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MISSISSIPPIAN SMALLER FORAMINIFERA OF SOUTHERN INDIANA, KENTUCKY, NORTHERN TENNESSEE, AND SOUTH-CENTRAL OHIO

A dissertation submitted to the

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by

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I hereby recommend that the thesis prepared under my supervision by James Elvin Conkin

entitled MISSISSIPPIAN SMALLER FORAMINIFERA OF SOUTHERN INDIANA, KENTUCKY, NORTHERN TENNESSEE, AND SOUTH-CENTRAL OHIO

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

Approved by:

Kenneth E. Caster

William Jenks

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CHARTS

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 south-central Ohio. The shale beds were found to contain more Foraminifera than the limestones, thus emphasis was placed upon these fossiliferous shales.

During this study, 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 revision are included: *Hyperammina* and *Thuramminoides*. A proposal is introduced to formalize the emendation of *Hyperammina* by Conkin in 1954. One specific revision is included : *Thuramminoides sphaeroidalis* Plummer. 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 classification of H. B. Brady, 1876, H. J. Plummer, 1939, and R. H. Cummings, 1955 is presented here. The Mississippian Foraminifera are, by this introduced classification, divided into four large groups:

Arenaceous

calcareous- extraneous grains in calcareous and/or ferruginous cement.

siliceous-extraneous grains in siliceous cement

Granular calcareous-equidimensional grains of calcite embedded in crystalline calcite

calcite granules secreted by the protoplasm, embedded in crystalline calcite?

calcite granules derived from a supersaturated limy sea bottom by the selection of extraneous calcareous material by the protoplasm?

Compound wall

inner wall layer of fibrous calcite; outer wall layer of microgranular layer of calcite, or altered from calcite

Amorphous calcite, or imperforate calcareous

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

The most important genus in stratigraphic division 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 (Lower Osagian).

Division of the Mississippian system into series characterized by certain species, genera, or faunal assemblages of Foraminifera as 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 interprete 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.

DEPOSITION OF TYPES

All figured specimens are deposited in the Cushman Foraminiferal Collection, United States National Museum, Washington 25, D. C.

Abbreviations used in referring to institutions in which types are deposited are:

C. F. C. - Cushman Foraminiferal Collection, U. S. National Museum, Washington 25, D. C.

P. R. I. - Paleontological Research Institute, Ithaca, New York.

U. C. - Department of Geology Museum, University of Cincinnati, Cincinnati 21, Ohio.

U. N. D. - Department of Geology, University of Notre Dame, Notre Dame, Indiana

B. M. (N. H.) - British Museum (Natural History) Cromwell Road, London 7, S. W., England.

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 (all three sides of the Cincinnati arch), southern Indiana, northern Tennessee, and south-central 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.

Previous work

Very 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) description of four genera of smaller Foraminifera (*Glomospira*, *Hyperammina*, *Paleotextularia*, and *Trepeilopsis*) from the Chesterian Kincaid formation of Illinois constitutes the first record of Mississippian smaller Foraminifera in the United States. Only cursory records of Foraminifera in the Mississippian have been noted by a handful of workers since Cooper's paper. Coryell and Rozanski (1942) reported one species, *Spirillina obduxa*, from the 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 lower Mississippian species of smaller Foraminifera in North America, *Hyperammina kentuckyensis*, was described by Conkin (1954, p. 166, 167, pl. 31, fig. 1-6), from southwest 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 fauna, from the Kinderhookian Rockford limestone of northern Indiana.

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

Present Work

This paper is based on collections from measured sections and/or stratigraphically placed outcrops from 89 localities in southern Indiana, Kentucky, northern Tennessee, and south-central 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 very calcareous Meramecian sequence. Greatest sampling was done in the Lower Mississippian.

Limestones in the Mississippian of the studied region seem to contain very 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 Kentucky (as well as of Indiana) and the occurrence of smaller Foraminifera in the Meramecian and Chesterian sequences to lesser degree.

The tentative correlation herein made with the type Lower Mississippian of Missouri are based on very complete sampling of the Mississippian sequence in 20 counties in Missouri. The smaller Foraminifera of the Mississippian formations of Missouri are now in the process of description for publication.

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STRATIGRAPHY

List of Localities

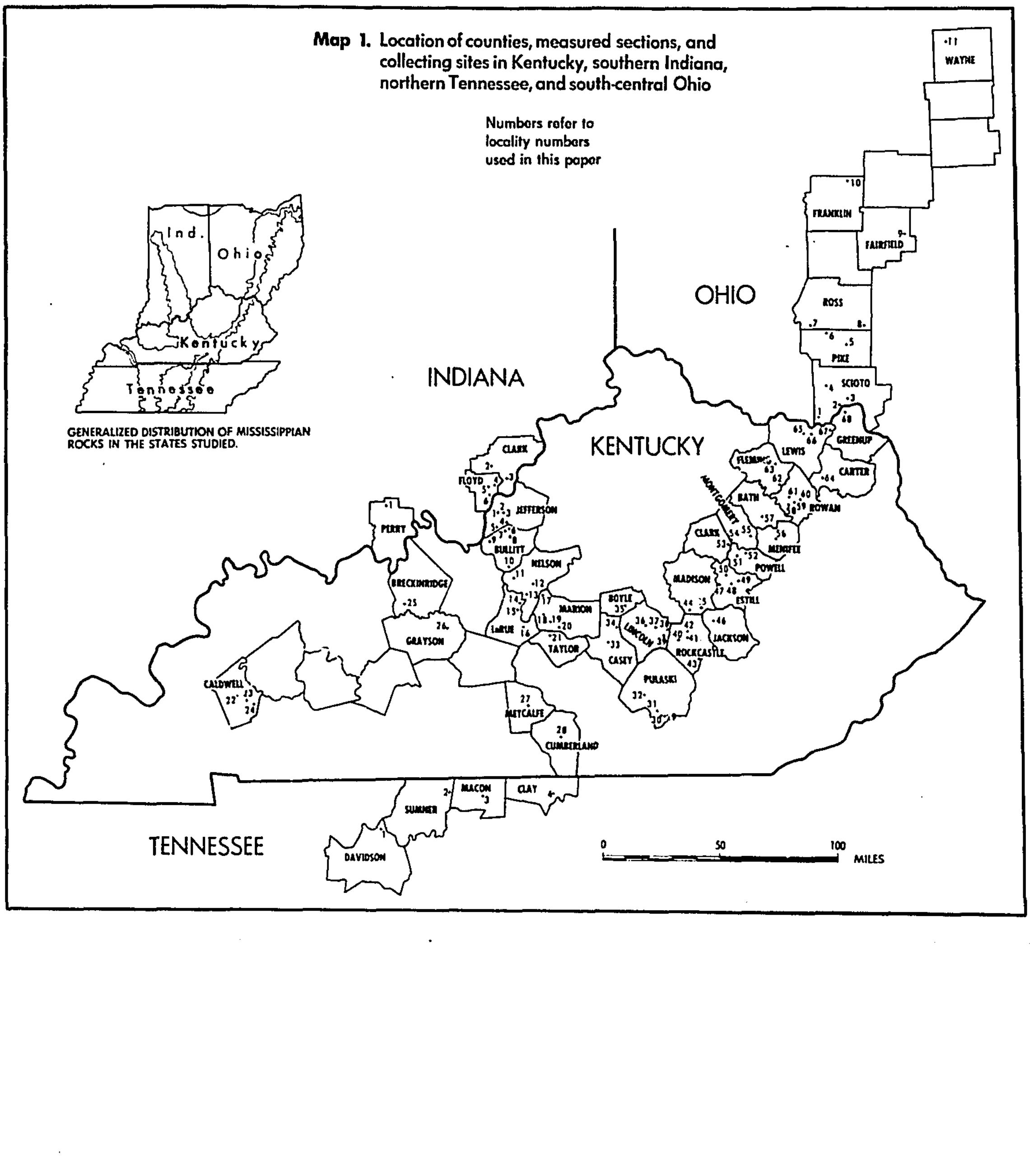
The geographic positions of 89 localities from which sections were measured and/or samples collected in Kentucky, southern Indiana, northern Tennessee, and south-central Ohio are presented here. The locality numbers used throughout the paper are preceded by the initial of the state in which they occur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

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.



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

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' 13" 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.

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' 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 upper part of Somerset shale member (Bed 1) of 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.
Raywick Quadrangle, Lat. 37° 31' 20" N, Long. 85° 23' 22" W.

K-20. Samples taken from the 6 foot fossiliferous shale in 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 Kincaid (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 measured 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 McKaughlin farm, one mile east of Waco. (Campbell, 1946, p. 866)

Moberley Quadrangle, Lat. 37° 34' 15" N, Long. 84° 7' 40" W.

K-48. Sample taken from lower 4 feet of 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.

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 north-east 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 (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 south-east 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 black shale at road level and above 40 feet of black shale 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° 33' 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", 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. Highway 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", 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. 387)

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 mea; ired 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 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

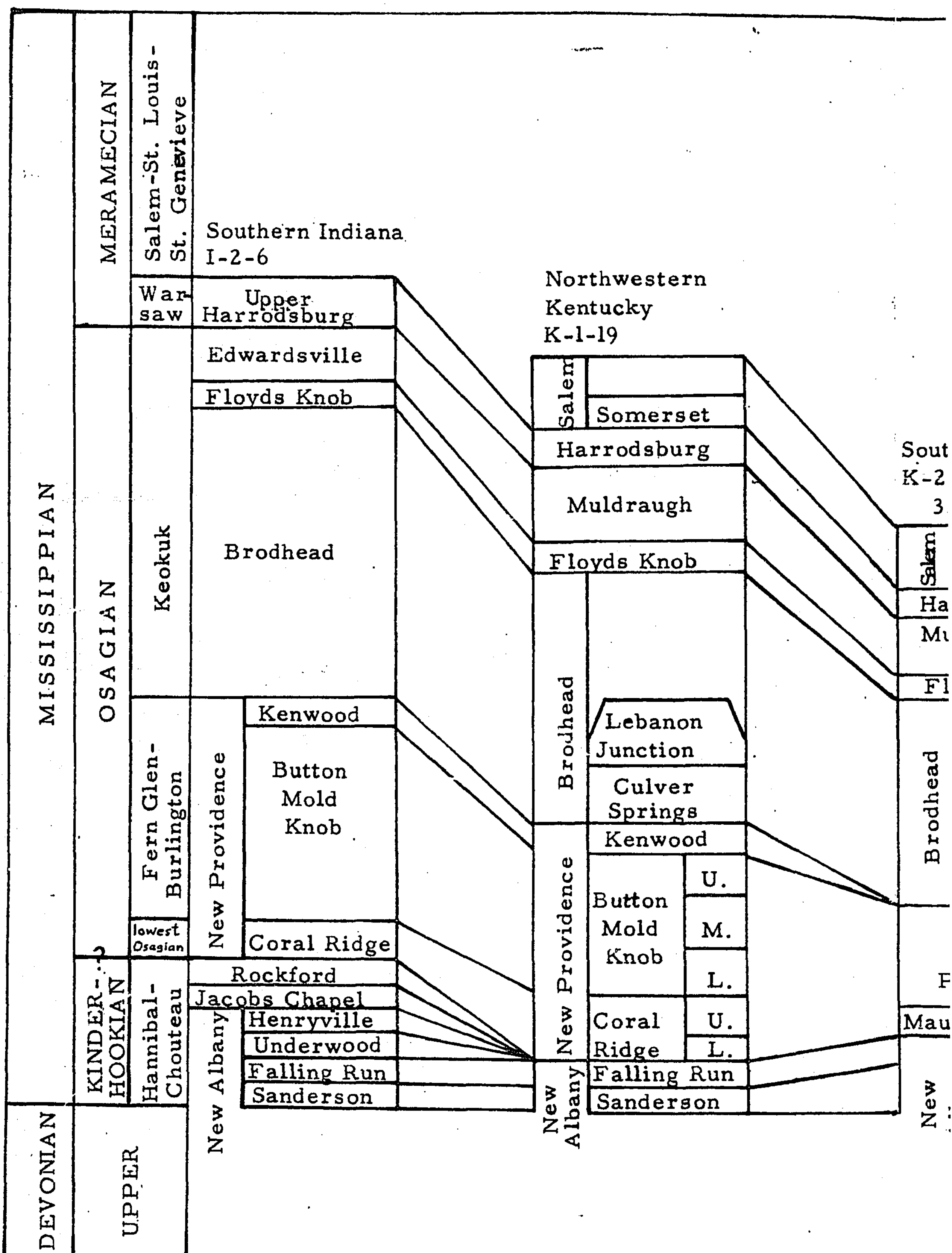
O-11. Sample from shale bed no. 4 in the lower 5 feet of the Black Hand sandstone (Bed 1) at Armstrong.

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 south-central 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 southern Kentucky.


MISSISSIPPIAN
DEVONIAN
MERAMECIAN
OSAGIAN
KINDER-HOOKIAN
UPPER
Salem-St. Louis-St. Genevieve
Warsaw
Keokuk
Fern Glen-Burlington
lowest Osagian
Hannibal-Chouteau
Southern Indiana
I-2-6
Upper Harrodsburg
Edwardsville
Floyds Knob
Brodhead
New Providence
Kenwood
Button Mold Knob
Coral Ridge
Rockford
Jacobs Chapel
New Albany
Henryville
Underwood
Falling Run
Sanderson
Northwestern Kentucky
K-1-19
Salem
Somerset
Harrodsburg
Muldraugh
Floyds Knob
Brodhead
Lebanon Junction
Culver Springs
Kenwood
New Providence
Button Mold Knob
U.
M.
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Coral Ridge
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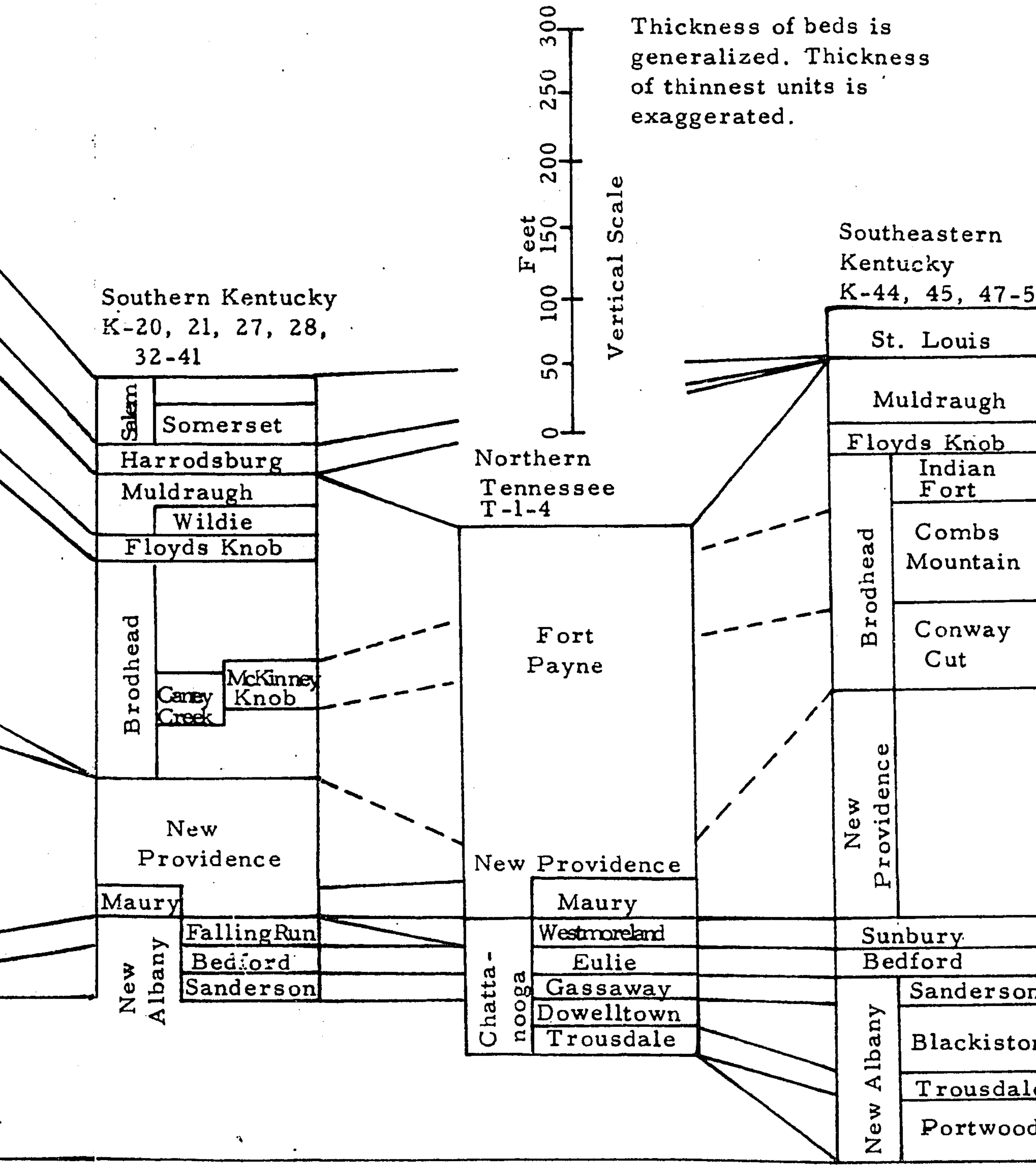
Chart 1 . Correlation of Upper Devonian and Lower and M
Formations in southern Indiana, Kentucky, nor
and south-central Ohio (after Stockdale, 1939,
Campbell, 1946, Plate 2).



..ower and Middle Mississippian
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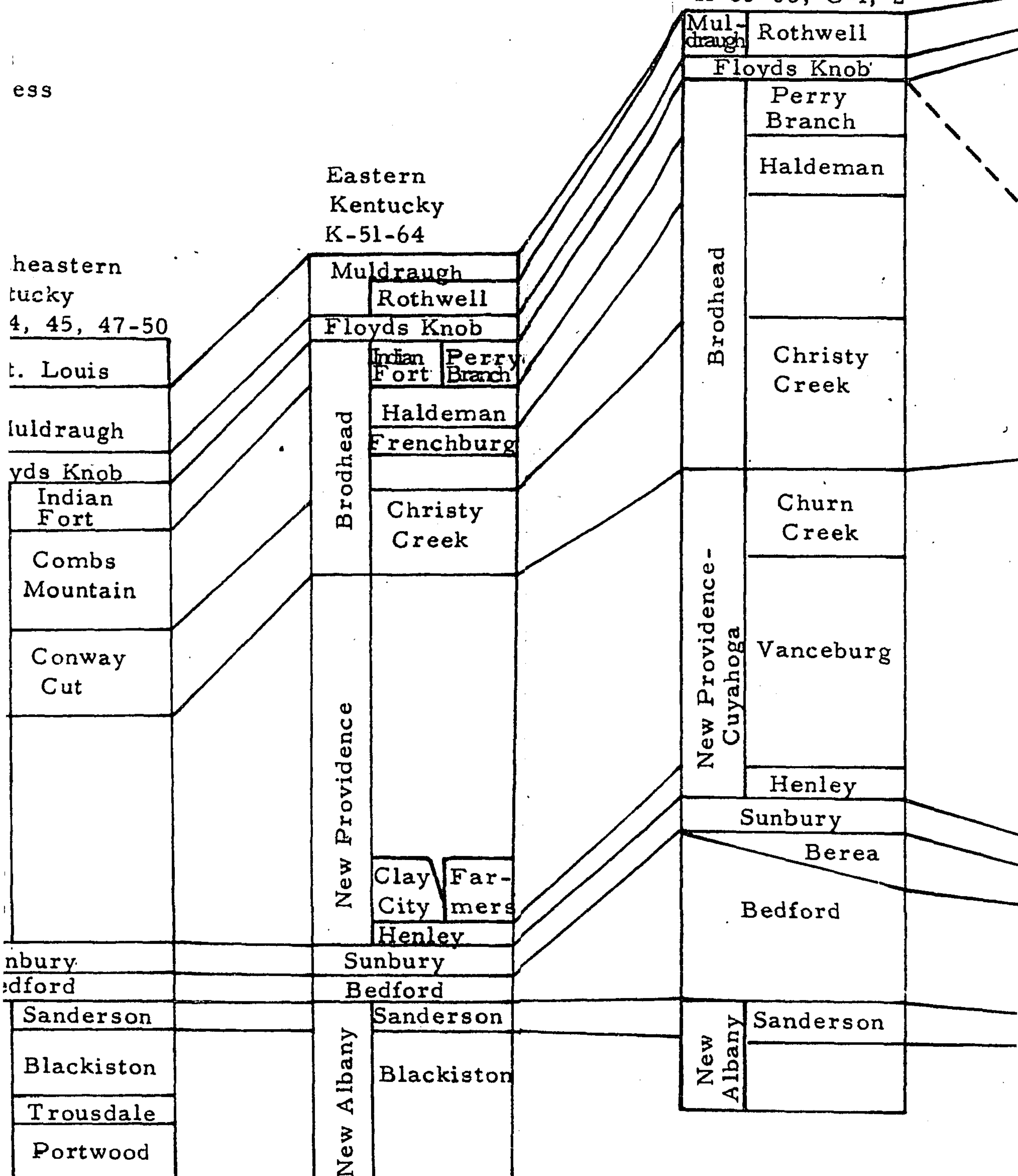

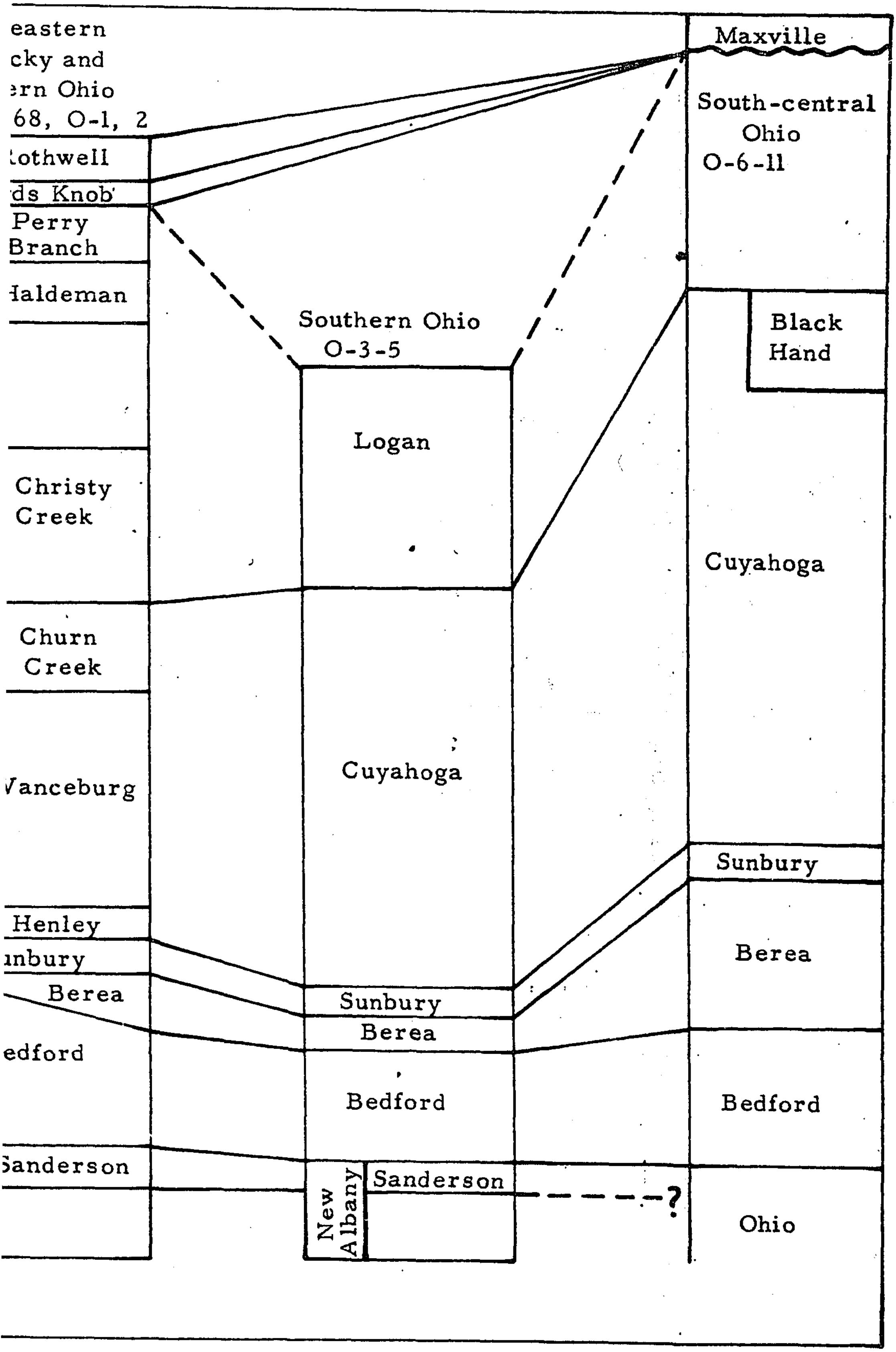
eastern
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ern Ohio
68, O-1, 2
Rothwell
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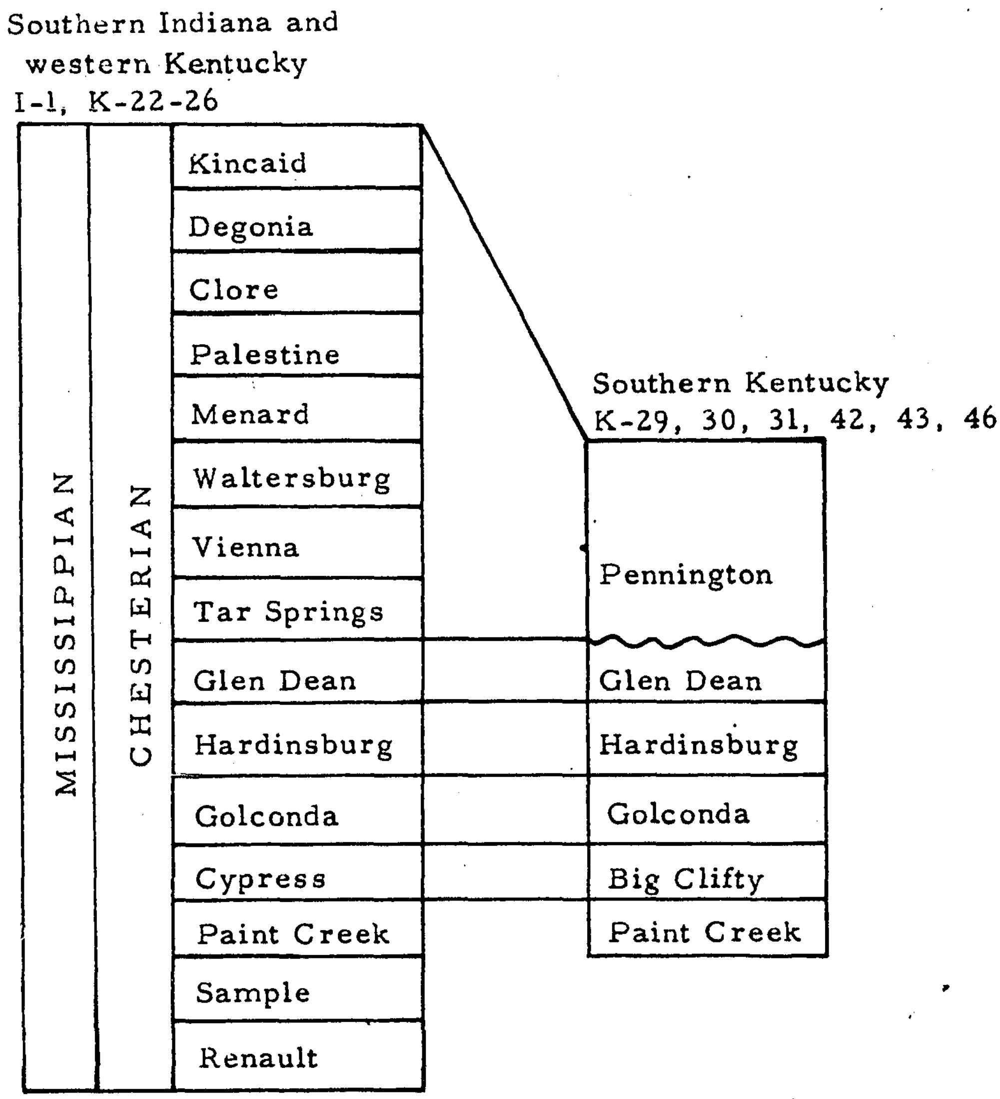
Perry Branch
Haldeman
Christy Creek
Churn Creek
Vanceburg
Henley
Sunbury
Berea
Bedford
Sanderson
Southern Ohio O-3-5
Logan
Cuyahoga
Sunbury
Berea
Bedford
New Albany
Sanderson
?
Maxville
South-central Ohio O-6-11
Black Hand
Cuyahoga
Sunbury
Berea
Bedford
Ohio

Chart 2. Correlation of Chesterian formations in western Kentucky and southern Indiana with the Chesterian formations in southern Kentucky.



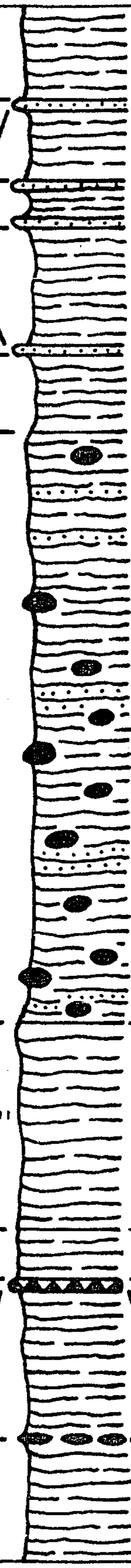
Measured Sections

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.

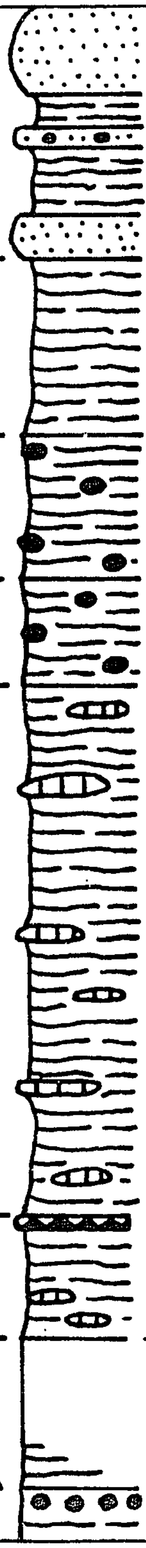
Samples were taken throughout 5.5 foot intervals, and/or from lithologically and/or stratigraphically distinct units thinner than 5.5 feet.

LOCALITY K-1



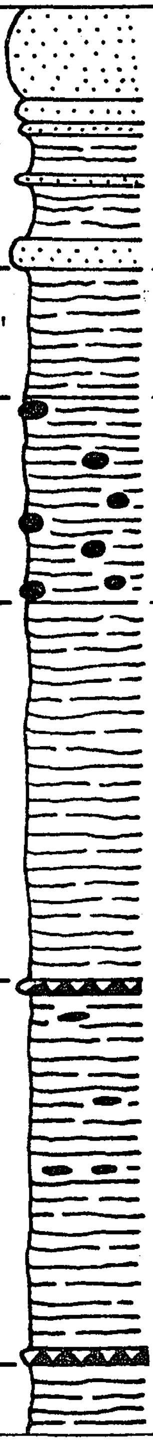
NEW PROVIDENCE FORMATION 158' exposed	KENWOOD SS. MBR.	8'	* 14. Shale, olive gray; covered above.
		6"	13. Siltstone.
		6'6"	*12. Shale, olive gray.
		1'9"	*11. Shale with two thin siltstone layers.
		11'6"	*10. Shale, olive gray.
		2.5"	9. Siltstone.
	BUTTON MOLD KNOB MEMBER	7'6"	*8. Shale, olive gray; 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; <u>Conularia</u> 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.

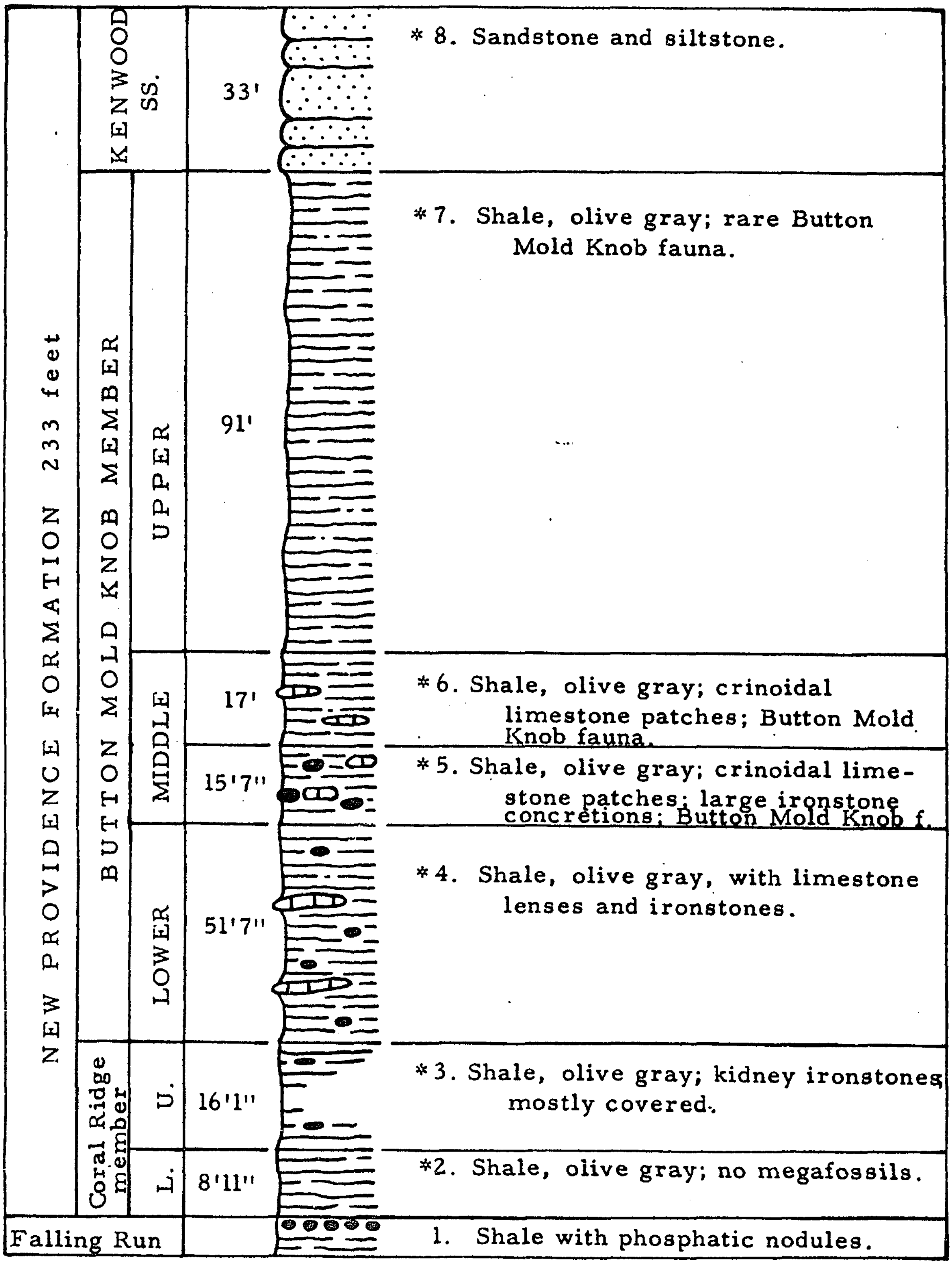
LOCALITY K-3

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.

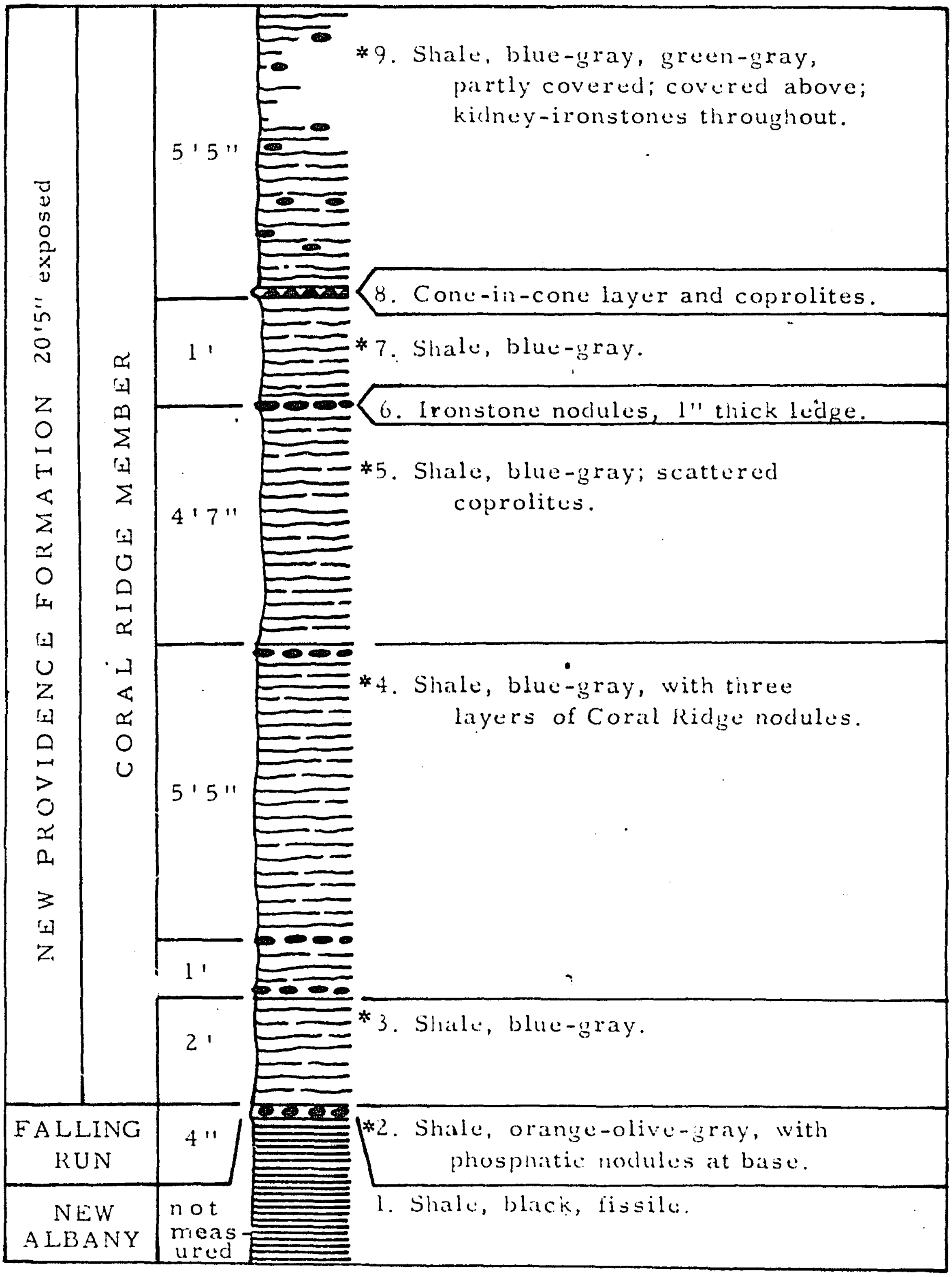
LOCALITY K-4

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.

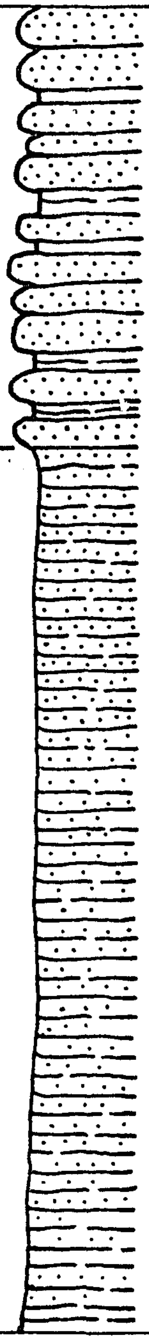
LOCALITY K-6


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.

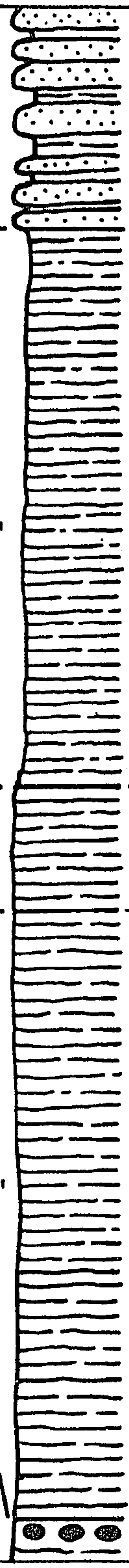
LOCALITY K-8


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

LOCALITY K-10

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

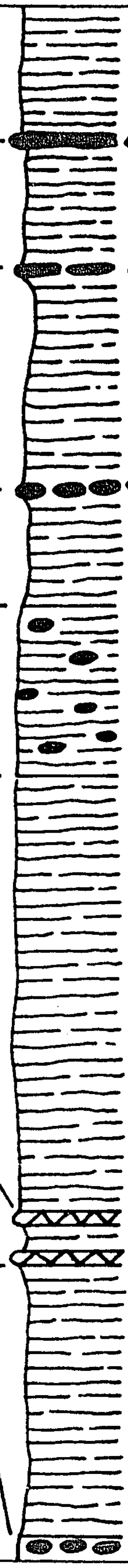


Formation	Member	Thickness	Description
NEW PROVIDENCE FORMATION	Keith Knob siltstone		*5. Siltstone and shale; not measured.
NEW PROVIDENCE FORMATION		10'6"	*4. Shale, blue brown gray to blue gray; browner at base.
NEW PROVIDENCE FORMATION		2'	*3. Shale, green gray; one <u>Bellerophon</u> noted.
NEW PROVIDENCE FORMATION		12'6"	*2. Shale, green gray; glauconitic in upper part.
Falling Run		5.5"	1. Shale, green gray, with phosphatic nodules.

