Contributions to the Ordovician Paleontology of Kentucky and Nearby States

The Ordovician Paleontology of Kentucky and Nearby States—Introduction
The Brachiopod Genus *Platystrophia*
Middle and Late Ordovician Plectambonitacean, Rhynchonellacean, Syntrophiacean, Trimerellacean, and Atrypacean Brachiopods
Additional Trilobites From the Ordovician of Kentucky
Edrioasteroids (Echinodermata)
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Conodonts and Conodont Biostratigraphy of Post-Tyrone Ordovician Rocks of the Cincinnati Region

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1066-A-G

Prepared in cooperation with the Commonwealth of Kentucky, University of Kentucky, Kentucky Geological Survey

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Edited by John Pojeta, Jr.

A. The Ordovician Paleontology of Kentucky and Nearby States—
Introduction, by John Pojeta, Jr.
B. The Brachiopod Genus *Platystrophia*, by Leonard P. Alberstadt
C. Middle and Late Ordovician Plectambonitacean, Rhynchonellacean, Syntrophiacean, Trimerellacean, and Atrypacean Brachiopods, by Herbert J. Howe
D. Additional Trilobites From the Ordovician of Kentucky, by Reuben James Ross, Jr.
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G. Conodonts and Conodont Biostratigraphy of Post-Tyrone Ordovician Rocks of the Cincinnati Region, by Walter C. Sweet

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By JOHN POJETA, JR.

CONTRIBUTIONS TO THE ORDOVICIAN PALEONTOLOGY OF KENTUCKY AND NEARBY STATES

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1066-A

Prepared in cooperation with the
Commonwealth of Kentucky,
University of Kentucky,
Kentucky Geological Survey

A summary of the lithostratigraphy and biostratigraphy of the area, a description of materials and methods, and a list of collecting localities for the six systematic paleontology papers in this series

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1979

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ILLUSTRATIONS

SYSTEM OF MEASUREMENT UNITS

The investigations underlying this series of reports were made over a period of years, and distances and stratigraphic measurements appear fairly uniformly in English units. Measurements of fossil specimens, on the other hand, follow the long-standing convention of appearing in metric units. Because of the dates of the investigations and the amount of resulting data, the English measurements have been retained. Conversions to metric units may be made by using the following conversion table:

To convert English unit:	To metric unit:	Multiply by:
Mile (mi)	Kilometer (km)	1.61
Foot (ft)	Meter (m)	.305

THE ORDOVICIAN PALEONTOLOGY OF KENTUCKY AND NEARBY STATES—INTRODUCTION

By JOHN POJETA, JR.

ABSTRACT

The introduction contains the general information common to the systematic paleontology sections that are included in the six accompanying reports (Chapters B–G). This general information consists of brief descriptions of the formations from which the fossils were collected, the environments of deposition of the formations, current thoughts on the placement of the Middle Ordovician-Upper Ordovician boundary in the area of study, a summary of the current stadial classification of the outcropping Ordovician rocks in the area of study, the methods used for extracting silicified fossils from limestone, and a locality register.

INTRODUCTION

This chapter and chapters B to G of Professional Paper 1066 are part of a series of papers primarily dealing with the Ordovician megafossils of Kentucky. Previous reports in this series have dealt with some of the trilobites (Ross, 1967) and brachiopods (Neuman, 1967); the parts of the fauna described in these reports are: the brachiopod genus *Platystrophia* (Alberstadt, chapter B); plectambonitacean, rhynchonellacean, syntrophiacean, and trimerellacean brachiopods (Howe, chapter C); trilobites (R. J. Ross, Jr., chapter D); edrioasteroids (Bell, chapter E); and asteroids (Branstrator, chapter F); the conodont biostratigraphy of the area is summarized by Sweet (chapter G).

Most of the material described consists of silicified specimens from central and north-central Kentucky (Blue Grass region). Some of the specimens are from the Cumberland River area of south-central Kentucky near the Tennessee border, and some are from nearby States, particularly Ohio and Indiana (fig. 1). The tristate area of Kentucky, Ohio, and Indiana is a classical one in the study of late Middle and Late Ordovician faunas of North America, and it is the type area for the American Upper Ordovician stages (Edenian, Maysvillian, and Richmondian). Once the megafaunas are redescribed in modern terms, this information can be used for a biostratigraphic synthesis of the area; this synthesis can then be compared with the biostratigraphic conclusions derived from the study of conodonts of the area, which are summarized in Bergström and Sweet (1966), Sweet and Bergström (1971) and Sweet herein.

This report contains the stratigraphic and locality information for each of the collections cited in the paleontological chapters. This information is gathered together in a locality register at the end of the introduction.

The U.S. Geological Survey, in cooperation with the Kentucky Geological Survey, began the geologic mapping of Kentucky in 1961. The scale used in this mapping program is 1:24,000 and the State is being mapped quadrangle by quadrangle; this project is now nearly completed. The mapping program resulted in the accumulation of large numbers of fossils, particularly from the Ordovician outcrop area, and faunal lists were published on many of the maps. In addition, Cressman (1973) published several lines of sections that included faunal lists. In part these faunal lists are documented herein, and the identifications provided supersede all previous identifications. The same collection numbers are used herein, on the quadrangle maps, and in Cressman (1973). The collections made by the mapping parties were augmented and expanded by various paleontologists of the U.S. Geological Survey, with especial concentration on silicified fossils in the Lexington Limestone. Silicification of the fauna above and below the Lexington Limestone is neither so well developed nor so widespread; where silicification of fossils was found in these intervals, collections were made. The

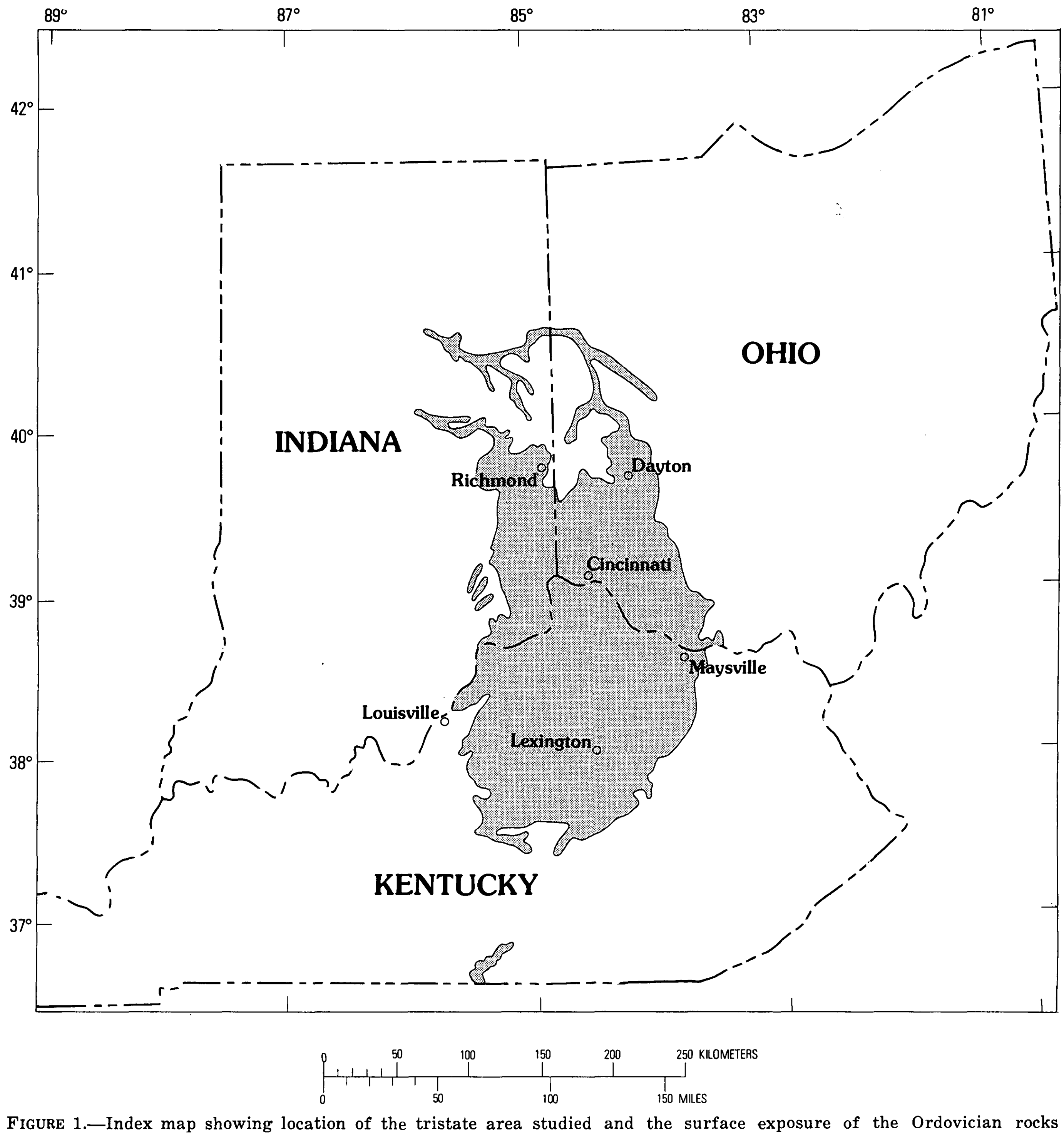

FIGURE 1.—Index map showing location of the tristate area studied and the surface exposure of the Ordovician rocks sampled (patterned). Modified from King and Beikman (1974).

new well-preserved material described herein is accurately located geographically and stratigraphically; it has presented an unparalleled opportunity to restudy the paleontology and biostratigraphy of a classical area.

