the corallite (Plate 5, fig. 2-4). Here the diameter at the lip is 1.2 X .9 cm, and the calice has a depth of 5 mm. Two septal orders are present, the majors having greater relief (about .25 mm) than the minors. Twenty-eight septa of each order were counted. No fossula is discernible in the calice. The walls of the calice slope downward from the lip at about 45°. At a point about two-thirds the way to the calice floor the slope increases to near-perpendicularity for the rest of the distance. The floor of the calice is concave and about 4.5 X 3 mm in diameter, at the level at which the slope of the wall changes.

The larger specimen was studied in three transverse sections with diameters of about 6 to 10 mm (Plate 18, fig. 4-6). No significant change in internal structure was noted through this interval. The major septa reach the axis, where some of their ends fuse, with some contortion in the very center of the corallite. There is, however, no noticeable whorl, nor is any axial structure produced. The minor septa are about one-fifth the length of the majors in the earliest stage studied, and reach about half the length of the majors in the latest stage. They are fairly straight,

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and do not appear to contact the sides of their adjacent major septa. The septa of both cycles are slightly thickened where they meet the corallite wall. The major septa of the lowest section are peculiarly kinky in a certain region (fig. 6), and the significance of this is not known. In this section, taken 8 mm above the base of the corallite, there are 23 major septa. In the middle section, taken 11 mm above the base, there are 26 major septa. In the highest transverse section, taken 15 mm above the base, there are 28 major septa.

The position of the cardinal septum is uncertain. In the highest section, however, at a point 270° from the angular location of the basal talon, where there should be a minor septum there is, instead, a long septum nearly reaching the axis. It is cut off from the axis by the distal juncture of the major septa to either side of it. Possibly this is the cardinal septum.

The nature of the theca is unclear, except that it does not seem to be a septal stereozone. It is thin, about the same thickness as the septa, and does not appear to be affected by stereomal thickening. On the outer surface of the corallite are distinct longitudinal ribs with narrow grooves separating them. The latter reflect the septa on the inside, and the former the septocoels.

The inner wall of the corallite is covered by a dissepimentarium consisting of rather small, abundant dissepiments,

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which appear as curved cross-bars when the septocoels are viewed in transverse section (Plate 18, fig. 8). These are apparently restricted, at least in later stages, to the portion of the interior from the distal ends of the minor septa out to the theca.

The tabularium has not been clearly seen in longitudinal section.

DISCUSSION - Ivanovskiy (1961) described Protocyathactis cybaeus as representing a new genus, as well as species. The following is his characterization of the species:

The three specimens studied are ceratoid or sub-cylindrical in form, with weak ribbing (presumably longitudinal) on the outer surface. The length does not exceed 3.5 cm, with a maximum diameter of 19 to 20 mm. The septa are of two orders. The major septa go straight to the axis, some joining distally with other septa, but do not produce an axial structure. The septa of the second order are one-third to one-half the length of the major septa, and their distal ends often contact the side of a major septum adjacent. All the septa have stereomal deposits on their sides, especially at the proximal end, and taper axially. In a section diameter of 11 mm are found 28 septa of each order. The tabulae are thin, complete, and may be horizontal(?) or weakly-convex. In the axis they are spaced no more than 1 mm from each other vertically. The dissepimentarium consists of abundant, small vesicular dissepiments.

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The early ontogeny of the species is unknown, due to incomplete preservation of the specimens. By mid-stage, all the mature characters are present.

The differences between the Brassfield form, and Ivanovskiy's specimens are few, but they leave sufficient question as to their relationship to make it advisable to stress their strong similarities, without declaring them conspecific. The minor septa in the Siberian form are contratingent, a relationship rarely seen in our specimen. In addition, Ivanovskiy makes a point of the stereomal thickening of the septa in his specimens, whereas this does not clearly take place in ours. His transverse section (fig. 3a) does not, however, indicate septa appreciably-thicker than ours. The imperfect preservation of the internal features in the Brassfield specimen might possibly have obscured what similarities there might be in this respect.

Of particularly strong significance is the fact that Ivanovskiy does not mention rejuvenescence, or the presence of a basal talon. He mentions that the imperfect preservation of his material made it impossible to study the earliest ontogenetic stages, and this might include destruction of the talons. It is more difficult, however, to rationalize his ignoring rejuvenescence, if it were present. Whatever the relationships between these two forms, it seems likely that they represent at least closely-related taxa on either side of the Ordovician-Silurian boundary.

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It is worthwhile comparing our form with Cyathophyllum cormorantense Twenhofel (1928) from the Jupiter Formation (Late Llandovery) of Anticosti Island. These are large corallites (the longest collected, a broken specimen, measures 150 mm long and 52 mm in diameter, while a second specimen has a diameter of 60 mm). Twenhofel reports that the length and diameter do not appear to be strongly-correlated. The calice is quite deep, 14 mm in a specimen 46 mm in diameter. This calice is 8 mm across the bottom and 25 mm across the top. The calice floor is flat or slightly-convex.

The septa are of two orders, though the minors sometimes appear nearly as long as the major septa. They are straight, and do not produce an axial structure (Twenhofel's transverse section shows them reaching close to, but not quite attaining, the axis). It is not clear if the minor septa are contratingent. The tabularium is as wide as the calice floor, and contains tabulae which appear to be mostly complete, slightly concave to slightly convex. These are spaced from 1 to 2 mm apart vertically. The vesicles of the dissepimentarium are small and abundant.

In general form, this species is quite similar to ours, and is quite possibly congeneric with it. The major points of difference lie in the great size of Twenhofel's corals (an unimportant difference taken alone), the great length

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of the minor septa, and the lack of rejuvenescence. What may be a talon is present in the specimen shown by Twenhofel in his fig. 2, a feature this form might, then, share with our own.

It is unfortunate that the septa do not reach the axis in Twenhofel's transverse section. Perhaps if the section were taken a bit lower, the nature of the axis would be more clear.

Distribution - Kentucky: Middle Llandovery (Brassfield Formation).

An apparently closely-related form occurs in the Late Ordovician (Upper Caradocian) of the Siberian Platform.

Brassfield distribution - Locality 46 (near College Hill, Kentucky) in the top of the Noland Member at this site.

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Family Tryplasmatidae Etheridge, 1907

(nom. correct. Hill, 1956, p. 310, pro Tryplasmidae Etheridge)

Rugosa lacking dissepimentarium; corallites solitary or fasciculate; septa acanthine, of two orders, or sometimes absent; trabeculae sometimes joined in longitudinal rows by stereomal deposits; theca a septal stereozone; tabulae generally complete, dominantly horizontal.

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Tryplasma Lonsdale, 1845

1845 Cyathophyllum (Tryplasma) Lonsdale, p. 613

1871 Pholidophyllum Lindström, p. 125

1873 Acanthodes Dybowski, p. 334 (non Agassiz, 1833; nec de Haan, 1833; nec Baly, 1864)

? 1882a Polyorophe Lindström, p. 16, 20

cf. 1883 Coelophyllum Roemer, p. 409 (non Scudder, 1875)

cf. 1889 Cyathopaedium Schlüter, p. 263 (pro Coelophyllum Roemer, non Scudder, 1875)

1894 Spiniferina Penecke, p. 592 (pro Acanthodes Dybowski, 1873; non Agassiz, 1833; nec de Haan, 1833; nec Baly, 1864)

1904 Aphyllostylus Whiteaves, p. 113

1927 Stortophyllum Wedekind, p. 30, 31

? 1937 Aphyllum Soshkina, p. 45, 94 (non Aphylum Bergroth, 1906, p. 604

1940 Pholadophyllum Lang, Smith & Thomas, p. 99 (nom. van. pro Pholidophyllum Lindström, 1871)

Type species - (SD Etheridge, Jr., 1907, p. 42), Tryplasma aequabile Lonsdale (1845, p. 613).

Type locality and horizon - Silurian, from the basin of the Kakva River, east side of the northern Ural Mountains, Russia.

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DIAGNOSIS - Solitary and fasciculate corals lacking dissepimentarium; theca a septal stereozone; septa acanthine, not reaching axis; axial structure absent; tabulae both complete and incomplete, generally of rather low relief; talons small when present.

DESCRIPTION - This is a rugose coral, usually solitary and cylindrical, though sometimes fasciculate. Tryplasma and its relatives are remarkable for their septal structure, which consists of longitudinal rows of trabeculae, generally projecting obliquely upward towards the axis, rather than solid sheets, as is usual in the rugosans. These are referred to as "acanthine" septa.

The theca is a septal stereozone, and the septa are represented by grooves on the outer surface of the theca.

The interior of the corallite contains tabulae, nearly all complete, and generally horizontal. In some species, the upper surfaces of these tabulae bear trabeculae.

The septa are of two orders, differentiated by the length and stoutness of the trabeculae. There is no dissepimentarium.

Rejuvenescence is a common feature of this genus. In addition, small basal talons occasionally occur, to provide basal support in standing.

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DISCUSSION - The name Tryplasma was first used (as a subgeneric connotation) by Lonsdale (1845, p. 613) in describing the corals found in Russia by Murchison, de Verneuil and von Keyserling. He expressed Tryplasma as a subgenus of Cyathophyllum Goldfuss, and applied it to two species (one new, the other previously-described by Hisinger). Lonsdale's figures and descriptions coincide with current concepts of this genus.

In 1907, Etheridge (p. 42) chose the new species introduced by Lonsdale, T. aequabile, as the type of the genus. This is a solitary form, with a broad tabularium and short acanthine septa of two orders. In their critical revision of Lonsdale's corals, Lang & Smith (1927, p. 461), apparently unaware of Etheridge's selection, duplicated his choice of T. aequabile Lonsdale as type of the genus. Unfortunately, they restricted themselves to simply listing the two species of Tryplasma found by Murchison et al. in Russia, and giving a brief diagnosis of the genus. They have no details to add on the description of the type species.

Lindström (1871) erected the genus Pholidophyllum for Cyathophyllum loveni Milne-Edwards & Haime (1851, p. 364) from the Silurian of Gotland (and reportedly occurring in other Northern Hemisphere localities as well). Apparently, Lindström was unaware of Lonsdale's specimens mentioned above, as C. loveni has all the earmarks of Tryplasma. Lang, Smith & Thomas (1940, p. 99) invalidly emended the generic

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name to Pholadophyllum.

Roemer (1883) introduced the generic name Coelophyllum into the literature. This German Devonian rugosan is a colonial form characterized by "wholly rudimentary" septa, complete, wide-spaced tabulae and the absence of a dissepimentarium. Roemer remarked that these characters were first considered distinctive by Schlüter (1880) who described a species based upon them, attributing that species to Calophyllum Dana (1846). Roemer considered it doubtful that Schlüter's species (Calophyllum paucitabulatum) truly belonged to Dana's genus, and also pointed out that Calophyllum was a source of some confusion, and had been differently-interpreted by various authors. Together with a recommendation that Calophyllum be dropped from use, due to the insufficient data afforded by Dana (no illustrations, and no species assigned to the genus), Roemer erected a new generic name, Coelophyllum, for Schlüter's species.

Schlüter (1889) then noted that the term Coelophyllum was preoccupied, and proposed the name Cyathopaedium in its stead. Roemer's description (there are no figures) gives the strong impression that this genus is identical to Tryplasma Lonsdale, and Sokolov (1962, p. 308) is also of this opinion. On the other hand, Hill (1956, p. 298) lists Cyathopaedium Schlüter as a genus separate from Tryplasma. Hill's figure of Cyathopaedium (which she attributes to Schlüter) appear quite different from Tryplasma, especially

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with regard to septal structure, and the coloniality of the former, such that it seems likely they are not congeneric.

From the Silurian of Gotland, Dybowski (1873) described the genus Acanthodes, a group of solitary and phaceloid species, introducing it as a new form. His figures and descriptions, however, mark it as probably Tryplasma. Penecke (1894) noted that Acanthodes was already in use as the generic name of a ganoid fish (by Agassiz), and so, changed the name to Spiniferina. Penecke's figures are more clear than Dybowski's, and plainly show the acanthine septa (with trabeculae inclined upward axially), the largely-complete tabulae in a broad tabularium, and the absence of a dissepimentarium, typical of Tryplasma. Though Penecke and Dybowski do not figure the same species, Dybowski's rather stylized drawing agrees sufficiently with Peneke's illustrations to make it clear that this form is congeneric with Tryplasma.

Whitfield's Aphyllostylus is based upon specimens from the Silurian of Manitoba, Canada, and while he included no figures in his paper, the description of this fasciculate coral agrees well with Tryplasma.

From the Silurian of Gotland, Wedekind (1927) introduced the genus Stortophyllum, based upon several solitary species. These corals seem to fit readily into Tryplasma, having acanthine septa, no dissepimentarium, and tabulae which, though often incomplete, still retain the general

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aspect of a broad tabularium lacking an axial structure that is typical of Lonsdale's genus. Stortophyllum also can have a small basal talon, for support of the corallite in a standing position. This, too, is found in Tryplasma.

Soshkina (1937) reported, as a new genus, Aphyllum, from Wenlock beds on the eastern slope of the Ural Mountains. As the name implies, she regarded the weak septal development as an important feature of this genus. Septa are usually absent from her specimens, and only rarely occur (then, as acanthine septa, with the trabeculae inclined upward axially). The tabulae are distinct, more-or-less horizontal, and (as suggested by Soshkina's figures) usually complete. There is no dissepimentarium. It seems quite possible that this form is actually a Tryplasma. The frequent absence of septa is unusual, and this form might fit in with Zelophyllum Wedekind (1927, p. 34 and 35) from the Silurian of Gotland, in which the trabeculae are also restricted to the wall, and do not protrude into the tabularium. On the other hand, future studied may show both Aphyllum and Zelophyllum to belong to Tryplasma, as junior synonyms.

Polyorophe Lindström (1882a) from the Silurian of Gotland, is similar to Tryplasma, but is generally considered as a separate genus, by virtue of the highly-developed talons it characteristically bears, often reaching far up along its side. As noted above, Tryplasma can also bear talons

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(at least, corals with all the earmarks of Tryplasma are found both without talons, and with small ones restricted to the very base, as is found in T. radicula, Plate 6, fig. 4). The wisdom of allowing the degree of talon development to signal a generic difference can only be judged after further study.

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Tryplasma radicula (Rominger)

Plate 6, fig. 1-4; Plate 21, fig. 6, 7

1876 *Cyathophyllum radicula* Rominger, p. 109-110, Plate XXXIX, fig. 3 (*partim*, see discussion)

? 1927 *Pholidophyllum hedströmi* Wedekind, p. 27-28, Plate 3, fig. 1-4; Plate 29, fig. 1

? 1927 *Pholidophyllum hedströmi* var. *attenuata* Wedekind, p. 28, Plate 3, fig. 6, 7; Plate 29, fig. 2

? 1927 *Pholidophyllum intermedium* Wedekind, p. 28, Plate 3, fig. 8, 9

? 1927 *Pholidophyllum intermedium* var. *articulata* Wedekind, p. 28, Plate 3, fig. 10, 11

? 1927 *Pholidophyllum tenue* Wedekind, p. 28, Plate 3, fig. 12; Plate 29, fig. 3

? 1927 *Pholidophyllum coniforme* Wedekind, p. 28, Plate 3, fig. 14; Plate 29, fig. 5

? 1949 *Amplexus brownsportensis* Amsden, p. 106-107, Plate XXVII, fig. 7-13 (*partim*)

1952 *Tryplasma radicula* Stumm, p. 842 (*partim*), Plate 125, fig. 1, 2, 7, 8, 9 (*non* fig. 3-6

1965 *Tryplasma* cf. *T. radiculum* Sutherland, p. 31-32 (*partim*), Plate 23, fig. 1, 3 (*non* fig. 2); Plate 24, fig. 1-6; Plate 25, fig. 1-6

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Type material - Lectotype (of Stumm, 1952, p. 842):
UMMP 8582a; Paratypes: UMMP 8582b-8582e, 8582g(?)

Type locality and horizon - Point Detour, Michigan; from the Manistique Group (Late Llandovery to Middle Wenlock).

Number of specimens studied - 4

DIAGNOSIS - Tryplasma species of solitary, trochoid corallites exhibiting frequent weak rejuvenescence at fairly-regular intervals; septa in two orders, their trabeculae not diverging noticeably from the plane of the septum (as occurs in T. cylindrica, q.v.); tabulae without spines on upper surfaces; talon may be present, restricted to base.

DESCRIPTION - The best-preserved specimen (Plate 6, fig. 2-4) attains a length of 20 mm and a final maximum diameter of 9 mm. The corallite increases in width through the first 1 cm of its length, beyond which it grows no wider than 9 mm. In this upper region, there is little if any net increast in width, although there are frequent variations. Weak rejuvenescence occurs at the following elevations (in mm) above the base: 6, 8, 9.5, 11, 13, 15, 16.5. The maximum diametric contraction involved is 1.5 mm.

At the base of this specimen is a skeletal deposit with a flattened bottom, 8 mm long, which is apparently a talon. It does not extend more than a few millimeters up the convex side of the corallite.

The calice wall has apparently been broken away at its lip, but what remains is vertical. The calice is 3.5 mm

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deep, with an essentially flat floor, as wide as the opening of the calice (about 5.5 mm across). The theca is just over 1 mm thick at the top, slightly thinner near the base. The calice is circular in cross-section (Plate 21, fig. 6) and contains acanthine septa of two orders, 28 septa of each order. The major septa consist of spines (trabeculae) up to 0.4 mm in length, spaced about 4/mm. The spines of the minor septa are about half as long, with about the same spacing. These spines do not noticeably diverge distally from the plane of the septum, as they do in the Brassfield form of T. cylindrica (Wedekind).

Both complete and incomplete tabulae are present, with no appreciable variation in their thickness (Plate 21, fig. 7). The complete tabulae are spaced about 1.5 mm apart, and are horizontal, or slightly convex or concave. Their surfaces are free of spines, in contrast with the radiating rows of spines on the tabulae of T. cylindrica (Plate 5, fig. 15).

Only UCGM 41951 has a basal talon, though at least one other specimen is sufficiently complete at the base to show a talon, were it present. With the exception of the talon, all specimens studied agree well with the one just described.

DISCUSSION - Rominger (1876) described the species Cyathophyllum radicula from the Manistique Dolomite (Late Llandovery to Middle Wenlock) at Point Detour, Drummond's Island in Lake Huron. He noted the frequency of rejuvenescence,

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and the presence of a talon. He also mentioned the two septal orders, and the fact that the flat calice is, in some specimens, invested with spines. The specimens with spinose tabulae may be T. cylindrica. Other specimens, he went on to say, have a more rounded, concave calice floor.

The description was accompanied by figures of ten specimens, concerning which Rominger said (p. 109-110): "The left-hand, outer vertical row of specimens is from Point Detour; the central row represents specimens from Masonville, Iowa; the right-hand row may be a different species. It occurs in the Niagara group of Louisville, and of Charleston, Indiana; the stems are of longer cylindrical growth, often curved and geniculated; their calyces rarely exhibit a naked diaphragm in the bottom, and the crenulated lamellae generally reach to the center. The surface of the stems is in both kinds longitudinally ribbed by septal striae."

The specimen selected as lectotype by Stumm (1952) is UMMP 8582a, probably that one figured in the upper left-hand corner of Rominger's assemblage. This specimen is from Point Detour. Two more specimens from this locality are UMMP 8582e and 8582g. These and three other specimens (UMMP 8582b, c, and d) from the Hopkinton Dolomite (Late Llandovery to Late Wenlock) at Masonville, Iowa are unfigured specimens of Rominger.

The lectotype of Cyathophyllum radicula Rominger (which is figured by Budge, 1972) is 1.6 cm long (as preserved), a

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trochoid corallite displaying three episodes of rejuvenescence, about equal in interval. Its diameter at the top is 1.25 cm (with a circular cross-section), but its maximum diameter is attained in an earlier rejuvenescent stage, and measures 1.45 cm. Each rejuvenescent segment is conical. The earliest stage is broken, but an apparent attachment scar remains at the base.

The calice is 8 mm deep, with a flat floor 6.5 mm across. Its walls are vertical near their base, and slightly less-vertical higher up. The calice floor is free of spines.

The septa are of two orders, thirty to each order. The spines of the major septa are 0.5 mm long, spaced 2.5 per mm. The spines of the minor septa are .25 mm long, and spaced 2.5 to 3.0 per mm. The spines of the major septa are somewhat thicker in the base than are those of the minors. None of the spines diverge noticeably at their distal ends from the plane of the septum.

No information is available at this time about the interior of the lectotype.

The main differences between the Brassfield form and the lectotype of Rominger's species lie in the greater width-to-length ratio of the latter, and in the somewhat greater thickness, and resultant wider spacing of its septal spines. While these differences clearly do carry some weight, the many similarities between Rominger's specimen and ours would seem of greater importance: frequent, rhythmic re-

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juvenescence, basal talon, bi-ordinal septa, non-divergent septal spines, flat, spine-free calice floor, and steep calice sides. The two unfigured specimens from Rominger's assemblage, collected from the same spot as the lectotype, are basically similar to that specimen: The calices have the same configuration as in the lectotype. The septa (visible only in 8582g) are of two orders, with major spines up to 0.7 mm long, and minor spines 0.25 to 0.3 mm long, both non-divergent distally. The calice floor and tabulae, where visible, are free of spines. They differ from the lectotype, however, in having rootlets, rather than a solid talon for attachment. Also, 8582g is not clearly rejuvenescent. Some tabulae are visible on the inside of this specimen. They do not lie parallel, and the edge of one nearly touches that of the other. In the center of the corallite, they are separated by about 2 mm, a distance similar to that found in our specimens. The width-to-length ratio for these two specimens of Rominger's is about 0.7 and 0.9, as compared with 0.9 for the lectotype, and 0.45 for the best-preserved of our specimens.

The differences between Rominger's specimens and our own seem more on the sub-specific than the specific level, and so they are here considered conspecific.

In his work on the rugose corals of Gotland, Wedekind (1927) described and figured many specimens showing similarities to our own. Unfortunately, his descriptions are

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often insufficient for gleaning much of the information one might seek, and the figures do not always make up for this deficiency. Nonetheless, in several cases, enough information may be obtained to make some interesting comparisons.

Pholidophyllum hedstroemi (Wedekind's P. hedströmi) resembles our form in possessing two orders of septal spines, and lacking spines on the tabulae. The corallite is relatively long and thin, as ours are, and displays frequent rejuvenescence. There is no indication of a talon, but a talon, as noted above, is not always in evidence in our specimens, and probably, its state of development reflects the attachment needs of the individual, to a largely-variable extent. The distinctly upward-pointing spines of the septa, however, (as compared with ours, which are normal to the wall) raise some question as to the identity of Wedekind's specimens with our own. This form is from the Dinophyllum-Chonophyllum horizon (Högklint beds, Lower Wenlock, according to Manten, 1971, p. 43) at Kneippbyn and Stenkyrke, Gotland.

A variety of this form, P. hedstroemi attenuata Wedekind, is from the higher levels of the upper Dinophyllum-Chonophyllum horizon at Kneippbyn. It is supposed to be distinctive by its more attenuated form, but the figures show no impressive difference between this and the species P. hedstroemi proper. It is not possible to determine from the information given if there are two orders of septa.

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Pholidophyllum intermedium Wedekind (1927) from Snäckgardet and Kneippbyn, Gotland (Lower Wenlock Högklint beds, according to Manten's geological map) is similar to the above species, except that Wedekind was here impressed by occasional strong concavity of the tabulae, sometimes sufficient to bring a tabula into contact with its lower neighbor. Again, the spines are directed upward, but the absence of a transverse section makes it impossible to detect two septal orders. Here, as above, the tabulae are free of spines.

Pholidophyllum tenue Wedekind (1927) comes from the highest level of the Dinophyllum-Chonophyllum horizon (Högklint beds, Lower Wenlock) near Kneippbyn, Gotland. It is relatively long and thin (averaging 11 mm in length and 6 mm in width). It appears to exhibit rejuvenescence (see Wedekind's Plate 29, fig. 3), though not quite as regularly as our form, and may possibly have a small talon on its convex side. Unfortunately, there is insufficient information from which to determine the presence of two septal orders. This fact, and the clear upward-pointing of the septal spines leaves the relationship between this form and T. radicula rather uncertain.

Pholidophyllum coniforme Wedekind (1927) is from the same horizon and locality as the previous species. Outwardly it resembles Tryplasma radicula from the Brassfield. It is relatively long and thin, reaching a length of 30 mm, and a

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width of 10.5 mm, displaying frequent and evenly-spaced rejuvenescence (at least seven times in 3 cm). Further, there is a talon at its base, similar to that in our specimen. Also present are rootlets, which have not been noted in our form (though they are present in the paratypes of this species, UMMP 8582e and g from the Hopkinton Dolomite). The corallite is trochoid and convex on one side. In Wedekind's Plate 29, fig. 5, the talon is on the convex side, but the rootlets seem to originate on the concave side. The tabulae are free of spines. Here again, though the resemblances are strong, Wedekind's specimens cannot be confidently identified with our form, due to the presence of upward-pointing septal spines, and the absence of any indication of the number of septal orders.

It seems quite possible that all of these Gotland forms belong to the same species, and this may be a variety of Tryplasma radicula (Rominger). Where Wedekind shows transverse sections, they always indicate two septal orders, with apparently non-diverging spines. Final judgement will have to wait for detailed examination of the types.

Amplexus brownsportensis was described by Amsden (1949) from the Brownsport Formation (Early Ludlow) of western Tennessee. The holotype (YPM 17666) is scolecoid and cylindrical, apparently with frequent weak rejuvenescence. Originally it measured 3.6 cm long and about 1 cm in width, but most of the specimen has been used to make a

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longitudinal and transverse thin section. The specimen has been silicified, resulting in difficulty with discerning the finer structure of the calice and interior. It could not be confidently determined if there are secondary septa lying between those visible in the calice. If there are (two possible minor septa are visible in an unfigured transverse section of the holotype), they are quite small, and have been all but obliterated. Adding to the difficulty of understanding the specimen is the fact that, at the time of death, the corallite was apparently rotating its axis through a 90° turn, so that the topography of the calice floor is distorted. All that can be determined at this point is that the tabulae apparently are without spines, and are incomplete more frequently than in our specimens. The calice walls appear rather less steep than in the Brassfield form, and the septal spines show no sign of axial divergence.

Two figured paratypes (YPM 17668 and 17670) were also studied. The former is scolecoid, quite cylindrical, but with no clear rejuvenescence. Through a preserved length of 2.5 cm, it maintains a diameter of approximately 1 cm. Its calice floor is narrow, with steeply-sloping, but non-vertical walls. The septa are of two orders, and there is no indication of spinal divergence distally. The calice is too poorly-preserved to be certain, but it appears that some of the septal spines may continue for a short distance

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towards the axis of the calice floor. This specimen is certainly not conspecific with the Brassfield form, and is possibly not truly a member of Amsden's species.

The second paratype (YPM 17670) is too poorly-preserved to give much information on the calice and septa, but in general form, it more closely resembles the holotype than did the other paratype. Its base is tapered, and there is a flat area at its lower end, suggesting an attachment scar.

In conclusion, while the holotype of Amsden's species has several points in common with ours (spine-free tabulae, possibly two orders of septa without distal divergence of the spines), its state of preservation leaves too many questions unanswered at this time to allow confident identity with the Brassfield specimens.

Sutherland's Tryplasma cf. T. radiculum (sic) bears strong resemblance to the Brassfield specimens, to the extent that they are likely conspecific. This is most clearly seen in his Plate 23, fig. 1. This specimen shows frequent, fairly equidistant rejuvenescence (fig. 1a), two orders of septa (fig. 1e), and spine-free tabulae (fig. 1f). The septal spines apparently do not diverge distally from the plane of the septum (fig. 1b, d). The specimen apparently is without a basal talon (fig. 1a), but this is not considered critical. The specimen is from the Henryhouse Formation (Ludlow in age) of Oklahoma.

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Distribution - Northern Michigan: Late Llandovery or Early to Middle Wenlock; Kentucky: Middle Llandovery (Brassfield Formation); Oklahoma: Ludlow

Budge (unpublished Ph.D. thesis, 1972) describes and figures specimens of T. radicula from the Portage Canyon Member of the Laketown Dolostone in Nevada and Utah. He estimates the age of this member as Early and Middle Silurian.

Possible occurrence - Forms possibly, but not clearly, conspecific with our own are found in the Dinophyllum-Chonophyllum horizon of the Högklint beds (Early Wenlock) of Gotland.

Brassfield occurrence - Localities 1 (near Panola) and 53 (near Irvine) in central Kentucky.

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Tryplasma cylindrica (Wedekind)

Plate 5, fig. 12-15; Plate 21, fig. 4, 5

? 1876 *Cyathophyllum radicula* Rominger, p. 109-110, Plate XXXIX, fig. 3 (*partim*)

cf. 1882a *Polyorophe glabra* Lindström, p. 16, 20

cf. 1896 *Polyorophe glabra* Lindström, p. 43-47

1906 *Polyorophe radicula* Foerste, p. 313, Plate 5, fig. 3A-E

1927 *Pholidophyllum cylindricum* Wedekind, p. 28, Plate 3, fig. 5, 13

? 1965 *Tryplasma* cf. *T. radiculum* Sutherland (*partim*), p. 31-32, Plate 23, fig. 2a-f (only)

cf. 1971 *Polyorophe glabra* Lavrusevich, p. 80-81

Type material - The location of the specimen or specimens figured by Wedekind is uncertain. Dr. Stefan Bengtson of the Department of Palaeobiology, Royal University of Uppsala, Sweden informs me that Wedekind's types are in two places: the Senckenberg Museum in Frankfurt-am-Main in Germany, and the Swedish Museum of Natural History at Stockholm.

Type locality and horizon - Wedekind's figured specimen(s) is from the *Dinophyllum-Chonophyllum* horizon of the Hogklint beds (Early Wenlock) at Snäckgärdet, Gotland.

Number of specimens studied - 5

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DIAGNOSIS - Solitary Tryplasma, scolecoid in form, with occasional weak rejuvenescence (less frequent and even-spaced than in T. radicula); acanthine septa of two orders, in both of which the spines diverge distally from the septal planes; tabulae both complete and incomplete, of varying thickness, with spines on their upper surface.

DESCRIPTION - The corallites of this species are generally scolecoid, though there is gradual upward expansion through the first centimeter of growth. Corallites up to 2 cm in length show little net expansion beyond this point, though locally there is frequent increase and decrease in width. In one specimen, within a space from 5 to 10 mm from its base, the diameter goes from 6 to 5.5 to 8 mm in an upward direction. The corallites are curved, but it has not been possible to this point to relate concavity or convexity to internal features, such as a cardinal septum.

The theca is thick, tapering upward in one individual from 1.0 to 0.6 mm through a length of 1.5 cm. The structure of the theca is unclear, but transverse sections suggest a septal stereozone. The outer surface of the corallite has longitudinal grooves and rounded ridges, the latter corresponding in position to the internal septa.

The calice has been observed only in a partially-preserved state. Its walls appear to have been steep (about 60° to 90° to the horizontal), and its floor was probably

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slightly convex, to judge from the topography of the tabulae. The septa are acanthine, and two distinct orders can be differentiated by the length and thickness of their spines (Plate 5, fig. 13, 15). Those of the major septa are about 0.3 to 0.4 mm long, and spaced about 4 per millimeter. Those of the minor septa are about 1/3 as long, and somewhat more slender, but have about the same spacing as the major spines. The spines of both septal orders have a tendency to diverge distally from the plane of the septum in which they originate.

The tabulae are for the most part gently convex, with some horizontal. In a longitudinal section (Plate 21, fig. 4), about half are incomplete. The complete tabulae are about 1.5 to 3.0 mm apart, with the incomplete tabulae between them. Characteristically, these structures are quite variable in thickness, ranging from about 0.4 to less than 0.1 mm thick. Their upper surfaces are studded with spines in a radial pattern, continuous with the acanthine septa of the walls (Plate 5, fig. 15).

If talons were originally present for attachment, they must have been restricted to the basal area of the corallite, as they are not observed in the preserved portions of the corallites studied.

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DISCUSSION - The lectotype of Rominger's Cyathophyllum radicula differs from the present form in several ways: C. radicula is more strongly- and rhythmically-rejuvenescent. It has talons, restricted to its basal portion, which seem to be lacking in T. cylindrica. Its septal spines do not diverge distally from the plane of the septum, as they do in T. cylindrica. Finally, the upper surfaces of the tabulae are free of spines in Rominger's species, but not in T. cylindrica. Rominger, however, in referring to the calice floor, says "bottom of cells flat, formed of a smooth or faintly carinated or granulose transverse diaphragm". This suggests that his assemblage, from the Manistique Dolomite (Upper Llandovery to Middle Wenlock) at Point Detour, Michigan, may include both Tryplasma cylindrica and T. radicula. If so, T. cylindrica is not included among the type suite of Rominger's species at the University of Michigan Museum of Paleontology.

Foerste's Polyorophe radicula, from the Waco bed, Noland Member of the Brassfield Formation (Middle Llandovery) in central Kentucky, appears to be identical to the present form. This is not unexpected, as Foerste's specimens come from the same horizon and general area as ours. They have the same scolecoid form, with occasional weak rejuvenescence, as our specimens have. The upper surfaces of the tabulae are invested with spines. Foerste makes no mention of two orders of septa (his count of 60 to 70 septa agrees with

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ours if both orders are counted), nor does he describe distal divergence of the septal spines from the plane of the septum. It is likely that Foerste did not notice these features, if they were present, rather than there being such a major discrepancy between his specimens and ours. Unfortunately, the location of his types is unknown.

Foerste's (1906) is the first description of the present species as it is currently understood. He recognized his specimens as distinct from those of Rominger, and chose to reflect this by using the same trivial name as Rominger had, but assigning his species to a different genus. Foerste's specimens are here considered referable to the genus Tryplasma, which makes it a junior homonym of Rominger's species. Hence, the name next assigned to it, chronologically, will have to replace Foerste's designation, and that is Tryplasma cylindrica (originally called Pholidophyllum cylindricum Wedekind, 1927). This is in keeping with the International Code of Zoological Nomenclature Article 57.

Wedekind's specimens are from the upper Dinophyllum-Chonophyllum horizon (Högklint beds, Lower Wenlock) at Snäckgärdet, Gotland. They are cylindrical in form, and lack (well-developed?) talons. The corallite dimensions are in agreement with ours. Further, the acanthine septa occur in two distinct orders, and the upper surfaces of the tabulae are spinose. There is a suggestion in Wedekind's fig. 13 that the tabulae (both complete and incomplete)

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are of different thicknesses, though not quite to the extent seen in our material. The thickness of the theca compares well with ours. The only major difference between Wedekind's form and our own is that the septal spines in his specimen(s) are longer than ours. On balance, it seems that this is more sub-specific in importance than specific. It is not possible to determine if the septal spines diverge axially from the septal plane in Wedekind's specimens from the information given. It seems possible that it may have been overlooked.

Polyorophe glabra, a species described first by Lindström, from the Silurian of Gotland (1882a,1896), and later by Lavrusevich (1971) from the Late Llandovery of Uzbekstan, is similar to our species in its generally cylindrical form, and has spinose tabulae. On the other hand, it has a strongly-developed talon, characteristically extending far up on one side of the corallite, and is not particularly scolecoid. P. glabra's acanthine septa do not appear to be distinctly differentiated into two orders, as is the case with the Brassfield form. Finally, the tabulae spines in Lindström's species align in a labyrinthine pattern, while those in the Brassfield form radiate distinctly outward from the center of the tabula. Lavrusevich chose as lectotype of P. glabra Lindström's (1896) Plate VIII, fig. 106, and gave its age as Early Wenlock.

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In his description and figures of Tryplasma cf. T. radicula from the Ludlovian Henryhouse Formation of Oklahoma, Sutherland (1965) may have included a specimen of T. cylindrica (Sutherland's Plate 23, fig. 2a-f). Figure 2e clearly shows the spines on the tabulae, and figure 2c suggests two orders of septa. The specimen itself (figure 2a) appears to have undergone repeated, rhythmical rejuvenescence, however, and it cannot be determined if there is distal spinal divergence, leaving the identity of this specimen open to question.

Distribution - Gotland: Early Wenlock; Kentucky: Middle Llandovery (Brassfield Formation); Possibly also in Oklahoma (Ludlow) and northern Michigan (Late Llandovery or Early or Middle Wenlock).

Brassfield occurrence - During this study, specimens were collected from locality 1 (Noland Member of the Brassfield, near Panola, Kentucky). Foerste's specimens are from this same general area. Those specimens which he figured are "from along the road north of Estill Springs, north of Irvine, Kentucky" (our localities 53-53a), and "from half a mile east of Waco, where the road to Cobb Ferry turns off from the pike to Irvine" (locality 45 of this study). He also reports specimens occurring "a mile southwest of Indian Fields, where the road from Kiddville joins the road from Indian Fields to Clay City" in central Kentucky.

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Tryplasma sp.

Plate 6, fig. 5

DESCRIPTION - A specimen of *Tryplasma* which cannot be neatly fit into either of the two species described from the Brassfield Formation, and about which insufficient information is obtainable for assigning it to another species at the moment, is here recorded.

The specimen consists of two corallites, one budded from the other (the only instance of such budding found in Brassfield *Tryplasma*). The parent has a diameter of 6 mm, and is curved in a plane roughly perpendicular to the axis of the bud. Its length, along the curved axis, is estimated to be at least 1.5 cm, with more hidden at either end in the rock. The tabulae are both complete and incomplete in the parent (but are not seen in the bud), and appear to be free of spines. There seem to be two orders of acanthine septa, but it is not clear if the trabeculae diverge axially from the plane of the septum (as they do in *T. cylindrica*).

The spacing of the tabulae cannot be seen in enough cases to be meaningful. The surfaces of the parent and bud are rugose, but there is no evidence of rejuvenescence.

Brassfield occurrence - Locality 46, at the top of the Noland Member, near College Hill, Kentucky.

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Family Calostylidae C.F. Roemer, 1883

Rugosa lacking dissepimentarium; includes solitary and colonial (at least one) forms; septa of both orders perforate, often mutually connected across the septocoels in marginarium by synapticulae; major septa commonly join axially to form spongy axial structure; tabulae thin, domed; theca a thin coating, usually worn away from all but the lowest portions of the corallite.

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Calostylis Lindström, 1868

1868 Calostylis Lindström, p. 421

1887 Hemiphyllum Tomes, p. 98

1930 Calostylis Smith, p. 261-262

Type species - (By monotypy), Calostylis cribraria Lindström (1868, p. 421) (= Clisiophyllum denticulatum Kjerulf, 1865, p. 22, 25).

Type locality and horizon - (of Lindström's material), Silurian (Salopian) of Gotland.

DIAGNOSIS - Solitary corals lacking dissepimentarium; theca generally quite thin, often missing from all but the base; septa perforate, but still retaining their integrity; septa of two orders, joined laterally by synapticulae; cardinal fossula sometimes developed, but only weakly; axial structure spongy; tabulae thin, usually convex.

DESCRIPTION - This genus consists of solitary corals whose septa are perforate. In all other respects, the corallite bears the characters of the Rugosa. In some species a basal talon is present. The theca is usually missing (worn away?) from all but the lowest portions of the corallite, leaving exposed the inner spongy texture of the proximal ends of the septa (see below). The calice is generally broadly-convex. There are two orders of septa, and these behave as in most rugose corals. The major septa extend to the

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axial region, and the minors stop some distance from the axis, such that their distal ends mark the limits of the calice walls. In some instances, a cardinal fossula and septum can be discerned.

The perforate nature of the septa of both orders, however, produces a distinctive internal aspect in this coral. Seen in vertical section, a septum looks like a piece of swiss cheese, with rather large circular and elliptical holes through it. In the peripheral region of the calice, the septa are joined laterally by synapticulae, which together with the perforate nature of the septa, gives the distinctive spongy appearance. The middle portions of the septa, as seen in transverse section, tend to be more complete, and appear as solid lines, without interruptions. Once the major septa reach the axis, however, they again break up, and intertwine, producing the spongy axial structure.

The tabulae are horizontal or broadly-convex. They have an uneven appearance when seen in longitudinal section, due to skeletal projections on both surfaces, but they are complete, with no evidence of holes or other interruptions in their surfaces.

DISCUSSION - Lindström (1868) introduced the name Calostylis for the genus of corals with perforate septa typified by his species Calostylis cribraria from the Silurian beds in the vicinity of Visby, Gotland. In 1870, Lindström

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(fide Smith, 1930) reported that he had received some specimens from Theodor Kjerulf that the latter (1865) had figured as Clisiophyllum denticulatum, and that these specimens were conspecific with C. cribraria. Hence, Lindstrom's species, the type of Calostylis, is actually Calostylis denticulatum (Kjerulf). This was accepted by Smith (1930) in his work on the Family Calostylidae, but we must reserve judgement, never having seen the original material. Certainly, Kjerulf's figures (text-fig. 32 on p. 25) are insufficient for a sound comparison with Lindström's.

Tomes (1887) proposed the generic name Hemiphyllum for coral material from the Silurian at Colwall and Wenlock, England. Nicholson (1887) and Smith (1930) considered this a junior synonym of Calostylis, with apparent justification.

Smith (1930, p. 258-260) gives an interesting account of the controversy surrounding the affinities of Calostylis and its relatives. The major disagreement concerned whether or not this genus belonged to the Rugosa or to the Scleractinia. The former position was championed by C.F. Roemer (1883), while the latter was supported by Lindström (1870). Through the years, many of the most prominent paleontologists found themselves in one camp or the other. As noted above, except for the perforateness of the septa, Calostylis corallites have all the prerequisites for belonging to the Rugosa, including two orders of septa, a cardinal fossula, and most important, a septal development pattern and arrangement

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typical of the Rugosa, reported by Frech (1890) and confirmed by Smith (1930, p. 260).

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Calostylis spongiosa Foerste

Plate 6, fig. 6-12, 14, 15; Plate 22, fig. 8-10

cf. 1865 Clisiophyllum denticulatum Kjerulf, p. 22, 25, fig. 32 on p. 25

cf. 1868 Calostylis cribraria Lindström, p. 421, Plate VI, fig. 1-3

1906 Calostylis spongiosa Foerste (partim), p. 322-323, Plate VII, fig. 3B-G (non 3A); Plate VII, fig. 1A, B

cf. 1917 Calostylis parvula Foerste, p. 200, Plate VIII, fig. 2a-f; Plate IX, fig. 5

1930a Calostylis spongiosa Smith, p. 270-271, Plate XII, fig. 1-7

cf. 1930a Calostylis tomesi Smith, p. 269-270, Plate XI, fig. 12-17

1931 Ptychophyllum riboltense Foerste, p. 185, Plate XIX, fig. 11

1931 Calostylis spongiosa Foerste (partim), p. 187, Plate XX, fig. 1b (non 1a)

cf. 1958 Calostylis concavifundatus Reiman (in Kal'o and Reiman), p. 28-29, Plate I, fig. 1, 2

? 1958 Calostylis luhai Kal'o (in Kal'o and Reiman), p. 29-30, Plate I, fig. 3-6

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Type material - Smith (1930a) says that Foerste's figured syntypes were lost in the Dayton, Ohio flood of 1913. Foerste sent him other specimens, which he placed in the British Museum under the numbers R26528 to R26533. Foerste's (1906) figures give a good picture of the external features of this species, but provide no information on the internal structure. As the material collected during this study is not from the type locality (or at least, from the locality of Foerste's figured specimens), a neotype would best be selected from the British Museum material.

Type locality and horizon - Foerste's figured specimens are all from the Waco bed, Noland Member of the Brassfield Formation, along the "road north of Estill Springs, north of Irvine, Kentucky." This is equivalent to our localities 53 and 53a. Foerste further reports specimens from other localities in this general area of central Kentucky, but as it appears that his concept of the species included what is here identified as C. lindstroemi Nicholson & Etheridge, it cannot be certain that C. spongiosa actually does occur at these other localities.

Number of specimens studied - 4

DIAGNOSIS - Calostylis of trochoid or sub-cylindrical (but not scolecoid) form, solitary corallites; theca usually well-preserved, but absent from the distalmost region, leaving an upper zone of exposed peripheral septal edges (cf.

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Montlivaltia and Thecosmilia, two scleractinian genera); cardinal fossula weakly-developed, present on convex side of corallite; septa not contratingent.

DESCRIPTION - Of the two Brassfield species of Calostylis, this is the more regular in form. The corallites are typically trochoid or sub-cylindrical, though the rate of expansion varies from specimen to specimen. Following are diameters (in mm) of three corallites at specific elevations (also measured in mm) above the base, measured along the convex side:

	Elevation						
Specimen	5	10	15	20	25	30	No. of Major septa
1	5	10	8	12	19	19	51
2	8	9	11	13	14	-	-
3	7	11	-	-	-	-	39

In the three largest specimens, the theca is well-preserved, and reaches to within a few millimeters of the calice rim. Above this limit, the proximal edges of the septa are exposed. In the smallest specimen, the theca is preserved only at the base. Two of the specimens have what appear to be basal attachment scars (Plate 6, fig. 11).

The calice rim is generally broadly-rounded, though not so broad as the calicular depression. The depth of the calice seems to decrease relative to its diameter as the cor-

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allite grows. In the smallest corallite, the calice depth is 2.5 mm, while its diameter across the calice rim is 10 mm. In the largest specimen, the depth is 4 mm and the diameter 17 mm. The two intermediate specimens both have calice depths of 2 mm and diameters of 10 and 13 mm. The smallest specimen has a relatively narrow convex axial structure, with a sharp moat separating it from the steep calice wall (Plate 6, fig. 15). In the larger specimens (Plate 6, fig. 6, 7, 11) the convex axial structure is less peaked, being wider relative to its height, and the walls of the calice are more rounded at the crest.

The septa, as viewed in the calice of a whole specimen, are more distinct than in C. lindstroemi (q.v.). They occur in two orders, of which the major septa are somewhat broader, and of greater relief than the minors. Most of the minor septa appear to be restricted to the spongy peripheral zone of the calice walls, leaving the major septa to continue across the corallite's calice floor alone, and tapering to the axial structure. In the peripheral zone, the synapticulae cross the septocoels, joining the sides of adjacent septa.

Perhaps the most distinctive feature of this species is the presence of a cardinal fossula. This appears as a rounded notch in the calice rim on the convex side of the corallite (Plate 6, fig. 6, 11), and sometimes continues as a groove across the calice floor. In transverse section, the area of the fossula shows a centrally-placed cardinal septum,

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flanked by two minor septa (Plate 22, fig. 8, upper part of figure). On either side of these latter is a major septum whose distal end curves away from the cardinal septum, and nearly contacts the side of the major septum next to it. This feature was not reported by Foerste, nor is it mentioned in any other description of a Calostylis species. Some of Foerste's figures, however, show a notch in the calice rim which may represent the fossula.

The septa are perforate, the pores being up to 0.3 mm across, circular or elliptical in form (Plate 22, fig. 10). Sometimes the perforations are connected, producing elongate patterns. Distally, the ends of the major septa appear to break up into paliform lobes, forming the spongy axial structure. Here the lobes fuse and flex, giving rise to a reticulum reminiscent of sponge spicules.

The tabulae are convex, and appear as distinct plates in the space between the peripheral spongy zone and the axial structure. In this region (Plate 22, fig. 10) they are spaced about 1 mm apart. They are rather obscured in the axial structure, but may be seen here as bridges between the spicule-like elements of this region.

DISCUSSION - Smith (1930a) discussed and figured specimens sent him by Foerste, identified as C. spongiosa. It seems that Smith probably did not differentiate between the two Brassfield species of Calostylis, essentially continuing Foerste's polythetic concept of C. spongiosa, but his fig-

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ures appear in good agreement with our idea of the species. Foerste, after the initial presentation of his species (1906) refigured it (1931), both under the name C. spongiosa (illustrated by the specimen of figures 3A and 3G of his original description), and once under the name Ptychophyllum riboltense (from the Late Llandoverian Dayton Formation of Lewis County, Kentucky), which looks strikingly similar to the specimen shown in our Plate 6, fig. 6.

In 1865, Kjerulf described Clisiophyllum denticulatum from Silurian strata on the Norwegian island of Malmo. The figure shows a rather contorted, trochoid corallite with steep, clearly-septate calice walls and a broad, convex axial structure that occupies the entire calice floor. Lindström (1868) later described the species Calostylis cribraria from the vicinity of Visby, Gotland (probably from the Lower Wenlockian Högklint beds), and upon it, based his new genus, Calostylis. This species was characterized by a cylindro-conical form, basally-attached, with the theca present only in patches. The calice region consists of a rounded rim, and a floor occupied by a broad, convex axial structure. The major septa were shown in Lindström's figure 1 to be fused in pairs distally prior to continuing to the axial structure.

As described in the "discussion" section of Calostylis (the genus), Lindström later examined specimens of Kjerulf's species, and came to regard his own as a junior synonym.

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Smith (1930a) described Calostylis denticulata from material at the Stockholm Riksmuseet that had been identified by Lindström, and from material in his own collection. His figures show that the septa of both cycles are far-more distinct in the spongy peripheral region than they are in C. spongiosa from the Brassfield, and they give no indication of possessing a cardinal fossula.. These facts, and the distal fusion of septa into pairs (shown in Lindström's figure 1, but not obvious in Smith's figures) indicate that that this European form and the Brassfield species are distinct, but the many similarities in other respects do suggest a rather close relationship.

Smith (1930a) erected the name Calostylis tomesi for a coral described by Tomes (1887) from the Wenlock Limestone (Late Wenlockian, according to Gignoux, 1950) of Wenlock, England. The septa of this species apparently fuse distally into pairs, as they do in the specimen figured by Lindström. It differs in this respect from C. spongiosa, as well as in apparently lacking a cardinal fossula, but the presence of a theca over most of the corallite, while being absent from the zone just below the calice rim, is quite reminiscent of Foerste's species. Also, the corallite of C. tomesi is trochoid, or sub-cylindrical, as is the case with C. spongiosa. Here, then, we have another case of a form, similar but apparently unrelated to Foerste's species.

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From the upper Laurel Formation (Middle Wenlockian) of Ohio, Foerste described Calostylis parvula. Basically, it differs from C. spongiosa in possessing what Foerste refers to as porous lamellose structures, apparently different from our synapticulae, connecting the sides of the septa in the manner of vesicular dissepiments. Also, this species frequently displays contratingency of minor septa on majors. Foerste speaks of a "cardinal side" of the corallite, but it is unclear if a cardinal septum or fossula are distinguishable.

In a joint paper, Kal'o & Reiman (1958) described two new species of Estonian Calostylis, which warrant comparison with our species. The first, C. concavifundatus, was described by Reiman from the Porkuny Stage (Late Ordovician or Early Llandovery) of Estonia. These are trochoid and sub-cylindrical corallites, with the theca absent from the uppermost portion of the sides. The perforate septa are of two orders, with the minors about half the length of the majors. Only the latter reach the axis, and they do not form an axial structure (an unusual situation in this genus). Their distal ends, however, may join. The concave tabulae are a distinguishing feature of this species, by virtue of which it differs form C. spongiosa. Other differences lie in the absence of a well-developed axial structure, as well as a cardinal fossula, in the former.

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The second species is C. luhai, described by Kal'o from the Adavere Stage (Late Llandovery, according to Manten, 1971) of Estonia. This species is also dealt with in the "discussion" section of C. lindstroemi (q.v.). It bears a strong resemblance to C. spongiosa, a fact that was realized by Kal'o also. He felt that the only important difference between the two species is that the septa of Foerste's species are more clearly divided into two orders. Kal'o's figures, however, suggest that the difference is not nearly so great as he implies. The factor that prevents the confident synonymizing of Kal'o's species with Foerste's is the absence of clear evidence of a cardinal fossula in the former. It would be worthwhile to examine closely Kal'o's type suite to see if this structure can be detected.

Distribution - Kentucky: Middle Llandovery (Brassfield Formation); Late Llandovery (Dayton Formation).

A very similar form, which may prove to be conspecific with the present species, is reported from the Late Llandovery (Adavere Stage) of Estonia.

Brassfield occurrence - During this study, specimens were found at localities 1 (near Panola) and 46 (near College Hill), both in central Kentucky. Foerste's figured specimens are from the Irvine region, in the vicinity of our localities 53-53a.

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Calostylis lindstroemi Nicholson & Etheridge

Plate 6, fig. 13, 16, 17; Plate 22, fig. 1-7

1878 Calostylis lindströmi Nicholson & Etheridge, p. 65-67, Plate V, fig. 2-2c

1906 Calostylis spongiosa Foerste (partim), p. 322-323, Plate VII, fig. 3A (non Plate VII, fig. 3B-G; Plate VIII, fig. 1A, B); non Smith, 1930

1930a Calostylis lindstromi Smith, p. 265-266, Plate X, fig. 18-22

1931 Calostylis spongiosa Foerste (partim), p. 187, Plate XX, fig. 1a (non 1b)

? 1958 Calostylis luhai Kal'o (in Kal'o & Reiman), p. 29-30, Plate I, fig. 3-6

Type material - Lectotype (Smith, 1930a, p. 266): R26210 in the British Museum (figured by Nicholson & Etheridge, Plate V, fig. 2, and by Smith, Plate X, fig. 18). Paratypes: R26210-26253, 26296-26271.

Type locality - The greenish mudstones of Penkill, near Girvan, Scotland, of Late Llandoverian age, according to Smith.

Number of specimens studied - 7

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DIAGNOSIS - Scolecoid, solitary Calostylis, often displaying marked increases and decreases in diameter; no fossula present; tabulae represented by extremely-thin lamellae connecting the elements of the spongy axial structure; theca seldom preserved, except at base.

DESCRIPTION - The scolecoid form of the corallite, and the almost total absence of theca, are the most obvious features of this species. The crests of the calice walls are relatively narrow, as opposed to their roundness and usual broadness in Calostylis spongiosa (q.v.). In well-preserved forms, the ratio of calice depth to calice diameter is greater than in this latter species. The absence of the theca exposes the spongy interior of the corallite. At the base of the corallite, where some theca may remain, one specimen (Plate 6, fig. 16, 17) has retained a small talon.

The smallest free corallite has a straight axial length of 17 mm, but is 22 mm long when measured along the curve of its convex side. Its diameter at the top is 7 mm. The largest specimen has a length of 45 mm. This corallite (Plate 6, fig. 16, 17) has a talon about 6.5 mm long at its extreme base. Through its lowest centimeter of length it gradually expands to a diameter of 7 mm. Above this is a swollen region, 1.5 cm long, reaching a diameter of 13 mm at its center. Beyond this, the diameter immediately contracts to 7 mm. Half a centimeter above this, the diameter

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expands to 10 mm, beyond which it remains constant.

The calice floor is usually poorly-preserved, but appears to have a convex floor. The spongy texture tends to camouflage the radial structure of the septa in the walls, moreso than in the other Brassfield species of Calostylis. Internally, the ontogenetic pattern is Streptelasma-like: as the corallite grew, the area occupied by the axial structure increased proportionally at the expense of the zone of radiating septa.

The septa are perforate, with holes up to 0.2 mm in diameter. Sometimes the holes connect with each other, forming elongate gaps (Plate 22, fig. 1). There are two septal orders, the minor septa remaining in the zone of the calice wall, and the majors extending on across the calice floor to mingle their distal ends in the axial structure of complexly-fusing paliform lobes.

The peripheral zone, containing both major and minor septa, is the most dense, and synapticulae crossing the septocoels to connect adjacent septa serve to accent the sponginess of the internal structure. The septa are broadest at the radial position where the minor septa come to an end, and from this point, the major septa continue toward the axis.

In longitudinal section (Plate 22, fig. 1) the tabulae are horizontal or convex distally. They appear to be extremely thin, but solid. The tabulae may be seen in continuing through the axial structure, connecting the inter-

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fused paliform lobes.

Both Nicholson & Etheridge, and Smith speak of specimens displaying buds, none of which have been found in the Brassfield Formation. Of interest in this context, however, is a small specimen (Plate 6, fig. 13) which is growing on the side of a worn fragment of Schizophaulactis densiseptatus (q.v.), a solitary rugosan.

DISCUSSION - Both Nicholson & Etheridge, and Smith stress the scolecoid form with varying diameter, and the near-absence of a theca. The spongy axial structure is said to account for about 1/3 of the total diameter (as is the case in our specimens). The spongy aspect of the interior is due to discontinuity of the septa,and presence of synapticulae is also noted. In addition, these authors note that these features are visible along the sides of the corallite due to absence of the theca. Nicholson & Etheridge state that the corallite length varies from 0.5 to 1 inch, and that the mean diameter is 2 lines (4.2 mm). Smith gives the length of the lectotype as 25 mm, and its width as 5 mm, comparable with most of our specimens. In both references, the septa are described as being of two orders, with only the major septa extending into the axial structure. Nicholson & Etheridge note the presence of plates representing tabulae, that occur between the wall and the axial structure. These do not occur in our form, and Smith indicated

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his inability to find these structures in his examinations. There is a possibility that the axial structure of Nicholson & Etheridge's specimens is more separated from the peripheral spongy zone than is the case in our specimens, which might indeed result in isolated tabulae visible between these two regions. There is a suggestion of this in Plate V, fig. 2c of the original reference, and in Plate X, fig. 22 of Smith's work. Should this prove to be real, there might be some question as to the validity of identifying our specimens with C. lindstroemi. The generally good agreement, however, in all other respects makes this difference seem more on the sub-specific level. Unfortunately, the lectotype has apparently not been sectioned.

Foerste (1906) erected the species Calostylis spongiosa for specimens from the Brassfield Formation north of Irvine, Kentucky. Judging from his description and figures, however, he based it upon specimens representing both species of this genus thus far identified from this unit. Only one of his figures (fig. 3A) appears to be referable to C. lindstroemi, and this is a scolecoid corallite with rather rounded calice rim, and nearly devoid of theca. Assuming that Foerste's figure is natural-size, the specimen is about 48 mm long, with an upper diameter of 14 mm. The calicular depression itself is about 7 mm across. The maximum diameter, 17.5 mm, lies at mid-length. In a later publication (1931), Foerste again figured this specimen, along with the specimen shown

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in figure 3G of his 1906 publication, under the name Calostylis spongiosa. There is insufficient information available from Foerste's figure to ascertain the relationships of this particular specimen. The scolecoid form and absence of a theca over nearly the entire corallite speak eloquently of C. lindstroemi. On the other hand, the broad, rounded calice rim is more like that found in C. spongiosa. On balance, it seems likely that this specimen does belong to Nicholson & Etheridge's species, especially in light of the fact that this species has been found, during this study, at the same locality as Foerste's specimens.

Kal'o (1958) described the species Calostylis luhai from the Adavere Stage(Late Llandovery according to Manten, 1971) of western Estonia, based upon specimens of ceratoid or sub-cylindrical form, with much-reduced epitheca. The septa reportedly are not clearly of two orders, and are supposedly well-defined only on the inner surface of the spongy peripheral zone. The axial structure appears to be as in our specimens, and the convex tabulae are wavy in cross-section, which is also the case in the Brassfield form. Synapticulae occur between the septa. Kal'o considered the weak development of the septa, and the supposed absence of two easily-distinguished orders to be important features of this species. Some of our specimens of C. lindstroemi, however, show these features, while others have more distinct septa. At any rate, Kal'o's figures indicate no appreciable

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difference between the septa of his specimens and ours. Possible differences of importance do, however, lie in the apparently greater separation of the axial structure from the spongy peripheral zone in Kal'o's form (also noted by Nicholson & Etheridge in their specimens of C. lindstroemi), and in the absence of a clear reference by Kal'o to a scolecoid form in his specimens. The combination of these two factors makes it best to regard this species as distinct from the Brassfield specimens of Calostylis spongiosa, pending further study.

Distribution - Scotland: Late Llandovery; Kentucky, and possibly Ohio: Middle Llandovery (Brassfield Formation).

Brassfield occurrence - Localities 1 (near Panola), 46 (near College Hill) and 53 (near Irvine), all in the Waco bed, Noland Member in central Kentucky. In addition, there is a possible occurrence of this species, on a slab from the Upper Brassfield Formation (UCGM 41859) from locality 13 (Todd Fork, near Wilmington, Ohio).

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Family Chonophyllidae Holmes, 1887

Solitary and colonial Rugosa, with dissepimentarium; rejuvenescence common; marginarium lonsdaleoid; theca a thin septal stereozone; tabulae broadly-domed, sometimes with supplementary plates.

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Strombodes Schweigger, 1819

1819 Strombodes Schweigger, Table VI

1873 Donacophyllum Dybowski, p. 80

1874 Donacophyllum Dybowski, p. 46

Type species - (SD M'Coy, 1849), Madrepora stellaris Linnaeus (1758, p. 795)

Type locality and horizon - According to Lang et al. (1940, p. 126): "(Silurian) on the shore: Kyllei and Slite, Isle of Gotland, Sweden".

DIAGNOSIS - Colonial rugose corals with dissepimentarium; corallum alternately phaceloid and cerioid, due to expansions at intervals of the dissepimentarium to contact a similar expansion in a neighboring corallite, the two being separated by a thecal deposit; marginarium lonsdaleoid; tabulae complete and incomplete, often axially-depressed and accompanied by supplementary plates.

DESCRIPTION - This genus consists of colonial corals with a growth-form alternating between phaceloid and cerioid. This results from expansions of the dissepimentarium of one corallite to join with a similar expansion from a neighbor. In this respect, the corallum resembles a rather stout, irregular colony of Tubipora, a modern alcyonarian popularly known as the "pipe-organ" coral, at least on a superficial level. At the point of juncture between these expansions,

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the two corallites are separated by a thecal deposit (Plate 23, fig. 3, 4).

The dissepimentarium consists of lonsdaleoid septa with dissepiments many of which are of rather large size. The septa are of two orders, and reach to or near the axis, without, however, forming an axial structure. The tabularium contains both complete and incomplete tabulae, commonly depressed axially and marginally, with supplementary plates in the peripheral moat.

DISCUSSION - Schweigger (1819, Table VI) described his genus, Strombodes, through the excellent expedient of a flow-sheet, thus showing its morphologic relationships to other genera. He included two species in this genus, Madrepora stellaris and M. truncata, both of Linnaeus.

M'Coy (1849, p. 10) considered the second of these species to be a true Cyathophyllum (C. dianthus Goldfuss, 1826), and consequently chose the first species, M. stellaris, as the type. Linnaeus (1758?), prior to his introduction of this species, had illustrated it in figures 11 and 14 of his plate on p. 312, but I have not personally seen these figures. As a result, the concept of Strombodes Schweigger used in this paper is based upon Hill's (1956) figure 2 on her p. 301, purporting to show Strombodes stellaris (Linnaeus).

Dybowski (1873, 1874) introduced the genus Donacophyllum, from the Ordovician and Silurian of the Baltic. Lang

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et al. (1940, p. 54) selected as type species D. middendorffi from the Ordovician of Estonia, the first species described by Dybowski (1874, p. 46-50) under this genus. Dybowski's description and figures strongly suggest that Donacophyllum is a junior synonym of Strombodes.

The long history of confusion of the species of Arachnophyllum Dana for members of the genus Strombodes Schweigger, is briefly discussed in the section dealing with the former genus.

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Strombodes socialis (Soshkina)

Plate 7, fig. 1; Plate 23, fig. 1-4; Plate 24, fig. 6, 7

cf. 1876 Diphyphyllum huronicum Rominger, p. 121, Plate XLV, fig. 1

cf. 1876 Diphyphyllum rugosum Rominger, p. 122, Plate XLV, fig. 2

1955 Cyathactis socialis Soshkina, p. 124-125, Plate XII, fig. 2a, b

1970 Strombodes (Strombodes) socialis Flügel & Saleh, p. 280-281, Plate 2, fig. 1, 2

1972 Strombodes sp. Bolton & Copeland, p. 30, Plate IV, fig. 5, 6

Type material - Holotype: PIN 587/2465

Type locality and horizon - Kochumdekskoy Suite (Middle and Upper Llandovery), layer B5, upper level of the Suite, on the right bank of the Podkamennaya Tunguska River, opposite the mouth of the Listvenichnoy River, Siberian Platform.

Number of specimens studied - approximately 6

DIAGNOSIS - Strombodes with a wide lonsdaleoid dissepimentarium, occupying one-half to two-thirds of the corallite radius, and consisting of rather large, elongate dissepiments; outermost dissepiments distinctly larger (in cross-section) than the more central ones; septa do not reach axis;

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tabulae mostly complete, often axially-concave and peripherally-convex; narrow zone between tabularium and dissepimentarium occupied by supplementary plates; increase apparently non-parricidal.

DESCRIPTION - This species consists of large coralla, generally about 12 cm across, as found in the field. The corallites are close-packed and mostly large. Individual corallites attain lengths of 4 cm and more, and maximum diameters of about 1.5 cm (with a few reaching 2 cm in width). Increase appears to be non-parricidal. At a given level, the interstices between these broader corallites are filled with the calices of younger corallites, which may be 0.3 cm or less in diameter. The calices are so close-packed as to give the impression in surficial view of a massive, cerioid corallum, with scattered phaceloid regions, and this is indeed the case (Plate 7, fig. 1; Plate 23, fig. 3, 4).

Sections show that thecal material, about 0.3 mm thick, is always present in the contact zone between corallites, with a thin mid-line dividing the theca of the contiguous corallites (Plate 23, fig. 3, 4).

The close-packing of the corallites distorts the circular cross-section into polygons. Calices observed were generally poorly-preserved. One large example with a diameter of 15 mm had a depth of 3 mm, and was more concave in the axis than at the margins.

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Externally, the thecae are longitudinally-striated (Plate 7, fig. 1), with irregularly-spaced rugae of about the same distinctness as the striations. In one slightly-worn corallite, the striations seem to be alternately deep and shallow, but this distinction is not evident on other well-preserved corallites in the same corallum.

The septa are lonsdaleoid peripherally, with minor septa only slightly shorter than majors. No fossula has been seen distinctly, but in Plate 23, fig. 2, two septa in the lower portion of the figure appear to curve together in the axis, encircling a third septum, somewhat in the manner of the cardinal fossula seen in Dinophyllum semilunum (q.v.). In a diameter of 1.5 cm (not counting the zone of coarse dissepiments into which the septa do not reach peripherally), there are 67 septa (approximate total for both orders).

The corallite interior consists of three zones (Plate 23, fig. 1, 3): an outer dissepimentarium, an inner tabularium, and an intermediate (though not ubiquitous) narrow zone of supplementary plates. Roughly, the tabularium accounts for 1/3 the diameter, the dissepimentarium for 1/2 the diameter, and the intermediate region of supplementary plates for 1/6 the diameter (where it is present).

The dissepimentarium consists of as many as 12 layers of vesicles, making an angle of about 40° with the corallite axis. In longitudinal section, the vesicles of one corallite

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are from 1 to 3 mm long, with a height:length ratio ranging from 1/2 to 1/7. There is no clear zonation of dissepiments by size vertically.

The tabularium structure appears chaotic in most views, but clearly consists of cupid-bow tabulae...that is, tabulae concave in the axis, convex on all sides surrounding the central depression, and finally, depressed peripherally to form a moat against the dissepimentarium. The tabulae are often incomplete, becoming plates tilted against the sides of the axial depression or the moat. In some cases, the central depression is absent, leaving flat tabulae surrounded by a moat.

The relief of the moat is often moderated by the presence of supplementary plates, which may have produced a totally flat tabularium floor at times.

The complexity of the tabularium makes it difficult to give a definitive idea of the tabular spacing, but the tabulae appear to be about 1/3 to 1 mm apart vertically. The supplementary plates of the intermediate zone are spaced 0.3 to 0.4 mm apart vertically.

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DISCUSSION - Rominger (1876) reported a coral, Diphyphyllum huronicum from the Manistique Group (Late Llandovery to Middle Wenlock) of Point Detour, Chippewa County, Michigan, which has many points in common with our own specimens. The holotype (UMMP 8592) could not be located, so that it is not possible to make a detailed analysis of the similarities and differences.

Rominger reported that his form consists of aggregate, flexuose corallites, one to two cm in diameter, bearing delicate longitudinal striae and deeper rugae. The corallites connect laterally by stout rugose prominences which, "in all the stems of a colony are uniformly directed to one side." The calices are moderately-deep, "dish-shaped with explanate margins", with about 60 septa merging into an axial "fascicle". There is a dissepimentarium, and the axial region of the corallite contains large vesicles, but apparently nothing that Rominger would consider a tabula, so that the outer and inner regions are ill-defined. Increase is by gemmation from the margins and the center of the calicular area. Those offsets occurring at the margin remain slender for a longer time than do the others.

Superficially, our form agrees with Rominger's in most important respects. Only one specimen (Plate 7, fig. 1) was found showing a good view of the corallites from the sides. This does not clearly show the rugose processes of the corallites directed uniformly to one side (though not

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enough of the corallum is exposed to permit proper analysis). The number of septa generally agree, but they do not form an axial structure as they appear to do in Rominger's form. The description of the internal structure of the Michigan specimen cannot be readily reconciled with features seen in the Brassfield material. In the latter, the tabularium and dissepimentarium may be differentiated without too much difficulty, though the complexity of the tabular surfaces, the abundance of incomplete tabulae, and the marginal narrow zone of supplementary plates bounding the tabularium may have presented the confused appearance that Rominger apparently encountered. Also, Rominger's example had coarser cell spaces in the central portion, whereas in our specimens, the dissepimental cells are coarser. Finally, the Brassfield specimens do not show parricidal budding, as Rominger's remark about gemmation from the center of the calicular area implies occurs in D. huronicum. Pending examination of the holotype, there seem to be no grounds for regarding these two forms as conspecific.

A specimen in the collection of the University of Michigan's Paleontology Museum (Plate 24, fig. 6, 7) indicates that the Brassfield species did extend into the same regions where Rominger's specimen was found. The specimen in question is better-preserved internally than our own, and appears to be conspecific with it. It comes from the top of the Fiborn Limestone Member of the Hendricks

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Dolomite (Early Late Llandovery, coeval with Noland Mem.) about 3 miles north of Hunts Spur, Mackinac County, Michigan. It agrees in all respects with the structure of our specimens, The cupid-bow tabulae, and zone of supplementary plates separating the tabularium from the dissepimentarium are clearly visible. Because of the more regular structure of its tabularium, the different internal zones are more distinct than in our material, possibly an indication of the variability of this species. Finally, the absence of an axial structure in this specimen adds to the likelihood that it is conspecific with the Brassfield form.