LOCALITY K-12

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

LOCALITY K-13

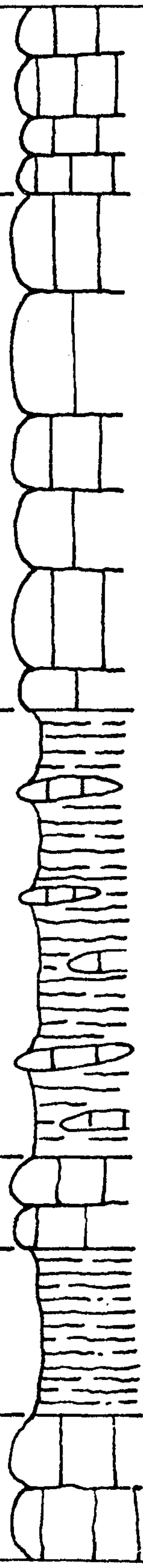


Formation	Thickness	Description
NEW PROVIDENCE FORMATION 54' exposed	4'9"	*12. Shale, olive gray; frequent ironstone chips, but no large ironstones noted; covered above.
		11. Ironstone bed.
	4'3"	*10. Shale, olive gray.
		9. Ironstones, large, in discontinuous band.
	8'	*8. Shale, blue gray; _Conularia_ in an ironstone chip.
		7. Ironstones, large.
	4'	*6. Shale, blue gray.
	5'6"	*5. Shale, blue gray; frequent kidney ironstones; common coprolites; _Conularia_, one _Bembexia ellenae_ noted.
	16'6"	*4. Shale, blue gray to olive gray.
	1'	*3. Shale, olive gray, with two thin calcareous bands with incipient con-in-cone structure.
	10'	*2. Shale, olive gray.
FALLING RUN	2"	*1. Shale, olive gray, with phosphatic nodules.

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

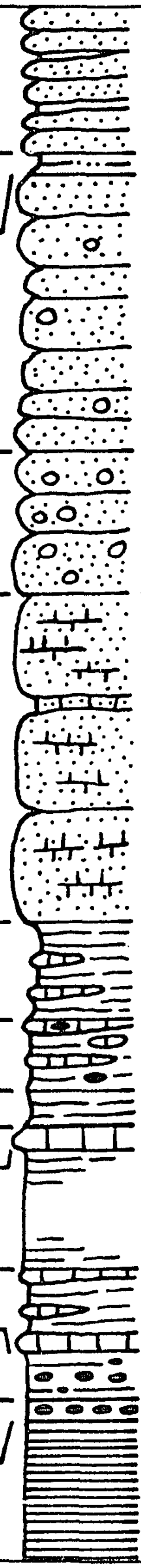


Formation	Member	Thickness	Description
ST. LOUIS LS.		10'	6. Limestone, fine grained to dense, blue gray.
SALEM LIMESTONE		30'	* 5. Limestone, fossiliferous, blue gray.
SALEM LIMESTONE	SOMERSET SHALE MBR.	25'	* 4. Shale, with limestone lenses; bryozoans.
HARRODSBURG LIMESTONE		3'	3. Limestone, massive,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

LOCALITY K-17

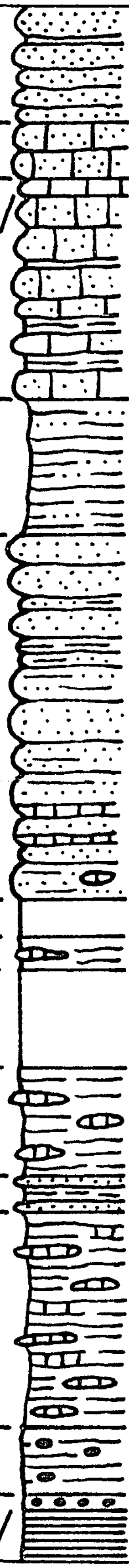
Formation	Thickness	Description
NEW PROVIDENCE FORMATION	5'6"	*5. Shale, green gray, partly covered.
NEW PROVIDENCE FORMATION	11'	* 4. Shale, green-gray.
NEW PROVIDENCE FORMATION	5'5"	*3. Shale, gray green; at top, common coprolites and one shark's tooth.
FALLING RUN	5"	*2. Shale, green gray, with phosphatic 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

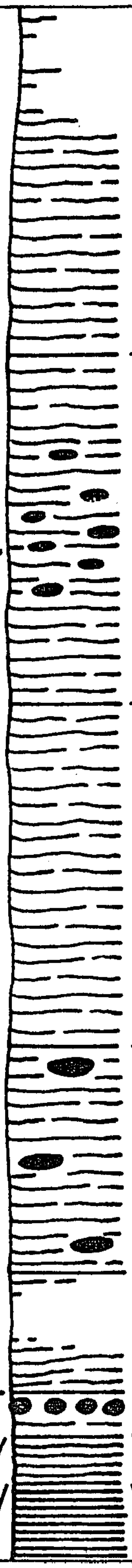


KEOKUK LIMESTONE	19'	*14. Siltstone, bluish, weathering brown; fossiliferous.
	10'	13. Limestone, cherty and silty.
	1'	*12. Limestone, crinoidal, oölitic?.
	44'	* 11. Limestone, cherty and silty; crinoidal in upper part; rare clay seams.
NEW PROVIDENCE FORMATION 190'	26'	*10. Shale, silty, soft, bluish; 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

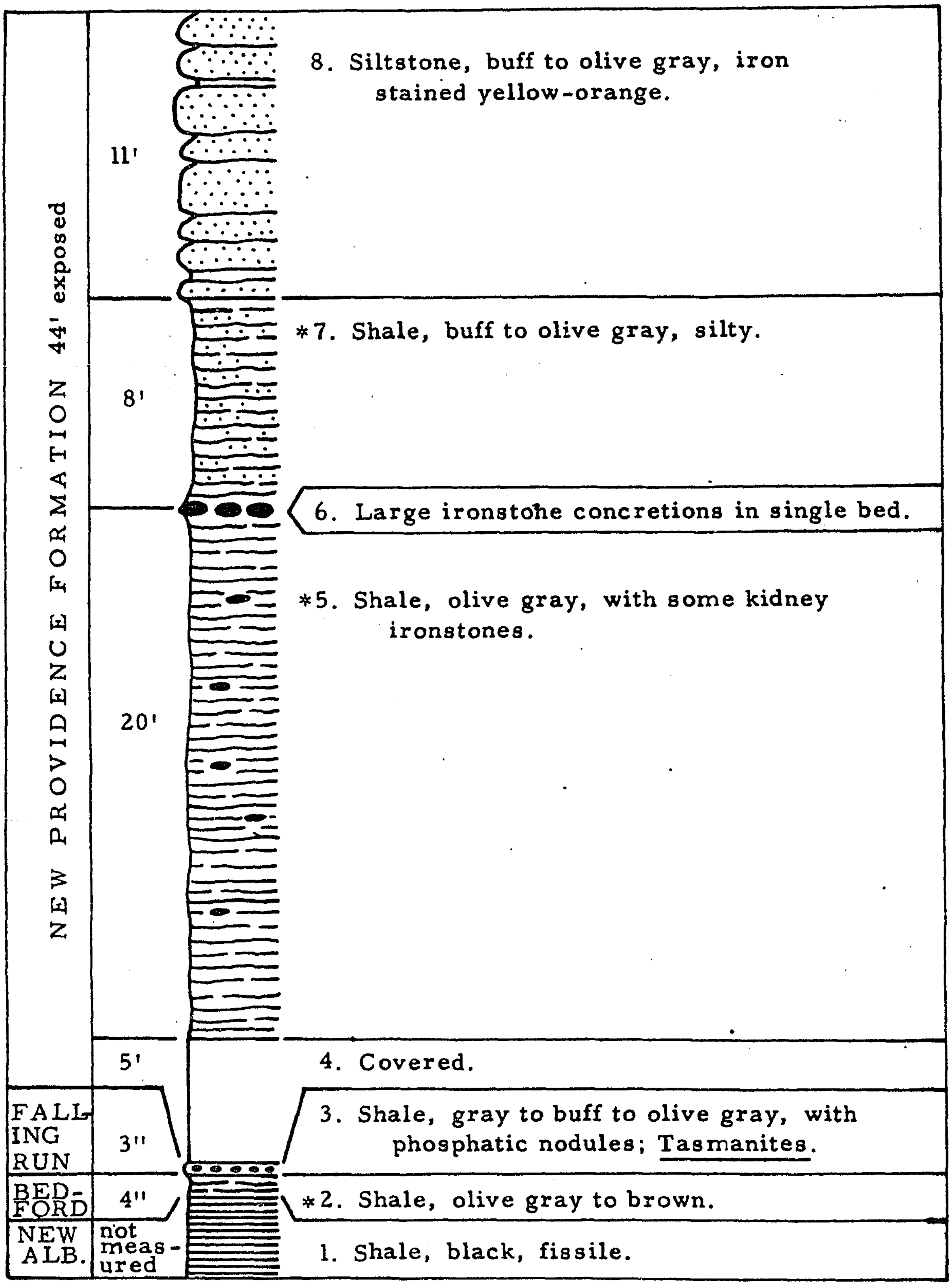
Formation	Thickness	Description
NEW PROVIDENCE FORMATION 17'6" exposed	4'	* 7. Shale, olive gray; covered above.
	10'	6. Covered.
	1'	* 5. Shale, olive gray.
	2'6"	* 4. Shale, olive gray to yellow, mixed.
Falling Run	3"	* 3. Shale, olive gray, with phosphatic nodules containing fossils.
BED-FORD	6"	*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

LOCALITY K-38

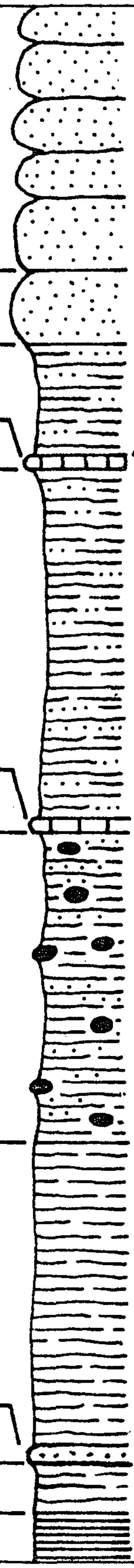


Formation	Thickness	Description
NEW PROVIDENCE FORMATION	5'6"	*8. Shale, blue gray, partly covered at top; rare coprolite? structures throughout.
NEW PROVIDENCE FORMATION	5'6"	*7. Shale, blue gray, with regular-sized kidney ironstones in middle portion; coprolite? structures of limonite.
NEW PROVIDENCE FORMATION	5'6"	*6. Shale, blue gray, softer than below; no kidney ironstones noted.
NEW PROVIDENCE FORMATION	3'6"	*5. Shale, with rare kidney ironstones which are larger than usual.
NEW PROVIDENCE FORMATION	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

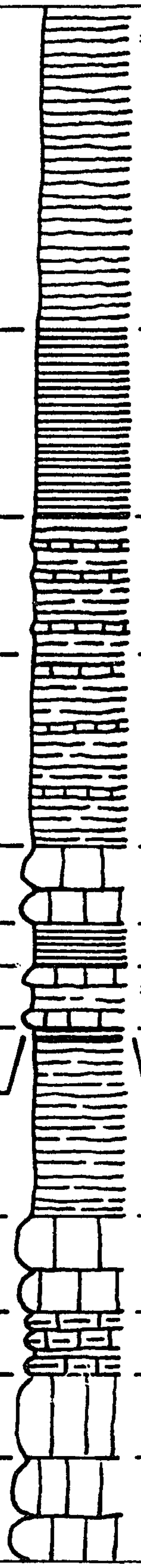


Formation	Member	Thickness	Description
BRODHEAD FORMATION	CONWAY SILTSTONE	50'	11. Siltstone, light gray to buff; worm markings and Taonurus.
		10'	10. Siltstone, olive gray.
		15'	9. Shale, gray to dark gray, very silty.
		8"	8. Limestone, dense, gray.
NEW PROVIDENCE FORMATION 125'		45'	* 7. Shale, silty, blue gray.
		8"	6. Limestone lenses.
		45'	*5. Shale, silty, dark gray to blue gray; ironstone concretions.
		26'	*4. Shale, clayey, blue gray to olive gray.
		1'	3. Siltstone lens, clayey.
		8'	*2. Shale, olive gray, clayey.
New Albany			1. Shale, black, fissile; not measured.

LOCALITY K-45

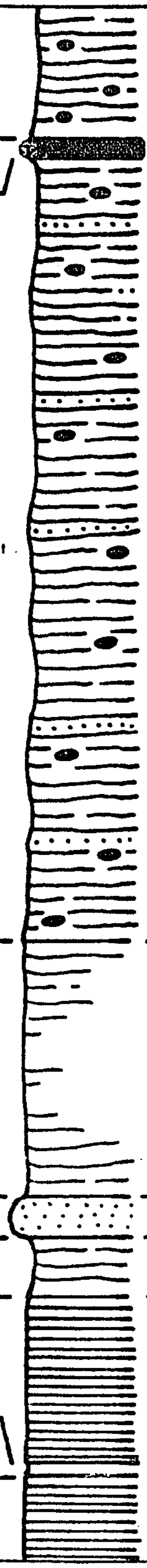
Brodhead	Conway siltstone	17'	*11. Shale, buff to olive gray, silty; with large ironstone concretions; covered above.
NEW PROVIDENCE FORMATION 143'		33'	10. Covered.
		11'	*9. Shale, olive gray.
		33'	*8. Shale, olive gray, partly blue gray, silty; rare small medium sized ironstones at top.
		22'	7. 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



Formation	Member	Thickness	Description
NEW ALBANY SHALE	BLACKISTON	10'	* 13. Shale, black and gray layers interbedded.
	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.
	MIDDLE	7'	10. Shale, subfissile, black, calcareous; *Lingulopora williamsana*.
		1'	9. Limestone.
		3"	8. Shale, fissile, black; no fossils.
		9"	* 7. Limestone and calcareous shale.
		1"	*6. Shale, calcareous, black.
	LOWER	2'1"	*5. Shale, earthy, greenish to black.
		1'	*4. Limestone, brown.
		6"	*3. Limestone, shaly, gray to black.
		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

Formation	Thickness	Description
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 ALBANY		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 *Lingula* and *Orbiculoidea*.
	2"	4. Shale, grayish yellow to gray, weathered; no fossils.
	5"-15"	3. Shale, black, fissile.
BED-FORD	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.

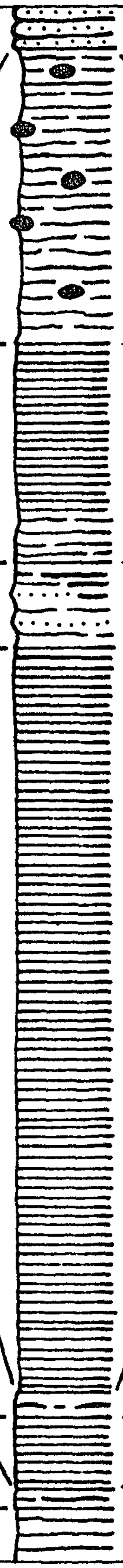
LOCALITY K-54

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

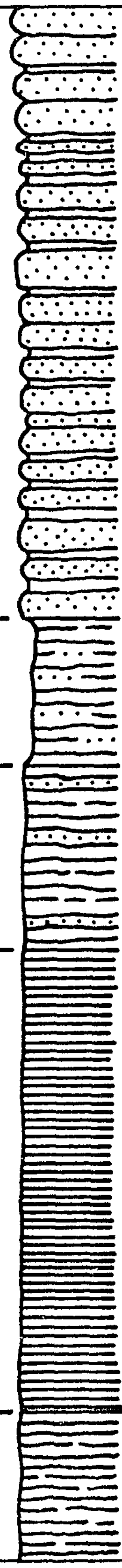
Formation	Thickness	Description
NEW PROVIDENCE FM.		*9. Shale, clayey, green gray; not measured.
NEW PROVIDENCE FM. — Clay City mbr.	1'6"	8. Siltstone, calcareous, hard, buff.
NEW PROVIDENCE FM.	4'6"	7. Shale, clayey, buff gray, weathered yellow.
SUNBURY SHALE	9'6"	6. Shale, black, fissile; upper foot weathered soft, coffee-colored.
BEDFORD SHALE	3'2"	*5. Contact seam; weathered shale.
		*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.
	1'	*2. Shale, clayey, olive green.
		1. Shale, black, fissile; not measured.

LOCALITY K-57



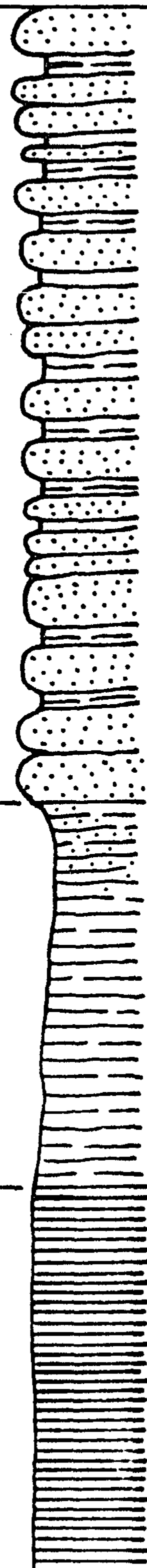
Formation	Thickness	Description
NEW PROVIDENCE FORMATION	2'	*9. Siltstone, shaly.
	18'	*8. Shale, olive gray, with ironstone concretions.
SUNBURY SHALE	14'	7. Shale, black, fissile; some softer gray and brown shale in lower 3 feet.
BEDFORD	5'4"	*6. Shale, gray to buff brown, sandy, calcareous.
NEW ALBANY SHALE	48'	5. Shale, black, fissile.
	1'	*4. Shale, gray.
	1'	3. Shale, black, fissile.
	1'	*2. Shale, clayey, gray to olive.
	3'	1. Shale, gray to black, semi-fissile.

LOCALITY K-58



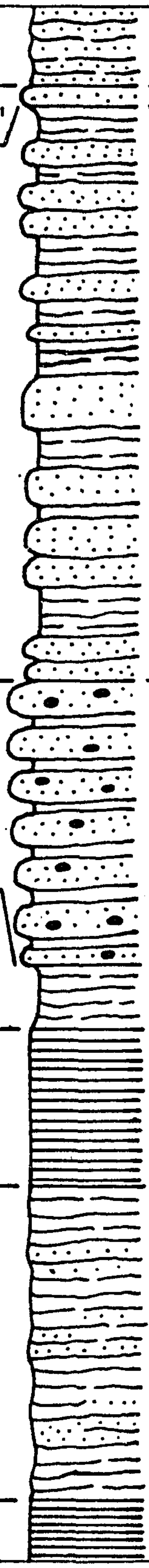
NEW PROVIDENCE FORMATION	FARMERS SILTSTONE	26'	*5. Siltstone with shale, blue gray.
		5'	* 4. Shale, silty, blue gray to gray.
		6'6"	*3. Shale, clayey, blue gray, with thin silty layers.
SUNBURY SHALE		16'	2. Shale, black, fissile.
BEDFORD SHALE			1. Shale, soft, sticky, yellow to buff to gray, some 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.

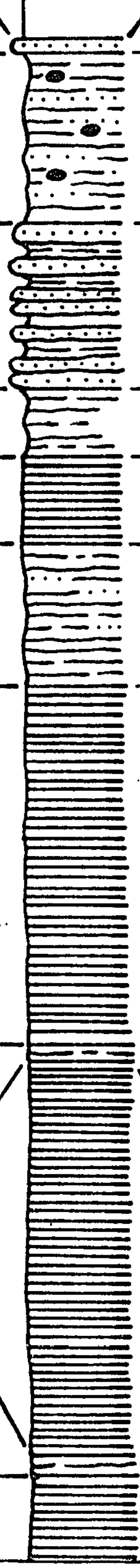
LOCALITY K-62



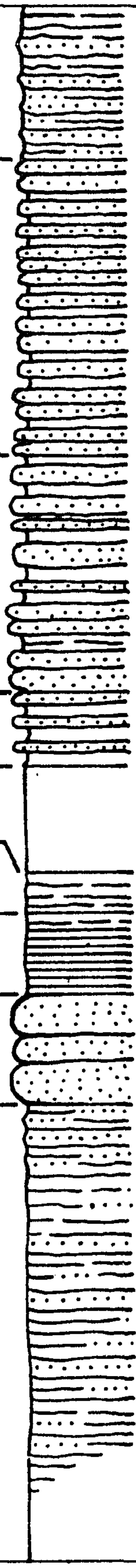
Formation	Member	Thickness	Description
NEW PROVIDENCE FORMATION		7'	8. Shale, very silty.
		6"-1'	7. Siltstone in single bed, gray to buff.
		85'	6. Shale and siltstone; no samples taken.
	Farmers siltstone	30'	5. Siltstone, in smooth even beds separated by shale partings; gray to buff; ironstone concretions; <u>Taonurus</u>.
	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.

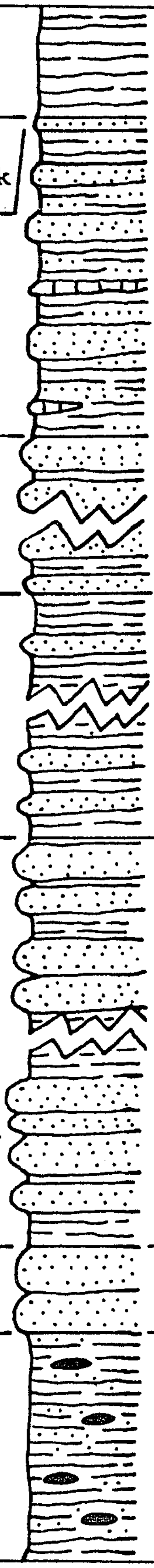


LOCALITY K-66



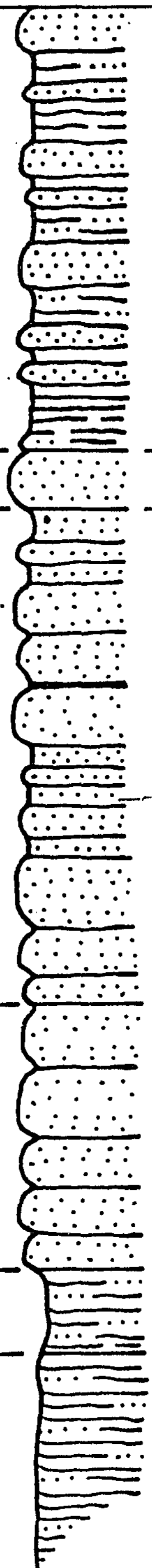
Formation	Member	Thickness	Description
NEW PROVIDENCE FORMATION (CUYAHOGA)	Churn Creek sh.	35'	* 9. Shale, very silty, light gray; worm markings.
	VANCEBURG SILTSTONE	64'	* 8. Siltstone in smooth even beds up to 3" thick, gray to drab, separated by shale partings up to 1" thick; <u>Taonurus</u>.
		53'	7. Siltstone and shale, clayey, drab; <u>Taonurus</u>.
		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



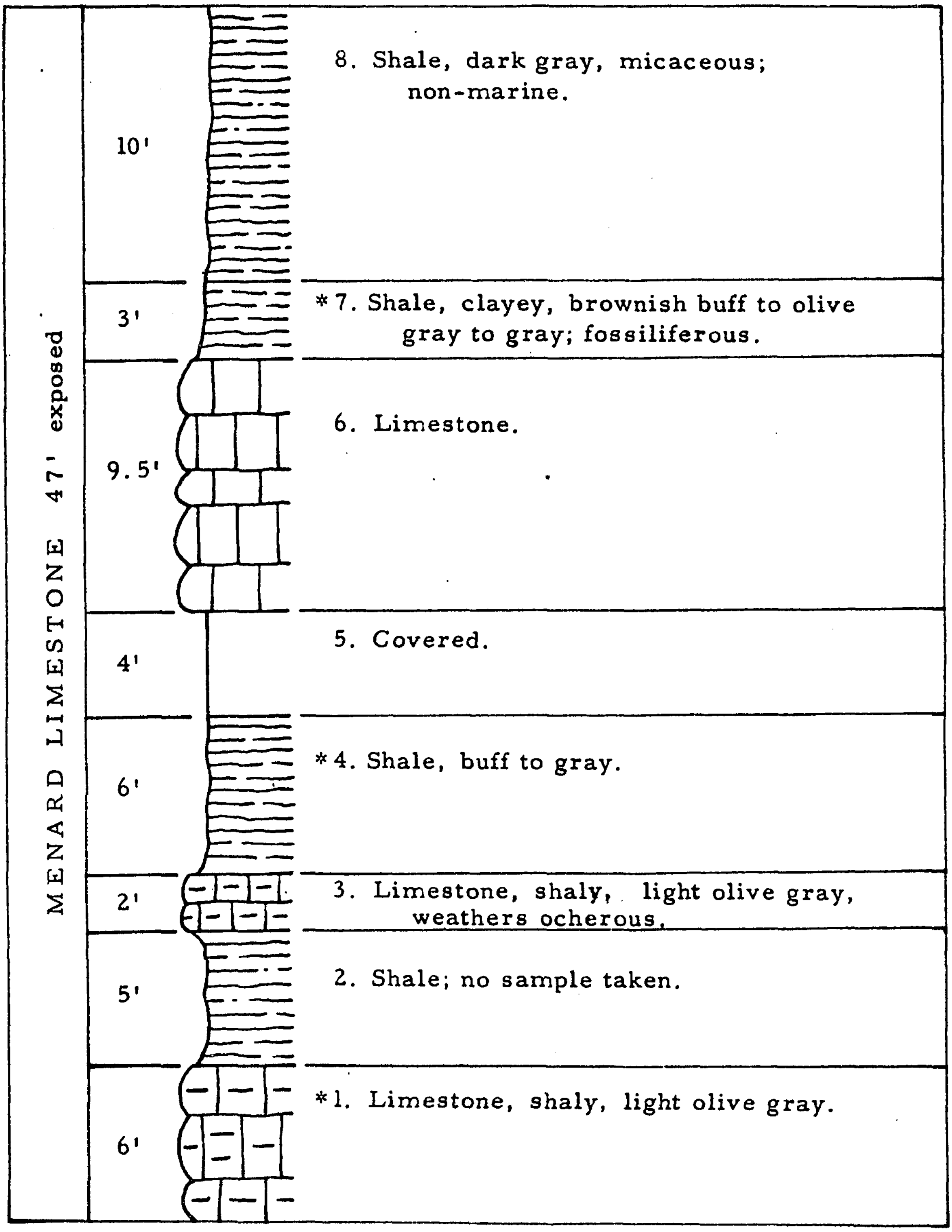
Formation	Member	Thickness	Description
ROTHWELL SHALE		6'	*8. Shale, clayey, olive gray and maroon.
FLOYDS KNOB FM.		thin streak	*7. Shale, silty, glauconitic, greenish black to olive gray.
BRODHEAD FORMATION 310'	Perry Branch siltstone	35'	*6. Siltstone, limestone lenses, and silty shale, olive gray 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



Formation	Member	Thickness	Description
BRODHEAD FORMATION 271'	HALDEMAN SILTSTONE	90'	*6. Siltstone and shaly siltstone, blue gray to olive gray, shalier in lower part; <u>Taonurus</u> and worm markings.
		10'	5. Siltstone, massive, buff to drab.
		100'	* 4. Siltstone, shaly, blue gray to olive gray; <u>Taonurus</u> and worm markings.
	CHRISTY CREEK SILTSTONE	55'	3. Siltstone tö 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

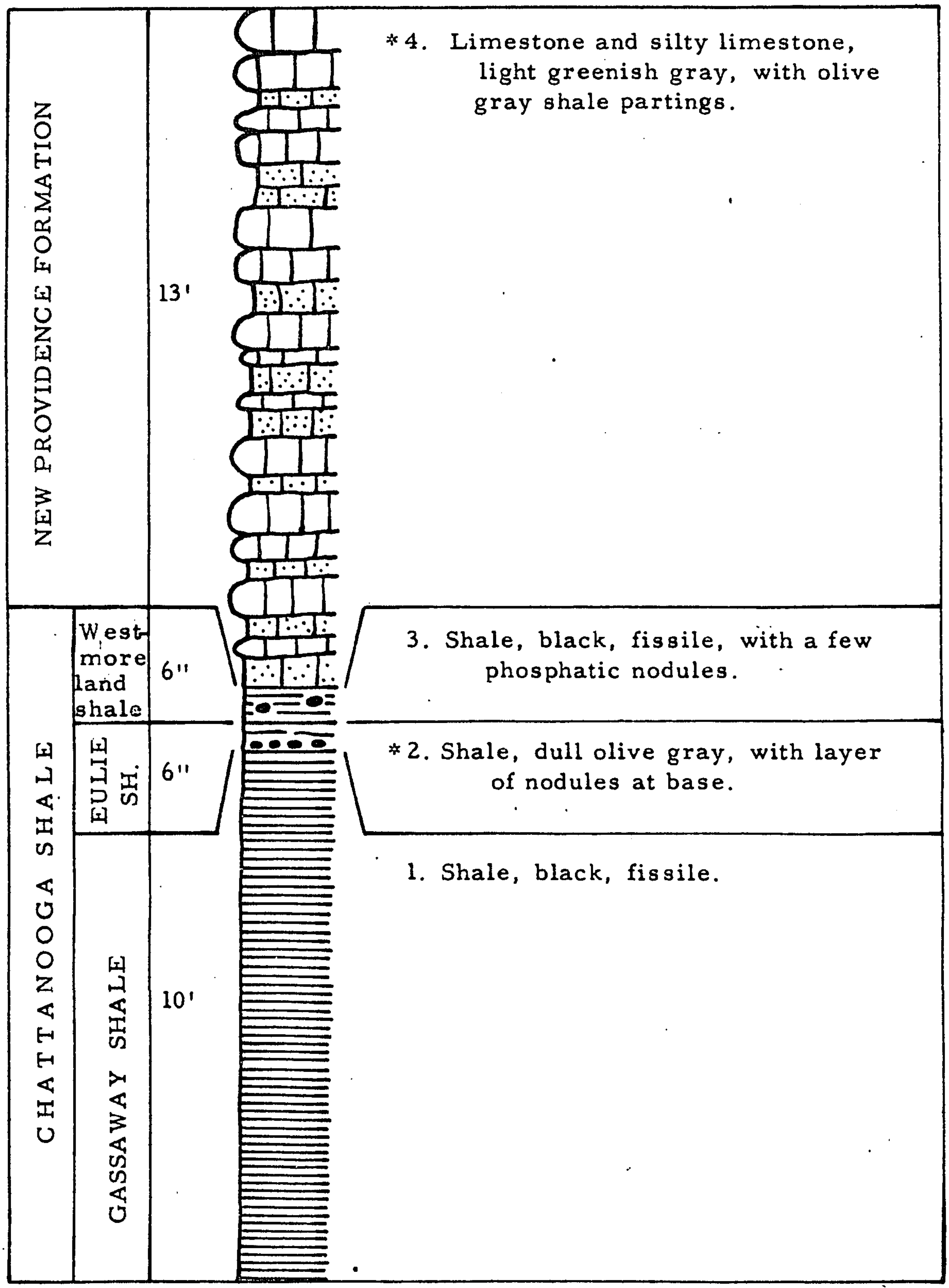

MENARD LIMESTONE 47' exposed
10'
8. Shale, dark gray, micaceous; non-marine.
3'
*7. Shale, clayey, brownish buff to olive gray to gray; fossiliferous.
9.5'
6. Limestone.
4'
5. Covered.
6'
*4. Shale, buff to gray.
2'
3. Limestone, shaly, light olive gray, weathers ocherous.
5'
2. Shale; no sample taken.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

LOCALITY I-6

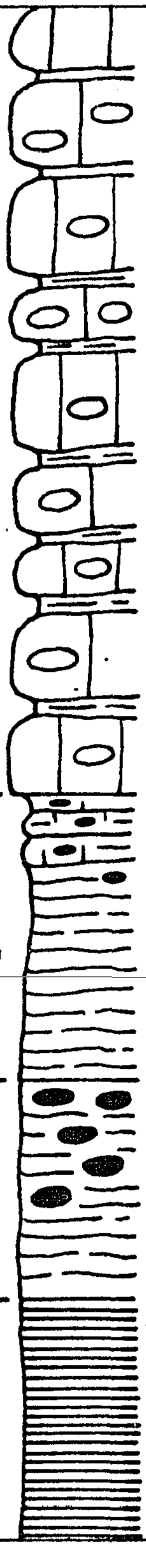
NEW PROVIDENCE FORMATION 101' exposed

Thickness	Description
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

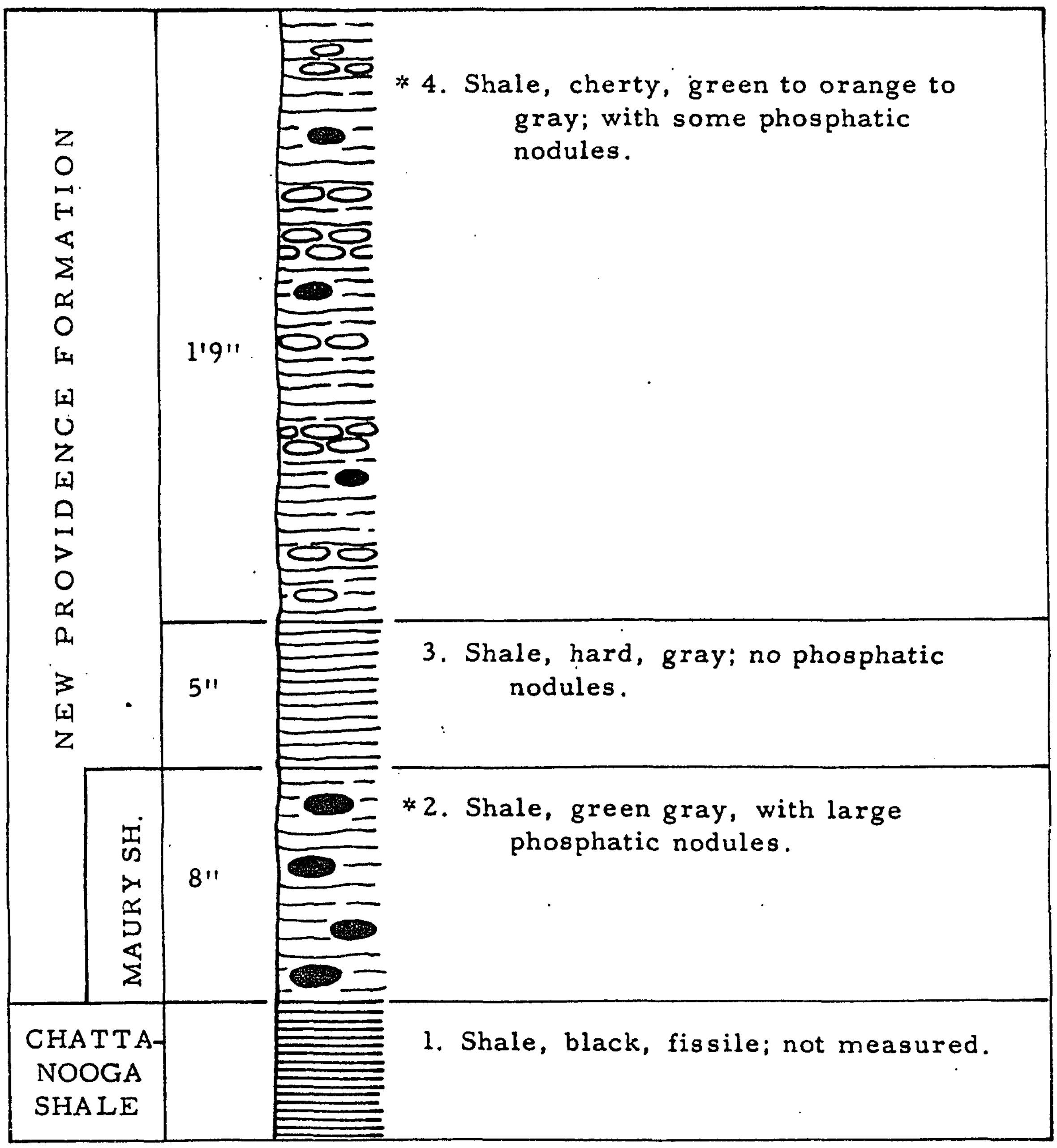

NEW PROVIDENCE FORMATION
13'
*4. Limestone and silty limestone, light greenish gray, with olive gray shale partings.
CHATTANOOGA SHALE
Westmoreland shale
6"
3. Shale, black, fissile, with a few phosphatic nodules.
EULIE SH.
6"
*2. Shale, dull olive gray, with layer of nodules at base.
GASSAWAY SHALE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

LOCALITY T-3

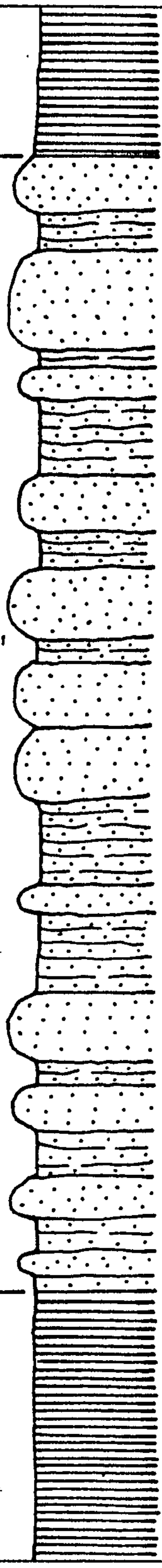


Formation	Thickness	Description
FORT PAYNE LIMESTONE		*4. Limestone, cherty, with thin shale seams; not measured; sample from lower 5 feet.
NEW PROVIDENCE FM.	12.5"	*3. Shale, gray to green gray; phosphatic nodules and glauconitic, calcareous, shale at top.
NEW PROVIDENCE — MAURY SH.	10"	2. Shale, hard, 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

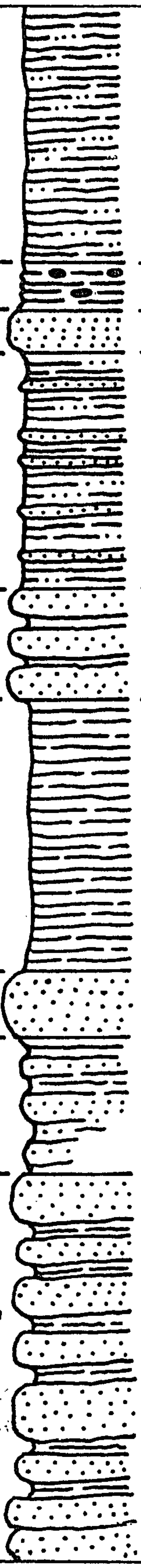

NEW PROVIDENCE FORMATION
MAURY SH.
CHATTA-NOOGA SHALE
1'9"
5"
8"
* 4. Shale, cherty, green to orange to gray; with some phosphatic nodules.
3. Shale, hard, gray; no phosphatic nodules.
*2. Shale, green gray, with large phosphatic nodules.
1. Shale, black, fissile; not measured.

