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ORDOVICIAN STROMATOPOROIDEA OF NORTH AMERICA

by

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Indiana University

and

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University of North Carolina

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CONTENTS

ORDOVICIAN STROMATOPOROIDEA OF NORTH AMERICA

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ABSTRACT

Ten genera and 37 species of North American Ordovician stromatoporoids, all in the family Labechiidae, are described and figured, including 10 new species.

INTRODUCTION

The late Dr. W. A. Parks made an attempt in 1910 to clarify the knowledge of Ordovician stromatoporoids, in which he described or redescribed 19 species and varieties, but still it was difficult to identify any species. In the past half century, several new forms have been added and some clarifications of the structure have been made. There are only about 77 species of Ordovician stromatoporoids known; 50 occur in North America, of which we have restudied, described, and figured 37 of the most important species, mostly from authentic specimens. This paper is a further attempt to clarify the structure, classification, nomenclature, and stratigraphic ranges of Ordovician forms; we have restudied specimens of every species we could obtain. As noted by Parks (1910, p. [295]), many Ordovician forms are in a "very bad state of preservation"; additional specimens, some well preserved, have served to make Ordovician stromatoporoids better but not completely known.

Ordovician stromatoporoids have been known since 1843, when Dr. John T. Plummer of Richmond, Indiana, discovered and named *Aulacera* from the latest Ordovician, a few miles south of Richmond. The next discovery was that by James Hall, 1847, who named *Stromatocerium rugosum* from the Black River of western New York and from Isle La Motte, Vermont. The Ordovician forms were first included in the hydrozoan order Stromatoporoidea by Nicholson, 1886. Some 11 valid genera of Ordovician stromatoporoids have been erected and about 77 valid species have been named, and 5 generic synonyms made. Ordovician stromatoporoids are now known from North America, including Baffin Island, Quebec,

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Anticosti, Ontario, Manitoba, Vermont, New York, Pennsylvania, Virginia, Alabama, Indiana, Ohio, Kentucky, Missouri, Tennessee, New Mexico, Colorado, Wyoming, Nevada, and Alaska. They have been described from the Ordovician of China, Manchuria, Korea (not from Japan), Siberia, the Urals, and the Baltic area. In the regions mentioned the Ordovician stromatoporoids are isolated or occur in great layers or biostromes. In a few places, as in Vermont and New York, they made reefs or bioherms.

Ordovician stromatoporoids occur in three kinds of coenostea: (1) thin flattish layers or parasitic, *Dermatostroma;* (2) in hemispherical masses, *Cystostroma, Rosenella, Pseudostylodictyon, Labechia, Pseudolabechia, Stromatocerium,* and *Labechiella;* or as (3) vertically erected cylindrical or branching forms, *Cryptophragmus, Aulacera,* and *Sinodictyon.* Most forms in life were attached to some substratum, frequently to other stromatoporoids. They are found attached to broken and overturned pieces of the same species, as *Labechia huronensis* from Indiana, indicating that they lived in shallow water where they were beaten by the waves. They, like other stromatoporoids, are made up of layers a few millimeters in thickness, as were the algae, corals, and bryozoans with which they occur, suggesting that the latilaminae are annual or seasonal growth layers, hence there were changes of seasons in the Ordovician.

Ordovician stromatoporoids are as well preserved as are any other fossils. They have been infiltrated with calcium carbonate and generally the original structures are as well preserved as are those of corals and Bryozoa with which they occur. Weathered specimens, such as *Labechia pustulosa* (Safford), are leached and partly dolomitized and the minute structure has been largely destroyed, preserving only the latilaminae and the mamelons. In other cases specimens weathered out have been silicified and the structure almost entirely destroyed, as is true of *Aulacera* from the late Ordovician of Manitoba. Some specimens of *Aulacera* from the Bernheim Forest of Kentucky, have been replaced by calcite or iron oxide inside, and the outside covered by *Dermatostroma,* simulating or preserving the surface characters of the *Aulacera.*

The oldest stromatoporoids known are those from the Middle Ordovician of Vermont and New York. We think the objects described by Yavorsky (Centralbl. Min., Geol. Paleo., 1932, Abt. B, p. 613) are not Cambrian in age; the first belongs to the Mesozoic genus *Actinostromaria,* and the second one has all the characteristics of the Devonian stromatoporoid *Anostylostroma.* The most primitive stromatoporoid known to us from the middle Chazyan from Isle La Motte, Vermont, has a skeleton composed of cysts only, which we named *Cystostroma.* We consider it to be the ancestor of all Silurian and Devonian stromatoporoids. *Pseudostylodictyon,* occurring in the same beds has regular laminae, no cysts or pillars, and might be considered to be even more primitive than *Cystostroma.*

Ordovician stromatoporoids have skeletons composed fundamentally of imbricating, arcuate plates or cysts, which overlap some of the underlying plates, with or without radial pillars. They all belong to the family Labechiidae. The surface is either smooth or with mamelons, and in some species there are small but typical astrorhizae. The cyst plates are composed of a thin dark, dense median layer generally with an upper thin layer of less dense or flocculent tissue and generally with a thicker lower layer of flocculent tissue.

In addition to the cysts in most of the genera, there are long round or flat pillars. The pillars are composed of loosely aggregated granular material somewhat more closely arranged on the outside of the pillars. The pillars seem to have been continuous, not superposed; they arose from the tops of the cysts and continued through the cyst plates. The pillars seem to have been composed of less easily preserved tissue than that of the cysts and often are only partially preserved, as in the type specimen of *Aulacera plummeri;* at other times there are only radial vacuities to show where the pillar had been, as seen in several species from the Liberty formation of Kentucky, and in *Cryptophragmus antiquatus* and *Labechia pustulosa.*

The tissue of both cysts and pillars is either compact of flocculent; in rare cases there are pores through the cyst plates. In no case is the tissue composed of, or provided with, the round dots or maculae as seen in the family Stromatoporidae.

Seven genera of stromatoporoids are confined to the Ordovician. Four, *Rosenella, Labechiella, Labechia,* and *Pseudolabechia* extend into the Devonian. Cyst plates or dissepiments are characteristic of the Ordovician forms but cyst plates occur in the skeletons of all the families of the Stromatoporoidea and in most of the genera. The presence of cysts, pillars, and astrorhizae in the Labechiidae is considered as sufficient proof that the family Labechiidae belongs to the order Stromatoporoidea and do not constitute a distinct order. The Labechiidae were ancestral to the other families of Stromatoporoidea, embracing a small group of genera, and it is more convenient to refer to the Ordovician forms as a family of the Stromatoporoidea.

Stromatoporoids might well be found in the Lower Ordovician; they should consist of arcuate cysts or some other modification of a sphere. Repair tissue throughout the order Stromatoporoidea is usually cystose, suggesting that cysts are primitive structures.

Ordovician stromatoporoids are difficult to identify because, (1) most of the early named species were described from surface features, and most subsequent references are based on outside characters; (2) Ordovician species commonly are poorly preserved because the structures were poorly calcified, as may be true of specimens of *Stromatocerium, Labechia, Aulacera,* and others; (3) many specimens have been dolomitized, as *Labechia pustulosa* from the type locality; others have been silicified during the weathering of the enclosing rock, leaving a form showing latilaminae but no other determinable structures (Parks, 1910, pl. 21, fig. 7); (4) as many as five synonyms have been made for one species (*Labechia huronensis*); (5) few persons who have identified species had adequate knowledge of stromatoporoids or their structures; (6) several of the types cannot be located.

Although we have studied all the types and topotypes possible to obtain and have devoted a great deal of time to Ordovician stromatoporoids, there are still some unsolved questions such as: is *Dermatostroma* a stromatoporoid? What is *Stromatocerium canadense?* We hope we have made it possible to identify most known species of the Ordovician of North America. We have not recognized subspecies because we cannot distinguish those taxa from species.

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We have received for study by gift or loan many Ordovician specimens, types or topotypes. We especially acknowledge assistance from the following persons: Mrs. Ruth G. Browne, Louisville, Kentucky; Dr. Guy Campbell, Corydon, Indiana; Dr. G. Arthur Cooper, U.S. Nat. Mus.; Dr. Rousseau H. Flower, New Mexico Institute of Mining and Technology; Dr. Otto Haas, American Museum of Natural History; Dr. Marshall Kay, Columbia University; Dr. T. G. Perry, Indiana University; Dr. Bruno M. Schmidt, Middlebury College; the late Dr. William H. Shideler, Miami University; Dr. W. J. Wayne, Indiana Geological Survey; Dr. Harry B. Whittington, Harvard University; Dr. D. J. McLaren and Dr. Alice E. Wilson, Geological Survey of Canada; and Dr. Charles W. Wilson, Jr., Vanderbilt University. Professor G. M. Ehlers of the University of Michigan, has sent us for study many specimens which had been collected by Dr. Carl Rominger, Professor R. C. Hussey, and him.

We also owe thanks to the late Dr. Charles F. Deiss, Chairman of the Geology Department of Indiana University, for obtaining quarters, apparatus and secretarial assistance; to the Graduate School of Indiana University, for providing a grant for the cost of the plates. Mr. George Ringer, Indiana Geological Survey, made the photographs. The retouching was done by J. J. Galloway, where necessary.

SYSTEMATIC PART

Phylum COELENTERATA

Class HYDROZOA Owen, 1843

Order STROMATOPOROIDEA Nicholson and Murie, 1878

Layered, calcareous, attached animal skeletons, composed of curved plates and pillars in Ordovician forms and of laminae and pillars in later forms. They occur in marine, shallow, warm water rocks of Ordovician, Silurian, and Devonian age. They have no spicules nor a cup-shaped body as do sponges, and they have no corallites as do corals. They are considered to be Hydrozoa by all living authorities.

Family **LABECHIIDAE** Nicholson, 1879

Family Labechiidae Nicholson, 1879, "Tabulate Corals of the Palaeozoic Period," pp. 28, 330.

Coenosteum laminar, massive, conical, columnar or fasciculate, without or with axial, cystose column. Skeleton composed of small or large curved, imbricating plates, forming latilaminae but rarely continuous microlaminae. Pillars thin to thick, long, round, flat or irregular, primitive or absent. Tissue of primary plates compact, usually with inner and outer flocculent layers. Primitive astrorhizae may occur.

Middle and Upper Ordovician abundant, Silurian uncommon, Devonian rare.

KEY TO GENERA OF LABECHIIDAE

1a. Pillars absent in all parts of the coenosteum
    2a. Coenosteum massive, without axial column or pillars .... Cystostroma
    2b. Coenosteum columnar, with axial column of cysts, (immature) .... Cryptophragmus and Aulacera
1b. Pillars represented by denticles or wrinkles on laminae
    2c. Coenosteum laminar or massive
        3a. Cysts and denticles dominant .... Rosenella
        3b. Laminae and wrinkles dominant .... Pseudostylodictyon
    2d. Coenosteum columnar; lateral sheaths like *Rosenella* .... Sinodictyon
1c. Pillars continuous through several layers of cysts
    2e. Pillars round in tangential section
        3c. Coenosteum columnar; pillars in mature stage
            4a. Lateral cysts strongly curved; pillars small .... Aulacera
            4b. Lateral cysts slightly curved; pillars large .... Cryptophragmus

3d. Coenosteum massive
4c. Pillars not in groups
5a. Cysts arched, imbricating .... Labechia
5b. Cysts edge to edge, simulating laminae .... Labechiella
4d. Pillars in diverging groups .... Pseudolabechia
3e. Coenosteum a thin encrustation .... Dermatostroma
2f. Pillars broad, many flanged in tangential section; cysts wide, low, simulating laminae .... Stromatocerium

Genus **CYSTOSTROMA** Galloway and St. Jean, 1957

Type species (originally designated), *Cystostroma vermontense* Galloway and St. Jean, in Galloway, 1957, Bull. Amer. Paleont., vol. 37, No. 164, p. 421. (Middle Ordovician, middle Chazy, one mile southeast of Isle La Motte village, Vermont.)

Coenosteum massive, without cystose column, composed of imbricating, curved plates, forming latilaminae a few millimeters thick. Tissue of compact primary plates usually with inner and outer flocculent layers. The lower plate may be composed of clusters of flocculent tissue, and between the clusters there may be pores which pass through all three plates. Pillars absent. Surface smooth or with small or large mamelons, and primitive astrorhizae.

Middle and Upper Ordovician: *C. vermontense,* middle Chazyan, Isle La Motte, Vt.; *C. simplex,* Carters ls., Tenn.; *C. minimum,* Bigby ls., Ky. and Black River or Trenton, Escanaba River, Mich.; *C. fritzae,* Richmondian, Haileybury, Ont.

This genus embraces the simplest, oldest, and most primitive stromatoporoids known, with skeleton composed only of arcuate cysts. It lacks the axial column of *Aulacera,* and lacks the pillars of *Labechia* and of the mature stage of *Aulacera.* It lacks the denticles of *Rosenella* and has smaller, more regularly imbricating cysts. The mamelons of *C. minimum* (Parks), and the large knobs of *C. fritzae,* n. sp., are not generic but only specific characters.

KEY TO SPECIES OF CYSTOSTROMA

1a. Surface smooth, without mamelons

2a. Cyst plates large, variable; without villi
........................*C. vermontense* Galloway and St. Jean
2b. Cyst plates small, uniform; villi abundant
........................*C. simplex* Galloway and St. Jean
1b. Surface with mamelons
2c. Mamelons small, 5-6 mm. diameter ......*C. minimum* (Parks)
2d. Mamelons large, 30-40 mm. in diameter ......*C. fritzae,* n. sp.

Cystostroma vermontense Galloway and St. Jean
Pl. 1, figs. 1a, b, c, 2

Cystostroma vermontense Galloway and St. Jean, 1957, in Galloway, Bull. Amer. Paleont., vol. 37, No. 164, p. 421, pl. 31, fig. 1; pl. 32, fig. 1; pl. 36, fig. 3 (M. Ord., Vt.)

Coenosteum.—Coenosteum massive; a fragmental specimen is 55 mm. high, 90 mm. wide, and 175 mm. long. Latilaminae conspicuous, smoothly curved, 2 to 6 mm. thick. Surface without mamelons, astrorhizae or papillae. Irregularly shaped cyst plates are 0.7 to 3 mm. in the longest dimension, and average 1 to 2 mm. in diameter.

Vertical section.—The latilaminae are prominently marked by thin layers of black, calcareous mud, obviously not a specific character but due to seasonal deposition. The low-arched cyst plates are variable in size, 0.3 to 3 mm. broad, and 0.2 to 0.7 mm. high, 1½ to 6 cyst plates in 4 mm. horizontally, and an average of 5 cyst plates in 2 mm. vertically. No pillars occur in seven sections. The cyst plates are composed of three layers, a median, thin, dense layer, an outer, indefinite, flocculent layer, and a lower, thick, flocculent layer which occupies much of the chamber space and joins with the outer layer of the plates below. In places the flocculent plates have clear vertical areas resembling pores. (Nicholson, 1886, pl. 8, fig. 5.)

Tangential section.— The cysts join to form round or polygonal patterns. The wall tissue is cut obliquely and appears thicker than in vertical section. There are no pillars nor astrorhizae.

Comparisons.—*Cystostroma vermontense* is characterized by the large size and variability in the size and shape of the cyst plates, by the thick lower plate, and by the lack of mamelons. It has larger and more variable cysts than *C. simplex* and lacks the small villi on the outer layer of the cyst plates.

In some specimens at the base of a latilamina there is a spherical chamber, about ½ mm. in diameter, attached to the substratum directly or by a spool-shaped neck. From the chamber, curving downward are two or three pairs of arcuate cysts, in structure like ordinary cysts, which may extend laterally into normal cysts of *Cystostroma,* and an alga covers the structure. The spherical chamber with its pairs of cysts may be the beginning of the coenosteum, which we named the protocoenosteum (1957, p. 45, pl. 36, fig. 3). Such spherical chambers are not found in the bodies of any coenostea. No other organism except the alga occurs with the described structure. In one slide (300-72) there are three similar structures (Pl. 1, fig. 2).

Occurrence.—Middle Ordovician, middle Chazyan, one mile southeast of Isle La Motte village, Vermont, collected by Dr. Marshall Kay, of Columbia University—the oldest known stromatoporoid occurrence in North America.

Holotype.—Indiana University, Paleo. Coll. No. KA2; slides Nos. 300-15, 16, 17, 18, 25, 26, 27.

Cystostroma simplex Galloway and St. Jean Pl. 1, figs. 3a, b

Cystostroma simplex Galloway and St. Jean, 1957, in Galloway, Bull. Amer. Paleont., vol. 37, No. 164, p. 421, pl. 32, fig. 2. (M. Ord., Tenn.)

Coenosteum.—Coenosteum massive, oval, 160 x 100 mm. in diameter and 80 mm. thick, composed of latilaminae 5 to 10 mm. thick, Surface smooth, without mamelons or astrorhizae.

Vertical section.—The skeleton is composed of arcuate cysts which are from 1 to 2 mm. broad and half as high, and regular within those limits; they tend to be flat on top with nearly vertical ends. The cystose plates are smaller at the junction of latilaminae. Each cyst overlaps about ⅓ of each subjacent cyst. Pillars absent. Cyst plates are tripartite, consist of a thin, dense, dark, median layer, 0.05 mm. thick, and thicker inner and outer layers; inner layer 0.15 mm. thick, composed of a thin light-colored upper compact layer and a thicker, gray, flocculent lower layer; outer layer

0.10 mm. thick, flocculent, from which extend upward, gray flocculent villi, about one-half as high as the cysts. The triple walls and the villi appear to be organic structures, for they differ from the chamber filling of clear, crystalline calcite. It is remarkable that a similar kind of wall structure occurs in the coral *Paleoalveolites paquettensis* Okulitch, including even the villi, indicating that early corals and the Labechiidae are related and in the same phylum.

Tangential section.—The cysts are cut into round or oblong figures. The walls are cut obliquely, are thicker than in longitudinal section, but the composition is the same. The villi appear as roundish, flocculent dots, abundant in some places, but not qualifying as pillars, because they are not developed from, nor do they cut the primary plates, as real pillars do in the Labechiidae.

This species is characterized by its simple structure, without pillars, mamelons or astrorhizae, the limited variability of the cysts, the tendency for the ends of the cysts to be vertical and the tops flat, the amount of overlap of the cyst plates, and the abundant villi.

Occurrence.—Common in the Middle Ordovician, basal Trenton, Carters limestone, at Mill Creek, seven miles south of Nashville, Tenn., collected by Prof. C. W. Wilson, Jr., of Vanderbilt University.

Holotype.—Part in the Vanderbilt University collection, and part in the Indiana University Paleo. Coll., slides 299-60, 61, 62.

Cystostroma minimum (Parks) Pl. 1, fig. 4a, b

Stromatocerium canadense var. *minimum* Parks, 1910, Univ. Toronto Studies, Geol. Ser. No. 7, p. 20, pl. 22, fig. 3. (M. Ord., Trenton, Bigby ls., Frankfort, Ky.)

Coenosteum.—Coenosteum massive to discoidal, at least 20 cm. in diameter and 5 cm. thick. The specimens from Escanaba River, Michigan, are massive cones, up to 27 cm. high and up to 18 cm. in diameter near the base. Surface has hemispherical mamelons, 2 mm. high, 3 mm. in diameter and 6 to 10 mm. apart, regular in size, shape, and distribution. Small astrorhizae, 2 to 3 mm. in diameter, occupy the summits of most of the mamelons; the astrorhizae have three to five radiating canals, and some of the canals branch sparingly.

Vertical section.—The coenosteum is composed of latilaminae, 10 to 15 mm. thick, in both Kentucky and Michigan specimens, and the mamelons are not ordinarily superposed from one latilamina to the next above; each latilamina is taken to be a year's growth, with cessation of growth in the cold seasons. The skeleton is composed entirely of low, arcuate cysts, which are from 0.5 to 3 mm. broad, averaging less than 1 mm., and averaging about ¼ mm. high; the cysts overlap from ⅓ to ½ of the two subjacent cysts, and the layers of cysts rise sharply over each mamelon. Narrow astrorhizal tubes occur in some mamelons, rarely between mamelons; some are perpendicular but most astrorhizal tubes make small angles with the vertical; they have no proper walls. The walls of the cysts consist of a dark, dense upper layer, 0.03 mm. thick, usually without an overlying flocculent layer, but with a lighter colored lower layer, 0.12 mm. thick, filling over half of the cyst vesicle. The lower plate is composed, in some specimens, of oval, gray clusters, with darker, flocculent centers, giving a vague moniliform appearance. The oval clusters are separated by thin, dark partitions extending into the thin, upper layer; in places there are pores between the clusters which pass through the upper plate. The chambers are filled with clear calcite. Pillars absent; foramina between cysts might be interpreted as remnants of pillars, but there is no pillar substance.

Tangential section.—The cysts curve in layers around the mamelons, in which there is usually a small astrorhiza with short canals. There are no indications of pillars.

Comparisons.—*Cystostroma minimum* is characterized by the massive form, with regular mamelons which do not make long mamelon columns, the small astrorhizae, and the usually bipartite walls of the cysts, with the lower, moniliform layer, and lack of pillars. It is indistinguishable from *Labechia pustulosa* (Safford), with which it occurs, excepting for the absence of pillars, but pillars are missing in parts of *L. pustulosa*. *Labechia huronensis,* from the Cincinnatian series, has smaller cysts, and round pillars.

Occurrence.—Common in the Bigby limestone of Trenton age, Frankfort, Kentucky; the type specimen, figured by Parks, is numbered 36930 in the U.S. Nat. Museum. A specimen from the U.S.

Nat. Museum is labeled "Holotype, *Stromatocerium canadense minimum* Parks. Trenton (Flanagan), Frankfort, Kentucky." It has abundant round pillars and is indistinguishable from *Labechia pustulosa* (Safford). It has no museum number. The pillars are so large and conspicuous that Parks could scarcely have missed seeing them, whereas his figure (1910, pl. 22, fig. 3) shows thin plates in the cysts and no pillars. We, therefore, hesitate to accept the unnumbered U.S. Nat. Mus. specimen as the type of subspecies, even if it is from the type locality. Bassler (1915, p. 1213) recognized the Museum's specimen as *Stromatocerium pustulosum* (Safford) and referred to No. 36930 as a plesiotype of *S. pustulosum*. In many large areas in the section, pillars are missing and cyst plates are thin, as shown in Parks' figure. We have part of a good topotype from the top of the Bigby limestone, at the Old Crow Distillery, Frankfort, Kentucky, collected by Dr. W. H. Bucher; Cat. No. 4087, Geological Museum of the University of Cincinnati. It also occurs in large masses in the Trenton on Escanaba River, three miles south of Bony Falls, Michigan; collected by R. C. Hussey; Univ. of Michigan, Cat. No. 39455, 39489, 39490, 39491.

Hypotype.—Indiana University Paleo. Coll., slides 299-68, 69; 302-32; 308-88.

Cystostroma fritzae Galloway and St. Jean, n. sp.

Pl. 2, fig. 1a, b

Coenosteum.—Coenosteum large, irregularly hemispherical, 60 cm. in diameter and 25 cm. high, composed of latilaminae 2 to 5 mm. thick. The surface is in general smooth but has groups of large, subconical knobs, 3 or 4 cm. in diameter and height. Astrorhizae apparently absent. In many places the latilaminae are separated by 1 to 3 mm. of lime mud, apparently laid down in the winter season; in other places there is no median arcuate layer in the winter parts of the latilaminae.

Vertical section.—The skeleton is composed of low, arcuate cysts, from 0.3 to 0.8 mm. broad, averaging about ½ mm., overlapping about ¼ to ⅓ of each subjacent cyst at each end. The chambers are 0.2 to 0.3 mm. high. The cyst plates are tripartite, with a thin, compact, median layer, 0.026 mm. thick, a thin, flocculent upper plate, and a thick, flocculent, lower plate, which usually fills the chamber cavity, but is not moniliform. Where the coenosteum is well preserved, the thick, lower layers of the cyst plates show clear, radial spaces, possibly pores (Nicholson, Mono., p. 89, pl. 8, fig. 5) which are common in the Labechiidae and which in places appear to pierce the dark, median layer of the cyst plates and extend through the upper plate. Pillars and astrorhizae are absent.

Tangential section.—The cut cysts appear as small circles and irregular curves. The median layer of the cyst walls appears as small circles and irregular curves with dark spots of variable size, but thicker than in vertical section. In places there seems to be pores in the median layer.

This species is characterized by large, conical knobs, and by low-arched, closely spaced cyst plates, and lack of pillars.

Occurrence.—Upper Ordovician, Richmondian, Liskeard formation, Farr Quarry, Haileybury, Lake Timiskaming, Ontario. The specimen was collected by Prof. Madeleine A. Fritz, of the University of Toronto, for whom we are pleased to name it.

Type.—Holotype in the Royal Ontario Museum of Zoology and Paleontology, and five slides, a fragment in the Indiana University Paleo. Coll. and slides 301-88, 89, 90, 91, 92; 302-76, 77.

Genus **CRYPTOPHRAGMUS** Raymond, 1914

Type species (originally designated), *C. antiquatus* Raymond, 1914, Canada Dept. Mines, Geol. Surv. Mus., Bull. No. 5, p. 8, pls. 1-4, holotype, pl. 1, fig. 1. (M. Ord., Pamelia ls., Aylmer, Quebec); Bassler 1932, Tennessee Div. Geol., Bull. 38, p. 102, 214; pl. 16, fig. 9; 1935, Jour. Washington Acad. Sci., vol. 25, No. 9, p. 404; Shrock and Raasch, 1937, Amer. Midland Natur., vol. 18, p. 536, pl. 2, figs. 1-3; Shimer and Shrock, 1944, Index Fossils of North America, p. 63, pl. 19, figs. 6-8; Wilson, 1948, Canada Geol. Surv., Bull. 11, p. 46, pl. 22, figs. 3-5; Yavorsky, 1955, Trudy Vsesoyuznogo Nauchno-issledovatelskogo Geol. Inst., Minister. Geol. i Okhrany Nedr, nov. ser., vol. 8, p. 68, pls. 31, 32, 34 (doubtful); Galloway, 1957, Bull. Amer. Paleont., vol. 37, No. 164, p. 426, pl. 32, fig. 8.

Thamnobeatricea Raymond, 1931, Bull. Mus. Comp. Zool. Harvard, Geol. Ser., vol. 9, No. 6, p. 180, pl. 2, figs. 4-6 (M. Ord., Bellefonte, Pa.)

Cladophragmus Raymond, 1931, *ibid.*, p. 182, pl. 3, figs. 1-4. (M. Ord. Ottawa, Ont.)

Rosenellina Radugin, 1936, Records of the Geology of the West Siberian Region, No. 35, p. 92, figs. 8, 9, 11.

Coenosteum upright, cylindrical or rarely branching, 2 to 20 mm. in diameter and up to 46 cm. long, consisting of a tube, with thin, cystose wall about 1 mm. thick; the tube is crossed by large, superposed, highly arched tabulae or cysts. The cysts are composed of a primary, median, compact layer, and thin inner and outer flocculent layers. Both inner and outer flocculent layers have irregular villi. The outer sheaths of cysts and large pillars when present are the adult stage of the *Cryptophragmus*.

Middle Ordovician, six species, Upper Ordovician doubtful.

The sheaths are rarely continuous with the axial tube or attached directly to it but are attached to mud or calcite between it and the axis. They seem to have been little calcified and ordinarily incapable of preservation, similar to the pillars of *Labechia pustulosa* and of *L. huronensis*. The sheath organism has the structure of *Labechia,* composed of curved plates and large, long pillars. It must have grown downward from the top of the column, after a cold season in which mud was deposited, making latilaminae. This genus differs from *Aulacera* in the larger pillars, and in not ordinarily developing the lateral layers, whereas *Aulacera* nearly always has the lateral layers of cysts and pillars. The pillars of *Cryptophragmus* are much larger and less well preserved than in *Aulacera,* and the lateral cyst plates are less curved and less well preserved than in *Aulacera*. Raymond mistook the pillars for tubes although he noted the papillae (1914, pl. 4, fig. 2) or "elevations are at the apertures of the tubes."

KEY TO SPECIES OF CRYPTOPHRAGMUS

1a. Not branching
- 2a. Axial cysts irregular .... *C. antiquatus* Raymond
- 2b. Axial cysts regular .... *C. gracilis* (Ulrich)
- 2c. Axial cysts unknown .... *C.* ? *rochensis* Wilson

1b. Branching
- 2d. With cysts outside the tube ....*C. parallelus* (Raymond)
- 2e. Without cysts outside the tube
  - 3a. Stems 10 mm. in diameter ....*C. arbusculus* Bassler
  - 3b. Stems 5-7 mm. in diameter *C. bifurcatus* (Raymond)

Crytophragmus antiquatus Raymond Pl. 2, figs. 2a, b, c, 3a, b, c

Cryptophragmus antiquatus Raymond, 1914, Canada Dept. Mines, Geol. Surv. Mus., Bull. No. 5, p. 1-10, pls. 1-4. (M. Ord., Pamelia ls., Aylmer, Que. and Carden twp., Ont.) ; Butts, 1926, Geol. Surv. Alabama, Spec. Rep. 14, p. 128, pl. 32, figs. 4-7; Raymond, 1931, Bull. Mus. Comp. Zool., Harvard, Geol. Surv., vol. 9, No. 6, p. 182, pl. 3, fig. 8; Shrock and Raasch, 1937, Amer. Mid. Natur., vol. 18, p. 536; Wilson, 1948, Canada Dept. Mines, Geol. Surv., Bull. 11, p. 46, pl. 22, figs. 3-5; Shimer and Shrock, Index Fossils of North America, 1944, p. 63, pl. 19, figs. 6-8.

Exterior.—Coenosteum upright, cylindrical, unbranched, up to 20 cm. long and 25 mm. in diameter, consisting, in immature stages, of an axial column 5 to 12 mm. in diameter, of large superposed, hemispherical cysts, which arch upward (Butts, 1926, pl. 32, figs. 4-7, shows the axial cysts arched downward) and a thin layer of small cysts composing the lateral walls of the tubular axis. The adult has sheaths or latilaminae, 2 to 5 mm. thick. There are no mamelons nor astrorhizae.

Vertical section.—The axial cyst plates consist of a thick, compact median plate, with thick flocculent upper and lower layers. In places the median plate of the large axial cysts is sharply bent upward into small hollow cones. The lateral cysts of the tube, when present, are 0.2 to over 1 mm. broad and arcuate rather than hemispherical. Outside of the zone of small cysts there may be a zone of disturbed cysts and pillars of the sheaths, more often a zone of clear calcite up to 2 mm. thick. In some cases there is a zone of mud 1 or 2 mm. thick. In one case the axial column is followed by a zone of calcite of varying thickness, and this by a well-preserved bryozoan, *Monticulipora.*

At the type locality near Ottawa, Canada, and in Loysburg and in Lee County, Virginia, the axial column or tube is covered by two to four layers of sheaths or latilaminae of different structure than the axial column, and only rarely connected to or grading from it. The sheaths generally lie on calcite or a layer of mud deposited in the non-growing season. The sheaths are composed of broad, arched cyst plates, perpendicular to the axial column, and large, long radial pillars; the pillars are oval to prismatic and tend to be round. The cyst plates have been largely destroyed or have not been preserved because of insufficient calcification in life. The pillars have been entirely destroyed or recrystallized, causing Raymond (pp. 4, 9) to mistake the pillars for "radial canals." The outer sheaths are like *Labechia* in the curved plates and large pillars. In several sections, and in Raymond's plate 4, figure 2, the pillars extend into the surrounding mudrock as papillae, showing that the radial structures are pillars rather than tubes, as Raymond thought.

Tangential section.—The pillars are large, closely spaced, four to six-sided or oval, tending to be round, 0.2 to 0.3 mm. in diameter, and the same distance apart. Cyst plates are rarely observable; they are indicated by a dark, granular network enclosing the spaces where the pillars had been. Numerous reported specimens of *C. antiquatus* do not have the outer sheaths, so that the sheaths are not necessary for the indentification of the species. The sheath zones may have been composed of soft material, with little calcareous structures, so that they were preserved only under favorable conditions.

Cross section.—The axial tube is 5 to 12 mm. in diameter, with sections of the axial tabulae. The wall of the axial tube consists of small, outwardly convex plates. The tube is followed by either clear calcite or mudrock, and these by a zone of curved, imbricating plates and large pillars. The layer of calcite or mud and radial zone may be repeated two or three times, making latilaminae. It is likely that the sheaths grew down from the growing upper end of the column. In the clear calcite zone there may be remnants of the curved plates and pillars.

Occurrence.—*C. antiquatus* has been reported from the Pamelia and Lowville limestones of the Black River group of Quebec, Ontario, New York, Pennsylvania, Virginia, Alabama, Kentucky, Tennessee, Missouri, and Indiana. We are indebted to Dr. Alice E. Wilson, of the Geological Survey of Canada, for loaning us a piece of one of Raymond's paratypes from Carden twp., Ontario, from which we have made sections for study (Pl. 2, fig. 3c), and to Dr. H. B. Whittington, of Harvard University, for loaning us five of Raymond's slides, two fragments of Raymond's material from Carden twp., Ontario, from which we made three slides, and a complete specimen of Raymond's Carden twp. material from which we made seven slides. Some of the Carden twp. specimens have no sheaths. We have specimens from the Lebanon limestone of Tennessee, and from the Middle Ordovician of Kentland, Indiana, which have no sheath zones, which is true of most reported occurrences excepting those from near Ottawa, Canada, and Lee Co. and Loysburg, Virginia.

Genus **AULACERA** Plummer, 1843

Type species (only species described), *Aulacera plummeri* Galloway and St. Jean. No species of *Aulacera* was named by Plummer, but the species was described and figured and is recognizable, hence is the type species under the Rules of Zoolog. Nomen., Opinion 46: "if only one species is involved, the generic description is equivalent to the publication of '*X-us albus,* n. g., n. sp.'" (U. Ord., late Richmondian, near Richmond, Ind.)

Aulacera Plummer, 1843, Amer. Jour. Sci., vol. 44, p. 293, fig. 8. The name is valid, under Rules of Nomenclature, Art. 2, and Opinion 46; a species is available as type species when it can be recognized from the original generic publication; Schuchert, 1919, Amer. Jour. Sci., 4th ser., vol. 47, p. 293, fig. 1; Kühn, 1928, Foss. Cat., Hydrozoa, p. 38; Ozaki, 1938, Jour. Shanghai Sci. Inst., sec. 2, vol. 2, p. 217; Kühn, 1939, in Schindewolf, Handbuch Paläozoologie, Bd. 2A, p. A53; Galloway, 1957, Bull. Amer. Paleont., vol. 37, No. 164, p. 422, pl. 31, fig. 2; pl. 32, fig. 3; pl. 37, figs. 1a-c.

Beatricea Billings, 1857, Geol. Surv. Canada, Rep. Prog. for 1853-6, p. 343. (Type species, *B. nodulosa* Billings, selected by Miller, 1889, N. A. Geol. Paleo., p. 155.) (U. Ord., Anticosti Island); 1865, Canadian Nat., 2d. ser., vol. 2, p. 405, figs. 1, 2; Nicholson, 1886, Palaeont. Soc., vol. 39, p. 86, pl. 8, figs. 1-8; Foerste, 1909, Bull. Sci. Lab. Denison Univ., vol. 14, p. 298; Parks, 1910, Univ. Toronto Studies, Geol. Ser., No. 7, p. 37, pl. 25; Yavorsky, 1955, Trudy Vsesoyuznogo Nauchno-issledovatelskogo Geol. Inst., Minister. Geol. i Okhrany Nedr, nov. ser., vol. 8, p. 69-80, pls. 32-42.

Coenosteum subcylindrical, with axial column usually made of large, hemispherical, upwardly curved cysts, simulating a tabulate tube; in some specimens the large cysts grade into the small, lateral cysts, showing that all are parts of the same organism. Lateral skeleton latilaminate, composed of small, imbricating, cyst plates. The cyst plates consist of a thin, dense, median layer, about 0.03 mm. thick, a thin flocculent outer layer, and a thick flocculent inner layer. Pillars present or absent in the inner part of the lateral zones, and with long, narrow, round pillars sporadically developed in the outer zone; pillars loose in texture, with outer more compact zone, but not hollow. Surface even or with mamelons or longitudinal ridges. Astrorhizae absent.

Upper Ordovician, abundant in and apparently confined to the Richmondian group. North America, Russia, and China. Seventeen species.

The axial zone of cysts grading into the lateral zone cannot be a generic character, for several of the species have both tubular and gradational axes; both phases occur in the same specimen. *Aulacera* differs from *Cystostroma* in the columnar form and in having pillars in the outer zone of adult specimens. It differs from *Cryptophragmus* in having the outer zone of imbricating cysts and small pillars. *Sinodictyon* is columnar with a cystose axis, sporadic lateral pillars, and there are strong denticles on axial and lateral cysts.

The genus *Aulacera* was named and described by Dr. John T. Plummer in 1843. It was the second stromatoporoid named, the first one named from North America, and moreover, was the first fossil named from Indiana.

The etymology of the word *Aulacera* was not given by Plummer, and we can only surmise what he had in mind. The gender of the word is important in that the endings of the names of species of the genus are affected. Probably the first two syllables were derived from the Greek *aulos,* a pipe. Because Plummer included the genus under the univalves, there is a possibility that he had an orthoceroid cephalopod in mind; if so, the second part of the word should have been *ceras.* If he meant the Latin term *aula,* which in poetic usage means the cell of a queen bee, the Latin term *cera,* meaning wax, would be logical, referring to the crude honeycomb appearance of the specimen on a broken edge, produced by imbricating cyst plates. Plummer may have used the term *cera* in reference to the tapering candle-like shape of the fossil. Words ending in *ceras* are neuter; adjectival, specific names are, therefore, neuter. The word ending *cera* would indicate feminine gender and the word *Aulacera* has been considered to be feminine by Kühn (1928, p. 38), Shimer and Shrock (1944, p. 63) and most recent authors. In conformity with our principle not to make changes unless we are sure that corrections need to be made, we are also considering the name *Aulacera* to be feminine, and the specific names are feminine, excepting *plummeri,* a patronym.

The same genus was named *Beatricea* by Billings in 1857 (p. 343), which name was used for the genus until the name *Aulacera* was resurrected by Schuchert in 1919 (p. 293), since then the genus has gone under both names. The recent text, Invertebrate Fossils by Moore, Lalicker and Fisher, preferred *Beatricea,* and Shimer and Shrock's *Index Fossils of North America,* 1944, used both *Beatricea* and *Aulacera,* as do Shrock and Twenhofel in *Principles of Invertebrate Paleontology,* 1953.

The generic name, *Aulacera,* is the valid name of the organism, for Plummer used Linnaean nomenclature. Although no species was named, the description and figure given by Plummer are entirely sufficient for recognition of the species. We have several topotypes from Plummer's original locality near Richmond, Indiana, one was described and figured by Galloway and St. Jean (Galloway, 1957, p. 423, pls. 31, 32, 37) who named it *Aulacera plummeri,* in honor of the discoverer of the genus. The generic name is valid according to the International Rules of Zoological Nomenclature, Opinion 46; a species is available as type species if it can be recognized from the original generic publication. Because only one species is involved, "the generic description is equivalent to the publication of '*X-us albus,* n. g., n. sp.' " We, therefore, consider that *Aulacera plummeri,* is the type of the genus *Aulacera,* for that species is different from *Beatricea undulata* Billings which becomes *Aulacera undulata* (Billings).

The type species of *Beatricea* is *B. nodulosa,* which was the first species described by Billings, and *B. nodulosa* was selected as the type species by Miller (1889, p. 155). *B. nodulosa* cannot be the type species of *Aulacera* because it is different from Plummer's species, and it has never been reported from the Midwest. *Beatricea undulata* cannot be the type species of *Aulacera* as indicated by Shimer and Shrock (1944, p. 63), for we find upon studying a type specimen of *B. undulata* that not only are the ridges more sharp in *B. undulata,* but internally, the cysts of *B. undulata* are twice as large as the cysts of *A. plummeri,* and the cysts are more highly convex and are arranged radially to the axis; whereas in *A. plummeri,* the cysts are low-arched and are arranged concentrically about the axis.

The genus *Aulacera* has a subcylindrical coenosteum, which is considered to have stood upright when it was alive, although nearly all specimens are found broken from their bases and lying in fragments. It is regrettable that the base has never been scientifically described; and although we have studied over a hundred specimens, not one shows the base. The base of *Aulacera* should have precisely the structure of *Cystostroma*. The center of the column is occupied generally by an axis of large, hemispherical cysts, which were convex upward, and in their superposition, formed a structure similar to a tabulate tube. In some specimens, the axial zone consists of large cysts which grade out into the lateral cysts. The lateral zone consists of small outwardly convex cysts, and in large specimens, there are scattered round, long, thin pillars in the outer zone. The cystose structure, with pillars, is similar to that of all Ordovician genera of stromatoporoids which belong in the family Labechiidae.

Most specimens are found with their long axis parallel to the bedding; none has been reported attached to a base, but the specimens must have stood upright in life, for all sides are alike. All authorities consider that they lived upright. Yavorsky (1957, p. 71) discussed the position in life, citing the observations of Hyatt (1865), Raymond (1914) and Schuchert (1919), some of whom saw specimens in an upright position but without bases. Yavorsky (1957, pl. 36) figured a specimen of *A. conica* with a flaring foot which he surmised was the broken attachment. The latilaminae are from 2 to 4 mm. thick, suggesting an age of three to five years for the small specimens 1 to 3 cm. in diameter, to 10 years or more for larger specimens 5 to 10 cm. in diameter. The specimens must have been broken from their bases by storms and killed and moved to their present locations, for none shows evidence of growth at the places where they are found. Bases should have the characters of *Cystostroma,* but that genus shows no evidence of having been a base of an erect form, nor do *Cystostroma* and *Aulacera* occur in the same part of the Ordovician.

The genus *Aulacera* is similar in the structure, particularly in the lateral zone, to a simple and primitive genus occurring in the Middle Ordovician, whose skeleton is composed entirely of arcuate cysts, *Cystostroma* Galloway and St. Jean, described above.

Aulacera also seems to be identical in the tubular axis with the older genus, *Cryptophragmus,* of the Black River group, which may consist of only a tubular form with large upwardly convex cysts and a few smaller lateral cysts. In other examples there are sheaths around the cystose axis which resemble the genus *Labechia*. In the case of *Aulacera*, we consider it established that the lateral zones are part of the organism.

We consider that *Aulacera* was derived from the older and simpler genus, *Cryptophragmus*, by the addition of a thick zone of cysts to the axial column and greater calcification of the outer zone. *Cystostroma* is considered to be the ancestor of *Cryptophragmus*. All of the genera of the family Labechiidae, excepting *Dermatostroma*, have skeletons composed of arcuate cysts of various sizes and shapes. A closely related genus is *Labechia*, which has strong, round pillars and the coenosteum is hemispherical to subconical.

The form of the coenosteum is a family character in the Idiostromatidae and a generic character in the genera *Clavidictyon*, *Cryptophragmus*, *Sinodictyon*, and *Aulacera*. Surface characters, such as ridges and mamelons, are found by experience to be rather constant characters and are considered by authors to be of specific value. There are gradations between the smooth *A. cylindrica* and *A. plummeri* with low ridges. There are, also, gradations in size of mamelons on the same specimen and between different specimens. Specimens occurring in any one locality have characters which are rather constant. For instance, no specimen of *A. nodulosa*, with large nodes, has been reported from the Midwest, although there are rare examples of *A. nodulifera* and *A. intermedia*.

The genus *Aulacera* is confined to the Richmond group; the oldest and simplest specimens occur in the lower Liberty formation of Kentucky, most of the specimens are small examples of *A. plummeri* and *A. cylindrica*, with rare examples of *A. nodulifera* and *A. intermedia*. The most favorable collecting locality is on Wilson Creek, two miles southwest of Deatsville, Kentucky. In east-central Indiana, south of Richmond, *Aulacera* occurs commonly in the Saluda and Elkhorn formations but not in the Liberty. The specimens in the region of Richmond, Indiana, mostly are of moderate size, with prominent, low, longitudinal ridges. Some specimens, such as the one figured by Plummer are four or five inches in diameter, and up to three feet long. Foerste (1919, p. 298) also reported *A. cylindrica* south of Richmond, and an intermediate form, partly ridged and partly smooth, in the Liberty formation, north of Canaan, Indiana. Specimens of *Aulacera* occur abundantly and are of largest size in the uppermost Richmond of Anticosti Island, where they may attain a diameter of 14 inches and a length of 15 feet. The genus has also been reported from Ohio, Lake St. John, Quebec, Rabbit and Club Islands, Lake Huron, Ontario, Manitoba, Akpatok Island in Ungava Bay, and Novaya Zemlya. Ozaki also found an *Aulacera,* apparently a typical specimen but smooth, in the Upper Ordovician of Shangtung. Yavorsky found ten species from the Ordovician of Russia, including three species first found in North America. The Russian specimens all seem to have small, arcuate cyst plates, as those in *A. plummeri* and pillars are rare and obscure, as is true of Indiana and Kentucky specimens. *A. undulata* has large, hemispherical cysts, and *A. radiata* has smaller and lower cysts than those of the *A. plummeri* group of species.

KEY TO SPECIES OF AULACERA

1a. Surface with vertical or spiral ridges
  2a. Ridges not making radii internally; cysts small, 0.5-1 mm. broad, not superposed
  A. plummeri Galloway and St. Jean
  2b. Ridges making radii of superposed cysts
    3a. Cysts large, 1-2 mm. broad, highly arched to semicircular .... *A. undulata* (Billings)
    3b. Cysts small, 0.5-1 mm. broad, low arc
      4a. Radii narrow, prominent .... *A. radiata,* n. sp.
      4b. Radii wide, vague *A undulatadirecta* (Yavorsky)

1b. Surface nodulose
  2c. Nodules round or oval, in vertical or spiral lines
    3c. Nodules large, at least 5 mm. diameter, 4-5 mm. high .... *A. nodulosa* (Billings)
    3d. Nodules small, 2-3 mm. diameter, 2-3 mm. high .... *A. nodulifera* (Foerste)
  2d. Nodules elongate in vertical lines
  A. intermedia (Foerste)

1c. Surface smooth, cysts small
  2e. Not overgrown by *Labechiella*-like organism
    3e. Pillars rare; cysts 2-3 times as broad as high
      4c. Coenosteum cylindrical ......*A. cylindrica* (Foerste)
        A. sibirica (Yavorsky)
      4d. Coenosteum conical ....*A. conica* (Yavorsky)
        A. vulgaris (Yavorsky)
    3f. Pillars common; cysts 3-8 times as broad as high ....*A. peichuangensis* Ozaki
  2f. Overgrown by *Labechiella*-like organism; inside like *A. cylindrica* ....*A. tenuipunctata* (Yavorsky)
    A. bacula (Yavorsky)
1d. Structures indefinite ....*A. telposensis* (Riabinin)

Aulacera plummeri Galloway and St. Jean — Pl. 3, figs. 1a, b; 2a, b; Pl. 12, figs. 1, 2, 3

Aulacera Plummer, 1843, Amer. Jour. Sci., vol. 44, p. 293, fig. 8. (U. Ord., u. Richmond, Richmond, Ind.); Schuchert, 1919, Amer. Jour. Sci., 4th ser., vol. 47, p. 293, fig. 1; Galloway, 1957, Bull. Amer. Paleont., vol. 37, No. 164, p. 422.

Aulacera plummeri Galloway and St. Jean, in Galloway, *ibid.,* p. 423, pl. 31, fig. 2; pl. 32, fig. 3; pl. 37, figs. 1a-c. (U. Ord., Saluda fm., S. of Richmond, Ind.)

Beatricea undulata Billings, 1865, (not Billings, 1857), Canadian Nat. and Geol., Ser. 2, vol. 2, p. 406, figs. 1, 2. (U. Ord., Rabbit Island, Lake Huron); Nicholson and Lydekker, 1889, Manual of Palaeontology, vol. 1, fig. 118A; Cumings, 1908, 32nd Ann. Rept. Geol. and Nat. Res., Indiana, p. 701. (U. Ord., Saluda ls., Ind.), pl. 1, fig. 1, (after Nicholson and Lydekker, 1889); Foerste, 1909, Bull. Sci. Lab. Denison Univ., vol. 14, p. 298, pl. 8, fig. 3. (U. Ord., Liberty fm., Ind. and Ky.); Yavorsky, 1955, Trudy Vsesoyuznogo Nauchno-issledovatelskogo Geol. Inst., Minister Geol. i Okhrany Nedr, nov. ser., vol. 8, p. 73, pl. 34, figs. 4, 5; pl. 35; fig. 1; pl. 36, fig. 6 .(U. Ord., Russia)

Coenosteum.—Coenosteum subcylindrical to club-shaped, usually enlarging upward, 12 to 50 cm. long, diameter 2 to 11 cm., normally 3 to 6 cm. Specimens 1-2 cm. in diameter are neanic. Plummer (1843, p. 294) reported his specimen to be about 3 feet long and 2 to 2¾ inches in diameter at the base. All specimens are fragments, generally 2 to 6 inches long, always broken at the lower end, usually also broken at the upper end, and the ends are sealed with mud, showing that the specimens were broken before burial. Surface with spiral or straight, longitudinal ridges, 5 to 10 mm. broad, 6 to 25 mm. from crest to crest, 1 to 5 mm. high. The ridges are not superposed from one latilamina to the next, as they are in *A. undulata* and *A. radiata.* Surface smooth between ridges, with small, round, blister-like plates averaging about 0.5 mm. in diameter; not papillate. The base is not preserved in any North American specimen. The apex may be conical or hemispherical. Astrorhizae absent.

Cross section.—The axial zone is 5 to 10 mm., ordinarily 6 to 8 mm., in diameter, simulating a tube, the cysts rarely grading into those of the lateral zone in size. The lateral zone consists of latilaminae or annual growth rings, 1 to 10 mm. thick, ordinarly 2 to 4 mm. thick. The skeleton is composed of small, outwardly convex cyst plates, of similar diameter vertically and circumferentially, regularly overlapping about ¼ of the subjacent plates. Each cyst plate embraces about ¼ of a circle; 6 to 10 cysts in 2 mm. radially, 2 to 5 in 2 mm. concentrically. Cyst plates tripartite, with a thin, dark, compact median layer, 0.03 mm. thick, a thin, gray, flocculent outer layer, a thick flocculent inner layer. Chambers filled with flocculent material from the cyst plates or with clear, crystalline calcite. Radial pores pierce the median and upper plates in places. Small, round, straight pillars 0.07 to 0.13 mm. in diameter, with light centers and thin, dark borders are intermittently present in the outer, mature part of the coenosteum, usually scarce, in some cases abundant (slides 299-39, 40), arising from the apex of the cysts, and continuing through several overlying cysts.

Longitudinal section.—The axial column is composed of large, thick, upwardly arched, hemispherical plates which are largely superposed. The median layers of the cysts are thin, dark and compact, extend around the column, and simulate the wall of a tube; the outer layers are flocculent and thin; the inner layers are thick, gray, flocculent, transversely fibrous, and tufted or moniliform, much like the cysts of the outer zone. Pillars in the outer layers are inclined upward about 70° to the axis, and slightly curved upward.

Comparisons.—*Aulacera plummeri* is characterized by large, low, widely spaced longitudinal ribs, by small, evenly convex and regularly imbricating cysts, and by the scarcity of pillars in the young stages. It differs from *A. undulata* in having larger ridges, small low, arched, regularly imbricating cysts, and the lack of superposition of the cysts in the ridges from one latilamina to the next, and in having long, round pillars.

After comparing the type of *Aulacera undulata* (Billings) from Anticosti Island, with topotypes of *Aulacera* from the Richmond, Indiana, area, it is apparent that the midwestern species is distinct from the Anticosti species. Because Plummer did not give a specific name to the species he discovered, we named it *Aulacera plummeri* in honor of Dr. John T. Plummer, who first named, figured, and described the genus, in 1843. Our specimens are topotypes from the upper Richmond, Whitewater, and Saluda formations, four miles south of Richmond, Indiana.

Some of the Indiana specimens have an abundance of pillars, especially in the outer part, but most of them have few pillars, even in the outer layers. Kentucky specimens from the basal Liberty formation, have few pillars, even in the outer layers, but are not consistently different from Indiana specimens, although they are slightly older and should be less specialized in size, number of pillars, and the like.

Preservation.—Most specimens are solidly infiltrated with calcium carbonate, and are as well preserved as other kinds of fossils, such as bryozoans and corals. Some specimens are crushed to half their original diameters, and other specimens are crushed at the upper end. Crushing indicates that these specimens were not fully calcified but were frail structures where they were broken from their moorings and covered with mud where we now find them.

Several specimens from Nelson County, Kentucky, were covered either directly, or after a layer of mud had accumulated, by *Dermatostroma,* in which cases the outer layer of *Aulacera* has been largely destroyed, but showing rootlike prolongations into the tissue of the *Aulacera* (specimen RB 5). In no case does the *Dermatostroma* have any organic structure, only coarsely crystalline calcite, although at the surface there are ridges, knobs and papillae as usually seen in *Dermatostroma* (RB 56). In several specimens the spiral ridges and cylindrical form are that of *A. plummeri* (RB 55, 56), but below the surface there is no organic structure, only coarsely crystalline, twinned calcite, and the central half of the specimens is calcite and iron oxide, or is empty. The ridges resembling those of *Aulacera* are mostly smooth, but in part have papillae as in *Dermatostroma papillatum*. In four specimens of *A cylindrica* the surfaces show ridges and nodules, resembling *A. nodulifera*, but outer layers are *Dermatostroma*, with ridges, nodes and papillae, with substrata of coarsely crystalline calcite or of mud, with no direct connection with the *Aulacera* which is cylindrical and not crushed. No specimens covered with *Dermatostroma* have been found in Indiana, only in Kentucky.

Type and occurrence.—From the Saluda formation, Elkhorn Creek, four miles south of Richmond, Indiana, collected by Wm. H. Shideler; Indiana University Paleo. Coll., slides 285-46; 299-35, 36; 300-9. Also found abundantly in the Liberty formation on Wilson Creek, two miles southwest of Deatsville, Kentucky, collected by Dr. Guy Campbell, of Corydon, Indiana, and Mrs. Ruth G. Browne, of Louisville, Kentucky. Reported by Foerste from Bullitt, Nelson, Marion, Casey, and Madison Counties, Kentucky. Also reported from Ohio, Ontario, and Russia. Not definitely known from Anticosti Island. It occurs also in the Richmond of Rabbit Island, three miles east of Manitoulin Island, Lake Huron, reported by Billings (1865, p. 406), and Univ. Mich. No. 6465. Rarely found in the Liberty of Indiana.

Aulacera undulata (Billings) Pl. 3, figs. 3a, b, c, d; Pl. 12, fig. 5

Beatricea undulata Billings, 1857 (for 1853-1856), Geol. Surv. Canada, Rept. Prog., p. 344; 1866, Geol. Surv. Canada, Cat. Sil. Foss. of Anticosti, p. 8, (U. Ord., Anticosti Island); Nicholson, 1886, Palaeont. Soc., vol. 39, p. 89; Whiteaves, 1897, Canadian Rec. Sci., vol. 7, p. 133; Parks, 1910, Univ. Toronto Studies, Geol. Ser. No. 7, p. 43, (part), pl. 25, fig. 1 (?); Twenhofel, 1927, Canada Dept. Mines, Geol. Surv., Mem. 154, p. 104; Foerste, in Foerste and Cox, 1936, Geol. Mag., vol. 73, p. 304. (U. Ord., Akpatok Island.)

Not *Beatricea undulata* Billings, 1865, Canadian Nat., ser. 2, vol. 2, p. 405, figs. 1, 2, (*Aulacera plummeri* Galloway and St. Jean, U. Ord., Rabbit Island, Lake Huron).

Beatricea sulcata Hyatt, 1865, Proc. Boston Soc. Nat. Hist., vol. 10, p. 19.

Aulacera undulata Galloway, 1957, Bull. Amer. Paleont., vol. 37, No. 164, p. 423, pl. 37, fig. 2. (U. Ord., Anticosti.)

Coenosteum.—Coenosteum subcylindrical, up to 10 feet, 5 in. in length and 14 inches in diameter (Billings, 1857, p. 344), usually in broken pieces, 4 to 6 cm. in diameter and 6 to 8 cm. long. Billings' type specimen is 4 to 5 cm. in diameter, in two pieces aggregating 18 cm. long before sectioning at one end. Surface with sharp, longitudinal or slightly spiral discontinuous ridges, 2 to 6 mm. high, and 5 to 10 mm. apart; small ridges are intercalated between larger ridges. Surface minutely papillate between the ridges, due to the highly arched cysts, not due to pillars nor overgrown object.

Cross section.—Axial column 6 to 7 mm. in diameter, with hemispherical cysts. Lateral zones consist of indistinct latilaminae 5 to 10 mm. thick. The skeleton is composed of large strong, outwardly convex cyst plates arranged perpendicular to the axial column. The cysts in the ridges are hemispherical, embracing ½ to ⅔ of a circle, and tend to be superposed, overlapping three-fourths or more of the preceding cyst; 0.9 to 1.8 mm. in length and two-thirds as high. Between the ridges the cysts are smaller and irregular in shape. The cyst plates have a thin, dark, compact, outer plate and a thick, flocculent, moniliform, inner layer. The chamber cavities were mostly open, now filled with coarsely crystalline calcite. There are no indications of pillars.

Longitudinal section.—The axis is composed of large, upwardly arched plates. There is no tube wall separating the axial zone from the lateral zone, but there is a sudden decrease in size of cysts. The lateral cyst plates seem to be irregularly arranged at first, then form ridges of larger more hemispherical cysts. The ridges are about 2 mm. wide and 5 or 6 mm. apart.

Comparisons.—This specimen differs from *A. plummeri,* with which it has been confused, in the larger cysts which make radial zones, not seen in *A. plummeri,* and there are no pillars.

Preservation.—The specimen is well preserved by infiltration of calcite, but the chambers are not completely filled.

Occurrence.—This species occurs in the Vauréal and Ellis Bay formations of late Richmond and Gamachian age, on Anticosti Island. Dr. Alice E. Wilson, of the Canadian Geological Survey, was kind enough to loan us a specimen marked "TYPE," and considered by the Survey to be one of J. Richardson's specimens used by Billings for his original description. It also has been doubtfully reported from the Richmondian of Manitoba. We do not find it in the region of the Cincinnati Arch.

Type.—Canadian Geological Survey, specimens Nos. 1969g, 2583 (two pieces of the same), collected by J. Richardson in 1856; not the one figured by Billings, 1865, which is *A. plummeri* from Rabbit Island, Lake Huron. Fragment, Indiana University Paleo. Coll., slides 299-88, 89, 90, 91; 300-54.

Aulacera radiata Galloway and St. Jean, n. sp. Pl. 4, figs. 1a, b; Pl. 12, fig. 4

Aulacera undulata Shimer and Shrock, (not Billings), 1944, Index Foss. of N.A. p. 63, pl. 19, figs. 19, 20. (Richmond, Anticosti Island.)

Coenosteum.—The type specimen, (No. 702A) figured by Shimer and Shrock, is a fragment 8 cm. in diameter and length. The surface has sharp intercalated, nearly straight, longitudinal ridges of different lengths, 8 to 15 mm. apart, separated by concave furrows. Surface with small contiguous papillae, which are the cysts, rather than the ends of pillars. The specimen is well preserved by infiltration of calcium carbonate, except the axial column which is largely missing and areas between latilaminae. Another specimen (No. 702B) is poorly preserved, with much recrystallized calcium carbonate, and vacuities lined with calcite; the outer 5 to 10 mm. is largely coarse crystals of calcite, but the specimen is embedded in calcareous clay, showing well the sharp ridges, 2 to 5 mm. high and 5 to 8 mm. apart.

Cross section.—The axial column is 4 to 5 mm. in diameter, and has a thick wall. The lateral zones consist of thin latilaminae, 1 to 2 mm. thick which are well preserved by infiltration of calcite (the inner and outer zones shown in Shimer and Shrock's figure are due to different preservation, not to different structure). Between latilaminae there are thin layers of calcite, imperfect cysts and thin, radial pseudopillars, all denoting imperfect calcification of the skeleton during life or possibly due to the presence of a non-calcareous parasite, similar to the parasitic *Dermatostroma costatum* and *Dermatostroma nodoundulatum* on Kentucky specimens of *Aulacera,* rather than poor preservation during fossilization. The skeleton is composed of small, arcuate cyst plates, convex outward, each cyst embracing 1/6 to 1/4 of a circle; four to five cysts in 2 mm. the broad way, and 8 to 10 in 2 mm. radially. Each cyst overlaps 1/2 or less of each subjacent cyst. The latilaminae rise sharply into narrow, radial ridges, or radii, 1 to 1.5 mm. thick, in which the cysts are smaller than those between the ridges, and there are some pillars. The rays are not solid, as seen by the eye or by the lens, but are better preserved and more highly infiltrated than the areas between the rays. The radii are from 20° to 30° apart; at the surface there are small, intercalated ridges, so they may be only 10° to 15° apart. The cyst plates are tripartite, with a dense, median layer, a thin, flocculent outer layer and a thick lower layer which completely fills the chambers. Small, round pillars, with broad bases, occur intermittently in the radial ridges. The pillars appear short and conical because they extend upward 20° to 30° from the cross section and consequently are cut obliquely.

Longitudinal, radial section.—The axial column is 4 to 6 mm. in diameter (not 13 mm., as interpreted by Shimer and Shrock, pl. 19, fig. 20); the large cysts, as wide as the column, are hemispherical in shape, not exactly superposed. The axial cyst plates are tripartite, with a thin, dense median layer, and thin upper and lower flocculent layers. The large axial cysts do not grade into the lateral cysts, but are covered by cyst plates averaging less than 1/2 mm. broad. The thin latilaminae are separated by thin layers of calcite, in which are small, flocculent pseudopillars. Round, radial pillars are developed only sporadically, and are mostly in the rays in the mature zone. They extend through a single latilamina and are inclined upward about 20° from the horizontal. Tangential sections show little of significance.

Comparisons.—*Aulacera radiata* is characterized by the sharp, straight ridges, the small, low cysts, which overlap about half of each subjacent cyst, and the narrow sharp, continuous radii. It differs from *A. undulata* in having much smaller cysts, only 1/3 the length and height of those of that species, and in the sharp, radial ridges. The cysts are only one-half the length of those of *Aulacera plummeri* in which there are no radii. *A. undulatadirecta* Yavorsky, is similar; but the radii are vague, the cysts are higher and do not overlap as much; there are no indications of pillars. Yavorsky's species appear to be a variation of *A. plummeri* rather than a distinctly different form, as is *A. radiata*.

Occurrence.—Richmondian and Gamachian, Anticosti Island.

Holotype.—Mus. Comp. Zool., Harvard College, No. 702A, and two figured slides; paratype No. 702B, and two slides. Fragment of holotype in Indiana University Paleo. Coll.; slides from 702A, 308-7, 8, 9; from 702B, paratype, 302-71, 72, 308-54.

Aulacera nodulosa (Billings) Pl. 4, figs. 2a, b; Pl. 12, fig. 6

Beatricea nodulosa Billings, 1857, (for 1853-1856), Geol. Surv. Canada, Rept. Prog., p. 344. (U. Ord., Anticosti Island); Billings, 1858, Canadian Nat., vol. 3, p. 332; 1866, Geol. Surv. Canada, Cat. Sil. Foss. Anticosti, p. 8; Nicholson, 1886, Palaeont. Soc., London, vol. 39, p. 86-90, pl. 8, figs. 4, 5; Whiteaves, 1895, Geol. Surv. Canada, Palaeozoic Fossils, vol. 3, pl. 2, p. 114; Parks, 1910, Univ. Toronto Studies, Geol. Ser. No. 7, p. 45, pl. 25, figs. 4, 5 (from Nicholson, 1886, pl. 8, figs. 4, 5); Foerste, 1924, Geol. Surv. Canada Mem. 138, p. 76. (U. Ord., Ontario and Quebec); Twenhofel, 1926, Nat. Hist., vol. 26, p. 518. (U. Ord., Anticosti Island.)

Coenosteum.—Coenosteum large, subcylindrical, usually 5 to 12 cm. in diameter (up to a foot in diameter and up to 15 feet in length, according to Billings, 1866, p. 406; p. 408, 30 feet!). The surface has large, regular, round or oval mamelons, arranged in vertical rows; 5 mm. or more in diameter, 4 to 5 mm. high (6 to 7 lines in length and half as wide, 1 to 3 lines high, Billings, 1857, p. 344), and 10 mm. from center to center. The mamelons are not developed in the syntype until the axial diameter is nearly 40 cm., so that neanic specimens may not be distinguishable from the young of *A. nodulifera.* The cyst plates at the surface appear as little knobs, 1/2 to 1 mm. in diameter. Astrorhizae absent.

Cross section.—The axial zone is 6 to 15 mm. in diameter, not simulating a tube in the syntype, as is mostly true for the genus, but the large, axial cysts grade into the small, lateral cysts. The lateral zones consist of latilaminae, 2 to 3 mm. thick, demarked by small cyst plates. The skeleton is composed of small, outwardly arcuate cyst plates, embracing 1/4 to 1/3 of a circle; 1/2 to 1 mm. broad and 1/2 as high. Each plate overlaps about 1/4 of the subjacent plates. The cyst plates are smallest and closest together at the junction of the latilaminae. The cyst plates are tripartite, with a thin, dense, median layer, a thick lower, flocculent layer, and a thin upper flocculent layer. The mamelons are not superposed from one latilamina to the next, and do not form mamelon columns nor radii.

Longitudinal section.—The axial column consists of large, hemispherical cysts. In the lateral zone, long, thin pillars are directed outward and upward at 20° to 30° from the horizontal, on one side of the syntype, in which they occur in the outer 10 mm. Some pillars appear to intersect as they turn outward in the mamelons. The pillars might be mistaken for tubes, for they were originally composed of loosely compacted material, as in many genera of the Labechiidae, and upon infiltration and crystallization, the pillars lost their original structure, and now appear as clear, granular calcite, much like the chamber fillings. Nicholson (1886, pl. 8, fig. 4) showed pillars in the first published figures of this species. The light, radial streaks of the inner layer of the cysts, shown by Nicholson (fig. 5), are a common feature of the genus; the light streaks were pores, and they extend through the median and upper cyst plates of this and other species of the genus.

Comparisons.—*Aulacera nodulosa* is characterized by the large mamelons. The nodules of the midwestern form, *A. nodulifera,* are smaller than they are in *A. nodulosa.* The small cysts and sporadic development of pillars are usual for the genus.

Occurrence.—*A. nodulosa* occurs in the Vauréal and Ellis Bay formations, latest Richmond and Gamachian of Anticosti Island, and the Stony Mountain formation of Manitoba. It has not been reported from the Upper Ordovician of Indiana, Ohio, or Kentucky.

Dr. Alice E. Wilson, of the Canadian Geological Survey, kindly loaned us a median slice of one of Billings' syntypes (No. 1971), from which we made four thin sections, on which much of the above description is based. She also loaned us a large specimen from Manitoba, with large nodes, but the interior was entirely destroyed.

Syntype.—Canadian Geol. Surv., No. 1971, and a thin section; Indiana University Paleo. Coll., slides Nos. 299-85, 86, 87.

Topotype.—Yale Peabody Mus. No. 19556, and 9200A, and thin sections; Indiana University Paleo. Coll., fragment and slides Nos. 302-38, 75.

Aulacera nodulifera (Foerste) Pl. 4, figs. 3a, b; Pl. 12, fig. 7

Beatricea nodulifera Foerste, 1909, Bull. Sci. Lab. Denison Univ., vol. 14, p. 299, pl. 7, fig. 13, pl. 8, fig. 5. (U. Ord., basal Liberty fm., 3 mi. southeast of Lebanon, Ky.); Parks, 1910, Univ. Toronto Studies, Geol. Ser., No. 7, p. 47, pl. 25, fig. 10.

Beatricea nodulosa Nicholson (not *B. nodulosa* Billings), 1886, Palaeont. Soc. London, vol. 39, p. 87, pl. 8, figs. 1-3. (U. Ord., Marion Co., Ky.); Shimer and Shrock, 1944, Index Fossils of N. A., p. 63, pl. 19, fig. 17. (Locality not given.)

Beatricea conosimilis Yavorsky, 1955, Trudy Vsesoyuznogo Nauchno-issledovatelskogo Geol. Inst., Minister Geol. i Okhrany Nedr, nov. ser., vol. 8, p. 78, pl. 40, fig. 1. (U. Ord., Urals.)

Coenosteum.—Coenosteum of moderate size, 4 to 5 cm. in diameter and in fragments 10 to 15 cm. long. Surface with small mamelons; 3 mm. in diameter, and 5 to 7 mm. apart laterally, round or oval lengthwise of the stem, and arranged in vertical or slightly spiral rows. Between the mamelons there are small papillae. Latilaminae 2 to 5 mm. thick. Astrorhizae absent.

Cross and vertical sections.—The axial column is 10 mm. in diameter and in fragments 10 to 15 cm. long. Surface with small superposed cysts. Lateral zones composed of latilaminae 2 to 4 mm. thick. Small, regularly arcuate cysts embrace 1/6 to 1/4 of a circle, 4 in 2 mm. broad and half as high. The cyst plates are tripartite, with a thin, dark, dense, median layer, a thin, upper flocculent layer, and a thick lower flocculent layer nearly filling the chamber. Each cyst overlaps about 1/3 of each subjacent cyst. Small, long, narrow pillars, which are intermittent in the outer part of the lateral zone, are common but are difficult to detect. They are inclined upward 20° to 30° from the horizontal.

Comparisons.—This species is characterized by the small nodes. The cysts, pillars, and axis appear to be identical with those of *A. plummeri*, *A. intermedia*, and *A. cylindrica*. The nodes are much smaller than those of *A. nodulosa* (Billings), who said (Billings, 1857, p. 344), "The surface of this species is covered with oblong, oval, or sub-triangular projections from one to three lines in height."

Occurrence and hypotypes.—This species occurs sparingly in the Liberty formation near Lebanon and Bardstown, Kentucky. We have two specimens, apparently typical of *A. nodulifera*, one from the upper Richmondian, Vauréal formation of Anticosti Island, Yale Peabody Mus., No. 9200B, and thin sections, Indiana University Paleo. Coll., fragment and slides 302-35, 73, and one from the Richmondian, Anticosti Island, Museum of Comparative Zoology, Harvard University (no number), and one slide; fragment in Indiana University Paleo. Coll., and slide 302-67.

Aulacera intermedia (Foerste) Pl. 4, fig. 4; Pl. 12, fig. 8

Beatricea nodulifera intermedia Foerste, 1909, Bull. Denison Univ. Sci. Lab., vol. 14, p. 300, pl. 8, figs. 4a, b. (U. Ord., Liberty fm., Marion Co., Ky.); Parks, 1910, Univ. Toronto Studies, Geol. Ser. No. 7, p. 47, pl. 25, fig. 9. (From Foerste.)

Coenosteum.—Coenosteum cylindrical, slightly tapering. Three incomplete specimens are 24 to 40 mm. in diameter. Surface with vertically elongate nodules, arranged in slightly twisted, longitudinal rows. Nodules 3 to 5 mm. from crest to crest, 0.5 mm. high, 1.0 to 1.5 mm. wide, and 3 to 12 mm. long. Astrorhizae absent.

Cross and vertical sections.—Latilaminae 2 to 4 mm. thick. The axial zone is about 5 to 10 mm. in diameter and consists of large cysts, variable in size, 2 to 7 mm. broad, 1 to 6 mm. high, which grade into the lateral cysts in one specimen and make a tube in another. The lateral cysts are highly arched and variable in size from axis to periphery, 0.2 to 2 mm. broad, averaging 0.5 mm. and half as high. The cystose plates consist of a thin, dense, median primary plate, a thin, flocculent upper layer, and a thick flocculent lower layer. Pillars are rare in the outer latilaminae and rare or absent in the inner latilaminae.

Comparisons.—*Aulacera intermedia* (Foerste) is characterized by small, elongate nodes. The large, cystose axial zone, which does not make a tube, applies to some specimens of other species also and the cysts are the same size as for *A. plummeri*, *A. nodulifera*, and *A. cylindrica*. *A. intermedia* differs from *A. nodulifera* in surface characters.

Occurrence.—*A. intermedia* occurs sparingly in the Upper Ordovician, basal Liberty formation of Kentucky, but has not been reported from Indiana, Ohio, nor from Russia. It has been reported from Manitoba by Okulitch (1943, Trans. Roy. Soc. Canada, ser. 3, vol. 37, sec. 4, p. 62-68). We are grateful to the University of Cincinnati Museum for the loan of a typical specimen; the exact locality in Kentucky is unknown. It also occurs rarely in the lower Liberty two miles southeast of Deatsville, Kentucky.

Hypotype.—University of Cincinnati Museum, No. 17542, one slide; Indiana University Paleo. Coll., slides, Nos. 299-48, 92. Liberty formation, Wilson Creek, two mi. southwest of Deatsville, Kentucky, collected by Mrs. Ruth G. Browne, Louisville, Kentucky, specimen RB 18, slides 308-11, 57, 58.

Aulacera cylindrica (Foerste) Pl. 5, figs. 1a, b; Pl. 12, figs. 9, 10

Beatricea undulata cylindrica Foerste, 1909, Bull. Sci. Lab. Denison Univ., vol. 14, p. 298, pl. 9, fig. 7. (U. Ord., Liberty fm., Ophelia, Ky.); Parks, 1910, Univ. Toronto Studies, Geol. Ser., No. 7, p. 44.

Beatricea sibirica Yavorsky, 1955, Trudy Vsesoyuznogo Nauchno-isseldovatel-skogo Geol. Inst., Minister. Geol. i Okhrany Nedr, nov. ser., vol. 8, p. 76, pl. 38, figs. 1-6; pl. 39, fig. 1. (U. Ord., Siberia.)

Beatricea conica Yavorsky, 1955, *ibid.*, p. 74, pl. 36, figs. 3, 4; pl. 37, fig. 1; pl. 39, figs. 2, 3. (U. Ord., Siberia.)

Beatricea vulgaris Yavorsky, 1957, *ibid.*, vol. 18, p. 45, pl. 22, figs. 1, 2. (U. Ord., Novaya Zemlya.)

Coenosteum.—Coenosteum small, subcylindrical or elongate conical, up to 25 mm. in diameter, in fragments up to 100 mm. long. Surface smooth, with minute, round, convex, cyst plates. The axial column is 6 to 8 mm. in diameter, and generally occupied by a single row of large, nearly superposed, upwardly arched cyst plates. Latilaminae 2 to 5 mm. thick. Astrorhizae absent.

Cross section.—The large axial cysts are covered by smaller, outwardly convex cyst plates. In one specimen, of the 16 or more in our collections, the axis is a zone in which the largest cysts grade into the lateral cysts (Pl. 5, fig. 1b). Cysts variable in size, 4 to 6 cysts in 4 mm. horizontally, 12 to 16 cysts in 4 mm. vertically, averaging 0.8 mm. broad, and one-third as high; regularly arcuate, making 1/6 to 1/4 of a circle. Cyst plates tripartite, consisting of an upper flocculent layer 0.15 mm. thick, a dense median layer 0.03 mm. thick, and a lower flocculent or tufted layer 0.3 mm. thick which fills most of the cystose vesicles. Small, long pillars are inclined slightly upward from the horizontal and occur rarely in the outer part of the lateral zone.

Comparisons.—*Aulacera cylindrica* (Foerste) closely resembles *A. plummeri* G. and St. J., with which it occurs, but the surface is smooth rather than undulate. It may be the young stage of *A. plummeri,* but many specimen of *A. plummeri,* with ridges, are much smaller than those of *A. cylindrica.* The name is useful in referring to one of the two smooth forms of *Aulacera. A. peichuangensis* is smooth but has flatter cysts and more pillars. We see no difference between Foerste's species and those of Yavorsky. The conical form of *A. conica* is not of itself sufficient to distinguish *A. conica* from *A. plummeri* or from *A. cylindrica.*

Occurrence.—This species occurs abundantly in the Liberty formation, two miles southwest of Deatsville, Kentucky. The material was collected by Mrs. Ruth G. Browne, Louisville, Kentucky, and Dr. Guy Campbell, Corydon, Indiana. The same or similar forms occur in Russia.

Hypotypes.—Indiana University Paleo. Coll., Nos. GC4, 20; RB 30, 34, 59, 60, 61, 62, 67, 68, 69; slides 302-20, 21, 22, 23, 24, 74; 308-31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42.

Genus **PSEUDOSTYLODICTYON** Ozaki, 1938

Type species (monotypic), *P. poshanense* Ozaki, 1938, Jour. Shanghai Sci. Inst., sec. 2, vol. 2, p. 208, pl. 24, fig. 2; pl. 25, figs. 1a-e. (M. Ord., Shantung); Galloway, 1957, Bull. Amer. Paleont., vol. 37, No. 164, p. 424, pl. 32, fig. 5.

Rosenella (part) Ozaki, 1938, Jour. Shanghai Sci., sec. 2, vol. 2, p. 216, pl. 32, fig. 1 (M. Ord., Shantung).

Coenosteum massive or attached to other stromatoporoids, strongly latilaminate, composed of long, regular laminae which may be wrinkled or straight, with or without denticles, and without cysts, pillars or astrorhizae.

Middle and Upper Ordovician, China, Vermont, and Texas. Six species.

Pseudostylodictyon differs from *Rosenella* in not being composed of cysts and generally lacking denticles. The presence of mamelons and mamelon columns is a specific character; a genus may have species with columns and other species without columns.

The genus has simple structure compared with most stromatoporoids, but it is most similar to the family Labechiidae.

KEY TO SPECIES OF PSEUDOSTYLODICTYON

1a. Mamelon columns strong
  2a. Latilaminae not wavy ....*P. poshanense* Ozaki
  2b. Latilaminae wavy ....*P. ? lamottense* (Seely)
1b. Mamelon columns vague or absent
  2c. Laminae not wrinkled
    3a. Laminae 8 to 10 in 2 mm. ....*P. ? eatoni* (Seely)
    3b. Laminae 20 or more in 2 mm...*P. ? chazianum* (Seely)
  2d. Laminae wrinkled in places
    3c. Without denticles ......*P. ? kayi* Galloway and St. Jean
    3d. With denticles and corrugations ......*P. ? montoyaense* Galloway, n. sp.

Pseudostylodictyon ? lamottense (Seely) Pl. 5, figs. 2a, b

Stromatocerium lamottense Seely, 1904, Rept. State Geol. Vermont, vol. 4, p. 147, pls. 69, 72, pl. 74, fig. 1 (M. Ord., B Chazy, Fisk's Quarry, Isle La Motte, Vt.)

Exterior.—Coenosteum massive in isolated masses "two to six or more feet in section," (Seely, 1904, p. 147) apparently not forming bioherms, surrounded by black limestone. The limestone is attached to the worn edge of the specimen. Surface with unequal mamelons, 3 to 6 mm. in diameter and 10 to 15 mm. apart. Astrorhizae absent.

Vertical section.—The specimens are composed of white latilaminae, 2 to 5 mm. thick and wrinkled in more or less parallel layers, and forming irregular mamelon columns 2 to 6 cm. long. The latilaminae are separated by black limestone, similar in thickness and contortion to the latilaminae, so that when the specimens are cut vertically and polished a striking, banded marble results. The banding obviously results from a winter's layer of lime mud on the living organism, which rejuvenated the next spring and formed annual layers. The banding is not the specific character, but rather the size of the wrinkles and the finer structure of the latilaminae are the specific characters. The latilaminae, the white bands, are composed of fairly regular laminae, 0.17 to 0.26 mm. thick, closely appressed, and numbering 15 to 18 in 2 mm. The laminae have a thin, dark upper layer, and a thick, flocculent lower layer, which is darker in places but is not moniliform. The lower layer is transversely fibrous in places. The laminae are not wrinkled, other than conforming to the wrinkles of the latilaminae, and do not make arcuate plates except at the top of the latilaminae where the mud stopped the growth of the organism. There are no denticles on the laminae, and there are no vertical or horizontal tubes or canals, nor astrorhizae, nor pillars.

The tangential section shows nothing diagnostic.

Comparisons.—This species differs from *P. ? eatoni* in the more wrinkled latilaminae. The size of the coenosteum and the alternating latilaminae and mud layers can scarcely be taxonomic characters. It occurs stratigraphically below *P. ? eatoni,* in the B Chazy horizon. The black limestone is composed of small euhedral crystals of calcite and smaller, rounded grains of calcite, with a thin matrix of black, carbonaceous material. *P. ? chazyanum,* from the basal or A Chazy, lacks the wrinkles of the latilaminae, and the laminae are finer.

Types.—B Chazy, Fisk's Quarry, Isle La Motte, Vermont, specimen figured by Seely, 1904, pl. 72. Our figures are from syntypes from Goodell's Quarry, collected by Seely, 1885, now in the Paleontological Collection of Middlebury College, and fragments in Indiana University, slides 301-59, 60, 61.

Pseudostylodictyon ? eatoni (Seely) Pl. 5, figs. 3a, b

Stromatocerium eatoni Seely, 1904, Rept. State Geol. Vermont, vol. 4, p. 146, pl. 71; pl. 74, fig. 2. (M. Ord., upper or C Chazy, Goodell's Ridge, south of Village, Isle La Motte, Vt.)

Description.—The following description is based on Seely's holotype in the Middlebury College Paleontological Collection.

Exterior.—Coenosteum massive, up to 20 cm. in diameter, composed of latilaminae 5 to 10 mm. thick. Surface with convex knobs 6 to 20 mm. in diameter. Astrorhizae absent.

Vertical section.—The latilaminae are broadly undulating, forming large, sharp knobs which do not make continuous mamelon columns. The latilaminae are in turn composed of fairly regular laminae, 0.12 to 0.2 mm. thick; 8 to 10 in 2 mm.; there is a thin upper layer, and a thick lower layer, which is moniliform in the type specimen (1904, pl. 71) but not conspicuously moniliform in other specimens (1904, pl. 74, fig. 2). The laminae lie mainly one on another, but there are numerous places in which the laminae are separated by clear spaces of differing width. In some places the lower layer has a transversely fibrous or porous appearance. The laminae are not wrinkled, and there are no denticles nor pillars. The laminae rise smoothly over the mamelon columns, in some cases leaving vacuities in the mamelons, but there are no astrorhizal nor axial tubes, nor are there astrorhizal canals.

Tangential section.—The tangential section shows irregular patterns made by the cut laminae.

Comparisons.—This species is simple for a stromatoporoid, lacking cysts, pillars, denticles, and astrorhizae. It is much like the type species of *Pseudostylodictyon* excepting for the monticular columns. It is much like *P. ? lamottense* from the B or middle Chazy. It might, with the other species of the genus, be considered as a calcareous alga, but there are no cells such as is usual in an alga.

Holotype.—The specimen figured by Seely, 1904, on pl. 71, in Middlebury College, Middlebury, Vt., from C Chazy horizon, Goodell's Ridge, Isle La Motte, Vt. A section from that specimen, slide 301-58, Indiana University Paleo. Coll., is figured on our Plate 5, figure 3b.

Pseudostylodicton ? kayi Galloway and St. Jean
Pl. 5, figs. 4a, b; Pl. 6, figs. 1a, b

Pseudostylodictyon kayi Galloway and St. Jean, 1957, in Galloway, Bull. Amer. Paleont., vol. 37, No. 164, p. 425, pl. 32, fig. 6. (M. Ord., middle Chazy, "Fleury" Quarry, one mile southeast of Isle La Motte village, Vt.)

Exterior.—Coenosteum massive, up to 20 cm. in diameter with latilaminae 5 to 10 mm. thick, and with large, irregularly developed, pointed mamelons 10 mm. in diameter and about 30 mm. apart. Astrorhizae absent.

Vertical section.—The laminae are fairly regular. They are 0.15 to 0.18 mm. thick, 10 or 12 in 2 mm., mostly closely appressed, but in zones of 4 to 6 laminae separated by narrow zones of calcite. The laminae have a thin dark upper layer and a thick lower flocculent or fibrous layer. In places the laminae are strongly wrinkled wtih some of the wrinkles open at the top. In addition to strong mamelons in places five to six laminae rise abruptly leaving a vacuity, as if the laminae had erupted.

Tangential section.—In places in the section there are conspicuous rings 0.14 to 0.18 mm. in diameter, made by the cutting of the wrinkles.

Comparison.—*P. ? kayi* differs from *P. ? eatoni* mainly in having wrinkled laminae; it also occurs at a lower horizon, middle instead of upper Chazy.

Occurrence and types.—The holotype, KA1, is from the middle Chazy, "Fleury" Quarry, one mile southeast of Isle La Motte village, Vermont. Collected by Marshall Kay. Indiana University Paleo. Coll., slides 300-21, 22, 23, 24. A paratype, KA5, from the same quarry, has abundant wrinkles of the laminae. Slides 300-19, 20.

Pseudostylodictyon ? chazianum (Seely) Pl. 6, figs. 2a, b

Stromatocerium lamottense var. *chazianum* Seely, 1904, Rept. State Geol. Vermont, vol. 4, p. 148, pl. 73, upper figure. (M. Ord., middle or B Chazy, South Hero, Vt.)

Exterior.—Coenosteum conical, several inches tall, composed of latilaminae 1 to 2 mm. thick; surface without regular mamelons or knobs, and without astrorhizae.

Vertical section.—Seely does not give a vertical thin section. Our description is drawn from a specimen labeled by Seely, from "A Chazy," South Hero, Vermont, although the text says "B Chazy." The specimen is somewhat silicified. The latilaminae are thin, averaging less than 2 mm., are undulating but not forming knobs, as in *P. ? eatoni,* nor wrinkles, as in *P. ? lamottense.* The laminae are thin, 0.02 to 0.03 mm. thick, numbering 20 or more in 2 mm. The laminae consist of a thin, dark upper layer and a thicker, gray, flocculent lower layer. There are no corrugations nor denticles, pillars, nor cysts.

The simplicity of this form suggests an alga, and the thin laminae of the hypotype (Pl. 6, fig. 2b) might be interpreted as cells of a calcareous alga.

Comparisons.—This species differs from *P. ? eatoni* in the thin laminae and few knobs; from *P. ? lamottense* in the thinner laminae and it lacks the wrinkled latilaminae of that form.

Types.—Syntypes were from the B Chazy horizon from Basin Harbor, Vermont, Appletree Point, South Hero, Vermont, and from Chazy, N. Y. Seely's specimens are in Middlebury College, Vermont., and part of one specimen from South Hero, Vermont, in Indiana University, slides 301-62, 63, and from the *Maclurites* beds, South Hero, ¼ mile west of Rt. 2, Grand Isle Co., Vermont, collected by Marshall Kay, 1954, specimen KB1, slides 300-30, 31, 32, 33, 34; specimen KB2, 300-35, 60, 73.

Pseudostylodictyon ? montoyaense Galloway, n. sp.

Pl. 6, figs. 3a, b

Exterior.—Coenosteum massive, more than 10 cm. in diameter. Surface smooth or papillate, without mamelons, but gently undulated, making nodes of various sizes and spacing. Latilaminae conspicuous, 2 to 8 mm. in thickness, averaging about 5 mm. Astrorhizae absent.

Vertical section.—The coenosteum is composed of laminae, which are thin, 10 to 12 in 2 mm., mostly parallel, rarely making arcuate plates. Most of the laminae consist of a lower, finely granular, nearly straight plate, and an upper plate to which are attached short, conical denticles or the upper plate is finely corrugated, making cones, 10 to 12 denticles or corrugations in 2 mm. In places the denticles and corrugations are regular and touch the overlying lamina, making oval galleries wider than high. Nodes are irregularly developed, but without axial structures common in mamelons, such as larger pillars, an axial tube or tubes and astrorhizal canals. Some places in some specimens show no denticles or wrinkles, but the laminae are flat, either directly superposed, or separated by carbonate crystals.

Tangential section.—The sections show small round spots in places which are the conical wrinkles. In other places there are annuli of laminae, indicating nodes, but not showing mamelons. Many tangential sections show no structure but granular areas.

Remarks.—The Montoya specimens have been considerably altered by calcification and dolomitization, but the structures are apparent in sections thicker than in unaltered specimens. The lack of large arcuate cyst plates is different than for *Rosenella* which is much coarser in structure. The specimens are intergrown with an alga, a sponge, and a coral in places.

Occurrence.—Abundant in the Upham formation of the Montoya group, of Upper Ordovician age, crest of Scenic Drive, El Paso, Texas, collected by R. H. Flower, 1958.

Holotype.—No. S6, and slides numbered S6, collections of the New Mexico Institute of Mining and Technology; part of holotype and slides 308-22, 23, 24, 25, in Indiana University Paleo. Coll. Paratypes Nos. S2, S3, S4, S5, S7, and S8, parts of S4 and S7 in Indiana University Paleo. Coll., and slides.

Genus **ROSENELLA** Nicholson, 1886

Type species (originally designated), *R. macrostyla* Nicholson, 1886, Palaeont. Soc., vol. 39, p. 84, pl. 7, figs. 12, 13 (Middle Silurian, Gotland); Nicholson, 1886, Ann. Mag. Nat. Hist., ser. 5, vol. 18, p. 19; Kühn, 1928, Foss. Cat., Hydrozoa, p. 46; Parks, 1907, Univ. Toronto Studies, Geol. Ser., No. 4, p. 23; No. 5, 1908, p. 42; Gorsky, 1935, Trans. Arctic Inst., vol. 28, p. 94; Ozaki, 1938, Jour. Shanghai Sci. Inst., sec. 2, vol. 2, p. 215; Yavorsky, 1955, Trudy Vsesoyuznogo Nauchno-issledovatelskogo Geol. Inst., Minister. Geol. i Okhrany Nedr, nov. ser., vol. 8, p. 67, pl. 30; Galloway, 1957, Bull. Amer. Paleont., vol. 37, No. 164, p. 424.

Coenosteum laminar or massive, composed of convex plates on which are conical denticles, or which have conical wrinkles. Plates compact, porous, or flocculent. Astrorhizae obscure. *Rosenella* differs from *Cystostroma* in the irregularity in size of the cysts and in having denticles.

Middle Ordovician, China, North America. Middle Silurian, Europe, North America. Devonian, Russia, Novaya Zemlya. About 12 species.

Rosenella cumingsi Galloway and St. Jean, n. sp. Pl. 6, figs. 4a, b

Exterior.—Coenosteum massive, at least 12 cm. in diameter. Surface not preserved, but a vertical weathered section shows latilaminae 2 to 5 mm. thick, and mamelon columns, with evenly convex mamelons 10 mm. in diameter and 5 mm. high. Astrorhizae and pillars absent.

Vertical section.—The skeleton is composed entirely of coarse arcuate cysts. Pillars are absent excepting for conical spines or denticles on the upper cyst plate. The denticles are uneven in size, thickness, and in distribution, and extend only a short way through the chambers. The cysts are irregular in shape and size; some are arcuate 1 mm. broad and ½ mm. high, but the cysts are mostly broad, irregularly undulating and low, about 8 in 2 mm. vertically, and 2 in 2 mm. horizontally. The cyst plates are tripartite, with a thin, dense median plate, 0.02 mm. thick, and a thick upper plate, 0.05 mm. thick, and a thin lower plate. The specimens have been infiltrated, recrystallized and partly silicified, so that as is usual with weathered-out specimens, the structures have been more or less destroyed, and description unsatisfactory.

Comparisons.—The tangential section shows nothing of consequence. This species is characterized by the thin, variable cyst plates, especially the thin, lower plate, and the mamelons, from which it differs from *R. woyuensis* Ozaki (1938, p. 215, pl. 31, figs. 1a-d), as well as in the stronger denticles. Such simple, as well as variable forms, cannot be distinguished with certainty. The irregularities of growth seem to be due to the rugged conditions of life.

Holotype.—Middle Ordovician, lower Trenton limestone, new lock above Amsterdam, New York, collected by Dr. E. R. Cumings, 1914; Indiana University Paleo. Coll., slides 299-66, 67; 300-84; paratype, Middle Ordovician, Black River limestone, Watertown, New York, also collected by Dr. Cumings, 1914; slide 235-21. It also occurs in the upper Black River limestone of Quebec, slides 302-43, 44, 45; from the Chaumont limestone east of McBride Bay, South Hero twp., Grand Isle Co., Vermont, 301-11-20, from the Chaumont limestone, Otter Creek, southwest of Fort Cassin, Vermont, 302-5, 6, 7, 8, and from the lower Trenton, Rockland fm., ½ mi. west of Bridge, Crown Point, New York, 302-4, 9. The Vermont and New York material was collected and presented to us by Prof. Marshall Kay of Columbia University.

Genus **LABECHIA** Edwards and Haime, 1851

Type species (monotypic), *Monticularia conferta* Lonsdale, 1839, in Murchison, Silurian System, p. 688, pl. 16, fig. 5 (Lower Silurian, Wenlock, England).

Labechia Milne-Edwards and Haime, 1851, Mon. Polyp. Foss. Terra. Paleo., p. 155, 279; Nicholson, 1879, "Tab. Corals Palaeo. Per.," p. 330, fig. 44;

1886, Palaeont. Soc., vol. 39, p. 81-84, fig. 13A, B; pl. 3, figs. 7-15; 1891, vol. 44, pl. 20, figs. 1-3; 1886, Ann. Mag. Nat. Hist., ser. 5, vol. 18, p. 11; Yavorsky, 1931, Bull. United Geol. and Prosp. Ser. U.S.S.R., vol. 50, fasc. 94, p. 1408 (Devonian age doubtful); Smith, 1932, Summ. Prog. Geol. Serv. Great Britain, for 1931, pt. 2, p. 23 (Visean, doubtfully a stromatoporoid); Ozaki, 1938, Jour. Shanghai Sci. Inst., sec. 2, vol. 2, p. 210-213, pls. 26-28; Kühn, 1939, in Schindewolf, Handbuch Paläozoologie, Band 2A, p. A50, A51; Yavorsky, 1955, Trudy Vsesoyuznogo Nauchno-issledovatelskogo Geol. Inst., Minister Geol. i Okhrany Nedr, nov. ser., vol. 8, p. 58-65, pls. 24-28, 41; *ibid.*, 1957, vol. 18, p. 29-36, pls. 13-17; Galloway, 1957, Bull. Amer. Paleont., vol. 37, No. 164, p. 427, pls. 31, 32.

Coenosteum laminar, encrusting or massive, possibly subcylindrical, consists of outwardly convex cyst plates, and large, round, long pillars. Pillars with light centers not hollow. Tissue of primary plates compact, with inner and outer flocculent layers. Surface papillate. Astrorhizae not typically developed.

Upper Ordovician and Silurian, Europe, Russia, China, North America. Upper Devonian, Russia. About 20 species.

The genus was named for Sir Henry de Labech; it is pronounced lă-bĕsh′-ĭ-ä.

KEY TO AMERICAN ORDOVICIAN SPECIES OF LABECHIA

1a. Mamelons 5 mm. in diameter or less
  2a. Cysts broad, low, thick; pillars large, *L. pustulosa* (Safford)
  2b. Cysts short, high, thin, regularly overlapping; pillars thin .... *L. huronensis* (Billings)
1b. Mamelons large, 10 mm. in diameter; pillars thick .... *L. macrostyla* (Parks)

Labechia pustulosa (Safford) Pl. 7, figs. 1a, b, 2a, b

Stromatopora pustulosa Safford, 1869, Geol. Tenn., p. 276, 285. (M. Ord., College Hill ls., Catheys fm., Nashville gr., Nashville, Tenn.)
Stromatocerium pustulosum Hayes and Ulrich, 1903, U.S. Geol. Surv. Folio 95, figs. 23, 24, (M. Ord., Catheys fm., Columbia Quadrangle, Tenn.); Bassler, 1932, Geol. Surv. Tenn., Bull. 38, p. 226, pl. 22, figs. 10, 11. (Hayes and Ulrich's figures repeated.) Wilson, C. W., Jr., 1948, Geol. Surv., Tenn. Bull. 53, p. 38, 41, 43, pl. 12, figs. 6, 7; 1949, Bull. 56, p. 119, 129, 143, pl. 12, figs. 6, 7.
?*Stromatocerium canadense* Nicholson and Murie, 1878, Jour. Linn. Soc. Zool., vol. 14, p. 223, pl. 3, figs. 9, 10. (M. Ord., Trenton, Peterborough, Ontario.)
?*Stomatocerium canadense* var. *minimum* Parks, 1910, p. 20, pl. 22, fig. 3. (M. Ord., Trenton, Frankfort, Ky.)

Surface.—Coenosteum massive, hemispherical to tuberose, up to 20 cm. in diameter and 10 cm. thick, composed of latilaminae 2 to 10 mm. thick. Surface with minute papillae, small cysts, and low conical mamelons, 5 mm. in diameter, 2 to 3 mm. high, and 10 to 12 mm. apart from center to center. Small astrorhizae with few canals may occupy the summits of the mamelons.

Vertical section.—The skeleton consists of small, slightly arched cysts ½ to 2 mm. broad and ¼ to ⅓ mm. high, the broader ones flattened and no higher than the shorter ones; each cyst overlaps ½ to ⅓ of the subjacent cysts, with a tendency to form layers of cysts only one cyst in thickness. The layers of cysts rise smoothly over the mamelons. The walls of the cysts consist of a thin, outer, dark, dense plate, 0.03 mm. thick, and a lower, thick, gray, flocculent, moniliform layer 0.16 mm. thick, leaving a narrow chamber cavity up to 0.13 mm. high, filled with clear calcite. An outer flocculent layer is thin or missing. Pillars are common, long, straight or curved, 0.10 to 0.25 mm. thick, and 4 occur in 2 mm. The pillars usually have been completely recrystallized or replaced by white calcite, rarely leaving a narrow, dark shell on the outside, and in many places cannot be detected. Astrorhizae are scarcely distinguishable in vertical sections in the mamelons and do not make vertical tubes.

Tangential section.—The cysts are cut at many angles, and many odd patterns of curves and gray masses result; around the mamelons the cyst plates curve in bands, with the cysts convex outward, presenting the same structure as seen in vertical section. The darker, abundant material in the section is the flocculent material of the lower, thick layer of the cysts. Astrorhizae are not distinguishable. Pillars are rarely distinguishable, but the few that can be recognized are round. In the Cannon limestone specimens from Flat Rock, Tennessee, which have smaller cyst plates than the typical form, the pillars are round, averaging 0.24 mm. in diameter and 0.5 mm. apart, some ringlike; the pillars surely never were hollow, but the centers have been recrystallized more than the borders (Pl. 7, fig. 2b).

Remarks.—The original locality and horizon of Safford's specimens are the College Hill limestone, in Nashville, Tennessee. "The section commences in the river beneath the wire bridge, and ascends to the top of Capitol Hill," (Safford, 1869, p. 276). The horizon of Safford's "*Stromatopora pustulosum*" has been determined to be lower and upper members of the Catheys formation, at Nashville. (Bassler, 1932, p. 109; Wilson, 1948, p. 35-44). The species was not described other than as "having conical pimple-like elevations on its surface," (Safford, 1869, p. 285). Both *Labechia* and *Cystostroma,* from the Trenton group, have mamelons, as does *Stromatocerium,* from the Black River group. These genera are distinguished by flat pillars in *Stromatocerium,* round pillars in *Labechia* and absence of pillars in *Cystostroma.* A stromatoporoid identified as *Stromatocerium pustulosum* by Hayes and Ulrich occurs abundantly in the Catheys limestone of the Columbia Quadrangle area, Tennessee; the specimen figured has slightly larger mamelons than the ones we have, but they may be the same species. Bassler (1932, p. 88) indicated that the middle part of the Cannon limestone is "filled with *Stromatocerium pustulosum*" and also (p. 112) named the middle Catheys the "*Stromatocerium pustulosum* bed" because of "many large colonies" of the species. It is much like *L. macrostyla* Parks in the strong, abundant, round pillars, but the cysts are larger, have thick lower, and less curved plates. On weathered specimens, the pillars and mamelons are first to dissolve, leaving holes. The presence of round pillars places this form in the genus *Labechia. Stromatocerium* has flat, vermicular, or irregular pillars. *Stromatocerium minimum* Parks (1910, p. 20, pl. 22, fig. 3), also from the Trenton group, has mamelons and arched cysts but no pillars, and is, therefore, *Cystostroma,* but the ostensible type specimen has large, round pillars, as in *Labechia pustulosa* (Safford).

Types and occurrence.—We have three specimens which appear to be topotypes, from which the above description is drawn, collected especially for us from Safford's type section, "beneath the wire bridge to the top of Capitol Hill" (Safford, 1869, p. 276; Wilson, 1948, p. 38, Loc. 18), from the lower four feet of the Catheys formation or *Constellaria* beds (Wilson, 1949, p. 140, 143) by Prof. C. W. Wilson, of Vanderbilt University. Indiana University Paleo. Coll., slides 302-81, 85, 92. Dr. Wilson also collected two poorly preserved specimens from the upper Catheys formation, City Quarry, Nashville, Tennessee; slides 302-86, 87. The species occurs rarely in the Bigby-Cannon limestone (Wilson, 1949, p. 119, 129) but is abundant in various layers and localities in the Catheys formation. We have parts of two specimens from the Cannon limestone of Flat

Rock, Nolensville Pike, southeast of Nashville, Tennessee, which has abundant round pillars and smaller cyst plates but it is identified with the Catheys form; slides 299-82, Pl. 7, figs. 2a, b. *L. pustulosa* also occurs at the top of the Benson formation, Valley View, Kentucky, and in the Flanagan formation, at Frankfort, Kentucky.

Labechia huronensis (Billings) Pl. 7, figs. 3a, b; 4a, b

Stenopora huronensis Billings, 1865, Canadian Geol. Surv., Pal. Foss., vol. 1, p. 185. (U. Ord., Richmond, Cape Smyth, Lake Huron, Ont.)

Not *Alveolites granulosus,* James, 1871, Cat. Foss., Cincinnati Group, p. 2. (U. Ord., Waynesville fm., Clarksville, Ohio) ; James, 1892, Jour. Cincinnati Soc. Nat. Hist., vol. 15, p. 148, fig. 9. Type, Univ. Chicago, No. 2250, vertical section by Parks, 1910, pl. 22, figs. 6, 10 (12)=*Stromatocerium granulosum* (James).

Tetradium huronense Foord, 1883, (part) Contr. Canadian Cambro-Sil. Micropal., vol. 1, p. 25, pl. 7, figs. 1, 1a. (U. Ord., Cape Smyth, Lake Huron, Ont.)

Stromatopora subcylindrica James, 1884, Jour. Cincinnati Soc. Nat. Hist., vol. 7, p. 20, fig. 1. (U. Ord., Waynesville, near Morrow, Ohio.)

Labechia ohioensis Nicholson, 1886, Palaeont. Soc., London, vol. 39, p. 31, 32, pl. 2, figs. 1, 2. (U. Ord., Waynesville, Ohio) ; 1886, Ann. and Mag. Nat. Hist., ser. 5, vol. 18, p. 13, pl. 2, figs. 1, 2. (U. Ord., Cape Smyth, Lake Huron, Ont.)

Labechia montifera Ulrich, 1886, Contrib. N. Amer. Paleont., vol. 1, p. 33, pl. 2, figs. 9, 9a. (U. Ord., Madison, Ind.) (Description and figures of internal characters are based on a specimen from the U. Ord., Waynesville, Ohio) ; Cumings, 1908, 32nd. Ann. Rept. Geol. and Nat. Res. Indiana, p. 704, pl. 1, figs. 2, 2a, 2b. (U. Ord., Saluda fm., Osgood, Ind., and Waynesville, Ohio.)

Labechia huronensis Whiteaves, 1897, Canadian Rec. Sci., vol. 7, p. 131. (U. Ord., Lake Huron and Lake Ontario, Ont.) ; Lambe, 1899, Ottawa Nat., vol. 13, p. 170.

Stromatopora indianiensis James, 1892, Jour. Cincinnati Soc. Nat. Hist., vol. 15, p. 92, (U. Ord., Elkhorn fm., 5½ mi. west of Connersville, Ind.)

Labechia subcylindrica Parks, 1910, Univ. Toronto Studies Geol. Ser. No. 7, p. 27, pl. 23, figs. 3, 4, 6, 7. James' type, from the Waynesville fm., Morrow, Warren Co., Ohio, in Walker Mus., University of Chicago, No. 1199.

Stromatocerium indianaense Foerste, 1916, Bull. Sci. Lab. Denison Univ., vol. 18, p. 302.

Stromatocerium huronense Foerste, 1924, Geol. Surv. Canada, Mem. 138, p. 74, pl. 2; pl. 3, fig. 2 is a *Stromatocerium.* (U. Richmond, Cape Smyth, Manitoulin Island, Canada).

Exterior.—Coenosteum massive, hemispherical or conical, up to 27 cm. in diameter and 12 cm. high. The mamelons are small round, dome-shaped, 2 to 3 mm. high, 2 to 5 mm. in diameter and 5 to 8 mm. apart; the surface may appear smooth because the mamelons are covered with rock, or have been broken off. Papillae are variable, from 4 to 24 may occur in 10 mm., averaging 16 in 10 mm. Latilaminae are prominent, from 2 to 10 mm. thick, often separated by layers of mud. Specimens with mamelons 5 to 8 mm. in diameter and nearly as high, with large, round pillars which diverge in each mamelon, are *L. macrostyla* Parks.

Vertical section.— The coenosteum displays arched cyst plates and long pillars. There are seven to nine cyst plates in 2 mm. vertically, and two to four plates in 2 mm. horizontally. The cyst plates are composed of a thin outer, compact layer 0.02 to 0.05 mm. thick, a thick, secondary, flocculent lower layer, which is 0.10 mm. thick, or which may fill the entire cystose vesicle; the outer, flocculent layer is thin. The pillars vary from 0.2 to 0.3 mm. thick. Three to five pillars occur in 2 mm., they extend through several rows of cysts, and may be slightly curved. The pillars are composed of loosely aggregated, granular material which tends to be arranged in vertical rows. There is no outside wall on the pillars, and the pillars are not hollow as considered by Nicholson (1886b, p. 13). There may be mamelon columns through one or several latilaminae, but some specimens do not show mamelons in section. In some specimens there are groups of dividing and flaring pillars (Galloway, 1957, p. 393, pl. 36, fig. 9, slide 285-80), which we interpret as pathologic not a taxonomic character.

Tangential section.—The pillars are round, of variable size, 0.15 to 0.4 mm. in diameter, and joined by the cyst plates in an irregular manner. The pillars have no walls and are not hollow. Some pillars join into stellate aggregates. Astrorhizae small, not usually developed. In poorly preserved specimens, the pillars and even the cysts may not be seen in the tangential section.

Remarks.—*Labechia huronensis* has been given many names, mainly because different authors could not recognize the species of Billings, and species were differentiated only by external shape. Much confusion also has resulted from descriptions based on specimens from widely spaced localities. For example, Ulrich (1886, p. 33) used a specimen from Madison, Indiana, to describe the external characteristics; and a specimen from Waynesville, Ohio, to describe and figure the internal characteristics of his *L. montifera.* Nicholson

(1886, p. 21) also named *L. ohioensis* for a specimen from Waynesville, Ohio. Later the same year, in another article, Nicholson (1886b, p. 13) based the description and figures of *L. ohioensis* on a specimen from Cape Smyth, Lake Huron, Ontario, which is a topotype of *L. huronensis* (Billings). This is the nearest to an authentic figure of *L. huronensis* (Billings) we know of. To add further confusion to the matter, Billings' type is a composite, consisting of *L. huronensis* growing on a *Tetradium,* a condition not recognized by either Billings nor Foord (1883, p. 25) and first pointed out by Foord in Nicholson (1886b, p. 14). Billings' type has apparently been lost; it is not in the Canadian Geological Survey Museum.

Comparisons.—*L. huronensis* has many small pillars, and smaller and more curved cysts than *L. pustulosa* (Safford) from the Trenton. The pillars are frequently poorly preserved and it takes several slides to determine the shape of the pillars. *L. macrostyla* Parks has many large pillars, as well as large mamelons. *L. huronensis* differs from the Silurian species of *Labechia* in having smaller pillars. It is a typical *Labechia* and not *Stromatocerium* which has flat pillars. At the type locality it occurs with a *Stromatocerium.* The identity of *L. huronensis* is based on Nicholson's figure of a topotype furnished by Foord (1886b, p. 14, pl. 2, figs. 1, 2), and on a topotype collected and figured by Foerste (1924, pl. 2, fig. 2.) The pillars in Foerste's specimen are abnormally large, up to 0.4 mm. in diameter, about as large as they are in *L. macrostyla* Parks, but the mamelons are smaller, and the pillars do not diverge in the mamelon columns.

Occurrence.—*Labechia huronensis* occurs at the localities given in the synonomy. It also occurs commonly in the Waynesville at Waynesville, Morrow, Clarksville, and Wilmington, Ohio. We have specimens from the Upper Ordovician, Saluda, and Whitewater formations in Indiana, and it seems to be an index fossil of those horizons. It occurs in abundance at the damsite in Muscatatuck State Farm; in the Versailles State Park, Ripley County; in the Tri-County Quarry, northwestern Switzerland County, and three miles west of Madison, Jefferson County, all in Indiana. It is the most common of the stromatoporoids in the Richmond group. Specimens indistinguishable from *L. huronensis* occur in the upper Maysville at the old Agawam Station on the L. & N. R. R., Clark Co., Kentucky, slides 301-30, 31; 308-64, 65, 66, 67, 77, 78, 79.

Topotype.—Foerste's specimen from Cape Smyth, Manitoulin Island, Geol. Surv., Canada, No. 5596, 3 slides; Indiana University Paleo. Coll., slides 308-96, 97. *Hypotype,* slide 299-33. Typical specimen, slide Nos. 278-20; 282-33, 99, 100; 285-47, 48, 49, 50, 73, 79, 80; 299-32-34, 38, 41, 96-100; 300-1, 2, 21, 22, 23, 24, 33, 34, 35, 36, 37, 38, 39, 40, 41, 77, 78, 79, 80; 302-39, 40, 41; 308-1-6, 89, 90, 91, 92, 93, 94, 95.

Labechia macrostyla Parks Pl. 8, figs. 1a, b

Labechia macrostyla Parks, 1910, Univ. Toronto Studies, Geol. Ser. No. 7, p. 25, pl. 22, fig. 12 (incorrectly numbered fig. 10); pl. 23, figs. 1, 2, 11. ("Lower Trenton Drift," Ann Arbor, Mich.)

Exterior.—Coenosteum massive, up to at least 10 cm. in length, composed of latilaminae, 5 to 10 mm. thick. Surface with large, dome-shaped mamelons, 6 to 10 mm. in diameter, 4 to 6 mm. high, and averaging 10 to 12 mm. apart from center to center. At the apex of each mamelon is a small astrorhiza, with three to six radiating grooves. The surface is covered with strong papillae, the ends of the pillars, which are larger on the mamelons, where they tend to coalesce; they are round and about ¼ mm. in diameter in the depressions, and up to ½ mm. in diameter on the mamelons.