Although it is now standard procedure for U.S. Geological Survey reports to use metric units of measure, much of the work reported here was done at a time when English units of measure were used. Thus, most of the stratigraphic measurements are given in feet, and the size of collections of silicified fossils is given in pounds. Because some of the field and laboratory work dates back to 1961, it was felt that it simply would not be sufficiently profitable to convert this mass of data to metric units. Further, many of the collections cited in the locality register are also listed on Cressman's (1973) stratigraphic sections and on published quadrangle maps, and as these publications used English units of measure, it facilitates comparison to use these here also. Where possible, as in the measurements of specimens, metric units of measure have been used.

ACKNOWLEDGMENTS

Most of the material described was collected by members of the U.S. Geological Survey; specimens not collected by members of that organization are individually acknowledged in the appropriate places in the text. Members of the U.S. Geological Survey who contributed significantly to the collecting of the Ordovician fossils in the area of study are: D. F. B. Black, E. R. Cressman, N. P. Cuppels, R. C. Green, A. B. Gibbons, O. L. Karklins, R. C. Kepferle, S. J. Luft, R. B. Neuman, W. F. Outerbridge, J. H. Peck, W. L. Peterson, John Pojeta, Jr., J. S. Pomeroy, R. J. Ross, Jr., G. C. Simmons, W. C. Swadley, G. W. Weir, the late D. E. Wolcott, and E. L. Yochelson. W. C. MacQuown, Jr., of the University of Kentucky, also collected specimens. David Oldham, Andrea Ludwig, Malikah Roberts, and L. W. Ward did much of the laboratory processing of silicified specimens.

LITHOSTRATIGRAPHY

The past decade has been one of intense interest in and much work on the lithostratigraphic classification of the Middle and Upper Ordovician rocks of the tristate area of Kentucky, Ohio, and Indiana. Much of the work in central and north-central Kentucky has resulted from the U.S. Geological Survey-Kentucky Geological Survey cooperative mapping program, and significant changes have been made in the lithostratigraphic classification of the Ordovician rocks of Kentucky above the Tyrone Limestone. All the rock units are now based upon well-documented and measured type sections. They have been mapped over all the outcrop area, and the facies relationships have been worked out. This new lithostratigraphic information is published in a number of works including: Weiss and Sweet (1964); Black and MacQuown (1965); Black, Cressman, and MacQuown (1965); Weir and Greene (1965); Weir, Greene, and Simmons (1965); Peck (1966); Simmons and Oliver (1967); MacQuown (1967); Weir and Peck (1968); Hatfield (1968); Ford (1968); Anstey and Fowler (1969); Peterson (1970); Cressman and Karklins (1970); Hrabar, Cressman, and Potter (1971); Wolcott, Cressman, and Connor (1972); Black and Cuppels (1973); Cressman (1973); Swadley, Luft, and Gibbons, 1975; Cressman and Noger, 1976; and Ethington and Sweet, 1977. In addition to these publications, much stratigraphic information is summarized on the various geologic quadrangle maps of the Blue Grass region of Kentucky; the names of the maps are listed for each locality in the locality register.

Weiss and Norman (1960a) summarized the development of the stratigraphic classification of the Ordovician rocks exposed in the Cincinnati, Ohio, region to 1960. Since that publication, Weiss and Sweet (1964); Ford (1967, 1972, 1974); Hatfield (1968); Osborne (1968, 1974); and Anstey and Fowler (1969) have given further consideration to the classification of the Ordovician rocks of southwestern Ohio. Recent consideration of the stratigraphic classification of the Ordovician rocks of southeastern Indiana can be found in Fox (1962); Brown and Lineback (1966); Brown and Anstey (1968); Hatfield (1968); Anstey and Fowler (1969); Gray (1972); and Hay (1977).

Herein, the lithostratigraphic information for the area of study is summarized in brief descriptions for each of the rock units, and in a series of stratigraphic columns for the various geographic areas where the formations crop out (fig. 2). The brief descriptions of the rock units are arranged alphabetically, and they are provided in order to allow readers to have some idea of the lithologic differences between units without having to refer elsewhere. Members of a formation are arranged in ascending order under the formation name. For the most part these descriptions are taken from or paraphrased from the works cited above; the work or works from which each rock description is taken are cited at the end of the description. Many of the units pinch out, and the thicknesses given are for their principal areas of outcrop. A number of authors have attempted to determine the environment of deposition of the formation they were describing; where such information is available, it is indicated below after the lithologic description of the formation. In figure 2, each column is taken from the author indicated, and in most cases each stratigraphic column is a composite of the area indicated.

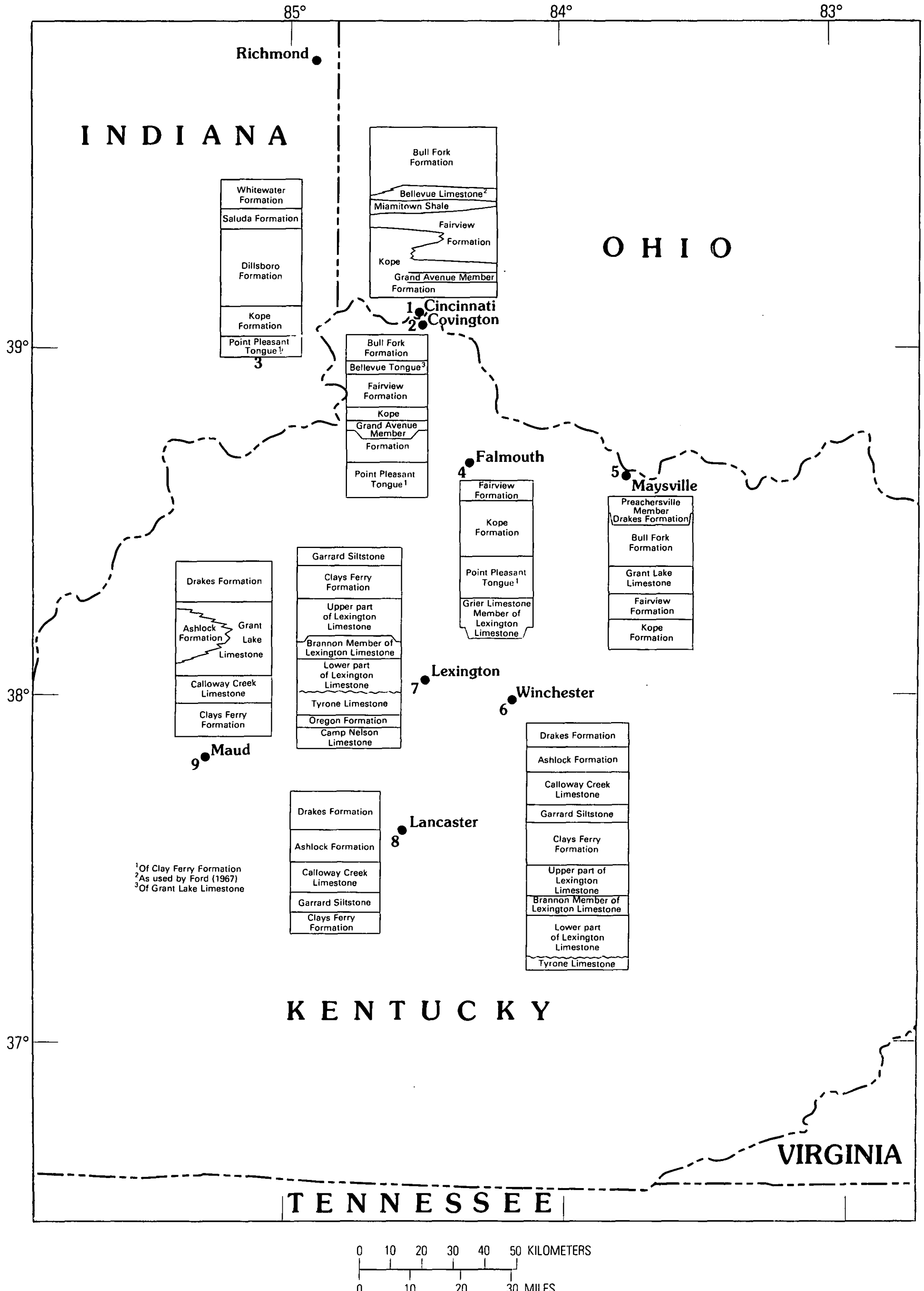

FIGURE 2.—Stratigraphic columns, mostly composites, for various geographic locations in the area of study. 1, at Cincinnati, Ohio, modified from Ford (1967, fig. 2) by the use of the name Bull Fork Formation for beds above Ford's "Bellevue Limestone," which Ford left unnamed. 2, at Covington, Ky., across the Ohio River from Cincinnati, Ohio, from Luft (1971). 3, southeastern Indiana, modified from Brown and Lineback (1966, fig. 1) by the addition of the Point Pleasant Tongue of the Clays Ferry Formation as suggested by Cressman (1973, p. 46). 4, at Falmouth, Ky., from Luft (1972). 5, at Maysville, from Peck (1966) fig. 2). 6, at Winchester, from Black (1974). 7, composite section for the greater Lexington-Frankfort area. 8, Lancaster, from Weir (1971); 9, at Maud, from Peterson (1972).