In the same paper, Rominger described a second species of what he considered to be Diphyphyllum: D. rugosum. He gave the locality as Louisville, Kentucky, in the Niagara Group. Possibly, his reference is to the Louisville Limestone, which is of Late Wenlock to Early Ludlow age. Rominger recognized a strong resemblance between this species and his D. huronicum, and saw them differing in the more slender corallites (1 cm) of the former. A difference of perhaps greater importance is the failure of the septa in D. rugosum to join axially to form an axial structure, in which respect it resembles our own form. Rominger also notes the prolific gemmation from the calice (parricidal budding) shown by this species, which, along with the slender form of the corallites, is probably the greatest difference between D. rugosum and our Brassfield material, making their conspecificity unlikely.

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Soshkina (1955) described Cyathactis socialis, a new form from the Middle or Upper Llandovery in the Siberian Platform. This is a shrub-like corallum with no evidence of parricidal increase. The corallites are elongate, and expand distally, with frequent and sharp lateral prominences. Daughter corallites arise at the rim of the calice, and diverge from the mother corallite as they grow upward. The major septa are thin, weakly bent and slightly twisted at the axis. They are discontinuous in the dissepimentarium (lonsdaleoid). The cardinal septum is shortened, lying in a parallel-sided fossula, and secluded from the axis by the distal juncture of neighboring septal ends. The minor septa are over half a radius in length, extending to the axial limit of the dissepimentarium. In a corallite diameter of 14 to 30 mm occur 33 to 36 septa of each order. The plates of the tabularium are cupid-bow in form, like those in our specimens, usually quite concave axially, with a deep moat against the dissepimentarium. The vesicles of the dissepimentarium are large and flattened, sloping axially, and make a dissepimentarium about 10 to 15 layers thick.

From an early ontogenetic stage, the septa are all equally thin. They do not appear to form an axial structure. In all important respects, then, Soshkina's C. socialis appears to be conspecific with our Brassfield specimens.

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Flügel & Saleh (1970) reported Soshkina's Cyathactis socialis, referring to it as Strombodes (Strombodes) socialis, from the Silurian Niur Formation at Ozbak-Kuh and E Gatch-Kuh in east Iran. The corallum is phaceloid, with fairly-cylindrical corallites, 45 to 60 mm long and 20 to 30 mm in diameter. Their outer surfaces are finely-striate longitudinally, and distinctively-rugose. In a diameter of 20 mm there are 70 septa (35 of each order). The major septa reach close to the axis, and a longer septum is felt by the authors to be the cardinal. The minor septa are barely half as long as the majors.

The dissepimentarium is about as broad as in our specimens, and the vesicles are of similar size. Reportedly there is no lonsdaleoid development of the septa in the Iranian form, but the figures suggest that this is indeed present, certainly to the degree found in our specimens. The tabularium is as found in our form, with cupid-bow tabulae fringed by a moat against the dissepimentarium. Numerous incomplete tabulae are to be found here.

The Iranian form differs from ours in no really important respects. The nature of the cardinal(?) septum in our form is not very clear, as the projections of the complex tabulae in transverse section rather cloud the central features. Doubtless this is the case in Soshkina's, as well as Flügel & Saleh's figures. In all cases it is difficult to be certain whether the axial end of the cardinal septum,

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where isolated from the axis, is so affected by axial linking of neighboring septa, or by a well in the tabula, along whose rim the neighboring septa skirt. The shorter dimensions of the minor septa in the Iranian form is probably more grounds for regarding it as a separate subspecies from ours and the Siberian material, than as a separate species.

Bolton & Copeland (1972) figured transverse and longitudinal sections of what they termed Strombodes sp., from the Thornloe Formation (Late Llandovery and Early Wenlock) of Mann Island, near the northeast shore of Lake Timiskaming, Ontario. In the figures, the diameter is about 1.25 cm, and the length at least 3.5 cm. Its dimensions thus agree generally with those of the Brassfield specimens, and with the UMMP specimen from the Fiborn Limestone of Michigan, which it most resembles.

The outermost portions of the dissepimentarium contain distinctly-larger dissepiments than those closer to the axis, a common pattern in this species. The peripheral ends of the septa are lonsdaleoid, and the septa do not quite reach the corallite axis, so that there is no axial structure.

The Timiskaming form appears to have rather fewer septa in a given diameter than either our form or or that of the Fiborn Member, having perhaps 44 septa of both orders in a diameter of 1 cm, as compared with approximately the same number in a diameter of about 0.6 cm in the Fiborn specimen. The importance of this is difficult to judge, however, as

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one does not know whether to compare the corallites as to total diameter, or to exclude the nearly septum-free peripheral region of the dissepimentarium (as was done in this case).

The tabulae are mostly flattish in the Timiskaming specimen, but some show evidence of peripheral convexity and axial depression. There is no clear intermediate zone of supplementary plates in a moat, but as noted above, this is not considered ubiquitous in this species. The similarities, then, are such that this specimen is considered conspecific with Strombodes socialis (Soshkina).

Distribution - Southwest Ohio: Middle Llandovery (Brassfield Formation; northern Michigan: Middle Llandovery; Lake Timiskaming, Ontario: Late Llandovery or Early Wenlock; Siberian Platform: Middle or Upper Llandovery; Iran: Silurian

Brassfield occurrence - Localities 7 and 7a, near Fairborn, Ohio.

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Family Arachnophyllidae Dybowski, 1873

Solitary and colonial Rugosa with dissepimentarium; major septa meet axially to join with steeply-domed tabulae in an axial boss, or else, somewhat withdrawn from axis where tabular domes sag axially.

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Arachnophyllum Dana, 1846

1846 Arachnophyllum Dana, p. 186

1873 Darwinia Dybowski, p. 148 (non Bate, 1857)

? 1885 Nicholsonia Schlüter, p. 53 (non Kiär, 1899, p. 37; nec Počta, 1902, p. 184)

1940 Arachniophyllum Lang, Smith & Thomas, p. 19 (nom. van. pro Arachnophyllum Dana, 1846); non Arachniophyllum Smyth, 1915, p. 558

Type species - (by monotypy, see discussion): Acervularia baltica Schweigger of Lonsdale (1839, partim: Plate XVI, fig. 8b-e; non 8, 8a), non Acervularia baltica Schweigger (1819, Table VI). = Strombodes murchisoni Milne-Edwards & Haime (1851, p. 428).

Type locality and horizon - According to Lang et al. (1940): "Silurian, Wenlock Limestone: Wenlock, Dudley, etc., England." Ziegler et al. (1974) give the age of the Wenlock Limestone as Late Wenlock.

DIAGNOSIS - Colonial Rugosa with dissepimentarium; corallum massive, with thamnasterioid septal arrangement; tabularia narrow, with incomplete, convex tabulae; dissepimentarium quite broad, continuous between adjacent tabularia; septa not dilated or carinate in tabularium, but are dilated in the marginal areas between tabularia, resulting in reduction of septocoels in this region to sutures between septa.

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DESCRIPTION - Arachnophyllum consists of colonial rugosans which are thamnasterioid in calicular arrangement, and cerioid in growth habit. The surface of the corallum consists of calicular pits, generally containing an axial boss, from which radiate dilated septa separated laterally by sutures. Most of these septa are continuous from one calicular pit to that of a neighbor, producing the thamnasterioid pattern. There is no theca separating neighboring corallites. Though there may be a bounding ridge marking the limits of each corallite, as in A. pentagonum (Goldfuss), yet the septa are continuous across it.

The platform within which the calicular pits lie is underlain by vesicular dissepiments, and is, in effect, a coenosteum. The pits may or may not be elevated above the level of this platform. In A. mamillare(Owen) (q.v.), they are each set at the peak of a mound. The septa are of two orders, with the minor septa going no further than the lip of the calicular pit (thereby defining it) and the majors extending to the axis, where they intertwine to form an axial structure. This structure commonly projects above the floor of the calice as an axial boss.

The septa are in some instances represented by trabeculae projecting upward from the surfaces of the dissepiments of the coenosteum, but piercing no more than one or two successive layers of vesicles.

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DISCUSSION - Dana (1846) introduced the genus Arachnophyllum with specific reference to Acervularia baltica Schweigger of Lonsdale (1839). This specimen was subsequently selected as the basis of Strombodes murchisoni by Milne-Edwards & Haime when they erected this species in 1851. As Lonsdale's was the only species described by Dana under his genus Arachnophyllum, this species (and thus, S. murchisoni) is the type by monotypy of Dana's genus.

Hill's (1956, p. 274) reference to a subsequent designation of this species as the type, by Lang & Smith (1927) is, then, erroneous. Lang & Smith's contribution was to note that Lonsdale's figures included two species of Arachnophyllum, and to restrict the type to those specimens shown in Lonsdale's figures 8b-e, which they considered to be A. baltica,sensu Lonsdale.

In the past, numerous authors have confused Arachnophyllum Dana with Strombodes Schweigger (q.v.). This is apparently because, as explained by Lang et al. (1940, p. 126-127),Milne-Edwards & Haime (1850, p. lxx) erroneously cited Strombodes pentagonus Goldfuss (1826, p. 62, Plate 21, fig. 2a, b), which morphologically belongs to Arachnophyllum, as the type of Strombodes. They were apparently unaware of the fact that M'Coy (1849, p. 10) had previously designated Madrepora stellaris Linnaeus as the type of Strombodes. The misuse of the name Strombodes persisted for quite some time.

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From the Silurian of the Baltic Area (Estonia), Dybowski (1873, p. 148) described the genus Darwinia. Though the description is a bit sketchy, the information obtainable from it, together with the figures, strongly suggests that this genus is a junior synonym of Arachnophyllum Dana. Dybowski stresses the colonial nature of the corallum, with calicular pits separated from one another by coenosteum, and that the septa are "perfect" only in the calicular pits (where the majors form an axial structure), and become broadened outside this area, where they extend into the coenosteum.

From the Middle Devonian of Germany, Schlüter (1885, p. 53) introduced the genus Nicholsonia, based upon two species he had previously described as Darwinia, and upon Strombodes diffluens Milne-Edwards & Haime (1851), which is clearly an Arachnophyllum. Lang et al. (1940, p. 89) designated one of these species, Darwinia perampla, as the type species of Nicholsonia, and stated that they consider this species congeneric with the type species of Arachnophyllum, thus making the former genus a subjective junior synonym of the latter. I have not seen the original description of D. perampla, and so cannot be confident of the validity of Lang et al.'s decision. Based upon the nature of Strombodes diffluens, and on the synonymy of Darwinia with Arachnophyllum, however, it seems likely that they are correct.

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Arachnophyllum mamillare (Owen)

Plate 7, fig. 2, 3; Plate 25, fig. 1, 3

1844 Astrea mamillaris Owen, p. 70, Plate 14, fig. 3

1876 Strombodes pygmaeus Rominger, p. 132-133, Plate XLVIII, fig. 3

1876 Strombodes mamillatus Rominger, p. 133, Plate XLVIII, fig. 4

? 1878 Lyellia striata James, p. 10

1887 Strombodes mammillaris Davis, Plate 123, fig. 4

1888 Strombodes pygmaeus Foerste, p. 120, Plate XIII, fig. 18

1901 Arachnophyllum mamillare Lambe, p. 182, Plate XV, fig. 4

1906 Arachnophyllum (Strombodes) mamillare-distans Foerste, p. 319-320, Plate 3, fig. 2A-C

1906 Arachnophyllum mamillare-wilmingtonensis Foerste, p. 320

1964 Arachnophyllum mammillare Stumm, p. 31, Plate 20, fig. 7-9

1966 Arachnophyllum mammillare Bolton, Plate VI, fig. 15

Type material - Repository of Owen's material is unknown.

Type locality and horizon - Owen reported this species from the coralline beds in the top of the Magnesian Cliff Limestone of Iowa and Wisconsin. Judging from his map (Plate 3), this area consists of the drainage basins of

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the Makoqueta and Wapsipinicon Rivers, southwest of the Mississippi River. As this species is reported by other authors from Silurian beds, it is likely that the horizon of the original material is the Kankakee or the Hopkinton Dolomite, though this cannot be certain.

Number of specimens studied - 3

DIAGNOSIS - *Arachnophyllum* with calices located on mammiform protuberances rising from a vesiculose surface; septal striae on corallum surface connect the calices with a thamnasterioid pattern, with no clear boundary between adjacent calice regions.

DESCRIPTION - This species consists of flat, expansive, holothecate coralla, built up by, and consisting of, generally broad, flattened vesicular dissepiments, with maximum thicknesses of 0.6 mm and breadths of 0.3 mm or more. The dissepiment walls are about 0.5 mm thick. Possible spines have been observed on the upper surfaces of the dissepiments when seen in thin-section, and these may correspond to the "granules" reported by Foerste (1906, p. 320) on the septal striae of the corallum surfaces. These have not been observed on our specimens, but our material appears less well-preserved than Foerste's.

The surface of the corallum is strewn with mammiform processes, each bearing a calicular pit of variable width at its apex. From the rim of this pit, the septa extend

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out to the flat surface of the common corallum in thamnasterioid pattern, where they flatten and broader to about 0.7 mm, as compared with less than 0.1 mm at the lip of the calice. Characteristically there is no border of any sort to set off the region of one mammiform process from that of its neighbors.

The septa appear to be present in two, or possibly three orders, with about 18 major septa. Outside of the calicular pit, however, the septa of the different orders are indistinguishable, resembling in this sense Schlotheimophyllum (q.v.). These relationships are most clearly seen in the holotype of Foerste's A. mamillare-distans (USNM 113639, shown on Plate 7, fig. 2). Here, a ropy axial structure is present, apparently formed of the distal ends of the major septa and the interstitial vesicular or tabular dissepiments (Plate 25, fig. 1). The calice rims are formed by a concentration of high-domed vesicles, and the calicular space between the wall and the axial structure appears to contain concave tabulae, which rise sharply to both the axis and the wall. In the inter-corallite regions of the uppermost zone in this specimen, the vesicular dissepiments are much lower than at earlier stages. Possibly this reflects a decrease in growth-rate, culminating in the death of the colony.

In this specimen, the mounds have a relief of about 7 mm, and are spaced about 1.0 to 1.5 cm apart. Their

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bases are about 1.0 cm wide, and the calice openings are about 3.0 to 3.5 mm across.

Two specimens were found in the course of field-work for this study. One, from locality 1, agrees in general with Foerste's specimen, except that the calices are somewhat more distant, and no axial boss has been observed. The surface is poorly-preserved.

The second specimen is from locality 53. Here the calices are more densely-distributed, about 1.5 cm apart, as in Foerste's specimen. The calicular pits are about 5.0 to 6.5 mm across their rims, and while there is no clear axial boss, weathered mammiform processes show a resistant axial structure of some sort. The surface of this specimen is quite uneven, such that the axes of the calices are not all parallel. In this sense, they resemble the specimen of Owen's figure. The local relief of the mammiform processes varies from about 0.5 to 1.2 cm.

DISCUSSION - Owen's original desdription of this species is: "Stars very much elevated, so as to form mamillary processes, irregular both as to size and distance apart; rays confluent." His figure resembles the more-irregular of the two specimens found in the field (from locality 53).

Rominger's (1876) Strombodes mamillatus agrees well with our concept of Owen's species. Mammiform processes rise from a common vesiculose surface, with no boundaries between them. Their centers are 1 to 2 cm apart. At their

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peaks is found a calicular pit, 4 to 5 mm across, with a "small styliform projection". From this pit the septa radiate outward to form a thamnasterioid pattern on the upper surface of the corallum, between the calices. In this region, the septa reportedly have granulose surfaces.

Rominger's description indicates that his figured specimen (UMMP 8605) is from Point Detour, Drummond Island, in Lake Huron, in which case the age would probably be Llandovery or Wenlock. The label for this specimen, however, indicates the specimen is from Niagaran beds at Masonville, Iowa. Rominger did supplementary collecting in this area for such species as Tryplasma radicula, which came from the Hopkinton Formation (Late Llandovery to Late Wenlock), so that it is possible that the museum label is correct.

James (1878) described Lyellia striata from undetermined strata in the region of Cincinnati, Ohio. Probably, "region" in this context refers to quite a wide area, as the Ordovician beds that underlie and surround the city of Cincinnati bear few corals, and almost certainly none of the type reported by James. It is likely, then, that James obtained his material from Silurian beds (possibly Brassfield) some distance from Cincinnati. This form is horizontally-expansive with a vesiculose coenosteum. Mammiform processes arise from the upper surfaces with their centers from about 4.2 mm to over 12.7 mm apart. At their crests are calicular pits, about 2.1 mm in diameter, with an axial pro-

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minence in each. Twelve to twenty septa are present at the crests, but reportedly do not extend into the body of the tube. The corallum surface is invested with coarse sinuous striae, probably like the thamnasterioid pattern of our species. From James' description, it seems likely that he was dealing with A. mamillare.

Davis (1887) figured a specimen identified as Strombodes mamillaris from the "Upper Niagara red clay near Louisville", Kentucky (probably strata of Late Wenlock or Early Ludlow age). This specimen closely resembles our material, having mammiform processes with rather broad apertures. An axial prominence appears to be present in the calicular pits. One point of difference, however, between this specimen and ours, is that the septal ridges do not attain the thickness that ours do in the coenosteum. In spite of this, it seems reasonable to identify this specimen as belonging to Owen's species.

From the Llandovery or Wenlock beds of Grand Manitoulin Island, Lake Huron, Lambe (1901) reported a specimen which he identified with Owen's species. The corallum is holothecate, with mammiform processes, each bearing a broad calicular pit. These prominences are spaced 1 to 2 cm apart. The septa are of two orders, totalling 36, with the majors attaining the axis, while the minors are restricted to the calice walls. The thamnasterioid septal pattern of the coenosteum includes septa with breadths of nearly 1 mm.

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It is probable that this specimen does indeed belong to Owen's species.

Foerste's A. mamillare-distans is from the southeast region of the Brassfield outcrop, in central Kentucky. His holotype, which was described above, is from about the same spot as our locality 1, near Panola, Kentucky, from the Noland Member of the Brassfield. Foerste felt his specimens were distinctive from other forms of the species by virtue of having narrower apertures and more widely-spaced mammiform processes. Considering the variability seen in other members of the species, Foerste's form does not seem to be sufficiently-distinctive to warrant a separate sub-species.

Stumm (1964) reports this species from the Louisville Limestone (Late Wenlock and Early Ludlow) near Louisville, Kentucky. It has all the important features of our form. The mammiform processes are about 3 mm high, and contain broad calicular pits, 4 mm across and 1 mm deep, some of which have weak axial bosses. The coenosteum is vesiculose, and its surface bears the usual thamnasterioid septal pattern.

Bolton (1966) reported this species from the Fossil Hill Formation (Middle Llandovery to Middle Wenlock) of Manitoulin Island. The mammiform processes are 3 to 4 mm in relief, and contain calicular pits about 4 mm across. About 38 septa (of all orders) were seen on the lip of one

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calice. The specimen agrees well with our concept of Owen's species.

There appears to be a rather smaller variety of this species. It was first described as Strombodes pygmaeus by Rominger (1876) from the Llandovery or Wenlock beds of Point Detour in Lake Huron. The specimen is obviously worn. It consists of a flattish surface dotted with calicular pits, about 2 mm wide and spaced 6 to 8 mm apart. Within these pits, the septa form a "small styliform projection". The coenosteal surface appears to have a thamnasterioid pattern of very fine septal ridges, each ridge bordered on both sides by a row of circular pores. The nature of these pores is unclear, but perhaps they reflect the wearing of the internal vesicular deposits.

This form is characterized by its narrow apertures and the close spacing of the mammiform processes. The coenosteal septal striations tend to be quite fine. James' Lyellia striata may belong to this group.

Foerste (1888) reported this form from the Dayton Formation (Late Llandovery), apparently in the vicinity of Wilmington, Ohio. In his paper, Foerste referred it to Rominger's Strombodes pygmaeus, but later (1906) he proposed the name Arachnophyllum mamillare-wilmingtonensis. As it appears that this form is identical to Rominger's S. pygmaeus, it seems appropriate that Rominger's should be the sub-specific name, rather than Foerste's. Foerste

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describes the mammiform processes as rather more prominent than they appear to be in Rominger's figure, with calice diameters about 2 mm, spaced about 4 to 10, but usually 6 mm apart. The elevation of the calices is about 2 mm above the coenosteum, and the coenosteum has a thamnasterioid pattern of septal ridges, about 0.3 mm broad.

At locality 12 (Ohio Brush Creek), a sample of this subspecies was found loose near the top of the Brassfield Formation (Plate 7, fig. 3). It is possibly from the Dayton Formation, originally, as that unit overlies the Brassfield in southwest Ohio, and the state of the specimen suggests transport. Beds of the Dayton Formation, however, were not found in this vicinity, so that the possibility that it comes from the Brassfield itself cannot be eliminated. Its stratigraphic position, then, remains uncertain.

The calicular pits are 2 mm in diameter, and are spaced with their centers about 5 to 7 mm from the nearest neighbor. The mammiform processes are quite worn, but appear to have had reliefs of about 2 to 2.5 mm. In the few calices that are reasonably-well preserved, about 16 septa may be seen, along with an axial protuberance whose diameter is about one-third that of the calice. The septal striae of the coenosteal platform are quite fine, with breadths of about 0.3 mm across (as compared with 0.7 mm in the two specimens found in the Brassfield in Kentucky during this study, and in Foerste's holotype of A. mamillare-distans.

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Distribution - Northern Michigan region: Llandovery or Wenlock; Kentucky: Middle Llandovery (Brassfield Formation), and Late Wenlock or Early Ludlow; Ohio: Late Llandovery.

Brassfield occurrence - Localities 1 (near Panola) and 53 (near Irvine) in central Kentucky. Foerste also reports this species from the vicinity of Incian Fields, in the same general area as the above localities, in Kentucky. All these specimens are from the Waco bed, Noland Member of the Brassfield Formation.

A subspecies of this form, A. mamillare pygmaeus, was found at locality 12, Ohio Brush Creek in southwest Ohio. Its precise stratigraphic position, however, is uncertain.

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Arachnophyllum granulosum Foerste

cf. 1826 Strombodes pentagonus Goldfuss, p. 62, Plate 21, fig. 2a, b

1906 Arachnophyllum (Strombodes) granulosum Foerste, p. 318-319, Plate 3, fig. 1

Type material - The repository of Foerste's specimen is not known.

Type locality - Waco bed, Noland Member of the Brassfield Formation, "half a mile east of Waco, Kentucky, where the road to Cobb Ferry turns off from the Irvine Pike".

Number of specimens studied - None found in the field.

DESCRIPTION - Foerste's description of this species is here given ad verbatim, followed by some observations:

"Corallum compound, explanate, thin; only a part of the corallum is preserved in the specimen figured, and this shows a maximum width of 70 millimeters and a thickness of scarcely 3 millimeters. The lower surface is not exposed. Polyparia opening above in shallow calices meeting along polygonal outlines rising but slightly above the middle parts of the calyx. A very narrow, filiform line forms a border between the calices; this line is interrupted at intervals by minute pits or pores, situated most frequently at the ends of the grooves between the septal ridges. Calices

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about 7 to 10 millimeters wide along their longer diameters, and from 6 to 7 millimeters wide transverse to this direction. Very shallow depressions, from which the septal ridges radiate, occur in an excentric position, so that the calices have the appearance of opening obliquely upon the surface. It is not known to what extent this oblique position of the slight depression is characteristic of the species. Septal ridges number about 14 or 15 in number. These begin at the margins of the shallow depressions and radiate toward the margins of the calices; those toward the nearest or rear border widen rapidly and are more triangular in outline; those toward the farther or anterior border are more nearly linear; those on the sides curve toward the anterior border. These septal ridges are quite flat or only gently convex in a transverse direction, and are separated by narrow and rather shallow, but very distinctive grooves. The surfaces of these septal ridges are marked by very minute granules. Somewhat coarser granules, very irregularly arranged, occupy the eccentric depressed area. In some calices the margins of the depressed areas are slightly, or even distinctly raised, producing the effect of a sharp circular border. In some cases the weathering away of one of the calicular layers leaves the depressed area of this layer distinctly above the general level of the next lower calicular surface. In vertical sections the corallites are seen to consist of successive calicinal floors supported by a rather coarse

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vesicular tissue, the cavities of which are rather wide but very shallow. Horizontal tabulae, closely arranged, appear to cross the region corresponding to the central, depressed part of less eccentric calices, but this part is not well exposed in the specimen at hand. Among the specimens so far described, this coral appears most nearly related to Strombodes alpenensis, Rominger."

DISCUSSION - Of the described species of Arachnophyllum, Foerste's specimen most closely resembles A. pentagonus (Goldfuss) 1826, from the Silurian rocks of Drummond Island, Lake Huron. In both cases, the calicular pit is within a shallowly-depressed region, bounded from the neighboring calicular areas by a fine ridge, forming a polygonal border. Septal striae radiate from the pit out to the bounding wall. The major points of difference are that the septal ridges of Foerste's specimen are somewhat broader than those generally encountered in A. pentagonum (though those of Goldfuss' figure are also rather broad); and the calicular pits do not seem to have the characteristic eccentricity of A. granulosum. Further, Goldfuss' species doesn't seem to have the granules on its septal ridges and in its calicular pits reported by Foerste in his specimen.

Foerste's reference to Strombodes alpenensis was to a form repreted from the Middle Devonian beds at Thunder

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Bay, Michigan by Rominger (1876, p. 133-134, Plate XXXVIII, fig. 1). This form is indeed similar to A. granulosum, the only obvious differences being that its calicular pits are not especially eccentric, and the axial ends of the septa are more attenuated.

It is quite possible that A. granulosum is but a variety of A. pentagonum, but in the absence of a specimen for closer study, it seems best at this stage to accept Foerste's contention that it represents a new species.

Distribution - Kentucky: Middle Llandovery (Brassfield Formation.

Brassfield distribution - From the Waco bed, Noland Member of the Brassfield, near Waco, Kentucky.

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Petrozium Smith, 1930

1930b Petrozium Smith, p. 307

Type species - (By the author's original designation):
Petrozium dewari Smith (1930, p. 307-308).

Type locality and horizon - Llandovery (Lower Silurian) of England

DIAGNOSIS - Colonial Rugosa with dissepimentarium; corallum phaceloid; corallites slender; septa of two orders; axial structure formed by stereomal deposits among distal ends of major septa; dissepimentarium narrow, generally no more than 3 to 4 dissepiments thick; tabulae sometimes depressed axially, and may have supplementary plates.

DESCRIPTION - This genus consists of species with phaceloid growth-habit. The theca is a septal stereozone. A dissepimentarium is present, rarely more than 2 or 3 layers thick. This generally has the form of large vesicles with limbs at nearly right angles to one another, perched upon each other in the manner of steps in a stairway.

The septa are thin, and sometimes bear carinae. The major septa extend to the axis where they form an axial structure consisting of their axial ends and deposits of stereome.

The tabulae are mostly complete, and are often depressed axially and peripherally to produce a lateral profile simi-

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lar to that of a volcano with a moat around its base. This peripheral moat contains supplementary plates.

DISCUSSION - The presence of an axial septal structure, and invariable coloniality of Petrozium serve to distinguish it from the Silurian genus Entelophyllum Wedekind (1927). In addition, the dissepimentarium of the latter genus typically consists of much smaller vesicles, and in more layers, than is usual in Petrozium.

From Palaeophyllum Billings (1858), Petrozium differs in having a dissepimentarium, and in the formation of an axial septal structure.

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Petrozium pelagicum (Billings)

Plate 7, fig. 8; Plate 22, fig. 11-14; Plate 25, fig. 2, 4

1862 Cyathophyllum pelagicum Billings, p. 108

1865a Cyathophyllum pelagicum Billings, p. 108

1874 Donacophyllum lossenii Dybowski, p. 50-51, Plate IV, fig. 6, 6a, 6b

1899 Diphyphyllum caespositum Lambe, p. 240 (non Diplophyllum caespositum Hall, 1852)

1901 Diphyphyllum caespositum Lambe, p. 158, Plate XIII, fig. 3, 3a, 3b (non Diplophyllum caespositum Hall, 1852)

cf. 1930b Petrozium dewari Smith, p. 307-308, Plate XXVI, fig. 20-28

1958b Petrozium losseni Kal'o, p. 114-115, Plate IV, fig. 11-17

Type material - Lambe (1901, Plate XIII, fig. 3, 3a, 3b) figured portions of what he said was the type of Billings' species. The catalogue of types in the collection of the Canadian Geological Survey (1960) says that the holotype of this species is missing, but a specimen in their type collection, numbered 2351a, is labelled as the "holotype-lectotype".

Type locality and horizon - Becscie Formation (Middle Llandovery) at Becscie River Bay, Anticosti Island, Canada.

Number of specimens studied - 8

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DIAGNOSIS - Petrozium undergoing parricidal budding; tabulae complete, depressed axially, but convex peripherally, with a moat separating tabularium from a single layer of strongly-convex vesicular dissepiments lining the theca.

DESCRIPTION - The corallum is dendritic, and apparently stood erect on the sea floor, like a shrub. The largest specimen studied (Plate 7, fig. 8) originally measured at least 16 cm in maximum breadth and at least 13 cm in height, expanding markedly from its relatively narrow proximal region. The asexual increase of the colony was accomplished by parricidal budding, with usually 2, and occasionally 3 buds forming at intervals of approximately 1.5 to 2 cm. The corallites are longitudinally-striate, and somewhat rugose. Their diameters change but little throughout their length, and range from 4 to 8 mm, most falling about midway in this range.

The theca is a septal stereozone, about 0.25 mm thick.

The septa taper axially. They are of two orders, the major septa reaching almost to the axis, and the minors rather long, often 1/2 to 2/3 the length of the majors. The minor septa sometimes become contratingent on either the cardinal or the counter side of a neighboring major septum. The cardinal septum is not obvious, so that it is difficult to determine the sense of contratingency. In a corallite 5 mm in diameter, a total of 43 septa (both majors and minors) were counted. In a section from another colony, 50 septa

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were counted in a diameter of 8 mm.

The tabular pattern is distinctive. The tabulae are complete, strongly convex, but distinctly depressed in the axis. Laterally they bend downward sharply, leaving a moat between the convex axis and the periphery of the corallite. Lining the walls of the corallite is a single layer of strongly-convex vesicular dissepiments, standing one upon the other. It is possible, however, that this layer is not ubiquitous. In vertical sections is sometimes appears on one side of the corallite, but not on the other (Plate 22, fig. 14).

Between the tabularium and this vesicular lining of the theca lie concave supplementary plates, in the moat. These may be continuous with the peripheral edges of the central tabulae, though this is uncertain. It is their concavity and the depression of the peripheral edges of the tabulae that forms the moat. In one specimen, the vertical spacing of the convex portions of the tabulae was about 7 in 5 mm. In the depressed central areas, the vertical spacing was about 2 per millimeter.

Where parricidally-budded portions of the corallum were observed in longitudinal section, the wall formed between buds had a distinct dark midline.

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DISCUSSION - This species was first described by Billings (1862) in a preliminary report, and again in 1865. Unfortunately, neither of these references was obtainable at the time of this writing.

Lambe (1899, 1901) described this species, and figured portions of what he called the type specimen in the latter paper. In this work, he described the species as an aggregate of upright, cylindrical corallites, increasing by lateral gemmation. The corallites were 5 to 8 mm in diameter, frequently contacting each other laterally (note the two corallites in Plate 7, fig. 8 of this work, at the top-central portion of the figure), and were marked by longitudinal striae and annular growth-lines. The septa were of two orders, the majors nearly reaching the axis, the minors about one-half as long. Depending upon the corallite diameter, the two orders totalled 40 to 50 septa in all. What was usually a single layer of vesicular dissepiments lined the inside wall of the corallite, appearing in transverse section as a second wall, less than 1 mm within the theca. The tabulae were spaced about 2 per millimeter, flat or concave in the axis, and down-flexed at the periphery.

GSC 2351a (Plate 25, fig. 2, 4), which is labelled as the type of the species, follows Lambe's description quite well. The corallites are cylindrical, about 6 yo 7 mm in diameter, with a theca about 0.3 mm thick. The septa number about 47 of both orders in a corallite of 7 mm diameter,

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and have a distinct midline. The minor septa are about half the length of the majors, and are occasionally contratingent upon them. The major septa reach nearly to the axis. The tabulae are complete, convex, with a flat or depressed axis, and sides that are down-flexed. They touch upon a single layer of vesicular dissepiments lining the corallite wall. The tabular axes are spaced slightly less than 1 mm apart vertically, and the lateral dissepiments stand about 1 mm apart at their upper surfaces. In all respects, this specimen agrees remarkably well with our material. The only source of difference is Lambe's statement that increase is by lateral gemmation. In our material, it is clearly parricidal, and the type material of Lambe's figures do not make clear the mode of asexual reproduction in the Canadian form. Agreement is so close, however, in all other respects, that the inclination is to consider the two forms conspecific.

Dybowski (1874) described the species Donacophyllum lossenii from the Tamsalu Stage (Middle Llandovery) of Dago Island (though Kal'o, 1958b, gives the locality as Hiiumaa Island, Estonia) in the Baltic. The specimens are described as represented by fragments 7 to 8 cm long, and 2 to 7 mm in diameter, in coralla resembling bundles of sticks. The corallites are commonly cylindrical, but by crowding, often display a tetragonal cross-section (not seen in our form). Asexual increase is reportedly through lat-

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eral budding. The epitheca is very thin(?) with distinct longitudinal striae and growth-lines.

In longitudinal section, the theca is lined with a single layer of vesicular dissepiments, each about 1 to 2 mm high, and 0.5 mm groad. The central 5 mm of a corallite with a total diameter of 7 mm is occupied by convex tabulae, spaced about 0.5 mm apart. They are axially flat or concave, and peripherally down-flexed to meet the dissepimentarium. The septa total 50 in a diameter of 7 mm. The major septa do not quite reach the axis, and the minors are only a little shorter. As Lambe noted, the transverse aspect of a corallite suggests the presence of two concentric walls.

Dybowski's description and figures are in good agreement with our concept of Billings' species, except, again, for the description of the mode of increase as lateral budding. Also, he shows the moat (as did Lambe) as floored with direct extensions of the down-flexed tabular peripheries, whereas in our form the continuity is not that clear. The agreement in all other details, however, is so good that it seems safe to consider Dybowski's form as conspecific with that in the Brassfield.

Kal'o (1958b) redescribed Dybowski's species, from the type locality. The corallites are united in a faggot-like colony, and are cylindrical, 6 to 9 mm in diameter. On their outer surfaces, they show a regular pattern of

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swelling. The epitheca is thin, longitudinally-striate and wrinkled. The calice is shallow. The septa are thin, slightly wavy, and most of the major septa nearly reach the axis. The minor septa are half to three-quarters the length of the majors. In the range of 6 to 9 mm in diameter, the number of septa varies from 20 to 23 of each order. The septa are very weakly carinate. The dissepimentarium is not present in all portions of the corallite, as was noted in our form. The dissepiments are oblong in vertical profile, about the same size as ours, or slightly smaller, and are usually present in 1 or 2 layers. The tabulae appear to be as in the Brassfield specimens: convex, and usually depressed axially, with their peripheral edges down-flexed.

It is well to compare our species with the type species of Petrozium, P. dewari Smith, 1930, from the Late Llandovery of Buildwas, Shropshire, England. The corallum is dendroid, with cylindrical corallites 8 to 10 mm in diameter when fully-developed, but in one specimen, as much as 20 mm. The epitheca is thin, and lightly striate longitudinally. Asexual increase is reportedly marginal, and non-parricidal. The septa are thin, tapering axially, and are moderately carinate. (Kal'o noted that P. losseni is less carinate than P. dewari). The major septa sometimes reach the axis, and an axial structure may be formed by stereome forming among the ends of the major septa. The minor septa are about half as long as the majors. In a diameter of 8 to 10 mm,

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there are 28 to 30 septa of each order, while in the corallite with a diameter of 20 mm, there are 40 of each order. The tabulae appear to be as in our form, strongly convex, but occasionally with depressed axial areas. They are downflexed peripherally, and either they, or a separate series of concave supplementary plates, connect with a rather broad dissepimentarium, which consists of apparently 3 of 4 layers of dissepiments. P. dewari differs from our form in the much-greater thickness of the dissepimentarium, the carination of the septa, and the formation of an axial structure of septal ends and stereome.

Distribution - Anticosti Island: Middle Llandovery; Estonia: Middle Llandovery; Ohio: Middle Llandovery (Brassfield Formation).

Brassfield occurrence - Localities 7 (near Fairborn, 14 (near Piqua), 15 (near West Milton), and 55 (near Ludlow Falls), all in southwestern Ohio.

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Craterophyllum Foerste, 1909

1909 Chonophyllum (Craterophyllum) Foerste, p. 101, 102 (non Barbour, 1911; nec Tolmachev, 1931)

1926 Naos Lang, p. 428-429

Type species - (SD Lang et al., 1940, p. 42): Chonophyllum (Craterophyllum) vulcanius Foerste (1909, p. 101)

Type locality and horizon - Brownsport Formation (Lower Ludlow) of Tennessee.

DIAGNOSIS - Large, solitary Rugosa with dissepimentarium; calice explanate so as to form an outward-sloping apron around the tabularium; in this apron, major and minor septa indistinguishable, all dilated, turning septocoels into sutures; septa do not extend into tabularium, where only incomplete tabulae are found, with rare complete ones.

DESCRIPTION - These are solitary corals of patelloid form. The calice wall is everted, save for a central calicular pit. The septa of the outer portions of the calicular platform are dialted, such that they are separated laterally from one another by sutures, rather than septocoels. The septa occur in vertical layers, with vesicular dissepiments between them to form a dissepimentarium. The calicular pit is free of septa, as both orders reach only as far as the walls of the pit. Thus, the axial region of the coral consists of complete and incomplete tabulae, with no septal

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ends. This character is the most striking difference between Craterophyllum and Chonophyllum Milne-Edwards & Haime, in which the major septa reach the axis.

DISCUSSION - While Foerste (1909a, p. 101) first used the name Craterophyllum parenthetically as Chonophyllum (Craterophyllum) vulcanius, suggesting a subgeneric status, at the end of his description of this species (p. 102) he states the following: "For these chonophylloid corals which have a flat base, upon which the calycular side arises in a manner resembling a low volcanic crater, the designation Craterophyllum is proposed. This term includes Craterophyllum vulcanius from the Brownsport bed, Craterophyllum canadense from the Anticosti Group, and an undescribed species from the Devonian limestone at Louisville, Kentucky." Foerste's taxon is today used as a generic designation, whatever his original intention.

Lang (1926) described a new genus, Naos, based upon Ptychophyllum pagoda Salter (1873, fide Lang, p. 428) from the Silurian of Arctic Canada. This species has all the earmarks of Craterophyllum Foerste, having a vesiculose dissepimentarium containing successive layered platforms of dilated septa, with the septa reaching only to the margin of the calicular pit. The tabularium consists solely of complete and incomplete tabulae with septal ends completely absent. As Hill (1956, p. 275) concludes, Naos appears to be synonymous with Craterophyllum Foerste.

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Craterophyllum(?) solitarium (Foerste)

1906 Chonophyllum solitarium Foerste, p. 317-318, Plate 4, fig. 2

Type material - Location of the original material figures and described by Foerste is not known.

Type locality and horizon - Waco bed, Noland Member of the Brassfield Formation, from the road running north of Estill Springs, north of Irvine, Kentucky. This is about equivalent to localities 53-53a of this study.

Number of specimens studied - None found in the field. Apparently, Foerste's description and figure are the only occurrence of this species in the literature.

DESCRIPTION - It is difficult to get a clear understanding of this species from the little information available. At first it was believed to be Schlotheimophyllum patellatum (Schlotheim) (q.v.), a species that occurs in the Brassfield Formation in Ohio. Judging by Foerste's description, these two species share a Fungia-like patellate form, and two orders of septa dilating and flattening towards the periphery of the horizontal calice wall, with a central depression. Foerste, however, reports dissepiments between his septa, whereas the septocoels of S. patellatum (and indeed, of nearly all members of the genus) are constricted to suture-thinness by the septal dilation, and the internal structure is trabecular. Further, it seems implicit in Foerste's de-

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scription (and unelucidated by his figure) that there are no septa in the central calicular pit. This, together with the vesicular internal structure, suggests that we are here dealing with a species of Craterophyllum, a taxon first erected as a sub-genus by Foerste in 1909, and therefore, not in existence as a concept at the time Foerste described this species.

As described by Foerste, his specimen has a width of at least 60 mm and a height of about 25 mm. A raises area with a relief of about 10 mm above the calice margin surrounds the central calicinal pit, which is about 9 or 10 mm in diameter. Distal from this raised rim, the septa dilate and flatten, while proximally they plunge down the wall of the pit, where they are thinner, and stand vertically. Between the septa are vesicular dissepiments. A total of about 60 septa, alternating in size, may be recognized. At the margins of the corallite, however, Foerste reports that the shallow grooves separating these septa number about 100, so that this is more likely the true septal number. The calice area outside of the central pit and rim is structurally "...a succession of calicinal plates resting upon intermediate vesicular tissue." The septa are represented by ridges on the calicinal plates. Foerste had no information on the presence or absence of tabulae in the central portion of the corallite.

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Distribution - Kentucky: Middle Llandovery (Brassfield Formation).

Brassfield occurrence - Waco bed, Noland Member, in the vicinity of localities 53 and 53a of this study, near Irvine, in central Kentucky.

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Family Hallíidae Chapman, 1893

Solitary Rugosa with dissepimentarium of relatively small, globose dissepiments; septa thin in marginarium, at least in later growth-stages, but thickened and in axial contact in tabularium, thinning with upward growth first along axial edges and in counter quadrants; cardinal septum typically elongate.

DISCUSSION - In certain forms, such as Pycnactis Ryder, the septa are dilated throughout most ontogenetic stages, and are regarded as inhibiting tabular and dissepimental development. Hill (1956) includes Pycnactis in this family probably because Ryder (1926) regarded it as part of a continuum with another of his genera, Phaulactis, which fits more readily into the family Hallíidae. Sokolov (1962), on the other hand, places Pycnactis in the Streptelasmatidae, apparently due to the absence of a dissepimentarium.

As I have decided to follow Hill (1956) in family assignments for the Rugosa, Pycnactis (q.v.) is here placed with the Hallíidae. At the same time, note is made of the problems that have caused Sokolov to place this genus in a different family.

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Pycnactis Ryder, 1926

1926 Pycnactis Ryder, p. 386

? 1936 Cymatelasma Hill & Butler, p. 516-517

Type species - Hyppurites mitratus Schlotheim (1820, partim)

Type locality and horizon - Silurian of Gotland

DIAGNOSIS - Solitary Rugosa with dilated septa commonly occupying entire cross-section; cardinal septum longer than others; septa pinnately-arranged; minor septa very short; tabulae present only at highest levels of corallite.

DESCRIPTION - Members of this genus are solitary, trochoid rugose corals, with a septal stereozone.

From a very early stage, the septa are dilated so as to reduce the septocoels to sutures. This condition persists, as well as the occupation of the entire radius of the corallite by septa, until very near the base of the calice, at which point the septa each come to an edge on their upper surfaces, allowing very shallow septocoels to form between them.

The cardinal septum is prominent from the brephic stage. and is the longest of the septa throughout most of the ontogeny. It is located on the convex side of the corallite. The minor septa are quite short, less than half the length of the major septa. They occur as wedges between the proximal ends of adjacent major septa.

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Tabulae are visible only in the highest levels of the corallite, but there is no evidence of a dissepimentarium.

DISCUSSION - Hill & Butler (1936) described the genus Cymatelasma from the Silurian (Upper Llandovery to Lower Ludlow) of England. Noteworthy features of this genus are dilation of the septa from the early stages of development, with gradual reduction of width and moderate withdrawal of the septa from the axis. The septa are commonly wavy, and often carinate. In the later stages of development, as septocoels result from the narrowing of the major septa (the minor septa are quite short relative to the majors), the septal stereozone remains quite broad. The tabulae are complete and inversely conical. There are no dissepiments.

The similarities between Pycnactis and Cymatelasma are strong. Both show marked dilation of the septa during most of the ontogeny of the corallite, except that in the later stages this dilation is more reduced in Cymatelasma than in Pycnactis. Hill & Butler do not make it clear if the cardinal septum in their genus is as prominent as in Pycnactis. Our material from the Brassfield resembles Cymatelasma in the pattern of dilation-reduction of the septa, and the retention of a broad stereozone, and resembles Pycnactis in the prominence of the cardinal septum throughout development

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of the coral. It is tempting to regard our Brassfield specimen as a link between these two genera, justifying the contention of Soshkina and Kabakovich (1962, p. 318) that they are synonymous. In the absence of further information, however, it seems best to reserve judgement on this matter. Largely on the basis of the developmental pattern of the cardinal septum, our material is assigned to Pycnactis Ryder, though the presence of Cymatelasma-like features is noted.

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Pycnactis tenuiseptatus sp. nov.

Plate 7, fig. 4, 5; Plate 26, fig. 1-8

cf. 1926 Pycnactis mitratus (Schlotheim) of Ryder p. 386-390, Plate IX, fig. 1-7; Text-fig. on p. 389

cf. 1926 Pycnactis mitratus, var. grandis Ryder, p. 390

cf. 1926 Pycnactis rhizophylloides Ryder, p. 390, Plate IX, fig. 8

Type material - Holotype: UCGM 41963 (see figures)

Type locality and horizon - Locality 48, southwest of Owingsville, central Kentucky, in the Brassfield Formation.

Number of specimens studied - 1

DIAGNOSIS - Pycnactis in which the dilation of the major septa decreases in the ephebic stage, leaving a more open axial area than is usual in this genus; elongate carinae present on sides of septa.

DESCRIPTION - The corallite is canine tooth-shaped, compressed laterally, trochoid, with a very sharp, edged base. It is weakly-rugose, and longitudinally-striate. The specimen studied measures 5 cm along the convex side, which curves through about 90° of arc. The cross-section is elliptical, of greatest diameter in the plane of curvature. Throughout the lower 3 cm of its length (along the convex side) the corallite increases gradually in diameter, until its cross-section

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measures about 16 X 13 mm. Beyond that, there is little change in the diameter, except at the distal-most end, where the calice appears to have been crushed, obliterating its structure.

In transverse section, the theca is a septal stereozone, in which the sutures between adjacent septa are defined by zig-zag lines. This reflects the presence of interlocking rib-like carinae running from the peripheral edge of the septum towards the axial edge, in an upward direction. Their orientation is precisely what would be expected of the trabeculae making up the septa, and the carinae probably represent thickening of these trabeculae. Their spacing is about 8-9 in 3 mm. In one longitudinal section (Plate 26, figure 1), small circular features just distal to the ends of the carinae suggest spines projecting from the sides of the septa into the septocoels, similar to those in so many of Sutherland's (1965) Henryhouse corals, and Amsden's (1949) Ptychophyllum cliftonense from the Brownsport Formation. Such lateral processes, however, cannot be confidently identified with the structures of our specimen.

The earliest stages revealled in thin-section show the septa reaching to the axis, with one septum on the convex side of the corallite (here taken to be the cardinal septum) distinctly thicker and longer than the others. The septocoels are non-existent, due to septal dilation. Septa appear to be intercalated along the sutures between extant

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septa. Just below the level where the corallite's rate of expansion decreases sharply, the septocoels become apparent for the first time, but are closed distally by the axial juncture of the septa (Plate 26, figure 5). Here there appears to be little or no twisting of the axial ends of the septa, and no involved axial structure is produced. The cardinal septum is no longer distinctive in size.

Above this level, the distal ends of the septa draw farther from the axis, leaving an open space. The major septa now are slender (maximum of .25 mm across, tapering distally) and curved, with the concave side toward the cardinal septum. The minor septa appear to be essentially restricted to the stereozone, which has grown quite thick (up to 3 mm). The highest section reveals the axial space wider still, with the major septa retaining concavity of their cardinal sides. Secondary septa now appear to protrude more from the stereozone, sometimes one-third to one-half the length of their adjacent major septa. Both orders of septa retain a tapered form, narrowing axially. What appears to be stereom has fused many of the distal ends of the septa on the cardinal side of the corallite. At no stage is there a prominent cardinal fossula.

In vertical section (Plate 26, figures 1, 2) it is seen that, from the level where the septa withdraw from the axis, the septocoels becoming open, the interior of the corallite becomes occupied by abundant incomplete tabulae, rising toward

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the axis to produce what must have been a convex calice floor. These dissepiments appear as transverse lines in the septocoels, usually concave towards the periphery of the corallite.

Discussion - Ryder (1926) gave a fairly detailed description of Pycnactis mitratus, his type species for Pycnactis. This species was originally described as Hippurites mitratus by Schlotheim (1820), but since at this time, the original reference is not obtainable, our comparison is with Ryder's specimens from the Wenlock of England. Most noteworthy in these is that the septal dilation almost completely squeezes out the septocoels until the later stages of development, when the septa withdraw slightly from the axis. As a result, there apparently is no development of tabulae or vesicular dissepiments. These features have generally been considered characteristic of the genus. P. mitratus, then, does not have septocoels to the extent encountered in our specimen, nor a comparable development of tabulae. It also does not display the thin, curving septa seen in the latter stages of the Brassfield specimen.

Nonetheless, the similarities between our specimen and Ryder's genus are unmistakable. The early stages are identical, with dilated septa filling the whole interior, and a prominent cardinal septum attaining the axis. The dark midlines of our septa are identical to Ryder's. Even the

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more open stages of the interior of P. mitratus are similar to ours, with the septa tapering axially. The mode of septal insertion is also identical between the two. Finally, and probably least conclusive, the exterior of Ryder's form is slightly striated longitudinally, with feeble annulations occasionally developed, as in our specimen. It is concluded that the Brassfield form does indeed belong to the genus Pycnactis, though not to its type species.

Also from the Wenlock of England, Ryder described a new variety of this species, P. mitratus grandis, differing from the rest of the species in attaining a much larger size.

Finally, from the Wenlockian of Gotland, Ryder described the species Pycnactis rhizophylloides, apparently distinctive only in the flattening of its convex (cardinal) side, somewhat in the manner of Rhizophyllum. Our specimen shows no such flattening, and in fact, is quite elliptical in all cross-sections.

Distribution - Kentucky: Middle Llandovery (Brassfield Formation).

Brassfield Occurrence - Locality 48, southwest of Owingsville, central Kentucky.

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Schizophaulactis gen. nov.

Type species - Cyathophyllum densiseptatum Foerste (1906, p. 314-315)

Type locality and horizon - Middle Llandovery; Noland Member of the Brassfield Formation, central Kentucky.

DIAGNOSIS - Solitary Rugosa in which septa form as protuberances on the proximal ends of pre-existing septa, where they join the theca, and split off from those septa toward the axial end; dissepimentarium present; in ephebic stage, proximal ends of septa thin, so that septa are thickest in axis; septa thin first on counter side of corallite.

DESCRIPTION - Only one species can thus far be assigned to this new genus, Cyathophyllum densiseptatum Foerste, 1906, so that the generic description must be based upon this species, which is described below.

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Schizophaulactis densiseptatus (Foerste)

Plate 7, fig. 6, 7; Plate 8, fig. 1-3; Plate 26, fig. 9-14

1906 Cyathophyllum densiseptatum Foerste, p. 314-315, Plate 6, fig. 2A-F

cf. 1969 Streptelasma eccentricum Neuman, p. 25-28, Fig. 20A-F, 21A-H

Type material - Foerste designated no type specifically, but did note that the specimens he showed in his Plate 6, fig. 2A-C were "typical specimens". With these three specimens he showed three more which he described as "possibly young specimens of the same species". The latter three specimens most closely approximate our material. Foerste's figured specimens are apparently lost. Several specimens in the collection of the U.S. National Museum, however, appear identical to our specimens, so that our material is identified with this species, as these museum specimens are labelled in what seems to be Foerste's handwriting. A neotype, UCGM 41944 , has been selected from the specimens found during this study (Plate 8, fig. 3; Plate 26, fig. 9-13).

Type locality - Locality 1, approximately 1/2 mile east of Panola, Kentucky, in the Waco bed of the Noland Member, Brassfield Formation.

Number of specimens studied - 41

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DIAGNOSIS - As for the genus.

DESCRIPTION - This species includes ceratoid corals of rather varied form. Usually they strikingly resemble a canine tooth, curving through as much as 90° of arc, in the cardinal-counter plane. This tooth-like aspect is emphasized in some specimens in which the cross-section is elliptical, with greatest diameter in the plane of curvature, giving "edges" to the "tooth".

In a representative specimen, the diameter reaches 1.4 X 1.1 cm at a level 2.5 cm above the base of the corallite (measured along the convex side). Beyond this level, the diameter increases very little, measuring 1.5 X 1.2 at 6 cm elevation. Other specimens, however, are less-cylindrical (Plate 7, fig. 6, 7; Plate 8, fig. 1, 2). One such corallite reaches a diameter of 2.2 X 2.0 cm in 4 cm of length.

The theca appears to be a septal stereozone, though it is usually difficult to discern its structure due to the generally worn condition of the specimens.

The corallites studied frequently showed, along their weathered sides, the proximal edges of the septa, between which were series of vesicular dissepiments of the marginarium, much thinner than the septa. These septal edges are often paired, due to the unusual mode of septal formation: splitting of a new septum from the proximal edge of an extant one, and gradually separating distally until there is

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no longer contact between the two.

In well-preserved specimens there is a slight axial boss formed of loosely-intertwining axial ends of the septa, with what appears to be incomplete tabulae among them. The proximal edges of the septa, showing their characteristic bifurcating pattern, rise to the edge of the calice, leaving a low area of calice floor midway between the theca and the axial boss.

The cardinal septum is on the convex side of the corallite. The cardinal fossula is not especially prominent until the later stages, and is generally more evident in the more rapidly-expanding individuals. In one specimen in which it is well-developed, it contains three septa: the cardinal, which traverses the fossula at a greater depth than the calice floor, and two other septa, one on either side of the cardinal, which fuse laterally to the cardinal side of their respective neighboring septa.

In the neanic stage of ontogeny (Plate 26, fig. 13) the septa reach nearly to the axis, but usually leave a small open space in their midst, occasionally crossed by a single septum. As growth proceeds, the septa appear to withdraw from the axial area in a manner typical of streptelasmatids, leaving a greater proportion of the transverse aspect occupied by the open axis. This space is invested with a spongy structure formed by the thinned distal septal edges, occasionally uniting together, with incomplete tabulae among them.

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Between the septa in the marginarium is a zone of vesicular dissepiments forming a dissepimentarium of rather narrow proportions.

During the foregoing neanic stage, as the corallite expanded regularly, the septa were broader than the septocoels. During the ephebic stage (Plate 26, fig. 10-12), however, as the septa begin withdrawing from the axial area, the septa on the counter side become thinner. The proximal portion of the septa on the cardinal side also undergo thinning from their proximal ends to about one-fourth the distance to the axis. This leaves a zone around the corallite of thin skeletal elements, less-resistant to weathering than is the inner area of thicker septa (Plate 26, fig. 10, 11, 14), so that the distal end of the corallite is often rounded on its outer edges, and the calice area appears a bit narrower than the areas just below it. This pattern of peripheral thinning of the septa may be seen in other rugose genera (cf. Phaulactis, p. 507, fig. D; and Aulophyllum, p. 513, fig. G in Hill, 1935; Bothrophyllum, p. 293 in Hill, 1956).

The septa begin as swellings on the proximal end of the cardinal side of an extant septum, and split away from that septum in a proximal-to-distal direction, until the new septum is completely free. The intermediate stages of septal development cause the extant septum to appear to be bifurcating proximally.

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TEXT-FIGURE 10

Series of ten transverse sections, more-or-less equidistantly-spaced, from a specimen (UCGM 41998) of Schizophaulactis densiseptatus (Foerste) 1906 from locality 1 of this study (near Panola, Kentucky, in the top of the Waco bed, Noland Member, Brassfield Formation). All sections are oriented right-side-up, with the convex side of this solitary rugose corallite toward the top of the figure (at the bound edge of the sheet). The sections are arranged in ascending order, from J (lowest in the corallite) up to A (highest in the corallite). Where possible, the septa have been numbered, the numbers continuing throughout the series of sections for the same septum, to show the author's interpretation of the pattern of insertion and development of the septa, and of other features of the internal structure. Thus, number 1 (apparently the cardinal septum) is thought to be the same septum seen in transverse sections of various levels (growth-stages) of the corallite. In each stage, where a septum has first been fully inserted at that level, its designating number is circled.

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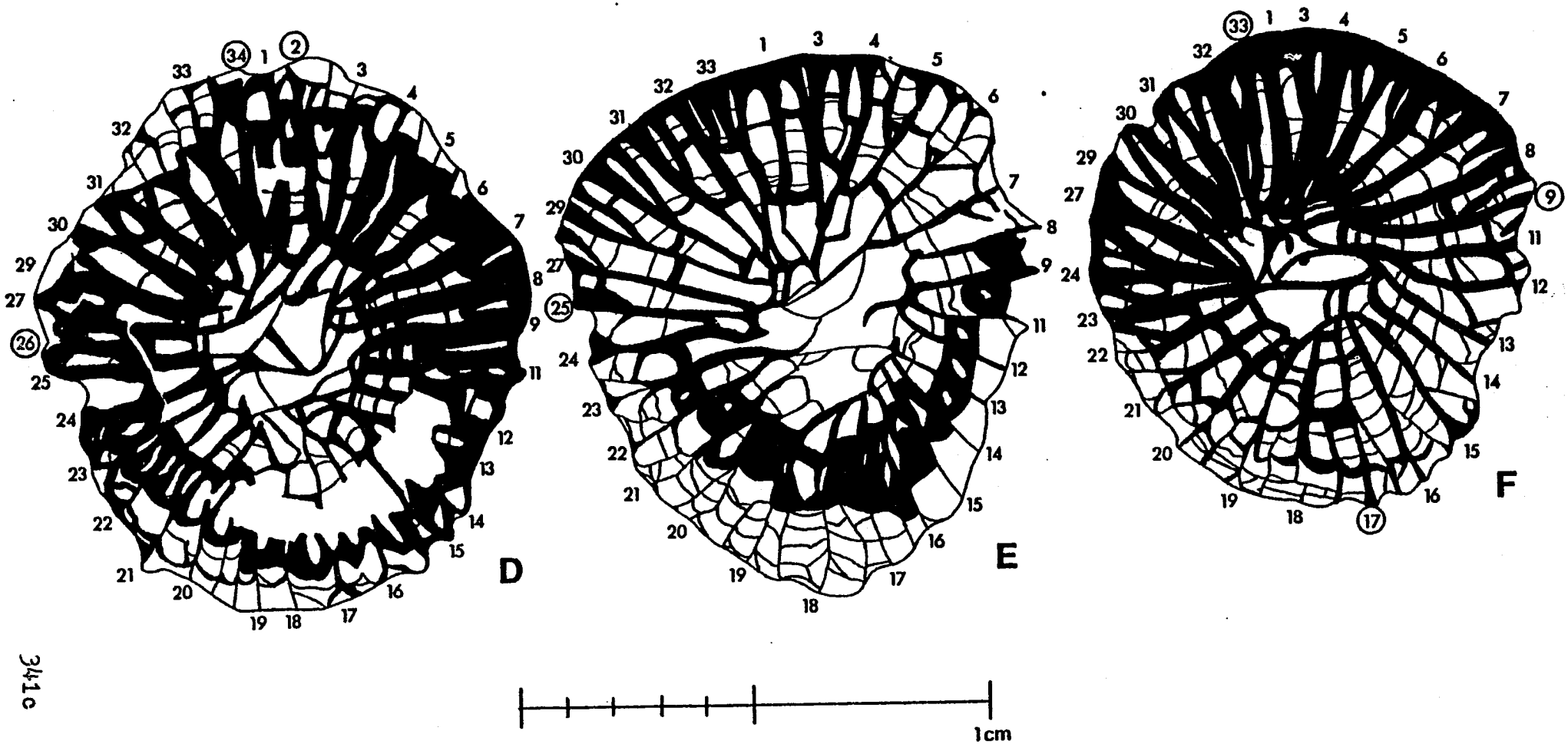

341c

341d

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The pattern of septal insertion was observed in one specimen from which eleven transverse sections were cut (Text-fig. 10). It was possible here to trace many of the septa of the later stages back to their origins in earlier stages. The lowest level studied was about 0.7 cm above the base, and contained 24 septa. The latest stage studied was about 2.5 to 3 cm higher, and contained 34 septa. Septal insertion appears to occur in four positions: to either side of the cardinal septum, and at positions about 90°, 180° and 270° from this location.

The presence of minor septa could not be clearly demonstrated. However, at a diameter of about 1.5 X 1.0 cm, probably well into the ephebic stage, the newly-formed septa seemed to remain short (about 1/5 to 1/6 the length of the extant septa), and occupied positions in the septocoels between the 34 pre-existing major septa. Unfortunately, the specimen was not long enough to show the further development of these possible minor septa.

DISCUSSION - Foerste (1906) described this species from specimens found near Panola (our locality 1) and Irvine (our localities 53-53a) in central Kentucky, in the top of the Noland Member, Brassfield Formation. His specimens appear to consist entirely of the more rapidly-expanding variety of the species. He described this form as attaining a length of 75 mm measured along the convex side, and a diameter of 30 mm. His specimens, as ours, were worn on the

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outer surface, exposing the proximal septal edges and vesicular dissepiments in the septocoels. The calice is rather broad and shallow, being 8 to 9 mm deep in specimens 28 mm in diameter. What he regarded as full-grown specimens had about 90 septa (presumably of all orders), with only the "primary septa reaching the center where the ends are more or less twisted and slightly raised above the immediately surrounding part of the bottom of the calyx." A somewhat inconspiculus cardinal fossula is located on the convex side of the corallite, containing one major and two "secondary" septa. The septocoels contain abundant dissepiments, curving upward and outward. The septa were described as, in cross-section, varying "between slightly convex and V-shaped on the side facing the exterior of the corallum". Presumably, Foerste was here referring to the bifurcative appearance produced in the process of forming new septa. His mention of major and minor septa is difficult to understand, unless he felt that one of each pair of septa in a bifurcation was a minor septum. Foerste's specimens are not definitive in this respect, but do appear, in places, to show this "splitting" pattern. Specimens in the non-type collection of the U.S. National Museum, identified by Foerste as belonging to this species, clearly are of the same form as our specimens. The number of septa in our form is comparable to that reported by Foerste. One of our specimens, the widest in our collection, with a calice 2 cm

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in diameter at a height 4 cm above the base, has 76 septa. There need be little hesitation in identifying our material with Foerste's species.

Neuman (1969) reported a form bearing certain similarities to the present species, Streptelasma eccentricum, from the Late Ordovician 5a beds at Herøy, in the Langesund-Skien area of Norway. The minor septa are more distinct than in our specimens, and they are contratingent to the cardinal side of the adjacent major septum. There is no evidence, however, that the septa form as swellings on the sides of extant septa, as they do in the Brassfield form. The axis appears to be vesiculose, consisting of highly-contorted incomplete tabulae, as found in our material. On the other hand, the Norwegian specimens lack the dissepimentarium, the differential thinning of the septa, the periphery of thin skeletal elements, and the mode of septal formation characteristic of S. densiseptatus. Also, Neuman's species has an eccentric axis, which ours lacks. Clearly, then, these are quite distinct species, belonging to different genera, but sharing some superficial features.

Distribution - Kentucky: Middle Llandovery (Brassfield Formation).

Brassfield occurrence - Locality 1 (near Panola), locality 53 (near Irvine), and locality 34 (near Raywick), all in central Kentucky. Questionable occurrence at locality 34 near Raywick, Kentucky (UCGM 42000)

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Family Cystiphyllidae Milne-Edwards & Haime, 1850

Rugosa with dissepimentarium; septa acanthine, typically holacanthine trabeculae, often extending onto the surfaces of the tabularium; tabulae typically display axial sag, even attaining inversely-conical form; dissepiments usually smaller than tabellae.

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Cystiphyllum Lonsdale, 1839

1839 Cystiphyllum Lonsdale, p. 691

1851 Conophyllum Hall, p. 399

Type species - (SD Milne-Edwards & Haime, 1850, p. lxxii): Cystiphyllum siluriense Lonsdale (1839, partim, non Plate 16 bis, fig. 2).

Type locality and horizon - Middle Silurian of England; according to Lang et al. (1940), Wenlock Limestone of Dudley, Worcestershire, England.

DIAGNOSIS - Solitary and compound rugose corals, sometimes bearing basal talons; corallites cylindrical or ceratoid, not tetragonal; septa consist of separate trabeculae, restricted to the thickness of one layer of dissepiments; tabellae of tabularium not readily-distinguishable from vesicles of dissepimentarium, such that these two zones appear continuous; calice inversely-conical, without axial boss.

DESCRIPTION - Cystiphyllum encompasses solitary and compound rugose corals of cylindrical or ceratoid form, in which the interior is filled with vesicular dissepiments and tabellae, with very under-stated septa. Most specimens, in fact, appear to contain nothing internally but dissepiments at first glance. The calice is fairly deep, and lacks an axial boss or structure. The tabularium and dissepimentarium are not

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markedly-differentiated.

The septa consist of rows of separate, trabecular elements radiating along the upper surfaces of the vesicular dissepiments and tabellae. These elements are short, and do not generally penetrate more than one layer of vesicles.

Basal attachment structures may be present.

DISCUSSION - Hall (1851) described, in a preliminary paper, the genus Conophyllum, based upon his C. niagarense from the Silurian of New York State. In 1852 (p. 114-115) he repeated his description of the genus, and gave his first description and figures for the type species. Apparently based on observations of weathered specimens, Hall interpreted the internal structure of the corals as a "cone-in-cone" of successive transverse "septa" (tabulae). His figures, however, suggest the presence of vesicular dissepiments in the peripheral zone, an interpretation all-the-more acceptable after the examination of weathered specimens of Cystiphyllum. While Hall recognized the similarity between Cystiphyllum and his genus, as indicated in both his 1851 and 1852 descriptions, he nonetheless considered them separate entities.

Today, Cystiphyllum and Conophyllum are generally regarded as synonymous, with priority belonging to the former. The evidence appears to bear out this view.

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Cystiphyllum spinulosum Foerste

1906 Cystiphyllum spinulosum Foerste, p. 321-322, Plate 5, fig. 1A-K

Type material - Location of Foerste's specimens not known.

Type locality and horizon - Foerste's figured specimens are from two localities in central Kentucky: along the road north of Estill Springs, north of Irvine, Ky. (equivalent of out localities 53-53a) and half a mile east of Waco, where the road to Cobb Ferry turns off from the pike to Irvine; Waco bed, Noland Member, Brassfield Formation.

Number of specimens studied - None found in field.

DESCRIPTION - Foerste's description is as follows:

"Corallum simple; moderately curved or nearly straight. Length of specimens found so far less than 50 millimeters. Exterior of corallum covered by an epitheca which is marked by longitudinal grooves, dividing the surface into low, narrow linear ridges as in species having conspicuous septa; septa, however, obsolete. Of these longitudinal ridges, about six occur in a width of 5 millimeters. Exterior also with fine transverse, radiating striae. Epitheca frequently absent, owing to weathering. In that case the vesicular structure is well exposed. Blister-like cavities, large and conspicuous, frequently 5 millimeters long and of equal or

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even greater width. The plates forming this vesiculose structure are convex above but concave as seen on the side of weathered surfaces of the coralla, since they curve upward and outward. The concave surface of these plates is marked by low longitudinal striations which correspond in frequency to the septal striae on the exterior of the corallum. Calyx only partially exposed in the larger specimens at hand, apparently of moderate depth; formed by the convex sides of the uppermost layer of plates. In most specimens the convex side of these plates as exposed in the calyx is covered with coarse granules interspersed with smaller granules; these may take the place of the obsolete septa; in a few specimens they are arranged in approximately radiate lines; in others this arrangement cna not be readily detected. While the usual appearance of these markings on the upper side of the plates is that of coarse granules, on well-preserved specimens they frequently are detected as short spines fully a millimeter in length. These spines have been seen in so many specimens that it is evident either that the coarse granules of weathered specimens represent the bases of the weathered spines, or that both spines and coarse granules occur in this species.

"This species may be distinguished by the coarsely vesicular structure, the septal striations on the lower side of the plates, and the coarse granules and short spines on the upper side."

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DISCUSSION - The information and figures provided by Foerste in this paper are sufficient only to determine that his specimens belong to the genus Cystiphyllum Lonsdale. The characters he points out as being distinctive (coarsely vesicular structure, septal striations, coarse granules and spines) are found in most species of Cystiphyllum. If additional material can be found at the Brassfield localities from which Foerste obtained his specimen, detailed study of the corallites should help determine their relationships on the specific level. For now, it is safe only to say that Cystiphyllum does occur in the Brassfield.

Distribution - Kentucky: Middle Llandovery (Brassfield Formation)

Brassfield occurrence - Foerste's figured specimens are from near Waco, Kentucky, and from near Irvine, Kentucky (the equivalent of localities 53-53a of this study). He also reports this species from near Panola, Kentucky (the equivalent of our locality 1). In all cases, the specimens are from the Waco bed, Noland Member of the Brassfield Formation.

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ORDER TABULATA

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Family *Favositidae* Dana, 1846

(*nom. transl.* Milne-Edwards & Haime, 1850 [*ex Favositinae* Dana, 1846])

Tabulate corals with massive cerioid coralla, hemispherical to ramose, consisting of narrow, prismatic corallites; corallite walls perforate on wall faces, in corners, or in both positions; when present, longitudinal elements consist of spines or tubercles; squamulae may be present, not necessarily aligned longitudinally; tabulae mostly complete, with incomplete tabulae only occasionally present; inter-corallite walls have distinct mid-line.

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Favosites Lamarck, 1816

1816 Favosites Lamarck, p. 204 (non Nicholson, 1874, p. 253)

? 1851 Astrocerium Hall, p. 399

cf. 1906 Boreaster Lambe, p. 323

? 1918 Actinopora Vinassa de Regny, p. 98-99

? 1930 Parafavosites Orlov, p. 122

? 1934 Paralleloporella Strand, p. 271 (pro Parallelopora Holtedahl, 1914, p. 13; non Bargatsky, 1881)

1934 Sapporipora Ozaki, p. 74 (in Shimizu, Ozaki & Obata)

1936 Eufavosites Rukhin, p. 96

? 1937 Asteriophyllum Porfiriev, p. 30, 33

Type species - (SD Milne-Edwards & Haime, 1850, p. lx):
Favosites gothlandicus Lamarck, 1816, p. 205.

Type locality and horizon - Silurian of Gotland

DIAGNOSIS - Corallum massive, with cerioid arrangement of corallites, producing a "honey-comb" appearance; dark mid-line in walls separates contiguous corallites; tabulae generally complete; septal spines vary in development, but never form lamellar septa; mural pores located only on faces of corallite walls.