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

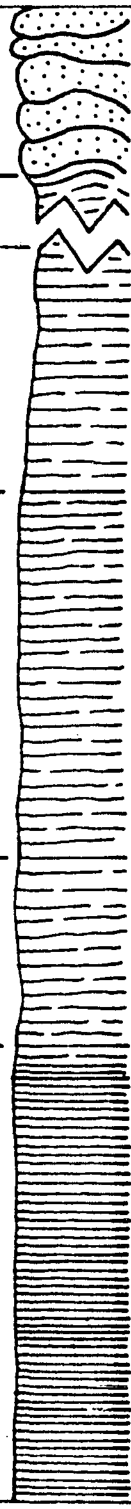


CUYAHOGA FORMATION - VANCEBURG MEMBER	16'	* 9. Shale, silty, brownish gray.
	1'	* 8. Shale, gray, platy; small ironstones.
	1'	7. Siltstone.
	9'	* 6. Shale, silty, with thin siltstones.
	3'6"	* 5. Siltstone, in three beds, with two 2 inch shale breaks.
	11'	* 4. Shale, gray green.
	2'	3. Siltstone, massive.
	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

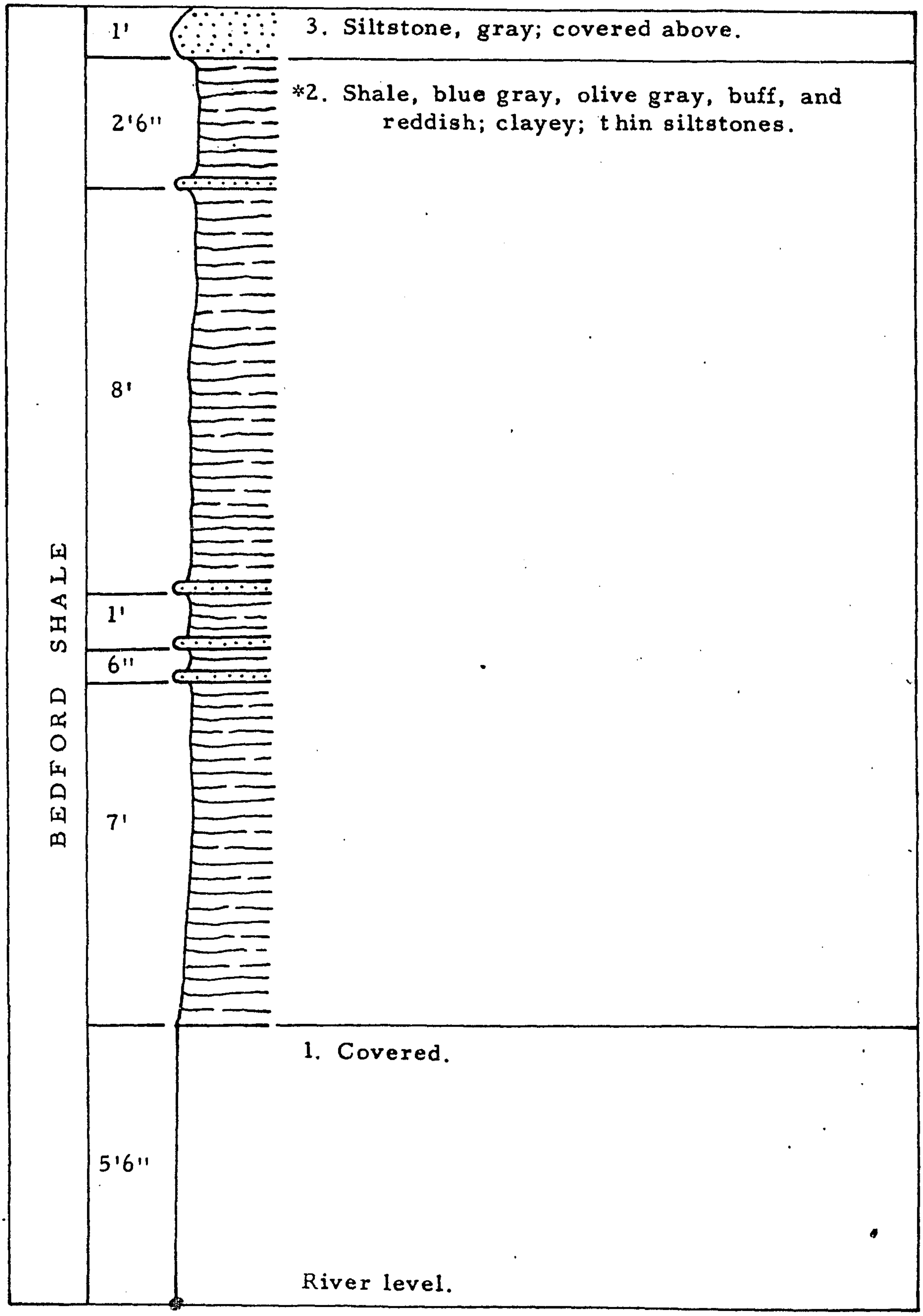
Formation	Thickness	Description
LOGAN FM.	16'	*6. Siltstone, blue gray, gray, thin to medium bedded, with silty shale.
CUYAHOGA FORMATION	64'	*5. Shale, blue gray.
	60'	4. Covered by slump.
	100'	*3. Shale, blue gray.
	5'6"	*2. Shale, blue gray, with thin siltstones.
	5'6"	1. Shale, not sampled.

LOCALITY O-4

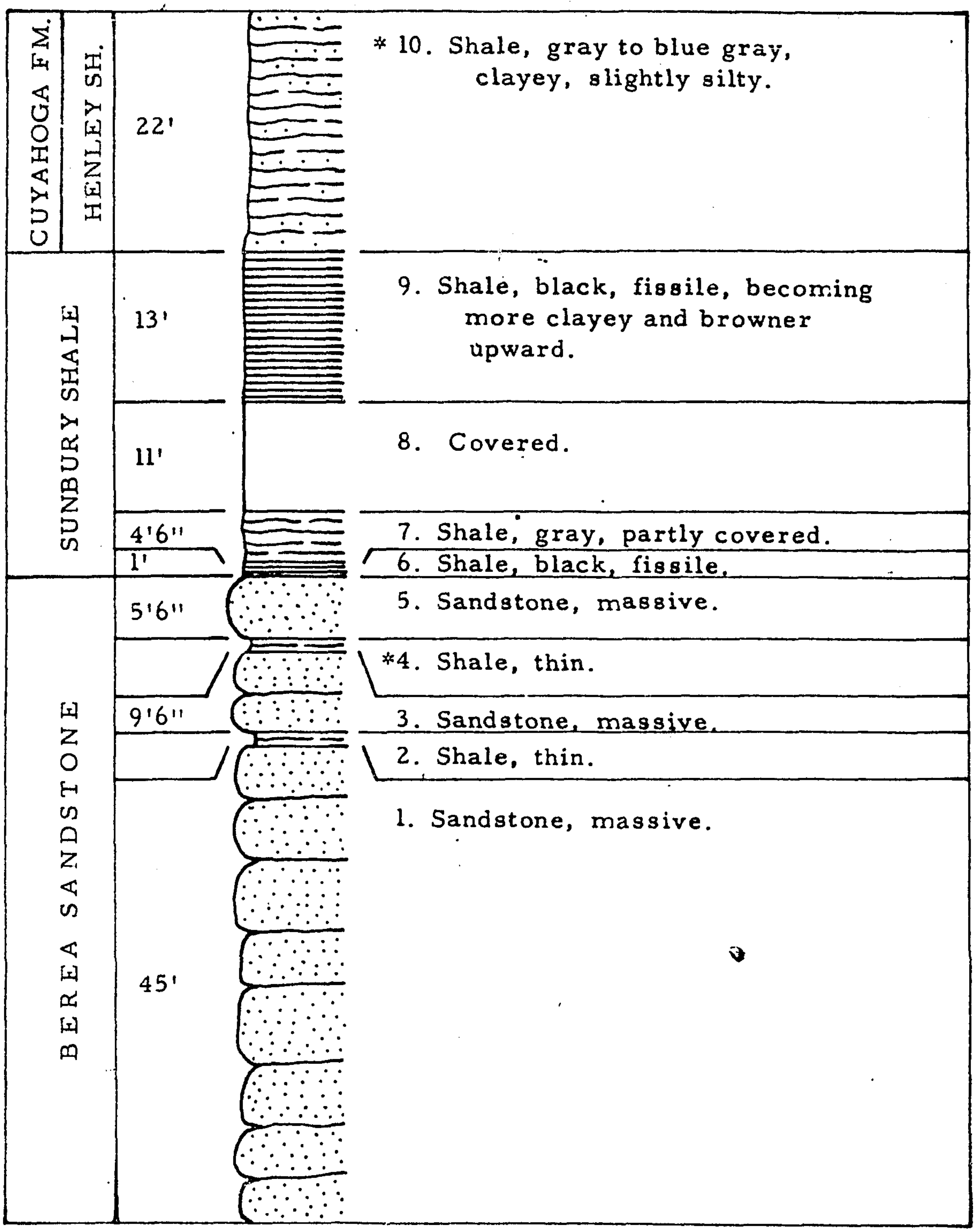


Formation	Thickness	Description
BEREA SS.		* 7. Sandstone, light gray to blue gray; beds contorted; not measured.
BEDFORD SHALE		6. Shale, not measured or sampled.
BEDFORD SHALE	2'	5. Shale, clayey, gray to yellow buff.
BEDFORD SHALE	3'	* 4. Shale, clayey, gray to yellow buff.
BEDFORD SHALE	2'	* 3. Shale, 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


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

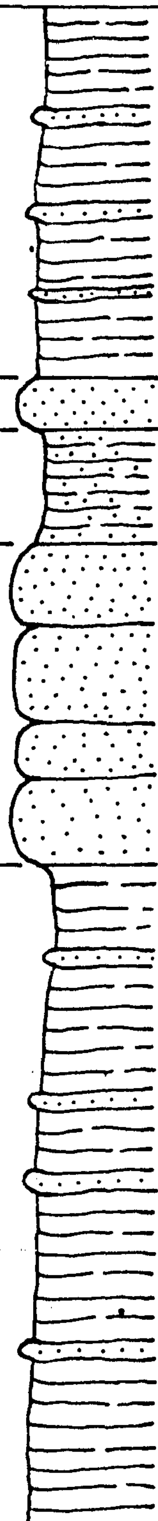
LOCALITY O-6


CUYAHOGA FM.
HENLEY SH.
22'
* 10. Shale, gray to blue gray, clayey, slightly silty.
SUNBURY SHALE
13'
9. Shale, black, fissile, becoming more clayey and browner upward.
11'
8. Covered.
4'6"
7. Shale, gray, partly covered.
1'
6. Shale, black, fissile.
BEREA SANDSTONE
5'6"
5. Sandstone, massive.
*4. Shale, thin.
9'6"
3. Sandstone, massive.
2. Shale, thin.
45'
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 H. B. Brady, 1881

Genus Crithionina Göes, 1894

C. palaeozoica, n. sp.

Genus Thuramminoides Plummer, 1945 emend.

T. sphaeroidalis Plummer, 1945 emend.

Family Saccamminidae Cushman, 1927

Subfamily Saccammininae Cushman, 1927

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.

Genus Tolypammina Rhumbler, 1895

T. botonunca Gutschick and Treckman, 1959

T. cyclops Gutschick and Treckman, 1959

T. jacobschapelensis, n. sp.

T. laocoön, 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 Opthalmidiidae

Genus Hemigordius Schubert, 1908

H. morillensis, n. sp.

Family Trochamminidae Cushman, 1929

Genus Trochammina Parker and Jones, 1959

T. ohioensis, n. sp.

Family Placopsilinidae

Subfamily Polyphragminae

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 allotted 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, eighteen 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 proloculus are not uncommon.

The most commonly occuring species is Hyperammina casteri, which is especially characteristic of the lower New Providence and lower Cuyahoga where Hyperammina 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 up in the New Providence formation, and is abundant at this level, from southeastern Kentucky to southern Ohio where *Hyperammina kentuckyensis* is absent or present only in the upper part of the New Providence. In eastern Kentucky the upper New Providence was not sampled and thus the lower range of *Hyperammina kentuckyensis* and the upper range of abundant *Hyperammina casteri* were not determined.

Hyperammina kentuckyensis is highly characteristic of and restricted to the Osagian of Kentucky, 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 Knob 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 it 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 Kincaid limestone.

Proteonina

Of the two species of Proteonina found in this study, P. cumberlandiae occurs most commonly in northwestern and southwestern Kentucky and in south-central 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 previously been described by Gutschick and Treckman (1959) from the Rockford limestone of northern Indiana. The most common of the three species is *T. spiralis* which occurs particularly in the lower part of the New Providence formation and Cuyahoga formation of Kentucky and Ohio respectively, 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 parts of the New Providence and Cuyahoga formations, but it also ranges upward into the Brodhead formation.

Trepeilopsis 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 the Brodhead formation; 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, 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 very 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 Kincaid limestones 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 occurrence of that species. A thin line indicates 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.

Chart 3. Occurrence of species by locality and bed number

(Localities I-2-6, T-1-4).

	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 botonunca					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).

	K-1					K-2			K-3						K-4					K-5	K-6			
	7	6	5	3	1	4	3	2	6	5	4	3	2	1	8	6	4	3	2	1	8	7	6	5
Ammobaculites gutschicki		X		X									X					X	X			X		
Ammovertella cf. A. inclusa							X	X																
A. cf. A. primaparva							X	X																
Crithionina palaeozoica													X	X										
Glomospira articulosa						X	X	X								X								
Hyperammina casteri	X	X		■	X	X	X	X			X	X	■		X			■	X			X	■	■
H. kentuckyensis	X	X				■	■								■	■		■	X	■		■	■	■
H. rockfordensis								■					■						X					
Involutina exserta		■	■	■		X							■	■				■	■					
I. semiconstricta		■		■	■			■			X		■	■				■	■					■
Proteonina cumberlandiae		X	X	X			X	■					■		X			■						
P. wallingfordensis		X		X				X							X									X
Stacheia cicatrix						X	X	X					X		X	X	X	X	X		X			
S. neopupoides																X								
Tolypammina cyclops								X																
T. jacobschapelensis																								
Thuramminoides sphaeroidalis	■	■		■	X	■	■	■	X	■	■	■	■	■	■	■		■	■			■	■	■
Trepeilopsis recurvidens						X							X											
T. spiralis						X	X	X					■		X	X			X				X	X
Ammovertella fragments								X																
Hyperammina fragments	X	X	X					X		X	X	X	X	X	X				X					X
Tolypammina fragments													X	X										
Trepeilopsis fragments							X								X			X						

s by locality and bed number (Localities K-1-9).

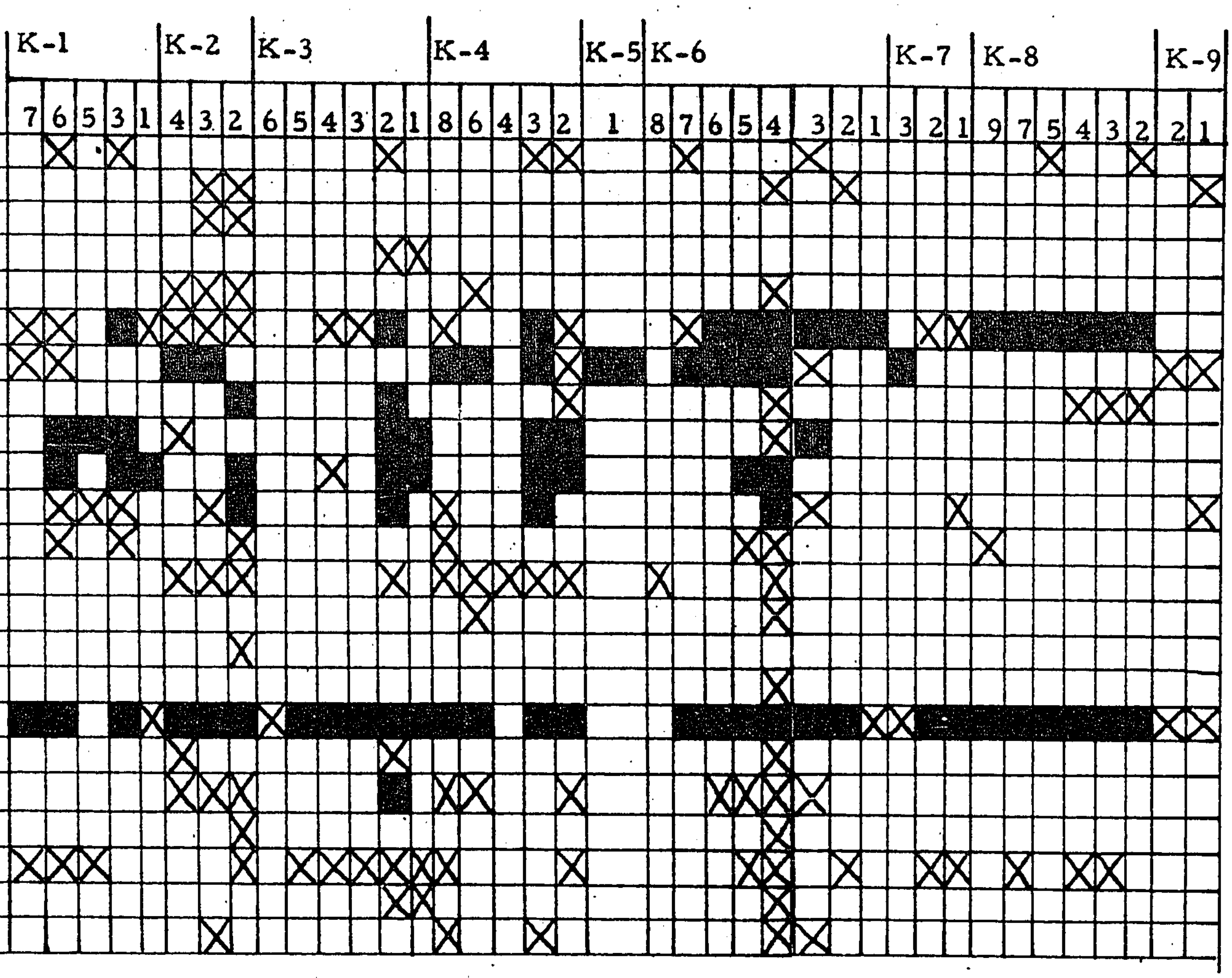


Chart 5. Occurrence of species by locality and bed number (Localities K-10-19).

	K-10		K-11				K-12					K-13									K-14						K
	2	1	5	4	3	2	5	4	3	2	1	12	10	8	6	5	4	3	2	1	10	8	7	5	3	2	5
Agathammina mississippiana								X																			
Ammobaculites gutschicki		X		X						X			X						X			X		X	X		
Crithionina palaeozoica															X	X	X										
Earlandia consternatio																											
Hyperammina casteri		X		■	■	■		■	X	■		■	■	X	X	■	■	X	■	X		X	X	X	■	■	
H. kentuckyensis	■	■														X					X						
H. rockfordensis								X		X							X		X			X		X			
Involutina exserta		■				X		■		■							X	■	■	■				■	■		
I. longexserta								X		X									X				X				
I. semiconstricta		■						■	■										■	■	■			■	■		
Proteonina cumberlandiae				X		X						X	X						■					X	X		
P. wallingfordensis										X																	
Stacheia cicatrix																						X		X			
Thuramminoides sphaeroidalis	■	■	■	■	■	■	■	■	X	■	X	■	■	■	■	■	■	X	■	■		■	■	■	X	X	
Tolypammina cyclops																											
Trepeilopsis spiralis		■						■	■										X		X			X			
Ammovertella fragments																					X						
Hyperammina fragments	X	X		X			X	X	X	X	X	X	X	X	X		X		X	X			X	X	X	X	
Tolypammina fragments																	X			X				X			
Trepeilopsis fragments																	X							X			
Ammovertella labyrintha																						X					

d number (Localities K-10-19).

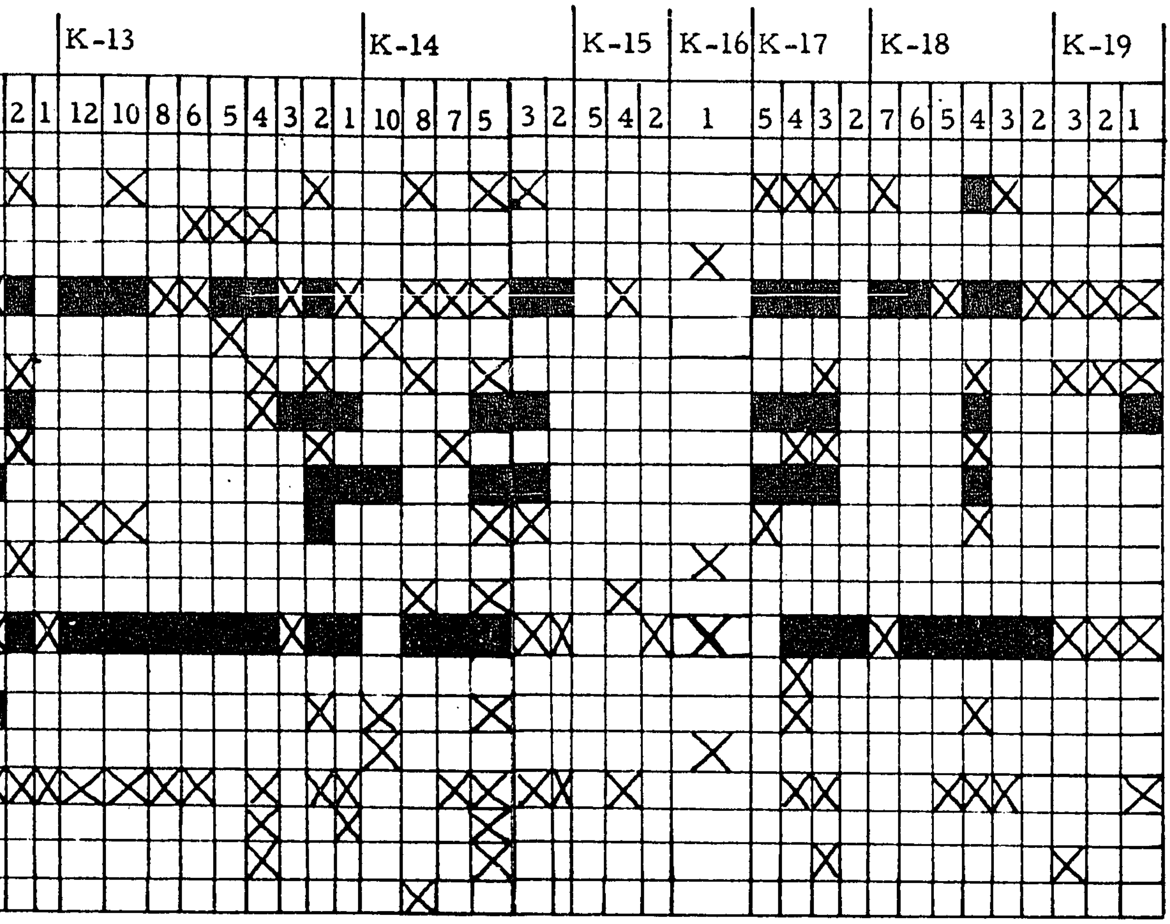


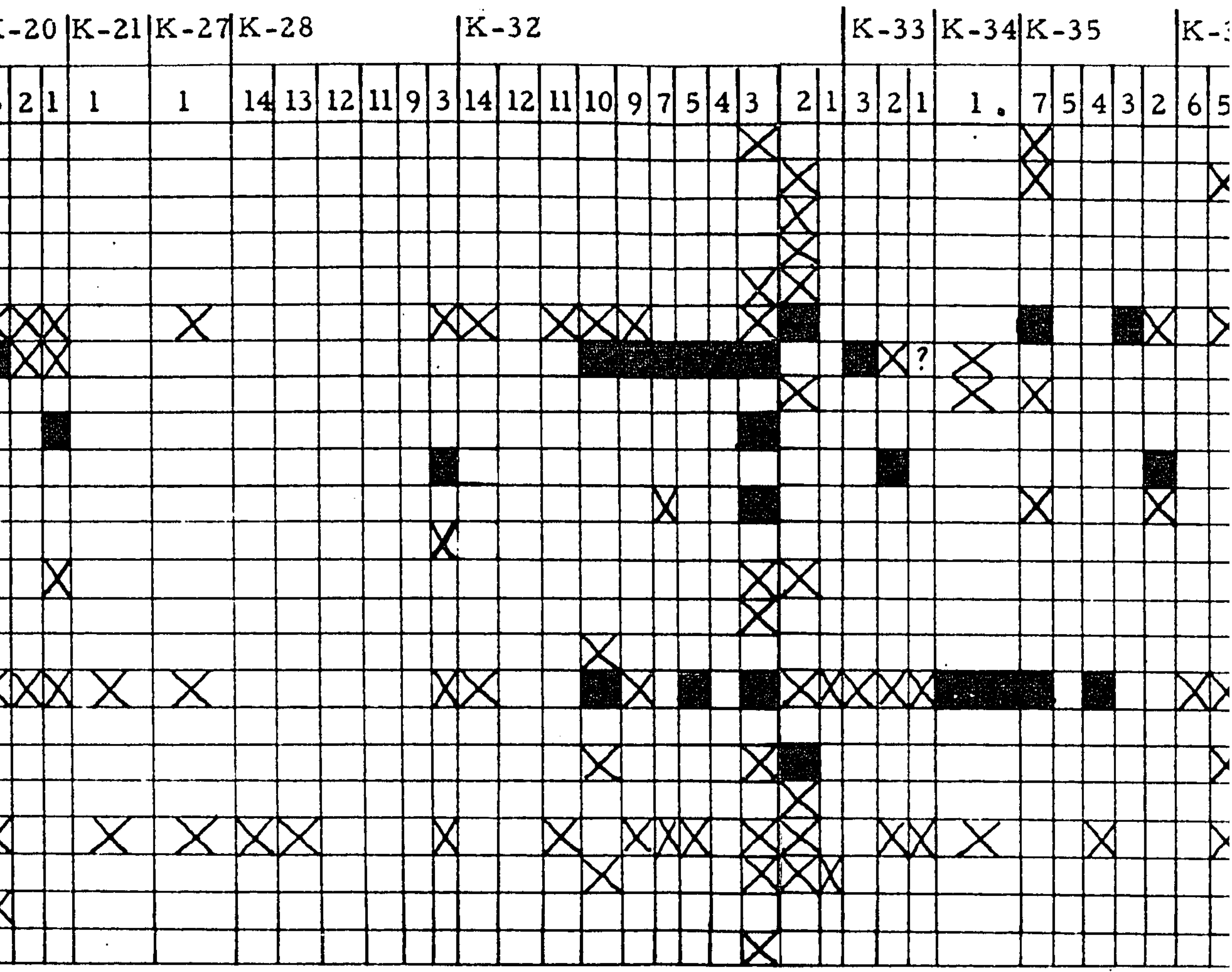
Chart 6. Occurrence of species by locality and bed number

(Localities K-20, 21, 27, 28, 32-41).

	K-20			K-21	K-27	K-28						K-32									
	3	2	1	1	1	14	13	12	11	9	3	14	12	11	10	9	7	5	4	3	2
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												■	■	■	■	■	■	
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
Trepeilopsis recurvidens																					
T. spiralis															X					X	■
Ammovertella fragments																					X
Hyperammina fragments	X			X	X	X	X				X			X		X	X	X		X	X
Tolypammina fragments															X					X	X
Trepeilopsis fragments	X																				
Involutina longexserta																				X	

y locality and bed number

, 28, 32-41).



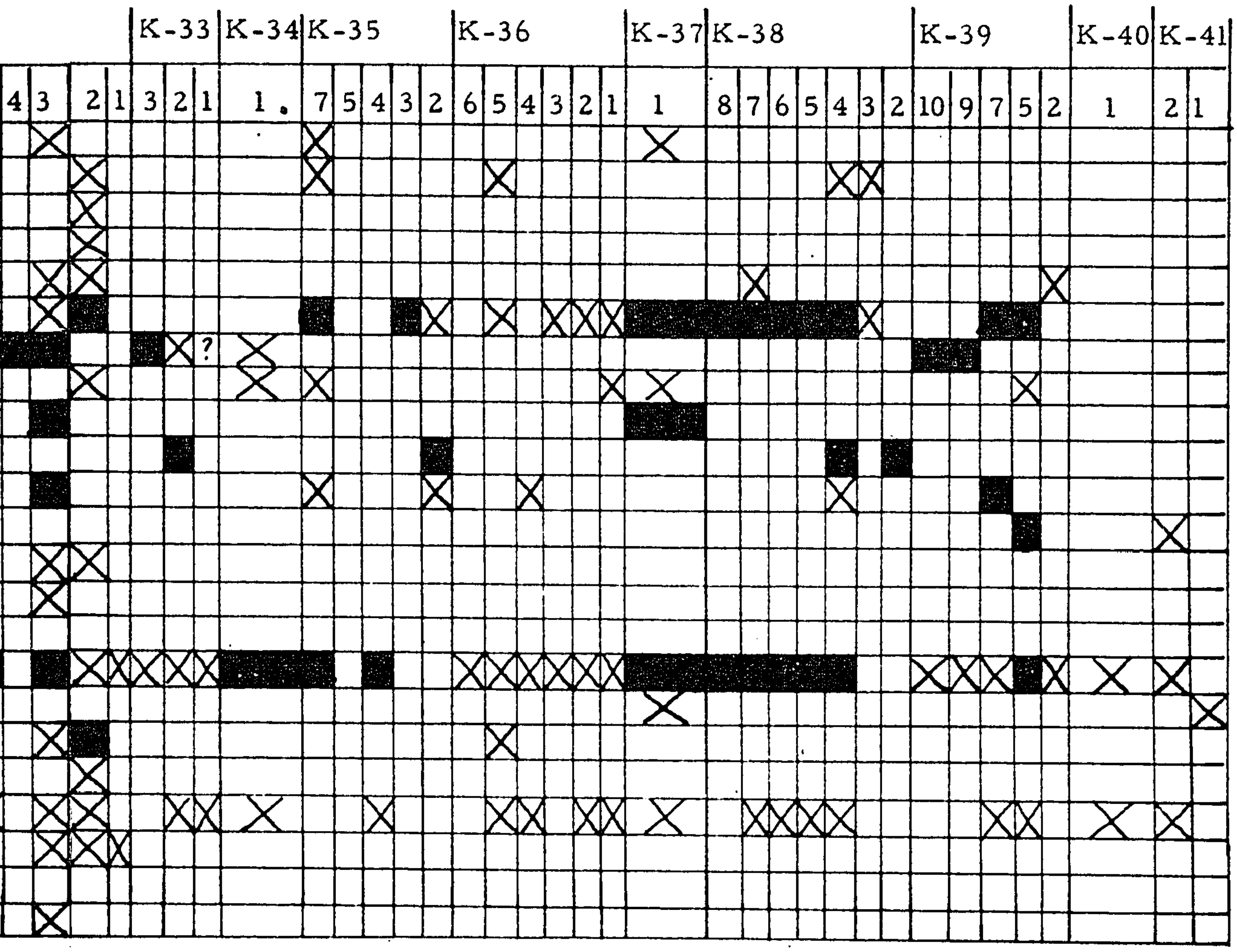

K-33
K-34
K-35
K-36
K-37
K-38
K-39
K-40
K-41
4 3 2 1 3 2 1 1. 7 5 4 3 2 6 5 4 3 2 1 1 8 7 6 5 4 3 2 10 9 7 5 2 1 2 1
?

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
	7	4	1	1	4	3	2	1	1	1	1	1	1
Agathammina mississippiana										X			
Climacammina mississippiana													
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							?
Ammovertella fragments											X		
Hyperammina fragments		■					X				X		X
Tolypammina fragments				X									

by locality and bed number

26, 29-31, 42, 43, 46).

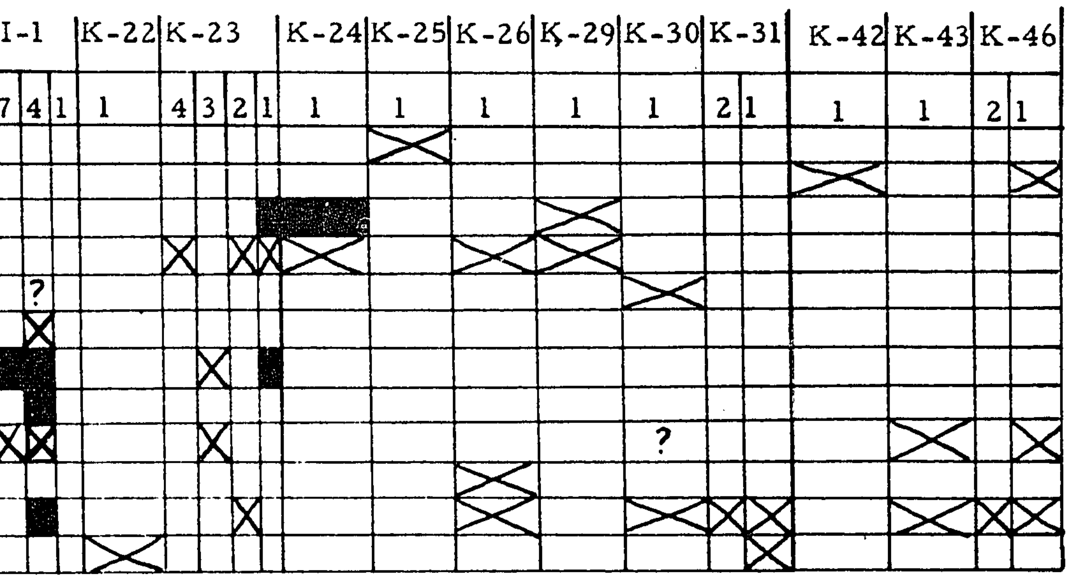


Chart 8. Occurrence of species by locality and bed number (Localities K-44, 47-50).

	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
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	
Trepeilopsis spiralis												X	X			X					
Hyperammina fragments	X	X	X	X		X		X			X	X	X		X	X		X	X		
Tolypammina fragments			X	X																	
Trepeilopsis fragments				X																	

urrence of species by locality and bed number (Localities K-44, 45,
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
es gutschicki		X	X	X				X								X									
ι casteri	X	■	■	■	■	X	■	■	X	■			X			■			X						
nsis															X	■									
nsis																	X								
niconstricta																			■						
allingfordensis		X		X			X									X									
des sphaeroidalis	■	■	■	X	■	■	■	■	■	■			X	X	X	■				X		X			
spiralis												X	X			X									
ι fragments	X	X	X	X		X		X			X	X	X		X	X		X	X			X		X	
fragments			X	X																					
fragments				X																					

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

	K-51				K-52						K-53					K-54				K-55				K-56		K-5	
	9	7	6	5	8	7	6	5	3	2	10	8	7	6	2	8	7	6	5	9	5	4	2	2	1	9	8
Agathammina mississippiana																											
Ammobaculites gutschicki		X	X		X	X										X	X	X									X
Ammovertella cf. A. inclusa			X												X												
Glomospira articulosa																											X
Hyperammina casteri	■	■	■	X	■	X					■	■	X				■	■	X	X				X		X	■
H. kentuckyensis																									X		
H. rockfordensis				X	X																						■
Involutina exserta								■	■					■							■			■			
I. longexserta																					X						
I. semiconstricta		■						■	■						■						■	■					■
Proteonina cumberlandiae			X					X																X			
P. wallingfordensis	X		X		■	X			X					■								X					X
Reophax minutissimus																											
Stacheia cicatrix																									X		X
S. neopupoides																											
Thuramminoides sphaeroidalis	■	■	■		X			X				■	X	X			X		■	X	X		X	X			X
Trepeilopsis glomospiroides		X	X	X																							X
T. recurvidens																								X			
T. spiralis		X	■	X							X	X				X	X	X		X			X	X			X
Ammovertella fragments			X									X															
Hyperammina fragments			X		X				X			X			X		X	X	X	X	X	X	X	X			
Tolypammina fragments			X																	X							X
Trepeilopsis fragments			X																							X	
Lituotuba semiplana					X																						

umber (Localities K-51-64).

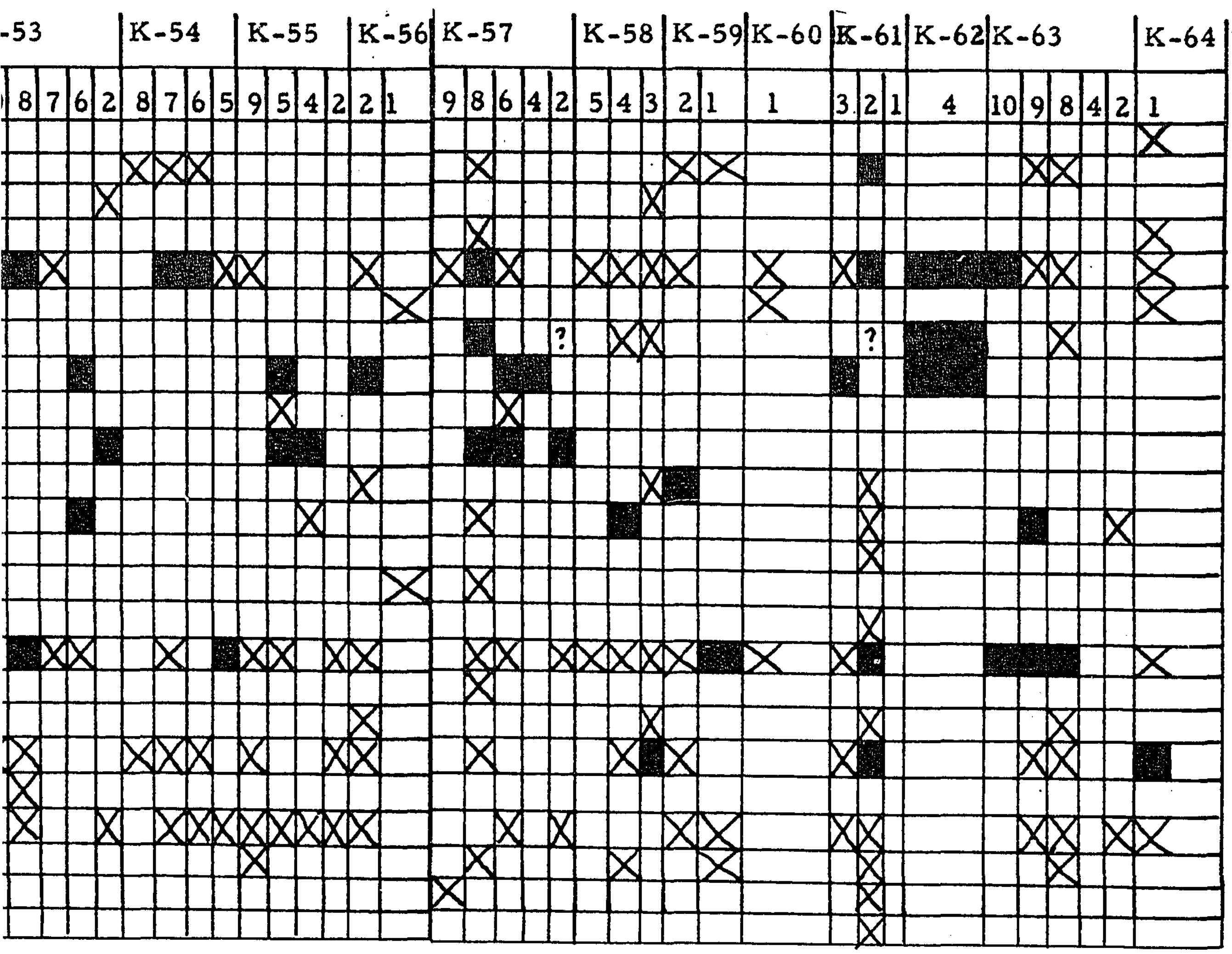


Chart 10. Occurrence of species by locality and bed number

(Localities K-65-68, O-1-11).

	K-65	K-66			K-67				K-68			O-1	O-2							O-3				O-4			
	1	9	8	1	8	7	6	1	6	4	1	2	9	8	6	5	4	2	1	6	5	3	2	7	4	3	2
Agathammina mississippiana																											
Ammobaculites gutschicki																											
Ammovertella cf. A. inclusa				X																							
A. cf. A. primaparva																											
Glomospira articulosa																X										X	
Stacheia cicatrix																											
Hyperammina casteri				X	X		X			X		X	■	■	X		X	X	X			■	■				X
H. rockfordensis																											
Involutina exserta				■								■										■				■	
I. semiconstricta	■			■								■													■	■	
Proteonina cumberlandiae														X	X							X					
P. wallingfordensis												X	X									■			X		
Reophax cf. R. arenatus					X																						
R. cf. R. lachrymosus																											
R. mcdonaldi		■																									
Stacheia neopupoides												X															
Thuramminoides sphaeroidalis	■				X		X			X			■	X	■	■	■	■	■	X		X	■				X
Tolypammina cyclops																											
Trepeilopsis glomospiroides																											
T. recurvidens																											
T. spiralis				■	X											X		X									
Trochammina ohioensis																											
Ammovertella fragments																											
Hyperammina fragments		X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X					
Tolypammina fragments																											
Trepeilopsis fragments																											
Hyperammina kentuckyensis					X	X	?			?																	

›y locality and bed number

-1-11).

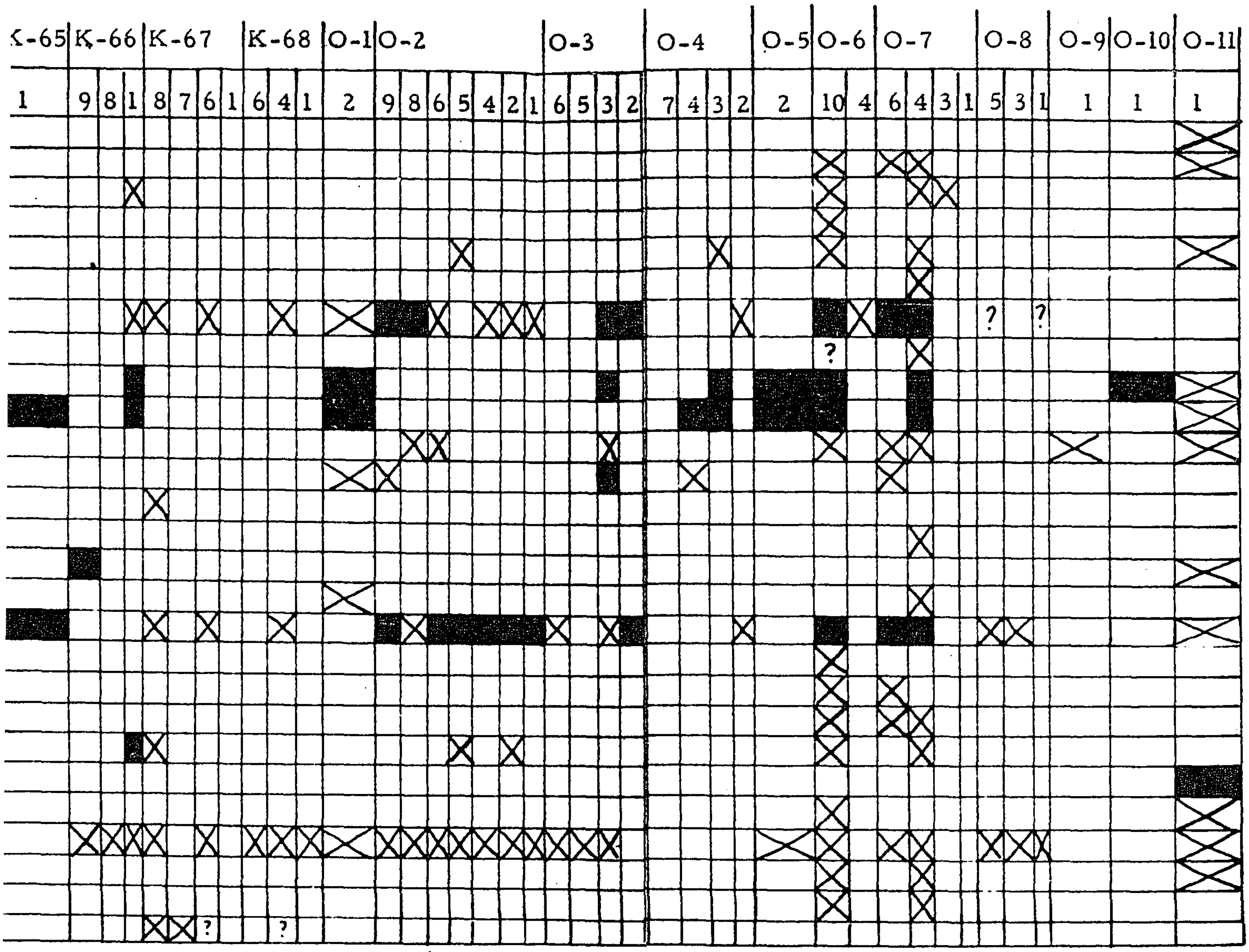


Chart 11. Range of species in southern Indiana (Localities (I-2-6).