ASHLOCK FORMATION

This unit is 125–145 feet (ft) thick. The lower part is chiefly limy and dolomitic mudstone; the middle part is chiefly limestone and argillaceous limestone; and the upper part is greenish-gray unfossiliferous limy and dolomitic mudstone overlain by gray thin-bedded fossiliferous silty granular limestone (Weir, Greene, and Simmons, 1965). The Ashlock Formation is divided into five members as follows (ascending):

TATE MEMBER

This member is 30–80 ft thick and is the basal unit of the Ashlock Formation. The Tate Member is chiefly greenish gray, laminated to thin-bedded, sparsely glauconitic, limy to dolomitic mudstone commonly grading at the top to argillaceous limestone; it contains few megafossils (Weir, Greene, and Simmons, 1965).

According to Weir and Peck (1968, p .168), their dolomitic mudstone lithofacies, to which the Tate Member belongs, was formed as very shallow quiet-water deposits, probably laid down on extensive flats.

About 5 to 15 ft above the base of the Tate Member is a persistent unit, from 4 to 8 ft thick, of thin beds of olive-gray fine- to coarse-grained silty limestone containing silicified large brachiopods and bryozoans. This is the Back Bed of the Tate Member (Weir, Greene, and Simmons, 1965). It forms part of the nodular-bedded fossiliferous limestone and mudstone lithofacies of Weir and Peck (1968), and thus was formed in a higher energy environment than the rest of the Tate Member.

GILBERT MEMBER

This member is 10–20 ft thick. It overlies the basal Tate Member of the Ashlock Formation and underlies the Stingy Creek Member. The Gilbert is composed of bluish to olive-gray, aphanitic to medium-grained limestone in crinkly beds a few inches thick. Gray limy siltstone occurs as partings and seams less than 1 in. thick. Contains abundant well-preserved megafossils (Weir, Greene, and Simmons, 1965).

According to Weir and Peck (1968, p. 168), the micrograined limestone lithofacies on the east side of the Cincinnati arch, of which the Gilbert Member is a part, was laid down in very shallow quiet-water, probably tide level lagoons, relatively free of terrigenous material.

STINGY CREEK MEMBER

The Stingy Creek Member ranges from 5 to 15 ft in thickness; it overlies the Gilbert Member and underlies the Terrill Member. It is a sequence of silty limestone and limy siltstone. The limestone is chiefly medium light gray, fine to medium grained, and silty. It is obscurely thin bedded, partly in lenticles about an inch thick and a few inches long; fossils are abundant. The limy siltstone is chiefly light bluish gray and is gradational with the limestone with which it is interbedded (Weir, Greene, and Simmons, 1965).

The Stingy Creek Member belongs to the same lithofacies as the Reba Member (Weir and Peck, 1968) and suggests the same environment of deposition.

TERRILL MEMBER

This unit is 5–15 ft thick; it overlies the Stingy Creek Member and underlies the Reba Member. The Terrill is mainly composed of greenish-gray laminated limy or dolomitic mudstone. Many bedding surfaces are covered by ripple marks or mud cracks. The basal few feet of the member is a limy silty mudstone lacking distinct bedding. The member contains few megafossils (Weir, Greene, and Simmons, 1965).

According to Weir and Peck (1968, p. 168), their dolomitic mudstone lithofacies, to which the Terrill Member belongs, was formed as very shallow quiet-water deposits, probably laid down on extensive flats.

REBA MEMBER

This member is the top unit of the Ashlock Formation, ranging from 10 to 25 ft in thickness. It is composed of micrograined limestone at the base, overlain by more or less silty, medium-grained limestone that at the top commonly grades into argillaceous limestone. Limestone in the lower 2–6 ft of the Reba Member is commonly in ledge-forming beds as much as a foot thick, is aphanitic and micrograined to very fine grained, and generally lacks megafossils. Most of the limestone in the member is fine to medium grained, has silty patches and partings in uneven beds a few inches thick, and contains abundant fossils (Weir, Greene, and Simmons, 1965). According to Weir and Peck (1968, p. 168), their nodular-bedded fossiliferous limestone and mudstone lithofacies, to which the Reba Member belongs, was deposited in a higher energy environment than that indicated by the Gilbert Member rocks, possibly wave agitated shoals on the sloping shelf.

BULL FORK FORMATION

The Bull Fork Formation is about 200 ft thick in its type area along the Ohio River near Maysville, Ky., and it thins toward the south. The unit is composed of alternating shale and limestone, the shale content gradually increasing from about 20 percent near the base to about 80 percent near the top of the formation. The shale is medium gray, grading to grayish green in the upper part; it is calcareous, plastic when wet, thin bedded, fissile to poorly fissile, and obscurely laminated. Shale occurs as thin partings and seams, and as sets from 1 in. to 4 ft thick between limestone beds. Fifty to 70 percent of the limestone in the unit is mainly gray with olive-gray to greenish-gray mottling. The limestone has a fair- to well-sorted very fine to medium-grained matrix enclosing medium to very coarse fossil fragments that are oriented subparallel to the bedding. Bedding is even to irregular, and beds range in thickness from 1 to 8 in. Large ripple marks occur locally. The formation is very fossiliferous (Peck, 1966).

According to Weir and Peck (1968, p. 168) their planar-bedded fossiliferous limestone and mudstone lithofacies, to which the Bull Fork Formation belongs, is probably indicative of intermittently wave disturbed sediments deposited in more protected, perhaps deeper water, than the nodular-bedded limestone and mudstone lithofacies.

SUNSET MEMBER

The Sunset Member is as much as 30 ft thick; it is composed of limestone and mudstone. The limestone is micrograined, in part silty and in part fine grained; bedding is variable. Near the base, limestone beds are irregular and nodular and from 1 to 3 in. thick; beds are even, and as much as 3.5 ft thick near the middle of the unit; towards the top of the unit beds are knobby surfaced and 1–3 in. thick. Fossils in limestone beds are varied but sparse compared to overlying and underlying formations. Mudstone is calcitic, greenish and bluish gray, occurs in sets a few inches thick, and is generally unfossiliferous (Weir, 1975).

CALLOWAY CREEK LIMESTONE

This formation is composed chiefly of limestone with interbedded shale and minor siltstone and ranges in thickness from 80 to 130 ft. Limestone makes up 70–80 percent of the formation. It is mostly gray, fine to medium grained, and in even beds 0.1–0.3 ft thick. Greenish-gray, limy shale makes up 15–25 percent of the formation and is interbedded with the limestone as partings or seams and, near the base, as thin sets as thick as 0.5 ft. Limy siltstone makes up about 5 percent of the Calloway Creek and occurs in even beds less than 0.5 ft thick, which are intercalated with shale and limestone in the lower third of the formation. The siltstone is gray to greenish gray and weathers yellowish brown. The formation is very fossiliferous (Weir, Greene, and Simmons, 1965).

According to Weir and Peck (1968) the Calloway Creek Limestone was deposited under approximately the same conditions as the Bull Fork Formation.

CAMP NELSON LIMESTONE

The maximum exposure of this unit is 320 ft; it is the basal formation of the Ordovician exposures in central Kentucky. The formation is composed of calcilutite interlaced with dolomite. The interlaced dolomite bodies resemble burrows (Wolcott, Cressman, and Connor, 1972; Cressman, 1973). See High Bridge Group.

CLAYS FERRY FORMATION

This formation ranges from 120 to 220 ft in thickness. It is characterized by the interbedding of shale and limestone in equal amounts. The Clays Ferry contains more shale than the Lexington Limestone, Garrard Siltstone, and the Calloway Creek Limestone but less shale than the Kope Formation (E. R. Cressman, written commun., 1975).

Cressman (1973, p. 45) commented on the depositional environment of the Clays Ferry Formation:

> *** The less fossiliferous parts of the Clays Ferry Formation *** closely resemble the interbedded calcisiltite and shale of the Logana and Brannon Members of the Lexington Limestone and were deposited in a similar environment; that is, in quiet water probably at least 25 m deep. The more fossiliferous parts of the Clays Ferry were probably deposited in at slightly shallower depths where the oxygenation and light would have, at least periodically, permitted the growth of the benthos. Yet, the currents were seldom strong enough to remove silt- and clay-sized particles or to comminute even thin and delicate shells.

POINT PLEASANT TONGUE

This unit is as much as 100 ft thick, and it overlies the Lexington Limestone and underlies the Kope Formation. Cressman (1973, p. 46) made the following comments about the Point Pleasant:

> *** At Cincinnati and eastward along the Ohio River, the Lexington Limestone and the Kope Formation are separated by about 100 feet of limestone and shale, interbedded in various proportions but averaging about half-and-half.*** The Point Pleasant Formation resembles the Clays Ferry Formation in the regular interbedding of limestone and shale, and much of the lower part of the Point Pleasant cannot be distinguished lithologically from the Clays Ferry to the south.***

Weiss and others (1965) described the lithology of the Point Pleasant Tongue in detail.

The lithologic similarity of the Point Pleasant to the Clays Ferry Formation suggests the same depositional environment for the former as for the latter.

According to Cressman (1973, p. 46): "The rocks in Gallatin County called Lexington Limestone by Brown and Anstey (1968) and Anstey and Fowler (1969) should also be termed Point Pleasant."