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DESCRIPTION - This genus consists of coralla with simple tubes joined laterally, sharing common walls which are split visually by a mid-line. The tubes are traversed by tabulae which are mostly complete, and their wall faces are pierced by 1 to 3 longitudinal rows of mural pores.

The walls bear (to varying degrees) longitudinal rows of septal spines, which are never fused into continuous laminae. These spines can be short or nearly absent, or they can be quite long, rectilinear, or even curved (as in Favosites hisingeri, which see). Corallite diameter may be fairly uniform or show great variation even in a small area of the surface, or yet again, it may vary over "fields", with areas of narrow corallites grading peripherally into areas of broader ones.

DISCUSSION - Favosites is probably one of the least-understood coral genera. Species descriptions show a pattern that strongly suggests that the meaning of variation in this genus is not understood. Additionally, Favosites taxonomy faces difficulty (shared by the taxonomies of other tabulate groups) that the hard parts may inadequately reflect the specific variations of the soft parts.

The generic name Favosites was first used by Lamarck in 1816 (p. 204), with a description that is brief, but in good accord with the general concept of the genus held today. No mention, however, was made of mural pores, an important feature of the corallum. Lamarck described two

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species, F. alveolata and F. gothlandica. Milne-Edwards & Haime (1850) designated the latter as type species, and Jones (1936, p. 8) chose a neotype for this species.

Calamopora Goldfuss (1829) has traditionally been regarded as a junior synonym of Favosites Lamarck, but as Oekentorp (1971; see discussion under Paleofavosites in this text) has shown, Goldfuss' genus has a type species which belongs to Paleofavosites Twenhofel (1914), a fact which automatically transfers Calamopora to junior synonymy with Paleofavosites, instead.

In 1851, Hall introduced Astrocerium, a tabulate coral genus of the New York Silurian similar to Favosites, but containing long, thin spines, distally inclined upward. He included four species in this genus (1851, 1852), and examination of his type material at the American Museum of Natural History (see Plate 29, fig. 1, 2, and discussion under Favosites hisingeri in this text) suggests they may be conspecific, and referable to his first-named, A. venustum. The relatively narrow corallite diameter, wide mural pores (on the wall faces) and elongate, upwardly-pointing septal spines appear to be an inadequate taxobasis on the generic level. Hall's original species, and subsequently-described "species" appear to intergrade in morphology to some degree, and more work is needed to determine if they really are separate species. If they are, they have more in common with one-another than with any other species of Favosites, thus

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constituting a distinct division of coral species that could reasonably be the basis of a separate genus. If, however, they intergrade with one-another to the extent of likely constituting a single species, it is questionable if that species would differ sufficiently from the other Favosites species to justify a separate genus.

Lambe (1906) introduced the genus Boreaster, based upon material collected by A.P. Low in Arctic Canada in 1904, during a Canadian Dominion Expedition. Both Hill & Stumm (1956, p. 463), and Lang, Smith & Thomas (1940, p. 28) attribute a Silurian age to the material on which Lambe based his new species, B. lowi, the type species of this genus. Lambe notes that the corallum is generally similar to that of Favosites, except that it possesses lamellar septa, of two orders. He showed mural pores occurring on the walls, on either side of the mid-point of each wall. Flat tabulae were also present. The nature of the septa seems to preclude the inclusion of this form in Favosites Lamarck, though the similarities are clear. In addition, the two orders of septa, if true, are unusual in tabulate corals.

Actinopora Vinassa de Regny (1918) is based upon Devonian coral species in which the point of juncture between several corallites takes the form of a "cross" or a 5-rayed "star", which apparently is a slightly-thickened area. The rays can extend for over one-third the width of a wall. The

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three species on which Vinassa de Regny based this genus (one from Central Asia, and two from the Carnic Alps on the northeastern border of Italy) agree with Favosites in all other respects. Another generic name was erected (by Porfiriev, 1937, see below) for favositids with this same peculiarity in the U.S.S.R. The validity of a separate generic designation in this case will have to await further study.

From the Upper Silurian of Fergana (in Turkestan), Orlov (1930) described a tabulate coral form which differed from Favosites by virtue of the presence of narrow tubes, lacking tabulae and spines, in the corallite walls at the junctures of several corallites (3 or more). Opinions differ as to the status of this genus. Bassler (1944) and Hill & Stumm (1956) consider it valid, while Sokolov (1962) regards it as a junior synonym of Favosites. It is possible that the small tubes represent parasites infesting the coral, but pending further study, the status of Orlov's genus, Parafavosites, remains uncertain.

In 1914, Holtedahl had proposed the name Parallelopora for specimens with the same features as Parafavosites, from the Silurian of Ellesmereland, Arctic Canada. Strand (1934) noted that this name was preoccupied, and modified it to Paralleloporella. Bassler (1944) provides a discussion of this genus, which he considers a junior synonym of Parafavosites.

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Ozaki (1934, in Shimizu, Ozaki & Obata) introduced the name Sapporipora for a Favosites-like form from the Silurian of northwestern Korea, characterized by rather narrow corallites (about 0.5 to 0.7 mm), wide pores (about one-third the width of the wall) occurring mostly in a single row on the wall face, and the appearance of new corallites usually at the junction of 4 pre-existent corallites. None of these features would preclude inclusion of this form in Favosites Lamarck.

In his report on favositids from the Lower Devonian of Transbaykal (U.S.S.R.), Rukhin (1936) used the term Eufavosites as a sub-generic designation, apparently to denote those Favosites species which are close in form to Lamarck's original concept (as, he applied the name to F. gothlandicus, the type species).

Porfiriev (1937) described Asteriophyllum, based on a new species from the Devonian rocks of the eastern slope of the Ural Mountains, U.S.S.R. It is characterized by the thickening of the juncture of three or four corallites, with a dark Y- or K-shaped figure appearing in the mass of calcareous deposits, as seen in transverse section (cf. Actinopora, discussed above in this section). As figured and described by Porfiriev, these dark "characters" do not necessarily have their lines coincident with the orientations of the mid-lines of the corallite walls, and so, are not necessarily portions of the mid-line of the wall occurring

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in the thickened zone. As was the case with Parafavosites, cited above, the status of this genus, with regard to Favosites, remains uncertain. It possibly is a case of parasitically-induced thickening of the walls, though it might also represent a meaningful generic taxobasis.

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Favosites favosus (Goldfuss)

Plate 8, fig. 4-6, 9; Plate 27, fig. 1-4; Plate 39, fig. 3, 4

1826 Calamopora favosa Goldfuss, p. 77-78, Plate XXVI, fig. 2a-c

non 1852 Favosites favosa? Hall, p. 126, Plate XXXIVA, fig. 5a-g

? 1875 Favosites favosa Nicholson, p. 229

1876 Favosites favosus Rominger, p. 21-22 (partim), Plate IV, fig. 3, 4 (fig. 1, 2 are questionable, as is Plate V, fig. 2)

1887 Favosites favosus Davis, Plate 8, fig. 1 (non fig. 2)

non 1890 Favosites favosus Foerste, p. 333

? 1919 Favosites favosus Williams, Plate XVIII, fig. 1

? 1925 Favosites favosus Hume, Plate IX, fig. 1

non 1926 Favosites cf. favosus Wilson, p. 16, Plate III, fig. 7

? 1928 Favosites favosus Twenhofel, p. 127 (partim)

cf. 1936 Angopora hisingeri Jones, p. 18-19, Plate II, fig. 4-7; Plate III, fig. 1, 2

non 1937 Favosites cf. F. favosus Teichert, p. 129-130, Plate VI, fig. 5, 6; Plate VII, fig. 2

1937 Favosites favosus Teichert, p. 130, Plate VII, fig. 1 (redescription of the holotype)

? 1939 Favosites favosus Shrock & Twenhofel, p. 254-255, Plate 28, fig. 3, 4

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1962a Favosites favosus Norford, Plate IX, fig. 13

1962b Favosites favosus Norford, p. 28,
Plate V, fig. 6, 7, 11

1964 Favosites favosus Stumm, p. 62-63, Plate 68, fig. 4

? 1965 Favosites crassimuralis Poltavtseva, p. 47,
Plate XI, fig. 1, 2 (non Zhizhina, 1957)

? 1966 Favosites favosus Bolton, Plate VI, fig. 12

1966 Favosites favosus Bolton, Plate VIII, fig. 1, 5

? 1968 Favosites favosus Bolton, Plate 13, fig. 19

Type material - The holotype is a silicified specimen in the collection of the Geological and Paleontological Institute at the University of Bonn, Germany, designated as the original of Goldfuss' Plate 26, fig. 2. It has been refigured and redescribed by Teichert (1937, p. 130, Plate VII, fig. 1), and is also figured and dealt with in the present work (see Plate 8, fig. 4-6, 9; Plate 27, fig. 1, 2; Plate 39, fig. 3, 4).

Type locality and horizon - From the Silurian strata of Drummond Island, in Lake Huron.

Number of specimens studied - 5

DIAGNOSIS - Favosites with distinctly-convex tabulae; spines abundant on corallite walls and on surfaces of tabulae; mural pores seem to occur in two rows on the wall faces; in many (but not all) cases, edges of tabulae are fluted by a series of marginal fossulae; corallite diameter apparently

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variable between colonies, ranging from 2 mm (and possibly as low as 1 mm) up to about 5 mm.

DESCRIPTION - The coralla from the Brassfield appear to have had a convex upper surface, and to have grown in a centrifugally radial manner. The base of one corallum shows periodic annulations, doubtless reflecting periodicity of tabular spacing. If a holotheca was originally present, it has not been preserved. The best-preserved specimen (UCGM 41957) was originally about 2.5 cm thick and 11 cm in maximum width.

The corallites range in diameter from about 2.0 to 2.5 mm, measured from the mid-line of the wall. They are mostly 6-sided, but other arrangements can be seen. The walls in some areas of each of our coralla appear thickened (up to 0.8 mm across), but this has proved to be due to lateral fusion (presumably secondary) of the rather abundant, thick septal spines. These spines (Plate 27, fig. 3) are spaced about 4 per millimeter vertically, and lie both normal to the walls, and projecting upward axially. The walls themselves may be fairly thick, as much as 0.3 mm.

The most striking feature of this form is the strong upward convexity of the tabulae, in many cases, the vertical relief equaling the distance across the base of the tabula. They are fairly close-spaced, usually 1.6 to 2.0 per millimeter, though they may be as sparse as 1 per millimeter, or so close as to produce incomplete tabulae. The upper sur-

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faces of the tabulae contain spines with their axes normal to the tabulae surface (Plate 27, fig. 3, and represented as dots in the corallite lumens in fig. 4). It is unclear if there is an orderly arrangement to these tabular spines, but in at least one case, they seem to describe part of a circle, concentric with the walls of the corallite.

Possible mural pores have been observed in thin-section. They occur on the wall faces, rather than in the corners, but the number of rows in unclear. In some cases, the gaps in the walls are wide (0.6 mm) and centered on the wall face, suggesting uniseriality, whereas in other cases, they are narrower, and off-center, as though part of a biserial, or even triserial arrangement of pores. In some cases, the wall bordering the pore appears thickened, but the preservation of our specimens is too poor to allow confident interpretation of the fine skeletal structure.

It has not been possible to establish the presence of peripheral fossulae in the tabulae of the Brassfield specimens, possibly due to their state of recrystallization. Examination of a specimen identified as Favosites favosus (no. 16199 in the collection of the Ohio State University Museum, and in nearly every way identical to the holotype,) indicates that these fossulae vary in their development, and are not present in every corallite of a colony. In all other respects, our specimens agree so well with the holotype, a search through the literature indicating this form to be

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quite distinctive, that it seems reasonable to assign the Brassfield specimen to Goldfuss' species. An eye should be kept, nonetheless, to the variations in corallite diameter found in different coralla, which may or may not justify splitting F. favosus into two or more species.

DISCUSSION - The holotype of Calamopora favosa Goldfuss is apparently the remnant of a broadly-convex colony. What remains is about 2/3 of the specimen figured by Goldfuss. It measures just short of 3 cm in maximum thickness, with a maximum width of 7 cm. Probably, its original diameter was at least 10 to 11 cm. The corallites are 3 to 4 mm in diameter, most falling midway between these extremes. Their walls are not especially thick, being about 0.2 mm across, and they are generously-furnished with spines, some of which project upward axially (though Teichert reported an absence of septal spines). The tabulae are distinctly convex upward, their relief commonly being up to 1/3 their diameter. In rare instances, however, the periphery of the tabulae may be convex, while the center is depressed, and sharply concave, resulting in a cone on the underside of the tabula (Plate 8, fig. 4, 9). This appears to be the feature seen on a number of spots in Goldfuss' figure 2a, and it is thus likely that this figure shows the specimen upside-down. It is clearly also the feature seen on the tabulae in his figure 2b, and here the view is described as basal. Nonethe-

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less, this axial depression of the tabulae appears to be the exception, rather than the rule, and nearly all the tabulae have smooth, convex upper surfaces. The upper surfaces of the tabulae are invested with spines, though these are not visible in all cases. In a few corallites, always seen from above, the periphery of the tabula may be seen to be downflexed into about 12 marginal fossulae. The tabulae are generally spaced 1.0 to 1.5 per millimeter. Their spacing seems to vary zonally, but not enough material is available to be certain. Mural pores are present, but it is not possible to add to Teichert's information regarding their arrangement; that they do not seem to be located in the corners. Goldfuss (fig. 2c) showed them arranged biserially on the wall faces, and other specimens apparently belonging to this species bear this out.

Hall's (1852) Favosites favosa? (sic), from the "Niagaran" (probably meaning simply fossiliferous Silurian) at Milwaukee, Wisconsin, clearly does not belong to Goldfuss' species. The tabulae are basically horizontal, with no evidence of spines either on their surfaces, or on the walls. There is no indication of marginal fossulae on the tabulae, nor is there mention of mural pores. Hall himself states that he chose to refer his specimens to Goldfuss' species because it was from a locality close to, and an age approximating that of the latter's fossils.

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Nicholson (1875) reported a species from the "Niagara Formation" (probably Brassfield or Dayton Formation) at Dayton, Ohio whose characters generally match those of Favosites favosus: corallite diameter is 2.1 to 4.2 mm ("one to two lines"); tabulae spaced 1.5 per millimeter, "usually more or less conspicuously curved, with their convexities directed upwards"; mural pores are biserially arranged on the wall faces; septal spines are present. There is no mention of marginal fossulae, or of spines on the tabulae. Though his description parallels well the features of our species, necessary information is lacking, and so it can only be questionably considered conspecific with Favosites favosus.

Rominger (1876) described several specimens under the name Favosites favosus. Two of these (Plate IV, fig. 3, 4) are certainly conspecific with Goldfuss' species. They are from Drummond Island, Lake Huron (the type locality of this species), and probably are from the Manistique Group (Late Llandovery to Middle Wenlock). The corallite diameters are, in one case about 2 to 4 mm, and in the other, about 3 to 5. The tabulae are convex and spinose, and have distinct marginal fossulae. The walls bear septal spines.

Besides these, Rominger figures three other specimens from the same locality (Plate IV, fig. 1, 2; Plate V, fig. 2), all of which have tabulae with marginal fossulae. In these cases, however, the tabulae are not distinctly convex, and there is no mention of spines on the tabulae. These show a

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variation of corallite diameter (between colonies) ranging from 2 to 6 mm. If these are to be included in Favosites favosus, despite their more-or-less flat tabulae, it must be assumed that the species is possessed of an enormous variability of corallite diameter, tabular topography, and fossular development, so much as to make it difficult to recognize its limits. Rominger recognized the possibility of such variation, and made the purely functional observation that "...yet on careful examination of large collections of these forms, we find them all so much linked together by intermediate gradations that no line can be drawn between one and another."

Davis (1887) figured two specimens which he attributed to Favosites favosus. His Plate 8, fig. 2 is a lateral view, and indicates horizontal tabulae. Stumm (1964) figured the specimen of Davis' figure 1 (USNM 52654), which has corallites 4 to 5 mm in diameter, convex, fossulated tabulae, and apparently biserial mural pores. Stumm notes that the tabulae are elevated above and depressed between the mural pores. The lack of mention of spines on the tabulae might be due to poor preservation, but is seems quite likely that this specimen belongs to Goldfuss' species. Davis had recorded the locality as the Niagaran ferruginous clay near Louisville, Kentucky, but Stumm questions this, noting that the lithology is very similar to that of the Manistique Dolomite of Michigan (Late Llandovery to Early Wenlock). The

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possibility of this being true seems greater, since Davis mentioned that the specimen had been collected by Nettelroth, rather than himself. Stumm also disagrees with the identification of the specimen in figure 2, and calls it Emmonsia tuberosa Rominger.

Foerste (1890) mentioned specimens that he attributed to Goldfuss' species, found at Collinsville, Alabama, and at Fair Haven, Ohio. In the first case, not enough information is given to allow identification in the absence of an illustration. In the second case, the information is again too meager, but the mention of horizontal tabulae makes it unlikely that these specimens are Favosites favosus.

Williams (1919) figured a specimen with large corallites (about 4 to 6 mm across) and fossulate tabulae from Fossil Hill, Manitoulin Island (probably the Fossil Hill Formation, equivalent in age to the Manistique Group of northern Michigan. It is quite possible that the identification is correct, but this must remain is question until the specimen (GSC 5118) is examined.

Hume's (1925) specimen from the "Lockport formation" of the Lake Timiskaming region of Canada must also remain in question. Most of the corallites are about 3.5 mm in diameter, and some do have what appears to be fossulate tabulae. In the absence of more information, however, the identification as Favosites favosus cannot be confidently accepted. Teichert (1937, p. 130) examined the holotype of Calamopora

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favosa Goldfuss, and saw good agreement between it and Hume's figure, but there is no indication that he had examined Hume's specimen himself.

Wilson's (1926) specimen from the Late Ordovician of British Columbia is almost certainly not F. favosus. Little information is given in the description and figure, and nothing is told of the tabulae. The great variation in corallite size (0.5 to 1.5 mm) in a small area (about 1 square centimeter) leads us to reject this specimen's conspecificity with our species.

Twenhofel (1928) reported F. favosus from the Gun River, Jupiter and Chicotte Formations (Middle Llandovery to Early Wenlock) of Anticosti Island. He apparently gave a composite description, noting corallite diameters of 4 to 5 mm, with septal spines present. Marginal fossulae of the tabulae are variably developed, distinct in some, hardly visible in others. Mural pores are usually arranged biserially. The tabulae may be convex, flat or concave. The information, though sparse, is generally in agreement with our concept of this species. The fact, however, that concave and flat tabulae are mentioned, leaves the identification open to question, especially in the absence of a figure. Further, Twenhofel does not mention in which of the above three formations the tabulae are flat or concave, so that while F. favosus probably does occur at Anticosti Island, it is not possible at this time to determine its horizon.

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Jones (1936) described a new genus and species, Angopora hisingeri, from the "Övre Visby Margelsten at Högklint, south of Visby, Gotland" (probably the Högklint beds of early Wenlock age). The holotype has mostly hexagonal corallites, attaining a fairly uniform diameter of about 1 mm, and having moderately-thick walls. Characteristic of this species is the presence of short lamellar septa which do not necessarily persist through the length of a corallite, and whose axial edges break up into long spines reaching sometimes more than half-way to the axis. The mural pores are biserially arranged, generally located near the corners of the corallite. Jones figured several specimens from England and Gotland, one of which (Plate II, fig. 7) has convex tabulae, with a hint of the presence of spines on their upper surfaces. Except for the discontinuity of the septa, their partly lamellar nature, and the smaller size of the corallites, it is quite similar to the Brassfield form. These differences, however, seem important enough to put down Jones' species as similar to, but not identical to our own. It is even more similar to a Kazakhstan form which was described by Poltavtseva (1965), discussed below.

Teichert's (1937) Favosites cf. F. favosus from the Silurian of the Brodeur Peninsula on Baffin Island, Canadian Arctic, is clearly not referable to this species. The corallite diameter is about 2.8 mm (some smaller), but the tabulae are much more closely-spaced (2.2 per millimeter)

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than has been reported in this species. Further, the tabulae are dominantly horizontal. There is no mention of marginal fossulae on their surfaces. Spines are apparently not well-developed on the walls (Teichert reports no spines present) and the tabulae seem to be free of spines. While this specimen does not seem referable to F. favosus, yet it is probably referable to another Brassfield species, Favosites sp. A (which see).

Shrock & Twenhofel's (1939) specimen from the Pike Arm Formation of northern Newfoundland (belonging to a group of sediments ranging in age from Llandovery to Middle Ludlow), offhand appears to be not conspecific with F. favosus. Its corallites are 4 to 6 mm in diameter, and have generally horizontal tabulae spaced 1 to 2 per millimeter. Spines are well-developed on the wall, but there is no mention of them on the tabulae. The flatness of the tabulae and absence of tabular spines makes it difficult to equate this specimen with Goldfuss' species, but mention is made of "periferal pits" in the tabulae where they join the wall. It thus seems best to leave the identification open to question.

Norford (1962a, 1962b) figured and described specimens that appear to be Favosites favosus from the Sandpile Group (considered by Norford on faunal evidence to be Late Early, or Early Middle Silurian) of northern British Columbia. The specimen figured in Norford's 1962a paper was shown only in surface view, but apparently has convex tabulae with mar-

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ginal fossulae. In his other paper, Norford refigured this specimen (fig. 6) and showed a transverse and longitudinal section of a second specimen, clearly displaying convex tabulae. The corallites were described as 4 to 5 mm in diameter, with circular mural pores arranged biserally for the most part, numerous septal spines spaced about 5 per millimeter longitudinally, and tabulae (some of which are reportedly flat) about 1 mm apart. No mention was made of spines on the tabulae.

Perhaps the most interesting occurrence of a specimen possibly belonging to this species is that of Favosites crassimuralis Poltavtseva (a junior homonym of a species described by Zhizhina in 1957), reported in 1965 from the Wenlock of Kazakhstan. The corallites are 5- and 6-sided, with diameters of 0.8 to 1.0 mm. Occasionally 4-sided corallites occur. The walls are 0.2 mm thick, with a well-defined midline. The tabulae are convex in the figure, though Poltavtseva reported them to be horizontal or weakly sagging (perhaps axially,. as seen in Goldfuss' specimen?), and are spaced 1 to 5 per millimeter, but usually 3 per millimeter. Though this is not mentioned in the text, spines appear to be present on the surfaces of the tabulae. The mural pores are 0.16 mm in diameter, arranged biserially. The acanthine septa consist of long (0.3 to 0.4 mm), thick spines pointing upward axially. There is no mention of marginal fossulae in the tabulae, and in this respect, and in the ususually

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small size of the corallites, the identification of Poltavtseva's species with Goldfuss' must remain tentative and questionable. In all other respects however, they are alike. There is even closer agreement with the Brassfield specimens, whose diameter of 2 mm is closer to the 1 mm of the Kazakhstan specimens, and in which the presence of fossulae has also not been demonstrated. What may be said is that Favosites crassimuralis is more similar to F. favosus, and to the Brassfield form, than to any other described species. If it actually does belong to Goldfuss' species, it is the only reported occurrence of F. favosus outside of North America.

Poltavtseva's species is quite similar to Angopora hisingeri Jones (discussed above). The corallite diameter, mural pore distribution, prominence of spines are all similar, and one of Jones' figures has convex tabulae. There is, however, no indication given by Poltavtseva that the septa of her species are comparable with those of Jones' species, so that the relationship between them must await comparison of the specimens directly.

Bolton (1966, 1968) figured specimens of what appears to be Favosites favosus from the Fossil Hill Formation (Middle Llandovery to Middle Wenlock) of Manitoulin Island. In all cases the marginal fossulae can be seen, and in Plate VIII, fig. 1 (1966), where the view is lateral, the mural pores appear to be biserially-distributed on the wall faces. The

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tabulae are convex. Corallite diameter ranges from about 4 to 7 mm.

Distribution - Drummond Island (Lake Huron): Late Llandovery or Early or Middle Wenlock; Anticosti Island: within the range of Middle Llandovery to Early Wenlock; Manitoulin Island (Lake Huron): within the range of Middle Llandovery to Middle Wenlock; northern British Columbia: Late Llandovery or Early Wenlock; Ohio and Kentucky: Middle Llandovery (Brassfield Formation); Iowa: Middle Silurian (based upon specimen no. 16199 in the Ohio State University Collection, from Monticello, agreeing closely with the holotype).

Questionable occurrences include Lake Timiskaming (eastern Canada): Wenlock; northern Newfoundland: Silurian; Louisville, Kentucky: Late Wenlock or Early Ludlow (if Davis' locality data is correct); Kazakhstan: Wenlock.

Brassfield occurrence - Localities 1 (near Panola), 46 (near College Hill) and 53a (near Irvine), all in central Kentucky, in the top of the Noland Member; and locality 13 (Todd Fork, near Wilmington, Ohio) in the top portion of the Brassfield Formation.

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Favosites hisingeri Milne-Edwards & Haime

Plate 8, fig. 8; Plate 27, fig. 5, 6; Plate 28, fig. 1, 2
Plate 29, fig. 1, 2; Plate 36, fig. 4

1843 Porites _____? Hall, p. 86, 91, Plate 22, fig. 3, 4

1851 Favosites hisingeri Milne-Edwards & Haime, p. 240, Plate XVII, fig. 2, 2a, 2b

? 1851 Astrocerium venustum Hall, p. 400 (nomen nudum in this particular reference)

1852 Astrocerium venustum Hall, p. 120, Plate XXXIV, fig. 1a-i

? 1852 Astrocerium parasiticum Hall, p. 122, Plate XXXIV, fig. 2a-i

? 1852 Astrocerium pyriforme Hall, p. 123, Plate XXXIVa, fig. 1a-e

1854 Favosites hisingeri Milne-Edwards & Haime, p. 259, Plate 61, fig. 1, 1a, 1b

1875 Favosites venusta Nicholson, p. 226

1876 Favosites venustus Rominger, p. 23, Plate V, fig. 3

1887 Favosites niagarensis Davis (partim), Plate 8, fig. 3 (non fig. 4; non Hall, 1852)

1887 Favosites venustus Davis, Plate 9, fig. 7, 10

? 1890 Favosites venustus Foerste, p. 335

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1902 Favosites fidelis Počta (incorrectly ascribed to Barrande by Počta), (partim), p. 227-228, Plate 105, fig. 5, 6; Plate 106, fig. 1, 2; (non? Plates 83, 88, 89, 94)

1902 Favosites fidelis var. clavata Počta (partim), p. 228-229, Plate 83, fig. 11-15; Plate 105, fig. 7, 8; Plate 106, fig. 5 (non Plate 90)

1902 Favosites intricatus Počta (incorrectly ascribed to Barrande by Počta), p. 233-235, Plate 88, fig. 11-18; Plate 91, fig. 10-12; Plate 95, fig. 1-12; Plate 102, fig. 2, 3

1906 Favosites hisingeri-aplata Foerste, p. 299-300, Plate 2, fig. 2; Plate 4, fig. 5

? 1919 Favosites hisingeri Williams, Plate XVII, fig. 2

1928 Favosites hisingeri Twenhofel, p. 129

1933 Favosites hisingeri Tripp, Plate XIII, fig. 1, 2a-c, 3, 4; Text-fig. 36a, b

1936 Favosites hisingeri Jones, p. 17-18

1937 Favosites hisingeri Teichert, p. 128-129, Plate V, fig. 3; Plate VI, fig. 2

1939 Favosites hisingeri Shrock & Twenhofel, p. 255, Plate 30, fig. 24, 25

? 1939 Favosites hisingeri Northrop, p. 150

1964 Astrocerium venustum Stumm, p. 60, Plate 58, fig. 7-9, 14-16

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Type material - Lectotype (by Jones, 1936, p. 17): the specimen figured by Milne-Edwards & Haime, 1854, Plate LXI, fig. 1, 1a (non 1b). Repository unknown.

Type locality and horizon - Benthall Edge, England. Age uncertain, possibly Wenlock.

Number of specimens studied - approximately 8

DIAGNOSIS - Favosites with corallites of fairly uniform diameter and aspect, usually 1.0 mm or narrower, rarely 1.5 mm across; corallites of different diameters tend to occur in fields which grade at their borders with other fields of different diameters; spines well-developed, often reaching nearly to corallite axis, and up-flexed distally; mural pores abundant, about 0.25 mm in diameter.

DESCRIPTION - In the Brassfield Formation this species occurs as hemispherical coralla, the largest found measuring about 18 cm in maximum diameter, with a thickness of 10 cm.

The corallites are characteristically quite narrow, more-so than those of the other Brassfield favositids. The largest are slightly over 1 mm in diameter, but most are rather narrower, down to about 0.5 mm. There is a tendency for the narrower corallites to occur in fields, doubtless areas of rapid proliferation, though some can be seen scattered among the broader corallites. This occurrence of fields seems to be an important diagnostic character of the species.

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The corallites are rather irregular in cross-sectional form, some being 6-, 5-, or 4-sided, while a few are even round. In addition, some are compressed into an elongate oblong shape, while others are equidimensional.

The tabulae are generally horizontal, and show periodicity of spacing. In the denser areas they are at most 0.25 mm apart, while in the sparser regions they may be as much as 1.0 mm apart. The average spacing is about 0.5 to 0.6 mm, and there are generally an average of 10 to 14 tabulae in a vertical space of 5 mm.

The corallites contain spines which, when well-preserved, appear long and thin, so long as to sometimes reach the axis. The number and arrangement of the spines, however, could not be determined, nor could it be ascertained whether they were horizontally-directed, or projected upward axially, as is characteristic in this species.

The mural pores are seldom seen in Brassfield specimens, but in transverse section they appear to be located in the center of the walls.

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DISCUSSION - The earliest valid use of this name is that of Milne-Edwards & Haime (1851), who assigned the following characters to the new species: The corallum has a somewhat swollen surface. The calices are only slightly unequal, in general regularly polygonal, and separated by somewhat thickened walls. The corallite diameters are approximately 1.5 mm. The transverse section of each tube shows 12 septal spines which are subequal, moderately-thickened, gently curved upward at their distal ends, and nearly reaching the corallite axis. The tabulae are thin, rather close-spaced, horizontal or a bit undulose. The figures accompanying this description are in excellent agreement with our specimens. The corallites shown are mostly less than 1.5 mm across, and are of fairly uniform diameter within a given area. There are about 9 tabulae in a vertical distance of 5 mm, and while there is a suggestion that their spacing is rhythmically zoned, this doesn't appear to be especially marked. The tabular spacing and arrangement are as found in our specimens. There are good grounds for regarding these corals as conspecific with ours.

Milne-Edwards & Haime, in this reference, reported this species from the "Silurien (inférieur)"of England (Tortworth), and the "Silurien (supérieur)" of Gotland, England (Wenlock Edge, Benthall Edge), and America (Niagara). They also reported it from what they questionably called the Devonian at Perry County, Tennessee. The first reference ("Lower

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Silurian") may actually be Ordovician, while the "Upper Silurian" may refer to the Wenlock. The Tennessee reference may possibly be to the Early Ludlow Brownsport Formation, though to my knowledge, neither Foerste nor Amsden reported this species from the Brownsport.

Specimens referable to the present species were figured by James Hall (1843) from western New York, in his report on the geology of the Fourth District of that state. His reference was to "Porites _____?" from the Niagara Group (Lockport Dolomite?, Late Wenlock through Middle Ludlow). Hall showed what appear to be two different specimens, one a probable natural vertical section. The corallites are a bit less than 1 mm in diameter, with close-spaced tabulae, apparently zoned. One specimen seems to have had most of the corallum dissolved away, leaving the more densely-tabulate zones as distinct layers with nothing between them.

In a preliminary exposition of the new genera of fossil corals that he intended to present in his 1852 work, Hall (1851) first used the name Astrocerium venustum. The name, however, was not elaborated upon or illustrated, but was simply listed with three other species names as examples of his new genus Astrocerium. As these were then undescribed species (due to be described in his 1852 work), A. venustum is a nomen nudum, and priority for the species name should go to Milne-Edwards & Haime's Favosites hisingeri of the same year.

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Hall's first valid use of the name Astrocerium venustum was in 1852. Here, along with other figures, he refigured his 1843 figure showing a corallum with the more sparsely-tabulate areas dissolved away, and referred his 1843 material, including this specimen, to A. venustum. Here, Hall mentions the narrowness of the corallites, showing specimens with tube diameters slightly over 1 mm, and also remarks on the 12 "ascending spiniform rays" (axially-rising acanthine septa), which are also illustrated. The tabulae are shown as close-spaced, and Hall notes the remarkable rhythmic zonation of their spacing.

The best-preserved of Hall's syntypes (AMNH 1470/2, shown here on Plate 29, fig. 1, 2) is in agreement with Hall's figures as to corallite diameter. A longitudinal section (Plate 29, fig. 1) shows the great abundance of the septa, about 5 occurring in 1 mm vertically, and their upward curve distally is clearly seen. The tabulae are about half the thickness of the corallite walls. Mural pores are abundant, about 3 per millimeter vertically, and are about 0.25 mm in diameter. They appear to be evenly-spaced, and in at least one instance, seem to occur biserially on the wall faces. Hall's material comes from the "Niagara Limestone" (probably the Lockport Dolomite, Late Wenlock through Middle Ludlow in age) at Lockport (site of the above specimen) and Rochester. This specimen (AMNH 1470/2) is here chosen

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as lectotype of Astrocerium venustum Hall, and is considered conspecific with our material, and with Favosites hisingeri Milne-Edwards & Haime.

Astrocerium parasiticum Hall (1852) is similar to A. venustum, but differs from it primarily in having markedly-narrower corallites interspersed among the full-sized ones. Also, there appear to be more spines in a cross-sectional area than in A. venustum (and our F. hisingeri), and its corallites seem to be a bit broader. It is quite possible that A. parasiticum is identical to the present species, as our understanding of the variations of this form is poor. Surely they are closely-related, but for the time being it is best to consider the relationship open to question. A. parasiticum is reported by Hall from the Niagara Group, in the "limestone near Lockport" (Lockport Dolomite?).

A third species described by Hall (1852) is Astrocerium pyriforme. From our concept of Favosites hisingeri, it seems to differ only in its pear-shaped characteristic form. Also there is a suggestion that the tabulae are more wide-spaced than is characteristic in our form, as Hall's figure 1d shows them separated by a distance greater than the tube diameter. Only a very short extent of three tubes is shown, however, and we note that such spacing is seen in limited portions of our own specimens. In light of the unusual shape of the corallum, it is best at this time to leave the relationship between A. pyriforme and F. hisingeri open to question.

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Hall's specimens come from his Niagara Group, in the Rochester Shale (Wenlock) of Rochester, Wolcott and Lockport, New York, and more rarely in "the limestone" (Lockport Dolomite?, Late Wenlock through Middle Ludlow) at Rochester and Lockport, New York.

In 1854, Milne-Edwards & Haime repeated their 1851 description of F. hisingeri (this time in English, rather than the original French), and figured two specimens, one from Benthall Edge, and the other from Wenlock Edge, England, probably of Wenlock age. In this description, the authors expressed the opinion that Hall's A. venustum was a synonym of their species.

Nicholson (1875) reported "Favosites venusta" (as he called Hall's species) from the Clinton Group (probably the Brassfield Formation) of Yellow Springs, Ohio. The corallum was large, hemispherical or spheroidal, with layering that probably reflected tabular zonation. The corallites were slender, ranging from about 1 mm down to about half a millimeter in diameter. The smaller ones were intercalated among the larger. No mention was made of the smaller corallites occurring in fields. Nicholson noted that the septa were formed of "very short spiniform projections". The tabulae were complete, horizontal or flexuose, with about 2 or 3 per millimeter. No information was given concerning mural pores. Doubtless, this form is F. hisingeri, agreeing with our specimens in all respects save for the reported short-

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ness of the spines, and the lack of mention of "fields" of corallites of similar diameter. The latter is probably more important than the former, as the spines could easily be affected by subsequent diagenetic alteration. The distribution of corallites in fields according to diameter is not necessarily developed to the same degree in all specimens, and might be missed. Consequently, it seems likely that Nicholson was dealing with the present species.

Rominger (1876) reported Favosites venustus from the Niagara Group (probably actually the Manistique Group, of Middle Llandovery through Middle Wenlock age) on Drummond Island, northern Michigan. The specimen he figured (UMMP 8442) appears identical to our form, even showing fields of smaller corallites. Rominger described the corallites as narrow, not over 1 mm wide, and of fairly equal size. The septa consisted of 12 rows of long spinules. The tabulae were close-spaced, horizontally-flat or gently convex. The mural pores occurred in one, or rarely two rows on each wall of the corallite. Rominger noted that the corallum occurred as a large, massive expansion, with an epitheca on the base. In all respects, the Drummond Island form appears to be identical to that of the Brassfield.

In his work on the fossil corals of Kentucky, Davis (1887) reported two species, Favosites venustus and Favosites niagarensis, of which the former, and part of the latter are apparently identical to F. hisingeri. These speci-

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mens were from the Louisville Limestone (Latest Wenlock and Earliest Ludlow) of Louisville, Kentucky.

Stumm (1964) described the Louisville material and illustrated some of Davis' hypotypes. He reported that the coralla are discoid to hemispherical, with the corallites averaging 1 mm across. The septa are formed by 12 rows of distally-rising spines, extending half-way to nearly the entire distance to the axis. Mural pores are usually uniserially-arranged. The tabulae are both complete and incomplete, horizontal or convex, close-spaced (about 4 per millimeter). Stumm considered this form different from Favosites hisingeri, remarking that the corallites of the latter are wider, averaging 1.5 mm across, and its tabulae not as close-spaced. He referred his material to Astrocerium venustum (which we judge to be a junior synonym of F. hisingeri). Stumm overestimates the diameter of the corallites in Milne-Edwards & Haime's species, and the tabular spacing has not yet proven sufficient grounds for separating species. Consequently, the Louisville corals are considered conspecific with our own.

Foerste (1890) reported Favosites venustus from the Brassfield Formation at Ludlow Falls and Fair Haven, southwestern Ohio. The corallites were 0.6 to 1.2 mm in diameter in specimens from Ludlow Falls, and reach a maximum of 1.3 mm at the second locality. In the Ludlow Falls material, the tabulae were 5 in 2.4 to 3.2 mm vertically, whereas in the

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second locality they are 5 in 1.9 mm (i.e., more close-spaced). The walls were "scarcely crenulated" in the Fair Haven specimens. Spines were reportedly in evidence only in some of the specimens. The vagueness of Foerste's description makes it best to reserve judgement on the identity of these corals.

Počta (1902), in his continuation of Barrande's work on the Lower Paleozoic of Bohemia, described three coral forms that resemble F. hisingeri. Following is an account of each:

The first of these three forms is Favosites fidelis. Počta attributed this species to Barrande, but as there is no firm evidence of a description of it in works by the latter, (except perhaps in manuscript), the authorship should be assigned to Počta. This form is distinctive for its small corallites and the distribution of the pores. The corallum resembles a loaf of bread: It is massive, flattened, thick, and convex underneath. No trace of a holotheca remains. The corallites reach a diameter of 1.0 to 1.5 mm, forming fairly-regular hexagons in cross-section. Their walls are thin, and finely-wrinkled transversely. The walls contain a medial line running along their centers.

Septal spines are frequently encountered, and vary in number. They sometimes reach the axis of the corallite. Počta noted that these spines may be present in some tubes of a corallum, while absent from others of the same specimen.

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The mural pores are numerous, very small, rounded. They occur in 3 to 5 longitudinal rows, and are also aligned horizontally. The tabulae are complete and close-spaced, with 1.6 to 1.8 per millimeter. They are rhythmically-zoned in terms of spacing, as shown in some of the figures (e.g., Plate 105, fig. 6; Plate 106, fig. 2). Only the figures of Plates 105 and 106 are confidently regarded as representing specimens of Favosites hisingeri. These specimens are from horizon e2 of Barrande (Wenlock, Ludlow, Pridoli and basal Lochkov, fide Kříž & Pojeta, 1974, p. 491). Those of Plates 83, 84, 89, and 94 are more questionable. It should be noted, however, that the mural pores are shown as fairly large (especially on Plate 94), similar to those seen in Hall's A. venustum (see Plate 29, fig. 1 of the present work). It seems sound to consider the indicated portion of Počta's F. fidelis conspecific with our material.

The second of Počta's forms (this time not attributed to Barrande) is Favosites fidelis var. clavata, from horizon e2 of Barrande (Wenlock, Ludlow, Pridoli and basal Lochkov, according to Kříž & Pojeta, 1974, p. 491).
The corallum is massive, convex distally. Počta refers to a "thick trunk" which gives the corallum the appearance of a club, but this is not shown in the figures provided. (Possibly this is similar to the pear-shaped Astrocerium pyriforme Hall, 1852.) No basal holotheca was present on the specimens Počta studied.

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The corallites are polygonal, of about the same size throughout the surface (0.8 to 1.3 mm across). The wall between tubes is 0.2 mm thick, and a dark mid-line runs through its middle, dividing the portion of the wall belonging to each corallite. Some walls are undulose in transverse section.

Many of the corallite tubes are empty, while in others are found 5 to 12 septal spines (in transverse view), straignt and fairly uniform in size. In broken corallites, the spines appear distributed without order, but they are absent in tubes with pleated walls, as though their function were served by the wall folds.

The tabulae are usually horizontal, but sometimes oblique. On average, there are 25 per centimeter (2.5 per millimeter). The mural pores are ordinarily in 3 rows, but where the tube is narrow, there are only two rows.

As this form has all the essential features of our own, they are considered conspecific. Only the specimens of Plate 90, especially figure 4 (showing small knobs on the upper surfaces of the corallite walls) seem questionable.

The third form, Favosites intricatus (attributed by Počta by Barrande, apparently invalidly), is from the f2 horizon (Early Devonian, fide Kříž and Pojeta, 1974, p. 490, 491, mostly Koneprusy and Slivenec Limestones of the Pragian). Characteristically, this form has an irregular surface, with corallite tubes directed in many directions as shown

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by the wearing down of what must have been several protuberances on a corallum. This resulted in a complex pattern of corallite orientations on the resulting cobble. Počta notes that large specimens often consist of several coralla.

The corallites are of about equal diameter, varying between 0.7 and 1.0 mm, with the mean at 0.8 mm. The corallites are separated by walls about 0.5 mm thick, sometimes greater. Often a dark median line may be seen in the walls.

Počta noticed the following categories with regard to spines:

1) They are totally absent, or else very short (0.12 mm), sparse and blunt.
2) They are well-developed, terminating in a blunt point. This category is further broken into two types:
   a) Spines stout, about 0.12 mm long, with broad bases, narrowing gradually distally toward a blunt point, their number about equalling the number of sides to the corallite.
   b) Spines more slender, longer (up to 0.18 mm), more numerous than the sides of the corallite (often 10 to 15 in transverse view).

Počta considered that these two categories of spinal pattern occur as variations in a single species, rather than marking separate taxa. This is because both patterns occur in a single corallum, and are not accompanied by correlated differences, other than the fact that those corallites with

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abundant spines have thicker walls than those devoid of spines. The spines are usually elevated distally, an important feature in F. hisingeri.

The tabulae are complete, often curved and generally "bulging downward" (concave?). About 35 occur in the space of 1 centimeter (3.5 per millimeter). The mural pores are quite large, sometimes in one, and at other times in two vertical rows. Their round apertures are spaced vertically about 32 per centimeter.

This form appears to have all the important features of Favosites hisingeri as we understand that species, and it is considered conspecific with the Brassfield form.

Foerste (1906) described what he considered a "variety" of the present species, Favosites hisingeri-aplata, from the Waco bed of the Noland Member, Brassfield Formation, on the east side of the Cincinnati Arch in central Kentucky. The type specimen (USNM 87171, shown on Plate 8, fig. 8, and Plate 27, fig. 5, 6 of the present work) is from "along the road north of Estill Springs, north of Irvine", that is, from the visinity of our localities 53 and 53a. Other specimens, according to Foerste, are from the vicinity of Panola (locality 1), Indian Fields, and Clay City, all in the same area in Kentudky.

The holotype has the following characters: It is about 6 cm in maximum diameter, with a thickness varying between 0.2 and 1.2 cm. The corallites of the basal side are posit-

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ioned with their longitudinal axes horizontal. These upflex distally, so that the corallites of the upper surface have their axes vertical. The corallites of the base appear to radiate from a center which is not included in the surviving portion of the corallum, suggesting that the corallum was originally low, lens-shaped, growing radially and centrifugally. The initial diameter was about 8 cm.

The corallites of the holotype are fairly uniform in size, nearly all under 1 mm in diameter, with only the very largest attaining 1 mm. The most common diameter is about 0.7 mm. Most corallites are 6-sided in transverse section, but some are 4- and 5-sided. The calices all contain abundant knobs on their walls which may represent spines, but which do not appear to be aligned (at least in surface view).

When viewed in thin-section, the specimen appears to have undergone considerable disruption through diagenesis. The tabulae are more wide-spaced than in others of our specimens, with about 3 or 4 occurring in 1 millimeter in the denser levels, while 1 millimeter separates them in the sparser regions. In many instances, the space between tabulae is greater than the tube diameter, and the greatest portion of our vertical section reveals areas sparsely-tabulated. Spines are almost absent from our sections, but this is likely due to alteration during the fossilization process. This is shown by a few small areas in the lower portion of the

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vertical section in which the plane-of-section transversely intersected several spines. There appear to be about 6 spines in a vertical distance of 1 mm. Mural pores have not been clearly seen.

Foerste wished to distinguish this form from the main body of F. hisingeri on account of its flatness. Whether or not this is justified, the form is clearly identical with our material on the species level.

Williams (1919) figured a coral he referred to Favosites hisingeri from Manitoulin Island in Lake Huron. This specimen, according to the Type Catalogue of the Canadian Geological Survey (1960, vol. I) is from the Fossil Hill Formation (Middle Llandovery through Middle Wenlock). The catalogue records the number of this specimen as GSC 5076, while Williams gave it as GSC 5075. Only one view of the specimen is shown, a surficial view showing the corallite apertures. These are of quite-uniform size, nearly all 1.5 mm across. Unfortunately, insufficient information is given to allow a valid judgement as to the identity of the specimen without studying the specimen itself. The uncertainty of the identification is compounded by the absence of a descriptive text accompanying the figure, and by the fact that the corallites are in the upper size-range of F. hisingeri, while also fitting into the size-range of other forms (such as Paleofavosites prolificus, which see).

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Twenhofel (1928) reported F. hisingeri from Anticosti Island, in the Gun River (Middle Llandovery), Jupiter (Late Llandovery), and Chicotte (Late Llandovery and Early Wenlock) Formations. The coralla are massive, generally showing lamination (reflecting rhythmic tabulae zonation). The corallites are thick-walled, 4- to 7-sided, and never exceed 1 mm in diameter. The tabulae are thinner than the walls, and are numerous (1 to 3 per millimeter), flat, convex or concave. The mural pores are large, circular, and arranged in one or two longitudinal rows. In the latter case, the rows are close, and the pores alternate. The septa consist of upward-flexing spines, some extending nearly to the axis of the corallite. There are one or two rows of spines on each wall, and each spine is apparently situated just above a pore. No figures accompanied the description of this Anticosti form. Nonetheless, the description indicates sufficiently good agreement with our specimens to consider them conspecific.

Tripp (1933) has taken a quite practical stand with regard to the favositids. He considered them best divided into form-groups, without commitment to their genetic relationships. His figures and descriptions of Gotland corals include some that are clearly F. hisingeri, with narrow tubes (1.5 mm and less in diameter), and very long, distally-upflexed spines. The tabulae are close-spaced, about 2 per millimeter. The mural pores occur in one, two, and sometimes

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three rows on the walls of the corallites. Most clearly similar to our material are Tripp's Text-figures 35 and 36 (representing his Groups V and VI, respectively), and the figures of his Plate XIII. The specimens of this plate are from Kneippbyn, with the exception of one, which is from Lickershamn. Judging from Manten's (1971) geologic map of Gotland, the Kneippbyn material is probably from the Högklint beds (Early Wenlock according to Manten, p. 43), while the Lickershamn material could be from the Hogklint, or from the Visby beds (Late Llandovery according to the same source).

Jones (1936) designated as lectotype of Favosites hisingeri the specimen figured by Milne-Edwards & Haime (1854) in their Plate LXI, figure 1. Figure 1a is another view of the same specimen, but figure 1b is a different specimen.

Teichert (1937) reported F. hisingeri from the Silurian of Southampton Island, in the northeastern Canadian Arctic. He studied a single specimen with corallites of fairly uniform size, none narrower than 1.2 mm, and a few larger than 1.5 mm. Most of the tubes were of this latter diameter. The corallite walls were about 0.1 mm thick, and were heavily-invested with spines. The maximum length of the spines was 0.5 mm, but most were shorter. It was not determined if the spines point upward distally. There were 8 to 10 tabulae in 5 mm, but the space between them could vary from 0.3 to 0.8 mm. They included flat, convex and concave examples. Teichert had no information about the mural pores,

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except that they were not located in the corallite corners. The corallites were rather larger than is usual in this species, but judging from other material encountered in the field, and in the literature, it seems best to regard this as merely a large variant of our species.

Shrock & Twenhofel (1939) reported F. hisingeri from Newfoundland, in the Goldson Formation, the Pike Arm Formation, and the Natlin's Cove Formation. According to Berry & Boucot (1970), the stratigraphy of Newfoundland is still only generally understood, so that these units might best be regarded simply as Silurian, for the moment. The corallites ranged in diameter from less than 0.5 mm to over 1.5 mm in a single specimen. The tabulae were unequally-spaced, averaging 2 per millimeter, and were usually horizontal and flat. The mural pores occurred biserially-arranged, or with no obvious pattern, and averaged 4 in each intertabular space. In well-preserved specimens, septal spines could be seen, some reaching nearly to the corallite axis. The Newfoundland material appears to be sufficiently close to the Brassfield form to allow an assumption of conspecificity.

A specimen at the Yale Peabody Museum (YPM 25634) is attributed to Twenhofel as a type. It is from the Pike Arm Formation, in the outer coral zone, on Fossil Point, in Pike Arm, New World Island. This is doubtless one of the specimens studied by Shrock & Twenhofel in this work. The corallite

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diameters are about 0.5 to 0.6 mm, and long spines are present. This specimen is identical to our F. hisingeri, and indeed, that name appears on its label.

Northrop (1939) reported F. hisingeri from the Gaspé region of maritime Canada, from the following units: Clemville (Late Llandovery), La Vieille (Late Llandovery through Late Wenlock), Gascons, Bouleaux and West Point (Early Ludlow) and Indian Point (Middle Ludlow) Formations. Unfortunately, the only information he gave is the corallite diameters, usually not over 1 mm, rarely reaching 1.3 mm. While it is quite possible that Northrop's material is indeed Favosites hisingeri, it is not possible to be reasonably certain, due to the lack of sufficient information.

Distribution - England: Wenlock?; New York State: within the range of Late Wenlock through Middle Ludlow; northern Michigan: within the range of Middle Llandovery through Middle Wenlock; Ohio: Middle Llandovery (Brassfield Formation); Indiana: Middle Llandovery (Brassfield Formation; Kentucky: Middle Llandovery (Brassfield Formation), and Late Wenlock or Early Ludlow; Anticosti Island: Middle Llandovery through Early Wenlock; Gotland: Late Llandovery?, Early Wenlock; northeastern Canadian Arctic: Silurian; Newfoundland: Silurian; Bohemia: within the range of Wenlock to Lower Devonian (Pragian)*

* See Kříž & Pojeta (1974) for discussion of the problems of using Barrande's stratigraphic designations.

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Brassfield occurrence - In southwest Ohio: localities 9 (near Lewisburg), 15 (near West Milton), and 55 (near Ludlow Falls, in clay layer at top of Brassfield); in Kentucky (central): localities 1*(near Panola) and 46 (near College Hill), both in the Noland Member; in Indiana: locality 26 (Elkhorn Falls, near Richmond).

* Questionable occurrence at locality 1.

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Favosites discoideus (Roemer)

Plate 8, fig. 7; Plate 28, fig. 3, 4

? 1851 Favosites forbesi Milne-Edwards & Haime (partim), p. 238

1854 Favosites forbesi Milne-Edwards & Haime (partim), p. 258-259, Plate LX, fig. 2, 2a, 2b

1860 Calamopora forbesi var. discoidea Roemer, p. 19-20, Plate II, fig. 10, 10a, 10b

1928 Favosites forbesi Twenhofel, p. 127-128

1933 Favosites forbesi Tripp, Plate XVI, fig. 1a, b

1934 Favosites cfr. forbesi Shimizu, Ozaki & Obata, p. 70, Plate XIII, fig. 1

1939 Favosites forbesi Shrock & Twenhofel, p. 254

? 1939 Favosites forbesi Northrop, p. 150

1949 Favosites discoideus Amsden, p. 90, (partim?), Plate XVIII, fig. 6, 7, 9; possibly(?) Plate XXXIV, fig. 13, 15

? 1964 Favosites discoideus Stumm, p. 62, Plate 58, fig. 10

Type material - Location of specimen figured by Roemer is unknown.

Type locality and horizon - From the "Silurian" of western Tennessee, possibly the Brownsport Formation, of Early Ludlow age, as Amsden (1949) has reported such corals from that unit.

Number of specimens studied - approximately 10

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DIAGNOSIS - Favosites in which the wider corallites (2.5 to 3.0 mm in diameter) are scattered in a matrix of smaller corallites, measuring down to less than 1.0 mm in diameter; corallum generally low, lens-shaped, with pedunculate base; tabulae wide-spaced; in larger coralla, corallite size-variation apparently becomes less marked.

DESCRIPTION - The coralla occur in lenses of low relief, not attached to any solid object (assuming the sediment was not indurated). Apparently this form lived in a manner similar to that of Siderastrea radians in the Florida Keys, and could have been readily detached from the sea floor. A typical specimen is 4 cm in diameter, with a height of 1.0 to 1.5 cm, few being larger as found in the Brassfield. The earliest portion of the corallum is in the center of the base, and growth was radial and centrifugal. No holotheca is preserved. The appearance of the base suggests that a peduncle was originally present.

The most obviously distinctive feature of this species is the great variability of corallite diameter within a small area. In a space about 0.5 square centimeter in area may be found corallites ranging from 3 mm down to 1 mm across. The former is about maximum for this species, so far as our specimens show, and there are many corallites 1.0 mm and even narrower on the same specimen.

The corallites are quite variable in cross-section, doubtless due to the requirements of packing, and 3-, 4-, 5-,

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and 6-sided corallites occur in a single specimen. The corallite walls are thin, perhaps 0.1 mm across.

The tabulae are relatively wide-spaced vertically, averaging 3 to 4 in 4 mm in the larger corallites, and possibly a bit closer in smaller ones. As a result, the surface of a corallum (Plate 8, fig. 7) often appears to have rather deep corallites. The tabulae are virtually all complete, due to this wide spacing, and while most are horizontal, some may be convex or concave upward (though without much relief).

Spines have not been clearly seen in our specimens. Mural pores also cannot be reported, though it seems likely they are present. The assignment of our specimens to the genus Favosites is based upon similarity to other reported species of that genus.

DISCUSSION - From the Silurian of western Tennessee, Roemer (1860) described Calamopora forbesi var. discoidea, as a new variety of Milne-Edwards & Haime's (1851) Favosites forbesi, a species from the Silurian and possibly Late Ordovician of England and the Silurian of Gotland. Roemer gave the following account of his corals:

The corallum is small, round, disc-shaped, convex upward, and either flat or slightly convex on its lower surface. In most cases, the corallum diameter is only 6 to 10 "lines" (1/2 to 5/6 inch), seldom reaching 1 inch. Sometimes the outline is more elliptical than circular. In the center of

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the base is a small curved peduncle. The corallite apertures are characteristically quite inequal in diameter, and of very irregular form. On the inner surfaces of the corallites, indistinct longitudinal striae are reported, and indicated in Roemer's figures as well (though Amsden, 1949 could not detect such features in similar corals collected by him in this area). Roemer felt that as his form grew, the inequality of the corallite diameters would disappear, though he had no evidence of this. He reported collecting specimens at Visby, Gotland (probably from the Högklint beds of Early Wenlock age according to Manten, 1971), which were identical to his own from Tennessee. Aside from the "indistinct" longitudinal striae reported in the calices, Roemer's material appears identical to ours, and they are regarded as conspecific.

Roemer identified his specimens with the specimens of Plate LX, fig. 2, 2a and 2b of Milne-Edwards & Haime's (1854) Favosites forbesi. This is a species reported by these authors in 1851, and first illustrated in 1854. Roemer noted a difference between these specimens (and his own) and what he referred to as the "typically-grown form of C. Forbesi" of Milne-Edwards & Haime's Plate LX, fig. 2c. Consequently, he termed his specimens a variety (subspecies) of Favosites (or as he called it, Calamopora) forbesi. It would seem that this is a perfectly valid selection of a lectotype on the part of Roemer, whether or not he intended it so. His spe-

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cimen, and those shown in Milne-Edwards & Haime's fig. 2, 2a and 2b apparently are distinct from the specimen chosen as lectotype, and I follow the practice of later authors (Amsden, 1949; Stumm, 1964) in regarding Roemer's "variety" as a distinct species, Favosites discoideus, to which I assign the Brassfield form. As may be seen in our synonymy, many authors have linked the form we call F. discoideus with F. forbesi Milne-Edwards & Haime, apparently because they were originally illustrated together under the same name.

Two other authors, Jones (1936) and Lecompte (1936), assigned a lectotype for F. forbesi. They did this independently of one another, and apparently unaware that Roemer had already made a selection. Their choices of lectotypes were done more purposefully, though, as their wording leaves no doubt that this was intended. Jones (in a January paper, probably pre-dating Lecompte's) specifically stated that he was chosing Lonsdale's (1839) Favosites gothlandicus Lamarck (Plate XV bis, fig. 4) as the lectotype (p. 10). Lecompte (p. 63-64) stated that Milne-Edwards & Haime had based their species on the specimen shown by Goldfuss (1829) on Plate 26, fig. 4b, identified as Calamopora basaltica. Lecompte's decision was apparently based upon the fact that this was the first post-Linnaean reference included in Milne-Edwards & Haime's synonymy. In both these cases, the specimen chosen resembles Roemer's lectotype far more than Roemer's specimen.

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Regardless, then, whose choice of a lectotype one feels is valid for F. forbesi, this species remains distinct from F. discoideus. Milne-Edwards & Haime's specimens which are considered conspecific with F. discoideus are from the Wenlock Limestone (Late Wenlock in age, according to Ziegler et al., 1974) at Dudley, England.

From Anticosti Island, Twenhofel (1928) reported what appears to be this species, identifying them as Favosites forbesi. He noted its presence in zone 4 of the Ellis Bay Formation (Early Llandovery), and that the species persists through the Becscie and Gun River Formations, to the top of the Jupiter Formation (Late Llandovery). The coralla are larger than ours, to 20 centimeters in diameter, and are hemispherical in form. The central portion of the base is is"conical" (pedunculate?), and the base shows concentric growth-lines on what Twenhofel considered a holotheca. The calices are distinctly unequal in size, and the larger corallites are about 3 mm across, while the smaller are 1.5 to 2.0 mm across with some narrower than 1 mm. The thin walls show evidence of spines in a few cases only. The tabulae are thin and horizontal, generally about 1 mm apart, and have "from 1 to 2 marginal fossulae to a side". The mural pores occur on the faces of the walls, in one or two rows, and are about 0.25 mm in diameter, spaced 1 mm apart. Each is encircled by a raised ring. Twenhofel's description is in good agreement with our specimens, and they are regarded as conspecific.

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From Gotland's Högklint marl (Early Wenlock), Tripp (1933) illustrated what he identified as Favosites forbesi. Included are a transverse and longitudinal section (Plate XVI, fig. 1a, b). The former shows the distinct inequality of corallite diameter, the greatest being 3 mm across, the smallest less than 1 mm. In the latter, the tabulae appear zoned, at most 1.5 mm, and at least under 0.5 mm apart. Their surfaces are flat, concave and convex, but rarely show much relief. Growth seems to have been radial, and the corallum was hemispherical. Tripp's material seems to be conspecific with ours.

The presence of Favosites discoideus was shown by Shimizu, Ozaki and Obata (1934, identified as "Favosites cfr. forbesi) in the Silurian rocks of northwestern Korea. The one specimen found was hemispherical, with large corallites relatively few, 2.5 to 3 mm in diameter, scattered among smaller ones, which reach down to less than 0.5 mm. These authors had no information on spines or mural pores. From what can be determined, this specimen has the superficial features of our own, and is tentatively regarded as conspecific with it.

Shrock & Twenhofel (1939) reported this species (identified by them as Favosites forbesi) from the Pike Arm Formation (outer coral zone) of northern Newfoundland. The age of this unit is imperfectly known, and is here noted as simply Silurian. The coralla are "conical" (presumably

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meaning pedunculate), and characterized by a large variation in corallite diameter (from less than 1 mm up to 3.5 mm), typical of this species. The corallite walls are thin, and no mural pores were observed. No figures accompanied this description, but there appears to be sufficient agreement with the Brassfield form to warrant regarding them as conspecific.

Northrop (1939) reported specimens of corals from the Port Daniel-Black Cape region of Gaspé (maritime Canada) which he identified as Favosites forbesi. This material came from the following units: the Clemville and Anse Cascon (Late Llandovery), La Vieille (Late Llandovery and all of the Wenlock), probably the Gascons (Early Ludlow), and the West Point and Indian Point Formations (Middle Ludlow). Northrop restricted himself to listing the size-ranges of the larger and smaller corallites of six specimens. In most cases, the larger corallites measured about 2 to 3 mm in diameter, sometimes reaching 3.5 mm. The narrowest corallites are 1 mm or less in diameter. In the absence of further data, we can only note the possible occurrence of Favosites discoideus (which would accommodate these measurements) in Gaspé.

Amsden (1949) reported Favosites discoideus from the Brownsport Formation (Early Ludlow in age) of western Tennessee. The corallum is hemispherical, with a convex to conical base. Attachment is by a narrow peduncle, and the

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rest of the base is reportedly covered by a holotheca. The largest specimen measures 5.5 cm in diameter. Amsden notes that while there is some variation in corallite size, the average diameter is 2.5 mm. His two figures on Plate XXXIV do not show the sort of corallite size pattern generally associated with our species, but his figures of Plate XVIII do. The specimen illustrated in figures 6 and 7 of this plate is the smallest Amsden collected, about 16 mm in greatest diameter. The larger corallites reach a maximum diameter of 2.5 mm, while the smallest are less than 1 mm. No septa are reported in these forms. The tabulae are apparently mostly flat or concave, spaced about 1 mm apart. The mural pores are numerous, and about 0.25 mm in diameter, located on the wall faces of the corallites. They are irregularly-spaced, but generally about 1 mm apart. Amsden regards the internal longitudinal elements reported by Roemer as non-existent. The agreement between the Brownsport and Brassfield specimens is such as to make them most likely conspecific (at least with regard to the specimens figured on Amsden's Plate XVIII).

Stumm (1964) reported Favosites discoideus from the Louisville Limestone (Late Wenlock and Early Ludlow) in the vicinity of Louisville, Kentucky. The upper surface of the corallum is flat, or convex with low relief. The lower surface is flat, with a concentrically-wrinkled "peritheca" (holotheca), and central point of attachment.

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The coralla are 2 to 7 cm across, and 0.5 to 2 cm thick. The corallites are bimodal in size, the larger being 3 to 4 mm across (slightly wider than those of our specimens), and the smaller averaging 1.5 mm in diameter. The corallites of the several sizes are scattered together. The mural pores are uni- or biserial. The tabulae are complete, horizontal, spaced 1 to 3 mm apart. This wide spacing of the tabulae is in good agreement with that seen in our specimens. Stumm's material is thus similar to our form, though the higher upper value for the corallite diameters and the smaller difference between the large and small corallites leaves his identification open to question.

There is obviously good agreement on what smaller specimens of Favosites discoideus (Roemer) look like, but no clear picture emerges of what their characters are in larger specimens. It seems, then, that much more work is needed before this form is sufficiently understood.

Distribution - Tennessee: Early Ludlow; England: Late Wenlock; Anticosti Island: Early to Late Llandovery; Gotland: Early Wenlock; Korea: Silurian; Newfoundland: Silurian: Ohio and Kentucky: Middle Llandovery (Brassfield Formation).

Brassfield occurrence - Localities 7a (near Fairborn), 55 (clay layer at top of Brassfield near Ludlow Falls) and possibly 11 (near West Union), all in southwestern Ohio; locality 50 (near Colfax) in central Kentucky.

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Favosites densitabulatus sp. nov.

Plate 9, fig. 6, 7; Plate 30, fig. 1, 2

1906 *Favosites gothlandica* Foerste, p. 298-299, Plate 2, fig. 1A, B (*non* Lamarck, 1816)

cf. 1937 *Favosites* cf. *F. favosus* Teichert, p. 129-130, Plate VI, fig. 5, 6; Plate VII, fig. 2

Type material - Holotype: UCGM 41945 (Plate 30, fig. 1, 2)

Type locality and horizon - Locality 1, near Panola, Kentucky, Waco bed, Noland Member, Brassfield Formation.

Number of specimens studied - 11

DIAGNOSIS - *Favosites* with very broad corallites (diameter = about 5 mm wall-to-wall, about 6 mm corner-to-corner); tabulae horizontal, so closely-spaced as to be almost touching in many cases; bases of tabulae show butress-like features in margin, possibly reflecting marginal fossulae as in *Favosites favosus* (Goldfuss); tabulae without spines.

DESCRIPTION - The coralla are expansive, the largest being 20 cm in maximum diameter (as preserved). This specimen indicates that corallum growth was centrifugally radial, and it may be reconstructed, assuming reasonable symmetry, as a low, upwardly-convex corallum, at least 24 cm in diameter, and at least 4 cm high.

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This species has the broadest corallites of all the Brassfield favositids, the wall-to-wall diameter generally being about 5 mm, and the corner-to-corner diameter about 6 mm. The corallites show no appreciable variation in diameter (such as are seen in Favosites forbesi), and are usually hexagonal.

Besides the great width of the corallites, the most striking aspect of this species is the close-spacing of its tabulae. These may be so densely-distributed as to nearly touch, or as far apart as 1 mm. Usually, though, they are 0.6 mm apart, and display periodicity of spacing. The tabulae are generally near-horizontal, though some show a slight up- or down-bowing in their axes. The margins of their undersides have buttress-like extensions that may reflect marginal fossulae, as are found in Favosites favosus.

The walls are about 0.25 mm thick, rather undulose, with a distinct dark mid-line. The mural pores are positioned on the wall faces, though their pattern could not be determined, and they appear to have a thickened rim around them. Spines appear to be present on the corallite walls, but not on the tabulae.

The combination of broad corallites and close-spaced tabulae is quite striking, and so far, this appears to be a distinctive species.

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DISCUSSION - The only mention of this species encountered in the literature is Foerste's (1906) report of a supposed Favosites gothlandica from the Waco bed, Noland Member of the Brassfield Formation, in central Kentucky. The localities given by Foerste are Irvine (our locality 53 or 53a), Panola (locality 1), Vienna, Indian Fields, and Tipton Ferry.

Foerste reported specimens up to 50 cm in diameter. The corallites were usually 4 to 5, and sometimes 6 mm across. The more-or-less flat tabulae were spaced 2 to 2.4 per millimeter. They reportedly have about 12 marginal depressions (apparently similar to those of F. favosus). Foerste noted the presence of rimmed mural pores (though not their arrangement), and was unable to clearly determine the presence of spines.

Teichert (1937) reported a favositid from the Silurian of the Brodeur Peninsula in the northeastern Canadian Arctic. This may be conspecific with another of the Brassfield species, but is mentioned here because of its similarity to F. densitabulatus. The tabulae are spaced quite closely, 2.4 per millimeter. The corallites, however, are usually about 2.8 mm (though sometimes less) in diameter, and this does not seem to fit into the range of variation of our species.

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Distribution - Kentucky: Middle Llandovery (Brassfield Formation); possibly in same unit in Ohio.

Brassfield occurrence - Localities 1 (near Panola) and 46 (near College Hill) in central Kentucky, in the Waco bed, Noland Member of the Brassfield. Possibly from locality 11, near West Union, Ohio. Foerste (1906) reports specimens from several other localities (see discussion of this species) in central Kentucky.

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Favosites sp. A

Plate 30, fig. 3, 4; Plate 39, fig. 1

1860 Calamopora gothlandica Roemer (partim), p. 18-19, Plate II, fig. 9, 9a, 9b (non Favosites gothlandicus Lamarck, 1816)

? 1902 Favosites tachlowitzensis Počta, p. 231-233, Plate 72-75, 78-80, 86

? 1902 Favosites tachlowitzensis, var. delicata Počta, p. 233, Plate 74

cf. 1934 Favosites kennihoensis Shimizu, Ozaki & Obata, p. 71, Plate XII, fig. 7; Plate XIII, fig. 2, 3

1937 Favosites cf. F. favosus Teichert, p. 129-130, Plate VI, fig. 5, 6

? 1937a Favosites kuklini Chernyshev, p. 69, Plate IV, fig. 2a, b

cf. 1949 Favosites brownsportensis Amsden, p. 87-88, Plate XVI, fig. 1-3

cf. 1957 Favosites kuklini Zhizhina & Smirnova, p. 22-24, Plate VI, fig. 1-4; Plate VII, fig. 1, 2

cf. 1957 Favosites crassimuralis Zhizhina, p. 29-30, Plate XI, fig. 1-4

cf. 1957 Favosites undulatus Tchernyshev (sic) var. fulvus Zhizhina, p. 30-31, Plate XII, fig. 1, 2

cf. 1967 Favosites gothlandicus Stasínska, p. 80, Plate XXIII, fig. 3a-c (non Lamarck, 1816)

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Type material - Specimen discussed below is UCGM 41958

Type locality and horizon - Specimen collected at locality 46, near College Hill, Kentucky, in the top of the Noland Member, Brassfield Formation.

Number of specimens studied - 1

DESCRIPTION - The corallum appears to have been originally hemispherical. The portion preserved has a maximum width of 11 cm and a thickness of 7 cm. The corallites present a generally uniform aspect in size (Plate 30, fig. 3) being about 2.5 to 3.0 mm in diameter, and are mostly hexagonal, with fairly equal sides. The tabulae are close-spaced, the closest nearly touching each other (sometimes to the point of becoming incomplete), and the widest-spaced being about 1 mm apart. On average, the spacing is about 8 to 10 in 5 mm. The tabulae tend to be weakly convex upward, and do not appear to have marginal pits, such as are found in F. favosus (which see). Their upper surfaces are free of spines.