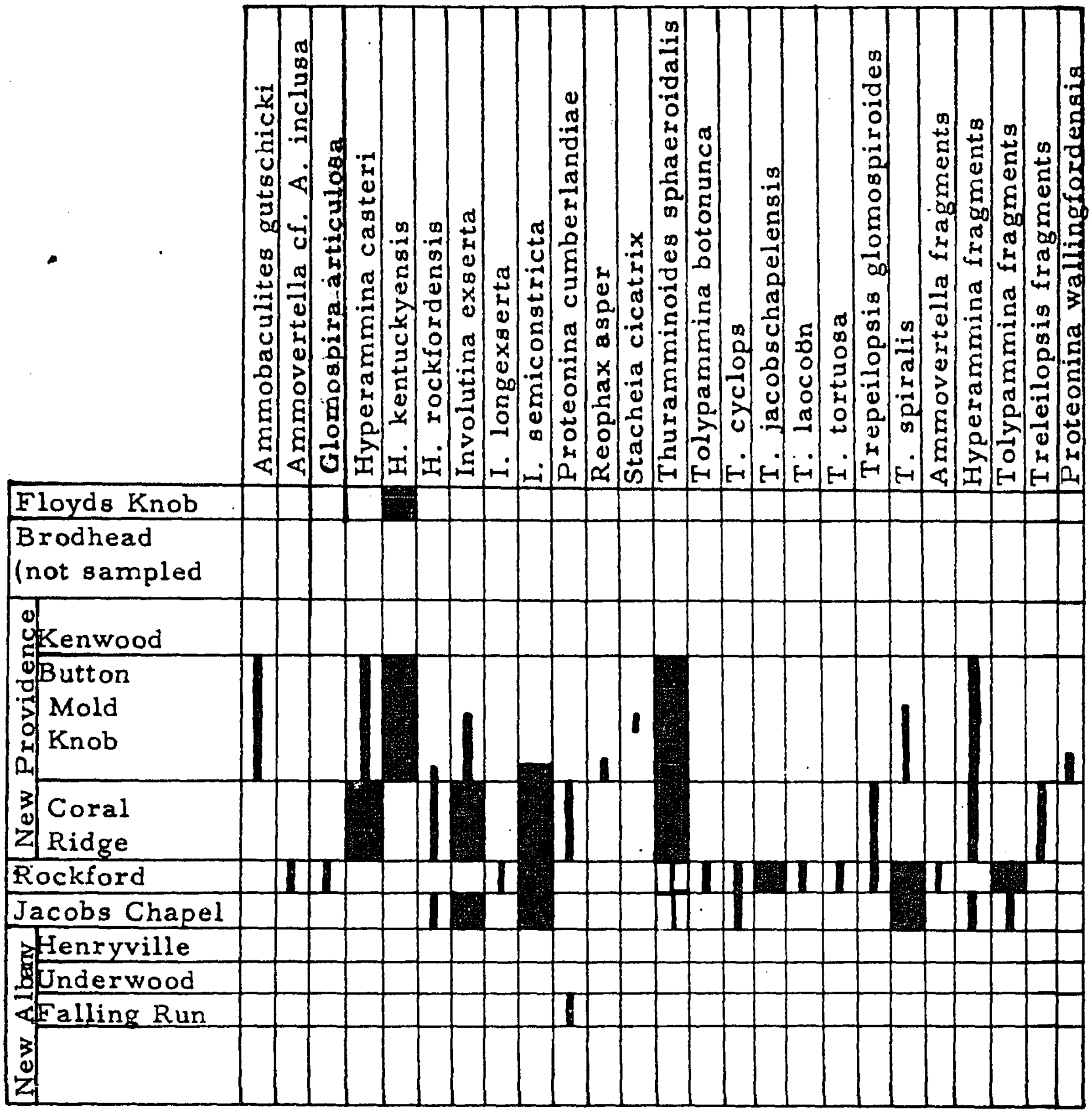


Chart 12. Range of species in northwestern Kentucky (Localities K-1-19).

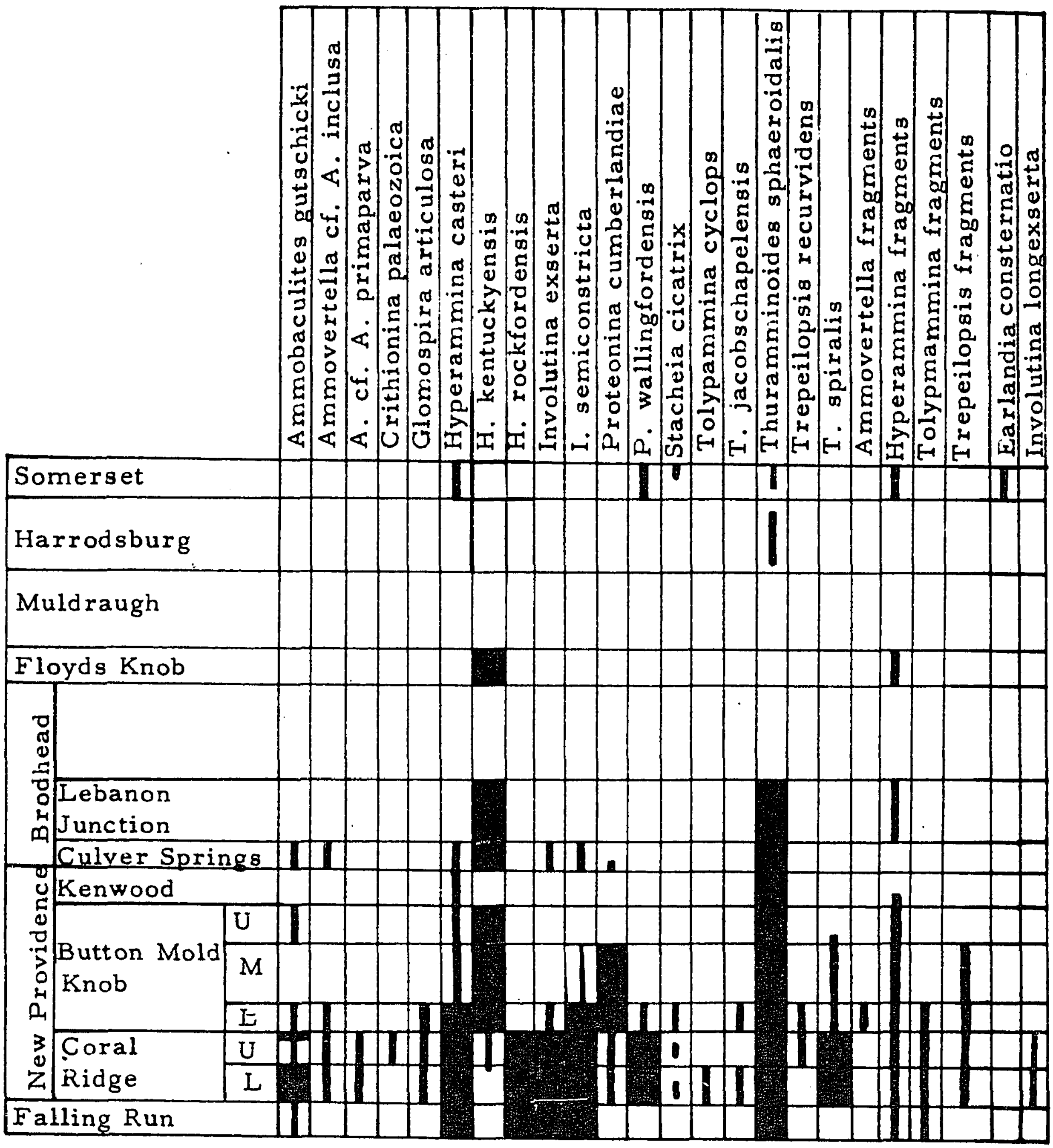


Chart 13. Range of species in southwestern Kentucky (Localities K-20, 21, 27, 28, 32-41).

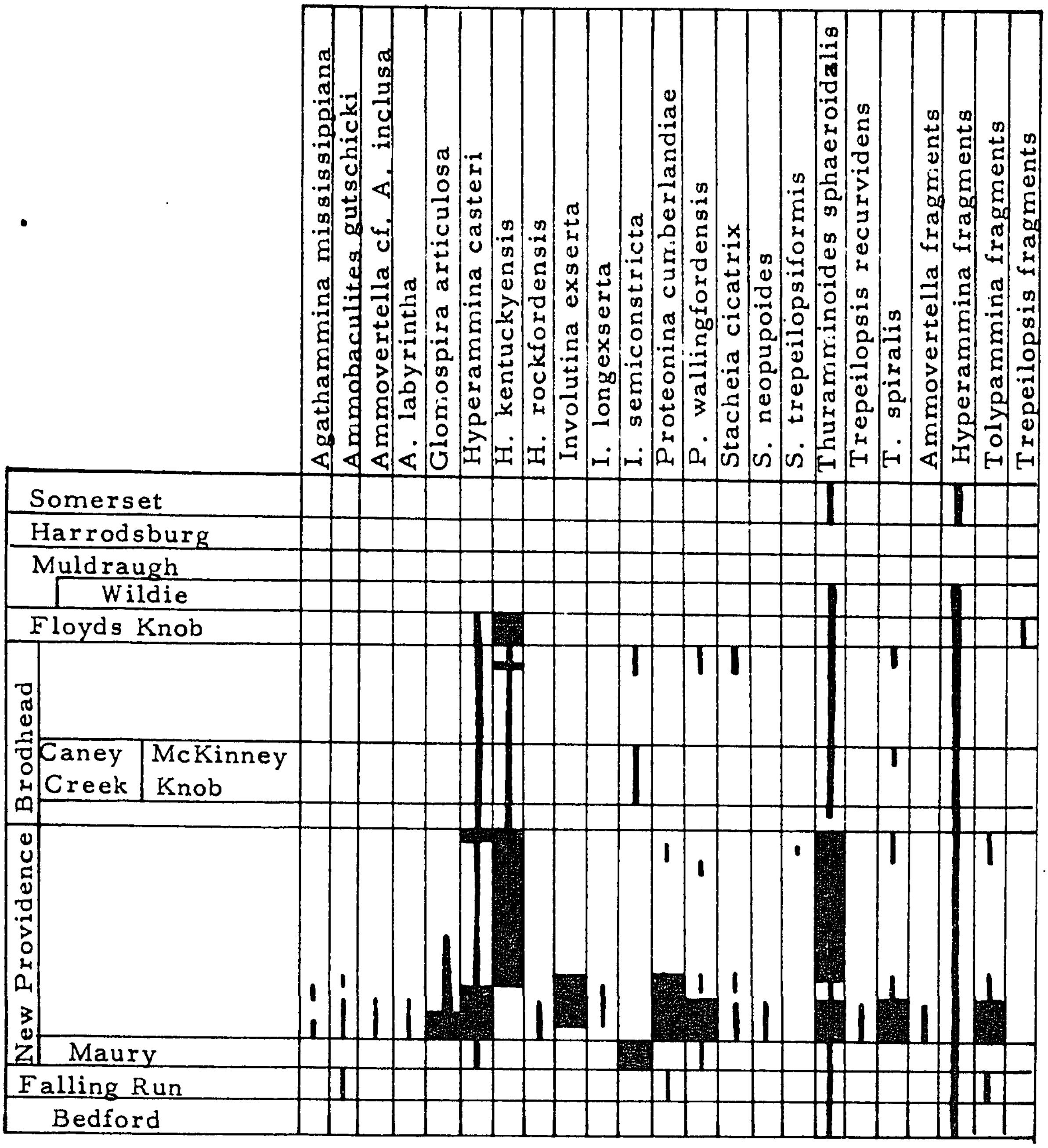


Chart 14. Range of species in southern Indiana (Locality I-1), and in western Kentucky (Localities K-22-26).

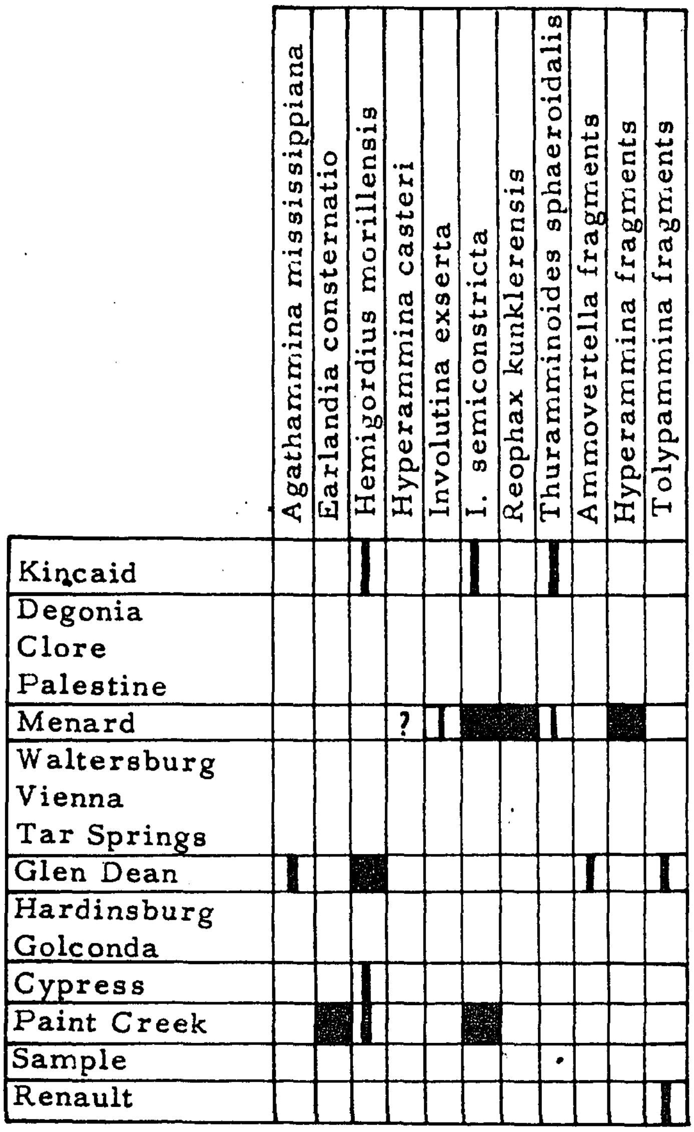
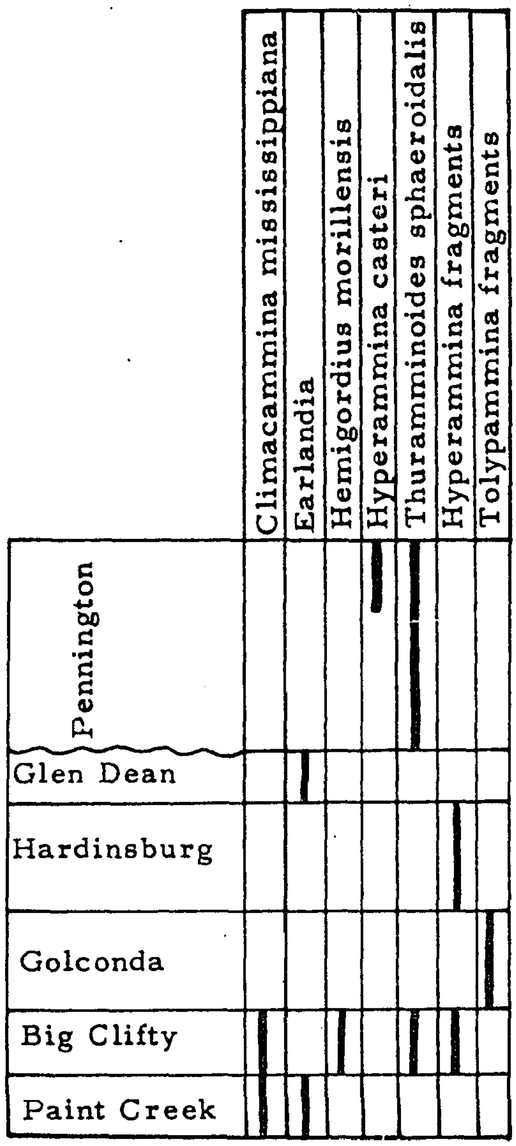


Chart 15. Range of species in southern Kentucky (Localities K-29-31, 42, 43, 46).



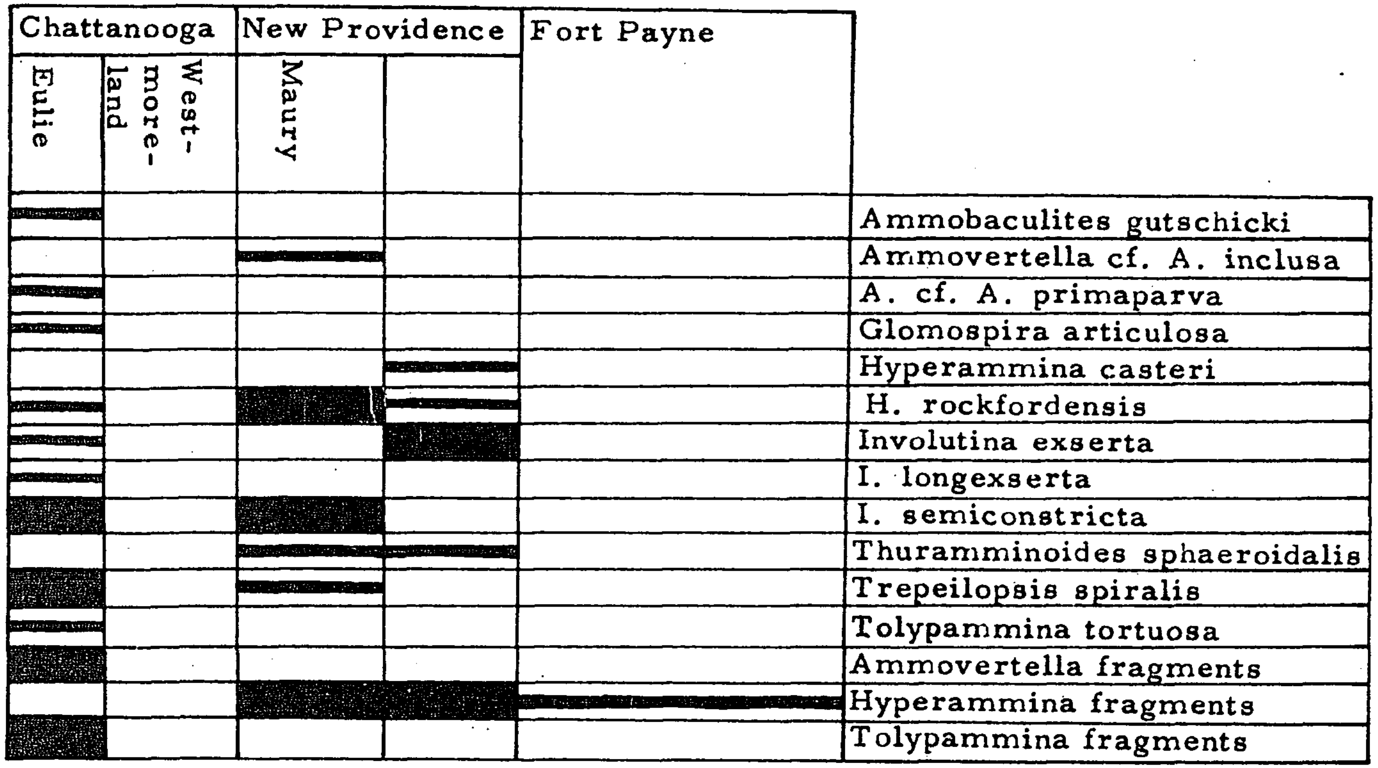


Chart 16. Range of species in northern Tennessee (Localities T-1-4).

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

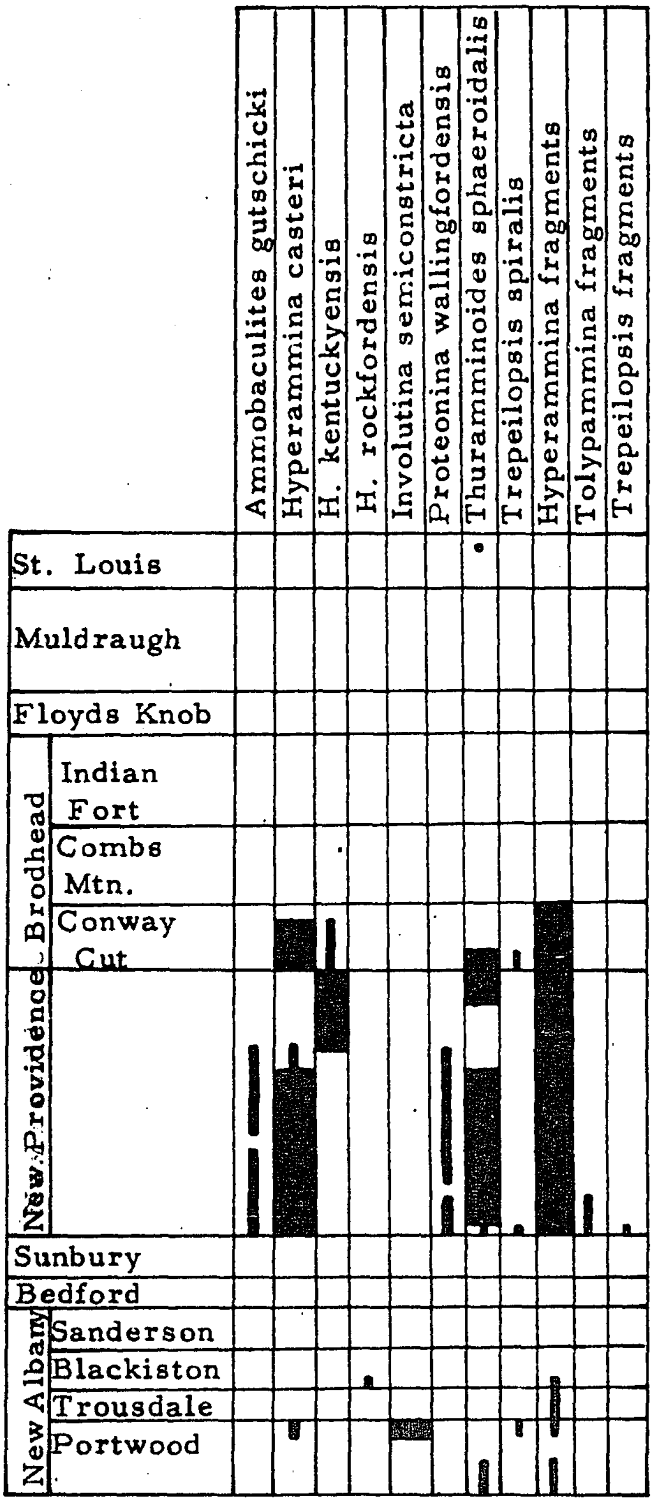


Chart 18. Range of species in eastern Kentucky (Localities K-51-64).

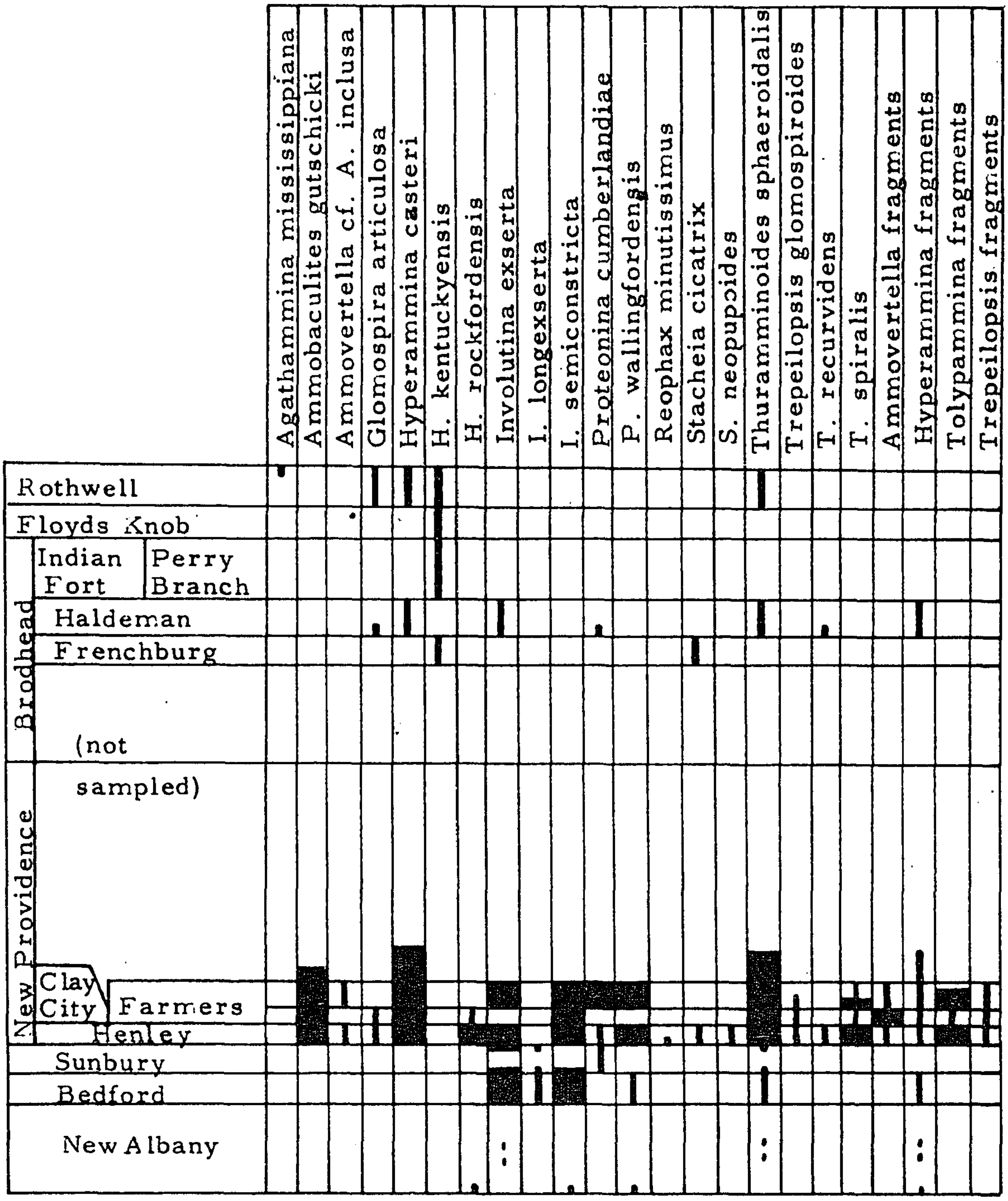


Chart 19. Range of species in northeastern Kentucky (Localities K-65-68), and in southern Ohio (Localities O-1-2).

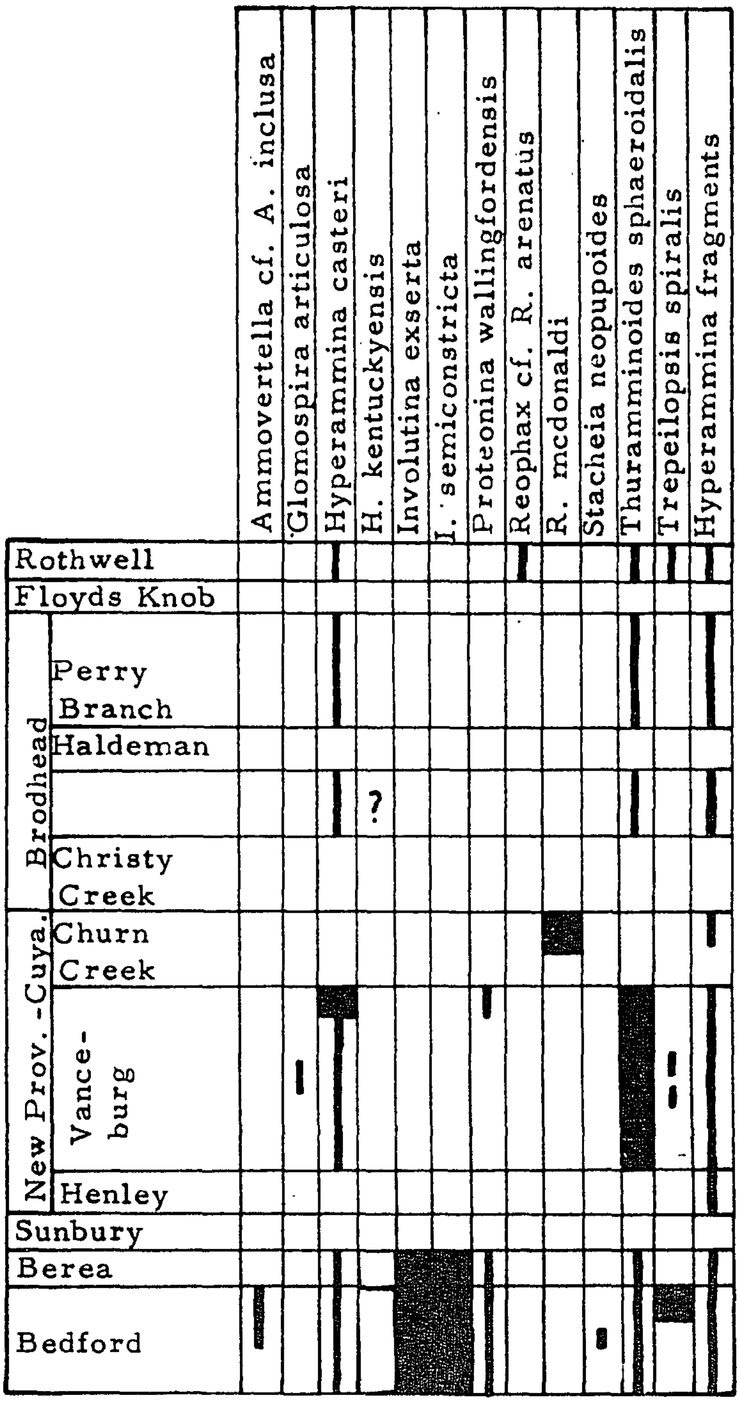


Chart 20. Range of species in southern Ohio (Localities O-3-5).

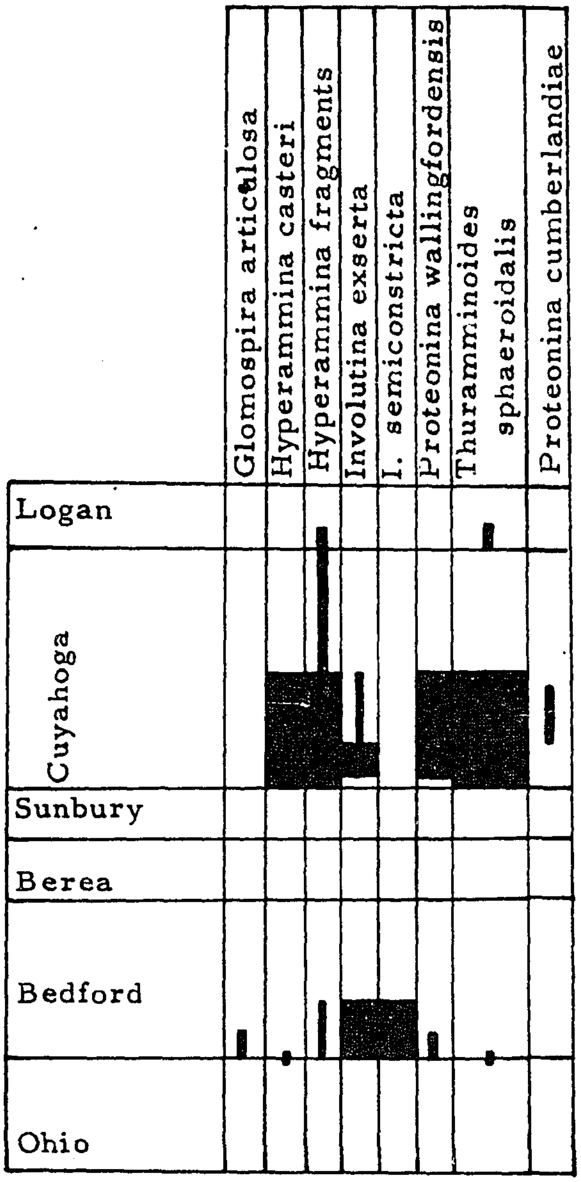


Chart 21. Range of species in south central Ohio (Localities O-6-11).

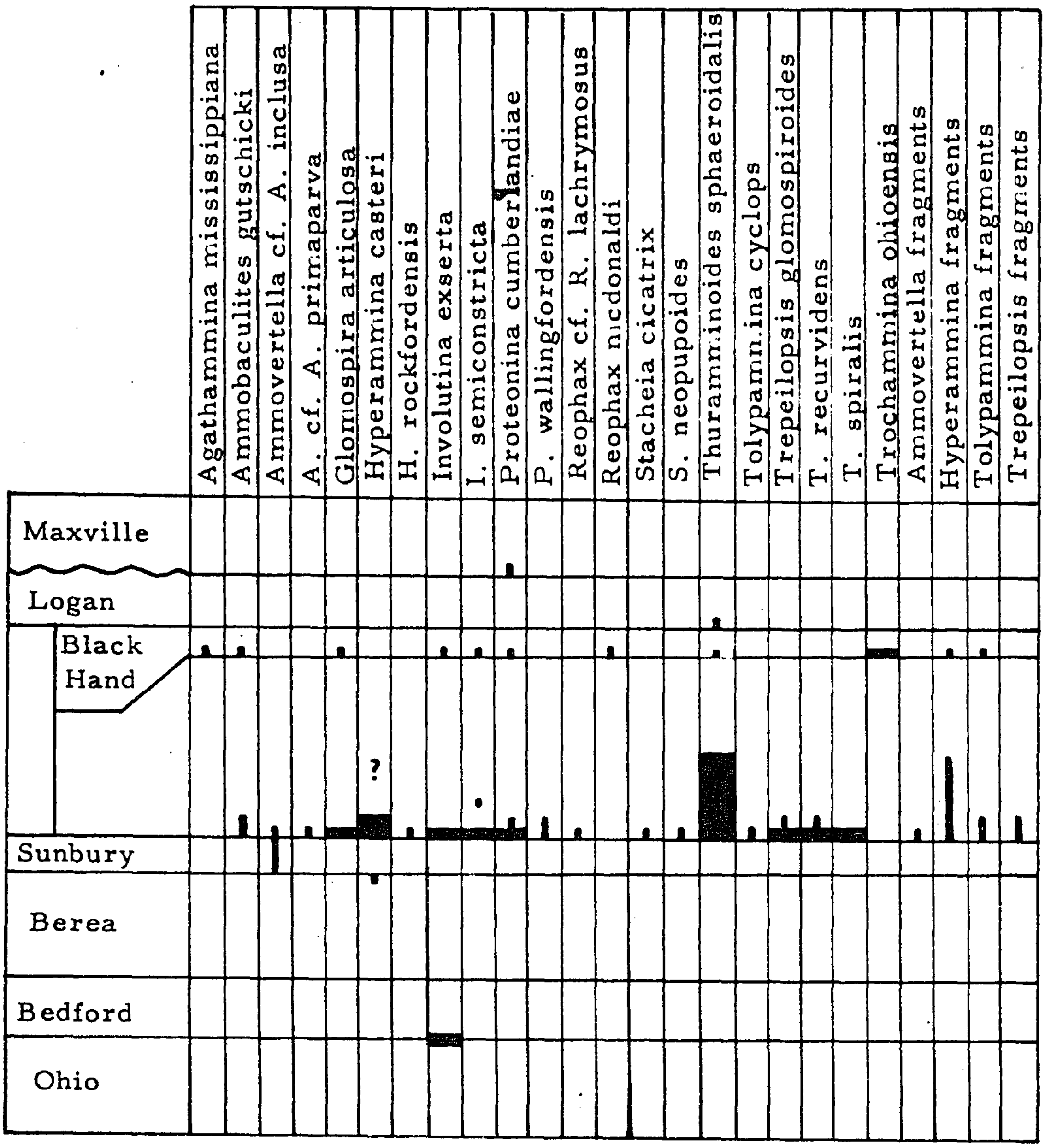
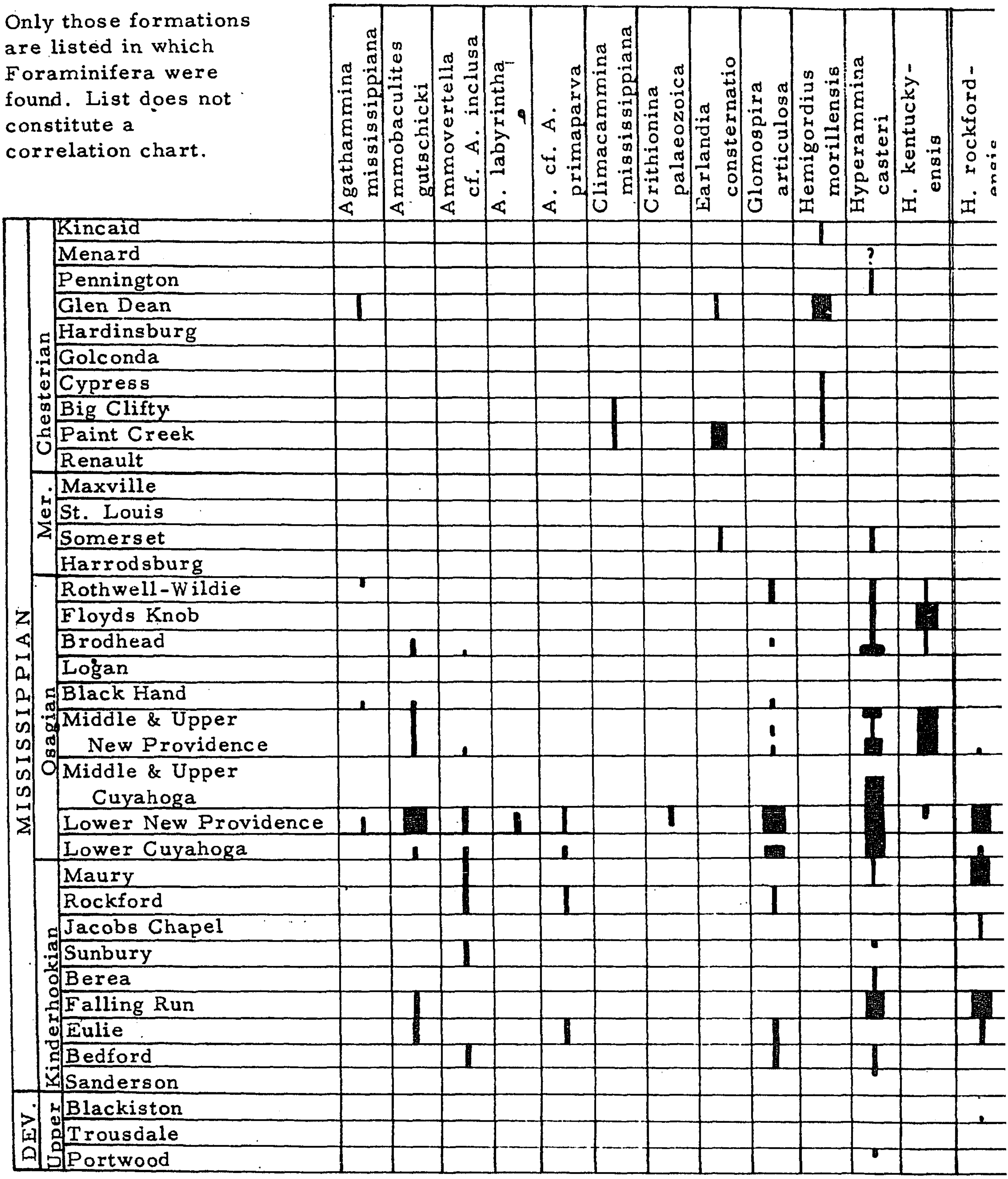
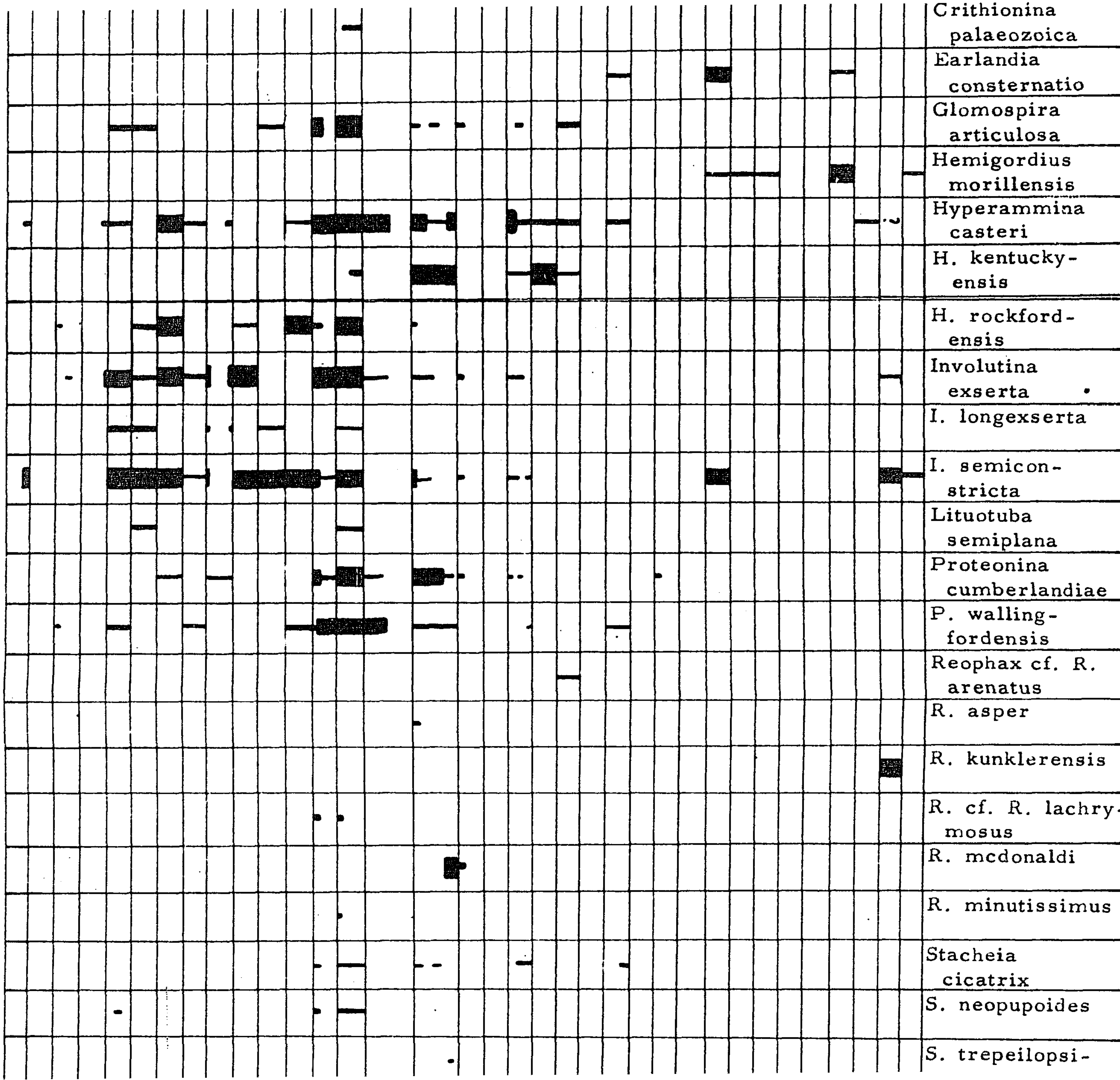
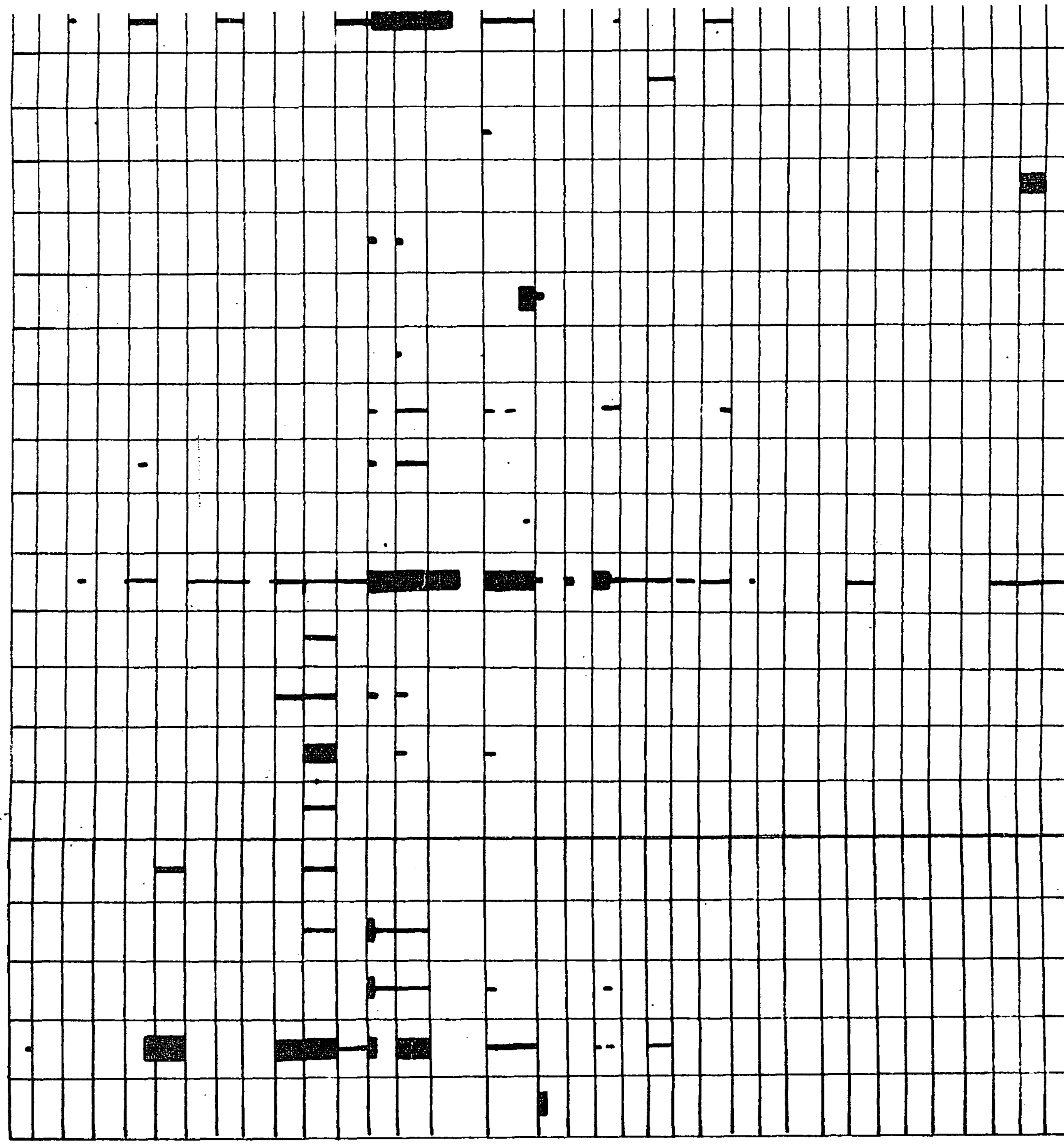


Chart 22. Range of species in the Mississippian and uppermost Devonian.