Although previously generally recognized as a rock unit of formation rank, the Point Pleasant is now treated as a tongue of the Clays Ferry Formation by the U.S. Geological Survey and the Kentucky Geological Survey (W C Swadley, S. J. Luft, and Anthony Gibbons, written commun., 1974; Swadley, 1975; Swadley, Luft, and Gibbons, 1975).

DILLSBORO FORMATION[1]

This formation is as much as 325 ft thick. It is composed of a sequence of highly fossiliferous argillaceous limestones and calcareous shales that lie between the shale of the lower part of the Kope Formation and the dolomitic limestone of the overlying Saluda Formation. Although the greater part of the Dillsboro Formation is shale, it contains about 30 percent limestone, significantly more than is typical of the underlying Kope Formation. The lower part of the Dillsboro Formation consists of moderately thick beds of rubbly weathering argillaceous limestone containing abundant shale partings; the upper part of the formation consists of thinly interbedded argillaceous limestone and calcareous shale (Brown and Lineback, 1966).

Much of the Dillsboro Formation is similar to the Bull Fork Formation and it may have been deposited in a similar environment.

DRAKES FORMATION

The Drakes Formation ranges from 120 to 150 ft in thickness. It is composed of grayish-green dolomitic or limy sparsely glauconitic silty mudstone to argillaceous, fine-grained dolomite or dolomitic limestone (Weir, Greene, and Simmons, 1965). On the south and east sides of the Jessamine dome the formation is divisible into (ascending) the Rowland and Preachersville Members; on the west side of the dome the formation is divisible into (ascending) the Rowland, Bardstown, and Saluda Dolomite Members.

[1] Dillsboro Formation of Brown and Lineback (1966) herein adopted for U.S. Geological Survey usage.

ROWLAND MEMBER

This member is from 40 to 60 ft thick and is the basal member of the formation. It is chiefly composed of grayish-green dolomitic or limy, sparsely glauconitic silty mudstone. The mudstone is obscurely bedded and weathers to platy fragments a fraction of an inch thick and a few inches across. Many bedding surfaces are covered by ripple marks or mud cracks. Fossils are very sparse.

According to Weir and Peck (1968), their dolomitic mudstone lithofacies, to which the Rowland Member belongs, is interpreted as very shallow quiet-water deposits, probably laid down on extensive flats.

PREACHERSVILLE MEMBER

The Preachersville Member ranges from 55 to 95 ft in thickness and forms the upper member of the Drakes Formation on the east side of the Jessamine dome. It is similar to the Rowland Member but contains 10 to 20 percent argillaceous, fine-grained dolomite of dolomitic limestone in resistant beds, a few inches to a few feet thick; commonly the thicker beds are near the base of the member (Weir, Greene, and Simmons, 1965).

OTTER CREEK CORAL BED

Southeast of Lexington, Ky., the base of the Preachersville Member is marked by the Otter Creek Coral Bed. This unit is a medium-light-gray limestone that weathers light olive gray to medium gray. Most of the limestone is medium grained and the unit is rich in colonial corals and other fossils. The coral bed has a sporadic distribution and ranges in thickness from 0 to 8 ft (Simmons and Oliver, 1967).

Peterson (1970) noted that the coral layers in the Bardstown Member are probably correlatives of the Otter Creek Coral Bed.

BARDSTOWN MEMBER

Thickness of this member ranges from 12 to 40 ft. It overlies the Rowland Member and underlies the Saluda Dolomite Member on the west side of the Jessamine dome. About 90 percent of the Bardstown Member consists of fine- to medium-grained, gray to greenish-gray muddy limestone that contains scattered to abundant fossils and fossil fragments. Beds are discontinuous and lenticular and commonly 1 to 8 in. thick. About 10 percent of the member is gray bioclastic and coquinoidal limestone composed of whole fossils and fossil fragments in a fine-grained to very coarse matrix cemented in part by sparry calcite. Colonial coral heads are concentrated in two to four layers in the middle two-thirds of the Bardstown

Member where they may form as much as 50 percent of the rock mass (Peterson, 1970).

SALUDA DOLOMITE MEMBER (OR SALUDA FORMATION IN INDIANA)

This unit is as much as 25 ft thick and forms the top of the Ordovician sequence on the western side of the Jessamine dome in Kentucky. It is distinguished from the underlying Bardstown Member because the fossiliferous limestone of the latter abruptly grades into the dolomite of the Saluda at the contact. Generally, the contact must be located by the application of dilute hydrochloric acid (Peterson, 1970).

Both in Kentucky and Indiana the Saluda is characterized by the presence of dolomite (Brown and Lineback, 1966), although north of the Ohio River in Indiana the Saluda is regarded as a separate formation where it is as much as 60 ft thick.

The most thorough study of the Saluda is that of Hatfield (1968), who came to the following conclusion about its environment of deposition (p. 24):

> *** The coralline zone which essentially surrounds the Saluda Formation, records circumscription by a low, broad coral bank of the shallow, quiet-water lagoon in which the formation was deposited. The encompassing bank of colonial corals isolated the Saluda lagoon from the surrounding open sea, allowing evaporation to produce penesalinity in lagoonal waters. Inflow of normal marine water through or over the coralline barrier replenished water lost by evaporation, but such inflow did not prevent frequent exposure of lagoonal sediments and attendant desiccation.***

HITZ LIMESTONE BED

Limestone and dolomite are dark gray to olive gray, very fine to medium grained, silty, laminated in part with hackly to blocky fracture. Limestone and dolomite occur in at least four distinct alternating layers 0.2–0.4 ft thick with limestone at base. Interbedded shale is grayish black to dusky brown, carbonaceous, calcareous, strongly fissile. Shale commonly occurs in two beds, one about 0.5 ft thick near the base and one 0.2 ft thick near the top (Kepferle, 1976).

FAIRVIEW FORMATION

This formation ranges from 70 to 110 ft in thickness. It consists of closely interbedded limestone and shale and minor limy siltstone in which no stratum is persistently thicker than 1.5 ft. The uninterrupted close spacing of the limestone strata in the bulk of the formation is a significant lithic property. Limestone makes up 50–60 percent of the formation, is mainly gray and chiefly of two types. Medium- to coarse-grained fossil fragmental limestone is dominant in the lower part. Fine-grained even-textured silty limestone containing few fossils is dominant in the upper part. Shale makes up 35–40 percent of the formation, is chiefly medium gray, calcareous, and silty, and occurs as partings and thin beds separating limestone beds. Limy siltstone makes up 5–15 percent of the formation (Peck, 1966; Ford, 1967).

Osborne (1973) is the most recent author to consider the environment of deposition of the Fairview Formation; he noted (p. 145):

> the Fairview Formation may have been deposited in slightly deeper water (lower mechanical energy) than the Kope Formation. There is no available physical or faunal evidence to suggest that the Fairview Formation was deposited under restricted conditions, therefore the assumed inverse relationship between mechanical energy at the depositional site and water depth may be justified.***

In the classification of Weir and Peck (1968), the Fairview Formation belongs to the planar-bedded fossiliferous limestone and mudstone lithofacies which they noted (p. 168) is probably indicative of intermittently wave disturbed sediments deposited in more protected, perhaps deeper water.

Ford (1968, p. 1784) commented that: "The Fairview biogenic limestone in southwest Ohio was deposited on shallow shoal banks that were intensively populated by * * * marine invertebrates." A similar environment existed in the central Bluegrass area during the time of deposition of the Clays Ferry biogenic limestone.

NORTH BEND TONGUE[2]

Ford (1967) defined this unit of the Fairview Formation. He noted (p. 929): "Both north and west of the City of Cincinnati-Delhi Township area, a part of the Fairview Formation grades progressively into the Wesselman Tongue of the Kope Formation. As a consequence, a lower Fairview tongue is separated from the main body of the formation. This unit is * * * the North Bend Tongue of the Fairview Formation." At the type section the unit is 12 ft thick.

GARRARD SILTSTONE

This unit ranges from 10 to 100 ft in thickness. It is chiefly limy siltstone with minor mudstone and limestone. The siltstone is gray and very limy when fresh. Most beds are 6–24 in. thick; thicker beds are commonly contorted. The interbedded mudstone and limestone are mostly in lenses a few inches thick and a few feet to a few tens of feet long (Weir, Greene, and Simmons, 1965).

Ford (1968, p. 1784) noted: "Assuming a common origin for the clastic sediment in the Kope and Gar-

[2] North Bend Tongue of Fairview Formation of Ford (1967) herein adopted for U.S. Geological Survey usage.

rard Formations, the northward decrease in particle size from silt in the Garrard Siltstone to clay in the Kope Formation suggests tectonic control of sedimentation from a southerly source area."

GRANT LAKE LIMESTONE

This formation is 110 feet thick at its type locality. It is chiefly irregularly bedded argillaceous limestone and minor interbedded shale. Limestone, which makes up 70–90 percent of the formation, is mainly medium to light gray and has light-olive-gray mottling. The dominant type of limestone consists of a micrograined to medium-grained poorly sorted argillaceous limestone matrix surrounding jumbled large fossil fragments and whole fossils. The beds are thin, very irregular, and rubbly weathering. Thin- to thick-bedded fine- to coarse-grained well-sorted clastic limestone in even beds occurs locally. Gray calcareous shale occurs as irregular partings and thin beds separating limestone layers. The Grant Lake is very fossiliferous throughout (Peck, 1966).