The walls are about 1/7 mm thick, and appear to have a dark mid-line (Plate 39, fig. 1). Spines seem to be present, but recrystallization makes it difficult to be certain of their character and abundance. For the same reason, the distribution of the mural pores is obscure, but if the few breaks in the corallite walls that do appear in section are mural pores, then it seems they are located on the wall faces, rather than in the corners. For this reason, the Brassfield form is placed in the genus Favosites Lamarck. The absence

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of thickened walls and of obvious squamulae discourages its being assigned to Squameofavosites Chernyshev.

DISCUSSION - Because of the lack of important information on this specimen, especially the distribution of spines and mural pores, it is difficult to pin down an identification. It is clear, however, that it represents a form distinct from the other Brassfield favositids. The combination of intermediate-sized corallites, with very close-spaced, spine-free tabulae, is distinctive. It could conceivably represent a sub-species of Favosites densitabulatus, from which it differs in having a considerably-narrower corallite, and in the apparent absence of marginal pits in the tabulae.

Roemer (1860) described favositids from the Brownsport Formation (Early Ludlow) of western Tennessee, which he assigned to F. gothlandicus Lamarck. They clearly differ, however, from the neotype of that species, which was assigned by Jones (1936). The coralla were "flat- or cake-shaped", with mostly 6-sided corallites fairly uniform in diameter, 2.5 to 3.0 mm. Four tabulae, apparently mostly horizontal, occurred in a vertical distance about equal to the diameter of the tube, representing a spacing about equivalent to that found in our specimen. The mural pores were irregularly distributed, sometimes in pairs, sometimes singly, even on the same corallite wall. In all characters observed in our specimen, Roemer's form agrees, and it is probable that these two forms are conspecific. Roemer also mentioned a variety

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of his form which he felt was distinguished solely by the smaller diameter of its corallites (1.0 to 1.5 mm). This variety he illustrated in his figure 11 of the same plate, and it cannot be confidently equated with our form.

Počta (1902) described Favosites tachlowitzensis, a species which he ascribed to Barrande (apparently as an unpublished manuscript name), from Tachlowitz, Bohemia, level e2 (consisting of rocks ranging in age from Wenlock to the base of the Lochkov, fide Kříž & Pojeta, 1974, p. 491). The corallites are mostly hexagonal, and fairly uniform in size, the diameter being 2.0 to 2.5 mm. The thin walls seem to thicken somewhat around the corallite apertures, and they are invested with granules (spines?). Spines, varying in length, are reported in some coralla. Mural pores are round, or occasionally oval, and are distributed in two rows, sometimes in alternate positions, on the walls. When a wall is particularly broad, a third row of pores may appear. The pores have no thickened rims. The tabulae are horizontal and complete, spaced 14 to 16 per centimeter. F. tachlowitzensis is similar to our form in the regularity of the corallite arrangement, most being 6-sided and of fairly uniform size. As a rule, however, they are narrower than ours, the broadest (2.5 mm) falling into the lower range of our corallites. The spacing of the tabulae is likewise not quite so close as in the Brassfield specimen, being somewhat less than the average spacing encountered in our corallites. Pocta illustrates the ropy sort of pattern shown by the cor-

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allite walls as seen on the surface of a weathered specimen, a pattern not seen in our specimen. Unfortunately, we have no data on the arrangement of mural pores in our form, and so this very important feature cannot be compared with the Bohemian material. It appears that our specimen may be related on the specific level to the Bohemian species, but it will be necessary to obtain more information on its morphologic features before a decision can be made.

Počta also described a variety of this species, F. tachlowitzensis delicata, from the same locality and horizon. The corallites of this form are nearly all hexagonal, of generally uniform diameter (averaging 2.5 mm). The walls are invested with granules which may form circles or squares around the mural pores. It is unclear if these granules may be septal spines. The pores are distinct, distributed in two rows on the wall faces. The tabulae are complete, horizontal, and evenly-spaced, at 16 in 1 cm, as they are in F. tachlowitz proper. Again, it is not possible to be certain of the relationship between this form and our own, due to lack of information on the mural pores and spines of the latter.

Shimizu, Ozaki & Obata (1934) described a coral fauna from the Ken-niho Limestone of northwestern Korea. The fauna suggested, by comparison with other parts of the world, an age of Late Valentian to Late Salopian (essentially, Early Wenlock to Early Ludlow). From this fauna, they described Favosites kennihoensis, a form with some features in common

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with our own. The massive corallum consists of corallites of rather uniform size, about 2 or more millimeters in diameter. Their walls are thin, sometimes longitudinally-wrinkled. Mural pores are "irregularly-distributed". The tabulae show alternation of spacing. Where densely-packed, they are 4 to 6 per millimeter, and where more sparse, they are 3 or less per millimeter. The tabulae are spaced in a pattern comparable with our form, but are not so distinctly convex. Further, our form does not show the longitudinally-wrinkled walls of the Korean form. The evidence weighs in favor of regarding these two as distinct species.

Teichert (1937) described some specimens from the Silurian beds of the Brodeur Peninsula (Stanley Point) on Baffin Island, Canadian Arctic. The corallites were both regularly and irregularly hexagonal, with some pentagonal. Most were 2.8 mm in diameter, but smaller corallites were not uncommon. The wall thickness was 0.1 to 0.2 mm. The tabulae were spaced 12 in 5 mm (somewhat closer than our average). Spines were not observed, and all that could be ascertained about the mural pores was that they didn't appear to be in the corners of the corallites. The interiors of the corallites appear to have been somewhat disrupted, but convex tabulae do not appear to be uncommon. The similarities between this form and our own are strong, and they are tentatively regarded as conspecific.

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Amsden's (1949) Favosites brownsportensis, from the Brownsport Formation (Early Ludlow) of western Tennessee, is quite similar to our form. The corallites of the holotype (YPM 17616) are mostly 3 to 4 mm in diameter, though there are fields where proliferation is apparently occurring, consisting of smaller corallites. The corallites are mostly 6-sided, but the sides are usually unequal. In a given region, they are generally fairly uniform in size. The tabulae are horizontal or slightly convex, and are close-spaced, about 5.5 in 5 mm where most densely distributed. The mural pores are up to 0.3 mm in diameter, and are located on the wall faces. No spines were observed in thin-section. Though the corallites are slightly larger than in our form, and the tabulae slightly sparser, still the general features of the Brownsport specimen are such that it might be part of a continuum, including our form, and possibly F. tachlowitzensis of Bohemia.

In 1937[a], Chernyshev described Favosites kuklini from the Llandovery of Novaya Zemlya. His reference was not obtainable, but Zhizhina & Smirnova (1957) described specimens from the eastern Taimyrs, of Llandoverian and Wenlockian age, which they attributed to Chernyshev's species. The coralla are massive, with radially-distributed corallites, 5 to 7 sided, not homogeneous in diameter, ranging from 2 to 4 mm wide. The corallite walls are thin (0.08 to 0.2, and sometimes up to 0.3 mm thick), weakly wavy. Thick, blunt spines

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are sparsely-distributed. Mural pores are distributed in two rows, and may be 0.24 to 0.4 mm in diameter. Occasionally the pores may occur in one or three rows. Most of the tabulae seem to be slightly convex upward, and depressed peripherally where they contact the walls (the same profile as in our corallites). About 6 to 10 tabulae occur in 5 mm vertically. This species (as described by Zhizhina & Smirnova) is similar to ours, but differs in the apparently greater range of corallite diameters, and more significantly, in the nature of the spines, which might be the squamulae of Squameofavosites.

In the same work, Zhizhina (alone) described Favosites crassimuralis from the Llandovery of the eastern Taimyrs. The massive corallum consists of radially-arranged corallites, usually 5- or 6-sided (except for very young corallites, which may be 3- or 4-sided). Their diameter is 2.5 to 3.5 mm. The walls are thick (0.25 to 0.4 mm), with a distinct mid-seam. In some cases, a wall may be weakly concave in one corallite and weakly convex where it faces on a neighboring corallite. The spines are stout, broad and pointed, about 0.2 to 0.25 mm in length. The mural pores are round, 0.2 to 0.3 mm in diameter, and distributed alternately in two rows. The tabulae are close-spaced, sometimes wavy. peripherally they often down-flex to join the wall (as in our form). They are spaced 12 to 13 in 5 mm, rather denser than the average in the Brassfield specimen. The Taimyr form

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differs from ours in the thickness of the walls and the nature of the spines.

In the same work, Zhizhina described Favosites undulatus fulvus, a new variety of a species originally described by Chernyshev. Again, this form is from the Llandovery of the eastern Taimyrs. The corallite is massive, with radially- or parallelly-distributed corallites, 4 to 7-sided, with rounded corners. The diameters are not particularly uniform, varying between 2.0 and 3.5 mm, sometimes less. The wall is 0.12 to 0.17 mm thick, rarely as much as 0.2 mm. The spines are short, broad and pointed. The pores are round, or sometimes oval, distributed on the walls in one or two rows. Their diameters can vary, even in a single specimen, from 0.28 to 0.36 mm. The tabulae are close-spaced, with flat or concave surfaces. They are spaced 11 to 13 in 5 mm vertically. Basically, the Brassfield form differs from Zhizhina's in having more regularly convex tabulae, and less-developed spines. Also, our tabulae are not generally as close-spaced as in the Taimyr form.

Stasínska (1967) described specimens from erratic boulders of Poland and from the Llandovery of Norway, that she identified as Favosites gothlandicus Lamarck. The coralla were massive, discoidal, with corallites 2.5 to 3.0 mm in diameter. The walls were straight, 0.1 to 0.2 mm thick, with a distinct mid-line. Mural pores, 0.2 mm in diameter, were arranged, usually in two, but sometimes in one or three

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rows, with the rows 0.2 to 0.5 mm apart. The tabulae were close-spaced, thin, mostly horizontal, but also weakly concave or convex. They were rather wavy in profile. Where most closely-spaced, they were about 2.5 to 6 per millimeter. Elsewhere they were about 2 per millimeter. Rather short spines were present. This form is similar to ours, differing only in the absence of consistently convex tabulae, and in the definite presence of spines on the walls. Also, the transverse section (Stasínska's figure 3a) suggests the presence of peripheral pits in the tabulae.

DISTRIBUTION - Kentucky: Middle Llandovery (Brassfield Formation); Tennessee: Early Ludlow; Baffin Island (Canadian Arctic): Silurian.

While several forms around the world (discussed above) bear similarities to this form, the Brassfield specimen is insufficiently-understood to allow its confident identification with any of them. In all likelihood, further study will show it to be conspecific with some of these forms.

BRASSFIELD OCCURRENCE - Locality 46, near College Hill, central Kentucky, in the top of the Noland Member.

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Paleofavosites Twenhofel, 1914

1829 Calamopora Goldfuss, 1829, p. 77, Plate XXVI, fig. 1a-c

1914 Paleofavosites Twenhofel, p. 24

1971 Palaeofavosites Oekentorp, p. 158-160

Type species - (Original designation): Favosites aspera D'Orbigny, 1850, p. 49 (? = Favosites alveolaris Lonsdale [non Goldfuss] 1839, p. 681).

Type locality and horizon - "Silurian: Wenlock, Shropshire, England, and Island of Dagö, Estonia" (fide Lang, Smith & Thomas, 1940, p. 94).

DIAGNOSIS - Identical to Favosites (which see), except that the mural pores are located in the corners of the corallites, rather than on the wall faces. This often results in the corallite corners being undulose.

DESCRIPTION - The genus Paleofavosites encompasses those favositid species which consist of simple, polygonal tubes, traversed with tabulae, and bearing mural pores in the corners of the tubes only (none on the wall faces). The corallite walls contain a mid-line, which separates the wall thickness belonging to each corallite from that of its neighbors.

Septal spines occur with varying degrees of prominence. They tend to be short, and essentially normal to the coral-

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lite wall. They never form continuous sheets.

When three corallites meet along a single corallite corner, there is an interdigitation of the mural pores. That is to say, first a pore will connect corallites A and B; above this is a pore connecting corallites A and C; above this, a tube again connects A and B , followed vertically by a tube connecting A and C, and so forth. The result of this is that the corallite corner does not define a straight line along the length of the corallite, as is the case in Favosites, but rather, a zig-zag line. The prominence of this zig-zag will presumably be proportional to the vertical closeness of successive pores.

DISCUSSION - Oekentorp (1971, p. 158-160) has discussed the taxonomic problems attending the nomenclatural history of this genus, and proposed a solution:

When Goldfuss (1829, p. 77) introduced the genus Calamopora into the literature, he described several species under that generic name, including C. alveolaris. This species was designated as the type of Calamopora by King (1850, p. 26; fide Oekentorp, 1971). It is characterized in part by the mural pores being located in the corners of the corallite tubes.

Lonsdale (1839, p. 681) described English corals under the name of Goldfuss' species, but as he considered Calamopora to be a junior synonym of Favosites Lamarck (1816),

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he referred to the specimens as Favosites alveolaris. Of the two specimens Lonsdale illustrated, that shown in his figure 2 (the "larger variety") was determined by Oekentorp (1971) to be identical to Goldfuss' C. alveolaris, after he studied the type material. For the smaller specimen (Lonsdale's figure 1), D'Orbigny (1850, p. 49) erected Favosites aspera, a species in which the pores were also located in the corallite corners, as in C. alveolaris.

Twenhofel (1914, p. 24), recognizing the distinctiveness of mural pores being restricted to corallite corners, erected the genus Paleofavosites (commonly wrongly modified by later authors to Palaeofavosites) to accommodate Favosites prolificus Billings (1865b), and F. capax Billings (1866) (Ordovician and Silurian of Anticosti Island) and Calamopora alveolaris Goldfuss (1829) and Favosites aspera D'Orbigny (1850). Twenhofel assigned the last of these species as the type of the genus. Later (1928, p. 125) Twenhofel stated that he chose F. aspera as the type species because he had believed it identical to Billings' later species, F. prolificus. As of this second writing, however, he no longer felt they were synonymous, and so he sought to change the type species designation to F. prolificus. This latter assignment of type species is invalid.

Inasmuch as the mural pores of both C. alveolaris and F. aspera are restricted to the corallite corners,

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they are congeneric. Consequently, Paleofavosites is a junior synonym of Calamopora. Arguing that the term Calamopora had not been used in the literature for half a century, and that Paleofavosites had in the meantime become firmly established in the minds of paleontologists, Oekentorp (1971) requested that a potentially chaotic situation be avoided through the use of the Plenary Powers of the ICZN to suppress Goldfuss' genus in favor of Paleofavosites. To keep the subjective synonymy from becoming an objective synonymy, he further proposed that F. asper D'Orbigny be retained as the type species of Paleofavosites, rather than allowing Goldfuss' C. alveolaris to remain as the standard for the concept of this genus.

In a recent letter (3 June 1975), Oekentorp informed me that he had submitted a partial list of references in which the name Paleofavosites Twenhofel (1914) had been used in recent years. This list (Oekentorp, 1974) was submitted in accordance with Article 79(b) of the International Code of Zoological Nomenclature, (in Oekentorp's words:) "which requires evidence that the name that is threatened has been used by at least five different authors in at least ten different publications in the last fifty years". Oekentorp was able to fulfill this requirement, but he indicates that as of the date of his letter to me, there has not yet been made a decision on his petition.

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Paleofavosites prolificus (Billings)

Plate 9, fig. 1-5; Plate 29, fig. 5, 6; Plate 36, fig. 1, 3

cf. 1826 Calamopora alveolaris Goldfuss, p. 77,
Plate XXVI, fig. 1a-c

cf. 1839 Favosites alveolaris Lonsdale, p. 681,
Plate 15 bis, fig. 1, 1a, 1b, 2, 2a, 2b

cf. 1850 Favosites aspera d'Orbigny, p. 49

1865b Favosites prolificus Billings, p. 429

1876 Favosites niagarensis Rominger, p. 23,
Plate V, fig. 1 (non Hall, 1852)

? 1890 Favosites niagarensis Foerste, p. 334

1899 Favosites aspera Lambe, p. 4-6, Plate I, fig. 2

1919 Paleofavosites asper Williams, Plate VI, fig. 1a, b;
Plate XVII, fig. 3

1928 Paleofavosites prolificus Twenhofel, p. 126

1933 Favosites aspera Tripp, p. 96, Plate 8, fig. 3;
Plate 9, fig. 1; Text-fig. 20

cf. 1936 Favosites alveolaris Lecompte, p. 66-68,
Plate XI, fig. 4

1940 Favosites asper Sugiyama, p. 126-127, Plate 19,
fig. 11; Plate 20, fig. 2-4; Plate 21,
fig. 9-11

non 1956 Paleofavosites prolificus Stearn, p. 60, Plate 4,
fig. 1; Plate 10, fig. 13

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1963 Palaeofavosites prolificus Nelson, p. 52, Plate 7, fig. 5

? 1966 Palaeofavosites asper Bolton, Plate I, fig. 25, 26

? 1968 Palaeofavosites asper Bolton, Plate 12, fig. 20

Type material - Repository of type material is unknown.

Type locality and horizon - Anticosti Island, within the range of Late Ordovician to Middle Wenlock. The precise horizon is unknown in the case of Billings' specimens, but he (and Twenhofel, 1928) indicate the species is found through the above range.

Number of specimens studied - approximately 100

DIAGNOSIS - Paleofavosites with corallites fairly uniform in diameter, generally 1.0 to 1.5 mm, and less frequently, 2.0 mm across; tabulae horizontal or concave; spines present on walls (small spines), but not on tabular surfaces; wall corners not strongly crenulate.

DESCRIPTION - This is one of the most frequently-encountered coral species in the Brassfield Formation. It often occurs as massive cobbles showing unmistakeable evidence of transport, but is also found in what is presumed to have been its growth-position, undisturbed after death. A maximum diameter of 30 cm is not unusual for a corallum of this species. The convexity of the upper surface of coralla varies, and there is no clear evidence of a peduncle or holotheca. It

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has never been observed to branch. Characteristically, the corallite diameter is fairly uniform at 1.0 to 1.5 mm (rarely 2.0 mm). Of course, smaller corallites occur among the larger ones where new corallites are produced, but they tend to be lost in the crowd of full-grown corallites. This is in contrast to the case of Favosites forbesi (which see), where large corallites are often surrounded and isolated by numerous small ones. Neither do the small corallites occur in fields, as they do in F. hisingeri (which see). These dissimilar patterns doubtless reflect differences in off-setting patterns.

The corallite walls are about 0.2 mm thick. It is not clear if there is a mid-line present. In some specimens, the corallite walls (as seen in transverse section) appear undulose, while in others they are straight.

In the few instances where mural pores have been observed, they occur in the corners of the corallites, rather than on the wall faces. They are narrow, resembling pinholes. In one section (Plate 29, fig. 6; Plate 36, fig. 3) they appear to be about 1 mm apart vertically. The zig-zag corallite junctures seen so often in vertical sections of Ordovician specimens of Paleofavosites are not obvious in our material.

Very short spines, barely visible in whole specimens (Plate 9, fig. 1) occur in the corallites. They are arranged roughly in longitudinal rows which, however, are poorly-

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defined. One count showed 8 in a vertical space of 2 mm (UCGM 41926). Spines do not seem to be present on the tabulae.

The tabulae are usually concave upward, or horizontal. They are spaced 0.5 to 2 mm apart, and this spacing shows distinct vertical zonation (Plate 9, fig. 1, 2; Plate 29, fig. 6). This zonation results in layers of the corallum alternating in their resistance to erosion, so that is is common to find a worn specimen whose base or side shows rugosity.

In the best-preserved specimen (UCGM 41926 , Plate 9, fig. 3), the lower surfaces of the tabulae often show an axially-located protuberance, similar to those seen in the holotype of Favosites favosus (Goldfuss) (Plate 8, fig. 4, 9). One corallite of the same specimen also has one tabula which appears to be radially-fluted, a feature also commonly seen in F. favosus (same figures), representing marginal fossulae.

DISCUSSION - Goldfuss (1826) described Calamopora alveolaris from loose rock fragments from the Eifel and Groningen areas of Germany. He reported the features as follows: The tubes are united in a bulbous mass (the corallum), and are 5- and 6-sided. They are fairly regular, straight, and of nearly equal thickness (diameter?). The tabulae are horizontal, and at each corner of the corallite, the tabula is depressed. Goldfuss believed these points might mark the mouths of mural pores. The mural pores are very numerous, and lie in the

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corners of the corallites. No indication is given of the corallite diameter, unless Goldfuss' figure 1a is natural size. If so, the corallites are rather broader than ours, commonly reaching 2.5, and often 3.0 mm. Goldfuss makes a point of showing the marginal pits of the tabulae. As noted in our description, one corallite of a specimen had what appeared to be such depressions, and it is possible that they are environmentally-induced features, rather than representing a specific taxobasis. They do appear in other species, including some belonging to other genera (e.g., Favosites favosus). Goldfuss' figure 1c shows septal spines similar in size (proportional to the corallite) to ours. The mural pores seem similar in size and arrangement to ours. The possibly greater diameter of the corallites, and the frequent occurrence of marginal pits in the German form, however, discourage identifying the Brassfield species with Goldfuss' material.

Lecompte (1936) described and figured the type of Calamopora alveolaris Goldfuss (the original of Goldfuss' figure). His observations substantiate our interpretation of Goldfuss' description and figures. Further, Lecompte noted that the probable age of Goldfuss' material is Silurian.

Lonsdale (1839) reported Favosites alveolaris from the Wenlock rocks of England. The diameters of his corallites are consistent with ours, in the area of 1 mm, but the corners between corallites are strongly zig-zagged, due to the

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presence of mural pores interlocking from several corallites. This longitudinal zig-zagging is not found to such a degree in our own specimens, so that the English form is not regarded as conspecific with that of the Brassfield.

D'Orbigny (1850) chose as the basis of his species, Favosites aspera, Lonsdale's (1839) figure 1 of F. alveolaris. He records as the date of original description of F. aspera the year 1847, but this publication has not been seen, and 1850 is commonly cited as the date of the original reference (e.g., Bassler, 1915, p. 941). This trivial name (aspera) has often been applied to forms similar to ours, but as noted above, Lonsdale's specimens are not considered conspecific with ours.

Billings (1865b) introduced the name Favosites prolificus for specimens from Anticosti Island ("Hudson River group and throughout the Middle Silurian"). The original description is: "Corallum forming large hemispheric or irregularly convex masses. Tubes about one line in diameter. Tabulae thin and either complete or imperfect, sometimes filling the tube with vesicular tissue. They are often very numerous, there being sometimes six or seven in one line. No septa or mural pores have yet been detected, and it may be that this species should be placed in another genus."

No figure accompanied this description. So far as it goes, the description agrees well enough with our specimens. Unfortunately, important information concerning the mural

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pores, corallite junctures, spines and topography of the tabular surfaces is lacking. Twenhofel (1914, p. 24) remarked that it had been found that F. prolificus has the pores in the corners. He later (1928, p. 125) expressed some doubt that F. aspera and F. prolificus were (as had by then come to be believed) identical. As the evidence discussed above shows, our form is not conspecific with either C. alveolaris or F. aspera. As specimens described under the name of Favosites (later Paleofavosites) prolificus are in general agreement with the Brassfield form, it seems best to use that name in the present work, pending investigation of type material.

From the "Niagara Group" of Point Detour, northern Michigan, Rominger (1876) described a form which he wrongly identified with Hall's Favosites niagarensis. It is probable that this specimen (UMMP 8438) comes from the Manistique Group (Late Llandovery through Middle Wenlock). The corallites are polygonal, about equal in diameter (generally 1.5 mm). The tabulae are flat and their spacing shows zonation. Delicate spines are present on the walls. The mural pores are situated close to the corners, and are not numerous. In all important characters this specimen is identical with the Brassfield form, and is considered conspecific with it.

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Foerste (1890) reported Favosites niagarensis (based on the similarity of his specimens to Rominger's material) from the "Clinton Group" (Brassfield Formation) in Ohio, noting it as the most common species in the unit. This commonness strongly suggests that Foerste was referring to the present species, but the paucity of data in his description (consisting of corallite diameters and tabula-spacing, garnished with occasional references to tube-crenulation) precludes any certainty of this.

Lambe (1899) reported Favosites aspera from Anticosti Island in the Canadian Maritime area, and from Stony Mountain and Stonewall, Manitoba. The age of Lambe's material is uncertain, but the Type Invertebrate Fossil Catalogue of the Canadian Geological Survey (1960, vol. I, p. 30) notes Upper Ordovician units (Stony Mountain Formation and Stonewall Formation) at Stony Mountain and Stonewall quarry, both in Manitoba. It is likely, then, that the Manitoba material is of about this age.

The coralla were massive and large. The form was convex upward, with a flat bottom. Lambe reported an "epitheca" covering the bottom, though this has not been seen in any of our specimens. The corallites averaged 2 mm in diameter, and were rather equal-sized in a given specimen. The tabulae were complete, horizontal or sometimes convex or concave, and were spaced usually 0.5 to 1.0 mm apart, sometimes more.

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Apparently the spacing shows vertical zonation. Small marginal pits were sometimes present, as a rule small and inconspicuous. The pores were of "moderate" size, in or near the angles of the walls, and quite numerous in some specimens. Spacing was about 0.75 mm apart. The pores were sometimes enclosed by a raised rim. In some rare instances, the pores were present on the faces of the corallite walls.

Septal spines occurred on the corallite walls in longitudinal rows, and were generally short. The corallite diameter varied between specimens, ranging down below 1 mm in some cases, while in others they range from 0.5 to 2 mm. The single figure accompanying the description shows a corallite in stereotype form, with rather large pores, nearly as wide as the distance between them. The wall is slightly zig-zagged. From the description and figures it seems that at least some of the specimens studied by Lambe belong to our species. The greatest discrepancy is the apparently greater diameter of the pores in the Canadian specimens. The spacing between the pores, however, is comparable to ours, and recrystallization may have affected the size of the pores in the Brassfield specimens, sometimes obliterating them completely. It seems, then, that Lambe's specimens may be considered conspecific with our own.

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Williams (1919) illustrated specimens of what he referred to as Paleofavosites asper (sic) from the Manitoulin and Fossil Hill Formations (Early and Middle Llandovery, respectively) of Manitoulin Island. The corallite diameters are fairly uniform, mostly 1.0 to 1.5 mm, and the mural pores are apparently small, and in the corners of the corallites. The resemblance to our specimens is such that they are regarded as conspecific.

Twenhofel (1928) reported Paleofavosites prolificus from the Late Ordovician through the Middle Wenlock ("throughout the Anticosti measures") of Anticosti Island. This range is similar to that of Propora conferta (which see) on the island. The specimens have corallites with diameters of 1 to 1.5 mm, and tabulae which are horizontal, concave or convex. The tabulae are spaced 0.33 to 2 mm apart. Submarginal pits are rarely visible, and indistinct even where they do occur. The mural pores are small, less than 0.25 mm in breadth, and spaced 8 to 9 in 5 mm. They are not often visible (as is the case with our specimens). They lie in the corallite corners, and the walls marginal to each pore are "arched to make a depression about the pore". This is taken to mean that the pores are at the ends of protuberances (lateral) in the corners, usually seen in Paleofavosites, and apparently weakly-developed in ours. Spines are present. Twenhofel noted that this species is one of the most common on Anticosti Island, and one of the most wide-ranging, run-

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ning from the base of the English Head Formation (Upper Ordovician) to the base of the Chicotte Formation (Uppermost Llandovery). The agreement between the Anticosti form and that of the Brassfield is such that they are probably conspecific.

Tripp (1933) recognized the lack of firm criteria for speciating favositids, and so resorted to using form-groups in his study of the Gotland favositids. His Aspera-forms are typified by the following: The corallites are 1 mm in diameter, with more-or-less constant size throughout the colony. Spines are seen only sporadically. The pores lie in the corners of the corallites, in small out-bayings of the walls, resulting in a waviness of the walls in longitudinal section. This waviness, to judge from his figures however, is not always marked. The pore diameter is 0.1 mm, which is 0.1 the corallite diameter. Tripp noted that this relationship of pore to tube diameter holds for all members of the Aspera-form known to him. The tabulae are mostly gently concave upward, and spaced about 2 per millimeter. (although the spacing is clearly zoned). The coralla are massive. Tripp's description and figures generally agree so well with our specimens that it is probable that the Gotland and Brassfield forms are conspecific. The figure of a specimen in best agreement with our material (Plate VIII, fig. 3) represents a specimen from the Högklint beds (Early Wenlock).

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Sugiyama (1940), in his study of the stratigraphy and paleontology of the Kitakami region of Japan, described several specimens similar to the present species, from the "Clathrodictyon" and "Halysites" Limestones. These horizons are assigned to the Salopian (Wenlock and Lower Ludlow) equivalents of England (see Hamada, 1958, Table 2, p. 95). The coralla are massive. In one of the three specimens he described, the corallites are usually 1.0 to 1.5 mm in diameter, with thin, straight walls, about 0.06 to 0.1 mm thick. Its tabulae are usually flat and complete, with 4 to 5 occurring in 2 millimeters vertically. The mural pores are of "moderate" size, in two rows located very close to the angles, but sometimes on the wall faces. Rarely, septal spines were observed, arranged in a regular manner.

A second specimen differed from the first in having smaller corallites (0.7 to 1.2 mm diameter), with tabulae normally concave.

A third specimen differed from the other two in having more numerous spines, and wavy walls.

Sugiyama regarded these specimens as similar enough to be conspecific. The available data indicate that these specimens are likely identical to the present species.

Stearn (1956) reported Paleofavosites prolificus from the Upper Ordovician of southern Manitoba (Interlake Group, Stonewall Formation, and especially the Stony Mountain Formation), but his corallites are two wide (uniformly 2.34 mm)

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to be considered conspecific with the present species, as we understand it.

Nelson (1963) reported this species (P. prolificus) from the Chasm Creek Formation (Upper Ordovician) of Manitoba. The corallites are fairly uniform in diameter, 1.5 mm. Mural pores occur in the corners of the corallites, and are about 0.1 mm in diameter. The tabulae are flat and close-spaced, about 4 to 6 occurring in a distance equal to the corallite diameter. In all features noted by Nelson, this form agrees with our own, and they are considered identical.

Bolton (1966, 1968) illustrated two specimens identified as Palaeofavosites asper (sic) from the Manitoulin Formation (Early Llandovery) of Manitoulin Island. Only surficial views are shown, and these are in good agreement with our specimens, showing massive coralla with a uniform corallite diameter of about 1.5 mm. Nothing is revealled of the interior. If investigation of the original specimens (GSC 20481 and GSC 17961) showed a zig-zagging of the corallite corners at the mural pores, then these specimens might correctly be assigned to d'Orbigny's species, as Bolton has done. If the zig-zagging is absent, or not pronounced, then it would be best to assign them to P. prolificus.

Our dealings with Paleofavosites prolificus in this study have served to emphasize the poor state of our taxonomic concepts concerning the favositids. P. prolificus and P. aspera, as understood in this study, differ basically in

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the greater degree of crenulation of the corallite corners in the latter. Yet, in several cases, it appears that such crenulation may occur in some parts of a specimen, and not in others. It is, then, similar to the matter of marginal fossulae in Favosites favosus, and in some Paleofavosites, these features being sometimes ubiquitous, sometimes sporadic, and sometimes absent from specimens which differ from one another in this respect.

It is possible that the development of crenulated sutures is related to the spacing experienced by the mural pores. Where only two or three corallite corners meet at a suture, then possibly communication through pores can be affected without resorting to the formation of tubes. On the other hand, when four corallites meet along a narrow suture, then they must alternate pore communication between opposing corallites. In this case, pore juncture between the east-west pair of corallites effectively forms the upper and lower walls of the pore junctures between the north-south pair. if this is so, then it would necessitate regarding P. prolificus as a junior synonym of P. aspera. Pending further study, however, they will be regarded as distinct.

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Distribution - Anticosti Island: Late Ordovician through Late Llandovery; northern Michigan: within the range of Late Llandovery to Middle Wenlock; Manitoba: Late Ordovician; Manitoulin Island: Early and Middle Llandovery; Gotland: Early Wenlock; Japan: Wenlock and Early Ludlow; Ohio (and possibly Indiana and Kentucky): Middle Llandovery (Brassfield Formation).

Brassfield occurrence - Ohio localities: 2 (north of Manchester), 7a (near Fairborn), 11 (near West Union), 14 (Piqua), 37 (Turtle Creek near Sharpsville).

Questionable occurrences include the following:

Ohio: localities 13 (Todd Fork Creek near Wilmington), 15 (near West Milton).

Indiana: locality 26 (Elkhorn Falls near Richmond).

Kentucky: localities 30 (near Seatonville) and 53a (near Irvine), the latter in the Noland Member.

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Family Halysitidae Milne-Edwards & Haime, 1850

nom. transl. Duncan, 1872 (ex Halysitinae Milne-Edwards & Haime, 1850)

Cateniform Tabulata, with ranks only one corallite thick; corallites circular or elliptical in cross-section; corallite walls two-layered; longitudinal elements (septa), when present, occur as acanthine septa, 12 in number; no mural pores present; space between neighboring corallites may contain an interstitial tube (smaller corallite?) which, like the larger corallites, is tabulate; tabulae of these interstitial tubes, and the peripheral portions of the interiors of the corallites, may be vesiculose (Cystihalysites); balken may occur in the margins of the small, intermediate corallites.

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Halysites Fischer von Waldheim, 1828

1813 *Alyssites* Fischer von Waldheim, p. 387

1828 *Halysites* Fischer von Waldheim, p. 15

1954 *Halysites* Thomas & Smith, p. 766 (*partim*)

1955 *Halysites* Buehler, p. 21, 24-25

1956 *Halysites* Duncan, p. 222-223 (*partim*)

1957 *Schedohalysites* Hamada, p. 397, 401

1957 *Acanthohalysites* Hamada, p. 397, 404

Type species - (By monotypy) *Tubipora catenularia* Linnaeus, 1767, p. 1270.

Type locality and horizon - "Thrown up on the shores of the Baltic" (*fide* Buehler, 1955, p. 24). Neotype (see section on systematics of *Halysites catenularius*) is from the Silurian of Gotland.

DIAGNOSIS - *Halysitidae* with circular or oval corallites arranged in ranks of 2 or more; interstitial tubes present between some or all corallites; tabulae in both corallites and interstitial tubes complete.

DESCRIPTION - These are corals of cateniform habit, that is, with corallites arranged like the vertical poles of a palisade, to form the ranks of the corallum. The individual walls of this palisade branch from each other and connect with other branches, so as to produce what looks, from above, like an aggregation of interlinked chains. Each corallite

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is prostrate basally, except for those which arise relatively late, through interstitial budding. Distally, the corallites flex upward, so that for its greatest length, each corallite has a vertically-directed axis.

There are two sorts or tubular structures constituting the corallum; the corallites, and the interstitial tubes (usually referred to as microcorallites or mesocorallites in the literature; see section on morphologic terms). The corallites are the larger and more obvious of these tubes, and the interstitial tubes alternate between all or some of the pairs of corallites in the ranks. Both sorts of tubes possess two-layered walls, of which the outermost is thin and optically-denser than the inner layer, and is continuous along the outer surfaces of the ranks, on both sides. Within the limits of the two sides of outer wall is the inner, coenosteum-like layer which directly lines both the corallites and the interstitial tubes.

A distinctive feature called "balken" is sometimes found in the form of vertical rods lying in the four corners of the interstitial tubes, parallel to the axis. These are of various forms, and are probably an important specific taxobasis for this genus (See Hamada, 1959, p. 282-284 for a discussion of this feature).

The corallites and interstitial tubes contain tabulae; those of the latter are generally closer-spaced than those of the former. Spines (acanthine septa) are found in the

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corallites (not, apparently, in the interstitial tubes) of some species, and their development within a given specimen varies.

DISCUSSION - It was Fischer von Waldheim who, in 1813 (p. 387) erected the genus Alyssites (Greek for "chain rock") for Tubipora catenularia Linnaeus (1767), a species he determined not to be a true Tubipora. In a subsequent paper (1828, p. 15) he used, for the first time, Halysites, thus altering the spelling (though not the meaning) of the original generic name. Fischer von Waldheim apparently considered this emendation completely insignificant, as he made no reference to it in his 1828 paper, and further states in this work (p. 15) that, "Les Membres de notre Société, ainsi que mes élèves, connoissent ce genre sous le nom de Halysites depuis 1806." If this reference to long-standing usage was actually to the orthography Halysites, it suggests that the author considered the latinized transliterations of the Greek word to be interchangeable in taxonomic usage, as they would be lexicographically.

Thomas and Smith (1954, p. 766), in their study of Halysites, considered Fischer von Waldheim's emendation to be correct. (Actually, they quote Lang, Smith & Thomas, 1940, p. 64, as judging this action a proper one, and noted its general acceptance.) Buehler, however (1955, p. 21) considered such an emendation to be contrary to the rules of the International Code of Zoological Nomenclature.but felt

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that a reversion to the use of Alyssites would cause undue confusion in the literature. He indicated his intention to petition the International Commission on Zoological Nomenclature to suppress Alyssites. Recently, however, Buehler informed me (personal communication) that such a petition never materialized, as he had become convinced that Fischer von Waldheim's emendation was legal. This does not seem to be the time or place to resolve the matter, and for the time being at least, the subsequent and commonplace rendition for the generic name will be used.

Fischer von Waldheim (1828, p. 15) noted Lamarck's introduction of the generic name Catenipora (1816), but considered it a synonym of his Halysites-Alyssites (1813). Nonetheless, Catenipora continued in use, appearing in Goldfuss' work (1826) and that of Hall (e.g., 1852). The latter seems to have been the last author to employ Catenipora as a valid generic name until its resurrection by Buehler, in 1955 (see Catenipora synonymy). Even in their taxonomic study of the genus Halysites, Thomas and Smith (1954) considered Catenipora escharoides (Lamarck, 1816), the type species of Catenipora Lamarck, to be congeneric with Halysites catenularius (Linnaeus, 1767), placing both species in Fischer von Waldheim's genus.

The upshot of this has been a long history of the use of Halysites for Catenipora (see discussion under Catenipora). As noted above, Buehler resurrected the term Catenipora as a

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valid generic name, and Hamada, in his important work on the Halysitidae (1957) accepted this, the while considering spiniferous specimens, otherwise assignable to Halysites, to belong to his genus, Acanthohalysites (p. 397, 404). It now seems that the development of spines in the halysitids may be gradational within a genus, perhaps even within a species, or a single specimen (as seems to be the case in Favosites), and consequently, Acanthohalysites is here considered a junior synonym of Halysites.

Duncan (1956), in her survey of Ordovician and Silurian corals of the western United States, used Catenipora (as well as Cystihalysites Chernyshev, 1941b, p. 70, based upon Cystihalysites mirabilis from the Upper Silurian of the southwestern Taimyrs in Siberia) as a subgenus of Halysites.

Hamada's (1957) Schedohalysites was intended to accommodate those halysitids in which the interstitial tubes are present in certain portions of the corallum, but not in others. It now appears that these structures are not necessarily ubiquitous in a corallum of Halysites, either as a result of the natural living form of the colony, or the vagaries of preservation. It seems best, then, to consider a corallum assignable to Halysites if it has any interstitial tubes at all, provided that it does not fall into the realm of Cystihalysites (in having vesicular dissepiments in the interstitial tubes and the peripheries of the corallite lumens). Consequently, Schedohalysites would be a junior synonym of Halysites.

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Halysites catenularius (Linnaeus)

Plate 29, fig. 3, 4; Plate 32, fig. 2, 3; Plate 38, fig. 2

1767 *Tubipora catenularia* Linnaeus, p. 1270-1271

? 1875 *Halysites catenularia* Nicholson, p. 227

? 1876 *Halysites catenulata* Rominger (*partim*), p. 78-79, Plate XXIX, fig. 1, 2 (*non* fig. 4)

? 1890 *Halysites catenulatus* Foerste, p. 337-338

1904 *Halysites cratus* Etheridge, p. 27-29, Plate I, fig. 1; Plate IV, fig. 3, 4; Plate VI, fig. 5, 6

? 1909 *Halysites catenularia* Foerste, p. 10

? 1928 *Halysites catenularia* Twenhofel, p. 125

? 1939 *Halysites catenularia* Shrock & Twenhofel, p. 255; Plate 29, fig. 18 (*possibly* 21, 23)

? 1939 *Halysites catenularia* Northrop, p. 153

1954 *Halysites catenularius* Thomas & Smith, p. 766-768, Plate XX, fig. 1a-c

1955 "The Genotype of *Halysites*" Buehler, p. 24-25

1955 *Halysites catenularius* Buehler, p. 28-29

1958 *Halysites cratus* Hamada, p. 101, Plate X, fig. 5, 6a, b

1961a *Halysites junior* Klaamann, p. 93-95, Plate XII, fig. 1-5, text-fig. 6

1962 *Halysites catenularius* Flügel, p. 316-317, Plate 22, fig. 4

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Type material - Neotype (of Thomas & Smith, 1954, p. 767): Specimen no. 1 of the Bromell Collection in the Paleontologiska Institution, Uppsala, Sweden; described and illustrated by Bromell (1728), p. 411, no. 5, and fig. 11 on the plate opposite p. 410. This specimen is figured by Thomas & Smith on their Plate XX, fig. 1a-c, and is shown in the present work on Plate 29, fig. 3, 4, and Plate 38, fig. 2.

Type locality - Silurian of Gotland

Number of specimens studied - 1

DIAGNOSIS - Halysites with nearly-ubiquitous interstitial tubes, lacking balken; corallites circular to elliptical in cross-section, measuring about 1.5 X 1.0 mm on the inside diameter; interstitial tubes tetragonal in cross-section, with longer side perpendicular to direction of rank extension, or else equal-sided (square); spines apparently absent, or else very weakly-developed; ranks frequently join to form lacunae.

DESCRIPTION - The original size and shape of the Brassfield corallum is difficult to deduce from the available material. The longest corallite is 3.5 cm in length, and seems to be based upon a very thin, apparently solid encrusting object. The length of the ranks varies considerably, most consisting of 3 to 7 corallites. The lacunae may be long and narrow (26 X 2 mm) or more nearly equilateral and smaller (7 X 4 mm).

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The corallites are elliptical to circular in cross-section. Their internal diameter parallel to the direction of rank extension is fairly constant at 1.5 mm, while the diameter across the rank varies from about 1.0 mm (in elliptical tubes) to 1.5 mm (in circular ones).

Between almost every pair of corallites is an interstitial tube. These are tetragonal in cross-section, rather variable in size (although always far smaller than the corallites). In the direction of rank extension, these are from 0.06 to 0.25 mm wide (mostly about 0.20 mm). Across the rank they are 0.06 to 0.3 mm wide. Characteristically, their greatest dimension lies perpendicular to the direction of rank extension.

The corallites and interstitial tubes are enclosed on two sides by a theca, about 0.2 mm thick. They are not, however, separated from the immediately-preceding or following corallite by this theca. Instead, between each pair of corallites lies a deposit of skeletal material which is optically less dense than the theca. Within this deposit lies the interstitial tube. The above-mentioned theca appears to consist of two layers, the outer accounting for about 1/3 of the thickness, represented by an optically denser deposit than the inner layer.

The tabulae of both the corallites and interstitial tubes are shallowly concave upward. Those of the former are spaced in the order of 1.6 to 1.8 per millimeter, and are

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nearly all complete. Those of the latter are spaced about 4.8 per millimeter. There is a suggestion of zonation in the tabular spacing in the corallites, but not enough material has been studied to determine the degree to which it occurs.

While no spines have been observed on the walls of the corallites, vertical sections reveal longitudinal striations on these walls which may reflect sutures or planes of the intercorallite region (Plate 32, fig. 3).

DISCUSSION - Linnaeus (1767) gave the name Tubipora catenularia to fossil corals "projicitur frequens ad Littora M. Balthici" ("frequently cast upon the shore of the Baltic Sea"), which he diagnosed as consisting of parallel tubes connected in contorted-plicated anastomozing laminae. He further noted the presence of a firm, erect skeleton, which in cross-section appears like simple series of chains. The tubes are equal (in diameter?), connected laterally. There appears to be no mention of interstitial tubes.

While preparing his discourse on the halysitids, Buehler realized the necessity for an adequate description of the type species of Halysites. This need was fulfilled by Thomas & Smith (1954) who selected a neotype (see above) from the Bromell Collection, as Bromell's work (1728) and specimens were referred to by Linnaeus in his synonymy for T. catenularia, and in some of his earlier works.

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Thomas & Smith (p. 767-768) described the neotype, whose general characters are as follows: The corallites are spaced along the chains about 5 in 10 mm, with calicular centers about 1.9 mm apart. The internal diameters are about 1.52 X 1.18 mm, with walls about 0.19 mm thick. There are usually 7 to 8 corallites to a long rank, and about 2 to 3 in a short one. The juncture of these ranks produces rather elongate lacunae, often only 1 to 2 mm wide and up to 30 mm in length. Between each pair of corallites is an interstitial tube, square or rectangular in cross-section. Bifurcation of ranks always occurs from these interstitial tubes. The interstitial tubes, when not equal-sided, are elongate at right angles to the direction of rank extension, and measure, on average, 0.31 X 0.19 mm.

The corallites contain tabulae which are complete, and either near-horizontal or gently concave upward, spaced about 2.2 to 2.4 per millimeter. The tabulae of the interstitial tubes have the same topography, and average 2.4 to 2.8 per millimeter. Septa (including spines?) are reportedly absent. Sections of the neotype, kindly loaned the author by the Paleontological Institution at Uppsala, Sweden, are shown on Plate 29, fig. 3, 4, and Plate 38, fig. 2.

There is good agreement between the neotype of Linnaeus' species, and the Brassfield specimen assigned to it. The corallites and interstitial tubes are of the same size and shapes, and the tabulae of both have the same topography in

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both specimens. The lacunae tend to be elongate in both specimens, and the theca is of the same type. Balken are apparently absent in the neotype, as they are in the Brassfield specimen. The only noticeable difference is that the tabulae of the neotype corallites are somewhat closer-spaced, and those of its interstitial tubes rather wider-spaced, than is the case in our specimen. The similarities seem strong enough, and the differences sufficiently trivial, to allow confident identification of the Brassfield form as H. catenularius.

Nicholson's (1875) reference to Halysites catenularia (sic) from the "Clinton Group" of southwest Ohio is based upon several specimens, and the information given is too vague for determination of the appropriateness with which he has used the name. His observation that septa can readily be seen in many cases, and the great range of the corallite diameters among his specimens (about 0.7 to 3.5 mm), together with the absence of any reference to interstitial tubes, leaves Nicholson's identification open to question.

Likewise, Rominger's descriptions and figures of specimens from the Silurian of northern Michigan at Drummond Island and Point Detour, identified as Halysites catenulata (sic) Linnaeus, must remain in question. It is clear that he was dealing with several species (a probability that he acknowledged, assigning them to Linnaeus' species only because he could find no break in their mutual intergradations).

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Some of his specimens with particularly large corallites diameters of 2 mm or more) may belong to Halysites labyrinthicus (Goldfuss), originally described from Drummond Island. Rominger's figure 4 has small corallites with nearly-parallel sides, and is a distinct species (possibly conspecific with Harmodites ramosa Fischer von Waldheim (1828, fig. 5). The absence of mention of interstitial tubes or septal spines makes it difficult to be certain of the species to which Rominger's specimens might be assigned.

Foerste (1890) reported halysitids from southwest Ohio, apparently from Brassfield strata. His information concerns only tube diameters, corallum sizes, and in one instance, tabular spacing, none of which is sufficient to determine species.

Etheridge (1904) described Halysites cratus from New South Wales, Australia. The age is not given, but is probably Silurian. The corallum consists of chains of varying length, consisting of 1 to 6 corallites, with 4 being the most common number. The lacunae are of variable form, and include equidimensional and quite-elongate examples. The corallites are elliptical to circular in cross-section, measuring 1.5 to 2.0 X 1.0 to 1.5 mm in diameter, elongate parallel to the direction of rank extension. Etheridge does not indicate whether this is the inside or outside diameter. Between the corallites lie tetragonal interstitial tubes, transversely-elongate, measuring 0.5 to 0.75 X 0.25 to 0.75 mm.

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The tabulae of these tubes are complete and horizontal, spaced 4 to 5 per millimeter. Those of the corallites are complete, and horizontal or concave, spaced 2 to 3 per millimeter. The sections in Etheridge's Plate VI, and the description do not indicate the presence of spines or balken in the interiors of the corallites. Despite the slightly greater length of the corallites, it seems reasonable to synonymize Etheridge's species with H. catenularius.

Foerste (1909) reported Halysites catenularius from the West Union "horizon" (Late Llandovery or Early Wenlock) of Kentucky. The only information he gave is that the corallite diameters are 2 mm along their greatest width, and there are colse-spaced, strongly-arched (convex?) tabulae in the corallite lumens. It seems doubtful that Foerste was here dealing with H. catenularius.

Twenhofel (1928) gave a vague reference to this species occurring at Anticosti Island, from the English Head Formation (Late Ordovician) through the Chicotte Formation (Early Wenlock). Commonly, the corallites are about 1 mm in diameter, and are spaced 4 per centimeter. This is in agreement with our specimen. Interstitial tubes, reportedly, are usually, but not always present. There is insufficient information to validate the identification of this species. The oldest of Twenhofel's specimens, the one from the English Head Formation, has no interstitial tubes, and the corallites are nearly square in outline, features which

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would certainly exclude it from Linnaeus' species as understood in this work.

Shrock & Twenhofel (1939) reported corals, some of which may belong to H. catenularius, from northern Newfoundland. They were from the Pike Arm and Natlins Cove Formations, of Silurian age. According to these authors, the corallites "range in length from 1 to 3 mm, with from 3 to 8 corallites in a distance of 10 mm, and in width from 0.5 to 1 mm. In most specimens there are tiny tubules between the corallites. These may be circular or quadrangular in transverse section. They range in length from 0.5 to 1 mm and in width from 0.3 mm to 0.75 mm. Both corallites and tubules are closely tabulate, with the tabulae in the former horizontal and spaced about 8 in 5 mm; in the latter, convex upward and spaced about 13 in 5 mm". Figure 18 of these authors, an enlarged transverse section of part of a rank, strongly resembles our form in size and shape of the corallites and interstitial tubes, and in the apparent absence of septal spines. If, however, the tabulae of the interstitial tubes are convex upward, as indicated in the description, then this specimen might be more-reasonably assigned to Halysites brownsportensis Amsden (1949). All-in-all, it seems wiser to await more detailed data before accepting the presence of H. catenularius in Newfoundland.

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Northrop (1939) reported this species from Gaspé, maritime Canada, in beds ranging in age from Late Llandovery to Middle Ludlow (the Clemville, La Vieille, Gascons, Bouleaux, West Point, and Indian Point Formations). Unfortunately, the only morphologic data given is the fact that interstitial tubes were present, and that there is much variety of form, certainly not enough information to validate the identification with Linnaeus' species.

Hamada (1958) reported Etheridge's Halysites cratus from what he considered Lower Ludlovian beds in southern Japan. The chains consist of 2 to 4, sometimes 5 corallites, surrounding lacunae of polygonal cross-section. The corallites are rounded-elliptical, about 1.6 X 1.4 mm in diameter (elongate in the direction of rank extension) and have a theca 0.1 mm thick. Between them lie interstitial tubes, tetragonal in cross-section (though Hamada says they are triangular), elongate transverse to the direction of rank extension. These are about 0.3 X 0.8 mm on a side. The tabulae in these, and in the corallites are complete and horizontal, spaced 2 to 3 per millimeter in the corallites and 3 to 4 in the interstitial tubes. Septal spines were not observed. Hamada considered his specimens similar to the neotype of H. catenularius (Linnaeus), but differing in lacking its labyrinthine lacunae and rather thick corallite walls. The difference in thecal thickness (0.1 mm, as compared to 0.19 in the neotype) is not here considered critical,

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nor is the configuration of the lacunae. (Etheridge's specimen, with which Hamada's is in good agreement, had both equidimensional and quite-elongate lacunae.) It seems, then, reasonable to assign Hamada's form to H. catenularius, as was done in the case of Etheridge's.

From the Yagarakhuskii horizon (Wenlock in age) near Saaremaa, Estonia, Klaamann (1961a) reported a new halysitid species which he named Halysites junior. This consists of ranks with as few as 2 and as many as 13 corallites, enclosing polygonal or elongate lacunae. The corallites are 1.8 to 2.3 mm in diameter. The theca is 0.25 to 0.30 mm thick, slightly less at the interstitial tubes, which appear to be nearly ubiquitous. These latter are tetragonal in cross-section, elongate at right angles to the rank extension, and usually have a width of 0.25 to 0.3 mm, though this can decrease to 0.05 to 0.1 mm. The tabulae of the corallites are usually complete, and horizontal to slightly concave upward, spaced 2 to 5 per millimeter. Those of the interstitial tubes are usually complete, horizontal, and spaced 4 to 5 per millimeter. Spines are reportedly absent, and there is no indication of the presence of balken. Halysites junior is very similar to the neotype of H. catenularius, and with our specimen of that species, except that its corallites are rather larger. Corallites whose diameters were of the lower limits reported by Klaamann (1.8 and 1.5 mm) would not be out-of-line with those of the

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neotype and the Brassfield specimen. Also, Klaamann reports that his material consisted of twenty specimens, so that it is unclear whether his range was to be found among several coralla, or within one. It is likely, in the face of all the other similarities, that Klaamann's species belongs to H. catenularius, and represents a form with unusually large corallites.

From the Silurian of Ozbak-Kuh, northeastern Iran, Flügel (1962) reported Halysites catenularius. This form consists of chains of up to 8 corallites enclosing what appear to be moderately-elongate lacunae. The corallites have diameters of 1.75 X 1.125 mm, elongate in the direction of rank extension, with walls 0.2 to 0.225 mm in thickness. The walls have an outer layer, optically-denser than the inner wall (as is the case with the Brassfield form), and this is 0.02 mm thick. The corallites in the Iranian form are spaced 5 per centimeter (as compared with about 4 per centimeter in our specimen), and their centers lie 2.0 to 2.5 mm apart (the same as in the Brassfield form). Between the corallites lie tetragonal interstitial tubes, with minimum dimensions of 0.3 X 0.4 mm, and maximum of 0.3 X 0.65 mm. Judging from Flügel's figure 4, these may be equidimensional, or elongate either in the direction of rank extension or perpendicular to that direction. The tabulae of the corallites are horizontal, spaced 2 to 3 per millimeter. Those of the interstitial tubes are 3 to 4 per

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millimeter. There appear to be no obvious septal spines, and no balken. As Flügel points out, his material agrees well with the neotype of Halysites catenularius, and there seems to be no sound reason for doubting his identification.

Distribution - Gotland: Silurian; Estonia: Wenlock; Ohio: Middle Llandovery (Brassfield Formation); Iran: Silurian; Australia: Silurian; Japan: Early Ludlow.

Reported occurrences deserving further study include: Anticosti Island: Llandovery to Early Wenlock; Newfoundland: Silurian; Gaspé: Late Llandovery to Middle Ludlow.

Brassfield occurrence:- Locality 14, near Piqua, in southwest Ohio.

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Halysites nitidus Lambe

Plate 31, fig. 3, 4; Plate 38, fig. 1

1899 Halysites catenularia, var. nitida Lambe, p. 71, 76, 77, Plate IV, fig. 2, 2a, 2b

? 1926 Halysites pulchellus Wilson, p. 15, Plate III, fig. 8, 9

1955 Halysites nitida Buehler, p. 49, Plate 8, fig. 4-7; Plate 9, fig. 1

? 1962a Halysites nitida Norford, Plate IX, fig. 7, 12

1964 Halysites louisvillensis Stumm, p. 79, Plate 80, fig. 8-10

1971 Acanthohalysites sp. Scrutton, p. 221-222, Plate 5, fig. 5, 6

Type material - Holotype: GSC 3035, the specimen figured by Buehler (1955) in his Plate 8, fig. 6, 7. The Catalogue of Type Invertebrate Fossils, Volume I, by T.E. Bolton (1960, p. 40) gives the above number as the catalogue number of the holotype, but Buehler gives the number as GSC 104761. His figures are of photographs supplied him by W.A. Bell of the Canadian Geological Survey, and it is not clear if the specimen or the number is in error.

Type locality and horizon - According to the GSC catalogue, the La Vieille Formation (Late Llandovery and Wenlock) at L'Anse à la Barbe, Chaleur Bay, in the Gaspé region of Quebec. (Lambe, p. 76, considered this unit to be of

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Lower Helderberg stratigraphic position.)

Number of specimens studied - 2

DIAGNOSIS - Halysites with corallite diameters generally 1.2 to 1.5 mm in direction of rank extension, and 0.7 to 1.0 mm at right angles to that direction; interstitial corallites tetragonal, not ubiquitous; corallites with 12 longitudinal rows of septal spines; ranks frequently join to form lacunae; balken absent.

DESCRIPTION - Two coralla have been found at two different localities. The larger (UCGM 41651) was found in life-position at locality 14, near Piqua, Ohio. Sections of this specimen are shown on Plates 31 and 38. About 5.5 cm of its original height remains, and the width of the upper portion of the corallum is 7 cm. The smaller specimen (UCGM 41997) is from locality 30, near Seatonville, Kentucky, and measures 4.5 cm high and 3.5 cm across the top. The lacunae are of variable pattern. In the Piqua specimen they include both equilateral forms (4 X 4 mm) and more elongate ones (7 X 3 mm). There are usually 3 to 5 corallites to a rank, the latter more commonly than the former. The pattern in the Seatonville specimen is similar.

The corallites of our specimens are elliptical, longer in the direction of rank extension that at right angles to that direction. Those of the Piqua specimen are rather varied in size and shape, one having inside diameters of

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2.0 X 0.7 mm, another having diameters of 1.3 X 0.8 mm. As is the case with our specimen of Halysites catenularius (Plate 32, fig. 2, 3), the length of the corallites is more variable than the width, some being quite elongate, while others are nearly circular in cross-section. The corallites of the Seatonville specimen are more uniform in size, typically 1.3 X 0.7 mm on the inside. The theca of the Piqua specimen (the better-preserved of the two) is about 1.2 mm thick, and consists of two layers, the outer being more optically-dense than the inner.

Between some of the corallites are tetragonal interstitial tubes, usually widest in the direction perpendicular to the rank extension. Typically these are 0.3 X 0.1 mm across, but one equidimensional representative measures 0.1 mm in both directions. These features are set in skeletal deposits with about the optical density of the inner thecal layer, but are apparently structurally-distinct from it. In this sense, the structure is similar to that found in H. catenularius. There is no evidence of balken in these specimens.

The spines are well-developed, up to 0.2 mm long.(Plate 38, fig. 1), and are inclined upward toward the axis. They do not, however, appear in every corallite, whether due to differential preservation, or to differential occurrence in life.

The tabulae of the corallites are concave upward, and spaced about 2 per millimeter. Those of the interstitial

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tubes are spaced about 6 per millimeter.

DISCUSSION - Lambe (p. 76, 77) gives the corallite diameters as 1.45 X 1.00 mm, and the average width of the interstitial tubes as 0.50 mm. The lacunae are reportedly long and narrow, 3 to 5 mm across, often with several parallel ranks. Spines are present, shown as pointing upward in the figure (also noted in our section). The tabulae of the corallite tubes are reported as flat or slightly convex (though in Lambe's figure they are nearly all flat or gently concave), spaced 2 to 4 per millimeter. Those of the interstitial tubes are reportedly straight (probably meaning horizontal) or slightly convex, at times vesicular.(incomplete, also seen in our material).

Wilson (1926) reported Halysites pulchellus, a new species from the Beaverfoot Formation (Late Ordovician or Llandovery) of British Columbia. The specimen was described as having corallites "oval" (elliptical?) in outline, 1 mm wide, with about 3 corallites in 5 mm (similar to our specimens). The walls were described as thicker than usual in so slender a species. The tabulae were complete, averaging 1.3 to 1.7 per millimeter. There was no mention of spines, and interstitial tubes were reportedly absent. Buehler (1955, p. 59) also reported the absence of spines and interstitial tubes. I have examined the much-recrystallized holotype however (GSC 6735), and found that it does indeed have

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spines. I was unable to detect interstitial tubes, though, so that despite strong similarities between Wilson's specimen and ours, it cannot be confidently said that they are conspecific.

Norford (1962a) figured a specimen from the Upper Sandpile Group (probably Llandovery or Early Wenlock) of British Columbia, which he identified with the present species. The corallites are about 1.5 mm in maximum diameter, and about 0.7 mm in minimum diameter, measured on the inside. Interstitial tubes [illegible] are present. The tabulae of the corallites are mostly horizontal or concave, spaced about 3.5 to 5.0 per millimeter. Those of the interstitial tubes are horizontal or slightly convex, spaced 5 to 6 per millimeter. As there are no spines clearly shown, it cannot be confidently said that this specimen is conspecific with Lambe's, though the other features are in good agreement with H. nitidus.

Stumm's Halysites louisvillensis from the Louisville Limestone (Late Wenlock and Early Ludlow) at Louisville, Kentucky appears to be conspecific with H. nitidus. The corallites are elliptical, slightly under 1 mm in maximum diameter, and about 0.8 mm in minimum diameter. Twelve septal spines are seen in cross-section. The interstitial tubes are tetragonal, small, averaging 0.1 mm across. The The corallite tabulae are complete, horizontal or slightly convex, spaced about 2 to 4 (and reportedly, 6) per millimeter.

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The tabulae of the interstitial tubes are horizontal, and more closely-spaced. There seems to be no significant difference between Stumm's species and H. nitidus, although it would be desireable to determine if the spines of H. louis villensis project upward axially, as they do in Lambe's species.

Scrutton (1970) reported an unidentified species of halysitid from what he regarded as sediments of Ludlow age in the Río Suripá region of Venezuela. The maximum inside diameters are 1.8 X 1.3 mm (in the largest corallites). The corallites occur as many as 7 to a rank. Between many of these are interstitial tubes, tetragonal or circular in section, with maximum dimensions of 0.45 to 0.25 mm, elongate across the chain of corallites. These are separated from the corallites by partitions which are enclosed, together with the corallites, in a theca 0.2 to 0.3 mm thick. This is the same structure as is found in our specimens. The tabulae of the corallites are horizontal or concave, spaced 2.6 to 3 per millimeter. They are rarely incomplete. The tabulae of the interstitial tubes appear horizontal or concave also, but there was no information on their spacing. Septal spines are reportedly present in some cases, up to 0.25 mm in length. Scrutton did not feel that this form could be referred to any known species, and hesitated to erect a new species, due to the poor state of preservation of his material. As described and figured, however, this form is quite

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similar to H. nitidus as understood in this work, and it seems safe to assign it to that species.

Distribution - Gaspé: Late Llandovery or Wenlock; Venezuela: Ludlow; Kentucky: Middle Llandovery (Brassfield Formation), and Late Wenlock or Early Ludlow; Ohio: Middle Llandovery (Brassfield Formation)

Possible occurrence in British Columbia (Llandovery or Early Wenlock).

Brassfield occurrence - Localities 14 (near Piqua, southwest Ohio), and 30 (near Seatonville, central Kentucky).

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Halysites(?) cf. H. meandrinus (Troost)

Plate 32, fig. 1

cf. 1840 Catenipora meandrina Troost, p. 68-69

cf. 1955 Halysites meandrina Buehler, p. 34-35, Plate 4, fig. 1

cf. 1967 Catenipora jarviki Stasínska, p. 47-48, Plate II, fig. 1a, b

cf. 1969 Halysites praecedens Webby & Semeniuk, p. 349-353, figures 2-6

Type material - Neotype (of C. meandrina Troost) is YPM 19237, selected by Buehler (1955, p. 35) and figured in his Plate 4, fig. 1.

Type locality - Lobelville Formation (now part of the Brownsport Formation), of Early Ludlow age, at Short Creek in Linden, Perry County, western Tennessee.

Number of specimens studied - 1

DIAGNOSIS (of H. meandrinus) - Species of Halysites in which ranks are generally long (often 10 or more corallites to a rank), and are seldom seen to form closed lacunae; interstitial tubes not ubiquitous; corallites generally 1.7 mm in diameter (parallel to rank extension) by 1.0 mm across the rank (measured inside corallite), though possibly there is a range downward from this size.

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DESCRIPTION (of Brassfield specimen) - The general aspect of the corallum is of long ranks (up to 10 corallites) linked together by shorter ranks of one or two corallites. The ranks are seldom observed to close around a lacuna. The area occupied by the colony thus contained a relatively-sparse population of polyps.

The corallites have inside diameters typically of 1.0 X 0.5 mm, widest in the direction of rank extension. The theca is about 0.3 mm thick. Each corallite is consistently distant from its daughter by an amount about equal to its long diameter. While the intervening spaces are certainly broad enough to accommodate interstitial tubes, none can be reported with confidence from the single specimen studied. The state of preservation of the specimen is so poor that the relatively-fine structure of an interstitial tube would probably be obscured.

There is some suggestion of spines in the corallites, but again, there has been too much alteration of the specimen to be certain. It has not been possible to make longitudinal sections, so that nothing is known of the tabulae.

DISCUSSION - The Brassfield specimen is quite fragmentary and poorly-preserved, so that the identification must necessarily remain tentative. The similarities, however, to H. meandrinus are distinct, and deserving of attention.

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Troost's original description of this species is quoted *in toto* below, because of the relative difficulty of obtaining his reference:

"The tubes and apertures are in size and form like those of *C. labyrinthica*," (size of this species was not given in Troost's work, but he did refer to its tubes as oval, rather than lanceolate), "but they do not contortuously anastomose as in the latter, and meandering in an irregular manner in every direction, they form no meshes. They seem to have formed large masses. I have a mass of compact limestone from the vicinity of Nashville of the size of five by four inches, which is water worn, and the Catenipora, being less soluble, and having thereby come to light, shows these lamellae running in every direction over the whole surface of the stone, sometimes appearing as chain-form apertures, sometimes showing their sides.

"It is only when worn down in that manner, that they are perceptible, but are invisible in the fractures of the rock.

"I discovered them, not only near Nashville but I found the same, though not in such large masses, in a more granular limestone, associated with Cyathophillum gracile and its associates near Brownsport, Perry county."

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The only critical morphologic information given here is the oval nature of the corallites, and the infrequency with which the ranks close to form lacunae. The Brassfield specimen displays these traits, but there is insufficient information to form a mental picture of the specimens with which Troost was dealing.

Buehler (1955) tells of finding two specimens (he appears to have worked with three) in the collection of the Yale Peabody Museum with coralla displaying features as described by Troost, and corallites with the size and form of those found in H. labyrinthicus (Goldfuss), from the same locality as Troost's specimens. From these he selected a neotype for Troost's species.

The neotype is YPM 19237, viewed from the bottom in Buehler's figure, and is silicified, as are the other two specimens associated with it in the YPM collection. It is larger than the Brassfield specimen, having corallite diameters (inside measurements) of 1.7 X 1.0 mm, and a rugose theca, about 0.4 mm thick. The corallites are situated about 1.0 mm apart, and this intervening space occasionally contains an interstitial tube. These latter are tetragonal in section, either equidimensional or with the longer side perpendicular to the direction of rank extension.

Four ranks are preserved whole in the neotype: Two consist of 10 corallites, one of 6, and one of 3. Two of the broken ranks contained at least 9 corallites. In this

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respect, the corallum is similar in configuration to the Brassfield specimen.

No septal spines were observed, and only a glimpse of the tabulae was seen when the neotype was examined. These latter appear to be gently concave upward, not convex as reported by Buehler, and are insufficiently-revealled to permit determination of their spacing.

Two specimens identified as H. meandrina are associated in the YPM collection with Buehler's neotype, though neither has a catalogue number. One of them is in close agreement with the neotype in all respects. The other is basically similar, though some of the corallites are unusually narrow (0.9 mm). On the same rock as this latter specimen, however, is a corallum with the basic form of H. meandrinus, but much more delicate in form (corallite diameters of 0.9 X 0.3 mm inside). The smaller corallum is not clearly attached to the larger, but lies between two of its ranks. If both of these corals are of the same species, then the Brassfield form surely lies on a morphologic continuum between them.

Stasínska (1967) described Catenipora jarviki from the Wenlock of Gotland near Visby (probably the Early Wenlock Högklint beds), a form bearing several similarities to our own. It is characterized by corallites with long diameters of 0.6 to 0.9 mm and short diameters of 0.4 to 0.5 mm, arranged in long ranks of up to ten corallites. These ranks enclose long, narrow lacunae. A transverse section of the

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holotype, exposing many corallites and ranks, shows few closed lacunae, and might approximate the pattern in the Brassfield specimen. The corallite walls are thin (0.06 mm), whereas ours are rather thick (0.3 mm). The "intercorallite walls" (presumably the spaces separating adjacent corallites) are 0.2 mm thick (our corallites are separated by 1 mm of skeletal deposits). Spines are present in the Gotland specimen, while their presence in ours is uncertain. Finally, the tabulae of C. jarviki are horizontal or weakly convex, while the nature of the tabulae in our specimen is unknown. The true relationship between the Gotland specimen and ours cannot be ascertained at this time, but the similarities should be noted for future reference.

Webby & Semeniuk (1969) introduced a new species, Halysites praecedens, from the Bowen Park Limestone and Canomodine Limestone (both Caradoc in age, Late Ordovician) of New South Wales, Australia. The corallum consists of very long ranks of corallites with only occasional T-shaped junctions between them. In one rank were counted 31 corallites. There are no enclosed lacunae. Corallites and interstitial tubes are distinct from one-another. The corallites are "oval" (elliptical) in cross-section, measuring 1.2 to 2.0 mm along the ranks, and 1.2 to 1.6 mm across the ranks. The interstitial tubes are square in cross-section, 0.2 to 0.5 mm on a side. The wall is 0.2 to 0.3 mm thick, consisting of a thin, discontinuous "epitheca", a middle fibrous layer with

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the fibers perpendicular to the outer wall, and an inner, non-fibrous layer. The last of these layers forms the barrier between the corallites and interstitial tubes. Tabulae are thin, mostly horizontal (though in the figure 6a, these authors show longitudinal sections of corallites with peculiar obliquely-directed tabulae, in what they refer to as "deformed" corallites), and spaced from 6 to 7 in 5 mm in the corallites, and 9 to 11 in the same interval in the interstitial tubes.

Webby & Semeniuk note the similarity of their species to H. meandrinus, noting that the two forms share much the same dimensions, but that rank junctions in the latter occur more frequently than in the former. The corallites are somewhat wider than those of the Brassfield specimen, but in good agreement with the neotype of Troost's species. The fact that H. meandrinus is poorly-understood makes it inadviseable to equate it with H. praecedens, especially in light of the considerable space of time separating them. Nevertheless, the many features shared by these two forms deserve closer scrutiny in future studies.