Vertical section.—Latilaminae, annual growth layers, are demarked by a concentration of flocculent material and reduced, closely spaced cyst plates, and by layers of mud. Astrorhizae do not form vertical tubes in the mamelon axes. The mamelons are confined to a single latilamina at least where there are interruptions in growth. The skeleton is composed of small, arcuate, imbricating cyst plates and abundant, large, long, round pillars. The cyst plates number about 4 in 2 mm. horizontally and 8 to 10 in 2 mm. vertically. In the holotype the cyst plates seem to consist of only one plate, but in the paratype and in other specimens, the cyst plates have thin, compact, upper plates, and thicker, lower flocculent layers, with obscure lower boundaries. The pillars are large, 0.3 to 0.4 mm. in diameter, extending through many cyst plates, diverging in the mamelons and converging between mamelons, five or six in 2 mm. The pillars have no definite outer boundaries, and are composed of gray, granular tissue, which tends to be arranged in vertical lines, much as if they were vertical rods and pores, probably layers of which the pillars are composed, but there is no axial canal (cf. Parks, 1910, p. 26).

Tangential section.—Obscure astrorhizal canals occur in the large mamelons. The cut cyst plates form an irregular reticulation, and the pillars are large, 0.2 to 0.4 mm. in diameter, abundant, mostly separated by one to two pillar diameters. The pillars are composed of granular bodies and have no definite boundaries, being fuzzy at the edges, show no indication of being hollow, but show indications of having had small, vertical pores and rods. A section across a mamelon, such as Parks' figure (1910, pl. 22, fig. 10 [12 in error]), will be oblique and will not show the shape of the pillars in transverse section.

Comparisons.—*L. macrostyla* differs from *L. huronensis,* in the larger mamelons, larger pillars, and the divergence of the pillars in the mamelons. This species occurs with *L. huronensis* in the Richmond and differs mainly in having larger mamelons, more abundant, and larger pillars. The pillars are round, but where the large pillars converge and coalesce the resulting compound pillar may be mistaken for the broad pillars of *Stromatocerium.*

Occurrence.—We have several well-preserved specimens of this species from the late Richmond, Elkhorn formation, from Elkhorn Falls, four miles south of Richmond, Indiana, and from Huffman's Dam, near Dayton, Ohio, and from the Whitewater formation, three miles west of Madison, Indiana. Typical examples occur in the Saluda formation one mile south of Milan, Indiana, and in the Waynesville formation in Ohio, but have not been reported from the Waynesville or Liberty formations of Indiana and Kentucky. It also occurs in the Leipers formation seven miles upstream from Rowena, Kentucky. It occurs in the Catheys formation of Nashville, Tennessee. It is not represented in material from the Richmond of Escanaba River, Michigan. A typical specimen, silicified but showing all structures, was collected by Dr. R. H. Flower, from the Upper Ordovician of Lone Mountain, south of Silver City, New Mexico. It occurs abundantly in the Cynthiana formation, "Strom. Zone," five miles southeast of Winchester, Kentucky. This species is unusual because of its long stratigraphic range from Trenton to late Richmond, but there seems to be no difference between the forms in the different horizons.

Lectotype.—"Lower Trenton Drift," Ann Arbor Mich.; U.S. Nat. Mus., No. 36929A, slides NM1-9, 10, collected by Dr. Carl Rominger, designated as "type specimen" by Parks (1910, p. 26), and "beautifully preserved." *Lectoparatype,* Parks pl. 23, figs. 2, 11, which is poorly preserved.

Typical specimens.—Indiana University Paleo. Coll., slides 282-59, 60; 301-25, 26, 27, 28, 29, 41, 42, 43, 44, 45, 46, 47; 302-3, 39, 40, 41; 308-14, 15, 16, 17.

Genus **STROMATOCERIUM** Hall, 1847

Type species (monotypic), *Stromatocerium rugosum* Hall, 1847, Pal. New York, vol. 1, p. 48, pl. 12, fig. 2 (M. Ord., Black River gr., Watertown, N.Y.); Seely, 1904, Rept. State Geol. Vt., vol. 4, p. 144, pl. 70; pl. 74, fig. 5; Parks, 1910, Univ. Toronto Studies, Geol. Ser., No. 7, p. 8, pl. 21, figs. 3-7; Kühn, 1928, Fossilium Catalogus, Hydrozoa, p. 47; 1939, in Schindewolf, Handbuch Paläozoologie, p. A 52, fig. 80; Galloway and St. Jean, 1955, Amer. Mus. Novitates, No. 1728, pp. 1-11, figs. 1-7 (holotype); Galloway, 1957, Bull. Amer. Paleont., vol. 37, No. 164, p. 431, pl. 33, fig. 3 (holotype).

Coenosteum hemispherical, latilaminate, composed mostly of broad cysts, some short and arcuate; pillars long, platelike or with flanges, not round. Primitive astrorhizae may occur.

Middle Ordovician, Black River, Trenton, and Cincinnatian, North America and Russia. Eight species.

KEY TO SPECIES OF STROMATOCERIUM

1a. Pillars broad, thick, diameter 0.3 mm.
  2a. Surface without mamelons ....*S. rugosum* Hall
  2b. Surface with large mamelons ....*S. tumidum* Wilson
1b. Pillars broad, thin, diameter 0.03 to 0.07 mm.
  2c. Pillars with narrow flanges
    3a. Pillars platelike, sporadic
      ....*S. canadense* Nicholson and Murie

3b. Pillars irregular in shape, abundant
4a. Pillars small, without vacuoles
..........................*S. amsterdamense* Galloway and St. Jean
4b. Pillars large, with vacuoles
..........................*S. leipersense* Galloway, n. sp.
2d. Pillars with broad flanges
3c. Cyst plates mostly straight, not overlapping
..........................*S. michiganense* Parks
3d. Cyst plates arched, overlapping *S. granulosum* (James)
2e. Pillars with few or no flanges
3e. Pillars in radial groups ....*S. australe* Parks
3f. Pillars not in radial groups
..........................*S. platypilae* Galloway, n. sp.

Stromatocerium rugosum Hall Pl. 8, figs. 2a, b, c

Stromatocerium rugosum Hall, 1847, Pal. New York, vol. 1, p. 48, pl. 12, figs. 2, 2a, 2b. (M. Ord., Black River ls., Watertown, N.Y.); Hitchcock, 1861, Proc. Boston Soc. Nat. Hist., vol. 7, p. 290, fig. 190; Chapman, 1861, Canadian Jour., new ser., vol. 6, p. 508, fig. 72; 1864, Expos. Min. Geol Canada p. 102, fig. 72; Nicholson and Murie, 1878, Jour. Linn. Soc. Zool., vol. 14, p. 222, 223; Winchell 1886, Geological Studies, p. 321, fig. 223 (from Hall's fig. 2b); Miller, 1889, North American Geol. Pal., p. 165, fig. 123; Lesley, 1890, Pennsylvania Geol. Surv., Rep. P4, vol. 3, p. 1102, text fig.; Whiteaves, 1896, Canadian Rec. Sci., vol. 7, p. 149; Seely, 1904, Rept. State Geol. Vermont, vol. 4, p. 144, pl. 70; pl. 74, fig. 5. (Ord., Isle La Motte, Vt.); Grabau and Shimer, 1909, N. A. Index Fossils, p. 46; Parks, 1910, Univ. Toronto Studies, Geol. Ser. No. 7, p. 11-15, pl. 21, figs. 3-7; Butts, 1926, Geol. Surv. Alabama, Spec. Rep. 14, p. 128, pl. 32, fig. 8; Wilson, 1948, Canada Geol. Surv. Bull. 11, p. 47, pl. 23, figs. 1-3; Shimer and Shrock, 1949, Index Fossils of N. A., p. 63, pl. 19, figs. 12, 13 (from Parks); Galloway and St. Jean, 1955, Amer. Mus. Nat. Hist., Novitates, No. 1728, 11 pp., 7 figs. (type specimen).

Stromatopora rugosa d'Orbigny, 1849-1850, Prod. Paléont. Strat. Univer., p. 26; Chapman, 1863, Canadian Jour., new ser., vol. 8, p. 197, fig. 169; Billings, 1863, Geol. Surv. Canada, Rept. Prog., p. 140, fig. 72; Billings, 1865, Geol. Surv. Canada, Pal. Foss., vol. 1, p. 213; Nicholson and Murie, 1878, Jour, Linn. Soc. Zool., vol. 14, p. 195, fig. 1, (from Billings); Lesley, 1890, Geol. Surv. Pennsylvania, Rep. P4, vol. 3, p. 1108, text fig. (after Billings, 1863).

Surface.—Coenosteum hemispherical; the type is 120 mm. in diameter, 78 mm. high and is a fragment 30 mm. thick. Parks reported coenostea up to eight inches in diameter. Surface irregular but without mamelons or distinct papillae. Astrorhizae are not observable at the surface, although they are obvious on a smoothed surface. Undulatory latilaminae are distinct on a weathered surface, 2 to 4 mm. thick, and must have been the "rugae" Hall had in mind.

The type specimen has been infiltrated with calcium carbonate, recrystallized, somewhat leached and in small part silicified, yet the structure can be satisfactorily made out. The chamber cavities are in part filled with clear, crystalline calcite, and in part filled with black, fine-grained, calcareous and carbonaceous material. The structures are white in a dark background, the reverse as seen in most stromatoporoids. The specimens from Isle La Motte mentioned by Hall (1847, p. 48) as abundant and "completely silicified," show no internal structure, as mentioned by Hall. Specimens from the solid limestone of Isle La Motte and elsewhere, are infiltrated with calcium carbonate and in part recrystallized, and structures can be seen satisfactorily.

Vertical section.— The skeleton consists mainly of broad cysts, which might be mistaken for laminae, some short, arcuate cysts, and long vertical pillars. The broad cyst plates are from 2 to 5 mm. broad, nearly flat, but are shown to be cyst plates rather than laminae, for they come down to the underlying cyst plates at the ends, and the cysts on two sides of the pillars frequently do not match. There are also narrow, arcuate cysts, ¼ to ½ mm. broad. The cyst plates are close together vertically, 7 to 10 in 2 mm. The cyst plates are tripartite, the median plate 0.05 mm. thick and composed of clear, granular calcite; the upper and lower plates are each about half as thick as the median plate, and composed of dark, finely granular, and flocculent tissue. The pillars are long, extend through one or two latilaminae; the pillars are in general straight, but they branch, bend, and some join other pillars; they are irregular in distribution, varying from 2 to 6 in 2 mm. They are narrow or broad, depending on the direction in which they are cut; where cut through the thin part of the pillar, they have a thickness of 0.12 to 0.3 mm., and when cut the broad way, the breadth runs up to 1/2 mm. or more. The pillars consist of a median zone of light-colored, finely granular calcite, the recrystallized original material, and an outer zone of dark, granular and flocculent tissue, precisely like the upper and lower layers of the cyst plates. The median cyst plate in some places joins the median zone of the pillars. We consider it unlikely that pillars or median cyst plates were hollow. Neither astrorhizal canals, tubes, nor columns are apparent in vertical sections.

Tangential section.—The pillars radiate from the mamelon centers, with short astrorhizal canals between. The astrorhizal centers are from 7 to 10 mm. apart. The astrorhizal centers do not have vertical tubes. The pillars are vermicular, variable in thickness, curve, branch, and have short, spinelike flanges, and some few pillars tend to be round. The pillars have a normal thickness of about 0.27 mm., and a normal breadth of 1 mm., but range in breadth up to 4 mm. Some of the pillars are outlined by black rims; most of the pillars are white calcite, and the interspaces or chambers are filled with dark, fine-grained material. In the early part of the latilamina the pillars are thinner than normal.

Comparisons.—*S. rugosum* is characterized by the broad cyst plates, and large pillars which radiate from the astrorhizal axes. *S. rugosum* has larger and broader pillars than any other species of the genus except *S. tumidum*. *S. canadense* may be the same species; it has thin, broad pillars.

Occurrence.—*S. rugosum* occurs in the Middle Ordovician, Black River of Watertown, New York, Escanaba River, Michigan, and has been reported from northeastern New York, northwestern Vermont, Paquette Rapids, Ontario; specimens from other localities and horizons should have identifications checked, especially those from the Trenton. It is remarkable that Seely (1904, pl. 74, fig. 5), and Parks (1910, pl. 21) correctly identified the species, considering that their specimens were not from the type locality, and neither had studied the type specimen. The above description is based on the holotype.

Holotype.—Middle Ordovician, Black River limestone, Watertown, New York. American Museum of Natural History, specimen No. 590/5, and eight thin sections, 590/5, A to H.

Stromatocerium tumidum Wilson Pl. 8, fig. 3

Stromatocerium rugosum tumidum Wilson, 1948, Can. Geol. Surv. Bull. 11, p. 47, pl. 23, fig. 3, (*S. tumidum* encrusting another stromatoporoid) ; ? figs. 6, 7, (M. Ord., Leray-Rockland beds, Paquette Rapids, Ottawa River, Ont.)

Exterior.—Coenosteum massive or tuberose. Surface with large, conical mamelons, 6 to 10 mm. in diameter, 5 to 10 mm. high, and 10 to 15 mm. apart from center to center. The surface of the type, and of a topotype we have sectioned, are silicified and so distorted by chalcedony in the form of beekite rings that smaller features have been destroyed; internally, the topotype has been in part silicified but the structures can be determined.

Vertical section.—The coenosteum is composed of latilaminae from 4 to 10 mm. thick. The skeleton is composed of thin, broad cyst plates, about 10 in 2 mm., and long, thick vertical pillars, about 5 in 2 mm. The cyst plates consist of a thin, dark, compact outer layer and a thick, flocculent, and moniliform lower plate. The earliest stage consists of arcuate cyst plates. The pillars are variable in thickness, 0.06 to 0.09 where cut the narrow way and up to 0.3 mm. where cut the broad way. Pillars have been infiltrated with calcium carbonate and recrystallized and now appear as clear calcite with no definite boundaries.

Tangential section.—Structures are obscure. The mamelons may have had astrorhizae. The pillars are thick and broad, as in *S. rugosum*.

Comparisons.—The large mamelons are the diagnostic feature.

Occurrence.—*S. tumidum* occurs at the top of the Black River and base of the Trenton, Leray-Rockland beds, Paquette Rapids, Ottawa River, Ontario, the same horizon as other typical species of *Stromatocerium*.

Topotype.—Part in the University of Cincinnati Museum, No. 22822, and part in the Indiana University Paleo. Coll., slides 299-76; 302-31.

Stromatocerium amsterdamense Galloway and St. Jean
Pl. 8, figs. 4a, b

Stromatocerium amsterdamense Galloway and St. Jean, in Galloway, 1957, Bull. Amer. Paleont., vol. 37, No. 164, p. 432, pl. 33, fig. 4. (M. Ord. Black River, Amsterdam, N.Y.)

Exterior.—Coenosteum massive; the incomplete holotype is 100 mm. wide, 70 mm. high and 30 mm. thick. Polished surfaces show low mamelons, 2 to 3 mm. in diameter and 8 to 10 mm. apart from center to center. Latilaminae are not well marked, 2 to 4 mm. thick.

Vertical section.—The skeleton consists of thin, flat cyst plates, so flat and broad that they might easily be mistaken for laminae. The cyst plates are from ½ to 5 mm. broad, thin, 0.02 to 0.03 mm., and appear to have been composed of only one layer; there are about 12 cyst plates in 2 mm. Pillars are long, mostly narrow, but variable from 0.02 to 0.2 mm in width; they widen, narrow and branch upward, and number about 6 in 2 mm. The cyst plates and pillars have been infiltrated and recrystallized, so that no original tissue remains. The cysts or interspaces are filled with dark, calcareous and apparently carbonaceous material, so that the appearance is the reverse of that of most stromatoporoids. Small low mamelons occur in the vertical section, but there are no mamelon tubes.

Tangential section.—The mamelons are conspicuous, marked by large vacuities, not astrorhizal tubes, but vacuities between latilaminae, and by pillars radiating from the mamelon centers, which are from 4 to 8 mm. apart. Vague astrorhizal canals, shown in black, radiate between the pillars, but do not clearly branch. The pillars are in general flat and thin 0.03 to 0.05 mm. thick, oval, vermicular and irregular in shape, with numerous small flanges. Some of the pillars are outlined by black borders, perhaps the original outer boundary tissue; most of the pillars are indicated by white finely granular calcite, the reverse of the original condition. There is no evidence that the pillars or the cyst plates were hollow.

Comparisons.—*S. amsterdamense* is characterized by the thin, broad cyst plates, and by the abundant small, thin, crooked and spiney pillars, as seen in tangential section. The cyst plates are also closer together, and the pillars are only one-fifth the breadth of those in *S. rugosum*. Superficially, the two species are similar, even to color and preservation.

Holotype.—Upper Black River limestone, at the new lock just above Amsterdam, New York, Indiana University Paleo. Coll., No. 4629; slides 235-11, 12; 299-44-47. The type specimen was collected by Dr. E. R. Cumings in 1914. It also occurs in the basal Trenton at Crown Point, New York (slides 302-11-14).

Stromatocerium canadense, Nicholson and Murie Pl. 9, figs. 1a, b

Stromatocerium canadense Nicholson and Murie, 1878, Jour. Linn. Soc. Zool., vol. 14, p. 223, pl. 3, figs. 9, 10. (M. Ord., Trenton ls., Peterborough, Ont); Parks, 1910, Univ. Toronto Studies, Geol. Ser., No. 7, p. 15, pl. 21, figs. 8, 9; pl. 22, figs. 1, 2.

Labechia canadensis Nicholson, 1886, Mon. Brit. Strom., pl. 2, figs. 3-5; 1891, p. 163, pl. 20, fig. 9; 1886, Ann. Mag. Nat. Hist., ser. 5, vol. 18, p. 14, pl. 2, fig. 5 (Russian specimen.)

Surface.—Coenosteum massive to laminar, some attached to other fossils. Surface with mamelons, 3 to 4 mm. in diameter, 4 to 6 mm. apart and 2 mm. high. On most mamelons there are three to five obscure, radiating grooves, qualifying as primitive astrorhizae. On and between the mamelons are prominent round papillae.

Vertical section.—There are prominent mamelons about 5 mm. apart. The skeleton consists mostly of broad, flat cysts, and of large, convex cysts in places. The cyst plates are tripartite, consisting of a median, thin, dark, compact layer, and outer, thin, light-colored, granular layer, and an inner, thick light-colored, flocculent layer. The cyst plates average about 8 in 2 mm. vertically. On the upper layer, in places, there are short, conical spines or denticles. In a few places the cyst plates are flat, close together, and without pillars of any kind. Pillars are unequally developed; mostly they are long and straight, some curved, mostly narrow, others broad, varying from none to 5 in 2 mm. The pillars are white and granular, obviously recrystallized, with dark borders, like the lower and upper plates of the cysts.

Tangential section.—Mamelons are indicated by concentric bands of cyst plates, and by radiating pillars; astrorhizae are obscure. The pillars are flat, averaging about 0.07 mm. thick, and 1 to 3 mm. broad. The pillars are vermicular and irregular, they curve, branch and have short, spinelike flanges. Some of the pillars have dark rims.

Comparisons.—The specimens have been infiltrated with calcium carbonate, and most of the skeletal material has been recrystallized. The chambers or galleries are filled with clear calcite. This form, as understood by Parks and by us, is a *Stromatocerium,* as first recognized by Nicholson and Murie, for the cyst plates are flat and the pillars are broad. The denticles on the outer plate are unusual for *Stromatocerium,* but the structures emphasize the close relationship to the labechioid genera *Cystostroma, Rosenella, Pseudostylodictyon,* and *Labechia.* The specimen from Girvan figured by

Nicholson (Mono., pl. 20, fig. 9) is likely not this genus, but a *Cystostroma*. Nicholson gave no tangential section of this species, and we have been unable to study the type specimen. Nor did Parks (1910, p. 15), in numerous specimens, determine or figure the shape of the pillars, whether round or flat, with flanges or without. Our specimens have scattered pillars, and resemble Parks' figures (1910, pl. 21, figs. 8, 9; pl. 22, fig. 1), and they also show flat pillars, much like the immature pillars of *S. rugosum* (Galloway and St. Jean, 1955, pl. 10, fig. 6). Considering the poor preservation and the great variation in the species noted by Parks (1910, p. 16), it may be that this species is really *S. rugosum* from the same horizon, showing irregular or injured growth and poor preservation. The sporadic pillars may not be a reliable character, because any species of *Stromatocerium* and *Labechia* may have places which show few or no pillars.

Occurrence.—*S. canadense* occurs at the top of the Black River and Lower Trenton, originally from Peterborough, Coutchiching, and Paquette Rapids, Ontario; it has also been reported from New York, Michigan, Kentucky, and Tennessee. We have specimens from the Black River from Fort Cassin, Vermont, and from Chazy and Pattersonville, New York, and from the lower Trenton from Escanaba River, Michigan and from the Cynthiana limestone, Cynthiana, Kentucky. Indiana University Paleo. Coll., slides 235-23; 299-65; 301-69, 70, 71, 72, 73, 74, 75, 76.

Stromatocerium leipersense Galloway and Ehlers, n. sp.

Pl. 9, figs. 2a, b

Exterior.—Coenosteum a large head, 14 cm. in diameter and 6 cm. thick. Surface nearly smooth, without mamelons or astrorhizae, but with abundant papillae, which are elongate and flanged, but not arranged in linear nor radial order. Astrorhizae absent.

Vertical section.—The skeleton is composed of straight or outwardly convex and overlapping cyst plates and long pillars. There are about four cyst plates in 2 mm. horizontally, and about 10 in 2 mm. vertically. The cyst plates appear to be composed of only one thin layer; the chambers are filled with clear calcite or with dusty appearing calcite. The pillars are continuous and variable in size, from 0.1 to 0.2 mm. thick, and some appear to split into two branches, or may cut from one flange to another in the same pillar. The pillars have round or vertically elongate vacuoles, 0.04 to 0.1 mm. in diameter. The appearance of tubules in some pillars is probably due to cutting a depression between two flanges.

Tangential section.—The pillars are irregular in size, 0.06 to 0.26 mm. thick and up to 0.6 mm. broad, irregular in shape with many short flanges. Each pillar has from one to six round vacuoles or tubules, averaging 0.05 mm. in diameter. There are also small round vacuoles outside the pillars, seen especially when the section is near the surface, and outlined by mud, in which case the vacuoles in the pillars are scarcely apparent. The pillars are arranged in haphazard manner and show no indication of astrorhizae nor mamelon columns.

Comparison.—The pillars of this species resemble those of *S. amsterdamense,* but they are larger, not arranged in radial lines, and have vacuoles.

Holotype.—A single specimen in the University of Michigan Paleontological Collections, No. 39500, Leipers formation, from the bank of the Cumberland River, opposite the downstream end of Belk Island, about seven miles upstream from Rowena, Kentucky, collected by Dr. G. M. Ehlers. Slides 01-15, 16, 17. Indiana University Paleo. Coll., slides 308-80, 81, 82.

Stromatocerium michiganense Parks Pl. 9, figs. 3a, b

Stromatocerium michiganense Parks, 1910, Univ. Toronto Studies, Geol. Ser., No. 7, p. 9, pl. 21, figs. 1, 2. (M. Ord., "Lower Trenton Drift" of Ann Arbor, Michigan.)

Exterior.—The type specimen, U. S. Nat. Mus., 56843, is now only a slab, 55x 38x 6 mm., polished on both sides. It has grown on and was overgrown by *Labechia macrostyla.* It is inconspicuously latilaminate, but there are no indications of monticules nor astrorhizae. The specimen is strongly infiltrated by calcium carbonate, the cysts and pillars recrystallized, but their shapes are well preserved.

Vertical section.—We have made three good sections of the holotype, one vertical and two tangential sections. The cyst plates are thin, 0.03 to 0.06 mm. thick, and composed of only one layer.

They are convex and overlapping or flat betweeen the pillars. There are six to eight plates vertically and up to four cyst plates horizontally in 2 mm. The pillars are long, thin where cut the narrow way, 0.07 to 0.10 mm. thick, and two to six times that thickness where cut the broad way. There are about four to six pillars in 2 mm. The pillars are composed of finely granular calcite, with thin, dark borders. Both cyst plates and pillars have been recrystallized. The cysts are smaller and closer together at the base of each latilamina. There are no indications of mamelon axes nor of astrorhizae.

Tangential section.—The pillars are thin, 0.07 to 0.09 mm., and broad, about 0.3 mm., branched so that the arms come together, making polygonal figures 0.3 to 0.4 mm. across, with frequent branches extending into the polygons, remindful of the figures made by the corallites and septa in *Tetradium,* but the polygons of the present species are not corallites. The flanges of the pillars branch at about 120°, and in places the flanges do not meet, as shown by Parks (1910, pl. 21, fig. 2).

Comparisons.—This species differs from others of the genus in the broad flanges of the pillars. It cannot be substituted as the type of *Stromatocerium* (Parks, 1910, p. 10), since *S. rugosum* Hall, 1847, is the monotypic type, and it is now well understood. The age of the only specimen known is in doubt, particularly as the type is intergrown with *Labechia macrostyla,* which occurs also in many places in the late Richmond. *Stromatocerium* is largely confined to the Black River and lower Trenton.

Type.—The holotype and only known specimen was collected by Dr. Carl Rominger from the lower Trenton Drift of Ann Arbor, Michigan. It should be looked for around Peterborough, Ontario, in the Trenton, where Nicholson and Murie found *Stromatocerium canadense.* U. S. Nat. Mus. No. 56843. Slides NM1-6, 7, 8.

Stromatocerium australe Parks Pl. 9, figs. 5a, b

Stromatocerium huronense var. *australe* Parks, 1910, Univ. Toronto Studies, Geol. Ser., No. 7, p. 24, pl. 22, fig. 11. (U. Ord., Leipers fm., Nashville, Tenn. Type U. S. Nat. Mus., No. 49507.)

Stromatocerium huronense australe Foerste, 1916, Bull. Sci. Lab. Denison Univ., vol. 18, p. 302.

Exterior.—Coenosteum massive, nodular, 7 cm. in longer diameter. Surface rough with adherent rock debris, showing mamelons in places, 5 mm. in diameter, 10 to 12 mm. apart; in places showing elongate pillars. The latilaminae are scarcely discernible; astrorhizae were not observed.

Vertical section.—The skeleton is well preserved for Ordovician forms, by infiltration of calcium carbonate. The skeleton consists of irregular arcuate cyst plates, many of which are fairly straight between pillars. The cyst plates consist of thin, dark, median plates with lower and upper thin granular plates. The pillars are mostly close together, about 4 in 2 mm. in the columns; between the columns the pillars are scarce. The pillars are mostly thin, 0.05 mm.; others, which are cut obliquely near the broad way, are much thicker and look hollow, as noted by Parks (1910, p. 24) due to lack of original calcification, as is true of the pillars of many Ordovician forms.

Tangential section.—There are mamelon columns, 4 to 8 mm. in diameter, composed of 12 to 24 radiating flat pillars, between which there are close cysts, part of which are curved inward toward the center of the column, part of which join each other, and part of which are fairly straight. The pillars have few flanges, and are from 0.1 mm. to 0.15 mm. in thickness, with irregular edges. Some of the pillars branch a few times. There appears to be no substance in the pillars other than crystallized calcite. The radiating columns show no indications of astrorhizae nor of an axial tube.

Comparisons.—This species is a real *Stromatocerium* as shown by the broad pillars. It is one of the better characterized species, but whether it is a variation of *Labechia huronensis* remains to be demonstrated. It is not unique in the variation in the number of pillars in different parts of the coenosteum; many Ordovician forms of *Stromatocerium* and *Labechia* have a variable number of pillars which Parks took to be a principle characteristic of his variety, stating that the pillars, "appear to be hollow and which fail entirely in many parts of a section, leaving vesicular tissue only," (1910, p. 24). Although we have many specimens of *Stromatocerium* from the Ordovician, including other specimens from the Leipers formation, this is the only specimen of *S. australe* we have seen. The flat pillars radiating from centers is an important characteristic, but does not occur in *Labechia huronensis,* which has round pillars, not flat, as considered by Parks, (1910, p. 23). The other specimens enumerated by Parks at the end of his original description of S. *australe,* most of which we have studied, belong to other genera and species, having no more in common than the variation in the number of pillars.

Type and occurrence.—Although Parks did not designate a type specimen, the only specimen figured is a vertical section of U.S. Nat. Mus., No. 49507, middle Cincinnatian, Nashville, Tennessee. That specimen was designated as the "Holotype" by Bassler (1915, p. 1213), and its age determined as Maysville (Leipers). The above description is drawn entirely from that specimen, of which we have five thin sections, three in the U.S. Nat. Mus., and Nos. 309-37, 38, in Indiana University Paleo. Coll.

Stromatocerium granulosum (James) Pl. 9, figs. 4a, b

Alveolites granulosus James, 1871, Cat. Foss. Cincinnati Group, p. 2. (U. Ord., Waynesville fm., Clarksville, Ohio); 1892, Jour. Cincinnati Soc. Nat. Hist., vol. 15, p. 148, fig. 9.

Stromatocerium huronensis Parks (part), 1910, Univ. Toronto Studies, Geol. Ser., No. 7, p. 20, pl. 22, figs. 6, 9, 12 (error for 10). James' type of *Alveolites granulosus.*

Exterior.—Coenosteum massive; surface with low mamelons, 4-5 mm. in diameter and 10-12 mm. apart from center to center. Latilaminae are 4 to 8 mm. thick. Astrorhizae are present but obscure. The description is drawn from a topotype similar to James' type.

Vertical section.—The skeleton is composed of thin, convex, overlapping plates and thin pillars, much as in *Labechia huronensis,* for the thin, flat pillars are rarely cut to show their breadth. There is no outer plate, and the inner plate is obscure.

Tangential section.—Some of the pillars are flat, with minute flanges, and radiate from the center of mamelons, as shown by Parks, (1910, pl. 22, fig. 12); many pillars have three radiating branches, others have broad flanges and join, making odd-shaped polygons or figures.

Comparisons.—This species has been confused with, and its characteristics have been attributed to, *Labechia huronensis* which has round pillars and which occurs higher in the Richmond. It differs from S. *michiganense* in having smaller pillars, with both broad and narrow flanges, and, in vertical section, the plates are arched and overlap.

Occurrence and types.—So far known only from the Waynesville formation near Clarksville, Ohio. The type is in the Walker Mus. Univ. of Chicago, No. 2250. A topotype, from the Fort Ancient member of the Waynesville formation, from Penquite Run, two mi. southwest of Clarksville, Ohio, from which the above description is largely drawn, is in the Mus. Paleont., University of Michigan, No. 7774, slides 01-18, 19, and a piece of the topotype in the Indiana University Paleo. Coll., slides 308-18, 19, 84, 85, 86.

Stromatocerium platypilae Galloway, n. sp.

Pl. 10, figs. 1a, b

Exterior.—Coenosteum a large head, at least 16 cm. in diameter, composed of thick latilaminae up to 15 mm. in thickness, well preserved by infiltration of calcium carbonate. The base is not preserved. Surface fairly smooth without mamelons, papillae or astrorhizae.

Vertical section.—The skeleton is composed of slightly up-arched cysts, which are thin, with thin median, lower, and upper plates. The cysts are larger and farther apart than in almost any other species of the genus, four or five in 2 mm., tending to be arranged edge to edge but many overlap subjacent cysts. Cutting through the cysts are fairly straight, flat, and thin vertical pillars. The pillars show a clear white line in the middle or on one side. The pillars number four or five in 2 mm., varying in distribution. The resulting frail skeleton had partly collapsed before fossilization, as shown at the upper left of Plate 10, figure 1a.

Tangential section.—The cysts make a pattern of oval figures, or make curved lines which show the dark median layer and the upper and lower layers. Cutting through the section in no readily apparent order, are the thin vertical pillars. They mostly show a median white layer, which is not a geometric line but is variable in width. The pillars cut through the cyst plates and join each other at various angles. There is no radial pattern nor suggestion of astrorhizae. The pillars are thin, about 0.03 mm., although they are not parallel-sided.

Comparison.—This species is a typical *Stromatocerium,* and the thin flat pillars distinguish it at once from other species of the genus. It lacks the flanges on the pillars of *S. michiganense.*

Holotype.—This type specimen was collected by Frank H. Walker, of the Kentucky State Geological Survey, Liberty formation, near Highway 30, 2½ miles northwest of Owingsville, Bath County, Kentucky. Indiana University, slides 308-20, 21, 68, 70, 71, 72, 73, 74. 78.

Genus **DERMATOSTROMA** Parks, 1910

Type species (originally designated), *Stromatopora papillata* James, 1878, The Paleontologist, No. 1, p. 1 (U. Ord., Maysville gr., Cincinnati, Ohio).

Dermatostroma Parks, 1910, Univ. Toronto Studies, Geol. Ser., No. 7, p. 29, pl. 23, figs. 8-10; Foerste, 1916, Bull. Sci. Lab., Denison Univ., vol. 18, p. 297, pl. 1, fig. 3.

Coenosteum laminar, encrusting foreign objects, 1-10 mm. thick and up to 10 cm. in diameter, consisting of several, irregular, undulating laminae, with oval chambers, the *D. papillatum* group, or of prisms, *D. ? corrugatum* group, or of clear calcite crystals with no recognizable organic structure, *D. costatum* group. Pillars large, conical, with lumina but not hollow, extending from peritheca to surface, and some short, small, solid pillars, or pillars absent. Tangential sections show round pillars becoming polygonal at their bases; tissue compact. Surface papillate, without or with small monticules, or weathered smooth. Astrorhizae unknown.

Ordovician, Black River to Richmond. North America. Thirteen species.

The surface of typical species resembles that of *Labechia,* as do the strong pillars, but the skeleton is not definitely cystose. The second group, *D. ? corrugatum, D. ? glyptum,* and *D. ? escanabaense,* has radially crystalline prisms and has no internal characacteristics of typical *Dermatostroma.* The third group, that of *D. costatum,* shows no internal structure, but a thin, structureless layer of crystals of calcite.

The forms assigned to *Dermatostroma* agree in being a thin encrustation, generally attached to other organisms, and in having papillae. They are not typical stromatoporoids.

KEY TO SPECIES OF DERMATOSTROMA

1a. Coenosteum composed of laminae and pillars; surface papillate
  2a. Surface papillate but not monticulate.
    3a. Pillars long (Cincinnatian)
      4a. Papillae uniform ....*D. papillatum* (James)
      4b. Papillae variable ....*D. diversum* Parks
    3b. Pillars short (Trenton) ....*D. cavernosum* Parks
  2b. Surface monticulate and papillate
    3c. Monticules 2 mm. in diameter ......*D. scabrum* (James)
    3d. Monticules 4 mm. in diameter...*D. canaliculatum Parks*
1b. Coenosteum composed of prisms; surface papillate
  2c. Prisms 0.4 to 0.8 mm. in diameter
    3e. Surface without sharp, vermiform ridges.
      ....*D. ? corrugatum* (Foerste)
    3f. Surface with sharp, vermiform ridges
      ....*D. ? glyptum* (Foerste)
  2d. Prisms 0.2 to 0.4 mm. in diameter
    ....*D. ? escanabaense* Galloway & Ehlers, n. sp.
1c. Coenosteum one or more wrinkled laminae lying on polygonal crystals of calcite; surface papillate
  2e. Surface costate
    3g. Costae without nodules ....*D. costatum* Galloway & St. Jean, n. sp.
    3h. Costae nodulate ....*D. nodoundulatum* Galloway & St. Jean, n. sp.
  2f. Surface monticulate ....*D. concentricum* Galloway & Ehlers, n. sp.
1d. Skeletal structure unknown; papillae elongate, in vertical rows; attached to orthoceroid cephalopod
  2g. Trenton ....*D. tyronense* Foerste
  2h. Pamelia ....*D. ottowaense* Wilson

Dermatostroma scabrum (James) Pl. 10, figs. 2a, b; Pl. 13, fig. 1

Stromatopora scabra James, U.P., 1879, The Palaeontologist, No. 3, p. 18; James, J. F., 1892, Jour. Cin. Soc. Nat. Hist., vol. 15, p. 91.

Labechia scabra Harper and Bassler, 1896, Cat. Foss. Trenton and Cincinnatian periods vicinity of Cincinnati, p. 3.

Dermatostroma scabrum Parks, 1910, Univ. Toronto Studies, Geol. Ser., No. 7, p. 31, pl. 24, figs. 1-3, (Cincinnatian, Warren Co., Ohio); Foerste, 1916, Bull. Sci. Lab. Denison Univ., vol. 18, p. 297, pl. 1, fig. 4. (Waynesville fm., Wilmington, Ohio.)

Exterior.—Coenosteum a thin encrustation on other organisms, up to 3 mm. in thickness. Surface with prominent papillae, 0.2 mm. in diameter and nearly as high, and 0.5 to 0.6 mm. apart, or 4 or 5 in 2 mm., and conical monticules 2 mm. in diameter, 1 mm. high, and 3 to 4 mm. apart from center to center. Astrorhizae absent. The name "*scabrum*" must have referred to the attached condition rather than to any rough surface feature.

Vertical section.—The skeleton is made up of three or four thick, undulating laminae, which leave irregularly oval spaces between. The laminae are nearly homogeneous, in places transversely fibrous and vaguely porous. The laminar tissue is light in color, compact, not maculate, and passes up into pillars. The pillars are elongate, conical, and extend from the thin, basal peritheca to the surface, though some pillars are discontinuous and some are superposed. The pillars are light in color, with a central lighter part, resembling ring-pillars.

Tangential section.—The tissue is light in color, mottled in appearance by crystals and finely crystalline patches of tissue. The pillars are round, from 0.1 to 0.3 mm. in diameter, largest toward the bases, where they may coalesce to form polygonal figures. The pillars have a halo of radiating tissue, surrounding a dark ring and a clear center, which is not a tube.

This species differs from *D. papillatum* in the larger papillae and the occurrence of monticules.

Occurrence.—*D. scabrum* occurs mainly in the lower Richmond of Ohio, Kentucky, and Indiana, and has been reported from the Maysville of Ohio, the Leipers of Tennessee, and the Richmond of Bentonsport, Iowa.

Hypotypes.—Miami University, No. 821, from the Leipers formation, attached to *Escharopora pavonia,* Mt. Parnassus, Columbia, Tennessee, Indiana University Paleo. Coll., slide 302-10; from the Richmond group, Kentucky end of the Madison, Indiana, bridge, attached to *Hebertella sinuata,* slide 299-50. University of Michigan, Mus. of Paleont. No. 15697, and slide; from the Upper Ordovician of Bentonsport, Iowa; and from the Cincinnatian of Lebanon, Kentucky.

Dermatostroma ? corrugatum (Foerste) Pl. 10, figs. 3a, b

Labechia (?) *corrugata* Foerste, 1910, Bull. Sci. Lab. Denison Univ., vol. 16, p. 86, pl. 1, fig. 11. (U. Ord. Whitewater fm., Dutch Creek, Wilmington, Ohio.)

Not *Dermatostroma corrugatum* Parks, 1910, Univ. Toronto Studies, Geol. Ser., No. 7, p. 34, pl. 24, figs. 7, 10, 11, 14 = *D. glyptum* (Foerste).

Coenosteum.—A flat or curved expansion, 2 to 7 mm. thick, not bifoliate, either grown on the sea bottom mud or attached to other objects. Surface papillate or smooth, the papillae variable about 3 or 4 in 2 mm., and with irregular nodes or ridges (not corrugations, as the name suggests), enclosing small papillate areas, 1.5 to 2 mm. in diameter. There are no mamelons nor astrorhizae.

Vertical section.—No vertical section has been published nor mentioned in the description. *D. corrugatum* of Parks is *D. glyptum.* Our specimen consists of one layer of vertical, contiguous prisms of fibrous, feathery calcite, 0.4 to 0.8 mm. in diameter, with the fibers diverging upward at 30 to 45 degrees from the horizontal, and darker in places, similar to the "fan structure" of the septa of Scleractinia ('Wells in Moore, Treatise on Invertebrate Paleontoloy, Part F, Coelenterata, p. F337, fig. 231). The prisms seem to be simple trabeculae (*ibid.,* p. F 251). There are no cyst plates, as in typical Labechiidae, nor laminae nor pillars, as in *D. papillatum* and *D. scabrum,* nor mere calcite crystals, as in *D. costatum* and *D. nodoundulatum.*

Tangential section.—The section consists of polygons, much the same from base to top, of fairly uniform diameter, 0.4 to 0.8 mm., radially fibrous, darker in some clusters of polygons, similar to the sclerodermites of Scleractinia (Wells, *ibid,* p. F337, fig. 231), and as well figured by Parks for *D. glyptum.* (1910, pl. 24, figs. 6, 10).

Comparison.—This species is like *D. glyptum* except for the lack of sharp, vermiform ridges. Inasmuch as *D. ? corrugatum* and *D. ? glyptum* came from the same locality and horizon, and the difference is only in the surface ridges of *D. ? glyptum,* and considering that Parks confused the two forms, it seems most probable that the two forms are the same species. The fibrous prisms, "fan structure" and sclerodermites, identical with the structure in Scleractinia, is too similar to be accidental, but it is remarkable that an Ordovician hydroid should have identical structure with a Recent coral, except for the smaller size of prisms, 0.03 mm. for Recent.

Occurrence.—Common in the Whitewater formation near Wilmington, Ohio, collected by Dr. W. H. Shideler. Topotype, Indiana Univ. Paleo. Coll., slide 308-98.

Dermatostroma ? glyptum (Foerste) Pl. 10, figs. 4a, b; Pl. 13, fig. 2

Labechia (?) *corrugata glypta* Foerste, 1910, Bull. Sci. Lab. Denison Univ., vol. 16, p. 87 (Whitewater fm., Wilmington, Ohio).

Dermatostroma glyptum Parks, 1910, Univ. Toronto Studies, Geol. Ser., No. 7, p. 33, pl. 24, figs. 4-6.

Dermatostroma corrugatum Parks, 1910, *ibid,* p. 34, pl. 24, figs. 7, 10, 11, 14. [Not *D. corrugatum* (Foerste)].

Dermatostroma glyptum Foerste, 1916, Bull. Sci. Lab. Dennison Univ., vol. 18 p. 298, pl. 1, fig. 2 (Whitewater fm., Wilmington, Ohio).

Coenosteum.—Specimens grew on muddy bottom or attached to other organisms, and are 1 to 4 mm thick. The surface is distinctive; papillae are strong and variable in size, about 3 or 4 in 2 mm. There are sporadic, long, sharp, vermicular ridges, which are the characteristic feature of the species, although the papillae are larger than those in *D. ? corrugatum.* There are small, irregular monticules, but no astrorhizae. It is unlikely that specimens may grow upward back to back, making a bifoliate structure (Parks, 1910, p. 34); more likely two or three layers develop one over the other, as in the specimen figured on Plate 10, figure 4a.

Vertical section.—One specimen (302-15) consists of three layers, of variable thickness, averaging about 1 mm., leaving irregular lacunae between. Each lamina is composed of vertical prisms, 0.4 to 0.8 mm. in diameter, each with "fan structure" and sclerodermites, similar to those in *D. ? corrugatum.* Another typical specimen (Univ. Mich. 7665) consists of one layer 2 to 4 mm. thick. There are several round centers of silicification in the middle of the layer of specimen U. M. 7665. The papillae are the rounded ends of the prisms.

Tangential section.—Since the laminae are thin the section cuts at different depths and the patterns of prisms, papillae and lacunae are not uniform. The tops of the prisms pass into papillae which are round and composed of radial fibers. The prisms have sharp, darker edges and are radially fibrous, and much of the tissue shows dark, fibrous centers (sclerodermites), and the lacunae are round to irregularly lobed.

Occurrence.—Whitewater formation, Dutch Creek, Wilmington, Ohio, collected by G. M. Austin, University of Michigan, No. 7665. Same locality, collected by W. H. Shideler, No. 815. Indiana University Paleo. Coll., part of specimen and slide 302-15.

Topotypes.—Two specimens, Indiana Univ. Paleo. Coll., slide 302-15, and Univ. Michigan Mus. Paleo., No. 7665 and slide 01-21.

Dermatostroma ? escanabaense Galloway and Ehlers, n. sp.
Pl. 11, figs. 1a, b; Pl. 13, fig. 3

Exterior.—Coenosteum encrusted on *Cystostroma minimum*, 3 to 5 mm. in thickness, consisting of one to three thick layers of vertical prisms. Surface nearly smooth with undulations, and where not weathered, with small papillae about 0.15 mm. in diameter, at the ends of the prisms. There are no mamelons nor astrorhizae.

Vertical section.—The layers are 1 to 5 mm. thick, with irregular spaces between; the papillae are preserved between layers and are contiguous, 0.18 to 0.4 mm. in diameter, averaging 0.24 mm., and composed of feathery fibers of calcite, diverging from the center to the edges of the prisms, but not making the "fan structure" as perfectly as in *D. ? corrugatum* and *D. ? glyptum*. There are indications of thick horizontal laminae or growth layers. There are no cysts, laminae, nor pillars.

Tangential section.—The section consists of polygons about 0.3 mm. in diameter, with thick-walled cylinders with light centers inside them, about 0.15 mm. in diameter. The walls of the cylinders are radially fibrous, some with smaller cells between.

Comparisons.—The prisms are scarcely half the size of those of *D. ? corrugatum* and *D. ? glyptum*, and the small rings are conspicuous in tangential section. This species resembles typical species of *Dermatostroma* mainly in the attached habit and the papillate surface.

Occurrence and type.—The holotype and only known specimen is attached to *Cystostroma minimum* (Parks), from the Middle Ordovician, Black River or Trenton, of Escanaba River, Delta County, Michigan, collected by Dr. Carl Rominger, Univ. Michigan, Museum of Paleontology, Cat. No. 39449, slides O1-23, 24. Indiana University Paleo. Coll., fragment and slides 308-98, 99.

Dermatostroma costatum Galloway and St. Jean, n. sp.
Pl. 11, figs. 2a, b; Pl. 13, figs. 4, 5, 6

Coenosteum.—Eleven specimens are cylindrical with smooth, nearly straight longitudinal ridges, of which four are nearly hollow or filled with coarse calcite, and exhibit no remnant of *Aulacera;* seven are outside of *Aulacera cylindrica* and *A. plummeri.* The specimens are from 20 to 50 mm. in diameter and from 5 to 10 cm. long. The ridges are rounded, 4 to 10 mm. across and 10 mm. apart, with rounded furrows of similar size between, and one specimen (RB11) shows papillae. There are no mamelons nor astrorhizae.

Cross section.—The inside is typical *Aulacera,* not showing any surface ridges as in *A. plummeri,* in seven specimens. The axial columns and cystose lateral structure of the *Aulacera* are well preserved, some with pillars. The outside structure of the *Aulacera* shows degeneration, the cysts are shorter, the arrangement less compact and less regularly arranged, pillars may fail, and the cysts are replaced, 1 to 5 mm. from the outside of the specimen by debris from the *Aulacera* and by clear, coarse crystals of calcite.

The outer layer, 0.2 to 5 mm. thick, the *Dermatostroma,* shows no organic structure, only *Aulacera* debris and granular calcite. In places there are toothlike processes, the papillae, which rarely occur in the specimens with smooth ridges.

Remarks.—The outer structure is deemed to be *Dermatostroma* because of the distinction from the host, the great destruction of the *Aulacera* (Plate 11, figures 2a, b; 302-19, 20), the papillae similar to those of *D. papillatum,* and the lack of similarity with algae, or any other group of organisms than the problematical stromatoporoid *Dermatostroma.*

The *Dermatostroma* appears to have been parasitic and attached to the *Aulacera* when both were alive, for the *Dermatostroma* grew entirely around the *Aulacera,* the outside cysts are disarranged, separated by the parasite, the lime of *Aulacera* was abstracted, and in no case is the *Dermatostroma* attached to a completed *Aulacera,* as would be true if the *Aulacera* had been dead and largely calcified. The *Dermatostroma* has partly to entirely absorbed the host *Aulacera,* which would not be true if the *Aulacera* had been dead long. None of the specimens has an outside shape of the cylindrical host, and in some the parasite has an oval section, whereas the *Aulacera* is cylindrical. The outside organism may be mistaken for *Aulacera plummeri.*

It may be that some of Yavorsky's species (1955, pl. 34, figs. 4, 5, pl. 40, fig. 1) are *Dermatostroma* on *Aulacera,* for one figure (pl. 34, fig. 5) shows papillae and some (1955, pl. 34, figs. 3, 6; pl. 36, figs. 3, 4; pl. 37, fig. 1) do not show cyst plates in the outer zone, but a confused mass of tissue similar to that in some of our slides (302-19, 20; 308-99).

Occurrence.—Abundant, attached to and largely replacing *Aulacera plummeri* and *A. cylindrica,* in the lower Liberty formation on Wilson Creek, two miles southwest of Deatsville, Kentucky, collected by Dr. Guy Campbell and Mrs. Ruth G. Browne.

Holotype.—From the above locality, collected by Mrs. Ruth G. Browne, Indiana University Paleo. Coll., No. RB11, slides 308-99, 100. Paratypes, RB5, 32, 33, 52, 56, GC1, 10, same locality, collector and depository; slides 302-19, 20; 308-10, 11; 309-8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20.

Dermatostroma nodoundulatum Galloway and St. Jean, n. sp.
Pl. 11, figs. 3a, b; Pl. 13, figs. 7, 8, 9

Coenosteum.—Four specimens are overgrown on four small specimens of *Aulacera.* The surface is longitudinally ridged; ridges slightly spiral, discontinuous and dividing. The ridges are mostly 3 mm. wide, 6 to 10 mm. apart and 2 mm. high. In one specimen (RB1) the ridges are 10 mm. wide, 15 mm. apart and 5 mm. high. Each ridge has oval, round or irregular nodes, about 2 mm. in diameter, 5 to 8 mm. apart along the ridges, and 1 to 2 mm. high.

The surface ridges, valleys and nodes, where well preserved, are covered with papillae; the papillae are oval vertically, about 6 in 2 mm., and 0.2 to 0.3 mm. high. Weathered surfaces show no papillae. The specimens are up to 9 cm. long and 4 cm. in diameter. Astrorhizae absent.

Cross section.—The *Aulacera* is round in section, but the *Dermatostroma* is oval in section, touching the *Aulacera* in places, in other places separated by clear calcite or by mud, from the *Aulacera*. There are in places radial clear lines resembling roots or the mycelium of a fungus, as well as clear spaces between zones of cysts. The *Dermatostroma* continued to grow on the upper surface after the host was thrown down into a horizontal position (RB75). In no place is there any definite tissue of the *Dermatostroma*, only clear calcite or a mass of disintegrated cysts (302-27). There are no pillars of either *Aulacera* or *Dermatostroma.*

Comparisons.—D. nodoundulatum differs from *D. costatum* and from other species of *Dermatostroma* in the prominent nodes. This species was at first mistaken for *Aulacera nodulifera* (Foerste), from the same general region and horizon in Kentucky, but the difference in shape and arrangement of the nodes on ridges, the papillae, the lack of continuity of the outer structures and the *Aulacera* structures inside, proves to us that the crust of the specimens is a different object than that in the inside *Aulacera.*

Types and occurrence.—Holotype, RB73, from the lower Liberty formation of Wilson Creek, two miles southwest of Deatsville, Kentucky, collected by Mrs. Ruth G. Browne, slides 302-23; 309-1, Indiana University Paleontological Collections, and three paratypes from the same locality, RB1, 74, 75. One specimen, RB1, has larger ridges and larger nodes but has papillae, and is separated from the *Aulacera* by calcite and disintegrated cysts; RB1, slides 302-24, 27.

Dermatostroma concentricum Galloway and Ehlers, n. sp.
Pl. 11, figs. 4a, b, c; Pl. 13, fig. 10

Exterior.—Coenosteum annular, 4 to 5 mm. thick, attached to a layer of calcite which in turn lies on an *Aulacera cylindrica.* The cylindrical, composite specimen is 8 cm. long, broken at both ends, and 4 cm. in diameter. Surface with low, rounded mamelons about

5 mm. in diameter, alternating in vertical rows about 10 mm. apart. The mamelons have summit irregularities but no definite astrorhizae. On and between the mamelons there are oval papillae, five or six in 2 mm., tending to be arranged in vertical rows; the papillae may be the wrinkles of the laminae but are not pointed as the wrinkles are in sections. The surface also has striations or slickensides, due to movement of the enclosing rock toward the base of the specimen as it stood in the rock; the base is not preserved.

Cross section.—The *Aulacera* has a central column of hemispherical cysts about 8 mm. in diameter, and the lateral zone of cysts is 14 mm. thick. The cysts, especially the outer ones, are about half destroyed by the parasitic attached organisms, only the thick, middle part is left intact, and some of the cysts and groups of cysts are upside down, indicating disturbance during the life of the specimen. There are no indications of pillars.

Surrounding the *Aulacera* is a cylinder of coarsely crystalline calcite, 2 to 4 mm. in thickness, which shows no organic structure of either the *Aulacera* or the outer organism.

The outer layer, 3 to 4 mm. thick, is an entirely different organism. It consists of eight concentric laminae. Each lamina is one granular or flocculent layer. Each lamina is regularly wrinkled, in places rising into denticles, from two to six in 2 mm., averaging 4 in 2 mm. Each wrinkle rises about halfway across the interlaminar space, rarely touching the overlying lamina, so that no solid structures as pillars, hold the laminae apart. There are neither pillars, pores, tubes nor fibers in the laminae. The innermost lamina lying on the calcite annulus is imperfectly formed, wrinkles are not apparent, but there are imperfect, radial pseudopillars, like those in parasitic specimens of *Dermatostroma* and in other parasitized species of *Aulacera*. There is no peritheca; it looks as if the calcite annulus were a part of the *Dermatostroma* which was parasitic on the *Aulacera* during the lives of both forms.

Longitudinal section.—Sections cut lengthwise of the specimen (Pl. 11, fig. 4b), show laminae, no cysts, and denticles in places are as numerous as the wrinkles; in places the laminae show two layers of granular tissue.

Tangential section.—The denticles and tops of wrinkles are round, 0.2 to 0.3 mm. in diameter and separated by a distance of half their diameter; they are composed of granular tissue without definite walls; some wrinkles make rings about 0.4 mm. in diameter with large, clear centers. A mamelon shows scattered oval or round patches of granular tissue in a clear calcite groundmass. There are no indications of astrorhizal canals.

Comparisons.—This species differs from other species of *Dermatostroma* in having larger and more regular laminae, more regular wrinkles, and denticles. It resembles "*Labechia?* sp. (Gen. et sp. nov?)" Ozaki (1938, p. 213, pl. 27, figs. la-e), but the wrinkles do not make loops as in Ozaki's form, and there are no continuous pillars. It does not have the cysts of *Rosenella;* it is like *Dermatostroma* in its parasitic habit and papillae, and in the concentric laminae and wrinkles, much as in *Dermatostroma costatum* (309-14).

Occurrence and holotype.—The only specimen known was collected by Dr. Carl Rominger in 1903 from the upper Richmond, at Blackbridge, 10 miles upstream from Louisville, Kentucky, University of Michigan, Museum of Paleontology, section 01-25. Indiana University Paleo. Coll., sections 308-62, 63.

CHECK LIST OF ORDOVICIAN GENERA AND SPECIES OF STROMATOPOROIDEA

Valid names are in Roman type; synonyms, unrecognizable forms and forms belonging to other genera are in italics; names in parentheses have been changed. An asterisk denotes species occurring in North America.

Actinostroma Nicholson, 1886b, not in Ordovician
Actinostroma ? sp. indet. Ozaki, 1938=Labechiella ohsei (Sugiyama), 1941
Actinostroma ? mingshankouensis Ozaki, 1938=Labechiella mingshankouensis (Ozaki)
Actinostroma ? trentonense Ulrich and Everett, 1890, a calcareous sponge
Actinostroma trentonensis Weller, 1903=Solenopora compacta (Billings), 1865, an alga
Alveolites Lamarck, 1801, a coral
Alveolites granulosus James, 1871=Stromatocerium granulosum (James)
Aulacera Plummer, 1843
Aulacera bacula (Yavorsky), 1955; (*Beatricea bacula* Yavorsky)
Aulacera ? conica (Yavorsky), 1955; (*Beatricea conica* Yavorsky)
Aulacera consimilis (Yavorsky), 1955; (*Beatricea consimilis* Yavorsky)
*Aulacera cylindrica (Foerste), 1909; (*Beatricea undulata cylindrica* Foerste)

*Aulacera intermedia (Foerste), 1909; (*Beatricea nodulifera intermedia* Foerste)
*Aulacera nodulifera (Foerste), 1909; (*Beatricea nodulifera* Foerste)
*Aulacera nodulosa (Billings), 1857; (*Beatricea nodulosa* Billings)
Aulacera peichuangensis Ozaki, 1938
*Aulacera plummeri Galloway and St. Jean, 1957; (Aulacera Plummer, 1843, no specific name)
*Aulacera radiata Galloway and St. Jean, n. sp.
Aulacera sibirica (Yavorsky), 1955; (*Beatricea sibirica* Yavorsky)
Aulacera sp. Plummer, 1843=Aulacera plummeri Galloway and St. Jean, 1957
Aulacera telposensis (Riabinin), 1939; (*Beatricea telposensis* Riabinin)
Aulacera ? tenuipunctata (Yavorsky), 1955; (*Beatricea tenuipunctata* Yavorsky)
Aulacera tenuitextilis Yavorsky; (*Beatricea tenuitextilis* Yavorsky)
*Aulacera undulata (Billings), 1857; (*Beatricea undulata* Billings)
Aulacera undulatadirecta (Yavorsky), 1955; (*Beatricea undulatadirecta* Yavorsky)
Beatricea Billings, 1857=Aulacera Plummer, 1843
Beatricea bacula Yavorsky, 1955=Aulacera bacula (Yavorsky), 1955
Beatricea conica Yavorsky, 1955=Aulacera ? conica (Yavorsky), 1955
Beatricea conosimilis Yavorsky, 1955=Aulacera conosimilis (Yavorsky)
Beatricea gracilis Ulrich in Foerste, 1920=Cryptophragmus gracilis (Ulrich)
Beatricea nodulifera Foerste, 1909=Aulacera nodulifera (Foerste)
Beatricea nodulifera intermedia Foerste, 1909=Aulacera intermedia (Foerste)
Beatricea nodulosa Billings, 1857=Aulacera nodulosa (Billings)
Beatricea regularis Stearn=Aulacera cylindrica (Foerste)
Beatricea sibirica Yavorsky, 1955=Aulacera cylindrica (Foerste)
Beatricea sulcata Hyatt, 1865=Aulacera undulata (Billings), 1857
Beatricea telposensis Riabinin, 1939=Aulacera telposensis (Riabinin)
Beatricea tenuitextilis Yavorsky,=Aulacera tenuitextilis (Yavorsky)
Beatricea tenuipunctata Yavorsky, 1955=Aulacera ? tenuipunctata (Yavorsky)
Beatricea undulata Billings, 1857=Aulacera undulata (Billings)
Beatricea undulata (Billings) Nicholson and Lydekker, 1889=Aulacera undulata (Billings)
Beatricea undulata cylindrica Foerste, 1909=Aulacera cylindrica (Foerste)
Beatricea undulatadirecta Yavorsky, 1955=Aulacera undulatadirecta (Yavorsky)
Beatricea vulgaris Yavorsky, 1957=Aulacera cylindrica (Foerste)
Cladophragmus Raymond, 1931=Cryptophragmus Raymond, 1931
Cladophragmus bifurcatus Raymond, 1931=Cryptophragmus bifurcatus (Raymond)
Cryptophragmus Raymond, 1914
*Cryptophragmus antiquatus Raymond, 1914
*Cryptophragmus arbusculus Bassler, 1932
*Cryptophragmus bifurcatus (Raymond), 1931; (*Cladophragmus bifurcatus* Raymond)
*Cryptophragmus gracilis (Ulrich) in Foerste, 1920; (*Beatricea gracilis* Ulrich)
Cryptophragmus gracilis Yavorsky, 1955=doubtful stromatoporoid
*Cryptophragmus parallelus (Raymond), 1931; (*Thamnobeatricea parallela* Raymond)
*Cryptophragmus ? rochensis Wilson, 1932
Cystostroma Galloway and St. Jean, 1957
*Cystostroma fritzae Galloway and St. Jean, n. sp.
*Cystostroma minimum (Parks), 1910: (*Stromatocerium canadense minimum* Parks)
*Cystostroma simplex Galloway and St. Jean, 1957
*Cystostroma vermontense Galloway and St. Jean, 1957

Dermatostroma Parks, 1910
*Dermatostroma canaliculatum Parks, 1910
*Dermatostroma cavernosum Parks, 1910
*Dermatostroma concentricum Galloway and Ehlers, n. sp.
*Dermatostroma ? corrugatum (Foerste), 1910; (*Labechia ? corrugata* Foerste)
*Dermatostroma costatum Galloway and St. Jean, n. sp.
*Dermatostroma ? escanabaense Galloway and Ehlers, n. sp.
*Dermatostroma delicatula (Parks) 1908; *Labechia delicatula* Parks, 1908 (Silurian)
*Dermatostroma diversum Parks, 1910; (*Dermatostroma papillatum diversum* Parks)
*Dermatostroma ? glyptum (Foerste), 1910; (*Labechia corrugata glypta* Foerste)
*Dermatostroma nodoundulatum Galloway and St. Jean, n. sp.
Dermatostroma ottawaense Wilson, 1948=Dermatostroma tyronense Foerste
*Dermatostroma papillatum (James), 1878; (*Stromatopora papillata* James)
Dermatostroma papillatum diversum Parks, 1910=Dermatostroma diversum Parks
*Dermatostroma scabrum (James), 1879; (*Stromatopora scabra* James)
*Dermatostroma tyronense Foerste, 1912
Labechia Edwards and Haime, 1851
*Labechia antiqua Wilson, 1948
*Labechia australis (Parks), 1910; (*Stromatocerium huronense* var. *australe* Parks)
Labechia canadensis (Nicholson and Murie), 1878 = Stromatocerium canadense Nicholson and Murie
Labechia changchiuensis Ozaki, 1938
Labechia ? chingchiachuangensis Ozaki, 1938
Labechia coreanica Yabe and Sugiyama, 1930
Labechia corrugata Foerste, 1910=Dermatostroma corrugatum (Foerste)
Labechia corrugata glypta Foerste, 1910=Dermatostroma glyptum (Foerste)
Labechia granulosa (James), 1871=Labechia huronensis (Billings)
*Labechia huronensis (Billings), 1865; (*Stenopora huronensis* Billings)
*Labechia macrostyla Parks, 1910
Labechia montifera Ulrich, 1886=Labechia huronensis (Billings), 1865
Labechia ohioensis Nicholson, 1886=Labechia huronensis (Billings), 1865
*Labechia pustulosa (Safford), 1860; (*Stromatopora pustulosa* Safford)
Labechia regularis Yabe and Sugiyama, 1930
Labechia regularis tenuis Yabe and Sugiyama, 1930
Labechia regulata (Endo), 1932; (*Stromatocerium regulatum* Endo)
Labechia shanhsiensis Yabe and Sugiyama, 1930; (*Labechina shanhsiensis* Yabe and Sugiyama)
Labechia ? sp. Ozaki, 1938 = Rosenella or Pseudostylodictyon
Labechia variabilis Yabe and Sugiyama, 1930
Labechiella Yabe and Sugiyama, 1930
Labechiella mingshankouensis (Ozaki), 1938; (*Actinostroma ? mingshankouensis* Ozaki)
Labechiella ohsei (Sugiyama), 1941; (*Labechiellata ohsei* Sugiyama)
Labechiellata Sugiyama, 1941, typographical error for Labechiella
Labechiellata mingshankouensis (Ozaki), Sugiyama, 1941, in error for Labechiella mingshankouensis (Ozaki), 1938
Labechiellata ohsei Sugiyama, 1941=Labechiella ohsei (Sugiyama)
Labechina shanhsiensis Yabe and Sugiyama, 1930,=Labechia shanhsiensis Yabe and Sugiyama, 1930, (*lapsus calami*)
Lophiostroma Nicholson, 1891
Lophiostroma ? sp. indet. Ozaki, 1938
Lophiostroma ? shantungensis Yabe and Sugiyama, 1930

Ludictyon Ozaki, 1938,=Sinodictyon Yabe and Sugiyama, 1930
Ludictyon vesiculatum Ozaki, 1938=Sinodictyon vesiculatum (Ozaki), 1938
Plumatalinia Nestor, 1960
Plumatalinia ferax Nestor, 1960
Pseudolabechia Yabe and Sugiyama, 1930
Pseudostylodictyon Ozaki, 1938
*Pseudostylodictyon ? chazianum (Seely), 1904; (*Stromatocerium lamottense chazianum* Seely)
*Pseudostylodictyon ? eatoni (Seely) 1904; (*Stromatocerium eatoni* Seely)
*Pseudostylodictyon ? kayi Galloway and St. Jean, 1957
*Pseudostylodictyon ? lamottense (Seely), 1904; (*Stromatocerium lamottense* Seely)
*Pseudostylodictyon ? montoyaense Galloway, n. sp.
Pseudostylodicyton poshanense Ozaki, 1938,=(*Pseudostylodicyton poshanensis* Ozaki)
Pseudostylodictyon sp. (Ozaki), 1938; (*Rosenella* ? sp. Ozaki)
Rosenella Nicholson, 1886
*Rosenella cumingsi Galloway and St. Jean, n. sp.
Rosenella ? sp. Ozaki, 1938,=Pseudostylodictyon sp. (Ozaki), 1938
Rosenella woyuensis Ozaki, 1938
Sinodictyon Yabe and Sugiyama, 1930
Sinodictyon columnare Yabe and Sugiyama, 1930
Sinodictyon vesiculatum (Ozaki), 1938; (*Ludictyon vesiculatum* Ozaki)
Stenopora Lonsdale, 1844, a bryozoan
Stenopora huronense Billings, 1865,=Labechia huronensis (Billings), 1865
Stromatocerium Hall, 1847
*Stromatocerium amsterdamense Galloway and St. Jean, 1957
*Stromatocerium australe Parks, 1910
*Stromatocerium canadense Nicholson and Murie, 1878
Stromatocerium canadense minimum Parks, 1910,=Cystostroma minimum (Parks)
Stromatocerium eatoni Seely, 1904; Pseudostylodictyon ? eatoni (Seely)
*Stromatocerium granulosum (James), 1871 (*Alveolites granulosus* James)
Stromatocerium huronense (Billings) Parks, 1910,=Labechia huronensis (Billings), 1865.
Stromatocerium huronense australe, Parks, 1910,=Stromatocerium australe (Parks), 1910
Stromatocerium lamottense Seely, 1904,=Pseudostylodictyon ? lamottense (Seely)
Stromatocerium lamottense chazianum Seely, 1904,=Pseudostylodictyon ? chazianum (Seely)
*Stromatocerium leipersense Galloway and Ehlers, n. sp.
*Stromatocerium michiganense Parks, 1910
Stromatocerium moniliferum Seely, 1904,=alga similar to Sphaerocodium
Stromatocerium montiferum (Ulrich), 1886,=Labechia huronensis (Billings), 1865
*Stromatocerium platypilae Galloway, n. sp.
Stromatocerium pustulosum Hayes and Ulrich, 1903,=Labechia pustulosa (Safford), 1869
Stromatocerium regulatum Endo, 1932,=Labechia regulata (Endo), 1932
Stromatocerium richmondense Miller, 1882,=Girvanella richmondensis (Miller), 1882, an alga
*Stromatocerium rugosum Hall, 1847
Stromatocerium rugosum tumidum Wilson, 1948,=Stromatocerium tumidum Wilson
*Stromatocerium tumidum Wilson, 1948; (*Stromatocerium rugosum tumidum* Wilson)

Stromatopora Goldfuss, 1826
Stromatopora cincinnatiensis James, orginal reference not known, referred to in a list by Mickleborough and Weatherby, 1878
Stromatopora compacta Billings, 1862,=Solenopora compacta (Billings), 1862, an alga
Stromatopora indianiensis James, 1892,=Labechia huronensis (Billings), 1865
Stromatopora lichenoides James, 1879,=Arthropora, bryozoan
Stromatopora ludlowensis James, 1884,=Ceramoporella, a bryozoan
Stromatopora lyoni James, original reference not known, referred to in a list by Mickleborough and Weatherby, 1878
Stromatopora ? manchuriensis Yabe and Sugiyama, 1930, not recognized, possibly a calcareous sponge, as Saccospongia
Stromatopora papillata James, 1878,=Dermatostroma papillatum (James), 1878
Stromatopora pustulosa Safford, 1869,=Labechia pustulosa (Safford), 1869
Stromatopora scabra James, 1879,=Dermatostroma scabrum (James), 1879
Stromatopora sp. Holtedahl, 1914, unrecognizable
Stromatopora subcylindrica James, 1884,=Labechia huronensis (Billings), 1865
Stromatopora tubularis James, 1884,=Ceramoporella, a bryozoan encrusting on a cephalopod
Tetradium Dana, 1841, a coral
Tetradium huronense Foord, 1883,=Labechia huronensis (Billings), 1865
Thamnobeatricea Raymond, 1931,=Cryptophragmus Raymond, 1914
Thamnobeatricea parallela Raymond, 1931,=Cryptophragmus parallelus (Raymond), 1931

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ADDENDUM

After the above paper was submitted for publication, one new genus of Ordovician stromatoporoid and two new genera and one new family of supposed Cambrian stromatoporoids were brought to our attention. Comments concerning *Stromatocerium canadense* Nicholson and Murie are based partly on the opportunity provided the junior author to examine slides of the Nicholson collection through the support of the National Science Foundation and with the aid and co-operation of Dr. Dighton Thomas, Curator of fossil Coelenterata at the British Museum of Natural History.

Genus **PLUMATALINIA** Nestor, 1960

Type species (monotypic) *Plumatalinia ferax* Nestor, 1960, Eesti Nsv Teaduste Akad. Toimetised, Füüsikalis-Matemaat. Tehniliste Teaduste, vol. 9, No. 3, p. 225-228, pls. 1, 2. (Upper Ordovician, Estonia.)

Coenosteum massive, with a basal epitheca, composed of rows of long, broad, low arched cyst plates presenting a laminar appearance which may or may not turn upward to form pillar columns. The columns are composed of a lacy intergrowth of tissue, giving rise to long, thick, round pillars. The surface has numerous round depressions and should be coarsely papillate due to the large pillar columns. Astrorhizae are absent in the type species.

The type species comes from the Pirgu stage (F_1c) which is Upper Ordovician in Estonia.

Nestor correctly considers *Plumatalinia* to be a member of the family Labechiidae, as indicated clearly by the presence of curved cyst plates and the absence of distinct laminae or laminae and short pillars. Nestor considers the genus to be close to *Pseudolabechia,* differing in that the columns lack diverging pillars characteristic of *Pseudolabechia.* The genus is close to *Pseudostylodictyon* Ozaki in the arrangement of cysts into small columns and in the low flat nature of the cysts. It differs in that there is anastomosing secondary tissue in the pillar columns, producing the large long pillars. The genus seems closer to *Pseudostylodictyon* than to *Pseudolabechia.* It is closely related to both genera. *Plumatalinia* differs from *Labechia* in that the pillars are thicker and lack distinct walls or solid zones of flocculent tissue.

Nestor says that the genus lacks monticules but has craters on the surface. Depressions on upper surfaces of stromatoporoid coenostea are unusual, though common on undersurfaces of latilaminae of mamillate species. The depressions are produced by the laminae which turn upward, hence inward, at the base of latilaminae. The pillar columns are about ¾ mm. in diameter in the type species, therefore, the coenosteal surface should display coarse papillae.

PRE-ORDOVICIAN STROMATOPOROIDS

We comment that so far as we know, the Chazy stromatoporoids are the oldest known. However, stromatoporoids were reported by Obrutschew (1926, Fortschr. Geol. Paläont., vol. 5, No. 15, p. 86, *et seq.*) but neither descriptions nor figures were presented. Cambrian stromatoporoids were reported by Yavorsky in 1932, and we discuss them in the foregoing paper and elsewhere (Galloway, 1957, pp. 389, 390; Galloway and St. Jean, 1957, p. 87). We have been informed by Dr. H. Nestor, of the Institute of Geology of the Estonian Academy of Sciences, and Dr. Erik Flügel, of the Naturhistorisches Museum, Vienne, Austria, of a paper published by V. K. Kalfina (1960, S. N. I. I. G. G. I. M. S., vol. 8) on Cambrian stromatoporoids of Siberia, in which two new genera and a new family are proposed. The genera are *Korovinella* and *Praeactinostroma;* the new family is Korovinellidae. We have not had an opportunity to see the paper. Dr. Nestor informs us (personal communication) that he has seen some supposed Cambrian stromatoporoids in Leningrad, which he thinks may not be true stromatoporoids. He does not say if they are Kalfina's specimens. Dr. Flügel informs us (personal communication) that *Praeactinostroma* is proposed for the previous species *Actinostroma vologdeni* Yavorsky which is one of the two previously known species of supposed Cambrian stromatoporoids that we have already questioned, based on its morphological appearance in published figures of thin sections. It will be interesting to learn the results of the Soviet investigation.

STROMATOCERIUM CANADENSE Nicholson and Murie

We have judged Nicholson and Murie's species to be a representative of the genus *Stromatocerium,* as did Parks, based on the deduction that the species possesses platelike rather than round pillars. Nicholson and Murie originally placed the species in the genus *Stromatocerium* and Nicholson later (1886 a, pl. 2, figs. 3-5; 1886 b, p. 14) removed the species to the genus *Labechia.* Unfortunately, the type specimen in the British Museum of Natural History, from Peterborough, Ontario, is poorly preserved so that pillars and cyst plates are completely altered, represented only by recrystallized calcite. Cyst plates are represented by remnants of thin median cyst plate layers in places, with no suggestion of an upper or lower flocculent layer. The pillars and pillar walls are almost completely destroyed. Pillars are mostly represented as streaks of clear calcite extending perpendicularly to the orientation of the cyst plates. Some of the streaks of recrystallized calcite are fractures in the specimen and are not really related to pillars, though most such altered areas represent the location of former pillars. The flat nature of the cyst plates, and the long continuous pillars extending through the cyst plates appear more as they do in the genus *Stromatocerium* than *Labechia,* and are the bases for our including the species in *Stromatocerium.* It is possible that Nicholson was correct in assigning the species to the genus *Labechia,* for no specimen in the Nicholson collection appeared to be a demonstrable *Stromatocerium.* In Nicholson's monograph (1886a, pl. 2, fig. 4) in an additional vertical section from the type specimen, enlarged 12 times, the pillars are slightly thinner than represented in the figure. Some of the vertical clear areas are not pillars as suggested in the figure but are extensions beyond the ends of detectable pillars. We have suggested that Nicholson's specimen from Girvan (Monograph, pl. 20, fig. 9) may be a *Cystostroma* because no pillars are illustrated. Pillars are distinct in nonfigured parts of the thin section used for the illustration by Nicholson. The specimen is not *S. canadense* but is another species belonging to the genus *Labechia.* As we suggested previously, topotype material of *S. canadense* from Peterborough, Ontario, needs to be collected and studied extensively.

Explanation of Plate 1

Specimens and slides, except where otherwise noted, are in the Indiana University Paleontological Collections.

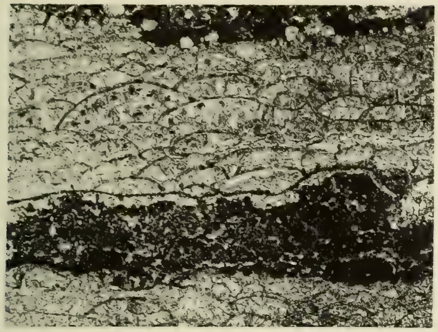
Figure Page

1. **Cystostroma vermontense** Galloway and St. Jean 12
   a. Vertical section of holotype, X 10, showing latilaminae separated by mud, cyst plates with thin, dark upper plate and thick, flocculent lower plate, without pillars and with few preserved chamber cavities. Indiana University Paleo. Coll., slide 300-17. Retouched.
   b. Vertical section same specimen, slide 300-18. Retouched.
   c. Tangential section, X 10, same specimen, showing cut cyst plates and no pillars. M. Chazy, quarry 1 mi. southeast of Isle La Motte, Vt., specimen KA2, slide 300-25. Retouched.

2. Three "protocoenostea" intergrown with alga, X 7. Upper Chazy, 1½ miles south of Isle La Motte, Vt., specimen KC4, slide 300-72. Unretouched.

3. **Cystostroma simplex** Galloway and St. Jean 13
   a. Vertical section of holotype, X 10, showing strongly curved cyst plates, dark, thick upper plate, with villi but without denticles or crenulations, and moderately thin lower, flocculent plate, slide 299-60. Retouched.
   b. Tangential section, X 10, same specimen, showing cut cyst plates and villi, but lack of pillars. Trenton, Carters ls., Mill Cr., 7 miles south of Nashville, Tenn., slide 299-62. Retouched.

4. **Cystostroma minimum** (Parks) 14
   a. Vertical section of topotype, X 10, showing a mamelon, cysts with thin upper plate, moderately thick, moniliform lower plate, open chambers, and lack of pillars. Trenton, Bigby ls., Old Crow Distillery, Frankfort, Ky., University of Cincinnati, No. 4087. Indiana University Paleo. Coll., slide 302-33. Unretouched.
   b. Tangential section, X 10, showing a mamelon with cysts surrounding it, but does not show an astrorhiza. Same specimen as 4a, slide 299-69. Unretouched.



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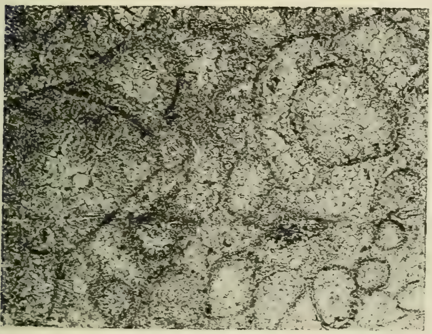

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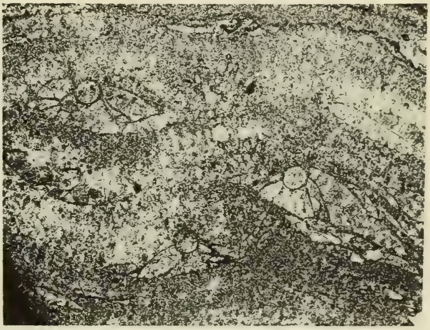

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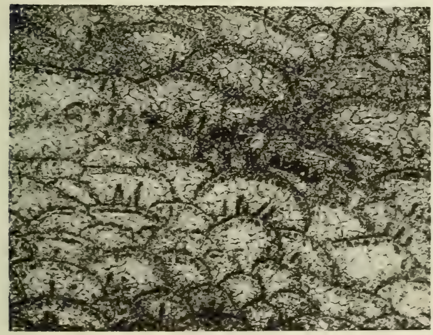

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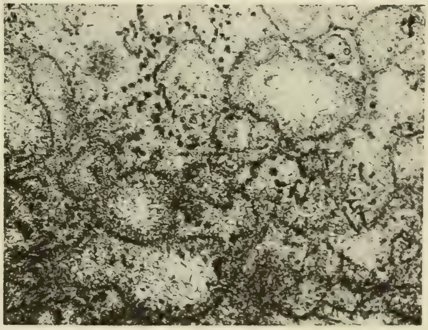

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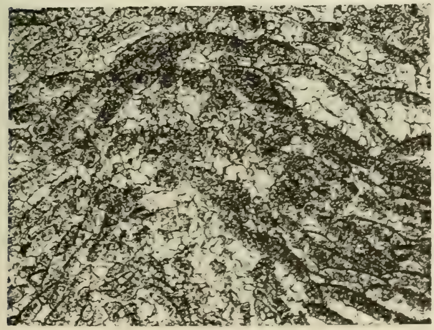

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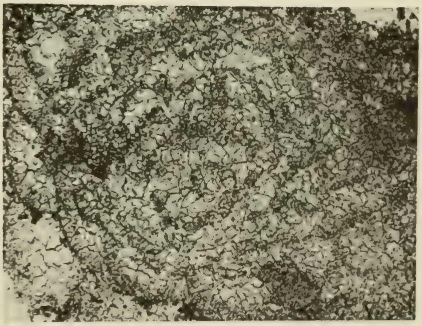

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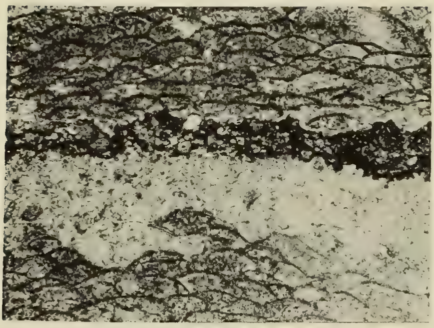

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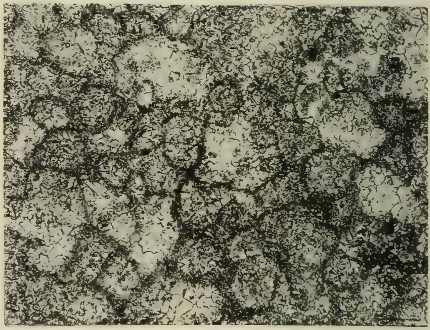

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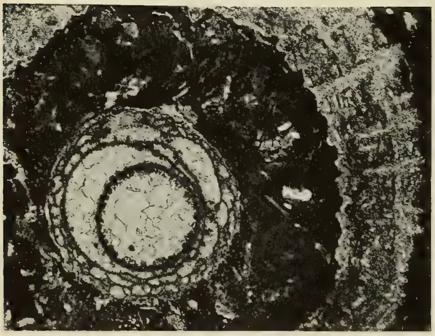

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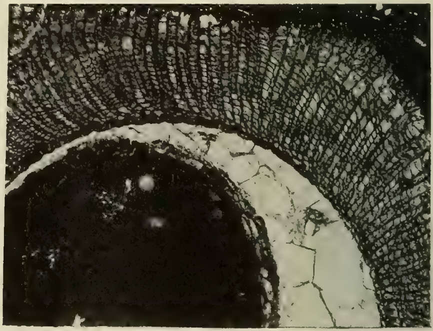

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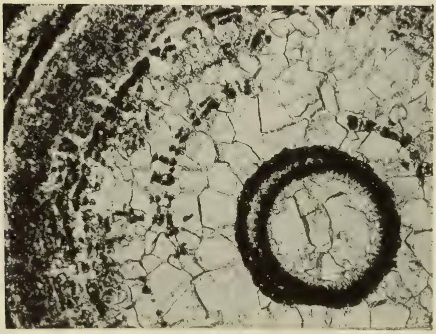

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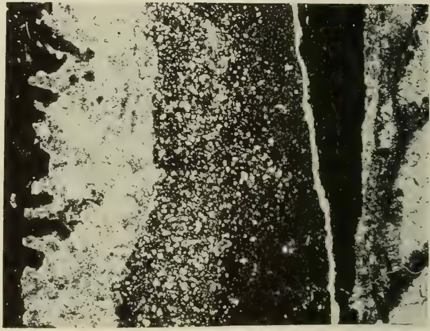

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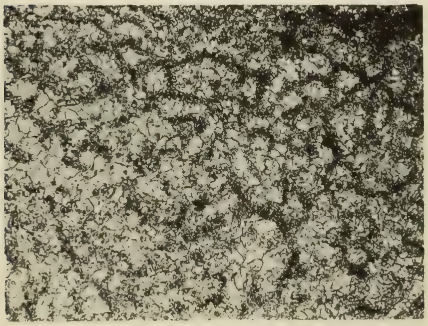

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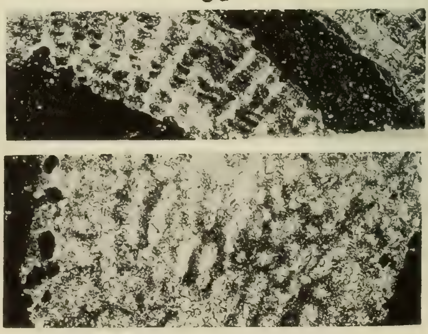

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Explanation of Plate 2

Figure Page

1. **Cystostroma fritzae** Galloway and St. Jean, n. sp. 16
   a. Vertical section of holotype, X 10, showing two latilaminae, low, arcuate cyst plates, with thin, dense upper plate and thick lower, flocculent plate, which generally fills the chamber cavity, and lack of pillars. Indiana University Paleo. Coll., slide 309-21. Retouched.
   b. Tangential section of same specimen, X 10, showing small cysts, and lack of astrorhizae. Upper Ord., Richmond gr., Liskeard fm., Farr Quarry, Timiskaming, Ont., collected by Dr. M. A. Fritz. Slide 301-89. Retouched.

2. **Cryptophragmus antiquatus** Raymond 19
   a. Cross section of topotype, X 6, sectioned presumably by Raymond, showing axial column, 4 mm. across, with axial tabulae and small cysts on the outside of the column, followed by a layer of mud, presumably laid down during the winter season, this followed by a summer layer of the adult stage, consisting of slightly curved cysts and by large pillars between the cysts. The pillar substance has been entirely replaced by calcite. The layer of organic material is a latilamina, or "sheath" of Raymond. Pamelia ls., Carden twp., Ontario, Can. Mus. Comp. Zool., Harvard University. Retouched.
   b. Cross section of another specimen, X 6, from the same place, showing a bryozoan not followed by a latilamina. Mus. Comp. Zool., Harvard University. Unretouched.
   c. Cross section of another specimen, X 4, from the same place. Axial column 3 mm. in diameter, followed by clear calcite with remnants of cysts and pillars, and this is followed by a sheath of the mature stage of the stromatoporoid, with two latilaminae, and this is followed by mud. Unretouched.

3. **Crypotyphragmus antiquatus** Raymond 19
   a. Longitudinal section of one of Raymond's topotypes, X 10, showing the axial column, 4 mm. in diameter, followed by mud, sheath, mud, outer sheath, and mud. Note the extension of the pillars into the mud, showing that the pillars cannot be tubes. Pamelia ls., Carden twp., Ont. Mus. Comp. Zool., Harvard University. Indiana University Paleo. Coll., slide 302-96. Unretouched.
   b. Tangential section, X 10, from the same specimen, showing round pillars and darker remnants of the fillings of the cyst chambers; slide 302-94. Unretouched.
   c. Part of a cross and tangential section of a fragment of Raymond's types, X 10, from the Pamelia limestone, Lot. 25, Con. VI, Carden twp., Ontario, loaned by the Geological Survey of Canada, No. 4320c, showing cysts and pillars replaced by clear calcite, and the chamber fillings by a darker material. Indiana University Paleo. Coll., slide 308-31. Unretouched.

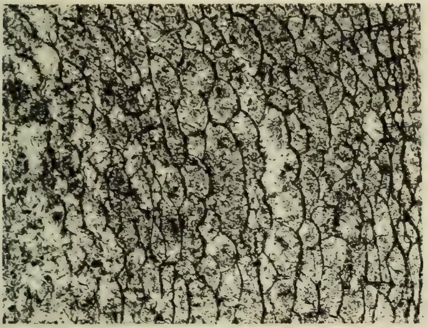
Explanation of Plate 3

Figure | Page

1. **Aulacera plummeri** Galloway and St. Jean 27
   a. Cross section of topotype, X 10, inner zone of cysts with poor calcification of structures and lack of pillars, outer zone of well-calcified cysts, and abundant pillars; slide 299-40. Unretouched.
   b. Vertical section of same specimen, X 10, showing inner zone poorly calcified and without pillars, and outer zone, well calcified, with pillars inclined outward and curving upward; slide 282-58. Upper Ord., Saluda fm., Elkhorn Cr., 4 miles south of Richmond, Ind. Unretouched.

2. **Aulacera plummeri** Galloway and St. Jean 27
   a. Vertical section of small hypotype, X 6, showing rapid gradation from large, axial cysts into small lateral cysts, with a few, small pillars in the outer zone; slide 302-26. Retouched.
   b. Cross section, same specimen, X 6, showing small cysts, outer thin and inner, thick flocculent plates, and a few small pillars in the outer zone; slide 302-26. Upper Ordovician, basal Liberty fm., Wilson Cr., 2 miles southwest of Deatsville, Ky. Collected by Ruth G. Browne. RB2. Retouched.

3. **Aulacera undulata** (Billings) 30
   a. Part of cross section of lectotype, X 10, showing larger cysts than in *A. plummeri*, strongly curved cysts in radial zones, moniliform lower plates, and lack of pillars. Indiana University Paleo. Coll., slide 299-88. Unretouched.
   b. Part of cross section, X 4, same specimen as for fig. 3a, showing radial zones of strongly convex cysts with irregular cysts between, moniliform lower cyst plates, and absence of pillars. Slide 299-89. Unretouched.
   c. Radial, longitudinal section, X 10, cutting a radial zone of cysts, showing their large size and hemispherical form. Same specimen as for fig. 3a. Slide 299-90. Unretouched.
   d. Oblique tangential section, X 10, showing round cysts, dark, compact outer plate and inner, thick moniliform plate, open chambers, and absence of pillars. Same specimen as for fig. 3a. Upper Ordovician, Vauréal fm., Battery Cliff, Anticosti Is., Can. Canadian Geol. Surv., No. 2583, marked "TYPE". Indiana University Paleo. Coll., slide 299-90. Retouched.



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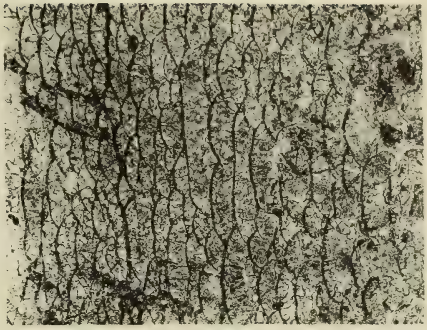

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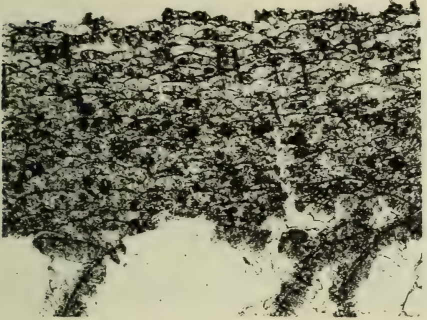

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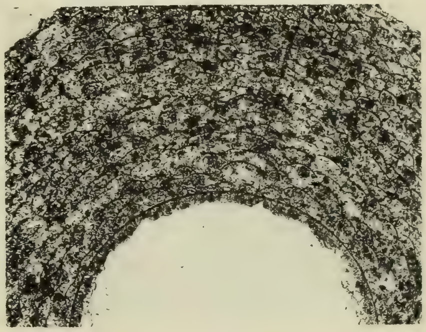

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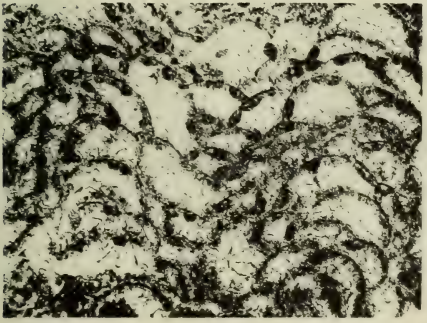

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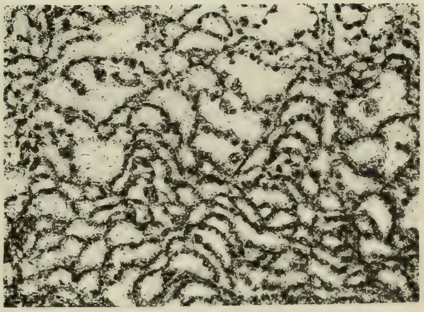

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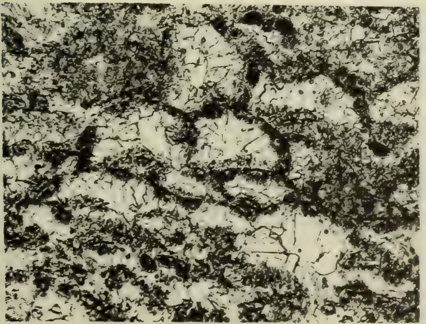

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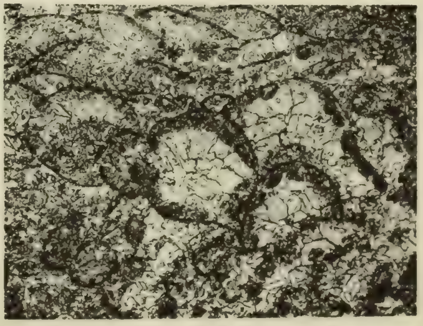

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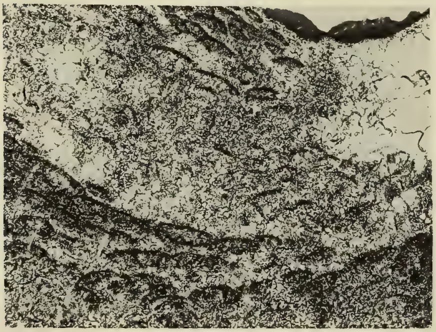

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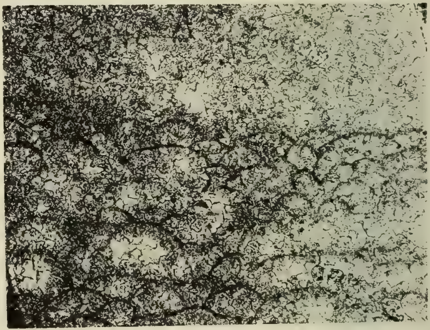

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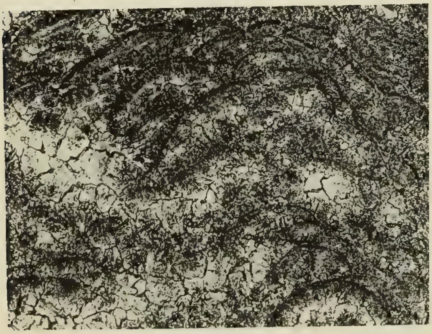

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Explanation of Plate 4

Figure | Page

1. **Aulacera radiata** Galloway and St. Jean, n. sp. 32
   a. Cross section of holotype, X 10, showing a ray of cysts little different from cysts between rays, a few pillars in the ray, small cysts with low plates of flocculent tissue nearly filling the chambers, and latilaminae separated by calcite with pseudopillars, denoting imperfect calcification in life. Specimen 702A, Mus. Comp. Zool., Harvard University, slide 302-70. Retouched.
   b. Vertical, radial section of holotype, X 10, cut between rays, showing latilaminae of small cysts, without pillars, the latilaminae separated by layers of calcite with pseudopillars. Specimen 702A. Richmondian, Anticosti Is., Can. Harvard University Paleo. Coll., slide 308-55. Unretouched.

2. **Aulacera nodulosa** (Billings) 34
   a. Cross section of topotype, not well preserved, X 10, showing a mamelon, latilaminae, small, low cysts and scattered, poorly preserved pillars. Indiana University Paleo. Coll., slide 299-85. Retouched.
   b. Cross section, nearer the center than fig. a, X 10, showing curved cysts but no pillars. Same specimen as for fig. a. Upper Ordovician, Vauréal fm., Battery Cliff, Anticosi Is., Can. Loaned by Canadian Geol. Surv., No. 1917. Indiana University Paleo. Coll., slide 299-86. Retouched.

3. **Aulacera nodulifera** (Foerste) 36
   a. Cross section of hypotype, X 10, showing large cysts rising into the nodes, but no pillars. Richmondian, Anticosti Is.. Mus. Comp. Zool. Harvard University. Fragment in Indiana University Paleo. Coll., and slide 302-67. Retouched.
   b. Cross section of hypotype, X 10, poorly preserved, showing cysts and a few strong pillars. Vauréal fm., Battery Point, Anticosti Is., Can. Peabody Museum, Yale University, No. 9200B. Collected by W. H. Twenhofel. Indiana University Paleo. Coll., fragment and slide 302-73. Retouched.

4. **Aulacera intermedia** (Foerste) 37
   Cross section of hypotype, X 10, showing inner curved cysts without pillars. The outer cysts were incompletely calcified in life. Lower Liberty fm., 2 miles southwest of Deatsville, Ky., collected by Ruth G. Browne, Louisville, Ky. Indiana University Paleo. Coll., RB18, slide 308-11. Unretouched.

Explanation of Plate 5

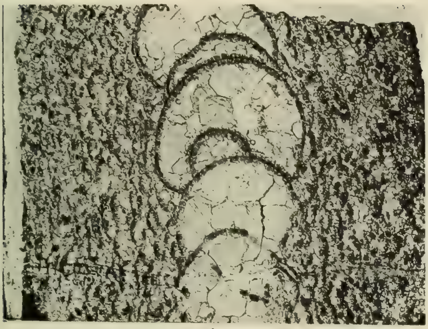
Figure Page

1. **Aulacera cylindrica** (Foerste) 38
   a. Vertical section of hypotype, X 3, showing axial column which is not a tube, large axial cysts, small lateral cysts which are incompletely calcified, and lack of pillars. Basal Liberty, 2 miles southwest of Deatsville, Ky., collected by Ruth G. Browne, RB69. Indiana University Paleo. Coll., slide 308-32. Retouched.
   b. Cross section of small specimen, X 3, showing gradation of larger cysts into small ones, and lack of pillars. RB68. Same locality and collector as for 3a. Indiana University Paleo. Coll., slide 302-74. Retouched.

2. **Pseudostylodictyon ? lamottense** (Seely) 40
   a. Vertical section of one of Seely's syntypes, X 10, showing wavy latilaminae separated by mud, the irregular laminae, without denticles, corrugations or pillars. Indiana University Paleo. Coll., slide 301-61. Retouched.
   b. Vertical section of the same specimen, X 3, to show irregular latilaminae separated by calcareous and carbonaceous mud and thin laminae. Middle of B Chazy, Goodell's Quarry, Isle La Motte, Vt., collected by H. M. Seely, 1885. Indiana University Paleo. Coll., slide 301-60. Retouched.

3. **Pseudostylodictyon ? eatoni** (Seely) 41
   a. Weathered surface of holotype, X 2/3, showing mamelons of various sizes. Same specimen as figured by Seely (1904, pl. 71). Upper or C Chazy, Goodell's Ridge, south of Isle La Motte, Vt. Unretouched.
   b. Vertical section of holotype, X 10, showing a mamelon, regular laminae with thin upper layer and thick, flocculent and moniliform lower layer, and lack of wrinkled laminae. Indiana University Paleo. Coll., slide 301-58. Retouched.

4. **Pseudostylodictyon ? kayi** Galloway and St. Jean 42
   a. Vertical section of holotype, X 10, showing a mamelon and eruption of several laminae, regular laminae with upper, thin, dark layer and lower, thick flocculent layer, and some wrinkled laminae. The laminae are separated into groups with clear calcite between, apparently due to noncalcification of laminae in life. Middle Chazy, 1 mile southeast of Isle La Motte village, Vt. Collected by Marshall Kay. Indiana University Paleo. Coll., KA1, slide 300-21. Retouched.
   b. Tangential section of holotype, showing rings where the section cuts the wrinkles of the laminae, and flocculent laminae. Same locality, collector and depository. Slide 300-24. Retouched.



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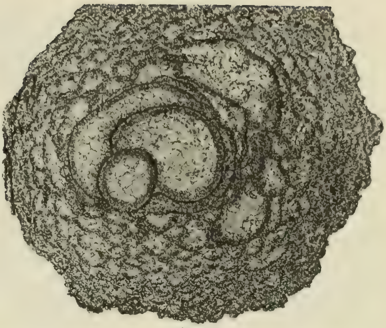

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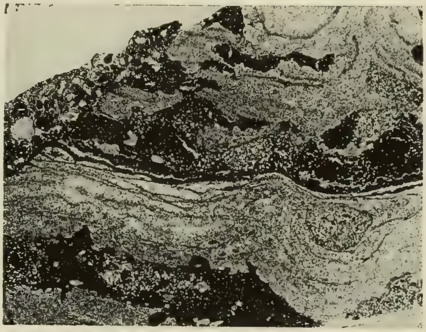

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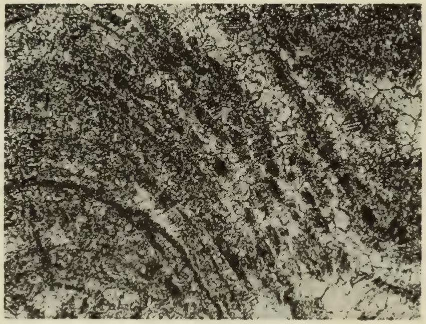

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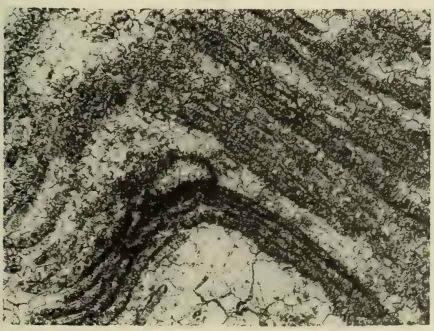

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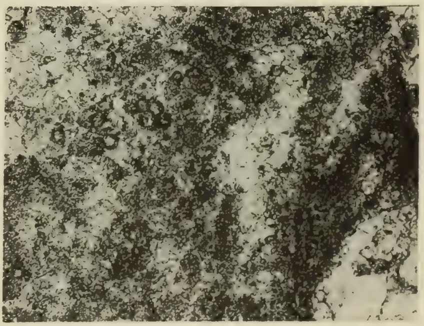

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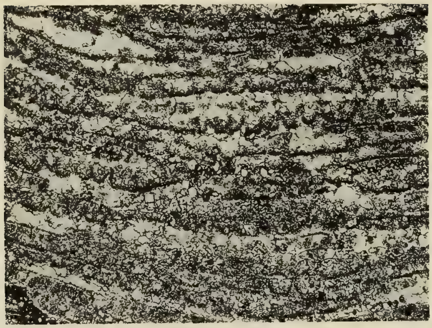

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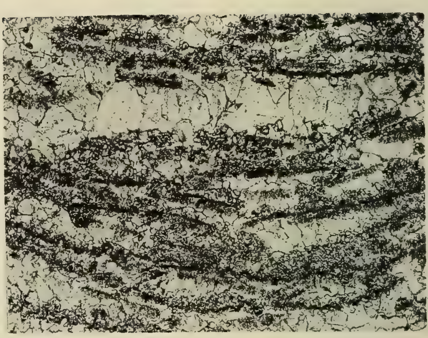

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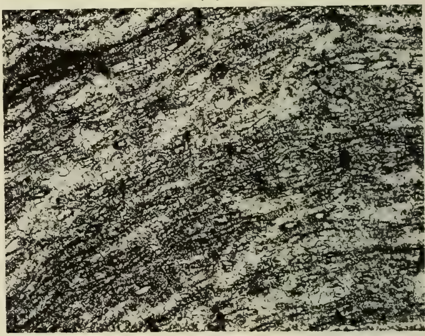

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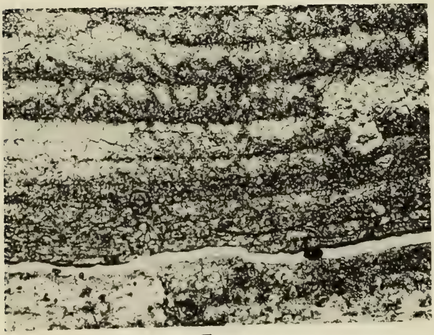

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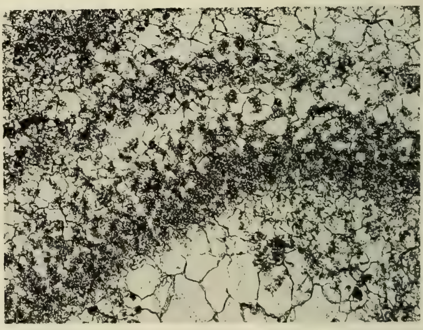

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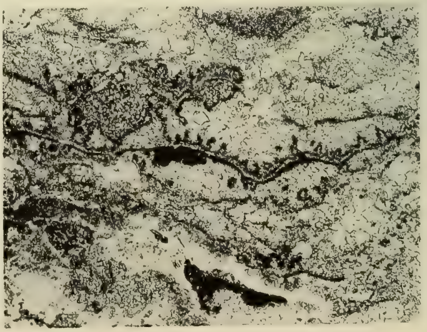

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Explanation of Plate 6

Figure Page

1. **Pseudostylodictyon ? kayi** Galloway and St. Jean 42
   a. Vertical section, paratype, X 10, showing regular, wrinkled laminae. Middle Chazy, "Fleury" Quarry, 1 mile southeast of Isle La Motte village, Vt. Collected by Marshall Kay, Indiana University Paleo. Coll., KA5, slide 300-20. Unretouched.
   b. Vertical section from the some specimen as for 1a, X 10, showing groups of laminae separated by calcite and few wrinkles; slide 300-19. Retouched.

2. **Pseudostylodictyon ? chazianum** (Seely) 43
   a. Vertical section of one of Seely's syntypes, X 10, labeled "A Chazy, South Hero, Vt.," although Seely's description (1904, p. 148) stated "B Chazy." Largely silicified, shows thin laminae. Indiana University Paleo. Coll., slide 301-63. Retouched.
   b. Vertical section of hypotype from near the type locality, X 10, showing the thin laminae, lack of corrugations, denticles, cysts, or pillars. Middle Chazy, *Maclurities* beds, South Hero, ¼ mile west of Route 2, Grand Isle Co., Vt. Collected by Marshall Kay, Indiana University Paleo. Coll., KB1 and slide 300-30. Unretouched.

3. **Pseudostylodictyon ? montoyaense** Galloway, n. sp. 44
   a. Vertical section of holotype, X 10, showing regular laminae, wrinkled laminae, and denticles. Slide 308-22. Unretouched.
   b. Tangential section of holotype, X 10, showing cut laminae and denticles; wrinkles are more common than usual. Upper Ordovician, Montoya gr., Upham fm., crest of Scenic Drive, El Paso, Texas. Collected by R. H. Flower, 1958. Part in New Mexico Inst. Min. Tech., No. S6, and slides, part in Indiana University Paleo. Coll., and slide 302-23. Unretouched.

4. **Rosenella cumingsi** Galloway and St. Jean, n. sp. 45
   a. Vertical section of holotype, X 10, showing irregular development of cysts and wrinkles and denticles on the thin cyst plates. Middle Ordovician, upper Black River, new lock above Amsterdam, N.Y. Indiana University Paleo. Coll., slide 300-84. Unretouched.
   b. Vertical section of paratype, X 10, showing the same features. Lower Trenton, Rockland fm., ¼ mile west of bridge, Crown Point, N.Y. KG1, Indiana University Paleo. Coll., slide 302-4. Unretouched.

Explanation of Plate 7

Figure | Page

1. **Labechia pustulosa** (Safford) 47
   a. Vertical section of topotype, X 10, showing thick, low cysts and vertical, calcite streaks where the pillars had been. Lower Catheys formation, Tennessee Central Railroad Station, Nashville, Tenn. Collected by C. W. Wilson, Jr., 1954. Indiana University Paleo. Coll., slide 302-83. Unretouched.
   b. Tangential section, X 10, of the same specimen, showing cysts and obscure, large round pillars. Slide 302-82. Retouched.

2. **Labechia pustulosa** (Safford) 47
   a. Vertical section of hypotype, X 10, showing the low cysts with thin upper plate and thick flocculent and moniliform lower plate, (the plates are smaller than those of the topotype), and abundant, large pillars replaced by calcite but leaving the outside rim in places. Cannon ls., Flat Rock on Nolensville Pike, southwest of Nashville, Tenn. Part in Vanderbilt University Paleo. Coll., part in Indiana University Paleo. Coll., slide 299-83. Unretouched.
   b. Tangential section, X 10, of same specimen, showing a mamelon, thick cysts, and many round pillars, some with darker rim. Slide 299-82. Unretouched.

3. **Labechia huronensis** (Billings) 50
   a. Vertical section of hypotype, X 10, showing typical, thin, curved cyst plates with lower, poorly defined, flocculent plate, and typical small, long, straight pillars which have vague, vertical rods and no definite outer boundary. Whitewater fm., Muscatatuck State Farm, Ind., Indiana University Paleo. Coll., slide 299-33. Unretouched.
   b. Tangential section, X 10, of same specimen, showing numerous small pillars which tend to be round but without definite boundaries. Slide 299-63. Unretouched.

4. **Labechia huronensis** (Billings) 50
   a. Vertical section of topotype, X 10, showing small, thin, arched, overlapping cyst plates, and large, straight and loose-textured pillars which are not hollow. Upper Richmond, Meaford fm., Cape Smyth, Manitoulin Is., Can. Specimen figured by Foerste, 1924, pl. 24, fig. 2. Canadian Geol. Surv., No. 5596. Indiana University, slide 308-96. Unretouched.
   b. Tangential section, same specimen, X 10, showing large round and coalescent pillars, which are loose-textured but not hollow, and joined by the cyst plates, simulating radial arms of pillars of *Actinostroma*. Slide 308-97. Unretouched.