In the classification of Weir and Peck (1968), the Grant Lake Limestone belongs to the nodular-bedded fossiliferous limestone and mudstone lithofacies which they regarded (p. 168) as representing a higher energy environment, possibly wave-agitated shoals on the sloping shelf.

BELLEVUE TONGUE (OR "BELLEVUE LIMESTONE" AS USED BY FORD, 1967)

The thickness of this unit is uncertain because the top is often eroded or poorly exposed: it can be 25 ft thick. It is a sequence of medium- to thin-bedded limestone and shale in which thin-bedded, massive, coquinite limestone predominates (Ford, 1967).

Ford (1967, p. 934) noted that the Bellevue thickened to the south and southeast of Cincinnati, Ohio, and that it may represent a northwesterly tongue of the Grant Lake Limestone. Luft (1971) mapped the unit as the Bellevue Tongue of the Grant Lake Limestone.

HIGH BRIDGE GROUP

Wolcott, Cressman, and Connor (1972) defined the High Bridge Group as including (ascending) the "Wells Creek Dolomite" (of drillers), Camp Nelson Limestone, Oregon Formation, and Tyrone Limestone; that is, all strata between the Knox Group and the Lexington Limestone. The "Wells Creek Dolomite" is not exposed at the surface, but as much as 500 ft of the remaining formations are exposed in the larger river valleys near the center of the Jessamine dome. The High Bridge Group contains the oldest rocks exposed in the area of study (Cressman and Noger, 1976; Whaley, 1973).

Cressman (1973, p. 9, 10) commented on the environment of deposition of the High Bridge Group: "The fine grain size of the carbonates of the High Bridge Group, the abundance of mud cracks in the Tyrone Limestone and the Oregon Formation, and the presence of algal mats and intraformational breccias, particularly in the Tyrone, indicate that these rocks were deposited as lime mud on tidal flats and in shallow lagoons." Cressman and Noger (1976) have also studied the environments of deposition of the High Bridge Group.

KOPE FORMATION

In surface exposures the Kope Formation is as much as 250 ft thick. The Kope differs from the partly equivalent and somewhat similar Clays Ferry Formation principally in containing more shale; the Kope is up to 90 percent shale and generally more than 75 percent shale, whereas the Clays Ferry Formation is 30–60 percent shale. Furthermore shale beds 3 ft or more thick are common in the Kope Formation but rare in the Clays Ferry. The interbedded limestones of the two formations are similar (Cressman, 1973; Anstey and Fowler, 1969).

Cressman (1973, p. 46) summarized thoughts on Kope deposition: "* * * Conditions were somewhat similar to those in which the Clays Ferry Formation was deposited. The dominance of shale may have resulted from deposition in deeper water or it may reflect proximity to the terrigenous source and distance from the carbonate shelf. The absolute depth was not great * * * a maximum of 25 m."

Anstey and Fowler (1969) stressed that the Kope (called "Eden Shale" by them) was probably deposited in deeper quieter water than laterally equivalent carbonate rocks. Ford (1968) suggested tectonic control of sedimentation of the Kope from a southerly source area.

The Kope is divided into (ascending):

GRAND AVENUE MEMBER[3]

Ford (1967, p. 925) proposed this name

> *** for a unit having distinct bulk lithologic characteristics within the upper part of the Kope Formation *** In approximately 11 feet of strata each terrigenous unit is no more than 2 feet thick and limestone beds are thicker and more closely spaced than is typical of the Kope Formation *** Compared with the remainder of the Kope Formation, the Grand Avenue Member shows a lower clastic content and higher bedding index.***

[3] Wesselman Tongue and Grand Avenue Member of Kope Formation of Ford 1967) herein adopted for U.S. Geological Survey usage.

Luft (1971) was able to map this unit and noted that it ranged from 10 to 13 ft in thickness.

WESSELMAN TONGUE[a]

Ford (1967, p. 928) proposed this name "* * * for a unit of Kope lithologic character which has lateral equivalents of Fairview lithologic character * * * The lower 30–40 feet of the type Fairview Formation * * * grades progressively northwestward into rocks of Kope lithologic type [and eventually] merges into and cannot be separated from the main body of the Kope Formation." The Wesselman Tongue ranges from 10 to 30 ft in thickness.

LEIPERS LIMESTONE

The Leipers Limestone (not shown in fig. 2) is 120–180 ft thick; it is gray, bluish-gray, and yellowish-gray limestone that weathers gray. The limestone is fine to coarse grained, clayey, and irregularly bedded. The formation contains many fossils, especially brachiopods (including abundant *Platystrophia*) and bryozoans, which give the rock a nodular appearance. In places the formation grades into very calcareous shale (Van Horn and Griffitts, 1969).

LEXINGTON LIMESTONE

In surface exposures, the Lexington Limestone ranges from 200 to 300 ft in thickness. It is a heterogeneous sequence of mostly bioclastic and fossiliferous limestone and minor shale, underlain by calcilutite of the Tyrone Limestone and overlain by interbedded limestone and shale of the Clays Ferry Formation (Cressman, 1973). The Lexington Limestone has 12 named members and several named beds (listed below in ascending order). The complex facies relationships of the members were illustrated by Black and MacQuown (1965) and Cressman (1973).

CURDSVILLE LIMESTONE MEMBER

The Curdsville Limestone Member ranges from less than 20 to 40 ft thick. It is the basal member of the Lexington Limestone and consists of bioclastic calcarenite and calcirudite, which is sandy and chert bearing in part. Subordinate calcisiltite and irregularly bedded to nodular fossiliferous limestone occur (Cressman, 1973).

Cressman (1973, p. 14) observed that:

> The Cursdville Limestone Member, like the rest of the Lexington Limestone, was deposited in normal marine water as shown by the fauna *** The bioclastic calcarenite and calcirudite, crossbedded in part, which makes up much of the lower 20 feet of the member was formed in a high-energy environment, probably in water above surf base ***; however, the interval also contains beds of calcisiltite, unabraded fossils and articulated pelecypods, all indicative of a low-energy environment. The close interbedding of calcarenite, calcirudite, and calcisiltite resulted from frequent changes or local variations in energy; the most likely explanation of the frequent changes is that the coarser fragments accumulated in small bars whereas finer material was deposited in topographic lows. Migration of the bars would have resulted in interbedding of coarser and finer grained sediments.
>
> The fossiliferous limestone of the upper part of the Curdsville was deposited in slightly deeper water. The currents were sufficient to supply oxygen and food but were not strong enough to break and abrade many of the shells ***
>
> The vertical sequence of rock types in the Curdsville, high-energy shallow-water deposits in the lower part grading to deeper water deposits at the top, record a marine transgression ***

LOGANA MEMBER

The Logana Member ranges from 0 to 50 ft in thickness; it overlies the Curdville Limestone Member and underlies or intertongues with the Grier Limestone Member. Over much of its outcrop area the Logana consists of three major divisions. The lower division is interbedded calcisiltite and shale, the middle division is mostly a brachiopod coquina, and the upper division is calcisiltite and shale similar to the lower division (Cressman, 1973).

Cressman (1973, p. 17) commented as follows on the environment of deposition of the Logana Member:

> *** The Logana Member was deposited during the culmination of the initial transgression of Lexington time, and it accumulated in deeper water than the calcarenite and fossiliferous limestone of the Curdsville Limestone Member below or the fossiliferous limestone of the Grier Limestone Member above. The interbedded calcisiltite and shale accumulated below wave base, as shown by the fine grain size and the absence of current structure ***
>
> The oxygen content of the bottom water was low as evidenced by the paucity of fossils, the absence of animal burrows, and the relatively dark color of both the shale and the limestone; and the sea floor was probably below the compensation depth *** In the present ocean this depth varies greatly, but it ranges from 25 to 45 m in clear coastal waters. At least periodically, though, the oxygen content was sufficient to permit the growth of pelecypods found in some beds ***

GRIER LIMESTONE MEMBER

This member ranges from 100 to 180 feet in thickness. It overlies the Logana or Curdsville Limestone Members and underlies the Perryville Limestone, Brannon, or Tanglewood Limestone Members. The Grier Limestone Member contains a variety of rock types, but the general aspect is of thin and irregularly to nodular-bedded, poorly sorted, abundantly fossiliferous limestone (Cressman, 1973).

In discussing the environment of deposition of this member Cressman (1973, p. 19) noted:

*** The abundance, kind, and state of preservation of the fossils and the poor sorting of the limestone indicate that most of the Grier Limestone Member was deposited in shallow, aerated, only moderately agitated water *** The lenticular and nodular beds very closely resemble structure in recent sediments that are attributed to churning by burrowing organisms *** most of the churning must have been by soft-body organisms.

Currents were sufficient to supply oxygen and food to the large fauna of suspension feeders, distribute crinoid columnals, and winnow some of the carbonate mud, but they were too weak to thoroughly comminute and sort the skeletal debris or to remove all of the lime mud *** Much of the Grier probably accumulated in depths of less than 15 m of water. ***

MACEDONIA BED

This unit has limited extent, where it is developed it is about 115–120 ft above the base of the Grier Limestone Member and is as much as 15 ft thick. The Macedonia Bed consists of argillaceous calcisiltite in even to broadly lensing smooth-surfaced beds 0.2–0.4 ft thick, interbedded with 10–40 percent shale. It is similar to the Logana and Brannon Members and was deposited under similar conditions (Cressman, 1973).