Distribution - Kentucky: Middle Llandovery (Brassfield Formation); similar forms in the Early Ludlow of Tennessee, Early Wenlock of Gotland, and Caradoc of Australia.

Brassfield occurrence - Locality 53a, near Irvine, central Kentucky.

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Catenipora Lamarck, 1816

1816 Catenipora Lamarck, p. 206

? 1826 Catenipora Goldfuss, p. 74 (partim)

1843 Catenipora Hall, illustration no. 22 (partim, non fig. 2)

1850 Halysites Milne-Edwards & Haime, p. lxii (partim)

1851 Halysites Milne-Edwards & Haime, p. 281 (partim)

1852 Catenipora Hall, p. 127-130 (partim, non p. 129-130)

1879 Halysites Nicholson, p. 226-231 (partim)

1880 Halysites Nicholson & Etheridge, Jr, p. 274-276 (partim)

1899 Halysites Lambe, p. 64-68 (partim)

? 1904 Halysites Etheridge, p. 15-22 (partim?)

1940 Catenipora Lang, Smith & Thomas, p. 33 (as synonym of Halysites)

1940 Halysites Lang, Smith & Thomas, p. 64-65 (partim) and p. 33

? 1941a Palaeohalysites Chernyshev, p. 36

1954 Halysites Thomas & Smith, p. 766 (partim)

1955 Catenipora Buehler, p. 21-22

1955 Quepora Sinclair, p. 96

1956 Catenipora Hill & Stumm, p. 469

1956 Catenipora Duncan, p. 222-223 (as a subgenus of Halysites)

? 1957 Eocatenipora Hamada, p. 396, 398

1957 Quepora Hamada, p. 396, 398-399

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1957 Catenipora Hamada, p. 396, 399-401

1961 Catenipora Flower, p. 47-49

1962 Catenipora Sokolov, p. 255-256

Type species - (SD Lang et al., 1940, p. 33): Catenipora escharoides Lamarck, 1816, p. 207

Type locality and horizon - Lamarck's original account (fide Buehler, 1955, p. 25): "Washed up on the shores of the Baltic". The neotype (selected by Thomas & Smith, 1954, p. 25) is from the Silurian of Gotland.

DIAGNOSIS - Similar to Halysites (which see) but completely lacking interstitial tubes.

DESCRIPTION - Excepting the absence of interstitial tubes, this genus is basically identical in appearance to Halysites. The presence of balken in Catenipora appears to be uncertain. Hamada (1959, p. 283) claims that this structure of the intercorallite region is absent in Catenipora (and common among Halysites-like chain-corals), with the single exception of a supposed specimen of Catenipora escharoides figured by Fischer-Benzon, a specimen he considered, in any case, anomalous. On the other hand, Flower (1961, p. 49)reports balken in his species, C. workmanae, though his figures are not clear enough to be convincing.

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The tabulae of the corallites are complete, and there is a double wall. The septal spines, as in Halysites, are variable in development from species to species, though C. escharoides, the type of Catenipora, has long spines, while the type species of Halysites, H. catenularius, has no noticeable spines.

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DISCUSSION - The purpose of the extensive synonymy given for this genus is to show that a considerable period of time passed while the name Catenipora was discarded in favor of Halysites and other generic names. As far as has been determined, Hall (1852) was the last author to use the name Catenipora in its currently-accepted sense (applying it to C. escharoides with illustrations showing no interstitial tubes, though he incorrectly applies the generic name to C. agglomerata Hall, which proves, in thin-section, to be a Cystihalysites), prior to an interregnum which ended with Buehler's resurrection of the name in 1955.

Chernyshev (1941a) erected the generic name Palaeohalysites for Halysites gotlandicus Yabe (1915) from the Silurian of Gotland. His purpose was to set aside this and related species without interstitial tubes from Halysites Fischer von Waldheim which has these features. His taxonomic criterion is the same as that for Catenipora, which predates his new name, by virtue of Lang et al.'s (1940) designation of C. escharoides as the type species.

The neotype of Catenipora escharoides (selected by Thomas & Smith, 1954, p. 25) bears prominent septal spines. For a Catenipora-like form from the Ordovician of Quebec, which lacked spines, Sinclair (1955) created the generic name Quepora. The variation of development that spines so commonly show in tabulates (as, Favosites), is persuasive that this alone is not a sound generic taxobasis; hence

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the suppression shown in the synonymy.

Hamada (1957) introduced the name Eocatenipora for Halysites cylindricus Wilson (1926) from the Upper Ordovician of British Columbia (see discussion of this species under Catenipora favositomima). This is a halysitoid tabulate coral, lacking interstitial tubes and spines, with occasional free corallites (corallites unattached laterally to neighbors over portions of their length). The relationship between this form and Catenipora Lamarck cannot be determined with confidence until careful study has been made of Wilson's specimens. As Sinclair (1955, p. 95) has pointed out, halysitoid corals are likely a polythetic group, and it is not even certain that Halysites cylindricus is co-familial with Halysites, Catenipora, etc.

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Catenipora gotlandica (Yabe)

Plate 9, fig. 8; Plate 33, fig. 1, 2; Plate 39, fig. 2

cf. 1829 Catenipora approximata Eichwald, Plate II, fig. 9 (fide Klaamann, 1966, p. 46)

cf. 1843 Catenipora agglomerata Hall, Illustration 22, fig. 2

cf. 1852 Catenipora agglomerata Hall, p. 129, Plate XXXV, fig. 2a-g

? 1876 Halysites catenulata Rominger (partim), p. 78-79, Plate XXIX, fig. 1 (non fig. 2, 4)

1915 Halysites gotlandicus Yabe, p. 34-35, Plate VII, fig. 1, 2

? 1919 Halysites catenularia Williams, Plate XIX, fig. 2

? 1938a Halysites gotlandicus Chernyshev, p. 128, Plate IV, fig. 3a, b

1955 Halysites gotlandicus Buehler, p. 57

1966 Catenipora cf. gotlandica Klaamann, p. 41-42, Plate VI, fig. 6; Text-fig. 18

cf. 1966 Catenipora approximata Klaamann, p. 46-48, Plate XI, fig. 1-4; Plate XII, fig. 1, 2; Text-fig. 22, 23

1972 Catenipora gotlandica Leleshus, p. 45-46, Plate XXI, fig. 3, 4

cf. 1972 Catenipora approximata Leleshus, p. 46-46, Plate XXII, fig. 1-4; Plate XXIII, fig. 1, 2

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Type material - Lectotype (of Leleshus, 1972, p. 45):
The specimen of Yabe's (1915) Plate VII, fig. 1, 2.

Type locality and horizon - Korpklint, north of Visby on the Island of Gotland. The horizon is probably the Högklint beds, which are of Early Wenlock age, acording to Manten.

Number of specimens studied - 3

DIAGNOSIS - Catenipora lacking balken; close-packed ranks of circular to broadly-elliptical corallites, with interior diameter generally 1.0 to 1.5 mm; septal spines prominent, apparently in 12 rows.

DESCRIPTION - This species occurs in the Brassfield as broadly-convex lenses. Their prime locality is in a bed of grey-green silty clay at locality 7a, where they occur as worn cobbles piled one upon the other, often upside-down. As a result of this usual wear, it is difficult to get an idea of the original size of the coralla. One such cobble, a fairly typical one, has a maximum diameter of 13 cm, a minimum diameter of 8 cm, and a thickness of 4.5 cm.

The corallites of these specimens are so densely-packed that it is necessary to look closely at them to be certain they are not favositid coralla. In this respect, they resemble the other species of Catenipora found near Fairborn, C. favositomima, sp. nov. (which, see). The latter, however, has larger, rounder, even more densely-packed corallites,

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and lacks spines, thus clearly differing from C. gotlandica.

The ranks are generally fairly short, containing a maximum of 4 corallites. Nonetheless, the lacunae tend to be quite narrow, moreso, in fact, than the corallites. The short chains may appear superficially longer than they really are because of a tendency for parallel chains to be linked by a very short chain (often a single corallite) to its neighbor, while continuing straight beyond the branching to make what looks like a single long chain, parallel to its neighbors. At other times, however, the lacunae may be polygonal, even equilateral, but always small.(see Plate 9, fig. 8; Plate 33, fig. 2).

The corallites measure from 1 to 2 mm on the inside diameter parallel to the direction of rank extension (most are 1.5 mm), and about 1.2 mm at right angles to this direction. They are sandwiched on two sides by the theca, which seems to consist of a single layer, 0.2 to 0.25 mm thick. In the intercorallite zones, and also sandwiched by the theca, is a solid carbonate deposit, apparently with a suture running through it lengthwise. In cross-section, this deposit usually is less than 1 mm across (parallel to the rank extension) and about 1 mm wide across this direction. Apparently, it is the same sort of structure found in C. favositomima. No balken have been observed in our specimens.

The corallites usually display well-developed septal spines (plate 33, fig. 1, 2; Plate 39, fig. 2), arranged

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in vertical rows with about 6 spines per millimeter, and reaching up to two-fifths the way to the axis of the corallite. The maximum number of spines seen in transverse section is 12. Commonly, a spine may be seen projecting directly from the portion of the wall consisting of the inter-corallite deposits.

The tabulae are usually somewhat convex upward, spaced about 4 per millimeter, though i: some deviations in higher and lower directions may be found.

DISCUSSION - The neotype of Catenipora approximata Eichwald, 1829 (chosen and described by Klaamann, 1966) bears a strong resemblance to this species. It is discussed under Catenipora favositomima in the present work. Eichwald's species differs from C. gotlandica in having larger, rounder corallites, which are even more close-packed than in the latter.

Hall (1843, 1852) described Catenipora agglomerata from the "Niagara Limestone" in Monroe County, New York. Buehler (1955), who chose as lectotype AMNH 1690/2, and figured it on his Plate 4, fig. 4, notes that a search of this locality revealed no outcrops. He supposes the specimen must have come from the till boulders of local streams, and that the lithology most closely resembles that of the Guelph Dolomite (of Ludlow age). Both the lectotype and the paratype closely resemble our Brassfield specimens in having rather rounded corallites of similar size, forming close-spaced and often sinuous ranks. Closer examination of these spe-

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cimens, however, shows that they apparently lack spines (or at least none are preserved), and that the intercorallite spaces are vesiculose, indicating that this form belongs to Cystihalysites Chernyshev (1941a).

Rominger's (1876) specimen of Halysites catenulata (sic) from the "Niagara group" at Point Detour, Michigan (his Plate XXIX, fig. 1, UMMP 8541) resembles our form in having rather rounded-elliptical corallites with well-developed spines. The corallites are commonly 2 mm long on the inside diameter, more often than is the case in our specimens, and the ranks are not nearly as close-packed as in our form. The intercorallite spaces, however, appear to be occupied by interstitial tubes, suggesting that this specimen may likely belong to the genus Halysites, possibly H. labyrinthicus (Goldfuss). Unfortunately, it was not possible to section the specimen, so that the structure is not definitely known.

Yabe's Halysites gotlandicus is the form most similar to ours. A holotype does not appear to have been originally assigned, but Leleshus (1972, p. 45) states that the holotype is the specimen figured by Yabe (Plate VII, fig. 1, 2). This comes from Korpklint, north of Visby, Gotland, and is probably derived (assuming it was in-place) from the Early Wenlock Högklint beds (age indicated by Manten, 1971). The corallites are rounded-elliptical in cross-section, with diameters of 1.9 X 1.7 to 2.1 X 1.6 mm (no indication if this is inside of outside measurement. There are no

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interstitial tubes present, though Buehler (1955, p. 57) believes some can be seen in Yabe's figure, and short spines occupy the lumens of the corallites. The tabulae may be flat of concave, and are spaced on average 3 per millimeter. Yabe's figure 1 suggests a somewhat sparser distribution of ranks than is usual in our specimens, but as has been noted, relatively broad lacunae do occur occasionally in our coralla. There is no significant difference, then, between the specimen described by Yabe, and our own specimens, and they are regarded as conspecific.

Williams identified as Halysites catenularia a specimen (GSC 5124) from the Fossil Hill Formation (Middle Llandovery through Middle Wenlock) of Manitoulin Island. This specimen has corallites with the same size and shape as our specimens, in a somewhat looser pattern of ranks, some of which contain up to 7 corallites. The specimen appears to be recrystallized, and shows no evidence of spines or interstitial tubes. Without sectioning the specimen, it is not possible to be certain of its identification.

Chernyshev (1938a) reported Halysites gotlandicus from the Silurian of Vaygach Island, northern Siberia. The corallum consists of chains of from 1 to 8 corallites. The lacunae are rather broad, or elongate and narrow, with the maximum breadth being 7 mm, and the maximum length 15 mm. The corallites range from elliptical to nearly circular in cross-section, 1.5 to 2.0 mm wide and 2.0 to 2.3 mm long.

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Their tabulae are complete, and horizontal to concave, spaced 2 to 2.4 per millimeter. Interstitial tubes are reportedly absent, and the apparent lack of spines was explained by Chernyshev as probably due to the strong recrystallization of the material. These specimens appear to be in generally good agreement with Yabe's material, but their corallites are somewhat larger than the Gotland form, and our own specimens. Chernyshev's inability to locate spines in the lumens makes his identification less convincing that would be desired, and the present species can only tentatively be reported from this region.

Buehler's reference to this species (1955, p. 57) consists of a quotation of the original description, with the type occurrence, and the remark (as noted above) that, while Yabe stated that there were no interstitial tubes in his material, his figures suggest their presence. Study of Yabe's figures convinces this author that there is no evidence of interstitial tubes, and that this species should be placed in Catenipora Lamarck.

Klaamann (1966) reported "Catenipora cf. gotlandica" from the Early Llandovery Juuru Stage of Estonia. It consists of circular to elliptical corallites grouped in winding chains which form loops containing 15 to 20 corallites. From Klaamann's figures, these loops appear to be free from connection with more than one outside rank of corallites, but only very small portions of the coralla are shown, so that

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the pattern of the lacunae is unclear. The long diameter of the corallites is 1.7 to 2.0 mm, and the short diameter is 1.3 to 1.5 mm, similar to the dimensions of our form. Wall thickness is 0.2 to 0.25 mm. The tabulae appear to be generally horizontal, with occasional weakly-concave or convex examples, some incomplete, and are spaced about 2.5 to 5 per millimeter. Spines are present in the corallite lumens, apparently spaced about 6 per vertical millimeter, in longitudinal rows, about the same arrangement as in our specimens. Klaamann felt his corallites were somewhat narrower than those of Yabe's specimen, but the figures do not seem to show any strong differences in this respect. The variations shown by the corallites of this species would seem to encompass both the Gotland and Estonian forms.

Leleshus (1972) reported Catenipora gotlandica from the Late Llandovery (horizon G) and Early Wenlock (horizon K) at Mount Daurich, Tadzhikstan. The coralla are discoidal or hemispherical, usually 100 to 250 mm in diameter (though in layer K coralla up to 1 meter in diameter and 40 cm thick were encountered). The corallites are rounded-elliptical in cross-section, with representative diameters of 2.3 X 1.4 mm, 1.8 X 1.6 mm, and 2.1 X 1.5 mm (in a single corallum). It is not indicated whether these are inside or outside diameters. The corallites are arranged in groups of 1 to 5, and occasionally as many as 10 in a rank. The lacunae reportedly tend to be rather elongate, about 3 to 30 mm long,

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and 1 to 3 mm wide. Thecal thickness is about 1.5 to 2 mm. There are no interstitial tubes. Short, sharp spines are encountered rather rarely in the corallites, though in a few they are abundant. The tabulae are horizontal, spaced about 3 to 3.5 per millimeter. Leleshus makes a rather curious statement: In the walls between corallites are occasionally encountered openings, 0.2 to 0.6 mm in diameter, through which the tabulae of one corallite pass into the lumen of the other corallite. As Leleshus points out, this is a rare occurrence in halysitids. His suggestion, however, that this is the result of some accident, cannot be substantiated without further study. Despite the somewhat greater size of the corallites, and sparseness of spines, this form is probably conspecific with ours.

In the same work, Leleshus described a specimen identified as Catenipora approximata Eichwald from layer G (Late Llandovery) at the same locality as his specimens of C. gotlandica. His specimens seem identical in general form with Klaamann's neotype of Eichwald's species (see discussion under Catenipora favositomima), and they are referred to here only to point out that this form, so similar to C. favositomima, occurs in the same locality and horizon as C. gotlandica, just as these two species occur at about the same locality and horizon in the Brassfield.

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Distribution - Gotland: Early Wenlock; Estonia: Early Llandovery; Tadzhikstan: Late Llandovery; Ohio: Middle Llandovery (Brassfield Formation)

A possible occurrence of this species is reported from the Silurian of Vaygach Island, off the north Siberian coast (Chernyshev, 1938a).

Brassfield distribution - Locality 7a, near Fairborn, southwestern Ohio. Specimens have been found in the talus, and in the clay-coral layer at this locality (discussed in the section on the Brassfield Lithosome).

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Catenipora favositomima sp. nov.

Plate 33, fig. 3, 4; Plate 37, fig. 2

cf. 1829 Catenipora approximata Eichwald, Plate II, fig. 9 (fide Klaamann, 1966, p. 46)

cf. 1876 Halysites compactus Rominger, p. 79, Plate XXIX, fig. 3

cf. 1915 Halysites gotlandicus Yabe, p. 34-35, Plate VII, fig. 1, 2

cf. 1926 Halysites cylindricus Wilson, p. 15, Plate II, fig. 6, 7

cf. 1966 Catenipora approximata Klaamann, p. 46-48, Plate XI, fig. 1-4; Plate XII, fig. 1, 2; Text-fig. 22, 23 (transl. of diagnosis on p. 91)

Type material - UCGM 41908, specimen figured on Plates 33 and 37 of this work.

Type locality and horizon - Brassfield Formation (Middle Llandovery) at locality 7, near Fairborn Ohio; from upper part of this unit.

Number of specimens studied - 1

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DIAGNOSIS - Catenipora apparently without balken; corallites generally circular in cross-section, large (1.8 to 2.0 mm inside diameter), arranged usually in long, parallel ranks so crowded as to often touch each other across the narrow lacunae; intercorallite space occupied by solid carbonate deposit with a lengthwise suture; spines apparently absent.

DESCRIPTION - The corallum was apparently a large, densely-populated hemisphere. The preserved portion has corallites 7 mm long, and is about 15 cm across the top. It forms about 120° of what originally was probably a 180° expanse. In surface aspect, the corallites are so large (1.8 to 2.0 mm across the inside diameter, with a circular cross-section) and close-packed as to have a favositid appearance (whence the trivial name). The lacunae are typically much longer than wide, one measuring 15.0 X 1.5 mm. It appears that as many as 9 corallites may comprise a rank, but this is difficult to determine, as corallites of parallel ranks sometimes touch due to the narrowness of the lacunae.

Spines have not been observed in thin-section, though enough corallites have been studied that, were they present, they should have been detected. This is in marked contrast to the stout spines found in Catenipora gotlandica (q.v.) from the same vicinity as the present species. Longitudinal lines lines often observed when longitudinal sections caught part of the intercorallite walls are not septal structures,

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but rather, reflect the structure of the skeletal deposits in this region (see below). The tabulae may be horizontal, convex, or concave, and are often incomplete. In areas where they are evenly-distributed, they are spaced 2 to 2.2 per millimeter. The spacing may occur in rhythmic zones, being 6 per millimeter in denser regions, and 2 per millimeter in some sparser regions.

The corallites are sandwiched between thecal deposits on two sides. This wall is about 0.2 mm thick, and does not appear to consist of two layers, as it does in Halysites catenularius (q.v.).

Also enclosed on two sides by this theca, and situated in the intercorallite spaces, are zones of solid carbonate deposits. These are about 0.3 mm wide (across the rank) and 0.4 to 0.7 mm long. They are divided by a lengthwise suture into two equal halves, and it is probably this suture and the boundaries with the theca that are seen as longitudinal lines in vertical sections of the corallite walls.

DISCUSSION - This is a very distinctive form of Catenipora, by virtue of its large, round, and densely-packed corallites. Yet, there are species from various parts of the world that closely-resemble it. When our form becomes better-known, perhaps it will be seen that its variations include some of these known species, but for the present, it seems best to regard it as a separate entity.

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Halysites compactus Rominger is a form closely-resembling ours in several details. It was described by Rominger (1876) from the Silurian beds (probably Llandovery or Wenlock) at Epoufette Point, Lake Michigan. The corallites are the same size and shape as ours, and have about the same wall thickness. Also, they appear to lack spines. Examination of the lectotype (UMMP 8543, selected by Buehler, 1955, p. 42, and figured by him on Plate 4, fig. 5, 6; Plate 5, fig. 2, 3) shows that the intercorallite spaces are filled with vesiculose deposits, indicating that this form belongs to the genus Cystihalysites Chernyshev, 1941b.

Yabe (1915) described Halysites gotlandicus from Korpklint, north of Visby, Gotland (probably from the Högklint beds of Early Wenlock age, according to Manten, 1971). Yabe's description of this species is given in the "Discussion" section of the treatment of Catenipora gotlandica in the present work. The most important difference between Yabe's species and C. favositomima is the presence of spines in the former.

Wilson (1926) described Halysites cylindricus from British Columbia (Upper Ordovician, unit unknown). The corallites, like ours, are circular in cross-section, but are considerably narrower, about 1 mm in diameter. Interstitial tubes are reportedly absent. There are 2.0 to 2.3 tabulae per millimeter. Wilson was impressed by the fact that some of the corallites appeared to be free, unattached

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laterally to other corallites in the plane of transverse section. The significance of this is unclear at this point. Wilson did not comment on the presence or absence of spines. The narrowness of the tubes, and the apparently free habit of some of the corallites set this species apart from our own, and as Buehler (1955, p. 59) points out, the latter character calls for some questioning of the appropriateness of placing this species in the Halysitidae.

Catenipora approximata was originally described by Eichwald (1829) from the alluvial deposits in the vicinity of Vilnus (Vilna?), Estonia. It was redescribed by Klaamann (1966), and a neotype was designated. The location and horizon are the Tamsalu Stage (Middle Llandovery, according to Manten, 1971) of the Estonian island of Hiyumaa. According to Klaamann, the corallum consists of large (diameter = 1.7 to 2.0 X 1.7 X 2.4 mm), circular, densely-packed corallites, about 4 to 6 in a rank, but sometimes as many as 9. The ranks are close-spaced, and often parallel. The thecal diameter is 0.15 to 0.2 mm. The tabulae are horizontal or slightly concave, and spaced about 2 to 3 per millimeter. Spines are arranged in 12 vertical rows within the corallites. Of all species encountered, this is the one closest to the present species, differing from C. favositomima solely in having septal spines. Klaamann did not present a clear picture of the nature of the intercorallite spaces, but they do not seem obviously dissimilar to ours. Should the

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Brassfield species prove, on further study, to have spines, there would be strong grounds for assigning it to C. approximata Eichwald.

Distribution - Ohio: Middle Llandovery (Brassfield Formation).

A species closely-resembling the present species occurs in Estonia, in rocks of Middle Llandovery age.

Brassfield occurrence - Locality 7, near Fairborn, in southwestern Ohio.

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Family Moniloporidae Grabau, 1899

Tabulate corals in which the corallum consists of corallites shaped like smoking-pipes; each new corallite arises at the base of the "bowl) of the parrent corallite, to which it remains attached by the "mouth-end" of its "stem"; corallum has proximal portion which grows attached-prostrate to a firm substrate (though not in a reticulate pattern), and may have a distal portion which arises from the proximal which is free-growing, unattached, and shrub-like in form; the theca is thick, consisting of two layers; septal elements, when present, consist of rather wide-spaced spines; vesicular dissepiments may or may not be present, but the living-space appears to never truly be cut-off by tabulae from continuity with t he lumen of the immediate ancestor and descendent of the corallite; each corallite is attached to the parent only at its proximal end, without transverse stolons connecting adjacent corallites laterally.

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Cladochonus M'Coy, 1847

1847 Cladochonus M'Coy, p. 227

1851 Pyrgia Milne-Edwards & Haime, p. 159, 310

1879 Monilopora Nicholson & Etheridge, Jr., p. 293

1885a Aulocystis Schlüter, p. 148-151

1887 Drymopora Davis, explanations to Plates LXX, LXXI, LXXII, and LXXIV

1899 Ceratopora Grabau, p. 414-416 (non Hagenow, 1851, nec Hickson, 1911 [fide Sokolov, 1962, p. 246])

1940 Monilipora Lang, Smith & Thomas, p. 86 (nom. van. pro Monilopora Nicholson & Etheridge, Jr., 1879)

1946 Plexituba Stainbrook, p. 424-426

1962 Grabaulites Sokolov, p. 246 (pro Ceratopora Grabau, 1899; non Hagenow, 1851, nec Hickson, 1911)

Type species - Cladochonus tenuicollis M'Coy, 1847, p. 227 (SD Milne-Edwards & Haime, 1850, p. lxxvi)

Type locality and horizon - Lower Carboniferous (Burindi), Dunvegan Shale, Dunvegan (on the Patterson River), New South Wales, Australia.

DIAGNOSIS - Moniloporidae with corallum consisting of a proximal attached or unattached prostrate phase, from which may arise a distal, freely-branching phase; attached phase never truly retiform; corallites not normally in lateral contact, except when crowded, and no more than three arise from a parent corallite.

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DESCRIPTION - The following description is quoted from an earlier work (Laub, 1972) on the genus Cladochonus:

"The corallum consists of a proximal prostrate region (attached or unattached, dendroid; or, when encrusting a pelmatozoan column, annular), and distal free region of trumpet- or pipe-shaped corallites with their interiors communicating only at point of origin. Corallites of the free-growing region may alternate the direction in which the aperture faces, producing a zig-zag branch (as in M'Coy's figure of C. tenuicollis), or the apertures may all face in the same general direction. The initial portion of the coralum consists of two corallites with apertures at opposite ends of a common stolon. Offsets occur at the base of the calice theca, or higher up towards the aperture, and occasionally in both positions in a single corallite. Offsets may be single, bifurcating, or rarely trifurcating. The theca is typically thick and in two layers. Thecal lamellae may be bowed to produce vesicular dissepiments. Pits are sometimes observed in the interior side of the theca. Rod-like structures are frequently embedded in the theca in longitudinal rows, with their tips usually protruding into the interior of the corallite to form acanthine septa."

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DISCUSSION - A discussion of the morphology and taxonomic status of the genus Cladochonus is presented by Laub (1972). The conclusions drawn in that paper are considered still valid, so that the present work will merely summarize those ideas, while adding a discussion of Grabaulites Sokolov (1962), a generic name that has recently come to my attention.

To 1972, Cladochonus was regarded as being free of spines and dissepiments, with a corallum attached only at its base, and branching freely, like a low shrub. Pyrgia was erected by Milne-Edwards & Haime (1851, p. 310) for two European Carboniferous species which restudy clearly showed to be congeneric with Cladochonus. In 1879, Nicholson and Etheridge (p. 293) proposed Monilopora, to accommodate Cladochonus crassus (M'Coy, 1844) from the Mountain Limestone (Lower Carboniferous) of Ireland. This species they considered distinct from Cladochonus by virtue of the habit of encircling pelmatozoan columns, and by the possession of a "reticulate" structure in the theca, as described by Rofe (1869). Hill & Smyth (1938) demonstrated that Monilopora crassa is merely the attached portion of the proximal end of a Cladochonus colony, and that a phase of freely-branching corallites extended from one of the attached corallites. The meaning of the reticulate structure is not yet resolved. Despite photographs offered by Hill & Smyth (1938) its na-

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ture remains unclear. Hill and Smyth's suppression of Monilopora under Cladochonus seems the best judgement.

In 1885, Schlüter introduced the genus Aulocystis for his A. cornigera from the Middle Devonian of Germany. With Cladochonus it shared a freely-branching growth-habit, and a thick theca. It differed, however, in possessing internal vesicular dissepiments and spines. Two genera subsequently proposed in the literature, Drymopora Davis (1887) and Ceratopora Grabau (1899) bear all the critical features of Aulocystis, and are here regarded as junior subjective synonyms of Schlüter's genus. Grabaulites was proposed by Sokolov (1962, p. 246) to replace Ceratopora Grabau, which he noted was a name already in use.

Specimens from the Devonian of New York (see Laub, 1972) show that corallites with the characters of Cladochonus and Aulocystis can coexist in a single corallum, and separate corallites from the same locality show a gradation of morphology from those bearing abundant dissepiments and spines, to those without dissepiments and obvious spines. Hence, it is clear that the definition of Cladochonus must be expanded to include the features of Aulocystis.

Finally, Stainbrook (1946) introduced Plexituba, from the Upper Devonian of Iowa. These corals, he said, had an adnate growth habit (that is, they are attached-prostrate, but do not form a reticulate pattern as does Aulopora), have thick walls, abundant dissepiments, and lack spines. Study

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of New York Devonian specimens, as stated above, shows a considerable variation in Cladochonus with respect to spines and dissepiments. Further, as Hill and Smyth showed (see above), Cladochonus does possess a proximal attached phase of several corallites. Grabau (1899, Plate 3, fig. 12; Plate 4, fig. 17, 18) figured specimens of his Ceratopora (=Cladochonus) attached to other fossuls. Consequently, there remain no differences between Cladochonus and Plexituba, and the latter must be regarded as a junior synonym of the former.

In effect, then, Cladochonus had the appearance, in life, of a low shrub, with a basal attached portion ("Plexituba"), from which arose freely-branching corallites, unattached except at the base ("Cladochonus" and "Anlocystis").

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Cladochonus sp. or spp. A and B

Plate 9, fig. 11, 12; Plate 10, fig. 1

Type material - Figured specimen of Cladochonus sp. A is UCGM 41987 . That of C. sp. B is one of several on a slab labelled UCGM 41859.

Type locality and horizon - Cladochonus sp. A is from locality 46 (near College Hill, Kentucky) in the top of the Noland Member, Brassfield Formation. Cladochonus sp. B is from near the top of the Brassfield Formation at locality 13, in Todd Fork Creek, near Wilmington, Ohio.

Number of specimens studied - 1 specimen of type A, 5 specimens of type B

DESCRIPTION - Fragments of auloporid colonies have been found at two localities, both in the extreme top of the Brassfield Formation. The material is quite small and, at this date, has not been sectioned to determine internal structure in detail. In some cases, however, it has been possible to clear the interior spaces of sediment to gain some knowledge of the internal arrangement. As has been noted (Laub, 1972) the corallites of various parts of a single corallum can have strikingly different forms. The specimens described in this section appear to fall into two categories, and have been designated Cladochonus sp. A and B. They are dealt with as separate species only tentatively, as the specimens

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are all too small to allow certainty that they do not come from a single species.

The first category, Cladochonus sp. A (Plate 10, fig. 1) is represented by one specimen (UCGM 41987) from locality 46. It comes from the type of the Noland Member, Brassfield Formation, and lay within an inch of the budded specimen of Calostylis sp. found here (Plate 6, fig. 5). The auloporid consists of a complete corallite with two offset corallites, one represented by a complete corallite, and the other by a stolon (see Laub, 1972, p. 367 for Cladochonus morphology).

The parent corallite is pipe-shaped, with a preserved length of 4 mm. The proximal end of the stolon is 0.5 mm in diameter. At the point of juncture with the calice, the lumen is about 1 mm in diameter. The axis of the calice appears to make an angle of about 115° with the axis of the stolon. The calice itself has a diameter of about 2 mm. The theca of the calice is thin, in the order of 0.1 mm or less.

There appears to have been some breakage of this group of corallites at the time of final deposition, such that the offsets are slightly disjointed from the parent. It is possible to determine, however, that the offsets, viewed from a vertical position along the plane of symmetry of the parent, make an angle of about 90° with each other. They arose at the antero-lateral portion of the calice, as is

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usually the case in Cladochonus, but while one originated at the base of the calice, its sibling arose slightly above this level on the other side. This suggests that these corallites were from the free portion of a colony, probably not in contact with the substrate.

The remaining material is designated Cladochonus sp. B, and consists of 5 fragmentary coralla on a large slab from near the top of the Brassfield at locality 13 (Todd Fork Creek). This is specimen UCGM 41859. On this same slab are two fragments of Favosites favosus (Goldfuss) (one overturned), and a Calostylis corallite. Both these species are characteristic of the fauna in the southeast portion of the Arch.

The only offsets seen here appear singly (in contrast with the double offset found in Kentucky). The most complete fragment consists of a line of 6 to 8 corallites (Plate 9, fig. 11, 12) whose stolons describe a portion of a circle 1 cm in radius. Both the stolons and the calices are about 1 mm in diameter, whereas the Kentucky specimen had a calice wider than its stolon. The calices all occur on the convex side of the line of stolons, though they are not all in quite the same plane. The stolons are only slightly narrower at their proximal end than at their distal end, whereas the stolon of the Kentucky specimen widened markedly in a distal direction. The distance from offset-to-offset in this Ohio specimen is about 4 mm.

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The other specimens on this slab appear to have the same general form as the one just described. In one case, a corallite is rather longer (6.5 mm), but has the same width and shape. A corallite in yet another cluster was partly worn on the side, and it was possible to clean the sediment from the stolon lumen. There appear to be no vesicular dissepiments, and there is no evidence of spines. There has been recrystallization of the corallite, and there were likely spines in life. The absence of dissepiments, however, is probably real, and not due to alteration. The theca is thin, probably just over 0.1 mm thick. The fragments from this locality almost certainly came from free, erect portions of shrub-like Cladochonus colonies.

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Cladochonus sp. C

Plate 9, fig. 9, 10; Plate 31, fig. 7

Type material - Figured specimen is UCGM 41693 and 41692

Type locality and horizon - Figured specimen is from the Brassfield Formation at locality 15, near West Milton.

Number of specimens studied - 5

DESCRIPTION - At two localities in the Brassfield Formation have been found specimens of what appears to be Cladochonus M'Coy. The coralla consist of short branching cylinders, about 0.75 mm in diameter, and up to 7 mm in length (most being rather shorter). They show no appreciable change in diameter throughout their length. They occur in thick clusters in the grey-green silty clay near West Milton (locality 15) and Ludlow Falls (locality 55) in southwest Ohio. Those at the latter locality occur, in one instance, on the same small rock as Striatopora flexuosa Hall (q.v.). It cannot be definitely demonstrated that there was much of a prostrate phase, most of the corallites appearing to have been part of a small, erect, shrub-like colony. In some instances, buds may be seen arising at right angles to the parent corallite, and shortly thereafter bending until about parallel with it. In some instances, two buds may be seen coming from a parent, which then bends its calice at an angle directed above the plane formed by the two

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offsets (as is common in dichotomously-branching species of Cladochonus).

The internal structure has not been well-preserved, unfortunately (Plate 31, fig. 7). The walls are about 1/6 mm thick, so that the lumen occupies more than half the total diameter of the corallite. Of significant importance is the fact that the dissepiments appear to be tabulae, separating the lumen into compartments. This is in contrast with the typical vesicular dissepiments of Cladochonus, and might call into question the propriety of placing this species in that genus. No spines were detected in the corallites.

Many of the corallites run parallel with one another, such that in many surfaces of the specimen, much of the field occupied by the corallum consists of transverse sections of these parallel tubes. The pattern is similar to that often seen in Syringopora (including S. reteformis of this study), but in no case has a stolon been observed connecting the sides of adjacent corallites.

A remarkable specimen was found at the old DeBoldt Quarry in southeastern Richmond, Indiana. This lay loose on an outcrop of Richmondian rocks (Whitewater, overlain by Saluda Formation), and its lithology indicates that it probably came from one of these units. Probably, the unit of origin was the Whitewater. The remarkable thing about this specimen is that it appears to be conspecific with

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the species of Cladochonus with which we are dealing here. The corallites are prostrate on what appears to be a bryozoan colony, and in places they bend upward, apparently in the start of an erect phase. They are of the same diameter (0.75 mm) as the Brassfield form, and show no change in diameter throughout their length, which appears to be as great as 7 mm. Offsets seem to form both singly and doubly, though insufficient material is exposed to be certain of this. The internal structure has not been observed. The Richmondian specimen is in the collection of the University of Cincinnati Geology Department, UCGM 41782

Of the other specimens of Cladochonus found in the Brassfield (Plate 10, fig. 1; Plate 9, fig. 11, 12) this form most resembles those from the top of this unit at Todd Fork (Cladochonus sp. B), locality 13, which show little change in diameter through the corallite lengths, in contrast with the gradually-broadening corallites (1mm proximally, 2 mm at the calice) of the specimen from locality 46 (Cladochonus sp. A). The Todd Fork specimens are somewhat thicker than the present form (about 1 mm throughout), stouter in general appearance, and somewhat more curved. They probably represent a separate species.

Distribution - Ohio: Middle Llandovery (Brassfield Formation); Indiana: Late Ordovician.

Brassfield occurrence - Localities 15 (near West Milton) and 55 (near Ludlow Falls) in southwestern Ohio.

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Family Syringoporidae Nicholson, 1879

Tabulate corals with corallum dendroid or fasciculate; corallites connected laterally by cross-tubes dispersed throughout the corallum; basal portion of corallum is auloporoid in habit, each corallite flexing upward to extend into the vertical, branching phase; theca consists of two layers; septal spines may be present inside corallites; tabulae horizontal and complete, or incomplete, and sometimes inclined at considerable angles to produce infundibuliform dissepiments with axial canal.

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Syringopora Goldfuss, 1826

1826 Syringopora Goldfuss, p. 75

1828 Harmodites Fischer von Waldheim, p. 19

1841 Caunopora Phillips, p. 18

1933 Kueichowpora Chi, p. 22

Type species - (SD Milne-Edwards & Haime, 1850, p. lxii): Syringopora ramulosa Goldfuss, 1826, p. 76.

Type locality and horizon - Carboniferous, "aus dem Uebergangskalk von Olne im Limburgischen," Germany.

DIAGNOSIS - Corallum fasciculate, consisting of a proximal portion of prostrate-unattached corallites, which flex upward to form a phase of more vertically-directed corallites; adjacent corallites connected by stolons; corallite interiors contain infundibuliform dissepiments, which meet to form an axial tube; development of septal spines variable; no mural pores present.

DESCRIPTION - This genus consists of species which are essentially like Cladochonus colonies, except that the distal, up-flexed portion of the corallite is longer, and generally parallel to its fellows, and there are cross-tubes (stolons) connecting neighboring tubes.

The proximal portion of the corallum is prostrate-attached, but rapidly assumes a prostrate-unattached, and then free growth-habit. The proximal portion of each corallite is

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sub-horizontal, and the distal portion flexes upward, and continues this upward growth for what generally becomes the greater portion of its total length. The corallites of the distal portions of the corallum are sub-parallel. Corallum increase is by off-set of the corallites.

The corallites are free of each other from the point of off-set, except where they are joined laterally to a neighbor by a tubular stolon. The stolons are important features in distinguishing the syringoporids from other corals.

Internally, the corallite wall consists of two layers, the outer being optically denser than the inner. Embedded in the inner layer, normal to the wall, are septal spines which are aligned longitudinally into a series of rows (reportedly 12). These rows are acanthine septa, and never form solid sheets.

The tabulae are infundibuliform (funnel-shaped). They consist of generally complete sheets of skeletal matter in the corallite lumens, which are depressed axially, so as to join with the depressed axial portion of the next-lower tabula, forming a hollow axial tube.

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DISCUSSION - Milne-Edwards & Haime (1850, p. lxii) indirectly designated Syringopora ramulosa Goldfuss as the type of this genus by declaring Syringopora Goldfuss a synonym of the younger generic name, Harmodites Fischer von Waldheim (1828), and assigning Syringopora ramulosa as the type species of Harmodites. Subsequently, Lang et al. (1940, p. 130) assigned Harmodites distans Fischer von Waldheim (1828, p. 19-20, fig. 1) as the type of Harmodites. (These authors give the locality and horizon of the species as Carboniferous of Russia.) The original illustration and description of this species leave little doubt that it is congeneric with S. ramulosa.

As type species of Caunopora Phillips (1841), Lang et al. (1940, p. 33) selected C. placenta from the Middle Devonian of England. Although Phillips (p. 18) ascribed this species to Lonsdale (Coscinopora placenta), Lang et al. (p. 33) indicated that Lonsdale obtained the specific name from Goldfuss (1826, p. 31), and further, these authors found that Lonsdale's specimen was not conspecific with Goldfuss'. They therefore assigned the species to Phillips, who was the first to use it without reference to Coscinopora. Lang et al. stated that Caunopora placenta Phillips was the type species of Caunopora Phillips by monotypy. As Phillips, however, described two species under this generic name, C. placenta is more properly considered the type species by subsequent designation of Lang et al. (1940).

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Lang et al. noted that Phillips' specimen of Caunopora placenta is actually a stromatoporoid enclosing a specimen of Syringopora, and Phillips' figure (Plate X, fig. 29), while not very clear, makes this conclusion credible. The former authors take the Syringopora corallum as the lectotype of C. placenta, thus making Caunopora a junior synonym of Syringopora.

Chi (1933) introduced the genus Kueichowpora from the Carboniferous of China. His figures of the type species clearly show the stolons and infundibuliform dissepiments so typical of Syringopora, of which Kueichowpora certainly seems to be a junior synonym. The bifurcation of its corallites also occurs in the type species of Syringopora Goldfuss.

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Syringopora reteformis Billings

Plate 10, fig. 2-4; Plate 11, fig. 1, 2; Plate 32, fig. 4; Plate 38, fig. 4

1858 Syringopora reteformis Billings, p. 170

? 1876 Syringopora tenella Rominger, p. 81, Plate XXX, fig. 4

? 1890 Syringopora (Drymopora) fascicularis Foerste, p. 338-339 (non Davis, 1887)

1899 Syringopora retiformis Lambe, p. 52, Plate II, fig. 3

1919 Syringopora retiformis Williams, Plate XVII, fig. 1

cf. 1926 Syringopora columbiana Wilson (partim), p. 17, Plate III, fig. 6 (non fig. 5)

? 1931 Syringopora cf. retiformis Foerste, p. 185, Plate XIX, fig. 13

? 1939 Syringopora retiformis Northrop, p. 155

? 1972 Syringopora sp. cf. S. retiformis Bolton & Copeland, Plate IV, fig. 7

Type material - Holotype (according to Williams, 1919): GSC 2617 (the specimen figured by Williams, 1919, Plate XVII, fig. 1). This specimen is shown in Plate 10, fig. 3, 4 of the present work.

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Type locality and horizon - The type catalogue of the Canadian Geological Survey gives the locality as Owen Sound, Ontario. The specimen is from the Fossil Hill Formation, which is Late Llandovery to Middle Wenlock in age.

Number of specimens studied - 9

DIAGNOSIS - Syringopora with corallites about 1 mm in diameter, usually with geniculating axes; cross-tubes sparse, corallites usually come in mutual contact through genicular approximation; spines extremely abundant in lumen; tabulae appear to be complete, possibly due to very narrow axial canal.

DESCRIPTION - The corallites are uniformly about 1 mm in diameter, and characteristically geniculate. Contact between them mostly occurs through the bending together of neighboring corallites, followed by sharp separation, or less frequently, through cross-tubes (stolons) with diameters equal to or slightly less than those of the corallites (Plate 10, fig. 3; Plate 11, fig. 2). It has not been possible to determine the length of the interval between stolons due to their sparseness.

The corallite walls are about 0.3 mm thick, and the lumen has a diameter of about 0.4 mm. The inner surfaces of the corallite walls are richly-invested with spines, spaced about 6 per millimeter, in longitudinal rows.

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The nature of the internal dissepiments is difficult to discern. Usually they appear as complete tabulae (Plate 32, fig. 4; Plate 38, fig. 4), but sometimes they may be seen as vesicular dissepiments, similar to those of Cladochonus. If we are dealing here with a true Syringopora (a situation that has not been established with certainty), it is probable that the dissepiments are infundibuliform (funnel-shaped) and concave upward, but possibly the axial tube is so narrow as to seldom appear in longitudinal section. The tabular plates are spaced about 5 or 6 per millimeter.

DISCUSSION - Billings' original description of the present species says: "Forming large masses; corallites much geniculated, frequently anastomosing or connecting by stout processes; diameter of corallites about two-thirds of a line [about 1.4 mm], distant from each other from half-a-line to a line and a-half [about 1 mm to 3.1 mm]; distance of connecting processes about one to three lines [about 2.1 to 6.3 mm], usually about 2 lines [about 4.2 mm]." This description agrees well with the holotype which was figured by Williams (1919), and with our Brassfield specimens. Billings' holotype (Plate 10, fig. 3, 4) is silicified, and partly free of the matrix. It was not possible to section it, but in the openings of some of the corallites are what appear to be spines (rather obscured by recrystallization).

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The wall thickness and lumen diameter are in the same proportion as in our specimens, but it was not possible to study the dissepiments.

Rominger's Syringopora tenella is quite similar to this species. The specimen shown is from the Silurian of Drummond's Island, Lake Huron, and was found in the drift. The corallites are reportedly 1 mm or less in diameter, and branching. They interconnect by approximation, rather than through distinct stolons. There is a faint longitudinal striation on the outer walls (not noted on the corallites of the holotype of S. reteformis, nor on the Brassfield specimens, possibly due to preservation) and the lumens show 12 spinose crests. The dissepiments are described as funnel-shaped, but not always developed, such that the lumens are often totally clear. Our specimens commonly show the chaotic pattern of corallites shown in Rominger's figure, and Lambe (1899) has reported this especially in the basal region of specimens that he identified with Billings' species. In view of the close similarities, it seems likely that S. tenella is a junior synonym of S. reteformis.

From the Clinton beds (probably Brassfield or Dayton Formation) of southwest Ohio, Foerste (1890) reported Syringopora (Drymopora) fascicularis (Davis, 1887). Different coralla had corallites with diameters ranging from 0.7 to 1.1 mm, with rugose sides. The corallites connected by approximation, rather than through stolons, and no spines

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or dissepiments were noted (with Foerste indicating that no careful search was made for them). While the description is reminiscent of the present species in most respects, the lack of any report of stolons makes it unwise to equate these two species.

Wilson (1926) reported a new species, Syringopora columbiana, from the Late Ordovician Beaverfoot Formation of British Columbia. This species does not appear to be conspecific with ours. The corallites are rather slender (0.5 to 0.75 mm in diameter), giving the corallum a much more delicate aspect than in our specimens of S. reteformis. It should be noted, however, that Wilson's figure 6, a twice-natural-size view of a polished section (of the holotype?) strongly resembles our species in general form. The corallites are geniculate and, while stolons are present, much of the connection between corallites is accomplished by approximation. If an ancestor of our form were sought, British Columbia might prove fertile ground.

Foerste (1931) figures a specimen identified as Syringopora cf. retiformis (sic) from what he considered to be the Dayton Formation (Late Llandovery) of Adams County, Ohio. This specimen has all the outward characters of the species, the corallites connecting more often through approximation than through stolons. Foerste probably was correct to associate his form with Billings' genus, but the figure alone does not provide sufficient information for certainty.

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Northrop (1939) reported Syringopora reteformis from the Bouleaux Formation (Early Ludlow) of the Gaspé region of Maritime Canada. The only pertinent facts supplied by his unillustrated description are that the corallite diameter ranges from 0.8 to 1.2 mm, and that lateral contact between corallites appears to be more due to approximation than stolons. Northrop, in fact, noted that it was uncertain that any stolons were present. In the absence of information on the internal structure, it is only possible to say that his specimen was probably, but not certainly, Syringopora reteformis.

Bolton and Copeland (1972) described Syringopora sp. cf. S. retiformis (sic) from the Thornloe Formation of Late Llandovery to Early Wenlock age, in the Lake Timiskaming region of eastern Canada. Their material bears a general resemblance to our specimens. The corallites are geniculate, and about 1 mm in diameter. The absence of of prominent spines when the specimen was studied internally, however, leaves the identification open to question.

Distribution - Ontario: Late Llandovery or Early or Middle Wenlock; Michigan: Silurian; Ohio: Middle Llandovery (Brassfield Formation) and probably Late Llandovery (Dayton Formation); Kentucky: Middle Llandovery (Brassfield Formation.

This species possibly occurs also in the Early Ludlow of the Gaspé region, Maritime Canada.

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Brassfield occurrence - Localities 7a (near Fairborn, Ohio), 11 (near West Union, Ohio), 23 (at the Highland County-Adams County border in Ohio), and 53 (near Irvine, Kentucky, in the Noland Member).

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Family Syringolitidae Waagen & Wentzel, 1886

(nom. transl. Sokolov, 1950, ex Syringolitinae Waagen & Wentzel, 1886)

Tabulate corals with massive corallum; corallites prismatic, pressed together (cerioid) or slightly diverging (fasciculate); cerioid corallites connected by mural pores, which pass through cross-tubes where corallites diverge and lose contact; tabulae strongly concave axially, sometimes resulting in a distinct axial tube; septal elements, where present, are spinose.

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Syringolites Hinde, 1879

1879 Syringolites Hinde, p. 244

Type species - (By monotypy) Syringolites huronensis Hinde 1879, p. 246.

Type locality and horizon - According to Lang et al. (1940, p. 129): "Silurian, Niagaran: near Manitouwaning, Great Manitoulin Island, Lake Huron, Canada".

DIAGNOSIS - Corallum similar to Favosites in general plan, but differing in having infundibuliform dissepiments resulting in the development of an axial tube; mural pores located on corallite walls; spines may be located on corallite walls and on upper surfaces of dissepiments.

DESCRIPTION - This is a coral of cerioid form, superficially resembling Favosites. The striking features of this genus lie in the infundibuliform tabulae (apparently both complete and incomplete), as in Syringopora. They are rather wide-spaced, and plunge in a biologically-proximal direction in the axis, so that each tabula forms a funnel, with its tube fitting into that of its neighbor below. In some instances, the axial tube is made discontinuous by the presence of a transverse tabula across it.

The upper surfaces of the tabulae bear radial ridges. Often, rows of spines appear to cap these ridges, one row to each ridge, but the relationship between them is not

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Hinde (1879, p. 244) reports that some specimens show the calice walls to be crenulated longitudinally (presumably as extensions of the radial ridges of the tabular surfaces). In addition, spines sometimes occur within the axial tubes.

The corallite wall faces bear mural pores, as are found in favositids.

DISCUSSION - In all descriptions and figures of members of the genus Syringolites Hinde, the tabulae are shown as complete. That is, the walls of each funnel are a single sheet.(e.g., Hinde, 1879; Hill & Jell, 1970). Only in the instance of the specimen reported as S. huronensis by Foerste (1906, p. 301-302, described below in the following section) are the tabulae incomplete. In this instance, a transverse section (Plate 31, fig. 2) reveals the funnels to be made up of several imbricating (vesicular) dissepiments. This genus is not sufficiently known at this stage to permit a confident judgement on the taxonomic importance of this difference, and so in this paper incomplete tabulae are considered acceptable in Syringolites.

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Syringolites sp. A, sp. nov.

Plate 10, fig. 5; Plate 31, fig. 1, 2

cf. 1879 Syringolites huronensis Hinde, p. 246,
Text-fig. A-D on p. 245

cf. 1896 Roemeria kunthiana Lindström, p. 14-17
Plate II, fig. 19-25; Plate III, fig. 26-29

1906 Syringolites huronensis Foerste, p. 301-303,
Plate 2, fig. 3; Plate 4, fig. 2
(non Hinde, 1879)

Type material - Holotype: USNM 84893 (specimen shown in our plates), described and figured by Foerste (op. cit. et loc. cit.).

Type locality and horizon - Waco bed, Noland Member of the Brassfield Formation (Middle Llandovery), "two miles southwest of Clay City, along the road immediately north of Tipton Ferry" in east-central Kentucky.

Number of specimens studied - None found in field; all data is based on holotype.

DIAGNOSIS - A species of Syringolites Hinde in which the axial tubes are formed not by the down-flexing of complete tabulae, but of individual vesicular dissepiments; in all other respects similar to S. huronensis Hinde.

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DESCRIPTION - The specimen studied is a thin (2 to 11 mm), flat corallum fragment of which the original diameter was probably about 7 to 8 cm, judging by the disposition of the basal corallites. Those corallites exposed in the base of the corallum have their axes horizontal, and are distinctly rugose. The axes of the corallites visible on the upper surface of the corallum are vertical (perpendicular to the surface). Corallum growth was centrifugally radial.

The corallites range in diameter from 2 to 3 mm, though most are 2 to 2.5 mm. Adjacent corallites share walls whose thickness is about 0.20 to 0.25 mm. In the axis of each corallite is a raised circular ring, 1 mm or less in diameter,,with its axis parallel to and coinciding with that of the corallite. The calice floor sloped down gently from the rim of the corallite wall to form a shallow dish, about 0.5 mm deep, at the foot of the central ring. The calices appear to have radial, rounded ridges and valleys reaching from the corallite wall (which they corrugate) to the foot of the axial ring. Additionally, the calice floors are studded with short spines which in some (but not most) cases appear to be aligned radially. Their relationship to the radial undulation of the calice floor is unclear.

The corallites contain vesicular dissepiments which are down-flexed axially to produce axial tubes, apparently continuous for the length of the corallite. Clearly, the axial ring visible in the calices reflects the juncture of a

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segment of the central tube with the upper surfaces of the dissepiments immediately proximal to it. This juncture appears in all cases to have been centered in the calice. The inner surface of each tube was furnished with spines.

The mural pores typical of Syringolites have not been observed in the Brassfield specimen, perhaps owing to the mediocre state of preservation.

DISCUSSION - It is not surprising that Foerste identified the Brassfield form of Syringolites as S. huronensis, which was described by Hinde (1879, p. 246) from Silurian rocks at Manitouwaning, Manitoulin Island in Lake Huron. Hill & Jell (1970, p. 173) designated as lectotype of this species specimen R19949 of the British Museum of Natural History, which they took to be the original of Hinde's fig. A. "Niagara dolomite (Wenlock)", the stratigraphic designation given by Hinde for his specimens, is interpreted as Manitoulin Dolomite (Llandovery) by Hill & Jell. The descriptions of Hinde, and of Hill & Jell indicate that in almost all respects, S. huronensis strongly resembles the Brassfield species. The corallite diameter (1.8 to 2.5 mm), the fluting of the calice floor and resulting corrugation of the corallite walls, the presence of spines on the calice floor (apparently better-aligned than in our specimen) and in the axial tube, and the centered position of the tube axis on the calice floor are all attributes held in common by S. huron-

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ensis and our Brassfield form.

The major difference between these two forms is in the nature of the axial tube. In Hinde's species, this structure is formed by the down-flexing of generally complete tabulae in the axis. In the Brassfield specimen, it is formed by similar axial down-flexing of vesicular dissepiments. Mural pores have not been observed in our specimen, probably due to poor preservation, and so cannot be compared with those reported in S. huronensis. Also, the "horizontal or gently saucered tabellae" crossing the tubes at wide intervals, as reported by Hill & Jell (p. 175) were not noted in the Brassfield form, but this, again, could be due to the state of its preservation.

The only other species generally assigned to Syringolites is Roemeria kunthiana Lindström (1896). The lack of evidence for distal divergence of the coralites or their lateral connection with syringoporoidal tubes makes it more reasonable to assign it to Syringolites than to Roemeria. Basically, this species has the same sort of axial tube structure as S. huronensis (thereby differing from the Brassfield form), and is distinguished from our species and from Hinde's by the presence of spines on the walls of the corallites between the tabulae. Hill & Jell (p. 175) report that Lindström's species often has the axial tubes in an eccentric position. R. kunthiana is from the Silurian of Gotland.

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The genus Syringolites is known from relatively few places (Canada, Kentucky, Gotland and Estonia - see Hill & Jell, p. 173-174), and apparently only a small number of specimens have been studied. It is possible, then, that as more information comes available, the structure of its axial tube will not be considered sufficient grounds for separating the Brassfield form of the genus from S. huronensis. For the moment, however, there is no real evidence of a continuum between them.

Distribution - Kentucky: Middle Llandovery (Brassfield Formation).

Brassfield occurrence - Foerste gives the following localities, all in the general vicinity of Irvine and Waco, Kentucky: "Two miles southwest of Clay City, along the road immediately north of Tipton Ferry" (the type locality, and source of the only specimen studied); "a mile southeast of Indian Fields, east of the home of Brownlow Bruner, where the road from Kiddville joins the road from Indian Fields to Clay City; half a mile east of Waco, where the road to Cobb Ferry starts off from the Pike to Irvine; along the road north of Estill Springs, north of Irvine" (localities 53 and 53a of this work). All reported occurences are in the Waco bed of the Noland Member, Brassfield Formation.

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Family Alveolitidae Duncan, 1872

Tabulata with massive coralla of hemispherical, encrusting or ramose form; corallites open at an angle to corallum surface, with compressed, crescentic apertures; mural pores large; septal spines sometimes present, often restricted to one wall of the corallite; septal scales may aldo be present (Sokolov, 1962, p. 231); tabulae complete.

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Alveolites Lamarck, 1801

1801 Alveolites Lamarck, p. 375 (non Defrance, 1816)

1887 Platyaxum Davis, explanations of Plates LX, LXI, LXIII

Type species - (SD Nicholson & Etheridge, Jr, 1877, p. 356) Alveolites suborbicularis Lamarck (1801, p. 376).

Type locality and horizon - Upper Devonian (Frasnian) near Düsseldorf, Germany.

DIAGNOSIS - Alveolitidae with corallum usually encrusting or ramose; corallite axes at about 45° to corallum surface at aperture, more nearly parallel to surface proximally; spines of variable development, sometimes a single spine or ridge in middle of lower wall of corallite; no squamulae present; corallite walls thick.

DESCRIPTION - These are tabulate corals with massive coralla, generally encrusting, or with an irregular upper surface, or even ramose in form.

Typically, the corallites have a vaulted upper wall, and a comparatively flat lower wall. Proximally, they are subparallel with the upper surface of the corallum, but distally they flex upward at about a 45° angle (as compared with about 90° for Crassialveolites). Their compressed cross-section results in a crescentic or semi-circular corallite aperture on the corallum surface.

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The corallite walls are rather thick relative to the lumen, but not generally as thick as that space is wide. The walls are perforate, but this is not always obvious in thin-sections.

Septal structures are commonly restricted to the middle of the lower wall of the corallite, where they may take the form of a single longitudinal ridge, though spines may be present in other cases.

The tabulae are thin and complete.

DISCUSSION - Nicholson & Etheridge, Jr (1877) present a lengthy discussion of the validity,and criteria for recognition of Alveolites Lamarck. They consider six groups of alveolitid corals, including the type species of the genus. Of the type species, A. suborbicularis Lamarck, they stress corallite obliquite, presence of mural pores and complete tabulae, the general shortness and layered arrangement of the corallites, and the presence of a single septal ridge in each corallite on the ventral wall. They note, however, that only the last of these traits might possibly serve as a criterion for distinguishing this genus from related genera. They conclude that "With our present knowledge it seems unwise to abandon the genus Alveolites altogether; but it is at the same time perhaps improbable that future investigations will justify its permanent retention." (p. 360-361).

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It seems that Nicholson and Etheridge may have underestimated the importance of corallite obliquity and compression of the apertures. In stressing the fact that such obliquity is observed in clearly non-alveolitid forms under exceptional circumstances, they overlook the fact that it is universal among species of the genus Alveolites. Nicholson and Etheridge were largely concerned with finding consistent means of distinguishing Alveolites from Favosites. As the latter is generally understood today (albeit, with a shaky understanding), obliquity and corallite compression may be ruled out as a typical feature. As noted above, other characters are needed for distinguishing Alveolites from other alveolitids, but its position as a distinct entity, differentiable from favositids, seems secure.

Platyaxum Davis (1887) is based upon (by subsequent designation of Lang et al., 1940, p. 102) P. turgidum Davis, probably from the Silurian beds near Louisville, Kentucky. (Lang et al. note that an earlier selection of a type species, Pachypora frondosa Nicholson from the Middle Devonian of Ontario, by Bassler (1915) is invalid, as this species is not among those included by Davis under Platyaxum. This genus appears to be a junior synonym of Alveolites Lamarck. It is distinctive for its erect, palmate growth-habit, with corallite apertures on both sides of the frond, and the corallites diverging from the mid-plane of the frond. The general corallite morphology is enough like Alveolites that,

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pending further study, it seems best to regard these two forms as congeneric.

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Alveolites labrosus (Milne-Edwards & Haime)

Plate 10, fig. 8, 9; Plate 24, fig. 1, 2

1851 *Coenites labrosus* Milne-Edwards & Haime, p. 302

1852 *Limaria laminata* Hall (*partim*), p. 143, Plate XXXIX, fig. 6c (*possibly* fig. 6a, b, d)

1854 *Coenites labrosus* Milne-Edwards & Haime, p. 277, Plate 65, fig. 6, 6a

1874 *Coenites lunata* Nicholson & Hinde, p. 151, fig. 2a-c

1875 *Coenites lunata* Nicholson, p. 55, fig. 25 a-c

1875 *Coenites laminata* Nicholson, p. 55, fig. 25d, e

cf. 1876 *Limaria laminata* Rominger, p. 45, Plate XVIII, fig. 2

cf. 1876 *Limaria crassa* Rominger, p. 45-46, Plate XVIII, fig. 1 (*non Coenites crassa* Davis, 1887)

? 1887 *Coenites laminata* Davis, Plate 4, fig. 5

1899 *Coenites lunata* Lambe, p. 28

? 1928 *Coenites labrosus* Twenhofel, p. 131

? 1939 *Coenites labrosus* Shrock & Twenhofel, p. 256-257, Plate 27, fig. 16

Type material - Repository unknown.

Type locality and horizon - Silurian of Dudley, England, probably from the Upper Wenlock Dudley Limestone.

Number of specimens studied - 1

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DIAGNOSIS - Alveolites with crescentic calices about 0.6 to 0.7 mm in length, generally separated from their nearest neighbors by this distance; calice opening distinctly indented by a lip which is sometimes bifurcated, projecting from its convex wall; concave (ventral) wall of corallite has broad median longitudinal ridge which does not appear in the aperture.

DESCRIPTION - The specimen collected is a laminar fragment of a corallum, maximum width about 1.5 cm, thickness about 1 mm. The corallites are shaped rather like quarter moons, one side of the aperture being invested with a broadly-jutting lip. The apertures lie in depressions, about 0.2 mm deep, and are usually about 0.6 to 0.7 mm long, and 0.3 mm across. These corallite apertures are widely-spaced, each being distant from its nearest neighbor by a distance about equal to its own width.

The corallite interiors show no dissepiments. Running along the lower (concave) wall in a longitudinal direction is a single ridge which appears to die out at a point where the sub-horizontal proximal portion of the lumen flexes in an upward direction distally, to attain the surface of the corallum. Thus, this basal "septal" ridge is not visible in the aperture of the corallite. Aside from this, no other longitudinal structures, including spines, have been observed in the interiors.

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DISCUSSION - Numerous cases were found in the literature of forms described with nearly all the characters of this rather distinctive species, except that the lip projecting into the aperture from the convex wall of some specimens was emarginated in the middle (bilobate). This apparently varies in its development. The specimen figured by Milne-Edwards & Haime (1854, Plate 65, fig. 6a) shows some apertures with a faintly-emarginated projecting lip, whereas others are quite like the mono-lobate lip of our specimen. The configuration of the lip, then, is not regarded as a specific criterion in this work.

Milne-Edwards' and Haime's original description of this species, and a subsequent description with figures (1854) present a form with lunate apertures about 0.7 mm long, having a mono-lobate or faintly bilobate "tooth" projecting from the convex corallite wall into the aperture. The spacing of these apertures is shown to be similar to that found in our specimen.

Hall (1852) described Limaria laminata from the lower part of the "Niagara Limestone" at Lockport, New York (probably of roughly Wenlockian age). His description is not very informative, stressing only the fact that the corallum consists of a series of laminae with extraneous deposits between them. His figures suggest that he was dealing with more than one species, but his figure 6c is most like our form. It shows a crescentic aperture, with lateral spacing

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as in our specimen, but with a distinctly bilobate apertural "tooth". If his other figures can serve as an index, the corallite openings are about the same size as ours, and it seems safe to consider his species conspecific with ours.

Coenites lunata was described in 1874 by Nicholson & Hinde, from the Silurian rocks at Owen Sound, Ontario. The original reference was, unfortunately, not available at the time of this writing. In the following year, however, Nicholson described and figured this species. The corallum is a thin crust, about 1.4 mm thick, containing lunate or crescentic calices about 0.5 to 0.6 mm long, and about 0.3 mm across. Their spacing is as in our specimen. The convex wall of the aperture contains a "single strong rounded tooth", giving the crescentic appearance. Nicholson appears to have been repeating his and Hinde's original description of the species, as a later treatment of this form by Lambe (1899) consists of this same description, but attributing it to Nicholson & Hinde.

Limaria crassa, a species erected by Rominger (1876), is based upon material from the Silurian of Michigan. It represents a form similar to ours, but not identical with it. The coralla are laminar growths, often with several being superimposed upon one-another. The corallites tend to be broadly kidney-shaped, though apparently not so distinctly lunate as in our specimen. There is sometimes a lip on the

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dorsal (our convex) margin, but this is absent in other corallites, leaving them unsymmetrically-oval in outline. Corallites are about the same size as in our form, but their spacing varies from [illegible] wide to quite narrow. The ventral surface of the corallite contains a longitudinal ridge, apparently like that found in our form. On the dorsal side, however, two others of similar size project, forking over the ventral ridge. Large pores are numerous in the corallites, and the thinner-walled corallites have dissepiments. Rominger's species is clearly distinct from ours. The pores, dissepiments and dorsal internal ridges are absent from A. labrosus, and Rominger's species has much more closely-spaced corallites than ours does. It rather more resembles the specimens shown by Hall (1852) in fig. 6a, b, and d of his description of L. laminata.

Another Rominger species, from the Silurian rocks at Point Detour, northern Michigan, is Limaria crassa. This is a laminar corallum with stoutly-walled corallites, sometimes more than a [illegible]diameter apart, and less than a millimeter wide. The convex side of the apertures has two rather obscure tooth-like crests, while the concave side has a more conspicuous crest on its median line. Judging from the figure and description, this may be a small variety of Rominger's Limaria laminata, in which case it would be a junior synonym of that species.

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Davis' (1887) figure of Coenites laminata from the "white clay" near Louisville, Kentucky (according to Stumm, 1964, p. 71, it is from the Louisville Limestone, which is Late Wenlock and Early Ludlow in age) is not clear enough to determine its relationship to Hall's species. This specimen was not illustrated by Stumm in his work on the corals of the Falls of the Ohio (1964), but Stumm placed Davis' concept into junior synonymy with another Davis species, Alveolites fibrosus. Stumm's figures of this species, including the holotype, do not resemble Hall's figures.

Twenhofel (1928) reports Coenites labrosus from the Jupiter and Chicotte Formations (Late Llandovery and Early Wenlock) on Anticosti Island. Unfortunately, he gives no diagnostic morphologic information, and so its presence on Anticosti Island must remain in question.

Shrock & Twenhofel (1939) report Coenites labrosus from the Pike Arm Formation (probably Llandovery, though possibly extending into the Wenlock, or even Ludlow) of northern Newfoundland. The corallum is encrusting in sheets about 1 mm thick. The lunate or crescentic corallite apertures are 0.65 to 0.85 mm long, and about a third as much across. A lip projects into the aperture from the convex side, but no tooth-like projection was observed on the concave side. The apertures are wide-spaced, though apparently not tothe extent found in our specimen. The corallite lumens are prostrate through most of their length, as ours are, and distally flex upward to appear at the surface. Between them,

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the deposits are reportedly flattened vesicles. These have not been observed in our specimen, but this is possibly due to the recrystallization to which it appears to have been subjected. Our interspaces appear to be solid. The Newfoundland form has no obvious mural pores, and a few poorly-preserved transverse tabulae were reported. The Newfoundland material can only questionably be identified with our species.

DISTRIBUTION - England: Late Wenlock; New York State: Middle Silurian; Ontario: Silurian (possibly Fossil Hill Formation, of Late Llandovery to Middle Wenlock age); Kentucky: Middle Llandovery (Brassfield Formation)

This species is possibly present in the Late Llandovery and Early Wenlock of Anticosti Island, and in the Silurian of northern Newfoundland.

Brassfield occurrence - Locality 1 (near Panola), in central Kentucky, in the top of the Noland Member.

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Alveolites labechii Milne-Edwards & Haime

Plate 31, fig. 5, 6; Plate 38, fig. 3

? 1839 Favosites spongites Lonsdale (partim), p. 683-684, Plate 15 bis, fig. 8, 8a, 8b (non fig. 8c, 8d, 8e; non Calamopora spongites Goldfuss, 1826)

1851 Alveolites labechii Milne-Edwards & Haime, p. 257

1854 Alveolites labechei Milne-Edwards & Haime, p. 262, Plate LXI, fig. 6, 6a, 6b

cf. 1876 Alveolites niagarensis Rominger, p. 40-41, Plate XVI, fig. 1, 2 (non Nicholson & Hinde, 1874)

cf. 1877 Alveolites undosus Miller, p. 262 (pro Alveolites niagarensis Rominger, 1876, non Nicholson & Hinde, 1874)

? 1890 Alveolites niagarensis Foerste, p. 336-337

cf. 1909 Alveolites inornatus Foerste, p. 103, Plate III, fig. 56

? 1919 Alveolites labechei Williams, Plate XIV, fig. 3

1928 Alveolites labechi Twenhofel, p. 130-131

? 1939 Alveolites labechei Northrop, p. 152

? 1966 Alveolites undosus Bolton, Plate VIII, fig. 6

Type material - Repository of types unknown. Milne-Edwards and Haime (1854, p. 262) report specimens at the "Parisian Museum" (Jardin des Plantes?), and the Museum of Practical Geology in London.

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Type locality and horizon - Milne-Edwards & Haime's material is from Wenlock and Benthall Edge, England (probably of Wenlock age).

Number of specimens studied - 3

DIAGNOSIS - Alveolites with apertures forming pattern reminiscent of pillow-lava on surface of encrusting corallum; apertures about 1.5 mm long (on interior) and about one-third as wide, though this varies; tabulae present in lumens, complete; spines probably present, to varying degrees, on all sides of lumen.

DESCRIPTION - The corallum is encrusting and expansive, the largest being 11 cm in diameter (maximum) and 2 cm in maximum thickness. The corallite apertures are separated only by the thickness of their walls, which is about 1/8 mm. They open obliquely on the surface in a pattern reminiscent of pillow-lava, and have an inside length (maximum dimension) of about 1.3 to 1.8 mm, and a breadth (minimum dimension) of about 0.3 to 0.8 mm (most often 0.5 mm). Spines appear to have been present in sparse distribution on all walls of the corallites, but this is not completely clear in the specimen sectioned. The tabulae of the lumens are horizontal, concave or convex, and are spaced about 1.7 to 2.0 per millimeter. No mural pores have been observed.