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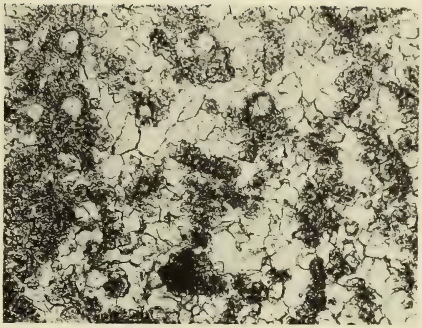

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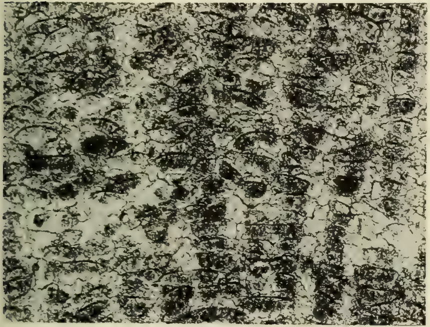

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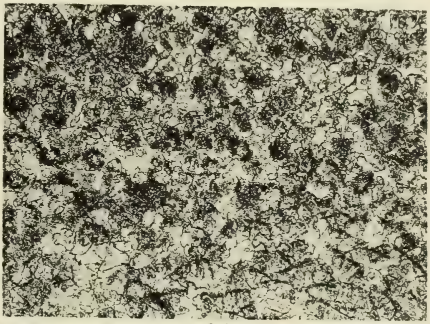

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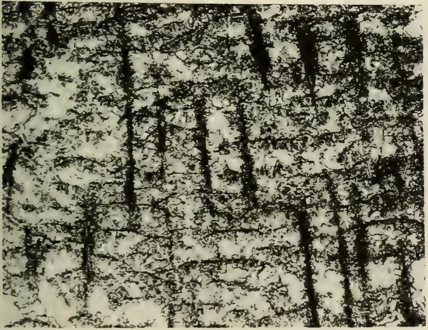

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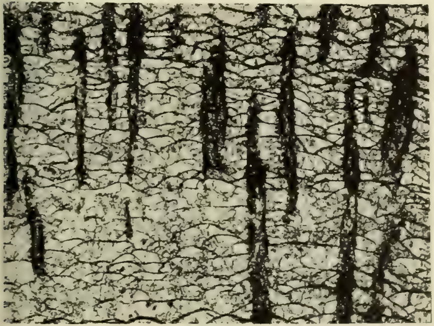

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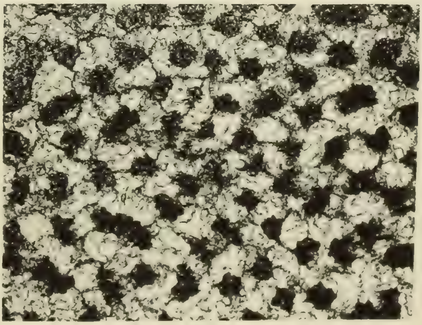

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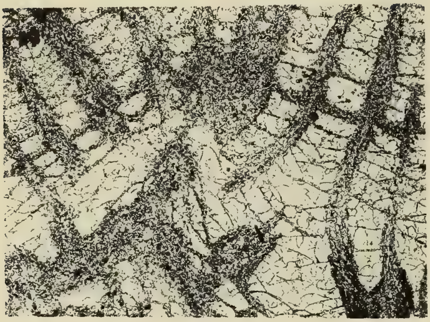

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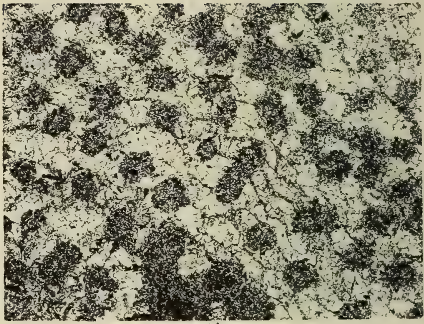

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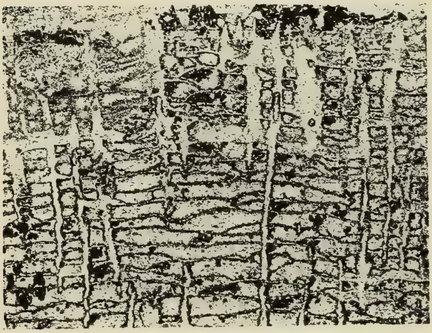

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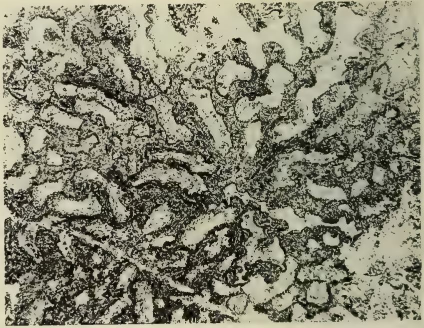

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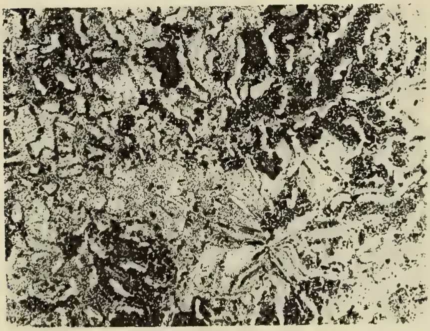

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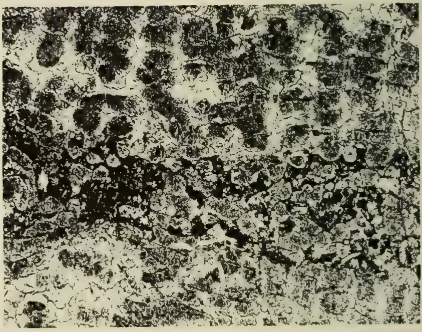

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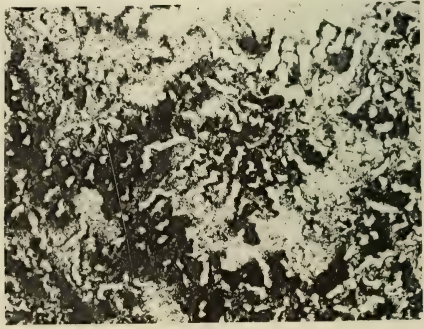

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Explanation of Plate 8

Figure Page

1. **Labechia macrostyla** Parks 53
   a. Vertical section of lectotype, one of Parks two syntypes, X 10 showing two latilaminae, one mamelon, thin, curved, overlapping plates, and large pillars, some confluent with variable texture. "Lower Trenton Drift," Ann Arbor, Mich. U. S. Nat. Mus., No. 36929A, slide NM1-9. Unretouched.
   b. Tangential section of the same specimen, X 10, showing large pillars of granular texture, some confluent, many joined by curved cyst plates, slide NM1-10. Unretouched.

2. **Stromatocerium rugosum** Hall 56
   a. Vertical section of holotype, X 6.7, showing broad, slightly curved cyst plates, and long thin pillars where cut the narrow way and broader pillars where cut the broad way. Middle Ordovician, Black River, Watertown, N. Y. Amer. Mus. Nat. Hist., slide No. 590/5B. Unretouched.
   b. Tangential section of same specimen, X 6.7, showing mature, thick, broad pillars in white, in radial arrangement, but no definite astrorhizae; slide 590/5C. Retouched.
   c. Tangential section, same specimen, X 6.7, showing immature, thin, broad pillars in white, radially arranged, but no astrorhizae; slide 590/5C. Retouched.

3. **Stromatocerium tumidum** Wilson 58
   Vertical section of partly silicified topotype, X 10, showing remnants of cyst plates and pillars, and mud between latilaminae. Middle Ordovician, Black River, Paquette Rapids, Ottawa R., Can. Univ. Cincinnati Museum, No. 22822; Indiana University, slide 299-76. Retouched.

4. **Stromatocerium amsterdamense** Galloway and St. Jean 59
   a. Vertical section of holotype, X 10, showing thin, broad cyst plates which approach laminae and long thin pillars with spurs. Upper Black River limestone, Amsterdam, N. Y. Indiana University Paleo. Coll., No. 4629, slide 235-11. Retouched.
   b. Tangential section, same specimen, X 10, showing a mamelon with radiating pillars; the pillars are small, irregular in shape, with many small flanges. Slide 299-47. Retouched.

Explanation of Plate 9

Figure Page

1. **Stromatocerium canadense** Nicholson and Murie 60
   a. Vertical section of hypotype, X 10, showing broad, thin cyst plates and thin pillars which are sporadic in occurrence. Middle Ordovician, top of Black River, Pattersonville, N. Y. Indiana University Paleo. Coll., slide 235-23. Unretouched.
   b. Oblique tangential section of same specimen, X 10, showing a mamelon with radial, thin, broad pillars with small flanges. The cyst plates are broad, thin and many have denticles on the upper side. Slide 299-65. Unretouched.

2. **Stromatocerium leipersense** Galloway and Ehlers, n. sp. 62
   a. Vertical section of holotype, X 10, showing small, arcuate cyst plates, long pillars of variable size, and small, round vacuities in the pillars. Upper Ordovician, Leipers fm., opposite Belk Is., 7 miles upstream from Rowena, Ky. Mus. Paleont. University of Michigan, No. 39500. Indiana University, slide 308-80. Retouched.
   b. Tangential sections of same specimen, X 10, showing irregular flanged pillars outlined by mud at left, and irregular pillars with many round vacuoles at right. Slide 308-81. Retouched.

3. **Stromatocerium michiganense** Parks 63
   a. Vertical section of holotype, X 10, showing curved and flat cyst plates, and long, straight mostly thin pillars, both outlined by dark material. Middle Ordovician, lower Trenton, from glacial drift, Ann Arbor, Mich. U. S. Nat. Mus., No. 56843; slide MN1-6. Unretouched.
   b. Tangential section of same specimen, X 10, showing broadly flanged, narrow pillars, which meet, forming polygons, and absence of mamelons and astrorhizae. Slide NM1-7. Retouched.

5. **Stromatocerium australe** Parks 64
   a. Vertical section of type specimen, X 10, showing thin pillars and close cyst plates in a mamelon. Upper Ordovician, Leipers fm., Nashville, Tenn. U. S. Nat. Mus., No. 49507; Indiana University Paleo. Coll., slide 309-37. Unretouched.
   b. Tangential section of same specimen, X 10, showing thin radiating pillars with few flanges, and thin, irregular, branching pillars between columns, where pillars are usually lacking. Indiana University Paleo. Coll., slide 309-38. Unretouched.

4. **Stromatocerium granulosum** (James 66
   a. Vertical section of topotype, X 10, showing arched cyst plates and thin plates and thin pillars. Upper Ordovician, Fort Ancient mem., Waynesville fm., Clarksville, Ohio. Mus. Paleont. University of Michigan, No. 7774, slides O1-18, 19; part in Indiana University Paleo. Coll., slide 308-18. Retouched.
   b. Tangential section of same specimen, X 10, showing platelike pillars with large and small flanges. Slide 308-19. Retouched.


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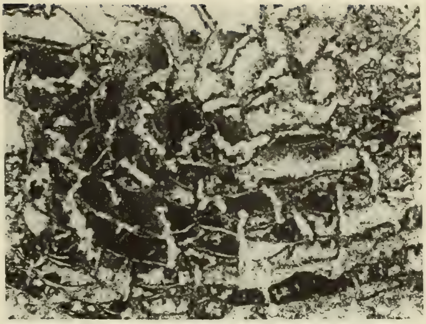
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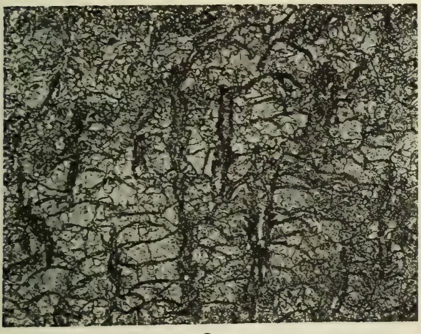
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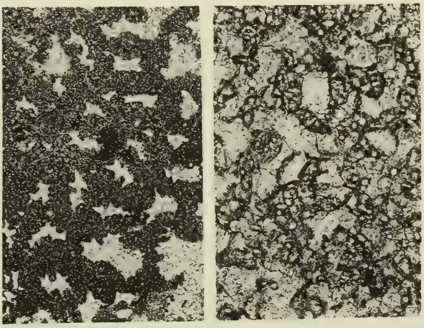
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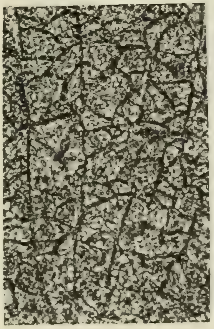
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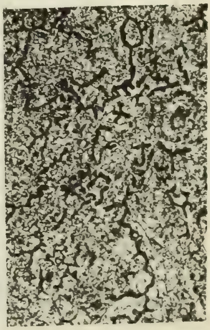
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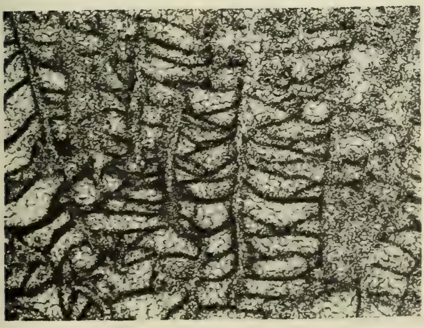
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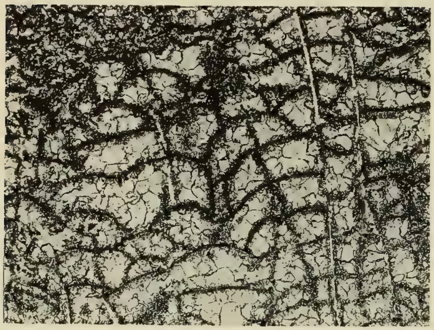

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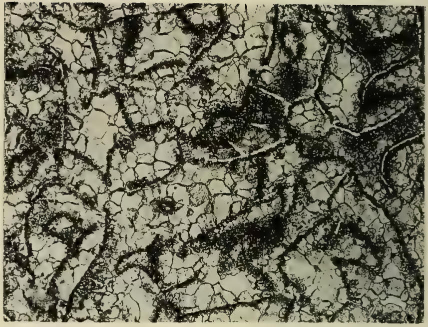

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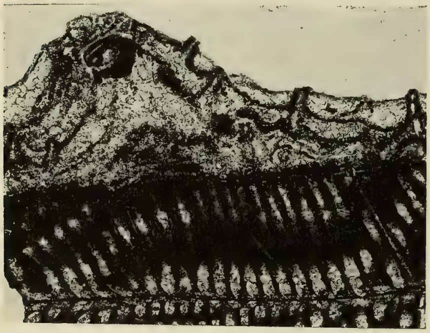

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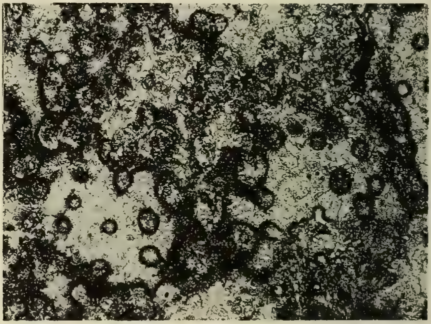

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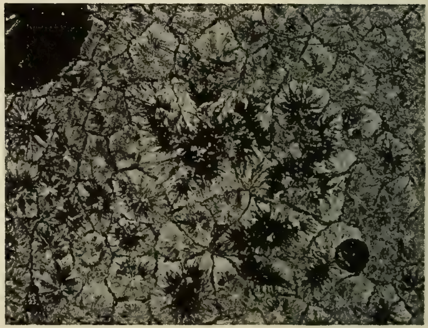

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Explanation of Plate 10

Figure | Page

1. **Stromatocerium platypilae** Galloway, n. sp. 67
   a. Vertical section of holotype, X 10, showing the large cysts with three thin plates, the thin, long, straight, rarely branching, vertical pillars, without flanges, mostly with a thin, median white line. Upper Ordovician Liberty fm., 2½ miles northwest of Owingsville, Ky. Indiana University Paleo. Coll., slide 308-70. Retouched.
   b. Tangential section of same specimen, showing the cyst plates with thin, dark line, and the flat or curved pillars with median white line; the pillars do not have flanges, but the white, median line is minutely variable in width. Indiana University Paleo. Coll., slide 308-68. Retouched.

2. **Dermatostroma scabrum** (James) 69
   a. Vertical section of typical specimen, X 10, attached to *Escharopora pavonia*. Upper Ordovician, Leipers fm., Mt. Parnassus, Columbia, Tenn. Miami University, No. 821. Indiana University, Paleo. Coll., fragment and slide 302-10. Retouched.
   b. Tangential section of same specimen, X 10, showing mamelons by lighter color and cut laminae, and round pillars with dark ring and light center. Same slide. Unretouched.

3. **Dermatostroma ? corrugatum** (Foerste) 71
   a. Vertical section of topotype, X 10, showing the contiguous prisms of fibrous, feathery calcite, with the fibers diverging upward, darker in places, and lack of laminae, pillars, cysts, galleries or tissue of typical Stromatoporoidea. Upper Ordovician, Whitewater fm., Wilmington, Ohio. Coll. by W. H. Shideler, Miami University. Indiana University Paleo. Coll., fragment and slide 308-98. Unretouched.
   b. Tangential section of same specimen, X 10, showing mamelons? prisms, with radiating fibers, darker in places. Slide 308-98. Unretouched.

4. **Dermatostroma ? glyptum** (Foerste) 72
   a. Vertical section of topotype, X 10, showing three layers with lacunae between, large, contiguous, fibrous prisms, and large papillae. Upper Ordovician, Whitewater fm., Wilmington, Ohio., collected by W. H. Shideler, No. 815. Indiana University Paleo. Coll., slide 302-15. Unretouched.
   b. Tangential section of same specimen, X 10, showing irregular surface and large prisms with radial, fibrous structure, and smaller, round, radially fibrous structures, the papillae. Slide 302-15. Retouched.

Explanation of Plate 11

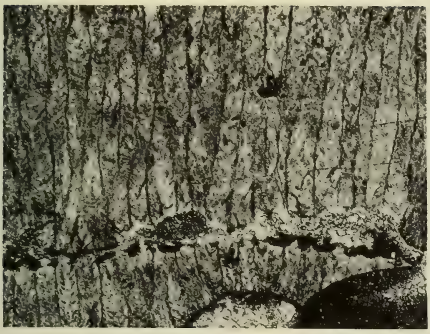
Figure | Page

1. **Dermatostroma ? escanabaense** Galloway and Ehlers, n. sp. 73
   a. Vertical section of holotype, X 10, showing the small, vertical prisms and the diverging fibers and indications of growth layers. Middle Ordovician, Black River of Trenton fm., Escanaba R., Delta Co., Mich., University of Michigan, No. 39449. Indiana University Paleo. Coll., slide 308-98. Left half retouched.
   b. Tangential section of same specimen, X 10, showing the small prisms, as compared with those of *D. glyptum*, each with a dark ring with light center inside, each terminating in a papilla. The radial fibers are obscure. Slide 308-99. Unretouched.

2. **Dermatostroma costatum** Galloway and St. Jean, n. sp. 74
   a. Cross section of holotype, X 10, showing outer layer with costae and papillae, consisting of debris of *Aulacera* cyst plates, and inner layer of less disturbed cyst plates. Upper Ordovician, Lower Liberty fm., Wilson Cr., 2 miles southwest of Deatsville, Ky. Collected by Ruth G. Browne. Indiana University Paleo. Coll., RB11, and slide 308-99. Slightly retouched.
   b. Cross section of paratype, X 10, showing outer thin layers with organic debris, lying on coarsely crystalline calcite with organic debris inclusions, which pass downward into *Aulacera* cysts and pillars partly destroyed. Same collection. RB5, slide 308-10. Slightly retouched.

3. **Dermatostroma nodoundulatum** Galloway and St. Jean, n. sp. 75
   a. Part of cross section of holotype, X 10, showing surface with papillae, outer zone of *Aulacera* debris and calcite, and inner zone of less disturbed *Aulacera* cysts. Upper Ord., basal Liberty fm., Wilson Cr., 2 miles southwest of Deatsville, Ky. Collected by Ruth G. Browne. Indiana University Paleo. Coll., RB73. Slide 308-23. Retouched.
   b. Paratype, X 10, showing papillae on outer layer of *Aulacera* debris, passing downward into calcite and less disturbed *Aulacera* cysts. Same locality, collection and depository. RB1, slide 302-27. Retouched.

4. **Dermatostroma concentricum** Galloway and Ehlers, n. sp. 76
   a. Cross section of holotype, X 10, cutting a mamelon, showing the disturbed cysts of the *Aulacera*, the calcite layer, and the wrinkled laminae of the *Dermatostroma*. Upper Ordovician, Blackbridge, 10 miles upstream from Louisville, Ky. Collected by Dr. Carl Rominger, 1903. Mus. Paleont., University of Michigan, specimen and slide 01-25. Indiana University Paleo. Coll., slide 308-62. Unretouched.
   b. Vertical section of holotype, X 10, showing only one layer in the laminae, which are flocculent and wrinkled, slide 308-63. Unretouched.
   c. Tangential section of holotype, X 10, showing round denticles and wrinkles, slide 308-63. Unretouched.



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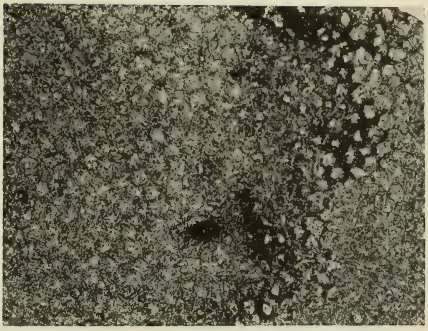

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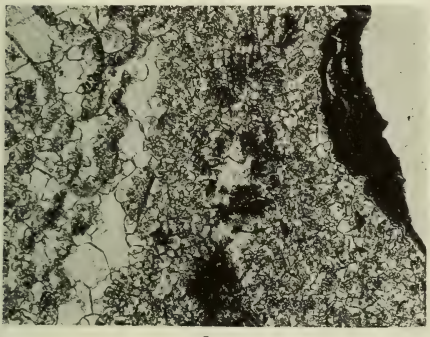

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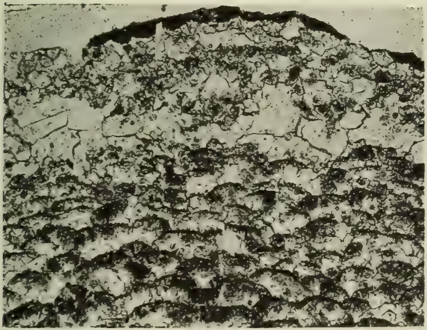

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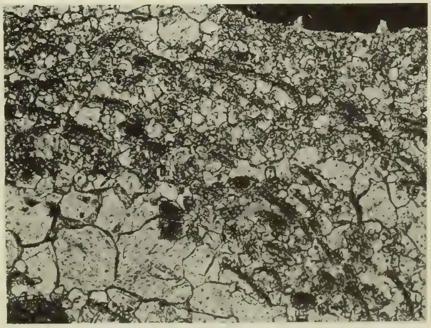

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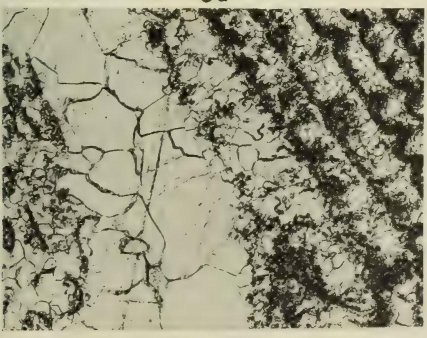

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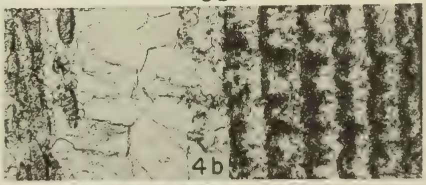

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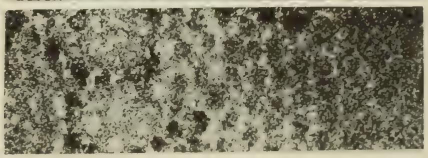

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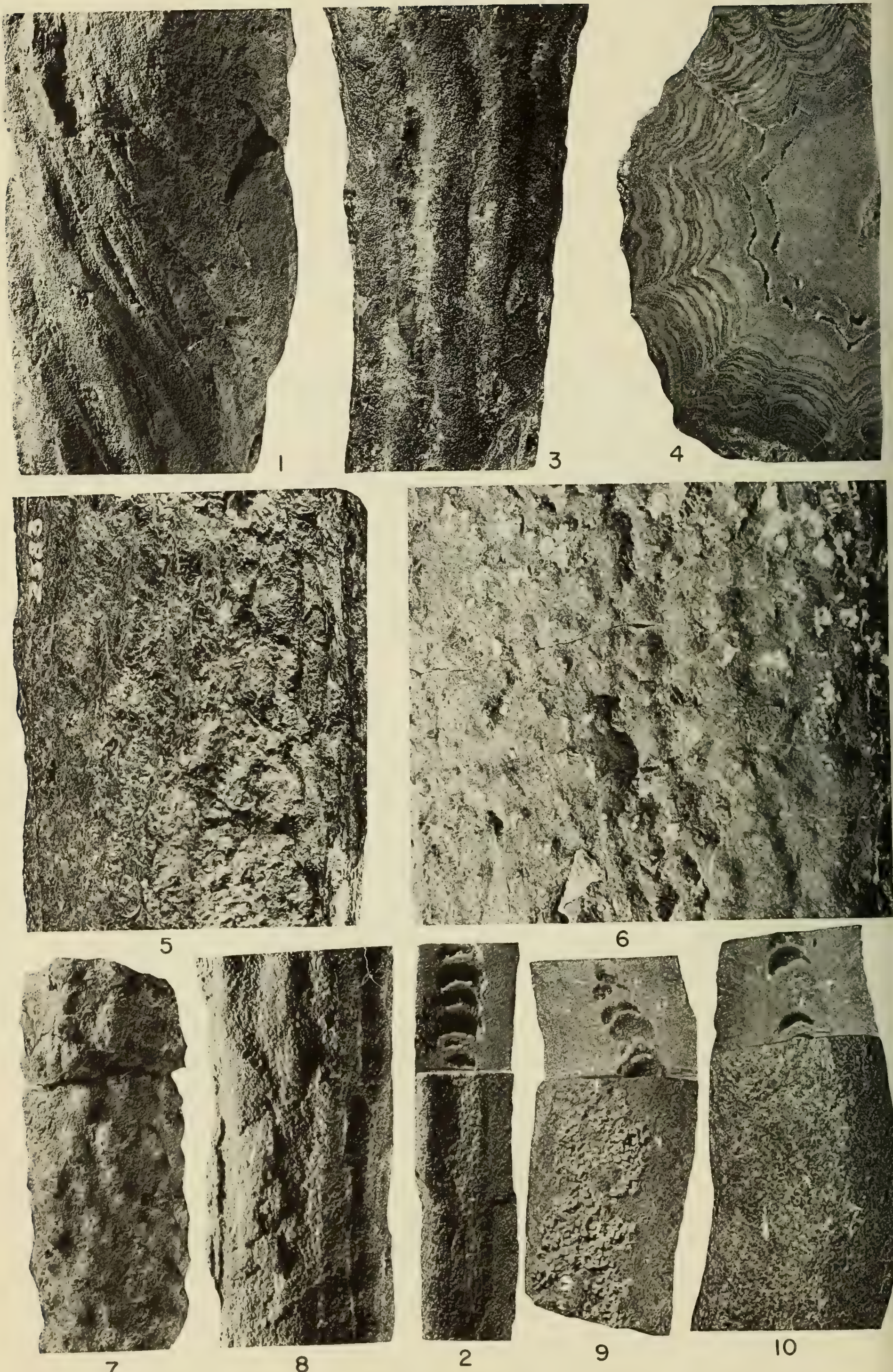
1
3
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8
2
9
10

Explanation of Plate 12

All figures natural size except No. 1

Figure		Page
1.	**Aulacera plummeri** Galloway and St. Jean .... Hypotype, X 2/3, with spiral, longitudinal ridges characteristic of large specimens. Basal Liberty fm., Wilson Cr., 2 miles southwest of Deatsville, Ky. Collected by Ruth G. Browne. Indiana University Paleo. Coll., No. RB4.	27
2.	**Aulacera plummeri** Galloway and St. Jean .... Paratype, immature. Same locality, horizon and collector. RB2.	27
3.	**Aulacera plummeri** Galloway and St. Jean .... Topotype, with nearly straight ridges. Whitewater fm., Elkhorn Cr., 4 miles south of Richmond, Ind. Collected by C. H. Hill.	27
4.	**Aulacera radiata** Galloway and St. Jean, n. sp. .... Holotype, showing thin rays of cysts. Richmondian, Anticosti Island. Mus. Comp. Zool., Harvard University, No. 702A.	32
5.	**Aulacera undulata** (Billings) .... Part of lectotype, with surface somewhat weathered, showing short, slightly spiral ridges. Late Richmond, Anticosti Island. Canadian Geol. Surv., No. 2583, Marked "TYPE." Collected by J. Richardson.	30
6.	**Aulacera nodulosa** (Billings) .... Topotype, showing large nodes in vertical lines. Upper Ordovician, Anticosti Is. Peabody Mus., Yale University, No. 19556.	34
7.	**Aulacera nodulifera** (Foerste) .... Small hypotype, too poorly preserved to furnish a thin section. Basal Liberty fm., 2 miles southwest of Deatsville, Ky. Collected by Ruth G. Browne. Indiana University Paleo. Coll., No. RB74.	36
8.	**Aulacera intermedia** (Foerste) .... Hypotype, poorly preserved, showing discontinuous ridges and elongate nodes. Basal Liberty fm., 2 miles southwest of Deatsville, Ky. Collected by Ruth G. Browne. No. RB20.	37
9, 10.	**Aulacera cylindrica** (Foerste) .... Hypotypes, curved specimens, showing lack of nodes and ridges. Basal Liberty fm., 2 miles southwest of Deatsville, Ky. No. RB60, 61.	38

Explanation of Plate 13
All figures natural size

Figure | Page

1. **Dermatostroma scabrum** (James) 69
Hypotype, showing monticules and papillae. Upper Ordovician, Richmond gr., Kentucky end of bridge, Madison, Ind. Indiana University Paleo. Coll., No. 5076, slide 299-50.

2. **Dermatostroma ? glyptum** (Foerste) 72
Topotype, showing surface ridges and papillae. Whitewater fm., Dutch Cr., Clinton Co., Ohio. Coll. by G. M. Austin. Mus. Paleont., University of Michigan, No. 7665, slide 01-21.

3. **Dermatostroma ? escanabaense** Galloway and Ehlers, n. sp. 73
Holotype, attached to *Cystostroma minimum*, showing irregular surface with small papillae. Black River or Trenton, Escanaba River, Delta Co., Mich. Collected by Dr. Carl Rominger. Mus. Paleont., University of Michigan, No. 39449; part in Indiana University Paleo. Coll., slides 308-98, 99.

4. **Dermatostroma costatum** Galloway and St. Jean, n. sp. 74
Holotype, attached to a largely destroyed *Aulacera*, showing nearly straight longitudinal ridges and papillae. Lower Liberty fm., Wilson Cr., 2 miles southwest of Deatsville, Ky. Collected by Ruth G. Browne. Indiana University Paleo. Coll., RB11, slides 308-99, 100.

5. **Dermatostroma costatum** Galloway and St. Jean, n. sp. 74
Paratype, oval in section 2¼ X 1¼ inches, attached to a layer of calcite 1-5 mm. thick, in turn attached to a cylindrical *Aulacera cylindrica*, 20 mm. in diameter, with the outside largely destroyed by the parasitic *Dendrostroma*. Liberty fm., 2 miles southwest of Deatsville, Ky. Collected by Ruth G. Browne. Indiana University Paleo. Coll., RB5, slides 308-10, 11.

6. **Dermatostroma costatum** Galloway and St. Jean, n. sp. 74
Paratype, young specimen, on immature and largely destroyed *Aulacera plummeri*. Same collection. No. RB52, slides 302-19, 20.

7. **Dermatostroma nodoundulatum** Galloway and St. Jean, n. sp. 75
Holotype, showing nodes on nearly vertical costae. The small, abundant papillae do not show in the figure. Lower Liberty fm., 2 miles southwest of Deatsville, Ky. Collected by Ruth G. Browne. Indiana University Paleo. Coll., No. RB73, slide 302-22.

8. **Dermatostroma nodoundulatum** Galloway and St. Jean, n. sp. 75
Paratype, attached to *Aulacera plummeri*, but spreading onto mud on both sides. Same collection. No. RB75, slides 308-56, 57.

9. **Dermatostroma nodoundulatum** Galloway and St. Jean 75
Paratype, attached to one side of *A. plummeri*, spreading out on both edges, with larger ridges and nodes than usual, with papillae. Same collection, No. RB1, slides 302-24, 27.

10. **Dermatostroma concentricum** Galloway and Ehlers, n. sp. 76
Holotype, showing surface with mamelons. Upper Richmond, Blackbridge, 10 miles upstream from Louisville, Ky. Collected by Dr. Carl Rominger. Mus. Paleont., University of Michigan, No. A, slide 01-25. Indiana University Paleo. Coll., sections 302-62, 63.


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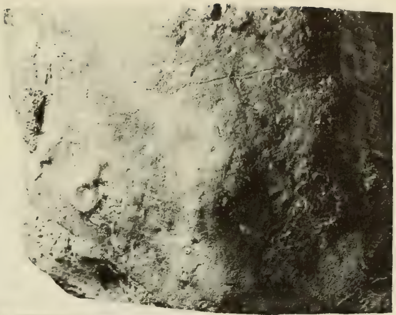
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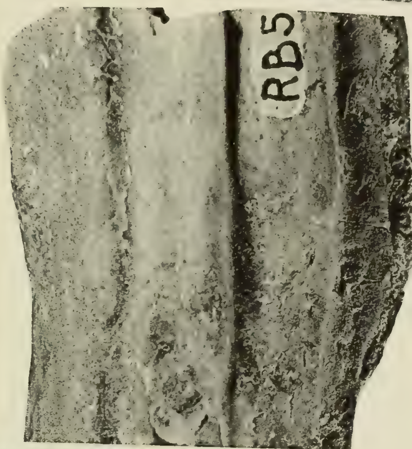

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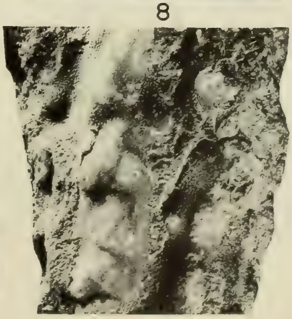
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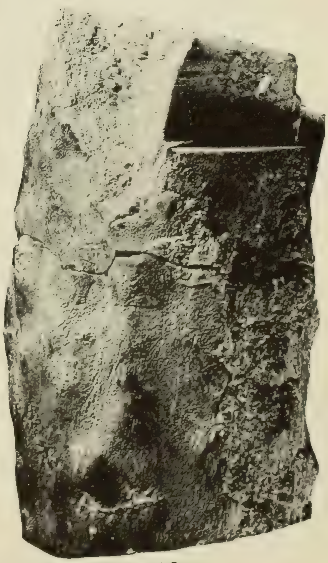
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INDEX VOLUME XLIII

NO. 194

Note: The left hand bold face figures refer to plates, the right hand light face figures refer to pages.

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573

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NAMES OF AND VARIATION IN CERTAIN INDO-PACIFIC CAMERINIDS—NO. 2. A REPLY

By

W. Storrs Cole

Cornell University

January 16, 1961

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CONTENTS

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NAMES OF AND VARIATION IN CERTAIN INDO-PACIFIC CAMERINIDS—NO. 2. A REPLY.*

W. Storrs Cole
Cornell University, Ithaca, N. Y.

ABSTRACT

This discourse presents additional evidence for the modification of the traditional classification of camerinids with undivided median chambers and is, in part, a reply to Smout and Eames (1960) who disagreed with the classification of certain Indo-Pacific species presented by Cole (1959). Whereas Smout and Eames recognize seven species assigned to two genera, an attempt is made to demonstrate that there are only three species belonging to one genus. The causes of the variation between individuals in a given species are discussed and applied to series of specimens.

INTRODUCTION

Many years ago in one of the first discourses on variation in American species of larger Foraminifera Vaughan (1933, p. 6) wrote: "Variation in several species of *Lepidocyclina* is discussed in some detail on subsequent pages . . . The amount of variation in many species of orbitoids is bewildering. Because of such variation and the difficulty of defining certain species, I have for years delayed publication on some of them. It would be expecting too much to hope that all interpretations made in this paper will remain unchallenged or unchanged. A more reasonable hope is that this study may help in a very difficult kind of research."

Although Vaughan had available the published conclusions of many workers and vast numbers of specimens in his own collection, there still remained much to be discovered concerning variation as most of the species not only of the orbitoids, but also of the other larger Foraminifera, had not been investigated in sufficient detail. In the years that have intervened Vaughan, Vaughan and Cole, and Cole among others have carried forward these studies.

Recently, Cole (1953; 1958*a;* 1958*b;* 1959; 1960) published a series of studies on variation in the camerinids both at the generic and the specific levels. He (1960, p. 189) decided that ". . . the only valid genera which can be distinguished by internal structure are *Camerina* and *Miscellanea*" in the camerinids with undivided chambers. In part this conclusion was based on a detailed study (Cole, 1959) of certain Recent and fossil species from the Indo-Pacific region.

As Vaughan predicted would be the case, certain interpretations which Cole (1953, p. 32; 1959) made have been challenged by Nagappa (1959) and by Smout and Eames (1960). Cole (1960) refuted the arguments of

*The cost of the printed plates was supplied by the William F. E. Gurley Foundation for paleontology of Cornell University.

Nagappa, and in this discourse an attempt will be made to invalidate the objections raised by Smout and Eames.

Although criticism is salutory and should be encouraged in all fields of human endeavor, and especially in science, one should expect that the criticism would be objective, logical, imaginative, and above all, informative. Moreover, the presentation of new data rather than a rearrangement of data already published would make any criticism vital rather than a sterile compilation of opinion from pre-existing data.

Therefore, for this reply to Smout and Eames (1960) I have prepared additional photomicrographs of external views and thin sections of certain critical species. In addition to my own considerable collection I have had made available to me through the courtesy of the U. S. National Museum Recent specimens from the Philippine area actually identified by Cushman (1921).

Cole (1959, p. 356) wrote: "In most cases thin sections were prepared from each of the variants. In the explanation of the plates a reference is given after each thin section to the variant which duplicates the external appearance of the specimen from which the thin section was made." It should be re-emphasized that suites of specimens which had identical external appearance were selected from each population. From each suite a specimen was preserved for the external appearance, whereas other, but identical, specimens were ground either for transverse sections or median sections. This practice was followed in preparing additional sections, some of which are illustrated.

Therefore, it is difficult to understand why Smout and Eames (1960) should disregard this stated association of external views with the thin sections and place certain specimens in one species, but relegate the corresponding thin section to another species.

On plate 28 (Cole, 1959) a specimen was illustrated as figure 2. The transverse section from an identical specimen was shown as figure 15, plate 30 and the corresponding median section was given as figure 5 on plate 30. Smout and Eames (1960, p. 111) assigned the transverse section (Cole's fig. 15, pl. 30) to *Operculinella* cf. *O. striatoreticulata* (Rutten), a middle to upper Eocene American species. They placed the other two specimens which were identical with the specimen from which the transverse section was made under *Operculinella venosa*.

In a similar manner the transverse section on plate 29, figure 5 was assigned to *Operculina gaymardi* although the corresponding photomicrograph of the external view (fig. 9, pl. 28) and that of the median section (fig. 8, pl. 30) were referred by them to *Operculinella venosa.*

The specimens discussed are deposited in the Cole collection at Cornell University and will be transferred eventually to the U. S. National Museum.

LOCALITIES

Recent material

Locality 1. *Albatross* station D5141, latitude 6° 09′ 00″ N., longitude 120° 58′ 00″ E., at a depth of 29 fathoms.

2. *Albatross* station D5142, latitude 6° 06′ 10″ N., longitude 121° 02′ 40″ E., at a depth of 21 fathoms.
3. *Albatross* station D5134, latitude 6° 44′ 45″ N., longitude 121° 48′ 00″ E., at a depth of 25 fathoms.
4. Tacloban Anchorage, Philippine Islands.
5. Espiritu Santo, New Hebrides, through the courtesy of Mrs. Esther R. Applin.

Fossil material

6. Station IS-F 310a-56, Ishigaki-shima, Yaeyamagunto Ryukyu-retto; deposit of gray sandy clay exposed in the north bank of the east branch of the Nagura-gawa about 2.45 miles from the mouth of the river (reference: Cole, 1959, p. 350).
7. Nakôshi, Haneji-mura, Okinawa-jima, through the courtesy of the late T. Wayland Vaughan (reference: Yabe and Hanzawa, 1925, p. 39).
8. L 444, Oneata, Lau Islands, Fiji (reference: Ladd and Hoffmeister, 1945, p. 90).

CAUSES OF VARIATION

Individuals of a given species of Foraminifera may differ from each other because of genetic influences or because of environmental controls. It may be assumed that individual variation within a given species in a population from one locality is controlled by plasticity within the species, whereas differences in a given species collected from different ecological situations are influenced in addition by external or environmental controls.

Vaughan (1933, p. 7) wrote: "The variations presented by some species of *Lepidocyclina* suggest that the phenomena may be fundamentally similar to the variations obtained by Jennings in his experimental study of *Difflugia corona.* This work of Jennings should be studied by everyone who is engaged in taxonomic work on foraminifera . . . From the accounts given in this paper of variation in single lots of specimens of species of *Lepidocyclina* and from work such as that of Jennings, it is obvious that to attach a different specific name to every variant in a lot of specimens of *Lepidocyclina* is an absurdity." Although Vaughan was concerned at that time with species of *Lepidocyclina,* it should be obvious that these observations can be applied to any species.

Heron-Allen (1915, p. 262) in describing the development of the tests of Foraminifera which were maintained in aquaria observed: ". . . in a tank in which I cultivated many generations of *Massilina secans* (d'Orbigny) in my laboratory at Selsey, in which the salinity was kept at a fixed standard by the addition of *tap* water (from my own wells) which was markedly hard owing to the presence of lime, some interesting and extraordinary modifications of the shells were brought about. In this case, far from the shells becoming weak and hyaline, they had a tendency to add striae and ridges of secondary shell-substance upon the surface of the shell, and marked carinations and denticulations round its periphery . . ."

Thus, there is abundant evidence not only from the observations cited, but also from other sources that variation between individual specimens may be controlled either by genetic factors or by environment. Although the paleontologist cannot study interbreeding populations, he should be able to make deductions particularly when he has abundant and well-preserved material for study.

In a study of American middle and upper Eocene species of *Operculinoides* (= *Camerina*) Cole (1958, p. 191) observed that individuals of a given species from shales had smaller, more delicate, and fragile tests than did individuals of this same species from limestone. He postulated that these differences resulted from environmental controls. This deduction regarding the fossil specimens is substantiated by the experiment of Heron-Allen with the cultures which he maintained.

CLASSIFICATION

Smout and Eames (1960) used the specific names *Operculina gaymardi* Deshayes, *O. ammonoides* (Gronovius), *O. hanzawai* Smout and Eames, and *Operculinella venosa* (Fichtel and Moll) for specimens which Cole (1959) classified as *Operculina ammonoides.* The specimens which Cole identified as *Operculina venosa* were reclassified by Smout and Eames as *Operculinella cumingii* (Carpenter).

Two separate but interlocking problems are involved in the different uses of the nomenclature. The first one is the definition of "*Nautilus*" *venosus* Fichtel and Moll. The second problem is a broader one inasmuch as it is concerned with the definition of genus and species in the broad sense.

Although much has been written concerning the species "*Nautilus*" *venosus*, the types have not been redescribed to my knowledge. Therefore, one must depend on the type figure. This figure is similar to specimens from the Philippine area (figs. 18, 19, Pl. 14) originally described by Carpenter as *Amphistegina cumingii*. However, other specimens from the Indo-Pacific (figs. 20-22, Pl. 14) somewhat resemble the type illustration of "*Nautilus*" *venosus*.

Although *Camerina* "*cumingii*" (figs. 18, 19, Pl. 14) is a distinct species, the question arises whether the other involute specimens (figs. 13-17, 20-22, Pl. 14) are another species, or whether this kind of specimen belongs at one end of a gradational series which includes evolute specimens known as *Camerina ammonoides* (figs. 1-12, Pl. 14).

The type illustration of *C. venosa* is an involute specimen with wavy sutures, several of which bifurcate. Most specimens of *C.* "*cumingii*" possess sutures which bifurcate, and at one time I considered this to be a specific character which could be used to prove that *C.* "*cumingii*" and *C. venosa* were the same. However, certain of the other kind of involute specimens occasionally have sutures which bifurcate (see: fig. 20, top and right side, fig. 22, upper left side, Pl. 14). Thus, this characteristic can not be used to define *C. venosa*.

However, the type illustration of *C. venosa* has wavy, unbeaded sutures which are limbate and the test is completely involute. Therefore, it is similar to the external appearance of *C.* "*cumingii*." The other kind of specimens has more regularly recurved sutures which normally are beaded or have a tendency to bead. The umbonal area has a distinct set of small bosses, and in the majority of the tests the spiral wall of the final volution does not cover the umbonal area (figs. 20-22, Pl. 14). The sutures are much narrower than those of *C. cumingii*.

Chapman and Parr (1937, p. 291) clearly stated these differences in their study and concluded that *C.* "*cumingii*" was a synonym of *C. venosa*, a conclusion which is correct from the information available.

Smout and Eames (1960, p. 111, 112) retained the species "*Operculinella cumingi*" and used the name *Camerina venosa* for specimens similar to those illustrated as figures 20-22, Plate 14. They state in separating this kind of specimen from *Camerina ammonoides* that "O. *venosa* has a thinner marginal cord, thinner chamber walls; also flattened polar regions, with the return to the margin at an obtuse angle to them. O. *ammonoides* has evolute chambers, while all but the last whorl of O. *venosa* are strongly evolute."

If the illustration (fig. 8, Pl. 15) of a specimen which was assigned by them to O. *venosa* is compared with a specimen of the evolute kind (fig. 11, Pl. 15) it will be found that both specimens have the same internal structure and differ only in the kind of coiling. As the kind of coiling is variable and complete gradation can be demonstrated, the separation used by Smout and Eames can not be maintained. The specimens to which they apply the name O. *venosa* belong to the *Camerina ammonoides* series. The gradation which occurs in this series will be discussed in detail later in this discourse.

Smout and Eames (1960, p. 112) argue that the genus *Operculinella* Yabe, 1918, based on *Amphistegina cumingii* (= *Camerina venosa*) should be retained, or another generic name substituted for it as they wrote: "Cole (1958) showed that there is insufficient difference between *Operculinella* and *Operculinoides* for generic distinction. He preferred to use *Operculinoides,* but *Operculinella* is obviously the senior name and the one of these two that should be conserved. Its actual validity is doubtful, however, and the possible prior synonyms will be discussed elsewhere."

Seemingly, an attempt will be made to re-establish *Palaeonummulites* Schubert, 1908, based on *Nummulina pristina* Brady, 1874, as Eames *et al* (1960, p. 448) wrote: "*Palaeonummulites* . . . is regarded as a prior synonym of both *Operculinella* Yabe 1918 and *Operculinoides* Hanzawa 1935."

However, the illustrations of *Nummulina pristina* are so similar to those of specimens assigned to *Operculinella* that the name *Palaeonummulites* can not be used as a prior name if the thesis is accepted that *Operculinella* is a synonym of *Camerina* (Cole, 1960, p. 196).

As Cole (1960) has given recently adequate proof that the former division of the camerinids without subdivision of the chambers has been based upon specific rather than generic characteristics, little can be added here. However, that discourse was not available to Smout and Eames at the time they wrote their paper. Inasmuch as they emphasized the retention of the genus *Operculinella,* it might be pertinent to discuss the status of this genus in more detail.

Smout and Eames (1960, p. 112) wrote: "The genus represented by *Operculinella* is, however, an important one. The numerous small nummuloid species that occur in the Tertiary and Quaternary can be classified rapidly as evolute or at least partially involute with a negligible proportion of cases of real difficulty. To ignore this traditional distinction would increase the number of species of *Operculina* to the point where, as in *Nummulites,* they become very difficult to comprehend."

As a dissent from this viewpoint it should be stated that the structure and form of many of the Tertiary to Recent specimens traditionally classified under various generic names, such as *Operculinella,* is identical with that of other specimens from the Eocene and Oligocene traditionally classified as *Camerina.* Thus, one had to determine the stratigraphic level from which the specimen was obtained before it could be assigned to a genus.

If a narrow, unimaginative viewpoint is maintained with regard to the classification of animals into genera and species, divisions will result which are artificial and empirical. The end product of such a classification is the proliferation of "form" genera and species without regard to the relationship of these animals in nature. The superficial "form" of the individual specimen which is selected at random as the type of the species may become the dominant factor upon which a generic classification later is based.

Types are essential to the classification, but only as a frame of reference which must be expanded as data is accumulated. "Form" genera and species also have their place in any paleontological classification because it is impossible in many cases to demonstrate that interbreeding would occur, and also where the natural position of the individuals can not be determined because of the lack of sufficient observation.

However, with sufficient data, even without the benefit of applying the criteria of interbreeding and an analysis of the soft parts, it should be possible to postulate natural relations to a greater degree than has been done by many taxonomists.

Smout and Eames (1960, p. 112) wrote: "it is only in the case of *Operculina gaymardi* and *O. ammonoides* that intergradation is found, and even then the use of two names is convenient." To me the maintenance of two names not only conceals the relationship between the individual specimens of a single population, but also is less convenient than the use of one name inasmuch as many individual specimens must be arbitrarily assigned to one or the other species.

Moreover, they deny the existence of intermediate specimens between the specimens selected as representative of other species which they define as they wrote (p. 112): "The existence of intermediate specimens . . . is not firmly established, nor is there proof of continuous variation between evolute and partially evolute species."

Sufficient photomicrographs have been published to demonstrate that the gradation is complete and that it is impossible to separate the individuals of the series in question except by subjective and artificial decisions so that many specimens would be classified as one species by a competent worker, whereas another equally competent authority would place these same specimens in another species and genus.

The end result of artificial and subjectively determined divisions is chaos so far as either the classification or the practical use of genera and species in stratigraphy is concerned. On the other hand if genera and species are based on a natural classification which recognizes variation and intergradation, it is possible to determine the geographic and stratigraphic ranges of the genera and species and to use them for correlation with some degree of assurance.

VARIATION IN CAMERINA AMMONOIDES

Smout and Eames (1960) in the rearrangement of the specimens assigned by Cole (1959) to the species "*Operculina*" *ammonoides* decided that the transverse section (Cole, 1959, pl. 29, fig. 5) which was made from a specimen similar to the one illustrated as figure 9, plate 28 (Cole, 1959) should be assigned to "*Operculina*" *gaymardi,* whereas the uncut specimen should be placed under the species "*Operculinella*" *venosa.*

Therefore, another specimen from the suite from which these specimens were selected originally was chosen and a transverse section was cut (figs. 7, 9, Pl. 15). This section was photographed X 20 for comparison with figure 5, plate 29 (Cole, 1959). The only difference which can be observed is that the second specimen is slightly thicker through the center.

This specimen (fig. 7, Pl. 15) also was photographed X 40 (fig. 9, Pl. 15). A specimen (fig. 8, pl. 29, Cole, 1959) assigned to "*O.*" *ammonoides* by Cole, but to "*Operculinella*" *venosa* by Smout and Eames (1960, p. 111), was rephotographed X 40 for comparison. In addition a specimen from Nakôshi which was similar to the specimen (fig. 17, Pl. 14) was made into a transverse section (fig. 10, Pl. 15) and a specimen from Espiritu Santo was cut for a transverse section (fig. 11, Pl. 15).

If the illustrations (figs. 8-11, Pl. 15) of these four specimens are studied, the similarities in internal structure, such as the wall structure, marginal cord, and axial plugs, are apparent. It should be noted here for those who have not made and studied thin sections that the axial plug may appear to be absent, or it may appear only at one side. This is the result of the position of the section. Moreover, the thickness of the axial plug is governed in part by the position of the section.

Although the internal structures are identical in these specimens, the shape of the test varies from completely involute (fig. 8, Pl. 15) to slightly evolute (fig. 10, Pl. 15) to evolute in the final whorl (fig. 9, Pl. 15) to evolute (fig. 11, Pl. 15). As the kind of coiling is reflected in the development of the alar prolongations, the completely involute specimen has long alar prolongations which extend to the axial plugs, whereas the evolute specimen is without alar prolongations and the partly evolute specimen (fig. 9, Pl. 15) has alar prolongations in the initial part, but lacks these in the final volution.

Inasmuch as Smout and Eames (1960, p. 110) assigned the specimens from Nakôshi (Cole, 1959, pl. 28, fig. 3; pl. 29, fig. 9; pl. 30, fig. 4) which Cole had identified as "*Operculina*" *ammonoides* to a new species which they named *Operculina hanzawai*, additional specimens were studied (figs. 2-17, Pl. 14; figs. 2-5, 10, Pl. 15) and sectioned.

In their discussion of this new species Smout and Eames (1960, p. 111) state: "The increased development of the alar prolongations of the chambers in the later whorls is, however, characteristic of neither species [O. *ammonoides* and O. *venosa* as interpreted by them] and cannot be satisfactory evidence of gradation between species." However, as the length of the alar prolongations is a function of the kind of coiling, it should vary with individual specimens depending on the amount of overlap of the spiral wall.

Figure 2, Plate 15 is identical with figure 9, plate 29 (Cole, 1959). Four additional transverse sections from Nakôshi (figs. 3-5, 10, Pl. 15) are illustrated and numerous external views (figs. 2-17, Pl. 14) are given. These should demonstrate that there is complete gradation from specimens with long alar prolongations to those without alar prolongations (figs. 4, 5, Pl. 15).

This series from Nakôshi integrates with the ones from Espiritu Santo (figs. 8, 11, Pl. 15) and Ishigaki-shima (fig. 9, Pl. 15) through the specimen illustrated as figure 11, Plate 15 which is the same as figure 3, Plate 15 and through figure 10, Plate 15 which is essentially the same as figure 8, Plate 15.

The most evolute and compressed specimen (fig. 5, Pl. 15) from Nakôshi from which a transverse section was made is similar in all respects to the specimen from Ishigaki-shima (Cole, 1959, fig. 4, pl. 29) which Cole identified as "O." *ammonoides,* but which Smout and Eames (1960, p. 110) reclassified as *Operculina gaymardi.* It is apparent that this specimen (fig. 5, Pl. 15) interconnects in structure with the other specimens from Nakôshi, Espiritu Santo, and Ishigaki-shima assigned to *Camerina ammonoides,* and it can not be considered a distinct species.

RECENT SPECIMENS FROM THE PHILIPPINE ISLANDS

In the representative lots of specimens from the Philippine Islands identified by Cushman (1921) the following observations may be helpful. Specimens identified as *Operculina discoidalis* (d'Orbigny) are *Camerina ammonoides,* one of which is illustrated (fig. 1, Pl. 14). Specimens identified as *Operculina granulosa* Leymerie are also *Camerina ammonoides* and one (fig. 23, Pl. 14) is illustrated. This specimen is identical with one from Apia Harbor, Uporu, Samoa Islands, illustrated by Yabe and Hanzawa (1925, fig. 13, Pl. 5). *Operculina elegans* Cushman (1921, p. 381) is almost identical with the specimen from Nakôshi illustrated as figure 8, Plate 14 and is identified as *Camerina ammonoides.*

Most, if not all, of the specimens identified by Cushman (p. 375) as *Operculina gaimairdi* d'Orbigny are *Camerina bartschi.*

Recently Graham and Militante (1959) published a report on Recent Foraminifera from the Puerto Galera area in northern Mindoro, Philippine Islands. On plate 12 they gave excellent illustrations of the *Camerina* which they found. Their figures 1-4, 7 and possibly figure 5 are *C. ammonoides* and figure 6 is *C. venosa.*

CAMERINA COMPLANATA AND CAMERINA BARTSCHI

"*Operculina*" *bartschi* Cushman (1921, p. 376) is a Recent species from the Philippine area, the type illustration of which is a sketch. Cole (1959, fig. 16, pl. 28) photographed a specimen to illustrate the external appearance. Smout and Eames (1960, p. 110) decided that this specimen should be referred to *Operculina gaymardi* Deshayes. In addition they (p. 113) assigned other specimens (Cole, 1959, fig. 16, pl. 29; fig. 2, pl.

31) from Oneata, Lau Islands, Fiji, identified by Cole as O. *complanata*, to O. *gaymardi*.

Yabe and Hanzawa (1925) identified specimens from Nakôshi as *Operculina bartschi* and gave an excellent series of illustrations. As the late T. Wayland Vaughan had presented me with a suite of these specimens a transverse section (fig. 3, Pl. 16) and a median section (fig. 8. Pl. 16) were prepared. Additional sections (figs. 1, 4, 5, Pl. 16) were made from specimens from Oneata and from the Philippine area (figs. 2, 6, 9, Pl. 16). These illustrations should be compared with those of *Camerina complanata* given by Cole (1959, figs. 3, 4, pl. 31).

All of these sections are similar except some have larger embryonic chambers. Smout and Eames (1960, p. 109) emphasized the size of the initial chamber as a specific feature of *Camerina complanata* as they noted "... the comparatively large megalosphere measuring about 0.35 mm. in diameter. Cole's pl. 29, fig. 16 may be this species but his pl. 31, fig. 2 has a small megalosphere and in this feature, the shape of the septa and the pace of the spire, the specimen agrees with the most laxispiral variants of *Operculina gaymardi*."

The measurements of the embryonic chambers of certain of these specimens are given in Table I.

Table 1.—Measurements of the embryonic chambers of *Camerina complanata*

	Pl. 16, fig. 1	Pl. 16, fig. 8	Pl. 16, fig. 9	pl. 31,* fig. 3	pl. 31,* fig. 2
Diameters of initial chamber...... μ	80x80	130x150	50x50	280x310	100x110
Diameters of second chamber .... μ	60x150	80x180	25x70	160x350	50x90
Distance across both chambers... μ	180	220	85	460	170

* Cole, 1959.

Several additional median sections were made from the original suite of specimens from which the specimen illustrated by figure 3, plate 31 (Cole, 1959) was obtained. The embryonic chambers vary in size from specimen to specimen. The smallest observed diameter across both chambers was 260μ. Thus, the embryonic chambers in these specimens vary from 260μ to 460μ.

Yabe and Hanzawa (1925, fig. 12, pl. 7) figured a specimen identified as *Operculina bartschi* from Nakôshi which as near as can be estimated has embryonic chambers which have a diameter across both chambers of about 400 μ. Thus, from two median sections from Nakôshi the range in diameter across both embryonic chambers is 220 to 400 μ.

The specimens from Nakôshi in external appearance are identical with those identified as O. *bartschi* from the Philippine area (compare fig. 16, pl. 28, Cole, 1960, with fig. 11, pl. 6, Yabe and Hanzawa, 1925). The internal structure of the specimens from Nakôshi (figs. 3, 8, Pl. 16), except for the size of the embryonic chambers, is identical with specimens (figs. 2, 6, 9, Pl. 16) from the Philippine area. However, the specimens of O. *bartschi* from Nakôshi in internal structure resemble specimens from Ishigaki-shima (figs. 3, 4, pl. 31, Cole, 1960) which were identified by Cole as O. *complanata* and accepted by Smout and Eames (1960, p. 109).

The major difference between the specimens identified as O. *bartschi* from Nakôshi and those assigned to O. *complanata* from Ishigaki-shima is in the external appearance as the specimens identified as O. *bartschi* have beaded surfaces, whereas those identified as O. *complanata* have smooth surfaces.

The specimens from Oneata, Lau Islands, Fiji (figs. 1, 4, 5, Pl. 16) represent the same kind of specimens previously identified as O. *complanata* by Cole (1945, p. 278, figs. D-G, pl. 12; figs. F-I, pl. 13; 1959, p. 361, fig. 16, pl. 29; fig. 2, pl. 31). The internal structure of these specimens (figs. 1, 4, 5, Pl. 16) is the same as that of O. *bartschi* (figs. 2, 6, 9, Pl. 16) from the Philippine area. These specimens differ, however, in external appearance as the specimens from Oneata have smooth surfaces, whereas those from the Philippine area have beaded surfaces.

Cole (1958*b*, p. 193) suggested "that the degree of beading is an individual rather than a specific character and is controlled to some extent by environmental factors." The experiment of Heron-Allen (1915, p. 262) substantiates this observation. Therefore, specimens identified previously as O. *bartschi* are ecologic variants of *Camerina complanata*. If this is the case, O. *bartschi* is a synonym of *Camerina complanata*.

However, if the size of the embryonic chambers is to be a governing factor in identification at least three species should be recognized, that is, one species for each population. The size of the embryonic chambers as well as the total size of the test is variable in most species of larger Foraminifera. Therefore, size is not a critical specific character.

CONCLUSION

If the thesis developed in this discourse is accepted and applied to the vast host of species which have been proposed, the nomenclature would be simplified and a classification would result which not only would more nearly approximate conditions in nature but also would be of more exact use in stratigraphy. It is impossible under present conditions to use species in the majority of cases for correlation as the same species commonly masquerades under many names. Nor has sufficient attention been given to the fact that many species are only ecologic variants, and, therefore, not true species.

Smout and Eames (1960) recognize seven species, all of which seemingly have similar, if not identical, geographic and stratigraphic ranges. Moreover, they place these species in two genera. The interpretation developed in this discourse is that there are only three species, namely, *Camerina ammonoides*, *C. complanata*, and *C. venosa*, belonging to one genus. Two lineages are represented, the *C. venosa* and the *C. complanata* ones, with *C. ammonoides* representing a sublineage of the *C. venosa* lineage.

The concepts expressed herein may be revolutionary, but if they stimulate work which leads eventually to a clarification of the classification of the camerinids the purpose of this discourse will be accomplished. Vaughan's preliminary work in 1933 has had this result with the classification of the American species of the *Lepidocyclina*. Although over 200 species and varieties had been proposed, detailed work has reduced the number of species significantly so that at present about 28 species are recognized.

It is not expected that all taxonomists will agree with the proposals set forth here as there have been and always will be the "lumpers" and the "splitters." But as data are accumulated and as workers attain experience in taxonomic work, the tendency to subdivide becomes less pronounced, and, thereby, a more natural classification evolves.

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PLATES

EXPLANATION OF PLATE 14

Figure		Page
1-17, 20-24.	**Camerina ammonoides** (Gronovius)	115, 118

1-17, 20-23. External views, x 10; 24, median section, x 20.

1. Specimen from the Philippine area (Recent) identified by Cushman (1921, p. 379) as *Operculina discoidalis* (d'Orbigny); USNM 15965.
2. Specimen from Nakoshi (fossil) which is identical with the specimen illustrated as figure 1.

3-17. Specimens from Nakoshi to demonstrate the variation in coiling and ornamentation of the test.

20-22. Specimens from Espiritu Santo (Recent); figure 21 is to be compared with figure 13.

23. Specimen from the Philippine area (Recent) identified by Cushman (1921, p. 381) as *Operculina granulosa* Leymerie; compare with figure 8; USNM 15985.

24. Median section from a specimen similar to figure 9.

17, 18.	**Camerina venosa** (Fichtel and Moll)	115

External views, x 10.

Specimens from the Philippine area (Recent) for comparison.

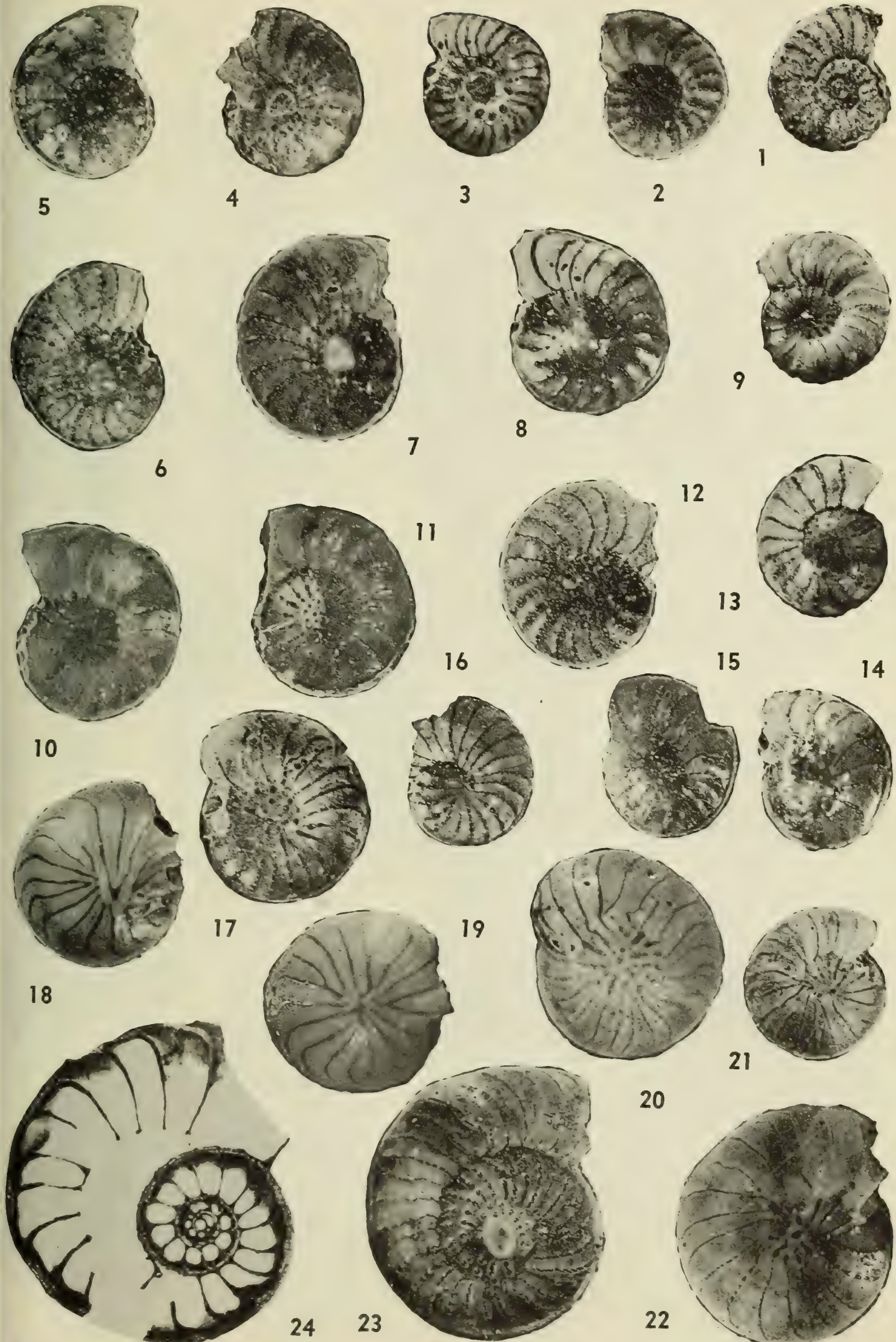
1. Loc. 3.—see text for description of localities.

2-17, 24. Loc. 7.

18-19. Loc. 2.

20-22. Loc. 5.

23. Loc. 4.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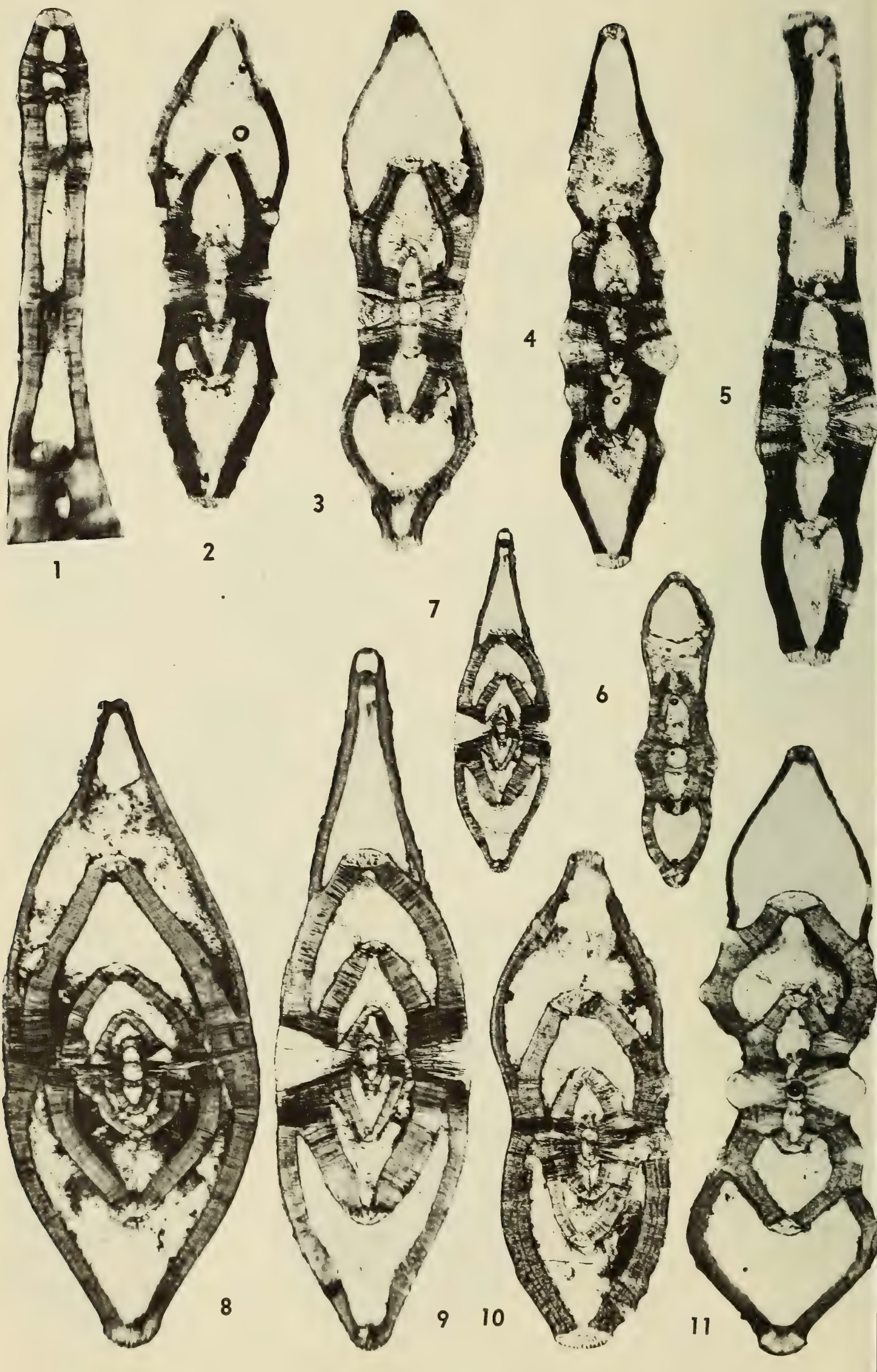
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EXPLANATION OF PLATE 15

Figure Page

Transverse sections, x 40, except figure 7, x 20.

1. **Camerina complanata** (Defrance) 120

Upper part of the specimen illustrated as figure 2, Plate 16, to show the structure of the spiral sheet and the marginal cord.

2-11. **Camerina ammonoides** (Gronovius) 115, 118

2. Specimen similar to the one (Cole, 1959, fig. 9, pl. 29) selected by Smout and Eames (1960, p. 110) to represent *Operculina hanzawai.*

3-5. Specimens to illustrate the progressive shortening of the alar prolongations as the test becomes more evolute and compressed; 3, see: fig. 2, Pl. 14; 4, see: fig. 8, Pl. 14; 5, see: figs. 10, 11, Pl. 14.

6. Small specimen.

7, 9. The same specimen; fig. 9 enlargement of fig. 7; see: fig. 9, pl. 28, Cole, 1959.

8. The same specimen illustrated as fig. 8, pl. 29, Cole, 1959.

10. A slightly evolute specimen; see: fig. 17, Pl. 14.

11. Evolute specimen; compare with fig. 7, pl. 28, Cole 1959 to demonstrate differences in the embracement of the final volution.

1. Loc. 1—see text for description of localities.

2-5, 10. Loc. 7

6, 8, 11. Loc. 5

7, 9. Loc. 6

EXPLANATION OF PLATE 16

Figure	Page

1-6, 9, x 20; 7, x 40; 8, x 12.5

1-9. **Camerina complanata** (Defrance) 120

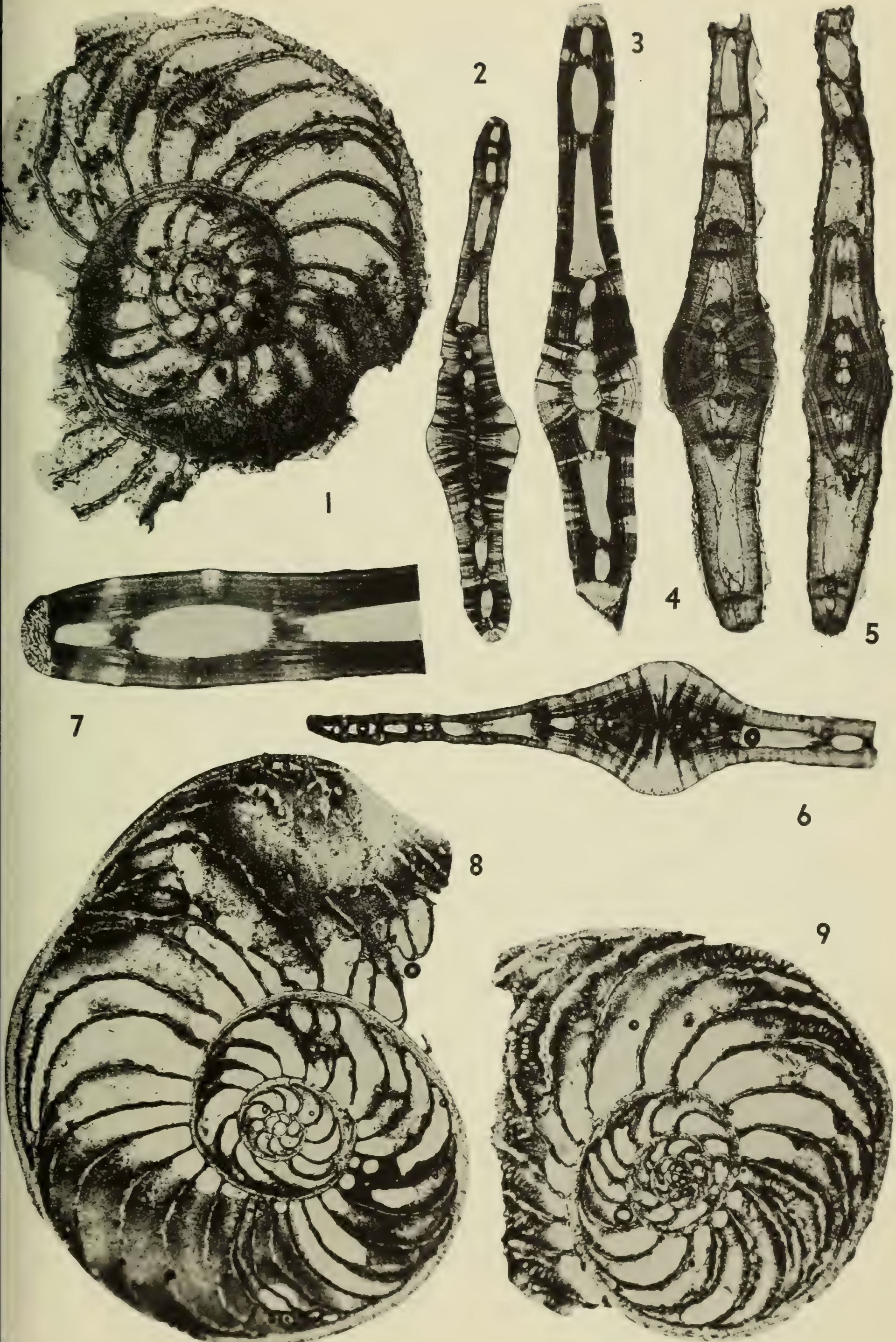
1, 8, 9. Median sections.

2-8. Transverse sections; see: fig. 1, Pl. 15 for an enlargement of fig. 2; 7, enlargement of the upper part of fig. 3.

1, 4, 5. Loc. 8—see text for description of localities.

2, 6, 9. Loc. 1

3, 7, 8. Loc. 7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MISSISSIPPIAN SMALLER FORAMINIFERA OF KENTUCKY, SOUTHERN INDIANA, NORTHERN TENNESSEE, AND SOUTHCENTRAL OHIO

By

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University of Louisville

December 1, 1961

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TABLE OF CONTENTS

CHARTS

MAP

This study is dedicated to
the University of Cincinnati.

MISSISSIPPIAN SMALLER FORAMINIFERA OF KENTUCKY, SOUTHERN INDIANA, NORTHERN TENNESSEE, AND SOUTHCENTRAL OHIO

James E. Conkin
University of Louisville

ABSTRACT

This paper is the first attempt at regional investigation of the occurrence in time and distribution in space of faunas of smaller Foraminifera in any Paleozoic system in North America. The investigation has been directed upon the Mississippian system, particularly aimed at examination of the Lower Mississippian sequence which I have long known to contain rather well-developed foraminiferal assemblages.

Geologic sections were measured and collections made from 89 geographic localities in southern Indiana, Kentucky, northern Tennessee, and southcentral Ohio. The shale beds were found to contain more Foraminifera than the limestones; thus emphasis was placed upon these fossiliferous shales.

During this study, Mississippian smaller Foraminifera were recognized for the first time from Ohio and Tennessee. Previous to this study, only one Mississippian formation in Kentucky was known to contain smaller Foraminifera (Conkin, 1954); during this study most of the Mississippian formations were found to contain smaller Foraminifera in greater or lesser amounts. This paper describes these Mississippian faunas and attempts to recognize usefulness of certain genera, species, and faunal assemblages in stratigraphy and correlation.

The Foraminifera herein described are allotted to 12 families, one of which, the Miliolidae, is new to the Mississippian system; to 18 genera, seven of which are new to the Mississippian system: *Agathammina, Climacammina, Crithionina, Proteonina, Stacheia, Thuramminoides,* and *Trochammina;* to 38 species, 18 of which are described as new species. One genus, *Thuramminoides,* is removed from the family Saccamminidae and placed in the family Astrorhizidae. Two generic revisions are included: *Hyperammina* and *Thuramminoides.* A proposal is introduced to formalize the emendation of *Hyperammina* made by Conkin in 1954. One specific revision is included: *Thuramminoides sphaeroidalis* Plummer, 1945. One genus, *Lugtonia* Cummings, 1955 and one species, *Thuramminoides teicherti* (Parr), (Crespin, 1958) are placed in synonomy.

A practical scheme of classification of wall structure of Mississippian Foraminifera, based on and modified after the classifications of H. B. Brady, 1876, H. J. Plummer, 1930, and R. H. Cummings, 1955, is presented here. The Mississippian Foraminifera are, by this introduced classification, divided into four large groups:

1) Arenaceous.
   A) calcareous—extraneous grains in calcareous or ferruginous cement or both.
   B) siliceous—extraneous grains in siliceous cement.
2) Granular calcareous—equidimensional grains of calcite embedded in crystalline calcite cement.
   A) calcite granules secreted by the protoplasm?
   B) calcite granules derived from a supersaturated, limy, sea bottom by selection of extraneous calcareous material by the protoplasm?
3) Compound wall—inner wall layer of fibrous calcite; outer wall layer of microgranular layer of calcite, or altered from calcite.
4) Amorphous calcite, or imperforate calcareous wall.

Paleozoic smaller Foraminifera are rather conservative in their evolution; nevertheless, certain genera are found to display enough biologic change to permit their use in zonation of the Mississippian sequence on a series level.

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The most important foraminiferal genus for zonation of the Lower Mississippian is *Hyperammina*. Evidence for the evolution of one species of *Hyperammina*, *H. kentuckyensis*, from another, *H. rockfordensis*, is presented, and the time of mutation is rather closely determined to be during upper Coral Ridge time (lowest Osagian).

Division of the Mississippian system of the studied area into zones characterized by certain species, genera, or faunal assemblages follows:

Chesterian—zone of *Millerella;* endothyrids; *Climacammina, Earlandia,* and *Hemigordius.*

Meramecian—zone of endothyrids; *Earlandia.*

Osagian—zone of *Hyperammina kentuckyensis,* and large *Thuramminoides sphaeroidalis;* this zone is divided into six subzones.

Kinderhookian—zone of abundant *Involutina* with rare occurrence of *Thuramminoides sphaeroidalis.*

Attempts were made to interpret the paleoecology of the individual species and to give information concerning the mode of deposition of the sediments in which the Foraminifera occur.

The enduring value of this paper lies in its presentation of detailed description of all the species, both previously known ones as well as new species (species descriptions from other geologic periods and other geographic areas can not be used to exemplify the genetic complex of a Mississippian form, even if of the same species); in the generic revisions; in the comments on genera and species; in the recognition of faunas, genera, and species which are restricted to definite portions of the Mississippian sequence; in the detailed measurement of geologic sections and accurate placement of individual species within the Mississippian system.

INTRODUCTION

PURPOSE

This paper presents the first broad paleontologic and stratigraphic coverage of smaller Foraminifera in the Mississippian system of North America. The purposes of this work are several: to describe the faunas found in the Mississippian sequence in Kentucky, southern Indiana, northern Tennessee, and southcentral Ohio; to give generic and specific revisions where necessary and to comment upon genera and species; to demonstrate the usefulness of Foraminifera and foraminiferal faunas for zonation of the Mississippian; to attempt recognition of evolutionary sequence of faunas; to present a number of measured sections; and to attempt interpretation of the paleoecology of the Mississippian beds in which smaller Foraminifera occur.

PREVIOUS WORK

Little effort has been expended upon Mississippian Foraminifera in North America with the exception of the genera *Endothyra* and

Millerella. These two genera are excluded from this study inasmuch as they are by definition not smaller Foraminifera.

Only a few papers have been published on Mississippian smaller Foraminifera of North America. The first paper contained Dawson's (1868, p. 285, text-fig. 82) description of *Earlandinita priscilla* (Dawson) from Nova Scotia. C. L. Cooper's (1947) report of four genera of smaller Foraminifera (*Glomospira, Hyperammina, Paleotextularia,* and *Trepeilopsis*) from the Chesterian Kinkaid* formation of Illinois constitutes the first record of Mississippian smaller Foraminifera in the United States. Only cursory records of Foraminifera have been noted by a handful of workers since Cooper's paper. Coryell and Rozanski (1942) reported one species, *Spirillina obduxa,* from the Chesterian Glen Dean limestone in Harding County, Illinois.

The Meramecian has heretofore not yielded smaller Foraminifera. Species of *Endothyra* of course are abundant in the Meramecian beds.

The first known Lower Mississippian species of smaller Foraminifera in North America, *Hyperammina kentuckyensis,* was described by Conkin (1954, pp. 166, 167, pl. 31, figs. 1-6), from southwestern Jefferson County, Kentucky. Conkin (1957, p. 1889) reported the first Lower Mississippian smaller Foraminifera from Ohio and Indiana, and recognized the stratigraphic value of the *Involutina*-dominated Kinderhookian Bedford shale and the *Hyperammina-Thuramminoides*-dominated Osagian beds in Ohio, Kentucky, and southern Indiana. In 1959, Gutschick and Treckman published the first comprehensive work on Mississippian foraminiferal faunas, from the Kinderhookian Rockford limestone of northern Indiana.

Gutschick (personal communication) has in press (International Geologic Congress, 1960) a comprehensive review of Mississippian micropaleontology, including the history of work on Mississippian Foraminifera in North America, so no further commentary will be presented here.

*Kinkaid formation, Weller, 1920 not to be confused with Kincaid formation Gardner, 1933 Midway group, Paleocene, Texas—Ed.

PRESENT WORK

This paper is based on collections from measured sections or stratigraphically placed outcrops or both from 89 localities in southern Indiana, Kentucky, northern Tennessee, and southcentral Ohio. Samples were taken from the shales and silty shales of the Lower Mississippian; from the limestones, shales, and sandstones of the Chesterian beds; and from the calcareous Meramecian sequence. Greatest sampling was done in the Lower Mississippian.

Limestones in the Mississippian of the studied region seem to contain few or no smaller Foraminifera, with the exception of the Kinderhookian Rockford limestone. In the Osagian, the limestones rarely produce a few fragments of *Thuramminoides* and *Hyperammina,* with the exception of the Floyds Knob formation, which in its shell breccia facies produces prolific numbers of well-preserved and gracefully slender *Hyperammina kentuckyensis.*

In this work, smaller Foraminifera are described from the Mississippian of Ohio and Tennessee for the first time. Previous to this paper, only one species of smaller Foraminifera, *Hyperammina kentuckyensis,* was known to occur in Kentucky (and this occurrence in only one formation, the Floyds Knob). Results of this study demonstrate the occurrence of smaller Foraminifera in nearly all formations of the Lower Mississippian of the studied area and the occurrence of smaller Foraminifera in the Meramecian and Chesterian sequences, but to a lesser degree.

ACKNOWLEDGMENTS

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The cost of illustration of this work has been met by the following institutions:

The Department of Geology of the University of Cincinnati
The Kentucky Geological Survey, Lexington, Kentucky
The University of Louisville

DEPOSITION OF TYPES

All figured specimens are deposited in the Cushman Foraminiferal Collection of the United States National Museum, Washington 25, D. C. Duplicate sets of specimens (unfigured paratypes, topotypes, or hypotypes) are deposited in three other institutions:

1. Paleontological Research Institution, Ithaca, New York. (Nos. 26403-26425.)
2. Department of Geology Museum, University of Cincinnati, Cincinnati 21, Ohio.
3. Department of Geology, University of Notre Dame, Notre Dame, Indiana.

In addition, the bulk of the unfigured types are retained by the writer in the geological collections of the University of Louisville.

STRATIGRAPHY

LIST OF LOCALITIES

The geographic positions of 89 localities from which sections were measured or samples collected or both in Kentucky, southern Indiana, northern Tennessee, and southcentral Ohio are presented here. The locality numbers used throughout the paper are preceded by the initial of the state in which they occur (except on Map 1 where space did not allow their inclusion), and are consecutively numbered within each state.

KENTUCKY

Jefferson County

K-1. Section measured down ravine below first lookout on road up Jacobs Hill, Iroquois Park, southern Louisville. Louisville West Quadrangle, Lat. 38° 9′ 22″ N, Long. 85° 47′ 8″ W.

K-2. Section measured on northwest side of Kenwood Hill, east of Jacobs Hill, southern Louisville. Louisville West Quadrangle, Lat. 38° 9′ 22″ N, Long. 85° 46′ 10″ W.

K-3. Section measured on south side of Kenwood Hill, east of Jacobs Hill, southern Louisville. Louisville West Quadrangle, Lat. 38° 9′ 7″ N, Long. 85° 46′ 3″ W.

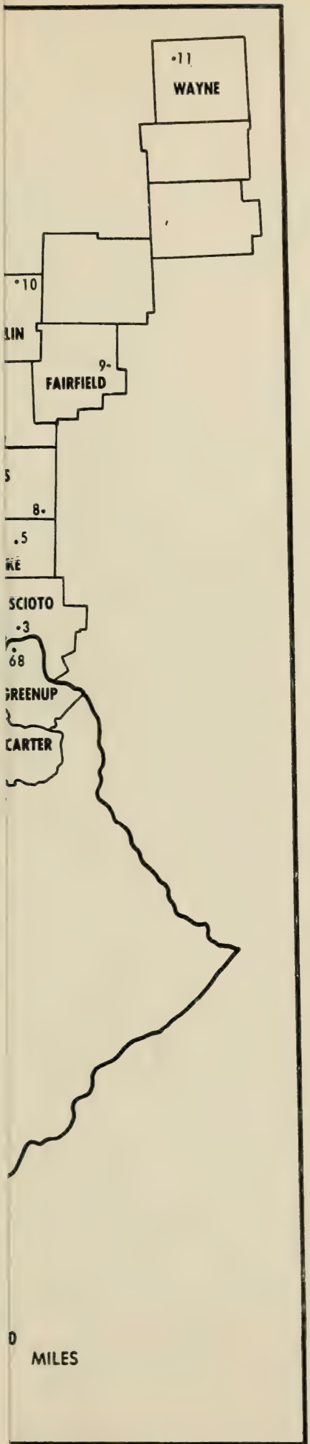
K-4. Section measured in east quarry of the Coral Ridge Brick and Tile Corp., Coral Ridge. Brooks Quadrangle, Lat. 38° 5′ 25″ N, Long. 85° 43′ 20″ W.

K-5. Sample from the Floyds Knob formation (Bed 1) at old quarry on Mitchell Hill Road, .2 miles from top of hill. Valley Station Quadrangle, Lat. 38° 4′ 40″ N, Long. 85° 46′ 12″ W.

Bullitt County

K-6. Section measured on west side of Button Mold Knob, east of County Road 1020, one mile south of the northern Bullitt County line. Brooks Quadrangle, Lat. 38° 4′ 40″ N, Long. 85° 42′ 35″ W.

K-7. Samples from the Button Mold Knob member (Bed 1) and the lowest shale bed in the Kenwood sandstone member (Bed 2) of the New Providence formation, and from the Floyds Knob formation (Bed 3) on road up Brooks Hill about one mile west of Brooks. (Stockdale, 1939, p. 141). Brooks Quadrangle, Lat. 38° 3′ 20″ N, Long. 85° 43′ 30″ W.



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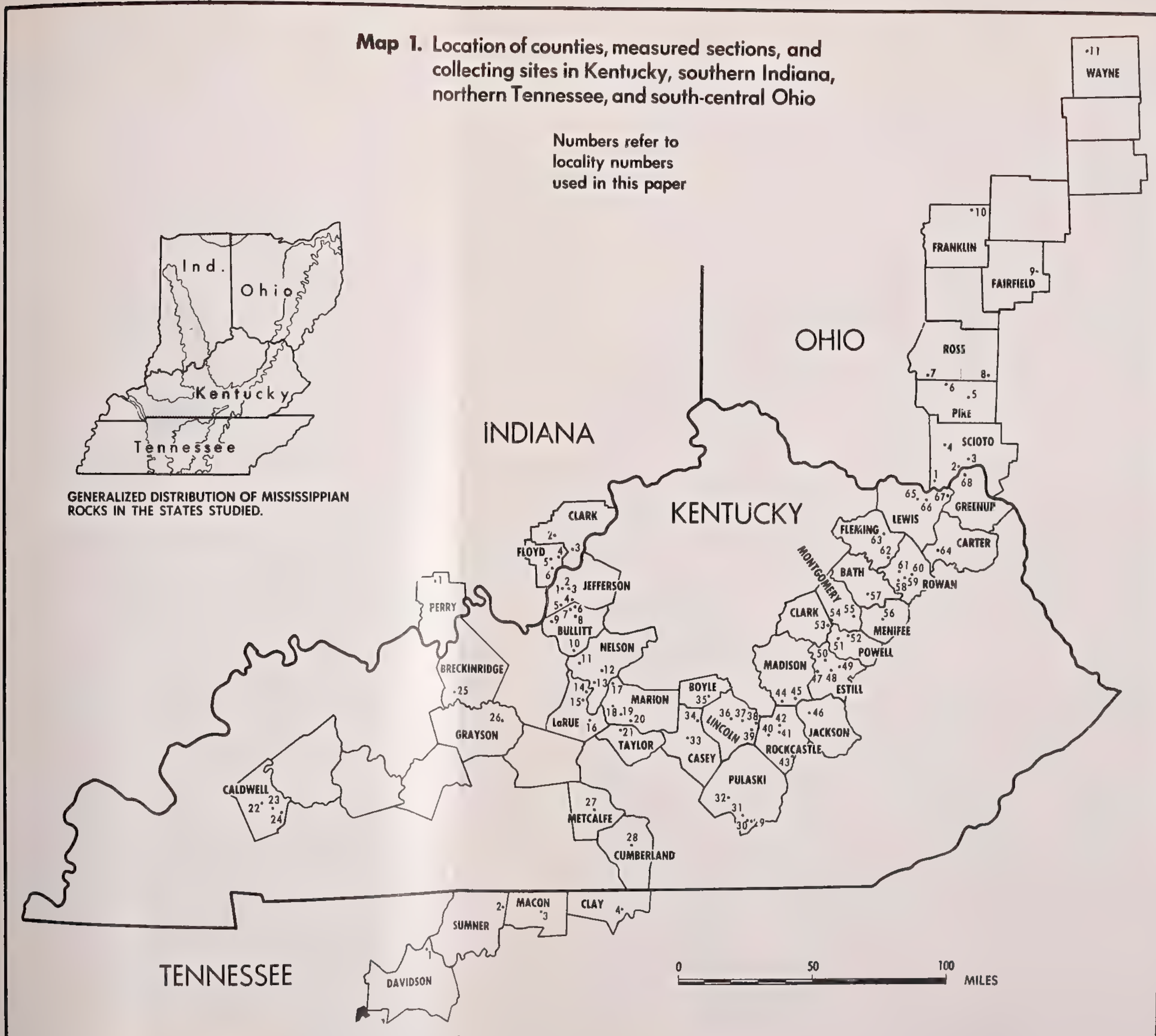


Map 1. Location of counties, measured sections, and collecting sites in Kentucky, southern Indiana, northern Tennessee, and south-central Ohio

K-8. Section measured in road cut where State Highway 61 and County Road 1020 join at Gap-in-Knob. Brooks Quadrangle, Lat. 38° 1′ N, Long. 85° 42′ 15″ W.

K-9. Samples from within the Brodhead formation 6″ to 10″ (Bed 1) and 16′ to 33′ (Bed 2) above road level in road cut north of Knob Creek Church on State Highway 44 about 9 miles west of Shepherdsville. Kosmosdale Quadrangle, Lat. 38° 55′ N, Long. 85° 53′ 15″ W.

K-10. Section measured on west slope of knob on northwest edge of Lebanon Junction. Lebanon Junction Quadrangle, Lat. 37° 54′ 24″ N, Long. 85° 44′ 15″ W.

Nelson County

K-11. Section measured in road cut along U.S. Highway 62, .5 miles southwest of Boston. Lebanon Junction Quadrangle, Lat. 37° 47′ 8″ N, Long. 85° 40′ 30″ W.

K-12. Section measured in road cut along U.S. Highway 31E, .5 miles southwest of Balltown. New Haven Quadrangle, Lat. 37° 44′ 7″ N, Long 85° 30′ 20″ W.

K-13. Section measured at Blue Gap, 2.65 miles north of RR tracks at New Haven on U. S. Highway 31E. New Haven Quadrangle, Lat. 37° 41′ 20″ N, Long. 85° 33′ 55″ W.

Larue County

K-14. Section measured along secondary road leading west up hill, .25 miles north of Athertonville. New Haven Quadrangle, Lat. 37° 38′ 22″ N, Long. 85° 36′ 38″ W.

K-15. Section measured along U. S. Highway 31E at Muldraugh Escarpment just northeast of White City; base of section about 3 miles southwest of Athertonville. (Modified after Stockdale, 1939, p. 208). Hodgenville Quadrangle, Lat. 37° 35′ 32″ N, Long. 85° 39′ 35″ W.

K-16. Sample from the upper part of the Somerset shale member (Bed 1) of the Salem limestone along road leading up hill northwest of old Ginseng Post Office, across West Fork of Otter Creek, 10 miles southeast of Hodgenville. Howardstown Quadrangle, Lat. 37° 30′ 27″ N, Long. 85° 35′ 15″ W.

Marion County

K-17. Section measured across from church on County Road 457 at Holy Cross. Loretto Quadrangle, Lat. 37° 40′ 22″ N, Long. 85° 26′ 52″ W.

K-18. Section measured in road cut 2.5 miles east of Marion-Nelson County line, west of Raywick on State Highway 84. Raywick Quadrangle, Lat. 37° 33′ 45″ N, Long. 85° 29′ W.

K-19. Samples taken from Falling Run member (Bed 1) of Sanderson formation and lower 6″ to 1′ (Bed 2) and 2′ to 3′ (Bed 3) of New Providence formation in road cut just across from St. Joseph Church, at St. Joseph. Raywick Quadrangle, Lat. 37° 31′ 20″ N, Long. 85° 23′ 22″ W.

K-20. Samples taken from the 6 foot fossiliferous shale in the Caney Creek member of the Brodhead formation (Bed 1), from near the top of the Brodhead formation (Bed 2), and from the Floyds Knob formation (Bed 3) along State Highway 55, 8.5 miles south-southwest of Lebanon, just north of Taylor County line near Findley Post Office. (Stockdale, 1939, p. 159). Spurlington Quadrangle, Lat. 37° 27′ 45″ N, Long. 85° 20′ 10″ W.

Taylor County

K-21. Sample taken from Somerset shale member (Bed 1) of the Salem limestone at Willowtown, 3.5 miles northwest of Soloma and up hill from Good Hope Baptist Church. (Stockdale, 1939, p. 210). Soloma Quadrangle, Lat. 37° 26′ 30″ N, Long. 85° 24′ 45″ W.

Caldwell County

K-22. Sample taken from the Renault limestone (shale) (Bed 1), in road cut at Flynn Creek at east edge of Princeton on U. S. Highway 62. Olney Quadrangle, Lat. 37° 7′ 34″ N, Long. 87° 50′ 22″ W.

K-23. Samples taken from the Paint Creek (Bed 1), Cypress (Bed 2), Menard (Bed 3), and Kinkaid (Bed 4) formations at Walches Cut on Illinois Central RR track about 1.9 miles east-northeast of Scottsburg. Princeton East Quadrangle, Lat. 37° 6′ N, Long. 87° 47′ W.

K-24. Sample from shale in Paint Creek limestone (Bed 1) west of farm north of Sand Lick Road about 2.5 miles east of Bald Knob. Princeton East Quadrangle, Lat. 37° 4′ 20″ N, Long. 87° 45′ 25″ W.

Breckenridge County

K-25. Sample from the Glen Dean limestone (Bed 1) in old abandoned quarry west of creek at Glen Dean. Glen Dean Quadrangle, Lat. 37° 39′ 10″ N, Long. 86° 32′ 30″ W.

Grayson County

K-26. Sample from Glen Dean limestone (Bed 1) one mile south of Grayson Springs on State Highway 88. Clarkson Quadrangle, Lat. 37° 26′ 50″ N, Long. 86° 13′ 25″ W.

Metcalfe County

K-27. Sample taken from transition between New Providence and Brodhead formations (Bed 1) in road cut on north side of Edmonton just south of South Fork of Little Barren River, on State Highway 80. Edmonton Quadrangle, Lat. 36° 58′ 50″ N, Long. 85° 36′ 47″ W.

Cumberland County

K-28. Section measured on big hill on State Highway 90 northwest of Burkesville. Waterview Quadrangle, Lat. 36° 47′ 37″ N, Long. 85° 22′ 32″ W.

Pulaski County

K-29. Sample from the Glen Dean limestone (Bed 1) on RR cut just east of Sloans Valley at Sloans Valley Tunnel. Burnside Quadrangle, Lat. 36° 56′ 40″ N, Long. 84° 33′ 30″ W.

K-30. Sample from upper 16.5 feet of Pennington shale (Bed 1) above 6 foot siltstone bed, 1.5 miles northwest of turnoff to Sloans Valley on U. S. 27. Burnside Quadrangle, Lat. 36° 57′ N, Long. 84° 34′ W.

K-31. Samples from the top of the Golconda limestone (Bed 1) at top of quarry and from the Hardinsburg shale (Bed 2) at Tatesville Quarry, .5 miles south of Tatesville on U. S. Highway 27. Burnside Quadrangle, Lat. 36° 56′ 45″ N, Long. 84° 34′ 40″ W.

K-32. Section at Fishing Creek, Lake Cumberland, west of Somerset. Delmer Quadrangle, Lat. 37° 3′ 55″ N, Long. 84° 41′ 20″ W.

Casey County

K-33. Samples from the silts in the Floyds Knob formation (Bed 3), the upper 10 feet of the Brodhead formation (Bed 2), and from the McKinney Knob siltstone member (Bed 1) of the Brodhead formation about 7 miles northwest of Liberty along State Highway 49 at steep hill from plateau to valley of Martins Creek. (Stockdale, 1939, pp. 210, 211). Bradfordsville NE Quadrangle, Lat. 37° 25′ 15″ N, Long. 85° 0′ 2.5″ W.

K-34. Sample from within lower 80 feet of the New Providence formation (Bed 1) in road cut on State Highway 78 west of junction of 78 and County Road 906 at Turkeyfoot Gap, one mile west of county line. Ellisburg Quadrangle, Lat. 37° 27′ 55″ N, Long. 84° 52′ 45″ W.

Boyle County

K-35. Section measured at exposures on slopes behind farm on north side of County Road 300, west of Junction City, and 1.4 miles west of State Highway 35. Junction City Quadrangle, Lat. 37° 35′ 22.5″ N, Long. 84° 48′ 15″ W.

Lincoln County

K-36. Samples from the lower 2-3″ of the New Providence formation (Bed 1); from the upper 40 feet of the New Providence formation (Bed 4); from the lower (Bed 2) and upper (Bed 3) part of the lower 70 feet of the New Providence formation; from shaly siltstone with calcareous concretions, about 70′ below the Floyds Knob, in the Brodhead formation (Bed 5); and from the Floyds Knob formation (Bed 6); along U. S. Highway 27, at Halls Gap, 4.5 miles south-southeast of Stanford. (Stockdale, 1939, pp. 162, 163). Halls Gap Quadrangle, Lat. 37° 27′ 40″ N, Long. 84° 38′ W.

K-37. Sample from the lower 2 feet of the New Providence formation, 3.3 miles west of Crab Orchard on the Halls Gap Road. Crab Orchard Quadrangle, Lat. 37° 25′ 45″ N, Long. 84° 32′ 30″ W.

K-38. Section measured in road cut on east side of U. S. Highway 150, at county line of Rockcastle and Lincoln counties, 2.6 miles south of intersection of 150 and State Highway 39. Brodhead Quadrangle, Lat. 37° 26′ N, Long. 84° 27′ 58″ W.

K-39. Samples taken from the Brodhead (Bed 1) and the Floyds Knob (Bed 2) formations; section measured from the New Albany through the New Providence formations; at Cruzes Gap, 3.2 miles south of Crab Orchard on State Highway 39. Crab Orchard Quadrangle, Lat. 37° 25′ N, Long. 84° 30′ 30″ W.

Rockcastle County

K-40. Sample from the lower part (Bed 1) of the New Providence formation, about 1.5 miles southeast of Brodhead on U. S. Highway 150. Brodhead Quadrangle, Lat. 37° 23′ N, Long. 84° 24′ 55″ W.

K-41. Samples taken from the uppermost part (Bed 1) of the Brodhead formation and the Wildie siltstone member (Bed 2) of the Muldraugh formation, just south of Renfro Valley on U. S. Highway 25. Wildie Quadrangle, Lat. 37° 23′ N, Long. 84° 19′ 50″ W.

K-42. Sample from the Paint Creek limestone (shale) (Bed 1) at top of road cut at top of hill about 4 miles north of Renfro Valley on U. S. Highway 25. Wildie Quadrangle, Lat. 37° 25′ N, Long. 84° 19′ W.

K-43. Sample from the Pennington marine limestone (Bed 1), on U. S. Highway 25, 1.1 miles north of the Rockcastle River, 2.6 miles south of Livingston. Bernstadt Quadrangle, Lat. 37° 14′ 40″ N, Long. 84° 13′ 15″ W.

Madison County

K-44. Section measured at Boone Gap, along U. S. Highway 25, 3.5 miles south-southwest of Berea. Berea Quadrangle, Lat. 37° 31′ 40″ N, Long. 84° 19′ 10″ W.

K-45. Section measured along U. S. Highway 421 at Big Hill, about 5 miles southeast of Berea. Big Hill Quadrangle, Lat. 37° 32′ 10″ N, Long. 84° 12′ 45″ W.

Jackson County

K-46. Samples taken from the horizon of the Big Clifty sandstone (Bed 1) and from shale in the Hardinsburg sandstone (Bed 2), at Clarks Station Quarry, 2.4 miles south of Morill on U. S. Highway 421. Johnetta Quadrangle, Lat. 37° 29′ 55″ N, Long. 84° 8′ 52.5″ W.

Estill County

K-47. Samples taken from the Trousdale formation (Bed 2) and upper 1.75 feet of the Portwood formation (Bed 1) on State Highway 52 at entrance to the McLaughlin farm, one mile east of Waco. (Campbell, 1946, p. 366). Moberley Quadrangle, Lat. 37° 34′ 15″ N, Long. 84° 7′ 40″ W.

K-48. Sample taken from lower 4 feet of the New Providence formation (Bed 1) at cliff along north side of L&N RR track, just east of Cow Creek where it joins the Kentucky River, 2.5 miles southeast of Irvine. (Stockdale, 1939, p. 121). Irvine Quadrangle, Lat. 37° 40′ 55″ N, Long. 83° 56′ 30″ W.

K-49. Sample taken from the Conway siltstone (Bed 2) and the lower part of the New Providence formation (Bed 1) along State Highway 52 below Estill County Quarry, at steep hill about 4 miles east of Irvine. (Stockdale, 1939, p. 168). Irvine Quadrangle, Lat. 37° 42′ 30″ N, Long. 83° 53′ 30″ W.

K-50. Section measured in L&N RR cut, .5 miles north of Hargett, 6 miles northwest of Irvine. (Measured by Campbell, 1946, p. 866). Palmer Quadrangle, Lat. 37° 47′ 7″ N, Long. 84° 0′ 53″ W.

Powell County

K-51. Section measured on Pompeii Hill up from quarry, .4 miles northeast of Clay City. Clay City Quadrangle, Lat. 37° 51′ 45″ N, Long. 83° 54′ 40″ W.

K-52. Section measured in road cut on County Road 213, 7.4 miles south of Jeffersonville. Means Quadrangle, Lat. 37° 53′ 8″ N, Long. 83° 51′ 49″ W.

Clark County

K-53. Section measured at Lulbegrud Creek along secondary road which leads east and then south from State Highway 52 at the north edge of Indian Fields, about .5 miles east of Indian Fields and .75 miles northwest of Powell County line. Levee Quadrangle, Lat. 37° 56′ 10″ N, Long. 83° 59′ 10″ W.

K-54. Section measured on west side of Lulbegrud Creek at barn on poor road, 1.1 miles in straight line east-southeast of Indian Fields. Levee Quadrangle, Lat. 37° 56′ N, Long. 83° 58′ 45″ W.

Montgomery County

K-55. Section measured along secondary road leading north from U. S. Highway 460, .6 miles north of junction, .25 miles east of bridge over Slate Creek, 2.25 miles east of Jeffersonville. (Measured by Stockdale, 1939, pp. 93, 94). Means Quadrangle, Lat. 37° 58' 30" N, Long. 83° 48′ 55″ W.

Menifee County

K-56. Samples from the Frenchburg freestone (Bed 1) and the Haldeman siltstone (Bed 2) at Frenchburg Quarry, .5 miles west of Frenchburg on U. S. Highway 460, and 300 yards north of the highway. Frenchburg Quadrangle, Lat. 37° 57′ 2.5″ N, Long. 83° 38′ 22″ W.

Bath County

K-57. Section measured along "Old Virginia State Road," .25 miles west of Olympia Springs. Olympia Quadrangle, Lat. 38° 3′ 37″ N, Long. 83° 40′ 45″ W.

Rowan County

K-58. Section measured in roadcut on U. S. Highway 60, .4 miles east of Bluestone, 5.5 miles west of Morehead, just northeast of RR track. (After fig. 7, Geol. Soc. Kentucky Field Trip Guidebook, 1955). Farmers Quadrangle, Lat. 38° 8′ 55″ N, Long. 83° 30′ 15″ W.

K-59. Samples from the Farmers siltstone member of the New Providence formation (Bed 2) and the New Providence formation (Bed 1), in road cut on U.S. Highway 60, .5 miles southwest of intersection of 60 and County Road 519, southwest of Morehead. Morehead Quadrangle, Lat. 38° 9′ 50″ N, Long. 83° 26′ 50″ W.

K-60. Sample from the Rothwell shale (Bed 1), on Morehead Lookout Tower road about 1.5 miles in straight line east of Morehead. Morehead Quadrangle, Lat. 38° 10′ 25″ N, Long. 83° 24′ 25″ W.

K-61. Section measured in road cut on State Highway 32, 1.85 miles south of Hilda Post Office. Haldeman Quadrangle, Lat. 38° 11′ N, Long. 83° 30′ W.

Fleming County

K-62. Section measured along State Highway 32, extending .7 miles west-northwest of Rowan County line, 9 miles southeast of Goddard. (Measured by Stockdale, 1939, p. 96). Plummers Landing Quadrangle, Lat. 38° 15′ 45″ N, Long. 83° 31′ 45″ W.

K-63. Section measured along county road leading from Wallingford to Poston School, at hill one mile northeast of Wallingford. (Modified after Stockdale, 1939, pp. 96, 97). Burtonsville Quadrangle, Lat. 38° 24′ 30″ N, Long. 83° 35′ 45″ W.

Carter County

K-64. Sample from the upper 6 feet of the Rothwell shale (Bed 1), in road cut on U. S. Highway 60, 2.75 miles southwest of Olive Hill. (Stockdale, 1939, p. 218). Olive Hill Quadrangle, Lat. 38° 17′ 30″ N, Long. 83° 13′ 15″ W.

Lewis County

K-65. Sample from green-gray shale (Bed 1) in New Albany at road level and above 40 feet of New Albany in road cut 2 miles west of Vanceburg and .3 miles southwest of bridge over Salt Lick Creek, on State Highway 10. Vanceburg Quadrangle, Lat. 38° 35′ 20″ N, Long. 83° 21′ 5″ W.

K-66. Section measured along road from Vanceburg to Tannery, at north side of Ganders Branch; bottom of section 1.25 miles south of C&O RR station at Vanceburg; section continues east-southeast up hill for .75 miles. (Measured by Stockdale, 1939, pp. 98, 99). Vanceburg Quadrangle, Lat. 38° 35′ 5″ N, Long. 83° 19′ W.

K-67. Section measured along poor secondary road at head of Montgomery Creek, leading up steep hill to Greenup County line; top of section 5 miles southeast of Garrison; bottom of section 2 miles along road south of Rexton Post Office. (Measured by Stockdale, 1939, pp. 187, 188). Brushhart Quadrangle, Lat. 38° 35′ 15″ N, Long. 83° 6′ 30″ W.

Greenup County

K-68. Section measured near south end of Ohio River bridge, along secondary road ascending bluff, in steep ravine and on hillside. (Measured by Stockdale, 1939, p. 181). Portsmouth Quadrangle, Lat. 38° 43′ 15″ N, Long. 82° 59″ 40′ W.

INDIANA

Perry County

I-1. Section measured in Kunkler Quarry, on U. S. Highway 460, 1.3 miles west of Uniontown Post Office. (After fig. 7, Geol. Soc. Kentucky Field Trip Guidebook, 1952). Lat. 38° 14′ N, Long. 86° 42′ W.

Clark County

I-2. Samples from the Button Mold Knob member (Bed 1) of the New Providence formation along secondary road 1.25 miles north of Carwood. Speed Quadrangle, Lat. 38° 27′ 30″ N, Long. 84° 52′ 30″ W.

I-3. Samples from the Coral Ridge (Bed 1) and Button Mold Knob (Bed 2) members of the New Providence formation at the Louisville Cement Company Quarry, on State Highway 60, 2.6 miles northwest of the intersection of Highway 60 and U. S. 31W, about 8 miles north of New Albany. Speed Quadrangle, Lat. 38° 24′ N, Long. 85° 38′ W.