CANE RUN BED

This unit also has limited extent: where it is present it is as much as 5 ft thick and is at the top of the Grier Limestone Member. The Cane Run Bed consists of argillaceous calcilutite and calcisiltite with abundant chert nodules; contorted bedding is common (Cressman, 1973).

PERRYVILLE LIMESTONE MEMBER

This member is as much as 60 ft thick. Cressman (1973, p. 23) described the unit as follows:

*** The Perryville Limestone Member of the Lexington Limestone as used herein, includes those beds between the calcarenite of the Tanglewood below and the interbedded calcisiltite and shale of the Brannon Member above. The nodular fossiliferous limestone at the top is the Cornishville Bed, the interbedded light-gray and brownish-gray calcilutite is the Salvisa Bed, and the fossiliferous brownish-gray calcilutite is the Faulconer Bed. I believe those assignments to be consistent with the original definitions. ***

Cressman (1973, p. 28) discussed the environment of deposition of the Perryville as follows:

*** The depositional environment of the Cornishville Bed was similar to that of the Grier Limestone Member.

Both the Faulconer and Salvisa Beds were deposited in shallow quiet water. Shallow water is suggested by the fauna in the Faulconer and by the light color of much of the Salvisa. The abundant micrite and lack of sorting are evidence of lack of turbulence. The fauna of the Faulconer Bed would have required marine water of approximately normal salinity, but the restricted fauna—ostracodes and gastropods—of most of the Salvisa Bed suggest more saline water.

The Perryville Limestone Member is separated from the temporally equivalent upper half of the Grier Limestone Member to the north by calcarenite. Thus, the shallow quiet water in which the Perryville was deposited was separated from the more agitated water to the north by a zone of calcarenite bars ***

FAULCONER BED

This bed is as much as 40 ft thick and is the basal unit of the Perryville Limestone Member. The Faulconer Bed consists of brownish-gray fossiliferous calcilutite in rough-surfaced beds commonly about 0.5 foot thick. Mollusks are the most conspicuous fossils (Cressman, 1973).

SALVISA BED

This unit is as much as 15 ft thick and is the middle bed of the Perryville Limestone Member. It consists of interbedded light-gray to light-olive-gray calcilutite interbedded with brownish-gray calcilutite. The brownish-gray calcilutite is similar to much of that in the Faulconer, and the Salvisa is characterized by the light-gray type. Beds are smooth surfaced (Cressman, 1973).

CORNISHVILLE BED

This is the top unit of the Perryville; it is as much as 10 ft thick and overlies the Salvisa Bed. It is mostly nodular bedded calcisiltite and fine-grained calcarenite containing abundant brachiopods and a few bryozoans (Cressman, 1973).

BRANNON MEMBER

This member is as much as 30 ft thick; it is underlain by the Perryville Limestone Member and is overlain or interbedded with the Tanglewood Limestone Member or the Sulphur Well Member. The Brannon Member consists of interbedded argillaceous calcisiltite and shale in nearly equal amounts. The calcisiltite is medium to light gray and is generally in smooth-surfaced tabular beds 0.2–0.3 ft thick. The shale is calcareous and is dark to medium gray in fresh exposures. Fossils are sparse in their occurrence. The uppermost beds of the Brannon Member are commonly contorted (Cressman, 1973).

Cressman (1973, p. 37) wrote of the depositional environment and noted that it was similar to that of the Logana Member. He suggested "that the depth of the water was mostly below wave base and below the compensation depth which is assumed to have been about 25 m. Periods of greater turbulence winnowed fine bioclastic debris from shallower areas, and the winnowed material was deposited in the deeper water to form the calcilutites."

SULPHUR WELL MEMBER

This member is as much as 35 ft thick and is bryozoan limestone in irregular to lenticular beds that are separated by thin shale beds and partings. The limestone is mostly poorly sorted bryozoan calcirudite containing much silt- and clay-sized calcite and dolomite matrix. The shale contains closely packed bryozoan fragments (Cressman, 1973). The Sulphur Well Member is underlain by the Brannon, Perryville Limestone, Grier Limestone, or Tanglewood Limestone Members and is overlain by the Clays Ferry Formation.

Cressman (1973, p. 37) discussed the environment of deposition of the Sulphur Well Member: "The Sulphur Well Member was deposited under conditions similar to those described for the Grier Limestone Member. It accumulated below surf base, mostly at depths of less than 15 m, in moderately turbulent normal marine water. It is uncertain what environmental factors caused the great abundance of bryozoans."

STAMPING GROUND MEMBER

This unit is as much as 15 ft thick. Lithologically it is similar to the Millersburg Member and the Greendale Lentil, being composed of fossiliferous nodular limestone and shale. The Stamping Ground Member is stratigraphically lower than the Millersburg Member and is both underlain and overlain by calcarenite of the Tanglewood Limestone Member. The depositional environment was similar to that of the Millersburg Member (Cressman, 1973).

GREENDALE LENTIL

This unit is 10–15 ft in thickness. Lithologically it is similar to the Millersburg Member consisting of irregularly bedded to nodular fossiliferous limestone and shale. About 75 percent of the unit is limestone and 25 percent is shale. However, the Greendale Lentil is not continuous with the Millersburg Member; it grades laterally in all directions into the Tanglewood Limestone Member (Cressman, 1973).

DEVILS HOLLOW MEMBER

This member ranges from 0 to 30 ft in thickness. It overlies or is interbedded with the Tanglewood Limestone Member and underlies the Millersburg Member. It consists of two distinctive lithologies, a coquina phase and a fine-grained phase. At the type locality the lower part consists of porous coarsely crystalline light-gray massive limestone containing a crowded mass of gastropod shells overlain by compact limestone (calcilutite) similar to that of the Tyrone Limestone and containing ostracodes. These two rock types intertongue, and the member may consist locally entirely of the calcilutite, entirely of the gastropod coquina, or of both types (Cressman, 1973).

Cressman (1973, p. 41) noted that:

> *** The calcilutites of the Devils Hollow Member *** were deposited at depths of less than a few meters in quiet protected waters of relatively high salinity. The association of gastropodal calcirudite with the calcilutite suggests an intertidal environment that had extensive algal mats on which gastropods fed; but I have seen no mudcracks or intraformational breccias, and most of the laminated beds do not closely resemble those known to be of algal origin. Therefore, the calcilutite probably accumulated as very shallow subtidal banks as pelletal lime mud and fossil debris *** The gastropodal calcirudite probably accumulated on beaches or possibly in channels between banks. The areal distribution of the Devils Hollow Member indicates that the sediments formed a narrow *** lagoon ***

MILLERSBURG MEMBER

This member ranges from 0 to 90 ft thick; it overlies and intertongues with the Tanglewood Limestone Member. The Millersburg is characterized by nodular bedding of the limestone, abundant whole and broken fossils, silt- and clay-sized carbonate matrix, and abundant shale (Cressman, 1973).

In discussing the environment of deposition of this member Cressman (1973, p. 43) observed:

> *** The abundance of unbroken fossils, poor sorting, the abundance of lime mud, and the large amount of shale suggest that most of the Millersburg was deposited in water of only moderate turbulence. The abundance of fossils suggests that much of the Millersburg *** was formed at depths of less than 15 m.
>
> The abundance of shale, as compared with the small amount in the otherwise similar fossiliferous limestone facies, may have resulted from a larger supply of mud in later Lexington time ***
>
> The nodular structure typical of the Millersburg Member resulted from burrowing by a dominantly soft-bodied infauna ***

STRODES CREEK MEMBER

This member is as much as 30 ft thick and is probably a lens within the Millersburg Member. It is readily recognized by its bouldery aspect attributable to a combination of pinch-and-swell bedding, ball and pillow structure, and bulbous stromatoporoids. The rock is chiefly limestone with minor amounts of gray to reddish-brown fissile shaly argillaceous calcisiltite as partings and in places as beds. The dominant limestone type is moderate-grayish-brown to gray dense nonfissile rock having the textural characteristics of a mudstone. It is composed mostly of clay- and silt-sized calcite particles and commonly contains disseminated rounded medium-to coarse-sand-sized fossil fragments; fractured surfaces are smooth and subconchoidal (Black and Cuppels, 1973).

Black and Cuppels (1973) compare the lithology of the Strodes Creek Member to that of the Faulconer Bed of the Perryville Limestone Member and part of the Devils Hollow Member; it may have developed in a similar depositional environment.

TANGLEWOOD LIMESTONE MEMBER

In general this member is between 60 and 100 feet thick, it is an extensive irregular body of bioclastic calcarenite that makes up much of the upper part of the Lexington Limestone. The Tanglewood Limestone Member typically consists of pinkish-gray medium-grained well-sorted bioclastic calcarenite. Beds are mostly 0.2–1 ft thick and are generally smooth surfaced and planar to wavy. Many beds contain alternating more or less phosphatic laminae from less than 1 to 5 mm thick. Low-angle, small- to medium-scale crossbedding is common (Cressman, 1973).

Cressman (1973, p. 31) commented on the environment of deposition:

> *** The broken and rounded skeletal fragments, the generally good sorting, the abundant sparry calcite cement, the lack of clay and silt, and the common crossbedding all indicate that the bioclastic calcarenite of the Tanglewood Limestone Member was deposited in very shallow, turbulent water *** The organic material was brought in from elsewhere—presumably from less agitated water where the Grier Limestone and Millersburg Members were accumulating —and was broken, abraded, and sorted in the area of the calcarenite deposition ***

NICHOLAS BED

This name is applied to the upper tongue of the Tanglewood Limestone Member north and northeast of Lexington, Ky. The unit is as much as 80 ft thick and cannot be distinguished lithologically from the rest of the member (Cressman, 1973).