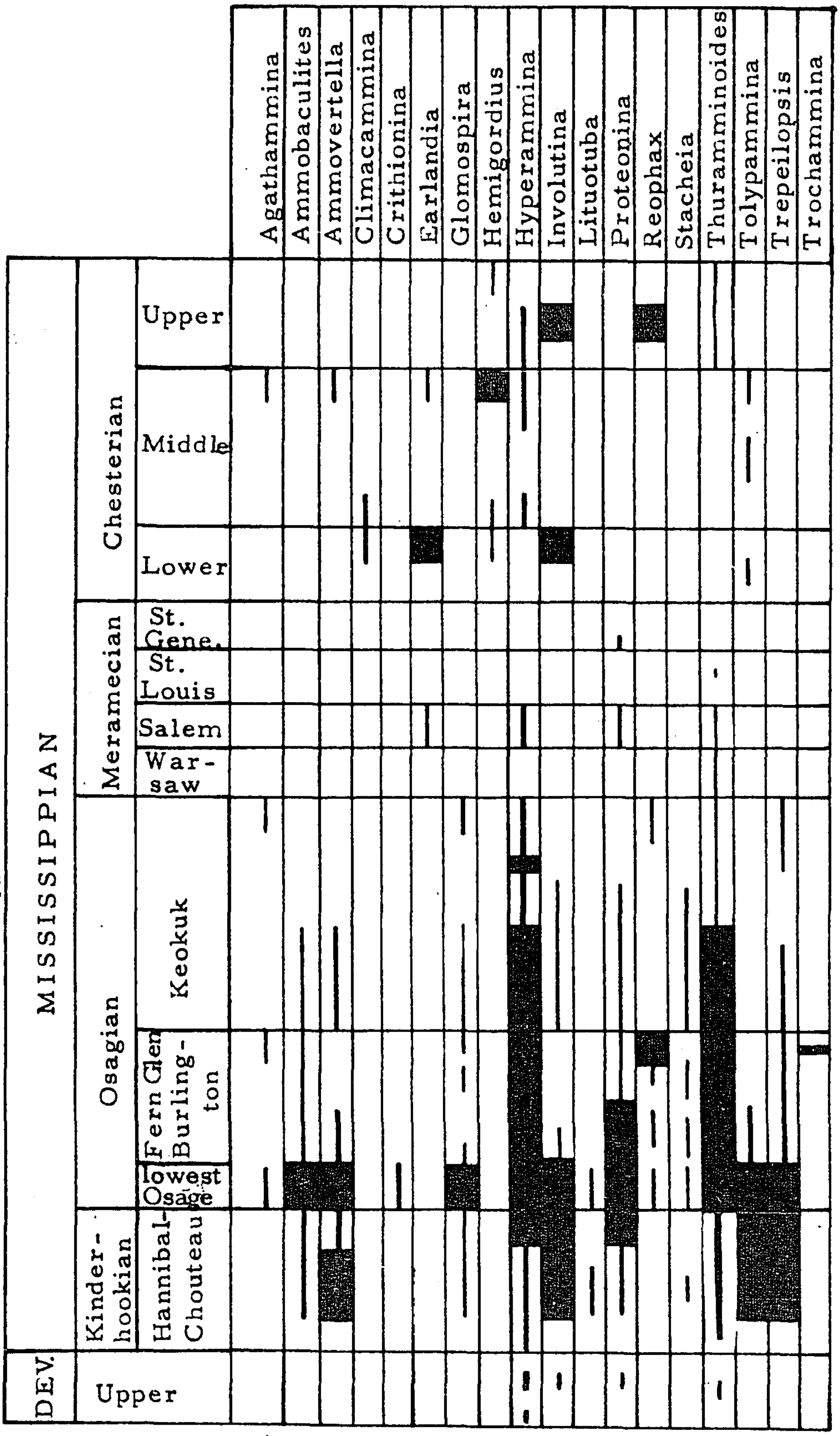


rmost Devonian.



P. walling-fordensis
Reophax cf. R. arenatus
R. asper
R. kunklerensis
R. cf. R. lachrymosus
R. mcdonaldi
R. minutissimus
Stacheia cicatrix
S. neopupoides
S. trepeilopsiformis
Thuramminoides sphaeroidalis
Tolypammina botonunca
T. cyclops
T. jacobschapelensis
T. laocoön
T. tortuosa
Trepeilopsis glomospiroides
T. recurvidens
T. spiralis
Trochammina ohioensis

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



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; these lenses are intercalated in the lower part of the New Albany shale. The fauna consists of the following recognized 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) list the following species from the following Devonian formations:

New Albany shale	*Thuramminoides sphaeroidalis* and *Hyperammina* spp.
Portwood formation	*Hyperammina* spp., *Proteonina* sp., *Thuramminoides sphaeroidalis*
Beechwood limestone	*Rhabdammina* ? sp.
Sellersburg limestone	*Lituotuba* sp., *Psammosphaera* sp., *Involutina* sp., *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 south-central 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 *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 botonunca*, *T. cyclops*, *T. jacobschapelensis*, *T. laocoön*, *T. tortuosa*, and *T. 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 theFern Glen-Burlington correlative, the Button Mold Knob member of the New Providence formation. These very early, perhaps the earliest known Osagian beds 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 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 completely proven by the presence of such characteristic Osagian genera as: Orbitremites, Beyrichoceras, Merocanites, Pericyclus (Tournaisian of Europe) and Wachsmuthicrinus. No megafossils are found in the Lower Coral Ridge member so that this unit might be either Osagian or Kinderhookian with age determinations based on megafossils; however, information gained from foraminiferal faunas lends some rather tenuous evidence supporting a Kinderhookian age for this unit (Lower Coral Ridge member).

In the present study, the foraminiferal faunas of the Lower New Providence formation (Coral Ridge, Clay City, Farmers, and Henley members of Kentucky) contain 26 species of smaller Foraminifera, while the lower Cuyahoga of Ohio (Henley shale member) contains 18 species.

From southern Indiana to eastern Kentucky, and in south-central Ohio, the lowest Osagian faunas consist of abundant Hyperammina casteri, Involutina exserta, I. semiconstricta, and Thuramminoides sphaeroidalis, with more or less abundant accurrences of Ammobaculites gutschicki, Hyperammina rockfordensis, Trepeilopsis spiralis, and fragments of Tolypammina and Trepeilopsis. Occurring 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 Toylpammina jacobschapelensis are found in the lowest Osagian (Lower New Providence and Lower Cuyahoga formations).

Osagian

Twenty-one species of smaller Foraminifera were found in the Osagian (exclusive of the lowest part). In Kentucky eighteen species occur in the Middle and Upper New Providence formation, thirteen species occur in the Brodhead formation, three in the Floyds Knob formation, seven in the Rothwell and/or Wildie members of the Muldraugh formation. In Ohio, five species are found in the Middle and Upper Cuyahoga formation (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 southeastern Kentucky. Proteonina cumberlandiae and Involutina 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 northwestern 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 in not found in Ohio or Tennessee.

A localized fauna consisting of nine species was found in thin shales in the lower five feet of the Black Hand sandstone at Armstrong (Locality O-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 known occurrence of R. mcdonaldi is in the Churn Creek member of the New Providence 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 eastern 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 Floyd Knob formation is not present in Ohio.

In the Muldraugh formation, Foraminifera were found in the Wildie sandstone and the Rothwell shale in southwestern, 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 E. 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 morilldensis, 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 Thurammminoides 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 formations.

Stratigraphic Division 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, 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 in 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 exserted 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 control alone. It can be further shown that the Foraminifera in the Mississippian can be used as basis for recognition of stratigraphic 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 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 subzones:

Subzone

1. Muldraugh-poor development of *Hyperammina kentuckyensis* and *Thuramminoides sphaeroidalis*
2. Floyds Knob-excellent development of *Hyperammina kentuckyensis*; rare *Thuramminoides sphaeroidalis*

3. Brodhead-poor development of *Hyperammina kentuckyensis* and moderate development of *Thuramminoides sphaeroidalis*; rare other Foraminifera, except locally a fauna is present which resembles that in the New Providence below
4. Upper Cuyahoga-Upper New Providence (Black Hand-Churn Creek-Kenwood members)- *Reophax mcdonaldi*-a possible marker?
5. Button Mold member of New Providence formation; divided into two parts:
   - 5a. Upper Button Mold Knob-common occurrence of short, stubby, *Hyperammina kentuckyensis* common; *Thuramminoides sphaeroidalis* sometimes associated with the Button Mold Knob fauna

5b. Lower Button Mold Knob- general absence of Button Mold Knob fauna; highest occurrence of _Hyperammina_ _rockfordensis_; common and large _Thuramminoides_ _sphaeroidalis_.

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 - carries rare, short, stubby _Hyperammina_ _kentuckyensis_; frequent to common, large _Thuramminoides_ _sphaeroidalis_; associated in Jefferson, Bullitt, and Nelson counties, Kentucky, and Clark County, Indiana with the Coral Ridge fauna of lowest Osagian age.

6b. Lower Coral Ridge member-absence of Hyperammina kentuckyensis; frequent to common occurrence of large Thuramminoides sphaeroidalis

Kinderhookian	Various faunas with much the same Foraminifera as in the Upper Devonian; common occurrence of Involutina; rare and small Thuramminoides sphaeroidalis; common Tolypammina and Ammovertella; rare occurrence of the land spore Tasmanites
Upper Devonian	Faunas much like the Kinderhookian, but sparser, with less species and individuals; less Thuramminoides sphaeroidalis, Involutina, Tolypammina, and Ammovertella; frequent Tasmanites and other spores

PALEOECOLOGY

Interpretation of ecology of the individual species has been 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 (stagnate 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 the Olentangy shale; these green shales carry a rather small fauna of arenaceous Foraminifera. In general, the test size is small, and simple in structure, with exception of Thuramminoides sphaeroidalis. This Devonian fauna consists of a small cosmopolitan group which possessed wide range of tolerence 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 which 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, either 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 very little fine silt present for the consturction of arenaceous tests, some Foraminifera, such as Involutina semiconstricta and I. exserta sometimes 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 and the green glauconitic? matter of such beds as the Maury shale in Tennessee, the Falling Run of southern Indiana and Kentucky, and even the Rockford limestone, probably indicate near shore conditions.

Transition Between Kinderhookian and Osagian

The Coral Ridge member is transitional (in its lower part) between the Kinderhookian and Osagian; no megafossils are found in the lower part, but the Coral Ridge fauna is present in the upper part; associated with the Coral Ridge fauna are small nodules of ironstone indicating some concretion 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 O-6), and in the lower few feet of the Cuyahoga formation at Jester Hill (Locality O-7).

The Middle New Providence contains the next most abundant fauna; in places it contains crinoidal biostromes and fossiliferous shales carrying the Button Mold Knob 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.

The Brodhead formation is too sandy to support significant amounts of Foraminifera; however, in some localities the Brodhead may contain shalier beds with a fair development of Foraminifera.

The Floyds Knob formation is a very 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 very shallow waters with land nearby;

very 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: very rare Hyperammina casteri, abundant and well preserved H. kentuckyensis, and very rare Thuramminoides sphaeroidalis. H. kentuckyensis is beautifully developed and very abundant throughout the formation, with best development in the limestones, but it is present in some numbers even in the siltstones.

Only one species, Thuramminoides sphaeroidalis has been found in the Harrodsburg (Warsaw) limestone. 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 Warsaw 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; that is, forms like Earlandia and Endothyra).

These forms lived in the shoal areas of a lagoon or shallow sea, where the water was saturated with calcium bicarbonate.

The granular calcareous *Earlandia* had 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.

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*, *Climacammina mississippiana*, and *Reophax kunklerensis*, are restricted to the Chesterian. *Hemigordius morillensis* is an amorphous calcareous form; *Climacammina mississippiana* is a calcareous form with a compound wall. Note than that forms restricted to and characteristic of the Chesterian have calcareous tests.

Thus it seems that the occurrence and distribution of smaller Foraminifera in the Mississippian beds is not completely controlled facieologically, but that evolutionary change 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/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 shaly or clayey siltstones interbedded in them.

In the pure limestone sequences, as in the Meramecian, arenaceous 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 provide a better environment for smaller Foraminifera in their alternation of shales and sands; 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 Paleozoic smaller Foraminifera is presented here (information taken partially from Plummer, 1930; Cummings, 1955; and St. Jean 1957):

Arenaceous
- calcareous-extraneous grains in calcareous and/or ferruginous cement
- siliceous-extraneous grains in siliceous cement

Granular calcareous-equidimensional grains of calcite embedded in crystalline calcite cement (subarenaceous wall of Brady, 1876)

calcite granules secreted by the protoplasm,
embedded in crystalline calcite
cement?

calcite granules derived from a supersaturated
limy sea bottom by the selection
of extraneous grains of calcareous
material by the protoplasm?

Compound wall

inner wall layer of fibrous calcite; outer wall
layer of microgranular calcite; or
altered from calcite

Amorphous calcite, or imperforate calcareous

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. Involved also in these discussions is the question 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 proposal seems unreasonable 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 Quaternary, Tertiary, and Mesozoic, and (3) ideas bearing on phylogenetic continuity of genera which obviously have stratigraphic ranges from Paleozoic to Recent (as in the Hyperammina) would be hopelessly confused, for the type of Hyperammina (a recent species) has a true 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. The Paleozoic Foraminifera often have their wall structure and chemical composition altered in many instances 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 very 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 terms such 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 advantages. 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 extablished, textural term, arenaceous (which when used in the restricted sense of Plummer, 1930 is quite exact).

SYSTEMATIC PALEONTOLOGY

Order Foraminifera d'Orbigny, 1826

Family Astrorhizidae H. B. Brady, 1881

Genus *Crithionina* Göës, 1894

Crithionina Göës, A., 1894, Kongl. Svensk. Vet. Akad., Handl., v. 25, no. 9, p. 14; *idem*, 1896, Mus. Comp. Zool. Bull., v. 29, p. 24; Rhumbler, L., 1903, Arch. Protisk., v. 3, p. 229; Cushman, J. A., 1910, United States Natl. Mus., Bull. 71, pp. 53-57.

Crithionina ? Moreman, W. L., 1930, Jour. Paleont., v. 1, no. 4, p. 45.

Type species: *Crithionina mamilla* Göës, 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. mammilla* Göës, 1894 and *C. rotundata* Cushman, 1910 are 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 an irregular and interstitial aperture.

I have studied the holotype of *Crithionina rotundata* and find that the internal labyrinthic structure is not as 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 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, pl. 3, 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 two specimens of a form which perfectly 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, n. sp.

Pl. 3, 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 net-work or mesh-work, spherical surface; thus there is rather definite regularity to the internal labyrinthic structure and the texture of the test wall in cross-section looks very much 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 of 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 rather regular network, (2) both species possess very 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 very 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.

specimen number	max. diam.	min. diam.	diam. of interior space	diam. of canals	locality number, formation, and bed no.
1, holotype, Pl. 3, fig. 9	1.40	1.20	.34	.03-.34	K-13, New Providence, bed 4
2	.81	.25	-	.08-.34	K-13, New Providence, bed 5
3	.90	.43	-	.03-.08	K-3, New Providence, bed 2
4	.91	.43	-	---	"
C. rotundata, U.S.N.M. no. 8259; Pl. 3, figs. 10, 11	.30-.60				Albatross Sta. D4327 off San Diego, Calif., 263-330 fathoms

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 type species, _C. mamilla_ Goës, 1894.

The exterior of the holotype of _C. palaeozoica_ is similar to the exterior of _C. rugosa_ Goës, 1896 while the surface of the paratypes of _C. palaeozoica_ are 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 very same species for 200 millions of years inasmuch as mutations occur at rather constant 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).

Type deposition. - Holotype and unfigured paratypes are deposited in the U. S. Natl. Museum (C. F. C.):

Holotype no.

Unfigured paratype nos.

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 in locations where these shales do not have megafossil faunas or truely calcareous beds.

Recent species of Crithionina are known from cool to cold waters and from moderately deep waters (Cushman, 1910, pp. 53-57). Thus the lower New Providence beds may have been laid down in cool waters of moderate depth; at least, no evidence for definately warm, shallow waters teeming with invertebrate life has been presented at the studied localities.

Remarks. - Crithionina palaeozoica derives its name from the Paleozoic sequence of rocks inasmuch as this is the first definitely known species of Crithionina to be reported from the Paleozoic.

Genus Thuramminoides Plummer, 1945, emend.

Thuramminoides Plummer, H. J., 1945, Univ. Texas, Publ. 4401, pp. 218, 219, pl. 15, figs. 4-10; Crespin, I., 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 sphaerodalis 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 of 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. Very few to 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 itself 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 exterior surface of the test wall. 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, pit-like 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 very 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 within, nor does the family definition allow inclusion of such forms within the Family Saccamminidae. However, Thuramminoides was erroneously 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 Family Astrorhizidae, has not been recognized previously. Thus, Thuramminoides can not be retained in the Family 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 Family Astrorhizidae. The Astrorhizidae include 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 in 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 T. 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, this species will remain of doubtful generic position.

Thuramminoides sphaeroidalis Plummer, 1945, emend.

Pl. 1, figs. 1-10; Fig. 1.

Thuramminoides sphaeroidalis Plummer, H. J., 1945, Univ. Texas, Publ. 4401, pp. 218, 219, pl. 15, figs. 4-10; Crespin, I., 1958, Australia Bur. Mineral Res., Geol. and Geophys., Bull. 48, pp. 40, 41, Pl. 3, figs. 9-11; pl. 31, figs. 1,2; Conkin, J. E., and Conkin, B. M., 1960, Geol. Soc. America, S. E. Sect., Abstracts, p. 8.

Thuramminoides teicherti (Parr), Crespin, I., 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 mm 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, pit-like 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 tublets) apparently functioned as multiple apertures; no evidence of dimorphism is indicated as microspheric and megalospheric forms are not distinguished; 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 the species 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 aperutres 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

Table 2. Measurements of Thuramminoides sphaeroidalis Plummer in mm.

specimen number	min. diam.	max. diam.	thick-ness	locality number, formation, and bed number
1, Pl. 2, fig. 1	1.50	1.55	.40	K-36, Brodhead, bed 5
2, Pl. 1, fig. 4	.47	.52	.10	K-7, Brodhead
3	.40	.47	.15	O-11, Black Hand, bed 1
4	.19	.22	.10	K-36, New Providence, bed 4
5	.38	.42	.12	"
6, Pl. 1, fig. 7	.81	.82	.42	"
7	.55	.62	.17	"
8, Pl. 1, fig. 9	1.20	1.85	.25	I-2 Button Mold Knob, bed 1
9, Pl. 1, fig. 8	.60	.70	.168	K-13, New Providence, bed 10
10	1.65	1.70	.50	K-4, Button Mold Knob, bed 6
11, Pl. 1, fig. 6	.75	.75	.17	I-6, Button Mold Knob, bed 8
12, Pl. 2, fig. 4	.98	1.00	.19	"
13, Pl. 2, fig. 2	.85	.90	.25	O-8, Cuyahoga, bed 5
14	.40	.42	.12	K-49, New Providence, bed 1
15, Pl. 1, fig. 5	.90	.90	.25	K-51, Clay City, bed 5
16, Pl. 1, fig. 3	.47	.487	.34	K-13, New Providence, bed 8
17, Pl. 1, fig. 10	.85	.86	.25	K-63, Henley, bed 8
18, Pl. 2, fig. 3	1.65	1.65	.45	K-19, New Providence, bed 3
19	2.15	2.15	.50	K-13, New Providence, bed 2
20, Pl. 1, fig. 1	.70	.70	.55	"
21	.67	.74	.27	K-37, New Providence, bed 1
22, Pl. 1, fig. 2	.37	.39	.37	O-11, Black Hand, bed 1

Table 3. Range in diameter of _Thuramminoides sphaeroidalis_ 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)
Black Hand sandstone:	.377-.993 (8 specimens)
Brodhead formation:	.369-.487 (4 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)

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 perfectly 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 perfectly fits the emendation of T. sphaeroidalis as presented here.

Deposition of types. - Figured topotypes and hypotypes are deposited in the U.S. Natl. Museum (C.F.C.):

Figured hypotypes, nos.

In addition, unfigured hypotypes are deposited in the following institutions:

P. R. I., no.

U. C., no.

U. N. D., no.

B. M. (N. H.), no.

Stratigraphic occurrence. - The stratigraphic range of the species Thuramminoides sphaeroidalis is the same as the genus, that is, Middle Silurian to Permian. (See Charts 3-18 and 22 for occurence of T. sphaeroidalis in the Mississippian).

Ecology. - The smallest example 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 (Note measurements on Table 2). 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 decreases 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 most Coral Ridge member outcrops indicates that *T. sphaeroidalis* could flourish in environmental conditions which were not condusive to the promotion (or preservation) 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 tests 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, or possibly the arenaceous setting was not conducive to preservation.

Family Saccamminidae Cushman, 1927

Subfamily Saccammininae Cushman, 1927

Genus *Proteonina* Williamson, 1858

Proteonina Williamson, W. C., 1858, Rec. Foram. Great Britain, London, p. 1; Cushman, J. A., 1948, Foraminifera, Cambridge, p. 78. (*non Proteonina* Terquem, O., 1875, Soc. Geol. France Mem., ser. 2, v. 10, p.)

Reophax Montfort, Brady, H. B., 1879, (pars), Quat. Jour. Micros. Sci., v. 19, p. 51, pl. 4, figs. 3a, 3b; *idem*, 1884, Rept. Voyage Challenger, Zool., v. 9, p. 289, pl. 30, figs. 1-5; Rhumbler, L., 1895, Kön. Gesell. Wiss. Göttinger, Nachr., p. 82. (*non Reophax* Montfort, D., 1808, Conch. Syst. v. 1, p. 331)

Difflugia Lamark, Egger, J. G., 1895, (pars), Kön. bay. Akad. Wiss. München, v. 18, p. 251. (non Difflugia Leclerg, ., Mus. Hist. Nat., Mem., v. 2, p. 474)

Saccammina Sars, Eimer, G. H. T., and Fickert, C., 1899, (pars), Zeitschr. Wiss. Zool., v. 65, pp. 671, 672. (non Saccammina Sars, M., 1869, Förh. Vidensk. -Selsk. Christiania, p. 248. (nomen nudum)

Type species: Proteonina fusiformis Williamson, 1858 (original designation; Recent, Great Britain)

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, n. sp.

Pl. 3, figs. 1-3; Pl. 10, 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 the 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).

Type deposition. - Holotype and figured paratypes are deposited in U.S. Natl. Museum (C.F.C.):

Holotype, no.

Figured paratypes, nos.

In addition, unfigured paratypes are deposited in the following institutions:

P.R.I., no.

U.C., no.

U.N.D., no.

B.M.(N.H.), no.

Stratigraphic occurrence. - Proteonina cumberlandiae occurs in the Sunbury shale of eastern Kentucky, the Kinderhookian

Table 4. Measurements of Proteonina cumberlandiae, n. sp. in mm.

specimen 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
1, Pl. 3, fig. 3	.460	.352	.218	.067	.050	O-9, Maxville, bed 1
2, Pl. 3, fig. 1	.806	.806	.545	.118	....	O-11, Black Hand, bed 1
3	.386	.269	.218	.126	.084	K-6, New Providence, bed 5
4	.503	.302	.201	.118	.101	K-6, New Providence, bed 4
5	.386	.252	.218	.118	.067	O-3, Cuyahoga, bed 3
6	.403	.319	.201	.084	.067	O-3, Cuyahoga, bed 3
7	.235	.168	.151	.067	.033	K-6, New Providence, bed 4
8	.369	.252	.210	.067	.050	I-3, New Providence, bed 2
9	.537	.537	.420	.101	....	O-2, Vanceburg, bed 6
10	.554	.554	.352	.084	....	" , bed 8
11	.521	.386	.319	.101	.084	K-59, Farmers, bed 2
12	.453	.335	.285	.084	.050	"
13	.369	.269	.218	.067	.033	"
14	.360	.244	.235	.084	.050	"
15	.436	.335	.285	.118	.101	I-3, Button Mold Knob, bed 2
16	.586	.440	.352	.151	.134	K-39, New Providence, bed 7
17	.386	.302	.252	.118	.067	"
18	.436	.285	.244	.134	.084	O-7, Cuyahoga, bed 4
19, holotype, Pl. 3, fig. 2	.436	.277	.252	.075	.067	K-31, New Providence, bed 2
20	.319	.235	.185	.067	.033	"
21	.352	.269	.185	.067	.042	I-2, Button Mold Knob, bed 1
22	.302	.218	.193	.084	.059	I-3, Coral Ridge, bed 1
23	.503	.503	.352	.101	....	K-38, New Providence, bed 6
24	.554	.386	.302	.168	....	K-36, New Providence, bed 1
25	.369	.335	.201	.084	.075	K-33, Falling Run, bed 3

Table 5. Range in measurements 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

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.)

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 generally was an absence of calcareous-rich sediments.

Proteonina wallingfordensis, n. sp.

Pl. 3, figs. 4-8; Pl. 10, 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 comparisons 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 very 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 relationships of these genera is obscure, as noted by Dunn (1942, p. 327). *Lagenammina* and the single-chambered and free forms of *Saccammina* may belong

Table 6. Measurements of Proteonina wallingfordensis, n. sp. in mm.

specimen 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
1	.436	.285	.319	.185	.118	K-10, New Providence, bed 2
2	.411	.319	.302	.109	.101	K-7, New Providence, bed 1
3	.369	.302	.302	.118	.067	O-3, Cuyahoga, bed 3
4	.487	.335	.403	.201	.168	K-6, New Providence, bed 5
5	.235	.201	.201	.084	.067	K-7, New Providence, bed 1
6	.369	.252	.310	.134	.067	O-3, Cuyahoga, bed 3
7	.436	.302	.328	.168	.084	K-32, New Providence, bed 5
8	.436	.269	.302	.185	.101	O-3, Cuyahoga, bed 3
9	.285	.201	.218	.101	.084	O-3 "
10	.470	.386	.386	.151	.143	K-32, New Providence, bed 3
11	.369	.269	.252	.118	.092	I-3, Button Mold Knob, bed 2
12	.302	.252	.235	.059	.047	K-18, New Providence, bed 5
13	.487	.302	.369	.252	.134	K-2, New Providence, bed 3
14, Pl. 10, fig. 6	.762	.521	.554	.252	.134	"
15	.302	.226	.269	.118	.101	K-4, Button Mold Knob, bed 3
16	.445	.302	.310	.151	.075	K-6, Button Mold Knob, bed 3
17	.403	.302	.285	.151	.084	K-4, Button Mold Knob, bed 8
18	.521	.403	.420	.235	.118	I-6, Button Mold Knob, bed 6
19, Pl. 3, fig. 4	.586	.436	.436	.201	.168	K-63, Farmers, bed 9
20, holotype, Pl. 3, fig. 7	.352	.269	.319	.118	.067	K-63 "
21, Pl. 3, fig. 6	.436	.319	.352	.193	.101	K-63 "
22, Pl. 3, fig. 8	.369	.302	.319	.118	.088	O-7, Cuyahoga, bed 4
23	.369	.302	.302	.118	.084	K-3, New Providence, bed 2
24	.604	.521	.503	.143	.118	K-1, New Providence, bed 3
25	.554	.420	.436	.201	.168	K-8, New Providence, bed 9
26	.436	.369	.420	.151	.118	"
27	.386	.302	.285	.176	.134	"
28	.436	.352	.360	.134	.084	I-3, New Providence, bed 1
29	.453	.352	.369	.134	.090	K-35, New Providence, bed 7
30	.403	.302	.319	.151	.101	K-58, New Providence, bed 5
31	.586	.453	.420	.235	.168	"
32	.510	.436	.450	.151	.126	K-39, New Providence, bed 5
33	.386	.335	.335	.118	.101	I-6, New Providence, bed 4
34	.335	.252	.269	.126	.084	K-2, Coral Ridge, bed 2
35	.554	.503	.470	.134	.126	O-7, Cuyahoga, bed 4
36	.470	.352	.335	.151	.118	K-6, New Providence, bed 2
37	.386	.319	.319	.101	.092	K-2, New Providence, bed 2
38	.570	.352	.436	.252	.134	K-35, Falling Run, bed 3
39, Pl. 3, fig. 5	1.000	.720	.840	.360	.240	O-1, Bedford, bed 2

Table 7. Range in measurements 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. 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
Proteonina wallingfordensis	spherical to nearly spherical	tapering, moderately long	1/4 to 2/5	1/6 to 1/2
P. cumberlandiae	teardrop to avocado shaped	rather long, slender	1/6 to 1/3	1/3 to 1/2
P. cervicifera Cushman and Waters, 1928	rounded, stout	cylindrical, stout, constricted	1/3 to 1/2	1/4 to 2/5
Lagenammina stilla Moreman, 1930	more or less ellipsoidal	short, rather pointed	1/12	1/4
L. sphaerica Moreman, 1930	almost perfectly spherical	elongate, slender	1/9	2/5
Saccammina aspera Stewart and Priddy, 1941	sub-spherical, oblate	short, narrow	1/9	1/6
S. moremani Ireland, 1939	spherical	short	1/4	1/8

ammina,

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
, ely	1/4 to 2/5	1/6 to 1/2	.235x.201 to 1.000x.840	Osagian, Kentucky
ong,	1/6 to 1/3	1/3 to 1/2	.235x.151 to .806x.545	Osagian, Kentucky
cal, on-	1/3 to 1/2	1/4 to 2/5	.5 to 1.1 long .9x.65	Middle Pennsylvanian, Texas
ointed	1/12	1/4	.44x.28	Silurian, Oklahoma
,	1/9	2/5	.65x.38	Silurian, Oklahoma
	1/9	1/6	.33x.32	Silurian, Indiana
	1/4	1/8	.86x.77	Silurian, Oklahoma

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 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 of avocado-shaped and its neck is shorter and stockier.

Type locality. - One mile northeast of Wallingford, along hill road leading to Boston School, Fleming County, Kentucky (Locality K-63). The holotype is from the Farmers siltstone (Bed 9).

Type deposition. - Holotype and figured paratypes are deposited in the U.S. Natl. Museum (C.F.C.):

Holotype, no.

Figured paratypes, nos.

In addition, unfigured paratypes are deposited in the following institutions:

P.R.I., no.

U.C., no.

U.N.D., no.

B.M.(N.H.), no.

Stratigraphic occurrence. - Like Proteonina cumberlandiae, P. wallingfordensis occurs in the Kinderhookian Falling Run member 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 as 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/or deep water, however, for species of the genus are found in other environmental situations where particulate material (generally siliceous sand and silt) are 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 and/or sand-bearing muds.

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 north-central Ohio in the less silty shales of the New Providence and lower Cuyahoga formations.

Family Hyperamminidae Eimer and Fickert, 1899

Subfamily Hyperamminae Cushman, 1910

Genus Hyperammina Brady, 1878, emend. Conkin, 1954

Hyperammina Brady, H. B., 1878, Ann. Mag. Nat. Hist., (ser. 5), v. 1, pp. 433, 434, pl. 20, figs. 2a, 2b; idem, 1884, Rept. Voyage Challenger, Zool., v. 9, pp. 257-260, pl. 23, figs. 4, 7-10; Cushman, J. A., and Waters, J. A., 1930, Univ. Texas, Bull. 3019, p. 33; Plummer, H. J., 1945, Univ. Texas, Publ. 4401, pp. 219, 220; Conkin, J. E., 1954, Cushman Lab. Foram. Research., Contr. v. 5, pt. 4, pp. 167, 168; Cummings, R. H., 1955, Micropaleontology, v. 1, no. 3, pp. 233, 234.

Nodosinella Brady, Cushman, J. A., (pars), 1927, Cushman Lab. Foram. Research, Contr., v. 3, pt. 3, p. 147, pl. 26, figs. 4, 5a, 5b. (non Nodosinella Brady, H. B., 1876, Pal. Soc. Mon., v. 30, p. 102)

Hyperamminella Cushman, J. A., and Waters, J. A., 1928, Cushman Lab. Foram. Research, Contr., v. 4, pt. 2, p. 36, pl. 4, figs. 3, 4. (non Hyperamminella de Folin, 1881, Soc. Hist. Nat. Toulouse, Bull. annee 15, p. 140. nomen nudum)

Hyperamminoides Cushman, J.A., and Waters, J.A., 1928, Cushman Lab. Foram. Research, Contr., v.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 general concept of Hyperammina and its relationship with Hyperamminoides Cushman and Waters, 1928 was 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 brings Brady's definition of 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 Hyperammina 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 quite 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 apparently 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 of 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 foraminifera 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

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 persistently 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."

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 of origin: original or altered] and calcareous 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

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 definitely 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 siliceous genera are few and rather rare.

Cummings (1955, p. 234) reports: "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) expresses 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 believes (1957, p. 41). However, it is not yet definitely 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 advocates just such restriction of Hyperammina when he suspects that Paleozoic Hyperammina are actually Earlandia. St. Jean (1957, p. 41) recognizes the type species of Hyperammina, H. elongata Brady, 1878 to be a Recent arenaceous form, but takes no notice of Cummings' work (1955, p. 233) which demonstrated that the type species has an arenaceous test of 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 fibrous crystalline calcite wall).

Further, I believe that St. Jean (1957, p. 41) has made a fundamental misinterpretaion of evolutionary thought in his discussion of 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 potentialites 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 very foundations of foraminiferal systematics is weakened by our lack of exact knowledge, most particularly among adventitious Foraminifera.

<u>Hyperammina casteri</u>, n. sp.

Pl. 4, figs. 1-18; Pl. 10, figs. 7, 8; Figs. 6, 7.