Floyd County

I-4. Samples from the Jacobs Chapel shale (Bed 1), Rockford limestone (Bed 2), and the lower 3 feet of the New Providence formation (Bed 3), one mile northwest of Jacobs Chapel Church and U. S. Highway 31W, where creek crosses Chapel Lane Road. New Albany Quadrangle, Lat. 38° 21′ 55″ N, Long. 85° 47′ 35″ W.

I-5. Sample from the Floyds Knob formation, at Spickert Knob, along road up the escarpment, 3.5 miles northwest of New Albany. New Albany Quadrangle, Lat. 38° 19′ 53″ N, Long. 85° 51′ W.

I-6. Section measured at Goetz Quarry, .5 miles west of New Albany city limits on U. S. Highway 460. New Albany Quadrangle, Lat. 38° 16′ 30″ N, Long. 85° 50′ 35″ W.

TENNESSEE

Davidson County

T-1. Sample from the Maury shale (Bed 1) at Bakers, a station on the L&N RR. (Campbell, sec. 43, 1946, p. 887). Ridgetop Quadrangle, Lat. 36° 22′ N, Long. 86° 17′ W.

Sumner County

T-2. Section measured 200 yards north of Garretts Creek Church, north of Westmoreland. (After Campbell, sec. 37, 1946, p. 885). Lat. 36° 33′ 30″ N, Long. 86° 14′ 30″ W.

Macon County

T-3. Section measured in road cut on State Highway 52, 8 miles west of Red Boiling Springs. (After Campbell, sec. 42, 1946, p. 887). Red Boiling Springs Quadrangle, Lat. 36° 30′ 8″ N, Long. 85° 57′ 20″ W.

Clay County

T-4. Section measured along State Highway 52, 4 miles southeast of Celina. (After Campbell, sec. 41, 1946, p. 887). Lillydale, Kentucky, Quadrangle, Lat. 36° 30′ 20″ N, Long. 85° 27′ 30″ W.

OHIO

Scioto County

O-1. Section measured at cliffs north of Buena Vista, on U. S. Highway 52. (Modified after Hyde, 1953, pp. 196, 197). Buena Vista Quadrangle, Lat. 38° 37′ 45″ N, Long. 83° 15′ 45″ W.
O-2. Section measured behind Greystone Motel on U. S. Highway 52, just west of Portsmouth. Pond Run Quadrangle, Lat. 38° 43′ 47″ N, Long. 83° 2′ 30″ W.
O-3. Section measured in road cut at hill 3 miles north of Portsmouth on U. S. Highway 23. Sciotoville Quadrangle, Lat. 38° 45′ N, Long. 82° 57′ W.
O-4. Section measured on secondary road leading north from State Highway 73 at Henley, up hill northeast of Henley. Otway Quadrangle, Lat. 38° 51′ N, Long. 83° 9′ 15″ W.

Pike County

O-5. Section measured at bridge over Beaver Creek, .75 miles southeast of Piketon. Waverly Quadrangle, Lat. 39° 3′ 30″ N, Long. 82° 59′ 50″ W.
O-6. Section measured along County Road 772, south of Nipgen and just south of Ross-Pike County line. Nipgen Quadrangle, Lat. 39° 11′ 14″ N, Long. 83° 9′ W.

Ross County

O-7. Section measured along Jester Hill Road, 1.5 miles south of U. S. Highway 50 at Bainbridge. Sunbury shale at sharp bend in road where poor road intersects Jester Hill Road. Sample of Bedford shale taken one mile south of Highway 50 on Jester Hill Road. Bainbridge Quadrangle, Lat. 39° 12′ 25″ N, Long. 83° 16′ 12″ W.
O-8. Section measured on N&W RR track, one mile north of Higby. Waverly Quadrangle, Lat. 39° 11′ 30″ N, Long. 82° 52′ W.

Fairfield County

O-9. Sample from shale in the Maxville limestone (Bed 1), Rush Creek Limestone Company Quarry, Rushville. Thornville Quadrangle, Lat. 39° 45′ 30″ N, Long. 82° 27′ 45″ W.

Franklin County

O-10. Sample from transition bed between Bedford shale and Ohio shale (Bed 1), at southeast side of dam at Central College. Westerville Quadrangle, Lat. 40° 46′ 15″ N, Long. 82° 52′ 50″ W.

Wayne County

O-11. Sample from shale bed no. 4 in the lower 5 feet of the Black Hand sandstone member (Bed 1) of the Cuyahoga formation at Armstrong. West Salem Quadrangle, Lat. 40° 54′ 40″ N, Long. 82° 0′ 30″ W.

CORRELATION CHARTS

Chart 1 shows the correlation of Upper Devonian and Lower and Middle Mississippian formations in southern Indiana, Kentucky, northern Tennessee, and southcentral Ohio. In general, only those names of formations and members are used in which Foraminifera were found. Each column is generalized from the measured sections at the localities indicated at the top of the column.

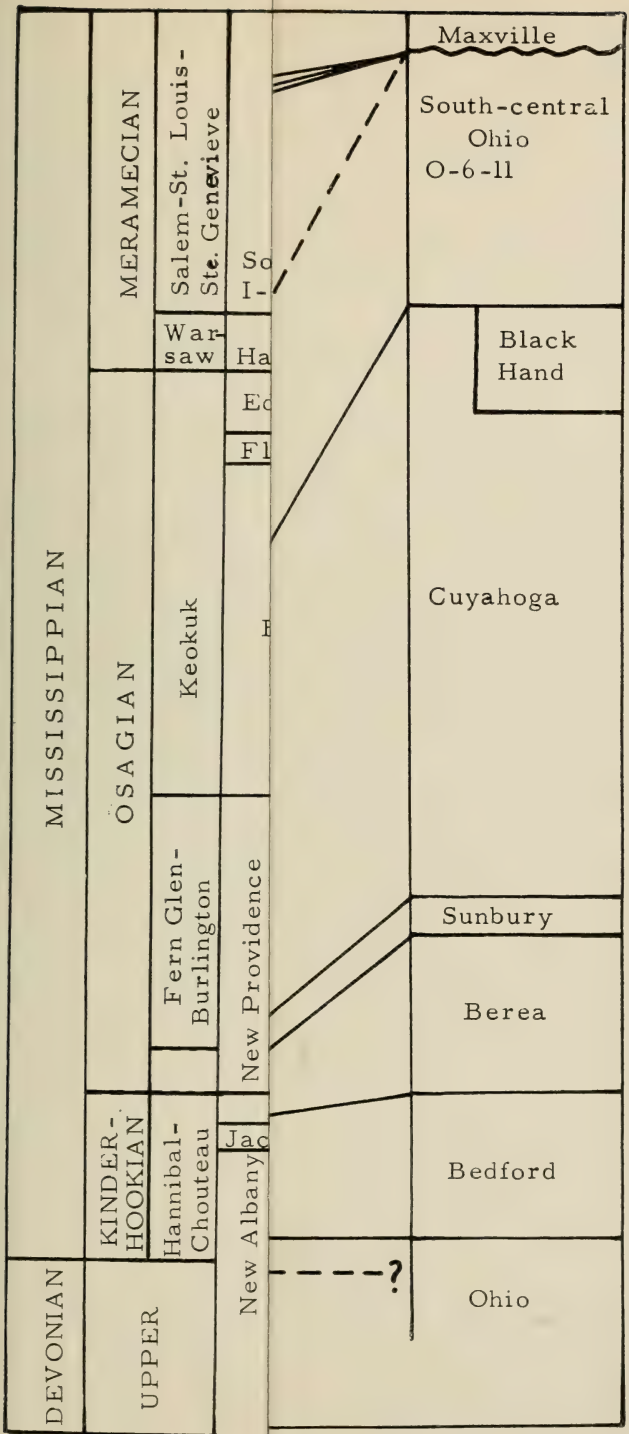
Chart 2 correlates the Upper Mississippian (Chesterian) formations of southern Indiana, and western and southeastern Kentucky.

MEASURED SECTIONS

Beds in which Foraminifera were found are indicated by an asterisk before the bed number. Not all other beds were sampled, but most were, and thus beds without an asterisk may generally be taken to be unfossiliferous as regards Foraminifera.

Most of the sections were measured by me; many of them in Kentucky and southern Indiana were based on Stockdale's (1939) locations and determinations as to stratigraphic level, and a few of the sections are given as measured by Stockdale. The sections in Tennessee are based on Campbell's (1946) work as to location and stratigraphic placement. The sections in Ohio are largely based on Hyde's (1953) locations and stratigraphic determinations, but most were measured by me.

Samples were taken throughout 5.5 foot intervals, or from lithologically and stratigraphically distinct units thinner than 5.5 feet.


Maxville
South-central Ohio O-6-11
Black Hand
Cuyahoga
Sunbury
Berea
Bedford
Ohio
MISSISSIPPIAN
DEVONIAN
MERAMECIAN
OSAGIAN
KINDER-HOOKIAN
UPPER
Salem-St. Louis-Ste. Genevieve
Warsaw
Keokuk
Fern Glen-Burlington
Hannibal-Chouteau
New Providence
New Albany

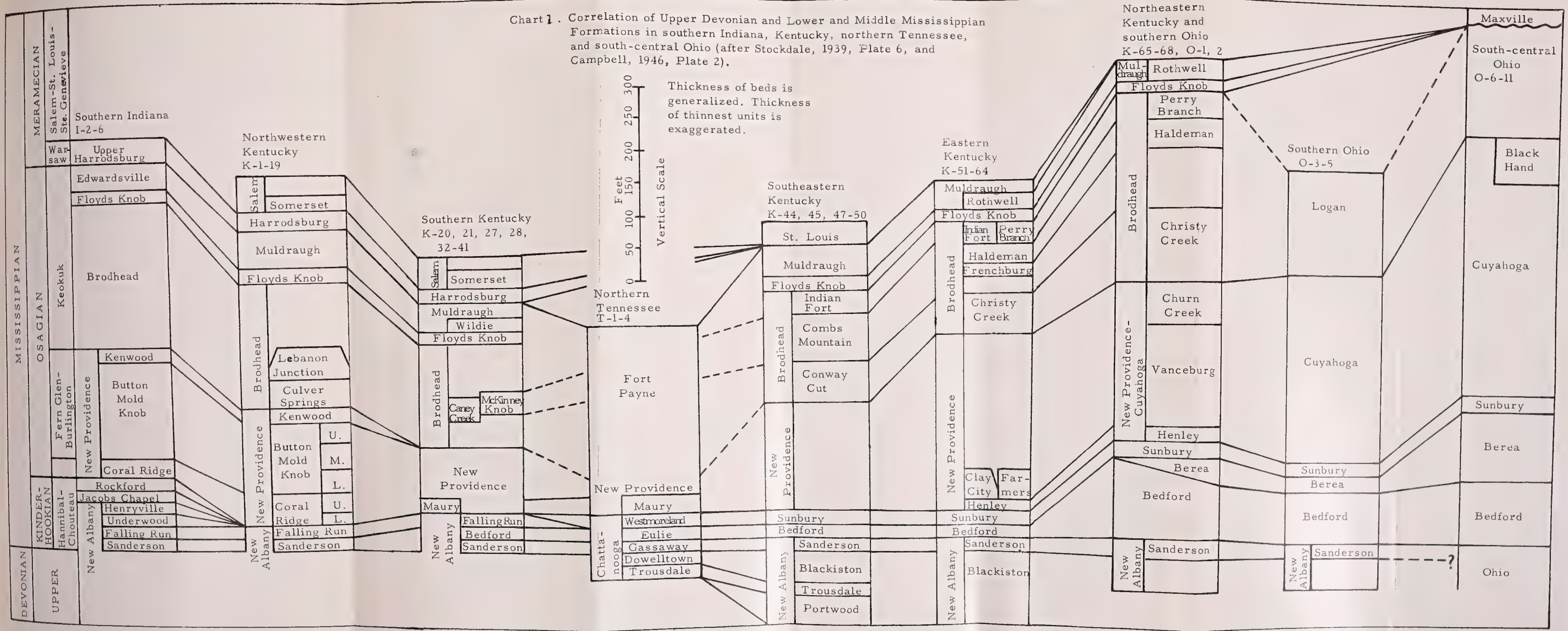
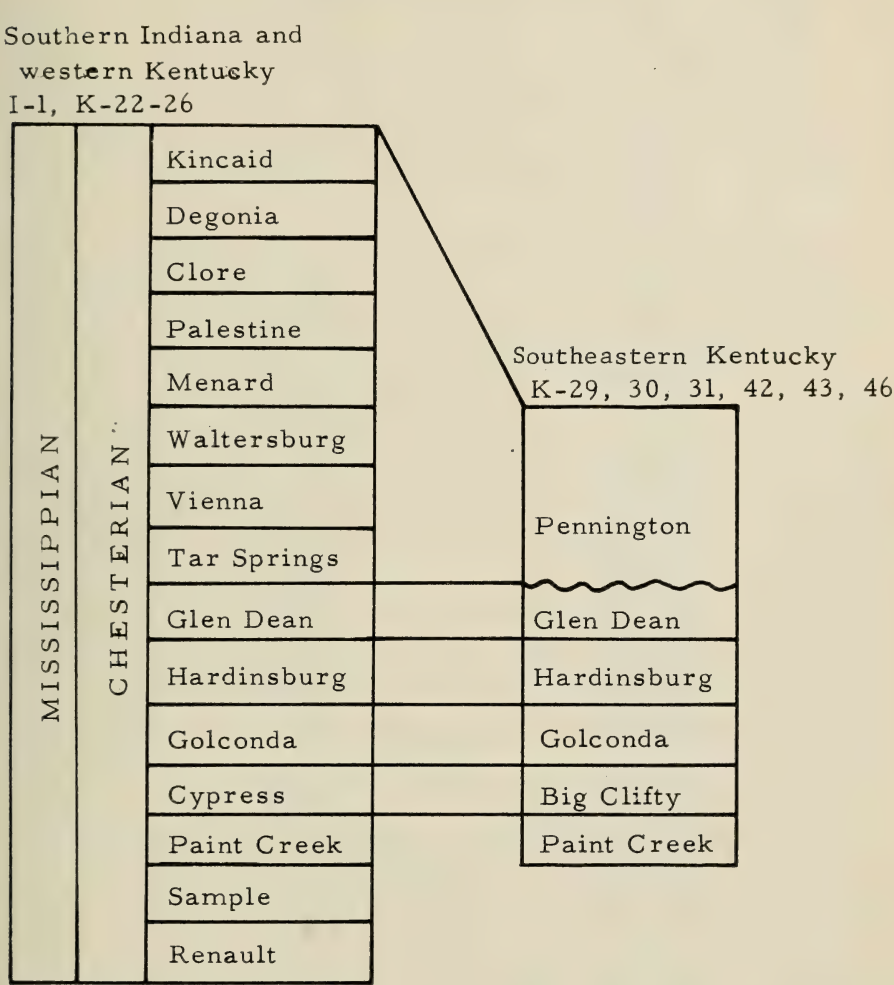


Chart 1. Correlation of Upper Devonian and Lower and Middle Mississippian Formations in southern Indiana, Kentucky, northern Tennessee, and south-central Ohio (after Stockdale, 1939, Plate 6, and Campbell, 1946, Plate 2).

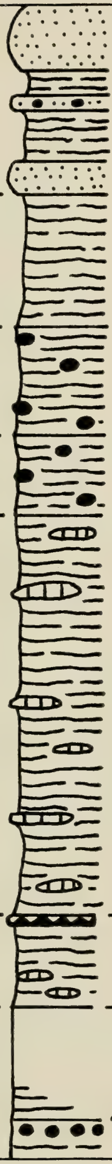
Chart 2. Correlation of Chesterian formations of southern Indiana, and western and southeastern Kentucky.



LOCALITY K-1

NEW PROVIDENCE FORMATION 158' exposed	KENWOOD SS. MBR.	8'	* 14. Shale, olive gray; covered above.
		6"	13. Siltstone.
		6'6"	*12. Shale, olive gray.
		1'9"	*11. Shale with two thin siltstone layers.
		11'6"	*10. Shale, olive gray.
		2.5"	9. Siltstone.
	BUTTON MOLD KNOB MEMBER	7'6"	*8. Shale, olive gray; no large ironstone concretions.
		73'	* 7. Shale, olive gray, silty at various horizons; large ironstone concretions, rarer in upper 17 feet.
		22'6"	* 6. Shale, olive gray; worm markings; _Conularia_ in float.
		3'	* 5. Shale, blue gray.
	Coral Ridge mbr.	3"	4. Double ironstone cone-in-cone.
		15'	* 3. Shale, olive gray; worm markings.
			2. Ironstone lenses.
		9'	* 1. Shale, blue gray; transitional to olive gray in upper part; covered below.

LOCALITY K-2



NEW PROVIDENCE FORMATION	KENWOOD SANDSTONE MEMBER		34'2"	8. Sandstone, buff; middle bed with ironstones; olive gray shales between sandstone beds.
	BUTTON MOLD KNOB MEMBER	Upper	27'1"	7. Shale, olive gray.
		Middle	21'8"	6. Shale, olive gray, with ironstone concretions; no megafossils.
			15'4"	5. Shale, olive gray, with ironstone concretions; Button Mold Knob fauna.
		Lower	81'	*4. Shale, olive gray, with fossiliferous limestone lenses.
	Coral Ridge member	Upper	19'2"	*3. Shale, olive gray, with rare limestone lenses; cone-in-cone layer ; Coral Ridge fauna.
		Lower	22'1"	*2. Shale, olive gray, mostly covered.
Falling Run				1. Shale, olive gray, with phosphatic nodules; not measured.

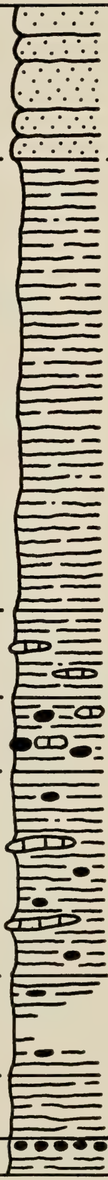
LOCALITY K-3

NEW PROVIDENCE FORMATION 189' exposed	KENWOOD SANDSTONE		35'	* 6. Siltstone, sandstone, and shale; buff to olive gray.
	BUTTON MOLD KNOB MEMBER	UPPER	17'9"	* 5. Shale, olive gray; no megafossils.
		MIDDLE	28'	* 4. Shale, bluish gray, ironstone concretions; no megafossils.
		LOWER	52'	* 3. Shale, bluish gray; very rare Button Mold Knob fauna.
	CORAL RIDGE MEMBER	UPPER	52'	* 2. Shale, bluish gray; cone-in-cone layers, kidney ironstone concretions; Coral Ridge fauna.
		L.	4'	* 1. Shale, olive gray; no megafossils; covered below.

LOCALITY K-4

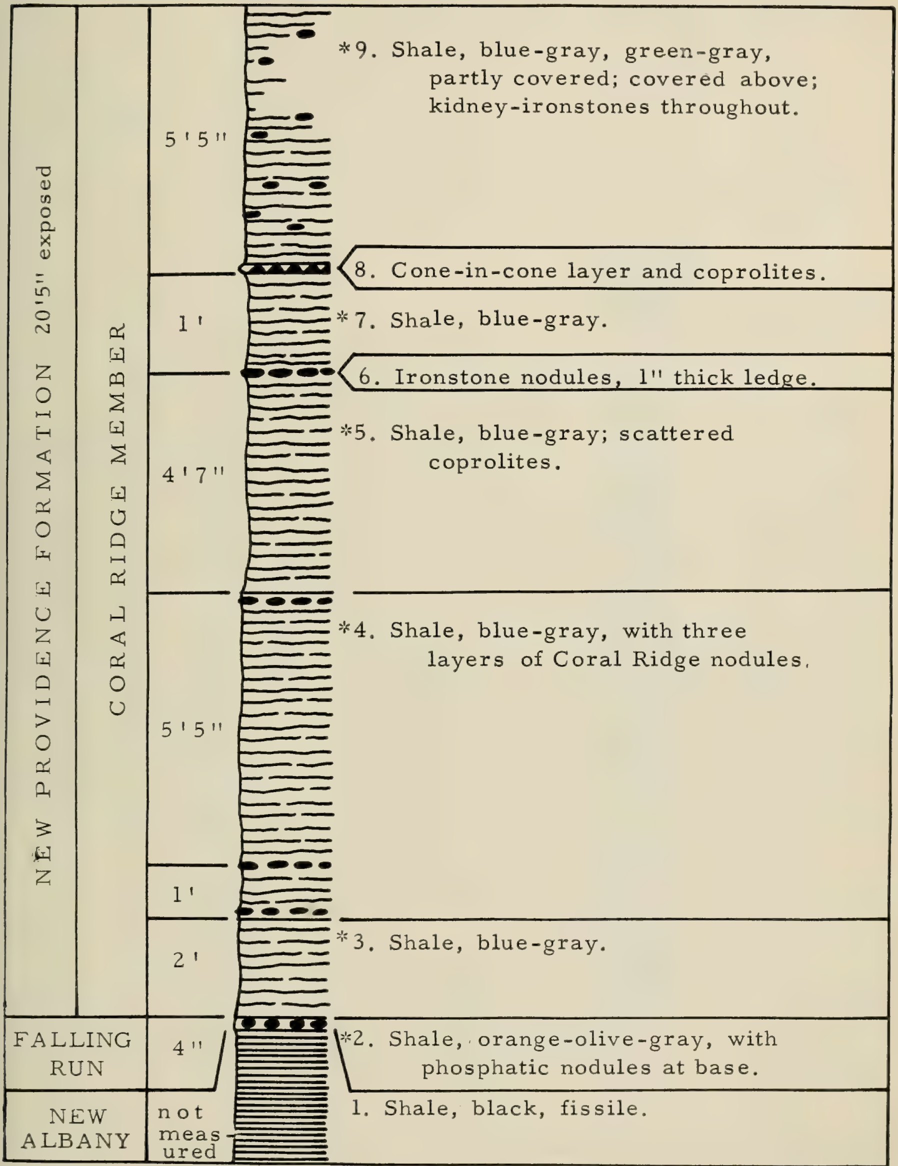
NEW PROVIDENCE FORMATION 114'	BUTTON MOLD KNOB MEMBER	MIDDLE	39'	*8. Shale, olive gray, soft; fossiliferous lenses, crinoidal concretions; large ironstone concretions.
			5'6"	7. Covered.
		LOWER	8'	*6. Shale, olive gray, soft, fossiliferous.
			11'	5. Covered.
			5'6"	*4. Shale, blue gray, soft; many fossils.
			20'	*3. Shale, blue gray; rare fucoids; no other megafossils noted.
	CORAL RIDGE MBR.	UPPER	15'10"	*2. Shale, blue gray; small kidney ironstones; cone-in-cone layers at top and base of unit; Coral Ridge fauna.
		LOWER	5'9"	*1. Shale, gray blue; no megafossils noted.

LOCALITY K-6

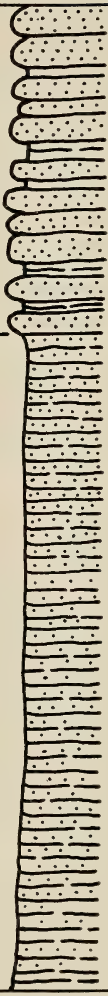


NEW PROVIDENCE FORMATION 233 feet	KENWOOD SS.		33'	* 8. Sandstone and siltstone.
	BUTTON MOLD KNOB MEMBER	UPPER	91'	* 7. Shale, olive gray; rare Button Mold Knob fauna.
		MIDDLE	17'	* 6. Shale, olive gray; crinoidal limestone patches; Button Mold Knob fauna.
			15'7"	* 5. Shale, olive gray; crinoidal limestone patches; large ironstone concretions; Button Mold Knob f.
		LOWER	51'7"	* 4. Shale, olive gray, with limestone lenses and ironstones.
	Coral Ridge member	U.	16'1"	* 3. Shale, olive gray; kidney ironstones mostly covered.
		L.	8'11"	*2. Shale, olive gray; no megafossils.
Falling Run				1. Shale with phosphatic nodules.

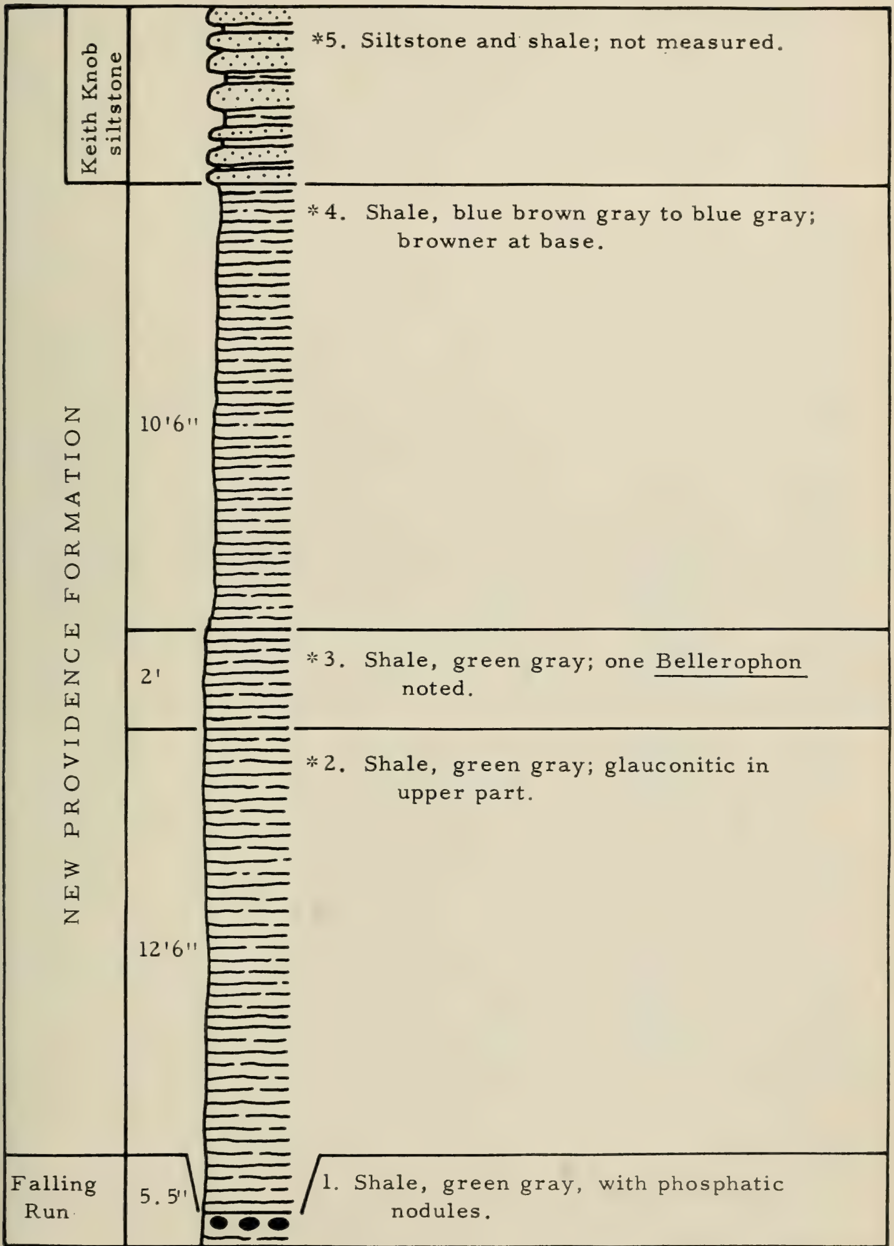
LOCALITY K-8


NEW PROVIDENCE FORMATION 20'5" exposed
CORAL RIDGE MEMBER
FALLING RUN
NEW ALBANY
5'5"
1'
4'7"
5'5"
1'
2'
4"
not measured
*9. Shale, blue-gray, green-gray, partly covered; covered above; kidney-ironstones throughout.
8. Cone-in-cone layer and coprolites.
*7. Shale, blue-gray.
6. Ironstone nodules, 1" thick ledge.
*5. Shale, blue-gray; scattered coprolites.
*4. Shale, blue-gray, with three layers of Coral Ridge nodules.
*3. Shale, blue-gray.
*2. Shale, orange-olive-gray, with phosphatic nodules at base.
1. Shale, black, fissile.

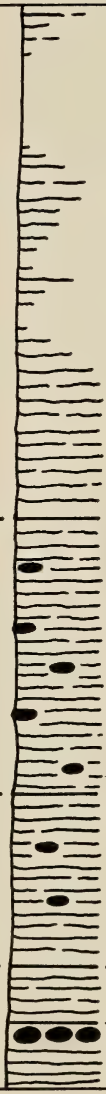
LOCALITY K-10

Formation	Member	Thickness	Section	Description
BRODHEAD FORMATION	LEBANON JUNCTION SILTSTONE MBR.	22'		* 2. Siltstone, massive, weathers shaly; blue gray to buff; worm markings; covered above.
	CULVER SPRINGS SHALE MEMBER	45'		* 1. Shale, silty, olive gray; buff in uppermost part; partly fossiliferous.

LOCALITY K-11

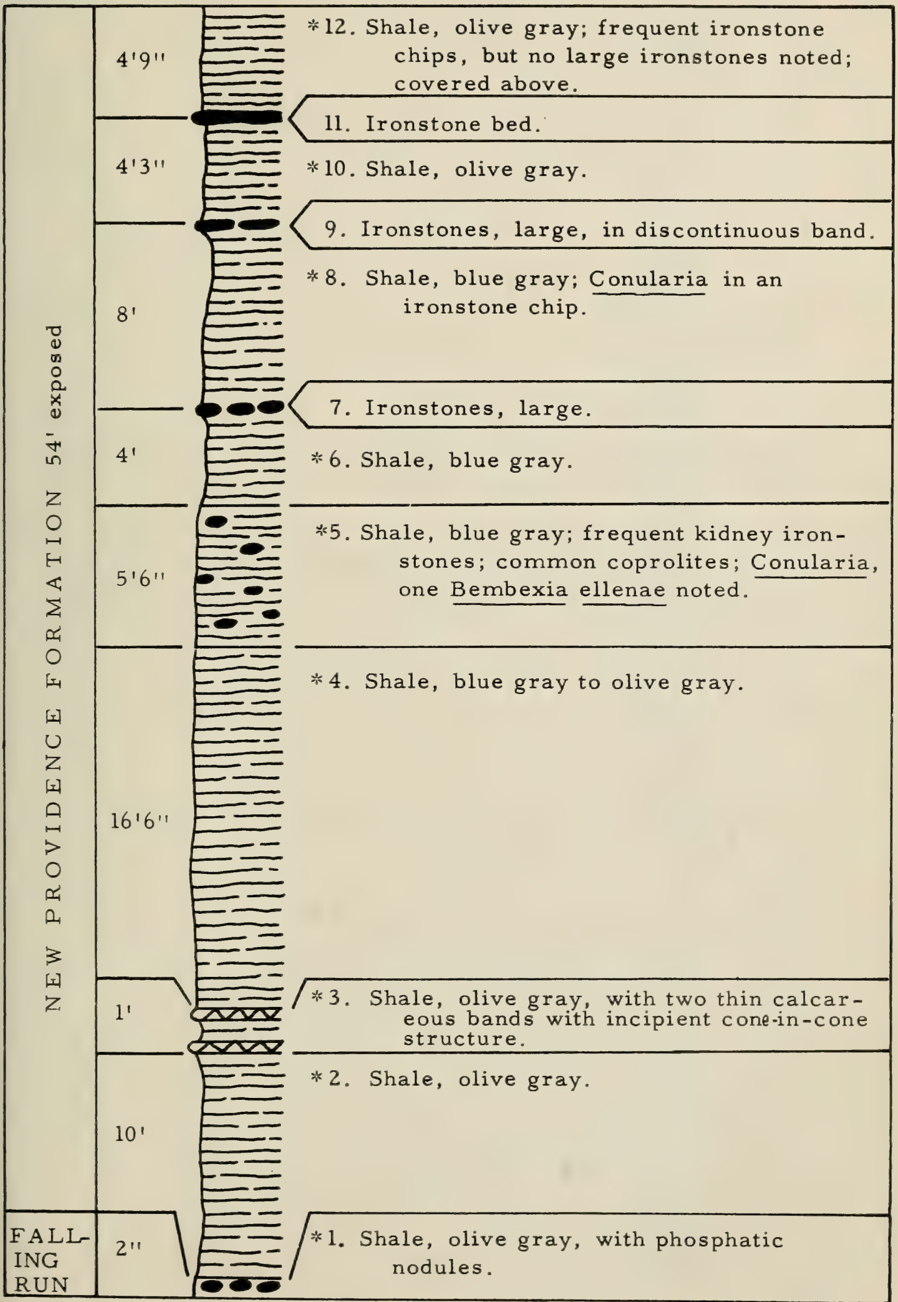


LOCALITY K-12

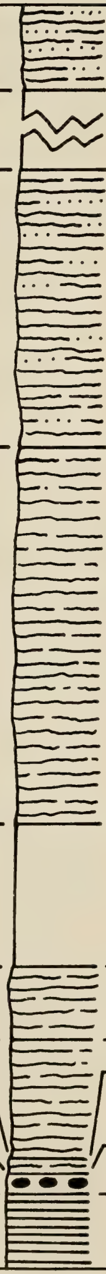


Formation	Thickness	Description
NEW PROVIDENCE FORMATION	5'6"	*5. Shale, green gray; partly to mostly covered.
	3'	*4. Shale, green gray; some kidney ironstone nodules; less fossiliferous than below; partly covered.
	1'6"	*3. Shale, green gray, fossiliferous; infrequent kidney ironstones; crinoid stems replaced by limonite.
	6"	*2. Shale, soft, green gray.
Falling Run	6"	* 1. Shale, hard, green gray, with phosphatic nodules.

LOCALITY K-13

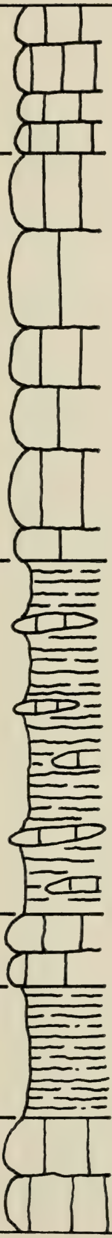


LOCALITY K-14



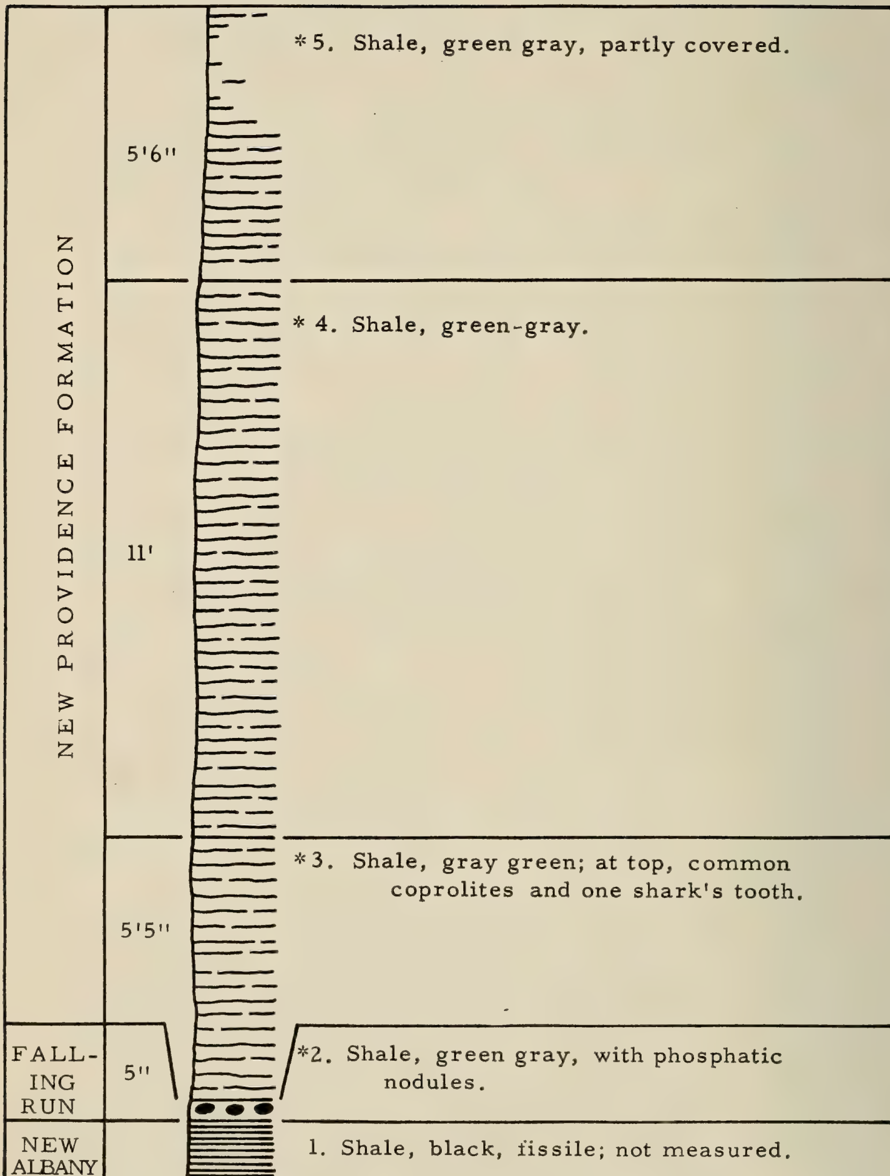
BROD-HEAD		*10. Siltstone, shaly; not measured.
NEW PROVIDENCE FORMATION		9. Covered; not measured.
	5'6"	*8. Shale, sandy, olive gray, slumped, weathered to red clay; gravel on surface.
	6'	*7. Shale, olive gray, clayey.
	2'	6. Covered
	1'	*5. Shale, olive gray to blue gray.
	1'6"	4. Shale, not sampled.
	3"	*3. Shale, olive gray to blue gray.
Falling Run	3"	*2. Shale, hard, olive gray, with large phosphatic nodules.
NEW ALBANY		1. Shale, black, fissile; not measured.

LOCALITY K-15



Formation	Thickness	Description
ST. LOUIS LS.	10'	6. Limestone, fine grained to dense, blue gray.
SALEM LIMESTONE	30'	* 5. Limestone, fossiliferous, blue gray.
SALEM LIMESTONE — SOMERSET SHALE MBR.	25'	*4. Shale, with limestone lenses; bryozoans.
HARRODSBURG LIMESTONE	3'	3. Limestone, massive, crinoidal; bryozoans.
HARRODSBURG LIMESTONE	9'	*2. Shale, crinoidal streaks; bryozoans.
HARRODSBURG LIMESTONE	8'	1. Limestone, massive, gray; bryozoans.

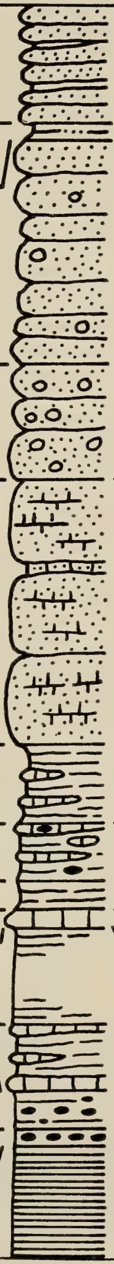
LOCALITY K-17



LOCALITY K-18

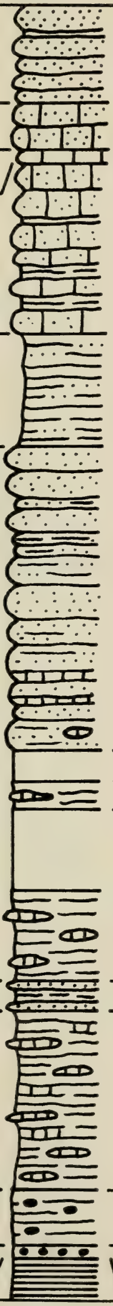
New Providence Formation 54' exposed	4'6"	8. Shale, olive gray, siltier than below, no ironstones, very rare coprolites; covered above.
	11'6"	*7. Shale, clayey, olive gray.
	1'	*6. Siltstone, shaly, ferruginous.
	15'	*5. Shale, clayey, olive gray; coprolites and ironstones.
	21'	*4. Shale, clayey, olive gray; coprolites.
	1'	*3. Shale, olive gray.
Falling Run	2.5"	*2. Shale, olive gray, with phosphatic nodules.
New Albany		1. Shale, black, fissile; not measured.

LOCALITY K-28



Formation	Thickness	Description
NEW PROVIDENCE FORMATION 192' exposed	25'	*14. Siltstone, hard, blue gray, with rare shaly spots; covered above.
	8"	*13. Shale, silty.
	45'	*12. Siltstone, massive, medium to fine grained; rare geodes noted.
	22'	*11. Siltstone, hard, gray blue, calcareous; frequent quartz geodes.
	56'	10. Siltstone, hard, gray, calcareous, massive, weathers like shale; rare, impure limestone seams.
	16'6"	*9. Shale, hard, blue gray; rare, impure limestones about 1 foot thick.
	11'	8. Shale, hard, blue gray, with ironstone-cherty-crinoidal-limestone seams.
	4'6"	7. Shale.
	1'	6. Limestone, crinoidal.
	8'6"	5. Shale, mostly covered.
	2'3"	4. Limestone and shale; 3 inch limestone bed at base.
Maury	8"	*3. Shale, green yellow gray, with phosphatic bed near middle; rare nodules.
	3.5"	2. Shale, brown, with phosphatic nodules.
New Albany		1. Shale, black, fissile; not measured.

LOCALITY K-32



KEOKUK LIMESTONE	19'	*14. Siltstone, bluish, weathering brown; fossiliferous.
	10'	13. Limestone, cherty and silty.
	1'	*12. Limestone, crinoidal, oölitic?.
	44'	* 11. Limestone, cherty and silty; crinoidal in upper part; rare clay seams.
NEW PROVIDENCE FORMATION 190'	26'	*10. Shale, silty, soft, bluish; fossiliferous.
	75'	* 9. Siltstone and shaly siltstone; no fossils noted in upper part; lower part with argillaceous limestone ledges; rare crinoidal limestone lenses near base; lower one-fourth fossiliferous.
	5'6"	8. Covered.
	5'6"	* 7. Shale, fossiliferous; thin limestone lenses.
	17'	6. Covered.
	16'6"	* 5. Shale, fossiliferous; common crinoidal limestone lenses up to 1.5' thick.
	5'6"	* 4. Shale with siltstone layers.
	39'	* 3. Shale, fossiliferous, with thin crinoidal limestone lenses, 1-2" thick, in upper part.
	8'	* 2. Shale, green gray, with ironstone nodules; snails?.
Falling Run	6"	* 1. Shale, green gray, with phosphatic nodules; New Albany shale below.

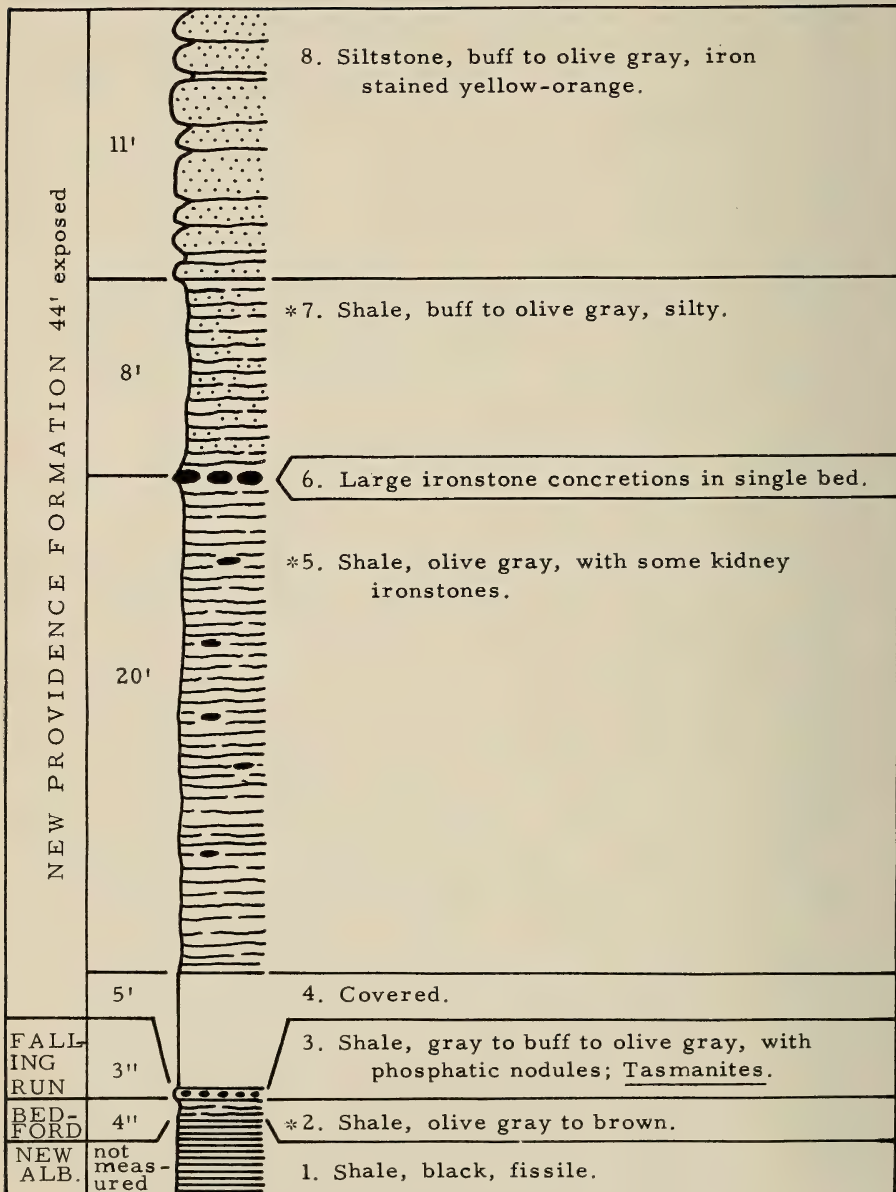
LOCALITY K-35

Formation	Thickness	Description
NEW PROVIDENCE FORMATION 17'6" exposed	4'	* 7. Shale, olive gray; covered above.
	10'	6. Covered.
	1'	* 5. Shale, olive gray.
	2'6"	* 4. Shale, olive gray to yellow, mixed.
Falling Run	3"	* 3. Shale, olive gray, with phosphatic nodules containing fossils.
BED-FORD	6"	* 2. Shale, gray, with plant fossils.
Sander-son		1. Shale, black, fissile, with many nodules; not measured.

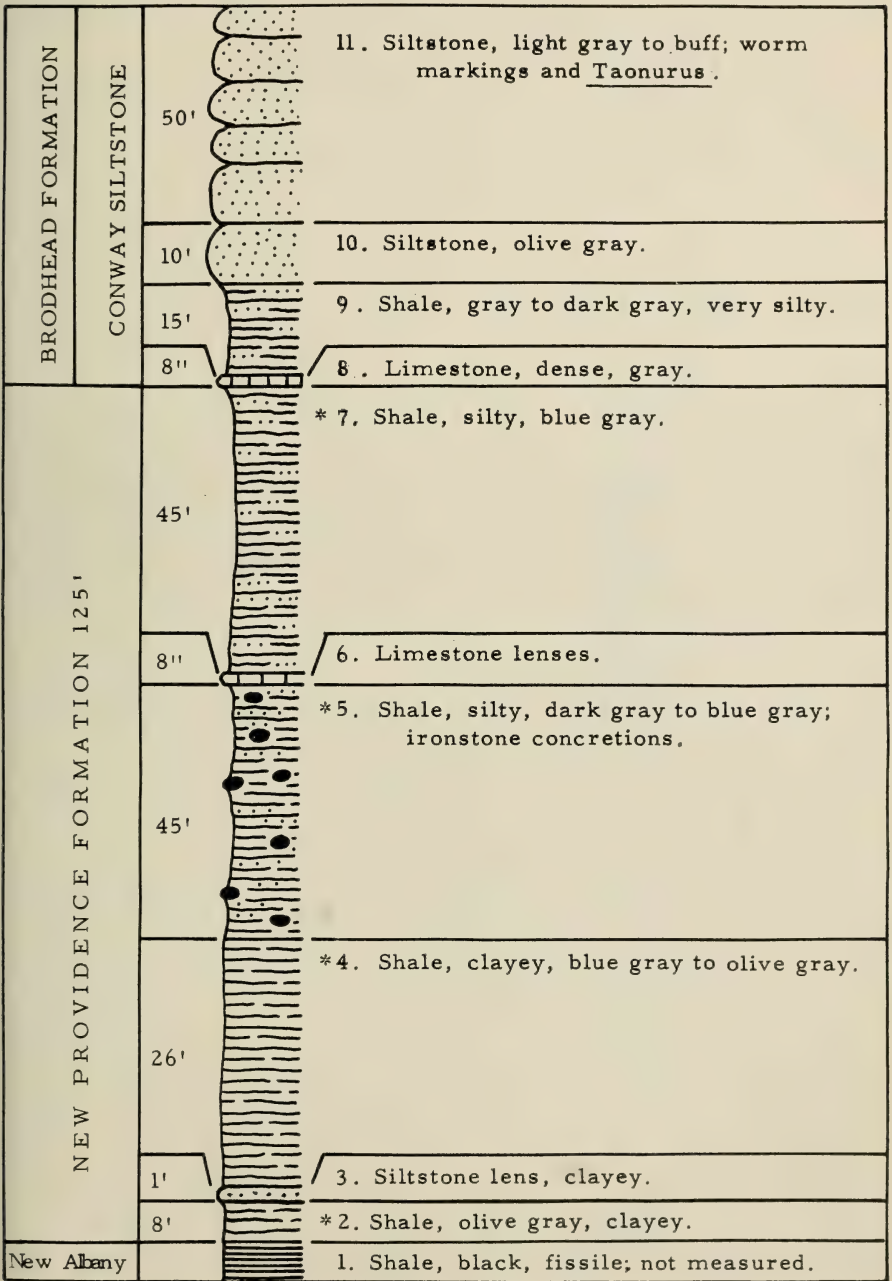
LOCALITY K-38

Formation	Thickness	Description
NEW PROVIDENCE FORMATION	5'6"	*8. Shale, blue gray, partly covered at top; rare coprolite? structures throughout.
	5'6"	*7. Shale, blue gray, with regular-sized kidney ironstones in middle portion; coprolite? structures of limonite.
	5'6"	*6. Shale, blue gray, softer than below; no kidney ironstones noted.
	3'6"	*5. Shale, with rare kidney ironstones which are larger than usual.
	2'	* 4. Shale, blue gray; partly covered.
F. R.	7"	*3. Shale, olive gray, with phosphatic nodules.
BED-FORD	7"	* 2. Shale, hard, gray, with some black shale in middle.
N. A.		1. Shale, black, fissile; not measured.

LOCALITY K-39



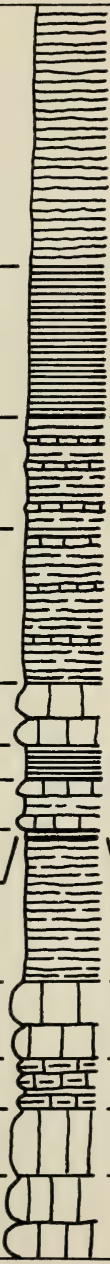
LOCALITY K-44



LOCALITY K-45

Formation	Member	Thickness	Lithology	Description
Brodhead	Conway siltstone	17'		*11. Shale, buff to olive gray, silty; with large ironstone concretions; covered above.
NEW PROVIDENCE FORMATION 143'		33'		10. Covered.
		11'		*9. Shale, olive gray.
		33'		*8. Shale, olive gray, partly blue gray, silty; rare small medium sized ironstones at top.
		22'		7. Covered.
		5'6"		* 6. Shale, blue gray to olive gray.
		5'6"		5. Covered.
		11'		* 4. Shale, blue gray to olive gray, silty, clayey.
		11'		* 3. Shale, olive gray, partly covered.
		11'		2. Covered.
N. A.				1. Shale, black, fissile; not measured.

LOCALITY K-50



NEW ALBANY SHALE	BLACKISTON	10'	* 13. Shale, black and gray layers interbedded.
NEW ALBANY SHALE	Trousdale	6'	*12. Shale, black, fissile; with *Schizobolus concentricus*, *Orbiculoides lodiensis*.
PORTWOOD FORMATION (Harg shale facies) 16'3"	UPPER	3'	*11. Shale, gray, calcareous, with hard shale layers.
PORTWOOD FORMATION (Harg shale facies) 16'3"	MIDDLE	7'	10. Shale, subfissile, black, calcareous; *Lingulopora williamsana*.
PORTWOOD FORMATION (Harg shale facies) 16'3"	MIDDLE	1'	9. Limestone.
PORTWOOD FORMATION (Harg shale facies) 16'3"	MIDDLE	3"	8. Shale, fissile, black; no fossils.
PORTWOOD FORMATION (Harg shale facies) 16'3"	MIDDLE	9"	* 7. Limestone and calcareous shale.
PORTWOOD FORMATION (Harg shale facies) 16'3"	MIDDLE	1"	*6. Shale, calcareous, black.
PORTWOOD FORMATION (Harg shale facies) 16'3"	LOWER	2'1"	*5. Shale, earthy, greenish to black.
PORTWOOD FORMATION (Harg shale facies) 16'3"	LOWER	1'	*4. Limestone, brown.
PORTWOOD FORMATION (Harg shale facies) 16'3"	LOWER	6"	*3. Limestone, shaly, gray to black.
PORTWOOD FORMATION (Harg shale facies) 16'3"	LOWER	8"	*2. Limestone, brown.
Hamilton limestone		1'	1. Limestone.

LOCALITY K-51

Formation	Thickness	Description
NEW PROVIDENCE FORMATION	4'	* 9. Shale, green gray, with some small ironstone nodules; covered above.
	5"	8. Ironstone bed.
	24'9"	* 7. Shale, green gray in part, red to purple in part; partly hard silty beds; kidney ironstone nodules; fucoids.
	8'	* 6. Shale, green gray, with some darker shale; partly covered.
	1'	* 5. Siltstone.
	1'9"	4. Shale.
SUN-BURY	5'10"	3. Shale, black, fissile, with some softer brown and dark gray clay shale.
Bedford	3.5"	2. Shale, gray to olive gray.
New Albany		1. Shale, black, fissile, with some soft yellow brown shale; not measured.

LOCALITY K-52

NEW PROVIDENCE	9"	9. Siltstone ledge; covered above.
	3'8"	*8. Shale, green gray.
Falling Run	2.5"	*7. Shale, green gray, with phosphatic nodules.
SUNBURY SHALE	14'	*6. Shale, black fissile; thin white sandstone layers with carbonaceous streaks in upper 2 feet.
	5"	*5. Shale, brownish gray, softer than above and below.
	7"	4. Shale, black, fissile; no fossils.
BEDFORD SHALE	5"	*3. Shale, upper 3" thin bedded; lower 2" hard chunky bed.
	3'2"	*2. Shale, hard and soft.
NEW AL-BANY		1. Shale, black, fissile; not measured.

LOCALITY K-53

Formation	Thickness	Description
NEW PROVIDENCE FORMATION	1'6"	*10. Shale, green gray to buff, covered above.
	5"	9. Siltstone, single bed, gray to drab, stained brown to black; no fossils.
	3'2"	*8. Shale, green gray to buff, clayey, iron stained.
Falling Run	4"	*7. Shale, hard, greenish, with phosphatic nodules.
SUNBURY SHALE	8.5"	*6. Shale, hard to soft, brown.
	5'10"	5. Shale, black, fissile; phosphatic nodules with <u>Lingula</u> and <u>Orbiculoidea</u>.
	2"	4. Shale, grayish yellow to gray, weathered; no fossils.
	5"-15"	3. Shale, black, fissile.
BEDFORD	0-10"	*2. Shale, siliceous, brittle, olive gray to blue gray; 6 feet long, wedge in Sunbury.
NEW ALBANY	2'	1. Shale, black, fissile; upper 2 feet sampled.

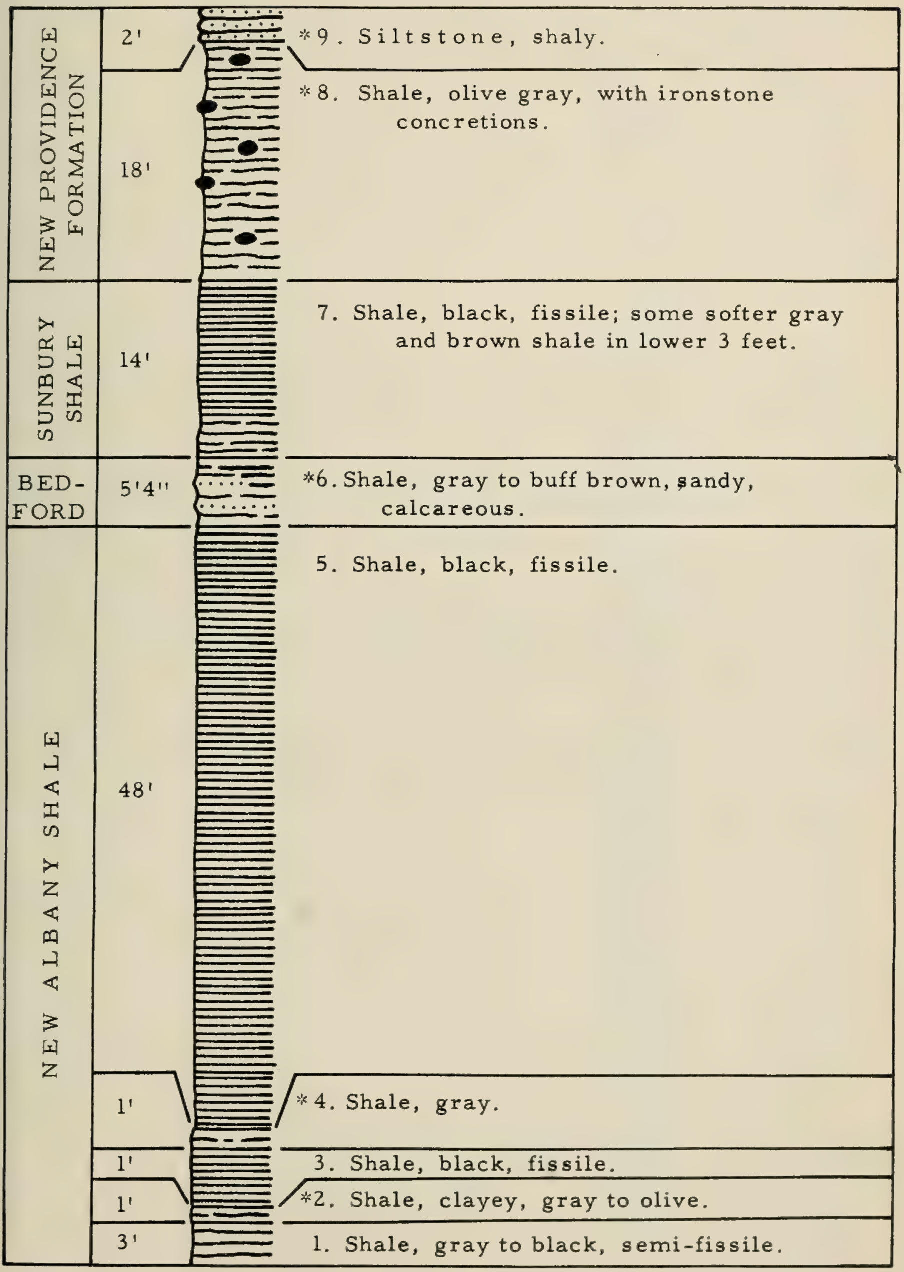
LOCALITY K-54

Formation	Thickness	Description
NEW PROVIDENCE FORMATION	3'	*8. Shale, green gray.
	1'	*7. Shale, green gray; no nodules; some brown shale.
	6"	*6. Shale, green gray; no nodules noted.
	6"	*5. Shale, green gray, some brown; no nodules noted.
Falling Run	3"	4. Shale, hard, green gray; phos. nodules
SUNBURY?	7"	3. Shale, hard, brown, some gray brown; some soft shale.
BEDFORD?	2"	2. Shale, soft, brown gray, clayey.
NEW ALBANY SH.	2'	1. Shale, black, fissile.

LOCALITY K-55

NEW PROVIDENCE FM.			*9. Shale, clayey, green gray; not measured.
NEW PROVIDENCE FM.	Clay City mbr.	1'6"	8. Siltstone, calcareous, hard, buff.
NEW PROVIDENCE FM.		4'6"	7. Shale, clayey, buff gray, weathered yellow.
SUNBURY SHALE		9'6"	6. Shale,. black, fissile; upper foot weathered soft, coffee-colored.
BEDFORD SHALE		3'2"	*5. Contact seam; weathered shale.
BEDFORD SHALE			*4. Shale, sandy, semi-fissile in part; clayey, olive gray to buff at base.
NEW ALBANY SHALE		47'	3. Shale, black, fissile; upper 5 feet and lower 1 foot sampled.
NEW ALBANY SHALE		1'	*2. Shale, clayey, olive green.
NEW ALBANY SHALE			1. Shale, black, fissile; not measured.

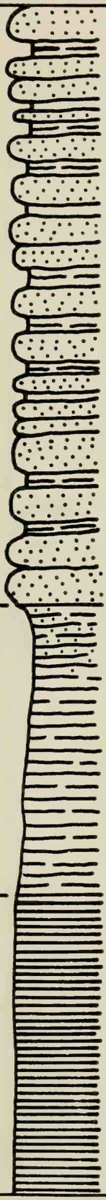
LOCALITY K-57



LOCALITY K-58

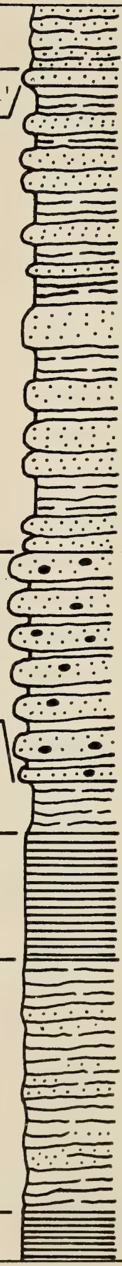
Formation	Member	Thickness	Description
NEW PROVIDENCE FORMATION	FARMERS SILTSTONE	26'	*5. Siltstone with shale, blue gray.
		5'	* 4. Shale, silty, blue gray to gray.
		6'6"	*3. Shale, clayey, blue gray, with thin silty layers.
SUNBURY SHALE		16'	2. Shale, black, fissile.
BEDFORD SHALE			1. Shale, soft, sticky, yellow to buff to gray; some black; spores; not measured.

LOCALITY K-61



NEW PROVIDENCE FORMATION (CUYAHOGA)	FARMERS SILTSTONE	20'	*3. Siltstone, in smooth, even beds, with intercalated shales, gray, green, and purple.
	HENLEY SHALE	10'	* 2. Shale, olive gray to blue gray, clayey; silty in upper part, and gray to buff; middle part weathered; samples taken from upper 2.5' and lower 2'.
SUNBURY SHALE		10'	* 1. Shale, black, fissile.

LOCALITY K-62

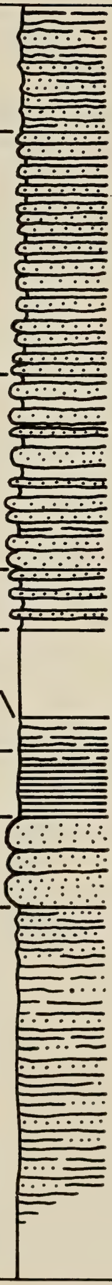


Formation	Member	Thickness	Description
NEW PROVIDENCE FORMATION		7'	8. Shale, very silty.
NEW PROVIDENCE FORMATION		6"-1'	7. Siltstone in single bed, gray to buff.
NEW PROVIDENCE FORMATION		85'	6. Shale and siltstone; no samples taken.
NEW PROVIDENCE FORMATION	Farmers siltstone	30'	5. Siltstone, in smooth even beds separated by shale partings; gray to buff; ironstone concretions; Taonurus.
NEW PROVIDENCE FORMATION	Henley shale	7'	*4. Shale, clayey, olive gray; sample taken from upper 2.5 feet.
Sunbury shale		17'	3. Shale, black, fissile.
BEDFORD SHALE		35'	2. Shale, partly arenaceous, blue gray, with pyrite.
New Albany			1. Shale, black, fissile; not measured.

LOCALITY K-63

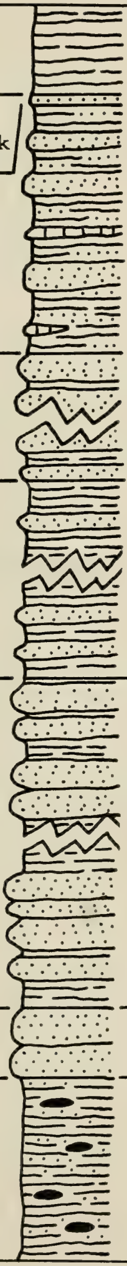
Formation	Member	Thickness	Description
			Covered.
NEW PROVIDENCE FM.		8"	11. Siltstone, gray to buff, in single bed.
NEW PROVIDENCE FM.		35'	*10. Shale, clayey, slightly silty, gray to drab, with ironstone concretions.
NEW PROVIDENCE FM.	Farmers siltstone	34'	*9. Siltstone, smooth even beds, separated by shaly partings; partly covered.
NEW PROVIDENCE FM.	Henley	13'	*8. Shale, clayey; partly covered.
SUNBURY		18'6"	7. Shale, fissile, black.
BEDFORD		35'6"	6. Shale, partly arenaceous, blue gray to olive gray; intercalated black fissile shales in lower part.
NEW ALBANY SHALE		82'	5. Shale, black, fissile.
NEW ALBANY SHALE		3'	*4. Shale, green gray.
NEW ALBANY SHALE		91'	3. Shale, black, fissile.
NEW ALBANY SHALE		3'	*2. Shale, green gray.
NEW ALBANY SHALE		10'	1. Shale, black, fissile; mostly covered.

LOCALITY K-66



Formation	Member	Thickness	Description
NEW PROVIDENCE FORMATION (CUYAHOGA)	Churn Creek sh.	35'	* 9. Shale, very silty, light gray; worm markings.
	VANCEBURG SILTSTONE	64'	* 8. Siltstone in smooth even beds up to 3" thick, gray to drab, separated by shale partings up to 1" thick; *Taonurus*.
		53'	7. Siltstone and shale, clayey, drab; *Taonurus*.
		15'	6. Siltstone, drab, evenly bedded, with shale partings.
	?	25'	5. Covered.
	Henley	10'	4. Shale, clayey, olive to maroon.
SUNBURY SHALE		17'	3. Shale, black, fissile; soft, weathered to gray brown in upper part.
BEREA SS.		25'3"	2. Sandstone, gray to brown; ripple marks.
BEDFORD SHALE		104'	* 1. Shale, sandy in upper 6 feet, in irregular beds, light gray to buff; light to medium gray, soft, sticky, plastic shale in lower part; lower 15 feet covered.

LOCALITY K-67

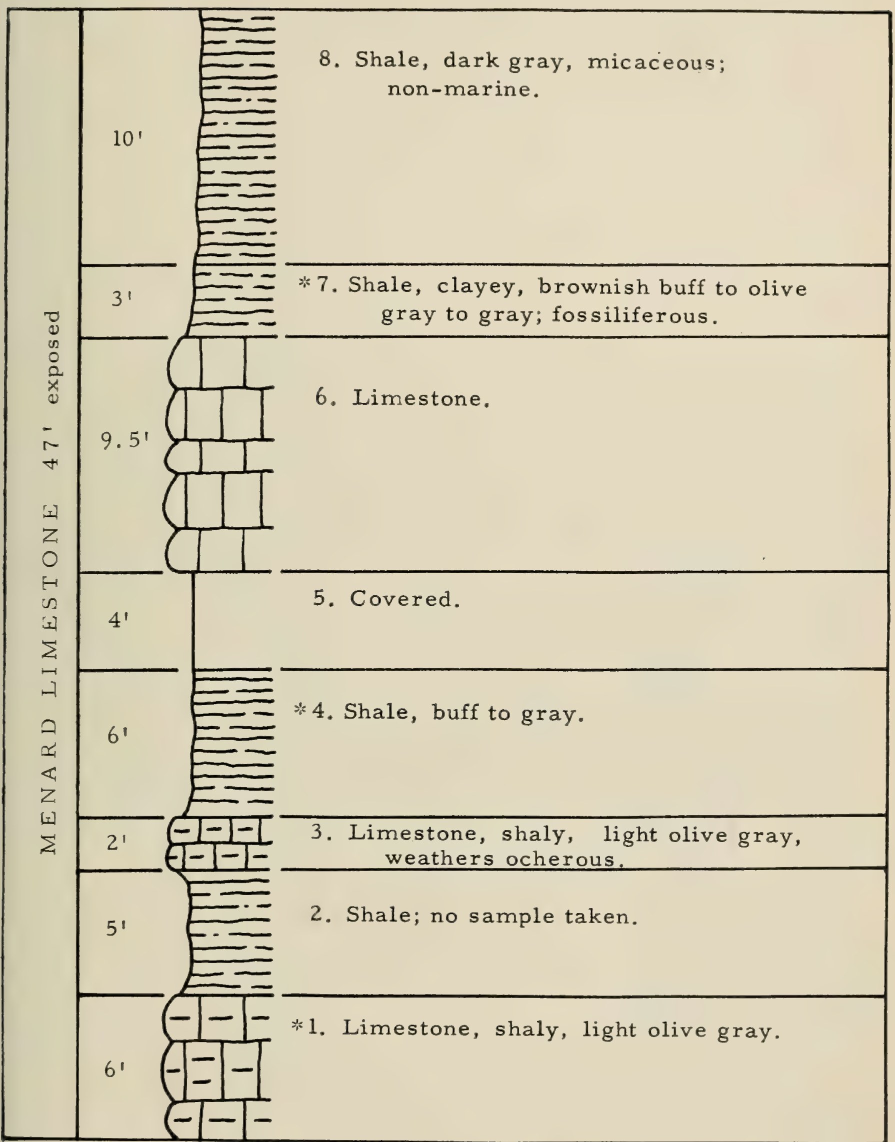


Formation	Member	Thickness	Description
ROTHWELL SHALE		6'	*8. Shale, clayey, olive gray and maroon.
FLOYDS KNOB FM.		thin streak	*7. Shale, silty, glauconitic, greenish black to olive gray.
BRODHEAD FORMATION 310'	Perry Branch siltstone	35'	*6. Siltstone, limestone lenses, and silty shale, olive gray and maroon; fossiliferous; partly covered.
	Haldeman siltstone	50'	5. Siltstone with shaly zones; fossiliferous.
		105'	4. Shale and siltstone, gray to drab; partly covered.
	CHRISTY CREEK SILTSTONE	120'	3. Siltstone, massive, gray to drab; sampled in lower part.
NEW PROVIDENCE FORMATION		10'	2. Siltstone, shaly, iron stained; worm markings.
		25'	*1. Shale, olive gray, silty, iron stained; ironstone lenses; worm markings.

LOCALITY K-68

BRODHEAD FORMATION 271'	HALDEMAN SILTSTONE	90'	*6. Siltstone and shaly siltstone, blue gray to olive gray, shalier in lower part; *Taonurus* and worm markings.
		10'	5. Siltstone, massive, buff to drab.
		100'	* 4. Siltstone, shaly, blue gray to olive gray; *Taonurus* and worm markings.
	CHRISTY CREEK SILTSTONE	55'	3. Siltstone to sandstone, massive, dark gray, weathering brown; worm markings.
		16'	2. Shale, silty, dark gray, weathering brown.
NEW PROVIDENCE FORMATION		36'	*1. Shale, silty, dark gray, with thin siltstone layers; covered below.

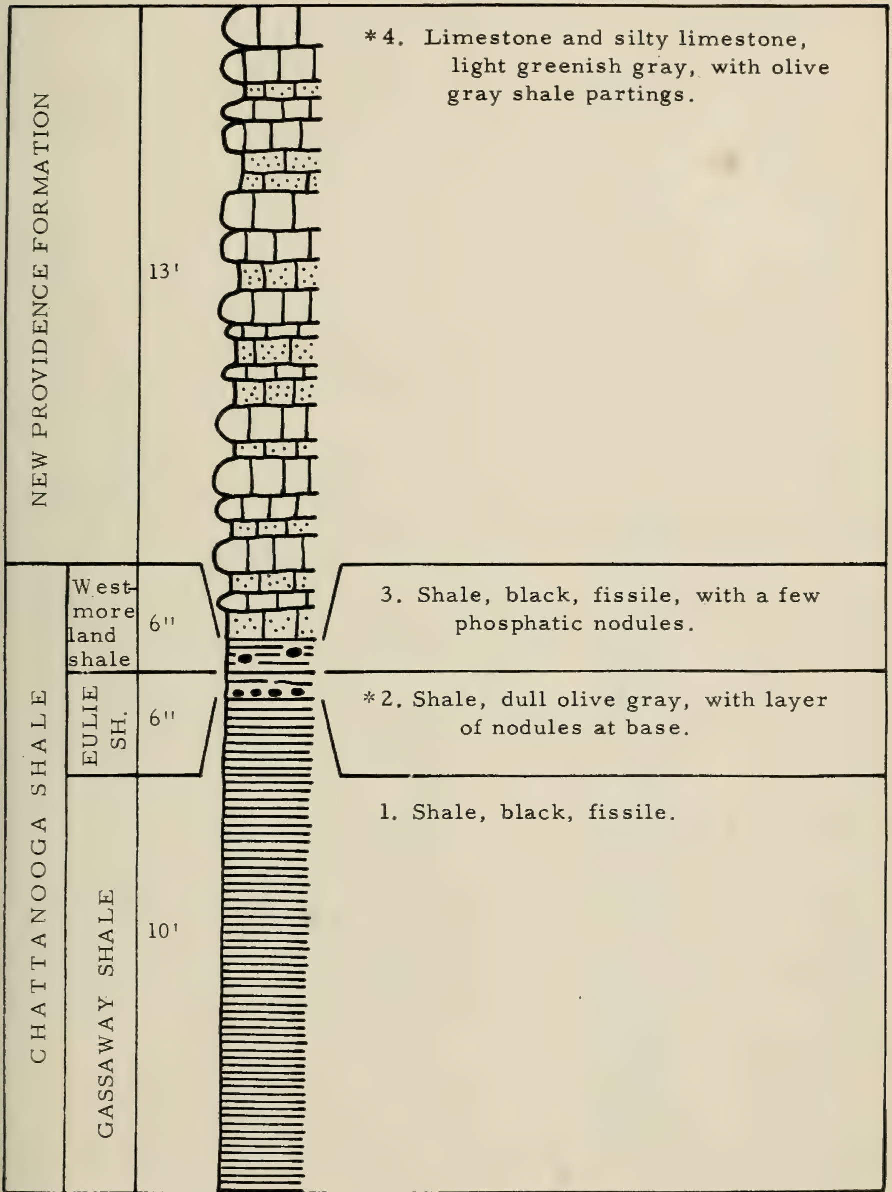
LOCALITY I-1


MENARD LIMESTONE 47' exposed
10'
8. Shale, dark gray, micaceous; non-marine.
3'
*7. Shale, clayey, brownish buff to olive gray to gray; fossiliferous.
9.5'
6. Limestone.
4'
5. Covered.
6'
*4. Shale, buff to gray.
2'
3. Limestone, shaly, light olive gray, weathers ocherous.
5'
2. Shale; no sample taken.
6'
*1. Limestone, shaly, light olive gray.

LOCALITY I-6

NEW PROVIDENCE FORMATION 101' exposed	27'	* 10. Shale, olive gray, partly covered; rare ironstone concretions; ironstone chips on surface.
	5'6"	9. Covered.
	33'6"	* 8. Shale, olive gray, partly covered; frequent large ironstone concretions, 6"-1' in diam.; ironstone chips on surface; fragments of Bembexia ellenae on surface, rare segmented worm markings.
	2'	* 7. Siltstone, shaly, brown; no megafossils.
	6'6"	* 6. Shale, brown; no megafossils.
	5'6"	* 5. Shale, brownish gray; rare kidney ironstones; no megafossils.
	22'	* 4. Shale, olive gray to blue gray; no megafossils.
	12'	3. Covered.
	3"	2. Cone-in-cone layer; quarry floor.
		* 1. Shale, gray; not measured.

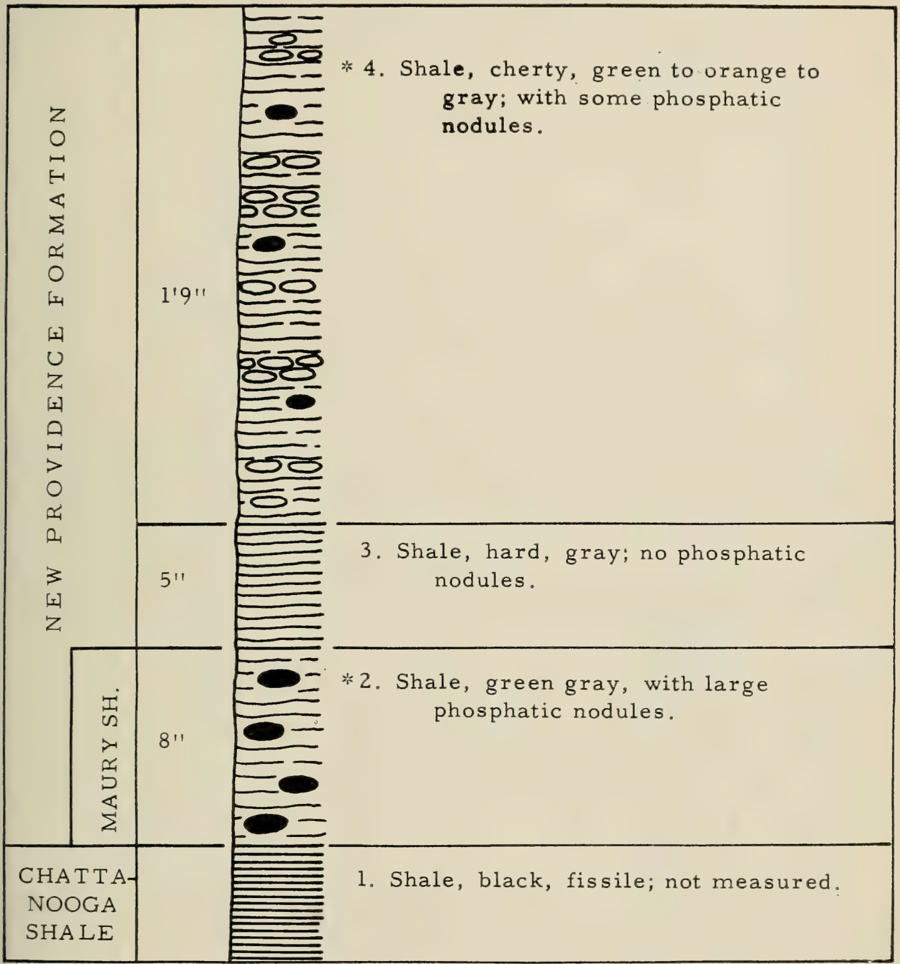
LOCALITY T-2


NEW PROVIDENCE FORMATION
13'
*4. Limestone and silty limestone, light greenish gray, with olive gray shale partings.
CHATTANOOGA SHALE
Westmoreland shale
6''
3. Shale, black, fissile, with a few phosphatic nodules.
EULIE SH.
6''
*2. Shale, dull olive gray, with layer of nodules at base.
GASSAWAY SHALE
10'
1. Shale, black, fissile.

LOCALITY T-3

Formation		Thickness	Description
FORT PAYNE LIMESTONE			*4. Limestone, cherty, with thin shale seams; not measured; sample from lower 5 feet.
NEW PROVIDENCE	FM.	12.5"	*3. Shale, gray to green gray; phosphatic nodules and glauconitic, calcareous, shale at top.
NEW PROVIDENCE	MAURY SH.	10"	2. Shale, hard, gray; upper 6 inches with large phosphatic nodules; some green gray shale; no fossils noted.
CHATTA-NOOGA SHALE			1. Shale, black, fissile; not measured.

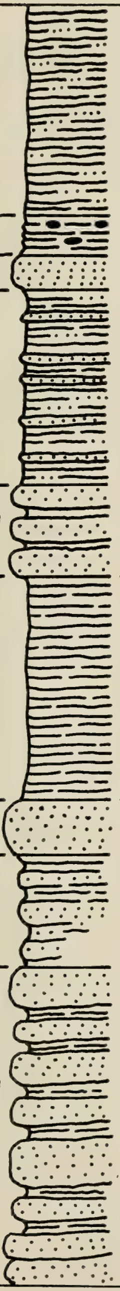
LOCALITY T-4


NEW PROVIDENCE FORMATION
MAURY SH.
CHATTA-NOOGA SHALE
1'9"
5"
8"
* 4. Shale, cherty, green to orange to gray; with some phosphatic nodules.
3. Shale, hard, gray; no phosphatic nodules.
* 2. Shale, green gray, with large phosphatic nodules.
1. Shale, black, fissile; not measured.

LOCALITY O-1

SUN-BURY	15'	3. Shale, fissile, black.
BEDFORD - BEREA	118'	*2. Sandstone, buff to tan to light gray, fine grained, evenly bedded, with siltstones and silty shale; some beds micaceous.
OHIO SHALE	27'	1. Shale, black, fissile; covered below.

LOCALITY O-2



CUYAHOGA FORMATION - VANCEBURG MEMBER	16'	* 9. Shale, silty, brownish gray.
	1'	* 8. Shale, gray, platy; small ironstones.
	1'	7. Siltstone.
	9'	* 6. Shale, silty, with thin siltstones.
	3'6"	* 5. Siltstone, in three beds, with two 2 inch shale breaks.
	11'	* 4. Shale, gray green.
	2'	3. Siltstone, massive.
	5'6"	* 2. Siltstone, shaly, green gray; partly covered.
	17'6"	* 1. Siltstones and sandstones up to 2.5 feet thick, with intercalated green gray shales up to 6 inches thick.

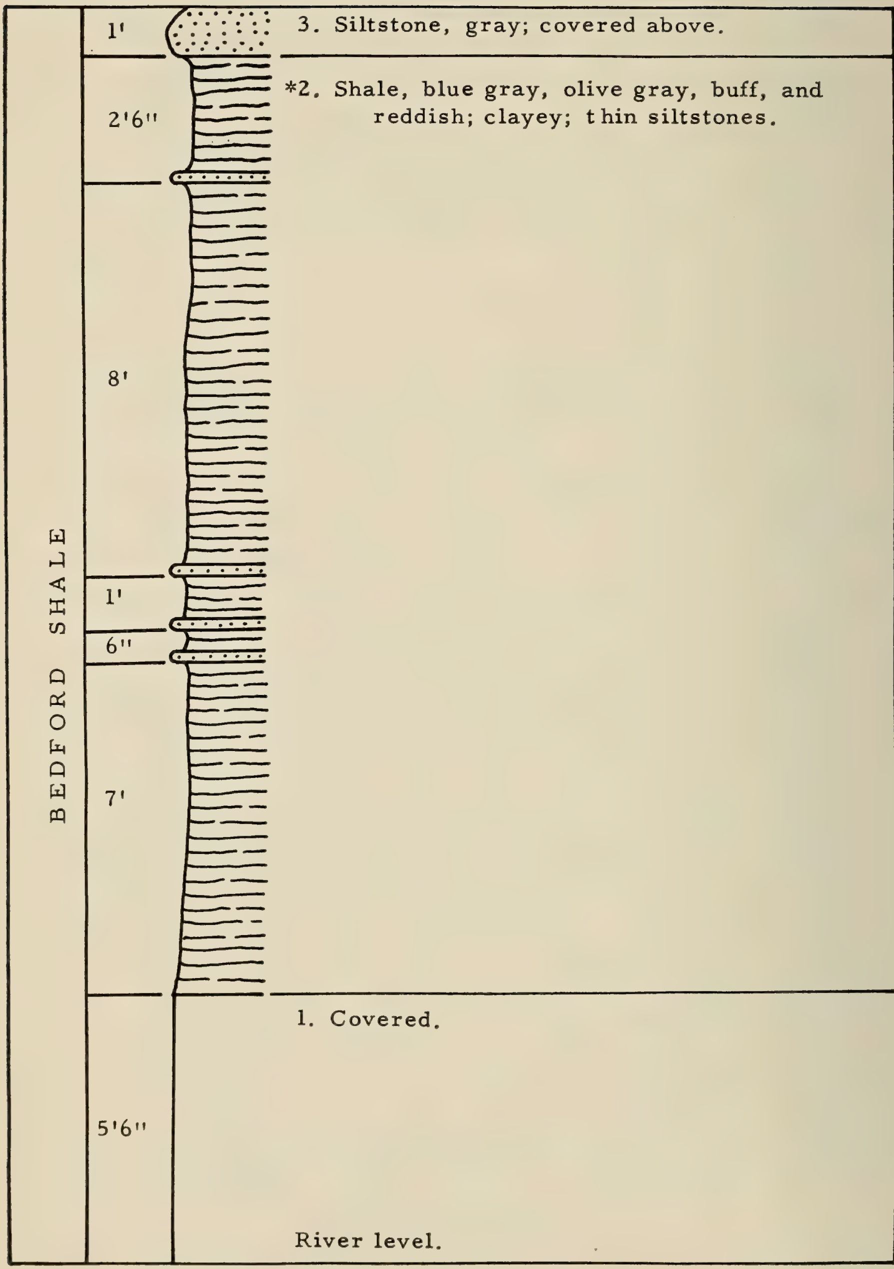
LOCALITY O-3

Formation	Thickness	Description
LOGAN FM.	16'	*6. Siltstone, blue gray, gray, thin to medium bedded, with silty shale.
CUYAHOGA FORMATION	64'	*5. Shale, blue gray.
	60'	4. Covered by slump.
	100'	*3. Shale, blue gray.
	5'6"	*2. Shale, blue gray, with thin siltstones.
	5'6"	1. Shale, not sampled.

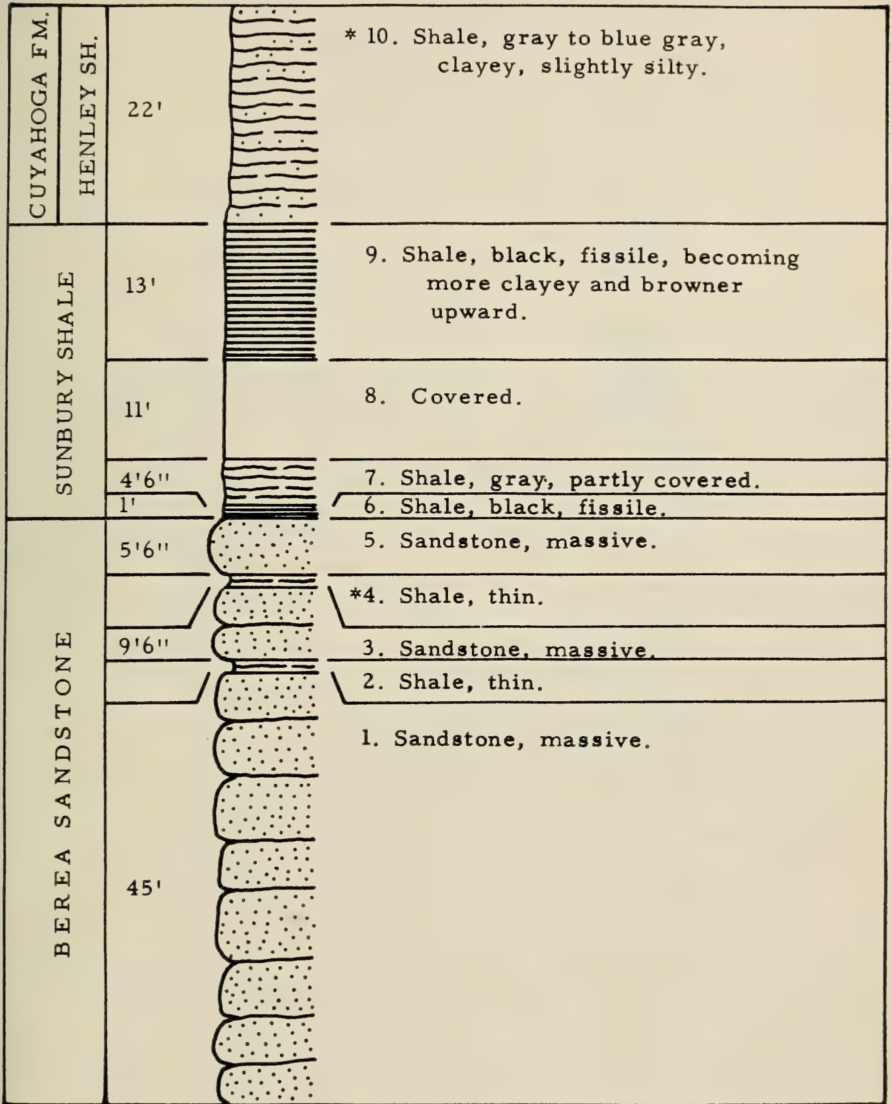
LOCALITY O-4

BEREA SS.		*7. Sandstone, light gray to blue gray; beds contorted; not measured.
BEDFORD SHALE		6. Shale, not measured or sampled.
	2'	5. Shale, clayey, gray to yellow buff.
	3'	* 4. Shale, clayey, gray to yellow buff.
	2'	* 3. Shale, clayey, gray to yellow buff.
?		* 2. Shale, gray to dark gray; spores; not measured, transition zone.
OHIO SHALE		1. Shale, black, fissile; not measured.

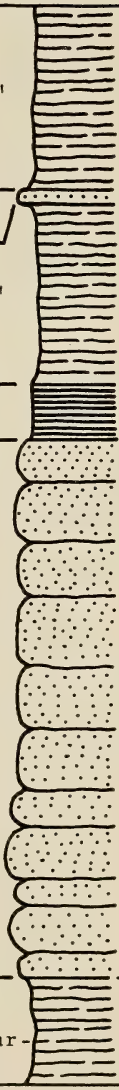
LOCALITY O-5


BEDFORD SHALE
1'
3. Siltstone, gray; covered above.
2'6"
*2. Shale, blue gray, olive gray, buff, and reddish; clayey; thin siltstones.
8'
1'
6"
7'
1. Covered.
5'6"
River level.

LOCALITY O-6

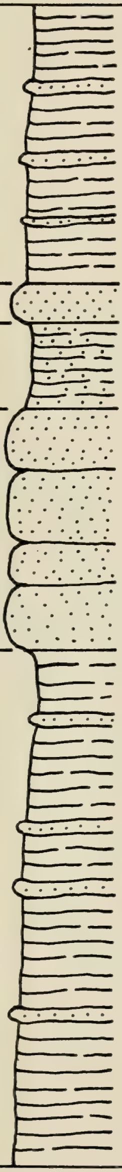

CUYAHOGA FM.
HENLEY SH.
SUNBURY SHALE
BEREA SANDSTONE
22'
13'
11'
4'6"
1'
5'6"
9'6"
45'
* 10. Shale, gray to blue gray, clayey, slightly silty.
9. Shale, black, fissile, becoming more clayey and browner upward.
8. Covered.
7. Shale, gray, partly covered.
6. Shale, black, fissile.
5. Sandstone, massive.
*4. Shale, thin.
3. Sandstone, massive.
2. Shale, thin.
1. Sandstone, massive.

LOCALITY O-7



Formation	Thickness	Description
CUYAHOGA FORMATION	30'6"	*6. Shale, greenish-gray, clayey; some maroon shale in upper part; covered above.
	1'-2'	5. Siltstone, buff to gray; "Buena Vista".
	27'6"	*4. Shale, gray, yellowish, buff, to reddish, clayey.
SUN-BURY	8'	*3. Shale, black, fissile; road intersection at base of Sunbury shale.
BEREA SANDSTONE	100'	2. Sandstone; measurement from well on Lester's Crabtree Farm.
BED-FORD SH.	not measur-ed	*1. Shale, gray to tan; sample taken 1 mile south of Hiway 50 on Jester Hill Rd.

LOCALITY O-8



Formation	Thickness	Description
CUYAHOGA FORMATION	8'	*5. Shale, gray, clayey, with a few thin sandstones; covered above.
	11"	4. Sandstone, medium grained, red brown.
	2'6"	*3. Shale, gray, silty and clayey.
	6'6"	2. Sandstone, medium grained, reddish brown.
	14'	1. Shale, gray, clayey with thin sandstones; sample from upper 2 feet.

STRATIGRAPHIC PALEONTOLOGY

COMPOSITION OF THE FAUNAS

A complete list of all Mississippian smaller Foraminifera reported in this study follows:

Order FORAMINIFERA d'Orbigny, 1826

Family **ASTRORHIZIDAE** Brady, 1881

Genus **CRITHIONINA** Goës, 1894
C. palaeozoica, n. sp.

Genus **THURAMMINOIDES** Plummer, 1945 emend.
T. sphaeroidalis Plummer, 1945 emend.

Family **SACCAMMINIDAE** Brady, 1884

Subfamily **SACCAMMININAE** Brady, 1884

Genus **PROTEONINA** Williamson, 1858
P. cumberlandiae, n. sp.
P. wallingfordensis, n. sp.

Family **HYPERAMMINIDAE** Eimer and Fickert, 1899

Subfamily **HYPERAMMININAE** Cushman, 1910

Genus **HYPERAMMINA** Brady, 1878 emend. Conkin, 1954
H. casteri, n. sp.
H. kentuckyensis Conkin, 1954
H. rockfordensis Gutschick and Treckman, 1959

Family **EARLANDIIDAE** Cummings, 1955

Genus **EARLANDIA** Plummer, 1930
E. consternatio, n. sp.

Family **REOPHACIDAE** Cushman, 1927

Subfamily **REOPHACINAE** Cushman, 1927

Genus **REOPHAX** Montfort, 1808
R. cf. *R. arenatus* (Cushman and Waters), 1927
R. asper Cushman and Waters, 1928
R. kunklerensis, n. sp.
R. cf. *R. lachrymosus* Gutschick and Treckman, 1959
R. mcdonaldi, n. sp.
R. cf. *R. minutissimus* Plummer, 1945

Family **TOLYPAMMINIDAE** Cushman, 1929

Subfamily **INVOLUTININAE** Cushman, 1910

Genus **INVOLUTINA** Terquem, 1862, emend. Loeblich and Tappan, 1954
I. exserta (Cushman), 1910
I. longexserta Gutschick and Treckman, 1959
I. semiconstricta (Waters), 1927

Genus **GLOMOSPIRA** Rzehak, 1888
G. articulosa Plummer, 1945

Genus **LITUOTUBA** Rhumbler, 1895
L. semiplana, n. sp.

Subfamily **TOLYPAMMININAE** Cushman, 1928

Genus **TOLYPAMMINA** Rhumbler, 1895
T. botonuncus Gutschick and Treckman, 1959
T. cyclops Gutschick and Treckman, 1959
T. jacobschapelensis, n. sp.
T. laocoon, n. sp.
T. tortuosa Dunn, 1942

Genus **AMMOVERTELLA** Cushman, 1928
A. cf. *A. inclusa* (Cushman and Waters), 1927
A. labyrintha Ireland, 1956
A. cf. *A. primaparva* Ireland, 1956

Genus **TREPEILOPSIS** Cushman and Waters, 1928
T. glomospiroides Gutschick and Treckman, 1959
T. recurvidens Gutschick and Treckman, 1959
T. spiralis Gutschick and Treckman, 1959

Family **LITUOLIDAE** Reuss, 1861

Subfamily **HAPLOPHRAGMIINAE** Cushman, 1927

Genus **AMMOBACULITES** Cushman, 1910
A. gutschicki, n. sp.

Family **TEXTULARIIDAE** d'Orbigny, 1846

Subfamily **TEXTULARIINAE** d'Orbigny, 1846

Genus **CLIMACAMMINA** Brady, 1873
C. mississippiana, n. sp.

Family**MILIOLIDAE** d'Orbigny, 1846

Genus **AGATHAMMINA** Neumayr, 1887
A. mississippiana, n. sp.

Family **OPHTHALMIDIIDAE** Cushman, 1927

Genus **HEMIGORDIUS** Schubert, 1908
H. morillensis, n. sp.

Family **TROCHAMMINIDAE** Cushman, 1929

Genus **TROCHAMMINA** Parker and Jones, 1959
T. ohioensis, n. sp.

Family **PLACOPSILINIDAE** Cushman, 1927

Genus **STACHEIA** Brady, 1876
S. cicatrix, n. sp.
S. neopupoides, n. sp.
S. trepeilopsiformis, n. sp.

The Foraminifera presented in the above faunal list are alloted to twelve families, one of which, the Miliolidae, is new to the Mississippian; to eighteen genera, seven of which are new to the Mississippian: *Agathammina, Climacammina, Crithionina, Proteonina, Stacheia, Thuramminoides,* and *Trochammina;* to 38 species, 18 of which are described as new species: *Agathammina mississippiana, Ammobaculites gutschicki, Climacammina mississippiana, Crithionina palaeozoica, Earlandia consternatio, Hemigordius morillensis, Hyperammina casteri, Lituotuba semiplana, Proteonina cumberlandiae, P. wallingfordensis, Reophax kunklerensis, R. mcdonaldi, Stacheia cicatrix, S. neopupoides, S. trepeilopsiformis, Tolypammina jacobschapelensis, T. laocoon,* and *Trochammina ohioensis.*

GENERA AND SPECIES IMPORTANT IN STRATIGRAPHIC DIVISION

HYPERAMMINA

Three species of *Hyperammina* occur in the studied area. Fragments of *Hyperammina* are common to abundant, many identifiable as to species. Specimens with proloculi are not uncommon.

The most commonly occuring species is *Hyperammina casteri,* which is especially characteristic of the lower New Providence and lower Cuyahoga where *H. kentuckyensis* is lacking, but *H. casteri* occurs in lesser numbers at many other levels from the Upper Devonian Portwood formation to the Chesterian Pennington shale, and possibly the Menard limestone. *H. casteri* ranges higher in the New Providence formation, and is abundant at this level, from southeastern Kentucky to southern Ohio where *H. kentuckyensis* is absent or present only in the upper part of the New Providence in southeastern Kentucky. In eastern Kentucky the upper part of the New Providence was not sampled and thus the lower range of

H. kentuckyensis and the upper range of abundant *H. casteri* were not determined in this area.

Hyperammina kentuckyensis is highly characteristic of and is restricted to the Osagian of Kentucky and southern Indiana, occurring most abundantly in the Floyds Knob and middle and upper New Providence formations.

Hyperammina rockfordensis, like *H. casteri,* occurs in the lower New Providence and lower Cuyahoga formations, but less abundantly; unlike *H. casteri, H. rockfordensis* does not occur above the lowest part of the middle New Providence formation (lower Button Mold member); *H. rockfordensis* ranges downward through the Kinderhookian to the Upper Devonian Blackiston formation.

INVOLUTINA

In abundance, *Involutina semiconstricta* and *I. exserta* are characteristic of the Kinderhookian and lowest Osagian. *I. longexserta* apparently is restricted to this zone but does not occur abundantly. *Involutina* was not found in the Meramecian, but collecting was restricted in this series. *I. semiconstricta* occurs commonly, but locally, in western Kentucky and southern Indiana, in the Paint Creek shale and in the shaly part of the Menard limestone (associated with *I. exserta*); the species is less commonly observed in the Kinkaid limestone.

PROTEONINA

Of the two species of *Proteonina* found in this study, *P. cumberlandiae* occurs most commonly in northwestern and southwestern Kentucky and in southcentral Ohio, while *P. wallingfordensis* occurs mostly from southeastern Kentucky to southern Ohio. Both species are often found together at the same locality, however.

Proteonina cumberlandiae occurs especially in the lower and middle New Providence formation, and in the lower part of the Cuyahoga formation. *P. wallingfordensis* is most abundant in the lower New Providence and lower Cuyahoga and in the middle Cuyahoga formation.

THURAMMINOIDES SPHAEROIDALIS

This long-ranging species in the Mississippian of the studied area is particularly characteristic of and abundant in, the New

Providence and Cuyahoga formations. The species also occurs in moderate numbers in the Brodhead formation. It ranges throughout the Mississippian in the studied area and has been found in the Blackiston formation of Upper Devonian age. *T. sphaeroidalis* from the Silurian and Devonian of Kentucky was reported by Conkin and Conkin (1960, p. 8). The species was originally described from the Pennsylvanian of Texas and has been identified in the Permian of Australia (Crespin, 1958).

TREPEILOPSIS

Three species of *Trepeilopsis* were found during this study. They had been described by Gutschick and Treckman (1959) from the Rockford limestone of northern Indiana. The most commonly occurring of the three species is *T. spiralis* which is found particularly in the lower part of the New Providence formation of Kentucky and Cuyahoga formation of Ohio, and in the Kinderhookian; however, *T. spiralis* ranges up into the Muldraugh formation, and down to the Upper Devonian Portwood formation. *T. recurvidens* occurs especially in the lower part of the New Providence and Cuyahoga formations, but it also ranges upward into the Brodhead formation. *T. glomospiroides* was found in the Rockford limestone of southern Indiana and in the lower parts of the New Providence and Cuyahoga formations.

AMMOVERTELLA

Fragments of *Ammovertella* were found from the Kinderhookian to the middle Chesterian; identifiable species are three: *A.* cf. *A. inclusa*, which ranges from the Bedford to Brodhead formations; *A. labyrintha*, which was found only in the lower part of the New Providence formation; and *A.* cf. *A. primaparva* which occurs in the Kinderhookian Eulie shale of Tennessee, the Rockford limestone of southern Indiana, and the lower part of the New Providence and Cuyahoga formations. Thus, *Ammovertella* is especially common in the Kinderhookian and lowest Osagian.

AMMOBACULITES

One species of *Ammobaculites*, *A. gutschicki*, was found in the studied area. This species represents the third identified species of the genus in the Mississippian of North America. *A. gutschicki* was found in the Kinderhookian Eulie and Falling Run shales. It ranges up through the upper Osagian Brodhead formation and correlatives; however, *A. gutschicki* occurs commonly only in the lower part of the New Providence formation in eastern and northwestern Kentucky.

AGATHAMMINA

One species of *Agathammina, A. mississippiana,* was found in this study to occur rarely and in few localities; the species has a stratigraphic range from the base of the Osagian to the top of the middle Chesterian. At present it has not been found commonly enough to have real stratigraphic value, but it does represent the earliest occurrence of the genus in North America, and indeed, of the family Miliolidae.

HEMIGORDIUS

Hemigordius morillensis was found only in the Chesterian beds of the studied area, especially in the shaly beds of the Glen Dean limestone in western Kentucky. The species was also found in the Paint Creek and Kinkaid limestone and the Big Clifty-Cypress sandstones but does not occur in numbers at any sampled locality.

EARLANDIA

The lowest known *Earlandia, E. consternatio,* was found in the Chesterian and Meramecian, but not below the Somerset shale member of the Salem limestone. *E. consternatio* is especially common in the Paint Creek shale in western Kentucky.

RANGE CHARTS

Charts 3 through 10 show the occurrence of species according to locality number and bed number. The bed number is the same as that on the measured sections. Where no measured section is given, the bed number refers to the bed number in the list of localities. A solid black square indicates that the species occurred commonly to abundantly in that bed. An "X" indicates that a species was found, but not commonly, in that bed.

Charts 11 through 21 show the range of species in the various more or less distinct lithologic provinces. A wide range line indicates common or abundant occurrences of that species. A thin line indi-

Occurrence of species by locality and bed number (Localities I-2-6, T-1-4).

CHART 3

	I-2	I-3		I-4			I-5	I-6							T-1	T-2		T-3		T-4	
	1	2	1	3	2	1	1	10	8	7	6	5	4	1	1	4	2	4	3	4	2
Ammobaculites gutschicki	X	X											X				X				
Ammovertella cf. A. inclusa					X														X		
A. cf. A. primaparva					X												X				
Hyperammina casteri	X	X	■	■									X			X			■	X	
H. kentuckyensis	■	X					■														
H. rockfordensis			X			X							X				X			X	
Involutina exserta	■	■	■			■			■		■					■	X		■		
I. longexserta																	X				
I. semiconstricta					■	■							X				■				
Lituotuba semiplana																	X				
Proteonina cumberlandiae			X																		
Reophax asper		X																			
Stacheia cicatrix	X								X												
Thuramminoides sphaeroidalis	■	■	■	■	X	X		■	■	■	■	■	■	■		X			X		X
Tolypammina botonuncus					X																
T. cyclops					X	X															
T. jacobschapelensis					■																
T. laocoön					X																
T. tortuosa					X												X				
Trepeilopsis glomospiroides			X		X																
T. spiralis	X				■	■											■		X		
Ammovertella fragments					X												X				
Hyperammina fragments	X	X	X			X			X	X	X	X		X	X	X	X			X	X
Tolypammina fragments					X	X											X				
Trepeilopsis fragments			X																		
Proteonina wallingfordensis													X								

Chart 4. Occurrence of species by locality and bed number (Localities K-1-9).

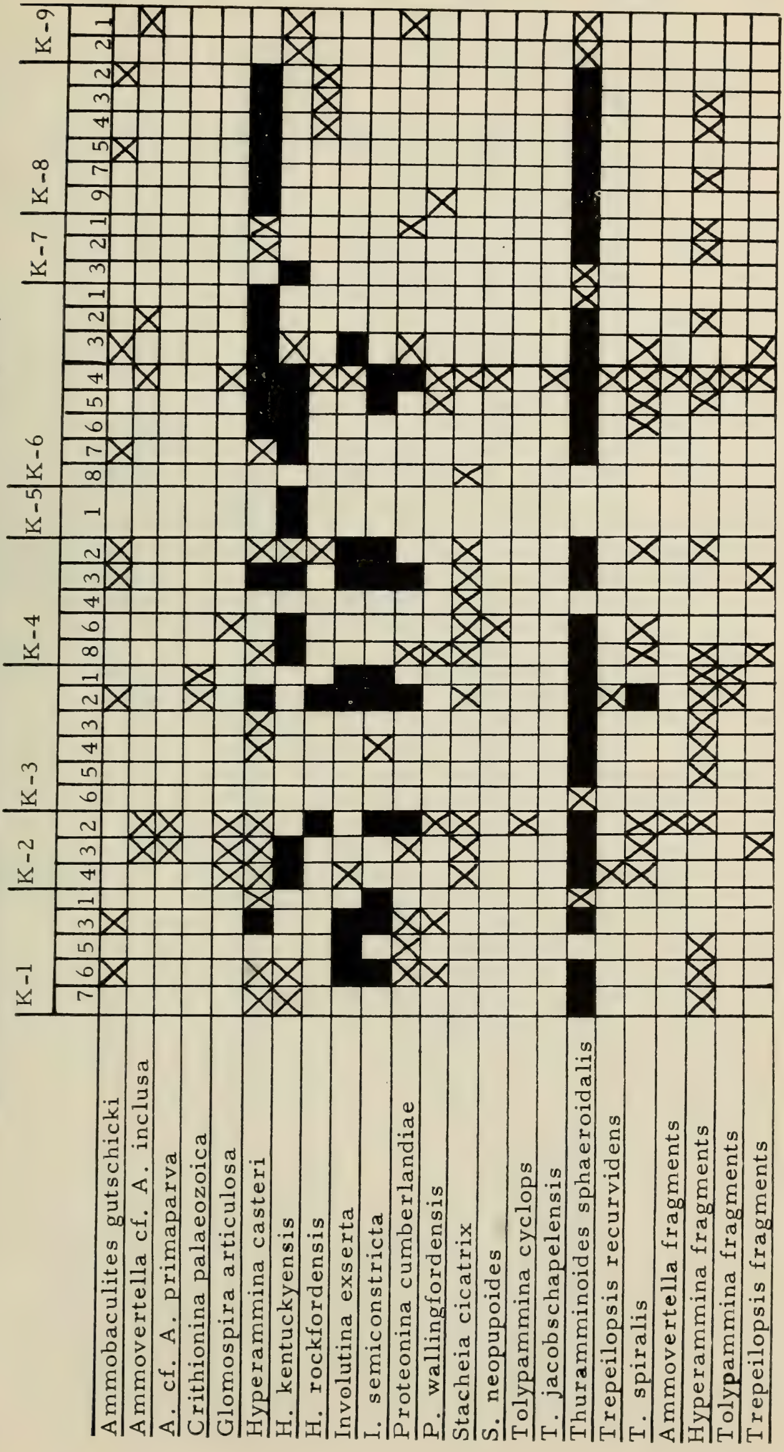
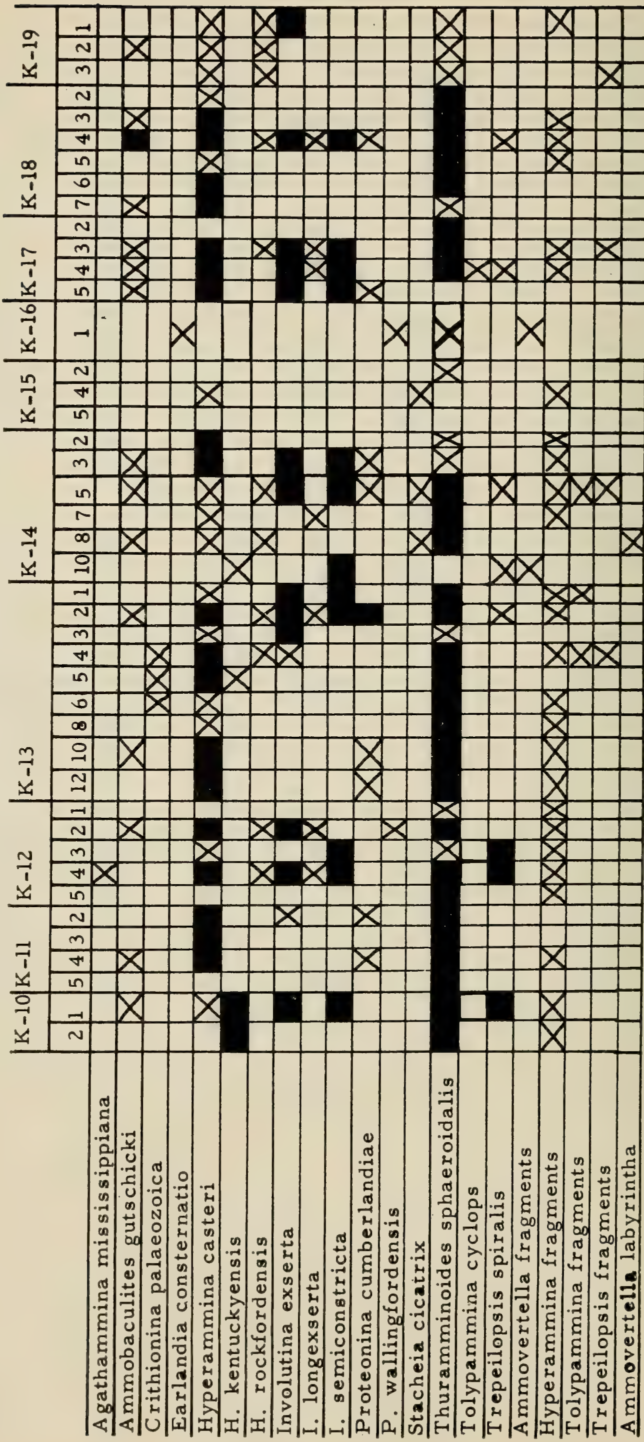


Chart 5. Occurrence of species by locality and bed number (Localities K-10-19).