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DISCUSSION - Milne-Edwards & Haime (1851, 1854) described this species from the Wenlock of England. The apertures are reportedly not very prominent on the surface, with maximum dimension being between 0.7 and 1.0 mm, and minimum dimension one-third as long. The walls are thin, and the aperture has a pillow-lava-like configuration like our own form. The inner process (presumably a septum or spine) is indistinct. Some of the apertures of their figure 6a show a process or spine on the convex (lower) wall, though not quite centered, and in some of the calices of our specimens, a thickening may be seen in this position (as well as elsewhere), which may be a spinal remnant. Their figure 6b shows that the tabulae are shaped and arranged similarly to those of the Brassfield specimens.

Milne-Edwards & Haime list as a synonym of their species Favosites spongites of Lonsdale (1839, non Goldfuss, 1826, which has a basal medial longitudinal ridge), from Benthall Edge, England (probably Wenlockian). It is difficult to judge the nature of this specimen. It appears low and expansive, with narrow apertures and internal tabulae similar to those in our form, and that described by Milne-Edwards & Haime. This is the specimen of his figure 8, 8a and 8b. The specimen of Lonsdale's figure 8 c-e is from Wenlock, England, and appears to have more-rounded apertures. There is no information available on spines.

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A form similar in apertural outline to the second specimen of Lonsdale is Alveolites niagarensis, described by Rominger (1876) from what is probably the Llandovery or Wenlock of Drummond's Island at Point Detour, northern Michigan (lectotype, Rominger's fig. 2), and from the drift in the lower peninsula of Michigan. As this name was preoccupied by a species of Nicholson & Hinde (1874), it was renamed A. undosus by Miller (1877). The apertures appear to be unthickened, and are rather rounder than in our form. Rominger reports spines around the walls of the lumen, apparently in longitudinal rows. In some cases, the spines do not appear in apertures, but Rominger attributes this to the vagaries of preservation. The tubes measure 0.5 to 1.0 mm in the longer direction (diameter), and contain tabulae which are "somewhat distant and oblique". Mural pores are present, and are of large size, producing pouch-like dilations "of the tube wall at the spot where situated". The degree of compression of the apertures reportedly varies, but in Rominger's figures they are considerably rounder than in our specimens. This fact, and the presence of large mural pores, which have not been seen in the Brassfield specimens, suggest that Rominger's species is distinct from our own.

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Foerste (1890) reported Rominger's species from what are probably Brassfield beds at Ludlow Falls, Ohio (near locality 55 of this study, source of our specimens). The average maximum dimension of his apertures is 1.2 mm, similar to ours. The shorter diameter varies from 0.4 mm to nearly the same length as the longer diameter, such that some of his apertures are reportedly quite as round as those of Rominger's specimens. The corallite walls of Foerste's specimens are crenulate, a feature not seen in our own specimens, unless Foerste is referring to spinal remnants. The tabulae are horizontal, spaced about 2.5 per millimeter. It is likely that Foerste's form is the same as ours, and that the roundness of some of the apertures indicated variability inherent in A. labechii. Without further study, however, we cannot be certain of this.

From the Brownsport Formation of western Tennessee (Early Ludlow in age), Foerste (1909) described Alveolites inornatus. Foerste's account of the aperture size (4 to 5 apertures in a width of 5 mm) is unclear, as he doesn't specify whether he speaks of the elongate or short dimension of the aperture. Judging from his figure, they are comparable to ours in size and shape. They vary, reportedly, in the degree of roundedness they display, but appear to be generally of the same pattern as ours, or within that range. Spines were not observed on the lumen walls, but Foerste notes that a longitudinal striation is sometimes seen along

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the median portion of the lower wall, and less-often on the upper wall (apparently similar to that found in our specimens of Alveolites labrosus, which see). Foerste reports no marginal pores in the walls. This form seems quite similar to our own, except for the reported presence of median striations. If these actually exist, it is unlikely that Foerste's specimen is conspecific with ours.

In at least two instances, A. labechii was reported by workers who supplied insufficient information to allow substantiation of their identification. Williams (1919) reported if from the "Lockport Formation" (probably Middle Silurian) of Manitoulin Island, Lake Huron. He supplied only a figure of a specimen (GSC 2642a) which appears to have apertures with the size and roundness of Hominger's A. niagarensis (= A. undosus) from the same general area.

Northrop (1939) reported the same species from the Gaspé region of Maritime Canada, but gave no morphologic data or figures. His material is from the La Vieille (Late Llandovery), the Gascons (Early Ludlow), the Bouleaux (Early Ludlow), and the Indian Point (Middle Ludlow) Formations.

From the Jupiter and Chicotte Formations of Anticosti Island (Late Llandovery to Early Wenlock), Twenhofel (1928) reported this species. The apertures are compressed, the long diameter being 0.5 to 1.0 mm, and the shorter usually no more than a third that length. The tabulae are oblique,

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about 2 per millimeter, complete as well as incomplete. Pores occur at the angular edges of the corallites. Spines appear to be present, but are poorly-preserved. Judging from Twenhofel's description, it appears that our species does indeed occur at Anticosti Island.

Bolton(1966) figured a specimen identified as Alveolites undosus from the Fossil Hill Formation (Middle Llandovery through Middle Wenlock) of Manitoulin Island. His specimen (GSC 20546) does have the general features of our species, the apertures being less rounded than in A. undosus, and about the same size as ours. Unfortunately, no other information is available than a figure of the upper surface, and so identification must await further study.

Of some interest is a specimen found in the upper Whitewater beds (Richmondian, Late Ordovician) at Richmond, southeast Indiana. This is an Alveolites remarkably similar to the Brassfield form. The apertures are slightly smaller (maximum dimension = about 1.1 mm, minimum = 0.5 mm), the walls are of the same thickness (1/8 mm), and the tabulae are of the same sort, mostly concave upward, and spaced about 2.5 to 4.0 per millimeter. No mural pores were observed in this specimen (UCGM 41781). The major difference between the Ordovician specimen and those from the Brassfield is that the former appears more spinose. Spines are present on all walls of the corallites (though not seen in every corallite). If the thickenings on the walls of the

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Brassfield specimens actually are spinal remnants, it is likely that we have here the same species in the Late Ordovician and the Early Silurian, on either side of an unconformity. It is possibly, on the other hand, related to A. undosus, in which case also, the same species occurs on both sides of the Ordovician-Silurian boundary in eastern North America. Rominger's report of abundant spines in his species agrees with the features of the Ordovician specimen, but the apertures of the latter do not seem to be quite so round.

Distribution - England: Wenlock; Ohio: Middle Llandovery (Brassfield Formation), and possible Late Ordovician (Whitewater Formation); Anticosti Island: within the interval of Late Llandovery to Early Wenlock.

This species possibly occurs on Manitoulin Island, in the interval from Middle Llandovery through Middle Wenlock (reported by Bolton, 1966).

Brassfield occurrence - Locality 55 (near Ludlow Falls, southwestern Ohio), in the grey-green clay at the top of the Brassfield Formation.

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Family Pachyporidae Gerth, 1921

Tabulate corals with corallites arranged in cerioid pattern in ramose coralla; corallites open approximately perpendicular to the corallum surface; corallite walls thickened by stereome, so that the mural pores are tunnel-like; septa spinose, or represented by low ridges; tabulae complete.

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Striatopora Hall, 1851

1844 Cyathopora Owen, p. 69 (nom. null. pro Cyathophora Michelin, 1843, p. 104)

1851 Striatopora Hall, p. 400

Type species - (By original designation): Striatopora flexuosa Hall, 1851, p. 400; 1852, p. 156.

Type locality and horizon - Lockport Formation (of Wenlock and Ludlow age) of New York State.

DIAGNOSIS - Pachyporidae in which proximal portions of the corallites lie parallel to the axis of each corallum branch, but distally flex away from axis to open on surface; corallite walls thicken distally; tabulae complete, flat; mural pores present; septal crests sometimes present in calices.

DESCRIPTION - This is a ramose tabulate coral in which the proximal portions of the corallites parallel the axis of the branch, while the distal portions curve from the axis in such a way as to open obliquely on the surface of the branch. The corallite aperture is always somewhat inclined toward the more distal end of the branch.

The corallite lumen contains complete tabulae, generally rather wide-spaced, and sometimes, spines. The walls are perforated by mural pores. In the corallite aperture, septal ridges are sometimes present.

The corallites, and their walls, broaden distally.

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DISCUSSION - The taxonomic history of this genus has involved some matters of judgement that introduce considerable subjectivity, and even mind-reading, into the status of the name Striatopora Hall. Michelin (1843) erected the name Cyathophora for a coralline, cerioid genus which (according to Lang et al., 1940, p. 43) is a Mesozoic scleractinian. In 1844, Owen introduced a new species, Cyathopora iowensis (p. 69), from what he called the "carboniferous limestone" of Iowa (but which Lang et al. claim is from Devonian rocks of that state). Judging from Owen's description and figure, it appears likely that this is a species congeneric with Striatopora Hall (1851).

The difficulties begin in trying to determine whether Owen was introducing a new genus (this being the first use of the generic spelling Cyathopora), or was simply misspelling Cyathophora Michelin. Lang et al. (p. 44) argue that "although it might be argued that Cyathopora Owen is not a mistake for Cyathophora but was erected as a new genus by him, nevertheless, in view of the absence of any definitive evidence to that effect, and as Owen was not in the habit of creating new genera, we prefer to regard Owen's term as an error for Cyathophora (a Jurassic hexacoral genus)." Lang et al. point out that other authors, including Lindström, Meek & Worthen, and Bassler concurred with this conclusion. To give this view its due, Owen did indeed not give any indication that he intended the raising of a new

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genus in introducing this species. On the other hand, he nowhere mentioned Michelin (though neither did he mention Goldfuss in describing Cyathophyllum caliculare), and his figure of Cyathopora bears not the least resemblance to Cyathophora Michelin.

If one chooses to accept what has been the historical view, that Owen's name was an invalid emendation (conscious or unconscious) for Cyathophora Michelin, then Hall's Striatopora must be the first valid name applied to the genus in question. On the other hand, if Cyathopora is valid as a generic name, it must displace Striatopora in usage. If Lang et al. have erred, it could only be in their judgement of what appears to be an entirely subjective matter, as the International Code of Zoological Nomenclature remains neutral in this affair. The long-established usage of Hall's generic name also argues in favor of upholding the historical view.

Hall first used the term Striatopora in 1851, in a brief paper whose purpose appears to have been to nail his name to genera which were to be described and figured in greater detail in his 1852 volume of Palaeontology of New York. In fact, in the former paper, Hall gives the page references for the latter publication.

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Striatopora flexuosa Hall

Plate 11, fig. 3, 4; Plate 24, fig. 3-5; Plate 36, fig. 2

1852 Striatopora flexuosa Hall, p. 156, Plate 40B, fig. 1a-e

? 1875 Striatopora flexuosa Nicholson, p. 55-56, fig. 26

1890 Striatopora (Cladopora?) proboscidalis Foerste, p. 337 (non Cladopora proboscidalis Davis, 1887).

? 1899 Striatopora flexuosa Lambe, p. 40

1901a Striatopora flexuosa Grabau, p. 148, fig. 45

1901b Striatopora flexuosa Grabau, p. 148, fig. 45

Type material - Three Hall syntypes are in the American Museum of Natural History under the number 1685.

Type locality and horizon - Hall cites the locality of his species as the shale of the Niagara Group at Lockport, New York. This is probably the Rochester Shale, which spans most of the Wenlock, according to Berry & Boucot (1970).

Number of specimens studied - 2 (one containing many fragments).

DIAGNOSIS - Striatopora with corallite apertures opening only slightly obliquely at the surface of the branches of the corallum, where they are positioned in shallow, polygonal depressions; striae run from aperture across floor of depression toward wall of depression; spines not in evidence; tabulae generally further apart than diameter of lumen.

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DESCRIPTION - This species has been found in the form of disjointed branching twigs at two localities. The best-preserved specimen (internally) is a small fragment, apparently about 8 mm in original diameter, from locality 37. Full-grown corallites in the interior of the cylindrical fragment are about 1.1 mm in diameter, with a polygonal outline. Smaller, presumably younger ones occur interstitially among the larger corallites. Apparently the corallites extend along the axis of the corallum branch, and eventually flex outwardly, to open on the surface, in a manner similar to the zoecia of a trepostome bryozoan (Plate 11, fig. 3; Plate 24, fig. 3, 4; Plate 36, fig. 2).

The corallite walls are less than 0.1 mm thick, with distinct, dark mid-lines. The tabulae are spaced farther apart than the diameter of the lumens, as a rule, being about 1 per millimeter. Occasional breaks in the corallite walls of this specimen (UCGM 41962) may represent mural pores. No spines have been observed in any of our specimens of this species.

Another specimen (UCGM 41994 ; Plate 11, fig. 4; Plate 24, fig. 5),from locality 55, has about the same internal features, as well as corallites of about the same size, as the specimen just described. Its diameter, however, and the diameters of most of the many fragments associated with it in a small rock, is smaller, about 2.5 mm. Occasional breaks appear in the walls of some of its corallites where

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they appear to bud from a neighbor. While preservation of the specimen from this locality is fairly poor, yet some details can be seen on the surface that weren't visible in the specimen from locality 37. The corallite apertures appear to open slightly obliquely upon the surface, facing upward. Each opens into a depressed area, up to 1.5 mm across, which gradually rises outwardly to a low bounding wall, giving it a polygonal outline. In most cases the aperture could not be clearly seen in the bottom of the depression, but in other cases, there sees to be a distinct deepening at the point where the aperture would be expected in this species. In rare instances, what appear to be grooves radiate from the inferred aperture outward toward the wall of the depressed area.

DISCUSSION - Hall's specimens consist of ramose, terete branches, with round apertures opening into polygonal depressions. The apertures open somewhat obliquely, facing upward, in the depression, and striae radiate from their rims, the longest being toward the upper walls of the depression. The figures and description closely agree with our specimens, and there is little hesitation in identifying the Brassfield form with Hall's species.

Nicholson's reference to this species (1875) consists simply of a reillustration of some of Hall's figures, with the statement that it is not uncommon in the Niagara Limestone of Thorold, Ontario. It is difficult at this point to

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determine to which unit Nicholson was referring, but probably the age is Llandovery or Wenlock.

Foerste (1890) reported a form of Striatopora from the Ludlow Falls region of southwestern Ohio, the same area as the source of some of our material. The coralla were ramose with an average diameter of 3 mm, tapering to about 2.2 mm within about an inch, in some cases. The thicker coralla seemed to branch more frequently than the more slender ones. The apertures were directed obliquely, outward and upward, opening into polygonal areas which were about 5 to 6 in a length of 5 mm (approximately comparable to our specimens). The floors of these depressions were often marked by striae radiating from the aperture, more obvious in large calicular regions. In some cases, Foerste reported, distinct pores could be seen connecting adjacent corallites. Judging from his description, and the fact that his material is from the same area as some of ours, it is probable that Foerste was dealing with S. flexuosa.

Foerste had identified his specimens with Davis' Cladopora proboscidalis (1887, Plate 97, fig. 21) from the Louisville Limestone (Late Wenlock and Early Ludlow) near Louisville, Kentucky. Davis' figure is unclear, but Stumm's figure of his type (1964, Plate 69, fig. 7) indicates that the apertures open into upward-directed grooves, rather than polygonal depressions.

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Lambe (1899) repeated Hall's description of this species, and noted that the Canadian Geological Survey had a specimen of this species from the Niagaran of Grey County, Ontario. As no figure or description accompanied this report, it is impossible to verify Lambe's identification.

Grabau (1901a, 1901b) reillustrated two of Hall's figures and gave a diagnosis of S. flexuosa, quite in agreement with Hall's concept of the species, and our own. He reported it as commonly occurring in the bryozoan bed of the Rochester Shale at Niagara and at Lockport, western New York State.

Distribution - New York State: Wenlock; Ohio: Middle Llandovery (Brassfield Formation).

Possible occurrences are those reported by Lambe and by Nicholson from the Llandovery or Wenlock of Ontario.

Brassfield occurrence - Localities 37 (near Sharpsville) and 55 (near Ludlow Falls) in southwestern Ohio.

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ORDER HELIOLITIDA

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Family Proporidae Sokolov, 1950

Massive, encrusting or hemispherical heliolitids with distinct corallites lying in matrix of vesiculose coenosteum; corallite boundaries marked by the vesicles of the coenosteum (i.e., no distinct, integrated walls), or else formed by lateral fusion of 12 longitudinal ridges representing thickened rows of septal spines; septal spines may be present even where thickened walls are lacking, by being based upon the sides of coenosteal dissepiments bordering the corallites; tabulae complete or incomplete, usually the former case; spines sometimes present on upper surfaces of coenosteal vesicles.

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Propora Milne-Edwards & Haime, 1849

1849 Propora Milne-Edwards & Haime, p. 262

1851 Lyellia Milne-Edwards & Haime, p. 150, 226

1878 Pinacopora Nicholson & Etheridge, p. 52

? 1913 Calvinia Savage, p. 65 (non Nutting, 1900)

? 1922 Cavella Stechow, p. 152 (pro Calvinia Savage, non Nutting, 1900)

1934 Koreanopora Ozaki, p. 68 (in Shimizu, Ozaki & Obata, 1934)

Type species - (By monotypy) Porites tubulatus Lonsdale, 1839, p. 687 (partim), Plate XVI, fig. 3, 3a, 3b (caeteris exclusis).

Type locality and horizon - Wenlock Limestone (Late Wenlock) at various localities in Shropshire, Herefordshire, Gloucestershire and Worcestershire, England.

DIAGNOSIS - Corallum of cylindrical corallites separated laterally by vesiculose coenosteum; corallites have distinct walls; corallite tabulae complete; corallite walls thickened in 12 spots around the circumference, forming 12 septal ridges, parallel to the corallite axis, and at the surface forming the 12 nodes of a thickened exsert aperture; coenosteum may contain trabeculae; no mural pores.

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DESCRIPTION - These are corals of which the corallum consists of cylindrical corallites separated from one another by a vesiculose coenosteum. The corallites contain complete tabulae, and each corallite has its own wall, separating it sharply from the coenosteum. The wall contains 12 longitudinal rows of spines or nodes, and these rows are usually thickened to greater or lesser degree, to form 12 septal ridges. In transverse view, these ridges are manifest as 12 nodes surrounding the periphery of the corallite. The nodes project above the level of the upper surface of the coenosteum, though it is not clear if this was the condition in life, or simply the result of a greater resistance to erosion on the part of the thickened parts of the wall than was possessed by the coenosteum. These 12 projections constitute the exsert margin of the corallites, noted by Milne-Edwards & Haime (1849, p. 262).

Corallites appear to arise directly from the coenosteum, rather than through offsets from older corallites. Vertical spines are seen to project from the dissepimental surfaces of the coenosteum in some forms.

DISCUSSION - Milne-Edwards & Haime (1849) first described Propora based upon Porites tubulatus Lonsdale (1839), from the Silurian of England. They were struck particularly by the protruding apertures of the corallites, marked by a surficial prolongation of each septal ridge into a knob at the corallum surface. It is not clear from the original descript-

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ion of this genus, nor from Lonsdale's description of the type species, if the coenosteum is vesicular. Hill & Stumm (1956, p. 460, 461) described the genus and figured the type species, showing a vesiculose state of the coenosteum, and so this genus is here accepted as having the structure usually attributed to it.

In 1851, Milne-Edwards & Haime erected Lyellia, based upon the heliolitid species L. americana from the Silurian of Drummond Island, Lake Huron. In all respects, this appears identical to Propora, and is regarded as a junior synonym of that genus.

Nicholson & Etheridge (1878) introduced the genus Pinacopora for Silurian heliolitids near Girvan, Scotland. Though their description of the genus and its type species, P. grayi, is replete with references to tabulate tubules between the corallites, the figures (e.g., Plate III, fig. 3d) clearly show a vesiculose coenosteum, often so narrow due to close approximation of the corallites, as to be about one dissepiment broad. In this, and in all other discernible features, the genus is identical to, and a junior synonym or Propora.

From the Lower Silurian of Illinois, Savage (1913) described the heliolitid genus Calvinia, distinguished by its vesiculose coenosteum, through which small tubules reportedly ran parallel to the corallites. Stechow (1922) noted that the name Calvinia was preoccupied, and renamed the genus Cavella. Except for the presence of the tubes, Savage's

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specimen would clearly be a member of the genus Propora. Though Savage's Plate II, fig. 15 suggests that these tubes are real features, it will be necessary to study the type material before a final determination can be made as to the relationships of this genus.

Finally, Ozaki (in Shimizu, Ozaki & Obata, 1934) described the genus Koreanopora from Silurian beds of northwest Korea (North Korea). This genus differs from the typical Propora solely in having a slight axial elevation of the tabulae in the corallites, a feature that seems more likely to be a normal variation for Propora. The two genera, then, are here felt to be synonymous.

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Propora conferta Milne-Edwards & Haime

Plate 34, fig. 2, 4

1851 Propora conferta Milne-Edwards & Haime, p. 225

1865b Heliolites affinis Billings, p. 427

1899 Propora conferta Lindström, p. 93-94, Plate VIII, fig. 32-39; Plate IX, fig. 1-23, 31, 32, 35

1909 Lyellia thebesensis Foerste, p. 95, fig. 69a, b

? 1913 Lyellia thebesensis Savage, p. 66-67, Plate III, fig. 6, 7

1928 Lyellia affinis Twenhofel, p. 133

1934 Propora cfr. magnifica Shimizu, Ozaki & Obata, p. 67, Plate X, fig. 9, 10; Plate XI, fig. 1 (non Propora magnifica Počta, 1902)

1934 Propora yabei Shimizu, Ozaki & Obata, p. 67-68, Plate XI, fig. 2, 3

1937 Plasmopora lambei Teichert, p. 53-54, Plate IV, fig. 13; Plate V, fig. 1, 2 (non Plasmopora lambii Schuchert, 1900)

1939 Lyellia affinis Northrop, p. 148

1939 Lyellia affinis Shrock & Twenhofel, p. 253, Plate 28, fig. 10, 11

? 1940 Propora conferta Jones & Hill, p. 209, Plate XI, fig. 5 (cet. excl.)

1940 Propora affinis Sugiyama, p. 141-142, Plate XXIV, fig. 1-3; Plate XXXII, fig. 1, 2

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1957 Lyellia thebesensis Foerste paucivesiculosa Bolton, p. 64-65, Plate VI, fig. 1-7

1957 Propora conferta Iskyul, p. 97-98, Plate VII, fig. 3, 4

1962a Lyellia affinis Norford, Plate VIII, fig. 17

1962 Propora conferta Sokolov, p. 425 (English translation), fig. 4

? 1972 Heliolitid undet. Bolton & Copeland, p. 30, Plate IV, fig. 1, 2

1972 Propora sp. Bolton, p. 26, Plate III, fig. 5, 8; p. 28, Plate IV, fig. 8, 13; p. 32, Plate VI, fig. 5, 9, 10, 11; p. 34, Plate VII, fig. 6, 17; p. 40, Plate X, fig. 2, 3

Type material - Lindström (1899, p. 93) has described two syntypes in the de Verneuil Collection, École de Mines, Paris.

Type locality and horizon - Late Ordovician of Estonia (Windau and Borckholm).

Number of specimens studied - 12

DIAGNOSIS - A species of the genus Propora with corallites from about 1 to about 2 mm in diameter, separated from the nearest neighbor by less than their diameter; corallite walls thickened into 12 longitudinal "septal" ridges; tabulae concave upward or horizontal, occasionally incomplete.

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DESCRIPTION - The coralla are gently to strongly convex upward. Within a single specimen, corallite diameters may range from 1.0 to 1.5 mm, though descriptions in the literature indicate an upward continuum to 2.0 mm. Characteristically, each corallite is spaced from its nearest neighbor a distance less than its diameter, and sometimes the coenosteum is all-but-absent between a pair of corallites. Where the upper surface of the corallum is exposed, the corallite rims are exsert, a character described by Milne-Edwards & Haime (1850, p. lix) as typical of the genus Propora. While this condition may have existed in life, it may also be due to the greater resistance of the thickened corallite wall to erosion than is possessed by the vesiculose coenosteum. None of the specimens so-far encountered can be confidently said to possess a holotheca.

Well-preserved corallites have the wall thickened in 12 places around the perimeter, producing a cog-wheel-like appearance, with the teeth pointing axially. This results in a corallite wall about 1/9 mm thick. The fact that all 12 of these "septal" thickenings appear concurrently in a given transverse section of a corallite argues for their being continuous longitudinal ridges, as does the absence of any discontinuity in wall thickness as seen in longitudinal section (see Plate 34, fig. 2, 4). The wall deposits are in optical discontinuity with the rest of the corallum.

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The corallites are contained in a matrix (coenosteum) of vesicular dissepiments. They appear to originate by differentiating directly from this "common tissue", rather than by budding from one-another. Strangely, they also appear to disintegrate distally, merging once again with the vesiculous tissue, without being bounded above by the wall deposits as would be expected if they were merely passing from the plane of the section. (This is not the case seen in Plate 34, fig. 4, in which the extension of the septal ridges upward after the disappearance of the rest of the corallite indicated that the corallite has merely passed out of the plane of section.) The spaces between neighboring corallites vary in such manner that there are as few as one, and as many as three or more dissepiments ranged laterally between them, depending upon the distance across the space. These dissepiments vary in size and convexity. A large one may be 1 mm across and 0.3 mm high. A rather small one may be 0.3 mm across and 0.1 mm high. In some specimens (Plate 34, fig. 4) these size-variations are grouped, giving the coenosteum a vertical zoning. Dissepiments cannot be definitely said to bear spines on their upper surfaces, as are seen in other forms of this genus.

The tabulae of the corallites are usually concave upward, occasionally horizontal, and seldom convex. They are spaced from 1/2 to 1/7 mm apart vertically, in bands correlating with those of the coenosteum. The tabulae are mostly complete, but some incomplete examples may be found as well.

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DISCUSSION - In the light of current data, Propora conferta was one of the most wide-spread of all Early Paleozoic coral species. In addition, it had a strong superficial resemblance to at least one much-older species (discussed below).

The present species was first described by Milne-Edwards & Haime (1851), without illustration, based upon material from Estonia. Their assignment of a Wenlockian age to the specimens is apparently wrong, a Late Ordovician age being likely correct (see discussion of Lindström, 1899 below). The important characters are as follows: Coralla poorly-preserved hemispherical masses; corallite diameter 2 mm, with calices close-spaced, making the zones of vesiculose "coenenchyme" (coenosteum) ill-developed. The corallite walls are serrated, with 12 projections. The tabulae are close-spaced. The description, while quantitatively vague, generally agrees well with our specimens.

Billings (1865b) reported as a new species Heliolites affinis from Anticosti Island. The syntype in the collection of the Canadian Geological Survey (GSC 2340) is from the Chicotte Formation (Late Llandovery through Early Wenlock), but I have not personally examined it. Lindström (1899) examined type P. conferta (see below) and typical specimens of H. affinis, and judged them conspecific (p. 93). The corallites of H. affinis are "from half a line to little less than one line in diameter, the more common width being about two-thirds of a line..." A line is 1/12 inch (just over 2 mm), so the corallite diameter ranges from slightly over 1 mm to

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about 2 mm, most being about 1.3 mm across. These coral-lites are in a vesiculose matrix (which, together with other features, indicates that this species belongs to Propora,

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and not Heliolites). The corallites are separated from one-another by about half their diameter, so that the intervening coenosteum is quite narrow. Sometimes the corallites are so close as to make their usually-round profile polygonal. As is common in Propora, the rims of the corallites are thin and exsert, well-preserved apertures displaying 12 small tubercles around the opening. Septa in some instances appear as striations of the corallite walls. The tabulae are usually horizontal, with three or four in 2 mm vertically.

In every respect, this description agrees with our material, and Billings' species is probably a junior synonym of P. conferta.

Lindström (1899) took the important step of searching out and describing the unfigured specimens on which Milne-Edwards & Haime's (1851) description of P. conferta was based. These were located in the École des Mines in Paris, in the care of Douvillé, who assured Lindström that the writing on their labels was in the hand of Jules Haime. The two specimens involved were collected by E. de Verneuil during his expedition in Russia (1844) with Murchison. One was from Borkholm, and the other from "Chavli Canal de Windau", both in Estonia. Lindström believed the second specimen was not in place, as there are no Silurian strata at that locality.

The coralla are in discoid or spheroidal masses, with corallites about 1.5 mm across. These tubes are so close-spaced as to leave little room for the vesiculose coenosteum.

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The apertural rims are only slightly exsert, and are crenulated into 12 small nodules. No spines were seen in the corallites, but the walls were fluted. The tabulae are variously-spaced, those of the Borkholm specimen (Lindström's Plate VIII, fig. 34) averaging about 4 per millimeter, while those of the Windau specimen (fig. 39) are about 2 to 3 per millimeter. The tabulae are mostly flat, or slightly concave. A very few are incomplete. The coenosteum is free of spines.

Lindström (p. 130) indicated that the Borkholm specimen is from the F-1 horizon, which is Late Ordovician in age (according to Manten, 1971). His description and figures indicate that Milne-Edwards & Haime's material is probably conspecific with ours, as these authors' less-detailed description suggested.

Foerste (1909) described Lyellia thebesensis from the vicinity of Thebes, Illinois. Stratigraphically, it lay 3 feet above the "Cape Girardeau"Limestone (now called the Girardeau Limestone) in the Edgewood Formation, of Early Llandovery age. Foerste's description is vague, but the important points are that the coralla are massive, with corallites slightly over 1 mm in diameter nearly in contact with one-another, leaving narrow intermediate spaces of coenosteum. This intermediary tissue is not distinctly vesiculose. The corallite walls are crenulate and longitudinally-striated. The corallites have 8 to 9 tabulae in 5 millimeters vertically.

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This description agrees well with the characters of the Brassfield specimens in all respects save the nature of the coenosteum. In our specimens, however, where corallites are closely-spaced, the interstitial deposits may indeed lose some of their vesicular aspect, so that it seems likely that Foerste's species is a junior synonym in name, of P. conferta.

Later (1913, p. 66-67), Savage described several more specimens from the Edgewood Formation near Thebes, Illinois, and Pike County, Missouri, which he assigned to Foerste's L. thebesensis. The description and figures, while poor, agree well-enough with Foerste's, and are tentatively assigned to P. conferta. Closer study of Savage's material, would be desireable before certainty of the identification is possible.

Bolton (1957) described Lyellia thebesensis paucivesiculosa, a new variety of Foerste's species, from the Manitoulin Formation (Early Llandovery) of Manitoulin Island, Lake Huron. The type specimen (ROM 783c1) has corallites 1.0 to 1.25 mm in diameter, with flat or concave tabulae spaced 1 to 3 per millimeter, showing some evidence of vertical zonation. The septa are solid ridges. This form is characterized by the extreme narrowness of the coenosteum between the corallites. Where corallites are especially close-spaced, the coenosteum appears tabulate, but it takes on a vesicular aspect where it is not so restricted. Bolton's material

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agrees well with the Brassfield specimens morphologically, and they are considered conspecific.

Shimizu, Ozaki and Obata (1934) described two species from the Silurian of northwestern Korea which appear to belong to Propora conferta. The first species, which they call Propora cfr. magnifica is not identical to Počta's species of that name, which has spinose septa. The Korean form has close-spaced corallites, about 1.3 mm in diameter, reportedly circular or crenulate in cross-section, and with definite walls. The tabulae are concave, spaced on average about 3 to 4 per millimeter, and appear to be zoned vertically.

The second Korean species, Propora yabei, has close-spaced corallites, about 1.0 mm in diameter, reportedly circular or slightly crenulate in cross-section. The tabulae are mostly horizontal, or slightly convex, spaced about 2.5 per millimeter, with no evidence of vertical zonation. The coenosteum, as with the above species, is vesiculose.

Teichert (1937) illustrated and described a coral from Iglulik Island in the northeast Canadian Arctic, which agrees in nearly all visible characters with the Brassfield specimens. The corallites are approximately 1.0 to 1.8 mm in diameter, with well-defined, thickened walls bearing 12 projections around the periphery. The corallites are very closely-spaced, often nearly contiguous laterally, and the coenosteum is definitely vesicular. The only area of dif-

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ference between Teichert's specimen and ours lies in the topography of the tabulae. While their spacing is in good agreement with that of the tabulae in our form, in Teichert's specimen there is a greater tendency toward convexity of the tabulae than in our specimens. (Teichert's Plate IV, figure 13 shows a specimen upside-down, as evidenced by the overlapping of the dissepiments.) Convex tabulae do occur in the Brassfield specimens, but not with the frequency shown in Teichert's section. The weight that this difference should carry is difficult to judge. Though it may seem trivial, the simplicity of Early Paleozoic corals makes it advisable to consider carefully even the least-obvious characters in studying relationships between these fossil organisms. Nonetheless, it would be consistent with the practice in the rest of the present paper to consider Teichert's form as probably conspecific with our own. Unfortunately, the only available information on the age is that it is Ordovician.

A number of workers have described and figured specimens from the Maritime Provinces of Canada that bear close resemblance to our corals. Lyellia affinis, described by Twenhofel (1928) from Anticosti Island reportedly occurs from zone 4 of the Ellis Bay Formation (variously assigned to the Late Ordovician and Early Llandovery) through the top of the Chicotte Formation (Early Wenlock). Twenhofel's descriptions are meager, and it is clear that he is speaking

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of a number of specimens collectively encompassing a realm of variation. Several of the important characters are reported here: The corallites are spaced apart by distances considerably less than their diameters (though the diameter is not given). Septa are well-developed in some specimens, though their nature is not disclosed.

Fortunately, a recent paper by Bolton (1972) lends support to the idea that this species ranged from Late Ordovician through Early Silurian time in the Anticosti Island region. In this paper, Bolton illustrated fossils from the stratigraphic sequence of this region, and P. conferta, as defined in the current work, appears at several stages, in each case identified by Bolton as Propora sp.

The earliest occurrence is in the upper member of the Vauréal Formation (Late Ordovician, Richmondian). This specimen (Bolton Plate III, fig. 5, 8) has close-spaced corallites, about 1.5 mm in diameter, with a vesiculose coenosteum. Tabulae are about 2 per millimeter, and are occasionally incomplete. Their general configuration is horizontal, with very shallow divergences to the concave or convex. Doubt is cast on the identification of this specimen with our material only by the absence of clear septal projections in the transverse section. It should be noted, however, that such projections in our specimens are often not preserved, and Bolton's figure is unclear.

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The next specimen is from member 5 of the Ellis Bay Formation, which Berry & Boucot (1970) consider Early Llandovery while Bolton assigns it a Late Ordovician are. In any event, it appears to be on the frontier between the Ordovician and Silurian. Thisspecimen is essentially identical to that from the Vauréal, except here the tabulae are somewhat wider-spaced, about 1 per millimeter. Septal projections are unclear in the transverse section, but some serration does seem to exist in several of the corallites of this figure.

Bolton next illustrates two specimens from member 6 of the Ellis Bay Formation. Both specimens (Bolton Plate VI, fig. 5, 11; fig. 9, 10) have corallites of similar size, roughly 1.0 to 1.2 mm in diameter. Here again, the structure of the walls is not sufficiently clear to discern longitudinal ridges. The tabulae in both specimens are dominantly horizontal, or shallowly-concave, and are spaced about 2 per millimeter in figure 10 (with no clear vertical zonation), while those in fig. 11 are from 1.5 to 4 per millimeter, and do show some zonation. The coenosteum is in many places quite narrow in both specimens, often limited to the breadth of a single dissepiment.

The next specimen is from the Becscie Formation (Middle Llandovery). Bolton's Plate VII, fig. 6, 17 show a specimen with close-spaced corallites, about 1.5 mm in diameter, with some evidence of longitudinal ridges with the corallites.

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the tabulae are dominantly horizontal, with some weakly convex or concave. Zonation of tabular spacing is quite distinct here, ranging from 1 per millimeter in the sparse zones to 4.5 per millimeter in the denser zones. Here again the coenosteum is often restricted to the width of a single dissepiment.

Finally, Bolton figures a specimen (Plate X, fig. 2, 3) from the Jupiter Formation (Late Llandovery). The corallite diameters range from about 1.0 to 1.2 mm, and the coenosteum is often restricted, as with Bolton's other figured specimens, to a width of one dissepiment. The tabulae are nearly all horizontal or shallowly concave, as are those of the Brassfield specimens. Their packing is zoned, ranging from 5 per millimeter down to 1.2 per millimeter respectively in the denser and sparser zones. The nature of the corallite walls cannot be discerned from the figure.

Here, then, we are presented with six specimens, ranging in age from Late Ordovician to Late Llandovery, all essentially within the same geographic area. In most respects, they closely-resemble our Brassfield specimens. The range of corallite diameters is within the realm of variation of our corals, as is the spacing of the corallites. "Septal projections occur in the Anticosti Island specimens in such a pattern as to imply that they probably were present initially, but have been lost through diagenesis by most of the corallites, or else have simply not been cap-

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tured in the process of making photographic plates. A third possibility is that these structures are not present in all corallites of a corallum, or occur only at some levels of a corallite. These assumptions are, of course, risky, but they occasionally are necessary in such comparative works as these. Finally, the spacing of the tabulae is variable, but appears to form a continuum which accommodates the internal arrangements in our corals. The topography of the tabulae (concavity, convexity) does not appear to occur in any meaningful pattern, so far as time distribution or correlation with other features is concerned. For our purposes in this work, it seems advisable to treat the predominant concavity of the tabulae in Brassfield specimens of this species as a subspecific character. Nonetheless, the question of validity of this assumption would be an important line of study. Certainly, the members of this species (if it is a single species) are sufficiently widespread geographically and stratigraphically to supply abundant material with which to work.

Northrop (1939) reported corals from Gaspé region of the Canadian Maritimes which he identified as Lyellia affinis. These occur in a sequence including the Anse Cascon (Late Llandovery), La Vieille (Late Llandovery through Wenlock) and Gascons, Bouleaux, West Point and Indian Point Formations (Ludlow). The description closely-approximates the characters of our specimens so far as it goes, though it

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is clear that Northrop is describing several specimens, rather than detailing the characters of a single coral. The corallites are closely-spaced, and are within one half a diameter from the nearest neighbor, separated by a vesiculose coenosteum. Corallite diameter is 1.0 to 1.7 mm. The corallite rims are exsert. There is no information given concerning septal structures or tabulae. Based on the available information, it seems likely that Northrop is dealing with P. conferta.

Shrock & Twenhofel (1939) described a coral from the Pike Arm Formation of northern Newfoundland, associated with a fauna that they considered correlative with that of the Jupiter Formation of Anticosti Island (Late Llandovery). Their description agrees well with the characters of the Brassfield form of P. conferta: The corallite diameter is 1.0 to 1.75 mm, with close-packed corallites seldom over half a diameter apart, often nearly contiguous. The corallite walls are crenulated. The tabulae are horizontal, concave and convex, spaced 2 to 4 per millimeter. The longitudinal section (fig. 11), however, shows one character different from typical Brassfield specimens: Incomplete tabulae are rather more abundant in this specimen than in ours. Judging by the degree of variation apparent within this species, it seems reasonable to regard Shrock & Twenhofel's specimen as identical to our species.

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Jones & Hill's (1940) Propora conferta cannot confidently be considered conspecific with our specimens. The three specimens figured are shown in three transverse and one longitudinal section. The corallite walls are crenulated. Only in figure 5 are the corallites particularly close-spaced, and here, with diameters of about 1 mm, they are spaced within one-half diameter of the nearest neighbor. The coenosteum (in figure 5b) is vesiculose. Tabulae are mostly concave upward, spaced about 5 per millimeter. The description speaks of short breaks in the corallite walls occasionally being visible in transverse sections. Such breaks have not been noted in our own material, and so the identification of these specimens from the Ludlow of Australia must be regarded as questionable.

Sugiyama (1940) described three specimens from the Kawauti Series of northeast Honshu Island, Japan. These are from the Clathrodictyon and Halysites Limestones, assigned to the Salopian (Wenlock and Early Ludlow) equivalents of England.(see Hamada, 1958, p. 95, Table 2). These specimens are similar to our own, though Sugiyama identified them as Propora affinis. Their features were described as follows: The corallites are close-packed (clearly spaced within a half diameter in Plate XXIV, fig. 1), and are 1.5 to 1.8 mm in diameter, with margins displaying varying crenulation. In one specimen (unfigured, from the Clathrodictyon Limestone) these crenulations result in 12 "minute

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nodulous protrusions" (presumably referring to the exsert corallite margins typical of Propora). In the second specimen (also from the Clathrodictyon Limestone), the walls are not as regularly-crenulated, and occasionally are even smooth (possibly the result of recrystallization). The tabulae are mostly horizontal, rarely slightly concave, and are spaced 5 to 7 per millimeter. The coenosteum is vesiculose. It seems reasonable to consider Sugiyama's specimens conspecific with our own.

Iskyul (1957) described Propora conferta from the Siberian Platform (23.5 kilometers upstream from the mouth of the Podkamennaya Tunguska River). The age is reported simply as "Silurian". The corallites are 1.0 to 1.2 mm in diameter, spaced 0.5 to 0.8 mm apart. Their walls are crenulated into 12 projections. The tabulae are mostly complete, and are horizontal, convex and concave (though of little relief in the latter two cases). Their spacing is about 4 to 5 per millimeter. The coenosteum is vesiculose. In all important respects the Siberian form agrees with ours, and they are considered conspecific.

Norford's (1962) figure of a coral identified as Lyellia affinis, from the Middle Llandovery Fisher Branch Dolomite of Manitoba reveals a strong superficial resemblance, though the specimen is unfortunately not sectioned. The corallites are about 1 mm in diameter, with exsert rims that are nearly in contact with neighboring corallites. The

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coenosteum appears to be vesiculose, though it is seen only superficially. Where they are visible, the tabulae appear to be packed about 3 per millimeter, with horizontal surfaces. Crenulation of the corallite walls is unclear in Norford's figure. All things considered, it seems likely that Norford's specimen does belong to the present species.

Sokolov (1962) illustrated a specimen which he identified as Propora conferta from the Llandovery of the Baltic region (Estonia?). The corallites are about 1.6 mm in diameter, and are spaced less than half a diameter apart. Their walls are thickened in about 12 places around the circumference, forming septal projections in transverse section. The coenosteum is vesiculose. The tabulae are horizontal, or sometimes shallowly concave or convex. The spacing of the tabulae varies rhythmically vertically, from 6 per millimeter to 2.5 per millimeter. Rarely they appear incomplete. In all essential features this specimen agrees with the Brassfield material.

Bolton & Copeland's (1972) "Heliolitid undet." from the Silurian of Lake Timiskaming, Canada, is apparently too badly-altered for determination of the nature of the coenosteum. It seems, then, that while it has features generally similar to Propora conferta, it is not possible to identify it with any confidence from the figures.

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A coral species quite distinct from P. conferta, and yet with interesting similarities, is Plasmopora lambii Schuchert (1900, p. 154). A syntype of this species (USNM 28140b) is shown on Plate 35, fig. 3 and 4 of the present work. Surficially, the specimens of the type series look like Propora conferta: The corallites are about 1.5 mm in diameter, spaced less than half a diameter from one another, and separated by a vesiculose coenosteum. The coralla are massive. In thin-section, however, the distinctive nature of Schuchert's species becomes clear (see figures). The corallites have no true walls, but rather, are in direct contact with the dissepiments of the coenosteum. These intrude along the line of the corallite boundaries, and in transverse section (fig. 4) sometimes give the corallite boundary a crenulated appearance. Further, the tabulae are nearly all incomplete, with the result that the corallite tabularium is vesiculose, and distinguished from the coenosteum solely by the greater width of its vesicles. The type material is from Baffin Land, Arctic Canada, and is reportedly of "Trenton" age (Late Middle and Early Late Ordovician).

The picture presented here, then, is of a form-group of corals with wide geographic and long stratigraphic range, varying in several characters, but so-far apparently forming a morphologic continuum, and thus referable to a single paleontologic species.

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Distribution - Estonia: Late Ordovician, Llandovery(?); Anticosti Island: Late Ordovician (Richmondian) through Late Llandovery, and possibly Early Wenlock; Illinois: Early Llandovery; Manitoulin Island: Early Llandovery; Manitoba: Middle Llandovery; Korea: Silurian; northeast Canadian Arctic: Ordovician; Gaspé region of maritime Canada: Late Llandovery into the Ludlow; northern Newfoundland: Late Llandovery; Japan: Wenlock and Early Ludlow; Siberian Platform: Silurian; Ohio: Middle Llandovery (Brassfield Formation)

Brassfield occurrence - Localities 7 (near Fairborn), 11 (near West Union), 13 (Todd Fork Creek near Wilmington), 14 (Piqua), 15 (near West Milton), 37 (Turtle Creek near Sharpsville) and 55 (near Ludlow Falls, in clay layer at top of the Brassfield), all in southwestern Ohio.

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Propora exigua (Billings)

Plate 34, fig. 1, 3

1865b *Heliolites exiguus* Billings, p. 428

1866 *Heliolites exiguus* Billings, p. 31, fig. 14

? 1880 *Heliolites exiguus* Nicholson & Etheridge, p. 250-251

1899 *Propora conferta*, var. *minima* Lindström, p. 95, ? Plate IX, fig. 24-26

1899 *Lyellia exigua* Lambe, p. 86, Plate V, fig. 3, 3a

1928 *Lyellia exigua* Twenhofel, p. 134-135

cf. 1939 *Lyellia exigua* Shrock & Twenhofel, p. 254, Plate 28, fig. 13, 14

1939 *Lyellia superba* Shrock & Twenhofel, p. 254, Plate 28, fig. 8, 9 (*non*? Billings, 1886; *nec* Lambe, 1899)

cf. 1940 *Propora conferta* Jones & Hill (*partim*), p. 209, Plate XI, fig. 4 (*non* fig. 3, 5a, 5b)

Type material - The holotype is listed in the *Catalogue of Type Invertebrate Fossils* of the Canadian Geological Survey (volume I, 1960, p. 28) as catalogue no. 2239. It has been illustrated by Billings (1866, fig. 14), and possibly by Lambe (1899, Plate V, fig. 3, 3a).

Type locality and horizon - According to the Canadian Survey type catalogue (*op. cit. et loc. cit.*), the Ellis Bay

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Formation (variously considered Late Ordovician or Early Llandovery), at Ellis Bay, Anticosti Island.

Number of specimens studied - 1

DIAGNOSIS - Propora with corallites generally less than 1 mm in diameter, separated from their nearest neighbors by a distance equal to or greater than their diameters; walls crenulate; coenosteal spines apparently absent; tabulae generallu complete.

DESCRIPTION - As preserved, the corallum is 28 mm across and 7 mm thick. It appears to have originally been a low, wavy, lens-like form, and to have grown directly upon the sediment surface, rather than cemented to a solid object, as it was found lying upside-down in the sediment (see Plate 34, fig. 1).

The corallites are 0.6 to 0.8 mm in diameter, and are almost all separated from the nearest neighbor by a distance at least equal to their diameters. The maximum such distance is about 0.8 to 1.0 mm. The corallites are each bounded by a definite wall, about 1/15 mm thick, which is thickened into what appear to be 12 longitudinal "septal" ridges. It is assumed that these ridges are continuous, rather than spinal swellings, because they appear in virtually every corallite seen in cross-section. It is, however, possible that they represent extensive stereomal deposits over rows of spines, but this is speculative.

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Of 60 tabulae counted in longitudinal section, 54 were complete. These included horizontal, as well as shallowly-concave and convex tabulae, with zoned spacing. In the sparser regions, they are spaced about 3 per millimeter, while in the denser regions they are 7 per millimeter. It is in this latter area that most of the incomplete tabulae occur.

The space between the corallites (the coenosteum) is vesiculose, and from 1 to 5 vesicles lie horizontally along the space between tubes. They vary in form from high (0.4 mm) and narrow (0.7 mm) to low (0.2 mm) and wide (1.4 mm). Very small and very large vesicles tend to occur in patches, but on the whole, the coenosteum displays the same zonation as the corallite tabulae, with coarse vesicles on about the same levels as the wide-spaced tabulae. The uppermost zone of the corallum contains a concentration of unusually-small vesicles, and may reflect a deterioration of conditions, leading to the death of the colony.

There appear to be no spines in the coenosteum.

DISCUSSION - Billings (1865) described the species as follows:

> Cells about half a line in diameter and somewhat more than their own width diatant from each other, with thin elevated margins, apparently not crenulated. Septa not visible in the only specimen collected. Tab-

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ulae numerous, four to six in one line. (Note: a line = 1/12 inch, or about 2.1 mm - R.S.L.) Coenenchyma minutely vesicular.

"As the specimen is somewhat worn, it is possible that the margins of the cells when perfect may be crenulated. The coenenchyma appears to be vesicular, but more specimens are required to decide this point.

"The species, on account of the small size of the cells and their greater proportional distance from each other, seems to be distinct from all the others."

Lindström (1899) described, as a new variety of Propora conferta Milne-Edwards & Haime (which see), P. conferta minima, from his horizon a (the Arachnophyllum beds, of Middle or Late Llandovery age, according to Manten, 1971, p. 33, 42) near Visby, Gotland. This form is discoid and flat, with very narrow corallite apertures, about 0.5 mm across, and separated from one another by at least one diameter. Lindström stressed that the calices are "perfectly smooth, without the least vestige of septa or septal flutings or cannelures." The tabulae are shown as mostly gently concave, about 4 per millimeter. The vesiculose coenosteum is free of spines. This form agrees in all respects with our concept of P. exigua, except for the absence of wall-fluting. Considering the ease with which this feature can be obscured in the process of fossilization (especially in such small

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corallites) it seems safe to consider this form conspecific with our own.

Lambe (1899) noted that the type specimen was the only one representing this species in the Canadian Geological Survey collection. He described it as being 45 mm long, 30 mm broad, and 13 mm high. The corallites were 0.75 mm wide, separated from each other by distances equal to or less than their diameters, but varying from 1 to 5 mm across. The tabulae were horizontal, spaced 2 to 5 per millimeter. The corallites had 12 faint septal ridges on the inner surfaces of their walls, and their rims on the surface of the corallum were exsert. The coenosteum was vesiculose, the vesicles being 0.16 to 0.5 mm wide. Lambe's figure 3a (of the holotype?) does indeed show some of the corallites within half a diameter of their nearest neighbor, but others seem more widely-spaced. In view of Billings' observations, and of the similarity of our specimen to that described by him and Lambe, it seems best to regard the spacing of the corallites as important, but somewhat variable. At any rate, in no case does our other species of Propora, P. conferta and P. eminula, have the combination of narrow corallites and relatively wide spacing seen in P. exigua.

Nicholson & Etheridge's reference to this species (1880) was merely to Billings' report (1866). They added nothing to the concept of the species, but did note that the coenosteum is vesiculose, and that the corallites are spaced

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more than a diameter apart.

Twenhofel (1928) reported this species from Anticosti Island, in the Ellis Bay Formation (variously regarded as Late Ordovician or Early Llandovery) and the Jupiter Formation (Late Llandovery). His specimens were both hemispheric and encrusting, with corallites 0.5 mm in diameter, separated by 1 to 2 mm from one another. The corallites contained faint "septa". The calices were exsert, and Twenhofel noted that there was a hint of the 12 nodules frequently seen about the corallite apertures of Propora. The tabulae were horizontal, spaced about 2 per millimeter. The vesicles of the coenosteum varied in width from 0.25 to 1 mm, and in height from 0.25 to 0.35 mm. The description fits well with our concept of P. exigua, though the corallites appear to be somewhat wider-spaced than usual, and it seems that Twenhofel's identification can be accepted.

Shrock & Twenhofel (1939) described and figured what they considered to be this species from the Silurian Pike Arm Formation of northern Newfoundland. This is a problematic case. In almost all respects, this form agrees well with P. exigua: The corallites are 0.75 mm in diameter, with 12 "septal" ridges occurring on their inner surfaces. The horizontal or gently-concave tabulae are spaced 3 or 4 per millimeter, and the coenosteum is vesiculose. The problem lies in the fact that the corallites are spaced as in P. conferta, rarely more than half a diameter apart. The

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transverse section shown in figure 14 shows that this is the rule, not the exception, in this specimen. It is possible that the corallite diameter is all-important, and that P. exigua can have corallites as close-spaced as those of P. conferta. On the other hand, it is important to consider the likelihood that P. exigua and P. conferta are one-and-the-same, representing end-points of a morphologic continuum. The decision on this matter seems best deferred until more material has been studied, but for now, they will be regarded as separate species, with the relationship of Shrock & Twenhofel's form left in question.

These same authors reported Lyellia superba from the same region and formation. The corallites are reportedly 0.5 to 0.6 mm in diameter, and spaced from one to three diameters apart. (Judging from the transverse section shown in their figure 8, the corallites are about one diameter from their nearest neighbor.) Septal ridges are "poorly-developed", and the tabulae, which are usually horizontal, average 4 per millimeter. The coenosteum is vesiculose. This form agrees sufficiently with our concept of P. exigua to indicate that it belongs to that species.

Jones & Hill's (1940) figure 4 of Propora conferta from the Late Silurian of New South Wales, Australia, shows a specimen with corallites about 1 mm in diameter, fairly wide-spaced (mostly about 1 diameter or less from the nearest neighbor). There is no longitudinal section shown of

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this specimen, but according to the description, the coenosteum is vesiculose. The authors reported discontinuous corallite walls, a feature not seen in our specimen, or reported in other representatives of P. exigua. In addition, some of their specimens have coenosteal spines, and extensions from the outer walls of the corallites into the coenosteum which are lacking in known specimens of P. exigua. It seems, then, that this specimen, though similar to our form, has too many unique features to be considered conspecific with it.

Distribution - Anticosti Island: Late Ordovician or Early Llandovery, and Late Llandovery; Newfoundland: Silurian; Gotland: Middle or Late Llandovery; Indiana: Middle Llandovery (Brassfield Formation).

Brassfield occurrence - Locality 26, at Elkhorn Falls, south of Richmond, Indiana.

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Propora eminula (Foerste)

cf. 1851 Lyellia americana Milne-Edwards & Haime, p. 226, Plate XIV, fig. 3, 3a

1906 Lyellia eminula Foerste, p. 306-307, Plate 3, fig. 6; Plate 4, fig. 3

Type material - Foerste designated as the holotype the specimen figured in his Plate 3, fig. 6, and Plate 4, fig. 3. Its repository is not known.

Type locality and horizon - North of Irvine, central Kentucky, in the same area as localities 53 and 53a of the present study, from the Waco bed, Noland Member of the Brassfield Formation.

Number of specimens studied - None found in the field.

DESCRIPTION - As Foerste desceibes it, the upper surface of the corallum is flat or somewhat convex, expanding from a narrower base, to reach a height of at least 25 mm, and a width of 40 mm in the holotype. The corallites are 1.2 to 1.5 mm in diameter, spaced from 0.70 to 2.0 mm apart. Their rims are exsert. There are 12 septa, consisting of stout spines, and the coenosteum is vesiculose.

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DISCUSSION - If Foerste's description is accurate, this species differs from the two other species of Propora from the Brassfield (all specimens from the northern outcrop area in Ohio and Indiana), in having broader corallites that P. exigua and more wide-spaced corallites than P. conferta. It differs from both in having spinose septa. Unfortunately, Foerste figured no thin-sections of his material, so that details of the internal structure cannot be determined.

This species is similar to, and perhaps identical to Lyellia americana Milne-Edwards & Haime (1851), from the Silurian rocks of Drummond Island, Lake Huron. This possesses the combination of broad corallites (somewhat over 2 mm in diameter), wide spaces between them (separated by one or two times their diameter), and a vesiculose coenosteum. It is not specifically stated that the septa are spinose, but their figure 3a shows rather pointed ends to the septa.

Similar forms have been described by other authors, including Rominger (1876, p. 15-16) from the Silurian of northern Michigan, and Twenhofel (1928) from the Chicotte Formation (Late Llandovery or Early Wenlock) of Anticosti Island. In the absence of more information on the internal structure of Foerste's material, it seems pointless to speculate further as to the relationships of this species.

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Distribution - Kentucky: Middle Llandovery (Brassfield Formation); Similar and possibly identical forms in the Silurian of northern Michigan, and the Late Llandovery or Early Wenlock of Anticosti Islands have been reported.

Brassfield occurrence - North of Irvine, central Kentucky (the area of localities 53 and 53a of this study), in the Waco bed, Noland Member.

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Family Heliolitidae Lindström, 1876

(pro Heliolithidae Lindström, 1873, ex Heliolithes Lindström, 1873)

Heliolitids with massive coralla; distinct corallites in matrix of tubular, tabulate coenosteum; walls of coenosteal tubes complete; tabulae of both the corallites and the coenosteal tubes are complete; corallites with complete, solid walls, bearing 12 longitudinal rows of spines, or else, 12 solid longitudinal sheets as septa; pseudocolumella sometimes present due to axial juncture or flexing of the septa; corallites without distinct halo of 12 coenosteal tubes around their perimeters.

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Heliolites Dana, 1848

non 1770 Heliolithes Guettard, p. 454 (non-Linnaean nomenclature)

1848 Heliolites Dana, p. 541 - 542

1849 Palaeopora M'Coy, p. 129 (objective synonym)

1850 Geoporites D'Orbigny, p. 49 (objective synonym)

1933 Helioplasma Kettnerova, p. 181

Type species - (by original designation): Astraea porosa Goldfuss, 1826, p. 64.

Type locality and horizon - Devonian, Eifel District of Germany.

DIAGNOSIS - Corallum of cylindrical corallites separated laterally by tubular coenosteum; corallites with complete tabulae; corallites may possess 12 longitudinal rows of spines; coenosteal tubes have complete walls and tabulae similar to those of corallites, but lack spines; mural pores absent.

DESCRIPTION - These are corals whose corallites are separated from one-another laterally by a tubular coenosteum. The corallites are traversed by complete tabulae, and their walls commonly bear 12 longitudinal rows of spines. The spines may be long, short, or absent, but they never form a complex axial structure, as in Stelliporella Wentzel.

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The coenosteal tubes are considerably narrower than the corallites, and their walls (in contrast to those in Palaeoporites Kiär, which see) are solid. They contain complete tabulae, but never spines.

DISCUSSION - Guettard (1770, p. 454) introduced the concept of this genus, and while he has often been credited with its authorship (by such writers as Hall, 1852; Rominger, 1876; and even by Dana, 1848 where this last author introduced the accepted name, Heliolites, for the first time in the literature), Lang, Smith & Thomas (1940, p. 186) point out that Guettard did not use Linnaean nomenclature. They thus regard his term, Heliolithes, invalid and accept Dana's (1848) name, Heliolites, as the correct form and originally-assigned name for the genus under Linnaean strictures. Most recent authors, including Hill & Stumm (1956) and Sokolov (1962) have concurred in assigning authorship to Dana.

Some confusion has arisen over the date of Dana's initial publication of this generic name. Both Hill & Stumm (1956, p. 460) and Sokolov (1962, p. 278 in the Russian edition) give 1846 as the date. On the other hand, Lang, Smith & Thomas (1940, p. 66), who show some care as to precise publication dates, give 1848 as the correct date. Both Lang, Smith & Thomas, and Sokolov (1962, p. 282 in the Russian edition), in their bibliographies, state that "Zoophytes", Dana's publication, appeared in several sect-

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ions: Pages 1-120 and 709-720 appeared in 1846. Pages 352-364 appeared on pages 178-189 of the 1846 volume of the American Journal of Science. The entire work appeared in March, 1848 (and the Atlas in November 1849). As the description of Heliolites appears on pages 541-542, it appears that the publication date of this generic name is 1848, the year in which the entire text was first published.

M'Coy (1849, p. 129) erected the generic name Palaeopora for "all the so-called Porites of the palaeozoic rocks", which had been described by Goldfuss (1826) as Astraea. Lang, Smith & Thomas (1940, p. 94) subsequently designated Goldfuss' A. porosa as the type species, thereby purposely making M'Coy's genus an objective junior synonym of Heliolites Dana.

D'Orbigny (1850, p. 49) introduced the genus Geoporites which he characterized as "...Porites of which the cellules are only corrugated, and simply emplaced in the midst of a porous mass." This could be accepted as a vague description of Heliolites Dana. D'Orbigny included nine species under this genus, among them Astraea porosa Goldfuss. Lang, Smith & Thomas (1940, p. 63) subsequently designated this latter species as the type of Geoporites, remarking in consequence that Geoporites was an absolute (objective) synonym of Heliolites Dana. As will be noted, this is the same procedure used by these authors 31 pages later to synonymize Palaeopora M'Coy with Dana's genus.

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Kettnerova (1933, p. 181) described the genus Helioplasma based upon material from the Lower Devonian of Bohemia. This genus was supposedly characterized by having a coenosteum consisting both of tabulate tubes, and of vesicular dissepiments. Judging from heliolitid material I have studied, it seems this condition is not greatly abnormal for Heliolites Dana, being (as shown in Kettnerova's Text-figure 2) a dominantly-tubular coenosteum with localized vesicular dissepiments. Consequently, this genus is considered a junior synonym of Heliolites.

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Heliolites spongiosus Foerste

Plate 11, fig. 5, 6; Plate 30, fig. 5, 6

1906 Heliolites spongiosa Foerste, p. 303-304, Plate 3, fig. 3; Plate 4, fig. 6; Plate 5, fig. 5

non 1949 Heliolites spongiosus Amsden, p. 84-85, Plate XIV, fig. 5-8

? 1964 Heliolites spongiosus Stumm, p. 59, Plate 57, fig. 1-3

Type material - Holotype: USNM 84892, the specimen figured by Foerste, and the one shown on Plates 11 and 30 of the present work.

Type locality and horizon - Waco bed, Noland Member of the Brassfield Formation, along the road north of Estill Springs, near Irvine, Kentucky, in the southeast corner of the Cincinnati Arch, central Kentucky. (This is the vicintiy of localities 53 and 53a of the present study.)

Number of specimens studied - 1 (the holotype, as none were found in the field).

DIAGNOSIS - Heliolites with corallites about 1.5 mm in diameter; coenosteum tubes varying considerably in diameter, giving spongy aspect to this area; corallite tabulae gently convex upward.

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DESCRIPTION - The holotype is the basis for this description, as it is the only specimen that has been found.

The specimen measures 6.25 X 5.00 cm in diameter, and is about 1.5 cm thick. The corallum appears to have originally been lens-shaped, and probably lay directly upon the sediment. There is no evidence of a holotheca preserved.

The corallites are about 1.5 mm in diameter, and are separated each from its nearest neighbor by about 1.1 to 1.5 mm. If septal structures were originally present, they have not been preserved. The tabulae are gently convex upward, spaced about 3 to 4 per millimeter, and are complete.

The coenosteum is separated from the corallites by definite walls, and characteristically consists of tubes varying considerably in diameter, with wide and narrow tubes mixed together. This results in a spongy aspect to the coenosteum in transverse view. So far as has been determined, the tube walls are continuous. In the specimen at hand, the tube diameters in the coenosteum range from 0.10 to 0.37 mm. The tubes contain tabulae spaced 4 to 7 per millimeter, nearly all gently convex upward or horizontal, with a few incomplete.

DISCUSSION - Amsden (1949) ascribed to Foerste's species some specimens from the Brownsport Formation (Early Ludlow) of western Tennessee. These resemble H. spongiosus in having corallites of similar size (slightly less than 2 mm across) with similar spacing. The tabulae of the corallites

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are also spaced about as in our species, and are generally horizontal, not quite convex. There are no septal structures preserved, if, indeed, they were present originally. The tabulae of the coenosteal tubes are also formed and spaced similar to those of our specimen. Unfortunately, the coenosteal tubes are fairly uniform in diameter, and do not present the spongy texture present in the holotype. This feature is of such importance in the concept of this species, that its absence even in a form so similar to our own, cannot be disregarded. While Foerste's holotype and Amsden's specimens may represent end-members of a morphologic continuum, it seems best at this point to regard them as specifically distinct.

Stumm (1964) reported Heliolites spongiosus from the Louisville Limestone (Late Wenlock and Early Ludlow) in the vicinity of Louisville, Kentucky. He describes his material as containing corallites averaging 2 mm in diameter without septal ridges. The corallite tabulae are described as "complete, horizontal, very closely set, averaging 3 mm apart." (It is likely that this measure of spacing is incorrect, as 3 mm is unusually wide-spread in corallites 2 mm across.) The coenosteal tubes are polygonal, 4 to 10 stretching between neighboring corallites, and average about 0.3 mm in diameter. Their tabular spacing is as in the corallites. Unfortunately, Foerste's figures are all of Brownsport specimens, and he gives insufficient information on the variations in the dia-

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meters of the coenosteal tubes to allow certainty of the identification of his material. Further, his figure 3, a transverse section through a corallum, shows a regular aureole around each corallite of approximately 20 coenosteal tubes, a pattern not encountered in the holotype.

Distribution - Kentucky: Middle Llandovery (Brassfield Formation).

Brassfield occurrence - Vicinity of localities 53 and 53a (near Irvine, Kentucky), in the Waco bed, Noland Member.

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Heliolites spongodes Lindström

Plate 10, fig. 6, 7; Plate 35, fig. 5, 6; Plate 37, fig. 1, 4

1876 Heliolites interstinctus Rominger, p. 12, Plate I, fig. 1 (non Linnaeus, 1767)

? 1880 Heliolites micropora Nicholson & Etheridge, p. 245 (non Eichwald, 1855)

? 1887 Heliolites barrandei Penecke, p. 271, Plate XX, fig. 1-3

? 1894 Heliolites barrandei Penecke, p. 591

1899 Heliolites barrandei Lindström, p. 58-59, Plate III, fig. 8-12, 17-27

1899 Heliolites barrandei var. spongodes Lindström, p. 60, Plate III, fig. 13-16; Plate IV, fig. 1

? 1906 Heliolites sp. Foerste, p. 304, Plate 3, fig. 4

? 1906 Heliolites subtubulata-distans Foerste, p. 304-306, Plate 3, fig. 5B

? 1906 Heliolites subtubulata-nucella Foerste, p. 304-306, Plate 3, fig. 5A (non H. nucella Amsden, 1949)

? 1954 Heliolites spongodes Schouppé, p. 166-168

1956 Heliolites interstinctus var. abnormis Yu, p. 619-620, Plate II, fig. 8, 9

? 1964 Heliolites subtubulatus Stumm, p. 59, Plate 57, fig. 6, 7 (non Palaeopora subtubulata M'Coy, 1854)

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cf. 1964 Heliolites romingeri Stumm, p. 59,
Plate 57, fig. 8-12
1973 Heliolites spongodes Galle, p. 31-33,
Plate VI, fig. 1-4; Text-fig. 7

Type material - Lectotype (Schouppé, 1954, p. 166): specimen shown by Lindström (1899), Plate III, fig. 13-16.

Type locality and horizon - Silurian of Gotland: strata b and c in the Visby area, according to Lindström. Based on Manten's work in Gotland (1971, p. 33-35, 43, map) these are Late Llandovery to Early Wenlock in age.

Number of specimens studied - 2

DIAGNOSIS - Heliolites with corallites approximately 1 mm in diameter; septa consist of twelve longitudinal rows of spines which flex upward in the axis; corallites spaced generally more than one diameter from nearest neighbor; coenosteal tubes of more-or-less constant diameter in a given corallum; corallite walls thickened.

DESCRIPTION - The corallum appears generally to have been hemispherical in life. Specimens have been found ranging from 2 cm in diameter (Plate 10, fig. 6, 7) and upward.

Corallite diameter is fairly constant at 1 mm. The corallite walls are thicker than those of the coenosteal tubes by an order of about 3. Around the corallite perimeter are 12 longitudinal rows of spines which point upward in the corallite axis. Here they appear at times to fuse

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with one another forming something of an axial structure. At other times, they remain separate, appearing as dots in the axis when seen in transverse section (Plate 37, fig. 4).

A distance generally greater than its diameter separates each corallite from its nearest neighbor. This distance is usually about 1 to 2 mm.

Corallite tabulae appear to be nearly all complete. Most are slightly concave upward, and spaced about 3 per millimeter. It could not be determined if the spacing is rhythmic.

In transverse view, the coenosteal tubes range is diameter between about 0.4 and 0.1 mm, with the wider tending to occur midway between corallites, and the narrower ones closer to the corallites. This zonation of the diameters results in a smooth, homogeneous aspect of the coenosteum, in contrast to the spongy appearance in H. spongiosus Foerste (which see), where broad and narrow tubes were intimately mingled.

The coenosteal tubes appear to arise interstitially with the divergence of two extant tubes, though it is unclear if budding actually takes place. The corallites, on the other hand, have not been observed in contact with one another, and may arise through direct differentiation of the coenosteal tissue.

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Rominger (1876) described, under the name Heliolites interstinctus (Linnaeus), a specimen from the Niagara Group (probably Wenlockian) at Louisville, Kentucky. This is a Heliolites with corallite diameters of about 1 mm, containing longitudinal rows of upward-pointing spines. The corallites are separated from one another by at least one diameter. A transverse thin-section in the type collection of the University of Michigan (UMMP 3908) shows the features described by Rominger, and has coenosteal tubules about 0.25 mm in diameter. The specimen figured by Rominger could not be located, but if this section was taken from that specimen, there is little doubt that it is conspecific with the Brassfield specimens.

Lindström (1899) described specimens which he identified as Heliolites barrandei Penecke from the Silurian of Gotland. As Manten (1971, p. 33) has pointed out, Lindström's designations for Gotland's stratigraphic divisions were based upon incorrect assumptions (using lithology to determine horizon and relative age), and are of but limited use. By comparing the localities cited by Lindstrom (1899, p. 59), it appears that H. barrandei, as he calls the species, occurs in the Wenlock, and possibly the Upper Llandovery and Ludlow of Gotland, as shown on Manten's geologic map, and correlated by him on p. 43.

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The name Heliolites barrandei was first validly used by Penecke (1887), who noted that it was a manuscript name of R. Hörnes at an earlier date. Unfortunately, I have been unable to obtain a copy of Penecke's paper of 1887, and so, have no grounds for judging the virtue of Lindström's identification. The name appeared several times more before 1899, including a reference by Penecke (1894, p. 591) to the species (insufficiently described to allow validation) in the Lower Devonian of the Graz, Austria area, and Wentzel's (1895) proposal of this species as the basis of a new heliolitid genus, Pachycanalicula (apparently a synonym of Heliolites).