<u>Description.</u> - 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 speciemns 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

transluscent 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 length 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 measuremenst 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. expansus (Plummer) (1945, pp. 223, 224). H. expansus 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. expansus, 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

Table 9. Measurements of Hyperammina casteri, n. sp., megalospheric form, in mm.

specimen number	diam. of proloc.	length of test	max. diam.	min. diam.	locality number, formation and bed number
1	.168	.545	.155	.126	K-66, Rothwell, bed 8
2, Pl. 4, figs. 14, 15	.335	2.100	.420.	.302	K-13, Brodhead, bed 10
3	.425	1.150	.325	.300	K-31, New Providence, bed 10
4	.233	.950	.225	.153	"
5	---	.750	.335	.302	O-3, Cuyahoga, bed 3
6	.250	.900	.260	.225	K-31, New Providence, bed 5
7	.201	.940	.244	.198	K-5, New Providence, bed 4
8	.252	.872	.2354	.185	"
9	.185	.790.	.193	.151	K-38, New Providence, bed 7
10, Pl. 4, fig 5	.193q	.704	.193	.138	"
11	---	1.042	.260	.193	K-3, New Providence, bed 2
12, Pl. 4, fig. 18	.450	1.625	.450	.350	K-31, New Providence, bed 2
13, Pl. 4, fig. 17	.250	1.550	.300	.190	"
14	.300	1.650	.350	.250	"
15	---	1.650	.650	.450	"
16	.176	.738	.160	.118	K-37, New Providence, bed 7
17	.134	.760	.134	.092	"
18, Pl. 4, fig. 7	.120	.840q	.151	.080	K-36, New Providence, bed 5
19	---	1.172	.319	.244	K-34, New Providence, bed 7
20	---	1.006	.252	.193	K-34, New Providence, bed 7
21	.185	.554	.201	.180	I-3, New Providence, bed 1
22	.168	.521	.151	.120	K-16, New Providence, bed 3
23, Pl. 4, fig.. 9	.244	1.126	.270	.210	"
24	---	1.376	.269	.218	"
25	.176	.670	.201	.151	K-13, New Providence, bed 5
26	.350	1.100	.300	.275	K-31, New Providence, bed 2
27	.250	2.325	.400	.200	K-12, New Providence, bed 2
28, Pl. 10, fig. 7	.225	1.350	.300	.200	"
29	---	1.475	.500	.350	"
30, Pl. 4, fig. 3	.134	.924	.164	.109	K-36, New Providence, bed 2
31	---	1.042q	.235	.176	K-11, New Providence, bed 2
32	.252	.790	.235	.168	K-17, New Providence, bed 3
33	---	1.208	.201	.118	K-5, Falling Run, bed 1
34	---	.670	.134	.088	"

Table 10. Measurements of Hyperammina casteri, n. sp., microspheric form, in mm.

specimen number	diam. of proloc.	length of test	max. diam.	min. diam.	locality number, formation, and bed number
1	---	.840	.285	.025	K-43, New Providence, bed 5
2	---	.670	.235	.025	"
3	---	.537	.269	.067	O-3, Cuyahoga, bed 3
4	---	.772	.218	.084	K-44, New Providence, bed 6
5	---	.586	.201	.050	O-7, Cuyahoga, bed 6
6	---	.521	.260	.050	K-43, New Providence, bed 4
7	.025	.503	.185	.025	K-50, New Providence, bed 6
8	.018	.319	.134	.018	K-62, New Providence, bed 10
9	---	.740	.201	.067	K-3, New Providence, bed 2
102	---	.335	.168	.033	O-2, Vanceburg, bed 6
11	---	.622	.252	.084	O-2 "
12	.075	.688	.151	.075	K-37, New Providence, bed 7
13	---	.740	.319	.059	"
14, Pl. 4, fig. 6	.025	.780	.218	.025	K-34, New Providence, bed 7
15	---	.640	.151	.033	I-3, New Providence, bed 1
16, Pl. 4, fig. 16	---	1.260	.425	.142	"
17	---	.940	.470	.168	K-11, New Providence, bed 5
18	.033	.487	.218	.033	K-57, New Providence, bed 3
19	.025	.355	.151	.025	"
20	---	.658	.269	.134	"
21, Pl. 4, fig. 8	---	.604	.168	.025	K-16, New Providence, bed 3
22, Pl. 4, fig. 11	.075	.806	.252	.075	"
23, Pl. 4, fig. 10	---	.746	.319	.168	"
24	.050	.924	.151	.050	"
25	---	.560	.185	.067	K-62, Henley, bed 8
26	---	.490	.190	.042	K-60, Henley, bed 2
27	---	.688	.168	.067	O-6, Henley, bed 10
28	---	.521	.218	.028	K-18, New Providence, bed 4
29, Pl. 4, fig. 1, holotype	.033	1.140	.285	.033	I-4, New Providence, bed 3
30, Pl. 4, fig. 2	.050	.772	.302	.050	"
31	---	.607	.386	.176	"
32	.033	.487	.105	.030	O-6, Henley, bed 10
33	.025	.670	.193	.025	K-60, Henley, bed 2
34, Pl. 4, fig. 4	---	.570	.302	.067	K-36, New Providence, bed 1
35	.050	.487	.126	.042	O-7, Cuyahoga, bed 4
36	.025	.640	.218	.025	K-13, New Providence, bed 3
37, Pl. 4, fig. 13	.018	.586	.201	.018	K-5, Falling Run, bed 1
38	---	.604	.244	.055	K-64, Bedford, bed 1

Table 11. Range in measurements of Hyperammina casteri, n. sp. in mm, and comparison with H. glabra Cushman and Waters.

	Hyperammina casteri megalospheric	Hyperammina casteri microspheric	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
Maximum diam.:	.134-.650	.105-.470	.120-.200
Minimum diam.:	.080-.350	.018-.075	---
Restored ranges			
Diam. of proloc.:	.120-.360	.015-.060	
Maximum diamet:	.107-.520	.084-.380	
Minimum diam.:	.080-.280	.015-.060	

H. casteri superficially resembles Reophax bucinna Gutschick and Treckman (1959, pp. 239, 240), but R. bucinna has a much larger proloculus (.08 to .10 mm), and its test is partially constricted internally. The generic position of R. bucinna is in doubt.

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 very 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 Co., Ind. (Locality I-4). The holotype is from the lower 3 feet of the New Providence formation (Bed 3).

Type deposition. - Holotype and figured paratypes are deposited in the U.S. Natl. Museum (C.F.C.):

Holotype, no.

Figured paratypes, nos.

In addition, unfigured paratypes are deposited in the following institutions:

P.R.I., nos.

U.C., no.

U.N.D., no.

B.M. (N.H.), no.

Stratigraphic occurrence. - Hyperammina casteri has a wider 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 limestone. 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 the 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 non-calcareous), shaly siltstones, and shaly sandstones; thus, like Involutina semiconstricta the species was

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 exists within the species rather than the species having 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. 5, figs. 1-9; Pl. 10, fig. 9; Fig. 8

Hyperammina kentuckyensis Conkin, J. E., 1954, Cushman Found. Foram. Research, Contr., v. 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; proloculus of all 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 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....

Table 12. Measurements of Hyperammina kentuckyensis Conkin, 1954, in mm.

specimen number	diam. of proloc.	length	max. diam.	min. diam.	locality number, formation, and bed number
1, Pl. 5, fig. 2 topotype	.101	.781	.118	.084	K-5, Floyds Knob, bed 1
2, Pl. 5, fig. 1 topotype	.067	1.208	.087	.050	"
3, Pl. 5, fig. 3 topotype	.092	.915	.112	.084	"
4	---	1.629	.226	.185	"
5	.105	.554	.095	.067	K-20, Brodhead, bed 2
6	---	.675	.118	.067	"
7	---	1.260	.126	.075	"
8	---	1.118	.252	.142	"
9	---	.974	.185	.084	K-33, Brodhead, bed 2
10, Pl. 5, fig. 9	.126	.858	.109	.075	I-2, Button Mold Knob, bed 1
11	.143	.604	.105	.092	"
12	---	.525	.118	.050	"
13, Pl. 5, fig. 7	---	.604	.118	.060	"
14	.109	.586	.092	.075	K-32, New Providence, bed 5
15, Pl. 5, fig. 5	.120	.850	.118	.084	"
16	.151	.850	.126	.105	"
17	.137	.436	.101	.101	"
18, Pl. 5, fig. 6	---	1.083	.134	.055	"
19	---	.974	.218	.168	"
20, Pl. 5, fig. 4	---	1.100	.134	.067	"
21, Pl. 5, fig. 8	.126	.704	.105	.069	K-6, Button Mold Knob, bed 5
22	.109	.570	.101	.075	"
23	---	.849	.134	.067	"
24	.151	.780	.151	.101	K-2, Button Mold Knob, bed 4
25	.176	.850	.134	.101	"
26	.109	.496	.092	.080	K-2, Button Mold Knob, bed 2
27	.168	.554	.126	.118	K-2, Coral Ridge, bed 1
28	.168	.688	.160	.120	"
29	---	.537	.105	.067	"

Table 13. Range in measurements of Hyperammina kentuckyensis Conkin, 1954, in mm.

Diameter of proloculus:	.067-.176
Length of test:	.436-.629
Maximum diameter:	.092-.252
Minimum diameter:	.050-.120
Diameter of lip:	.087-.244
Diameter of aperture:	.025-.134

> 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 very close affinities to *H. elegans* Rauser-Cernoussova and Reitlinger, 1937 and to *H. kentuckyensis* Conkin, 1954.

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 *Hyperammina 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).

Type deposition. - The original types of Hyperammina kentuckyensis were deposited in 20 institutions in the U.S., including the U.S. National Museum, Cushman Foraminiferal collection, holotype no. 64548 and five paratypes nos. 64549-64553. Paratypes were also deposited in institutions in six foriegn countries. (See Conkin, 1954, pp. 166, 167) for institutions and type numbers.)

Hypotypes are deposited in the U.S. Natl. Museum (C.F.C.):

Figured hypotypes, nos.

In addition, unfigured hypotypes are deposited in the following institutions:

P.R.I., no.

U.C., no.

U.N.D., no.

B.M. (N.H.), no.

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 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 the 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 limestones. 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 and/or siltstone. 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" (Table 12, specimen no. 8).

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 very 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. Very probably the water was colder in New Providence and Brodhead times than in Floyds Knob time.

Remarks. - Hyperammina kentuckyensis is 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 studied examples of Hyperammina kentuckyensis exhibit slight effervescence with strong hydrochloric acid. This effervescence may indicate the original presence of calcareous cement in the test of H. kentuckyensis. The types of H. kentuckyensis described from the limestone of the Floyds Knob formation in Jefferson County, Kentucky (Conkin, 1954) were recovered from acid residues. Any calcareous material originally present in the test would have been dissolved before the specimens were recovered.

Hyperammina rockfordensis Gutschick and Treckman, 1959

Pl. 5, figs. 10-13; Pl. 10, fig. 10; Fig. 9.

Hyperammina rockfordensis Gutschick, R. C., and Treckman, J. F., 1959, Jour. Paleont., v. 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 number	diam. of proloc.	length of test	max. diam.	min. diam.	locality number, formation and bed no.
1	.126	.436	.100	.084	K-3, Coral Ridge, bed 2
2	.101	.335	.084	.067	K-39, New Providence, bed 5
3	.118	.403	.084	.070	I-3, Coral Ridge, bed 1
4	.109	.369	.050	.050	K-58, New Providence, bed 3
5	.134	.411	.075	.075	"
6	.138	.369	.084	.084	"
7	.105	.328	.067	.055	"
8	.109	.369	.067	.059	"
9	.134	.436	.080	.070	"
10, Pl. 10, fig. 10	.105	.521	.059	.050	K-17, New Providence, bed 3
11	.110	.503	.067	.054	"
12	.126	.420	.084	.070	"
13	.140	.640	.101	.101	"
14	.112	.369	.059	.059	K-57, New Providence, bed 8
15 1	.118	.420	.075	.067	"
16	.118	.487	.084	.067	K-3, New Providence, bed 2
17	.118	.436	.092	.084	K-13, New Providence, bed 2
18	.109	.521	.067	.055	K-18, New Providence, bed 3
19	.126	.658	.092	.067	K-12, New Providence, bed 2
20	.151	.658	.118	.084	K-14, New Providence, bed 3
21	.160	.670	.118	.109	K-13, New Providence,

Table 15. Range in measurements of *Hyperammina rockfordensis* Gutschick and Treckman, 1959 in mm.

	As measured	Restored	Original types
Diam. of proloc.	.092-.160	.092-.128	.110-.130
Maximum diam.	.050-.118	.040-.094	.090-.110
Minimum diam.	.050-.109	.040-.087	.070-.090

<u>Comparison and affinities</u>. - <u>Hyperammina rockfordensis</u> has its closest affinities to <u>H. kentuckyensis</u>, but <u>H. rockfordensis</u> differs from <u>H. kentuckyensis</u> 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 <u>Hyperammina rockfordensis</u> is the ancestral stock from which <u>H. kentuckyensis</u> was derived. This belief is based on several considerations. <u>H. rockfordensis</u> has its closest affinities to <u>H. kentuckyensis</u> and is directly succeeded in time by <u>H. kentuckyensis</u> (<u>H. kentuckyensis</u> does not occur below the Osagian and <u>H. rockfordensis</u> is typically a Kinderhookian apecies known only from the lower Osagian). The transition from <u>H. rockfordensis</u> to <u>H. kentuckyensis</u> occurred in Coral Ridge time inasmuch as few specimens of <u>H. rockfordensis</u> were noted in the Button Mold Knob member and <u>H. kentuckyensis</u> is infrequently 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 to 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.

Type deposition. - Figured hypotypes are deposited in the U. S. Natl. Museum (C. F. C.):

Figured hypotypes, nos.

In addition, unfigured hypotypes are deposited in the following institutions:

P. R. I., no.

U. C., no.

U. N. D., no.

B. M. (N. H.), no.

, 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 Button Mold Knob members of the New Providence formation and in the Henley shale of Ohio. The age of the very 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 oldest known 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, most 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 nocules, rare and thin ferruginous and fossiliferous limestone lenses; pyritized, marcasatized, and 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 worm trails?) are known.

In all events, it is demonstrated that H. rockfordensis "preferred" muddy bottoms in which there was 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 continue 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 very 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, its position in an unstable framework of sedimentation (fairly quick chamges 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 was sufficient amount of fine silt to allow construction of a fairly thick arenaceous test. The species did not require calcareous salts for its existance; nevertheless, as is shown by its occurrence in the Rockford limestone, this species was tolerant of calcareous muds.

Family Earlandiidae Cummings, 1955

Genus *Earlandia* Plummer, 1930

Nodosinella Brady, H. B., 1876, (*pars*), Paleont. Soc., v. 30, p. 66

Earlandia Plummer, H. J., 1930, Univ. of Texas, Bull. 3019, pp. 12, 13; Cushman, J. A., 1948, Foraminifera, Cambridge, p. 86; Cummings, R. H., 1955, Micropaleontology, v. 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 Hyper-_ammina_ 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. (1958, p. 231) in the Earlandiidae.

In Europe, Earlandia ranges stratigraphically from the Middle Tournasian 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 relationships of Earlandia and Paleozoic species of Hyperammina in regards to general morphology and wall structure is discussed in this work under the genus Hyperammina and the species H. kentuckyensis. 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), believe 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 with smooth, porcellenous appearing tests and with many external growth lines (external constrictions) 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, n. sp.

Pl. 5, figs. 14-16; Pl. 10, 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 measurements 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 very similar to Hyperammina kentuckyensis in its morphology, but the test of E. consternatio is less prominantly constricted; furthermore, the test of E. consternatio is completely calcareous.

Type locality. - Farm off of Sand Lick Road, Caldwell County, Kentucky (Locality K-24). The holotype is from shale in the Paint Creek limestone (Bed 1).

Type deposition. - The holotype and figured paratypes are deposited in the U. S. Natl, Museum (C. F. C.):

Holotype, no.

Figured paratypes, nos.

In addition, unfigured paratypes are deposited in the following institutions:

P. R. I., no.

U. C., no.

U. N. D., no.

B. M. (N. H.), no.

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 occurs only in calcareous and fossiliferous shales. Seemingly then, the species required an environment in which the water was charged with calcium bicarbonate. Inasmuch as the tests are rather delicate, the species should be, and has been found to be, restricted to fine-grained sediments.

Remarks. - The remarkable similarity which exists between Earlandia consternatio and Hyperammina kentuckyensis either indicates the perfection of isomorphism between analogous genera of Foraminifera, or it may indicate that H. kentuckyensis is a silicified Earlandia.

The trivial name is proposed because of the surprising similarity which exists between Earlandia consternatio and Hyperammina kentuckyensis.

Family Reophacidae Cushman, 1927

Subfamily Reophacinae Cushman, 1927

Genus *Reophax* Montfort, 1808

Reophax Montfort, D., 1808, Conch. Syst., v. 1, p. 331; Brady, H. B., 1884, (*pars*), Rept. Voyage Challenger, Zool., v. 9, p. 289; Chapman, F., 1902, (*pars*), The Foraminifera, London, p. 137; Cushman, J. A., 1930, Univ. Texas, Bull., no. 3019, p. 37; *idem*, 1948, Foraminifera, Cambridge, p. 90, pl. 3, figs. 27, 28; Cummings, R. H., 1955, Micropaleontology, v. 1, no. 3, pp. 234, 235, pl. 1, figs. 7, 8, 13, 16, 18, text-figs. 8, 9. *non Reophax*, Rhumbler, L., 1895, Nachr. K. Gesell. Wiss. Göttinger, p. 82

Haplostiche Schwager, C., 1865, Ver. Vaterl. Nat. Württemburg, Jahresh., v. 21, p. 92, figs. 2a-2c. (*non Haplostiche* Reuss, A. E., 1861, K. Böhmen Gesell. Wiss., Sitzber., v. 1, p. 15)

Nodulina Rhumbler, L., 1859, K. Gesell. Wiss. Gottingen, Nachr., pp. 85, 86.

Protoshista ? Eimer G. H. T., and Fickert, C., 1899, Zeitschr. Wiss. Zool., v. 65, pp. 677, 678, text-fig. 21.

Lugtonia ? Cummings, R. H., 1955, Micropaleontology, v. 1, no. 3, p. 231, pl. 1, figs. 9-12, 20, text-fig. 6; Crespin, I., 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 definitionof 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 altered 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 tests 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 reophaciids 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 (1958, p. 65) 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 Visean 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 are 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. 5, fig. 19; Pl. 10, fig. 12; Fig. 11.

Nodosinella arenata Cushman, J. A., and Waters, J. A., 1927, Cushman Lab. Foram. Research, v. 3, p. 147, pl. 26, figs. 2, 3.

Nodosinella? arenata, Warthin, A. S., 1930, Okla. Geol. Surv., Bull. 53, p. 28, pl. 2, fig. 8.

Reophax arenatus, Plummer, H. J., 1945, Univ. Texas, Publ. 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 rather fine quartz grains in a moderate amount of siliceous cement.

Measurements. - See Table 18 for measurements of *Reophax* cf. *R. arenatus*.

Comparison and affinities. - The present specimens very 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.

Type deposition. - The two hypotypes of *Reophax* cf. *R. arenatus* are deposited in the U. S. Natl. Museum (C. F. C.):

Figured hypotype, no.

Unfigured hypotype, no.

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 very soft, clayey, plastic when wet, olive-gray to maroon shale. This shale contains only small amounts of fine to medium sized silt grains. No macrofossils were observed. The absence of invertebrate groups (other than Foraminifera) would indicate an environment of deposition not suitable for the promotion of marine life.

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."

The lack of shallow water animal groups, and the absence of prominent characteristic shallow water sedimentary structures may indicate off shore conditions of moderately deep, cool waters. However, the presence of some maroon shales may suggest well aerated conditions on a muddy sea bottom. Perhaps deposition occurred very near shore in areas with prevailing ecological conditions inimical to invertebrate life. Nevertheless, if the Rothwell shale were laid down in shallow waters, some characteristic faunal, floral or physical elements of shallow water deposition should be presented.

Reophax asper Cushman and Waters, 1928

Pl. 5, fig. 24; Fig. 115.

Reophax asperus Cushman, J. A., and Waters, J. A., 1928, Cushman Lab. Foram. Research, Contr., v. 4, p. 37, pl. 4, fig. 7.

Reophax asper Cushman, J. A., and Waters, J. A., 1930, Univ Texas, Bull., no. 3019, pp. 37, 38, pl. 2, fig. 10.

Description. - Test elongate, very 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*.

Table. 18. Measurements of Reophax arenatus (Cushman and Waters), 1927 in mm.

specimen number	length	max. diam.	length of last chamber	no. of chambers	diam. of proloc.
1, Pl. 5, fig. 19	.746	.403	.453	2	.369
2, Pl. 10, fig. 12	.658	.302	.403	2	.201

Table 19. Measurements of Reophax asper Cushman and Waters, 1928.

specimen number	length	max. diam.	length of last chamber	no. of chambers	diam. of proloc.
1, Pl. 5, fig. 24	.570	.226	.252	5	.084

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 apecies of Reophax considered in this paper because of the rugosity of the test.

Type deposition. - The single figured hypotype is deposited in the U.S. Natl. Museum (C.F.C.), no.

Stratigraphic occurrence. - The figured specimen was found in the Button Mold Knob member (Bed 2) of the New Providence formation at the Louisville Cement Co. Quarry, Clark Co., 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 other species of Reophax of this study, but R. asper apparently "preferred" a muddy bottom in which there were sufficient quartz sand 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 calcareous and does not contain calcareous megafossils.

Reophax kunklerensis, n. sp.

Pl. 5, figs. 20-23; Pl. 10, fig. 14; Fig. 12.

Description. - Test small, rather slender, straight to gently curved, consisting of small proloculus and a succession of 7 to 9 moderately inflated chambers which expand in diameter quiet evenly until the last chamber; last chamber is as broad as or only slightly broader than preceding chamber, and up to 3.6 times broader in diameter than the first chamber; last chamber longer than preceding chambers due to the tapering neck of the aperture and of a 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; proloculus ranges in size from .03 to .05 mm; 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

Table 20. Measurements of Reophax kunklerensis, n. sp. in mm.

specimen number	length	max. diam.	length of last chamber	no. of chambers	diam. of proloc. (or first chamber)
1, Pl.5, fig. 20 holotype	.503	.143	.118	7.5	.050
2	.503	.134	.134	7	(.059)
3, Pl.10, fig. 14	.529	.130	.101	8	(.042)
4	.537	.151	.143	7	(.092)
5, Pl. 5, fig. 22	.570	.134	.134	9	.037
6, Pl. 5, fig. 23	.590	.134	.134	9	.042
7	.521	.126	.134	6	(.084)
8, Pl. 5, fig. 2	.420	.118	.118	7	.033

Table 21. Range in measurements of Reophax kunklerensis, n. sp. in mm.

Length of test:	.420-.590
Max. diam.:	.118-.151
Length of last chamber:	.101-.143
Number of chambers:	7-9
Diam. of proloc:	.033-.050

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.

Deposition of types. - Holotype and figured paratypes are deposited in the U. S. Natl. Museum (C. F. C.):

Holotype, no.

Figured paratypes, nos.

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 acidation.

Ecology. - The lower three feet of the upper shale is a marine, soft, plastic when wet, buff to tan to brown, calcareous and very 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, non-fossiliferous 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 very fine-grained calcareous muds which contained only small amounts of silt.

The invertebrate fauna is restricted in the number of invertebrate 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 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 consists of a rather small array of arenaceous genera which characteristically live in silty or aandy muds: Hyperammina, Involutina, and Reophax.

Remarks. - Reophax kunklerensis derives its name from the Kunkler Quarry, west of Uniontown Post Office, Perry County, Indiana.

Reophax cf. R. lachrymosus Gutschick and Treckman, 1959

Pl. 5, fig. 18; Pl. 10, fig. 13; Fig. 13.

Reophax lachrymosus Gutschick, R. C., and Treckman, J. F., 1959, Jour. Paleont., v. 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 1.36 and 1.4 times greater than the breadth; present specimens 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*.

Comparison and affinities. - The present specimens are very 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 alightly 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 about 2.3 times longer than broad.

Type deposition. - The two figured hypotypes are deposited in the U.S. Natl. Museum (C.F.C.), nos.

Stratigraphic occurrence. - *Reophax* cf. *R. lachrymosus* is herein recorded from the lower New Providence formation of Kentucky and the lower 3 feet of the Cuyahoga formation in 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.

Table 22. Measurements of Reophax cf. R. lachrymosus Gutschick and Treckman, 1959, in mm.

specimen number	length of first chamber	diam. of first chamber	length of last chamber	diam. of last chamber	locality number, formation and bed number
1. Pl. 5, fig. 18	.268	.180	.235	.185	K-58, New Providence, bed 3
2, Pl. 10, fig. 13	.235	.168	.252	.168	O-7, Cuya-hoga, bed 4

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 small silt grains present.

Reophax mcdonaldi, n. sp.

Pl. 5, figs. 25-30; Pl. 10, 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 5 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 which 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.

Table 23. Measurements of Reophax mcdonaldi, n. sp. in mm.

specimen number	length	max. diam.	length of last chamber	no. of chambers	diam. of proloc. (or first chamber)
1, Pl. 5, fig. 25 holotype	.640	.269	.235	5	.151
2, Pl. 5, fig. 26	.678	.269	.319	3	.151
3, Pl. 5, fig. 30	.738	.302	.302	3-4	(.151)
4	.704	.230	.269	4	(.118)
5, Pl. 5, fig. 28	.658	.235	.235	4-5	(.118)
6	.678	.285	.319	3	(.193)
7 (lost)	.840	.319	.302	4	(.235)
8, Pl. 5, fig. 29	.704	.319	.470	3	(.226)
9	.622	.252	.277	3	(.168)
10	.740	.369	.453	2-3	(.226)
11	.554	.269	.235	3-4	(.160)
12, Pl. 5, fig. 27	.622	.252	.285	3	(.134)
13	.440	.201	.185	3	(.143)

Table 24. Range in measurements of Reophax mcdonaldi, n. sp. and comparison with R. tumidulus Plummer, 1945.

Length of	R. mcdonaldi	R. tumidulus
Length of test:	.554-.840	1.05
Max. diam.:	.201-.369	.40
Length of last chamber:	.185-.470	---
No. of chambers:	3-5	4
Diam. of proloc.:	.151	.030

Table 25. Measurements of Reophax cf. R. minutissimus Plummer, 1945, in mm.

specimen number	length	max. diam.	min. diam.	length of last chamber
1, Pl. 5, fig. 17	.487	.252	.084	.252

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 in 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).

Type deposition. - Holotype and figured paratypes are deposited in the U.S. Natl. Museum (C.F.C.):

Holotype, no.

Figured paratypes, nos.

In addition, unfigured paratypes are deposited in the following institutions:

P.R.I., no.

U.C., no.

U.N.D., no.

B.M. (N.H.), no.

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 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 test 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" (which I believe to be 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. 5, fig. 17.

Reophax minutissimus Plummer, H. J., 1945, Univ. Texas, Publ. 4401, pp. 230, 231, pl. 17, figs. 25-30.

Description. - Test small (proloculus missing) consisting of 4 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.

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.

Type deposition. - The one figured hypotype is deposited in the U.S. Natl. Museum (C.F.C.), no.

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 ot 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 magafossils 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, A. E., 1862 (pars), Akad. Wass. Wian, Sitz., math.-natw. Cl., Jahrg. 44, Abt. 1, p. 365.

Involutina Terquem, O., Acad. Imp. Metz, Mem., ann. 42 (ser. 2, ann. 9), 1860-1861. pp. 450, 451.

Involutina Terquem, O., emend. Loeblich A. R., and Tappan H., 1954, Washington Acad. Sci., Jour., v. 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) have shown 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 inplied when Loeblich and Tappan (1954, p. 308) conclude: "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. 6, figs. 4-6, 8; Pl. 10, figs. 16, 17, 19; Fig. 21.

Ammodiscus exsertus Cushman, J. A., 1910, United States Natl. Mus., Bull. 71, pt. 1, pp. 75, 76, figs. 97a, 97b (in text).

Involutina exsertus (Cushman), Gutschick, R. C., and Treckman, J. F., 1959, Jour. Paleont., v. 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 tublular 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 number	width	length	thick-ness	no. of whorls	diam. of proloc.	locality number, formation, and bed number
1, Pl. 10, fig. 19	.604	.622	.118	3	?	K-6, New Providence, bed 4
2	.269	.386	.084	3.5	.016	K-1, New Providence, bed 3
3	.335	.402	.050	3.5	.016	K-6, New Providence, bed 3
4	.352	.453	.050	3.5	.016	"
5	.335	.521	.101	3.5	?	K-1, New Providence, bed 2
6	.252	.420	.039	6	.016	O-7, Cuyahoga, bed 4
7	.277	.319	.033	4	.016	"
8	.285	.436	.033	5	.016	"
9	.386	.453	.084	2.5	.016	K-17, New Providence, bed 3
10	.377	.453	.101	2.5	.016	"
11	.386	.529	.118	2.5	.025	"
12, Pl. 10, fig. 16	.269	.369	.042	3	.016	O-6, Henley, bed 10
13	.319	.377	.050	3	.012	K-14, New Providence, bed 3
14	.335	.420	.050	5.5	.016	O-1, Bedford, bed 2
15	.285	.369	.050	4	.016	K-65, Bedford, bed 1
16, Pl. 6, fig. 4	.335	.562	.067	3	.017	K-14, New Providence, bed 5
17, Pl. 6, fig. 5	.277	.302	.067	2.5	?	"
18	.386	.521	.067	3	?	"
19	.470	.570	.067	5	?	O-4, Bedford, bed 3
20. Pl. 10, fig. 17	.570	.586	.084	3.5	?	"
21	.235	.335	.067	2	.016	T-2, Eulie,

Table 27. Range in measurements of <u>Involutina</u> <u>exserta</u> (Cushman), 1910 in mm.

Diameter of proloculus:	.012-.025
Width 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 very little agglutinated matter.

Type deposition. - Figured hypotypes are deposited in the U.S. Natl. Museum (C.F.C.):

Figured hypotypes, nos.

In addition, unfigured paratypes are deposited in the following institutions:

P. R. I., no.

U. C., no.

U. N. D., no.

B. M. (N. H.), no.

Stratigraphic occurrence. -*Involutina exserta* is known from: the Silurian (Moreman, 1930, p. 58; Dunn, 1942, p. 338); the Mississippian Kinderhookian beds 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 of Ohio.

Variant 1 has been found only at the following localites and in the following stratigraphic units:

Nipgen, Ohio (Locality O-6), Cuyahoga formation, Henley shale member, lower one foot 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. 6, figs. 7, 9,; Pl. 10, fig. 18; Fig. 22.

Involutina longexserta Gutschick, R. C., and Treckman, J. F., 1959, Jour. Paleont., v. 33, no. 2, pp. 241, 242, pl. 35 figs. 10-14.

Table 28. Measurements of Involutina longexserta Gutschick and Treckman, 1959, in mm.

specimen number	width	length	thickness	no. of whorls	locality number, formation and bed no.
1	.470	.570	.067	3?	K-32, New Providence, bed 3
2	.403	.899	.134	2?	K-13, Coral Ridge, bed 2
3	.335	.655	.067	2?	"
4, Pl. 10, fig. 18	.335	.739	.109	2?	"
5, Pl. 6, fig. 9	.404	.720	.084	2?	"
6	.335	.394	.059	?	K-12, New Providence, bed 4
7	.335	.503	.059	3?	K-18, New Providence, bed 4
8	.310	.554	.042	2?	K-12, New Providence, bed 2
9	.403	.706	.067	2?	K-52, Sunbury, bed 5
10	.302	.763	.033	2	K-57, Bedford, bed 6
11, Pl. 6, fig. 7	.269	.554	.067	2?	"
12	.352	.604	.033	2?	"

Table 29. Range in measurements of Involutina longexserta Gutschick and Treckman, 1959, in mm.

Width: .269-.470

Length: .394-.899

Thickness: .033-.134

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 (10 and 12) 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 thecoiled 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 Table28.

Deposition of types. - Figured hypotypes are deposited in the U.S. Natl. Museum (C.F.C.):

Figured hypotypes, nos.

In addition, unfigured hypotypes are deposited in the following institutions:

P. R. I., no.

U. C., no.

U. N. D., no.

B. M. (N. H.), no.

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.

Involutina semiconstricta (Waters), 1927

Pl. 6, figs. 1-3; Pl. 10, fig. 20; Fig. 20.

Ammodiscus semiconstrictus Waters, J. A., 1927, Jour. Paleont., v. 1, p. 132, pl. 22, fig. 1.

Ammodiscus semiconstrictus var. regularis Waters, J. A., 1927, Jour. Paleont., v. 1, p. 132, pl. 22, fig. 2.

Cornuspira semiconstrictus, Harlton, B. H., 1933, Jour. Paleont., v. 7, pp. 9, 10, pl. 2, figs. 2a, 2b.

Involutina semiconstrictus (Waters), Loeblich A. R., and Tappan, H., 1954, Washington Acad. Sci., Jour., v. 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 very small, .008 to .028 mm in diameter, spherical to elliptical in form; second chamber tubular, planispiral, of 3 to 8 whorls, and moderately constricted externally;

aperture circular in cross-section, formed by 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 very 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 synonomous 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 30.

Table 30. Measurements of <u>Involutina semiconstricta</u> (Waters), 1927, in mm.

specimen number	max. diam.	thick- ness	no. of whorls	diam. of proloc.	locality number, formation, and bed no.
1	.369	.025	5	?	K-23, Kincaid, bed 4
2	.252	.017	5.5	.012	"
3	.252	.050	3.5	.008	I-1, Menard, bed 7
4	.453	.067	5	.033	"
5, Pl. 6, fig. 2	.537	.092	5	.021	K-23, Paint Creek, bed 1
6	.369	.067	3	.016	"
7	.386	.025	5	.008	K-3, New Providence, bed 2
8	.335	.017	5	.016	O-7, Henley, bed 4
9	.411	.025	6	.020	"
10	.352	.050	5	.016	K-18, New Providence, bed 4
11	.352	.033	4	.050	O-8, Cuyahoga, bed 3
12, Pl. 6, fig. 1	.420	.033	8	.016	I-4, Jacobs Chapel, bed 1
13	.436	.046	5	.016	"
14, Pl. 10. fig. 20	.330	.067	6	.016	I-4, Rockford, bed 2
15	.403	.050	7.5	.016	"
16	.403	.101	4.5	.020	K-66, Bedford, bed 1
17	.594	.075	7	.020	O-4, Bedford, bed 3
18	.210	.050	3	.008	T-2, Eulie, bed 2
19	.374	.059	6.5	.016	"
20	.260	.033	5.5	.008	"

Table 31. Range in measurements of <u>Involutina</u> <u>semiconstricta</u> (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

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 are. 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 8); 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 6 1/2 and 7) than the Kinderhookian forms, but more than the Chesterian forms.

Type deposition. - Figured hypotypes are deposited in the U. S. Natl. Museum (C. F. C.):

Figured hypotypes, nos.

In addition, unfigured hypotypes are deposited in the following institutions:

P. R. I., no.

U. C., no.

U. N. D., no.

B. M. (N. H.), no.

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 16-22 for details of occurrence.)

Ecology. - Involutina semiconstricta is recorded dominantly from soft, fine-grained, plastic shales which have very 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 semi-lithographic limestone of the Louisiana limestone at Louisiana, Missouri. Thus, it seems well extablished 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 and very small grain-sized material is available for building an agglutinate test. For these reasons, the cement secreted by the protoplasm makes most of the test, thus producing a depauperate test. Two specimens of Variant 1 were also recovered from the dark, soft shales of the Chesterian Kincaid 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 occurrences of Involutina semiconstricta in various kinds of sediments (fissile black shales; 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) demonstrated eloquently the versatility of the species in adapting to various ecological conditions existant 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.

Glomospira Rzehak, 1888

Trochammina Jones, T. R., and Parker, W. K., 1880, (_pars_), Quart. Jour. Geol. Soc., v. 61, p. 304.

Glomospira Rzehak, A., 1888, Verb. k. k. Geol. Reichs., p. 191; Cushman, J. A., 1928, Cushman Lab. Foram. Research, Special Publ. no. 1, p. 102.

Gordiammina Rhumbler, L., 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. 6, fig. 10; Pl. 11, fig. 1; Fig. 17.

Glomospira articulosa Plummer, H. J., 1945, Univ. Texas, Publ. 4401, p. 233, pl. 16, figs. 21-25; Ireland, H. A., 1956, Jour. Paleont., v. 30, no. 4, p. 847, text-fig. 4, figs. 7-10; Gutschick, R. C., and Treckman, J. F., 1959, Jour. Paleont., v. 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 itself around 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 very fine grained with siliceous grains in siliceous cement; color of wall white to gray to vellow 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).

Table 32. Measurements of Glomospira articulosa Plummer, 1945, in mm.

specimen number	max. diam. of test	max. diam. of tube	locality number, formation, and bed number
1	.740	.280	K-56, Haldeman, bed 2
2	.780	.300	"
3	.806	.250	"
4, Pl. 6, fig. 10	.520	.150	K-32, New Providence, bed 3
5	.554	.120	K-40, New Providence, bed 1
6	.554	.130	K-17, New Providence, bed 4
7	.310	.080	O-6, Henley, bed 10
8	.390	.110	"
9, Pl. 11, fig. 1	.470	.200	O-7, Cuyahoga, bed 4
10	.806	.370	O-6, Henley, bed 10
11	.503	.120	"
12	.436	.080	K-32, New Providence, bed 2
13	.335	.100	"
14	.370	.080	K-54, New Providence, bed 6
15	.320	.100	I-4, Rockford, bed 2
16	.335	.100	T-2, Eulie, bed 2

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, figs. 7-16) figured specimens are generally smaller.

Deposition of types. - Figured hypotypes of Glomospira articulosa are deposited in the U.S. Natl. Museum (C.F.C.):

Figured hypotypes, nos.

In addition, unfigured hypotypes are deposited in the following institutions:

P.R.I., no.

U.C., no.

U.N.D., no.

B.M. (N.H.), no.

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 of *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 adaption (not in Lamarckian sense) which afforded considerably more strength and resistance to breaking of the test in the moderately agitated waters of a lagoon, or perhaps shallow shoal area. In any event, a ball-of-twine-like coiling of the tubular second chamber would offer greater protection in instances where the animal was unattached.

Lituotuba Rhumbler, 1895

Lituotuba Rhumbler, L., 1895, Nachr. Köngl. Gesell. Wiss. Göttingen, p. 83.

Trochammina Brady, H. B., 1879, Quart. Jour. Micros. Sci., (N. S.), v. 19, p. 59, pl. 5, fig. 6.

Type species. - Trochammina lituriformis H. B. Brady, 1897 (designated by Cushman, 1910).

Rhumbler's (1895, pp. 83, 84) description of the genus Lituotuba follows:

> "Ich vereinige in disem Genus alle diejenigen biformen Arten der von Bütschle und Nenwage 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, n. sp.

Pl. 6, figs. 11, 12; Pl. 11, 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 2 1/4 to 2 1/2 whorls, then uncoils and becomes rectilinear, with the rectilinear portion in nearly the same plane and directed at right angles to the preceeding 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. exerta* Moreman, 1930.

Comparison and affinities. - *Lituotuba semiplana* has close affinities to *L. exerta* Moreman, 1930 but differs from *L. exerta* in having (1) nearly planispiral coils, (2) lesser number of whorls (about 2 1/2 in *L. semiplana*, but 4 to 5 in *L. exerta*), (3) slight external constriction, 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 number	diam. of proloc.	max. diam. of tube	length	max. diam.	max. diam. of neck	min. diam. of neck	diam. of aperture
1, Pl. 6, fig. 11 holotype	.02	.08	.269	.20	.08	.07	.03
2, Pl. 6, fig. 12	.03	.07	.290	.20	.10	.06	.03
3, Pl. 11, fig. 2	.05	.07	.290	.24	.10	.07	.03
L. exserta Moreman, Pl. 7, figs. 5, 6				.34-.48			

Type deposition. - Holotype and figured paratypes are deposited in the U. S. Natl. Museum (C. F. C.):

Holotype, no.

Figured paratypes, nos.

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 non-calcareous 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.

Genus *Tolypammina* Rhumbler, 1895

Hyperammina Brady, H. B., 1879, (*pars*), Quart. Jour. Micr. Sci., v. 19, p. 33; *idem,* 1884, (*pars*), Rept. Voyage Challenger, Zool., v. 9, pp. 260, 261.

Tolypammina Rhumbler, L., 1895, Nachr. Kön. Ges. Wiss. Göttingen, p. 83; Cushman, J. A., 1910, United States Natl.

Mus., Bull. 71, p. 66; idem, 1928, The Foraminifera, Cambridge, p. 98.

Serpulella Eimer, G. H. T., and Fickert, C., 1899, Zeitschr. Wiss. Zool., v. 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 darstellend, 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 the 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 non-attachment 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) have 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 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 when 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 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 detailed consideration of the original wall composition and structure would closely 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 botonunca, Gutschick and Treckman

Pl. 6, fig. 13; Fig. 24.

Tolypammina botonuncus Gutschick, R. C., and Treckman, J. F., 1959, Jour. Paleont., v. 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 specimens of *Tolypammina botonunca* and comparison with Gutschick and Treckman's types of the species.

Comparison and affinities. - Gutschick and Treckman (1959, p. 245) discussed the species Tolypammina botonunca:

> "The species is characterized by its button-hook shape with less than one whorl of the second chamber, constriction at its 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 very well with the original description of the species by Gutschick and Treckman (1959, p. 245); the only differences noted were that the present hypotype has generally smaller size, lesser 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.

Type deposition. - Figured hypotype of Tolypammina botonunca is deposited in the U.S. Natl. Museum (C.F.C.):

Figured hypotype, no.

Stratigraphic occurrence. - Tolypammina botonunca is found only in 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 botonunca 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. 6, figs. 14, 15; Pl. 11, fig. 3; Fig. 25.

Tolypammina cyclops Gutschick, R. C., and Treckman, J. F., 1959, Jour. Paleont., v. 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, semi-circular 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 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 very large size; nevertheless, the third specimen of the present material is still larger.

Deposition of types. - Figured hypotypes are deposited in the U. S. Natl. Museum (C. F. C.):

Figured hypotypes, nos.

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

Table 34. Measurements of Tolypammina botonunca in mm, and comparison with holotype and paratype of Gutschick and Treckman, 1959 (p. 245).

	Pl. 6, fig. 13	Holotype	Paratype
Length of test:	1.02	.85	1.20
Diam. of proloc.:	.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 number	diam. Of proloc.	length of test	diam. of coiled portion	diam. of end of tube	locality number, formation, and bed n umber
1, Pl. 11, fig. 3	.084	.403	.168	.092	I-4, Rockford, bed 2
2, Pl. 6, fig. 14	.101	1.450	.252	.151	"
3, Pl. 6, fig. 15	.235	.692	.570	.252	I-4, Jacobs Chapel, bed 1

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.)

Ecology. - This species undoubtedly had much the same ecological requirements as *Tolypammina jacobschapelensis*.

Tolypammina jacobschapelensis, n. sp.

Pl. 6, figs. 16-21; Pl. 11, fig. 5; Fig. 23.

Description. - Test consists of an attached proloculus and a second chamber in the form of a long, aimlessly sinuous tube, semi-circular 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 is from the Rockford limestone (Bed 2).

Deposition of types. - The holotype and figured paratypes are deposited in the U. S. Natl. Museum (C. F. C.):

Holotype, no.

Figured paratypes, nos.

Table 36. Measurements of Tolypammina jacobschapelensis, n. sp. in mm.

specimen number	diam. of proloc.	length of proloc.	diam. tube near proloc.	diam. end of tube	length of test
1	.168	.201	.101	.201	1.350
2	.185	.235	.109	.252	.850
3, Pl. 6, fig. 18	.084	.101	.050	.252	2.000
4	.210	.252	.134	.101	1.050
5	.235	.269	.151	.151	1.100
6, Pl. 6, fig. 17	.151	.185	.084	.134	1.500
7	.252	.269	.151	.134	1.400
8, Pl. 6, fig. 16 holotype	.134	.201	.101	.193	1.500
9	.134	.201	.084	.105	.700
10	.151	.185	.101	.134	1.200
11	.168	.235	.134	.218	1.150
12	.168	.201	.134	.235	1.050
13	.126	.143	.075	.084	.550
14	.168	.180	.101	.109	1.350
15	.168	.218	.084	.101	.800
16	.126	.160	.075	.109	.850
17, Pl. 6, fig. 20	.269	.285	.118	.134	.800
18	.218	.201	.109	.134	.700
19, Pl. 6, fig. 21	.252	.386	.201	.285	2.100

Table 37. Range in measurements of Tolypammina jacobschapelensis, n. sp. in mm, and comparison with T. cyclops Gutschick and Treckman, 1959 (p. 246).