	-37	K-38							K-39					K-40	K-41	
		8	7	6	5	4	3	2	10	9	7	5	2	1	2	1
Aga	X															
Amr						X	X									
Amr																
A. l																
Glor			X										X			
Hyp	■	■	■	■	■	■	X				■	■				
H. k									■	■						
H. r	X											X				
Invo	■															
I. s						■		■								
Pro						X					■					
P. v												■			X	
Stac																
S. n																
S. t																
Thu	■	■	■	■	■	■			X	X	X	■	X	X	X	
Tre	X															X
T. s																
Amr																
Hyp	X		X	X	X	X					X	X		X	X	
Toly																
Tre																
Invo																

Chart 6. Occurrence of species by locality and bed number (Localities K-20, 21, 27, 28, 32-41).

	K-20			K-21	K-27	K-28						K-32											K-33		
	3	2	1	1	1	14	13	12	11	9	3	14	12	11	10	9	7	5	4	3	2	1	3	2	1
Agathammina mississippiana																				X					
Ammobaculites gutschicki																					X				
Ammovertella cf. A. inclusa																					X				
A. labyrintha																					X				
Glomospira articulosa																				X	X				
Hyperammina casteri	X	X	X		X						X	X		X	X	X				X	■				
H. kentuckyensis	■	X	X												■	■	■	■	■	■			■	X	?
H. rockfordensis																					X				
Involutina exserta			■																	■					
I. semiconstricta											■													■	
Proteonina cumberlandiae																	X			■					
P. wallingfordensis											X														
Stacheia cicatrix			X																	X	X				
S. neopupoides																				X					
S. trepeilopsiformis															X										
Thuramminoides sphaeroidalis	X	X	X	X	X						X	X			■	X		■		■	X	X	X	X	X
Trepeilopsis recurvidens																									
T. spiralis															X					X	■				
Ammovertella fragments																					X				
Hyperammina fragments	X			X	X	X	X				X			X		X	X	X		X	X			X	X
Tolypammina fragments															X					X	X	X			
Trepeilopsis fragments	X																								
Involutina longexserta																				X					

	K-34	K-35					K-36						K-37	K-38							K-39					K-40	K-41	
	1	7	5	4	3	2	6	5	4	3	2	1	1	8	7	6	5	4	3	2	10	9	7	5	2	1	2	1
Agathammina mississippiana		X											X															
Ammobaculites gutschicki		X						X										X	X									
Ammovertella cf. A. inclusa																												
A. labyrintha																												
Glomospira articulosa															X										X			
Hyperammina casteri		■			■	X		X		X	X	X	■	■	■	■	■	■	X				■	■				
H. kentuckyensis	X																				■	■						
H. rockfordensis	X	X										X	X											X				
Involutina exserta													■															
I. semiconstricta						■												■		■								
Proteonina cumberlandiae		X				X			X									X					■					
P. wallingfordensis																								■			X	
Stacheia cicatrix																												
S. neopupoides																												
S. trepeilopsiformis																												
Thuramminoides sphaeroidalis	■	■		■			X	X	X	X	X	X	■	■	■	■	■	■			X	X	X	■	X	X	X	
Trepeilopsis recurvidens													X															X
T. spiralis								X																				
Ammovertella fragments																												
Hyperammina fragments	X			X				X	X		X	X	X		X	X	X	X					X	X		X	X	
Tolypammina fragments																												
Trepeilopsis fragments																												
Involutina longexserta																												

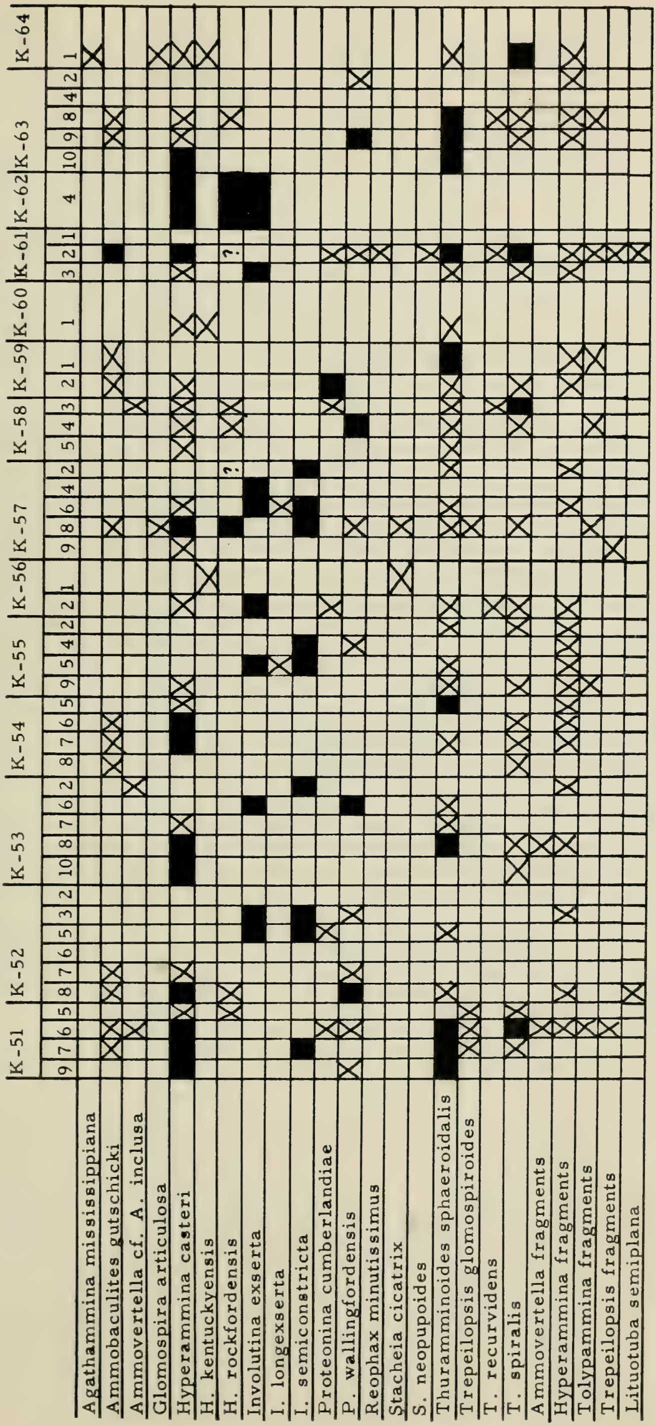
Chart 7. Occurrence of species by locality and bed number (Localities I-1, K-22-26, 29-31, 42, 43, 46).

	I-1			K-22	K-23				K-24	K-25	K-26	K-29	K-30	K-31		K-42	K-43	K-46	
	7	4	1	1	4	3	2	1	1	1	1	1	1	2	1	1	1	2	1
Agathammina mississippiana										X									
Climacammina mississippiana																X			X
Earlandia consternatio								■	■			X							
Hemigordius morillensis					X		X	X	X		X	X							
Hyperammina casteri		?											X						
Involutina exserta		X																	
I. semiconstricta	■	■				X		■											
Reophax kunklerensis		■																	
Thuramminoides sphaeroidalis	X	X				X							?				X		X
Ammovertella fragments											X								
Hyperammina fragments		■					X				X		X	X	X		X	X	X
Tolypammina fragments				X											X				

Chart 8. Occurrence of species by locality and bed number (Localities K-44, 45, 47-50).

	K-44				K-45						K-47		K-48	K-49			K-50								
	7	5	4	2	11	9	8	6	4	3	2	1	1	3	2	1	13	12	11	7	6	5	4	3	2
Ammobaculites gutschicki		X	X	X				X								X									
Hyperammina casteri	X	■	■	■	■	X	■	■	X	■			X			■			X						
H. kentuckyensis															X	■									
H. rockfordensis																	X								
Involutina semiconstricta																			■						
Proteonina wallingfordensis		X		X			X									X									
Thuramminoides sphaeroidalis	■	■	■	X	■	■	■	■	■	■			X	X	X	■				X		X			
Trepeilopsis spiralis												X	X			X									
Hyperammina fragments	X	X	X	X		X		X			X	X	X		X	X		X	X			X		X	
Tolypammina fragments			X	X																					
Trepeilopsis fragments				X																					

Chart 9. Occurrence of species by locality and bed number (Localities K-51-64).



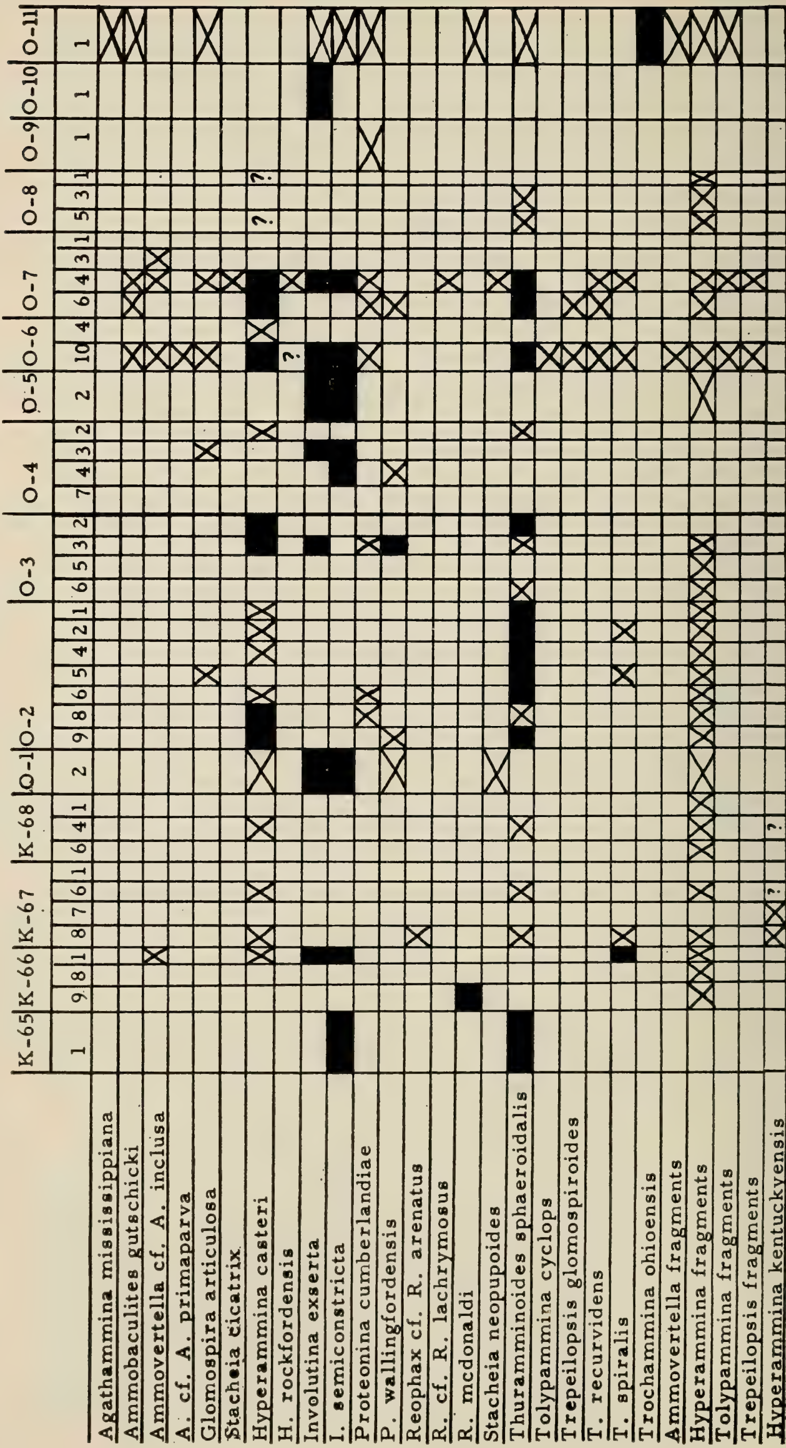


Chart 10. Occurrence of species by locality and bed number (Localities K-65-68, O-1-11).

Chart 11. Range of species in southern Indiana (Localities I-2-6).

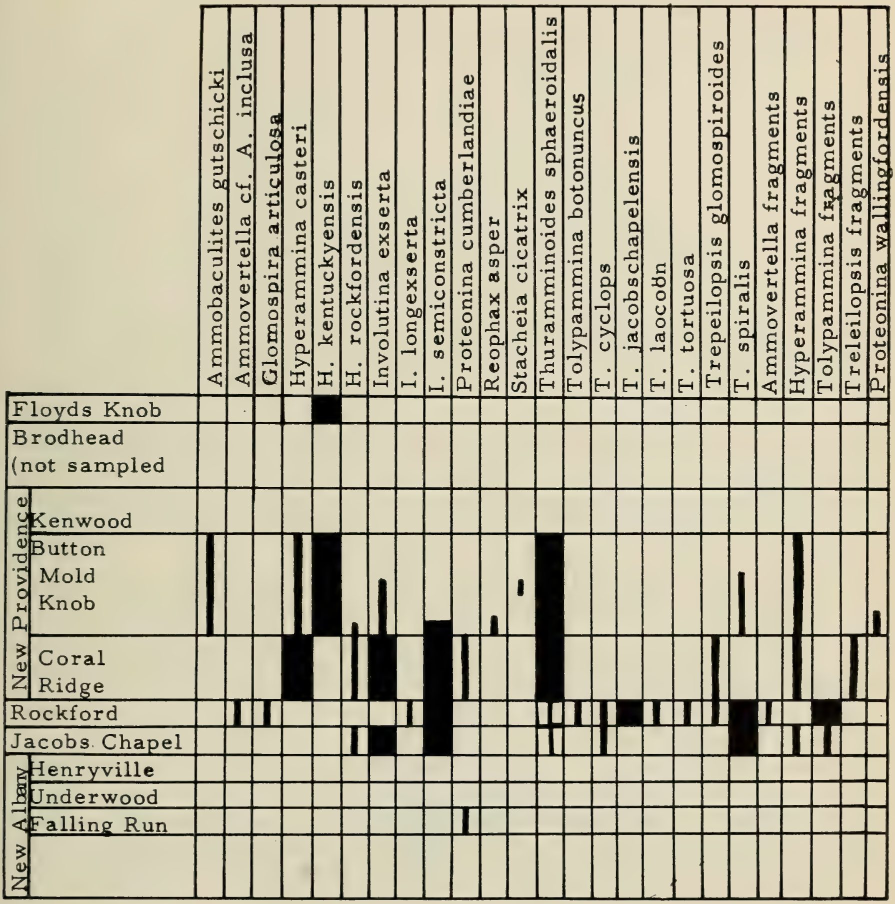


Chart 12. Range of species in northwestern Kentucky (Localities K-1-19).

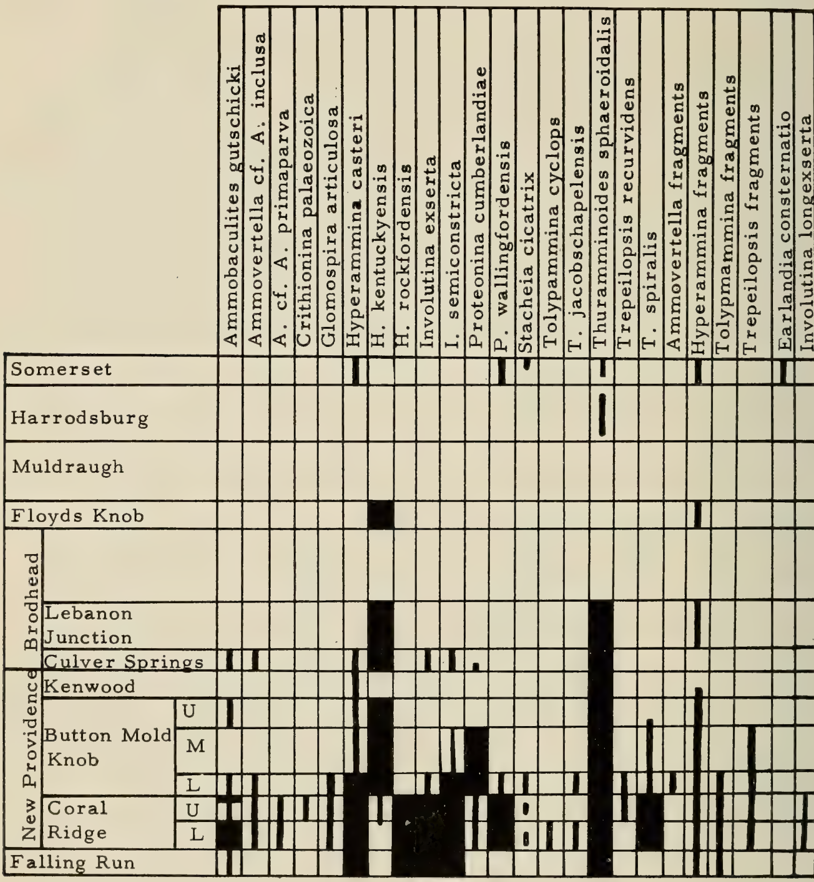


Chart 13. Range of species in southwestern Kentucky (Localities K-20, 21, 27, 28, 32-41).

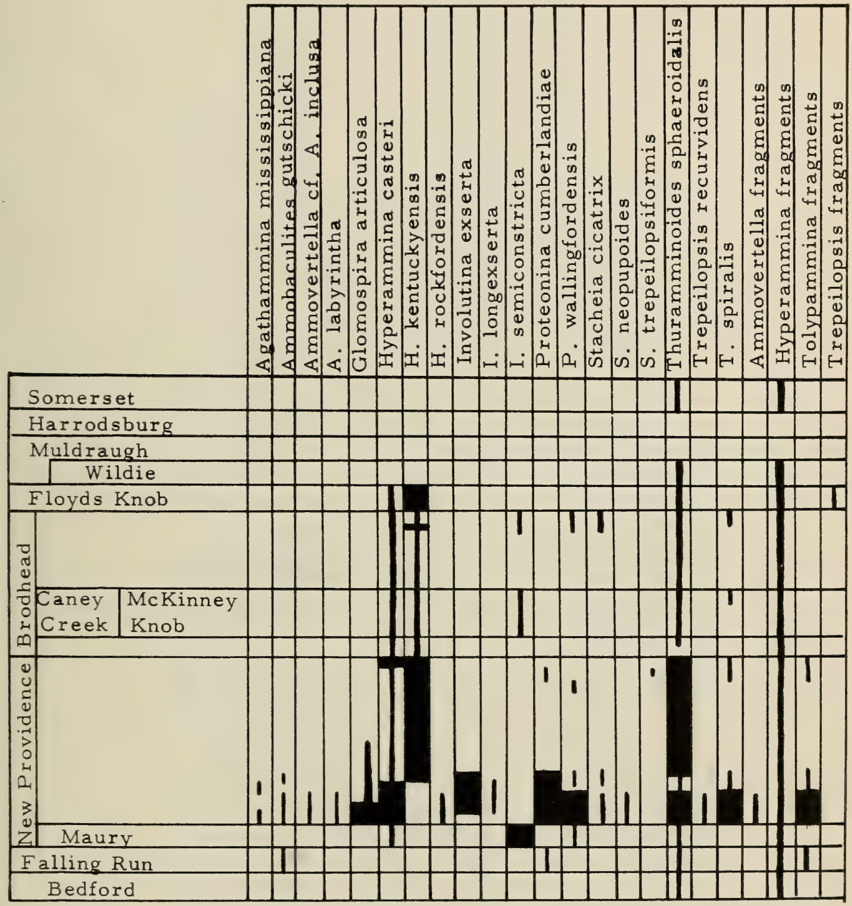


Chart 14. Range of species in southern Indiana (Locality I-1), and in western Kentucky (Localities K-22-26).

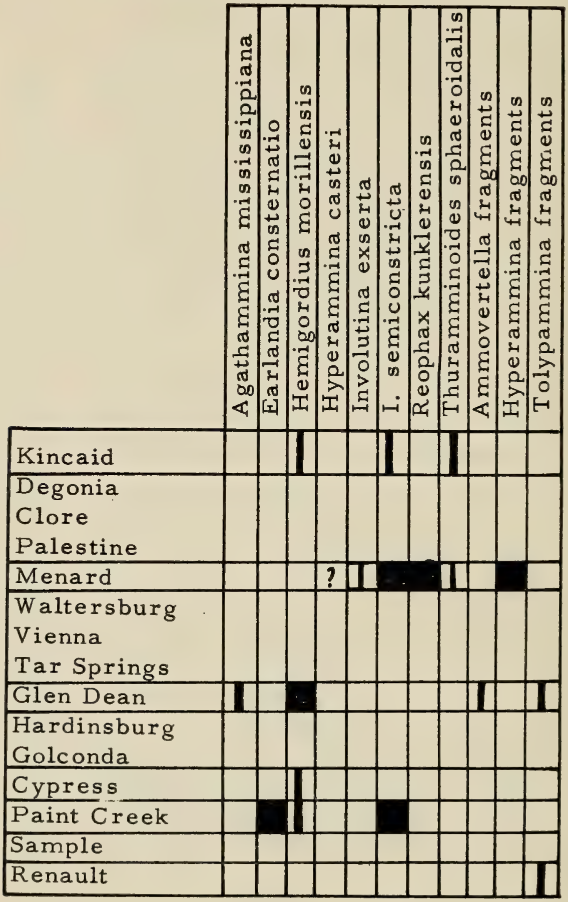


Chart 15. Range of species in southeastern Kentucky (Localities K-29-31, 42, 43, 46).

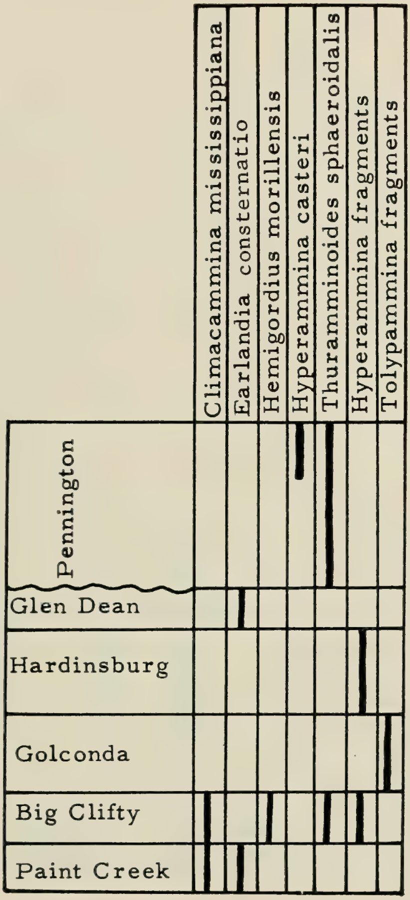


Chart 16. Range of species in northern Tennessee (Localities T-1-4).

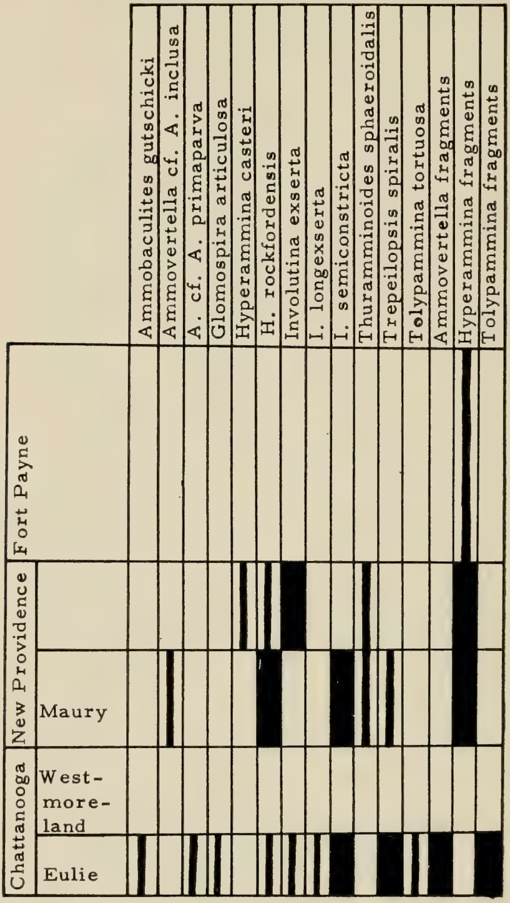


Chart 17. Range of species in southeastern Kentucky (Localities K-44, 45, 47-50).

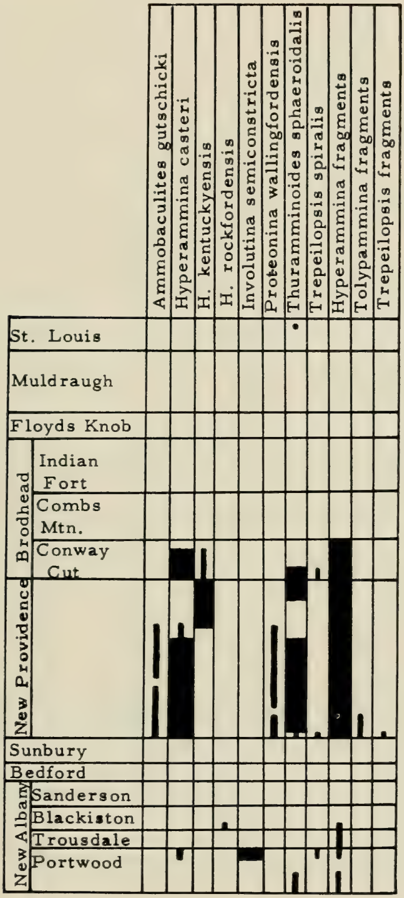


Chart 18. Range of species in eastern Kentucky (Localities K-51-64).

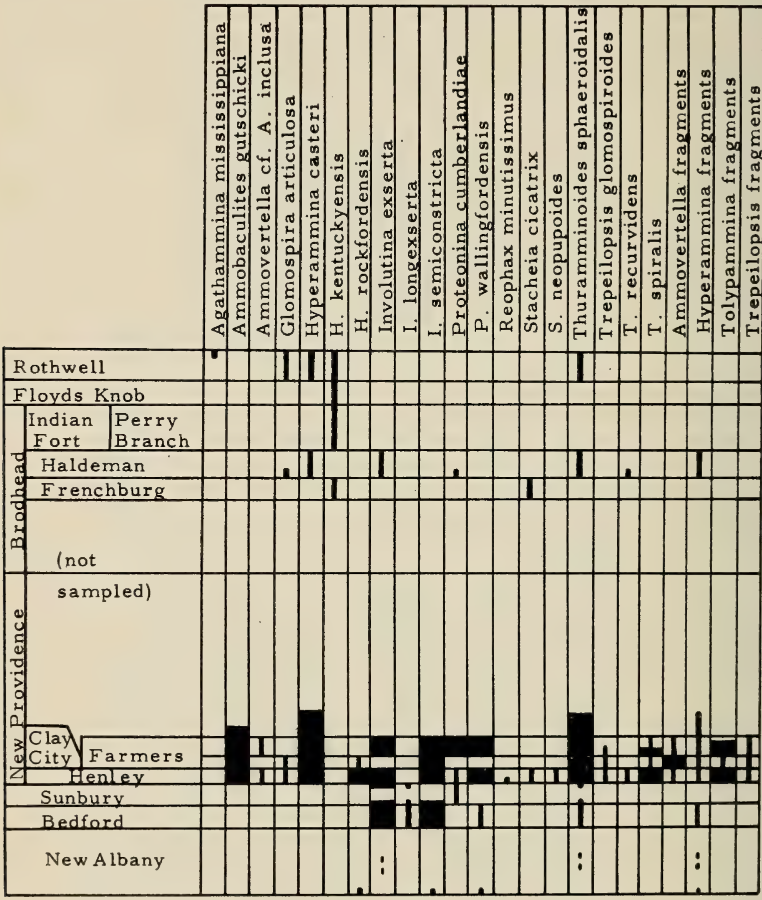


Chart 19. Range of species in northeastern Kentucky (Localities K-65-68), and in southern Ohio (Localities O-1-2).

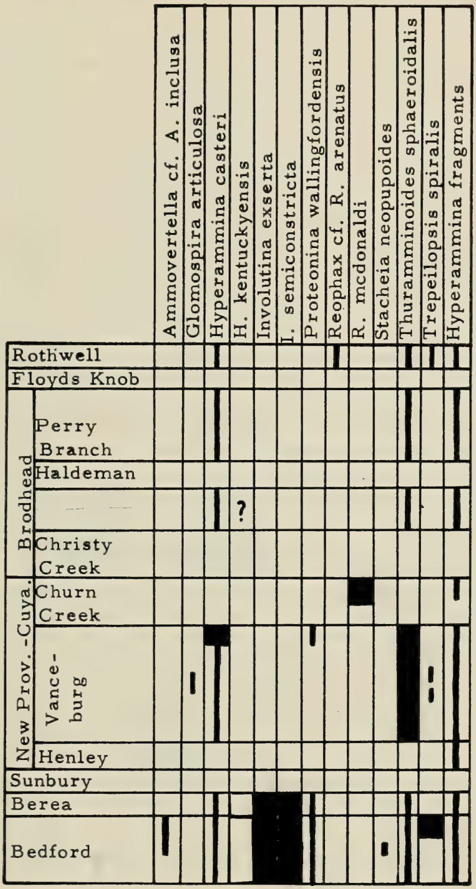


Chart 20. Range of species in southern Ohio (Localities O-3-5).

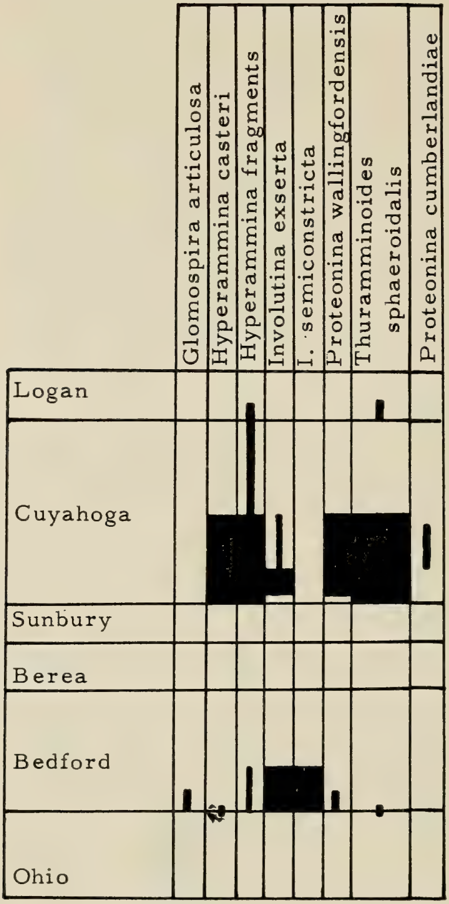
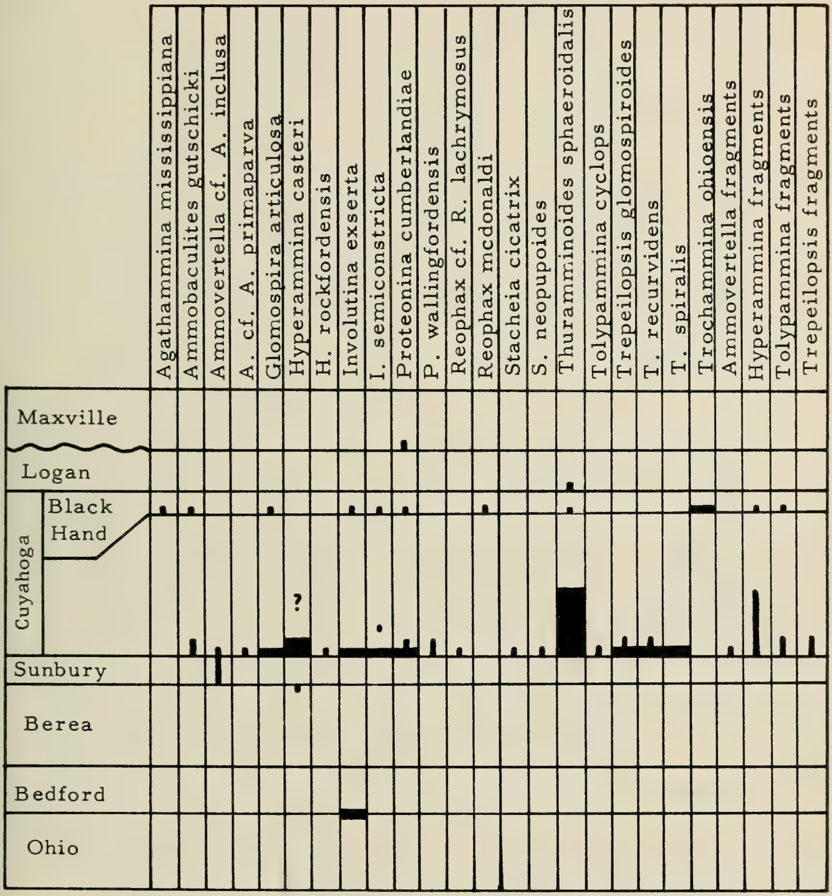


Chart 21. Range of species in southcentral Ohio (Localities O-6-11).



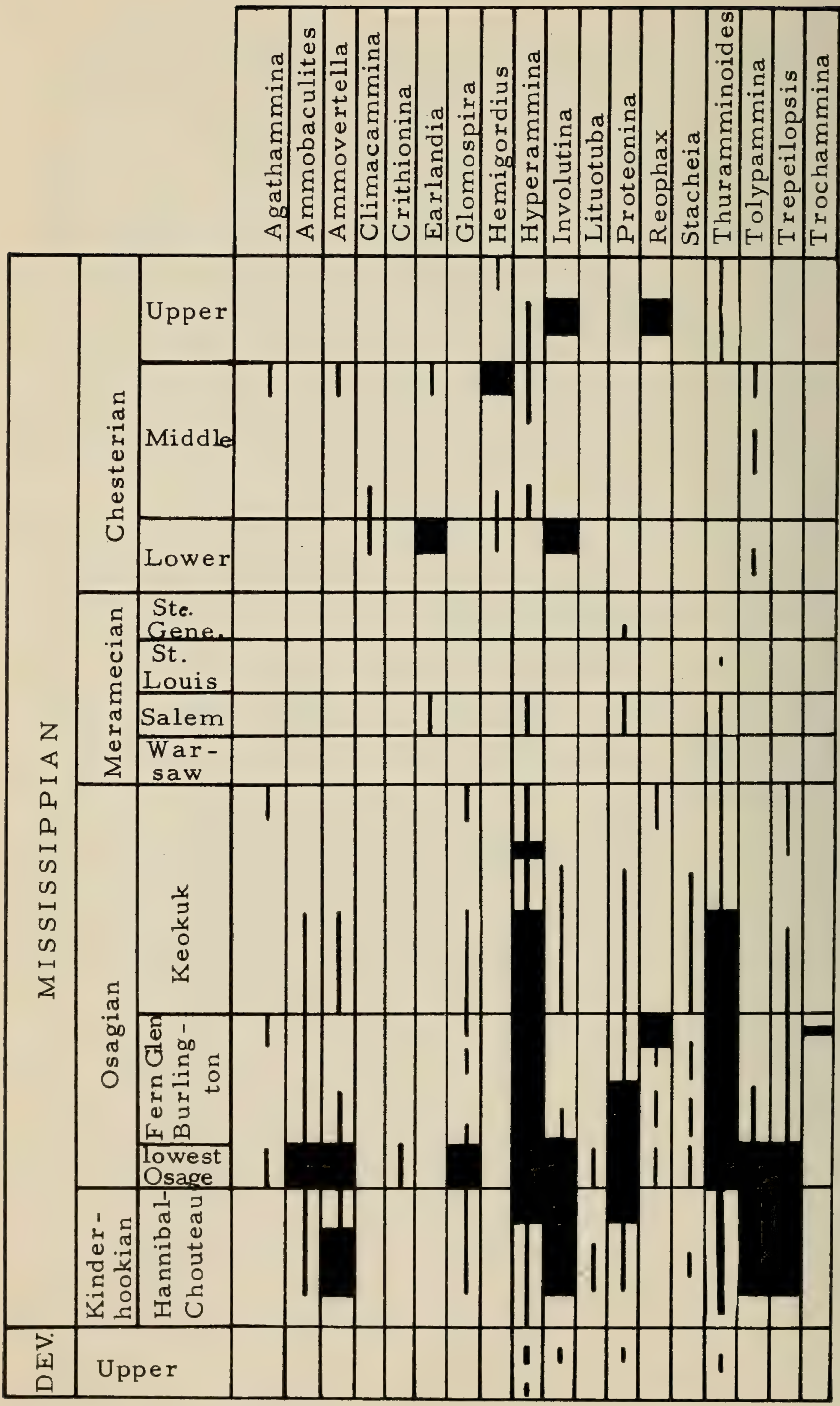


Chart 23. Stratigraphic range of genera in southern Indiana, Kentucky, northern Tennessee, and southcentral Ohio in terms of the North American type Mississippian.

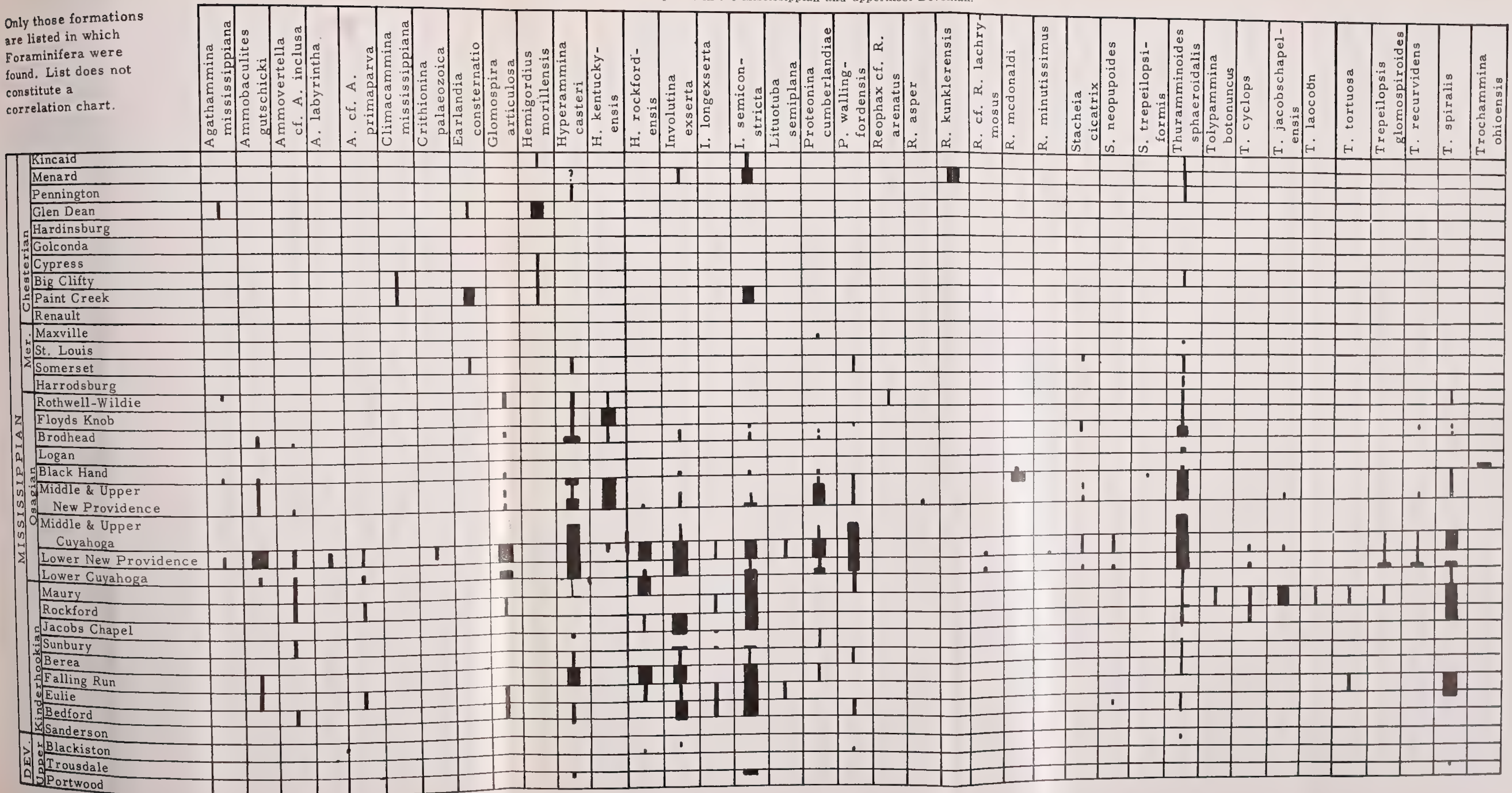
ıian.

Only those
are listed i
Foraminife
found. List
constitute a
correlation

				R. cf. R. lachrymosus	R. mcdonaldi	R. minutissimus
MISSISSIPPIAN	Chesterian	Kincai				
		Menar				
		Pennir				
		Glen I				
		Hardir				
		Golcor				
		Cypre				
		Big C				
		Paint				
		Renau				
	Mer.	Maxvi				
		St. Lc				
		Some:				
		Harrc				
	Osagian	Rothw				
		Floyd				
		Brodh				
		Logar				
		Black				
		Middl Ne				
		Middl Cu				
		Lowe				
		Lowe				
	Kinderhookian	Maur				
		Rock				
		Jacol				
		Sunbı				
		Bere				
		Falli				
		Eulie				
		Bedf				
		Sand				
DEV.	Upper	Blac				
		Trou				
		Port				

Chart 22. Range of species in the Mississippian and uppermost Devonian.

Only those formations are listed in which Foraminifera were found. List does not constitute a correlation chart.



cates occurrence of that species, but rarely or in small numbers. A given species may occur at only one locality in a particular member or formation; these charts indicate the sum total of occurrences at all the localities on each chart.

Chart 22 shows the range of the species in the Upper Devonian and Mississippian formations in which Foraminifera were found. Again the thick lines indicate common to abundant occurrences, and the thin lines, relatively rare ones. The presence of a given species in any formation or member represents the sum total of occurrences of this species at all localities.

The range of the genera in terms of the type Mississippian section is given on Chart 23. In the case of *Ammovertella, Hyperammina, Tolypammina,* and *Trepeilopsis,* the indicated range is partially based on fragments not identifiable as to species.

ANALYSIS OF MISSISSIPPIAN AND UPPER DEVONIAN FAUNAS

UPPER DEVONIAN

Limited sampling of the Upper Devonian shales in connection with the present study of the Mississippian system has revealed the presence of a sparse fauna of smaller Foraminifera in the lenses of green to gray-green to buff-yellow shale which are intercalated in the lower part of the New Albany shale. The fauna consists of the following species: *Involutina exserta, I. semiconstricta, Hyperammina casteri, H. rockfordensis, Proteonina wallingfordensis, Thuramminoides sphaeroidalis,* and *Trepeilopsis spiralis.* It is now known that the Middle Devonian limestones of Kentucky also contain some smaller Foraminifera. Conkin and Conkin (1960, p. 8) listed the following Foraminifera from the following Devonian formations:

New Albany shale: *Thuramminoides sphaeroidalis* and *Hyperammina* spp.

Portwood formation: *Hyperammina* spp., *Proteonina* sp., and *Thuramminoides sphaeroidalis.*

Beechwood limestone: *Rhabdammina*? sp.

Sellersburg limestone: *Lituotuba* sp., *Psammosphaera* sp., *Involutina* sp., and *Hyperammina* spp.

KINDERHOOKIAN

Twenty-one species of smaller Foraminifera were found to occur in the Kinderhookian, from southern Indiana through Kentucky and northern Tennessee to southcentral Ohio (except in southeastern Kentucky where the Kinderhookian was not sampled). Two species, *Involutina semiconstricta* and *I. exserta,* were found to be abundant throughout this area; associated with these two species, *Trepeilopsis spiralis* was found in abundance, but at few localities; in addition, fragments of *Ammovertella, Tolypammina,* and other species of *Trepeilopsis* occur. Occurring less frequently and at various localities were 18 other species: *Ammobaculites gutschicki, Ammovertella* cf. *A. inclusa, A.* cf. *A. primaparva, Glomospira articulosa, Hyperammina casteri, H. rockfordensis, Involutina longexserta, Lituotuba semiplana, Proteonina cumberlandiae, P. wallingfordensis, Stacheia neopupoides, Thuramminoides sphaeroidalis, Tolypammina botonuncus, T. cyclops, T. jacobschapelensis, T. laocoon, T. tortuosa,* and *Trepeilopsis glomospiroides.*

Notably absent in the Kinderhookian beds is the Osagian form, *Hyperammina kentuckyensis;* also *H. casteri* and *Thuramminoides sphaeroidalis* are only moderately well developed in these beds.

LOWEST OSAGIAN

The most prolific Mississippian foraminiferal fauna in the studied region is found in the lowest part of the Osagian, below the Fern Glen-Burlington correlative (the Button Mold Knob member of the New Providence formation). These early beds, perhaps the earliest known Osagian in North America, were recognized and designated as the Coral Ridge member of the New Providence formation by Conkin (1957). On the basis of a megafossil fauna, the Coral Ridge fauna of Conkin (1957), the upper part of the Coral Ridge member was determined to be slightly younger than known Kinderhookian beds and slightly older than known Osagian beds. Nonetheless, an Osagian age for the Coral Ridge fauna is proven by the presence of such characteristic Osagian genera as: *Orbitremites, Beyrichoceras, Merocanites, Pericyclus* (Tournaisian of

Europe), and *Wachsmuthicrinus*. No megafossils (except *Scalarituba*) are found in the lower part of the Coral Ridge member so that this unit might be either Osagian or Kinderhookian with age determination based on megafossils; however, information gained from foraminiferal faunas lends some rather tenuous evidence supporting a Kinderhookian age for this unit.

In the present study, the foraminiferal faunas of the lower New Providence (Coral Ridge, Clay City, Farmers siltstone, and Henley members of Kentucky) contain 26 species of smaller Foraminifera, while the lower Cuyahoga of Ohio (Henley shale member of Ohio) contains 18 species.

From southern Indiana to eastern Kentucky, and in south central Ohio, lowest Osagian faunas consist of abundant *Hyperammina casteri, Involutina exserta, I. semiconstricta,* and *Thuramminoides sphaeroidalis* with more or less abundant occurrence of *Ammobaculites gutschicki, Hyperammina rockfordensis, Trepeilopsis spiralis,* and fragments of *Tolypammina* and *Trepeilopsis*. Occuring less frequently, and at varying localities, 12 other species were found: *Agathammina mississippiana, Ammovertella* cf. *A. inclusa, A. labyrintha, A.* cf. *A. primaparva, Crithionina palaeozoica, Glomospira articulosa, Hyperammina kentuckyensis, Stacheia cicatrix, S. neopupoides, Tolypammina cyclops, Trepeilopsis glomospiroides,* and *T. recurvidens*. Rarely *Lituotuba semiplana, Reophax* cf. *R. lachrymosus, R. minutissimus,* and *Tolypammina jacobschapelensis* are found in the lowest Osagian.

OSAGIAN

Twenty-one species were found in the Osagian (exclusive of the lowest part). In Kentucky, 18 species occur in the middle and upper New Providence, 13 species occur in the Brodhead formation, three in the Floyds Knob formation, seven in the Rothwell and Wildie members of the Muldraugh formation. In Ohio, five species are found in the middle and upper Cuyahoga, and nine in the Black Hand sandstone. Abundant *Thuramminoides sphaeroidalis* and *Hyperammina kentuckyensis* are especially characteristic of the middle and upper New Providence formation from southern Indiana to southern Kentucky. *Proteonina cumberlandiae* and *In-*

volutina semiconstricta occur commonly in northwestern Kentucky. *Ammobaculites gutschicki, Glomospira articulosa, Hyperammina casteri, Involutina exserta, Proteonina wallingfordensis,* and *Trepeilopsis spiralis* are of less common occurrence from southern Indiana to southwestern Kentucky.

In northeastern Kentucky and southern Ohio, *Thuramminoides sphaeroidalis* and *Hyperammina casteri* are commonly occurring species in the middle and upper Cuyahoga. Lesser numbers of *Glomospira articulosa, Proteonina wallingfordensis,* and *Trepeilopsis spiralis* also occur in these beds. *Hyperammina kentuckyensis* is rarely found in northeastern Kentucky, and the species is not found in Ohio and Tennessee.

A localized fauna consisting of nine species was found in the thin shales in the lower five feet of the Black Hand sandstone at Armstrong (Locality 0-11) in central Ohio. This Black Hand fauna consists of common *Trochammina ohioensis,* with less common *Agathammina mississippiana, Ammobaculites gutschicki, Ammovertella* cf. *A. inclusa, Glomospira articulosa, Involutina exserta, I. semiconstricta, Proteonina cumberlandiae, Reophax mcdonaldi,* and *Thuramminoides sphaeroidalis;* in addition, fragments of *Hyperammina* and *Tolypammina* occur. The only other know occurrence of *R. mcdonaldi* is in the Churn Creek member of the New Providence formation of northeastern Kentucky.

The Brodhead formation of Kentucky and the Logan formation of Ohio were not extensively sampled, but *Hyperammina casteri, H. kentuckyensis,* and *Thuramminoides sphaeroidalis* occur in the Brodhead of northwestern to northeastern Kentucky. The following species were less commonly observed in the Brodhead of northwestern to northeastern Kentucky: *Ammobaculites gutschicki, Ammovertella* cf. *A. inclusa, Glomospira articulosa, Involutina exserta, I. semiconstricta, Proteonina cumberlandiae, P. wallingfordensis, Stacheia cicatrix, Trepeilopsis recurvidens,* and *T. spiralis.*

In the Logan formation of Ohio, only *Thuramminoides sphaeroidalis* and fragments of *Hyperammina* were found.

The Floyds Knob formation is especially characterized by abundant and well-developed *Hyperammina kentuckyensis,* with lesser *H. casteri* and *Thuramminoides sphaeroidalis.* The Floyds Knob formation is not present in Ohio.

In the Muldraugh formation, Foraminifera were found in the Wildie sandstone and the Rothwell shale in eastern and northeastern Kentucky, but nowhere in abundance. Seven species were identified from the Muldraugh: *Agathammina mississippiana, Glomospira articulosa, Hyperammina casteri, H. kentuckyensis, Reophax* cf. *R. arenatus, Thuramminoides sphaeroidalis,* and *Trepeilopsis spiralis.*

MERAMECIAN

Only five species of smaller Foraminifera were found in the Meramecian, but this may be due partly to restricted sampling which in turn was due to the abundance of limestone in the series (limestones were found not to be significantly productive of smaller Foraminifera). However, among these five species is the oldest known occurrence of *Earlandia, E. consternatio.*

The Somerset shale member of the Salem limestone in northwestern Kentucky yielded *Earlandia consternatio, Hyperammina casteri, Proteonina wallingfordensis,* and *Thuramminoides sphaeroidalis.* In the Somerset shale of southwestern Kentucky only *T. sphaeroidalis* and fragments of *Hyperammina* were observed.

Smaller Foraminifera are known from the St. Louis limestone at only one locality, in Rockcastle County, Kentucky, where *Thuramminoides sphaeroidalis* was found, poorly developed. No Ste. Genevieve smaller Foraminifera were encountered; however, in the Ste. Genevieve correlative in Ohio, the Maxville limestone, one species, *Proteonina cumberlandiae,* was found in the thin green shales which are intercalated between the limestone layers.

CHESTERIAN

Nine species of smaller Foraminifera were found in the Chesterian series, two of which, *Climacammina mississippiana* and *Hemigordius morillensis,* were not found in lower beds. Collecting was generally restricted to the shalier formations and as a result the records of occurrences of Foraminifera in the Chesterian are rather scattered stratigraphically. The more commonly occurring species were *Earlandia consternatio, Hemigordius morillensis,* and *Involutina semiconstricta.* Less commonly observed species were: *Agathammina mississippiana, Climacammina mississippiana, Hyperammina casteri,* *Involutina exserta,* and *Thuramminoides sphaeroidalis. Reophax kunklerensis* is present only in the shaly portion of the Menard limestone in Perry County, Indiana. Fragments of *Hyperammina, Ammovertella,* and *Tolypammina* were found in several formations at various localities in the Chesterian.

ZONATION OF THE MISSISSIPPIAN BASED ON SMALLER FORAMINIFERA

It has been assumed by many foraminiferalogists, particularly those who have worked on the magnificent Recent, Tertiary, and Mesozoic faunas, or even by those who concentrate upon the fusulinids, that arenaceous Foraminifera in general are so conservative, slowly evolving, and of such simple makeup, that they would be of little use in stratigraphic paleontology and correlation. It was thought that their usefulness lay primarily in their being indices for types of depositional environment; or in essence, they were strongly controlled by facies.

This conservative picture of the arenaceous Foraminifera has been fostered by the provincial nature of the works on Paleozoic smaller Foraminifera. Workers have been overly occupied with the description of faunas from small geographic areas (often one or two outcrops) and usually from small intervals in geologic time, often a member of a formation, or formation. Several faunas of smaller Foraminifera have been described from the Ordovician to the Permian of the United States, but no real effort has been exerted to attempt recognition of the ecological requirements of the faunas in a horizontal dimension or the recognition of evolution in a vertical dimension with time. No broad monographic work has been attempted to correlate the various faunas over different regions of the country, and to cite any stratigraphic significance of the arenaceous Foraminifera.

It is quite true that arenaceous Foraminifera in general are conservative and slowly evolving forms, and that they are of value in the recognition of facies and interpretation of environment of deposition; however, it is possible to demonstrate change within arenaceous Foraminifera in the Mississippian and to recognize species, genera, and faunas which are restricted to certain parts of the system, surely not by facies alone. It can be further shown that the Foraminifera in the Mississippian can be used as a basis for recognition of foraminiferal zones within the system and for stratigraphic division and correlation within a region, if not between regions.

Based on the information derived from this study, I introduce a foraminiferal zonation of the Mississippian of the studied area as follows:

Stratigraphic Name: Zones (species, genera, faunas)

Chesterian: *Millerella, Climacammina, Hemigordius, Earlandia,* and endothyrids.

Meramecian: Endothyrids and *Earlandia.*

Osagian: *Hyperammina kentuckyensis* and *Thuramminoides sphaeroidalis*; includes all formations from the top of the Muldraugh to the base of the Coral Ridge member of the New Providence; this zone is divided into six more or less locally applicable subzones:

1. Muldraugh—poor development of *Hyperammina kentuckyensis* and *Thuramminoides sphaeroidalis.*
2. Floyds Knob—excellent development of *H. kentuckyensis;* rare *T. sphaeroidalis.*
3. Brodhead—poor development of *H. kentuckyensis* and moderate development of *T. sphaeroidalis;* rare other Foraminifera; locally a megafossil fauna is present which resembles (but is distinct from) that in the New Providence below.
4. Upper Cuyahoga—upper New Providence (Black Hand-Churn Creek members) *Reophax mcdonaldi* — a possible marker.
5. Button Mold Knob member of the New Providence formation; divided into two parts:
   - 5a. Upper Button Mold Knob—common occurrence of short, stubby, *H. kentuckyensis;* common occurrence of *T. sphae*roidalis, sometimes associated with the Button Mold Knob megafossil fauna.
   - 5b. Lower Button Mold Knob—highest occurrence and near absence of *H. rockfordensis* in lower part; common and large *Thuramminoides sphaeroidalis; H. kentuckyensis*; general absence of Button Mold Knob megafossil fauna.
6. Coral Ridge member of New Providence formation-Henley shale member of Cuyahoga formation—most prolific smaller foraminiferal fauna in the Mississippian; divided into two parts:
   - 6a. Upper Coral Ridge—rare, short, stubby *H. Kentuckyensis; H. rockfordensis;* frequent to common large *T. sphaeroidalis;* associated in Jefferson, Bullitt, and Nelson counties, Kentucky, and Clark County, Indiana, with the Coral Ridge megafossil fauna of lowest Osagian age.
   - 6b. Lower Coral Ridge member—absence of *H. kentuckyensis; H. rockfordensis;* frequent to common occurrence of large *T. sphaeroidalis.*

Kinderhookian: Various faunas with much the same Foraminifera as in the Upper Devonian; abundant occurrence of *Involutina;* rare and small *T. sphaeroidalis;* common *Tolypammina, Ammovertella,* and *H. rockfordensis;* rare occurrence of the land spore *Tasmanites.*

Upper Devonian: Faunas much like the Kinderhookian, but sparser, with fewer species and individuals; fewer *T. sphaeroidalis, Involutina, Tolypammina,* and *Ammovertella;* frequent *Tasmanites* and other spores.

PALEOECOLOGY

Interpretation of ecology of the individual species is attempted in the Systematic Paleontology portion of this paper. More general considerations as to the relationships between the faunas and the lithology of beds is presented here. Lithology represents the fossilized environment. Ideally then, it may be possible under favorable conditions of preservation to reconstruct the life relations of organisms to their chemical, physical, and biological environment.

UPPER DEVONIAN

The "black shales" of the Upper Devonian contain no Foraminifera; this is in keeping with the chemical and physical conditions of formation of dark organic muds (stagnant waters, reducing conditions, lack of oxygen, low pH, state of incomplete oxidation of organic matter); such extremely restricted environment could be exploited only by forms of life capable of living in a nearly anaerobic state, and either primitive (unspecialized), or highly specialized for life in such restricted environment.

There are, however, small and thin green to green-gray shale layers intercalated between the black shale beds in the lower part of the New Albany shale and in the Olentangy shale; these green shales carry a rather small fauna of arenaceous Foraminifera. In general, the test size is small, and the test is simple in structure, with the exception of *Thuramminoides sphaeroidalis.* This Devonian foraminiferal fauna consists of a small cosmopolitan group which possessed wide range of tolerance for various kinds of environment.

KINDERHOOKIAN

The black and brown shales of the Sunbury carry no Foraminifera, but intercalated small lenses of gray to gray-green shales carry a small fauna of five genera and seven species.

The Jacobs Chapel shale, soft, clayey, greenish-gray, contains only four genera and six species, but a large number of individual specimens. The small areal distribution, the fine-grained, clayey muds, and the diminutive nature of the megafossils occurring in the formation, may indicate lagoonal conditions which, because of the gentleness of the wave action, might promote the growth of such fragile forms as *Tolypammina* which are found in this unit in numbers.

The Kinderhookian beds generally consist of fine-grained, gray to buff to greenish-gray shales; however, some fine-grained limestones are present, such as the Rockford limestone. In these fine-grained sediments, with little fine silt present for the construction of arenaceous tests, some Foraminifera, such as *Involutina semiconstricta* and *I. exserta,* built smooth tests with few silt grains and abundant cement (this type of test is herein called Variant 1); in other beds which carry sufficient fine-grained silt, these two species are often present as Variant 2 which has a coarse texture to the tests and only a small amount of cement compared to Variant 1.

A typical fine-grained limestone of Kinderhookian age is the Rockford limestone of southern Indiana. The Rockford is a dense, glauconitic, and ferruginous limestone which may have been laid down in a restricted environment of a lagoon; it contains a high concentration of tolypamminids; I have observed that tolypamminids are rather characteristic of fine-grained sediments, particularly dense limestone.

The phosphatic nodules of such beds as the Maury shale in Tennessee, the Falling Run of southern Indiana and Kentucky, and even the green glauconitic grains in the Rockford limestone, probably indicate near shore conditions.

LOWEST OSAGIAN

The Coral Ridge member of the New Providence formation may be (in its lower part) transitional between the Kinderhookian and Osagian; no megafossils, other than the problematic *Scalarituba,* are found in the lower part. The upper part of the Coral Ridge member contains the Coral Ridge fauna of lowest Osagian age. Associated with the Coral Ridge fauna are small nodules of ironstone indicating some concentration of carbonates in the muds at the time of deposition. It is interesting to note that the greatest abundance of genera, species, and the greatest number of individual Foraminifera occur in the lowest part of the New Providence formation, in the Coral Ridge member, or in the lower few feet of the New Providence formation where the Coral Ridge member is not recognized. The most abundant foraminiferal fauna in Ohio occurs in the lower few feet of the Henley shale, at the base of Bed 10, at Nipgen (Locality 0-6), and in the lower few feet of the Cuyahoga formation at Jester Hill (Locality 0-7).

OSAGIAN

The middle New Providence formation contains the next most abundant fauna; in places it contains crinoidal biostromes and fossiliferous shales carrying the Button Mold Knob megafossil fauna.

The upper part of the New Providence becomes silty and the Kenwood sandstone and its equivalents are too silty and sandy to promote even moderate numbers of Foraminifera, except in the intercalated shaly beds.

The Brodhead formation is in general too sandy to support significant numbers of Foraminifera; however, in some localities the Brodhead may contain shalier beds with a fair development of Foraminifera.

The Floyds Knob formation is a variable lithologic unit, ranging from a shell breccia to oölitic limestone to siltstone to silty shale, all glauconitic. The Floyds Knob sediments must have been deposited in shallow waters with land nearby; minor unconformity is evidenced by the glauconite grains and occasional erosional surfaces, sometimes with a number of limestone pebbles in the basal beds of the formation. Only three species of Foraminifera were found to occur in the Floyds Knob: rare *Hyperammina casteri,* abundant and well-preserved *H. kentuckyensis,* and rare *Thuramminoides sphaeroidalis. H. kentuckyensis* is beautifully developed and abundant throughout the formation, with best development in the limestones, but present in some numbers even in the shaly siltstones.

MERAMECIAN

The limestones of the Meramecian were not extensively examined, but evidence derived from the samples studied indicates that the highly calcareous nature of the sediments militates against numbers of arenaceous Foraminifera having occupied the Meramecian seas. An ideal environment for promotion of arenaceous Foraminifera would be one of clayey muds, with fine-grained silt present in quantities sufficient for the construction of tests. The arenaceous Foraminifera were not adapted to live in highly calcareous sediments in the absence of fine-grained silts or fine-grained sand. Meramecian seas were dominated by calcareous tests (granular calcareous and compound walled forms; that is, forms like *Earlandia* and *Endothyra*). These forms lived in the shoal areas of lagoons or shallow seas, where the water was saturated with calcium bicarbonate.

Only one species, *Thuramminoides sphaeroidalis*, has been found in the Harrodsburg (Warsaw) limestone.

The granular calcareous *Earlandia* has its lowest occurrence in the Somerset shale member of the Salem limestone.

In the St. Louis limestone (shale) only *Thuramminoides sphaeroidalis* has been found among the arenaceous forms.

In shale streaks in the Maxville limestone (Ste. Genevieve correlative) one specimen of *Proteonina* is reported. It is of course true that nearly all Meramecian beds contain endothyrids in greater or lesser numbers.

CHESTERIAN

The Chesterian beds are dominated by *Millerella* and the endothyrids. Other Foraminifera are rare with only seven genera and nine species here reported from the studied region. One genus, *Climacammina*, is unknown in the beds below the Chesterian. *Hemigordius morillensis*, *C. mississippiana*, and *Reophax kunklerensis* are restricted to the Chesterian. *H. morillensis* is an amorphous calcareous form; *C. mississippiana* is a calcareous form with a compound wall. Note that most forms restricted to and characteristic of the Chesterian have calcareous tests or tests with cement dominantly calcareous.

It seems that the occurrence and distribution of smaller Foraminifera in the Mississippian beds are not completely controlled by facies, but that evolutionary changes can be observed within the genera of Foraminifera (*Hyperammina,* for example), and within groups—faunas replacing one another vertically in time.

In summary, most Mississippian smaller Foraminifera occur in clayey shales which contain much silt and fine-grained sand or fine-grained sand which is necessary for construction of an arenaceous test. Beds which best exemplify this type of lithology are in the lower Osagian and Kinderhookian series.

Sandstone beds do not carry Foraminifera unless there are shales or clayey siltstones interbedded with them.

In the highly calcareous limestone sequences, as in the Meramecian, smaller Foraminifera are nearly absent. The best development of smaller Foraminifera in limestone is in the impure, argillaceous, and silty limestones.

The Chesterian beds of western Kentucky provided a better environment for smaller Foraminifera in their alternation of shales and sands than does the dominantly limestone Chesterian sequence of southeastern and eastern Kentucky; in the Chesterian series, smaller Foraminifera occur mostly in the calcareous shales.

WALL STRUCTURE

Detailed discussions of problems of wall structure and composition are included under generic and specific descriptions in the Systematic Paleontology portion of this paper (under the genera *Hyperammina, Ammobaculites, Reophax,* and *Earlandia*); however, a few general statements are presented here.

Primary concern here is with the smaller Foraminifera; *i.e.,* those Foraminifera which can be identified without sectioning; therefore, wall structure in larger Foraminifera is not considered.

A practical classification of wall structure and wall composition of Mississippian smaller Foraminifera is presented here (information taken partially from Brady, 1878; Plummer, 1930; and Cummings, 1955).

1) Arenaceous
   - A) calcareous—extraneous grains in calcareous or ferruginous cement or both
   - B) siliceous—extraneous grains in siliceous cement

2) Granular calcareous—equidimensional grains of calcite embedded in crystalline calcite cement (subarenaceous wall of Brady, 1876)
   A) calcite granules secreted by the protoplasm, embedded in crystalline calcite cement?
   B) calcite granules derived from a supersaturated limy sea bottom by the selection of extraneous grains of calcareous material by the protoplasm?
3) Compound wall—inner wall layer of fibrous calcite; outer wall layer of microgranular calcite or aragonite?, or altered from calcite or aragonite?
4) Amorphous calcite, or imperforate calcareous (porcellaneous)

Controversy over wall structure and wall composition revolves around questions of original microstructure of the test wall and composition of the cementing material (whether originally calcareous, ferrugino-calcareous, siliceous; or whether wholesale replacement by silica of original calcareous or ferrugino-calcareous tests has taken place). Secondary disputation concerns the source of the grains that are incorporated into and are a part of the test wall, whether the grains may be secreted by the protoplasm, or are chosen by the protoplasm from extraneous particles (organic or inorganic fragments) on the sea bottom, or both. Involved also in these discussions are the questions as to the time of origin of the various types of tests, and which types of tests are primitive and which advanced.

Most Paleozoic smaller Foraminifera have been thought to be arenaceous; however, there are a number of Upper Paleozoic smaller Foraminifera with crystalline calcareous tests which possess an inner wall layer of fibrous calcite, such as *Nodosinella* (Cummings, 1955, p. 224). Perhaps the fibrous wall structure evolved in Devonian times; at least I know of no earlier record of this type of wall microstructure.

I can not accept the proposition advanced by some workers that all Paleozoic arenaceous Foraminifera are actually the results of secondary replacement by silica of an original crystalline calcite test. Such a proposition seems unsound for several reasons: (1) no definitive, compelling petrographic work on the test microstructure has been presented which embodies comprehensive thin-sectioning of representatives of all arenaceous families, Recent and fossil, (2) truly arenaceous Foraminifera are represented in the Quaternary, Tertiary, and Mesozoic, and (3) ideas bearing on phylogenetic continuity of genera which obviously have stratigraphic ranges from Paleozoic to Recent (as in *Hyperammina*) would be hopelessly confused, for the type of *Hyperammina* (a Recent species) has a truly arenaceous wall.

As a basis for clear understanding of wall structure and wall composition of fossil arenaceous Foraminifera, Recent arenaceous forms should first be examined, for much more detail of wall structure can be seen in them than in the Paleozoic forms. Certainly some Paleozoic Foraminifera have had their wall structure and chemical composition altered by weathering and various types of replacement, *i.e.*, silicification, dolomitization.

The terminology of the texture of the wall of smaller Foraminifera is discussed in the Systematic Paleontology portion, but additional notes may be added here as to usage of the term "arenaceous". In opposition to some present workers, but in agreement with H. J. Plummer (1930), I consider the term arenaceous to be a good one to describe the granular nature of smaller foraminiferal tests. Further, I see no objection to the use of the term arenaceous merely because it happens to be a term used in describing grain size in sedimentary rocks. Can not a word have more than one meaning, particularly when the term appears in two rather different disciplines? A better substitute terminology has not been devised. Certainly such terms as siltaceous, lutaceous, or the like would be subject to the same inexactness as is the term arenaceous. Description of wall texture in numerical terms (measurement of individual grains) is an exercise in preciseness, but such method would have questionable advantage. A detailed study of grain size by precise measurements of individual grains would be a valid line of research, but certainly should not be directed soley for the purpose of invalidating the well-established textural term, arenaceous (which used in the restricted sense of Plummer, 1930, is quite exact).

SYSTEMATIC PALEONTOLOGY

Order FORAMINIFERA d'Orbigny, 1826

Family **ASTRORHIZIDAE** Brady, 1881

Genus **CRITHIONINA** Goës, 1894

Crithionina Goës, 1894, Kongl. Svensk. Vet. Akad., Handl., vol. 25, No. 9, p. 14; *idem*, 1896,Mus. Comp. Zool., Bull., vol. 29, p. 24; Rhumbler, 1903, Arch. Protisk., vol. 3, p. 229; Cushman, 1910, U. S. Nat. Mus., Bull. 71, pp. 53-57.

Crithionina [?] Moreman, 1930, Jour. Paleont., vol. 1, No. 4, p. 45.

Type species, *Crithionina mamilla* Goës, 1894.

The generic definition of *Crithionina* as given by Cushman (1910, p. 53) follows:

> Test spherical, lenticular, or variously shaped, interior either labyrinthic or with a single chamber, apertures small and scattered or indistinct, wall thick, composed of sponge spicules or very fine sand, often chalky in appearance.

Crithionina seems to be a genus compounded of two distinct test types: one such as *C. mamilla* Goës, 1894 and *C. rotundata* Cushman, 1910 is labyrinthic internally; the other type of test is composed of a large to rather large hollow interior surrounded by a relatively thick wall composed of sand, sponge spicules, shells of other organisms, mica flakes, with irregular and intersitial apertures.

I have studied the holotype of *Crithionina rotundata* and find that the internal labyrinthic structure is not so regular as depicted by Cushman (1910, p. 57, figs. 64, 65). For this reason then, the Paleozoic genus *Thuramminoides* (with a regularly arranged interior) is not congeneric with *Crithionina.*

The geologic range of *Crithionina* has been given as Silurian to Recent (Cushman, 1948, p. 71). Cushman's record of the Paleozoic occurrence of the genus was based on Moreman's (1930, p. 45, pl. 5, figs. 7, 11) report of *C. rara* from the Silurian Chimney Hill limestone of Oklahoma and on Parr's (1942, p. 107, figs. 9, 10) record of *C. teicherti* from the Permian of Australia.

Crithionina rara Moreman, 1930 is in doubt; it may be a species of *Thuramminoides,* perhaps *T. sphaeroidalis;* however, inasmuch as the types of *C. rara* are unavailable for study and no description or figures of the internal structure of the species was given, the generic affinities must remain in question and the present writer can not accept Moreman's form as congeneric with *Crithionina*. *C. teicherti* Parr has been referred to *Thuramminoides* by Crespin (1958, p. 41, figs. 12, 13). *T. teicherti* (Parr) is herein considered a junior subjective synonym of *T. sphaeroidalis* (see discussion of *T. sphaeroidalis*).

I have found in this study specimens of a form which fit the generic concept of *Crithionina* as exemplified by Recent species, including the type species, *C. mamilla*. The new species, *Crithionina palaeozoica*, is the first undoubted fossil species of *Crithionina* yet reported, older than Miocene.

Crithionina palaeozoica, new species Pl. 19, fig. 9; Fig. 19

Description.—Test free, subglobose, a rounded to tumidly elliptical mass, with a hollow central chamber the diameter of which is one-third to one-half the diameter of the entire test; test wall is thick and cavernous, about .5 mm thick, consisting of passages, irregularly contorted and progressing from the central cavity to the surface of the test where the passages intersect the surface of the test to form apertures; some passages are large (some up to .34 mm in diameter) and others are small (some as small as .03 mm); viewed from within the central cavity, the proximal ends of the passages appear to form on all sides a network or meshwork, spherical surface; thus, there is some regularity to the internal labyrinthic structure, and the texture of the test wall in cross-section looks like the texture of a bath sponge; the test wall is arenaceous, consisting of agglutinated fine siliceous silt grains in siliceous cement (regardless of the original wall composition); the color is white to orange-buff.

Measurements.—See Table 1 for measurements of *Crithionina palaeozoica* and for comparison with measurements of *C. rotundata* Cushman, 1910.

Comparison and affinities.—*Crithionina palaeozoica* is strikingly similar to *C. rotundata* Cushman, 1910 in that: (1) the labyrinthic structure is arranged to form a regular network, (2) both species possess similar structure (passages extending from the central hollow to and piercing the surface of the test to form apertures of various sizes), (3) the labyrinthic wall is thick, occupying about one-third of the diameter of the test, and (4) the central chamber wall (the inner margin of the test wall) forms a spherical network surface enclosing the central hollow.

Table 1. Measurements of *Crithionina palaeozoica*, n. sp., in mm. and comparison with *C. rotundata* Cushman, 1910

	Pl. 19, fig. 9 holotype	unfigured paratypes	*C. rotundata*, U.S.N.M. No. 8259 Pl. 19, figs. 10, 11
Max. diam.	1.40	.81-.91	.30-.60
Min. diam.	1.20	.25-.43	
Diam. of interior space	.34		
Diam. of canals	.03-.34	.03-.08	

Crithionina palaeozoica is also similar to the other species of *Crithionina* which possess a labyrinthic test wall enclosing a hollow interior, such as *C. lens* Goës, 1903 and the types species, *C. mamilla* Goës, 1894.

The exterior of the holotype of *Crithionina palaeozoica* is similar to the exterior of *C. rugosa* Goës, 1896 while the surface of the paratypes of *C. palaeozoica* is similar to the surface of *C. lens* Goës, 1903.

Crithionina palaeozoica differs from *C. rotundata* in: (1) being much smaller (*C. rotundata* is 2.1 to 4.3 times larger than *C. palaeozoica*), (2) having the labyrinthic structure of the test wall somewhat more regular than in *C. rotundata*, and (3) different test composition (the holotype of *C. rotundata* is only slightly cemented, with minute silt particles, muscovite flakes, and shells of other animals, whereas the test of *C. palaeozoica* is rather rigid and composed of siliceous silt grains in siliceous cement (regardless of the original composition of the cement).

Inasmuch as *Crithionina rotundata* is Recent, and only two species, *C. pisum* (Colom, 1945, p. 4) and *C.* sp. (Parr, 1942, p. 78), both of which are Miocene, are heretofore known in the fossil form, the four above characters are considered of specific importance. Evolution would not have preserved the same species for 200 millions of years inasmuch as mutations occur at rather constance rates within particular groups of organisms. With such an immense lapse of time, the genetic complex of a species almost certainly would have been transmuted into other species.

Type locality.—Blue Gap on U. S. Highway 31E, 2.65 miles north of New Haven, Nelson County, Kentucky (Locality K-13). The holotype is from the Coral Ridge member of the New Providence formation, 22 feet to 27 1/2 feet above the Falling Run member of the Sanderson formation (Bed 4).

Stratigraphic occurrence.—*Crithionina palaeozoica* is known to occur only in the Button Mold Knob and Coral Ridge members of the New Providence formation in Kentucky. (See Charts 4, 12, and 22).

Ecology.—*Crithionina palaeozoica* is known to occur only in the olive-gray to blue-gray, soft and plastic shales of the New Providence formation and at localities where these shales do not have megafossil faunas or calcareous beds.

Recent species of *Crithionina* are known from cool to cold waters and from moderately deep waters (Cushman, 1910, pp. 53-57).

Remarks.—*Crithionina palaeozoica* derives its name from the Paleozoic sequence of rocks inasmuch as this is the first known species of *Crithionina* to be reported from the Paleozoic.

Genus **THURAMMINOIDES** Plummer, 1945, emend.

Thuramminoides Plummer, 1945, Univ. Texas, Pub. 4401, pp. 218, 219, pl. 15, figs. 4-10; Crespin, 1958, [Australia] Bur. Mineral Res., Geol. and Geophys., Bull. 48, pp. 40-42, pl. 3, figs. 9-13; pl. 31, figs. 1, 2.

Type species, *Thuramminoides sphaeroidalis* Plummer, 1945 (monotypic genus).

Thuramminoides was erected by Plummer (1945, pp. 218, 219) on material from the Pennsylvanian (lower Strawn shale) in San Saba County, Texas. Only the type species is known.

Plummer's original definition of *Thuramminoides* (1945, p. 218) follows: "The external characters of this globose unilocular test are like those of *Thurammina,* but internally it is labyrinthic."

The definition of *Thurammina* Brady, 1879 (from Cushman, 1948, p. 80) follows:

> Test typically free, usually nearly spherical, sometimes compressed; chambers typically single, occasionally divided; wall thin, chitinous, with fine sand; apertures several to many, at the end of nipple-like protuberances from the surface, occasionally wanting.

The original generic definition of *Thuramminoides* Plummer, 1945 is hereby emended on the basis of topotypes (Plummer's Station 205-T-148) from the Texas Pennsylvanian and specimens collected from the Mississippian beds herein studied:

The original shape of the test was spherical, but most specimens have been distorted into discoidal or lenticular forms, sometimes broken. The biconcave, compressed tests of *Thuramminoides* often resemble red blood corpuscles. The exterior surface is smooth to moderately rough with a thick test wall composed of quartz sand embedded in siliceous cement. There is no evidence of secondary replacement in the siliceous cement or quartz grains of the test wall in any of the hundreds of specimens of *Thuramminoides* studied. There are no characteristically astrorhizoid apertures present in *Thuramminoides,* but there are multiple tubular openings of two sizes in the test wall. A few small protuberances are rarely seen on the exterior of the test; these are not considered to be apertures.

The interior of *Thuramminoides* is not really labyrinthic as originally described. The test wall surrounds a moderate-sized hollow sphere (proloculus?). The test wall is occupied by centripetal tubes which extend from the boundary of the hollow sphere toward the surface of the test; in some instances, the centripetal tubes pierce the surface of the test. In most cases, however, the centripetal tubes do not perforate the surface of the test. In addition, there are small tubelets in the outer part of the test wall which do not always run perpendicular to the surface of the test wall; these tubelets pierce the surface of the test in a great number of instances. Carbonaceous matter is sometimes observed in the interior of *Thuramminoides* where the interior centripetal tubular structure is not present. In cases where the centripetal tubular structure is absorbed or destroyed, there seems generally to be small to medium-sized, pitlike polygonal to rounded depressions on the interior part of the test wall.

Thuramminoides has affinities to the genus *Crithionina,* a genus which includes the "labyrinthic species" *C. lens* Goës and *C. rotundata* Cushman, 1910. *C. rotundata* Cushman (1910, pp. 64, 65) is especially close to *Thuramminoides.* The description of *C. rotundata* was given by Cushman (1910, pp. 56, 57):

> Test free, subspherical, composed of loosely agglutinated sand grains; surface with many pores leading by canals through the thick walls to the simple central chamber with many circular or roughly polygonal openings which ramify into canals leading to the surface; wall of the central chamber and canals is firmer than the rest of the test, usually showing in these firmer portions a reddish-brown cement; color dark grayish brown. Diameter 3-6 mm.

The interior "labyrinthic" part of the test (irregular tubular structure) of *Crithionina* is not regular enough for this genus to be congeneric with *Thuramminoides.* The centripetal tubular structure in *Thuramminoides* radiates out equally and regularly in all directions on a definite geometric plan, like a sunburst of tubes from a hollow sphere.

Thuramminoides may have affinities to Hauesler's (1890, p. 69) genus *Thuramminopsis* from the Jurassic of Switzerland. *Thuramminopsis* is apparently arenaceous and possesses a network of tubular structures on the interior side of the test wall (this network indicates a "labyrinthic" interior to the test).

The centripetal tubular structure of *Thuramminoides* is singular, and such structure is not observed, nor does the family definition allow inclusion of such forms, within the Saccamminidae. However, *Thuramminoides* was referred to the Saccamminidae by Plummer, and later workers have followed her lead; the similarity of the internal structure of *Thuramminoides* to *Crithionina,* a member of the Astrorhizidae, has not been recognized previously. Thus, *Thuramminoides* can not be retained in the Saccamminidae inasmuch as the family does not embrace tests with labyrinthic or centripetal tubular internal structure. *Thuramminoides* is hereby removed from the Saccamminidae and placed in the Astrorhizidae. The Astrorhizidae includes in its definition those arenaceous genera which have either labyrinthic or centripetal tubular interiors.

Stratigraphically *Thuramminoides* is known in the United States from the rocks of Middle Silurian through Middle Pennsylvanian periods. In Australia, the only other country in which *Thuramminoides* has been reported, the genus is known from Permian strata.

After Plummer's erection of the genus from the Middle Pennsylvanian shales of Texas, *Thuramminoides* was not reported in any other beds or areas until Conkin (1957, p. 1884) cited a *Thuramminoides-Hyperammina* zone from the Osagian rocks of Kentucky and Ohio. Conkin (1958, p. 17) recognized *Thuramminoides* in the Lower Mississippian New Providence formation (Coral Ridge member) and the Underwood shale at the Gap-in-Knob section, north of Shepherdsville, Bullitt County, Kentucky. (See Chart 23 for range of *Thuramminoides* in the Mississippian as determined in this study.)

Crespin (1958, pp. 40-42) demonstrated the presence of *Thuramminoides* in the Permian of Australia, recognized *T. sphaeroidalis,* and placed *Crithionina teicherti* Parr in *Thuramminoides. T. teicherti* (Parr) is considered in this work a junior subjective synonym of *T. sphaeroidalis*.

Conkin and Conkin (1960, p. 8) in discussing the discovery of Silurian and Devonian Foraminifera in Kentucky, recognized for the first time the occurrence of *Thuramminoides sphaeroidalis* in these two systems.

It is interesting to recall that Moreman (1930, p. 45, pl. 5, figs. 7, 11) reported a new species of Foraminifera under the name of *Crithionina rara*. Moreman's species may be a true *Crithionina,* or may be the first reference to a *Thuramminoides*. Inasmuch as the types of *C. rara* are not available for study, this species will remain of doubtful generic position.

Thuramminoides sphaeroidalis Plummer, 1945, emend. Pl. 17, figs. 1-10; Pl. 18, figs. 1-4; Pl. 26, figs. 1-3, Fig. 1

Thuramminoides sphaeroidalis Plummer, 1945, Univ. Texas, Pub. 4401, pp. 218, 219, pl. 15, figs. 4-10; Crespin, 1958, [Australia] Bur. Mineral Res., Geol. and Geophys., Bull. 48, pp. 40, 41, pl. 3, figs. 9-11; pl. 31, figs. 1, 2; Conkin and Conkin, 1960, Geol. Soc. America, S. E. Sect., Abstracts, p. 8.
Thuramminoides teicherti (Parr), Crespin, 1958, [Australia] Bur. Mineral Res., Geol. and Geophys., Bull. 48, pp. 41, 42, pl. 3, figs. 12, 13.

Description (specific emendation).—Test free, unilocular; test shape spherical in life; fossils may retain original sphericity, but usually are preserved as flattened, disk-shaped to lens-shaped masses which range in size from .118 to 2.15 mm. in the Mississippian forms, and up to 2.50 mm. in Crespin's Australian Permian forms; test arenaceous with fine to medium-sized quartz sand grains embedded in a moderate to large amount of siliceous cement; when in excess, cement gives the test a glossy appearance externally; internally, the species is not labyrinthic, but consists of many centripetal tubes which occupy the test wall and radiate outward from the central hollow sphere toward the surface of the test; some of the centripetal tubes pierce the surface, most of the tubes do not; in the outer portion of the test wall much smaller tubelets are disposed at various angles to the surface of the test; many of these tubelets pierce the surface but others do not; the test wall is moderately thick to thick; carbonaceous material is sometimes observed in the interior of the test when the centripetal tubular structure has not been preserved; in such instances, there are vestiges of this centripetal tubular structure on the interior surface of the test wall in the form of small to medium-sized, pitlike polygonal to rounded depressions; distinct astrorhizoid apertures are lacking; rarely a few, small protuberances are present but these are not regarded as necks of apertures; the two sets of tubes (the centripetal tubular structures and the smaller, erratically oriented tubelets) apparently functioned as multiple apertures; no evidence of dimorphism is indicated as microspheric and megalospheric forms are not distinguishable; color of test is variable, ranging from white to gray to buff to orange and brown.

A summary of the essential elements of the emendation of *Thuramminoides sphaeroidalis* follows:

Topotypes of *Thuramminoides sphaeroidalis* were found not to be labyrinthic in the interior as described by Plummer (1945, p. 219); the interior of the test is hollow, surrounded by a thick test wall which possesses centripetal tubular structure identical to that possessed by the Mississippian specimens of the species; these large tubes may or may not pierce the surface of the test. In addition, the outer part of the test wall contains many smaller tubelets which are irregularly arranged, but most pierce the surface of the test. No typical astrorhizoid apertures present, but apertures are multiple.

Measurements.—See Table 2 for measurements of present specimens of *Thuramminoides sphaeroidalis* and Table 3 for range in measurements of *T. sphaeroidalis* and for comparison of the range of measurements of Plummer's Pennsylvanian and Crespin's Permian specimens.

Comparison and affinities.—The Mississippian specimens of *Thuramminoides sphaeroidalis* agree in all respects with topotypes collected by me, and exhibit all features shown in Plummer's published figures. In general, the Mississippian specimens are much better preserved than Plummer's Pennsylvanian material. The Mississippian collections contain many well-preserved spherical specimens (Plummer postulated an original spherical shape for her specimens although none was close to this). Most of the Mississippian examples are flattened as were Plummer's and Crespin's. All presently known Silurian and Devonian forms of the species agree with the Mississippian ones and also with Plummer's type figures and topotype material.

Crespin's new name, *Thuramminoides teicherti* (Parr), based on *Crithionina teicherti* Parr, 1942, (Crespin, 1958, pp. 41, 42, pl. 3, figs. 12, 13) is invalid inasmuch as this species is conspecific with *T. sphaeroidalis*. *T. teicherti* exemplifies every characteristic of *T. sphaeroidalis* as shown by examination of topotypes of *T. sphaeroidalis* and by the Mississippian specimens of the species, as well as the features that are shown by Plummer's published figures of the types of *T. sphaeroidalis;* in addition, *T. teicherti* fits the emendation of *T. sphaeroidalis* as presented here.

Stratigraphic occurrence.—The stratigraphic range of the species *Thuramminoides sphaeroidalis* is the same as that of the genus: Middle Silurian to Permian. (See Charts 3-18 and 22 for occurrence of *T. sphaeroidalis* in the Mississippian.)

Ecology.—The smallest examples of *Thuramminoides sphaeroidalis* occur in the Devonian part of the New Albany shale. The species generally increases in size with decreasing geologic age although there are exceptions due to the nature of the enclosing sediments. The largest forms of the species are found in the Permian of Australia (Crespin, 1958, p. 40) where the largest specimen is reported to be 2.5 mm in diameter. The Pennsylvanian forms of Plummer exhibited a maximum size of 1.6 mm. (Plummer, 1945, p. 219). The largest Mississippian specimens of the species occur in the Coral Ridge and Button Mold Knob members of the New Providence formation in which beds the species rarely reaches a diameter of 2.15 mm. Above the Brodhead formation, however, the size of the test diminishes with decrease in geologic age. The most favorable environment for growth and proliferation of *Thuramminoides sphaeroidalis* in the Mississippian existed during deposition of the fine silt-bearing, plastic shales of the Coral Ridge and Button Mold Knob members of the New Providence formation in Kentucky and southern Indiana. The absence of megafossils in the outcrops of the lower part of the Coral Ridge member indicates that *T. sphaeroidalis* could flourish in environmental conditions which were not condusive to the promotion of prolific invertebrate life in general. Yet, *T. sphaeroidalis* was tolerant of calcareous mud and muddy water environment as is shown by its abundance in the calcareous shales of the Button Mold Knob member of the New Providence formation. In Ohio, the Cuyahoga formation contains much smaller forms of *T. sphaeroidalis;* this smallness of test and poor development of the species in the Cuyahoga formation is correlated with more and coarser silt and sand grains on the east side of the Cincinnati arch in Ohio. The New Providence beds in eastern Kentucky, all along the strike of the Mississippian beds, again show smaller test and much more meager development of *T. sphaeroidalis* due to deposition of sediments under environmental conditions much like those of the shales in the Ohio Cuyahogan sequence.

Thuramminoides sphaeroidalis has not been found in the strictly sandstone beds; the species is present in the Black Hand sandstone of eastern Ohio only in the thin intercalated plastic shale units. Thus, *T. sphaeroidalis* "preferred" clayey shales in which there were sufficient small silt grains to allow construction of an arenaceous test.

Table 2. Measurements of *Thuramminoides sphaeroidalis* Plummer, 1945, in mm.

specimen and type number	min. diam.	max. diam.	thickness	locality number, formation, and bed number
Pl. 17, fig. 1	.70	.70	.55	K-13, New Providence, bed 2
Pl. 17, fig. 2	.37	.39	.37	O-11, Black Hand, bed 1
Pl. 17, fig. 3	.47	.49	.34	K-13, New Providence, bed 8
Pl. 17, fig. 4	.47	.52	.10	K-9, Brodhead, bed 1
Pl. 17, fig. 5	.90	.90	.25	K-15, Clay City, bed 5
Pl. 17, fig. 6	.75	.75	.17	I-6, Button Mold Knob, bed 8
Pl. 17, fig. 7	.81	.82	.42	K-36, New Providence, bed 4
Pl. 17, fig. 8	.60	.70	.17	K-13, New Providnce, bed 10
Pl. 17, fig. 9	1.20	1.85	.25	I-2, Button Mold Knob, bed 1
Pl. 17, fig. 10	.85	.86	.25	K-63, Henley, bed 8
Pl. 18, fig. 1	1.50	1.55	.40	K-36, Brodhead, bed 5
Pl. 18, fig. 2	.85	.90	.25	O-8, Cuyahoga, bed 5
Pl. 18, fig. 3	1.65	1.65	.45	K-19, New Providence, bed 3
Pl. 18, fig. 4	.98	1.00	.19	I-6, Button Mold Knob, bed 8

Table 3. Range in diameter of *Thuramminoides sphaeroidalis* Plummer, 1945, in mm.

Permian (Australia)	.39-2.50
Pennsylvanian (Texas)	.70-1.60
Big Clifty sandstone	.403-.550 (3 specimens)
Glen Dean limestone	1.00 (1 specimen)
Paint Creek limestone	.118-.210 (4 specimens)
Brodhead formation	.369-.487 (4 specimens)
Black Hand sandstone	.377-.993 (8 specimens)
Cuyahoga formation	.487-.900 (8 specimens)
Henley shale	.650-.850 (2 specimens)
Button Mold Knob member and equivalents	.218-2.00 plus (44 specimens)
Coral Ridge member and equivalents	.235-2.15 (27 specimens)
Sunbury shale	.244-.420 (5 specimens)
Falling Run member	.235-.900 (4 specimens)
New Albany shale	.235-.285 (4 specimens)

Family **SACCAMMINIDAE** Brady, 1884

Subfamily **SACCAMMININAE** Brady, 1884

Genus **PROTEONINA** Williamson, 1858

Proteonina Williamson, 1858, Rec. Foram. Great Britian, London, p. 1; Cushman, 1948, Foraminifera, Cambridge, p. 78.

Reophax Montfort, Brady, 1879, (*pars*), Quart. Jour. Micros. Sci., vol. 19, p. 51, pl. 4, figs. 3a, 3b; *idem,* 1884, Rept. Voyage Challenger, Zool., vol. 9, p. 289, pl. 30, figs. 1-5; Rhumbler, 1895, Kön. Gesell. Wiss. Göttingen, Nachr., p. 82. (*non Reophax* Montfort, 1808, Conch. Syst. vol. 1, p. 331)

Difflugia Lamark, Egger, 1895, (*pars*), Kön. bay. Akad. Wiss. München, vol. 18, p. 251. (*non Difflugia* Leclerc, 1815, Mus. Hist. Nat., Mem., v. 2, p. 474)

Saccammina Sars, Eimer and Fickert, 1899, (*pars*), Zeitschr. Wiss. Zool., vol. 65, pp. 671, 672. (*non Saccammina* Sars, 1869, Förh. Vidensk.-Selsk. Christiania, p. 248, (*nomen nudum*)

Type species, *Proteonina fusiformis* Williamson, 1858, (original designation. Recent, Great Britian).

The generic definition of *Proteonina* was given by Cushman (1948, p. 73):

> Test free, a fusiform or flask-shaped undivided chamber; wall a thin chitin layer on which are cemented sand grains, mica flakes, other tests, *etc.;* aperture usually circular, often with a slight neck which may become elongate.

The Mississippian species of *Proteonina* have tests composed of siliceous grains in siliceous cement (regardless of the composition of the original test wall).

The affinities of *Proteonina* Williamson, 1858, *Lagenammina* Rhumbler, 1911, and *Saccammina* Sars, 1869 are obscure. *Lagenammina* and part of *Saccammina* (the free, single chambered forms) may belong to the genus *Proteonina.*

The genus *Proteonina* ranges stratigraphically at least from the Silurian to the Recent (see Chart 23 for the range of *Proteonina* in the Mississippian). The genus is undoubtedly primitive and conservative in its evolution.

Proteonina cumberlandiae, new species — Pl. 19, figs. 1-3; Pl. 26, figs. 4, 5; Figs. 2, 3

Description.—Test consists of a single chamber with a tapering neck which is broken off some specimens; aperture circular, at open end of neck; chamber teardrop to avocado-shaped, from 1.3 to 2.5 times longer than broad; test more or less compressed in present specimens so that original proportions of test were more slender; neck rather slender and from about one-third to one-half the length of the chamber; wall of fine siliceous grains in siliceous cement; color of test light gray to yellowish gray.

Measurements.—See Table 4 for measurements of *Proteonina cumberlandiae,* Table 5 for range in measurements in the species, and Table 8 under *P. wallingfordensis* for comparison of this species with those to which it is similar.

Comparison and affinities.—See discussion under *Proteonina wallingfordensis.*

Type locality.—Hill side along road on side of Fishing Creek, Lake Cumberland, near Somerset, Pulaski County, Kentucky (Locality K-32). The holotype is from the New Providence formation, 8.5 to 25 feet above the Falling Run member of the Sanderson formation (Bed 2).

Stratigraphic occurrence.—*Proteonina cumberlandiae* occurs in the Sunbury shale of eastern Kentucky, the Kinderhookian Falling Run member of the Sanderson formation, throughout the Osagian New Providence formation in Kentucky and southern Indiana, sparingly in the Brodhead formation, and in the Osagian Cuyahoga formation of Ohio, including the Henley, Vanceburg, and Black Hand members; one specimen was found in a shale break in the Meramecian Maxville limestone. (See Charts 3-6, 9-13, 18, 21, and 22 for details of occurrence.)

Table 4. Measurements of *Proteonina cumberlandiae,* n. sp., in mm.

specimen and type number	*length of test*	*length of chamber*	*diam. of chamber*	*diam. of base of neck*	*diam. of end of neck*	*locality number, formation, and bed number*
Pl. 19, fig. 3	.460	.352	.218	.067	.050	O-9, Maxville, bed 1
Pl. 19, fig. 1	.806	.806	.545	.118	.118	O-11, Black Hand, bed 1
Pl. 19, fig. 2 holotype	.436	.277	.252	.075	.067	K-31, New Providence, bed 2

Table 5. Range in measurements of 25 specimens of *Proteonina cumberlandiae,* n. sp., in mm.

Length of test	.235-.806
Length of chamber	.168-.806
Diam. of chamber	.151-.545
Diam. of base of neck	.067-.168
Diam. of end of neck	.033-.134

Ecology.—*Proteonina cumberlandiae* undoubtedly had much the same ecological requirements as did *P. wallingfordensis.* The species is known to occur only in silt-bearing shales and shale breaks in sandstone and limestone. Thus *P. cumberlandiae* "preferred" muddy sea bottoms with silt and fine-grained sand, in which there was generally an absence of calcareous-rich sediments.

Proteonina wallingfordensis, new species — Pl. 19, figs. 4-8; Pl. 26, fig. 6; Figs. 4, 5

Description.—Test consists of a single chamber with a tapering neck; test shaped like a Florence flask, with chamber originally nearly spherical (compressed in most specimens), or in instances slightly oblate; neck about one-sixth to one-half the length of the chamber, and about one-fourth to two-fifths the diameter of the chamber at the apertural end of the neck; wall of fine siliceous grains in siliceous cement; color of wall white to light gray to yellowish-gray.

Measurements.—See Table 6 for measurements of *Proteonina wallingfordensis,* Table 7 for range in measurements of the species, and Table 8 for comparison of the species with those to which it is similar.

Comparison and affinities.—The two species of *Proteonina* found in this study are distinguished from each other as shown on Table 8. Inasmuch as *Proteonina* is a simple form even among smaller Foraminifera, it is in instances difficult to distinguish various species. Furthermore, the genera *Lagenammina* and *Saccammina* include some species which are not clearly distinguishable from *Proteonina.* All three genera have been reported from the Silurian to Recent. The relationship of these genera is obscure, as noted by Dunn (1942, p. 327). *Lagenammina* and the single-chambered and free forms of *Saccammina* may belong in *Proteonina;* such Paleozoic forms of these two genera from the United States all are composed of siliceous grains in siliceous cement, and apparently, in their fossilized state are without the chitinous base of Recent forms.

Table 6. Measurements of *Proteonina wallingfordensis,* n. sp., in mm.

specimen and type number	*length of test*	*length of chamber*	*diam. of chamber*	*diam. of base of neck*	*diam. of end of neck*	*locality number, formation, and bed number*
Pl. 26, fig. 6	.762	.521	.554	.252	.134	K-2, New Providence, bed 3
Pl. 19, fig. 4	.586	.436	.436	.201	.168	K-63, Farmers, bed 9

Pl. 19, fig. 7, holotype	.352	.269	.319	.118	.067	K-63, Farmers, bed 9
Pl. 19, fig. 6	.436	.319	.352	.193	.101	K-63, Farmers, bed 9
Pl. 19, fig. 8	.369	.302	.319	.118	.088	O-7, Cuyahoga, bed 4
Pl. 19, fig. 5	1.000	.720	.840	.360	.240	O-1, Bedford, bed 2

Table 7. Range in measurements of 39 specimens of *Proteonina wallingfordensis,* n. sp., in mm.

Length of test	.235-1.000
Length of chamber	.201-.720
Diam. of chamber	.201-.840
Diam. of base of neck	.059-.360
Diam. of end of neck	.047-.240

Table 8 gives a comparison of the present species of *Proteonina* and of several Paleozoic species of *Proteonina, Lagenammina,* and *Saccammina* which are somewhat similar to the two species of *Proteonina* herein described. As seen on Table 8, *P. wallingfordensis* and *P. cumberlandiae* are distinct from the species with which they are compared. *P. wallingfordensis* with its spherical chamber is similar to *Lagenammina sphaerica, Saccammina aspera, P. cervicifera,* and *S. moremani.* However, the neck of *P. wallingfordensis* differs from the neck of all these other species in that it is broader than the neck of *S. aspera* and *L. sphaerica,* longer than the neck of *S. moremani,* and more slender and more tapering than the neck of *P. cervicifera.*

Proteonina cumberlandiae differs from *Lagenammina stilla* in having a broader and longer neck, and from *L. sphaerica,* the neck of which is similar, in not having a spherical chamber but rather a teardrop to avocado-shaped chamber.

Proteonina cumberlandiae and *P. wallingfordensis* differ from each other in that the chamber of *P. wallingfordensis* is spherical rather than teardrop or avocado-shaped and its neck is shorter and stockier.

Type locality.—One mile northeast of Wallingford, along hill road leading to Poston School, Fleming County, Kentucky (Locality K-63). The holotype is from the Farmers siltstone (Bed 9).

Stratigraphic occurrence.—Like *Proteonina cumberlandiae, P. wallingfordensis* occurs in the Kinderhookian Falling Run member

Table 8. Comparison of several species of *Proteonina*, *Lagenammina*, and *Saccammina* with *P. cumberlandiae*, n. sp. and *P. wallingfordensis*, n. sp.

	shape of chamber	*shape of neck*	*minimum diam. of neck/diam. of chamber*	*length of neck/ length of chamber*	*length and diameter of test in mm.*	*age and location of holotype*
Proteonina wallingfordensis	spherical to nearly spherical	tapering, moderately long	1/4 to 2/5	1/6 to 1/2	.235x.201 to 1.00x.84	Osagian, Kentucky
P. cumberlandiae	teardrop to avocado shaped	rather long, slender	1/6 to 1/3	1/3 to 1/2	.235x.151 to .806x.545	Osagian, Kentucky
P. cervicifera Cushman and Waters, 1928	rounded, stout	cylindrical, stout, constricted	1/3 to 1/2	1/4 to 2/5	.5 to 1.1 long .9x.65	Middle Pennsylvanian, Texas
Lagenammina stilla Moreman, 1930	more or less ellipsoidal	short, rather pointed	1/12	1/4	.44x.28	Silurian, Oklahoma
L. sphaerica Moreman, 1930	almost perfectly spherical	elongate, slender	1/9	2/5	.65x.38	Silurian, Oklahoma
Saccammina aspera Stewart and Priddy, 1941	sub-spherical, oblate	short, narrow	1/9	1/6	.33x.32	Silurian, Indiana
S. moremani Ireland, 1939	spherical	short	1/4	1/8	.86x.77	Silurian, Oklahoma

of the Sanderson formation, throughout the Osagian New Providence formation of Kentucky and southern Indiana, and throughout the Osagian Cuyahoga formation of Ohio. Above the Osagian, *P. wallingfordensis* was found in the Somerset shale member of the Salem limestone. Unlike *P. cumberlandiae, P. wallingfordensis* occurs also in the Blackiston, Bedford, and Maury shales, as well is in shale in the Berea sandstone. (See Charts 3-6, 8-13, 17-22 for details of occurrence.)

Ecology.—Recent species of *Proteonina* are rather widely distributed in cool to cold and rather deep to deep waters. *Proteonina* is not restricted to cold and deep water or both, for species of the genus are found in other environmental situations where particulate material (generally siliceous sand and silt) is available for construction of tests. I have recovered Recent specimens of *Proteonina* from bay bottom muds in Corpus Christi Bay, Nueces County, Texas, associated there with silt or sand-bearing muds or both.

Proteonina wallingfordensis occurs most often in the area from southeastern Kentucky to southern Ohio in the silty shales of the New Providence and Cuyahoga formations, while *P. cumberlandiae* is more abundant in northwestern and southwestern Kentucky and in southcentral Ohio in the less silty shales of the New Providence and lower Cuyahoga formations. This "preference" for the less silty shales by *P. cumberlandiae* is perhaps reflected in its more slender test, while *P. wallingfordensis* with its stockier test seemingly was able to live in a more silty environment.

Family **HYPERAMMINIDAE** Eimer and Fickert, 1899

Subfamily **HYPERAMMINAE** Cushman, 1910

Genus **HYPERAMMINA** Brady, 1878, emend. Conkin, 1954

Hyperammina Brady, 1878, Ann. Mag. Nat. Hist., ser. 5, vol. 1, pp. 433, 434, pl. 20, figs. 2a, 2b; *idem,* 1884, Rept. Voyage Challenger, Zool., vol. 9, pp. 257-260, pl. 23, figs. 4, 7-10; Cushman and Waters, 1930, Univ. Texas, Bull. 3019, p. 33; Plummer, 1945, Univ. Texas, Pub. 4401, pp. 219, 220; Conkin, 1954, Cushman Lab. Foram. Research, Contr., v. 5, pt. 4, pp. 167, 168; Cummings, 1955, Micropaleontology, v. 1, No. 3, pp. 233, 234.

Nodosinella Brady, Cushman, (*pars*), 1927, Cushman Lab. Foram. Research Contr., vol. 3, pt. 3, p. 147, pl. 26, figs. 4, 5a, 5b. (*non Nodosinella* Brady, 1876, Pal. Soc. Mon., v. 30, p. 102).

Hyperamminella Cushman and Waters, 1928, Cushman Lab. Foram. Research, Contr., vol. 4, pt. 2, p. 36, pl. 4, figs. 3, 4. (*non Hyperamminella* de Folin, 1881, Soc. Hist. Nat. Toulouse, Bull. année 15, p. 140. *nomen nudum*).

Hyperamminoides Cushman and Waters, 1928, Cushman Lab. Foram. Research, Contr., vol. 4, p. 112. (New generic name substitution.)

Type species, *Hyperammina elongata* Brady, 1878 (original designation. Recent, Atlantic Ocean).

Conkin (1954, p. 167) summarized Brady's generic concept of *Hyperammina*:

> H. B. Brady (1878, pp. 433, 434, pl. 20, figs. 2a, 2b) first defined *Hyperammina* with *H. elongata* as the genotype, and in 1884 (pp. 257-260, pl. 23, figs. 4, 7-10) emended his original definition . . . Brady considered *Hyperammina* to have: an arenaceous test , free or adherent, [attached tests have since been referred to other genera] with an elongate tubular, singular or branching, second chamber; aperture open or only slightly constricted; interior smooth; exterior roughly or smoothly finished with test tapering toward the aperture; and a proloculus of varying bulbosity and shape.

The generic concept of *Hyperammina* and its relationship with *Hyperamminoides* Cushman and Waters, 1928 were discussed by Conkin (1954, pp. 167, 168); this discussion amounted to a generic emendation of *Hyperammina* although no formal statement of emendation was made in the 1954 paper.

I now formally propose that the 1954 (pp. 167, 168) discussion of the generic concept of *Hyperammina* be recognized as constituting generic revision of *Hyperammina*. To this end, I repeat the essential elements of my generic emendation, which added to Brady's definition, bring *Hyperammina* up-to-date and capable of embracing all species of *Hyperammina* and *Hyperamminoides*, as informally stated in 1954 (pp. 167, 168):

> (1) the second chamber may be nontapering, may taper towards the proloculus, or in a few species taper toward both the aperture and the proloculus ('hourglass tapering'); (2) aperture may be moderately or strongly constricted; and (3) exterior may be marked by transverse constrictions of varying strength. . . No clear generic definition is possible for either *Hyperammina* or *Hyperamminoides* as long as *Hyperamminoides* is accepted as a valid genus. *Hyperamminoides*, therefore, should be suppressed in favor of *Hyperammina*. The three characters considered diagnostic of *Hyperamminoides* by Cushman and Waters (constricted aperture, siliceous test, and tapering shape of test) and the one character considered diagnostic of *Hyperamminoides* by Plummer (the rapidly expanding nature of the second chamber) are here considered only of specific value. All the above characters are exhibited in varying degrees by species of *Hyperammina*.

Considerable misunderstanding as to the nature of the test wall in *Hyperammina* has arisen. Cushman's treatment of the test wall is vague and his terminology is not precise. Generally, in describing species of *Hyperammina,* Cushman referred to the test wall as "arenaceous" or "agglutinated". Arenaceous, or agglutinate, to Cushman meant extraneous grains in a secreted cement; the cement could be ferruginous, calcareous, or rarely siliceous, usually with an interior chitinous lining. Thus, when Cushman used the term arenaceous without comment, he tacitly assumed that the test wall contained either ferruginous or calcareous cement. When Cushman dealt with Paleozoic *Hyperammina,* as well as with many other Paleozoic genera, his tacit assumption as to the nature of the test wall was not always well founded, as in all instances he apparenetly made no real determination as to the chemical nature of the cement, and in many instances did not describe the chemical composition of the agglutinated grains.

Cushman and Waters described several faunas from the Pennsylvanian of Texas (1927, 1928, 1930) in which the test wall composition was stated to be arenaceous; these statements by Cushman and Waters were assumptions based on preconceived ideas as to the test wall composition. However, Cushman and Waters (1928, p. 36) based their generic definition of *Hyperamminoides* on the fact that it had siliceous cement (which cement they considered to be original).

Plummer clearly understood the unnecessary difficulties attending lack of precision in the nomenclature and description of the nature of the test wall in smaller Foraminifera. Among Plummer's contributions to the nomenclature of arenaceous forms was the proposal to adopt (1930, p. 7):

> . . . the word 'adventitious' as a satisfactory comprehensive term to describe all shells composed of an extraneous material bound by cement. The term 'arenaceous' will be employed strictly according its etymology, that is, for tests composed of mineral grains obviously selected from their surroundings and cemented into a firm investment by a protoplasmic secretion.

Plummer (1945, p. 219) described the test wall composition in Pennsylvanian *Hyperammina*:

> The shell of the Texas Pennsylvanian species in this generic group [*Hyperammina*] consists of siliceous grains bound by an insoluble siliceous cement, which is generally subordinate enough to leave the surface distinctly dull and rough but commonly of fine texture. . .

The true nature of the wall composition of the type species of *Hyperammina, H. elongata* Brady, a Recent species, was not known until Cummings (1955, pp. 233, 234) examined the type material in the British Museum (Natural History) and reported that this material has a

. . . calcareous or ferrugino-calcareous cement, whereas the wall of *Hyperamminoides* is stated to have a siliceous cement. Such a fundamental difference of secretory activity in the cytoplasm can not be regarded as mere specific variation, as Conkin would suggest. However, tests of *Hyperammina* often undergo secondary alteration by silicification in Paleozoic sediments. This has been noted in several populations of *Hyperammina neoglabra* Conkin from different localities in the British Carboniferous. *Hyperamminoides* is therefore included within the genus *Hyperammina,* in the present work, on the grounds that the former is based on secondarily silicified specimens of the latter.

Conkin (1956, p. 193) attempted to clarify Cummings' misunderstanding of his concept of the wall structure in *Hyperammina* and its junior subjective synonym *Hyperamminoides*:

. . . I would not suggest that cement secreted by the protoplasm of a foraminifer is of mere specific value. Until Dr. Cummings' announcement, I knew of no reference to [Paleozoic] *Hyperammina* possessing calcareous or ferrugino-calcareous cement secreted by the cytoplasm; indeed, the generic definition of both *Hyperammina* and *Hyperamminoides* [here the writer was following Plummer's description of the chemical nature of the cement in *Hyperammina* inasmuch as Brady had not defined it precisely] had clearly required that these two genera possess siliceous cement. Therefore, the specific variation to which I referred was not a variation between siliceous cement [regardless or origin: original or altered] and calcareous or ferrugino-calcareous cement, but was a variation in the proportion of siliceous cement [regardless of origin: original or secondary] to cemented grains.