Lindström's (1899) is the earliest work to which I am privy, in which a clear description of supposedly H. barrandei specimens is given. He describes the corals as large, flat or somewhat domed discs with a wrinkled holotheca. The corallite diameters in what he regarded as the older specimens (though his age assignments here are unreliable) are about 0.5 mm, while those of the "younger" specimens reach 1.0 mm. The septa are spinose, judging from the figures (though his description implies they are proximally solid, protruding little from the wall, and distally break up into spines), and the spines curve upward distally, such that their intertwined ends may appear as a columellar structure in transverse section.

The tabulae in the corallites appear to be, generally, about 0.3 mm apart, comparable to the spacing in our specimens. They are horizontally-oriented.

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The coenosteal tubes are polygonal, and appear to be fairly uniform in diameter. It is not clear from Lindström's figures if the tubes close to the corallites tend to be larger than those midway between neighboring corallites.

Lindström shows (Plate III, fig. 27) a series of four serial transverse sections, in which the development of a new corallite may be seen, the corallite gradually taking shape directly from several coenosteal tubes between a number of older corallites. It may be significant that the differentiating coenosteum is in part contiguous on a neighboring corallite.

Lindström's material appears to be identical to our own, insofar as the two forms are understood.

Lindström (ibid, p. 60) describes as a new variety of H. barrandei, called spongodes, a form of coral which appears to occur in the Högklint, and possibly the Visby beds of Gotland (Early Wenlock and Late Llandovery, according to Manten, 1971, p. 43). Lindström uses his previously-mentioned system of stratigraphic designation to cite the horizons of occurrence of this coral type, presenting a problem in determining just what the horizons are. Judging from the localities he cites, however, Manten's geologic map indicates that they are probably from the above-stated horizons.

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Lindström distinguishes this form from other members of the species by its growth-form: "sponge-like, irregularly lobate masses expanding from a narrow basis, having short fingerlike processes from the rounded edges, and with calicles on all sides." The corallites are quite narrow, "scarcely" 0.5 mm across. The septa consist of sheets of variable length, which split up distally into spines, curving upward in the corallite axis. The coenosteum consists of narrow, polygonal tubes. Lindström cites another sort of growth-form characterized by branches, 4 to 5 mm in diameter. The figures accompanying this description closely resemble our corals, save for their somewhat narrower corallites (0.5 mm *versus* approximately 1 mm in the Brassfield form). In light of other material described in the literature (see below), it seems safe to consider the Gotland corals conspecific with ours, despite this difference. This is the earliest occurrence in the literature of a name that can be confidently identified with our form.

Lindström (*ibid*, p. 60) synonymized his variety with *Heliolites micropora* Nicholson & Etheridge (1880, *non* Eichwald, 1855). Nicholson & Etheridge described this species not for the purpose of reporting it from Girvan (with which area their paleontologic work dealt). Rather they included this species in a list of the species of *Heliolites* Dana of which they were aware. Their description is quite brief and sketchy, limiting itself to an account of

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corallite diameters and distances between corallites, as well as growth form. Concerning the septa, only their number (12), and the fact that they are short and delicate are mentioned. Surely, the description gives insufficient grounds for synonymizing Nicholson & Etheridge's material with Lindström. The latter supplied these authors with the only specimen of this species they were able to study (Nicholson & Etheridge, p. 245). Lindström (1899, p. 60) states that the material he supplied them is identical with H. barrandei spongodes, but that he had previously confused it with Eichwald's species (H. micropora), sending Nicholson the specimen under that name. Having subsequently studied the types of Eichwald's species, however (at the Museum of the University of St. Petersburg), he became persuaded that this was quite different from his Gotland form, which he then designated Heliolites barrandei spongodes.

From the Waco bed of the Noland Member, Brassfield Formation, Foerste (1906) reported Heliolites sp. The locality is north of Irvine, Kentucky, the equivalent of localities 53-53a of this study. The specimen appears to be somewhat hemispherical, with corallites about 1 mm in diameter, spaced with their centers 1 to 2 mm apart. Examination of the specimen (USNM 87172) substantiates Foerste's report of the presence of septal spines in the corallites, extending toward the axis. Dots present in the axes of the corallites as seen in transverse section suggest axial flexing of the

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spines, presumably upward, as in our form. Arrangement of the tabulae in the corallites is difficult to determine, but those of the coenosteal tubes appear to be spaced about 3 per millimeter. The coenosteal tubes are about 0.3 mm in diameter. This form may be conspecific with our own, though its features are not sufficiently clear to allow certainty.

In the same work, Foerste described what he considered two varieties of Heliolites subtubulatus M'Coy from the Waco bed, Noland Member of the Brassfield, in central Kentucky. The first, Heliolites subtubulatus distans, is from half a mile east of Waco, Kentucky, and is represented by a flat corallum with concentric holotheca. The corallites are about 0.75 mm in diameter, separated from one-another by 1.5 to 2.0 mm. This combination of narrowness of corallites and their wide spacing, Foerste considered to set the form apart from the rest of the species. The coenosteal tubes are 0.2 to 0.25 mm in diameter, rather in the narrow range of ours. The corallite tabulae are spaced 3 to 4 per millimeter, while those in the coenosteal tubes are 4.5 to 5.5 per millimeter. In these measurements, the form is in basic agreement with our specimens. As Foerste was unable to get a good look at the septal structure, we cannot be certain of the relationship between his material and our own, despite the fact that they agree in most respects.

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Foerste's second form, Heliolites subtubulata mucella, is from the same locality and horizon as his Heliolites sp. (see above). Basically, this form seems identical to the last, except that it grew more vertically than horizontally. Again, there is insufficient information to be certain how closely it is related to our specimens.

Schouppé (1954) chose as lectotype of Heliolites spongodes (elevating Lindström's variety to species level), the specimen figured by the latter in his Plate III, fig. 13-16. He went on to report the presence of this species in the horizon which he designated as ef_1 (Upper Silurian, see his p. 170) of the Paleozoic sequence of Graz, in the Carnic Alps. He regarded the material described by Lindström (1899) as H. barrandei, as distinct specifically from Penecke's (1887) H. barrandei, so that he assigned the former to Heliolites spongodes.

Schouppé's material consists of flat coralla with bulbous surface protrusions. The corallite diameters are mostly 0.5 mm, with isolated cases reaching 0.7 mm (thus, narrower than ours). The corallite walls, and those of the coenosteal tubes are thin. From 1 to 6 tubes lie between adjacent corallites. The corallites contain 12 short septa. The coenosteal tubes are regularly polygonal, 0.1 to 0.15 mm in diameter, rather narrow compared with ours. The septa consist of longitudinal rows of spines pointing upward axially. The corallite tabulae are fairly flat, with about 3 per millimeter. The tabulae of the coenosteal tubes are closer-spaced.

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Schouppé furnishes no figures with his description. This fact, as well as the unusually-narrow coenosteal tubes, makes it best to reserve judgement as to the relationship between his material and ours.

Yu (1956) reported a heliolitid from the Middle Silurian of northwestern Kansu Province, China, which he referred to as Heliolites interstinctus abnormis, a new variety. His specimen was done-shaped, with a concentrically-wrinkled base. The corallites were 0.8 to 1.1 mm in diameter, most commonly 0.9 mm, and these were separated from one-another by about 1 to 2 mm. Their walls were about 0.05 mm thick, somewhat thicker than the walls of the coenosteal tubes (as is the case with our form). Septal spines occurred in the corallites, reaching to the axis where they often unite in pairs. (It is unclear from the description whether it is adjacent or opposite spines that unite.) The corallite tabulae were generally complete, sometimes slightly concave or convex, spaced 2.6 to 3.0 per millimeter. The coenosteal tubes were polygonal, between 0.2 and 0.4 in maximum diameter. Apparently, this form agrees in all important respects with ours, and they are regarded as conspecific.

Stumm (1964) described a coral under the name Heliolites subtubulatus (M'Coy) from the Louisville Limestone (Late Wenlock to Early Ludlow) of northern Kentucky and southern Indiana. His description is cursory, but his figure 7 bears a certain resemblance to our material.

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Nonetheless, we are not prepared at this point to judge the relationships between the two forms in the absence of further information on Stumm's specimens, UMMP 3908 and 3911.

In the same work, Stumm described Heliolites romingeri, a new species based upon the specimen identified as H. interstinctus (Linnaeus) by Rominger (1876, discussed above), from the Louisville Limestone (Late Wenlock to Early Ludlow) at Louisville, Kentucky. This form closely-resembles ours in most respects. The corallites are about 1 mm in diameter, and are spaced as in our specimens. The coenosteal tubes average 0.3 mm in diameter. The corallite tabulae are complete, horizontal, and average 1 mm apart, while those of the coenosteal tubes are twice as close-spaced. Stumm speaks of 12 long septa typically joined axially together. His figure 12, however, suggests the situation may be more complex than that, and the possibility of upward-curving spines cannot be precluded. The holotype, UMMP 8421, is too badly recrystallized, according to Stumm, to allow analysis of its internal structure, so that Stumm's analysis of this species is based upon topotypes. Similarly, Rominger's description of his H. interstinctus (see above), which we have found in good agreement with our own material, was presumably based upon more information than that obtained solely from his figured specimen, which is the same specimen that Stumm considered too altered for analysis of internal features.

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Galle (1973) reported H. spongodes from Bohemia, in the upper part of the Liteň Formation (Wenlock), and the Kopanina Formation (Ludlow). The coralla are discoid and holothecate. Corallite diameters are 1.0 to 1.1 mm, with the corallite walls slightly thicker than those of the coenosteal tubes, though not greatly thick. The corallites are spaced somewhat closer than ours, usually within a diameter of one another. Long spines are present in longitudinal rows, the spines curving upward and intertwining in the axis, sometimes forming a plaited axial structure. The corallite tabulae are complete, sometimes a bit wavy in vertical section, usually 2 to 2.4 per millimeter. The coenosteal tubes are 0.2 to 0.4 mm in diameter, with tabulae spaced about 3 to 3.4 per millimeter. Only the closer spacing of the corallites in Galle's material differs from ours, a difference which, however, does not seem as important as the similarities between these forms. They are therefore considered conspecific.

Distribution - Reports of material confidently regarded as belonging to this species, come from Gotland: Late Llandovery(?), Wenlock, Ludlow(?); Falls of the Ohio region (northern Kentucky, southern Indiana): Late Wenlock to Early Ludlow; Bohemia: Wenlock, Ludlow; Kansu Province, China: Middle Silurian.

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Brassfield occurrence - Localities 1 (near Panola) and 46 (near College Hill), in central Kentucky, from the Noland Member.

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Family *Palaeoporitidae* Kiär, 1899

(*nom. transl.* Sokolov, 1962 [*ex Palaeoporitinae* Kiär, 1899])

Longitudinal skeletal elements (walls, septa) trabecular, commonly thickened and porous; coenosteum tubular; tabulae not obvious, due to sparseness of spacing, as well as camouflage by irregular ("spongy") structure of coenosteum and corallites; corallite walls not well-defined.

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Palaeoporites Kiär, 1899

Type species - (by monotypy): Palaeoporites estonicus Kiär (1899), p. 18-21, Plate III, fig. 1-4.

Type locality and horizon - Porkuni Stage (F_2), Lower Llandovery of Estonia.

DESCRIPTION - As there are only one or two species assigned to this genus (Sokolov, 1962, p. 278 in Russian edition), the following description is based largely Kiär's account (1899) of the type species:

The corallum is spherical or knobby. The corallites stand out more on slightly-weathered surfaces of the corallum than in thin-section, due to the rather irregular structure of the interior. The skeletal material is made of trabeculae, bundles of carbonate mineral shaped like rods. The corallites have 12 septa, and reside in a matrix of tubular coenosteum. A weakly-developed columella consisting of the distal ends of perhaps 12 to 15 trabeculae, appears as an aggregate of bumps in the axial floor of the calices.

The outstanding feature of this genus is the irregularity of the internal structure. In a sense, Palaeoporites among the heliolitids is similar to Calostylis (which see) among the rugosans. The coenosteal tubes (often, not always), the corallite walls and the septa are frequently pierced by openings, which may be pores, or possibly even irregular gaps. The corallite walls are not well-developed,

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in that they are not significantly thicker than the walls of the coenosteal tubes (compare this with Heliolites spongodes, which see). This fact, and the frequent perforation of the corallite walls results in the corallites being lost in a sea of coenosteum, discernible only on close inspection, in which case the radial septa mark them. The septa, too, are often discontinuous, making the corallites even more obscure.

The septa consist of two or more rows of trabeculae per septum, narrowing often to one single row toward the axis. The septal trabeculae vary in length. They curve distally from their base at the corallite wall, such that their distal ends may appear in the axis, to help form the knobby columella. Synapticulae may connect neighboring septa laterally.

Tabulae occur in the corallites and in the coenosteal tubes, though they are usually obscured by the chaotic pattern of the skeletal elements (longitudinal). Kiär refers to the tabulae as "thickened but irregular".

Another important feature of this genus (and one seen clearly in our species) is the fact that the thickening of the coenosteal tubes as seen in transverse section is quite inhomogeneous. Zones of considerable thickening are found next to zones of considerably less thickening, contributing further to the irregular appearance of the internal structure.

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Palaeoporites sp.

Plate 35, fig. 1, 2; Plate 37, fig. 3

? 1890 Heliolites subtubulatus Foerste, p. 232-233
(non Palaeopora subtubulata M'Coy, 1854)

Type material - Specimen figured is UCGM 41932

Type locality and horizon - Specimen figured is from the Brassfield Formation at locality 11, near West Union, Ohio, from cross-bedded talus block.

Number of specimens studied - 2

DESCRIPTION - Corallum is laminar, two inches or more in diameter, with what appear to be discontinuities of growth, or sharp decreases in corallum width followed by recovery of original diameter, at certain levels. The thickest corallum is approximately 5 mm thick.

As is typical of this genus, the corallites are obscure, and not immediately differentiable visually from the coenosteum, as may be seen in Plate 35, fig. 2. They are more apparent on the surfaces of weathered coralla. The corallites are approximately 1.0 mm in diameter, and appear (based on observations on relatively small portions of thin-sections, where they are clear) to be spaced about one diameter from the nearest neighbor. Their walls do not seem to be appreciably thicker than those of the coenosteal elements.

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In transverse section, the corallites display 12 septal elements which vary somewhat in length. Some of these seem to join axially with their neighbors, but preservation is too poor for this to be certain. The septal elements are likely continuous lamellae, rather than longitudinal rows of spines, as there are invariably 12 of them in the section, but this too is not certain. The proximal end of each element is thickened, and connects directly with the coenosteal tissue, such that the former have the appearance of being one with the coenosteal wall structures, while affecting a radiating configuration, their sole distinguishing mark.

The coenosteum consists of tubes with discontinuous walls. The perimeters of the corallites may also be discontinuous (Plate 37, fig. 3). There are approximately 4 to 5 coenosteal tubes in a length of 1 mm across a transverse section. The walls of these tubes are someeimes thickened to almost equal the tube diameter (though it is possible that this is an artifact of recrystallization, as elsewhere, the walls are only about half so thick).

Little is discernible in vertical section (Plate 35, fig. 1. The corallites are not readily-differentiable from the coenosteum, and no tabulae have been observed at all. Again, the possibility that this is due to recrystallization of the narrow tubes cannot be ruled out.

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DISCUSSION - As this is the only species of heliolitid with a Heliolites-like tubular coenosteum that we have found in the Brassfield north of the Ohio River, it is worth comparison with material identified as Heliolites subtubulatus (M'Coy) by Foerste (1890) from the Clinton beds (probably Brassfield) at Ludlow Falls, Ohio (our locality 55). This is a laminar form with corallites 0.6 to 0.75 mm in diameter, apparently spaced about a diameter or more appart. The corallites are circular in outline, and contain 12 septa. The coenosteal tubes are about 0.2 mm in diameter. Judging from the wording of his description (there are no figures) Foerste did not section his material. In light of this fact, and in the absence of more detailed information on his specimens, we can only questionably identify them with our own corals of the present species.

Distribution - Brassfield Formation (Middle Llandovery) of southwestern Ohio.

Brassfield occurrence - Localities 11 (West Union) and 15 (West Milton) in southwestern Ohio.

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PLATES AND PLATE EXPLANATIONS

With few exceptions, size relations have been standardized on these plates. Except where indicated, figures of whole specimens are natural size, while figures of thin-sections are approximately X3.5. Plates 36 to 39 show thin-sections at an approximate magnification of X30. The figures of these last four plates were made using a photomicroscopy assembly, with crossed nicols. All others of the thin-sections (Plates 12 to 35) were made by using the slide as a negative in a photographic enlarger.

Not all specimens shown on these plates are from the Brassfield Formation. In several instances, holotypes of Brassfield species are shown, though they are from different localities and horizons, and in the case of Plasmopora lambii, an Ordovician heliolitid from the Canadian Arctic (Plate 35), an attempt is made to show interesting similarities of form between a Brassfield species and one from a much-different time and place.

Prefixes preceeding catalogue numbers indicate the institution serving as repository for the specimen. These abbreviations are explained on page i at the beginning of this work.

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PLATE 1

All figures are X1

Fig. 1-3, Streptelasma scoleciforme sp. nov., from top of the Noland Member, Brassfield Formation at locality 1, near Panola, Kentucky. Holotype of the species. Fig. 1: side view; fig. 2: basal view; fig. 3: calice view; (UCGM 41942)

Fig. 4-6, Streptelasma scoleciforme sp. nov., three small specimens from locality 1, at same outcrop and level as specimen shown in fig. 1-3; (UCGM 41981)

Fig. 7, 8, Streptelasma scoleciforme sp. nov., two side views of a single specimen from same site as the specimens of the above figures; (UCGM)

Fig. 9-11, Dinophyllum stokesi (Milne-Edwards & Haime), Collected by George C. Simmons in 1965, from Waco bed of Noland Member, Brassfield Formation, in southwest corner of Panola, Kentucky Quadrangle, 12,750 feet north and 4450 feet east of the southwest corner of this quadrangle. Fig. 9: lateral view; fig. 10: calice view; fig. 11: lateral view of convex side; Uncatalogued specimen, designated (by locality number) 7450a in U.S. Geol. Surv. collection.

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Fig. 12-15, Dinophyllum stokesi (Milne-Edwards & Haime), from Noland Member, Brassfield Formation at locality 46 (College Hill, Kentucky). Fig. 12-14: lateral views; fig. 15, calice view; (UCGM 41959)

Fig. 16, 17, Dinophyllum semilunum sp. nov., from locality 7a, near Fairborn, Ohio. Specimen found in place in middle of the clay-coral bed described in "Brassfield Lithosome" section of this work. Two lateral views of a single specimen; (UCGM 41983)

Fig. 18, 19, Dinophyllum semilunum sp. nov., from locality 7a, near Fairborn, Ohio. Found loose on east side of quarry, probably from same clay-coral bed as specimen in fig. 16, 17. Calice and lateral views; (UCGM 41924)

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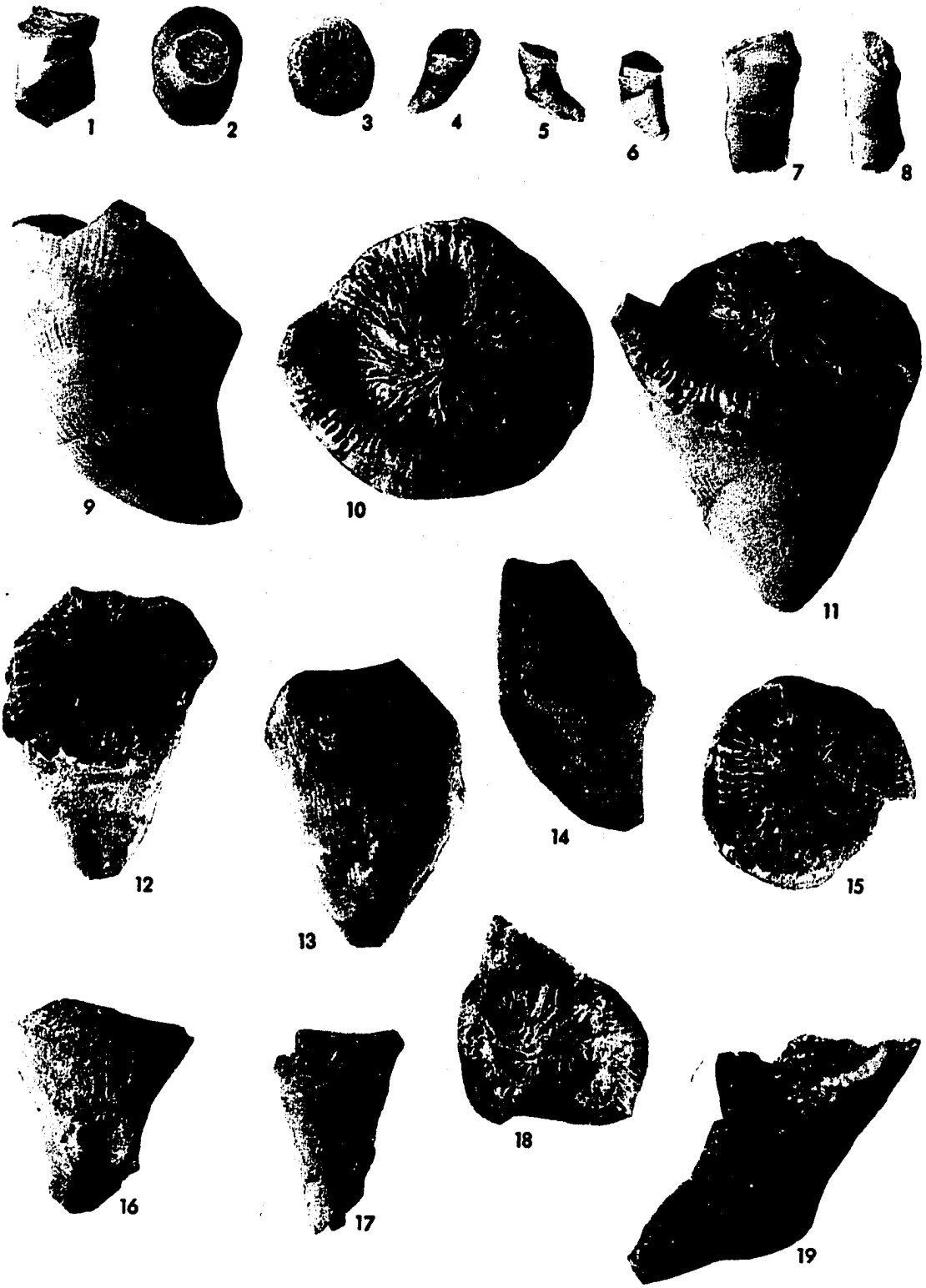

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PLATE 2

All figuresare X1 except where otherwise indicated.

Fig. 1-4, Dinophyllum hoskinsoni (Foerste). Fig. 1, lateral view of paratype, USNM 84783, the original of Foerste's Plate IX, fig. 1; fig. 2, lateral view of lectotype, USNM 84783, the original of Foerste's Plate IX, fig. 2. Both specimens from near New Carlisle, Ohio, probably Brassfield Formation. Fig. 3, 4, calice and lateral view, slightly greater than X1, of a specimen from locality 46, type Noland Member, Brassfield Formation near College Hill, Kentucky. (UCGM 41960)

Fig. 5, 10-11, Dalmanophyllum(?) obliquior (Foerste), holotype, USNM 84794, original of Foerste's figure 14, from the Brassfield Formation at Hanover, Indiana. Fig. 5, 11, two lateral views; fig. 10, same view as fig. 11, X2.

Fig. 6-9, 12-17, 20-23, Dalmanophyllum linguliferum (Foerste). Fig. 6, 7, 12-14, lectotype, USNM 87175, original of Foerste's Plate 5, fig. 2C, from north of Irvine, Kentucky (about locality 53-53a of this work); fig. 6, 7 are X2; fig. 8, 9, original of Foerste's Plate 5, fig. 2E, F, from same locality as lectotype, (USNM 87175); fig. 15-17, a specimen from top of the

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Noland Member, Brassfield Formation at locality 1, near Panola, Kentucky (UCGM 41952 , fig. 15 is X2); fig. 20-23, another specimen from same locality, seen calice view and threelateral views (UCGM 41935).

Fig. 18, 19, 24, Dalmanophyllum sp., aff. D. minimum (Ryder), from lag-2 of the Högklint, near Visby, Gotland. Fig. 18: calice view, X1.5; fig. 19: view of convex side, X1.1; fig. 24: lateral view, X1.0. Note basal attachment-scar. (UCGM 41955)

Fig. 25-28, Rhegmaphyllum daytonensis (Foerste). Fig. 25: lateral view of USNM 93518, Cyathophyllum celator daytonensis Foerste, X1.1. Fig. 26-28, three specimens comprising USNM 84796, also C. celator daytonensis. All four specimens were collected by Foerste and constitute the type series of Foerste's subspecies. All four specimens are from the Brassfield Formation at Dayton, Ohio. Because of a possible misplacement of a label, USNM 93518 was thought to be the holotype, but evidence points to the specimen of fig. 27 (USNM 84796) as being the true holotype (see discussion in text under section on this species).

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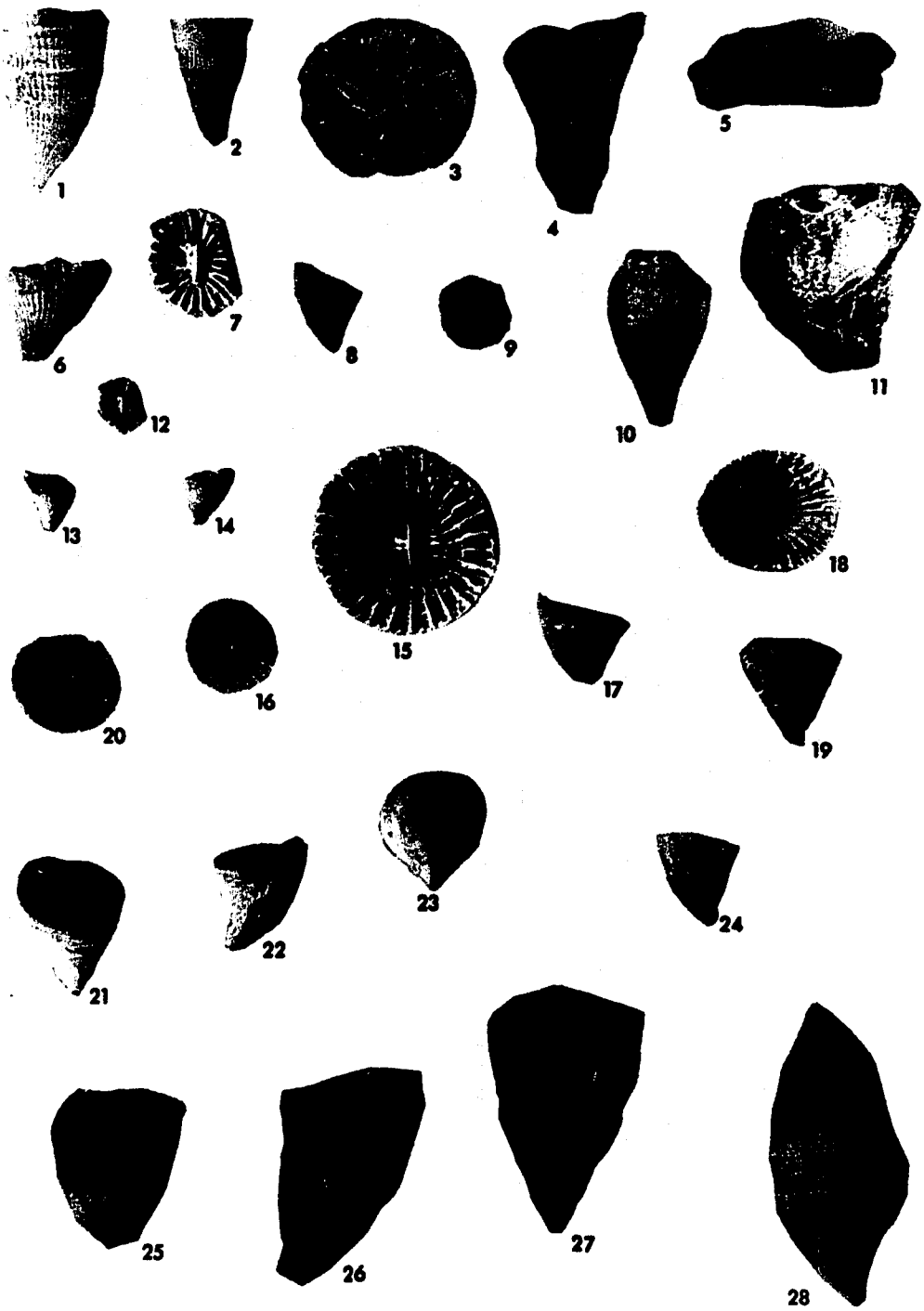

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PLATE 3

All figures are X1 except where otherwise indicated.

Fig. 1-17, Rhegmaphyllum daytonensis (Foerste).

Fig. 1-5: lectotype of Zaphrenthis charaxata Foerste, original of Foerste's figure 4C. Fig. 1 and 2 are X2.5 and X2.0 respectively. From Waco bed in the top of the Noland Member, Brassfield Formation north of Irvine, Kentucky (locality 53-53a of this study); USNM 87178. Fig. 6-8: a paratype of Zaphrenthis charaxata, USNM 87178, from same locality and horizon as above specimen. Fig. 8 is X2.3. Fig. 9-10: specimen from locality 37, Sharpsville in Highland County, Ohio (UCGM 41984). Fig. 11: specimen, X2.3, from lower (dolomitic) Brassfield Formation at locality 7a, in quarry floor near Fairborn, Ohio. Note surface expression of the carinae, and compare with fig. 2, 8 and 14 of this plate; (UCGM 41968). Fig. 12-14: specimen from locality 11, near West Union, Ohio. Note carinae on septa. Fig. 14 is X2.5; (UCGM 41938). Fig. 15-17: specimen from locality 11. Fig. 15 is X1.3. Note counter-clockwise axial whorl, also seen in fig. 1 of this plate; (UCGM 41939).

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Fig. 18-20, Schlotheimophyllum benedicti (Greene), from locality 15, near West Milton, Ohio. Specimen is from clay-pocket in top of the Brassfield Formation; (UCGM 41700).

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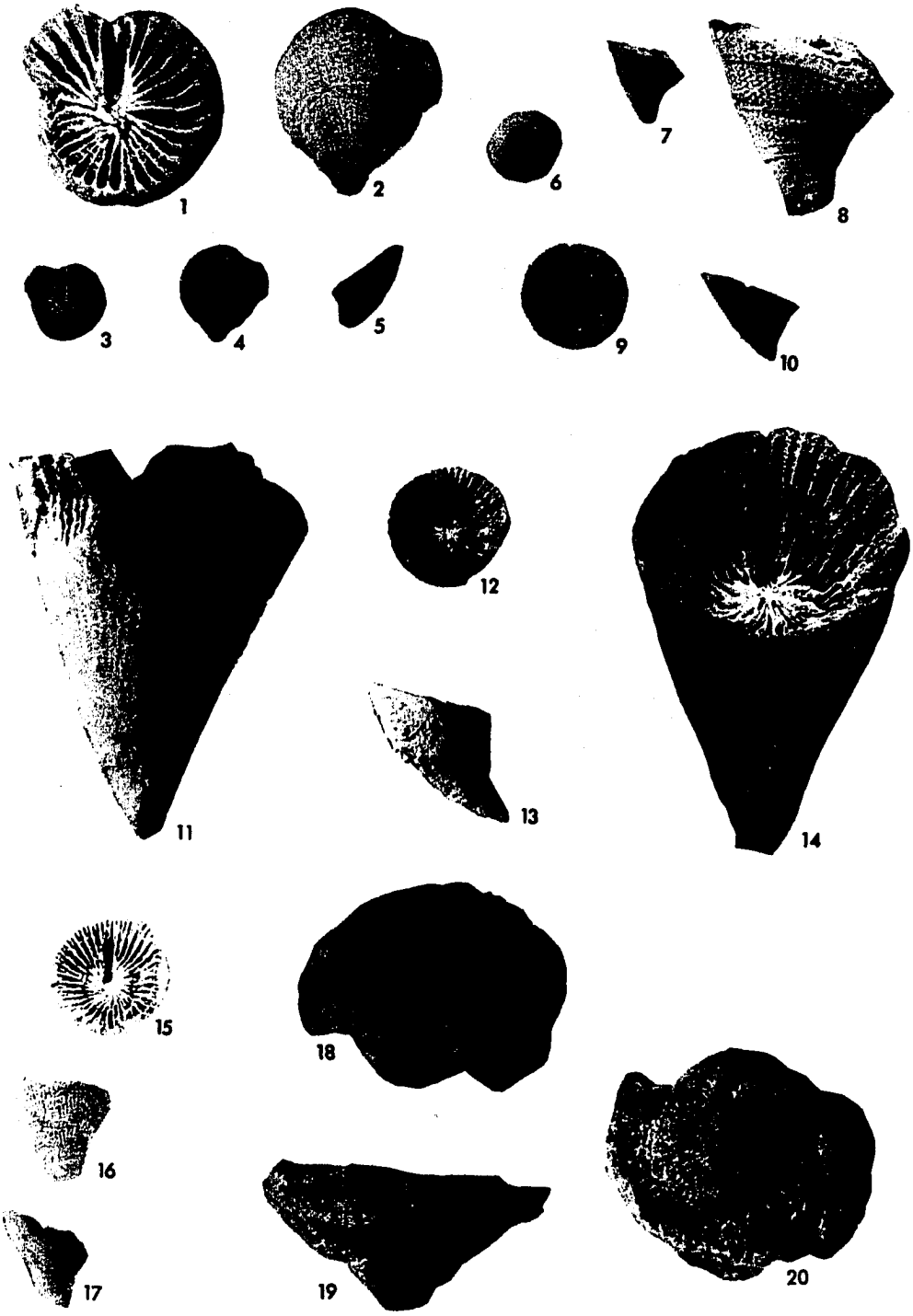

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PLATE 4

All figures are X1.

Fig. 1-4, Schlotheimophyllum benedicti (Greene), AMNH 23505, the lectotype of Ptychophyllum benedicti Greene, and the original of Greene's fig. 5, from Louisville Formation, Louisville, Kentucky.

Fig. 5-7, Schlotheimophyllum ipomaea (Davis), MCZ 8164, the lectotype of Ptychophyllum ipomaea Davis, from the Louisville Formation at Louisville, Kentucky.

Fig. 8, 9, Paliphyllum cf. P. suecicum Neuman, from locality 7a near Fairborn, Ohio. Specimen is probably from the clay-coral bed described in section on "Brassfield Lithosome". Note the basal talon in fig. 8, and the medial lamella in fig. 9; (UCGM 41970). See thin-sections, Plate 19, fig. 1, 4, 5.

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PLATE 5

All figures are X1 except where otherwise indicated.

Fig. 1, Schlotheimophyllum patellatum (Schlotheim), from locality 7a, near Fairborn, Ohio, in talus block; (UCGM 41971).

Fig. 2-5, Protocyathactis cf. P. cybaeus Ivanovskiy, from locality 46, Noland Member, Brassfield Formation near College Hill, Kentucky. Figs. 2-4 are different views of one specimen (UCGM 41956); fig. 5 is a second specimen (UCGM 41985).

Fig. 6, 7, Cyathactis typus Soshkina, from locality 1, in top layer of the Brassfield Formation (Noland Member) near Panola, Kentucky; (UCGM 41943).

Fig. 8, 10, Cyathactis sedentarius (Foerste). These are two views of one of the specimens comprising USNM 87177, Cyathophyllum sedentarium Foerste; from the Brassfield Formation north of Irvine, Kentucky (locality 53-53a of this study).

Fig. 9, 11, Cyathactis sedentarius (Foerste). This is another specimen included under USNM 87177. It is the holotype of Cyathophyllum sedentarium Foerste, the original of Foerste's Plate 6, fig. 3B. From same locality as the previous specimen.

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Fig. 12, 13, Tryplasma cylindrica (Wedekind), from locality 1, at the top of the Noland Member, Brassfield Formation, near Panola, Kentucky. Note the two orders of acanthine septa, and the irregular orientation of the spines, in contrast with those of T. radicula (q.v.); (UCGM 41937). Fig. 13 is approximately X4.

Fig. 14, 15, Tryplasma cylindrica (Wedekind), from the same horizon and locality as the previous specimen. Fig. 15 is an enlarged view of the calice floor, showing its covering of spines. Compare with T. radicula, Plate 6, fig. 2, 3, which lacks spines on its tabular surfaces. (UCGM 41948). Fig. 15 is approximately X4.

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PLATE 6

All figures are X1 except where otherwise indicated.

Fig. 1-4, Tryplasma radicula (Rominger). Fig. 1: slab of dolomite representative of top of Noland Member, Brassfield Formation at locality 1, near Panola, Kentucky. Slab contains two corallites of this species; (UCGM 41978). Fig. 2-4: specimen from same locality and horizon, with enlargements (fig. 2 is X2, fig. 3 is approximately X2.5) to show the nature of the acanthine septa (with more regularly-oriented spines than T. cylindrica, Plate 5, fig. 13) and the absence of spines from tabular surfaces (compare with Plate 5, fig. 15); (UCGM 41951).

Fig. 5, Tryplasma sp., a budding corallite from locality 46, in the Noland Member of the Brassfield Formation near College Hill, Kentucky; (UCGM 41987).

Fig. 6-12, 14, 15, Calostylis spongiosa Foerste. Fig. 6-9: corallite from locality 1, top of Noland Member, Brassfield Formation near Panola, Kentucky. Note clearly-defined theca, absence of theca from distal-most portion of corallite, and clearly-defined cardinal fossula. Note also the nodular nature of the septa (due to synapticulae) and the spongy axial structure. Fig. 6 is X2; (UCGM 41954). Fig. 10: specimen from Noland Member,

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Brassfield Formation, at locality 46, near College Hill, Kentucky. Note the more cylindrical form than in the previous specimen; (UCGM 41988). Fig. 11, 12: specimen from locality 1, same horizon and locality as specimen of figure 6-9. Note cardinal fossula and basal attachment scar. Fig. 12 is approximately X2; (UCGM 41980). Fig. 14, 15: small, presumably young specimen from locality 1, same horizon and locality as the previous specimen; (UCGM 41977).

Fig. 13, 16, 17, Calostylis lindstroemi Nicholson & Etheridge. Fig. 13: small specimen growing on worn fragment of Schizophaulactis densiseptatus from the Waco bed of the Noland Member, Brassfield Formation at locality 53, near Irvine, Kentucky; (UCGM 41986). Fig. 16, 17: typically scolecoid specimen from locality 1, near Panola, Kentucky, in the top of the Noland Member, Brassfield Formation. Fig. 17 is enlarged (approximately X2) to show the virtual absence of a theca (typical of this species), resulting in exposure of the spongy synapticular structure of the interior, and the presence of a basal talon; (UCGM 41979).

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PLATE 7

All figures are X1 except where otherwise indicated.

Fig. 1, Strombodes socialis (Soshkina), from the Brassfield Formation at locality 7, near Fairborn, Ohio. Note Note the small tabulate colony growing on the corallite in the middle-upper portion of the figure; (UCGM 41921).

Fig. 2, 3, Arachnophyllum mamillare (Owen). Fig. 2: holotype of A. mamillare-distans Foerste (USNM 113639), original of Foerste's Plate 3, fig. 2A, from the Brassfield Formation at Panola, Kentucky (locality 1 of this study). Fig. 3: specimen from locality 12, near Jacksonville, Adams County, Ohio. This specimen was found loose on a ledge high in the Brassfield Formation, and could be from that unit, or from the over-lying Dayton Formation. It is believed to be A. mamillare-pygmaeus (Rominger), a subspecies of the present species; (UCGM 41989).

Fig. 4, 5, Pycnactis tenuiseptatus sp. nov., from the Brassfield Formation at locality 48, near Owingsville, Kentucky. This is the holotype of the species; (UCGM 41963).

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Fig. 6, 7, Schizophaulactis densiseptatus (Foerste). Two views of a specimen from the top of the Noland Member, Brassfield Formation at locality 1, near Panola, Kentucky. This is a rather stout corallite for the species; (UCGM 41996).

Fig. 8, Petrozium pelagicum (Billings), a corallum (reduced in size to X.6) from the Brassfield Formation at locality 7, near Fairborn, Ohio; (UCGM 41990).

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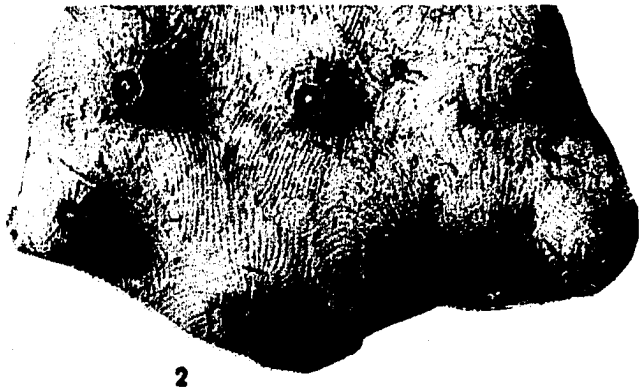

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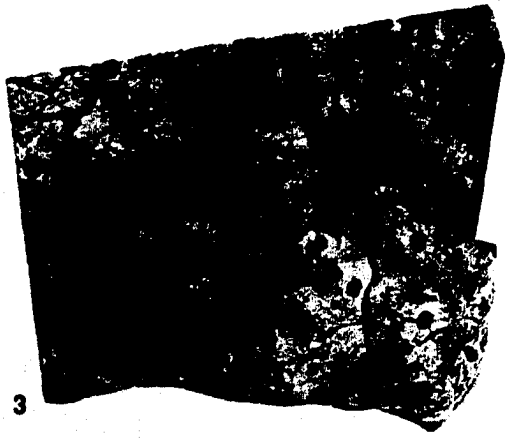

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PLATE 8

All figures are X1 except where otherwise indicated.

Fig. 1-3, Schizophaulactis densiseptatus (Foerste).
Fig. 1, 2: calice and lateral view of specimen from top of Noland Member, Brassfield Formation at locality 1, near Panola, Kentucky. Note pairing of septa and distinct cardinal fossula. This specimen displays a sharp expansion in diameter, to a degree seldom seen in the specimens studied; (UCGM 41982).
Fig. 3: a canine-shaped specimen from same locality and horizon. This specimen is the lectotype of the species; (UCGM 41944).

Fig. 4-6, 9, Favosites favosus (Goldfuss), holotype of Calamopora favosa Goldfuss, from the Silurian of Drummond Island, Lake Huron. This specimen, apparently without a catalogue number, is from the collection of the Geological and Paleontological Institute of Bonn, West Germany, and is the original of Goldfuss' Plate 26, fig. 2. Fig. 4: basal view of specimen; fig. 5: view of top; fig. 6: view of side (note upward convexity of tabulae); fig. 9: enlarged view (X2.5) of portion of lower surface (same as upper-left corner of fig. 4), showing common axial depressions and marginal fossulae in the tabulae.

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Fig. 7, Favosites forbesi Milne-Edwards & Haime, aspinosa, subsp. nov. Specimen found loose at locality 7a, near Fairborn, Ohio. It is possibly from the clay-coral bed described in "Brassfield Lithosome" section; (UCGM 41922). Holotype of the subspecies.

Fig. 8, Favosites hisingeri Milne-Edwards & Haime. Holotype of Favosites hisingeri-aplata Foerste, original of Foerste's Plate 2, fig. 2, and Plate 4, fig. 5, from the Waco bed, Noland Member, Brassfield Formation near Irvine, Kentucky (locality 53-53a of this study); USNM 87171.

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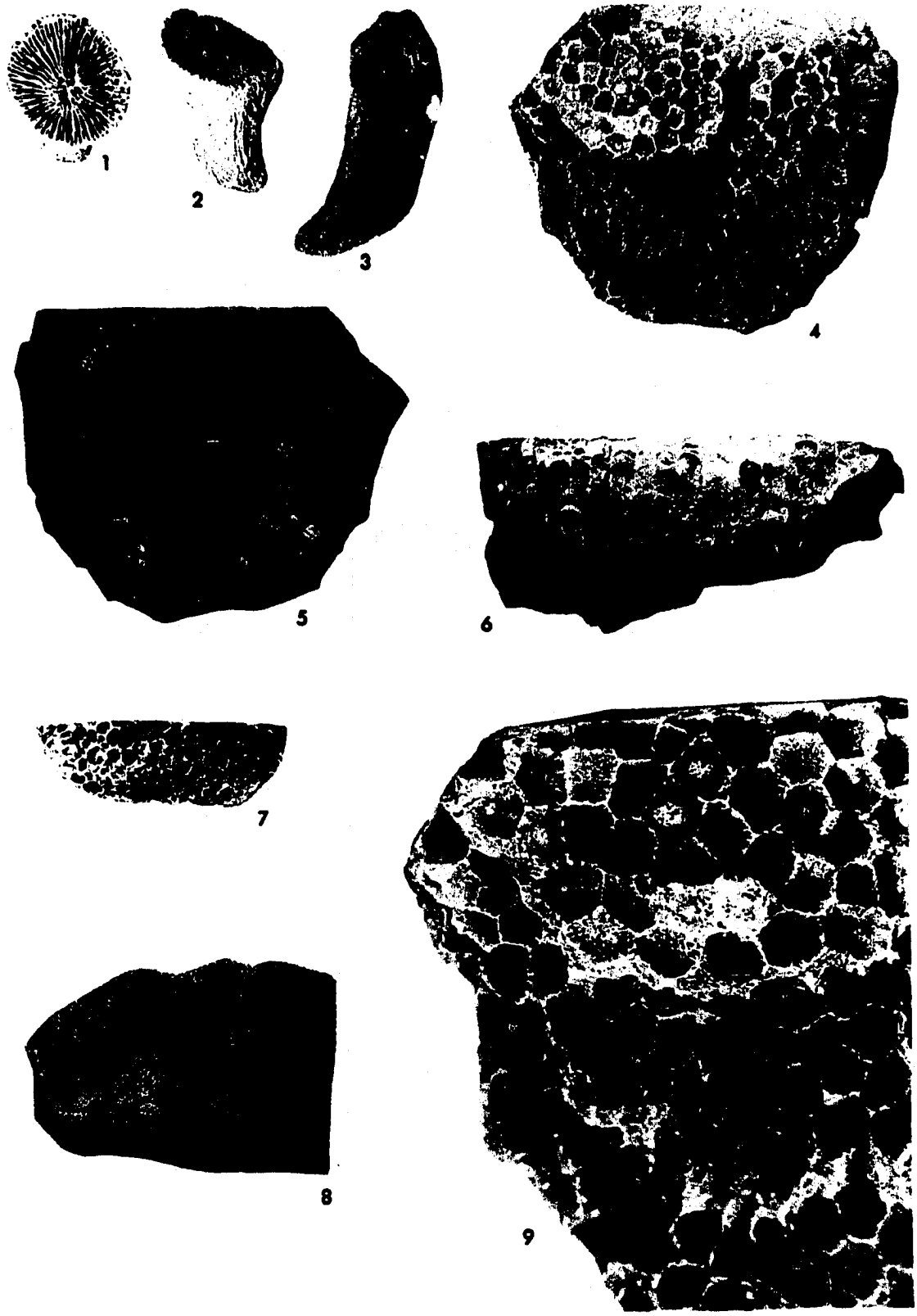

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PLATE 9

All figures are X1 except where otherwise indicated.

Fig. 1-5, Paleofavosites prolificus (Billings), from locality 7a, near Fairborn, Ohio in the Brassfield Formation. Specimen collected in-place, just below the clay-coral bed (see "Brassfield Lithosome"). Fig. 1, 4: magnified (X2) and natural-size views of one piece of the corallum. Note fine spines on corallite walls. Fig. 2, 3: magnified views of biological top (approx. X1.5) and bottom (X2) respectively of a second fragment of the same corallum. Note spines in fig. 2, and axial depressions in tabulae in fig. 3 (compare with Plate 8, fig. 4, 9). Fig. 5: view of biological top of same specimen, natural size; (UCGM 41926)

Fig. 6, 7, Favosites densitabulatus sp. nov., from locality 46, Noland Member, Brassfield Formation near College Hill, Kentucky; (UCGM 41991)

Fig. 8, Catenipora gotlandica (Yabe), locality 7a, Brassfield Formation near Fairborn, Ohio. Specimen found in-place in the clay-coral layer (see explanation for fig. 1-5); (UCGM 41973).

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Fig. 9, 10, Cladochonus sp. C, from locality 15, Brassfield Formation near West Milton, Ohio. Specimen was found loose, but probably comes from a clay pocket near the top of the unit. Fig. 9 is X1.5; (UCGM 41693)

Fig. 11, 12, Cladochonus sp. B, from locality 13, Brassfield Formation at Todd Fork Creek near Wilmington, Ohio. Fig. 12 is an enlargement (X2) of this specimen, which consists of five or six corallites in uniserial arrangement; (UCGM 41859).

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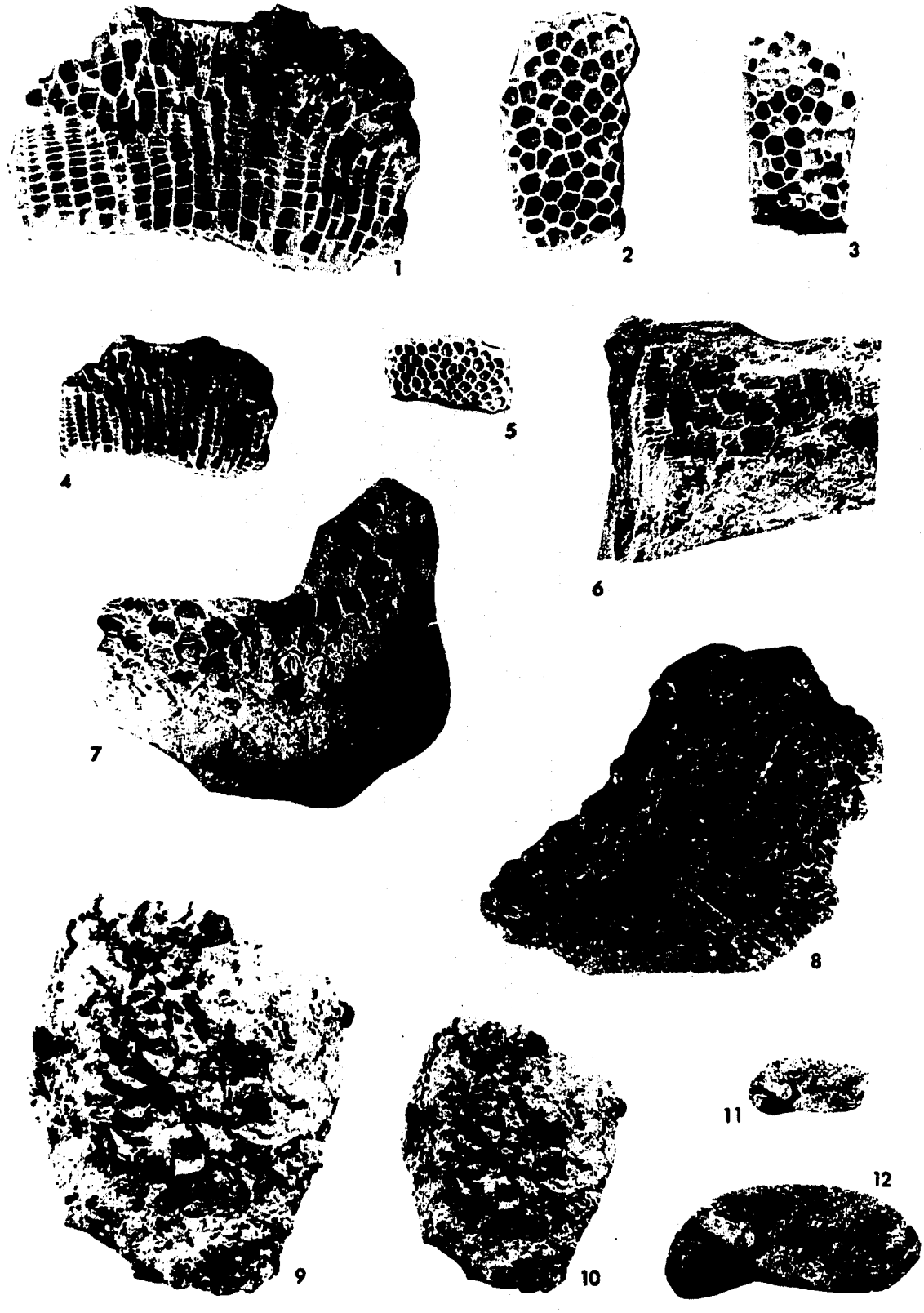

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PLATE 10

All figures are X1 except where otherwise indicated.

Fig. 1, Cladochonus sp. A, from locality 46, Noland Member, Brassfield Formation near College Hill, Kentucky. Note the dichotomous offsets. The specimen is enlarged X2.2; (UCGM 41987).

Fig. 2-4, Syringopora reteformis Billings. Fig. 2: specimen from locality 7a, Brassfield Formation near Fairborn, Ohio, in loose block from above the clay-coral bed described under "Brassfield Lithosome"; (UCGM 41993). Fig. 3, 4: holotype of the species, GSC 2617, from Owen Sound, Ontario, showing apical and lateral views.

Fig. 5, Syringolites sp. A sp. nov., USNM 84893, original of Foerste (1906), Plate 2, fig. 3; Plate 4, fig. 2, where it was identified as S. huronensis Hinde. Specimen is from the Waco bed, Noland Member, Brassfield Formation near Clay City, Kentucky.

Fig. 6, 7, Heliolites spongodes Lindström, from locality 46, Noland Member, Brassfield Formation near College Hill, Kentucky. Fig. 7 is an enlargement (X2.5) of the upper surface of this specimen, a hemispherical corallum, where weathering has revealled the skeletal structure; (UCGM 41992).

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Fig. 8, 9, Alveolites labrosus Milne-Edwards & Haime, from locality 1, at the top of the Noland Member, Brassfield Formation near Panola, Kentucky. Fig. 9 has been enlarged X2.6 natural size; (UCGM 41950).

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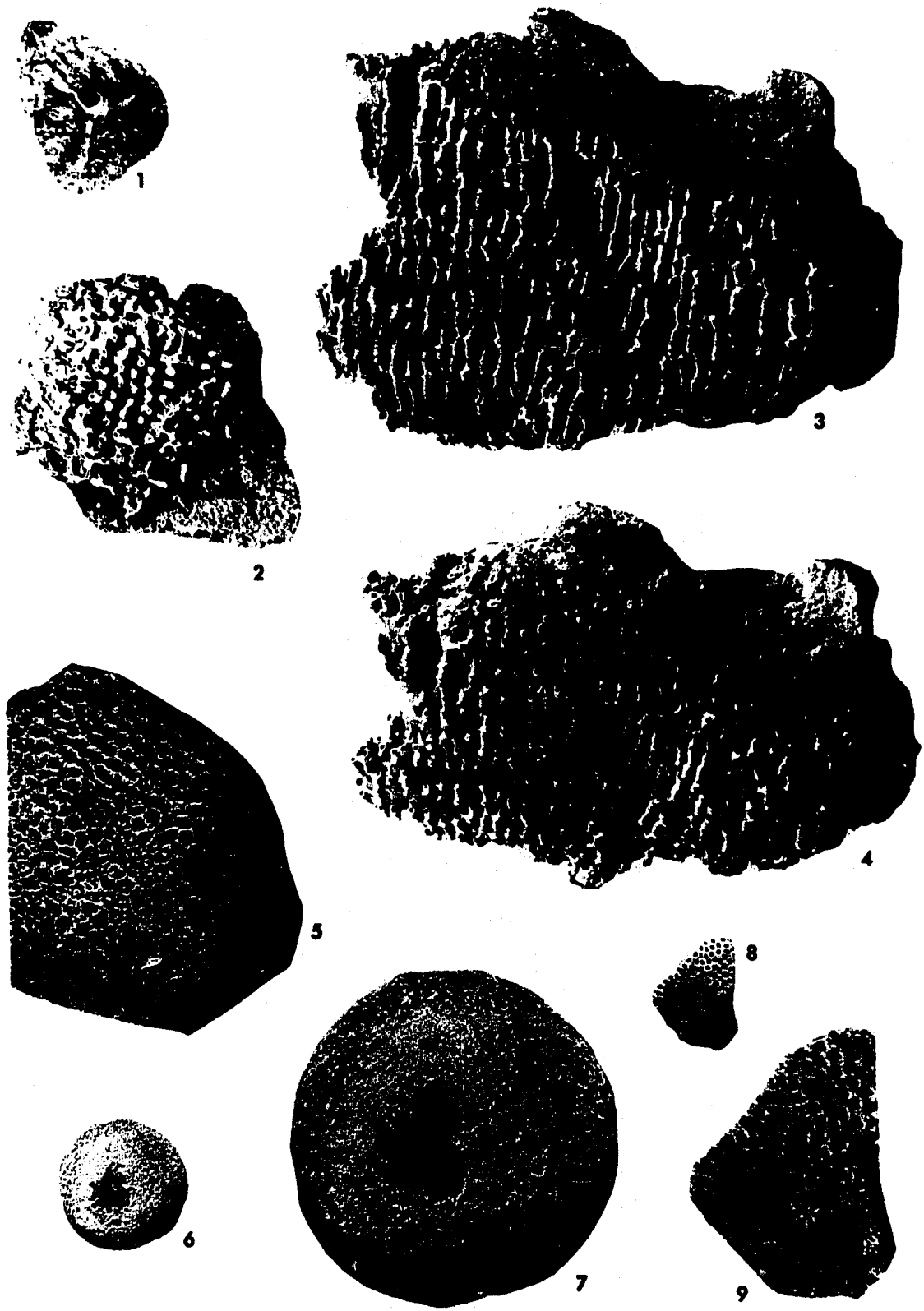

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PLATE 11

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Fig. 1, 2, Syringopora reteformis Billings, from locality 11, in the Brassfield Formation near West Union, Ohio. Fig. 2 is an enlarged detail of the corallum (X2), showing a stolon joining two corallites on the right-hand side; (UCGM 41813).

Fig. 3, 4, Striatopora flexuosa Hall. Fig. 3: specimen (enlarged X2) from locality 37, Brassfield Formation near Sharpsville, Ohio (UCGM 41962). Fig. 4: specimen from clay pocket at top of the Brassfield at locality 55, near Ludlow Falls, Ohio, enlarged X2.25; (UCGM 41994).

Fig. 5, 6, Heliolites spongiosus Foerste, USNM 84892, holotype of the species, original of Foerste (1906) Plate 3, fig. 3; Plate 4, fig. 6; Plate 5, fig. 5. Specimen is from the Waco bed, Noland Member, Brassfield Formation near Irvine, Kentucky (locality 53-53a of this study). Fig. 6 is an enlarged detail (X3) of the holotype. Note inequality of size of the coenosteal tubes.

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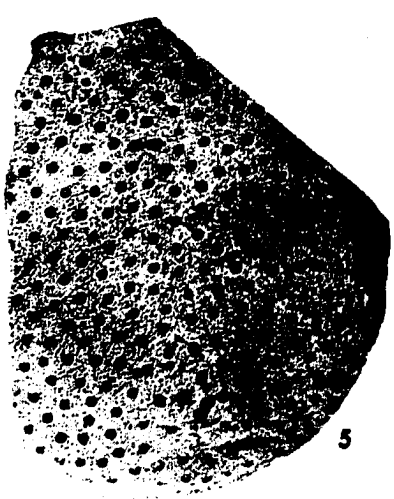

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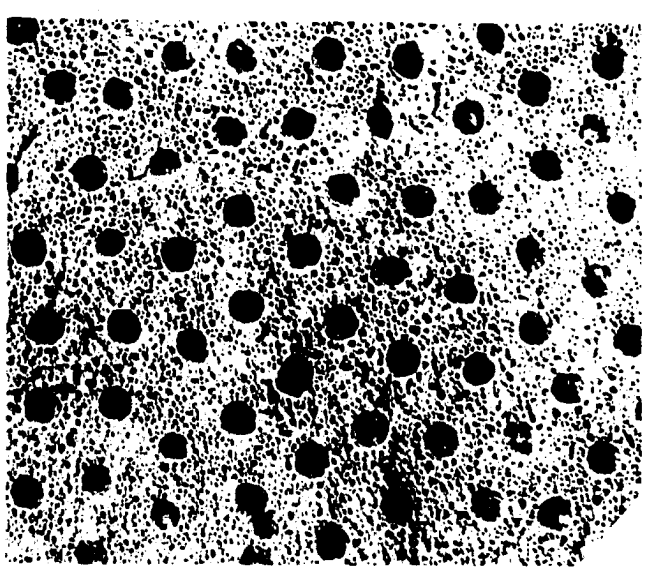

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PLATE 12

All figures are X3.5

Fig. 1-8, Streptelasma scoleciforme sp. nov., from the top of the Noland Member, Brassfield Formation at locality 1, near Panola, Kentucky. Fig. 1-4: holotype of the species, UCGM 41942. Fig. 1 and 2 are transverse sections, with two lower in the corallite than 1. Both are shown right-side-up, and with the same radial orientation. Fig. 3 and 4 are vertical sections from both sides of the plane-of-section. Fig. 5-8: four transverse sections from another specimen (UCGM 41953), from progressively-lower levels, and roughly equidistant. All are right-side-up, and have the same radial orientation.

Fig. 9, 10, Dinophyllum hoskinsoni (Foerste), USNM 87843, lectotype of Streptelasma hoskinsoni Foerste, the original of Foerste's fig. 2. The transverse section was taken immediately below the calice floor. The entire specimen is shown on Plate 2, fig. 2.

Fig. 11, 12, Dinophyllum stokesi (Milne-Edwards & Haime). Fig. 11: transverse section, taken just below calice floor, from specimen collected in Waco bed, Noland Member of the Brassfield Formation, U.S. Geol. Surv.

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locality 7450, 16,150 feet south and 17,250 feet west of northeast corner of Palmer Quadrangle, Estill County, Kentucky. Collected 1965 by George C. Simmons. Specimen is uncatalogued, designated by field number in U.S. Geol. Surv. collection as 7450b. Convex side of the corallite is toward the top of the page.

Fig. 12: longitudinal section of distal portion of corallite from the Noland Member, Brassfield Formation at locality 46, near College Hill, Kentucky. Transverse sections of this specimen are shown on Plate 13, fig. 1-3, and the whole specimen is shown on Plate 1, fig. 12-15. Note the convexity of the tabulae; (UCGM 41959).

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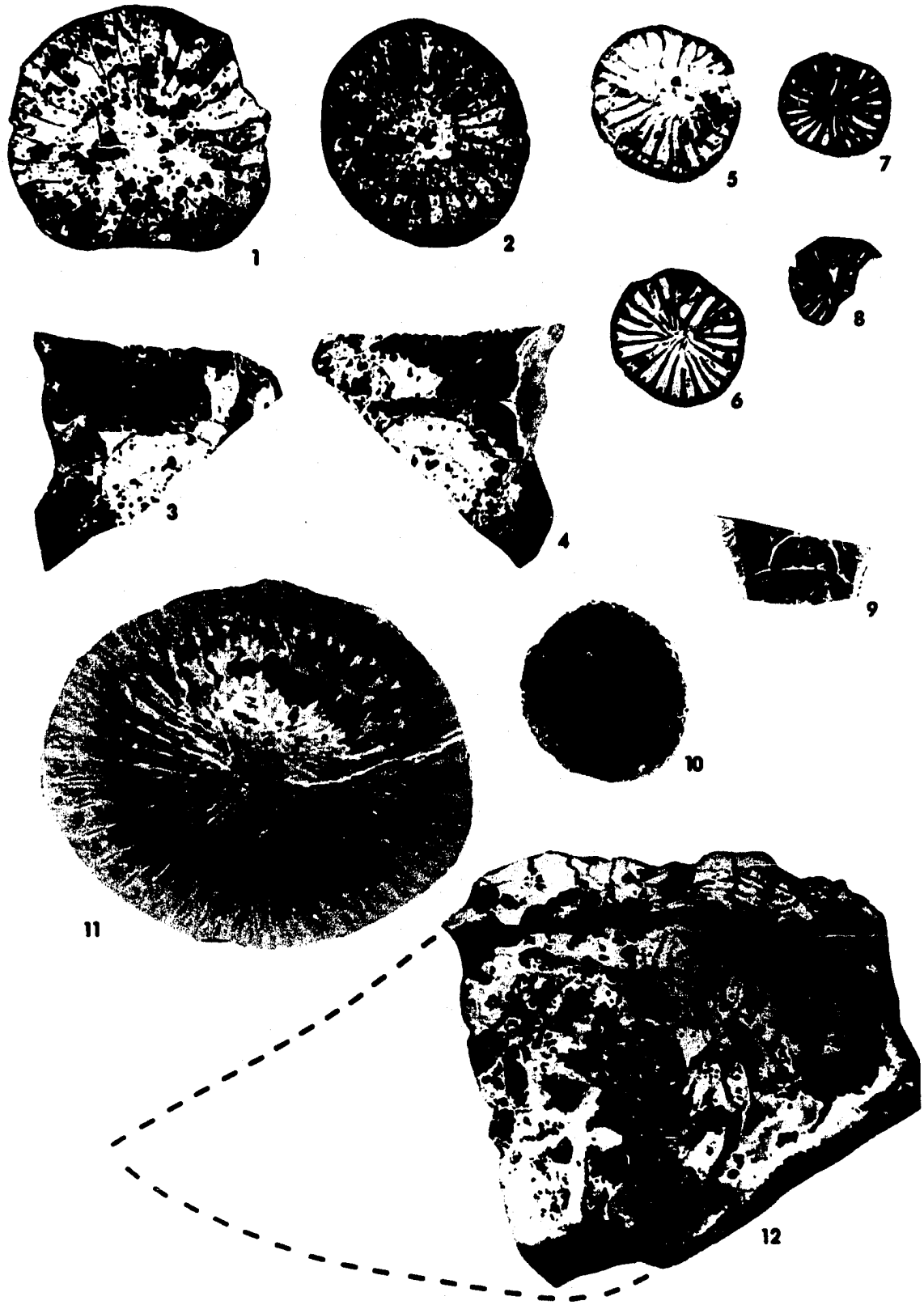

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PLATE 13

All figures are X3.5

Fig. 1-3, Dinophyllum stokesi (Milne-Edwards & Haime), transverse sections through specimen shown on Plate 1, fig. 12-15 (longitudinal section shown on Plate 12, fig. 12). All three sections are oriented with the convex side of the corallite toward the top of the page, and all are right-side-up. From fig. 1 to 3, the sections are progressively lower in the corallite, all being proximal to the portion shown in longitudinal section on the previous plate; (UCGM 41959).

Fig. 4-6, Dinophyllum hoskinsoni (Foerste) from the Noland Member, Brassfield Formation near College Hill, Kentucky (at locality 46). Fig. 4: longitudinal section (note symmetry of tabulae, and compare with lectotype on Plate 12, fig. 9). Fig. 5, 6: transverse sections from the same specimen (UCGM 41960), both right-side-up and with same radial orientation. Fig. 5 is from immediately below the calice floor (top surface of the longitudinal section), and fig. 6 is from the bottom cut surface of that section. Entire specimen is shown on Plate 2, fig. 3, 4.

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Fig. 7, Dinophyllum semilunum sp. nov., from locality 7a, the Brassfield Formation near Fairborn, Ohio. Note the conical convexity of the tabulae in this longitudinal section. UCGM 41975

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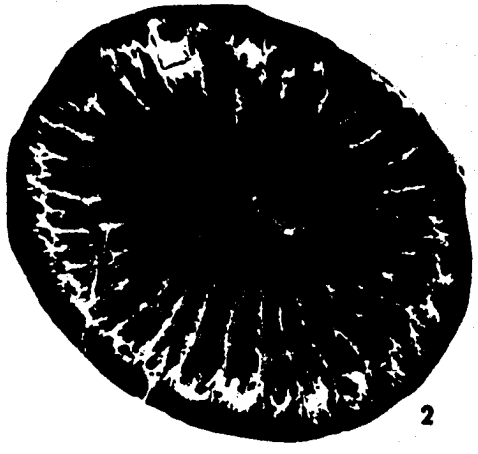
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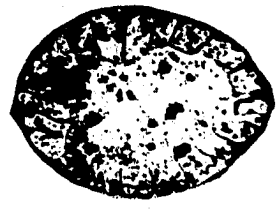
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PLATE 14

All figures are X3.5

Fig. 1-7, Dinophyllum semilunum sp. nov., from the Brassfield Formation near Fairborn, Ohio (locality 7a). This is a series of transverse sections, all right-side-up and with the same radial orientation. Fig. 1 is the highest section, being from immediately below the calice floor, and the rest are progressively lower. Note that the stereome remains in the septocoels of the cardinal side of the corallite (as judged by the presence of a presumed cardinal fossula in later stages longer than in the other areas. Note also the distinct counter-clockwise axial whorl. The holes in fig. 7 were probably produced by a boring organism. (UCGM 41924).

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PLATE 15

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Fig. 1, 2, Dinophyllum(?) obliquior (Foerste), USNM 84794, holotype of Streptelasma obliquior Foerste, the original of Foerste's fig. 14. Fig. 1 is a transverse section from immediately below the calice floor, while fig. 2 is a second transverse section from lower in the corallite. They do not necessarily have the same radial orientation. The specimen is from the Brassfield Formation at Hanover, Indiana.

Fig. 3-12, Dalmanophyllum linguliferum (Foerste). Fig. 3, 4: paratype of Lindstroemia lingulifera Foerste, USNM 87175, the original of Foerste's Plate 5, fig. 2E, F, shown in longitudinal and transverse section (the latter from just below the calice floor). Specimen is from the Noland Member, Brassfield Formation near Irvine, Kentucky (locality 53-53a of this study). Fig. 5-8: series of transverse sections from the specimen shown on Plate 2, fig. 20-23, all right-side-up and with the same radial orientation. From fig. 5 to fig. 8 the sections are lower in the corallite. Fig. 9, 10: longitudinal and transverse section (the latter from just below the calice floor) from the specimen shown on Plate 2, fig. 15-17. Fig. 11, 12: same sections from a specimen found at locality 1, same locality and horizon as the previous

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specimen; (UCGM 41946). In both these specimens, the convex side of the corals in the transverse sections is toward the top of the page.