	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

Table 38. Measurements of Tolypammina laocoön, n. sp. in mm.

Pl. 6, fig. 23, holotype

Length of test:	.76
Diam. of proloc.:	.10
Diam. of coiled portion:	.23
Length of coiled portion:	.21
Min. diam. of tube:	.08
Max. diam. of tube:	.13

In addition, unfigured paratypes are deposited in the following institutions:

P. R. I., no.

U. C., no.

U. N. D., no.

B. M. (N. H.), no.

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.)

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, snails, etc.; 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 very 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 semi-lithographic 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 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 of Campbell and thus is based on a geographic name.

Tolypammina laocoön, n. sp.

Pl. 6, fig. 23; Fig. 26

Description. - Test free (at least 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 is in this manner: from the proloculus the second chamber describes a small and tight U-shaped loop, 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 was 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; shell 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 laocoön. See Table 34 under T. botonunca for comparison with measurements of that species.

Comparison and affinities. - Tolypammina laocoön has no close affinities to any known Tolypammina. Although superficially somewhat similar to T. botonunca Gutschick and Treckman, 1959,

T. laocoön differs from T. botonunca in that it; (1) is free (unattached at least 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).

Type deposition. - The holotype is deposited in the U. S. Natl. Museum (C. F. C.):

Holotype, no.

Stratigraphic occurrence. - Tolypammina laocoön is recorded only from the Rockford limestone at its type locality, Jacobs Chapel, Indiana.

Ecology. - Tolypammina laocoön apparently "preferred" fine-grained shales and calcareous muds. The unattached mode of life may indicate that the species lived in less agitated waters than most species of Tolypammina.

Remarks. -Tolypammina laocoön is named because of the serpentine-like coiling of the early portion of the second chamber.

Tolypammina tortuosa Dunn, 1942

Pl. 6, fig. 22; Pl. 11, fig. 4; Fig. 27

Tolypammina tortuosa Dunn, 1942, Jour. Paleont., v. 16 no. 3, p. 341, pl. 44, figs. 19-21, 32.

Description. - Test mostly attached, (some portions are free and occasionally have rounded tubular portions to the second chamber); 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 measuremants of *Tolypammina tortuosa* in mm.

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 number	diam. of proloc.	min. diam. of tube	max. diam. of tube	locality number, formation, and bed number
1	.07	.10	.15	I-4, Rockford, bed 2
2, Pl. 6, fig. 22	.08	.05	.17	"

<u>Type deposition.</u> - Figured hypotypes are deposited in the U. S. Natl. Museum (C. F. C.):

Figured hypotypes, nos.

<u>Stratigraphic occurrence.</u> - <u>Tolypammina tortuoaa</u> 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).

<u>Ecology.</u> - <u>Tolypammina tortuosa</u> undoubtedly lived in much the same environment as did other tolypamminids.

<u>Remarks.</u> - Five specimens of the species were recovered.

Genus <u>Ammovertella</u> Cushman 1928

<u>Psammophis</u> Schellwien, E., 1898, Palaeontographia, v. 44, pt.s. 5-6, p. 265 (<u>non</u> <u>Psammophis</u> Boie, 1827 (<u>fide</u> Cushman, J. A., 1948, Foraminifera, Cambridge, p. 98)

<u>Ammovertella</u> Cushman, J. A., 1928, Cushman Lab. Foram. Research, Contr., v. 4, p. 8; <u>idem</u> 1948, Foraminifera Cambridge, p. 98.

Type species: <u>Psammophis</u> <u>inversa</u> Schellwien, E., 1898.

Description. - The generic definition of Ammovertella was given by Cushman (1948, p. 98):

> "Test attached, with proloculum 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 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 very 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 _Amovertella_ 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. 7, fig. 8; Pl. 11, figs. 6-9, Fig. 29.

Psammophis inclusa Cushman, J. A., and Waters, J. A., 1927 Cushman Lab. Foram. Research, Contr., v. 3, p. 148, pl. 26, fig. 12.

Ammovertella inclusa (Cushman, J. A., and Waters, J. A.,) 1930 Univ. Texas, Bull. 3019, pp. 44, 45, pl. 7, fig. 13; Ireland, A., 1956, (_pars_), Jour. Paleont., v. 30, no. 4, pp. 853, 854, text-figs. 5-12 _non_ _Ammovertella inclusa_ (Cushman, J. A., and Waters, J. A.), Ireland, A., 1956, Jour. Paleont., v. 30, no. 4, pp. 853, 854, text-figs. 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 portions; in some specimens the tube laps back on top of previous portions of the test; cross-section of tube semi-circular; 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

Table 40. Measurements of Ammovertella cf. A. inclusa (Cushman and Waters), 1927, in mm.

specimen number	length of test	width of test	min. diam. of tube	max. diam. of tube	locality number, formation, and bed number
1, Pl. 7, fig. 8	.480	.440	.033	.092	K-2, New Providence, bed 2
2	.710	.436	...	.101	I-2, Button Mold Knob, bed 1
3, Pl. 11, fig. 6	.521	.335	.033	.101	K-2, New Providence, bed 2
4, Pl. 11, fig. 7	.554	.420	...	.118	K-32, New Providence, bed 2
5	.537	.403	.033	.084	"
6	.521	.302	...	.084	"
7, Pl. 11, fig. 9	.503	.420	.033	.101	"
8	.460	.285	.033	.067	"
9	.328	.294	.033	.084	"
10	.570	.453	.033	.134	O-6, Henley, bed 10
11	.319	.285	.025	.067	"
12	.537	.403	...	.118	K-51, New Providence, bed 6
13	.302	.252	...	.059	K-32, New Providence, bed 2

Table 41. Range in measurements of <u>Ammovertella</u> cf. <u>A</u>. <u>inclusa</u> (Cushman and Waters), 1927, in mm. and comparison with the holotype.

		holotype (all but length are estimated from original fig.)
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

Table 42. Measurements of <u>Ammovertella</u> <u>labyrintha</u> Ireland, 1956, in mm.

Pl. 7, fig. 9

Diam. of proloc:	.084
Diam. of tube:	.05-.08
Diam. of test:	.79

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*.

Deposition of types. - Figured hypotypes are deposited in the U.S. Natl. Museum (C.F.C.):

Figured hypotypes, nos.

In addition, unfigured paratypes are deposited in the following institutions:

P.R.I., no.

U.C., no.

U.N.D., no.

B.M. (N.H.), no.

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---6-14) reported the species from the Upper Pennsylvanian of Kansas.

The present specimens were found as rather scattered occurrences from the Brodhead 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 non-calcareous 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 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 near 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 calcareous shales of the Button Mold Knob member.

Ammovertella labyrintha Ireland, 1956

Pl. 7, fig. 9; Pl. 11, fig. 10; Fig. 28.

Ammovertella labyrintha Ireland, H. A., 1956, Jour. Paleont. v. 30, p. 854, text-figs. 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.

Comparison and affinities. - Present specimens seem to fit well the descriptions and figures given for Ammovertella labyrintha by Ireland (1956, p. 854, text-figs. 6--1, 2).

Type deposition. - Figured hypotypes are deposited in the U. S. Natl. Museum (C. F. C.):

Figured hypotypes, nos.

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 feet to 16 1/2 feet above the New Albany shale, near Athertonville, Larue County, Kentucky (Locality K-13) and in the lower 2 1/2 feet to 5 1/2 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. 7, fig. 10; Pl. 11, fig. 11; Fig. 31.

Ammovertella primaparva Ireland, H. A., 1956, Jour. Paleont., v. 30, no. 4, p. 854, 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 in roughly the same direction; adjacent walls are fused so that the whole test forms a planoconvex mass; tube makes up to 4 back and forth bends (or 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 its meandering manner of the 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 portion of the second chamber and in having the earlier portion of the test less embraced by the meandering of the second chamber.

Deposition of types .- Figured hypotypes are deposited in the United States Natl. Museum (C.F.C.):

Figured hypotypes, nos.

Table 43. Measurements of Ammovertella cf. A. primaparva Ireland, 1956, in mm.

specimen number	width of test	length of test	no. of meanders	diam. of tube (min.)	locality number, formation, and bed number
1	.319	.386	4	.067	K-2, New Providence, bed 2
2, Pl. 7, fig. 10	.335	.386	7	.033	O-6, Henley, bed 10
3	.294	.269	4	.042	K-32 New Providence, bed 2
4	.453	.369	8	.017	I-4, Rockford, bed 2
5, Pl. 11, fig. 11	.352	.386	7	.063	"

Table 44. Range in measurements of Ammovertella cf. A. primaparva Ireland, 1956, and measurements of Ireland's holotype of the species, 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
Diam. of tube, min.:	.017-.067	.02

Stratigraphic occurrence. - Ireland (1956) described *Ammovertella primaparva* from the Upper Pennsylvanian of Kansas. The present specimens are derived from the Kinderhookian Eulie shale of Tennessee and the Rockford limestone of southern Indiana, the lower part of the Osagian Henley shale (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* very 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.

Trepeilopsis Cushman and Waters, 1928

Turritellella Cushman, J.A., and Waters, J.A., 1927
Cushman Lab. Foram. Research, Contr. v. 3, p.
(*non Turitellella* Rhumbler, L., 1903, Archiv. Prot., v. 3, p. 283).

Trepeilopsis Cushman, J.A., and Waters, J.A., 1928,
Cushman Lab. Foram. Research, Contr., v. 4, p. 38.

Type species: <u>Trepeilopsis</u> <u>grandis</u> (Cushman and Waters), 1928 (original designation).

Cushman's generic definition (1948, p. 99) of <u>Trepeilopsis</u> is as follows:

> "Test attached to <u>Productus</u> spines, with a proloculum 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 <u>Trepeilopsis</u> Cushman and Waters, 1928, and <u>Turritellella</u> Rhumbler, 1903.

I would broaden the generic definition of <u>Trepeilopsis</u> more than did Cushman and Waters. The generic definition of <u>Trepeilopsis</u> as I view it should require that species of <u>Trepeilopsis</u> be attached to some object, brachiopod spine, large 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.

<u>Turritellella</u> would have generic characters very similar to <u>Trepeilopsis</u> except the test must be free (unattached) and may not

have the latter portion of the second chamber recoil backward over the initial 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) interprets 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 relegated to *Trepeilopsis*. Chart 23 shows the range of *Trepeilopsis* in the Mississippian as determined in this study.

Trepeilopsis glomospiroides Gutschick and Treckman, 1959

Pl. 7, figs. 1, 2; Pl. 11c fig. 13; Figs. 32, 33.

Trepeilopsis glomospiroides Gutschick, R. C., and Treckman, J. F., 1959, Jour. Paleont., v. 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 5 to 7 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 very fine grained 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.

Deposition of types. - Figured hypotypes are deposited in the U. S. Natl. Museum (C. F. C.):

Figured hypotypes, nos.

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

Table 45. Measurements of <u>Trepeilopsis glomospiroides</u> Gutschick and Treckman, 1959, in mm.

specimen number	length	no. of coils	max. diam.	locality number, formation, and bed number
1	.475	5	.252	O-7, Cuyahoga, bed 6
2, Pl. 7, fig. 1	.650	7	.302	K-51, New Providence, bed 6
3	.450	7	.218	K-53, New Providence, bed 8
4, Pl. 7, fig. 2	.425	7	.235	I-4, Rockford, bed 2
5, Pl. 11, fig. 13	.550	5	.226	"

Table 46. Range in measurements of <u>Trepeilopsis glomospiroides</u> Gutschick and Treckman, 1959, in mm.

Length: .425-.650

No. of coils: 5-7

Max. diam.: .218-.302

limestone of southern Indiana, the lower New Providence formation of Kentucky, and lower Cuyahoga formation of Ohio. See Charts 3, 9-11, 18, 21 and 22 for details of occurrence.

Ecology. - Trepeilopsis glomospiroides is known to occur only in dense (fine -grained) limestones and in fine-grained, calcareous or non-calcareous plastic shales. T. glomospiroides has not been observed in medium to coarse grained limestones. It is believed that the species lived on a argillaceous or calcareous-argillaceous muddy bottom, in quiet waters; the Rockford limestone has already been interpreted as possibly lagoonal (See discussion under Hyperammina rockfordensis). The lower part of the New Providence formation (the Coral Ridge member) in southern Indiana and Jefferson and northern Bullitt counties, Kentucky, possesses a shallow water fauna (the Coral Ridge fauna), described by Conkin 1957.

Trepeilopsis recurvidens Gutschick and Treckman, 1959

Pl. 7, figs. 3, 4; Pl. 11, fig. 12.

Trepeilopsis recurvidens Gutschick, R. C., and Treckman, J. F., 1959, Jour. Paleont., v. 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 6 to 8 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 very fine 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 T. mississippiana Cooper, 1947 (p. 87, pl. 20, figs. 34-41) in being more regularly coiled.

Deposition of types. - Figured hypotypes of Trepeilopsis recurvidens are deposited in the U.S. Natl. Museum (C.F.C.):

Figured hypotypes, nos.

Table 47. Measurements of <u>Trepeilopsis recurvidens</u> Gutschick and Treckman, 1959, in mm.

specimen number	length	no. of coils	max. diam.	locality number, formation, and bed number
1, Pl. 11, fig. 12	.675	7	.420	K-56, Haldeman, bed 2
2, Pl. 7, fig. 4	.625	6	.319	O-7, Cuyahoga, bed 6
3	.500	6-7	.252	O-6, Henley, bed 10
4, Pl. 7, fig. 3	.700	7-8	.269	O-7, Cuyahoga, bed 6

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 non-calcareous 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 spinesor spicules, or other elongate organic fragments. Sponge spicules are very 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.

Trepeilopsis spiralis Gutschick and Treckman, 1959

Pl. 7, figs. 5-7; Pl. 11, fig. 14; Fig. 34,

Trepeilopsis spiralis Gutschick, R. C., and Treckman, J. F., 1959, Jour. Paleont., v. 33, no. 2, pp. 244, 243, 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 very 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 49, Range in measurements of *Trepeilopsis spiralis* Gutschick and Treckman, 1959, in mm.

Length of test:	.500-1.100
Number of coils:	6-12
Max. diam. of test:	.151-.386

Deposition of types. - Figured hypotypes of Trepeilopsis spiralis are deposited in the U. S. Natl. Museum (C. F. C.):

Figured hypotypes, nos.

In addition, unfigured paratypes are deposited in the following institutions:

P. R. I., no.

U. C., no.

U. N. D., no.

B. M. (N. H.), no.

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, A., 1846, (*pars*) Foram. Foss. Bass. Tert. Vienne, p. 137.

Haplophragmium Brady, H. B., 1884, (*pars*), Rept. Voyage Challenger, Zool., v. 9, pp. 301, 302.

Ammobaculites Cushman, J. A., 1910, United States Natl. 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, later 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 three oldest know Ammobaculites: A. leptos (pp. 247, 248, pl. 37, figs. 12, 13), A. pyriformis (pp. 248, 249, pl. 37, figs. 14,--17, 19, 21-25, text-figs. 3a, 3b) and A.? sp. (p. 249, pl. 37, figs. 18, 20, 26, 27) from the Kinderhookian Rockford limestone. The species described in the present study, A. gutschicki, is therefore the fourth 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 the 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 revolves primarily around the nature of the cement. If all Foraminifera (save a minute number, as in the Family Silicinidae) originally had 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. 1819) 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 assumes the granularity in the tests of *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 would 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 Ammobaculities 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 paleo-ecology 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 the wall structure, chemical composition, and their relationships to elements of taxonomy, classification, and phylogeny of the Foraminifera.

Ammobaculites gutschicki, n. sp.

Pl. 7, figs. 11-12; Pl. 11, 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.

Table 50. Measurements of <u>Ammobaculites</u> <u>gutschicki</u>, n. sp. in mm.

specimen number	length	diam. of coil	no. of cham. in last whorl	length of recti-linear part	diam. of recti-linear part	no. of recti-linear cham.	locality number, formation, and bed number
1, Pl. 7, fig. 12	.670	.369	5	.403	.201	2	K-13, New Prov., 10
2, Pl. 7, fig. 14	.670	.244	4	.470	.218	3	"
3	.503	.235	4	.319	.168	3	"
4, Pl. 7, fig. 13	.537	.176	3	.386	.185	3-4	"
5, Pl. 7, fig. 22	--	.440	5.5	--	--	--	O-7, Cuya-hoga, 6
6, Pl. 7, fig. 19	.537	.252	4.5	.285	.155	2	K-17, New Prov., 5
7	.640	.235	5	.369	.201	3	I-3, New Prov., 2
8	.530	.201	4	.369	.160	3	K-11, New Prov., 4
9	.604	.218	4	.386	.185	3	I-6, Coral Ridge, 1
10	.640	.260	5	.403	.168	3	K-10, New Prov., 1
11	.622	.244	4.5	.436	.185	3	K-17, New Prov., 3
12	.658	.319	5	.335	.185	2	"
13, Pl. 7, fig. 16	.688	.277	4.5	.470	.252	3	K-12, New Prov., 4
14	.521	.244	4	.352	.193	3	K-18, New Prov., 4
15	.453	.285	5	.218	.176	1	"
16	.622	.352	5	.352	.252	2	K-17, New Prov., 3
17, Pl. 7, fig. 17	.604	.252	4	.403	.210	3	"
18	.658	.218	4	.453	.218	3	K-14, New Prov., 5
19, Pl. 7, fig. 15	.386	.260	5	.269	.175	2	K-13, New Prov., 2
20	.586	.235	5	.319	.168	2	K-13, New Prov., 2

Table 51. Range in measurements 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

Comparison and affinities. - Ammbaculites 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).

Type deposition. - Holotype and figured paratypes are deposited in the U.S. Natl. Museum (C.F.C.):

Holotype, no.

Figured paratypes, nos.

In addition, unfigured paratypes are deposited in the following institutions:

P.R.I., no.

U.C., no.

U.N.D., no.

B.M.(N.H.), no.

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 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, H. B. , 1871, (*pars*), Geol. Soc. Glasgow, Trans., v. 3, suppl., p. 13. (*nomen nudum*)

Climacammina Brady, H. B., 1873, Geol. Surv. Scotland, Mem., Expl. Sheet 23, p. 94; *idem*, 1876, Paleont. Soc. Mon., v. 30, pp. 67, 68; Cushman, J. A., 1948, Foraminifera, Cambridge, p. 120.

Bigenerina d'Orbigny, Brady, H. B., 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)."

Climacammina mississippiana , n. sp.

Pl. 8, 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 wall 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. 8, figs. 1, 2, 6	C. mississippiana, n. sp. paratype Pl. 8, figs. 3, 4, 5.	C. cylindrica
Length of test:		.971	.554	2.000
Length of uniserial chambers:	3-	.193	.210	
	2-	.118	.118	
	1-	.118	.118	
Diam. 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		
Diam. of biserial chambers:	5-	.252		
	4-	.252		
	3-	.160		
	2-	.134		
	1-	.118		
Diam. of proloculus:		.118?		
Thickness of outer wall:		.080		
Thickness of inner wall:		.050		

<u>Comparison and affinities.</u> - <u>Climacammina mississippiana</u> has its closest affinities to <u>C. cylindrica</u>; however, <u>C. mississippiana</u> differs from <u>C. cylindrica</u> in having: (1) smaller number of biserial chambers, (2) smaller number of uniserial chambers, (three instead of four as in <u>C. cylindrica</u>), and (3) size only about one-half that of <u>C. cylindrica</u>.

<u>Type locality.</u> - 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).

<u>Type deposition.</u> - Holotype and the figured paratypes are deposited in the U.S. Natl. Museum (C.F.C.):

Holotype, no.

Figured paratypes, Nos.

<u>Stratigraphic occurrence.</u> - <u>Climacammina</u> 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 <u>Climacammina</u> in the Mississippian of North America is the report of a <u>Climacammina?</u> zone in the Greenbrier limestone (top of the Reynolds limestone) in West Virginia (Flowers, 1956, pp. 7, 8). The species of <u>Climacammina ?</u> 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 definitely 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, Morill being located north-northeast of Mt. Vernon in Rockcastle, County.

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 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 quite 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 indicative 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 oölitic-pisolitic 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 apecies of the genus to be described from North America.

Family Miliolidae d'Orbigny, 1846

Genus *Agathammina* Neumayr, 1887

Serpula Geinitz, H. N., 1846, (*pars*), Verstein. Deutsch. Zechsteingebirge und Rothliegenden, Heft 1, p. 6, pl. 3, figs. 3-6 (*fide* Cushman, J. A., 1948, Foraminifera, Cambridge, p. 177)

Agathammina Neumayr, M., 1887, Sitzber. K. Akad. Wiss. Wein, Math.-Naturiv. Cl., v. 95, pt. 1, p. 171; Cushman, J. A., 1927, Cushman Lab. Foram. Research, Contr., v. 3, pt. 4, p. 188; *idem*, 1928, Cushman Lab. Foram. Reaearch, Spec. Publ. no. 1, pp. 145, 146.

Type species: *Serpula pusilla* Geinitz, 1848 (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."

inasmuch as the structure of the test wall of Paleozoic adventitious Foraminifera is insufficiently known to allow conclusive judgement as to the question of original wall structure versus replacement and the real nature of isomorphism among Foraminifera.

Agathammina mississippiana, n. sp.

Pl. 7, figs. 23-25; Pl. 11, 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 very large spherical proloculus, followed by an undivided, tubular second chamber disposed in two coils; whorls planispirally or nearly planispirally coiled around the proloculus producing the milioline appearance of the mature test; the ends of the elongate axis slightly pointed and are formed by the sharp bending of the second chamber at the ends of the elongate axis; all whorls are slightly involute but parts of all whorls and the proloculus are visible; 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, formed by the constricted end of the open tubular second chamber; test opaque to translucent, white to gray to orange-buff in color; test wall composed of fine-grained siliceous silt grains in insoluble 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 average 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) very large proloculus, (2) less number of coils (two in A. mississippiana compared to five to six in A. protea), and (3) a more rounded 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 feet to 5 1/2 feet of the New Providence formation (Bed 4).

Type deposition. - Holotype and figured paratypes are deposited in the U.S. Natl. Museum (C.F.C.):

Holotype, no.

Figured paratypes, nos.

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. 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 lineage of the family Miliolidae is extended backward in time one geologic period.

Table 53. Measurements of Agathammina mississippiana, n. sp. in mm.

specimen number	length	width	thickness	locality number, formation, and bed number
1, Pl. 7, fig. 24	.657	.420	.185	K-25, Glen Dean, bed 1
2, Pl. 7, fig. 25	.924	.503	.193	D-11, Black Hand, bed 1
3	.630	.420	.185	K-32, New Providence, bed 3
4, Pl. 7, fig. 23	.453	.260	.176	K-35, New Providence, bed 7
5	.369	.126	.101	"
6	.537	.335	.134	K-12, New Providence, bed 4
7	.570	.252	.143	K-37, New Providence, bed 1

Table. 54. Measurements of Hemigordius morillensis, n. sp. in mm, and comparison with H. calcarea Cushman and Waters, 1928.

specimen number	diam. of juvenarium	diam. of test	axial width of test	diam. of proloc.	no. of whorls in juven.	no. of plani-spiral whorls	locality number, formation and bed no.
1	.07	.16	.03	.01 micro.	3	1.75	K-26, Glen Dean, bed 1
2, Pl. 7, fig. 26 holotype	.10	.30	.08	.03 meg.	2	2.5	K-46, Big Clifty, bed 1
3	.02	.30	.03	.02 meg.	none	4	K-24, Paint Creek, bed 1
H. calcarea	.14	.35	?	?	3	1.5	Pennsylvanian, Texas

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 soft muddy sea bottom where fine silt 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 of 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."

Further, Conkin and Conkin (1956, p. 895) discuss 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 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 on sandy, littoral sea bottoms. I have observed the dominance of miliolids in the Recent beach and very near shore sands 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.

Thus there is excellent evidence for believing that the present Agathammina-bearing beds originated in shallow water, near shore, silty mud environment, with no significant concentration of calcareous salts. Perhaps the environment of deposition was similar to that in which the present day Miliammina thrive. The absence or near absence of megafossil assemblages, except in the Glen Dean limestone at Locality K-25, indicates that the environment of deposition was not favorable for promotion of abundance of normal marine invertebrate life; however, the occurrence of one specimen of Agathammina mississippiana in the Glen Dean limestone indicates that the species could adapt itself to a calcareous muddy bottom, and could live in association with normal marine invertebrate life. The completely silicefied Glen Dean specimen of Agathammina (composed of chalcedony) occured with other silicified invertebrates, *e.g.*, a very large *Pentremites spicatus* was recovered in acid residue of the same sample; however, the bulk of the fauna at the Glen Dean type locality is not silicified.

Family Opthalmidiidae

Genus *Hemigordius* Schubert, 1908

Cornuspira Schultze, Howchin, W., 1895, Roy. Soc. South Australia, Trans., v. 19, pp. 195, 196, pl. 10, figs. 1-3. (*non* Schultze, M., 1854, Organismus Polythal., Leipzig, p. 40)

Hemigordius Schubert, J. R., 1909, Jahrb. K. K. Geol. Reichs., for 1908, v. 58, p. 381; Cushman, J. A., 1928, Cushman Lab. Foram. Research, Spec. Publ. No. 1, p. 161.

Type species: *Cornuspira schlumbergei* 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 unbonate; 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, n. sp.

Pl. 7, fig. 26; Pl. 11, fig. 17; Fig. 30.

Description. - Test free, discoidal, circular in outline; juvenarium consists of a proloculus and 2 to 3 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 much 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. harltoni of Crespin (1958, pp. 79, 80, pl. 16, figs. 1-6; pl. 31, fig. 6).

Comparison and affinities. - Hemigordius morillensis seems to be similar to H. calcarea Cushman and Waters 1928; unfortunately the figures of H. calcarea are very 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).

Type deposition. - Holotype and figured paratypes are deposited in the U. S. Natl. Museum (C. F. C.):

Holotype, no.

Figured paratypes, nos.

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 Kincaid 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 absence of the species in non-calcareous shale and its presence on limy mud bottoms demonstrates the ecological restriction of this species to a calcareous environment.

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, W.C., 1858, (pars), Foraminifera Great Britain, Fol., London, p. 50, pl. 4, figs. 93, 94. (non Rotalina d'Orbigny, A., 1846, Foraminifères fossiles du Bassin tertiarie de Vienne, Paris, p. 149)

Trochammina Parker, W. K., and Jones, T. R., 1859, Ann. and Mag. Nat. Hist. (ser. 3), no. 4, p. 347; Brady, H. B., 1879, Quart. Jour. Micros. Sci., v. 19, p. 54.

Lituola Lamarck, Parker, W. K., and Jones, T. R., 1865, (*pars*), Philos. Trans., p. 325. (*non* *Lituola* Lamarck, J. B., 1804, Ann. Mus., v. 5, p. 243)

Haplophragmium Reuss, Siddall, ., 1879, (*pars*). (*fide* Cushman, J. A., 1948, Foraminifera, Cambridge, p. 106); (*non* *Haplophragmium* Reuss, A. E., 1860, Akad. Wiss. Wien, Sitz., v. 40, p. 218)

Ammoglobigerina Eimer, G. H. T., and Fickert, C., 1899, Zeitschr. fur Wissenschaftliche Zoologie, v. 65, no. 4, p.

Type species: *Nautilus inflatus* Montagu, 1808 (monotypic genus).

Brady (1879, p. 54) presents a very complete and clear account of the vissicitudes of the genus *Trochammina* and gives 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. IV, 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, n. sp.

Pl. 7, figs. 27, 28; Pl. 11, 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 the mid-point of the apertural face, at the base of the last chamber; aperture slit-like and rather rectangular, .84 mm in length and .25 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 number	maximum diameter	maximum width	no. of chambers in outer whorl dorsal	ventral
1, holotype, Pl. 7, fig. 27	.50	.24	3	3
2	.37	.23		
3	.42	.29	4	4
4	.52	.13	4	4
5	.47	.24	4?	3
6	.45	.24	3?	3?
7	.45	.25	3?	3?
8	.45	.24	3?	3?
9, Pl. 7, fig. 28	.60	.28	4?	3?

Table 56. Range in measurements 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 strikingly 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).

Type deposition. - Holotype and figured paratypes are deposited in the U. S. Natl. Museum (C. F. C.):

Holotype, no.

Figured paratypes, nos.

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 non-calcareous Black Hand sandstone and its absence elsewhere may indicate the "preference" of *T. ohioensis* for a sandy, muddy environment of deposition.

Remarks. - *Trochammina ohioensis* is the first species of *Trochammina* reported from the Mississippian of the studied area.

Family Placopsilinidae

Subfamily Polyphragminae

Genus *Stacheia* H. B. Brady, 1876

Stacheia Brady, H. B., 1876, Paleont. Soc. Mon. 30, p. 107; Cushman, J. A., 1927, Cushman Lab. Foram. Research, Contr., v. 3, pt. 1, p. 42; *idem*, 1927, Cushman Lab. Foram. Research, Contr., v. 3, pt. 4, p. 189; *idem*, 1928, Cushman Lab. Foram. Research, Spec. Publ. No. 1, p. 178.

Stacheia Brady, H. B., emend. Chapman, F., 1895, Ann. and Mag. Nat. Hist. (ser. 6), v. 16, p. 321.

Type species: *Stacheia marginuloides* H. B. 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). Apertures 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, usually not observed; openings at the distal portion of the elongate forms may contain the apertures. Test 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, n. sp.

Pl. 9, figs. 1-3; Pl. 11, figs. 20, 21; Fig. 37.

Description. - Test adherent, forming medium to large sized irregularly to poorly rounded, compressed, semi-globular to discoidal, or less often irregular masses, all fused into a unit (globular, oval, or irregular in shape); attached generally to sponge spicules and bryozoan fragments; test arenaceous with siliceous grains in siliceous cement (regardless of original composition of 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 specimen or in the original material of Brady (1876, p. 16, pl. 9, figs 6-8) and inasmuch as Stacheia is a generalized genus, 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.

Type deposition. - Holotype and figured paratypes are deposited in the U.S. Natl. Museum (C.F.C.):

Holotype, no.

Figured paratypes, nos.

Table 57. Measurements of Stacheia cicatrix, n. sp. in mm.

specimen number	maximum length	maximum diameter	locality number, formation, and bed number
1	1.40	.90	K-20, Caney Creek, bed 1
2, Pl. 9, fig. 1	1.70	.82	K-2, Button Mold Knob, bed 4
3, Pl. 9, fig. 2	1.30	1.20	I-2, Button Mold Knob, bed 3
4	.99	.35	K-4, Button Mold Knob, bed 4
5	1.40	.87	K-32, New Providence, bed 3
6	1.20	.69	K-4, Button Mold Knob, bed 3
7	2.50	1.40	K-32, New Providence, bed 2
8, holotype, Pl. 9, fig. 3	1.60	.84	K-2, New Providence, bed 2
9	.84	.37	K-14, New Providence, bed 5
10, Pl. 11, fig. 21	1.10	.89	K-4, Coral Ridge, bed 2

Table 58. Range in measurements of Stacheia cicatrix, n. sp. in mm and comparison with S. acervalis Brady, 1876.

	S. cicatrix	S. acervalis
Maximum length:	.84 - 2.5	.8
Maximum diameter:	.35 - 1.4	

In addition, unfigured paratypes are deposited in the following institutions:

P. R. I., no.

U. C., no.

U. N. D., no.

B. M. (N. H.), no.

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 part of the New Providence formation. In Ohio, the species is known only from the Osagian Henley shale (Cuyahoga formation). See Charts 3-6, 9-13, 18, 21, and 22 for details of occurrence.

Ecology. - Stacheia cicatrix apparently was restricted to calcareous and shaly beds which contain megafossil remains, inasmuch as the species was primarily adherent in its living habit (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, n. sp.

Pl. 9, figs. 4, 5; Pl. 11, fig. 19; 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 light 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 number	length	diameter	locality number, formation and bed number
1	.97	.37	K-6, New Providence, bed 4
2, Pl. 9, fig. 5 holotype	.89	.30	K-4, New Providence, bed 6
3, Pl. 11, fig. 19	.66	.30	K-32, New Providence, bed 3
4	.77	.29	O-7, Cuyahoga, bed 4
5, Pl. 9, fig. 4	.94	.45	K-61, New Providence, bed 2
6	.50	.25	O-1, Bedford-Berea, bed 2
S. congesta Brady, 1876, pl. 9, fig. 1-5.	.7-1.5		Carboniferous, Scotland
S. pupoides Brady, 1876, pl. 8, fig. 17.	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, pl. 7, figs. 1 a, 1 b; 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; it differs from S. pupoides in having more prominent sutures and less fusiform test.

Type locality. - East Quarry of the Coral Ridge Brick Company, 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.

Type deposition.- Holotype and figured paratypes are deposited in the U. S. Natl. Museum (C. F. C.):

Holotype, no.

Figured paratypes, nos.

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, 10, 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, n. sp.

Pl. 9, 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 suceeded by three nearly rectilinear large segments, the last of which exhibits overlapping of segments at right angles to the section sutures; central rod or spine dissolved, leaving 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, 167 1/2 to 175 feet above the Falling Run member of the Sanderson formation (Bed 10).

Type deposition. - Holotype is deposited in the U. S. Natl. Museum (C. F. C.):

Holotype, no.

Stratigraphic occurrence. - Stacheia trepeilopsiformis has been found only as a single specimen in the upper part of the New Providence

Table 60. Measurements of Stacheia trepeilopsiformis, n. sp. in mm and comparison with S. pupoides Brady, 1876.

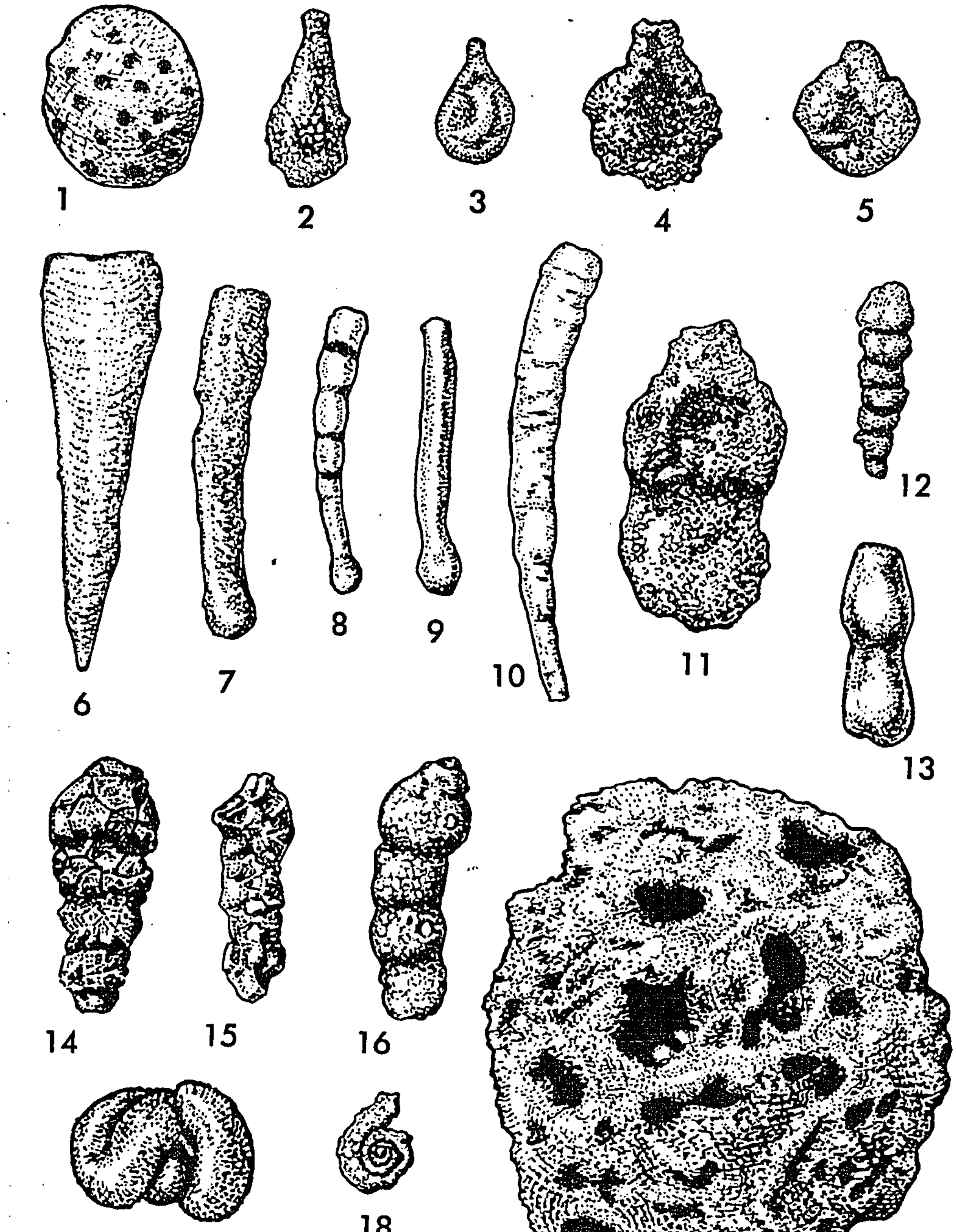
specimen number	length	distal diameter	proximal diameter	locality number, formation, and bed number
1, holotype, Pl. 9, figs. 6, 7	1.0	.35	.18	K-32, New Providence, bed 10
S. pupoides	1.0	-	-	Carboniferous of Great Britain

formation in southern Kentucky in an area where the New Providence formation probably contains beds younger than Fern Glen-Burlington.

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 indicates 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 waters where shaly beds were interspersed within deltaic silts.