Crespin (1958, p. 35), in a study of the Permian hyperamminids of Australia, discussed the relationship between *Hyperammina* and *Hyperamminoides,* and concluded:

After studying innumerable tests, I agree with Conkin in using *Hyperammina* rather than *Hyperamminoides,* for the following reasons: (1) The difference in the shape of the proloculus is neither a definite generic nor a specific character. . . The amount of increase in width of the test is surely specific rather than a generic character, (2) Plummer (1945) remarks that the tests of *Hyperammina* are mostly much longer than those of *Hyperamminoides.* Evidence against this view is shown in the two species described by Parr (1942) from Western Australia. The tests of *'Hyperamminoides' acicula* are up to 20 millimetres long; the greatest length of *Hyperammina coleyi* is given as 9 millimetres, and (3) Cummings (1955) found that the test of *Hyperammina* had calcareous or ferrugino- calcareous cement, but no species with calcareous cement were found during the present investigation. The tests were presistently siliceous, as found by Conkin (1956). As already commented here, there seems to be little or no evidence of secondary silicification of arenaceous tests in the Australian Permian or in the rocks in which the foraminifera are found.

Plummer (1945, p. 223) placed considerable importance on the proportion of cementing material to arenaceous grains in the constitution and texture of the test of the two genera; thus in discussing *Hyperamminoides* Plummer remarked:

> The strong shell wall is composed of fine, siliceous cement. . . Most of the species exhibit such an abundance of siliceous cement in the shell wall, that the surface is very smooth and even glossy, but sufficient variation exists in both genera to render this feature too unstable to serve as a generic character.

I reiterate here my belief that the amount of cement (whether originally ferrugino-calcareous or siliceous) is at most of only specific value. In many instances it is doubtful whether the proportion of cement to cemented grains is of any taxonomic value. The cement is considered to be secreted by the protoplasm and the kind of cement should not vary within a species or genus. Actually it is considered that genera in any subfamily, and perhaps the genera of a family, should possess the same kind of cementing material. Some families of Foraminifera as presently conceived do not have the same test composition displayed in all the genera within the family. Many families undoubtedly contain unnatural groupings of genera.

It is known that some Protozoa do secrete siliceous test material and I can see no inherent difficulty in believing that some Paleozoic Foraminifera may have used silica as cement. Actually *Miliammina,* and others of the Silicinidae (Cretaceous and Recent), possess siliceous cement, although admittedly such truly siliceous genera in post-Paleozoic rocks are few and rarely encountered.

Cummings (1955, p. 234) reported: "Usually, representatives of the genus *Hyperammina* are found in the British Carboniferous in an unaltered condition." However, in the Pennsylvanian of Texas (Plummer, 1945, p. 261), unaltered *Earlandia* (with calcareous cement) occur in the same beds and at the same localities as does *Hyperammina.* The presence of *Hyperammina* (with siliceous cement) and unaltered *Earlandia* (with calcareous cement) in the same beds at the same localities lends support for the possession of an original siliceous cement by *Hyperammina.* If there has been secondary replacement of the *Hyperammina* then the silicification would have been extremely selective, leaving *Earlandia* completely unaltered.

St. Jean (1957, p. 41) expressed the following suspicion:

> Because of the transversely fibrous type of wall found in the diverse species of the fauna [Pennsylvanian Stanton fauna from Dubois Co., Indiana], it is suspected that all Paleozoic Foraminifera referred to the genus *Hyperammina* are actually *Earlandia.*

If all Paleozoic *Hyperammina* originally possessed a calcareous test as has been advocated by St. Jean (1957), then *Hyperammina* would become a junior subjective synonym for *Earlandia* Plummer, 1930 only if *Hyperammina* and *Earlandia* both possess granular calcite tests, as St. Jean believed (1957, p. 41). However, it is not yet established whether *Earlandia* was "arenaceous" in the sense of Plummer (1930 p. 7); that is, whether the calcareous granules were "selected" from the calcareous material on the sea bottom in warm, shallow seas, highly charged with carbonates, or whether the calcareous granules in the calcite cement were secreted by the protoplasm of the foraminifer.

If we were to entertain hypothetically the assignment of *Hyperammina* to the granular calcareous Earlandiidae Cummings, 1955, then what is the phylogenetic relationship of the Paleozoic *Hyperammina* and the Recent *Hyperammina?* Even the most ardent advocate of original crystalline calcareous wall constitution could hardly maintain the restriction of the genus *Hyperammina* to the Recent. In essence, St. Jean advocated just such restriction of *Hyperammina* when he suspected that Paleozoic *Hyperammina* are actually *Earlandia.* St. Jean (1957, p. 41) recognized the type species of *Hyperammina, H. elongata* Brady, 1878 to be a Recent arenaceous form, but took no notice of Cummings' work (1955, p. 233) which demonstrated that the type species has an arenaceous test of quartz sand grains in calcareous or ferrugino-calcareous cement.

Inasmuch as the type species of *Hyperammina* is arenaceous, there may well be, in the Paleozoic beds, silicified *Earlandia* which thus come to "mimic" *Hyperammina,* but the arenaceous *Hyperammina* can not be secondarily calcified to "mimic" *Earlandia* (which genus possessed a granular calcareous wall).

Further, I believe that St. Jean (1957, p. 41) made a fundamental misinterpretation of evolutionary thought in his discussion of his *Earlandia bulbosa* (which in reality is most likely a new species of *Earlandia,* not *Hyperammina bulbosa*):

> As it seems unlikely that this genus [*Hyperammina*] would be so far ranging, the Pennsylvanian *Hyperammina bulbosa* is placed under the genus *Earlandia.*

Although the exact zoological relationships between Paleozoic and Recent *Hyperammina* are unknown, primitive and simple forms of life possessing wide tolerances for and potentialities for adaptation to various chemical, physical, and biological factors of environment, should have long geologic ranges, especially if the life forms are adapted to live in an environment which has persisted basically unchanged throughout immense lengths of geologic time.

A further difficulty may be involved in the correct interpretation of wall structure and composition as Cummings mentioned (1955, p. 234):

> As Plummer (1945) noted, complete specimens of *Hyperammina* are rare, and fragments are difficult to distinguish from members of the Rhizamminidae. Some records of the latter group in the Upper Paleozoic may be the result of incomplete preservation of Hyperamminidae.

Fragments of some of the members of the Rhizamminidae occasionally may be mistaken for fragments of *Hyperammina;* many species of *Hyperammina* are described from fragmental material (lacking the proloculus). It is interesting to note that at least some of the species of the Rhizamminidae are reported to have an outer calcareous layer (Cushman, 1948, p. 73).

The foregoing discussion of possible silicification and original calcareous test composition and structure has not convinced me that all Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian *Hyperammina* in the United States and all Australian Permian *Hyperammina* are secondarily silicified.

Much more work needs to be done on the wall structure of Paleozoic Foraminifera along the lines of Cummings' contribution. Not enough faunas have been described, and not enough concern has been given to the composition of the test wall; perhaps silicification has been extremely selective in replacing only certain types of Foraminifera, or environmental conditions differing so much in various areas have promoted silicification in one area and not in another.

At present state of knowledge of wall structure and composition of Paleozoic smaller Foraminifera, no sweeping conclusions should be attempted which bear upon the nomenclature of genera and ideas of phylogeny. Assumptions as to wall structure, as yet unverified, can not be used as guides in systematics. I believe that problems of wall composition and structure are much more complex than generally recognized and that the foundation of foraminiferal systematics is weakened by our lack of exact knowledge, most particularly among arenaceous Foraminifera.

Hyperammina casteri, new species Pl. 20, figs. 1-18; Pl. 26, figs. 7, 8; Figs. 6, 7

Description.—Megalospheric form: Test consists of a proloculus of varying shape (oblate to spherical to somewhat pointed prolate to rounded prolate) and a straight to nearly straight second chamber which gradually and more or less regularly expands from a diameter less than that of the proloculus to a diameter greater than that of the proloculus; in a few instances, the test tapers toward the aperture after having expanded slightly in that direction; most tests show faint to moderate external constrictions at irregular intervals; test size varies greatly, with some specimens as much as three times larger than others and with all sizes between represented by yet other specimens; nearly all specimens are flattened so that measurements other than length are exaggerated about one and one-third times their original size; aperture formed by slightly to moderately constricted end of tube; apertural end of most specimens broken; test wall opaque to translucent and generally rather smooth with large proportion of siliceous cement, but wall may be rather granular with a lesser proportion of cement; color of wall varies from white to cream to gray.

Microspheric form: Test consists of a tiny pointed proloculus and a rather rapidly expanding second chamber which ceases to expand after achieving considerable length; the general shape of the test is that of an elongated cone; the proloculi of some specimens are extremely long and pointed; the pointed tips of the tiny proloculi are broken off of many specimens; aperture formed by slight constriction of open end of cone; however, the apertural end is usually broken; nearly all specimens are flattened as in the megalospheric form; measurements of test corrected for distortion show that the test was about three times to six times longer than broad; a few tests show less expansion of the second chamber and have the length about seven times longer than the width; in other respects the microspheric form closely resembles the megalospheric form.

Measurements.—See Table 9 for measurements of the megalospheric form and Table 10 for measurements of the microspheric form of *Hyperammina casteri.* Table 11 shows the range in measurements of *H. casteri,* a comparison in the ranges of the measurements of *H. casteri* and *H. glabra,* and the ranges of the measurements of the tests of *H. casteri* which have been hypothetically restored to their original dimensions, before flattening occurred.

Comparison and affinities.—The megalospheric form of *Hyperammina casteri* is somewhat similar to the megalospheric form of *H. glabra* Cushman and Waters (1927, p. 146); however, *H. casteri* is proportionally broader, with a maximum diameter (for a given length) attaining nearly three times that of *H. glabra* and a proloculus diameter ranging to nearly two and one-half times greater than that of *H. glabra.*

The microspheric form of *Hyperammina casteri* is distinct from all forms of *Hyperammina* in the present study because of its conical shape; however, the microspheric form is similar in its conical shape to *H. expansa* (Plummer) (1945, pp. 223, 224). *H. expansa* expands at a much faster rate than does *H. casteri* and in general has a larger proloculus. Plummer did not give measurements for the proloculus of *H. expansa,* but the proloculi of three topotypes (from Plummer's Locality No. 128) range from .042 to .067 mm. in diameter. Also, the microspheric form of *H. casteri* resembles *H. johnsvalleyensis* Harlton (1933, p. 8). The microspheric form of *H. casteri* superficially resembles *Reophax buccina* Gutschick and Treckman (1959, pp. 239, 240), but *R. buccina* has a much larger proloculus (.08 to .10 mm.), and its test is partially constricted internally. The generic position of *R. buccina* is in doubt.

Table 9. Measurements of *Hyperammina casteri*, n. sp., megalospheric form, in mm.

specimen and type number	*diam. of proloc.*	*length of test*	*max. diam.*	*min. diam.*	*locality number, formation, and bed number*
Pl. 20, figs. 14, 15	.335	2.100	.420	.302	K-13, Brodhead, bed 10
Pl. 20, fig. 5	.193	.704	.193	.138	K-38, New Providence, bed 7
Pl. 20, fig. 18	.450	1.625	.450	.350	K-31, New Providence, bed 2
Pl. 20, fig. 17	.250	1.550	.300	.190	K-31, New Providence, bed 2
Pl. 20, fig. 7	.120	.840	.151	.080	K-36, New Providence, bed 5
Pl. 20, fig. 9	.244	1.126	.270	.210	K-16, New Providence, bed 3
Pl. 26, fig. 7	.225	1.350	.300	.200	K-12, New Providence, bed 2
Pl. 20, fig. 3	.134	.924	.164	.109	K-36, New Providence, bed 2
Pl. 20, fig. 12		.670	.134	.088	K-5, Falling Run, bed 1

Table 10. Measurements of *Hyperammina casteri*, n. sp., microspheric form, in mm.

specimen and type number	*diam. of proloc.*	*length of test*	*max. diam.*	*min. diam.*	*locality number, formation, and bed number*
Pl. 20, fig. 6	.025	.780	.218	.025	K-34, New Providence, bed 7
Pl. 20, fig. 16		1.260	.425	.142	I-3, New Providence, bed 1
Pl. 20, fig. 8		.604	.168	.025	K-16, New Providence, bed 3
Pl. 20, fig. 11	.077	.806	.252	.075	K-16, New Providence, bed 3
Pl. 20, fig. 10		.746	.319	.168	K-16, New Providence, bed 3
Pl. 20, fig. 1, holotype	.033	1.140	.265	.033	I-4, New Providence, bed 3
Pl. 20, fig. 2	.050	.772	.302	.050	I-4, New Providence, bed 3
Pl. 20, fig. 4		.570	.302	.067	K.-36, New Providence, bed 1
Pl. 20, fig. 13	.018	.586	.201	.018	K-5, Falling Run, bed 1

Table 11. Range in measurements of *Hyperammina casteri*, n. sp., in mm., and comparison with *H. glabra* Cushman and Waters

	H. casteri megalospheric 34 specimens	*H. casteri* microspheric 38 specimens	*H. glabra* megalospheric
Diam. of proloc.	.120-.450	.018-.075	.150
Length of test	up to 2.30	up to 1.26	up to 3.00
Max. diameter	.134-.650	.105-.470	.120-.200
Min. diameter	.080-.350	.018-.075	
Restored ranges			
Diam. of proloc.	.120-.360	.015-.060	
Max. diameter	.107-.520	.084-.380	
Min. diameter	.080-.280	.015-.060	

The megalospheric and microspheric forms of *Hyperammina casteri* taken together are roughly similar in appearance to the megalospheric and microspheric forms of *H. elegans* (Cushman and Waters) (1928, p. 36). However, *H. elegans* is much larger (up to 5 mm. long and 1 mm. in diameter) and is more strongly constricted.

Type locality.—One mile west of Jacobs Chapel, Clark County, Indiana (Locality I-4). The holotype is from the lower three feet of the New Providence formation (Bed 3).

Stratigraphic occurrence.—*Hyperammina casteri* has a longer stratigraphic range than do the other species of the genus encountered in this study. The species ranges in Kentucky from the Upper Devonian part of the New Albany black shale upward and throughout the Kinderhookian and Osagian; in the Meramecian the species has been found only in the Somerset shale member of the Salem limestone; in the Chesterian, *H. casteri* occurs in the upper part of the Pennington shale, while questionable specimens of *H. casteri* were found in the shaly part of the Paint Creek and Menard limestones. The species occurs in the Kinderhookian and Osagian of southern Indiana. In Ohio, *H. casteri* has been found in the Osagian Cuyahoga formation. *H. casteri* occurs rather often (in the Kinderhookian and lower Osagian) in association with *H. rockfordensis*, and less often in association with *H. kentuckyensis*, within the Osagian sequence. See Charts 3-22 for details of occurrence of *H. casteri* in the Mississippian.

Ecology.—*Hyperammina casteri* occurs in a wide variety of shales (calcareous and noncalcareous), shaly siltstones, and shaly sandstones; thus, like *Involutina semiconstricta,* the species was tolerant of a wide range of environmental conditions. There is no gradual change in size with decreasing geologic age, nor apparently any other change in the morphology which can be correlated with stratigraphic level. Various sized specimens are found even in the same sample. The great variety in size and shape assumed by *H. casteri* may indicate that polymorphism existed within the species rather than the species having had simple alternation of microspheric and megalospheric generations.

Remarks.—This new species is named in honor of Dr. K. E. Caster, Professor of Geology at the University of Cincinnati.

Hyperammina kentuckyensis Conkin, 1954 Pl. 21, figs. 1-9; Pl. 26, fig. 9; Fig. 8

Hyperammina kentuckyensis Conkin, 1954, Cushman Found. Foram. Research, Contr., vol. 5, pt. 4, pp. 166, 167, pl. 31, figs. 1-6.

Description.—Conkin gave this specific description of *Hyperammina kentuckyensis*:

Megalospheric form shows an oblate proloculus and a moderately curved, undivided second chamber, tapering initially toward the aperture, then expanding toward the aperture the remainder of the test, producing a necking at the position of reversal of direction of tapering (this double tapering of the early part of the second chamber is herein termed 'hourglass tapering'); test moderately constricted externally at irregular intervals; part of test between last constriction and moderately constricted aperture, slightly inflated forming a distinct lip which ranges up to 16 percent of the total length of the test; wall cream colored and smoothly finished, consisting of minute siliceous grains in siliceous cement; rarely a specimen approaches a cylindrical shape, . . . but this is merely an individual abberation within the species.

Microspheric form shorter, stouter, and less curved than megalospheric form; proloculi of microspheric forms broken off; very early part (less than 10 percent of total length of second chamber) narrow, and very gradually expanding, followed by a rapid expansion, and thereafter approaching a cylindrical shape, but always retaining a definite expansion; . . . aperture slightly constricted; lip as in megalospheric form; wall same as in megalospheric form, but thicker.

Measurements.—See Conkin (1954, p. 166) for measurements of type specimens, Table 12 (this paper) for measurements of topotypes and hypotypes, and Table 13 for range in the measurements.

Comparison and affinities.—*Hyperammina kentuckyensis* was originally compared to *H. glabra* Cushman and Waters, 1927, as follows (Conkin, 1954, p. 167):

The megalospheric form of *Hyperammina kentuckyensis* differs from the megalospheric form of *H. glabra* in having: (1) numerous moderately developed, though distinct, external constrictions, (2) pronounced 'hourglass' tapering of the early part of the second chamber, (3) distinct lip structure, and (4) oblate proloculus . . . The microspheric form of *Hyperammina kentuckyensis* has no close affinities to any known microspheric form of *Hyperammina*.

Gutschick and Treckman (1959, p. 238) described a new species, *Hyperammina rockfordensis*, as having close affinities to *H. elegans* Rauser-Cernoussova and Reitlinger, 1937 and to *H. kentuckyensis* Conkin, 1954.

Table 12. Measurements of *Hyperammina kentuckyensis* Conkin, 1954, in mm.

specimen and type number	*diam. of proloc.*	*length of test*	*max. diam.*	*min. diam.*	*locality number, formation, and bed number*
Pl. 21, fig. 2, topotype	.101	.781	.118	.084	K-5, Floyds Knob, bed 1
Pl. 21, fig. 1, topotype	.067	1.208	.087	.050	K-5, Floyds Knob, bed 1
Pl. 21, fig. 3, topotype	.092	.915	.112	.084	K-5, Floyds Knob, bed 1
Pl. 21, fig. 9	.126	.858	.109	.075	I-2, Button Mold Knob, bed 1
Pl. 21, fig. 7	—	.604	.118	.060	I-2, Button Mold Knob, bed 1
Pl. 21, fig. 5	.120	.850	.118	.084	K-32, New Providence, bed 5
Pl. 21, fig. 6		1.083	.134	.055	K-32, New Providence, bed 5
Pl. 21, fig. 4		1.100	.134	.067	K-32, New Providence, bed 5
Pl. 21, fig. 8	.126	.704	.105	.069	K-6, Button Mold Knob, bed 5

Table 13. Range in measurements of 29 specimens of *Hyperammina kentuckyensis* Conkin, 1954, in mm.

Diameter of proloculus	.067-.176
Length of test	.436-1.629
Maximum diameter of test	.092-.252
Minimum diameter of test	.050-.120
Diameter of lip	.087-.244
Diameter of aperture	.025-.134

In the present paper (under *Hyperammina rockfordensis*) I document the derivation of *H. kentuckyensis* from *H. rockfordensis* (or stated another way, the transformation in time of *H. rockfordensis* into *H. kentuckyensis*).

Although the two species are intimately related and *Hyperam-*

mina kentuckyensis is derived from *H. rockfordensis*, *H. kentuckyensis* differs from *H. rockfordensis* in having: (1) distinct hourglass tapering, (2) the second chamber expanding more rapidly, (3) distinct constrictions, and (4) rather less granularity to the test wall.

Type locality.—This species was described by Conkin (1954, pp. 166, 167) from the Mississippian (upper Osagian) Floyds Knob formation (Bed 1) on the north side of Mitchell Hill in southwestern Jefferson County, Kentucky (Locality K-5).

Stratigraphic occurrence.—*Hyperammina kentuckyensis* is restricted to beds of Osagian age in Kentucky and southern Indiana; the species is not known from the Mississippian of Ohio or Tennessee. (See Charts 3-6, 8, 9, 11-13, 17-19, and 22 for details of occurrence.)

Ecology.—*Hyperammina kentuckyensis* is best developed and most abundant in the coquinas (crinoid, bryozoan, and brachiopod breccias) of the Floyds Knob formation as presented at the type locality. The nature of the Floyds Knob formation has never been studied in detail except for tracing of its distribution and significance as a datum within the Osagian rocks of Kentucky and southern Indiana (Stockdale, 1931). The universal presence of glauconite grains or pellets, coupled with the presence in some places of rounded to angular pebbles of limestone near the base or within the formation, strongly suggests unconformity, or certainly near shore deposition. This conclusion is further supported by the coquina of abundant brachiopod fragments and other invertebrate fragmental remains. Significant portions of the formation are in places composed of beds of oölitic limestone. The origin of and the chemical and physical environment of deposition of oölitic beds is well known. Oölites today are formed in marine waters that are of high alkalinity (and thus supersaturated with calcareous salts), high pH, tropical temperature, and shallow depth, as in shoal areas where agitation of water by waves causes the formation of concentric bands of calcium carbonate around some foreign particle as a nucleus. (For ecological significance of oölitic limestones, see Henson, 1950, pp. 215-238, and Conkin and Conkin, 1958, p. 151.)

In most areas, the Floyds Knob formation is a glauconitic limestone or siltstone or both. Where the limestone is absent or poorly developed, tests of *Hyperammina kentuckyensis* are distorted in appearance and generally smaller in size. Among these apparently depauperate forms there is occasionally found a "giant".

Hyperammina kentuckyensis is known to be well developed, but of smaller size, in the New Providence formation (particularly in the calcareous shales of the Button Mold Knob member); the species is rare in the Coral Ridge member of the New Providence formation in which beds the transformation from *H. rockfordensis* to *H. kentuckyensis* occurred. The species is less well developed in the slightly calcareous siltstones of the Brodhead formation. Undoubtedly the water was colder in New Providence and Brodhead times than in Floyds Knob time.

Remarks.—*Hyperammina kentuckyensis* was probably the first species of smaller Foraminifera to be described from the Lower Mississippian of North America.

Only a few specimens of the several hundred examples studied of *Hyperammina kentuckyensis* exhibit slight effervescence with strong hydrochloric acid. This effervescence may indicate the original presence of calcareous material in the test of *H. kentuckyensis*. The types of *H. kentuckyensis* described from the limestone of the Floyds Knob formation in Jefferson County, Kentucky, were recovered from acid residues. Any calcareous material originally present in the test would have been dissolved before the specimens were recovered. However, it may be noted that in washed shale samples which have not been treated with acid, specimens of *H. kentuckyensis* (siliceous) occur with calcareous megafossils which are not replaced by silica. The rare effervescence in *H. kentuckyensis* mentioned above probably is due to calcareous material in the main cavity of the test or in tiny spaces which may occur between siliceous grains.

Hyperammina rockfordensis Gutschick and Treckman, 1959
Pl. 21, figs. 10-13; Pl. 26, fig. 10; Fig. 9

Hyperammina rockfordensis Gutschick and Treckman, 1959, Jour. Paleont., vol. 33, No. 2, p. 238, pl. 34, figs. 1-5, text-figs. 1A-1C.

Description.—Test consists of a prolate to spherical proloculus, the diameter of which is equal to or greater than the maximum diameter of the second chamber, and a straight or nearly straight undivided second chamber which enlarges only slightly distally so that the apertural region of the second chamber is only slightly larger in diameter than the initial portion of the second chamber; a slight amount of hourglass tapering is noted on some tests; test slightly constricted externally; apertural end is broken off of all present specimens; wall constructed of fine siliceous grains in siliceous cement; wall color white to buff to gray.

Measurements.—See Table 14 for measurements of present specimens of *Hyperammina rockfordensis* and Table 15 for range in measurements of the species.

Table 14. Measurements of *Hyperammina rockfordensis* Gutschick and Treckman, 1959, in mm.

specimen and type number	*diam. of proloc.*	*length of test*	*max. diam.*	*min. diam.*	*locality number, formation, and bed number*
Pl. 26, fig. 10	.105	.521	.059	.050	K-17, New Providence, bed 3
Pl. 21, fig. 12	.160	.670	.118	.109	K-13, New Providence, bed 2
Pl. 21, fig. 13	.118	.554	.084	.067	K-57, New Providence, bed 8
Pl. 21, fig. 10	.118	.738	.101	.084	K-13, New Providence, bed 2
Pl. 21, fig. 11	.092	.822	.088	.062	K-13, New Providence, bed 2

Table 15. Range in measurements of 24 specimens of *Hyperammina rockfordensis* Gutschick and Treckman, 1959, in mm., and comparison with the original types

	As measured	*Restored*	*Original types*
Diam. of proloculus	.092-.160	.092-.128	.110-.130
Max. diam. of test	.050-.118	.040-.094	.090-.110
Min. diam. of test	.050-.109	.040-.087	.070-.090

Comparison and affinities.—*Hyperammina rockfordensis* has its closest affinities to *H. kentuckyensis,* but *H. rockfordensis* differs from *H. kentuckyensis* in having: (1) only slight hourglass tapering in some specimens, (2) the second chamber expanding only slightly from the proximal to the distal end so that the proloculus possesses the greatest diameter observed in the whole test (or at least a diameter equaled only by the greatest diameter of the second chamber), (3) a test only slightly to moderately constricted (if at all), and (4) rather more granularity to the test wall.

It appears that *Hyperammina rockfordensis* is the ancestral stock from which *H. kentuckyensis* was derived. This belief is based on several considerations. *H. rockfordensis* has its closest affinities to *H. kentuckyensis* and is directly succeeded in time by *H. kentucky-ensis* (*H. kentuckyensis* does not occur below the Osagian and *H. rockfordensis* is typically a Kinderhookian species known only from the lower Osagian). The transition from *H. rockfordensis* to *H. kentuckyensis* occurred in Coral Ridge time inasmuch as few specimens of *H. rockfordensis* were noted in the lower part of the Button Mold Knob member and *H. kentuckyensis* is rarely encountered in the lower part of the Coral Ridge member of the New Providence formation.

The morphological features of *Hyperammina rockfordensis* could be, with moderate exaggeration, made to correspond on a specific level with the morphological features of *H. kentuckyensis*. Indeed, rarely a specimen seems to fit in either species and can be identified only by its association with distinctive forms of one or the other species. Thus, I believe that the material presented in the Kinderhookian *H. rockfordensis* and the lower Osagian forms of *H. kentuckyensis* exhibits as well as can be hoped for among Paleozoic simple arenaceous Foraminifera the transformation of one species into another. The geologic range, the time of first appearance of *H. kentuckyensis,* the time of last occurrence of *H. rockfordensis,* and the morphological affinities of the two species are consistent with the interpretation of the evolution of *H. kentuckyensis* from *H. rockfordensis.*

Stratigraphic occurrence.—Hyperammina rockfordensis is known from the Kinderhookian Rockford limestone of northern Indiana (Gutschick and Treckman, 1959). The species is herein recognized from the Upper Devonian Blackiston formation; in the Kinderhookian, from the Eulie and Maury shales of Tennessee, the Falling Run member of the Sanderson formation and the Jacobs Chapel shale of southern Indiana. *H. rockfordensis* was found to occur especially in the Coral Ridge member of the New Providence formation and in the lower few feet of the New Providence formation where the Coral Ridge member is not recognized. The species occurs rarely in the lower part of the Button Mold Knob member of the New Providence formation and in the Henley shale of Ohio. The age of the lowest beds (lower Coral Ridge member) of the New

Providence formation is in doubt. The lower part of the Coral Ridge member does not contain a megafossil fauna and may be partially Kinderhookian in age. Conkin (1957) adequately demonstrated a low Osagian age for the megafossil fauna from the upper part of the Coral Ridge member in Jefferson and Bullitt counties, Kentucky, and Clark County, Indiana. (See Charts 3-6, 8-13, 16-18, 21, and 22 for details of occurrence of *H. rockfordensis* in the Mississippian.)

Ecology.—In Kentucky, nearly all specimens of *Hyperammina rockfordensis* are found in the Coral Ridge member of the New Providence formation, or equivalent parts of the New Providence formation; the characteristics of the Coral Ridge member were given by Conkin (1957, p. 116):

upper part: Shale, green-gray to blue-gray, with ironstone lenses, ironstone cone-in-cones, flat, variously shaped, dark gray to blue-gray, small ironstone nodules, some phosphatic nodules, rare and thin ferruginous and fossiliferous limestone lenses; pyritized, marcasitized, silicified, Coral Ridge fauna.

lower part: Shale, green-gray, virtually free of ironstones of even the smallest size, with worm markings; no megafossils noted.

Inasmuch as *Hyperammina rockfordensis* occurs in the Coral Ridge member of the New Providence formation and in the Rockford limestone, we must consider the ecological conditions existing during the deposition of the Coral Ridge member and the Rockford limestone in order to hope to present something of the ecology of the species.

The fossils of the Coral Ridge fauna are pyritized, marcasatized, and some individuals are replaced partially by silica; the fauna is associated with a large number of small lens-shaped ironstone nodules and beds of ironstone cone-in-cone layers; phosphatic-ferruginous thin lenses are present at Kenwood Hill (Locality K-3).

It seems as if the Coral Ridge fauna is a biocoenosis in that (1) most species present complete growth series from young to adult individuals, (2) fragmentary specimens are rare, (3) no real evidence of currents is preserved in the fine, clayey, plastic shales, and (4) the pelecypods are preserved with both valves tightly closed. The great amount of iron sulphide in the sediments may indicate the sudden death of the fauna *en masse* because of reducing conditions and the release of poisonous sulphides. The presence of abundant coprolite-like structures may also indicate conditions of incomplete oxidation, but the presence of the large number of impure calcareous ironstones and the absence of carbonaceous material in the sediments would seem to indicate shallow water deposition; nevertheless, the presence of several goniatite genera (*Merocanites, Pericyclus,* and *Beyrichoceras*) does not restrict the environment to shallow water. *Hyperammina rockfordensis* is present in the lower part of the Coral Ridge member where no megafossils (except *Scalarituba*) are known. In all events, it is demonstrated that *H. rockfordensis* "preferred" muddy bottoms in which there were sufficient amounts of fine silt to allow construction of a fairly thick arenaceous test.

The Rockford limestone lithology was characterized by Gutschick and Treckman (1959, pp. 230, 231) as a:

> . . . yellow-grey fine-grained argillaceous crinoidal limestone with small black rounded phosphatic pebbles in its basal part. There are also 1 to 2 inch interbeds of calcareous fossiliferous shale. The HCl acid residues are largely made up of fine silty granular siliceous porous aggregates, undoubtedly argillaceous, and arenaceous Foraminifera in abundance. There are some quartz sand grains, silicified fragmental fossil material, pyrite, rare glauconite, and occasional radial aggregates of fine needle-like crystals of millerite.

Gutschick and Treckman continued by discussing the fauna of the Rockford limestone, mentioning the several cephalopods which apparently were found in the shale units.

> . . . Other large fossils are scarce because of limited exposures, but include both large and diminutive forms of brachiopods, corals, bryozoans, gastropods, trilobites, abundant echinoderm debris and fish fragments.
>
> The microfaunas include conodonts, holothurian sclerites, microcrinoids, ostracodes, worm tubes, and other material. Most, if not all, are calcareous or phosphatic and are found in the water washings of the calcareous shale interbeds. . . . The major portion of the fauna of the Rockford is diminutive which suggests some restrictions in general normal marine conditions.

The acid residues of the Rockford limestone of southern Indiana consist of fine muds, plus arenaceous grains, fossils, and fossil fragments. The presence of glauconite and pebbles of phosphate must indicate near shore environment.

The possibility that the Rockford limestone represents lagoonal deposits should at least be considered. The fine-grained muds, the presence of diminutive elements of the fauna, the thinness of the Rockford limestone, and its position in an unstable framework of sedimentation (fairly quick changes in environments as presented by various different lithologies in rather thin beds below and above) may indicate deposits laid down near a fluctuating sea shore.

In conclusion, it can be remarked that *Hyperammina rockfordensis* was well adapted to fine-grained sediments where soft muddy bottoms were the rule, but where there were sufficient amounts of fine silt to allow construction of a fairly thick arenaceous test.

Family **EARLANDIIDAE** Cummings, 1955

Genus **EARLANDIA** Plummer, 1930

Nodosinella Brady, 1876, (*pars*), Paleont. Soc., vol. 30, p. 66.
Earlandia Plummer, 1930, Univ. of Texas, Bull. 3019, pp. 12, 13; Cushman, 1948, Foraminifera, Cambridge, p. 86; Cummings, 1955, Micropaleontology, vol. 1, No. 3, p. 228.

Type species, *Earlandia perparva* Plummer, 1930 (original designation by Plummer, 1930).

Description.—H. J. Plummer (1930, pp. 12, 13) described *Earlandia* from the Pennsylvanian Brownwood shale at Bridgeport, Wise County, Texas.

> Test free, very elongate, composed of a globular or subglobular proloculus and an elongate, nonseptate, second chamber; shell wall of minute crystalline calcareous granules bound by a calcareous cement, imperforate, smoothly finished; aperture a broad circular opening at the end of the tube. . . . The salient distinguishing character of *Earlandia* n. gen. is the constitution of the shell wall, which is identical with that of *Endothyra* and *Nodosinella*. *Hyperammina* is its morphological equivalent with a typically adventitious test (arenaceous in Pennsylvanian strata). *Hyperamminoides* [synonym of *Hyperammina* Brady, 1876] another very closely allied structure is composed of fine siliceous sand grains smoothly finished with much siliceous cement and is especially characterized by the constricted aperture at the end of the enlarging second chamber.

Cummings (1955, p. 227) erected the new family Earlandiidae to embrace those genera which are, "Tubular or uniserial tests in which the wall is composed of equidimensional granules of calcite bound by calcium cement." Cummings placed *Earlandia* Plummer, 1930, *Earlandinella* Cummings, n. g. (1955, p. 230), and *Lugtonia* Cummings, n. g. (1955, p. 231) in the Earlandiidae.

In Europe, *Earlandia* ranges stratigraphically from the Middle Tournaisian into the Lower Permian (Cummings, 1955, p. 235, text-fig. 10). In Australia *Earlandia* is reported from the Permian (Crespin, 1958, pp. 58, 59). *Earlandia* has been recorded from North America only in the Pennsylvanian; however, this paper extends the stratigraphic range of *Earlandia* downward into the Middle Mississippian.

The relationship of *Earlandia* and Paleozoic species of *Hyperammina* in regard to general morphology and wall structure is discussed in this work under the genus *Hyperammina*. Some workers, as Plummer (1930, 1945) and Conkin (1954), have held (or tacitly assumed) that Paleozoic species of *Hyperammina* are congeneric with Recent *Hyperammina;* but others, as St. Jean (1957) believed that all Paleozoic species of *Hyperammina* are in reality species of *Earlandia* which have been secondarily replaced and recrystallized. The latter group of workers hold that Paleozoic *Hyperammina* are not congeneric with Recent *Hyperammina.* I admit that some Paleozoic *Hyperammina* may eventually prove to be *Earlandia;* nevertheless, I can not accept the thesis that all Paleozoic *Hyperammina* are merely replaced and recrystallized *Earlandia.*

Earlandia consternatio, new species Pl. 21, figs. 14-16; Pl. 26, fig. 11; Fig. 10

Description.—Test moderate-sized, elongate; proloculus (broken off of all specimens) followed by an undivided tapering and slightly arcuate second chamber; test constricted at rather regular intervals; test wall of calcium carbonate particles in crystalline calcite cement; wall imperforate; aperture formed by slightly constricted open end of second chamber; prominent lip present; test smooth with texture of unglazed porcelain; color, pastel gray.

Measurements.—See Table 16 for measurements of *Earlandia consternatio* and Table 17 for range in measurement of *E. consternatio* and comparison with *E. perparva* Plummer, 1945. See Table 13 for comparison with *Hyperammina kentuckyensis.*

Comparison and affinities.—Earlandia consternatio is similar to the type species of *Earlandia, E. perparva,* but *E. consternatio* has a more constricted aperture, is less elongate (rather more cylindrical than *E. perparva*), and is larger.

Earlandia consternatio is similar to *Hyperammina kentuckyensis* in its morphology, but the test of *E. consternatio* is less prominently constricted; furthermore, the test of *E. consternatio* is completely calcareous.

Type locality.—Outcrop on slope west of farm off of Sand Lick Road, Caldwell County, Kentucky (Locality K-24). The holotype is from shale in the Paint Creek limestone (Bed 1).

Stratigraphic occurrence.—Earlandia consternatio is known only from two Chesterian formations, the Paint Creek and Glen Dean limestones, and one Meramecian formation, the Somerset shale member of the Salem limestone. (See Charts 5, 7, 14, 15, and 22 for details of occurrence of *E. consternatio* in the Mississippian.)

Ecology.—*Earlandia consternatio* was found only in calcareous and fossiliferous shales. Seemingly then, the species required an environment in which the water was charged with calcium bicarbonate.

Remarks.—The remarkable similarity which exists between *Earlandia consternatio* and *Hyperammina kentuckyensis* seems to indicate the perfection of isomorphism between analogous genera of Foraminifera.

The specific name is proposed because of the surprising similarity which exists between *Earlandia consternatio* and *Hyperammina kentuckyensis.*

Table 16. Measurements of *Earlandia consternatio,* n. sp., in mm.

specimen and type number	*length minus proloc.*	*max. diam.*	*min. diam.*	*locality number, formation, and bed number*
Pl. 21, fig. 16	1.700	.190	.100	K-24, Paint Creek, bed 1
Pl. 21, fig. 14, holotype	1.200	.180	.080	K-24, Paint Creek, bed 1
Pl. 21, fig. 15	.800	.120	.050	K-24, Paint Creek, bed 1

Table 17. Range in measurements of six specimens of *Earlandia consternatio,* n. sp., in mm. and comparison with *E. perparva* Plummer, 1945

	E. consternatio	*E. perparva*
Length of test	.61-1.70	1.00
Max. diameter	.10-.19	.08
Min. diameter	.03-.10	
Diam. of proloculus		.030

Family **REOPHACIDAE** Cushman, 1927

Subfamily **REOPHACINAE** Cushman, 1927

Genus **REOPHAX** Montfort, 1808

Reophax Montfort, 1808, Conch. Syst., vol. 1, p. 331; Brady, 1884, (*pars*), Rept. Voyage Challenger, Zool., vol. 9, p. 289; Chapman, 1902, (*pars*), The Foraminifera, London, p. 137; Cushman, 1930, Univ. Texas, Bull., No. 3019, p. 37; *idem,* 1948, Foraminifera, Cambridge, p. 90, pl. 3, figs. 27, 28; Cummings, 1955, Micropaleontology, vol. 1, No. 3, pp. 234, 235, pl. 1, figs. 7, 8, 13, 16, 18, text-figs. 8, 9. (*non Reophax,* Rhumbler, 1895, Nachr. K. Gesell. Wiss. Göttingen, p. 82

Haplostiche Schwager, 1865, Ver. Vaterl. Nat. Württemburg, Jahresh., vol. 21, p. 92, figs. 2a-2c. (*non Haplostiche* Reuss, 1861, K. Böhmen Gesell. Wiss., Sitzber., vol. 1, p. 15)
Nodulina Rhumbler, 1895, K. Gesell. Wiss. Göttingen, Nachr., pp. 85, 86.
Protoshista [?] Eimer and Fickert, 1899, Zeitschr. Wiss. Zool., vol. 65, pp. 677, 678, text-fig. 21.
Lugtonia [?] Cummings, 1955, Micropaleontology, vol. 1, No. 3, p. 231, pl. 1, figs. 9-12, 20, text-fig. 6; Crespin, 1958, [Australia] Bureau Mineral Res., Geol. and Geophys., Bull. 48, pp. 65, 66, pl. 7, figs. 6, 7.

Type species, *Reophax scorpiurus* Montfort, 1808.

The generic definition of *Reophax* as given by Cushman (1930, p. 37) follows:

Test free, elongate, composed of several undivided chambers, ranging from overlapping to remotely separated ones connected by stolon-like necks, in a straight or curved linear series; wall single, of agglutinated material, firmly cemented, sand grains, mica scales, sponge spicules or other foraminifera; aperture simple, terminal, sometimes with a slight neck.

Cushman's generic definition for *Reophax* (1948, p. 90) differs essentially from his 1930 generic definition only in the mention of a chitinous base for the test wall.

Cummings (1955, pp. 231, 232) divided *Reophax* into two genera. *Reophax* was retained by Cummings for those forms which are agglutinate and possess stolon-like necks, while a new genus, *Lugtonia,* based on *Nodosinella concinna* Brady, 1876 as the type species, was erected with the purpose of embracing those forms which have succeeding chambers overlapping preceding chambers and a test wall of original granules of calcium carbonate in calcareous cement. Cummings placed *Lugtonia* in his new family Earlandiidae which he defined in the following manner (1955, p. 227): "Tubular or uniserial tests in which the wall is composed of equidimensional granules of calcite bound by calcareous cement."

Cummings' basis for the genus *Lugtonia* was some 450 specimens from the British Lower Carboniferous, all of which are silicified. Thus, in reality, *Lugtonia* was erected only on the basis of its possession of overlapping chambers in contrast to the presence of stolon-like necks connecting the chambers in the genus *Reophax s.s.;* Cummings noted (1955, p. 231) that, "[Lugtonia] must be distinguished on the basis of chamber form," . . . "original microstructure of wall unknown. . ." Cummings has assumed without conclusive evidence that the wall of *Lugtonia* is secondarily silicified from an original wall of calcareous granules in calcareous cement.

While discussing his specimens of *Hyperammina,* Cummings (1955, p. 234) noted: "Usually, representatives of the genus *Hyperammina* are found in the British Carboniferous in an unaltered state." It seems strange that in the British Carboniferous all *Lugtonia,* and *Reophax* to a varying degree, should be completely secondarily replaced by silica while the *Hyperammina* of that region are usually unaltered, agglutinate test with ferrugino-calcareous cement. It becomes singular when we remember that North American Mississippian and Pennsylvanian, and Australian Permian *Hyperammina* are reported to possess siliceous cement. Further, I am not convinced that all reophacids with overlapping chambers are or were originally composed of calcareous granules in calcareous cement. *Reophax* with overlapping chambers described in the present paper are composed of quartz grains in siliceous cement, not of calcareous granules in calcareous cement.

Crespin's (1958, p. 65) new species which was referred to *Lugtonia, L. thomasi,* does not fit Cummings' generic definition in that *L. thomasi* Crespin was described as: "Wall thick, finely arenaceous, composed chiefly of regular sized quartz grains in considerable cement, giving the test a smooth, polished appearance." Crespin recognized the difficulties in referring her new species to *Lugtonia;* she noted (1958, p. 35):

> Tests of certain foraminifera from Western Australia have been referred to the new genus *Lugtonia* of Cummings (1955). All features are similar to this form, but the wall of the test though polished is definitely arenaceous, quartz grains of varying size being set in a siliceous cement. Cummings placed the genus in his new family Earlandiidae as he regards the present siliceous test as secondary to granular calcareous structure. However, for the present the Western Australian specimens are included in the Reophacidae.

Further, Crespin (1958, p. 35) noted in her discussion of the genus *Hyperammina*:

> As already commented here, there seems to be little or no evidence of secondary silicification of arenaceous tests in the Australian Permian or in the rocks in which the foraminifera are found.

It is certain that the only basis for differentiation of *Lugtonia* as a distinct genus is in the lack of stolon-like necks which connect the chambers in *Reophax, s.s.* and the possession of overlapping chambers in *Lugtonia.* The overlapping of the preceding chambers by succeeding chambers may or may not be of generic significance.

Until the *Reophax, s.l.* of the world are studied as to wall structure, and the forms with overlapping chambers are found to invariably possess original calcareous granules in calcareous cement, I have no course but to use *Reophax, s.l.* and to consider *Lugtonia* as of doubtful generic status.

If it be found that the overlapping nature of the chambers is truly of generic value, then *Lugtonia* could be considered a valid genus only if it be removed from the family Earlandiidae and placed in the Reophacidae, a family of arenaceous Foraminifera.

Cummings indicated in text-figure 10 (1955, p. 235) that *Lugtonia* is known in the British Isles from the upper part of the Viséan and Namurian, with some species restricted to the Namurian. However, he records *Reophax, s.s.* (in the upper Paleozoic) throughout the Carboniferous and Permian. In the rest of the world, true *Lugtonia* has not yet been recognized, but *Reophax, s.l.* with overlapping chambers is found almost universally in the geologic column from Paleozoic to Recent. Thus, seemingly, *Lugtonia* has no wide stratigraphic significance. (See Chart 23 for stratigraphic range of *Reophax, s.l.* in the Mississippian as determined in this study.)

Reophax cf. **R. arenatus** (Cushman and Waters), 1927 Pl. 21, fig. 19; Pl. 26, fig. 12; Fig. 11

Nodosinella arenata Cushman and Waters, 1927, Cushman Lab. Foram. Research, vol. 3, p. 147, pl. 26, figs. 2, 3.
Nodosinella? arenata, Warthin, 1930, Okla. Geol. Sur., Bull. 53, p. 28, pl. 2, fig. 8.
Reophax arenatus, Plummer, 1945, Univ. Texas, Pub. 4401, pp. 225, 226, pl. 17, figs. 1-3.

Description.—Test stocky, consisting of a globular proloculus and a second distinctly pyriform chamber of a greater diameter than the proloculus; aperture at open end of tapering neck of second chamber; wall composed of fine quartz grains in a moderate amount of siliceous cement.

Measurements.—See Table 16 for measurements of *Reophax* cf. *R. arenatus.*

Comparison and affinities.—The present specimens closely resemble Plummer's figured specimens of *Reophax arenatus* (1945, pl. 17, figs. 1, 3). Only two specimens were found in the present study;

thus the range of variation of *Reophax* cf. *R. arenatus* in the Mississippian system is not known.

Stratigraphic occurrence.—*Reophax* cf. *R. arenatus* has been found only in the Rothwell shale member (Bed 8) of the Muldraugh formation at Garrison, Lewis County, Kentucky (Locality K-67).

Ecology.—The specimens of *Reophax* cf. *R. arenatus* are from a soft, clayey, plastic when wet, olive-gray to maroon shale. This shale contains only small amounts of fine to medium-sized grains. No macrofossils were observed.

Brady (1884, p. 289) noted the wide depth tolerance of *Reophax*:

> The genus *Reophax* is cosmopolitan and its bathymetrical range extends from almost the deepest portion of the sea-bottom yet explored [as determined by the Voyage of the Challenger 1873-1876] to the shallow waters of the Laminarian zone.

Reophax asper Cushman and Waters, 1928 Pl. 21, fig. 24; Fig. 15

Reophax asperus Cushman and Waters, 1928, Cushman Lab. Foram. Research, Contr., vol. 4, p. 37, pl. 4, fig. 7.

Reophax asper Cushman and Waters, 1930, Univ. Texas, Bull., No. 3019, pp. 37, 38, pl. 2, fig. 10.

Description.—Test elongate, coarse grained, consisting of five chambers which are somewhat obscure in outline due to rugosity of test wall; chambers oblate and gradually expanding in diameter; last chamber roughly pyriform; wall composed of angular quartz grains in a small amount of siliceous cement.

Measurements.—See Table 19 for measurements of *Reophax asper.*

Comparison and affinities.—The present specimen is remarkably similar to the figured type of Cushman and Waters (1930, pl. 2, fig. 10) but is slightly smaller and apparently has one less chamber. *Reophax asper* is distinctive among the species of *Reophax* considered in this paper because of the rugosity of the test.

Table 18. Measurements of *Reophax* cf. *R. arenatus* (Cushman and Waters), 1927, in mm.

specimen and type number	*length of test*	*max. diam.*	*length of last chamber*	*no. of chambers*	*diam. of proloculus*
Pl. 21, fig. 19	.746	.403	.453	2	.369
Pl. 26, fig. 12	.658	.302	.403	2	.201

Table 19. Measurements of *Reophax asper* Cushman and Waters, 1928, in mm.

	Pl. 21, fig. 24
Length of test	.570
Max. diameter	.226
Length of last chamber	.252
Number of chambers	5
Diameter of proloculus	.084

Stratigraphic occurrence.—The figured specimen was found in the Button Mold Knob member (Bed 2) of the New Providence formation at the Louisville Cement Company Quarry, Clark County, Indiana (Locality I-3).

The species was originally reported by Cushman and Waters, 1930, from the Upper Pennsylvanian of Texas.

Ecology.—*Reophax asper* probably had ecological requirements similar to the other species of *Reophax* of this study, but *R. asper* apparently "preferred" a muddy bottom in which there were sufficient quartz silt grains available for construction of a test. High concentrations of calcareous salts certainly were not required inasmuch as the species occurs in the lower part of the Button Mold Knob member of the New Providence formation which at this locality is not significantly calcareous and does not contain calcareous megafossils.

Reophax kunklerensis, new species — Pl. 21, figs. 20-23; Pl. 26, fig. 14; Fig. 12

Description.—Test small, slender, straight to gently curved, consisting of small proloculus and a succession of seven to nine moderately inflated chambers which expand in diameter evenly until the last chamber; last chamber is as broad as or only slightly broader than preceding chamber, and up to three to six times broader in diameter than the first chamber; last chamber longer than preceding chambers due to the tapering neck of the aperture and is of pyriform shape; last chamber as broad as long or nearly so, while preceding chambers are about 1.5 to 1.6 times broader than long; wall composed of rather coarse quartz grains in a small amount of siliceous cement; no dimorphism is evident.

Measurements.—Table 20 gives the measurements of *Reophax kunklerensis,* and Table 21 the range in measurements of the species.

See Table 25 under description of *R. minutissimus* for comparison of *R. kunklerensis* with that species.

Comparison and affinities.—*Reophax kunklerensis* is similar to *R. minutissimus* Plummer, 1945; however, *R. kunklerensis* is shorter and more slender and has more chambers than does *R. minutissimus*.

Reophax kunklerensis differs from *R. mcdonaldi* in that *R. kunklerensis* is shorter, has more chambers (and these chambers less rounded), is more slender, and expands more from the proloculus to the last chamber.

Type locality.—Kunkler Quarry, on hill side, south side of U.S. Highway 460, 1.3 miles west of Uniontown Post Office, Perry County, Indiana (Locality I-1). Types are from the upper shale (Bed 7) of the Menard limestone.

Stratigraphic occurrence.—*Reophax kunklerensis* is known to occur only in the lower three feet of the upper shale portion of the Menard limestone, just above the nine-and-one-half foot quarried limestone. The limestone units were merely spot checked for Foraminifera by acidization.

Ecology.—The upper shale of the Menard limestone is a marine, soft, plastic when wet, buff to tan to brown, calcareous and fossiliferous, thin-bedded unit. This fossiliferous shale, lying immediately above the main limestone unit of the formation and lying immediately below more than 10 feet of dark gray, nonfossiliferous shales, represents a depositional environment perhaps transitional from typical marine waters to quiet muddy waters of lagoons.

Reophax kunklerensis has a moderate amount of cement (at present siliceous, regardless of its original chemistry) and a considerable amount of silt particles in its test. *R. kunklerensis* was adapted to live in fine-grained calcareous muds which contained only small amounts of silt.

The invertebrate fauna of the upper shale is restricted in the number of animal groups present. The dominant groups recovered from the shale are the crinoids (many wing plates of *Pterotocrinus menardensis*), the brachiopods (thin valved *Derbya*), fenestrate bryozoans, and rare solitary lophophyllid corals. The invertebrate fossil shells are mostly complete (*i. e.*, both valves of thin-shelled brachiopods are commonly intact). Some fragmentation occurred perhaps as a result of post-depositional compaction of the shale; little breccia is present; thus, wave action was not pronounced.

The foraminiferal fauna of the Menard limestone (shale) consists of a small array of arenaceous genera which characteristically live in silty or sandy muds: *Hyperammina, Involutina,* and *Reophax.*

Remarks.—Reophax kunklerensis derives its name from the Kunkler Quarry, west of Uniontown Post Office, Perry County, Indiana.

Table 20. Measurements of *Reophax kunklerensis,* n. sp., in mm.

specimen and type number	*length of test*	*max. diam.*	*length of last chamber*	*no. of chambers*	*diam. of proloculus (or of first chamber)*
Pl. 21, fig. 20, holotype	.503	.143	.118	7.5	.050
Pl. 26, fig. 14	.529	.130	.101	8	(.042)
Pl. 21, fig. 22	.570	.134	.134	9	.037
Pl. 21, fig. 23	.590	.134	.134	9	.042
Pl. 21, fig. 21	.420	.118	.118	7	.033

Table 21. Range in measurements of eight specimens of *Reophax kunklerensis,* n. sp., in mm.

Length of test	.420-.590
Max. diameter	.118-.151
Length of last chamber	.101-.143
Number of chambers	7-9
Diam. of proloculus	.033-.050

Reophax cf. **R. lachrymosus** Gutschick and Treckman, 1959 Pl. 21, fig. 18; Pl. 26, fig. 13; Fig. 13

Reophax lachrymosa Gutschick and Treckman, 1959, Jour. Paleont., vol. 33, No. 2, pp. 240, 241, pl. 34, figs. 20-25, text-fig. 2A, 2B.

Description.—This species is represented in the present material by only two fragmentary specimens which consist of two chambers each; these chambers are elongate and pyriform; the last chamber has a length of 1.36 and 1.4 times greater than the breadth; present specimens are flattened on one side; surface of test finely granular, of fairly small quartz grains in a moderate amount of siliceous cement; color of test white and gray.

Measurements.—See Table 22 for measurements of *Reophax* cf. *R. lachrymosus.*

Table 22. Measurements of *Reophax* cf. *R. lachrymosus* Gutschick and Treckman, 1959, in mm.

specimen and type number	*length of first chamber*	*diam. of first chamber*	*length of last chamber*	*diam. of last chamber*	*locality number, formation, and bed number*
Pl. 21, fig. 18	.268	.180	.235	.185	K-58, New Providence, bed 3
Pl. 26, fig. 13	.235	.168	.252	.168	O-7, Cuyahoga, bed 4

Comparison and affinities.—The present specimens are similar to the last two chambers of Gutschick and Treckman's paratype of *Reophax lachrymosus* (1959, pl. 34, fig. 23), but the present specimens are proportionally slightly broader. *R. lachrymosus* is similar to *R. bendensis* Plummer, 1945, as Gutschick and Treckman pointed out (1959, p. 240); however, *R. bendensis* is generally much larger. Plummer (1945, pl. 17, fig. 8) shows a youthful specimen of a size nearly that of *R. lachrymosus;* however, the present specimens are somewhat broader than *R. bendensis* which has chambers 2.3 times longer than broad.

Stratigraphic occurrence.—*Reophax* cf. *R. lachrymosus* is herein recorded from the lower New Providence formation of Kentucky and the lower three feet of the Cuyahoga formation of Ohio. This species was originally described from the Rockford limestone of northern Indiana. See Charts 10, 21, and 22 for details of occurrence of *R.* cf. *R. lachrymosus* in the studied area.

Ecology.—The specimens of this species were found only in soft, plastic when wet, shales. Thus, the species was adapted to live in muddy environments with only small amounts of silt grains present.

Table 23. Measurements of *Reophax mcdonaldi,* n. sp., in mm.

specimen and type number	*length*	*max. diam.*	*length of last chamber*	*no. of chambers*	*diam. of proloculus (or of first chamber)*
Pl. 21, fig. 25,	.640	.269	.235	5	.151
Pl. 21, fig. 26	.678	.269	.319	3	.151
Pl. 21, fig. 30	.738	.302	.302	3-4	(.151)
Pl. 21, fig. 28	.658	.235	.235	4-5	(.118)
Pl. 21, fig. 29	.704	.319	.470	3	(.226)
Pl. 21, fig. 27	.622	.252	.285	3	(.134)

Table 24. Range in measurements of 13 specimens of *Reophax mcdonaldi,* n. sp., in mm. and comparison with *R. tumidulus* Plummer, 1945

	R. mcdonaldi	*R. tumidulus*
Length of test	.554-.840	1.05
Max. diameter	.201-.369	.40
Length of last chamber	.185-.470	
No. of chambers	3-5	4
Diam. of proloculus	.151	.030

Reophax mcdonaldi, new species — Pl. 21, figs. 25-30; Pl. 26, fig. 15; Figs. 14, 16

Description.—Test small, rather stocky, straight to slightly curved, with a fairly large proloculus and a succession of up to five moderately inflated chambers which enlarge in diameter only slightly in some specimens, but which in most specimens enlarge gradually up to twice the diameter of the first chamber; chambers about 1.2 to 1.5 times broader than long, except the last chamber which is as long as it is broad or nearly so, due to the tapering neck of the aperture whch gives the last chamber its broad pyriform appearance; test coarse textured, composed of quartz grains in a moderate amount of siliceous cement.

Measurements.—See Table 23 for measurements of *Reophax mcdonaldi* and Table 24 for range in the measurements of the species, and for comparison with *R. tumidulus* Plummer.

Comparison and affinities.—*Reophax mcdonaldi* most closely resembles *R. tumidulus* Plummer (1945, p. 231, pl. 17, fig. 31). However, *R. mcdonaldi* has more chambers, is shorter, less broad, and expands more than *R. tumidulus. R. mcdonaldi* differs from *R. kunklerensis* in being larger, broader, and expanding less and having fewer chambers.

Type locality.—Road cut along Vanceburg-Tannery Road, 1.25 miles south of Vanceburg, Lewis County, Kentucky (Locality K-66). Holotype and all figured measured specimens on Table 23 are from the Churn Creek shale member of the New Providence formation (Bed 9).

Stratigraphic occurrence.—*Reophax mcdonaldi* is apparently restricted to the Osagian, occuring only in the Churn Creek shale member of the New Providence formation in Kentucky and in shale in the Black Hand sandstone member of the Cuyahoga formation of Ohio. (See Charts 10 and 19-22 for details of occurrence.)

Ecology.—*Reophax mcdonaldi* is known only in shaly siltstone and shale in sandstone. The nature of the test reflects this species' "preference" for silty or sandy environments by having its wall constructed of moderate to coarse-grained silt or sand, with a small to moderate amount of siliceous cement. No megafossils are present in the enclosing sediments except for "worm markings" (poorly preserved specimens of *Scalarituba*). Thus, *R. mcdonaldi* was capable of living in muddy, sandy, waters where animals other than "worms" were apparently unable to establish themselves.

Remarks.—This new species of *Reophax* is named for Mr. Donald McDonald, Curator of the Geology Museum at the University of Louisville.

Reophax cf. **R. minutissimus** Plummer, 1945 Pl. 21, fig. 17

Reophax minutissimus Plummer, 1945, Univ. Texas, Pub. 4401, pp. 230, 231, pl. 17, figs. 25-30.

Description.—Test small (proloculus missing), consisting of four evenly and rather rapidly expanding chambers; first three chambers are moderately inflated and 1.7 to 2.7 times broader than long; last chamber as long as broad and pyriform; length of test is 1.94 times longer than width; test coarse grained, of quartz grains in siliceous cement.

Measurements.—Table 25 gives measurements of *Reophax* cf. *R. minutissimus.*

Table 25. Measurements of *Reophax* cf. *R. minutissimus* Plummer, 1945, in mm.

	Pl. 21, fig. 17
Length	.487
Max. diameter	.252
Min. diameter	.084
Length of last chamber	.252

Comparison and affinities.—This specimen closely resembles Plummer's figured paratype (1945, pl. 17, fig. 26) of *Reophax minutissimus.* The present specimen is somewhat broader than Plummer's figured specimens, but this may be due to incompleteness of the present specimen (only four chambers are preserved) and certainly one specimen could hardly exemplify a species.

Stratigraphic occurrence.—A single specimen of *Reophax* cf. *R. minutissimus* was found in the basal part of the Henley shale member (Bed 2) of the Cuyahoga formation (New Providence formation), one to two feet above the Sunbury shale at Locality K-61 (south of Hilda Post Office, Rowan County, Kentucky).

Ecology.—The Henley shale member of the Cuyahoga formation is a soft, plastic when wet, olive-gray shale with small amounts of fine to medium-sized silt grains. The absence of megafossils in the basal portion of the Henley shale at Locality K-61, and the recovery of only one specimen of *Reophax* cf. *R. minutissimus* may indicate that environmental conditions were far from optimum even for this species.

Family **TOLYPAMMINIDAE** Cushman, 1929

Subfamily **INVOLUTININAE** Cushman, 1910

Genus **INVOLUTINA** Terquem, 1862,

emend. Loeblich and Tappan, 1954

Ammodiscus Reuss, 1862, (*pars*), Akad. Wiss. Wien., Sitz., math-natu. Cl., Jahrg. 1861, 44, Abt. 1, p. 365.

Involutina Terquem, 1862, Acad. Imp. Metz, Mem., ann. 42 (ser. 2, ann. 9), 1860-1861, pp. 450, 451.

Involutina Terquem, emend. Loeblich and Tappan, 1954, Washington Acad. Sci., Jour., vol. 44, No. 10, pp. 308-310, figs. 2a, 2b.

Type species, *Involutina silicea* Terquem, 1862 (monotypic genus).

The emended generic definition of *Involutina* Terquem, 1862 as given by Loeblich and Tappan (1954, pp. 308, 309) follows:

> Test free, discoidal, with proloculus followed by an undivided planispiral tubular chamber, which slightly overlaps preceding whorls at the lateral margins; occasional irregular surficial constrictions possibly denoting stages of growth, but without internal septa; wall finely agglutinated, of sand grains with considerable cement; aperture at the open end of the tube.

Loeblich and Tappan (1954, p. 308) showed that *Ammodiscus* Reuss, 1862 is a junior synonym of *Spirillina* Ehrenberg, 1843 and that the generic name *Ammodiscus* should be suppressed. The type species of *Involutina, I. silicea* Terquem, 1862, was found to be an agglutinate form, completely undivided internally, and thus capable of embracing all species formerly relegated to the genus *Ammodiscus,* other than those forms which possess a hyaline calcareous test.

The emended definition of *Involutina* by Loeblich and Tappan did not make a definite reference to those forms of "*Ammodiscus*" which, in addition to being agglutinate and undivided internally, possess a final rectilinear portion (neck) such as *Involutina* (formerly *Ammodiscus*) *exserta*. I believe that such meaning was implied when Loeblich and Tappan (1954, p. 308) concluded: "Thus the species previously considered as *Ammodiscus* will fall in the same genus *Involutina*."

Loeblich and Tappan (1954, p. 308) removed the genus *Involutina* Terquem, 1862 from the family Silicinidae and relegated it to the family Tolypamminidae Cushman, 1929 and the subfamily Involutininae Cushman, 1910.

Chart 23 gives the range of *Involutina* in the Mississippian as determined in this study.

Involutina exserta (Cushman), 1910 Pl. 22, figs. 4-6, 8; Pl. 26, figs. 16, 17, 19; Fig. 21

Ammodiscus exsertus Cushman, 1910, United States Nat. Mus., Bull. 71, pt. 1, pp. 75, 76, figs. 97a, 97b (in text).

Involutina exserta (Cushman), Gutschick and Treckman, 1959, Jour. Paleont., vol. 33, No. 2, p. 241, pl. 35, figs. 8, 9.

Description.—Test biconcave, consisting of a small proloculus and a second chamber planispirally coiled, of two to six volutions, becoming uncoiled and aligned at nearly a right angle to preceding whorls, and in the same plane as preceding whorls; aperture formed by open end of tubular second chamber; test rough, with medium-sized grains in a moderate amount of cement (Variant 2, see Comparison and affinities); in a few cases the test is clear and glossy and made up largely of cement (Variant 1); color of test, white to gray-white to rusty.

Measurements.—See Table 26 for measurements of *Involutina exserta* and Table 27 for the range in measurements of this species.

Table 26. Measurements of *Involutina exserta* (Cushman), 1910, in mm.

specimen and type number	*diam.*	*length*	*thickness*	*no. of whorls*	*diam. proloc.*	*locality no., formation, and bed number*
Pl. 26, fig. 19	.604	.622	.118	3		K-6, New Providence, bed 4
Pl. 22, fig. 8	.335	.521	.101	3.5		K-1, New Providence, bed 2

Pl. 26, fig. 16	.269	.369	.042	3	.016	O-6, Henley, bed 10
Pl. 22, fig. 4	.335	.562	.067	3	.017	K-14, New Providence, bed 6
Pl. 22, fig. 5	.277	.302	.067	2.5		K-14, New Providence, bed 6
Pl. 22, fig. 6	.386	.521	.067	3		K-14, New Providence, bed 6
Pl. 26, fig. 17	.570	.586	.084	3.5		O-4, Bedford, bed 3

Table 27. Range in measurements of 22 specimens of *Involutina exserta* (Cushman), 1910, in mm.

Diameter of proloculus	.012-.025
Diameter of test	.235-.386
Length of test	.319-.622
Thickness of test	.033-.118

Comparison and affinities.—By reference to Tables 27 and 31 it will be seen that the infraspecific variation is as great within *Involutina exserta* as it is within *I. semiconstricta.*

The forms in the present study resemble some of those found in the Rockford limestone by Gutschick and Treckman (1959, p. 241, pl. 35, figs. 8, 9); nevertheless, most of the present forms vary considerably from the Rockford specimens in having more rugged, coarser grained tests and larger size (herein called variant 2). The whorls in the present material are usually partly or completely obscured by the rough wall texture. A comparison of two morphological features of several present specimens of *Involutina exserta* and of several of Gutschick and Treckman's forms (1959, p. 241) from the Rockford limestone follows:

	length of test	*diameter of test*
Present specimens:	.430 mm.	.362 mm.
Rockford specimens:	.410 mm.	.330 mm.

One variation of the species (herein called variant 1) is composed largely of cement with little agglutinated matter.

Stratigraphic occurrence.—*Involutina exserta* is known from: the Silurian (Moreman, 1930, p. 58; Dunn, 1942, p. 338); the Mississippian Kinderhookian Rockford limestone of Indiana (Gutschick and Treckman, 1959, p. 241); and the Recent (the holotype is from the sea off Japan).

From the stratigraphic information collected in this study, *Involutina exserta* appears to be especially abundant in the Kinderhookian and lower Osagian beds. No specimens were found in the Meramecian. With the exception of an isolated occurrence in the brown, plastic shaly part of the Menard limestone, no specimens were found in the Mississippian above the Osagian Brodhead formation of Kentucky, nor above the middle Osagian Black Hand sandstone member of the Cuyahoga formation of Ohio.

Variant 1 has been found only at the following localities and in the following stratigraphic units:

Nipgen, Ohio (Locality O-6), Cuyahoga formation, Henley shale member, lower one foot and from three to 4.5 feet (Bed 10).

Jester Hill, Bainbridge, Ohio (Locality O-7), Cuyahoga formation, Henley shale member, lower 11 feet (Bed 4).

Armstrong, Ohio (Locality O-11), plastic shale in lower 5 feet of the Black Hand sandstone (Bed 1).

(See Charts 3-7, 9-14, 16, and 18-22 for details of occurrence.)

Ecology.—Apparently *Involutina exserta* had much the same ecological requirements as *I. semiconstricta* inasmuch as the two species are in some instances associated with one another in the same beds, but *I. exserta* generally occurs in more arenaceous sediments where fine to medium silt grains are available in sufficient quantity to construct the rather stout agglutinate test (variant 2).

Involutina longexserta Gutschick and Treckman, 1959 Pl. 22, figs. 7, 9; Pl. 26, fig. 18; Fig. 22

Involutina longexserta Gutschick and Treckman, 1959, Jour. Paleont., vol. 33, No. 2, pp. 241, 242, pl. 35, figs. 10-14.

Description.—Test planispiral becoming uncoiled; coiled portion circular to oblately elliptical; second chamber coiled for a few volutions and then uncoiled at right angles to the preceding whorls, but still in the same plane; proloculus obscured by the coarse texture of the test; length of uncoiled portion of test is greater than or equal to the minimum diameter of the coiled portion; number of whorls varies from more than two to more than three; aperture circular, formed by open end of tube; wall structure arenaceous with medium coarse-grained silt and a moderate amount of insoluble cement (variant 2); color of test, white to gray.

Measurements.—See Table 28 for measurements of *Involutina longexserta* and Table 29 for range in measurements of the species.

Comparison and affinities.—I have studied paratypes of *Involutina longexserta* and am convinced of the validity of the species; however, some difficulty is experienced in deciding whether particular specimens are complete tests of *I. exserta* or fragments of *I. longexserta*. I have followed the practice of referring to *I. longexserta* only those specimens which are undoubtedly comparable to the types of the species.

The present specimens possess fewer whorls than do the studied paratypes or figured types, and most present specimens have more coarsely arenaceous wall structure with less cement than do the types. In the present material, the internal coiled portion is almost completely obscured, but enough can be observed to ascertain the presence of only a small number of whorls. As to the general shape of the test in the present material, the coiled portion is less circular in outline than that of the types, although two specimens do resemble three of the Rockford types (Gutschick and Treckman, 1959, pl. 35, figs. 12-14) including the holotype. None of the forms in the present material attains the maximum length of the Rockford specimens (.91 mm.); however, some of the present material closely approaches this dimension. On the other hand, the diameter of the coiled portion of the present specimens varies from .269 to .470 mm. while the diameter of the coiled portion of the original types of *I. longexserta* ranges only from .210 to .270 mm.

The range of variation within *Involutina longexserta* can readily be appreciated from the above statements and by reference to Table 29.

Stratigraphic occurrence.—*Involutina longexserta* was originally described from the Rockford limestone of northern Indiana (Gutschick and Treckman, 1959).

As determined in this study, *I. longexserta* has a stratigraphic range from the Upper Devonian New Albany shale to the lower New Providence formation. (See Charts 3, 5, 6, 9, 11-13, 16, 18 and 22 for details of occurrence.)

Ecology.—Apparently *Involutina longexserta* required much the same type of environment as did both *I. exserta* and *I. semiconstricta*. The species occurs more frequently in the fine- to medium-grained, silt-bearing New Providence shales than in the less silty Kinderhookian shales; this, coupled with the observation that the present tests of *I. longexserta* are of medium coarse arenaceous texture with a moderate amount of cement, seems to indicate an inherent "preference" for an arenaceous environment.

Gutschick and Treckman's types of *Involutina longexserta* possess a clearer and more glossy test than do the specimens observed in this study. The fine-grained texture of the Rockford tests is probably due to the more calcareous and less silty nature of the sediments in the Rockford limestone.

Table 28. Measurements of *Involutina longexserta* Gutschick and Treckman, 1959, in mm.

specimen and type number	*diam.*	*length*	*thickness*	*no. of whorls*	*locality number, formation, and bed number*
Pl. 26, fig. 18	.335	.739	.109	2?	K-13, Coral Ridge, bed 2
Pl. 22, fig. 9	.404	.720	.084	2?	K-13, Coral Ridge, bed 2
Pl. 22, fig. 7	.269	.554	.067	2?	K-57, Bedford, bed 6

Table 29. Range in measurements of 12 specimens of *Involutina longexserta* Gutschick and Treckman, 1959, in mm.

Diameter	.269-.470
Length	.394-.899
Thickness	.033-.134

Involutina semiconstricta (Waters), 1927 Pl. 22, figs. 1-3; Pl. 26, fig. 20; Fig. 20

Ammodiscus semiconstrictus Waters, 1927, Jour. Paleont., vol. 1, p. 132, pl. 22, fig. 1.

Ammodiscus semiconstrictus var. *regularis* Waters, 1927, Jour. Paleont., vol. 1, p. 132, pl. 22, fig. 2.

Cornuspira semiconstrictus, Harlton, 1933, Jour. Paleont., vol. 7, pp. 9, 10, pl. 2, figs. 2a, 2b.

Involutina semiconstrictus (Waters), Loeblich and Tappan, 1954, Washington Acad. Sci., Jour., vol. 44, No. 10, p. 306.

Description.—Test planispiral, circular, biconcave; test in some instances elliptical as a result of secondary distortion; diameter of test .210 to .594 mm.; proloculus small, .008 to .028 mm. in diameter, spherical to elliptical in form; second chamber tubular, planispiral, of three to eight whorls, and moderately constricted externally; aperture circular in cross-section, formed by the open end of tube; medium-sized specimen has an apertural diameter of .37 mm.; wall composed of siliceous grains in siliceous cement; color of wall, gray to orange-buff to white.

Two general variations in test composition are recognized in the Mississippian forms of *Involutina semiconstricta*: Variant 1, clear and glossy and dominantly of cement with little agglutinate material; Variant 2, more robust test with much more agglutinate material and less cement. These variants are discussed under ecology.

Measurements.—See Table 30 for measurements of several Mississippian specimens and Table 31 for range in measurements and comparison with Pennsylvanian forms.

Comparison and affinities.—I have examined specimens from Plummer's Pennsylvanian localities in Texas and agree with her (1945, p. 232) in considering *Involutina semiconstricta* var. *regularis* (Waters) to be synonymous with *I. semiconstricta* (Waters). However, I am not convinced that *I. semiconstricta* var. *regularis* is a juvenal form of *I. semiconstricta;* rather, I believe that the relationships between the diameter of test, thickness of test, number of whorls, and size of proloculus indicate wide individual variation in adult forms in regard to these anatomical features. The wide infraspecific variation in *I. semiconstricta* can be appreciated by reference to Table 31.

By measurement and study of the various anatomical features of *Involutina semiconstricta* attempts were made to uncover evidence of change within the species with time. There seems to be a trend toward increase in the test diameter with decreasing geologic age. The Devonian beds were found to yield the smallest known tests of *I. semiconstricta;* the largest recorded tests of the species are found in the Pennsylvanian. Within the Mississippian sequence, the Chesterian *I. semiconstricta* are the smallest, with the Kinderhookian next largest and the Osagian forms still larger, but smaller than the Pennsylvanian forms. The small average size of the Chesterian specimens presents the exception to the gradual increase in size, and may be the result of insufficient sampling of Chesterian beds; the Chesterian beds sampled in this study yielded few smaller Foraminifera.

As regards the number of whorls per test, the Pennsylvanian forms possess the largest number (as many as 10 whorls). In the Mississippian materials studied, the Kinderhookian forms of *Involutina semiconstricta* have the greatest number of whorls (up to eight); this number of whorls is comparable to that which I observed in medium-sized specimens of *I. semiconstricta* from Plummer's Pennsylvanian material. The Chesterian forms possess the least number of whorls (up to 5) while the Osagian and Devonian forms possess less (up to 6½ and 7) than the Kinderhookian forms, but more than the Chesterian forms.

Stratigraphic occurrence.—Involutina semiconstricta has a rather wide stratigraphic distribution in the North American Upper Paleozoic sequence. The species was first described from the Pennsylvanian of Oklahoma (Waters, 1927); Plummer (1945) reported the species from the Pennsylvanian of Texas; Gutschick and Treckman (1959) found it in the Kinderhookian Rockford limestone of northern Indiana.

Involutina semiconstricta is herein recognized from Upper Devonian, Kinderhookian, Osagian, and Chesterian beds. It is especially abundant in the Kinderhookian and lower Osagian beds. The highest known Osagian examples of *I. semiconstricta* are in the fine-grained, olive-gray shale streaks in the Black Hand sandstone of Ohio. No Meramecian forms were found. (See Charts 3-14 and 16-23 for details of occurrence.)

Ecology.—Involutina semiconstricta is recorded dominantly from soft, fine-grained, plastic shales which have fine to medium-sized silt grains; these beds usually have a paucity of marine megafossils. *I. semiconstricta* is in some instances (as in the Bedford shale) found in association with carbonaceous matter and chitinized land spores of the genus *Tasmanites* and other spores. *I. semiconstricta* is also known to the writer from the semilithographic limestone of the Louisiana limestone at Louisiana, Missouri. Thus, it seems well established that the species "preferred" fine-grained sediments.

The variation in the composition of the agglutinated test is believed to be due to ecological conditions present on the sea bottom at the time of deposition of the sediments. For example, in the Upper Devonian part of the New Albany shale of Kentucky, the Eulie shale (New Albany equivalent) of Tennessee, the Kinderhookian Rockford limestone and Jacobs Chapel shale of southern Indiana, the Bedford and Sunbury shales of eastern Kentucky, the basal few feet of the Osagian Henley shale of Ohio, and the shale in the Black Hand sandstone of Ohio, *Involutina semiconstricta* is present in the form of Variant 1, a clear and glossy test with a great proportion of cement and little agglutinated material. In these aforementioned sediments only small amounts of small grain-sized material are available for building an agglutinate test. For these reasons, the cement secreted by the protoplasm makes up most of the test, thus producing a depauperate skeleton. Two specimens of Variant 1 were also recovered from the dark, soft shales of the Chesterian Kinkaid formation.

In a study of the Upper Pennsylvanian (Virgilian) microfauna of the Deer Creek formation of Kansas and northern Oklahoma, *Involutina semiconstricta* was the only species of Foraminifera found in the strictly black fissile shale member (Larsh-Burroak shale) (Conkin, B., 1954, p. 16); these black shales in the Pennsylvanian cyclothems are seemingly similar lithologically to the Devonian black shales.

The occurrence of *Involutina semiconstricta* in the Mid-Continent Pennsylvanian black shales and in the small gray-green shale lenses within the Devonian "Black shale" demonstrates the ability of this species to live under unfavorable environmental conditions. Reducing conditions, low pH (with consequent unavailability of calcareous and ferruginous-calcareous salts for cementation of arenaceous grains to make an agglutinate test) would militate against support of all life except the most hardy and unspecialized forms (or forms particularly specialized to live in stagnant reducing conditions).

In more arenaceous beds and in better aerated waters, such as those found in the Osagian, the tests of *Involutina semiconstricta* are found to be more robust, to have a more granular appearance, and to have a smaller percentage of cement compared to arenaceous material.

Thus, the occurrence of *Involutina semiconstricta* in various kinds of sediments (fissile black shale; sublithographic limestone; green gray, blue gray, and buff plastic shales; gray and spore-bearing carbonaceous shales; silty shales; and soft, plastic, green-gray shales within black fissile shales) demonstrates eloquently the versatility of the species in adapting to various ecological conditions existent in diverse sites of sedimentary deposition. The more conservative, the more unspecialized nature of the species would also account for the geologic longevity of *I. semiconstricta*.

Table 30. Measurements of *Involutina semiconstricta* (Waters), 1927, in mm.

specimen and type number	*max. diam.*	*thick-ness*	*no. of whorls*	*diam. of proloc.*	*locality number, formation, and bed number*
Pl. 22, fig. 2	.537	.090	5	.021	K-23, Paint Creek, bed 1
Pl. 22, fig. 1	.420	.033	8	.016	I-4, Jacobs Chapel, bed 1
Pl. 26, fig. 20	.330	.067	6	.016	I-4, Rockford, bed 2
Pl. 22, fig. 3	.352	.033	6.5	.016	T-2, Eulie, bed 2

Table 31. Range in measurements of 21 specimens of *Involutina semiconstricta* (Waters), 1927, in mm.

	Present specimens	*Pennsylvanian forms*
Maximum diameter	.210-.594	.393-1.525
Thickness	.017-.101	.059-.166
No. of whorls	3-8	5-10
Diam. of proloculus	.008-.050	.008-.055

Genus **GLOMOSPIRA** Rzehak, 1888

Trochammina Jones and Parker, 1880, (*pars*), Quart. Jour. Geol. Soc., v. 61, p. 304.

Glomospira Rzehak, 1888 Verb. k.k. Geol. Reichs., p. 191; Cushman, 1928, Cushman Lab. Foram. Research, Special Publ. No. 1, p. 102.

Gordiammina Rhumbler, 1895, Nachr. Ges. Wiss. Göttingen, p. 84.

Type species, *Trochammina gordialis* Jones and Parker, 1860 (monotypic genus).

Cushman's (1948, p. 96) generic definition of *Glomospira* follows:

Test free, with a proloculum and long, tubular, undivided, second chamber winding about its earlier coils in various planes; wall arenaceous with much cement; aperture at the end of the tube.

All specimens studied in this paper were composed of quartz grains in insoluble silica cement.

Chart 23 shows the range of *Glomospira* in the Mississippian as determined in this study.

Glomospira articulosa Plummer, 1945 Pl. 22, fig. 10; Pl. 27, fig. 1; Fig. 17

Glomospira articulosa Plummer, 1945, Univ. Texas, Pub. 4401, p. 233, pl. 16, figs. 21-25; Ireland, 1956, Jour. Paleont., vol. 30, No. 4, p. 847, text-fig. 4, figs. 7-10; Gutschick and Treckman, 1959, Jour. Paleont., vol. 33, No. 2, pp. 242, 243, pl. 35, figs. 17-19.

Description.—Test consists of a proloculus (usually not visible) and a gradually expanding tubular second chamber which coils around itself in a haphazard manner so as to form a tightly wound knot of varying, but always compact, shape; aperture at open end of tube; wall fine grained with siliceous grains in siliceous cement; color of wall, white to gray to yellow gray.

Measurements.—See Table 32 for measurements of *Glomospira articulosa.*

Comparison and affinities.—Because of variability within the species no two specimens look exactly alike; however, the present specimens are conspecific with the specimens figured by Plummer (1945, p. 233) and by Gutschick and Treckman (1959, pp. 242, 243).

The present examples of *Glomospira articulosa* are in general of the same size as those figured by Gutschick and Treckman (1959) and by Plummer (1945), but a few specimens are larger than most members of the species; Ireland's (1956, text-fig. 4-7-10) figured specimens are generally smaller.

Stratigraphic occurrence.—Glomospira articulosa was recorded by Plummer (1945, p. 233) from the Lower and Middle Pennsylvanian of Texas; the species was reported from the Upper Pennsylvanian of Kansas by Ireland (1956, p. 847). Gutschick and Treckman (1959, p. 242, 243) reported the species from the Rockford limestone of northern Indiana.

In the present work, *Glomospira articulosa* was found in the

Kinderhookian and Osagian beds, but not stratigraphically above them. (See Charts 4, 6, 9-13, 16 and 18-22 for details of stratigraphic occurrence.)

Ecology.—*Glomospira articulosa* occurs in the Mississippian of the studied region primarily in clayey, plastic shales without significant carbonates. However, *G. articulosa* was adapted to live in the calcareous mud environment that existed on the sea bottom during deposition of the Rockford limestone. The possibility of the Rockford limestone having been deposited in a lagoon is discussed in the section on *Hyperammina rockfordensis.*

Cushman noted (1928, p. 102) that Recent species most commonly occur in cool water. Perhaps the shape (coiled like a ball of twine, the "Gordian Knot" of Plummer, 1945) was an adaptation (not in Lamarckian sense) which afforded considerably more strength and resistance to breaking of the test in moderately agitated waters.

Table 32. Measurements of *Glomospira articulosa* Plummer, 1945, in mm.

specimen and type number	*max. diam. of test*	*max. diam. of tube*	*locality number, formation, and bed number*
Pl. 22, fig. 10	.520	.150	K-23, New Providence, bed 3
Pl. 27, fig. 1	.470	.200	O-7, Cuyahoga, bed 4
16 specimens	.310-.806	.080-.370	

Genus **LITUOTUBA** Rhumbler, 1895

Lituotuba Rhumbler, 1895, Nachr. Kongl. Gesell. Wiss. Göttingen, p. 83.
Trochammina Brady, 1879, Quart. Jour. Micros. Sci., (N.S.), vol. 19, p. 59, pl. 5, fig. 6.

Type species, *Trochammina lituiformis* H. B. Brady, 1897 (designated by Cushman, 1910).

Rhumbler's (1895, pp. 83, 84) description of the genus *Lituotuba* follows:

Ich vereinige in diesem Genus alle diejenigen biformen Arten der von Butschle und Neuwage schon als chaotisch erkannter Ordnung *Trochammina,* deren Anfang spiral eingerollt, deren Ende aber noch gerade gerstrecht ist. Hierher also; *Lituotuba* (*Trochammina*) *filum* Schmid; *Lituotuba centrifuga* (Brady); *L. lituiformis* (Brady). Fossil in Kohlenkalk.

Chart 23 shows the stratigraphic range of *Lituotuba* in the Mississippian of the studied area.

Lituotuba semiplana, new species Pl. 22, figs. 11, 12; Pl. 27, fig. 2; Fig. 18

Description.—Test free, consisting of a spherical proloculus and tubular undivided second chamber which coils in nearly the same plane for 2¼ to 2½ whorls, then uncoils and becomes rectilinear, with the rectilinear portion in nearly the same plane and directed at right angles to the preceding part of the second chamber; aperture circular, somewhat constricted; wall of second chamber with slight constrictions externally; wall of fine siliceous grains in siliceous cement; color white to gray.

Measurements.—See Table 33 for measurements of *Lituotuba semiplana* and comparison with *L. exserta* Moreman, 1930.

Comparison and affinities.—*Lituotuba semiplana* has close affinities to *L. exserta* Moreman, 1930 but differs from *L. exserta* in having (1) nearly planispiral coils, (2) lesser number of whorls (about 2½ in *L. semiplana*, but 4 to 5 in *L. exserta*), (3) slight external constrictions, and (4) smaller size.

Type locality.—North of Garrett Creek Church, north of Westmoreland, Sumner County, Tennessee (Locality T-2). The holotype is from the Eulie shale (Bed 4).

Table 33. Measurements of *Lituotuba semiplana,* n. sp., in mm. and comparison with *L. exserta* Moreman, 1930

specimen and type number	*diam. of proloc.*	*max. diam. of tube*	*length of test*	*max. diam. of test*	*max. diam. of neck*	*min. diam. of neck*	*diam. of aperture*
Pl. 22, fig. 11, holotype	.02	.08	.269	.20	.08	.07	.03
Pl. 22, fig. 12	.03	.07	.290	.20	.10	.06	.03
Pl. 27, fig. 2	.05	.07	.290	.24	.10	.07	.03
L. exserta				.34-.48			

Stratigraphic occurrence. — *Lituotuba semiplana* has been recovered from the Kinderhookian Eulie shale of Tennessee (Locality T-2, Bed 4) and the lower Osagian New Providence formation in Kentucky (Locality K-52, Bed 8; Locality K-6, Bed 2).

Ecology. — *Lituotuba semiplana* occurs in the noncalcareous parts of the Eulie and lower New Providence shales, where invertebrate megafossil assemblages are absent. The species required a sediment with fine siliceous grains with which to construct its test.

Subfamily TOLYPAMMININAE

Genus TOLYPAMMINA Rhumbler, 1895

Hyperammina Brady, 1879, (*pars*), Quart. Jour. Micr. Sci., vol. 19, p. 33; *idem,* 1884, (*pars*), Rept. Voyage Challenger, Zool., v. 9, pp. 260, 261.

Tolypammina Rhumbler, 1895, Nachr. Kon. Ges. Wiss. Göttingen, p. 83; Cushman, 1910, United States Nat. Mus., Bull. 71, p. 66; *idem,* 1928, The Foraminifera, Cambridge, p. 98.

Serpulella Eimer and Fickert, 1899, Zeitschr. Wiss. Zool., vol. 65, p. 674.

Type species, *Hyperammina vagans* Brady, 1879 (original designation, by Rhumbler, 1895, p. 83).

Description.—Rhumbler's (1895, p. 83) original description of *Tolypammina* follows the definition of his subfamily Girvanellinae (now obsolete):

> Gehäuse mehr oder weniger festgewachsen, mit kugliger oder ovaler Anfangskammer, sonst eine gleich weite Röhre darstelland, welche sich in unregelmässigen Hin-und Herwindungen aufknäuelt.

The generic definition of *Tolypammina* as given by Cushman (1910, p. 66) follows:

> Test typically adherent by its under surface, but may become free, consisting of an elongate oval proloculum and a long irregular tube, unbranched, composed of sand grains and reddish brown cement.

There has been some doubt as to the relationship between *Tolypammina* and *Ammovertella.* The salient generic characteristics of the two genera have been critically reviewed and commented upon by Ireland (1956, p. 838):

> The test of *Tolypammina* is generally a free tube circular in cross-section and attached only in the initial stage and at various points in the later stage where support of the long tube is needed. Growth of the tube is always in random directions. The lower wall of the tube, where attached, is generally of agglutinated particles, though in some cases the surface of the object of attachment is used as part of the lower wall. The initial stage may be straight, slightly coiled, or with one or two whorls . . . *Ammovertella* is generally attached throughout the length of the tube, but the terminal portion may be unattached and circular in outline. Growth from the proloculus is sinuous, back and forth in a plane with test generally enlarging in the same direction. In the final stage the tube may make a partial or complete encirclement of the early portion of the test. A lower wall is not found because the surface of attachment serves as the bottom of the test; and the cross-section of the tube is semi-circular, flat on the bottom and convex on top. Tubes bent back over the top of the test use the older portions of the tube as a bottom surface.

Ireland apparently overlooked that part of Cushman's description of *Ammovertella* (1928, p. 98) in which the early planispiral portion of the tube is mentioned. Thus, like *Tolypammina, Ammovertella* may or may not be planispirally coiled initially.

Generic differentiation between *Tolypammina* and *Ammovertella* usually has been made upon the basis of summation and analysis of the nature of: (1) attachment (or nonattachment or degree of attachment), (2) winding of the second chamber, (3) presence or absence of lower wall (and method of construction), and (4) cross-sectional shape of the proloculus and second chamber; nevertheless, there are instances of gradation between the two genera, and in some cases it has been difficult to make generic allocation of doubtful species.

Gutschick and Treckman (1959, p. 241) recognized the problems involved in differentiation of species of *Tolypammina* and *Ammovertella* as follows:

> We are following the diagnosis outlined by Ireland (1956, p. 838) for the characteristics of this genus [*Tolypammina*]. It must be recognized that such vermicular adnascent tests show great variation which makes it difficult taxonomically. We find that some Rockford tolypamminids contradict some of Ireland's criteria for distinguishing between *Tolypammina* and *Ammovertella*. The semi-circular cross-section of the tube is like *Ammovertella;* the presence of an agglutinate floor wall is like *Tolypammina*. Coiling in the early stages is characteristic of *Tolypammina;* [Here, as Ireland, Gutschick and Treckman make no mention of the planispiral nature of the early portion of *Ammovertella* as originally described by Cushman] however when the forms have one or two whorls in the early stage, a semi-circular second chamber, and may or may not have a wall along the surface of attachment, it is difficult to decide to which genus they belong. The attached tests, early development of coiling, and the late uncoiling into simple tube, not writhing, seems to favor their assignment with *Tolypammina*.

A practical method, and I believe the best means, of differentiation between *Tolypammina* and *Ammovertella* is offered here. The basis for generic differentiation lies primarily in the configuration of the second chamber with other characters considered of secondary significance.

The second chamber of *Tolypammina* is sinuous and tortuous but does not wind in the same general plane, and the windings of the second chamber do not fuse into a planoconvex unit. *Tolypammina* is more or less free of attachment, with the tubular second chamber rounded in cross-section where free, and semicircular in cross-section where attached.

In contrast to *Tolypammina, Ammovertella* exhibits a sinuous, tortuous, (back and forth) maze of windings of the second chamber in the same general plane; this maze of windings is fused into a planoconvex unit. The floor of the test (if present) is more or less flat, depending on the nature of the surface to which it is attached; the sides and top of the test are convex. The latter portion of the second chamber may utilize the earlier portions as bases for attachment.

In summary then, the principle generic characteristic of *Ammovertella* is considered to be the winding back and forth of the second chamber in the same general plane with the fusion of the winding tube into a planoconvex unit; initial portion of the tube may be planispiral.

Inasmuch as little is known concerning the test wall of arenaceous Foraminifera, I am unwilling to undertake a detailed speculation on the original wall composition of Paleozoic *Tolypammina* and *Ammovertella*. The present specimens are arenaceous, consisting of siliceous grains in siliceous cement (regardless of original composition). A more or less detailed consideration of the original wall composition and structure would follow the lines of the discussions of wall composition and structure of *Hyperammina* (Conkin, 1954; Cummings, 1955; and Conkin, 1956); such course, at present state of knowledge of wall structure of Paleozoic Foraminifera, most likely would be unfruitful.

Chart 23 shows the stratigraphic range of *Tolypammina* in the Mississippian as determined in this study.

Tolypammina botonuncus Gutschick and Treckman, 1959
Pl. 22, fig. 13; Fig. 24

Tolypammina botonuncus Gutschick and Treckman, 1959, Jour. Paleont., vol. 33, No. 2, p. 245, pl. 36, figs. 15, 16.

Description.—Test attached, consisting of a bulbous proloculus, followed by a tubular, undivided, second chamber (with a thin floor wall); second chamber coils around and closely embraces the proloculus for about 3/4 whorl, then narrows and bends almost at a right angle, then finally uncoils to form a straight tube which expands gradually; proloculus only moderately elevated above the level of the 3/4 planispiral whorl of the second chamber; cross-section of the second chamber rather triangular (controlled by mode of attachment); wall finely arenaceous with siliceous silt in siliceous cement (regardless of original composition of the test wall); color of test, gray to white-gray.

Measurements.—See Table 34 for measurements of present specimen of *Tolypammina botonuncus* and comparison with Gutschick and Treckman's types of the species.

Comparison and affinities.—Gutschick and Treckman (1959, p. 245) discussed the species *Tolypammina botonuncus*:

> The species is characterized by its button-hook shape with less than one whorl of the second chamber, constrictions at the bend, and linear portion of the mature part of the test. It is similar to *Tolypammina cyclops,* n. sp., but does not have the complete coil around the proloculus, is smaller, and more unidirectional.

The present specimen compares well with the original description of the species by Gutschick and Treckman; the only differences noted were that the present hypotype has generally smaller size, less height to the proloculus (not projecting much above the level of the 3/4 planispiral whorl), a triangular cross-section of the second chamber, and a small irregular wedging to the second chamber.

Stratigraphic occurrence.—*Tolypammina botonuncus* is recorded only from the Kinderhookian Rockford limestone of northern Indiana (Gutschick and Treckman, 1959, p. 245) and in this study from the Rockford limestone of southern Indiana (Locality I-4, Bed 2).

Ecology.—Apparently *Tolypammina botonuncus* had much the same ecological requirements as the other species of *Tolypammina.*

Remarks.—Only one specimen of this species was found in this study.

Tolypammina cyclops Gutschick and Treckman, 1959 Pl. 22, figs. 14, 15; Pl. 27, fig. 3; Fig. 25

Tolypammina cyclops Gutschick and Treckman, 1959, Jour. Paleont., vol. 33, No. 2, pp. 245, 246, pl. 36, figs. 1, 2, 4, 6, 7, 10-14.

Description.—Test attached, composed of a spherical proloculus and a tubular second chamber, semicircular in cross-section; second chamber coils a little more than one time around the proloculus before uncoiling; uncoiled portion describes a sinuous path; height of proloculus greater than the second chamber and projects above the level of the coiled portion; second chamber partially floored with a thin layer of arenaceous material of siliceous grains in siliceous cement; wall of test composed of siliceous grains in siliceous cement; color of test, white to light gray.

Measurements.—See Table 35 for measurements of hypotypes of *Tolypammina cyclops.*

Comparison and affinities.—The three present measured specimens closely resemble Gutschick and Treckman's species and two of them fit well within the range of measurements given for the types of *Tolypammina cyclops*. The third specimen of the present material however, is much larger than those figured by Gutschick and Treckman (1959, pl. 36, figs. 1, 2, 4, 6, 7). The figures 10-14 on plate 36 of Gutschick and Treckman are of large size; nevertheless, the third specimen of the present material is still larger.

Stratigraphic occurrence.—*Tolypammina cyclops* was originally described from the Rockford limestone of northern Indiana. *T. cyclops* was found sparingly in the Rockford limestone and Jacobs Chapel shale in southern Indiana, and in the lower New Providence and Cuyahoga formations. (See Charts 3-5, 10-12, 21, and 22 for details of occurrence.)

Table 34. Measurements of *Tolypammina botonuncus* Gutschick and Treckman 1959, in mm. and comparison with holotype and paratype

	Pl. 22, fig. 13	*Holotype*	*Paratype*
Length of test	1.02	.85	1.20
Diam. of proloculus	.12	.15	.14
Diam. of whorl	.18	.24	.22
Min. diam. of tube	.07	.08	.08
Max. diam. of tube	.16	.14	.13

Table 35. Measurements of *Tolypammina cyclops* Gutschick and Treckman, 1959, in mm.

specimen and type number	*diam. of proloc.*	*length of test*	*diam. of coiled portion*	*diam. of end of tube*	*locality number, formation, and bed number*
Pl. 27, fig. 3	.084	.403	.168	.092	I-4, Rockford, bed 2
Pl. 22, fig. 14	.101	1.450	.252	.151	I-4, Rockford, bed 2
Pl. 22, fig. 15	.235	.692	.570	.252	I-4, Jacobs Chapel, bed 1

Ecology.—This species undoubtedly had much the same ecological requirements as *Tolypammina jacobschapelensis.*

Tolypammina jacobschapelensis, new species Pl. 22, figs. 16-21; Pl. 27, fig. 5; Fig. 23

Description.—Test consists of an attached proloculus and a second chamber in the form of a long, aimlessly sinuous tube, semicircular in cross-section, and attached throughout its length, or becoming unattached near its end; proloculus in the shape of half an egg and usually somewhat pointed at the initial larger end, though in some instances the initial end is rounded; apertural end broken off all specimens; the surface of attachment of the proloculus and the tubular second chamber may be partially or entirely covered with a thin floor, or the floor may be absent altogether; tube usually enlarges gradually but may maintain its initial diameter which is from about one-half to three-fourths the diameter of the proloculus, or rarely the tube may diminish in diameter; wall finely granular, composed of quartz grains in siliceous cement; color of test white, rarely reddish-orange.

Measurements.—Measurements of *Tolypammina jacobschapelensis* are given in Table 36, and the range in the measurements of this new species and comparison with *T. cyclops* are given in Table 37.

Comparison and affinities.—*Tolypammina jacobschapelensis* is somewhat similar to *T. cyclops* Gutschick and Treckman, 1959, from the Rockford limestone of northern Indiana, but the second chamber of *T. jacobschapelensis* does not coil around the proloculus, and the proloculus of *T. jacobschapelensis* is usually pointed at its tip rather than being completely spherical; furthermore, the proloculus of *T. jacobschapelensis* is attached, while that of *T. cyclops* is unattached.

Type locality.—Campbell's (1946, p. 856) type locality for the Jacobs Chapel shale, one mile west of Jacobs Chapel, Clark County, Indiana (Locality I-4). The holotype and paratypes are from the Rockford limestone (Bed 2).

Stratigraphic occurrence.—*Tolypammina jacobschapelensis* has been found only in the Rockford limestone in southern Indiana and in the lower New Providence formation in northwestern Kentucky. (See Charts 3, 4, 11, 12, and 22 for details of occurrence.)

Table 36. Measurements of *Tolypammina jacobschapelensis,* n. sp., in mm.

specimen and type number	*diam. of proloculus*	*length of proloculus*	*diam. of tube near proloculus*	*diam. of end of tube*	*length of test*
Pl. 22, fig. 18	.084	.101	.050	.252	2.000
Pl. 22, fig. 17	.151	.185	.084	.134	1.500
Pl. 22, fig. 16 holotype	.134	.201	.101	.193	1.500
Pl. 22, fig. 20	.269	.285	.118	.134	.800
Pl. 22, fig. 21	.252	.386	.201	.285	2.100
Pl. 27, fig. 5	.134	.193	.088	.151	.950
Pl. 22, fig. 19	.193	.201	.101	.151	.650

Table 37. Range in measurements of 22 specimens of *Tolypammina jacobschapelensis,* n. sp., in mm. and comparison with *T. cyclops* Gutschick and Treckman, 1959

	T. jacobschapelensis	*T. cyclops*
Diameter of proloculus	.084-.269	.075-.150
Length of proloculus	.101-.285	.09-.15
Diam. of tube near proloc.	.050-.201	—
Diam. of end of tube	.084-.285	.06-.20
Length of test	up to 2.10	up to ca. 2.0

Ecology.—The environment of deposition of the sediments of the Rockford limestone is discussed in the present work under the ecological portion of *Hyperammina rockfordensis.*

The Jacobs Chapel calcareous shale bears a diminutive macrofauna of rather varied groups of organisms, including microblastoids, brachiopods, and snails; however, the ostracodes and Foraminifera do not show signs of "dwarfing".

Both the Rockford limestone and the Jacobs Chapel shale have diminutive faunal elements which are reminiscent of the "dwarf" macrofauna of the Louisiana limestone of Missouri; thus, it seems clear that the Rockford limestone and Jacobs Chapel shale present evidence of somewhat restricted environmental conditions of deposition, perhaps sedimentation in calcareous muddy lagoons, or depositional sites closely associated with such lagoons. In lagoonal environments, water depth would be shallow and the water should be slightly agitated. The land close at hand could act as a source for the green phosphatic substance which mottles the Rockford limestone.

I have observed that Mississippian species of *Tolypammina* are found mostly in dense (fine-grained to semilithographic) limestones, sometimes associated with algal limestones.

In some beds, such as the Greenbrier limestone of West Virginia, *Tolypammina* is present almost to the exclusion of other Foraminifera and thus presumedly was able to live under environmental conditions unfavorable to other Foraminifera. Only one other genus of Foraminifera, *Climacammina,* has been reported from the Greenbrier limestone of West Virginia (Flowers, 1956, p. 10).

Near White Sulphur Springs, Greenbrier County, West Virginia, I collected *Tolypammina* in abundance from dense limestone in the upper and middle parts of the Greenbrier limestone. The association of *Tolypammina* at this locality with well-preserved dasycladacean algae is proof of shallow water. Oölites are abundantly present which indicates at least slightly agitated water. It follows necessarily from the limestone lithology of oölites and the green calcareous algae, that the sea water was alkaline and supersaturated with calcium bicarbonate.

The mostly attached and encrusting nature of the *Tolypammina* may account for the ability of such animals with seemingly delicate, sinuous, long, and tubular tests to maintain themselves in shallow, somewhat agitated water.

Tolypammina is thus seen to be characteristically associated with calcareous shales and argillaceous limestones, in near shore warm waters of shallow depth. The associated diminutive faunal elements lend evidence for a somewhat restricted environment, not promoting development of macrofossil assemblages of robust or even normal-sized individuals; the depositional site may have been a lagoonal or shoal area.

Remarks.—This new species is named for the type locality of the Jacobs Chapel shale and thus is based on a geographic name.

Tolypammina laocoon, new species Pl. 22, fig. 23; Fig. 26

Description.—Test free in its early portion, consisting of a large spherical proloculus followed by a tortuously coiled, glomospiroid, undivided, rather tightly embracing, second tubular chamber; the coiling in the holotype is in this manner: from the proloculus the second chamber describes a small and tight U-shaped loop which turns back toward the proloculus and passes beneath the proloculus and a part of the U-shaped loop; the second chamber then continues in a tight coil around the proloculus for the distance of one whorl (nearly planispirally coiled), the first formed loop being used as part of the attachment; the loop and end of the spiral chamber are in, or nearly in, conjunction one with another; the coil then abruptly bends downward and progresses to the other side of the test (or left), then continues across the diameter of the cross-section of test; the remaining portion of the second chamber then abruptly bends downward and finally turns upward to form a gradually enlarging linear and rounded tube; test rather robust; test wall finely arenaceous, of siliceous grains in siliceous cement (regardless of original composition); apertural end of tube broken off; color of wall, white to gray-white.

Measurements.—See Table 38 for measurements of *Tolypammina laocoon.*

Table 38. Measurements of *Tolypammina laocoon,* n. sp., in mm.

	Pl. 22, fig. 23, holotype
Length of test	.76
Diam. of proloculus	.10
Diam. of coiled portion	.23
Length of coiled portion	.21
Min. diam. of tube	.08
Max. diam. of tube	.13

Comparison and affinities.—*Tolypammina laocoon* has no close affinities to any know *Tolypammina.* Although superficially somewhat similar to *T. botonuncus, T. laocoon* differs from *T. botonuncus* in that it: (1) is free (unattached) in early portion, (2) has a rounded tubular second chamber, and (3) has a glomospiroid configuration in the initial portion of the second chamber.

Type locality.—Jacobs Chapel, southern Indiana (Locality I-4); type locality for Jacobs Chapel shale; holotype is from the Rockford limestone (Bed 2).

Stratigraphic occurrence.—*Tolypammina laocoon* is recorded only from the Rockford limestone.

Ecology.—*Tolypammina laocoon* apparently "preferred" fine-grained shales and calcareous muds. The tortuously coiled earlier portion of the test may have been an adaptation to strengthen the test and may have acted as a substitute for the stability of a more attached living habit.

Remarks.—*Tolypammina laocoon* is named because of the serpentine-like coiling of the early portion of the second chamber.

Tolypammina tortuosa Dunn, 1942 Pl. 22, fig. 22; Pl. 27, fig. 4; Fig. 27

Tolypammina tortuosa Dunn, 1942, Jour. Paleont., vol. 16, No. 3, p. 341, pl. 44, figs. 19-21, 32.

Description.—Test mostly attached (some portions are free and are rounded and tubular); proloculus large, elevated above height of second chamber; proloculus is surrounded by the second chamber for three-fourths of a whorl, then the second chamber coils and bends in a tortuous manner, not always in the same plane; test generally with a floor wall, occasionally not; tubes often crowded and somewhat intertwined; the overall shape of the test is determined by the mode of attachment; test wall of fine siliceous grains in siliceous cement; color of test, white.

Measurements.—See Table 39 for measurements of *Tolypammina tortuosa.*

Comparison and affinities.—The present specimens seem to be conspecific with *Tolypammina tortuosa* Dunn, 1942, from the Silurian Brassfield limestone of Missouri.

Table 39. Measurements of *Tolypammina tortuosa* Dunn, 1942, in mm.

specimen and type number	*diam. of proloculus*	*min. diam. of tube*	*max. diam. of tube*	*locality number, formation, and bed number*
unfigured specimen	.07	.10	.15	I-4, Rockford, bed 2
Pl. 22, fig. 22	.08	.05	.17	I-4, Rockford, bed 2

Stratigraphic occurrence.—*Tolypammina tortuosa* is known to occur in the Middle Silurian and the Lower Mississippian. The species was found in the Kinderhookian Rockford limestone (Bed 2) at Jacobs Chapel, Indiana, (Locality I-4) and in the Eulie shale (Bed 2) near Westmoreland, northern Tennessee, (Locality T-2).

Ecology.—*Tolypammina tortuosa* undoubtedly lived in much the same environment as did the other tolypamminids.

Remarks.—Five specimens of the species were recovered.

Genus **AMMOVERTELLA** Cushman, 1928

Psammophis Schellwien, 1895, Palaeontographia, vol. 44, pts. 5, 6, p. 265. (*non Psammophis* Boie, 1827, *fide* Cushman, 1948, Foraminfera, Cambridge, p. 98).

Ammovertella Cushman, 1928, Cushman Lab. Foram. Research, Contr., vol. 4, p. 8; *idem,* 1948, Foraminifera, Cambridge, p. 98.
Type species, *Psammophis inversa* Schellwien, 1898.

Description.—The generic definition of *Ammovertella* was given by Cushman (1948, p. 98):

> Test attached, with proloculus and long, tubular second chamber, early portion planispiral, later and larger portion bending back and forth but progressing forward in one general direction; wall clearly arenaceous with much cement; aperture at end of the tube.—Pennsylvanian to Recent. Schellwien proved the arenaceous character of the wall by test with polarized light.

The salient features of the genus *Ammovertella* as I conceive of them have already been given in the section devoted to the genus *Tolypammina.* A summary of the generic characters of *Ammovertella* will suffice here: *Ammovertella* presents a sinuous, tortuous (back and forth) maze of windings of the second chamber in the same general plane; this maze of windings is fused into a planoconvex mass. The floor of the test (if present) is more or less flat; the sides and top of the test are convex. The later portion of the second chamber may utilize the earlier portions as bases for attachment. The initial portion of the second chamber may or may not form itself into one or a few planispiral coils. In essence then, the principal generic character of *Ammovertella* is considered to be the winding back and forth of the second chamber in the same general plane with fusion of the winding tube into a planoconvex mass.

All tests of *Ammovertella* in the present material are composed of siliceous grains in siliceous cement (regardless of original wall composition).

Chart 23 shows the range of *Ammovertella* in the Mississippian as determined in this study.

Ammovertella cf. **A. inclusa** (Cushman and Waters), 1927 Pl. 23, fig. 8; Pl. 27, figs. 6-9; Fig. 29

Psammophis inclusa Cushman and Waters, 1927, Cushman Lab. Foram. Research, Contr., vol. 3, p. 148, pl. 26, fig. 12.

Ammovertella inclusa (Cushman and Waters), 1930, Univ. Texas, Bull. 3019, pp. 44, 45, pl. 7, fig. 13; Ireland, 1956, (*pars*), Jour. Paleont., vol. 30, No. 4, pp. 853, 854, text-fig. 5-12. (*non Ammovertella inclusa* [Cushman and Waters], Ireland, 1956, Jour. Paleont., vol. 30, No. 4, pp. 853, 854, text-fig. 5—6-11, 13, 14).

Description.—Test attached, consisting of a proloculus and a gradually expanding tubular second chamber which is planispirally coiled for one or two volutions in the present specimens, then meanders in the same general plane back and forth and partially embraces the coiled portion; in some specimens the tube laps back on top of previous portions of the test; cross-section of tube semicircular; tubular portion fused together to form a planoconvex mass; wall of test composed of fine siliceous grains in siliceous cement; color of wall, white to gray to yellowish gray.

Measurements.—Table 40 gives measurements of *Ammovertella* cf. *A. inclusa;* Table 41 gives the range in measurements of the species and the measurements of Cushman and Waters' holotype.

Comparison and affinities.—The present specimens are only compared to *Ammovertella inclusa* inasmuch as the illustration given by Cushman and Waters (1930, pl. 7, fig. 13) shows only the upper convex side of the test; however, Cushman and Waters' description of the test allows comparison of the present material with *A. inclusa.*

The form which Ireland described (1956, pp. 853, 854, text-fig. 5— 6-11, 13, 14) as *Ammovertella inclusa* does not seem to be conspecific with *A. inclusa* inasmuch as Ireland's specimens apparently lack the planispirally coiled early portion of the second chamber; only one figure (text-fig. 5— 12b) shows a planispiral coil. In other respects these forms closely resemble the figure of the holotype of *A. inclusa.*

Stratigraphic occurrence.—Cushman and Waters (1930, pp. 44, 45, pl. 7, fig. 13) described *Ammovertella inclusa* from the Upper Pennsylvanian of Texas. Ireland (1956, pp. 853, 854, text-fig. 5— 12) reported the species from the Upper Pennsylvanian of Kansas.

The present specimens were found as rather scattered occurrences from the Bedford shale to the lower part of the Brodhead formation. (See Charts 3, 4, 6, 9-13, 16, 18, 19, 21, and 22 for details of occurrence.)