Fig. 13, 14, Dalmanophyllum sp., transverse and longitudinal section (the former from just below the calice floor) from a specimen from the Hogklint beds of Gotland; the whole specimen is shown on Plate 2, fig. 18-19, 24. Convex side of corallite is toward top of page in the transverse section. UCGM 41955

Fig. 15-19, Rhegmaphyllum daytonensis (Foerste).
Fig. 15, 16: a paratype of Zaphrenthis charaxata Foerste, USNM 87178, shown in two successive transverse sections (progressively lower) from the specimen shown on Plate 3, fig. 6-8. Fig. 15 is from just below the calice floor. In both sections, the cardinal side is toward the top of the page. Fig. 17-19: specimen from Brassfield Formation at locality 11, near West Union, Ohio. Fig. 18 is a transverse section from must below the calice floor (at the top surface of the longitudinal section, fig. 19), while fig. 17 is from the gap in that section. Both transverse sections are right-side-up, with the convex (cardinal) side of the corallite toward the top of the page. The whole specimen is shown on Plate 3, fig. 12-14 (UCGM 41938)

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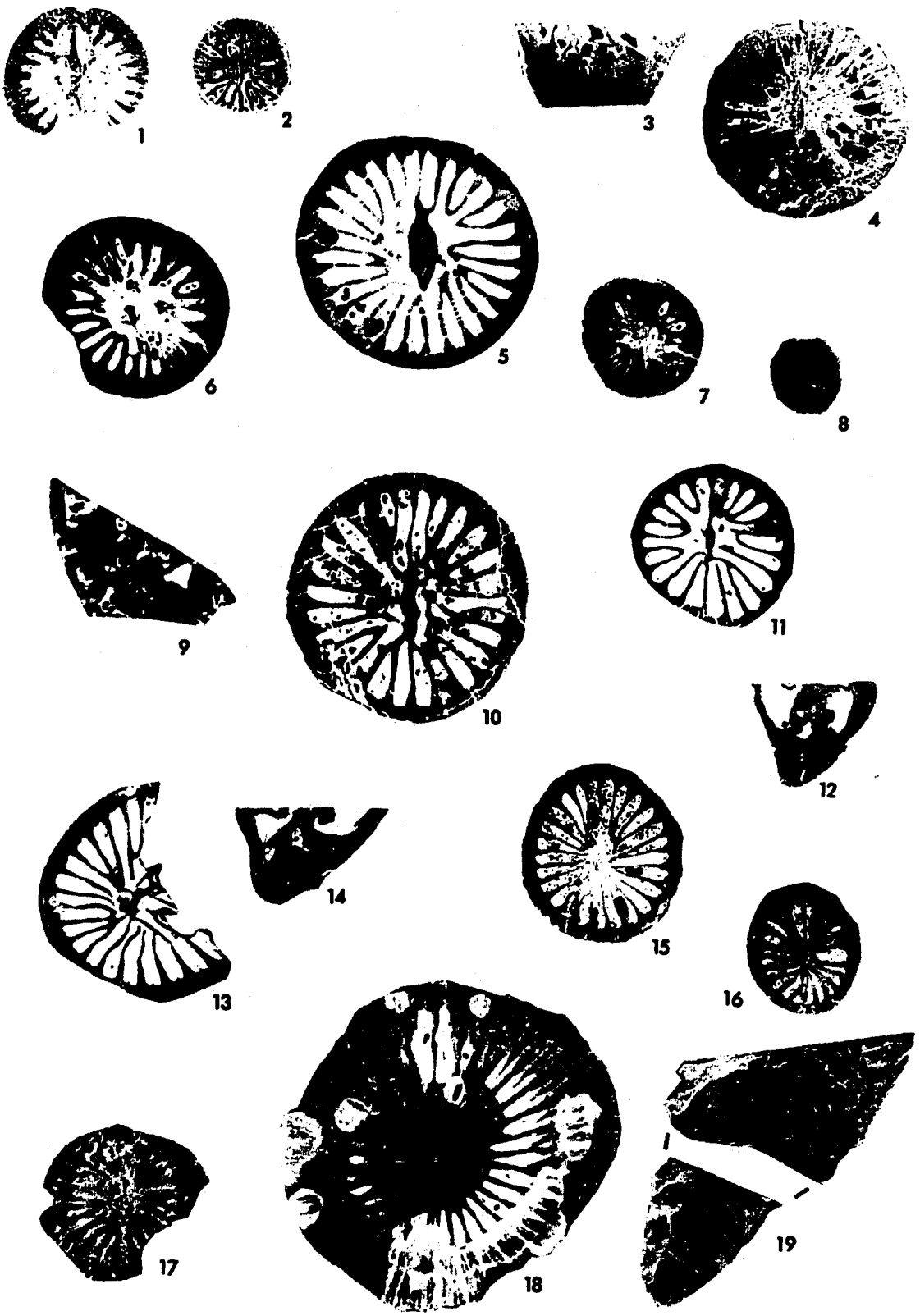

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PLATE 16

All figures are X3.5

Fig. 1-12, Rhegmaphyllum daytonensis (Foerste). Fig. 1, 2: transverse section (from just below calice floor) and longitudinal section of holotype of Cyathophyllum celator daytonensis Foerste (USNM 84796), from the Brassfield Formation at Dayton, Ohio. These sections are from the specimen shown on Plate 2, fig. 27. Note the carinae on the septa, visible in both sections. Fig. 3-11: series of nine transverse sections from a single specimen (UCGM 41964) from the Brassfield Formation at locality 50, near Colfax, Kentucky. The sections are progressively lower in the corallite, and all are right-side-up, and have the same radial orientation. Fig. 12: transverse section from a specimen (UCGM 41939) from the Brassfield Formation at locality 11, near West Union, Ohio. The section is from just below the calice floor. The whole specimen is shown on Plate 3, fig. 15-17.

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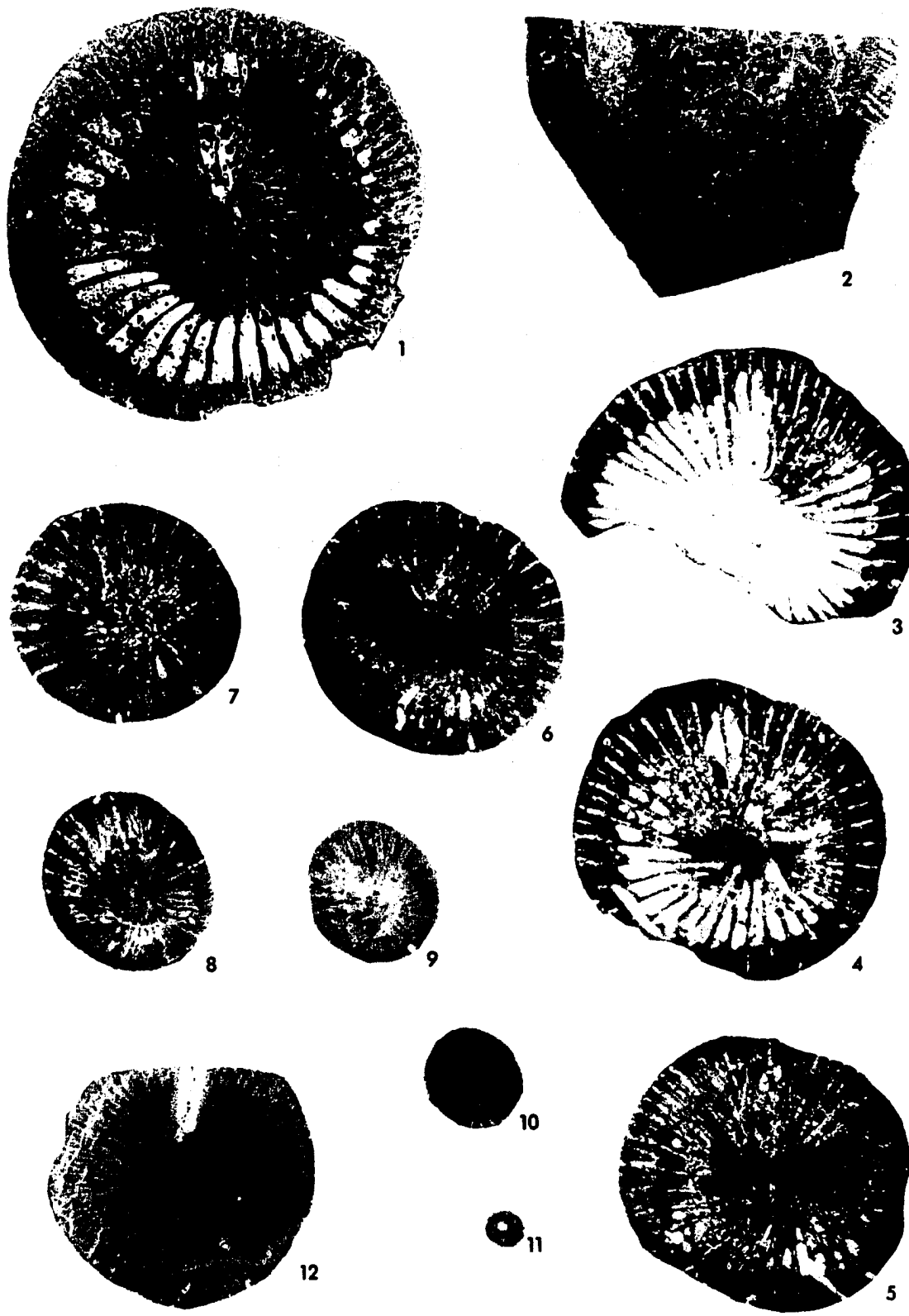

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PLATE 17

All figures are X3.5

Fig. 1, 2, Schlotheimophyllum benedicti (Greene), from the Brassfield Formation at locality 15, near West Milton, Ohio. These are (respectively) a longitudinal and a transverse section of the specimen shown on Plate 3, fig. 18-20. The dark segment of the cross-section (toward the top of the page) is the rejuvenescent side of the specimen, where the septocoels are filled with calcite spar (corresponding to the left side of the lower surface of fig. 1). The remaining 60% of the calice cross-section, which is whitish, is filled with sediment, and represents the lower surface of the right side of the longitudinal section. (UCGM 41700)

Fig. 3-5, Schlotheimophyllum benedicti (Greene), lectotype of Ptychophyllum benedicti Greene (AMNH 23505), the original of Greene's fig. 5. The specimen, shown on Plate 4, fig. 1-4, is from the Louisville Limestone near Louisville, Kentucky. Fig. 3, 5: transverse sections, mounted right-side-up, but with their mutual radial orientation uncertain, from respectively lower and higher portions of the corallite. Fig. 4: longitudinal section.

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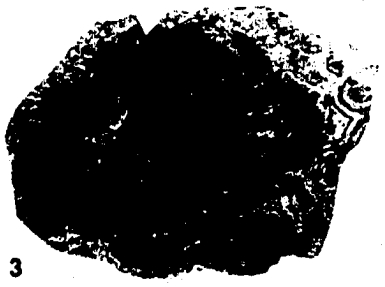
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PLATE 18

All figures are X3.5

Fig. 1-3, Paliphyllum primarium Soshkina, from the Brassfield Formation near West Union, Ohio. Fig. 1: longitudinal section, right-side-up, showing dissepimentarium and distal edges of the septa. Fig. 2, 3: transverse sections, right-side up and with the same radial orientation. Fig. 2 is from a lower portion of the corallite than fig. 3; (UCGM 41821).

Fig. 4-8, Protocyathactis cf. P. cybaeus Ivanovskiy, from the Noland Member, Brassfield Formation at locality 46, near College Hill, Kentucky. Fig. 4-6: series of transverse sections, from higher to lower in the corallite, all right-side-up, and with same radial orientation. Fig. 7: longitudinal section of corallite base, with the talon to the left. Fig. 8: longitudinal section from distal end (top) of corallite, taken at right angle to the plane of the section shown in fig. 7. The rejuvenescent portion is toward the left in fig. 8, where the calice was at the time of the coral's death. All sections are from the specimen shown on Plate 5, fig. 2-4. (UCGM 41956)

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PLATE 19

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Fig. 1, 4, 5, Paliphyllum cf. P. suecicum Neuman, from the Brassfield Formation at locality 7a, near Fairborn, Ohio. The specimen, UCGM 41970, was found loose, and probably came from the clay-coral bed described under "Brassfield Lithosome". Fig. 1, 5: transverse sections (respectively higher and lower), both right-side-up and with the same radial orientation. Note the pali in the axis of both sections. Fig. 4: longitudinal section, right-side-up. Fig. 1 comes from the upper surface, and fig. 5 from the lower surface of this section. Note the contratingent septa. Sections are from specimen shown on Plate 4, fig. 8, 9.

Fig. 2, 3, Paliphyllum cf. P. suecicum Neuman, from the same locality, and probably the same horizon as the above specimen. Fig. 2: transverse section, from just below the calice floor, probably right-side-up. Fig. 3: longitudinal section of same specimen, showing the gap from which the transverse section came. Note the medial lamella in the axis of the transverse section, as well as the contratingent septa; (UCGM 41974).

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PLATE 20

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Fig. 1, 2, Schlotheimophyllum patellatum (Schlotheim), from the Brassfield Formation at locality 7a, near Fairborn, Ohio; found loose above the hematitic horizon. Fig. 1: vertical section through axial area (to right) and one side of the calicular platform (to left). Note ropiness of axial structure. Fig. 2: vertical section of same specimen (UCGM 41971), crossing several septa. The whole specimen is shown on Plate 5, fig. 1.

Fig. 3-5, Paliphyllum regulare sp. nov., from same locality as the above specimen. Found in-place in the clay-coral layer described in "Brassfield Lithosome". Fig. 3: longitudinal section of entire corallite. Fig. 4, 5: transverse sections of same specimen, relative orientations uncertain. Fig. 4 is from the upper gap, and fig. 5 from the lower gap in fig. 3; (UCGM 41969).

Fig. 6-8, Cyathactis typus Soshkina, from the top of the Noland Member, Brassfield Formation at locality 1, near Panola, Kentucky. Fig. 6: longitudinal section, with the basal talon to the right. Fig. 7, 8: two transverse sections, both right-side-up and with the same radial orientation. Fig. 7 (from the top) shows

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the talon extension to the right. All sections are from the specimen shown on Plate 5, fig. 6, 7. (UCGM 41943)

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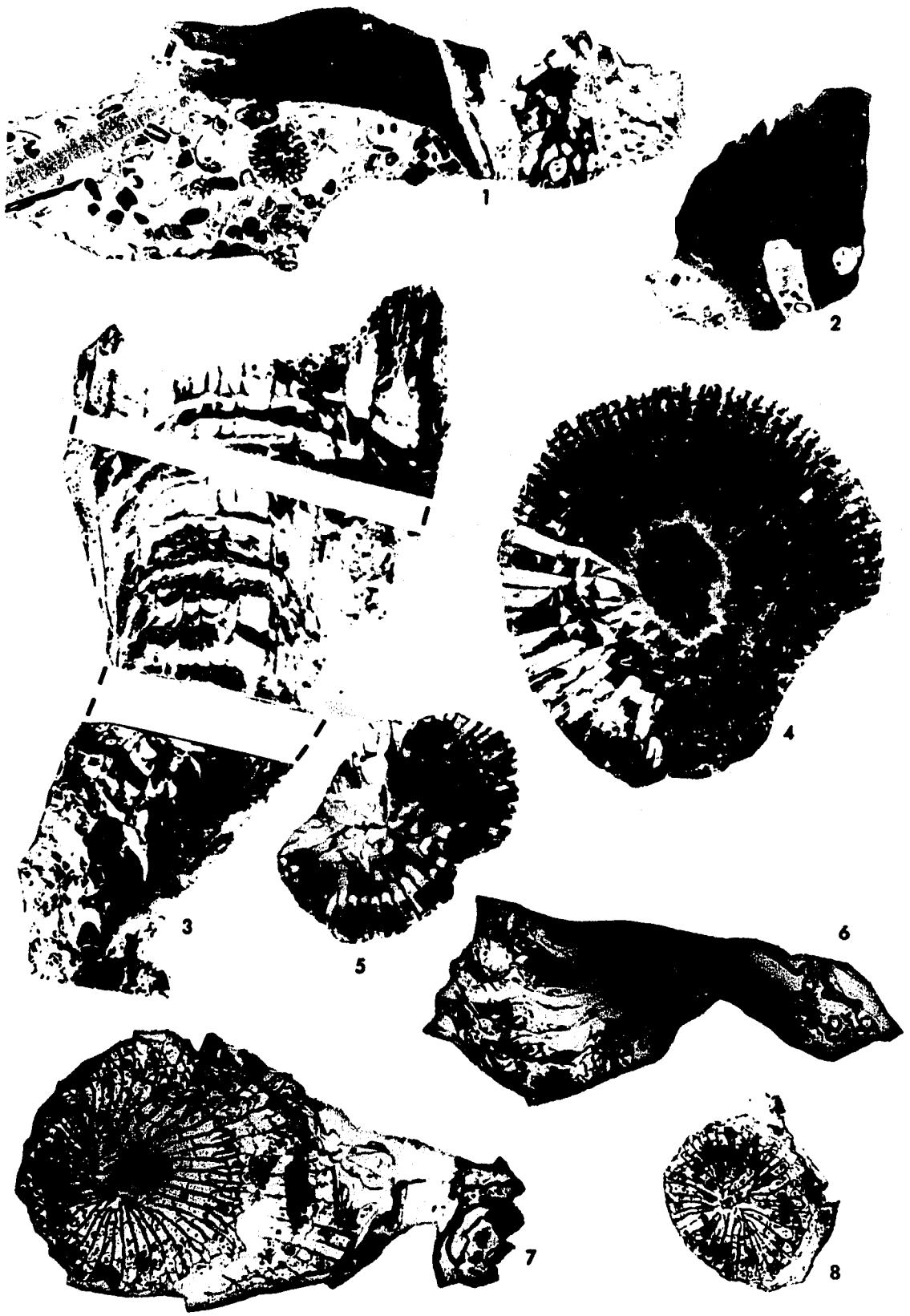

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PLATE 21

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Fig. 1-3, Cyathactis sedentarius (Foerste), USNM 87177, from the Noland Member, Brassfield Formation near Irvine, Kentucky (locality 53-53a of this work). It is one of several specimens, including the holotype, included under this specimen, and is shown on Plate 5, fig. 8, 10. Fig. 1, 2: transverse sections, respectively higher and lower in the corallite. Fig. 3: longitudinal section of same specimen. Fig. 1 was taken from the upper surface of this longitudinal section, and fig. 2 from the lower surface.

Fig. 4, 5, Tryplasma cylindrica (Wedekind), from the top of the Noland Member, Brassfield Formation at locality 1, near Panola, Kentucky. Fig. 4: longitudinal section. Fig. 5: portion of a transverse section; (UCGM 41947).

Fig. 6, 7, Tryplasma radicula (Rominger), from the same locality and horizon as the previous specimen. Fig. 6: transverse section. Fig. 7: longitudinal section, showing basal attachment structure. The specimen is shown on Plate 6, fig. 2-4. (UCGM 41951)

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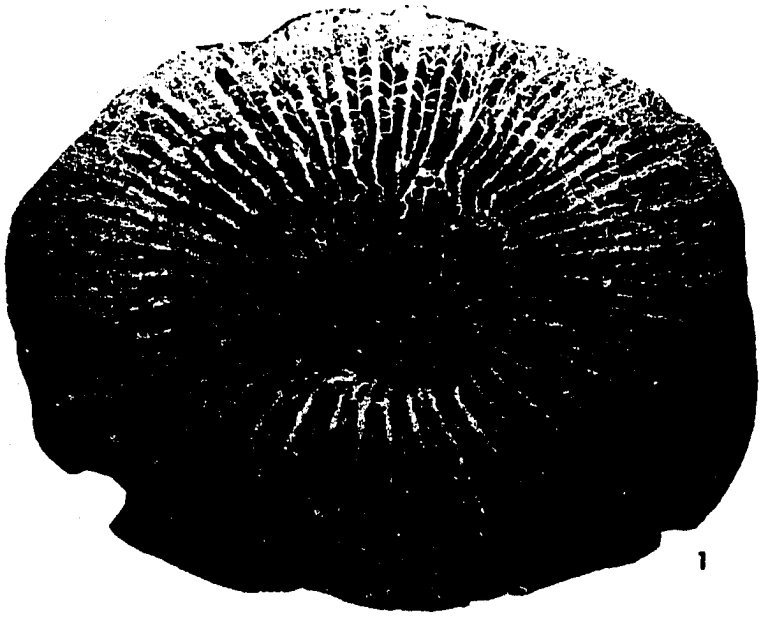
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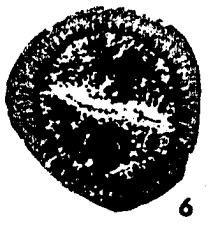
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PLATE 22

All figures are X3.5

Fig. 1-7, Calostylis lindstroemi Nicholson & Etheridge, from the top of the Noland Member, Brassfield Formation, at locality 1, near Panola, Kentucky. Fig. 1, 2: longitudinal and transverse sections from UCGM 41941 . Fig. 3-7: five of seven transverse sections taken approximately equidistantly from a corallite about 3.8 cm long. The sections are from progressively lower levels in the corallite, and the second and third lowest (which would be between fig. 7 and 6) are missing. The sections are all right-side-up, and have the same radial orientation; (UCGM 41995).

Fig. 8-10, Calostylis spongiosa Foerste, from the same locality and horizon as the specimens of fig. 1-7. Fig. 8 and 9 ate transverse sections, and fig. 10 is a longitudinal section from UCGM 41954 , the specimen shown on Plate 6, fig. 6-9. Fig. 8 is from immediately below the calice floor, from the upper surface of the transverse section, while fig. 9 is from the lower cut surface. Both transverse sections are right-side-up, and have the same radial orientation. In the longitudinal section, the convex side of the corallite is toward the left, in the transverse sections, it is toward the top of the page. Note cardinal fossula (fig. 8).

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Fig. 11-14, Petrozium pelagicum (Billings), found in-place in the Brassfield Formation at locality 15, near West Milton, Ohio, in a clay pocket just below the upper contact. Fig. 11-13: series of transverse sections from progressively lower in the corallite, relative orientations uncertain. Fig. 14: longitudinal section of same corallite; (UCGM 41763).

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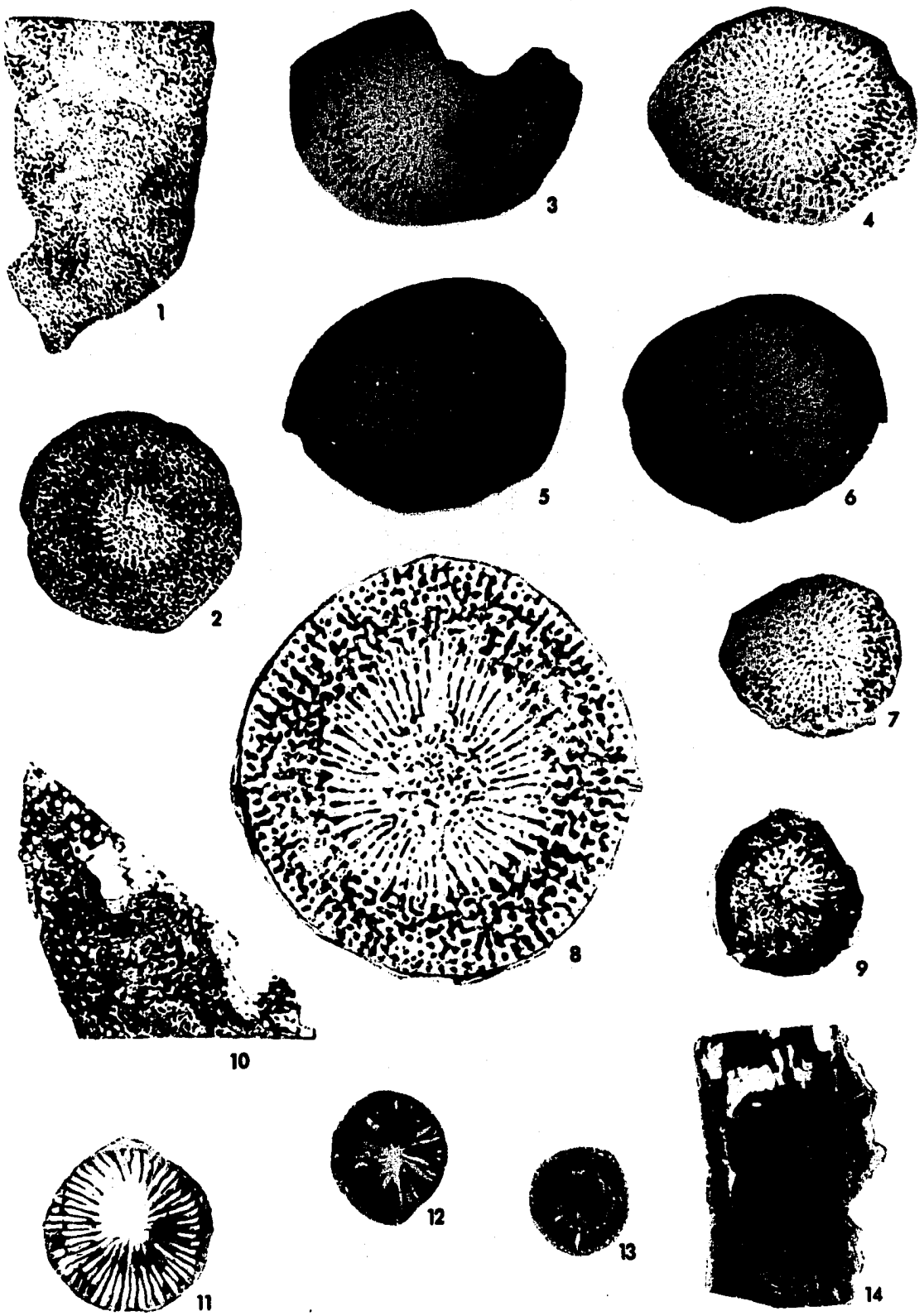

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PLATE 23

All figures are X3.5

Fig. 1, 2, Strombodes socialis (Soshkina), from the Brassfield Formation at locality 7, near Fairborn, Ohio. Found in-place near the top of this unit. Fig. 1 is a longitudinal, and fig. 2 a transverse section from a single corallite of the specimen shown on Plate 7, fig. 1. The transverse section is right-side-up, and comes from the upper surface shown in fig. 1. (UCGM 41921)

Fig. 3, 4, Strombodes socialis (Soshkina) from the Brassfield Formation at locality 7a, near Fairborn, Ohio. Fig. 3: longitudinal section of several corallites. Fig. 4: transverse section of several corallites. Note thecal layer between contiguous corallites; (UCGM 41925).

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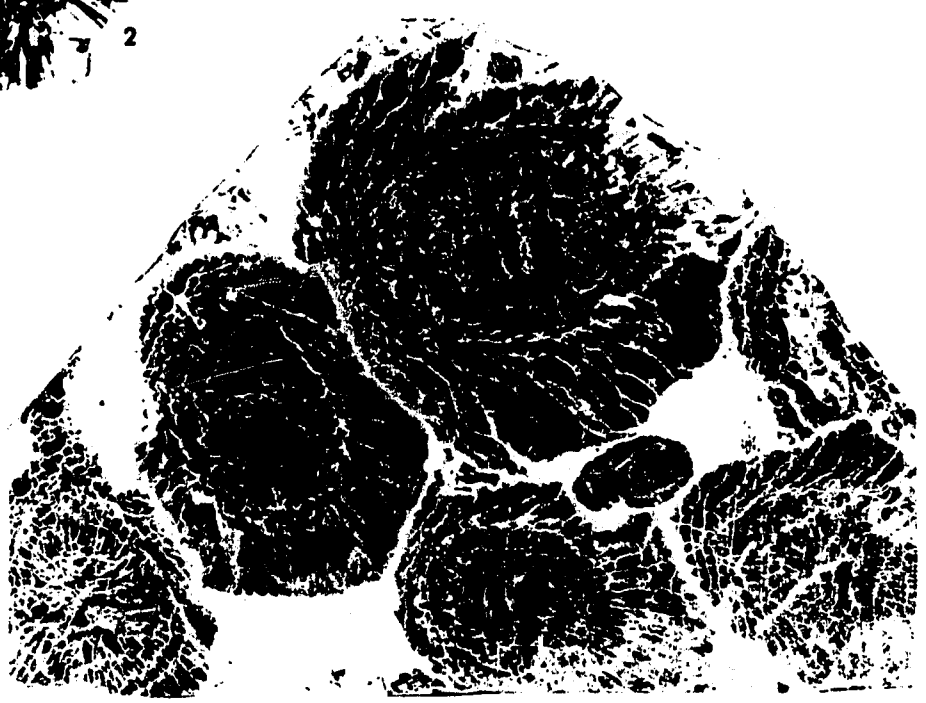

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PLATE 24

All figures are X3.5

Fig. 1, 2, Alveolites labrosus Milne-Edwards & Haime, from the top of the Noland Member, Brassfield Formation at locality 1, near Panola, Kentucky. Fig. 1: transverse section (parallel to upper surface of corallum). Fig. 2: vertical section. (UCGM 41950).

Fig. 3-5, Striatopora flexuosa Hall. Fig. 3, 4: longitudinal and transverse sections (respectively) of a specimen (UCGM 41962) from the Brassfield Formation at locality 37, near Sharpsville, Ohio. This is the specimen shown on Plate 11, fig. 3. Fig. 5: longitudinal section of a second specimen (UCGM 41965) from a clay layer at the top of the Brassfield Formation at locality 55, near Ludlow Falls, Ohio.

Fig. 6, 7, Strombodes socialis (Soshkina). This specimen is from the top of the Fiborn Limestone Member of the Hendricks Dolomite (Middle Silurian), three miles north of Hunts Spur, Mackinac County, Michigan (UMMP 61690). Compare the transverse (fig. 6) and longitudinal (fig. 7) sections shown here with those of Brassfield specimens of this species on Plate 23.

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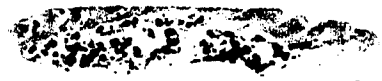

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PLATE 25

All figures are X3.5

Fig. 1, 3, Arachnophyllum mamillare (Owen), holotype of A. mamillare-distans Foerste (USNM 113639), from the specimen shown on Plate 7, fig. 2). Both fig. 1 (a vertical section) and fig. 3 (a transverse section) include more than one corallite.

Fig. 2, 4, Petrozium pelagicum (Billings), lectotype of Cyathophyllum pelagicum Billings (GSC 2351a) from the Becscie Formation (Lower Silurian) at Becscie River Bay, Anticosti Island, shown in transverse (fig. 2) and longitudinal (fig. 4) section.

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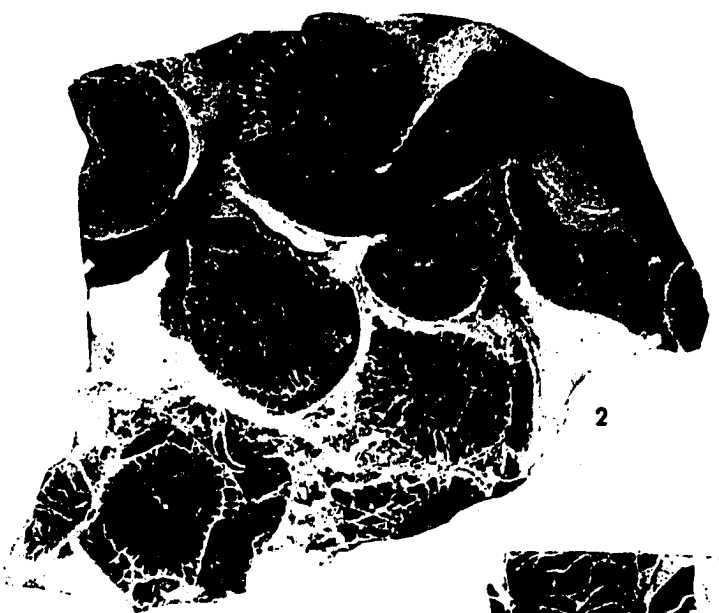

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PLATE 26

All figures are X3.5

Fig. 1-8, Pycnactis tenuiseptatus sp. nov., holotype of the species, UCGM 41963, from the specimen shown on Plate 7, fig. 4, 5. Fig. 1, 2: mirror-image longitudinal sections of the specimen. Note carinae on sides of the septa. Fig. 3-8: series of transverse sections, roughly equidistant, and progressively lower in the corallite. All are right-side-up, and have the same radial orientation.

Fig. 9-14, Schizophaulactis densiseptatus (Foerste). Fig. 9-13: neotype of the species (UCGM 41944), sections from the specimen shown on Plate 8, fig. 3. Fig. 9: longitudinal section, with convex side of corallite to the left. Note the dissepimentarium and the complicated tabularium. Fig. 10-13: series of transverse sections, progressively lower in the corallite. All are right-side-up, and have the same radial orientation. The convex side of the corallite is toward the top of the page. Fig. 14: transverse section of another specimen, from the Waco bed, Noland Member of the Brassfield Formation, from U.S. Geol. Surv. locality 7450-SD, 16,150 feet south and 17,250 feet west of

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of the northeast corner of the Palmer Quadrangle, Estill County, Kentucky. Collected in 1965 by George C. Simmons. Specimen uncatalogued, designated by its field locality number as 7450c in the U.S. Geol. Surv. collection.

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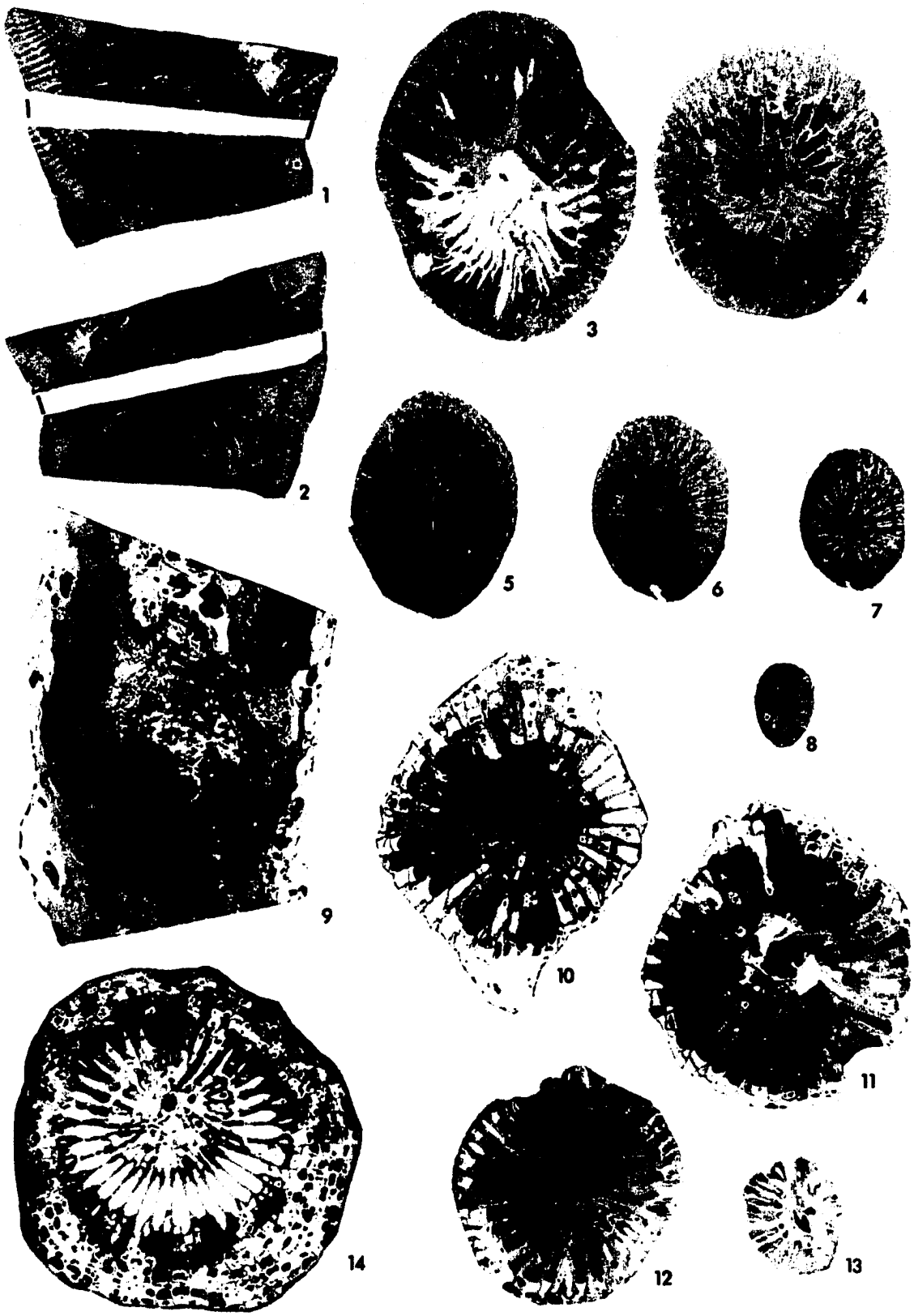

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PLATE 27

All figures are X3.5

Fig. 1, 2, Favosites favosus (Goldfuss). Transverse (fig. 1) and vertical (fig. 2) sections of the holotype of Calamopora favosa Goldfuss, which is shown on Plate 8, fig. 4-6, 9.

Fig. 3, 4, Favosites favosus (Goldfuss) from the Noland Member, Brassfield Formation at locality 46, near College Hill, Kentucky. Fig. 3: transverse section. Fig. 4: vertical section. (UCGM 41957). The small size of the corallites may preclude this specimen from Goldfuss' species. The good agreement in all other features, however, suggests that it may be ancestral to, or a subspecies of F. favosus sensu stricto.

Fig. 5, 6, Favosites hisingeri Milne-Edwards & Haime. Vertical (fig. 5) and transverse (fig. 6) sections of the holotype of F. hisingeri-aplata Foerste, which is shown on Plate 8, fig. 8.

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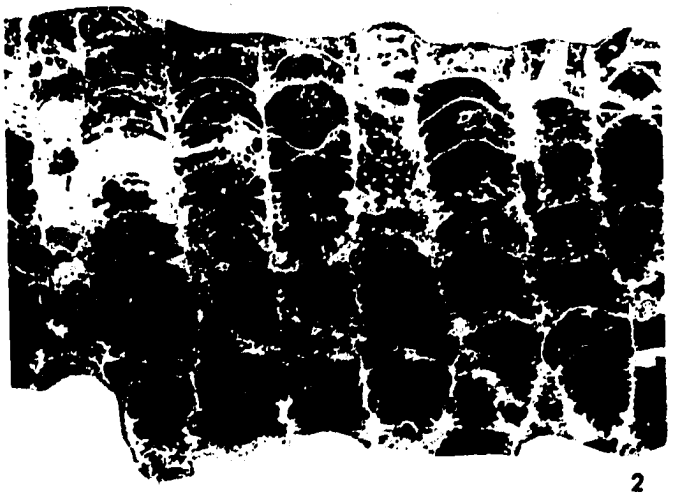

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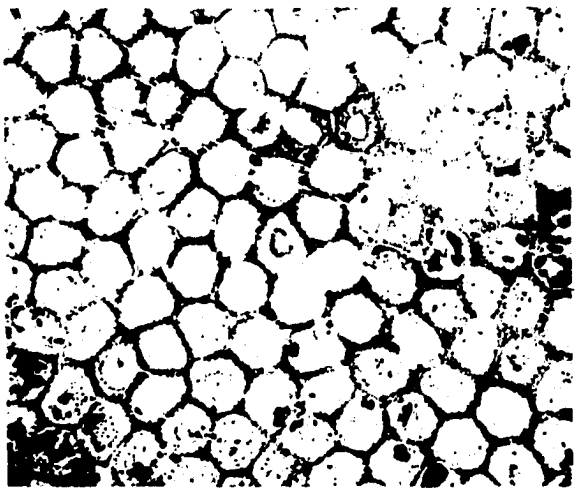

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PLATE 28

All figures are X3.5

Fig. 1, 2, Favosites hisingeri Milne-Edwards & Haime, from the clay bed at the top of the Brassfield Formation at locality 55, near Ludlow Falls, Ohio. Fig. 1: transverse section. Fig. 2: vertical section. The radial features seen in some corallites in fig. 1 are long septal spines; (UCGM 41966).

Fig. 3, 4, Favosites forbesi Milne-Edwards & Haime. Transverse (fig. 3) and vertical (fig. 4) sections of a new subspecies, F. forbesi aspinosus, from the Brassfield Formation at locality 11, near West Union, Ohio. (UCGM 41828)

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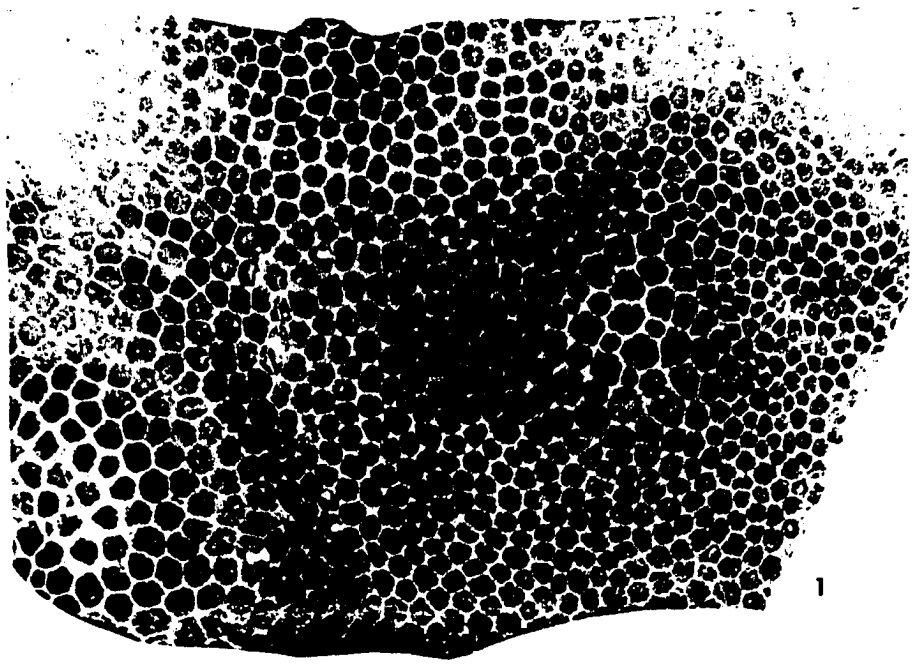

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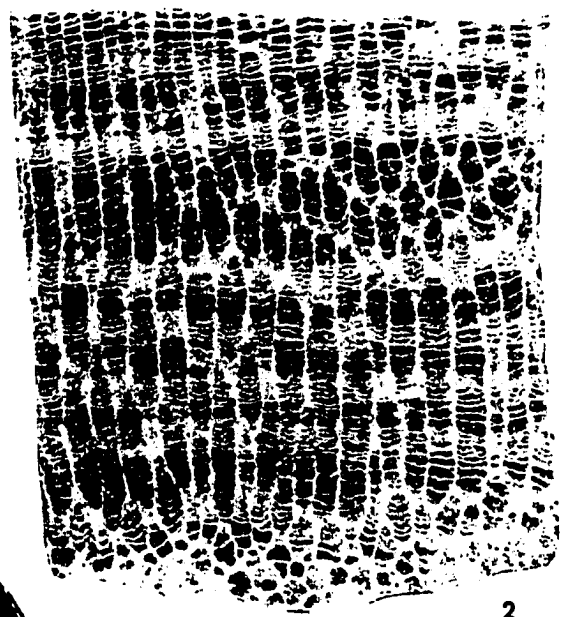

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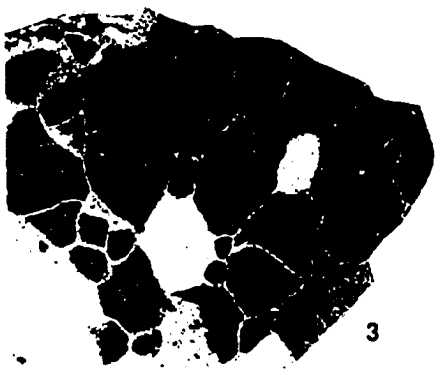

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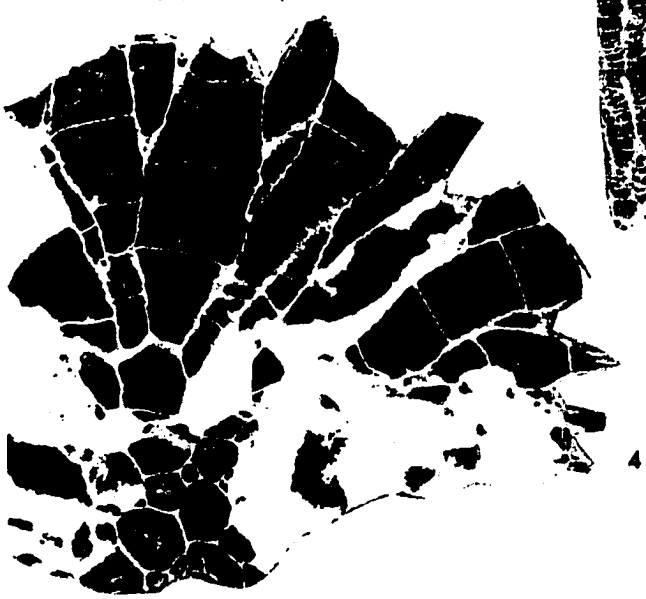

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PLATE 29

All figures are X3.5

Fig. 1, 2, Favosites hisingeri Milne-Edwards & Haime, lectotype of Astrocerium venustum Hall (AMNH 1470/2), from Lockport, N.Y., probably the Lockport Formation. Fig. 1: vertical section. Fig. 2: transverse section.

Fig. 3, 4, Halysites catenularius (Linnaeus). Lectotype of Tubipora catenularia Linnaeus, no. G681 in the collection of the Paleontological Institute at Uppsala, Sweden. This is no. 1 of the Bromell Collection at the Institute. Fig. 3: transverse section. Fig. 4: longitudinal section.

Fig. 5, 6, Paleofavosites prolificus (Billings), from the Brassfield Formation at locality 7a, near Fairborn, Ohio. Fig. 5, transverse section. Fig. 6: vertical section. (UCGM 41976). Note mural pores in corners of the corallites, espceially in fig. 6., shown in greater detail on Plate 36, fig. 3.

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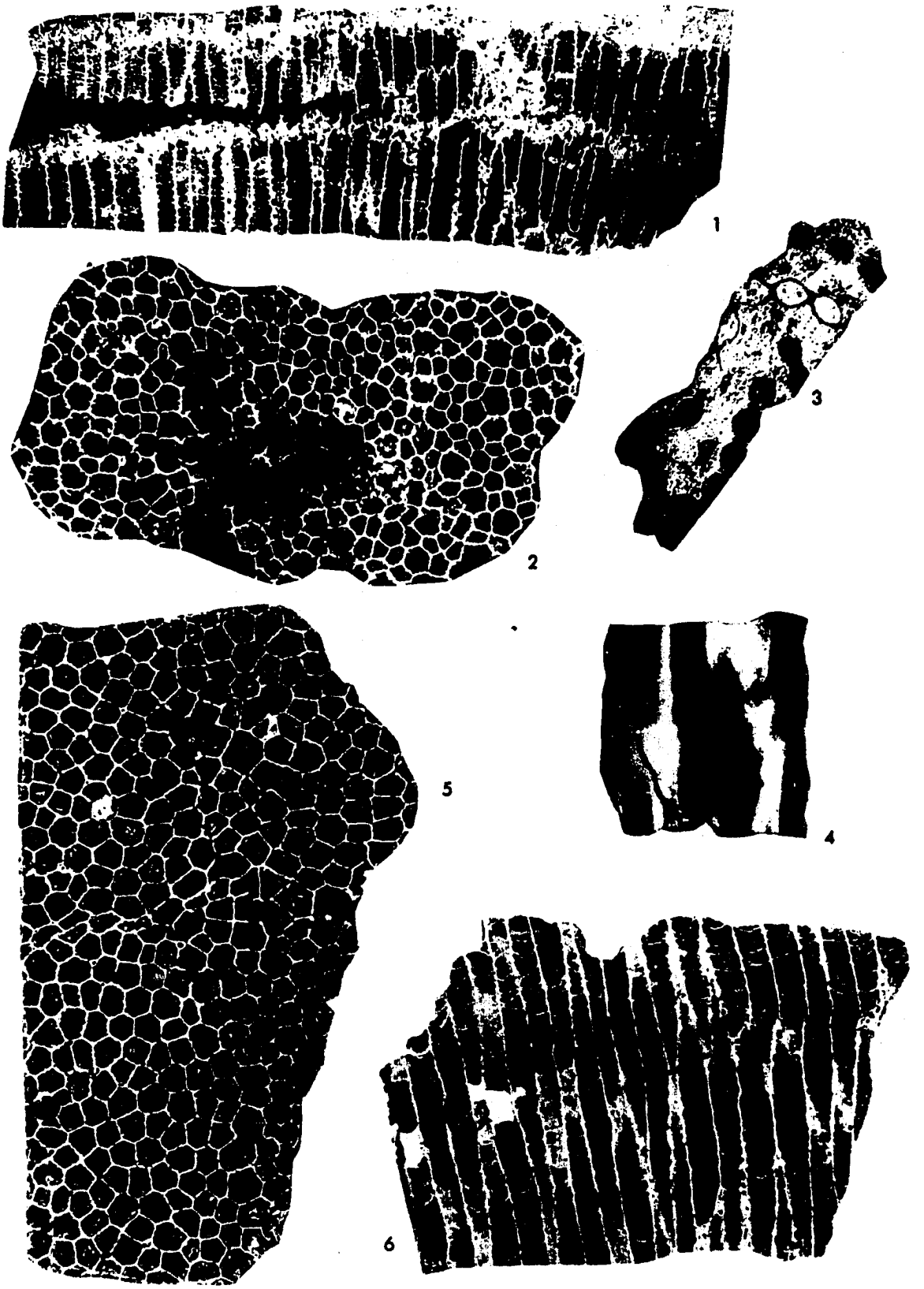

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PLATE 30

All figures are X3.5

Fig. 1, 2, Favosites densitabulatus sp. nov., holotype of the species, (UCGM 41945), from the top of the Noland Member, Brassfield Formation at locality 1, near Panola, Kentucky. Fig. 1: transverse section. Fig. 2: vertical section. Note close-spacing of the tabulae, in proportion to the corallite diameter.

Fig. 3, 4, Favosites sp. A, from the Noland Member, Brassfield Formation at locality 46, near College Hill, Kentucky. Fig. 3: transverse section. Fig. 4: vertical section; (UCGM 41958)

Fig. 5, 6, Heliolites spongiosus Foerste, holotype of the species. Specimen is shown on Plate 11, fig. 5, 6. These are a transverse (fig. 5) and vertical (fig. 6) section of the holotype. (USNM 84892)

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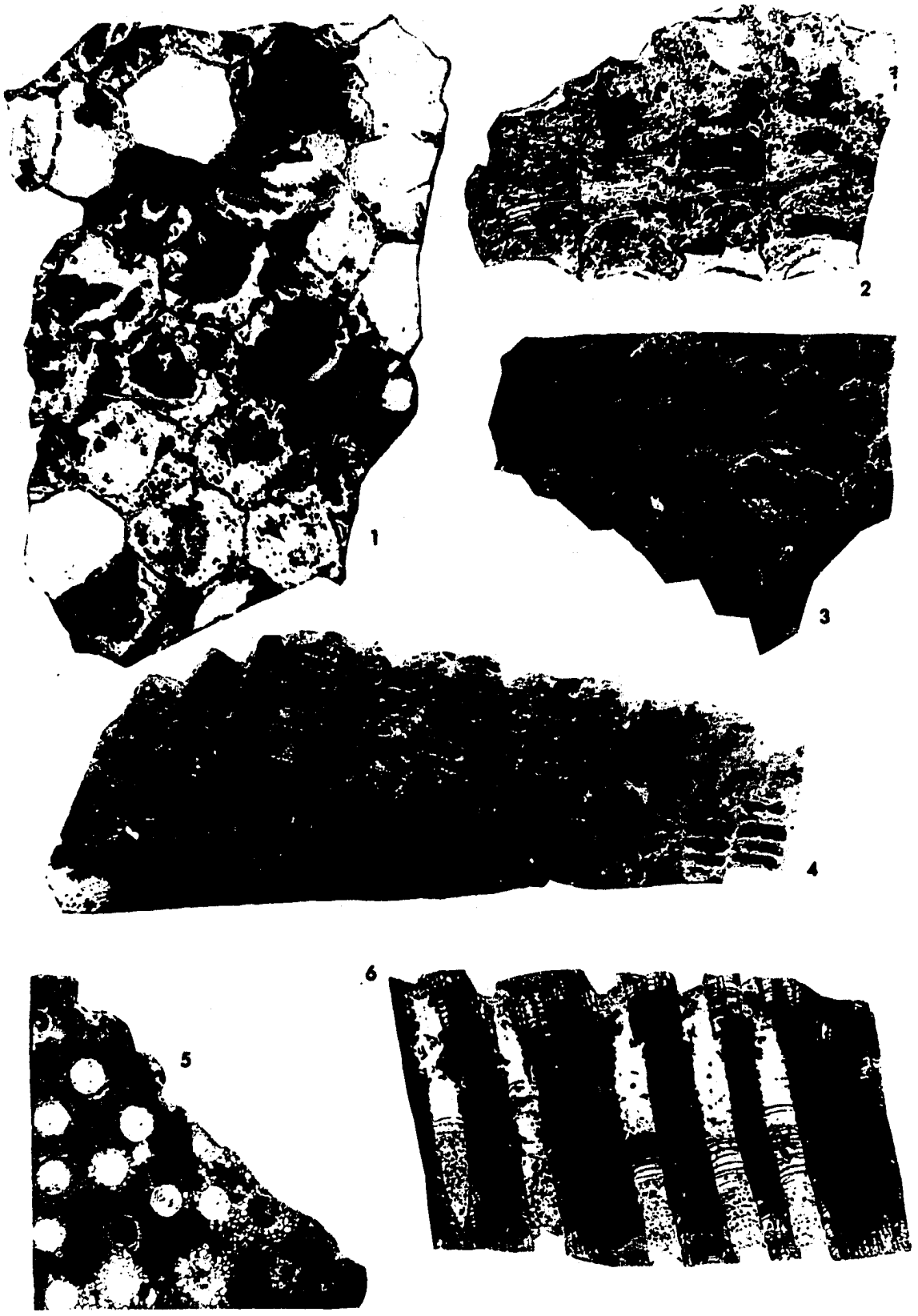

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PLATE 31

All figures are X3.5

Fig. 1, 2, *Syringolites sp. A, sp. nov.*, a vertical (fig. 1) and transverse (fig. 2) section of the specimen shown on Plate 10, fig. 5, illustrated by Foerste as *S. huronensis* Hinde. (USNM 84893)

Fig. 3, 4, *Halysites nitidus* Lambe, from the Brassfield Formation (in-place, about 2/5 the way up from its lower contact) at locality 14, near Piqua, Ohio. Fig. 3: vertical section. Fig. 4: transverse section. Note the well-developed, upward-projecting spines, and the interstitial tubes. See Plate 38, fig. 1 for a more detailed view; (UCGM 41651).

Fig. 5, 6, *Alveolites labechii* Milne-Edwards & Haime, from the clay bed at the top of the Brassfield Formation at locality 55, near Ludlow Falls, Ohio. Fig. 5: transverse section. Fig. 6: vertical section; (UCGM 41967).

Fig. 7, *Cladochonus sp. C*, from near the top of the Brassfield Formation at locality 15, near West Milton, Ohio. This is a section of the specimen shown on Plate 9, fig. 9, 10 (UCGM 41692).

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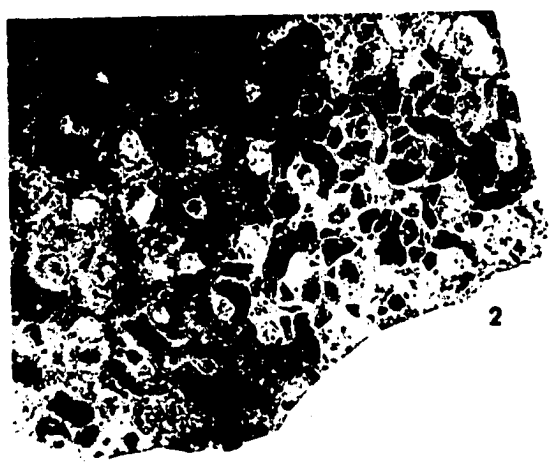
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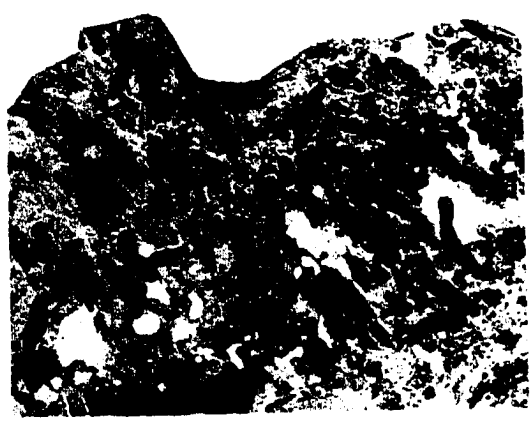
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PLATE 32

All figures are X3.5

Fig. 1, Halysites(?) cf. H. meandrinus (Troost), a transverse section of a specimen from the Noland Member, Brassfield Formation at locality 53a, near Irvine, Kentucky; (UCGM 41961).

Fig. 2, 3, Halysites catenularius (Linnaeus), from the Brassfield Formation at locality 14, near Piqua, Ohio. Specimen found in a talus block. Fig. 2: transverse section. Fig. 3: longitudinal section; (UCGM 41650). Compare these figures with the type of the species, on Plate 29, fig. 3, 4.

Fig. 4, Syringopora reteformis Billings, from near the top of the Brassfield Formation at locality 11, near West Union, Ohio. This is a section of the specimen shown on Plate 11, fig. 1, 2. Note the abundance of spines, and the apparent absence of infundibuliform tabulae. (UCGM 41813) Specimen found not-in-place.

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PLATE 33

All figures are X3.5

Fig. 1, 2, Catenipora gotlandica (Yabe), from the clay-coral bed (described in "Brassfield Lithosome") in the Brassfield Formation at locality 7a, near Fairborn, Ohio. Fig. 1: a longitudinal section. Fig. 2: a transverse section (note spines). These sections are from the specimen shown on Plate 9, fig. 8.

Fig. 3, 4, Catenipora favositomima sp. nov., from the Brassfield Formation (probably near the top) at locality 7, near Fairborn, Ohio. Fig. 3: longitudinal section (note striation of the interior). Fig. 4: transverse section; (UCGM 41908). Holotype of the species.

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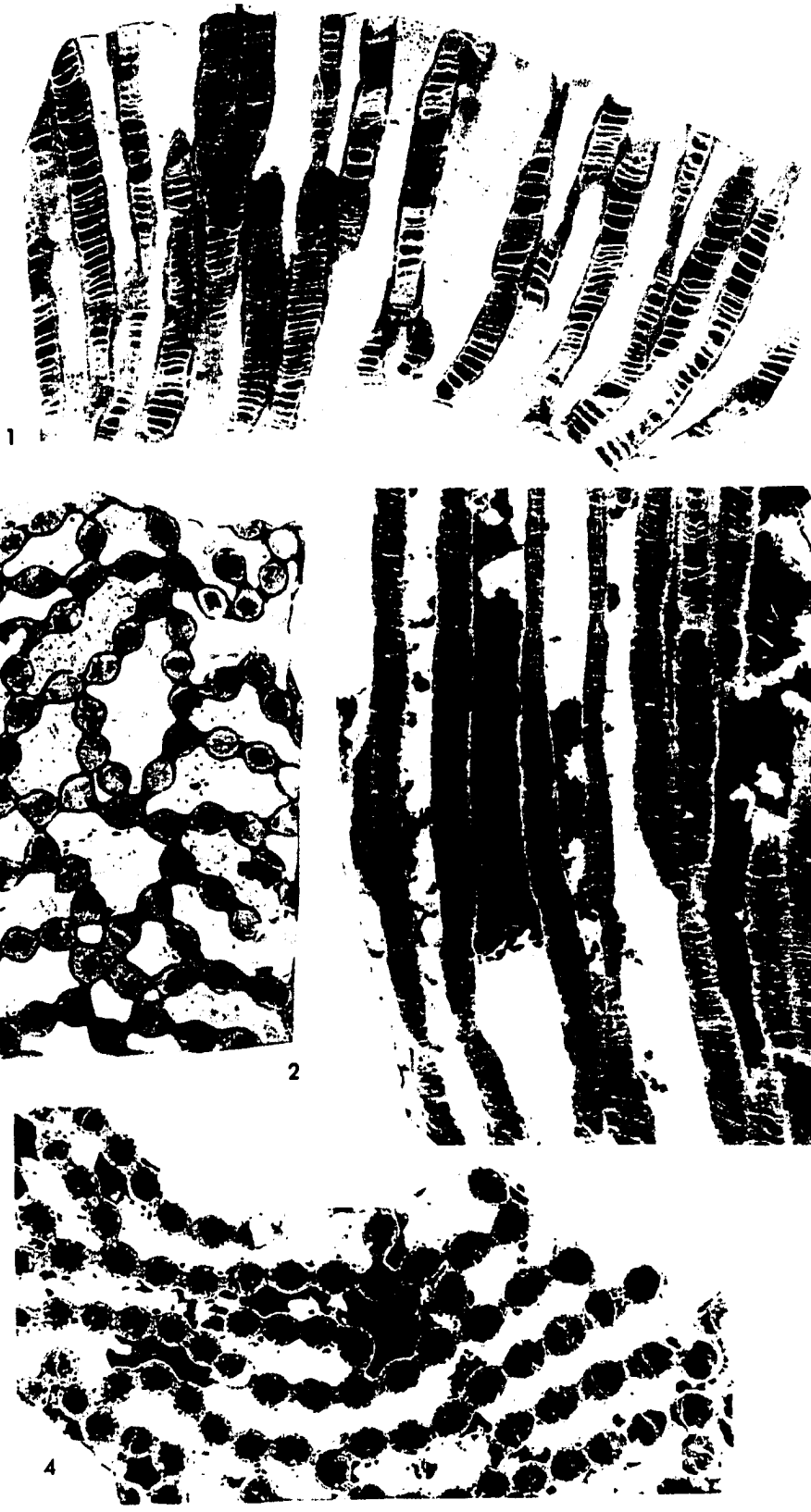

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PLATE 34

All figures are X3.5

Fig. 1, 3, Propora exigua (Billings), from the Brassfield Formation at locality 26, Elkhorn Falls, near Richmond, Indiana. Fig. 1: vertical section of specimen lying in pelmatozoan debris. The figure is oriented so that the corallum is right-side-up biologically. In actuality, it lay upside-down as preserved in the rock. Fig. 3: transverse section of same specimen; (UCGM 41765).

Fig. 2, 4, Propora conferta Milne-Edwards & Haime, from the Brassfield Formation at locality 13, Todd Fork Creek near Wilmington, Ohio. Fig. 2: transverse section. Fig. 4: vertical section, right-side-up. Note the twelve longitudinal "septal" ridges within the corallites; (UCGM 41851).

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PLATE 35

All figures are X3.5

Fig. 1, 2, Palaeoporites sp., from the Brassfield Formation at locality 11, near West Union, Ohio. Fig. 1: vertical section; fig. 2: transverse section; (UCGM 41932)

Fig. 3, 4, Plasmopora lambii Schuchert, vertical (fig. 3) and transverse (fig. 4) sections of a syntype (USNM 28140b) from the Trenton beds of Baffin Land, Arctic Canada. This specimen is figured to show the similarities and differences between it and Propora conferta (previous plate). See text discussion of P. conferta for details.

Fig. 5, 6, Heliolites spongodes Lindström, from the top of the Noland Member, Brassfield Formation at locality 1, near Panola, Kentucky. Fig. 5: transverse section (note up-turned spines in corallite axes, appearing as dots in the plane-of-section). Fig. 6: vertical section; (UCGM 41936).

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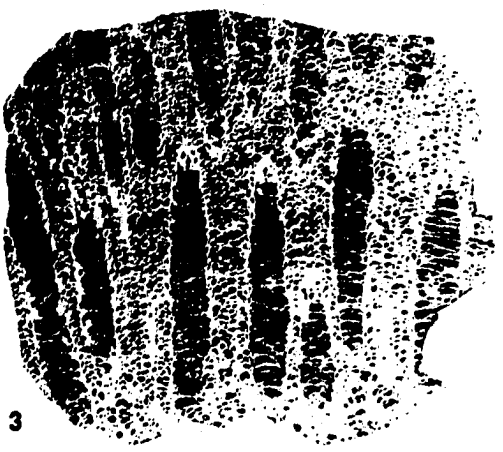

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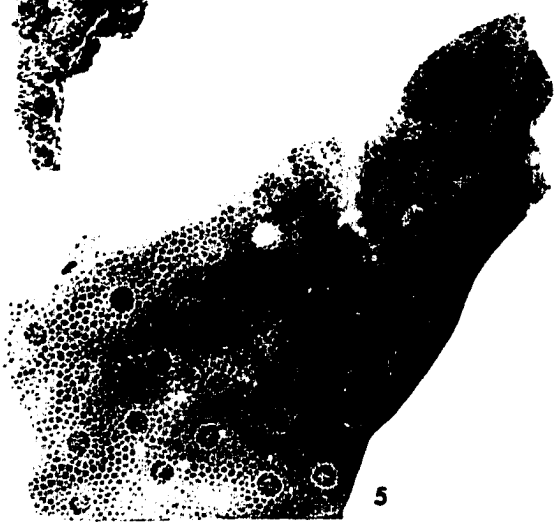

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PLATE 36

All figures are approx. X30

Fig. 1, 3, Paleofavosites prolificus (Billings), two specimens from the Brassfield Formation at locality 7a, near Fairborn, Ohio. Fig. 1: transverse section of UCGM 41972 , showing details of wall structures, and position of mural pores in the corners. Fig. 3: detail of Plate 29, fig. 6, a vertical section showing spacing of mural pores and tabulae.

Fig. 2, Striatopora flexuosa Hall, detail of Plate 24, fig. 4, a transverse section.

Fig. 4, Favosites hisingeri Milne-Edwards & Haime, detail of a transverse section of UCGM 41940 , from near the top of the Brassfield Formation at locality 15, near West Milton, Ohio. Note the long, abundant spines.

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PLATE 37

All figures are approximately X30

Fig. 1, 4, Heliolites spongodes Lindström. Fig. 1: vertical section; fig. 4: transverse section. These are details, respectively, of Plate 35, fig. 6, and Plate 35, fig. 5. Note the spines up-turned in the corallite axis.

Fig. 2, Catenipora favositomima sp. nov., transverse section, a detail of Plate 33, fig. 4. Note the structure of the inter-corallite region.

Fig. 3, Palaeoporites sp., transverse section, a detail of Plate 35, fig. 2.

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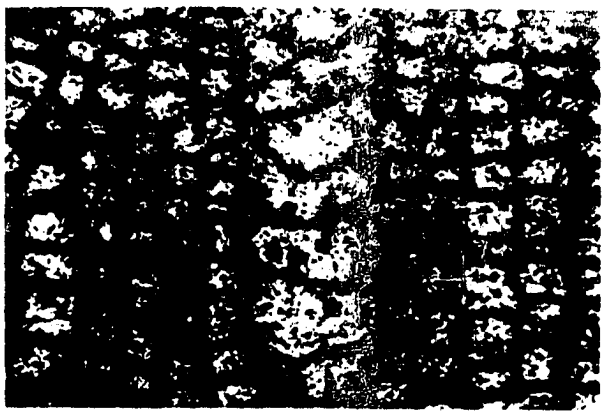

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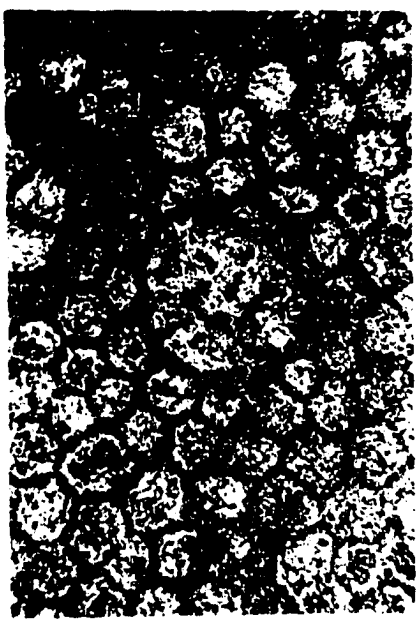

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PLATE 38

All figures are approx. X30

Fig. 1, Halysites nitidus Lambe, longitudinal section, detail of Plate 31, fig. 3. Note the upward-projecting spines, and their longitudinal alignment.

Fig. 2, Halysites catenularius (Linnaeus), transverse section, detail of Plate 29, fig. 3, the type.

Fig. 3, Alveolites labechii Milne-Edwards & Haime, transverse section, detail of Plate 31, fig. 5.

Fig. 4, Syringopora reteformis Billings, longitudinal section of a single corallite, detail of Plate 32, fig. 4.

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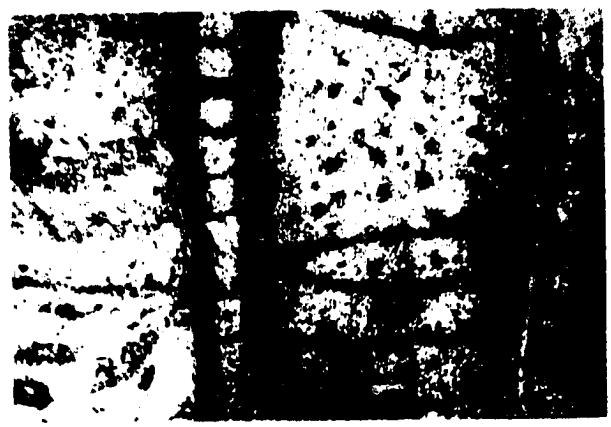

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PLATE 39

All figures are approx. X30

Fig. 1, Favosites sp. A, transverse section, detail of Plate 30, fig. 3. Note the splitting of the dark mid-line of the wall at the juncture of three corallites near the middle of the figure.

Fig. 2, Catenipora gotlandica (Yabe), transverse section, detail of Plate 33, fig. 2, showing the spines.

Fig. 3, 4, Favosites favosus (Goldfuss), details of Plate 27, fig. 1 and fig. 2 respectively (transverse and vertical sections), the holotype of Calamopora favosa Goldfuss. In fig. 4, the vertical section, the spines occur both on the corallite wall (along the right side of the figure) and the tabula surface (along the lower edge of the figure). Silicification has disrupted much of the structure.

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