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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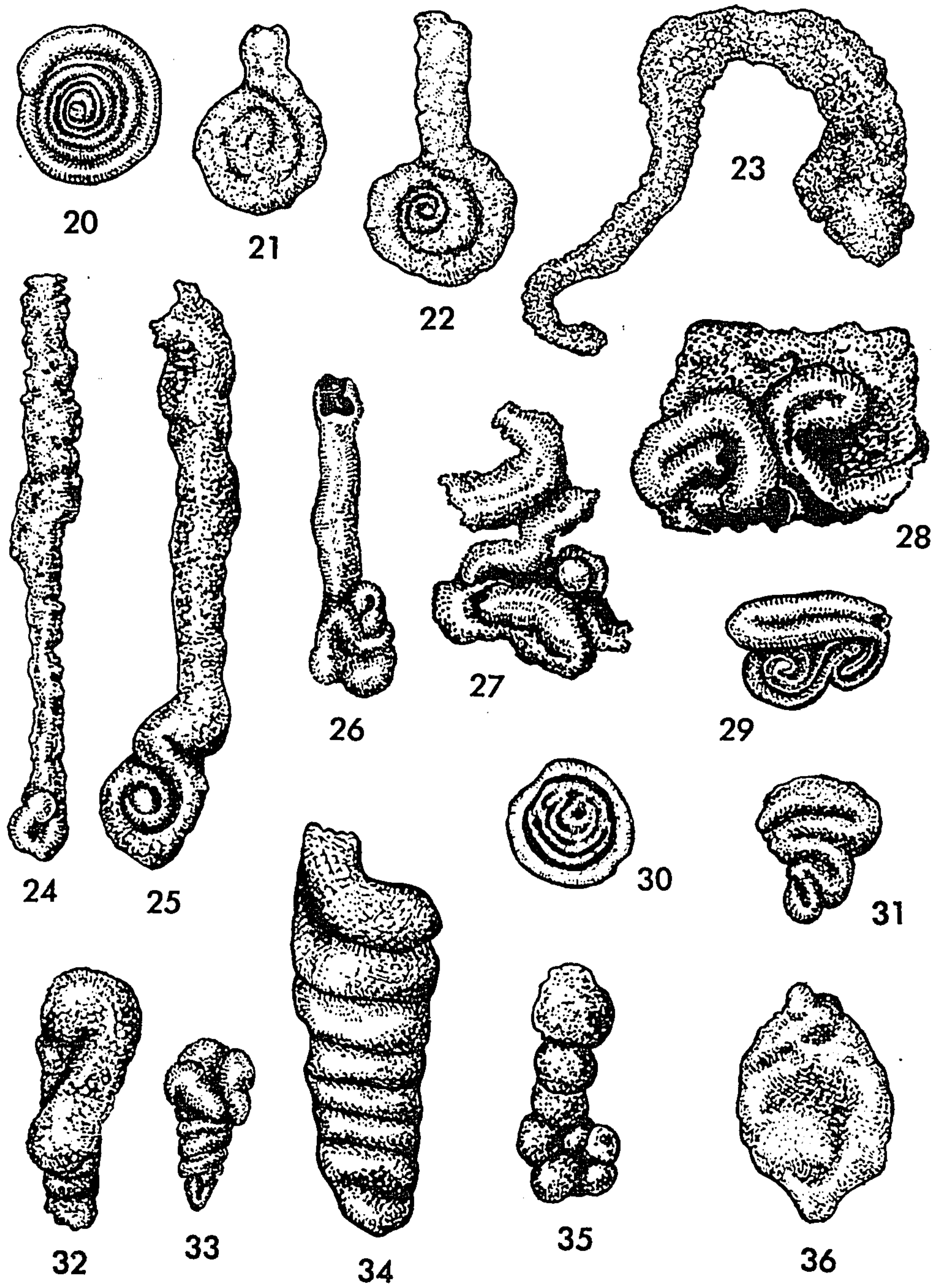
Figures 20-36

20, Involutina semiconstricta (Waters); 21, Involutina exserta (Cushman); 22, Involutina longexserta Gutschick and Treckman; 23, Tolypammina jacobschapelensis, n. sp.; 24, Tolypammina botonunca Gutschick and Treckman; 25, Tolypammina cyclops Gutschick and Treckman; 26, Tolypammina laocoön, 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, 33, Trepeilopsis glomospiroides Gutschick and Treckman; 34, Trepeilopsis spiralis Gutschick and Treckman; 35, Ammobaculites gutschicki, n. sp.; 36, Agathammina mississippiana, n. sp.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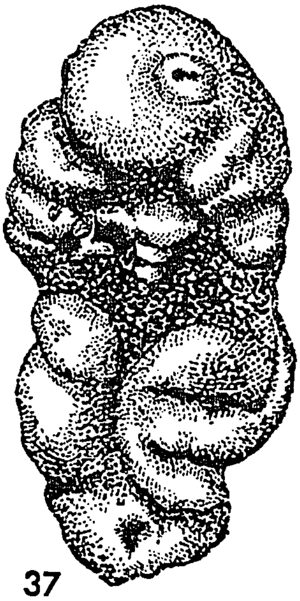
Figures 37-43

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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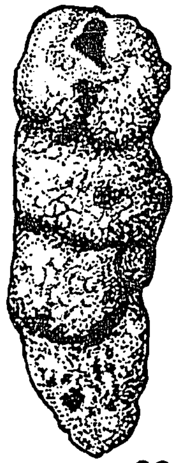

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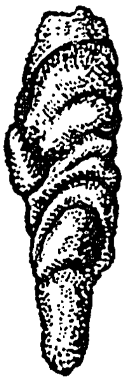

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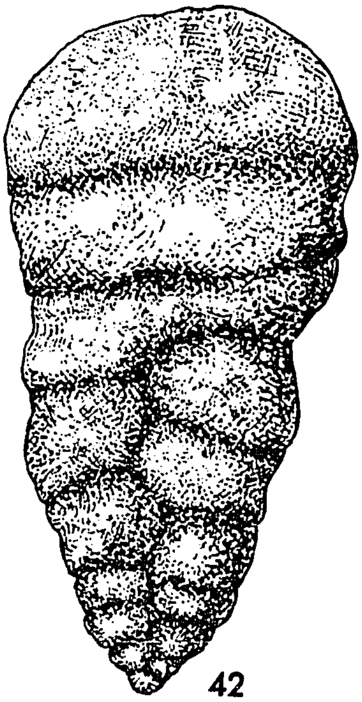

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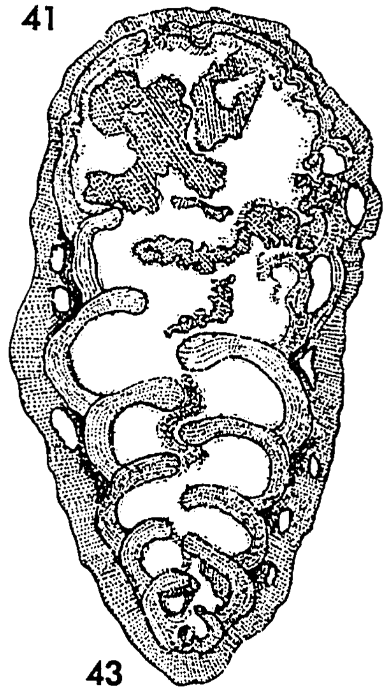

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Explanation of Plate 1

Figure	All figures X 50	Page
1-10.	<u>Thuramminoides</u> <u>sphaeroidalis</u> Plummer. . .	155

1. Spherical test showing surface con-configuration of centripetal tubes. Specimen 20, Table 2.

2. Spherical test with outer wall destroyed, showing casts of tube ends. Specimen 22, Table 2.

3. Spherical test, slightly crushed, showing ends of large centripetal tubes. Specimen 16, Table 2.

4. Broken specimen showing interior of test. Tube structure destroyed. Specimen 2, Table 2.

5. Broken test showing rounded pits on interior wall where tubes pierce surface. Specimen 15, Table 2.

6. Flattened test with internal tubular structure visible through translucent outer wall. Specimen 11, Table 2.

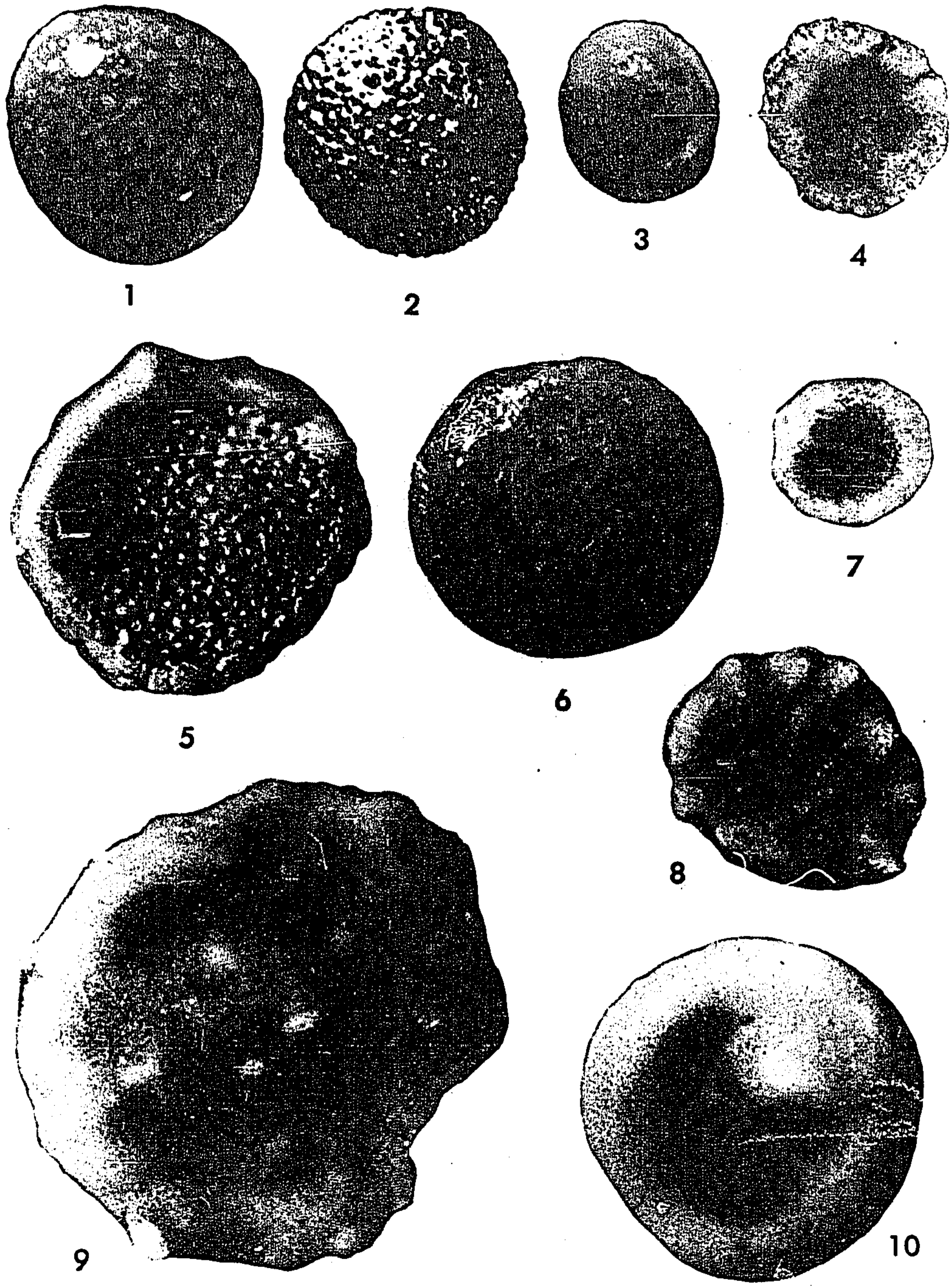
7. Small collapsed test with shape like a red blood corpuscle. Specimen 6, Table 2.

8. Flattened test with several protuberances, not taken to be apertural necks. Specimen 9, Table 2.

9. Large flattened test with protuberances. Specimen 8, Table 2.

10. Test of the most common variety, with a low protuberance. Specimen 17, Table 2.

PLATE 1



Explanation of Plate 2

Figure	All figures X 50	Page
1-4.	<u>Thuramminoides</u> <u>sphaeroidalis</u> Plummer. . .	155

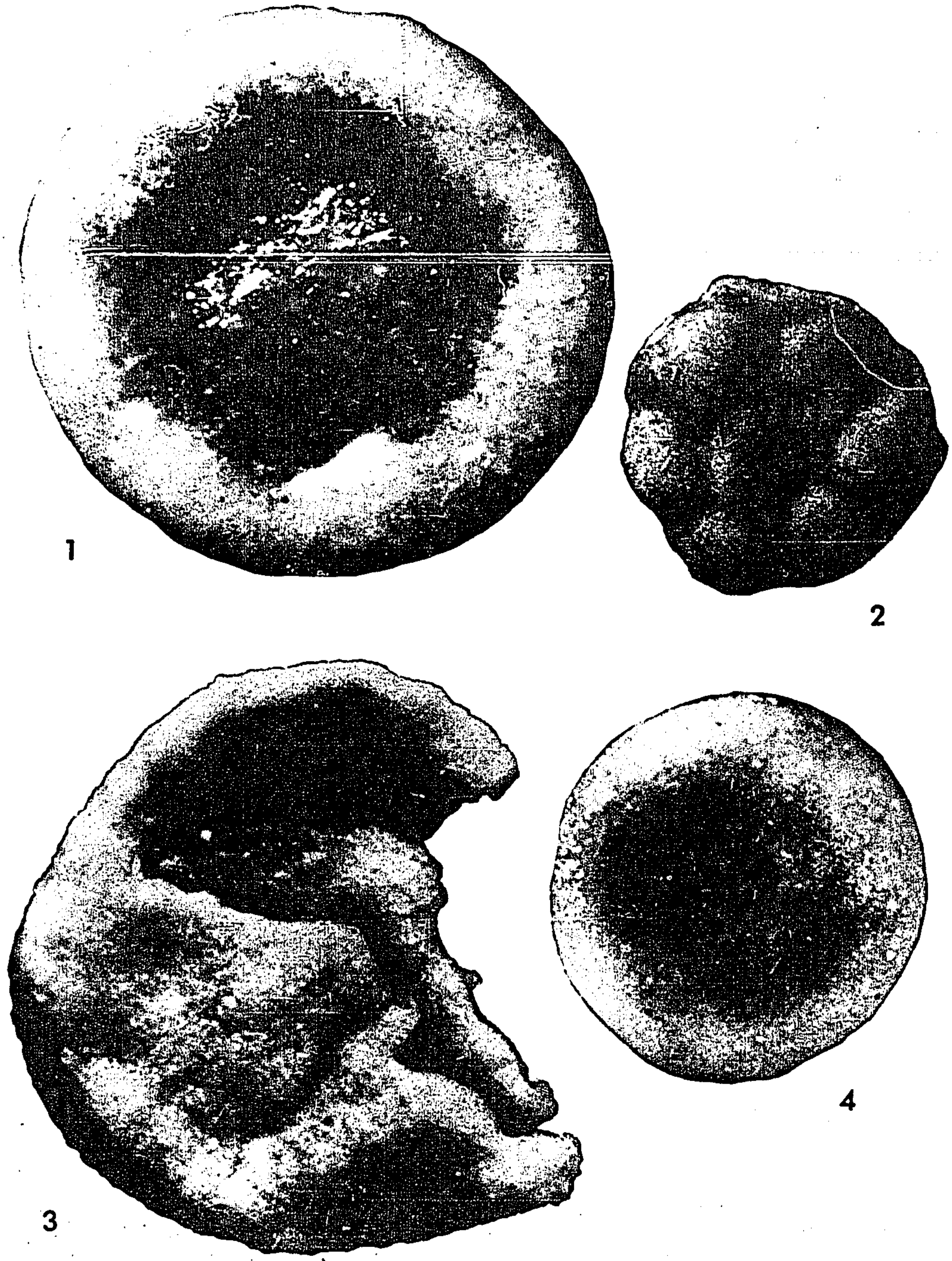
1. Large test of typical appearance. Dark filling visible through translucent outer wall. Specimen 1, Table 2.

2. Test with large low protuberances. Specimen 13, Table 2.

3. Large broken test with internal structure destroyed. Specimen 18, Table 2.

4. A typical flattened test. Specimen 12, Table 2.

PLATE 2



Explanation of Plate 3

All figures X 50

Figure	Page

1-3. Proteonina cumberlandiae, n. sp. 165

1. Large specimen with neck missing. Specimen 2, Table 4.

2. Holotype, showing teardrop shape. Test compressed. Specimen 19, Table 4.

3. Test more elongate than usual. Specimen 1, Table 4.

4-8. Proteonina wallingfordensis, n. sp. 169

4, 6, 8. Tests showing typical round to oblate chamber and stocky tapering neck. Specimens 19, 21, and 22, Table 6.

5. Large specimen of typical shape. Specimen 39, Table 6.

7. Holotype. Specimen 20, Table 6.

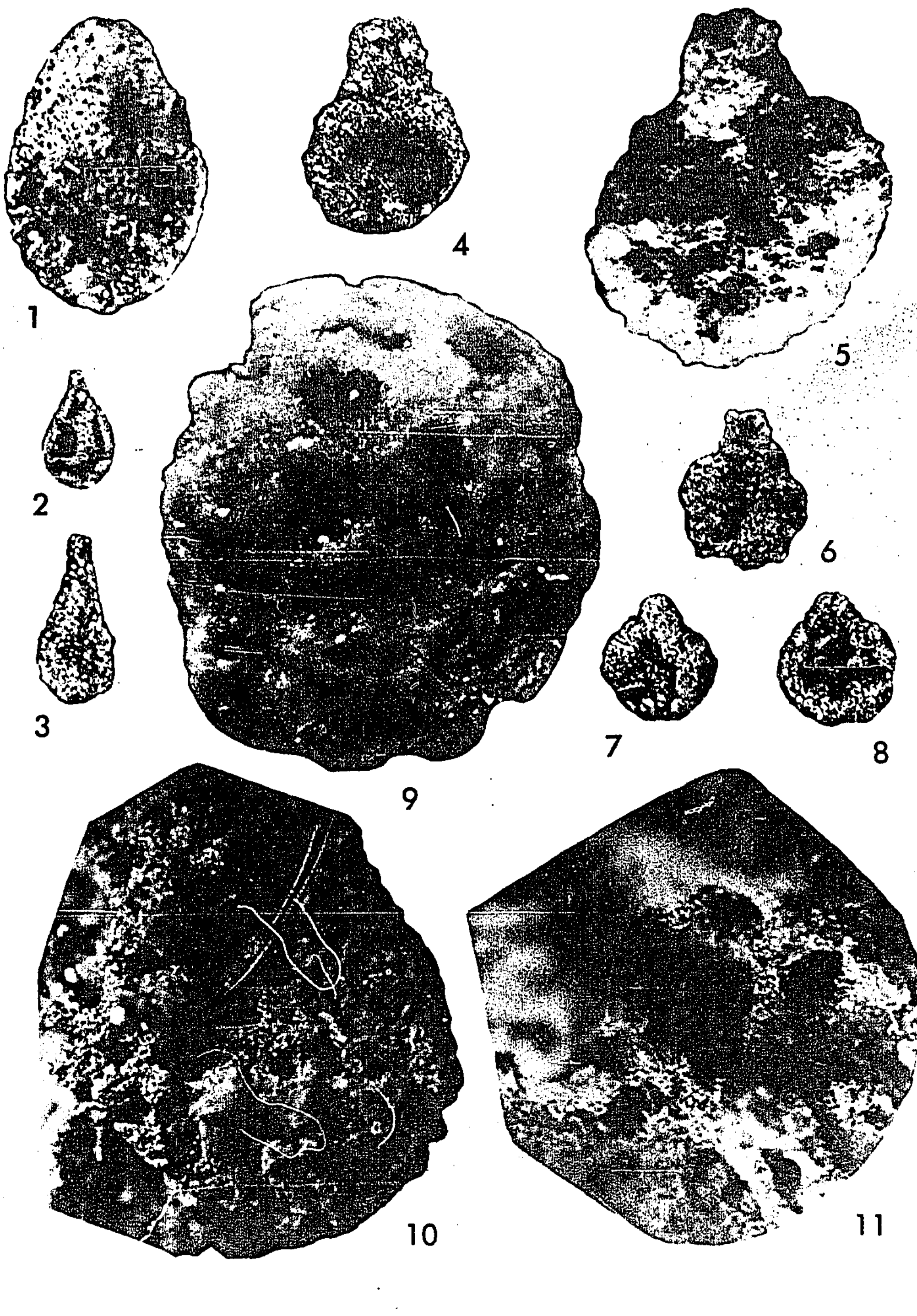
9. Crithionina palaeozoica, n. sp. 144

Holotype, showing spongey texture of test wall. Specimen 1, Table 1.

10, 11. Crithionina rotundata Cushman, 1910 146

Fragments of the holotype. Shows less regularity to test wall than in Crithionina palaeozoica, n. sp. Table 1.

PLATE 3



Explanation of Plate 4

All figures X 50

Figure		Page
1-18.	Hyperammina casteri, n. sp.	192

1. Holotype, microspheric form. Test broken at apertural end, but well developed otherwise. Specimen 29, Table 10.

2. Microspheric form, broken at apertural end. Specimen 30, Table 10.

3. Megalospheric form, slightly constricted. Specimen 30, Table 9.

4. Microspheric form, slightly constricted, with proloclus missing. Specimen 34, Table 10.

5, 7, 12. Megalospheric forms with apertural ends broken off. Specimens 10, 18, and 34, Table 9.

6. Microspheric form with extremely long and pointed tip. Apertural end broken off. Specimen 14, Table 10.

8, 11. Microspheric forms, less conical than most. Specimens 21 and 22, Table 10.

9. Megalospheric form, apertural end broken. Proloculus somewhat pointed. Specimen 23, Table 9.

10. Microspheric form showing apertural end with slightly constricted aperture. Specimen 23, Table 10.

Explanation of Plate 4 (continued)

Figure

13. Microspheric form. A typical small specimen. Specimen 37, Table 10.

14, 15. Fragments of a very large megalospheric form. Specimen 2, Table 9,

16. Large microspheric form. Proloculus missing. Specimen 16, Table 10.

17. Large megalospheric form. Apertural end partly broken. Specimen 13, Table 9.

18. Large megalospheric form with oblate proloculus. Apertural end broken. Specimen 12, Table 9.

PLATE 4

Explanation of Plate 5

All figures X 50

Figure		Page
1-9.	Hyperammina kentuckyensis Conkin	200

1. Topotype showing slender, constricted test, hourglass tapering of early part of second chamber, and oblate proloculus. Specimen 2, Table 12.

2, 3. Topotypes. Specimens 1 and 3, Table 12.

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. Specimens 20, 15, 18, 13, 21, and 10, Table 12.

10-13. Hyperammina rockfordensis Gutschick and Treckman 209

Tests showing rather cylindrical second chamber with few faint constrictions. Specimens 23, 24, 21, and 22, Table 14.

14-16. Earlandia consternatio, n. sp. 222

14. Holotype, proloculus missing. Shows tapering nature of test. Constrictions less prominent than in Hyperammina kentuckyensis, but otherwise shape of test is similar. Specimen 4, Table 16.

15, 16. Small and large specimens. Proloculi missing. Specimens 5 and 3, Table 16.

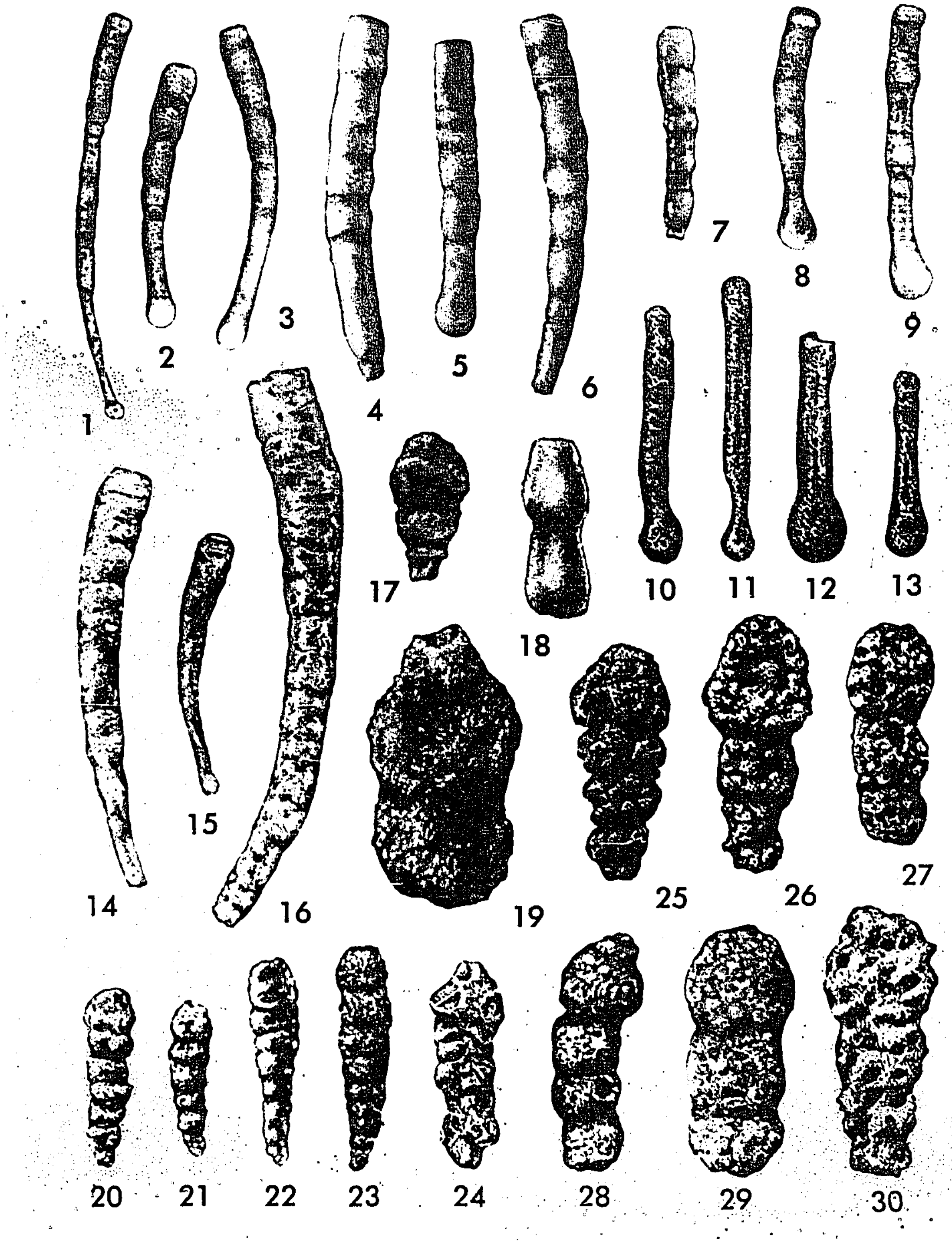
17. Reophax cf. R. minutissimus Plummer 249

Specimen 1, Table 25.

Explanation of Plate 5 (continued)

Figure		Page
18.	Reophax cf. R. lachrymosus Gutschick and Treckman	241
	Broken specimen. Specimen 1, Table 22.	
19.	Reophax arenatus (Cushman and Waters)	231
	Specimen 1, Table 18.	
20-23.	Reophax kunklerensis, n. sp.	237
	20. Holotype, showing typical slender test with oblate overlapping chambers. Specimen 1, Table 20.	
	21-23. Specimens 8, 5, and 6, Table 20.	
24.	Reophax asper Cushman and Waters	234
	Specimen 1, Table 19, showing rugose wall of angular quartz grains.	
25-30.	Reophax mcdonaldi, n. sp.	244
	25. Holotype. Specimen 1, Table 23. Shows typical stocky test with inflated, oblate, overlapping chambers and pyriform last chamber.	
	26-30. Tests showing variation of form within the species. Specimens 2, 12, 5, 8, and 3, Table 23.	

PLATE 5



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Explanation of Plate 6

All figures X 50

Figure		Page
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	1. Variant 1. Delicate test composed of much cement. Specimen 10, Table 30.	
	2. Variant 2. Robust test composed of much silt and relatively small amount of cement. Specimen 5, Table 30.	
	3. Variant 1. Specimen 21, Table 30.	
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7, 9.	Involutina longexserta Gutschick and Treckman	258
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11, 12.	Lituotuba semiplana , n. sp.	278
	11. Holotype. Microspheric form. Specimen 1, Table 33.	
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	14. Specimen 2, Table 35.	
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	16. Holotype, showing partially walled floor of test, and proloculus shaped like half an egg with pointed end. Specimen 8, Table 36.	
	17, 18. Specimens with pointed proloculi. Specimens 6 and 3, Table 36.	
	19, 20. Specimens with rounded proloculi. Figure 19 shows under side of test with attached proloculus. Specimens 22 and 17, Table 36.	
	21. Large specimen with pointed proloculus. Specimen 19, Table 30.	
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23.	Tolypammina laocoön, n. sp.	298
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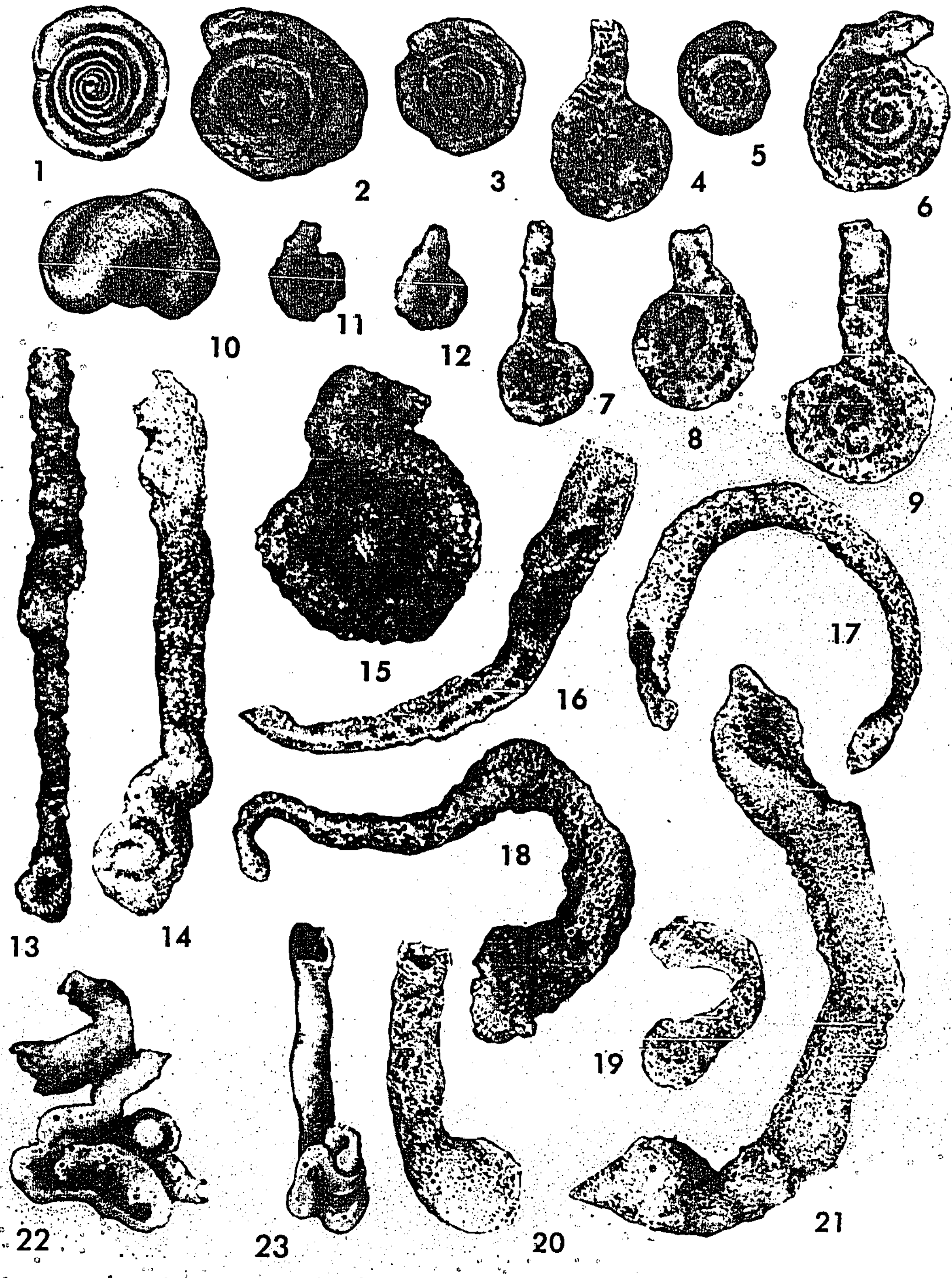
PLATE 6



Explanation of Plate 7

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5-7.	Trepeilopsis spiralis Gutschick and Treckman	324
	Specimens 13, 19, and 7, Table 48.	
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Explanation of Plate 7 (continued)

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	12-22. Specimens showing variation within the species. Specimens 1, 4, 2, 19, 13, 17, 24, 6, 27, 26, and 5, Table 50. Figure 22 shows a broken test of unusually large size.	
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26.	Hemigordius morillensis, n. sp.	359
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	27. Dorsal view of holotype. Specimen 1, Table 55.	
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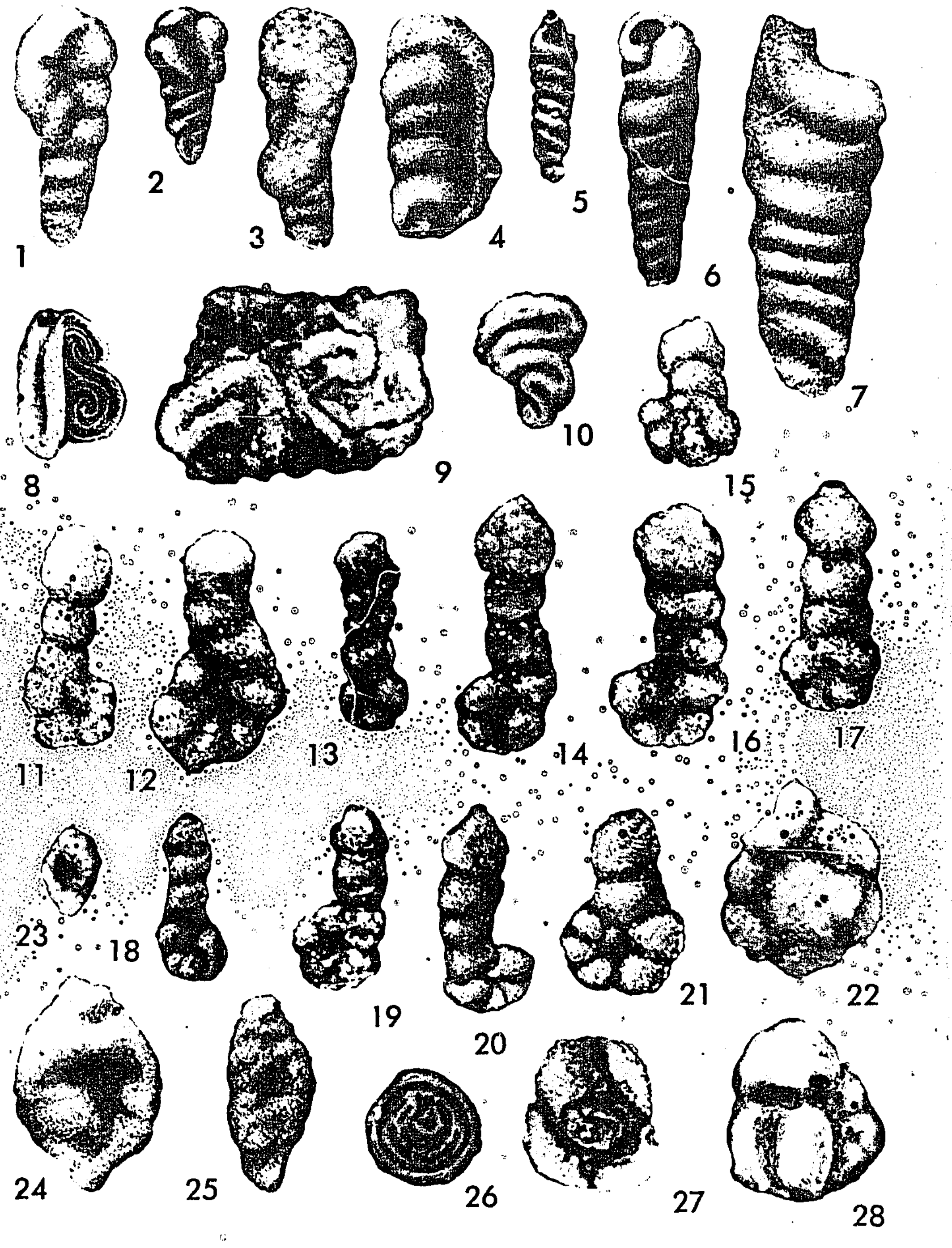
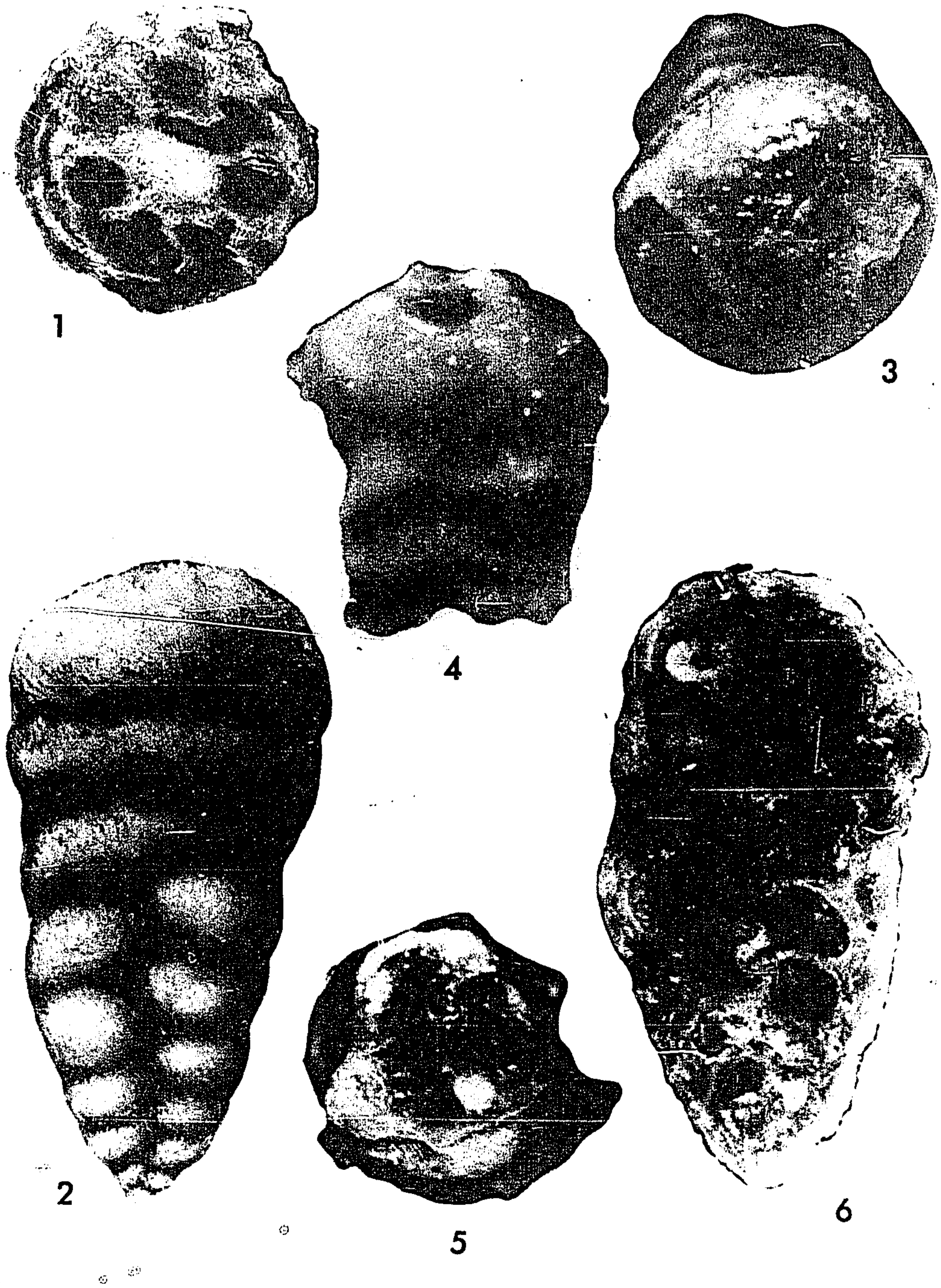
PLATE 7



Explanation of Plate 8

All figures approximately X 90

PLATE 8



Explanation of Plate 9

All figures X 50

Explanation of Plate 10

All figures X 50

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4, 5.	Proteonina cumberlandiae, n. sp.	165
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Explanation of Plate 10 (continued)

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16, 17, 19.	Involutina exserta (Cushman)	253
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18.	Involutina longexserta Gutschick and Treckman	258
	Thin section of Specimen 4, Table 28.	
20.	Involutina semiconstricta (Waters)	263
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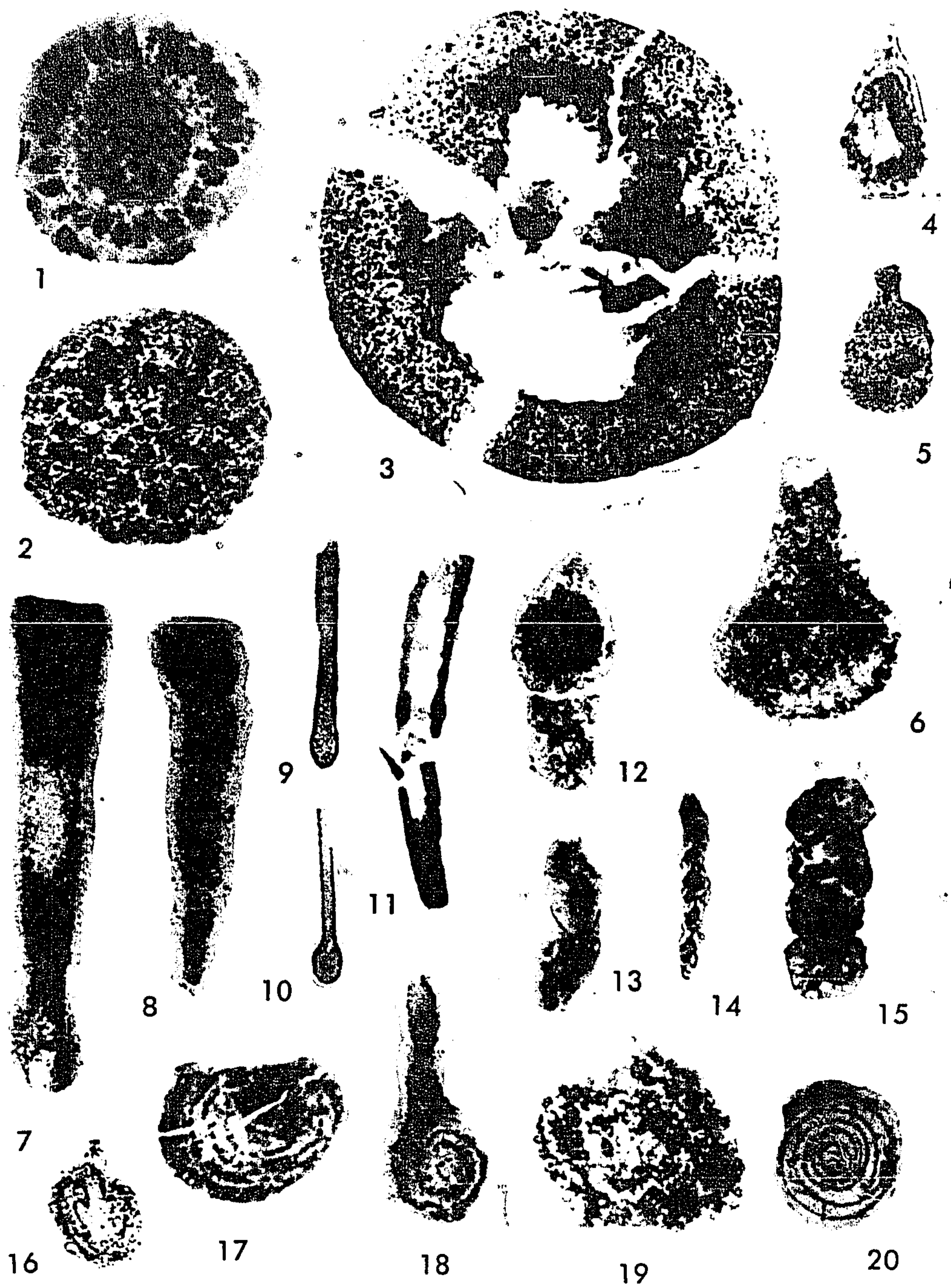
PLATE 10



Explanation of Plate 11

All figures X 50

Figure		Page
1.	Glomospira articulosa Plummer	273
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2.	Lituotuba semiplana, n. sp.	278
	Thin section of Specimen 3, Table 33, megalospheric form, showing nearly planispiral coiling.	
3.	Tolypammina cyclops Gutschick and Treckman	289
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4.	Tolypammina tortuosa Dunn	301
	Thin section showing intertwining of tubular chamber.	
5.	Tolypammina jacobschapelensis, n. sp.	292
	Thin section showing pointed tip of proloculus and partial floor wall. Specimen 20, Table 36.	
6-9.	Ammovertella cf. A. inclusa (Cushman and Waters)	305
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Explanation of Plate 11 (continued)

Explanation of Plate 11 (continued)

Figure		Page
17.	Hemigordius morillensis, n. sp.	359
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18.	Agathammina mississippiana, n. sp.	351
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20, 21.	Stacheia cicatrix, n. sp.	372
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PLATE 11