Ecology.—Ammovertella cf. *A. inclusa* is recorded in this work only in soft, blue-gray to olive-gray, plastic when wet shales which contain fine-grained silt, and are in instances, calcareous with well-developed megafossil faunas (such as the Button Mold Knob member of the New Providence formation which carries the Button Mold Knob fauna).

No specimens of *Ammovertella* have been observed in strictly siltstone or sandstone beds in the studied area. Thus, it seems that *Ammovertella* cf. *A. inclusa,* and probably *Ammovertella* in general, "preferred" a soft, muddy sea bottom. This species could live in calcareous or noncalcareous sediments, with or without a well-developed megafauna. Where megafaunas were present, the species would utilize the living organisms or hard fragmental parts of dead organisms as objects of attachment.

The habit of attachment may have been an adaptation to an agitated environment of deposition. A moderately shallow-water environment is evidenced by the association of the species with the Button Mold Knob fauna and the stratigraphic proximity of the dominantly molluscan Coral Ridge fauna. The alkalinity of the water must have been fairly high in order to allow formation of the calcareous shales and crinoidal bioherms within the Button Mold Knob member.

Table 40. Measurements of *Ammovertella* cf. *A. inclusa* (Cushman and Waters), 1927, in mm.

specimen and type number	*length of test*	*width of test*	*min. diam. of tube*	*max. diam. of tube*	*locality number, formation, and bed number*
Pl. 23, fig. 8	.480	.440	.033	.092	K-2, New Providence, bed 2
Pl. 27, fig. 6	.521	.335	.033	.101	K-2, New Providence, bed 2
Pl. 27, fig. 7	.554	.420		.118	K-32, New Providence, bed 2
Pl. 27, fig. 8	.537	.403	.033	.084	K-32, New Providence, bed 2
Pl. 27, fig. 9	.503	.420	.033	.101	K-32, New Providence, bed 2

Table 41. Range in measurements of 13 specimens of *Ammovertella* cf. *A. inclusa* (Cushman and Waters), 1927, in mm. and comparison with the holotype

		holotype (all but length are estimated from original figure)
Length of test	.302-.710	.850
Width of test	.252-.453	.540
Min. diam. of tube	.025-.033	.063 (earliest part not visible)
Max. diam. of tube	.067-.134	.220

Ammovertella labyrintha Ireland, 1956 Pl. 23, fig. 9; Pl. 27, fig. 10; Fig. 28

Ammovertella labyrintha Ireland, 1956, Jour. Paleont., vol. 30, p. 854, text-fig. 6— 1, 2.

Description.—Test consists of a tortuous, labyrinthic maze of intertwining tubes, partially attached at the base of the fused unit to a substratum, and partially free or attached to other tubes; present specimens only fragmentary; test wall gray to dull tan.

Measurements.—See Table 42 for measurements of *Ammovertella labyrintha.*

Table 42. Measurements of *Ammovertella labyrintha* Ireland, 1956, in mm.

Pl. 23, fig. 9	
Diam. of proloculus	.084
Diam. of tube	.05-.08
Diam. of test	.79

Comparison and affinities.—Present specimens seem to fit well the descriptions and figures given for *Ammovertella labyrintha* by Ireland (1956, p. 854).

Stratigraphic occurrence.—*Ammovertella labyrintha* is known to occur in the Pennsylvanian and Permian of Kansas. Herein the species is reported from the lower part of the New Providence formation, 11 to 16.5 feet above the New Albany shale, near Athertonville, Larue County, Kentucky, (Locality K-13) and in the lower 2.5 to 5.5 feet of the New Providence formation at Fishing Creek near Somerset, Pulaski County, Kentucky, (Locality K-32).

Ecology.—Apparently *Ammovertella labyrintha* had much the same ecological requirements as other ammovertellids.

Ammovertella cf. **A. primaparva** Ireland, 1956 Pl. 23, fig. 10; Pl. 27, fig. 11; Fig. 31

Ammovertella primaparva Ireland, 1956, Jour. Paleont., vol. 30, No. 4, p. 834, text-fig. 6— 8-12.

Description.—Test attached, consisting of a tiny proloculus and a gradually expanding tubular second chamber which meanders back and forth in a plane and usually progresses roughly in the same direction; adjacent walls are fused so that the whole test forms a planoconvex mass; tube makes up to eight crossings, making four complete meanders in the present specimens; cross-section of the tube semi-circular; as noted by Ireland (1956, p. 854), the later more randomly winding portion of the second chamber is readily broken off, and it is not preserved in the present specimens; wall composed of siliceous grains in siliceous cement; color of wall, white to light yellowish-gray.

Measurements.—Table 43 gives the measurements of *Ammovertella* cf. *A. primaparva;* Table 44 gives the range in measurements of *A.* cf. *A. primaparva* and measurements of Ireland's types of the species.

Comparison and affinities.—The present specimens are fragmentary, and for this reason are compared with *Ammovertella primaparva;* however, the specimens of this paper closely resemble text-fig. 6— 8, 9, and 11 as given by Ireland (1956).

Ammovertella primaparva is similar in the meandering manner of its second chamber to the type species of *Ammovertella, A. inversa* (Schellwien), 1898, but *A. primaparva* does not possess the planispirally coiled initial portion of the second chamber. *A. primaparva* differs from *A. inclusa* (Cushman and Waters), 1927 in lacking the planispirally coiled early portion of the second chamber and in having the earlier portion of the test less embraced by the meandering of the second chamber.

Stratigraphic occurrence.—Ireland (1956) described *Ammovertella primaparva* from the Upper Pennsylvanian of Kansas. The present specimens are from the Kinderhookian Eulie shale of Tennessee and the Rockford limestone of southern Indiana, the lower part of the Osagian Henley shale member of the Cuyahoga formation of Ohio, and the lower part of the Osagian New Providence formation of Kentucky. (See Charts 3, 4, 10, 12, 16, 21, and 22 for details of occurrence.)

Ecology.—*Ammovertella* cf. *A. primaparva* likely had ecological requirements similar to those of *Ammovertella* cf. *A. inclusa*, except *A.* cf. *A. primaparva* has been found in the Rockford limestone. As discussed under *Hyperammina rockfordensis* and *Tolypammina jacobschapelensis*, the Rockford limestone may represent deposition in a lagoonal environment.

Table 43. Measurements of *Ammovertella* cf. *A. primaparva* Ireland, 1956, in mm.

specimen and type number	*width of test*	*length of test*	*no. of crossings*	*min. diam. of tube*	*locality number, formation, and bed number*
Pl. 23, fig. 10	.335	.386	7	.033	O-6, Henley, bed 10
Pl. 27, fig. 11	.352	.386	7	.063	I-4, Rockford, bed 2

Table 44. Range in measurements of five specimens of *Ammovertella* cf. *A. primaparva* Ireland, 1956, and measurements of the holotype, in mm.

	Present specimens	*holotype*
Width of test	.294-.453	.25 (lower part)
Length of test	.269-.386 (lower part)	.60 (whole test)
No. of meanders	up to four	three
Min. diam. of tube	.017-.067	.020

Genus **TREPEILOPSIS** Cushman and Waters, 1928

Turritellella Cushman and Waters, 1927, Cushman Lab. Foram. Research, Contr., vol. 3, p. 38. (*non Turritellella* Rhumbler, 1903, Archiv. Prot., vol. 3, p. 283)

Trepeilopsis Cushman and Waters, 1928, Cushman Lab. Foram Research, Contr., vol. 4, p. 38.

Type species, *Trepeilopsis grandis* (Cushman and Waters), 1928 (original designation).

Cushman's generic definition (1948, p. 99) of *Trepeilopsis* is as follows:

> Test attached to *Productus* spines, with a proloculus and long, tubular, second chamber, early portion spirally coiled, later bending back and making nearly a straight tube over the earlier whorls; wall finely arenaceous with much cement; aperture at the end of the tube.

There is some question as to the relationship between *Trepeilopsis* Cushman and Waters, 1928, and *Turritellella* Rhumbler, 1903.

I would broaden the generic definition of *Trepeilopsis* more than did Cushman and Waters. The generic definition of *Trepeilopsis,* as I view it, should require that species of *Trepeilopsis* be attached to some object, brachiopod spine, sponge spicule, or such; the final portion of the second chamber may or may not recoil backward over the earlier part of the second chamber.

Turritellella would have generic characters similar to *Trepeilopsis* except the test must be free (unattached) and may not have the later portion of the second chamber recoil backward over the earlier part of the second chamber.

Among the trepeilopsids there are some species, such as *Trepeilopsis spiralis* Gutschick and Treckman which seemingly fit the generic definition of *Turritellella;* however, Gutschick and Treckman (1959, p. 244) interpret their Rockford *T. spiralis* as a *Trepeilopsis* which was wound around a calcareous cylindrical spine which has been dissolved leaving a hollow enclosed by windings. Such solution of a calcareous spine would make the test superficially like *Turritellella.*

It may be added here that a test in question must show definite evidence of attachment on the inner side of the second chamber or the example should not be placed in *Trepeilopsis.*

Chart 23 shows the range of *Trepeilopsis* in the Mississippian as determined in this study.

Trepeilopsis glomospiroides Gutschick and Treckman, 1959
Pl. 23, figs. 1, 2; Pl. 27, fig. 13; Fig. 33

Trepeilopsis glomospiroides Gutschick and Treckman, 1959, Jour. Paleont., vol. 33, No. 2, pp. 243, 244, pl. 35, figs. 29-31.

Description.—Test attached to a spine, spicule, or similar object; test consists of a proloculus (broken off of all present specimens) and a gradually enlarging tubular second chamber which winds tightly and spirally around the object of attachment for about five to six coils (in present specimens) and then winds in a glomospiroid fashion over the latest coils and the end of the object of attachment;

aperture formed by open end of tube; wall of fine siliceous silt in siliceous cement; color of wall white to yellowish-gray.

Measurements.—See Table 45 for measurements of present specimens of *Trepeilopsis glomospiroides* and Table 46 for range in measurements of the species.

Comparison and affinities.—The present specimens are in general slightly smaller than Gutschick and Treckman's types of the species but otherwise are identical with them.

Stratigraphic occurrence.—*Trepeilopsis glomospiroides* was originally described from the Rockford limestone of northern Indiana. *T. glomospiroides* was found in this study to occur in the Rockford limestone of southern Indiana, the lower New Providence formation of Kentucky, and the lower Cuyahoga formation of Ohio. (See Charts 3, 9-11, 18, 21, and 22 for details of occurrence.)

Table 45. Measurements of *Trepeilopsis glomospiroides* Gutschick and Treckman, 1959, in mm.

specimen and type number	*length*	*no. of coils*	*max. diam.*	*locality number, formation, and bed number*
Pl. 23, fig. 1	.650	7	.302	K-51, New Providence, bed 6
Pl. 23, fig. 2	.452	7	.235	I-4, Rockford, bed 2
Pl. 27, fig. 13	.550	5	.226	I-4, Rockford, bed 2

Table 46. Range in measurements of five specimens of *Trepeilopsis glomospiroides* Gutschick and Treckman, 1959, in mm.

Length	.425-.650
No. of coils	5-7
Max. diam.	.218-.302

Ecology.—*Trepeilopsis glomospiroides* is known to occur only in dense (fine-grained) limestone and in fine-grained, calcareous or noncalcareous plastic shales. *T. glomospiroides* has not been observed in medium to coarse-grained limestones. It is believed that the species lived on an argillaceous or calcareous-argillaceous bottom, in quiet waters; the Rockford limestone has already been interpreted as possibly lagoonal (see discussion under *Hyperammina rockfordensis*).

Trepeilopsis recurvidens Gutschick and Treckman, 1959
Pl. 23, figs. 3, 4; Pl. 27, fig. 12; Fig. 32

Trepeilopsis recurvidens Gutschick and Treckman, 1959, Jour. Paleont., vol. 33, No. 2, p. 244, pl. 35, figs. 25, 26.

Description.—Test attached to a spine, spicule, or similar object; test consists of a proloculus (broken off of present specimens) and a gradually enlarging tubular second chamber which spirals tightly around the object of attachment for six to eight coils, then uncoils and turns back over the preceding coils in a broadly winding path directed toward the proloculus; aperture at open end of tube; wall finely grained, of siliceous silt in siliceous cement; color of test, light gray.

Measurements.—See Table 47 for measurements of *Trepeilopsis recurvidens.*

Comparison and affinities.—The present specimens closely resemble the figured specimens of *Trepeilopsis recurvidens* Gutschick and Treckman (1959, pl. 35, figs. 25, 26) and unfigured paratypes of this species in my possession. Gutschick and Treckman give .90 mm. as the length of the holotype. Unfigured paratypes of the species measure .60 to .75 mm. in length.

Trepeilopsis recurvidens differs from *A. mississippiana* Cooper (1947, p. 87, pl. 20, figs. 34-41) in being more regularly coiled.

Stratigraphic occurrence.—*Trepeilopsis recurvidens* was originally described from the Rockford limestone of northern Indiana. The species was found to occur, in the present study, in the Cuyahoga formation undifferentiated and in the Henley shale member of the Cuyahoga formation in Ohio; in Kentucky the species occurs in the Button Mold Knob member of the New Providence formation and in the Haldeman siltstone member of the Brodhead formation. (See Charts 4, 6, 9, 10, 12, 13, 18, 21, and 22 for details of occurrence.)

Ecology.—*Trepeilopsis recurvidens* was found only in clayey shales of the lower part of the Cuyahoga formation, the plastic Henley shale, in the calcareous shales of the Button Mold Knob member, and in the olive-gray to drab-gray shale breaks in the Haldeman siltstone member. *T. recurvidens* seems to have lived on soft, calcareous or noncalcareous muddy sea bottoms. This species, and *Trepeilopsis* in general, have not been observed in strictly siltstone or sandstone beds. Species of *Trepeilopsis* in general were attached to and coiled around spines or spicules, or other elongate organic fragments. Sponge spicules are often used for support and attachment. Although, ecologically, the sponges today are most abundant in water just below tide level, representatives of the Porifera are known to be widely distributed even at great depths of the ocean.

Table 47. Measurements of *Trepeilopsis recurvidens* Gutschick and Treckman, 1959, in mm.

specimen and type number	*length*	*no. of coils*	*max. diam.*	*locality number, formation, and bed number*
Pl. 27, fig. 12	.675	7	.420	K-56, Haldeman, bed 2
Pl. 23, fig. 4	.625	6	.319	O-7, Cuyahoga, bed 6
Pl. 23, fig. 3	.700	7-8	.269	O-7, Cuyahoga, bed 6

Trepeilopsis spiralis Gutschick and Treckman, 1959 Pl. 23, figs. 5, 6; Pl. 27, fig. 14; Fig. 34

Trepeilopsis spiralis Gutschick and Treckman, 1959, Jour. Paleont., vol. 33, No. 2, pp. 243, 244, pl. 35, figs. 20-24.

Description.—Test attached to a spine, spicule, or similar object; test consists of a proloculus (broken off of present specimens) and a tubular second chamber which winds tightly and spirally around the object of attachment, gradually enlarging, and consisting in present specimens of about 6 to about 12 coils; aperture formed by open end of tube; wall of fine-grained silt in siliceous cement; color of wall, white to gray to rusty.

Measurements.—See Table 48 for measurements of *Trepeilopsis spiralis* and Table 49 for range in measurements of the species.

Comparison and affinities.—The present specimens are identical with Gutschick and Treckman's figured specimens and with unfigured paratypes in my possession.

Table 48. Measurements of *Trepeilopsis spiralis* Gutschick and Treckman, 1959, in mm.

specimen and type number	*length*	*no. of coils*	*max. diam.*	*locality number, formation, and bed number*
Pl. 27, fig. 14	.950	12?	.302	K-32, New Providence, bed 2
Pl. 23, fig. 7	1.050	8	.386	K-12, New Providence, bed 4
Pl. 23, fig. 5	.470	6-7	.126	I-4, Rockford, bed 2
Pl. 23, fig. 6	.750	10	.235	T-2, Eulie, bed 2

Table 49. Range in measurements of 19 specimens of *Trepeilopsis spiralis* Gutschick and Treckman, 1959, in mm.

Length of test	.500-1.100
Number of coils	6-12
Maximum diameter of test	.151-.386

Stratigraphic occurrence.—Trepeilopsis spiralis occurs in the Eulie shale of Tennessee; the Rockford limestone and Jacobs Chapel shale of southern Indiana; the Bedford shale, the New Providence formation, the Conway Cut and the Haldeman siltstone members of the Brodhead formation, and the Rothwell shale member of the Muldraugh formation of Kentucky. (See Charts 3-6, 8-13, 16-19, 21, and 22 for details of occurrence.)

Ecology.—Trepeilopsis spiralis occurs in soft, plastic shales, in shale breaks within siltstone, and in fine-grained limestone, possibly lagoonal. The ecological requirements for the species were probably much like those of *T. recurvidens* and *T. glomospiroides*.

Family **LITUOLIDAE** Reuss, 1861

Subfamily **HAPLOPHRAGMIINAE** Cushman, 1927

Genus **AMMOBACULITES** Cushman, 1910

Spirolina d'Orbigny, 1846, (*pars*), Foram. Foss. Bass. Tert. Vienne, p. 137.
Haplophragmium Brady, 1884, (*pars*), Rept. Voyage Challenger, Zool., vol. 9, pp. 301, 302.
Ammobaculites Cushman, 1910, United States Nat. Mus., Bull. No. 71, pp. 114, 115.

Type species, *Spirolina agglutinans* d'Orbigny, 1846 (original designation, by Cushman, 1910. Miocene, Austria).

The generic definition of *Ammobaculites* was given by Cushman (1910, p. 114) as follows:

Test free, chambered, early portion close coiled in one plane, latter portion uncoiled and made up of a more or less linear series of chambers; wall coarsely arenaceous, fairly thick; aperture single at the center of the terminal face of the uncoiled portion, but in the coiled portion at the base of the apertural face.

Gutschick and Treckman (1959, pp. 247-249) described the oldest known *Ammobaculites*, *A. leptos*, *A. pyriformis*, and *A.*? sp. from the Kinderhookian Rockford limestone of northern Indiana. The species described in the present study, *A. gutschicki*, is, therefore, the third known species from the Mississippian system. Chart 23 shows the range of *Ammobaculites* in the Mississippian as determined in this study.

Gutschick and Treckman (1959, p. 249) noted concerning *Ammobaculites*? sp.:

> Specimens recovered from acid residues are vesicular and indicate that the animal must have formed its test of agglutinate lime sand grains cemented together with a siliceous paste. It is the siliceous material which is preserved.

Again quoting Gutschick and Treckman (1959, p. 249) concerning wall composition:

> Composition and nature of wall structure have become important criteria for classification of Foraminifera. If we are to regard these as important generic characteristics and recognize isomorphism as valid (Ireland, 1956; Cummings, 1955), then the Rockford form would become a new genus related to the agglutinate silica grained *Ammobaculites* and the calcareous test *Endothyranella*.

Again, in *Ammobaculites* the spector of wall structure and wall composition arises. Some workers on Paleozoic Foraminifera would hold to strict isomorphism in Foraminifera. Thus, it has been conceived that *Ammobaculites* and *Endothyranella* are isomorphs. According to some workers, *Ammobaculites* would be considered to have siliceous grains in siliceous cement while *Endothyranella* would be considered to have calcareous grains (whether extraneous or secreted by the protoplasm) in calcite cement; others consider *Endothyranella* to have a completely fibrous calcite structure and composition. However, Cushman in his original generic definition of *Ammobaculites* (1910, p. 114) described the wall as coarsely arenaceous (arenaceous to Cushman presumedly meant grains of various composition embedded in ferruginous, calcareous, or ferrugino-calcareous cement).

I believe that the crux of the wall problem lies primarily in the nature of the cement. If all Foraminifera (save a minute number, as in the family Silicinidae) had originally calcareous, ferruginous, or ferrugino-calcareous cement, and if nearly all siliceous cement represents secondary replacement of original ferruginous, calcareous, or ferrugino-calcareous cement, then I can not accept the principle of isomorphism; that is, I would be quite hesitant to say that genera of Foraminifera are so selective in the type of extraneous particles which they incorporate into their test wall that such selection of extraneous particles would constitute a valid basis for generic differentiation.

St. Jean (1957, pp. 18, 19) disavows the possession of an arenaceous test by any Paleozoic Foraminifera. In line with this assumption, St. Jean (1957, p. 41) suspected that:

> . . . all Paleozoic Foraminifera referred to the genus *Hyperammina* are actually *Earlandia*. The type of *Hyperammina, H. elongata* Brady (1878, p. 433, pl. 20, fig. 2) is a Recent arenaceous form from the Arctic Sea.

Thus, St. Jean assumed the granularity in the tests of Paleozoic *Hyperammina* to be due to secondary recrystallization of an original calcite test. What are the relationships between Paleozoic *Hyperammina* and Recent *Hyperammina* (which are undoubtedly arenaceous)? I should think that the phylogeny of Recent *Hyperammina* extends back to the Paleozoic *Hyperammina,* although such a proposition is difficult of proof, as is also (it may be noted) the negation of the statement. After all, no one seriously believes the genus *Lingula* among the inarticulate brachiopods does not have a stratigraphic range from Cambrian to Recent. Certainly it is admitted that the smaller Foraminifera have relatively simple test shapes, and thus there are not a great number of structures which can be used for specific and generic criteria.

In another vein, if arenaceous (agglutinate) or adventitious (in the sense of Plummer, 1930, p. 7) Foraminifera are known in the Paleozoic (a proposition nearly all workers in the past have agreed to), then the cement in any given genus may have been: (1) originally ferruginous, calcareous, or ferrugino-calcareous, (2) siliceous, or (3) originally ferruginous, calcareous, or ferrugino-calcareous and secondarily replaced by silica. If all Paleozoic arenaceous tests were originally calcareous, ferruginous, or ferrugino-calcareous, then I would disavow isomorphism; thus *Ammobaculites* would be congeneric with *Endothyranella* (the chemical nature of the extraneous grains is not here considered of generic importance). If some Paleozoic Foraminifera originally possessed siliceous cement (secreted of course by the protoplasm), then I would admit the principle of isomorphism and then Paleozoic *Ammobaculites* (at present with siliceous cement) and *Endothyranella* would be distinct genera.

I can see no reason to believe that the nature of the extraneous particles in arenaceous Foraminifera (in the sense of Plummer, 1930, p. 7) would of necessity constitute a criterion for generic, or even specific differentiation. It has been manifestly demonstrated that arenaceous genera can use particles of many materials to incorporate into their test wall in instances where the "preferred" particles are not available. Of course, some Foraminifera are more selective than others in their "choice" of extraneous particles to incorporate into their test wall; some species are extremely "demanding" in their selection of particles for test construction.

In conclusion, until the Quaternary, Tertiary, Mesozoic, and Paleozoic Foraminifera have been thoroughly monographed as to their wall structure and composition (with basic investigation directed at adequate redescription of the available types of smaller Foraminifera, as well as study of ecology of Recent Foraminifera and paleoecology of fossil Foraminifera), most statements concerning the nature of wall structure of smaller Foraminifera are conjectural. Indeed, we know very little about wall structure and wall composition of Foraminifera in general. The obscure references to arenaceous tests, without clear statements as to the true nature of the cementing material, and to lesser extent the nature of extraneous particles (in adventitious tests) have served magnificently to confound and delude present workers in their study of the Foraminifera. Currently, the nature of the test wall in Foraminifera is so beclouded that no worker can remain unconfused when discoursing on wall structure and chemical composition, and their relationships to elements of taxonomy, classification, and phylogeny of the Foraminifera.

Ammobaculites gutschicki, new species Pl. 23, figs. 11-22; Pl. 27, fig. 15; Fig. 35

Description.—Test consists of planispiral and rectilinear portions; planispiral part indistinct in inner portion, but outer whorl composed of three to five-and-one-half gradually enlarging inflated chambers; rectilinear portion consists of as many as five slightly enlarging oblate and inflated chambers; final chamber of rectilinear series, subequally long as broad and pyriform due to tapering neck of aperture; test wall moderately coarse-grained with moderate amount of siliceous cement; test generally somewhat compressed; color of test, white to reddish-orange.

Measurements.—See Table 50 for measurements of *Ammobaculites gutschicki* and Table 51 for range in measurements of the species and comparison with *A. pyriformis* Gutschick and Treckman, 1959.

Comparison and affinities.—*Ammobaculites gutschicki* has its closest affinities to *A. pyriformis* Gutschick and Treckman (1959, pp. 248, 249, pl. 37, figs. 14-17, 19, 21-25), especially in the nature of the coiled portion of the test, but *A. gutschicki* differs markedly in that the rectilinear portion has fewer chambers (up to five) than *A. pyriformis* (which has six or more rectilinear chambers); in addition, the rectilinear chambers of *A. gutschicki* are oblate rather than prolate as are the rectilinear chambers in *A. pyriformis.*

Type locality.—Blue Gap, 2.65 miles north of New Haven, Nelson County, Kentucky, (Locality K-13) on U.S. Highway 31E. Holotype from the New Providence formation, 44 to 49.5 feet above the Falling Run member of the Sanderson formation (Bed 10).

Table 51. Range in measurements of 27 specimens of *Ammobaculites gutschicki*, n. sp., in mm. and comparison with *A. pyriformis* Gutschick and Treckman, 1959

	A. gutschicki	*A. pyriformis*
Length of test	.386-.688	.750-1.050
Diam. of coiled portion	.176-.440	.250-.280
No. of chambers in outer whorl	3-5.5	4-6
Length of rectilinear part	.277-.658	
Diam. of rectilinear part	.092-.252	
No. of rectilinear chambers	1-5	6 or more

Stratigraphic occurrence.—*Ammobaculites gutschicki* is found in the Falling Run member of the Sanderson formation, in the New Providence formation, especially in the lower part (Coral Ridge member and equivalent beds) in Kentucky and southern Indiana, in the Brodhead formation in Kentucky and less frequently in the Cuyahoga formation in Ohio. The species also occurs in the Eulie shale of northern Tennessee. Thus, *A. gutschicki* is known to occur only in the Kinderhookian and Osagian. (See Charts 3-6, 8-13, 16-18, 21, and 22 for details of occurrence.)

Ecology.—*Ammobaculites gutschicki* occurs especially in the soft, plastic when wet, blue-gray and olive-gray shales of the New Providence, and, in the somewhat more silty shales of the Brodhead

Table 50. Measurements of *Ammobaculites gutschicki*, n. sp. in mm.

specimen and type number	*length*	*diam. of coil*	*no. of chambers in last whorl*	*length of rectilinear part*	*diam. of rectilinear part*	*no. of rectilinear chambers*	*locality number, formation, and bed number*
Pl. 23, fig. 12	.670	.369	5	.403	.201	2	K-13, New Providence, bed 10
Pl. 23, fig. 14	.670	.244	4	.470	.218	3	K-13, New Providence, bed 10
Pl. 23, fig. 13	.537	.176	3	.386	.185	3-4	K-13, New Providence, bed 10
Pl. 23, fig. 22		.440	5.5				O-7, Cuyahoga, bed 6
Pl. 23, fig. 16	.688	.277	4.5	.470	.252	3	K-12, New Providence, bed 4
Pl. 23, fig. 17	.604	.252	4	.403	.210	3	K-17, New Providence, bed 3
Pl. 23, fig. 15	.386	.260	5	.269	.175	2	K-13, New Providence, bed 2
Pl. 23, fig. 11 holotype	.604	.252	4.5	.420	.185	3	K-61, Henley, bed 2
Pl. 23, fig. 18	.436	.185	4	.277	.126	2	K-18, New Providence, bed 3
Pl. 23, fig. 21	.521	.335	5.5	.269	.193	2	K-14, New Providence, bed 3
Pl. 23, fig. 20	.586	.252	4.5	.390	.176	3	K-14, New Providence, bed 3

and Cuyahoga formations; there are rather small to moderate amounts of silt in these beds and the silt is usually of small to medium size.

Remarks.—This new species is named for Dr. Raymond C. Gutschick, Head of the Dept. of Geology at the University of Notre Dame, in recognition of his pioneering work on Lower Mississippian smaller Foraminifera.

Family **TEXTULARIIDAE** d'Orbigny, 1846

Subfamily **TEXTULARIINAE** d'Orbigny, 1846

Genus **CLIMACAMMINA** Brady, 1873

Textularia Defrance, Brady, 1871, (*pars*), Geol. Soc. Glasgow, Trans., vol. 3, suppl., p. 13. (*nomen nudum*)
Climacammina Brady, 1873, Geol. Surv. Scotland, Mem., Expl. Sheet 23, p. 94; *idem,* 1876, Paleont. Soc. Mon., vol. 30, pp. 67, 68; Cushman, 1948, Foraminifera, Cambridge, p. 120.
Bigenerina d'Orbigny, Brady, 1884, (*pars*), Rept. Voyage Challenger, Zool., v. 9, pp. 371, 372.

Type species, *Textularia antiqua* Brady 1871, (monotypic genus).

Cushman's (1948, p. 120) generic definition of *Climacammina* follows:

Test free, early portion biserial, later uniserial; wall arenaceous, mostly of fine fragments but including coarser ones, cement calcareous; aperture in the biserial portion textularian, in the uniserial portion irregularly cribrate, terminal . . . I have examined Brady's specimens of *Climacammina antiqua* as well as duplicates which have been treated with acid. The cement is calcareous, but the arenaceous fragments are of various sorts and sizes. The test is truly arenaceous as stated by Brady in his original description of the genus. The original specimens show the characteristic distortion and collapsing so frequently seen in the Textulariidae.

The stratigraphic range of *Climacammina* was considered by Cushman (1948, p. 120) to be Carboniferous to Permian. However, Cushman (1928, p. 120) reported the range of the genus to be "Carboniferous to Permian . . . Tertiary and Recent(?)", and noted:

The *Bigenerina robusta* H. B. Brady (Rep. Voy. Challenger, Zoology, vol. 9, p. 1884, p. 371, pl. 45, figs. 9-16) and some Tertiary species have essentially the characters of *Climacammina,* but there seems to be a very wide gap where no representatives of the genus are known if these are the same as the Paleozoic forms.

Chart 23 shows the range of *Climacammina* in the Mississippian as determined in this study.

There has been some doubt as to the relationships between *Climacammina* and *Bigenerina*. Brady (1876, pp. 371, 372) rejected the genus *Climacammina;* however, *Climacammina* was considered valid by Cushman (1948, p. 120).

The specific definition of the Recent *Bigenerina robusta* Brady (1881, p. 53) was given as follows:

> Test elongate, compressed in its earlier (biserial) portion, cylindrical in its later (uniserial) growth. Uniserial segments numerous, short, somewhat irregular, often ventricose at their periphery. Aperture simple and Textularian in the biserial segments, becoming multiple and porous in the uniserial portion, the pores either arranged in a ring or irregularly distributed in the central part of the exposed face of the terminal chamber. Interior non-labyrinthic. Length, about 1/5 inch (4.8 mm.).

The original generic definition of *Bigenerina* by D'Orbigny (1826, p. 261) requires *Bigenerina* to possess a single terminal aperture in the uniserial portion, the figures of the type species, *B. nodosaria* d'Orbigny, 1826 (p. 11, figs. 9-12) demonstrating beyond doubt the single terminal aperture of the genus *Bigenerina.*

It seems reasonable that *Bigenerina robusta* Brady, 1881, be relegated to *Climacammina* in that it fits well within the generic concept of *Climacammina,* except its interior is not labyrinthic. The type species, *C. antiqua* (Brady), 1871 is labyrinthic (Brady, 1876, p. 68), but not all species which have been referred to *Climacammina* are labyrinthic. The lack of examples of *Climacammina* between the Tertiary and Permian is no evidence that they did not exist. Ultimate knowledge concerning the geologic range of any fossil is determined empirically and therefore is rather fortuitous. *Climacammina* often occurs in hard limestones and its presence there would have to be determined from thin sectionings.

In any event, stratigraphic discontinuity can not be given preference over biologic evidence (identical morphology) in discerning the geologic ranges of species, or any taxon above the species. The paleontologic record is supreme; it is the measure for ascertaining the time-stratigraphic ranges of all taxa of higher or lower catagories.

Climacammina mississippiana, new species   Pl. 24, figs. 1-6; Figs. 41-43

Description.—Test elongate, approximately five times longer than broad; test consists of two portions, the earlier portion consisting of about 11 biserial textularian chambers, followed by a series of three uniserial chambers; the textularian series has inflated chambers taking on a rounded wedge shape; the uniserial series has nearly cylindrical chambers; the last (or third) uniserial chamber becomes rounded and only slightly bluntly pointed at the middle of the apertural face; the uniserial chambers possess cribrate apertures; the apertural face of the uniserial chamber is pierced by eight or possibly slightly more, partially triangular apertures (the two present specimens are imperfectly preserved); sutures originally distinct and depressed, but both specimens exhibit evidence of wear; internally the test wall is seen to be composed of two layers, both calcareous, the inner layer is crystalline calcite completely secreted by the protoplasm of the foraminifer, while the outer layer is arenaceous with calcite cement (see Fig. 43).

Measurements.—Table 52 gives the measurements of *Climacammina mississippiana* and a comparison with the measurements of *C. cylindrica* Cushman and Waters, 1928.

Table 52. Measurements of *Climacammina mississippiana,* n. sp. in mm. and comparison with *C. cylindrica* Cushman and Waters, 1928

		C. mississippiana, n. sp. holotype, Pl. 24, figs. 1, 2, 6	paratype, Pl. 24, figs. 3-5	*C. cylindrica*
Length of test		.971	.554	2.000
Length of uniserial chambers	3-	.193	.210	
	2-	.118	.118	
	1-	.118	.118	
Diameter of uniserial chambers	3-	.462	.436	.600
	2-	.470	.369	
	1-	.403	.360	
Length of biserial chambers	5-	.185		
	4-	.101		
	3-	.084		
	2-	.075		
	1-	.068		
Diameter of biserial chambers	5-	.252		
	4-	.252		
	3-	.160		
	2-	.134		
	1-	.118		
Diameter of proloculus		.118?		
Thickness of outer wall		.080		
Thickness of inner wall		.050		

Comparison and affinities.—*Climacammina mississippiana* has its closest affinities to *C. cylindrica;* however, *C. mississippiana* differs from *C. cylindrica* in having: (1) smaller number of biserial chambers, (2) smaller number of uniserial chambers, (three instead of four as in *C. cylindrica*), and (3) size only about one-half that of *C. cylindrica.*

Type locality.—Clark's Station Quarry, 2.4 miles south of Morill on Highway 421, Jackson County, Kentucky, (Locality K-46). Holotype is from the horizon of the Big Clifty sandstone (Bed 1).

Stratigraphic occurrence.—*Climacammina* has been reported from the Permian of Texas, the Pennsylvanian of Texas (Cushman and Waters, 1930, p. 56), and the Pennsylvanian of Oklahoma (Warthin, 1930, p. 31). The only record of *Climacammina* in the Mississippian of North America is the report of a *Climacammina*? zone in the Greenbrier limestone (top of the Reynolds limestone) in West Virginia (Flowers, 1956, pp. 7, 8). The species of *Climacammina*? of Flowers is a true *Climacammina;* I have collected samples and prepared thin sections of the Greenbrier limestone which yielded specimens of *Climacammina* along with *Tolypammina* spp. and dasycladacean algae in the pisolitic limestone portions of the upper Greenbrier in Greenbrier County near White Sulphur Springs, West Virginia.

In Europe, *Climacammina* is known to range from the Permian downward into the Lower Carboniferous. In Russia, *Climacammina antiqua* (Brady), 1876 has been reported from the Lower Carboniferous around Leningrad (Mikhailov, 1939, p. 62, pl. 4, figs. 17, 18).

In the present study *Climacammina* was found in the lower Chesterian Paint Creek limestone and Big Clifty sandstone; thus, the geologic range of *Climacammina* is extended downward to the Upper Mississippian in North America.

Ecology.—Of the two specimens of *Climacammina mississippiana* found in this study, one is from the calcareous, clayey, and fossiliferous shale of the upper portion of the Paint Creek limestone (Bed 1), south of Mt. Vernon in Rockcastle County, Kentucky, (Locality K-42) and the other specimen is from a marine shale at the horizon of the Big Clifty sandstone (Bed 1) at Morill, Jackson County, Kentucky, (Locality K-45). These two localities are about 17 miles apart.

Flowers commented on the sediments within which the *Climacammina* zone occurs in the Greenbrier limestone of West Virginia (1956, p. 8):

> The *Climacammina*? faunal zone can nearly always be found in wells having little clastic material in the upper part of the Greenbrier limestone. In southeastern West Virginia where there is a large increase in clastic material at the location of this zone, both the Greenbrier and the Mauch Chunk are universally thick in this area, making it difficult to locate with any certainty, either the stratigraphic position of the Reynolds limestone or the top of the Greenbrier limestone. Where this is the case, the position of the *Climacammina*? zone cannot always be determined.

The occurrence of *Climacammina mississippiana* in the calcareous shale of the Paint Creek limestone is in keeping with the calcareous nature of the test, but the occurrence of *C. mississippiana* in the less calcareous shales at the horizon of the Big Clifty sandstone raises questions as to whether the Big Clifty specimen might have been reworked from one of the lower limestones or calcareous shales.

Climacammina in general flourished in the warm and shallow seas of high carbonate alkalinity as evidenced by its occurrence in the Greenbrier limestone in association with the characteristically warm and shallow water sedimentary structures, the oölites and pisolites. Nevertheless, *Climacammina mississippiana* occurs, so far as is known, in calcareous shales in Kentucky, demonstrating that the species of *Climacammina* are not restricted to the oölite-pisolite limestone facies.

Remarks.—The cribrate aperture and the labyrinthic interior of *Climacammina mississippiana* clearly distinguishes it from any superficially similar species of *Bigenerina* d'Orbigny, 1826. Thus, *C. mississippiana* becomes the first Mississippian species of the genus to be described from North America.

Family **MILIOLIDAE** d'Orbigny, 1846

Genus **AGATHAMMINA** Neumayr, 1887

Serpula Geinitz, 1846, (*pars*), Verstein. Deutsch. Zechsteingebirge und Rothliegenden, Heft 1, p. 6, pl. 3, figs. 3-6 (*fide* Cushman, 1948, Foraminifera, Cambridge, p. 177).

Agathammina Neumayr, 1887, Sitzber. K. Wiss. Wein, Math.-Naturiv. Cl., vol. 95, pt. 1, p. 171; Cushman, 1927, Cushman Lab. Foram. Research, Contr., vol. 3, pt. 4, p. 188; *idem,* 1928, Cushman Lab. Foram. Research, Spec. Pub. No. 1, pp. 145, 146.

Type species, *Serpula pusilla* Geinitz, 1846 (subsequent designation by Cushman, 1927, p. 188).

The type description of *Agathammina* was given by Neumayr (1887, p. 171):

Ich fasse unter diesum Namen Formen zusammen mit unregelmässig miliolides Aufrollung, unvollkommender Kammerung und Sandiger Schale mit kalkigens cement. Vorwiegend carbonische und permische Arten.

Cushman's (1928, p. 146) generic definition of *Agathammina* follows:

Test tubular, undivided, winding about an elongate axis; wall imperforate, calcareous, with arenaceous material at the surface; aperture formed by the open end of the tubular chamber.

The miliolid genus *Agathammina* has been reported from the Recent (Cushman, 1929, p. 21), the Tertiary (Grzybowski, 1896, p. 282), the Pennsylvanian (Cushman and Waters, 1930, p. 59; Galloway and Ryniker, 1930), and the Permian (Cushman and Waters, 1928, p. 43).

Agathammina mississippiana is the first Mississippian species of the genus to be reported. (See Chart 23 for the range of *Agathammina* in the Mississippian.)

All specimens of *Agathammina mississippiana* are composed of fine-grained siliceous silt in siliceous cement. The problem of test wall composition again looms. In one specimen of the present material, I concede that there must have been siliceous replacement of the original arenaceous test inasmuch as the test is composed completely of chalcedony. None of the present specimens effervesces with acid.

Inasmuch as the tubular second chamber of the present specimens is not divided, the specimens can not be referred to the family Silicinidae. A possible course of action would be to erect a new genus, the generic essence of which might be expressed as a form with a proloculus followed by a tubular and undivided second chamber which winds about an elongate axis, and is composed of siliceous silt grains in siliceous cement. This temptation is resisted inasmuch as the structure of the test wall of Paleozoic arenaceous Foraminifera is insufficiently known to allow conclusive judgement as to the questions of original wall structure versus replacement, and the real nature of isomorphism among Foraminifera.

Agathammina mississippiana, new species Pl. 23, figs. 23-25; Pl. 27, fig. 18; Fig. 36

Description.—Test configuration varies from narrowly spindle-shaped in the early one coil stage to broadly oval (shaped like a *Quinqueloculina* or *Spiroloculina*) in the mature two-coil stage; test compressed; test consists of a spherical proloculus, followed by an undivided, tubular second chamber disposed in two coils; whorls nearly planispirally coiled around the proloculus producing the milioline appearance of the mature test; the ends of the elongate axis are slightly pointed and are formed by the sharp bending of the second chamber around the ends of the axis; length of test attains a size as much as 2.9 times the width, but the average ratio of length to width is slightly less than 2 to 1; aperture terminal, rounded to elliptical, formed by the constricted open end of the tubular second chamber; test opaque to translucent, white to gray to orange-buff in color; test wall composed of fine-grained siliceous silt in siliceous cement.

Comparison and affinities.—*Agathammina mississippiana* is similar to *A. protea* Cushman and Waters, 1928 in that: (1) the measurements of *A. protea* given by Cushman and Waters (1928, p. 43) fall well within the range of dimensions of *A. mississippiana,* (2) a prominent milioline shape is possessed by the mature forms of both species, (3) ratio of length to width of test is about 2 to 1 in both species, (4) both species have forms which vary from narrowly elongate to broadly elongate shape, and (5) both species are nearly planispirally coiled.

Although *Agathammina mississippiana* has closest affinities to *A. protea, A. mississippiana* differs specifically from *A. protea* in having (1) less number of coils (two in *A. mississippiana* compared to five or six in *A. protea*) and (2) a more rounded to elliptical aperture than the subtriangular aperture of *A. protea.*

Agathammina mississippiana is also somewhat similar to *A. pusilla,* the type species of the genus. Galloway and Ryniker (1930, p. 8) believed that *A. protea* Cushman and Waters, 1928 is conspecific with *A. pusilla.* However, I consider *A. protea* to vary significantly, and certainly specifically, from *A. pusilla* in having much more regular and planispiral coiling.

Measurements.—See Table 53 for measurements of *Agathammina mississippiana* and for comparison with *A. protea.*

Type locality.—Road cut along U. S. Highway 31E, .5 miles southwest of Balltown, Nelson County, Kentucky, (Locality K-12). The holotype is from the lower 2 to 5.5 feet of the New Providence formation (Bed 4).

Stratigraphic occurrence.—*Agathammina mississippiana* occurs in the Osagian of Kentucky in the lower New Providence formation and the Rothwell shale member of the Muldraugh formation; in the Chesterian, it occurs in the Glen Dean formation. In Ohio, the species is recorded from only the Osagian Black Hand sandstone member of the Cuyahoga formation. (See Charts 5-7, 9, 10, 13, 14, 18, 21, and 22 for details of occurrence.)

This is the first known reference to *Agathammina* in the Mississippian System. Thus the time of origin and the lineage of the family Miliolidae is extended backward in time one geologic period.

Table 53. Measurements of *Agathammina mississippiana,* n.sp., in mm.

specimen and type number	*length*	*width*	*thick-ness*	*locality number, formation, and bed number*
Pl. 23, fig. 24, holotype	.657	.420	.185	K-25, Glen Dean, bed 1
Pl. 23, fig. 25	.924	.503	.193	O-11, Black Hand, bed 1
Pl. 23, fig. 23	.453	.260	.176	K-35, New Providence, bed 7

Ecology.—*Agathammina mississippiana* with only one known exception is restricted ecologically to soft, plastic shales, dominantly with no large amount of carbonates present. Thus the species was apparently best adapted for life on a muddy sea bottom where fine silty grains were available.

The members of the family Miliolidae are characteristic of shallow water. The strictly calcareous imperforate (porcellaneous) forms, such as the genus *Miliola,* where they appear in plethora are characteristically associated with reefs, as in shallow water environment of lagoons, fore-reef shoals, or bank reefs. The ecology of the

Eocene *Miliola* limestones of the Middle East was considered by Henson (1950, p. 230):

> Typical *Miliola* limestones occur in shallows of barrier-reef lagoons and in littoral shoal areas of fringing-reefs. Along flat, foreland shores and in analogous shallow-water environments where reef development is in patches rather than belts, the reef and back-reef facies may be intricately intermingled. . . . *Miliola* limestones, recognizably modified by mixture with other material, may also be formed in open littoral zones.

Futher, Conkin and Conkin (1956, p. 895) discussed the ecological significance of the *Nummoloculina* limestones from the lower Cretaceous of the Sierra Madre Oriental of Mexico, southwest and east Texas, Louisiana, and central Florida as follows:

> There is excellent evidence for a lagoonal origin of some of the subsurface Lower Cretaceous limestones of southwest Texas and the other areas as noted above in that they: (1) are dense, gray to dark-colored, organic limestones containing carbonaceous matter, hydrogen sulphide gas, and in some places anhydrite, with frequent to abundant miliolids (to the near exclusion of other fossils) and (2) alternate with reef nucleus rocks and fossils (algae, reef foraminifers, rudistids and other mollusks with smaller amounts of corals and bryozoans. . . . From consideration of their ecology it is clear that miliolids occuring in abundance are facies foraminifers characteristic of back-reef and inter-reef environments.

I do not, of course, imply that reef conditions existed in areas where the present specimens were found (in fact it is clear that no reefs were present), but it is desirable to establish the fact that miliolids have a propensity for shallow water environments. It is well known that miliolids are frequently found in sandy, littoral zones. I have observed the dominance of miliolids in the Recent beach and very near shore sand, seaward from Padre Island in Nueces County, near Corpus Christi, Texas. Again, it is well established that miliolids live in the shallow and somewhat brackish water of bays.

Family **OPHTHALMIDIIDAE** Cushman, 1927

Genus **HEMIGORDIUS** Schubert, 1908

Cornuspira Howchin, 1895, Roy. Soc. South Australia, Trans., vol. 19, p. 195, pl. 10, figs. 1-3 (*non Cornuspira* Schultze, 1845, Organismus Polythal., Leipzig, p. 40).

Hemigordius Schubert, 1909, Jahrb. K. K. Geol. Reichs., 1908, vol. 58, p. 381; Cushman, 1928, Cushman Lab. Foram. Research, Spec. Pub. No. 1, p. 161.

Type species, *Cornuspira schlumbergeri* Howchin, 1895.

Cushman's generic definition (1948, p. 192) of *Hemigordius* follows:

> Test free, early coils not entirely planispiral, later planispiral and completely involute, but not umbonate; wall calcareous, imperforate; aperture formed by the open end of the tube.—Carboniferous and Permian. I have topotypes of the type species, and it is certainly close to *Cornuspira.*

Chart 23 shows the range of *Hemigordius* in the Mississippian as determined in this study.

Hemigordius morillensis, new species Pl. 23, fig. 26; Pl. 27, fig. 17; Fig. 30

Description.—Test free, discoidal, circular in outline; juvenarium consists of a proloculus and two to three non-planispiral whorls; diameter of juvenarium making up as much as 45 percent of the diameter of the tubular, undivided second chamber; juvenarium succeeded by as many as four planispiral whorls; megalospheric form may be completely planispiral; test not completely involute, with portions of preceding whorls visible; exterior of test rarely possesses secondary deposits which obscure the nature of the internal coiling; aperture rounded; wall calcareous and imperforate.

Measurements.—See Table 54 for measurements of *Hemigordius morillensis* and for comparison with *H. calcarea* Cushman and Waters, 1928.

Table 54. Measurements of *Hemigordius morillensis,* n. sp., in mm. and comparison with *H. calcarea* Cushman and Waters, 1928.

	Pl. 23, fig.26, holotype	unfigured paratypes	*H. calcarea*
Diam. of juvenarium	.10	.02, .07	.14
Diam. of test	.30	.16, .35	.35
Axial width of test	.08	.03	
Diam. of proloculus	.03	.01, .02	
No. of whorls in juvenarium	2	0, 3	3
No. of planispiral whorls	2.5	1.75, 4	1.5

Comparison and affinities.—*Hemigordius morillensis* seems to be similar to *H. calcarea* Cushman and Waters, 1928; unfortunately the figures of *H. calcarea* are poor. The only original measurement given for *H. calcarea* was the diameter. I have prepared the measurements of *H. calcarea* in Table 54 from examination of Pl. 6, figs. 1-2 of Cushman and Waters, 1928.

Hemigordius morillensis seems to differ from *H. calcarea* in having: (1) whorls more planispirally arranged, (2) lesser number of whorls in the juvenarium, and (3) a pronounced microspheric form.

Type locality.—Clark Station Quarry, Morill, Jackson County, Kentucky, (Locality K-46). The holotype is from the shale at the horizon of the Big Clifty sandstone (Bed 1).

Stratigraphic occurrence.—*Hemigordius morillensis* is herein reported only from the Chesterian beds, occuring in Kentucky in the calcareous shales of the Paint Creek limestone, basal shales of the Big Clifty-Cypress sandstone, the calcareous shale of the Glen Dean limestone and in the Kinkaid shale. (See Charts 7, 14, 15, and 22 for details of occurrence.)

Ecology.—*Hemigordius morillensis* occurs primarily in calcareous shale. The test is completely calcareous crystalline. The species displayed a definite "preference" for limy mud bottoms.

Remarks.—There is no evidence of replacement of the calcareous crystalline test.

Family **TROCHAMMINIDAE** Cushman, 1929

Genus **TROCHAMMINA** Parker and Jones, 1859

Nautilus Montagu, 1808, (*pars*), Testacea Britania, Suppl., p. 81, pl. 18, fig. 3.

Rotalina d'Orbigny, Williams, 1858, (*pars*), Foraminifera Great Britain, Fol., London, p. 50, pl. 4, figs. 93, 94 (*non Rotalina* d'Orbigny, 1846, Foraminiferes fossiles du Bassin tertiarie de Vienne, Paris, p. 149).

Trochammina Parker and Jones, 1859, Ann. and Mag. Nat. Hist. (ser. 3), No. 4, p. 347; Brady, 1879, Quart. Jour. Micros. Sci., vol. 19, p. 54.

Lituola Lamarck, Parker and Jones, 1865, (*pars*), Philos. Trans., p. 325. (*non Lituola* Lamarck, 1804, Ann. Mus., vol. 5, p. 243).

Haplophragmium Reuss, Siddall, 1879, (*pars*), (*fide* Cushman, 1948, Foraminifera, Cambridge, p. 106); (*non Haplophragmium* Reuss, 1860, Akad. Wiss. Wien, Sitz., vol. 40, p. 218).

Type species, *Nautilus inflatus* Montagu, 1808 (monotypic genus).

Brady (1879, p. 54) presented a complete and clear account of the vicissitudes of the genus *Trochammina* and gave the generic definition of *Trochammina* Parker and Jones, 1859 in the restricted sense of Brady:

The genus *Trochammina* was established by Messrs. Parker and Jones (Annals and Mag. Nat. Hist., 1859, ser. 3, vol. LV, p. 347), for a group of arenaceous foraminifera characterized primarily by their thin, smooth finely-cemented tests.

Although the name was originally applied to a rotalid shell (*Nautilus inflatus* Montagu, 1808, Test. Brit., Suppl., p. 81, pl. 18, fig. 3—*Rotalina inflata* Williamson, 1858, Rec. For. Gt. Br., p. 50, pl. 4, figs. 93, 94), the author prefers to regard the trochoid, often adherent variety (*Tr. squamata* J. and P.), as the type of the genus. The tenuity and fine texture of the arenaceous investment rather than the mere general contour has very properly been accepted as the essential distinction, and fresh forms possessing this character have one by one been added to the genus until it has come to include a series having a very wide range of morphological variation. Not only have we trochoid and rotaliform, but nautiloid, milioline, spirilline, and as we shall presently see, lageniform and nodosarian modifications of the type. In addition to these there are certain simple adherent organisms, described by d'Orbigny under the name *Webbina* (Foram. Canaries, p. 125), whose natural affinity is with the same group; in point of fact the term *Trochammina,* with these repeated additions, has come to comprehend an assemblage of forms having the dimensions of a family rather than a genus. The series is now altogether too bulky and diverse to be zoologically convenient, and it is necessary to consider whether it may not be subdivided with advantage. Prof. von Reuss makes a distinct genus of the spirilline non-septate forms to which he gives the name *Ammodiscus,* and their term has been generally adopted by German authors. If we accept *Webbina* to distinguish the simple adherent varieties and *Ammodiscus* for the free, non-septate forms, and limit the application of *Trochammina* to the well differentiated septate modifications of the type, to which it was first applied, there only remains the *Nodosaria*-like species to be provided for, and for these the term *Hormosina* (from ὅρμος, a necklace) would be a suitable generic or subgeneric appellation.

Trochammina ohioensis, new species — Pl. 23, figs. 27, 28; Pl. 27, fig. 16; Fig. 38

Description.—Test trochoid, moderately compressed, earlier chambers more globose, chambers of last whorl moderately inflated and the largest in size; test of three whorls. The last whorl consists of three to four chambers; sutures on both dorsal and ventral sides nearly straight, or slightly curved; aperture on the ventral side of test, extending to mid-point of the apertural face, at the base of the last chamber; aperture slitlike and rather rectangular, .084 mm. in length and .025 mm. in height; test usually somewhat distorted, crushed; wall coarsely arenaceous of siliceous grains in siliceous cement.

Measurements.—See Table 55 for measurements of *Trochammina ohioensis* and Table 56 for range in the measurements and for comparison with *T. arenosa* Cushman and Waters, 1927.

Table 55. Measurements of *Trochammina ohioensis,* n. sp., in mm.

specimen and type number	*maximum diameter*	*maximum width*	*no. of chambers in outer whorl*	
			dorsal	*ventral*
Pl. 23, fig. 27, holotype	.50	.24	3	3
Pl. 23, fig. 28	.60	.28	4?	3?

Table 56. Range in measurements of nine specimens of *Trochammina ohioensis,* n. sp. in mm. and comparison with *T. arenosa* Cushman and Waters, 1927

	T. ohioensis	*T. arenosa*
Maximum diameter	.37-.60	.65
Maximum width	.13-.29	.18
No. of chambers in outer whorl: dorsal	3-4	4
ventral	3-4	4

Comparison and affinities.—Trochammina ohioensis is similar to *T. arenosa,* but *T. ohioensis* differs from *T. arenosa* in having more inflated chambers, much coarser quartz sand grains in siliceous cement, and generally smaller test.

Unfortunately the shape and dimensions of the aperture in *Trochammina arenosa* are unknown. *T. arenosa* is based on one specimen; however, the species is reported (Cushman and Waters, 1927, p. 152) as being "common" in the Pennsylvanian of Texas. Thus, presumably a characteristic form was figured; nevertheless, the range of individual variation remains unknown.

Type locality.—All specimens are from shale streaks in the Black Hand sandstone (Bed 1), at Armstrong, Ohio, (Locality O-11).

Stratigraphic occurrence.—Trochammina ohioensis is known only from the Osagian Black Hand sandstone of Ohio.

Ecology.—The occurrence of *Trochammina ohioensis* only in the silty and sandy shale of the noncalcareous Black Hand sandstone and its absence elsewhere may indicate the "preference" of *T. ohioensis* for a muddy sand environment.

Remarks.—Trochammina ohioensis is the first species of *Trochammina* reported from the Mississippian of the studied area.

Family PLACOPSILINIDAE Cushman, 1927

Subfamily POLYPHRAGMINAE Rhumbler, 1913

Genus STACHEIA Brady, 1876

Stacheia Brady, 1876, Paleont. Soc. Mon. 30, p. 107; Cushman, 1927, Cushman Lab. Foram. Research, Contr., vol. 3, pt. 1, p. 42; *idem*, 1927, Cushman Lab. Foram. Research, Contr., vol. 3, pt. 4, p. 189; *idem*, 1928, Cushman Lab. Foram. Research, Spec. Pub. No. 1, p. 178.

Stacheia Brady, emend, Chapman, 1895, Ann. and Mag. Nat. Hist., ser. 6, vol. 16, p. 321.

Type species, *Stacheia marginuloides* Brady, 1876, first species (subsequent designation by Cushman, 1927).

Brady's (1876, p. 107) definition of *Stacheia* follows:

Test (normally) adherent, composed either of numerous segments subdivided in their interior, or of an acervuline mass of chamberlets, sometimes arranged in layers, sometimes confused. Texture subarenaceous, imperforate.

Chapman (1895, p. 321) emended *Stacheia* Brady, 1876:

Test adherent or free; composed of numerous segments subdivided in their interior, or of an acervuline mass of chamberlets, sometimes arranged in layers, sometimes confused, or of a thick-walled test with acervuline or labyrinthic structure and with the interior subdivided into numerous elongate sinuous cavities (the latter characters especially applying to the Rhaetic representatives of the genus). Aperture simple, but irregular, terminal or scattered over the surface of the test. Texture subarenaceous, composed of fine sand, sometimes admixed with coarser material, and with a calcareous or chitinous cement; imperforate . . . In his 'Monograph of the Carboniferous and Permian Foraminifera' Dr. Brady lays particular stress upon the fact that in the Carboniferous strata *Stacheia* is always parasitic (adherent); and such is undoubtedly the case with specimens from that formation. In the Rhaetic assemblage the tests are more often perfectly free in their mode of growth. The flat complanate or frondose form (*S. dispansa*) is by far the best represented species, in point of numbers, in the Rhaetic washings; and this form appears to have flourished on the sea-bottom, spreading horizontally and growing so numerously as to make a separation band at frequent intervals in the clay deposits.

Most of the present *Stacheia* are adherent, usually either to sponge spicules or bryozoan fragments. Apertures are usually not observed; openings at the distal portion of the elongate forms may contain the apertures. The test is smooth or moderately smooth, containing fine siliceous grains in much siliceous cement. Perhaps the silica cement in these arenaceous forms indicates replacement of original calcareous cement. Most species of *Stacheia* exhibit rather wide latitude of individual variation; the specific characteristics are not strongly pronounced. Many of the specimens are adherent and thus the configuration of the test is somewhat controlled by their mode of attachment and by the shape of the object to which they are attached. The free living forms also exhibit irregularity in the shape of their tests. The adherent mode of life and the arenaceous nature of the test would seem to cause the species of *Stacheia* to be provincial in their distribution. Wider geographic distribution might have been attained if the genus had been adherent to floating algal masses; however, the arenaceous nature of the test would seem to restrict the genus to the benthos.

Stratigraphically, *Stacheia* has been reported from the Silurian and the Pennsylvanian of North America. This is the first record of the genus in Mississippian rocks. Chart 23 shows the range of *Stacheia* in the Mississippian as determined in this study.

Stacheia cicatrix, new species Pl. 25, figs. 1-3; Pl. 27, figs. 20, 21; Fig. 37

Description.—Test adherent, forming medium to large-sized irregularly to poorly rounded, compressed, semiglobular to discoidal, or less often irregular, masses, all fused into a unit; attached generally to sponge spicules and bryozoan fragments; test arenaceous with siliceous grains in siliceous cement; color of test gray to buff-white.

Measurements.—See Table 57 for measurements of *Stacheia cicatrix* and Table 58 for range of measurements of *S. cicatrix* and comparison with *S. acervalis.*

Comparison and affinities.—*Stacheia cicatrix* resembles *S. acervalis* Brady, 1876 in general appearance. Inasmuch as little internal structure is discernable in thin sections of the present specimens or in the original material of Brady (1876, p. 16, pl. 9, figs. 6-8) and inasmuch as *Stacheia* is a generalized genus, the precise definition of species of *Stacheia* is difficult. *S. cicatrix* differs from *S. acervalis* in having: (1) more regularly rounded individual masses fused into a unit, (2) stronger amalgamation of the individual rounded masses, and (3) a larger size to the fused mass.

Type locality.—Northwest side of Kenwood Hill, southern Louisville, Jefferson County, Kentucky, (Locality K-2). The holotype is from the Coral Ridge member (Bed 2) of the New Providence formation.

Stratigraphic occurrence.—*Stacheia cicatrix* has been found only in the Osagian New Providence and Brodhead formations and in the Meramecian Somerset shale member of the Salem limestone in Kentucky. The species is most abundant below the Brodhead formation, especially in the lower and middle parts of the New Providence formation. In Ohio, the species is known only from the Osagian Henley shale member of the Cuyahoga formation. (See Charts 3-6, 9-13, 18, 21, and 22 for details of occurrence.)

Table 57. Measurements of *Stacheia cicatrix,* n. sp., in mm.

specimen and type number	*length*	*diameter*	*locality number, formation, and bed number*
Pl. 25, fig. 1	1.70	.82	K-2, Button Mold Knob, bed 4
Pl. 25, fig. 2	1.30	1.20	I-2, Button Mold Knob, bed 3
Pl. 25, fig. 3, holotype	1.60	.84	K-2, New Providence, bed 2
Pl. 27, fig. 21	1.10	.89	K-4, Coral Ridge, bed 2

Table 58. Range in measurements of 10 specimens of *Stacheia cicatrix,* n. sp. in mm. and comparison with *S. acervalis* Brady, 1876

	S. cicatrix	*S. acervalis*
Maximum length	.84-2.5	.80
Maximum diameter	.35-1.4	

Ecology.—*Stacheia cicatrix* apparently was restricted to shaly beds which contain megafossil remains, inasmuch as the species was primarily adherent in its living habit (to sponge spicules or bryozoan fragments). The generic definition of *Stacheia* requires that its species possess calcareous cement. *S. cicatrix* contains no calcareous cement. It is possible that the tests of *S. cicatrix* have been replaced by siliceous material. In any event, I am unwilling to erect a new genus based on this species inasmuch as our lack of precise information concerning original wall structure and chemical composition of Paleozoic Foraminifera and processes of possible replacement of these ancient forms precludes such action.

Remarks.—The trivial name for this new species is derived from the resemblance of the test to a scar.

Stacheia neopupoides, new species Pl. 25, figs. 4, 5; Fig. 40

Description.—Test adherent, elongate, small to moderate-sized; externally the test appears as a mass, cylindrical to somewhat tapering, composed of an irregular series of indistinct, curved chambers; test delicate, usually attached to a sponge spicule; test texture fine-grained or smooth; test wall of fine siliceous grains in siliceous cement; color, gray to yellow-gray.

Measurements.—See Table 59 for measurements of *Stacheia neopupoides* and for comparison with *S. pupoides* Brady, 1876 and *S. congesta* Brady, 1876.

Table 59. Measurements of *Stacheia neopupoides,* n. sp. in mm. and comparison with available measurements of *S. pupoides* Brady, 1876 and *S. congesta* Brady, 1876

specimen and type number	*length*	*diameter*	*locality number, formation, and bed number*
Pl. 25, fig. 5, holotype	.89	.30	K-4, New Providence, bed 6
Pl. 27, fig. 19	.66	.30	K-32, New Providence, bed 3
Pl. 25, fig. 4	.94	.45	K-61, New Providence, bed 2
3 unfigured paratypes	.50-.97	.25-.37	
S. congesta	.7-1.5		Carboniferous, Scotland
S. pupoides	1.0		Carboniferous, Scotland

Comparison and affinities.—Stacheia neopupoides has closest affinities to *S. pupoides* Brady, 1876 and *S. congesta* Brady, 1876. It is with some reluctance that a new species is erected in view of the similarities between the present specimens and *S. congesta* and *S. pupoides*. However, inasmuch as *S. congesta* and *S. pupoides* are primarily European species (*S. pupoides* has been reported by Cushman and Waters, 1930, p. 73, figs. 1a, 1b; pl. 12, fig. 8 from the Pennsylvanian of Texas) and the genus *Stacheia* was undoubtedly an arenaceous and encrusting or attached form, I feel that the present material is not conspecific with either *S. congesta* or *S. pupoides.*

Stacheia neopupoides seemingly has closest affinities to *S. pupoides* but differs from *S. pupoides* in having more prominent sutures and less fusiform test.

Type locality.—East Quarry of the Coral Ridge Brick and Tile Corp., at Coral Ridge, southwestern Jefferson County, Kentucky, (Locality K-4). Holotype is from the Button Mold Knob member (Bed 6) of the New Providence formation.

Stratigraphic occurrence.—*Stacheia neopupoides* occurs in the lower Osagian beds of Kentucky and eastern Ohio and in the Kinderhookian Bedford shale. See Charts 4, 6, 9, 13, 18, 19, 21, and 22 for details of occurrence.

Ecology.—*Stacheia neopupoides* seems to have been adapted to live in fine-grained, slightly calcareous muds.

Remarks.—*Stacheia neopupoides* receives its trivial name from its similarity to *S. pupoides.*

Stacheia trepeilopsiformis, new species Pl. 25, figs. 6, 7; Fig. 39

Description.—Test adherent to spines, rods, or other cylindrical objects; early portion apparently consisting of a series of uniserial or nearly uniserial (perhaps slightly trochoid), moderately inflated segments (two to three) which are fused into a broad cone-shaped mass, the proximal portion of which is pointed; no evidence of attachment found at the base; the fused mass succeeded by three nearly rectilinear large segments, the last of which exhibits overlapping of segments at right angles to the section sutures; object of attachment missing, leaving a rounded or oval opening; wall arenaceous with calcite cement; no evidence of replacement.

Measurements.—See Table 60 for measurements of *Stacheia trepeilopsiformis* and for comparison with *S. pupoides* Brady, 1876.

Comparison and affinities.—*Stacheia trepeilopsiformis* has its closest affinities to *S. pupoides* Brady, 1876, but *S. trepeilopsiformis* differs from *S. pupoides* in having lesser number of segments per test length, and in addition, the test of *S. trepeilopsiformis* is generally less rapidly expanding distally proximally than *S. pupoides;* however, this is not always the case (Brady, 1876, pl. 8, figs. 20, 26).

Type locality.—Fishing Creek, Lake Cumberland, west of Somerset, Pulaski County, Kentucky, (Locality K-32). Holotype is from the upper part of the New Providence formation, 167½ to 175 feet above the Falling Run member of the Sanderson formation (Bed 10).

Stratigraphic occurrence.—*Stacheia trepeilopsiformis* has been found only as a single specimen in the upper part of the New Providence formation in southern Kentucky in an area where the New Providence formation probably contains beds younger than Fern Glen-Burlington.

Table 60. Measurements of *Stacheia trepeilopsiformis,* n. sp., in mm. and comparison with *S. pupoides* Brady, 1876

	pl. 25, figs. 6, 7; holotype	*S. pupoides*
Length of test	1.00	1.00
Distal diameter	.35	
Proximal diameter	.12	

Ecology.—*Stacheia trepeilopsiformis* is an arenaceous, calcareous form and is found in calcareous shales intercalated between siliceous siltstones. It is difficult to present much concerning the ecological requirements of a species from observation of one specimen; nevertheless, the sediments in which the specimen occurs indicate the existence of a calcareous, marine mud environment in close proximity to sites of silt and sand deposition; the paucity of fossils in the sediments may indicate restricted marine environment in near shore shallow water where shaly beds were interspersed within deltaic silts.

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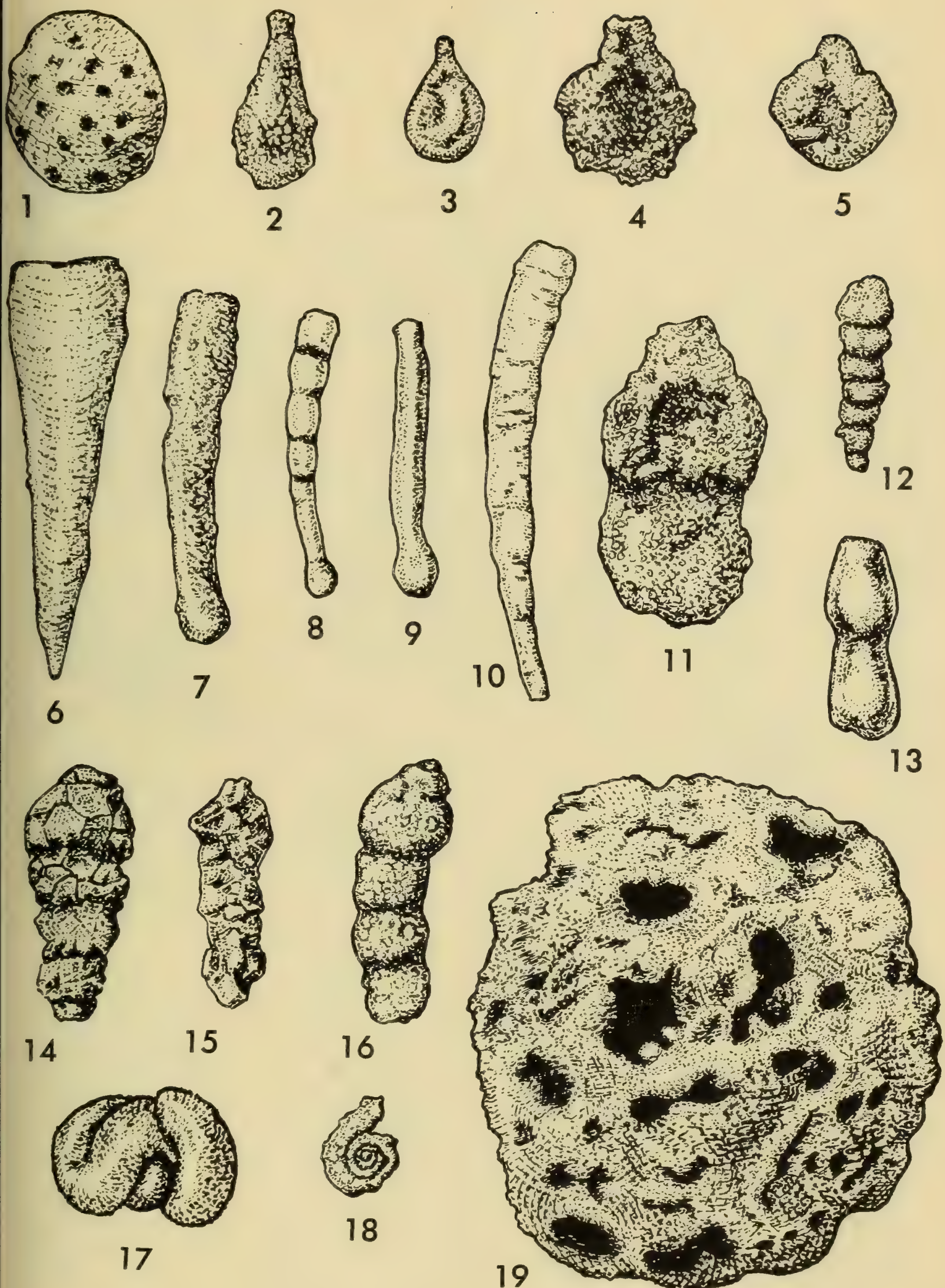
PLATES

FIGURES

Explanation of Figures

Figures 1-19

1. **Thuramminoides sphaeroidalis** Plummer; 2, 3, **Proteonina cumberlandiae,** n. sp.; 4, 5, **Proteonina wallingfordensis,** n. sp.; 6, 7, **Hyperammina casteri,** n. sp.; 8, **Hyperammina kentuckyensis** Conkin; 9, **Hyperammina rockfordensis** Gutschick and Treckman; 10, **Earlandia consternatio,** n. sp.; 11, **Reophax** cf. **R. arenatus** (Cushman and Waters); 12, **Reophax kunklerensis,** n. sp.; 13, **Reophax** cf. **R. lachrymosus** Gutschick and Treckman; 14, 16, **Reophax mcdonaldi,** n. sp.; 15, **Reophax asper** Cushman and Waters; 17, **Glomospira articulosa** Plummer; 18, **Lituotuba semiplana,** n. sp.; 19, **Crithionina palaeozoica,** n. sp.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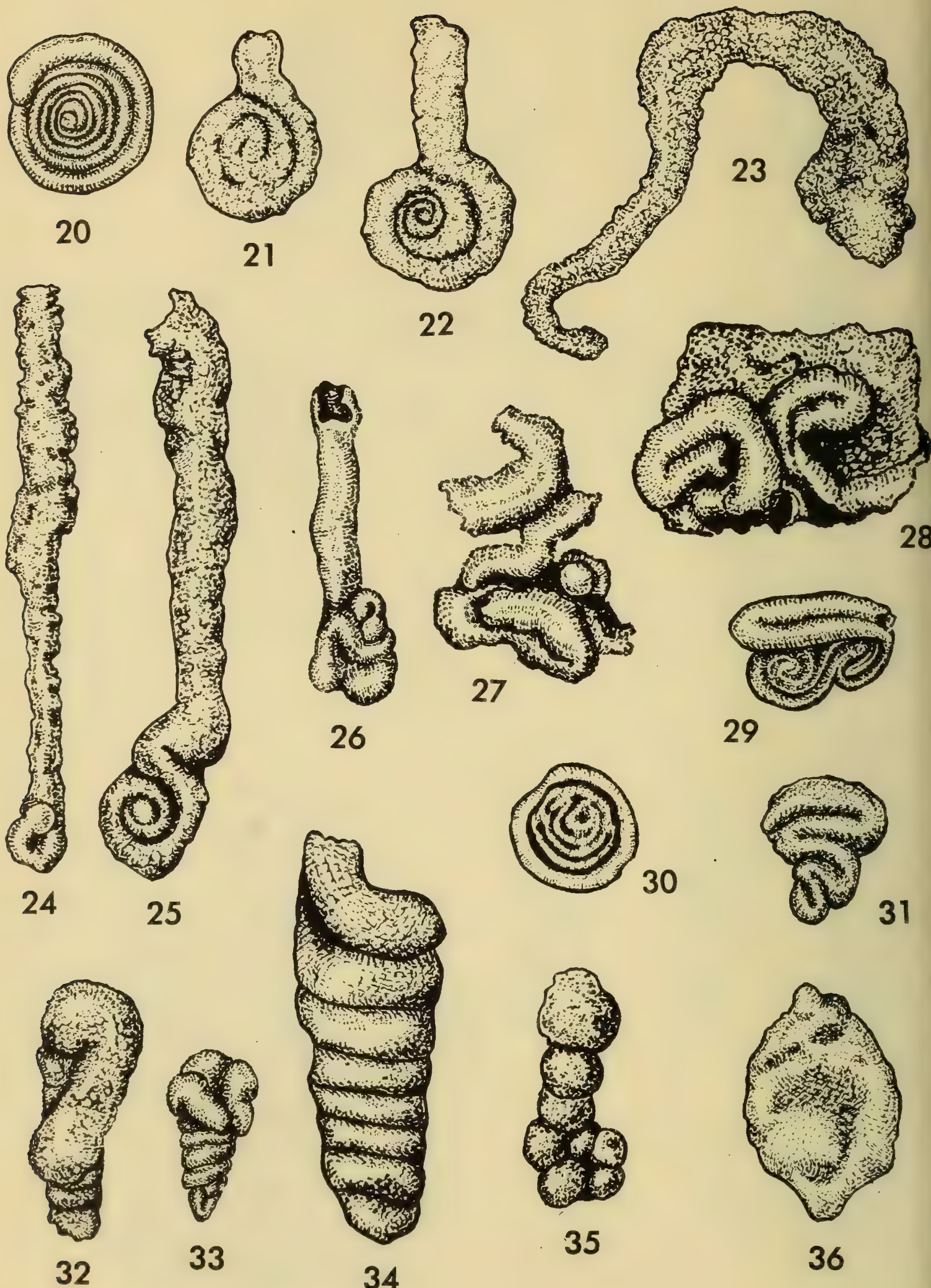
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Explanation of Figures

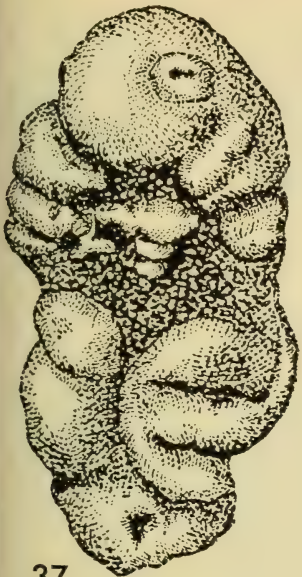
Figures 20-36

20, **Involutina semiconstricta** (Waters); 21, **Involutina exserta** (Cushman); 22, **Involutina longexserta** Gutschick and Treckman; 23, **Tolypammina jacobschapelensis,** n. sp.; 24, **Tolypammina botonuncus** Gutschick and Treckman; 25, **Tolypammina cyclops** Gutschick and Treckman; 26, **Tolypammina laocoon,** n. sp.; 27, **Tolypammina tortuosa** Dunn; 28, **Ammovertella labyrintha** Ireland; 29, **Ammovertella** cf. **A. inclusa** (Cushman and Waters); 30, **Hemigordius morillensis,** n. sp.; 31, **Ammovertella** cf. **A. primaparva** Ireland; 32, **Trepeilopsis recurvidens** Gutschick and Treckman; 33, **Trepeilopsis glomospiroides** Gutschick and Treckman; 34, **Trepeilopsis spiralis** Gutschick and Treckman; 35, **Ammobaculites gutschicki,** n. sp.; 36, **Agathammina mississippiana,** n. sp.

Explanation of Figures

Figures 37-43

37, **Stacheia cicatrix,** n. sp.; 38, **Trochammina ohioensis,** n. sp.; 39, **Stacheia trepeilopsiformis,** n. sp.; 40, **Stacheia neopupoides,** n. sp.; 41-43, **Climacammina mississippiana,** n. sp.



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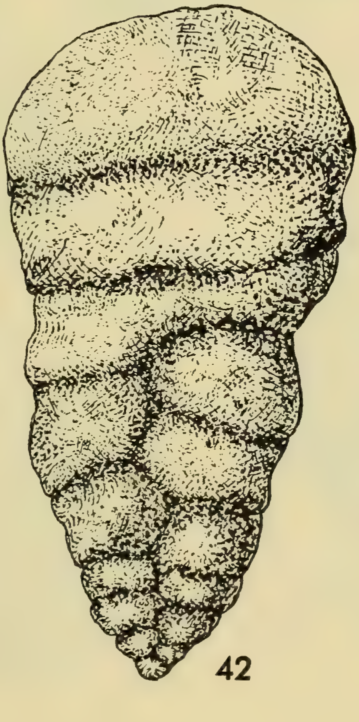

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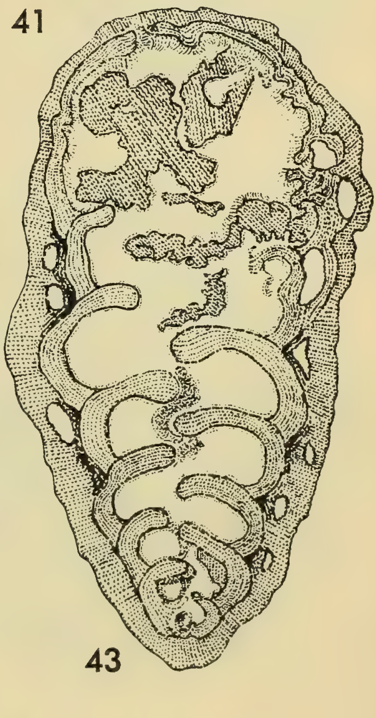

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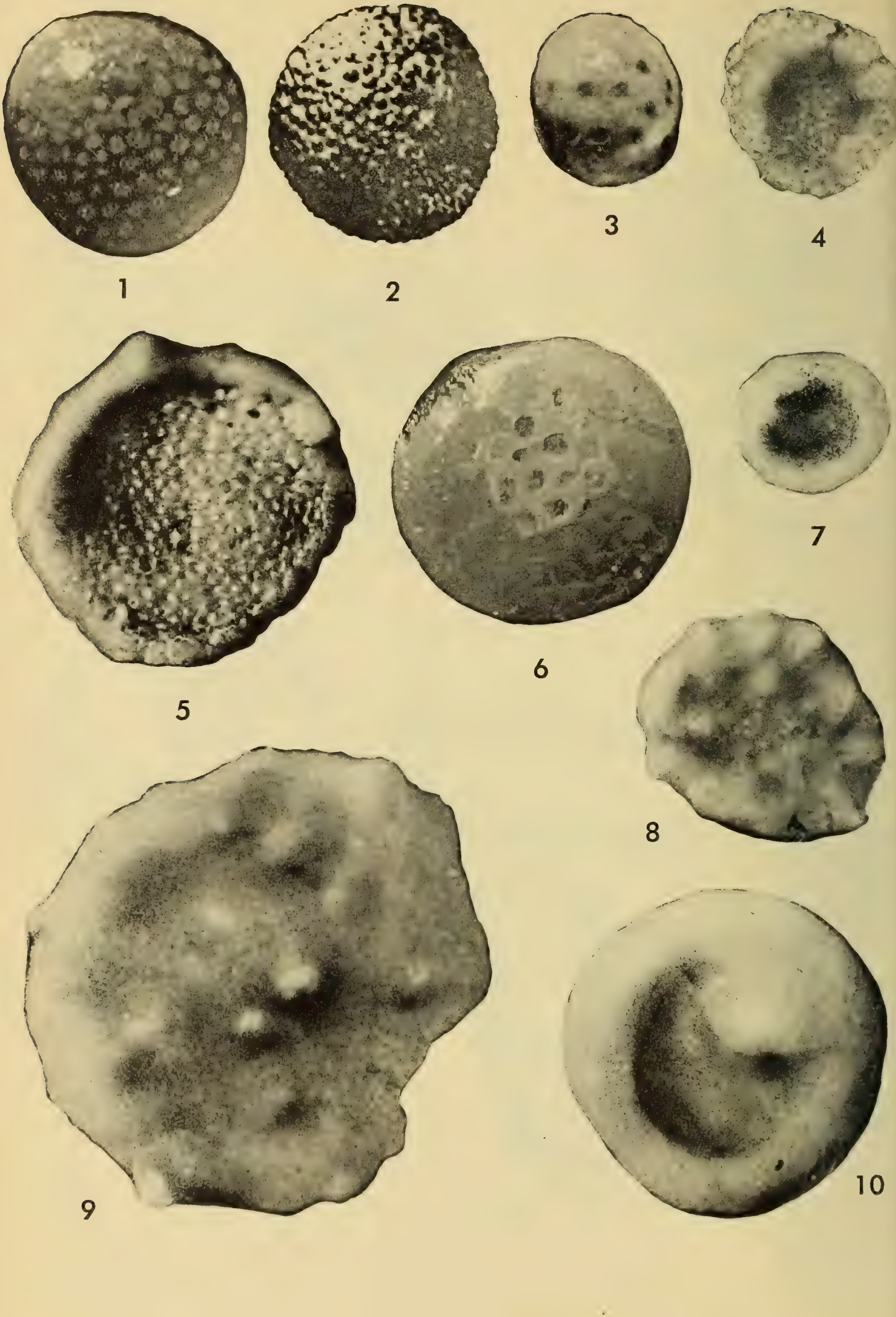
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Explanation of Plate 17

Figure | All figures X 50 | Page

1-10. **Thuramminoides sphaeroidalis** Plummer 243

1. Spherical test showing surface configuration of centripetal tubes. No. 628628 USNM.
2. Spherical test with outer wall destroyed, showing casts of tube ends. No. 628629 USNM.
3. Spherical test, slightly crushed, showing ends of large centripetal tubes. No. 628625 USNM.
4. Broken specimen showing interior of test. Tube structure destroyed. No. 628617 USNM.
5. Broken test showing rounded pits on interior wall where tubes pierce surface. No. 628624 USNM.
6. Flattened test with internal tubular structure visible through translucent outer wall. No. 628621 USNM.
7. Small collapsed test with shape like a red blood corpuscle. No. 628618 USNM.
8. Flattened test with several protuberances, not taken to be apertural necks. No. 628620 USNM.
9. Large flattened test with protuberances. No. 628619 USNM.
10. Test of the most common variation, with a low protuberance. No. 628626 USNM.

Explanation of Plate 18

Figure — All figures X 50 — Page

1-4. **Thuramminoides sphaeroidalis** Plummer 243
1. Large test of typical appearance. Dark filling visible through translucent outer wall. No. 628616 USNM.
2. Test with large low protuberances. No. 628623 USNM.
3. Large broken test with internal structure destroyed. No. 628627 USNM.
4. A typical flattened test. No. 628622 USNM.

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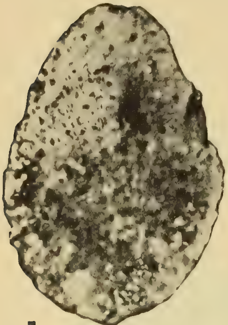
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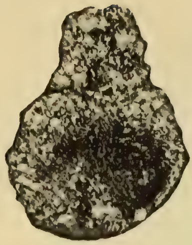
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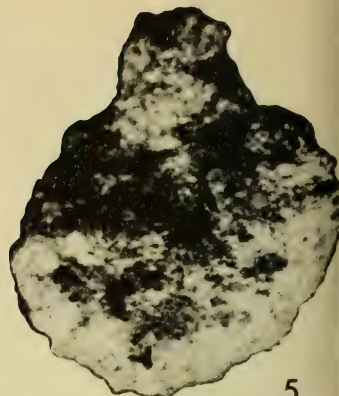
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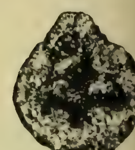
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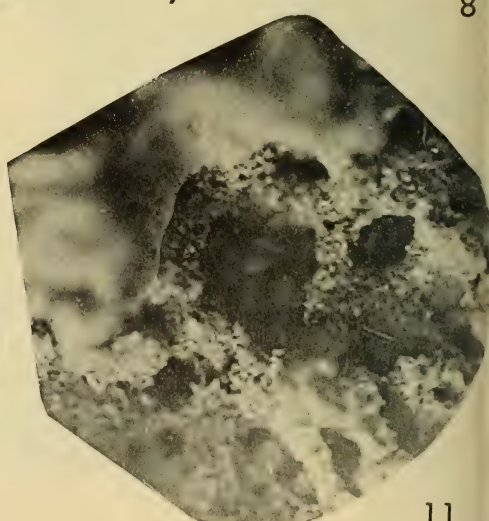
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Explanation of Plate 19

Figure — All figures X 50 — Page

1-3. **Proteonina cumberlandiae,** n. sp. 248
1. Large specimen with neck missing. No. 628634 USNM.
2. Holotype, showing teardrop shape. Test compressed. No. 628632 USNM.
3. Test more elongate than usual. No. 628633 USNM.

4-8. **Proteonina wallingfordensis,** n. sp. 250
4, 6, 8. Tests showing typical round to oblate chamber and stocky tapering neck. Nos. 628638, 628640, 628641 USNM.
5. Large specimen of typical shape. No. 628642 USNM.
7. Holotype. No. 628637 USNM.

9. **Crithionina palaeozoica,** n. sp. 238
Holotype, showing spongy texture of test wall. No. 638653 USNM.

10, 11. **Crithionina rotundata** Cushman 239
Fragments of the holotype. Shows less regularity to test wall than does *Crithionina palaeozoica*, n. sp.

Explanation of Plate 20

Figure — All figures X 50 — Page

1-18. **Hyperammina casteri,** n. sp. 260

1. Holotype, microspheric form. Test broken at apertural end, but well developed otherwise. No. 628644 USNM.
2. Microspheric form, broken at apertural end. No. 628650 USNM.
3. Megalospheric form, slightly constricted. No. 628662 USNM.
4. Microspheric form, slightly constricted, with proloculus missing, No. 628651 USNM.

5, 7, 12. Megalospheric forms with apertural ends broken off. Nos. 628655, 628658, 628659 USNM.

6. Microspheric form with extremely long and pointed tip. Apertural end broken off. No. 628645 USNM.

8, 11. Microspheric forms, less conical than most. Nos. 628647, 628648 USNM.

9. Megalospheric form, apertural end broken. Proloculus somewhat pointed. No. 628660 USNM.
10. Microspheric form showing apertural end with slightly constricted aperture. No. 628649 USNM.
13. Microspheric form. A typical small specimen. No. 628652 USNM.

14, 15. Fragments of a large megalospheric form. No. 628654 USNM.

16. Large microspheric form; proloculus missing. No. 628646 USNM.
17. Large megalospheric form; apertural end partly broken. No. 628657 USNM.
18. Large megalospheric form with oblate proloculus; apertural end broken. No. 628656 USNM.


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Explanation of Plate 21

Figure — All figures X 50 — Page

1-9. **Hyperammina kentuckyensis** Conkin 264
1. Topotype showing slender, constricted test, hourglass tapering of early part of second chamber and oblate proloculus. No. 628664 USNM.
2, 3. Topotypes. Nos. 628663, 628665 USNM.
4-9. More or less well-developed specimens, all showing characteristic constriction of test and development of lip at apertural end. Proloculus missing on figures 4, 6, and 7. Nos. 628669, 628670, 628668, 628667, 628671, 628666 USNM.

10-13. **Hyperammina rockfordensis** Gutschick and Treckman 267
Tests showing rather cylindrical second chamber with few faint constrictions. Nos. 628674, 628675, 628672, 628673 USNM.

14-16. **Earlandia consternatio,** n. sp. 273
14. Holotype, proloculus missing. Shows tapering nature of test. Constrictions less prominent than in *Hyperammina kentuckyensis*, but otherwise shape of test is similar. No. 628677 USNM.
15, 16. Small and large specmens. Proloculi missing. Nos. 628679, 628678 USNM.

17. **Reophax** cf. **R. minutissimus** Plummer 285
No. 628698 USNM.

18. **Reophax** cf. **R. lachrymosus** Gutschick and Treckman 282
Broken specimen. No. 628689 USNM.

19. **Reophax** cf. **R. arenatus** (Cushman and Waters) 278
No. 628681 USNM.

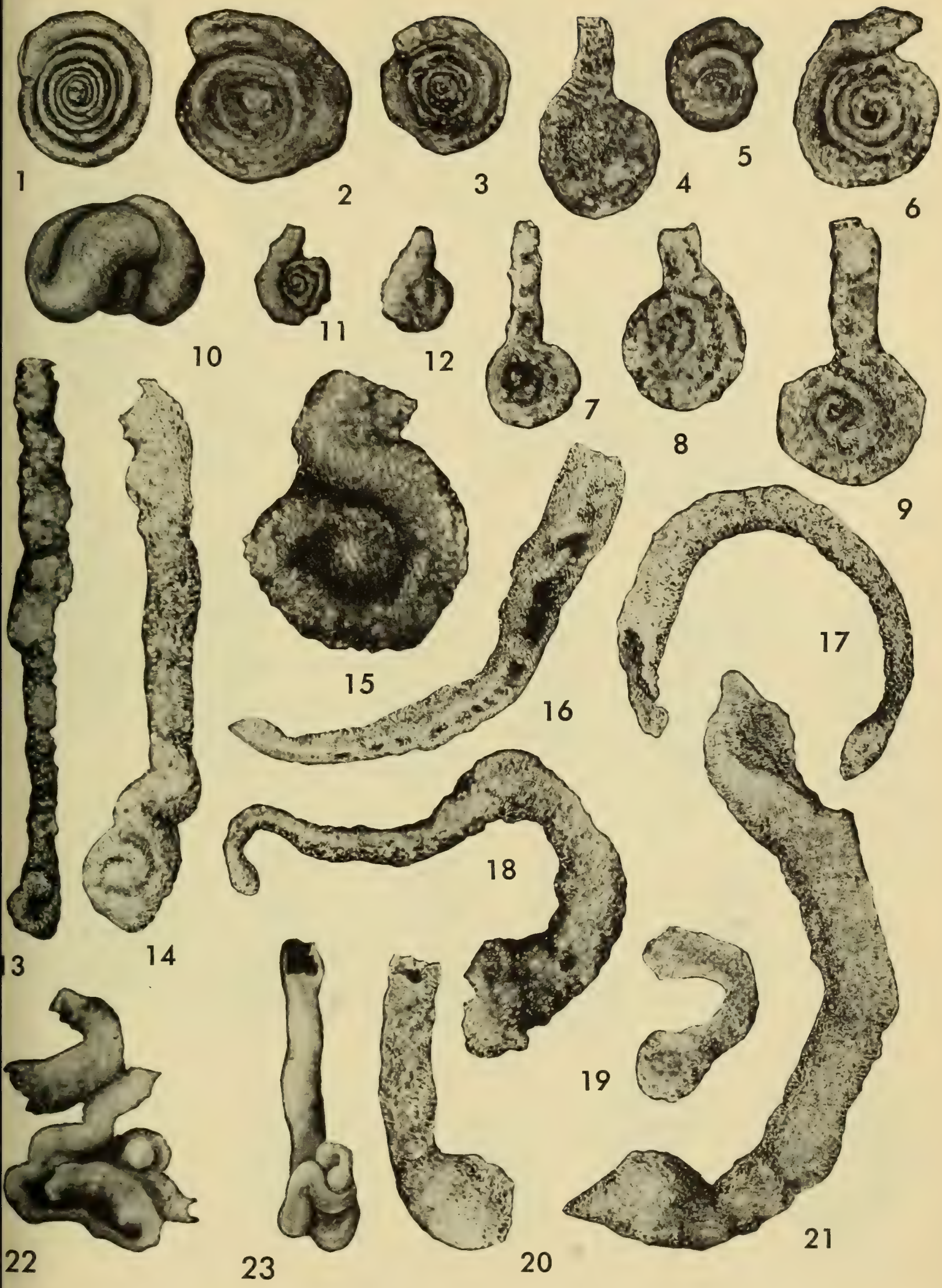
20-23. **Reophax kunklerensis,** n. sp. 280
20. Holotype, showing typical slender test with oblate overlapping chambers. No. 628684 USNM.
21-23. Nos. 628687, 628685, 628686 USNM.

24. **Reophax asper** Cushman and Waters 279
Specimen showing rugose wall of angular quartz grains. No. 628683 USNM.

25-30. **Reophax mcdonaldi,** n. sp. 284
25. Holotype. Shows typical stocky test with inflated, oblate, overlapping chambers, and pyriform last chamber. No. 628691 USNM.
26-30. Tests showing variation of form within the species. Nos. 628692, 628696, 628694, 628695, 628693 USNM.

Explanation of Plate 22

Figure	All figures X 50	Page
1-3.	**Involutina semiconstricta** (Waters)	291
	1. Variant 1. Delicate test composed of much cement. No. 628710 USNM.	
	2. Variant 2. Robust test composed of much silt and relatively small amount of cement. No. 628709 USNM.	
	3. Variant 1. No. 628712 USNM.	
4-6, 8.	**Involutina exserta** (Cushman)	287
	All specimens are Variant 2, with large proportion of silt and little cement. Nos. 628701, 628705, 628703, 628699 USNM.	
	5. Specimen with neck broken off.	
7, 9.	**Involutina longexserta** Gutschick and Treckman	289
	Nos. 628708, 628706 USNM.	
10.	**Glomospira articulosa** Plummer	296
	No. 628713 USNM.	
11, 12.	**Lituotuba semiplana,** n. sp.	297
	11. Holotype, microspheric form. No. 628715 USNM.	
	12. Megalospheric form. No. 628716 USNM.	
13.	**Tolypammina botonuncus** Gutschick and Treckman	301
	No. 628718 USNM.	
14, 15.	**Tolypammina cyclops** Gutschick and Treckman	302
	14. No. 628719 USNM.	
	15. Fragment of exceptionally large specimen. No. 628720 USNM.	
16-21.	**Tolypammina jacobschapelensis,** n. sp.	304
	16. Holotype, showing partially walled floor of test, and proloculus shaped like half an egg with a pointed end. No. 628722 USNM.	
	17, 18. Specimens with pointed proloculi. Nos. 628724, 628723 USNM.	
	19, 20. Specimens with rounded proloculi. Fig. 19 shows underside of test with attached proloculus. Nos. 628728, 628725 USNM.	
	21. Large specimen with pointed proloculus. No. 628726 USNM.	
22.	**Tolypammina tortuosa** Dunn	308
	No. 628730 USNM.	
23.	**Tolypammina laocoon,** n. sp.	307
	Specimen showing winding of early portion of second chamber. No. 628729 USNM.	



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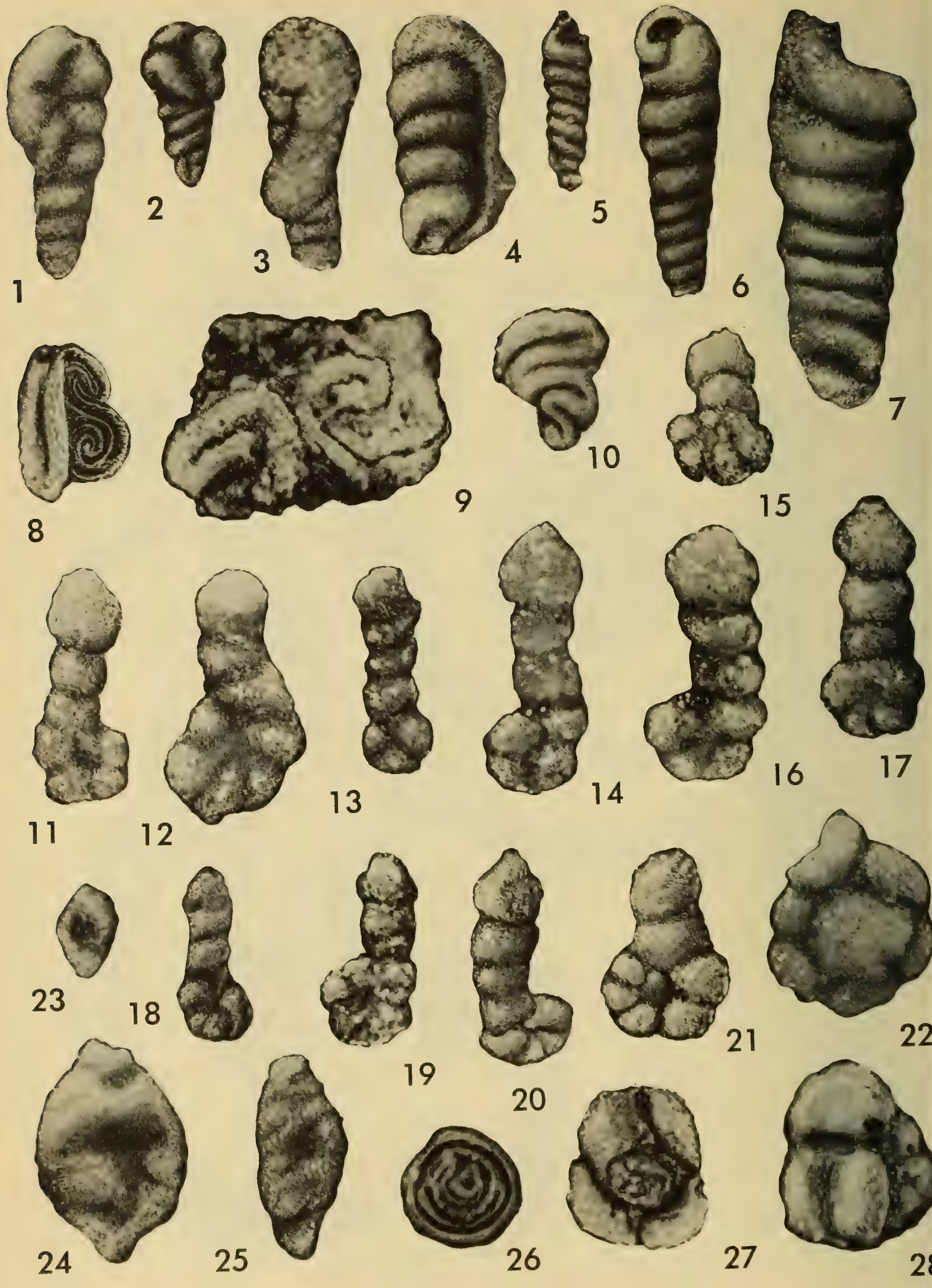

Explanation of Plate 23

Figure — All figures X 50 except where noted — Page

1, 2. **Trepeilopsis glomospiroides** Gutschick and Treckman 315
Specimen showing glomospiroid winding of last portion of second chamber. Nos. 628740, 628742 USNM.

3. 4. **Trepeilopsis recurvidens** Gutschick and Treckman 316
Specimens showing last portion of second chamber returning toward proloculus. Nos. 628745, 628743 USNM.

5-7. **Trepeilopsis spiralis** Gutschick and Treckman 318
Nos. 628747, 628748, 628746 USNM.

8. **Ammovertella** cf. **A. inclusa** (Cushman and Waters) 309
Specimen showing underside of test, early planispiral portion, and later embracing windings of second chamber. No. 628734 USNM.

9. **Ammovertella labyrintha** Ireland 312
Specimen showing maze of fused windings of second chamber. No. 628736 USNM.

10. **Ammovertella** cf. **A. primaparva** Ireland 313
Specimen showing rather regular meandering of earlier portion of test. Later more irregularly winding portion is missing. No. 628738 USNM.

11-22. **Ammobaculites gutschicki,** n. sp. 322
11. Holotype, showing oblate rectilinear chambers and pyriform last chamber. No. 628750 USNM.
12-21. Specimens showing variation within the species. Nos. 638623, 638625, 638624, 638630, 638628, 638629, 638631, 638627, 638633, 638632 USNM.
22. Broken test of unusually large size. No. 638626 USNM.

23-25. **Agathammina mississippiana,** n. sp. 331
23. X 28. No. 638637 USNM.
24. Holotype. No. 638635 USNM.
25. X 31. No. 638636 USNM.

26. **Hemigordius morillensis,** n. sp. 334
Holotype, showing rather irregularly winding early portion and planispiral later portion of tubular chamber. No. 638639 USNM.

27, 28. **Trochammina ohioensis,** n. sp. 336
27. Dorsal view of holotype. No. 638641 USNM.
28. Ventral view of flattened specimen. No. 638642 USNM.

Explanation of Plate 24

Figure All figures approximately X 90 Page

1-6. **Climacammina mississippiana,** n. sp. 326

1, 2. Holotype. Apertural and lateral views. No. 638654 USNM.

3-5. Broken specimen showing only uniserial portion. No. 638655 USNM.

6. Polished section of holotype showing biserial-uniserial chamber arrangement.

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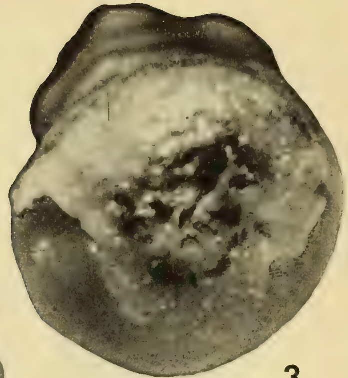

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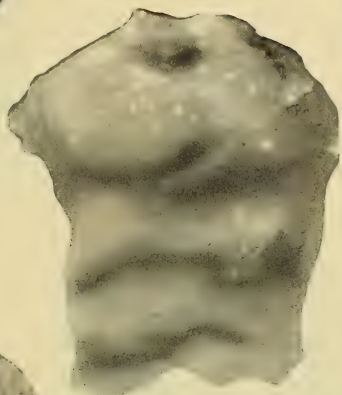

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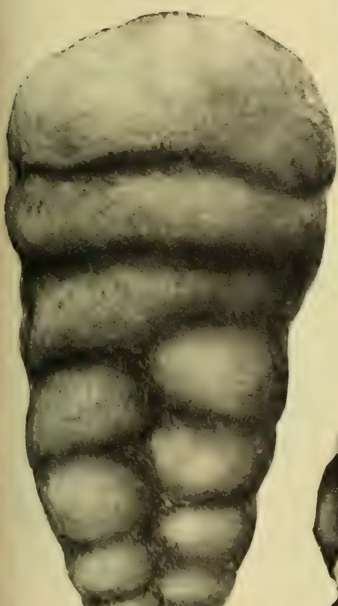

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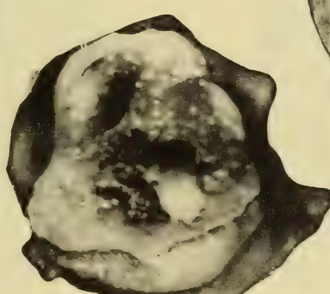

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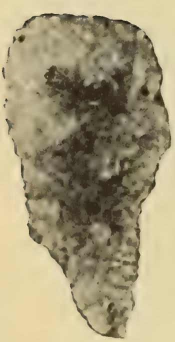

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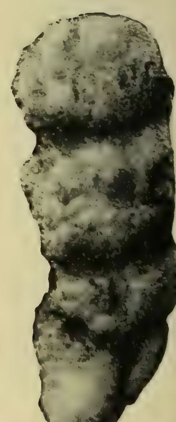

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Explanation of Plate 25

Figure | All figures X 50 | Page

1-3. **Stacheia cicatrix,** n. sp. 339
1, 2. Nos. 638645, 638646 USNM.
3. Holotype. No. 638644 USNM.
4, 5. **Stacheia neopupoides,** n. sp. 341
4. No. 638651 USNM.
5. Holotype. No. 638649 USNM.
6, 7. **Stacheia trepeilopsiformis,** n. sp. 342
Two views of holotype. No. 638652 USNM.

Explanation of Plate 26

Figure	All figures X 50	Page
1-3.	**Thuramminoides sphaeroidalis** Plummer	243
	1, 2. Thin section showing centripetal tubes, cut longitudinally near edge of test and transversely near center. Nos. 628630, 628631 USNM.	
	3. Dark material in center appears chitinous. No. 628639 USNM.	
4, 5.	**Proteonina cumberlandiae,** n. sp.	248
	Thin section. Nos. 628635, 628636 USNM.	
6.	**Proteonina wallingfordensis,** n. sp.	250
	Thin section. No. 628643 USNM.	
7, 8.	**Hyperammina casteri** n. sp.	260
	7. Thin section of megalospheric form. No. 628661 USNM.	
	8. Thin section of microspheric form with proloculus missing. No. 628653 USNM.	
9.	**Hyperammina kentuckyensis** Conkin	264
	Thin section of specimen in fig. 5, Pl. 5. No. 628670 USNM.	
10.	**Hyperammina rockfordensis** Gutschick and Treckman	267
	Thin section showing thickening of wall at junction of proloculus and second chamber. No. 628676 USNM.	
11.	**Earlandia consternatio,** n. sp.	273
	Thin section of specimen with proloculus missing. No. 628680 USNM.	
12.	**Reophax** cf. **R. arenatus** (Cushman and Waters)	278
	Thin section. No. 628682 USNM.	
13.	**Reophax** cf. **R. lachrymosus** Gutschick and Treckman	282
	Thin section. No. 628690 USNM.	
14.	**Reophax kunklerensis,** n. sp.	280
	Thin section showing overlapping nature of chambers. No. 628688 USNM.	
15.	**Reophax mcdonaldi,** n. sp.	284
	Thin section showing overlapping chambers. No. 628697 USNM.	
16, 17, 19.	**Involutina exserta** (Cushman)	287
	Thin sections. Nos. 628702, 628704, 628700 USNM.	
18.	**Involutina longexserta** Gutschick and Treckman	289
	Thin section. No. 628707 USNM.	
20.	**Involutina semiconstricta** (Waters)	291
	Thin section, Variant 1. No. 628711 USNM.	


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

Explanation of Plate 27

Figure — All figures X 50 — Page

1. **Glomospira articulosa** Plummer 296
Thin section showing irregular winding in tight knot of tubular chamber. No. 628714 USNM.
2. **Lituotuba semiplana,** n. sp. 297
Thin section, megalospheric form, showing nearly planispiral coiling. No. 628717 USNM.
3. **Tolypammina cyclops** Gutschick and Treckman 302
Thin section. No. 628721 USNM.
4. **Tolypammina tortuosa** Dunn 308
Thin section showing intertwining of tubular chamber. No. 628731 USNM.
5. **Tolypammina jacobschapelensis,** n. sp. 304
Thin section showing pointed tip of proloculus and partial floor wall. No. 628727 USNM.

6-9. **Ammovertella** cf. **A. inclusa** (Cushman and Waters) 309
Thin sections showing winding tube fused into a unit (specimen in fig. 9 is lost). Nos. 628732, 628733, 628735 USNM.

10. **Ammovertella labyrintha** Ireland 312
Thin section showing complicated maze of windings of second chamber, No. 628737 USNM.
11. **Ammovertella** cf. **A. primaparva** Ireland 313
Thin section showing regular meandering of tubular second chamber. No. 628739 USNM.
12. **Trepeilopsis recurvidens** Gutschick and Treckman 316
Thin section. No. 628744 USNM.
13. **Trepeilopsis glomospiroides** Gutschick and Treckman 315
Thin section showing irregular winding about upper end of spiral. No. 628741 USNM.
14. **Trepeilopsis spiralis** Gutschick and Treckman 318
Thin section showing spine or spicule about which tube is wound. No. 628749 USNM.
15. **Ammobaculites gutschicki,** n. sp. 322
Thin section showing planispiral coiling of early portion and rectilinear arrangement of later portion. No. 638634 USNM.
16. **Trochammina ohioensis,** n. sp. 336
Thin section. No. 638643 USNM.
17. **Hemigordius morillensis,** n. sp. 334
Thin section showing planispiral coiling of outer whorls. No. 638640 USNM.
18. **Agathammina mississippiana,** n. sp. 331
Thin section showing coiling; test much altered. No. 638638 USNM.
19. **Stacheia neopupoides,** n. sp. 341
Thin section. No. 638650 USNM.

20, 21. **Stacheia cicatrix,** n. sp. 339
Thin sections. Nos. 638647, 638648 USNM.

INDEX

Light face figures before bold face figures refer to Figure numbers; **bold face** to Plate numbers; light face to pages.

.3/3

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AN ANALYSIS OF CERTAIN TAXONOMIC PROBLEMS IN THE LARGER FORAMINIFERA

By

W. Storrs Cole
Cornell University

November 10, 1961

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CONTENTS

AN ANALYSIS OF CERTAIN TAXONOMIC PROBLEMS IN THE LARGER FORAMINIFERA*

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ABSTRACT

Although the major thesis of this discourse is variation in species of larger Foraminifera, two separate, but interrelated problems are discussed. Certain definitions which have been published for genera of camerinids with undivided median chambers are analyzed. The conclusion is that these definitions are not valid because the types of these genera are species whose structures are the same as species upon which other generic names have been based. Variation in *Lepidocyclina* (*Lepidocyclina*) *canellei* Lemoine and R. Douvillé is shown, and four formerly recognized species are considered to be variants of this species. Certain inferences are drawn concerning the possible influence of environment on the variation in the structure of the test of *L.* (*L.*) *canellei.* Illustrations are given of most of the species which are discussed.