MIAMITOWN SHALE [4]

This formation was proposed by Ford (1967); it is as much as 35 ft thick in Ohio but is not distinguishable in northern Kentucky. Ford (1967, p. 931) defined the unit as follows:

> *** The name Miamitown Shale is proposed here for the thin shale that overlies the Fairview Formation. It consists of shale and mudstone with a few thin, widely spaced limestone interbeds. The limestone contains a high proportion of terrigenous detritus and a diagnostic gastropod-pelecypod faunal assemblage *** Nodular bedding is common *** Lithologically the Miamitown Shale represents a return to conditions of Kope deposition. ***

[4] Miamitown Shale of Ford (1967) herein adopted for U.S. Geological Survey usage.

OREGON FORMATION

The Oregon Formation overlies the Camp Nelson Limestone and is as much as 60 ft thick. The formation is characterized by finely crystalline calcareous dolomite (Cressman, 1973). See High Bridge Group.

TYRONE LIMESTONE

The Tyrone Limestone overlies the Oregon Formation and ranges from 60 to 100 ft in thickness. The Tyrone is typically calcilutite, though in places it contains much interlaced dolomite. Mud cracks occur throughout the formation (Cressman, 1973). See High Bridge Group.

WHITEWATER FORMATION

This unit is as much as 85 ft thick and forms the top of the Ordovician sequence in southeastern Indiana; it overlies the Saluda Formation. Brown and Lineback (1966) defined the formation as follows:

> *** A variety of limestone types interbedded with calcareous shale constitutes the Whitewater. Among the limestone types are thin-bedded fossiliferous argillaceous limestone, thin-bedded ostracodal limestone, medium-bedded relatively unfossiliferous limestone, medium-bedded limestone with burrows, and rubbly weathering argillaceous limestone. In general, the Whitewater contains more limestone than most parts of the Cincinnatian below the Saluda.***

Fox (1962, p. 640) commented on the depositional environment of the Whitewater Formation:

> "*** Earthy limestone members of the Whitewater were laid down on submerged, calcareous, mud flats analogous to those west of Andros Island on the Bahama Banks."

MIDDLE ORDOVICIAN-UPPER ORDOVICIAN BOUNDARY

Between 1959 and 1974, faculty and students at the Ohio State University Department of Geology, along with colleagues at other institutions, have produced a 19-part study of the American Upper Ordovician Standard sequence of rocks (Cincinnatian Series) exposed in southwestern Ohio and adjacent states (Sweet and others, 1959; Weiss and Norman, 1960a, b; Pulse and Sweet, 1960; Weiss, 1961; Carpenter and Ory, 1961; Weiss and others, 1965; Osborne, 1967, 1968, 1969, 1970, 1971a, b; 1973; Kohut and Sweet, 1968; Sweet and Bergström, 1971; Booth and Osborne, 1971; Lobo and Osborne, 1973; and Sweet and others, 1974). This study by Ohio State University has largely concentrated on the conodont biostratigraphy and the sedimentary petrology of the Cincinnatian rocks, but has also dealt with lithostratigraphy and environmental interpretations of the rocks.

Because the Cincinnatian Series is the American Upper Ordovician Standard, any rocks that can be correlated with this standard are by definition Late Ordovician in age. The Cincinnatian Series is divided into three stages, Edenian, Maysvillian, and Richmondian in ascending order. In central Kentucky and along the Ohio River are surface exposures of rocks older than Edenian, and it is a matter of deciding where the Middle Ordovician-Edenian boundary falls in these areas.

Except for conclusions drawn from conodonts (Bergstrom and Sweet, 1966; Sweet and Bergstrom, 1971; Ethington and Sweet, 1977; Sweet, herein), little has been published in recent years about the age of the Ordovician rocks below the Edenian in the area of study. Bucher, Caster, and Jones (1939) placed the Mohawkian-Cincinnatian (Middle Ordovician-Upper Ordovician) boundary at Cincinnati, Ohio, at the top of the Point Pleasant or River Quarry Beds, which they placed in the "Cynthiana Formation." The base of their Edenian was the *Triarthrus* fauna of the Fulton Beds in what they called the "Utica Formation." Their Mohawkian-Cincinnatian boundary is essentially equivalent to the Middle Ordovician-Upper Ordovician boundary as used by earlier workers (Weiss and Norman, 1960a). Although Caster, Dalve, and Pope (1955, 1961) included the Point Pleasant in the Cincinnatian Series (Upper Ordovician), they did not assign this formation to any stage. They did indicate that Point Pleasant beds were older than Edenian, and that they belonged to the "Cynthiana Formation."

Twenhofel and others (1954, correlation chart, column 45) placed all of the Ordovician rocks of southwestern Ohio, northern Kentucky, and southeastern Indiana in the Cincinnatian Series and regarded all of them as Late Ordovician in age. They placed what they called the "Cynthiana Formation" of this area in the Edenian (early Late Ordovician) Stage. These same workers (correlation chart, column 44) regarded what they called the "Cynthiana Limestone" of central Kentucky as crossing the Middle Ordovician-Upper Ordovician boundary. The name "Cynthiana Formation" is no longer used by the U.S. Geological Survey (Cressman, 1973). The beds exposed along the Ohio River formerly assigned to this unit are now placed in the Point Pleasant Tongue of the Clays Ferry Formation. In central Kentucky the name "Cynthiana Formation" was used for rocks now placed in the lower part of the Clays Ferry Formation and upper part of the Lexington Limestone.

Bergstrom and Sweet (1966), Karklins (in Cressman and Karklins, 1970), and Sweet and Bergstrom (1970) showed that the upper part of the Lexington Limestone at its reference section in central Kentucky correlates with the Edenian-age rocks exposed around Cincinnati, Ohio. Sweet and Bergstrom (1970) suggested that south of Frankfort, Ky., and near Clays Ferry, Ky., the upper 70–80 feet of the Lexington Limestone correlate with the lower 70–80 feet of the Kope Formation at Cincinnati, Ohio, and are thus Edenian in age. They noted (1970, p. 242): "* * * [that] southeastward from Cincinnati the contacts between lithic units rise with respect to those between conodont-biostratigraphic units." Karklins (in Cressman and Karklins, 1970, p. 21) indicated that bryozoans of Upper Ordovician aspect occur as low as the upper part of the Brannon Member of the Lexington at the reference section of the latter formation. As indicated by Cressman (1973) this is approximately 100 ft below the top of the Lexington Limestone.

Sweet and Bergstrom (1971) summarized all of the recent biostratigraphic information available on the Middle Ordovician-Upper Ordovician boundary in the area of study, particularly with reference to the Kope Formation, Lexington Limestone, and Clays Ferry Formation, all of which are at or cross this boundary. Their figure 2 (1971, p. 616) summarized their conclusions of the ages of the formations throughout the area of this work. In central Kentucky both the Lexington Limestone and the Clays Ferry Formation cross the Middle Ordovician-Upper Ordovician boundary, although toward the southeast the Lexington Limestone is entirely Middle Ordovician in age. The Point Pleasant Tongue of the Clays Ferry and the Kope Formation are not shown to be older than Edenian (early Late Ordovician), although the Kope Formation ranges upward into Maysvillian time (middle Late Ordovician). Sweet (1979) (fig. 3) indicates that the Point Pleasant Tongue crosses the Middle Ordovician-Upper Ordovician boundary. Thus, all rock units above the Kope Formation, Point Pleasant Tongue of the Clays Ferry Formation, Clays Ferry Formation, and much of the Lexington Limestone are Late Ordovician in age. For outcrops of the Clays Ferry Formation, its Point Pleasant Tongue, and the Lexington Limestone, it is necessary to determine where the boundary is, although the general picture is that the top of the

Lexington Limestone (bottom of the Clays Ferry Formation)

*** becomes younger southeastward from the northwestern part to the center of the Cincinnati Region, then older toward the southeastern part of the area of exposure. These correlat'ons also indicate that, in the central Cincinnati Region *** Frankfort Lexington-Cynthiana, Kentucky, area *** and at least as far northeast as southern Clermont County, Ohio *** the uppermost 21 to 24 m of the Lexington Limestone is Edenian in age, for this part of the Lexington correlates very well with the lower 21 to 24 m of the Kope Formation at Cincinnati *** and the Kope Formation in Cincinnati is the reference standard for the North American Edenian Stage *** (Sweet and Bergström, 1971, p. 619). The lower part of the Lexington Limestone and all rock units below it are Middle Ordovician in age.

OTHER BIOSTRATIGRAPHIC BOUNDARIES

Sweet and Bergström (1971) indicated that the top of the Shermanian Stage of New York is at essentially the same stratigraphic level as the bottom of the Edenian Stage of Ohio, Indiana, and Kentucky and that much of the classical Trentonian Stage overlaps the basal Cincinnatian Series. They suggested (p. 624) that the Shermanian-Edenian boundary be used as the boundary between the Champlainian and Cincinnatian Series, that is as the Middle Ordovician-Upper Ordovician boundary. They further recommended that the upper Champlainian and Cincinnatian Series be divided into six stages: Rocklandian, Kirkfieldian, Shermanian, Edenian, Maysvillian, and Richmondian in ascending order. In 1974 (p. 194), Sweet and Bergström indicated that for the stage below the Rocklandian the name Blackriveran be maintained.