INTRODUCTION

In an earlier study (Cole, 1957*a*) *Lepidocyclina* (*Lepidocyclina*) *supera* (Conrad) 1865 was demonstrated to be a synonym of *L.* (*L.*) *mantelli* (Morton), 1833, and *L.* (*L.*) *parvula* Cushman, 1919 was placed in the synonomy of *L.* (*L.*) *giraudi* R. Douvillé, 1907. Although *L.* (*L.*) *mantelli* is considered to be a valid species, proof will be given that *L.* (*L.*) *giraudi* is a synonym of *L.* (*L.*) *canellei* Lemoine and R. Douvillé, 1904.

The conclusion reached is more sweeping than indicated above as several species which have become entrenched in the literature are assigned also to the synonomy of *L.* (*L.*) *canellei.* They are *L.* (*L.*) *asterodisca* Nuttall, *L.* (*L.*) *miraflorensis* Vaughan, and *L.* (*L.*) *waylandvaughani* Cole. These species are invalidated with considerable regret as they have been cited in many publications and certain of these species have been assigned either restricted geographic or stratigraphic ranges.

In the interval since Vaughan (1933, p. 6) wrote "The amount of variation in many species of orbitoids is bewildering," evidence has accumulated to prove the correctness of his observation. Species of larger Foraminifera are variable! Specific names have been given to supposedly recognizable species, but new data have shown that these names have been based upon the variable form and structure of a limited number of specimens rather than upon a complete analysis of the available specimens which should be included in the species.

As many specific names designate a "form" group within a variable species, they do not express a natural relationship. It is entirely possible to

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identify these "form" groups of individuals to which specific names are given. However, the problem arises that another group of specimens may have characteristics which are intermediate between two species. The tendency is to assign another specific name to such specimens, and, finally the literature contains so many specific names that one becomes bewildered.

The difficulties inherent in any classification in which variability in the species is not recognized is compounded by the use of a "form" species as the type of a genus. Several generic names may be given, each of which is supposed to distinguish at the generic level either one species or a group of species from all other species. Yet, these supposedly distinct genera are based upon ecologically or otherwise controlled "form" species which in reality represent only one kind of a variable species. The proliferation of generic names which have been applied to the camerinids with undivided median chambers is an example of the lack of recognition of the variability which occurs in the species of *Camerina.* Although the synonyms of *Camerina* have been discussed (Cole, 1960), additional evidence for the suppression of the superfluous generic names will be given in another section of this discourse.

In the preliminary study of the larger Foraminifera entirely too much emphasis has been placed upon the concepts that the species are limited in time and space by rapid evolution and that a species can be distingushed by relative comparisons with other species.

Lepidocyclina mantelli and *L. supera* were maintained as distinct species because *L. mantelli* was assumed to be restricted to the Marianna limestone, whereas *L. supera* was supposed to be a marker for the Byram marl and related formations. Cole (1957*a*, p. 38) demonstrated that *L. supera* was a synonym of *L. mantelli.* Previous to this he (1953*b*, p. 6) wrote "If these localities represent the lower Oligocene, as it is known in Florida, such species as *Lepidocyclina mantelli* and *Operculinoides dius* might be expected to occur instead of Eocene species." Later, he (1957*a,* p. 34) could state "the *L.* (*L.*) *mantelli* and the *L.* (*Eulepidina*) zones should be combined."

Although the zonation of the American Oligocene proposed by Gravell and Hanna (1938, p. 987) was modified by the recognition that the stratigraphic range of *L.* (*L.*) *mantelli* was more extensive than had been assumed, the appreciation of variability in a species warns of the possible errors which may occur in developing zonation which is based upon "form" species.

Until this study was undertaken, *L.* (*L.*) *miraflorensis* has been cited as a species restricted to the La Boca marine member of the Panama formation (lower Miocene). If the concept developed in this discourse that *L.* (*L.*) *miraflorensis* is one of the synonyms of *L.* (*L.*) *canellei* is accepted, the supposed unique stratigraphic position of this species as the only American species of *Lepidocyclina* restricted to the lower Miocene will be destroyed.

This is regrettable! However, in the end the problem of stratigraphic correlation may be assisted as other evidence will be sought and a zonation based on the supposed restricted occurrence of *L.* (*L.*) *miraflorensis* will not become entrenched in the literature. Moreover, some of the difficulties in the identification of the species will be eliminated.

Under the influence of superficial appearance species have been defined, and, thereby, supposedly separated from other species by such statements as "Lateral chambers short . . . *L. canellei*"—"Lateral chambers long . . . *L. miraflorensis*" (Cole, 1957*a*, p. 33). On the other hand a plea of convenience is often made in statements such as the following: "These species certainly cannot be separated generically since their specific independence is in question, but one resembles *Operculina* while the other resembles *Assilina*. The latter name is nowadays reserved for Paleocene and Eocene species which form a distinct lineage, so it is convenient to assign both Recent species to *Operculina*" (Smout and Eames, 1960,p.111).

Such statements as those quoted which were selected for illustrative purpose from a multitude of similar expressions must be baffling indeed to anyone attempting taxonomic and stratigraphic research. Are not those of us who are engaged in this kind of research defeating our purpose when we attempt to separate species on preconceived ideas of how much individuals within a species vary, or by a defense of some long established generic or specific name?

Although it has been logical to define species and genera in relative terms when our data were limited, this condition no longer exists with the progress that has been made in the study of larger Foraminifera.

There will be some who object in a serious and conscientious manner that the thesis of this discourse is incorrect, and that the combinations of species proposed is absurd. To some the stellate pattern of *L.* (*L.*) *asterodisca* far overbalances the internal structure of these specimens. Therefore, they will maintain *L.* (*L.*) *asterodisca,* as I have done in the past, is a separate species characterized by its stellate outline.

Others, however, will agree that the internal structure of *L.* (*L.*) *asterodisca* and *L.* (*L.*) *waylandvaughani* is so similar that these two species should be united, the more so because some topotypes of *L.* (*L.*) *waylandvaughani* have an irregular outline (see: Cole, 1928, fig. 1, pl. 35) although these irregular specimens occur infrequently in collections from the vicinity of Tampico.

But, these same persons who accept the identity of *L.* (*L.*) *asterodisca* and *L.* (*L.*) *waylandvaughani* will object to combining these names under *L.* (*L.*) *canellei.* The superficial appearences of the vertical sections of *L.* (*L.*) *waylandvaughani* are indeed different from those of *L.* (*L.*) *canellei* on first inspection. But, detailed study of the illustrations given here and elsewhere should demonstrate that the fundamental internal structures are the same. One is influenced at first by the thinner floors and roofs of the lateral chambers in the so-called typical specimens of *L.* (*L.*) *canellei.* However, as the specimens are studied in detail these thinner floors and roofs become insignificant and the overall structural similarity becomes apparent.

It is more impressive to have a long list of species from a given locality than to have one with few species. There is no objection to this except one begins to believe that identifications can be made with certainty and, therefore, assigns certain species, at least, to restricted geographic or stratigraphic positions. Such may be the case with regard to some species and some genera. It is not implied here that the time tested and well-known species and genera are not restricted geographically and stratigraphically.

But, until species and genera are evaluated rather completely, caution must be used. Above all the natural relationships should be established by a consideration to the limit of our data regarding variability which may occur in individuals because of environmental conditions or because of genetically controlled plasticity.

The specimens used in this study are deposited in the Cole collection at Cornell University and eventually will be transferred to the U. S. National Museum.

LOCALITIES

Cuba

Loc. 1—Northwest of Cienfuegos, one kilometer on Palmira road at Pueblo Grifo, Santa Clara Province (Palmer sta. 336-see: Palmer, 1948, p. 299) ; gift of the late Mrs. D. K. Palmer.

St. Lucia, Windward Islands, West Indies

2 —La Titance, Lavoutte (sta. 6138) ; P. H. Martin-Kaye, collector.

Mexico (Tampico Embayment area)

3 —Five miles west of La Laja on the road to Ozulama at Bajada de Chichimeca, State of Vera Cruz (Huasteca Petroleum Company no. J 24-1462) ; W. S. Cole, collector.

4—Between kilometer posts 17-18 on the Aguila Petroleum Company's narrow-gauge railroad between Potrero and Tanhuijo, State of Vera Cruz (sta. S. C. M-S 1) ; W. S. Cole, collector (reference: Cole and Gillespie, 1930).

5 —Quarry on the Huasteca Petroleum Company's golf course opposite Tampico, State of Tamaulipas; bed of sandy clay overlying massive sandstone (sta. SC 3ABA) ; W. S. Cole, collector (reference: Cole, 1928, p. 221-223, pl. 4).

6—Cut on the Panuco River side of a street below the Palacio Peñal in Tampico (sta. SC 1000) ; W. S. Cole, collector.

7—About 700 feet from the station Andonegui on the electric trolley line between Tampico and Miramar (sta. SC 111) ; W. S. Cole, collector.

8—Arbol Grande near Tampico (sta. SC 1C) ; W. S. Cole, collector (reference: Vaughan, 1933, p. 15, 25, 26).

Panama Canal Zone

9—Low garden islet 0.25 miles northeast of landing at Barro Colorado Island; soft sandy calcareous siltstone (sta. 53) ; S. M. Jones and W. P. Woodring, 1947, collectors (reference: Cole, 1953*b*, p. 6).

CONFUSION IN DEFINING A GENUS

In a review of certain genera of the camerinids Cole (1960, p. 190) wrote" . . . there are only two valid genera of all those that have been proposed for camerinids with undivided chambers. They are *Camerina* and *Miscellanea*." He (Cole, 1960, p. 196) emphasized that ". . . There are no structural differences which may be used to distinguish between *Camerina, Planocamerinoides* (=*Assilina* of authors), *Operculina, Operculinoides, Ranikothalia* and *Paraspiroclypeus*. These genera have been defined in terms of intergradational features which are specific rather than generic diflerences."

In 1953 Eames (p. 390) had defined *Operculinella* Yabe (1918, p. 126) as follows: " . . . miniature *Nummulites*-like forms of small size, with a very small megalospheric nucleoconch, with little difference in size between the two generations, with or without a tendency to flare in old age." Later, Eames *et al* (1960, p. 448) wrote "*Palaeonummulites* Schubert 1908 (type species *Nummulina pristina* Brady 1874) is regarded as a prior synonym of both *Operculinella* Yabe 1918 and *Operculinoides* Hanzawa 1935." Finally, Smout and Eames (1960, p. 112) stated: ". . . The genus represented by *Operculinella* is, however, an important one."

If the genus *Palaeonummulites* (=*Operculinella* and *Operculinoides*) is to be maintained to include certain species of camerinids with undivided chambers, the species included in this genus should conform to the definition of the genus, and it should be possible to separate this group of species from other groups of species.

The critical criteria given in the definition of *Operculinella* cited are: 1. Miniature *Nummulites*-like forms; 2. The small size of the embryonic chambers; 3. The size relationship between the megalospheric and microspheric generations; and 4. The tendency to develop a flange in the terminal whorl.

These criteria to be valid must stand against data from different species. Four species are chosen for the analysis although others could be added or substituted for those selected. The type species of *Operculinella* is "*Nummulites*" *cumingii* (Carpenter) [=*Camerina venosa* (Fichtel and Moll)]. *Operculinoides* was based on "*Nummulites*" *willcoxi* Heilprin. Therefore, these two species were selected.

The American species "*Operculinella*" *cojimarensis* D. K. Palmer (1934, p. 259) from the Cuban Miocene is one of the species which most nearly resembles the type of *Operculinella*, therefore it was chosen. Finally, *Camerina pengaronensis* (Verbeek) from the Eocene of the Indo-Pacific region was selected as this species has been assigned traditionally to *Nummulites* (=*Camerina*).

The comparison can be made best in tabular form (Table 1) in which the critical statements in the definition of *Palaeonummulites* (=*Operculinella*) are contrasted with data from the selected species. As all the species are "minute *Nummulites*-like forms" this statement is not used in the table.

The species *cojimarensis* does not conform to the definition given of *Palaeonummulites* because the microspheric specimens are at least twice the

Table 1.—Comparison of selected species of camerinids

Statements in definition	Species formerly assigned to:			
	Operculinella		*Operculinoides*	*Camerina*
	venosa[1]	*cojimarensis*[2]	*willcoxi*[3]	*pengaronensis*[4]
Diameter (megalospheric specimens) ..... mm	2.0-4.4	2.7-5.5	2.6-3.9	3.0-4.0
Internal distance across both megalosperic embryonic chambers ..... μ	90-130	220	140-270	230-320
Diameter (microspheric specimens) ..... mm	3.0	9-12	5.1-6.0	6.0-9.0
Terminal whorl	With or without flange	With or without flange	Without flange	Without flange

[1] After Cole, 1959, p. 362.

[2] After D. K. Palmer, 1934, p. 259; specimens illustrated on Plate 28.

[3] After Cole, 1953*c*; 1958*b*, p. 274.

[4] After Cole, 1957*b*, p. 753; Doornink, 1932, p. 283.

size of megalospheric specimens, yet in other respects it is similar to the type species of *Operculinella.* However, some megalospheric specimens do have a diameter greater than any specimens of *"Operculinella" venosa* which I have examined. Therefore, this species may be so large that it can not be considered "miniature."

"Operculinoides" willcoxi, the type species of *Operculinoides* which is stated to be a synonym of *Palaeonummulites,* more nearly resembles *Camerina pengaronensis* than it does *"Operculinella" venosa* or *"O." cojimarensis.*

This brief analysis is indicative of the problems which arise in attempting to group the species of camerinids into genera when the definition of the genus is stated in relative terms. It should be reemphasized that "These genera have been defined in terms of intergradational features which are specific rather than generic differences" (Cole, 1960, p. 196).

From the data available it seems impossible to develop definitions based upon distinctive structures of the test which would serve to separate these four species into readily recognizable genera. Therefore, it would seem reasonable to include them in one genus, a grouping which would emphasize the relationship of the species to each other and which would separate this group of species from all other groups of species whose tests had different structures.

Drooger (1960, p. 312) in reinstating the genus *Ranikothalia* Caudri, 1944, attempted to demonstrate that the test of species which he assigned to this genus did have structures which were different, if only in degree, than those of other species of camerinids. Although this approach is the sound one, it may lead to serious error unless it can be demonstrated that the structures differ sufficiently to be distinctive.

Cole (1953*c*, p. 32; 1960, p. 192) demonstrated that the structure of the test of species assigned to the genus *Ranikothalia* was similar to that of species referred to *Camerina.* Therefore, he placed *Ranikothalia* among other generic names in the synonomy of *Camerina.* Drooger (1960, p. 312) in reinstating *Ranikothalia* wrote (p. 314): "Cole (1953, p. 10) is perfectly right in stating that the difference between *Ranikothalia* and other nummulitic genera is one of degree."

Drooger (1960, p. 314) advanced the argument that ". . . the presence of the coarse canal system, completely open to the exterior both of the marginal cord and through the double row of coarse pores along the sutures . . ." as well as the stratigraphic distribution of the species assigned to *Ranikothalia* were additional reasons for recognizing this genus.

As Drooger (1960, p. 314) pointed out ". . . such sutural openings, though of much thinner structure, were described and figured already by Carpenter (1862, p. 259, pl. 17) for recent *Operculina* specimens." Barker (1939, p. 309) obtained ". . . Canada-balsam preparations of *Camerina variolaria* (Lamarck) that show excellently developed vertical canals in the bosses of clear shell material in the umbonal area . . ."

Cole (1953*c*, fig. 10, pl. 2) has shown that the marginal cord of *Camerina variolaria* (Lamarck) is as coarse and as completely open to the surface as that of *Camerina planulata* (Lamarck) (Cole, 1960, fig. 4, pl. 23), a species which he (1960, p. 195) decided was the same as "*Nummulites*" *nuttalli* Davies. He placed "*Nummulites*" *nuttalli* in the synonomy of *C. planulata.*

In Europe *C. planulata* occurs in the lower Eocene, whereas *C. variolaria* is found in the upper Eocene. As the structure of *C. variolaria* is so similar to that of *C. planulata,* it would seem reasonable, if the genus *Ranikothalia* is to be maintained, to assign both of these species to that genus.

Another of the arguments for retaining the generic name *Ranikothalia* given by Drooger (1960, p. 314) was ". . .the species are restricted in time (Paleocene—? Early Eocene) and space (southern Asia, Togoland, Caribbean)".

However, it would appear that *C. variolaria* belongs to the same group of species as does *C. planulata.* If this is accepted, the range of this group of species would be Paleocene to upper Eocene at the minimum, thus the argument that *Ranikothalia* is confined to the lowermost Tertiary would be invalidated.

If criteria, such as the size of the embryonic chambers, the number of nepionic chambers, the total size of the test, the size relationships of the megalospheric and micospheric specimens and similar relationships were to be applied to the species of the genus *Cycloclypeus,* this genus would have to be split into several genera. In so doing a subjectively derived, artificial set of generic names would result which would destroy the unity given by one generic name. Moreover, many species would have to be assigned arbitrarily to one or the other of the genera defined in such artificial and relative terms.

Two subgenera of the genus *Cycloclypeus* have been proposed, but these subgenera have been defined as possessing different structures than those of *Cycloclypeus* (*Cycloclypeus*). *Radiocycloclypeus* was based upon stellate specimens and *Katacycloclypeus* was defined as possessing concentric, annular, thickened rings upon the surface of the test.

It may be questioned, however, whether these structures are of sufficient magnitude to warrant subgeneric rank as the internal structure of these specimens is identicial to that of specimens assigned to the subgenus *Cycloclypeus.* These superficial modifications could be considered to be specific characteristics rather than subgeneric ones.

Tan (1932, p. 71) in discussing *Cycloclypeus* (*Cycloclypeus*) *indopacificus* stated "These annuli appear to be either rows of large pillars (Pl. XX, fig. 6) or irregular folds (vide Douvillé's fig. 6 on Pl. V) which never attain the same regularity and continuity as with *Katacycl. annulatus.*"

In studies (unpublished) which I have made of *Cycloclypeus* collected on Guam, I had difficulty in attempting to separate certain specimens on the presence or absence of the annular folds into subgenera and had to rely on thin sections by which *Cycloclypeus annulatus* could be recognized readily and distinguished from other species. As *Cycloclypeus annulatus* is a typical representative of the subgenus *Katacycloclypeus*, the presence or absence of the annular folds should be so constant that specimens could be identified subgenerically without the difficulties encountered.

Cole (1960, p. 198) suggested that in genera, such as *Camerina* and *Cycloclypeus*, the phylogenetic relationships are best expressed by indicating lineages within the genera rather than attempting to use either subgeneric or different generic names for species which differ in degree, but not in fundamental structure, from other species. If this suggestion is followed, a natural, but flexible, classification results, and the confusion entailed by arbitrarily assigning species to genera which have been defined in relative terms is eliminated.

Stratigraphic correlation based upon species is not only more accurate but also less liable to error than that based upon generic ranges. Although it is accepted that genera have longer stratigraphic ranges than do species, it is not appreciated by many stratigraphers that certain of the so-called index genera are recognized by subjectively determined definitions. Therefore, a certain supposedly stratigraphically restricted genus may have a longer range in geologic time than implied because species which should be included in this genus are assigned to another genus.

It is easier to recognize species such as *Camerina catenula* (Cushman and Jarvis) (Cole, 1958*b*, p. 270) than to decide to which genus this species should be referred if multiple generic names for camerinids with undivided median chambers are maintained. This species has been assigned by competent authorities to *Miscellanea, Operculinoides, Pellatispirella,* and *Camerina.* It is remarkable that specimens of this species of the kind illustrated by Cole and Herrick (1953, figs. 6, 15, 16, pl. 4 among others) have not been assigned by someone to *Operculina.* If this had happened, *C. catenula* would have been assigned at one time or another to three genera which are synonyms of *Camerina* as well as to two genera which are not synonyms of *Camerina.*

VARIATION IN A SPECIES OF CAMERINA

Although variation in species of *Camerina* has been discussed recently by Cole (1961: see also papers listed in this reference on p. 123, 124) additional illustrations are given of *Camerina dia* (Cole and Ponton) on Plate 29 as individuals of this species vary greatly especially as viewed in transverse section.

The specimen illustrated by figure 4, Plate 29 is compressed, whereas the specimen illustrated by figure 5, Plate 29 is inflated. If only these two specimens were available, it is easy to understand how they could be assumed to represent two distinct species. However, the specimen illustrated by figure 2, Plate 29, is intermediate between the other two specimens.

If time had been available, it would have been possible to prepare a series of illustrations which would form a completely integrated series. However, the evidence as presented here and elsewhere seems to substantiate the synonymy given for this species (Cole, 1958*b*, p. 270).

VARIATION IN *LEPIDOCYCLINA CANELLEI* LEMOINE AND R. DOUVILLÉ

THE SPECIFIC NAMES

Lepidocyclina (*Lepidocyclina*) *canellei* Lemoine and R. Douvillé (1904, p. 20) was described from specimens collected at Peña Blanca, Panama Canal Zone. This locality on the Rió Chagres was submerged by Gatun Lake, but abundant specimens of this species can be obtained from many localities in this area which are above the level of the lake (Woodring, 1958, p. 24). The type locality of this species is assigned by Woodring (1957, p. 29, 117) to the middle member of the Caimito formation of Oligocene age. Recently, Cole (1953*b*, p. 18) redescribed and illustrated this species.

L. (*L.*) *canellei* has been reported elsewhere from Venezuela (Gravell, 1933, p. 24), Jamaica (Vaughan, 1928, p. 290; Cole, 1956, p. 213) and Trinidad (Vaughan and Cole, 1941, p. 70). Vaughan (1933, p. 15) reported a "dwarf variety of *L. canellei* at Arbol Grande station, near Tampico."

Vaughan (1928, p. 292) named specimens from Jamaica *L.* (*Lepidocyclina*) *matleyi,* a species which Cole (1956, table 3) considered to be a synonym of *L.* (*L.*) *canellei.* Vaughan and Cole (1932, p. 510) gave the name *L.* (*L.*) *pancanalis* to small specimens from U. S. G. S. loc. 6025, a locality formerly known as Bohio Ridge Switch, Panama Canal Zone. They reported that *L. pancanalis* occurred also in Antigua (Vaughan and Cole, 1932, p. 511) and in Trinidad (Vaughan and Cole, 1941, p. 71). Later, Cole (1953*b,* p. 18) decided that *L.* (*L.*) *pancanalis* was based on small specimens of *L.* (*L.*) *canellei* and was another synonym of *L.* (*L.*) *canellei.*

R. Douvillé (1907, p. 307) described *L.* (*L.*) *giraudi* from specimens obtained from the Oligocene of Pointe Macabou and vicinity, Martinique, French West Indies, where it was associated with *Spiroclypeus bullbrooki* Vaughan and Cole (1941, p. 54), the only species of *Spiroclypeus* known to date from the Americas.

Vaughan and Cole (1941, p. 71) found *L.* (*L.*) *giraudi* in Oligocene sediments in Trinidad where it was associated with *Spiroclypeus bullbrooki.* In Trinidad these two species are associated with *Heterostegina antillea* Cushman, *Lepidocyclina* (*Eulepidina*) *tempanii* Vaughan and Cole (=*L.* (*E.*) *tournoueri* Lemoine and R. Douvillé), *L.* (*E.*) *undosa* Cushman and *L.* (*E.*) *yurnagunensis* Cushman. Vaughan and Cole (1941, p. 120) noted that certain specimens from Trinidad which they referred to *L.* (*L.*) *giraudi* "might without great impropriety be referred to *L. parvula* Cushman."

Cushman (1919, p. 58) described a species from the Oligocene of Antigua to which he applied the name *Lepidocyclina parvula.* Vaughan (1933, p. 16) discussed this species in detail and described (1933, p. 17) from Arbol Grande near Tampico, State of Tamaulipas, Mexico, and several other Mexican localities, a variety which was named *L. parvula crassicosta* Vaughan and Cole.

In 1928 Cole (p. 21) named specimens found in a quarry on the golf course of the Huasteca Petroleum Company opposite Tampico *L.* (*L.*) *waylandvaughani.* Vaughan wrote Cole (1928, p. 22) concerning these specimens: "It appears to me to be more closely related to *L. parvula*

Cushman, but that species is usually thicker through the center, even to being inflated and the papillae are coarser. However, there is a tremendous amount of variation. Since I have not yet reached a positive decision regarding what to do with the form I hesitate to advise you. Because of the two differences above mentioned, I should hesitate to apply the name *parvula* to it, but the form runs very close to the flatter varieties of *parvula*."

At this same locality Cole (1928, p. 22) found microspheric specimens in association with *L.* (*L.*) *waylandvaughani* which he identified as *Lepidocyclina* aff. *L. morgani* Lemoine and R. Douvillé. Vaughan (1933, p. 16) assigned these specimens to *L.* (*L.*) *parvula*, but at the same time he (1933, p. 13) accepted *L.* (*L.*) *waylandvaughani* as a valid species.

Cole (1945, p. 30) accepted this revision by Vaughan in which the megalospheric specimens from this locality at Tampico were assigned to *L.* (*L.*) *waylandvaughani*, whereas the associated microspheric specimens (Cole, 1945, fig. 9, pl. 7) were referred to *L.* (*L.*) *parvula*.

Still another specific name was introduced when Vaughan (1927, p. 4) gave the name *L.* (*L.*) *miraflorensis* to certain specimens from the Panama Canal Zone which Cushman (1918, p. 93) had misidentified as *L.* (*Eulepidina*) *vaughani*. Cole (1953*a*, p. 333) studied topotype specimens of *L.* (*L.*) *miraflorensis* and published several new illustrations.

Woodring (1960, p. 29) has remarked that "The still younger La Boca marine member of Panama formation, also assigned to the early part of the early Miocene, contains the last species in the Canal Zone: two lepidocycline species *L. miraflorensis* and *L. parvula* (Cole, 1953*a*). *L. parvula* later was synonymized with *L. giraudi* (Cole, 1957*a*, p. 41). The Culebra and La Boca species of *Lepidocyclina* also occur in late Oligocene formations in the Canal Zone, with the exception of *L. miraflorensis*."

Nuttall (1932, p. 34) described a stellate species from the Alazan formation (Oligocene) of the Tampico Embayment area of Mexico as *L.* (*L.*) *asterodisca*. Gravell and Hanna (1937, p. 528) found stellate specimens in cores from the Anahuac formation (Oligocene) from a well in Texas which they named *L.* (*L.*) *texana*. Cole (1953*b*, p. 18) combined these two species, and later discussed and illustrated (1958*a*, p. 201) additional specimens from Cuba.

Thus, the specific names *L.* (*L.*) *asterodisca*, *L.* (*L.*) *canellei*, *L.* (*L.*) *giraudi*, *L.* (*L.*) *miraflorensis*, *L.* (*L.*) *parvula and L.* (*L.*) *waylandvaughani* became established. However, in a study of the variation which may occur in species of *Lepidocyclina* Cole (1957*a*, p. 41) demonstrated that *L.* (*L.*) *parvula* was a synonym of *L. giraudi,* a conclusion which was accepted by Grimsdale (1959, p. 28). At the present time six species, as *L.* (*L.*) *mantelli* must be included, of *Lepidocyclina* (*Lepidocyclina*) are recognized as occurring in the Americas above the top of the Eocene.

The thesis developed in the next section of this discourse is that there are only two species of the subgenus, *L.* (*L.*) *canellei* and *L.* (*L.*) *mantelli,* in the Americas. *L.* (*L.*) *asterodisca, L.* (*L.*) *giraudi,* L. (*L.*) *miraflorensis* and *L.* (*L.*) *waylandvaughani* are synonyms of *L.* (*L.*) *canellei* as they were based upon selected "forms" within a variable species.

VARIATION

It has long been known that *L.* (*L.*) *asterodisca,* except for a stellate pattern, is similar in equatorial section to specimens referred to such species as *L.* (*L.*) *giraudi* and *L.* (*L.*) *waylandvaughani.* As a stellate pattern has been assumed to be a specific charater in the genus *Lepidocyclina,* it was possible to prepare a key for the recognition of the species in which this feature was used (Cole, 1957*a*, p. 33). In the use of this character the internal structures were ignored. In addition, the other Oligocene species assigned to the subgenus *Lepidocyclina* were placed in the key on the characteristics of the vertical sections as it was admitted that all of these species had similar, if not identical, equatorial sections.

Since that time certain problems have arisen which cast doubt on the validity of this key, and, thereby, on the species which the key was assumed to differentiate. As additional thin sections were prepared and studied, it became apparent that *L.* (*L.*) *asterodisca, L.* (*L.*) *canellei, L.* (*L.*) *giraudi, L.* (*L.*) *miraflorensis* and *L.* (*L.*) *waylandvaughani* were one species. The various specific names were based upon the superficial "form" of certain specimens rather than upon an analysis of the basic structures of the test.

Moreover, environmental factors influence the development of the test. Therefore, one kind of test normally predominates at a given locality. At locality 4 many of the specimens (figs. 1, 4, Pl. 30; fig. 2, Pl. 34) are similar to the types of *L.* (*L.*) *parvula* Cushman (1919, figs. 3-7, pl. 3) (=*L.* (*L.*) *giraudi*), whereas at locality 5 the specimens (fig. 9, Pl. 30; figs. 2, 6, 7, Pl. 38; figs. 1, 3, 9, Pl. 39) which are topotypes of *L.* (*L.*) *waylandvaughani* have an appearance which is distinctive and at first glance different from those at locality 4. Moreover, the small to medium size specimens at locality 5 are so similar to *L.* (*L.*) *canellei* that Vaughan (1933, p. 15) considered them to be a dwarf variety of that species.

At locality 1 specimens (fig. 2, Pl. 30) occur which are the same as the types of *L.* (*L.*) *waylandvaughani* and other specimens (figs. 5, 6, 13, Pl. 30) are identical with *L.* (*L.*) *parvula* (= *L.* (*L.*) *giraudi*). The microspheric specimens (fig. 3, Pl. 36) at locality 5 had been referred to *L.* (*L.*) *parvula* (=*L.* (*L.*) *giraudi*) although the associated megalospheric specimens had been named *L.* (*L.*) *waylandvaughani.*

Thus, in one population (loc. 4) the megalospheric and microspheric specimens had been assigned to the species *L.* (*L.*) *parvula* (=*L.* (*L.*) *giraudi*). At a second locality (loc. 5) the megalospheric specimens had been named *L.* (*L.*) *waylandvaughani,* whereas the microspheric specimens had been referred to *L.* (*L.*) *parvula* (=*L.* (*L.*) *giraudi*). At the third locality (loc. 1) both species seemingly are present.

Although there are inconsistencies in this terminology in referring megalospheric and microspheric specimens to different species, it might still be possible that there are several distinct species. Therefore, numerous thin sections were made and other localities were studied.

Specimens (figs. 1, 3-7, Pl. 34) from locality 3 were first identified as *L.* (*L.*) *miraflorensis* because of their size, shape, and the open, regularly aligned lateral chambers (fig. 7, Pl. 34). But, other specimens (fig. 3-5, 7, Pl. 34) from this sample which seemingly contained only one species of *Lepidocyclina* were similar to topotype specimens of *L.* (*L.*) *waylandvaughani.*

Additional thin sections (figs. 4-8, Pl. 39) of *L.* (*L.*) *canellei* from locality 9 were prepared to supplement those already published (Cole, 1953*b*, figs. 1, 3, 4, 11, 12, 16, pl. 16).

The vertical sections which are illustrated can be grouped into species by superficial form as follows:

1. *L.* (*L.*) *canellei* Lemoine and R. Douvillé
Plate 30, figures 8, 9; Plate 38, figures 2, 7; Plate 39, figures 3-6 8, 9.
2. *L.* (*L.*) *giraudi* R. Douvillé
Plate 30, figures 1, 4, 5, 6, 10, 12, 13; Plate 34, figures 2, 8;
Plate 36, figure 3; Plate 37, figure 3; Plate 38, figure 1.
3. *L.* (*L.*) *miraflorensis* Vaughan
Plate 34, figure 7.
4. *L.* (*L.*) *waylandvaughani* Cole
Plate 30, figures 2, 3, 7, 11; Plate 34, figures 1, 3-6; Plate 38, figures 3, 6; Plate 39, figures 1, 2.

Admittedly, this is a subjectively determined listing as such features as the strength of the pillars became the critical feature upon which the specimen was assigned to a given species.

The specimen illustrated as figure 1, Plate 38 (*L. giraudi* kind) has the same internal structure as does figure 4 of this same plate except it is more inflated and the pillars on one side are stronger. Figure 3, Plate 38 is almost identical with figure 1, Plate 39 (a topotype of *L. waylandvaughani*) except the roofs and floors of the lateral chambers are slightly more curved in figure 1, Plate 39 than they are in figure 3, Plate 38. Other topotype specimens (Cole, 1952, figure 10, plate 18) of *L.* (*L.*) *waylandvaughani* have lateral chambers with straight roofs and floors. Thus, it seems logical to group these specimens under one specific name rather than two as the specimen illustrated as figure 4, Plate 38 is intermediate between the other two specimens.

If illustrations of *L.* (*L.*) *miraflorensis* (Cole, 1953, pl. 43) are compared with those given of *L.* (*L.*) *canellei* on Plate 39, it will be observed that the internal structure of those two species is the same. Likewise, specimens such as those illustrated by figures 3, 9, Plate 39, have the same internal structure as *L.* (*L.*) *canellei* does. But, specimens such as those illustrated by figures 8, 9, Plate 30 are intermediate between *L.* (*L.*) *canellei* and *L.* (*L.*) *waylandvaughani.*

Cole (1958*a,* p. 201) has given a number of illustrations of equatorial and vertical sections of *L.* (*L.*) *asterodisca.* If these are compared with the illustrations given in this article, it will be observed that the internal structure of this species which was named because of its stellate pattern is the same as specimens assigned to *L.* (*L.*) *canellei.* The first comparison should be between the specimen illustrated as figure 3, Plate 38, and the one shown as figure 10, plate 23 (Cole, 1958*a*).

In the study (Cole, 1958*a*) of *L.* (*L.*) *asterodisca* it was found that the associated microspheric specimens where not stellate, only the megalospheric specimens developed the stellate pattern.

Another pair of species should be mentioned in this connection. They are *L.* (*Eulepidina*) *tournoueri* Lemoine and R. Douvillé (figure 5, Plate 32) and *L.* (*Eulepidina*) *dartoni* Vaughan (Cole, 1953*b*, figures 1-8, plate 19). Except for the stellate pattern, it is impossible to separate these two species.

They should be combined under the name *L.* (*E.*) *tournoueri.* It should be recognized that in *Lepidocyclina* the stellate pattern is produced only by certain individuals, probably under the influence of ecological conditions, and that this pattern is not genetically produced. Therefore, it does not have value as a specific character.

Specimens assigned previously to the species *L.* (*L.*) *asterodisca*, *L.* (*L.*) *canellei*, *L.* (*L.*) *giraudi*, *L.* (*L.*) *miraflorensis* and *L.* (*L.*) *waylandvaughani* have identical equatorial sections. The species, therefore, have been recognized by differences in the shape of the test and by the structure observed in the vertical sections.

Although *L.* (*L.*) *mantelli* (Morton) (Cole, 1957*a*, p. 38) has a similar equatorial section to that of *L.* (*L.*) *canellei*, the vertical section is markedly different. In *L.* (*L.*) *mantelli* the lateral chambers have noticeably thick roofs and floors, the chamber openings are slitlike, and they are never in alignment. Therefore, *L.* (*L.*) *mantelli* is retained as a valid species.

The supposed differences used in the recognition of these species are summarized in Table 2.

Such differences as do appear can be more readily interpreted as the result of individual variation in most cases produced by ecological rather than genetically produced structures. Moreover, it has been well established that all of these supposed species have the same stratigraphic ranges. The only useful purpose in retaining different specific names would be to define populations developed under different ecological conditions. However, any advantage so gained would be offset in concealing the fact that only one species was present at the different locilities. Moreover, the usual concept of a species would be violated.

THE SPECIES ILLUSTRATED

Many of the specimens illustrated have been mentioned already in the text. However, other specimens which may not have been mentioned are included in the illustrations for completeness and may be useful in making additional comparisons. With the exception of localities 4 and 9 all the species of larger Foraminifera found at the other localities are illustrated.

Camerina cojimarensis (D. K. Palmer) .... Plate 28
  dia (Cole and Ponton) .... Plate 29

Table 2.—Major differences between the species

Species	Shape	Pillars	Lateral chambers	
			Roofs and floors	Alignment
L. (*L.*) *asterodisca*	Stellate	Few, small	Identical with *L. waylandvaughani*	
canellei	Compressed to inflated lenticular	Few, small	Thin	Regular
giraudi	Inflated lenticular	Many, large	Moderately thick	Some irregularity
miraflorensis	Compressed lenticular	Few, small	Identical with *L. canellei*	
waylandvaughani	Compressed lenticular	Few, small	Moderately thick	Some irregularity

Lepidocyclina (*Lepidocyclina*) *canellei* Lemoine and R. Douvillé . . . Plate 30; Plate 31; Plate 32, figures 1-4; Plate 33; Plate 34, figures 1-8; Plate 35, figures 1, 2, 4, 5; Plate 36; Plate 37; Plate 38

(*Eulepidina*) *tournoueri* Lemoine and R. Douvillé . . . Plate 32, figure 5; Plate 34, figure 9; Plate 35, figure 3.

PALEOECOLOGICAL IMPLICATIONS

At locality 1 there were abundant specimens of *Camerina dia* in association with a modest number of specimens of *Lepidocyclina* (*Lepidocyclina*) *canellei*. At locality 3 there were abundant, large size specimens of *L.* (*L.*) *canellei* and a modest number of specimens of *C. dia,* or just the reverse of the situation at locality 1.

At locality 4 *Heterostegina antillea* in modest numbers occurred with rare specimens of *C. dia* and numerous specimens representing two species of *Lepidocyclina, L.* (*L.*) *canellei* and *L.* (*E.*) *undosa.* At localities, such as locality 5, *L.* (*L.*) *canellei* in abundance was associated with numerous specimens of *Streblus mexicanus mecatepecensis* (Nuttall) and *Elphidium.*

At locality 9 *L.* (*L.*) *canellei* in abundance occurred with *Miogypsina antillea* (Cushman) and other species of *Lepidocyclina.* However, camerinids were not found at this locality.

These associations suggest that ecological controls were operative to some extent. Cole (1957*b,* p. 751) had written ". . .*Heterostegina* require(s) warm, shallow protected situations. *Operculina* (=*Camerina*) favors partly protected conditions, but is more tolerant of greater depth and lower temperatures." Elsewhere he (Cole, 1959, p. 354) stated "The average depth at which *Heterostegina* occurred in the vicinity of Bikini and the Philippine Islands was 25 to 32 fathoms."

Bandy (1960, p. 11) wrote, "Most rotaloids with pillars are inner shelf inhabitants, as represented by the cosmopolitan *Streblus*. . . *Streblus* is euryhaline and eurythermal whereas the others mentioned are stenohaline and stenothermal."

The abundance of *Streblus* and *Elphidium* at locality 5 as well as the character of the sediments, massive cross-bedded sandstones between which occur thin, fossiliferous beds of sandy clay, suggest that these sediments accumulated in shallow water in a somewhat protected situation such as a large bay. This is the environment suggested for such localities as 1, 3 and 5 of which locality 5 represents the shallowest environment with the most variable conditions and locality 3 represents the deepest environment of these three localities.

In contrast to these localities the sediments at locality 9 in which *Miogypsina* occurred with *Lepidocyclina*, but without camerinids seemingly were deposited in waters which were too deep or too cold for the camerinids.

The faunal association at locality 4 is suggestive of conditions which represent intermediate conditions, probably those which occur near the lower limit of the ecological controls favorable to the camerinids.

Specimens of *L.* (*L.*) *canellei* with weak pillars and thin floors and roofs of the lateral chambers would be those of the deeper environments, whereas specimens with larger pillars and thicker floors and roofs of the lateral chambers would represent kinds which inhabited shallower and probably warmer water. Stellate specimens of *L.* (*L.*) *canellei* are associated commonly with abundant specimens of *Heterostegina,* and seemingly are developed in the situations which are optimum for the development of *Heterostegina.*

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PLATES

This study was made subsequent to the ones by Cole and Applin and Cole which had been accepted for publication (Contrib. Cushman Found. Foram. Res., v. 12, pt. 4, 1961). Therefore, some of the specific names of *Lepidocyclina* used in those articles have been changed.—Editor's note.

Explanation of Plate 28

Figure Page

1-7. **Camerina cojimarensis** (D. K. Palmer) 378, 379

1. Central part, X 40, of a median section of a megalospheric specimen.

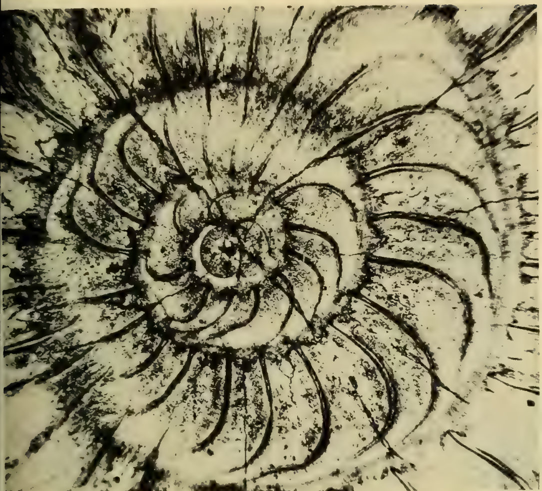
2. Transverse sections; 2, X 20; 3, X 12.5; of megalospheric specimens.

4. Transverse section, X 12.5, of a microspheric specimen.

5,6. Median sections; 5, X 20; 6, X 12.5, of megalospheric specimens.

7. Part of a median section, X 12.5, which is not ground to the median plane in the central area of a microspheric specimen.

1-7. Loc. 2—see text for locality descriptions.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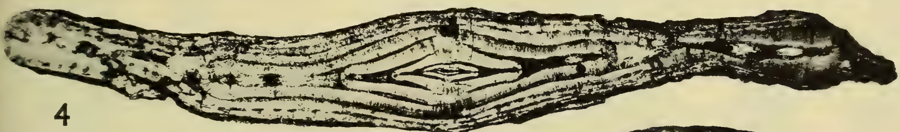
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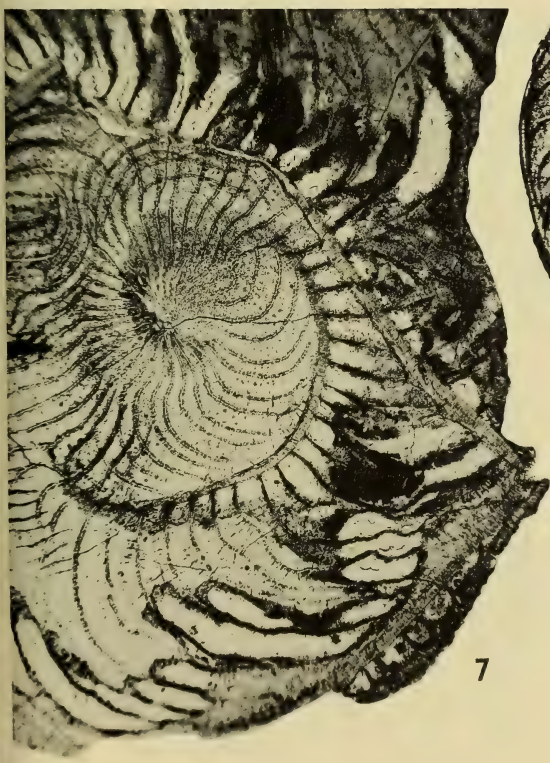
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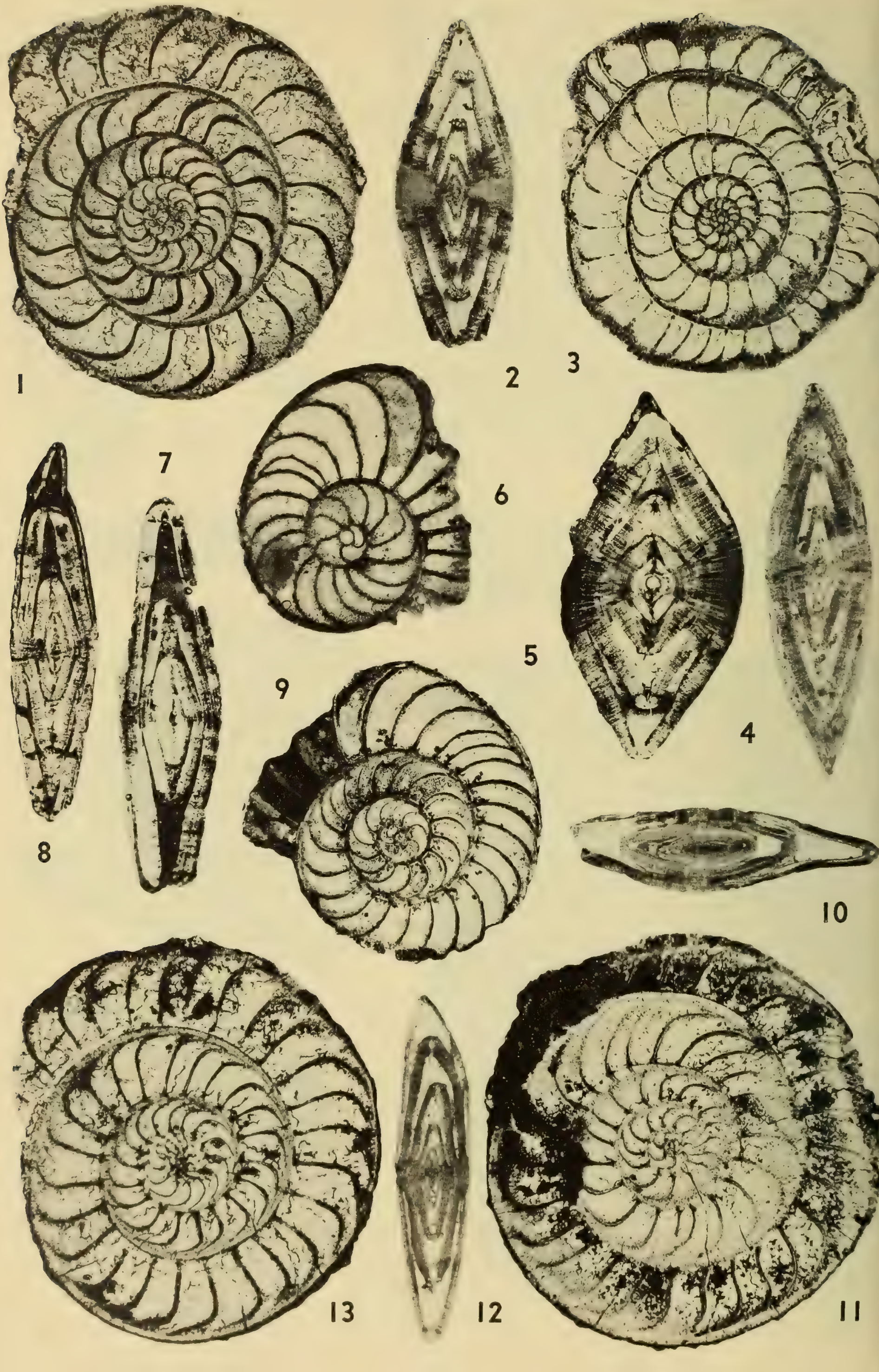
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Explanation of Plate 29

Figure Page

All figures, X 20.

1, 3, 6, 9, 11, 13. Median sections.

2, 4, 5, 7, 8, 10, 12. Transverse sections.

1-5, 12. Loc. 1—see text for locality descriptions.

6, 9, 10. Loc. 8.

7, 8, 11, 13. Loc. 3.

Explanation of Plate 30

Figure Page

1-13. **Lepidocyclina (Lepidocyclina) canellei**
Lemoine and R. Douvillé.................................... 386, 387, 388, 391

Figures 1-7, 10, 11, X 20; 8, 9, 12, 13, X 40.

1-13. Vertical sections of megalospheric specimens to illustrate variation.

1, 4, 10. Loc. 4—see text for locality descriptions.

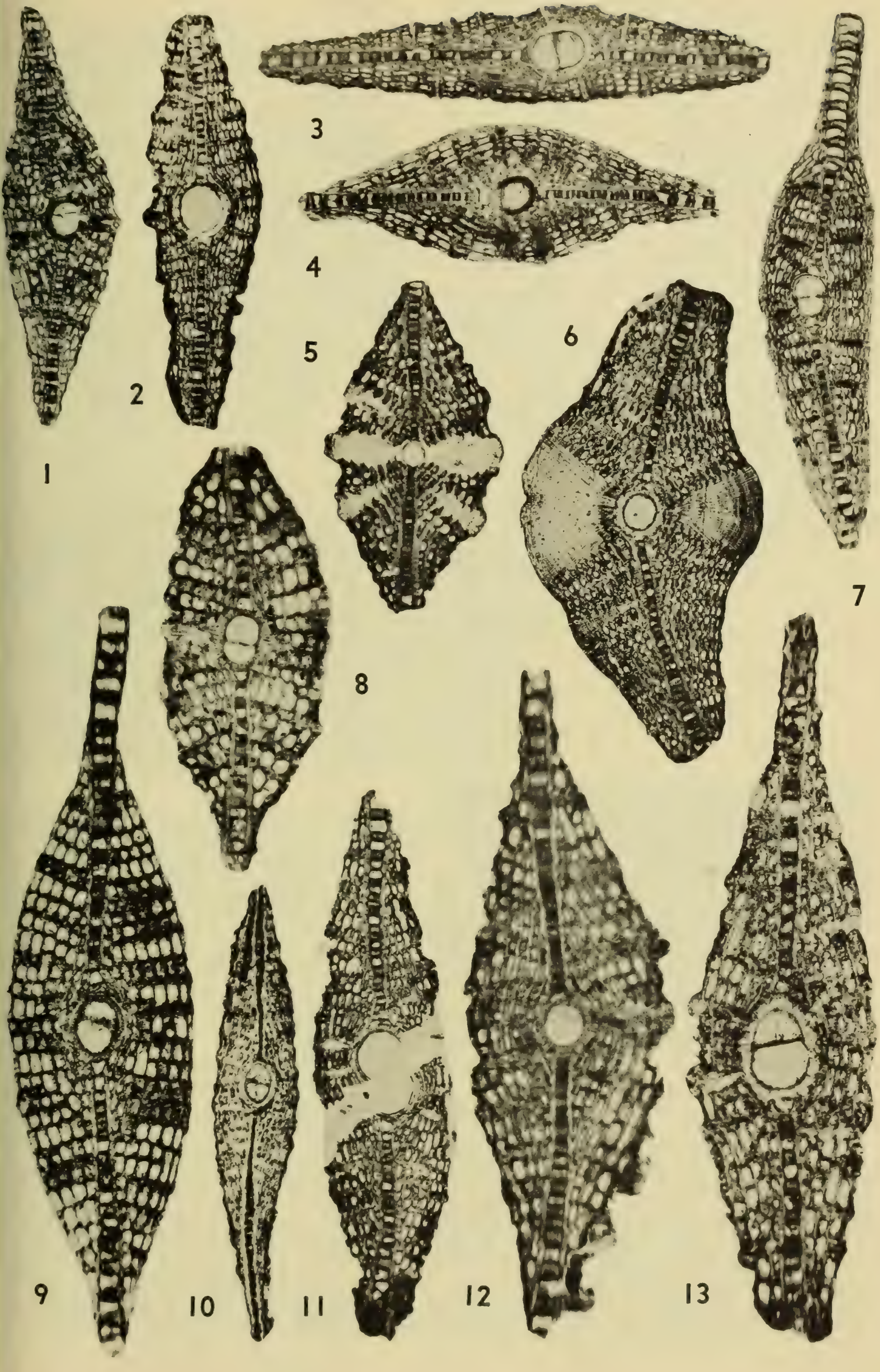
2, 5, 6, 13. Loc. 1.

3, 8, 11. Loc. 6.

7. Loc. 7.

9. Loc. 5.

12. Loc. 8.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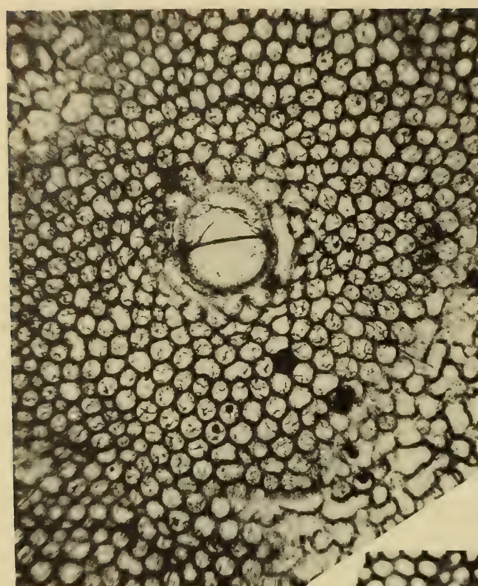

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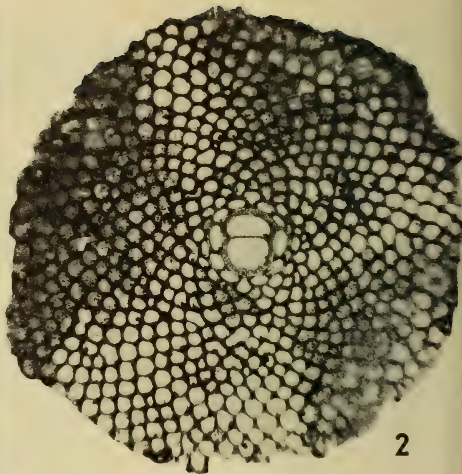

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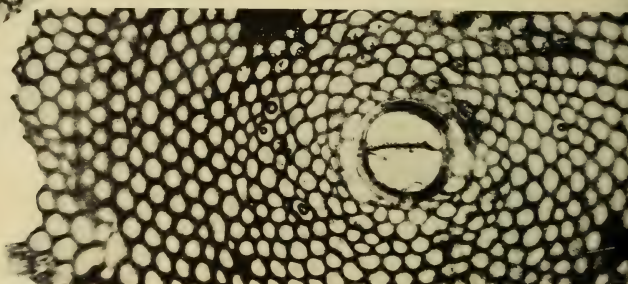

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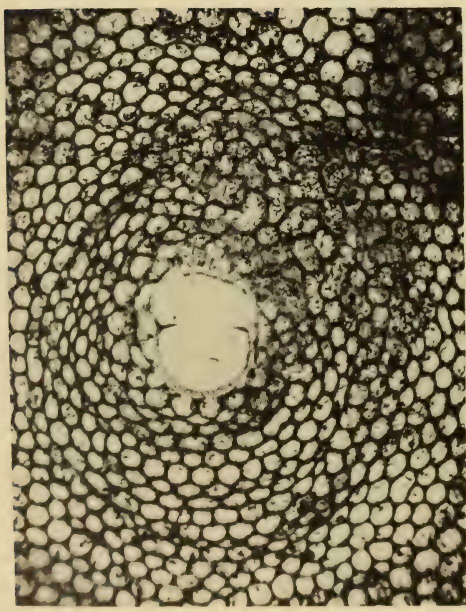

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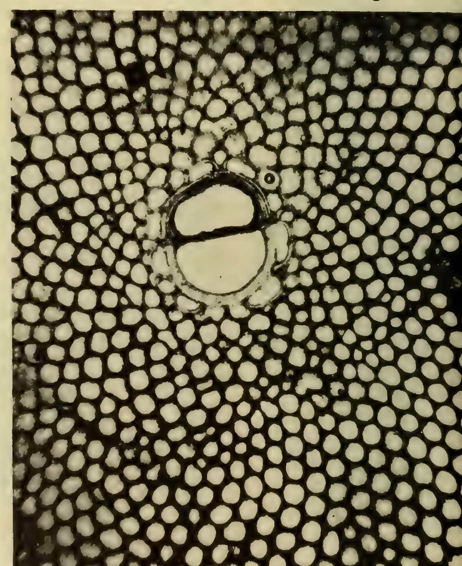


Explanation of Plate 31

Figure | Page

1-5. **Lepidocyclina (Lepidocyclina) canellei**
Lemoine and R. Douvillé.. 391

1. Part of an equatorial section, X 40, of a megalospheric specimen the peripheral equatorial chambers of which are illustrated as figure 1, Plate 36.
2. Equatorial section, X 40; the vertical section of a similar specimen is illustrated as figure 8, Plate 30.
3. Part of an equatorial section, X 40, of a specimen illustrated previously as figure 11, plate 7 (Cole, 1945).
4. Part of an equatorial section, X 40, the peripheral equatorial chambers of which are illustrated as figure 5, Plate 35.
5. Part of an equatorial section, X 40; the vertical section of a similar specimen is illustrated as figure 7, Plate 30.

1. Loc. 4—see text for locality descriptions.
2. Loc. 6.
3. Loc. 4.
4. Loc. 3.
5. Loc. 7.

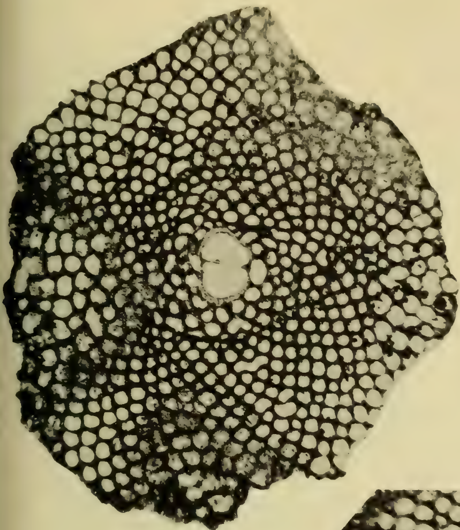
Explanation of Plate 32

1, 5. Loc. 6—see text for locality descriptions.

2. Loc. 1.

3. Loc. 4.

4. Loc. 5.



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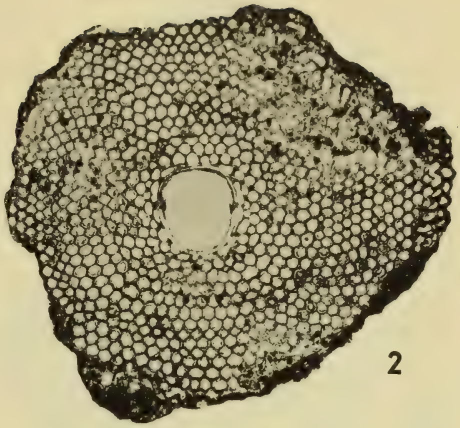

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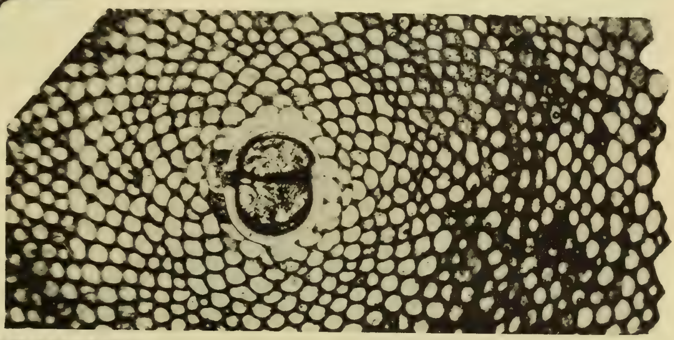

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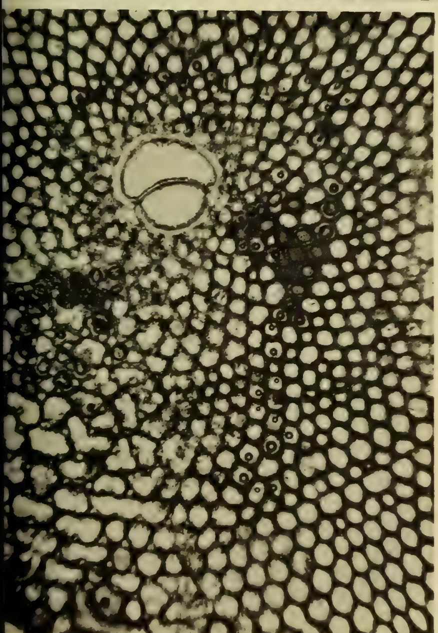

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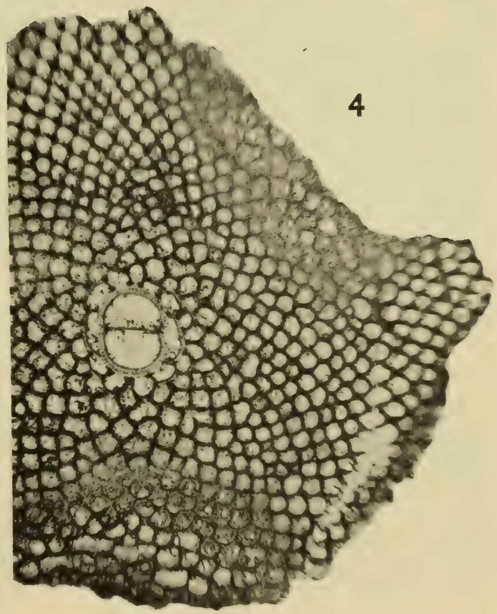

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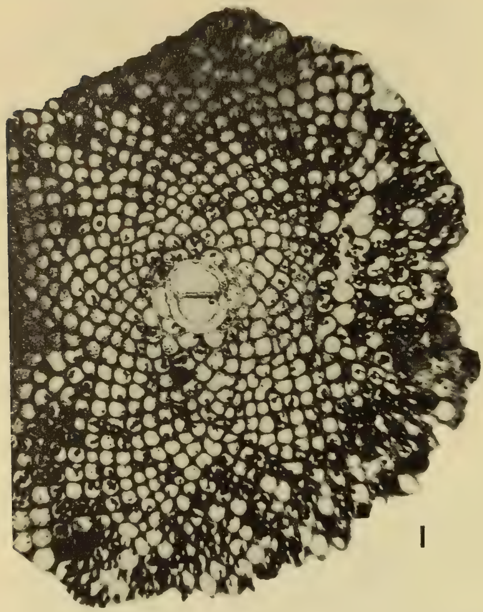

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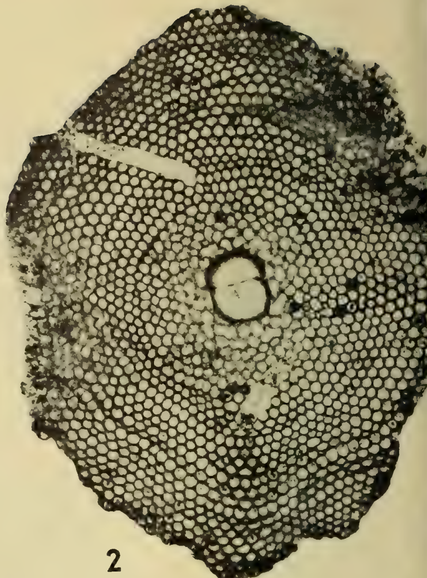

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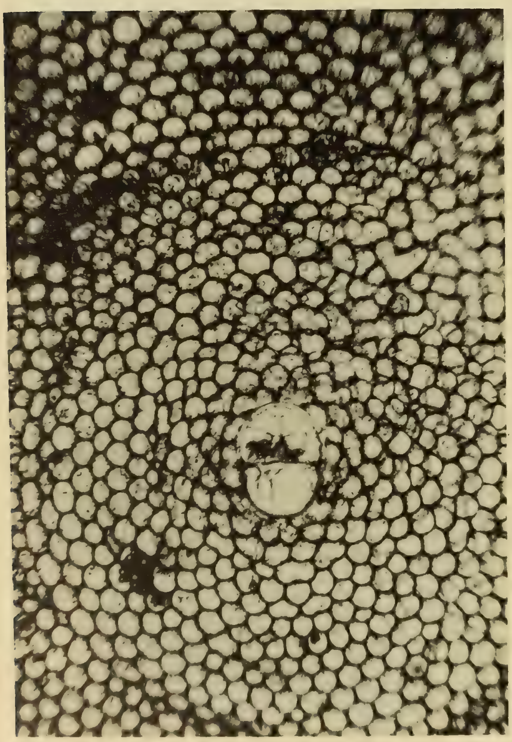

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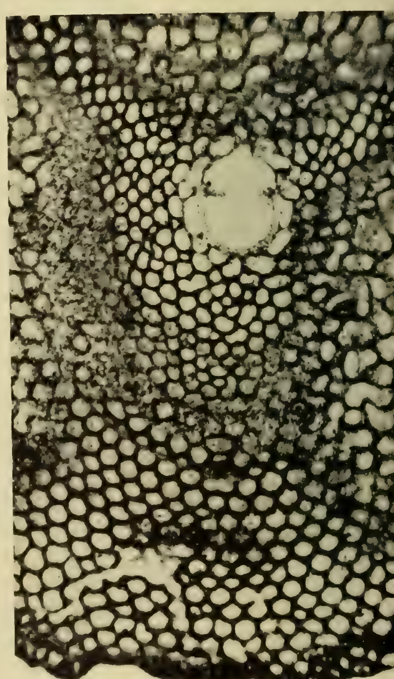


Explanation of Plate 33

Figure | Page

1-4. **Lepidocyclina (Lepidocyclina) canellei** Lemoine and R. Douvillé 391

1. Equatorial section, X 40.
2. Equatorial section, X 20; the vertical section of a similar specimen is illustrated as figure 2, Plate 30.
3. Part of an equatorial section, X 40, of the same specimen illustrated as figure 4, Plate 35.
4. Equatorial section, X 40; the vertical section of a similar specimen is illustrated as figure 6, Plate 30.

1. Loc. 6—see text for locality descriptions.

2, 4. Loc. 1.

3. Loc. 3.

Explanation of Plate 34

Figure Page

1-8. **Lepidocyclina (Lepidocyclina) canellei**
Lemoine and R. Douvillé.. 386, 387, 391

1. Part of a vertical section, X 40, of the same specimen illustrated as figure 3 of this plate.

2-5, 8. Vertical sections, X 20.

6, 7. Parts of vertical sections, X 40.

9. **Lepidocyclina (Eulepidina) tournoueri**
Lemoine and R. Douvillé.. 391

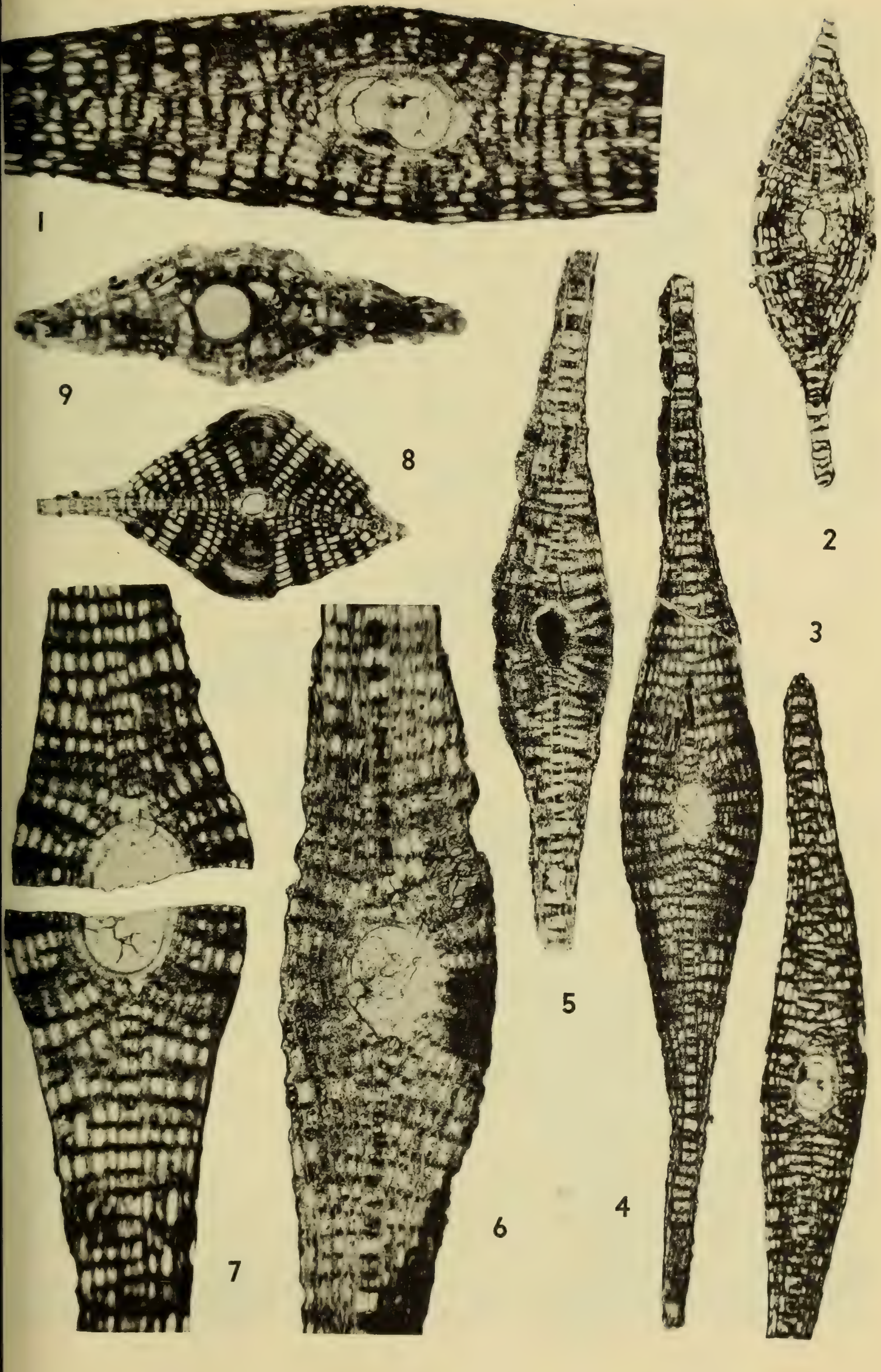
Vertical section, X 40, of a small specimen.

1, 3-7. Loc. 3—see text for locality descriptions.

2. Loc. 4.

8. Loc. 1.

9. Loc. 6.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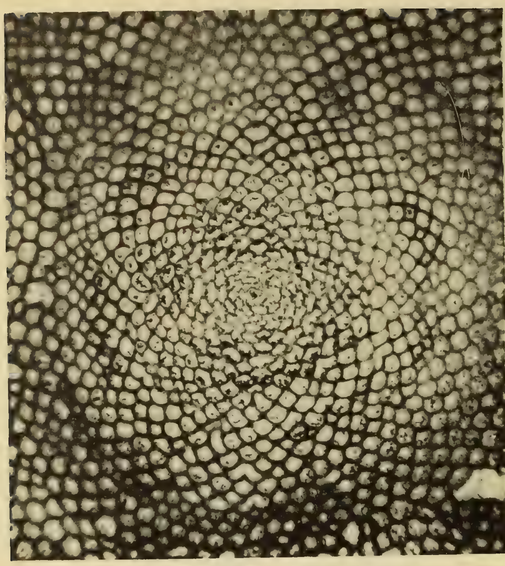

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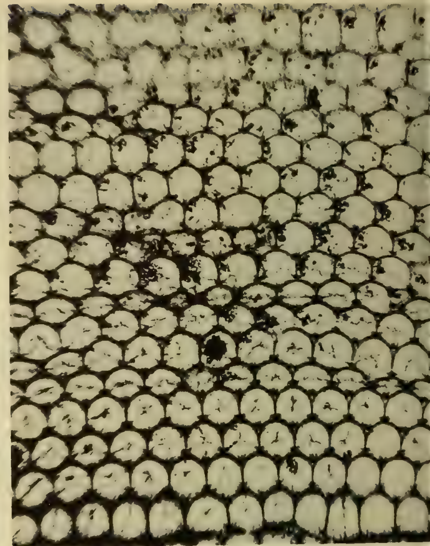

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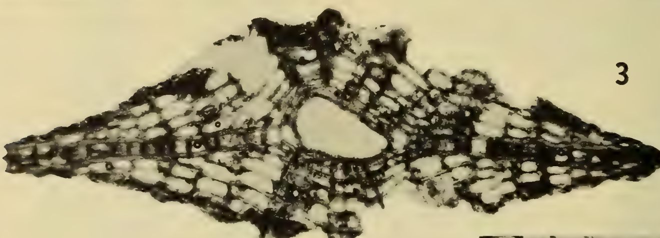

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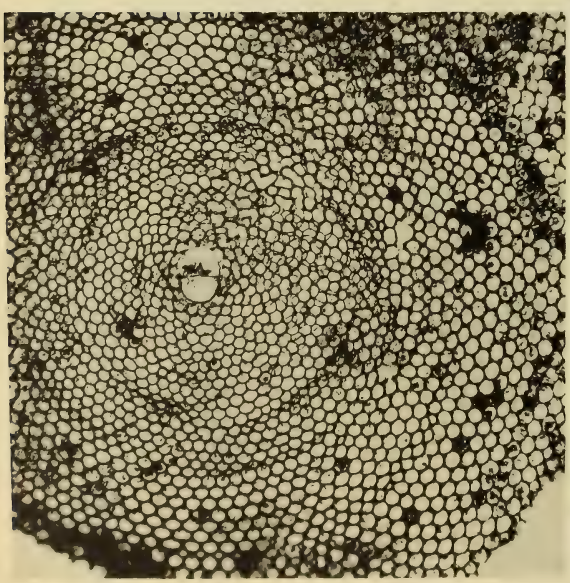

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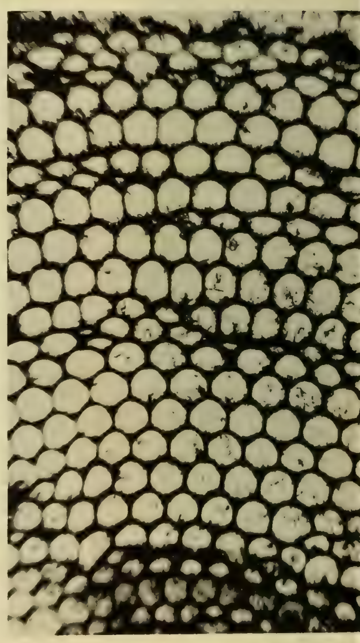


Explanation of Plate 35

Figure | Page

1, 2, 4, 5. **Lepidocyclina (Lepidocyclina) canellei** Lemoine and R. Douvillé 391

1. Central part, X 40, of an equatorial section of a microspheric specimen.
2. Peripheral equatorial chambers, X 40, of the specimen illustrated as figure 4, Plate 37.
4. Part of an equatorial section, X 20.
5. Peripheral equatorial chambers, X 40, of the specimen illustrated as figure 4, Plate 31.

3. **Lepidocyclina (Eulepidina) tournoueri** Lemoine and R. Douvillé 391

Vertical section, X 40, of a small megalospheric specimen; the relatively large lateral chambers with straight roofs and floors are typical of this species.

1. Loc. 5—see text for locality descriptions.

2, 4, 5. Loc. 3.

3. Loc. 6.

Explanation of Plate 36

Figure Page

1-5. **Lepidocyclina (Lepidocyclina) canellei**
Lemoine and R. Douvillé 387, 391

1. Peripheral equatorial chambers, X 40, of the specimen illustrated as figure 1, Plate 31.

2. Part of an equatorial section, X 40, of a specimen similar to the one illustrated as figure 12, Plate 30.

3. Vertical section, X 20, of a microspheric specimen.

4. Part of an equatorial section, X 20, of a microspheric specimen.

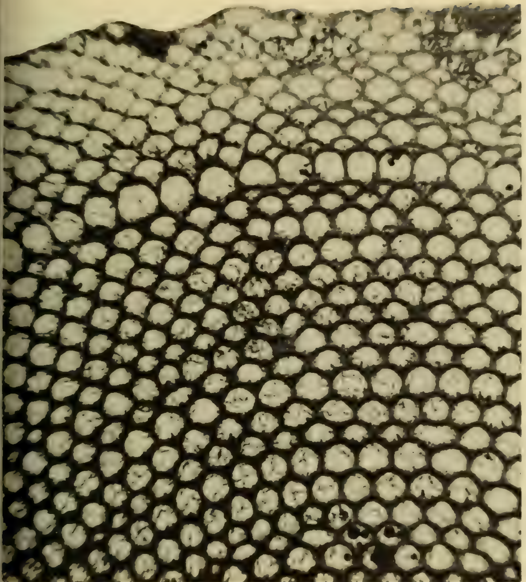
5. Part of an equatorial section, X 40, of a specimen similar to the one illustrated as figure 5, Plate 30.

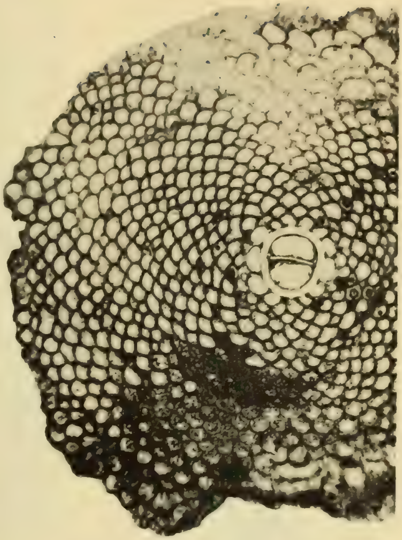
1, 3. Loc. 5—see text for locality descriptions.

2. Loc. 8.

4. Loc. 7.

5. Loc. 1





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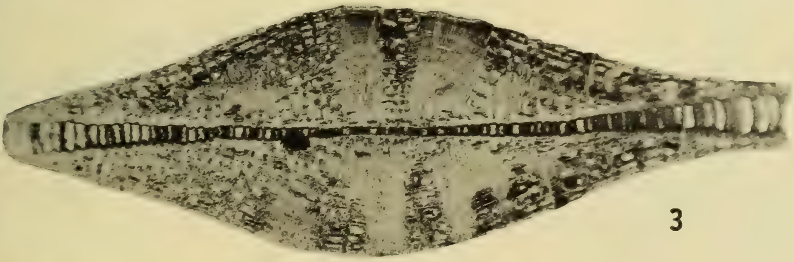

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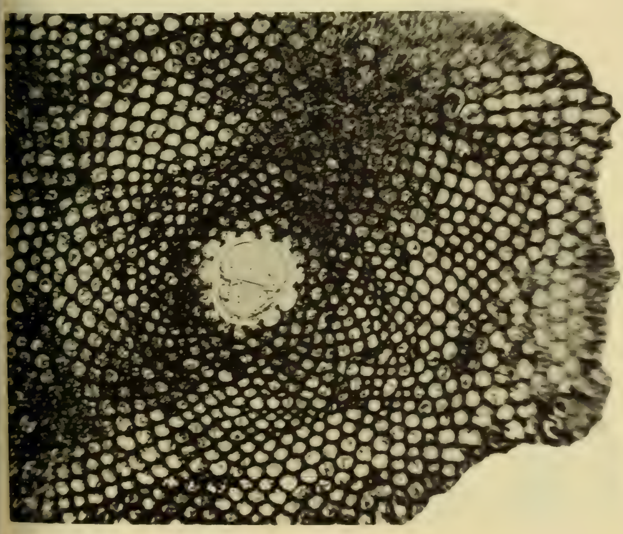

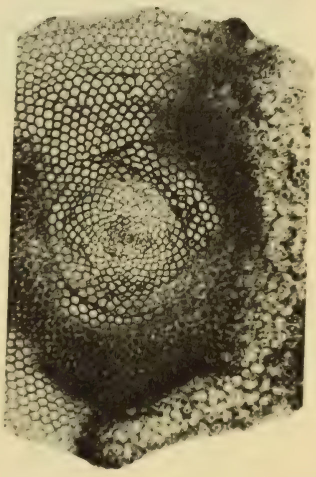

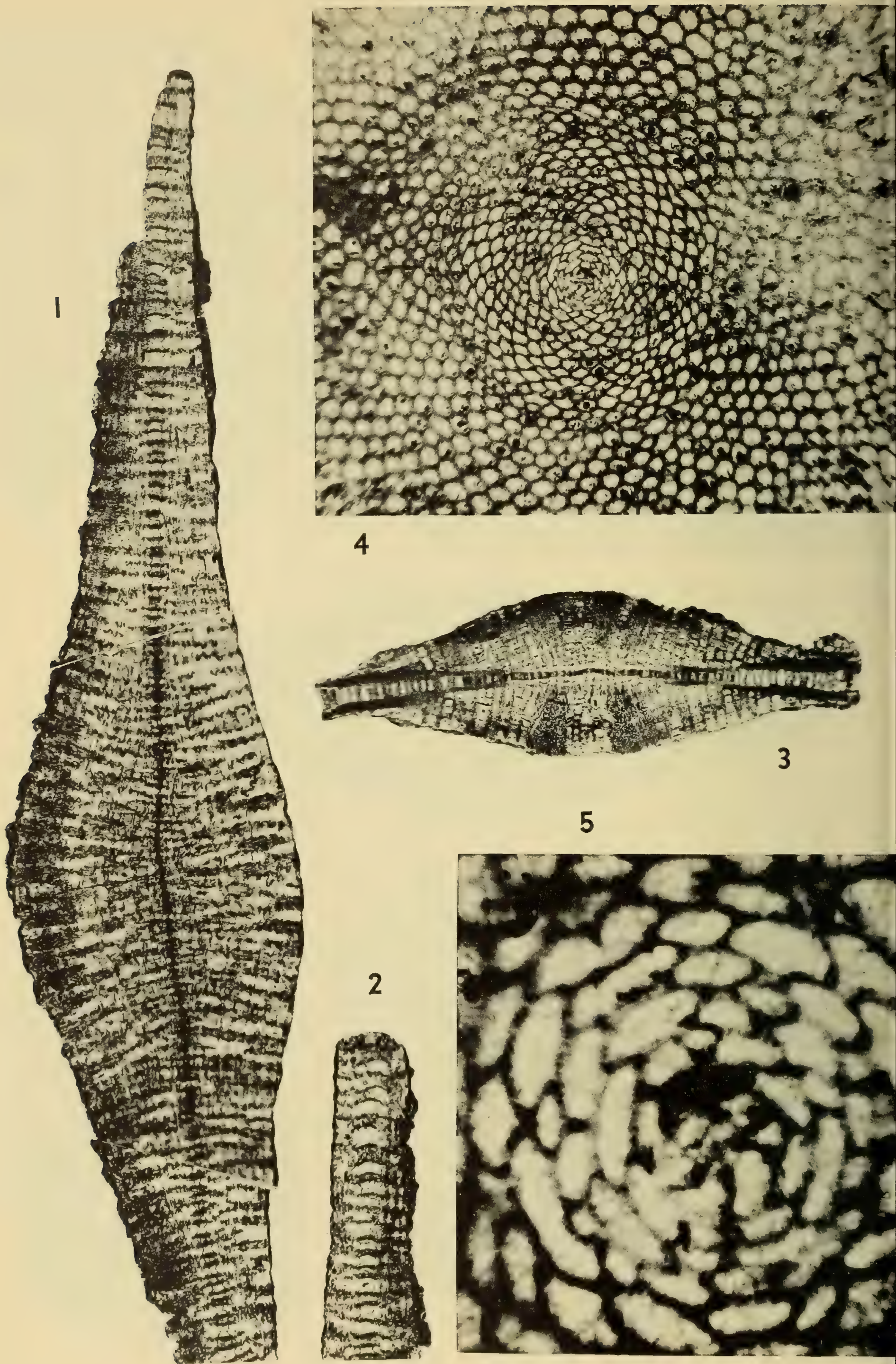
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Explanation of Plate 37

Figure | Page

1-5. Lepidocyclina (Lepidocyclina) canellei
Lemoine and R. Douvillé 391

1, 2. Parts of the same vertical section, X 20, of a microspheric specimen.

3. Vertical section, X 20, of a microspheric specimen with large pillars.

4, 5. Parts of the same equatorial section, 4, X 40; 5, X 230, of a microspheric specimen to illustrate the initial equatorial chambers.

1, 2, 4, 5. Loc. 3—see text for locality descriptions.
3. Loc. 7.

Explanation of Plate 38

Figure | Page

1-7. **Lepidocyclina (Lepidocyclina) canellei** Lemoine and R. Douvillé 386, 387, 388

1. Part of a vertical section, X 40, of the specimen illustrated as figure 4, Plate 30.
2. Vertical section, X 40.
3. Part of a vertical section, X 40, of the specimen illustrated as figure 3, Plate 30.
4. Part of a vertical section, X 40, of the specimen illustrated as figure 2, Plate 30.
5. Part of an equatorial section, X 40.
6. Vertical section, X 20.
7. Part of a vertical section, X 40, of the specimen illustrated as figure 3, Plate 39.

1. Loc. 4—see text for locality descriptions.

2, 5-7. Loc. 5.

3. Loc. 6.

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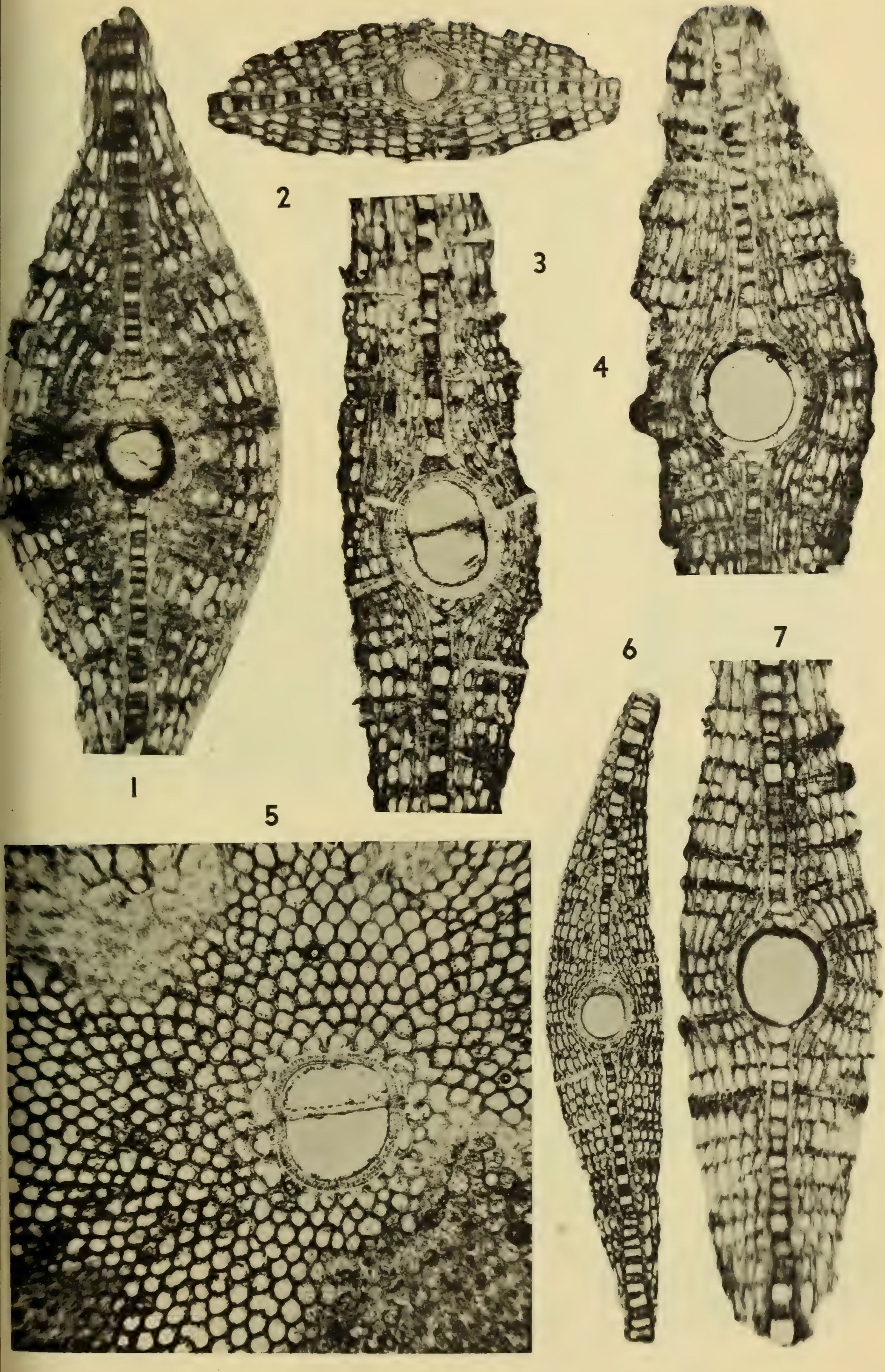
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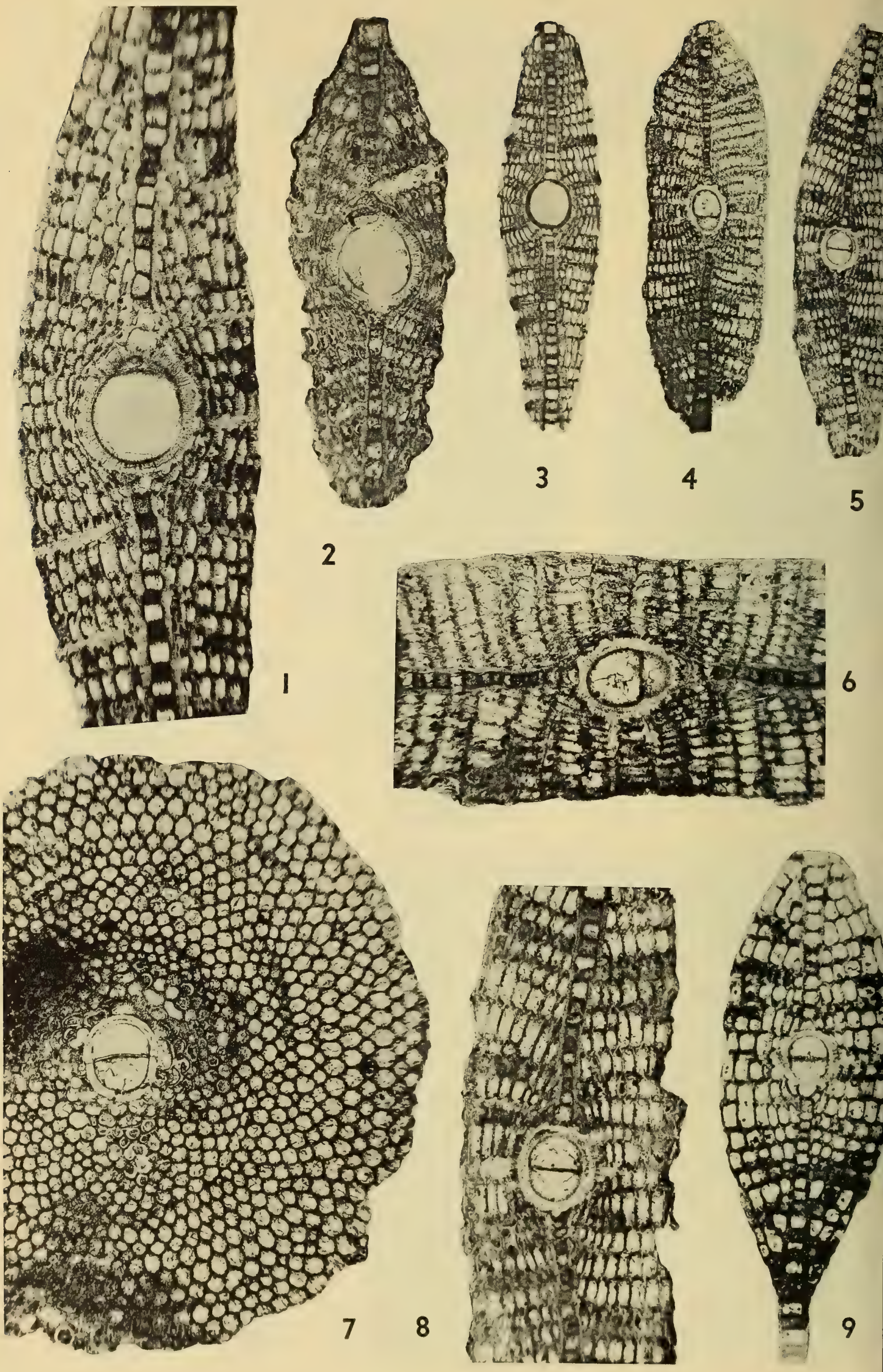
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Explanation of Plate 39

Figure | Page

1-9. **Lepidocyclina (Lepidocyclina) canellei** Lemoine and R. Douvillé.. 386, 387, 388

1. Part of a vertical section, X 40, of the specimen illustrated as figure 6, Plate 38.
2. Vertical section, X 40, of a small specimen.
3. Vertical section, X 20.

4, 5. Vertical sections, X 20.

6. Part of a vertical section, X 40, of the specimen illustrated as figure 4 of this plate.
7. Part of an equatorial section, X 40.
8. Part of a vertical section, X 40, of the specimen illustrated as figure 5 of this plate.
9. Vertical section, X 40.

1, 3, 9. Loc. 5—see text for locality descriptions.

2, 4-8. Loc. 9.

73

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RUDIST ASSEMBLAGES IN CUBA

By

L. J. Chubb

Geological Survey, Jamaica

November 21, 1961

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CONTENTS

RUDIST ASSEMBLAGES IN CUBA

L. J. Chubb
Geological Survey, Jamaica

ABSTRACT

The existence of separate *Barrettia* and *Titanosarcolites* assemblages in Cuba having been questioned, this paper explains how these faunas may be distinguished, and the localities where they may be found; makes a necessary correction; gives a more definite age (Campanian) than was previously possible for the *Barrettia* fauna; and recapitulates the corrected faunal lists, including the larger Foraminifera found with *Barrettia* and *Titanosarcolites.*

INTRODUCTION

In 1905 the writer read a paper before the First Caribbean Geological Conference, in Antigua, entitled *Rudist Assemblages of the Antillean Upper Cretaceous,* which was subsequently published (Chubb, 1956). The principal purpose of this paper was to prove that the oft repeated statement that *Barrettia* and *Titanosarcolites* occur together in the Caribbean area is erroneous, and an attempt was made to show that in Jamaica, Cuba, and the other Antillean islands, there are two distinct rudist faunas, with hardly a species in common—an older associated with *Barrettia* and a newer associated with *Titanosarcolites.* Another still older rudist fauna, characterized by *Tepeyacia,* was recognised in Cuba.

In a separate section of the paper the age of the different rudist faunas was briefly discussed. This problem was treated on a regional basis, in the light of evidence from different parts of the Antillean and Central American area.

Recently Torre (1960, pp. 53-64) criticized the opinions expressed in this paper, in so far as they concern Cuba. With regard to the *Tepeyacia* fauna we are in agreement both as to its existence and its age, which we believe to be Cenomanian-Turonian. Our differences are mainly concerned with two questions: (a) the existence within the Habana formation of a *Barrettia* fauna, distinct and separate from the *Titanosarcolites* fauna, and (b) the age of the *Barrettia* fauna.

These two problems were considered separately in the original publication (Chubb, 1956), but throughout his paper Torre confused them, never discussed the first problem apart from the second, and attributed to the writer views that he does not hold. In this paper, for the sake of clarity, the two problems will be discussed independently.

BARRETTIA AND TITANOSARCOLITES FAUNAS IN CUBA

Torre made no attempt to examine the foundations of the writer's belief that two distinct faunas exist in the Habana formation. He seemed to treat it as merely a personal opinion, based perhaps on guesswork. Actually the separation of the two faunas was achieved by a meticulous and detailed analysis of all published fossil lists available to the writer, especially those of the Utrecht geologists who investigated considerable areas of Cuba in the years 1933 and 1938-9. The work of these geologists is of exceptional value because they were diligent collectors, and they recorded the exact site of every find, gave it a distinguishing letter and number, and pinpointed it on their maps. Thus it became possible to ascertain which rudist species were associated together in Cuba.

The lists referred to will be found in the publications of Rutten (1936, p. 37), MacGillavry (1937, p. 24), Thiadens (1937, pp. 43-4), Vermunt (1937a, pp. 36-7), Van Wessen (1943 pp. 57-8) and Hermes (1945, pp. 20-1). Much information may be extracted from these lists.

A study of Vermunt's list will show that at locality H870, in Piñar del Río, the following rudists were collected: *Barrettia monilifera, B. multilirata, Torreites sanchezi, Biradiolites* cf. *aquitanicus, B. tschoppi, Tampsia rutteni, Chiapasella cubensis,* and *Plagioptychus* sp. Obviously, as all these species were found together they must be regarded as members of one fauna. Rutten's list shows that at locality H550, in northern Santa Clara (Las Villas), the following species were found: *Barrettia monilifera, Torreites sanchezi, Parastroma* sp., *Biradiolites cubensis, Parabournonia hispida,* and *Chiapasella cubensis.* It will be noted that three species are common to both lists. All the species at both these localities are associates of *Barrettia* and must be regarded as members of the *Barrettia* fauna.

Locality H698 in MacGillavry's list of Camaguey rudists may be considered next. Here were found *Titanosarcolites giganteus, Bournonia thiadensi, B.* cf. *bournoni, Biradiolites lumbricoides* and *Parastroma guitarti.* Vermunt's list shows that locality H774, in Piñar del Río, yielded *Titanosarcolites giganteus, Orbignya* sp. (determined as *O. mullerriedi* by MacGillavry, 1937, p. 111), *Praebarrettia sparcilirata, Bournonia thiadensi, Chiapasella pauciplicata,* and *Caprinula* cf. *annulata.* Two species are common to the lists. Being associated with *Titanosarcolites* the fossils from both these localities belong to the *Titanosarcolites* fauna.

It will be noticed that not one of the species found at the *Barrettia* localities, H550 and H870, was found at the *Titanosarcolites* localities, H698 and H774. If Thiaden's list of rudists in southern Santa Clara (Las Villas) be compared with Rutten's list of those in northern Santa Clara, it will be found that there is not one species common to the two. The former list includes *Titanosarcolites* in several localities, the latter includes *Barrettia.*

If all the abovementioned fossil lists of the Utrecht geologists be analysed and compared, it will be found that none of them recorded *Barrettia* from the same locality as *Titanosarcolites,* and the rudist species associated with the former genus were always different from those associated with the latter, with one possible exception, *Biradiolites aquitanicus.* If they are plotted on a map it will be found that the *Barrettia* localities are always many kilometers away from the *Titanosarcolites* localities.

These statements are not guesses, they are not opinions, they are not theories, they are facts.

The main purpose of Torre's article seems to be to demonstrate that there is only one rudist assemblage in the Habana formation, including both *Barrettia* and *Titanosarcolites.* If this is true it should be easy to prove, for it is only necessary to cite a few localities where the two genera may be found together, but there is no mention of even one such locality throughout his article.

Torre laid great stress on, and repeatedly referred to, a brief mention in the writer's paper (Chubb, 1956, p. 11, lines 8-13) of the limestones of Loma Yucatan. The fauna of these limestones was referred to only incidentally, not as a representative, but as a doubtful example of the *Barrettia* fauna; it was expressly stated that *Barrettia* had not been found there. These limestones were provisionally included in the *Barrettia* beds mainly because *Vaccinites* occurs in them, and elsewhere in the Antillean area this genus is generally associated with *Barrettia,* for example at 3 km. W. S. W. of San Diego de Los Baños, Pinñar del Rio. *Vaccinites* is also found with *Barrettia* in Puerto Rico, and the same genus has recently been found in Jamaica, 5 km. southeast of Lucea, Hanover, where it again occurs with *Barrettia.* It was, therefore, thought that a further search of the Loma Yucatan limestones would probably reveal the presence of *Barrettia.* But if Dr. Mario Sanchez Roig denies the existence of this genus in these limestones (Torre, 1960, p. 57) his word must be accepted. Evidently the Loma Yucatan limestones contain an intermediate rudist fauna, newer than that of *Tepeyacia* and older than that of *Barrettia*. It is preferable to call this the *Durania* fauna, rather than to use Torre's term, *Durania* and *Vaccinites* fauna, as the latter genus occurs in other horizons.

Torre observed that the only way to clarify the problem of the existence of distinct *Barrettia* and *Titanosarcolites* faunas in Cuba would be by an exhaustive investigation, including field-work, collection, and stratigraphic study. To assist in this programme some localities will be suggested where the investigation might be carried out profitably:

(a) The *Barrettia* fauna (without *Titanosarcolites*) may be found in Piñar del Río west of Verracos and southwest of San Diego de los Baños; in Las Villas about six to seven km. east and southeast of Esperanza, one km. west of Bernia, and three km. northwest of Pastora; in Camaguey at about 17 km. and 27 km. west of Camaguey city on the La Florida road, at Arroyo Hondo, and at 8 km. west and 14 km. east of Sibanicu. It is possible, but not certain, that *Barrettia* might also be found in Las Villas at seven to eight km. east of Fomento, at five to six km. northwest of Cabaiguan, and at four km. south of Camajuani.

(b) The *Titanosarcolites* fauna (without *Barrettia*) may be found in Piñar del Río west of San Juan y Martinez and thence in a northeasterly direction to the neighbourhood of Guayabo; in Las Villas, west of Jutia and immediately north and east of Fomento; in Camaguey, east of Ciego de Avila, west and north of Piedrecitas, around Ingenio Grande and in an area five km. southeast thereof, at five km. and 17 km. north-north-east of San Francisco on the road to Veinte y Uno, and at four to six km. south of Berrocal.

Special attention should be paid to an exposure about 1½ km. southwest of San Diego, Piñar del Río (H802). Although in his stratigraphic paper Vermunt (1937a, pp. 36-37) recorded only *Barrettia* and species belonging to the *Barrettia* fauna at this locality, in another paper (1937b, p. 263) *Titanosarcolites giganteus* was added to the list. This record is thought to be erroneous, perhaps a slip of the pen, perhaps a printer's error. However that may be, this is the only definite locality known to the writer where it has been claimed, by any geologist who has worked in Cuba, that *Barrettia* and *Titanosarcolites* occur together.

It is also suggested that the Loma Yucatan fauna should be sought, not only in the hill of that name north of Camaguey, but also in northern Piñar del Río, around and between the harbours of Bahia Honda and Cabañas.

When this work has been accomplished and the existence of the two faunas in the Habana formation recognised, it may be possible to find the solution of other problems, such as why, in Piñar del Río, Las Villas, and Camaguey, the outcrops of *Barrettia* limestone always lie some 10 to 30 km. north of those of *Titanosarcolites* limestone.

AGE OF THE BARRETTIA FAUNA

There is no need to discuss here the age of the *Titanosarcolites* fauna as there is general agreement that it is Maestrichtian. The question of the age of the *Barrettia* fauna was dealt with only briefly in the earlier paper (Chubb, 1956, pp. 16-17). It was considered on a regional basis in the light of evidence drawn from Jamaica, Cuba, and south Mexico.

The following facts were mentioned: (a) that in the St. Ann's Great River section, Jamaica, the shales below a *Barrettia* limestone yield Turonian-Coniacian fossils; (b) that in northern Las Villas, Cuba, Rutten (1936, pp. 7, 36) found Turonian-Coniacian ammonites apparently below a *Barrettia* limestone; (c) that in Chiapas, south Mexico, Mullerried (1936, p. 160) reported Turonian-Coniacian ammonites, not below, but above *Barrettia;* (d) that the apparent inconsistency would be resolved if it were assumed that *Barrettia* ranged from Upper Turonian to Lower Senonian; (e) that recent evidence suggested that *Barrettia* ranged into the Campanian in Puerto Rico and Cuba; and finally (f) that Campanian Foraminifera had been found in the shales below *Barrettia* in St. James, Jamaica. No attempt was made to draw any final conclusion from these varied pieces of evidence.

Torre, however, persists in treating the mention of the Turonian-Lower Senonian as the writer's considered opinion of the range of *Barrettia,* and devotes much space to attempts to discredit it. He is tilting at windmills. He is evidently unaware that in the last few years a considerable amount of research on the problems of the Caribbean Cretaceous has been carried out (Chubb, 1958a; 1958b; 1959; 1960a; 1960b) and that new evidence has led to the possibility of a more exact evaluation of the age of the *Barrettia* beds.

As Mullerried's reported discovery of Turonian-Coniacian ammonites above *Barrettia* in south Mexico conflicted with evidence from other areas, it was decided to visit Chiapas, in order to study the Cretaceous sequence personally. Accordingly, after the Twentieth Session of the International Geological Congress in Mexico City (September 4-11, 1956) the writer spent a full month in the state (Chubb, 1959). Most of Mullerried's faunal horizons were discovered, but unfortunately not the *Barrettia* and ammonite zones. It was found, however, that Campanian rocks rested directly upon Turonian, both Coniacian and Santonian were absent, and the opinion was formed that the Chiapas *Barrettia* horizon was probably Campanian.

The *Barrettia* bed in St. Ann's Great River, Jamaica, which is underlain by beds with a Turonian-Coniacian fauna, is now known to be overlain by beds with a Campanian one. The possibility, therefore, arises that this *Barrettia* bed might be Santonian, as was suggested in a paper read to the Mexico Congress in 1956 (in press), but it is now regarded as more probably basal Campanian (Chubb, 1960a, p. 91), the Santonian being absent. As previously mentioned the St. James *Barrettia* bed is underlain by a thick shale formation yielding Upper Campanian Foraminifera and is succeeded by 800 meters of beds without diagnostic fossils, above which lies the basal bed of the Maestrichtian with the first *Titanosarcolites.* This *Barrettia* bed is, therefore, believed to be Upper Campanian (Chubb, 1960a, p. 88).

In another recent publication (Chubb, 1960b, p. 17) it was stated that "the genus *Barrettia* could perhaps be regarded as an index fossil of the Campanian in Jamaica as well as in the other Greater Antilles," and it might be added, in south Mexico.

Torre (1960, p. 57) quoted the occurrence of orbitoidal Foraminifera, such as *Pseudorbitoides,* with *Barrettia,* as evidence of a Maestrichtian age. Evidently he does not know of the work of Bronnimann (1957, p. 591) who, after an exhaustive study of *Pseudorbitoides israelskyi* Vaughan and Cole, including topotype material from Louisiana, and specimens from Mississippi, Texas, Chiapas, Cuba, Haiti, and Puerto Pico, concluded that this species is restricted to the Campanian.

The Utrecht geologists included the larger Foraminifera in their fossil locality lists. By an analysis of these lists it is possible to ascertain which Foraminifera were associated with *Barrettia* and which with *Titanosarcolites;* the former may be regarded as Campanian, the latter as Maestrichtian. *Pseudorbitoides israelskyi* and *P. trechmanni* were found with *Barrettia* but not with *Titanosarcolites.*

Three species were reported to be common to both groups, *Vaughanina cubensis, Orbitoides browni,* and *Lepidorbitoides minima.* According to Bronnimann (1957, p. 591) *V. cubensis, Orbitoides palmeri,* and *Sulcoperculina dickersoni* form an assemblage which is diagnostic of late Maestrichtian beds, and as would be expected, all three were found in the *Titanosarcolites* limestones of Cuba.

Vaughanina cubensis, however, would not be expected in the *Barrettia* beds, and Rutten alone, among the Utrecht geologists, reported it there, not in his palaeontological paper (1935, p. 528) but only in his stratigraphical paper (1936, p. 36). Possibly the report may have been due to a mistaken identification, as there has been considerable confusion between this species and *Pseudorbitoides israelskyi* (Bronnimann, 1954, pp. 91-93).

CONCLUSION

In the Upper Cretaceous rocks of Cuba four successive rudist faunas may be recognised. The fossil lists previously published (Chubb, 1956, pp. 10-13) require revision owing to the separation of the Loma Yucatan fauna from the *Barrettia* fauna. The larger Foraminifera of the Campanian and Maestrichtian are included in the lists.

(a) *Tepeyacia* fauna of the Provincial limestones; the age is probably Cenomanian-Turonian.

Caprinuloidea perfecta Palmer
Coalcomana ramosa (Boehm)
Sabinia sp.
Ichthyosarcolites sp.
Tepeyacia corrugata Palmer

(b) *Durania* fauna of the Loma Yucatan limestones. The age is believed by Torre, following Albear and MacGillavry, to be Upper Campanian; but in view of the absence of orbitoidal Foraminifera a somewhat earlier age, perhaps Santonian or Coniacian, may be suggested.

Durania curasavica (Martin)
D. lopeztrigoi (Palmer)
Vaccinites macgillavryi Palmer
Torreites tschoppi MacGillavry
Praebarrettia coralli (Palmer)

(c) *Barrettia* fauna of the lower Habana formation. The age is Campanian.

RUDISTS

Plagioptychus antillarum (Douvillé)
Antillocaprina crassitella MacGillavry
Biradiolites cubensis Douvillé
B. macgillavryi Vermunt
B. tschoppi Vermunt
B. cf. *acuticostatus* d'Orbigny
B. cf. *lameracensis* Toucas
B. cf. *aquitanicus* Toucas
Parabournonia hispida Douvillé
Radiolites macroplicatus Thiadens *non* Whitfield
Chiapasella cubensis Rutten
Tampsia rutteni Vermunt
Vaccinites vermunti MacGillavry
Torreites sanchezi Douvillé
Parastroma sanchezi Douvillé
Barrettia monilifera Woodward
B. multilirata Whitfield

FORAMINIFERA

Vaughanina cubensis Palmer (according to Rutten)
Orbitoides browni (Ellis)
Torreina torrei Palmer
Lepidorbitoides minima Douvillé
L. planasi Rutten
L. cubensis (Palmer)
L. rooki Vaughan & Cole
L. aguayoi Palmer
Pseudorbitoides trechmanni Douvillé
P. israelskyi Vaughan & Cole

(d) *Titanosarcolites* fauna of the upper Habana formation. The age is Maestrichtian.

RUDISTS

Mitrocaprina tschoppi (Palmer)
Antillocaprina annulata (Palmer)
A. pugniformis (Palmer)

Titanosarcolites giganteus (Whitfield)
Biradiolites galofrei (Palmer)
B. aquitanicus Toucas
B. lumbricoides Douvillé
Bournonia planasi Thiadens
B. thiadensi Vermunt
B. cancellata (Whitfield)
B. cf. *bournoni* Des Moulins
Thyrastylon adhaerens (Whitfield)
Chiapasella bermudezi Palmer
C. pauciplicata Mullerried
Orbignya mullerriedi Vermunt
Parastroma guitarti (Palmer)
Praebarrettia cf. *peruviana* (Gerth)
P. sparcilirata (Whitfield)
P. porosa Palmer

FORAMINIFERA

Sulcoperculina dickersoni (Palmer)
Vaughanina cubensis Palmer
Orbitoides apiculata Schlumberger
O. browni (Ellis)
O. palmeri Gravell
Lepidorbitoides estrellae van Wessem
L. macgillavryi Thiadens
L. minima Douvillé
L. minor (Schlumberger)
L. nortoni (Vaughan)
L. palmeri Thiadens
L. rutteni Thiadens
L. rutteni var. *armata* Thiadens
L. tschoppi van Wessem

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INDEX VOLUME XLIII

Light face figures refer to page numbers. Bold face figures refer to plate numbers. For index to Bulletins 194 and 196 see those Bulletins.

I

J

K

L

M

N

O

P

Q

R

S

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