In the interval from the Blackriveran through the Richmondian Sweet and others (1971) and Sweet and Bergström (1974) recognized their conodont faunas 7 through 12 based on the North American midcontinent sequence. In the same interval, Bergstrom (1971) and Sweet and Bergström (1974) recognized three conodont zones based on the Appalachian and European sequences. Sweet and Bergström (1971, fig. 2) placed the Middle Ordovician portion of the Lexington Limestone in the Kirkfieldian and Shermanian Stages. Thus, the Lexington Limestone ranges in age from Kirkfieldian to Edenian and contains conodont faunas 9 to 11 of Sweet and others (1971) and Sweet and Bergström (1974); it is late Middle and early Late Ordovician in age.

The conodonts of rocks below the Lexington Limestone have been little studied to date, and Sweet and Bergström (1971) did not assign any of the High Bridge Group to a particular stage; they merely indicated that it is pre-Kirkfieldian in age and that the Tyrone Limestone is separated from the Lexington Limestone by an unconformity. Cressman (1973, p. 12, 13) discussed the disconformity between the Tyrone Lmestone and the Curdsville Limestone Member of the Lexington Limestone and came to the conclusions that little or none of the Curdsville could be the time equivalent of the uppermost part of the Tyrone, and that the Tyrone-Lexington disconformity probably does not indicate any great interval of time. Twenhofel and others (1954) placed the Camp Nelson Limestone in the Blackriveran Stage and correlated the Oregon Formation and Tyrone Limestone with the Rockland Limestone of New York State usage. Cooper (1956) placed the High Bridge Group in the Wildernessian correlating it with the Rockland and Hull Limestones of New York State and Ontario, Canada. Sweet (1979) (fig. 3) places the Tyrone Limestone in the Kirkfieldian Stage.

In summary, based largely on the work of Sweet and Bergström (1971, fig. 2; and Sweet, 1979, fig. 3) the outcropping formations in the area of study can be assigned to the following Middle and Upper Ordovician stages. The High Bridge Group forms the oldest part of the succession and is probably Blackriveran, Rocklandian, and Kirkfieldian in age; a disconformity marks the top of the High Bridge Group, but it probably does not represent a significant time gap. The Lexington Limestone ranges in age from Kirkfieldian to Edenian. The Clays Ferry Formation including the Point Pleasant Tongue ranges in age from Shermanian to Edenian. The Kope Formation at Cincinnati, Ohio, is entirely Edenian in age, although east and west of this city the upper part of the Kope is Maysvillian in age. The Garrard Siltstone may span the Edenian-Maysvillian boundary, although Sweet (1979) (fig. 3) regards it as Edenian in age. The Calloway Creek Limestone is entirely Maysvillian in age as is the Fairview Formation throughout most of its outcrop; the lower part of the latter unit is Edenian in age near Cincinnati, Ohio. The Grant Lake Limestone is largely Maysvillian in age, although near Maysville, Ky., the upper part of this unit is Richmondian in age. The Dillsboro Formation ranges in age from Maysvillian to Richmondian. The Saluda Formation, Whitewater Formation, Bull Fork Formation, and Drakes Formation are all Richmondian in age. The Ashlock Formation is Maysvillian and Richmondian in age.

MATERIALS AND METHODS

The bulk of the fossils described here are from nearly 1,100 collections made between 1961 and 1972.

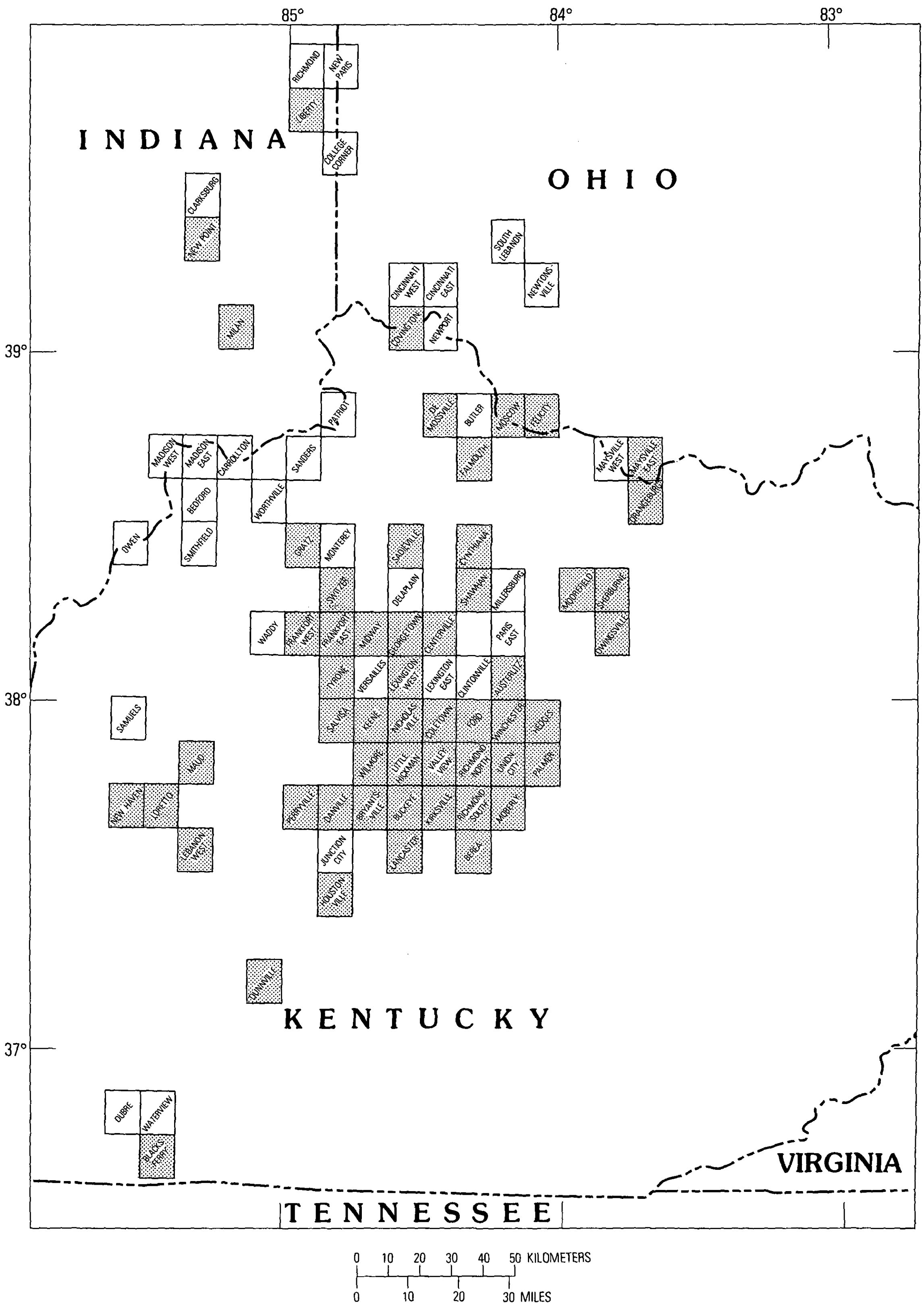

FIGURE 3.—Index to 7.5-minute quadrangles in the study area from which fossil collections were made. Pattern indicates quadrangles whose collections are discussed in chapters of this report.

About 30 of these collections are from Ohio and Indiana, the rest being from the State of Kentucky. Altogether, collections were made from 87 7.5-minute quadrangles (fig. 3). Although all Ordovician formations in the tristate area of Kentucky, Ohio, and Indiana were sampled for fossils, the bulk of the collections represent three rock units: High Bridge Group, 92 collections; Clays Ferry Formation, 186 collections; and Lexington Limestone, 519 collections. Only those collections specifically cited in the paleontological chapters of this report are listed in the locality register.

Early in the collecting program it was discovered that silicification of fossils is widespread in the Ordovician rocks of Kentucky, and the bulk of the megafossils described is from over 200 collections having silicified fossils; whether or not a collection contained silicified fossils is noted in the locality register. Although each formation in the area of outcrop was examined for the presence of silicified fossils, most of the silicified specimens are from the Lexington Limestone, which has the most widespread silicification both stratigraphically and geographically. Altogether nearly 36,000 pounds of limestone containing silicified fossils was collected. From the High Bridge Group we collected 4,576 pounds of limestone containing silicified fossils from 25 localities. There were 116 collections, totalling 22,261 pounds, from the Lexington Limestone containing silicified fossils. From the rock units above the Lexington Limestone we had 64 collections, totaling 8,875 pounds, which contained silicified fossils. After preparation, about 180,000 specimens of silicified fossils were available for study; these included sponges, solitary and colonial corals, bryozoans, brachiopods, bellerophonts, other monoplacophorans, cephalopods, gastropods, pelecypods, polyplacophorans, scaphopods, hyoliths, cornulitids, ostracodes, trilobites, asteroids, "carpoids," crinoids, edrioasteroids, other echinoderms, and receptaculitids. The three most abundant groups in numbers of specimens were: brachiopods, nearly 90,000 specimens; mollusks, more than 55,000 specimens; and bryozoans, nearly 19,000 specimens.

It took a great deal of time to acid etch the large volume of rock involved and to sort and pick the specimens once they were released from the matrix. The techniques used to free silicified fossils from the limestone were largely those developed by G. A. Cooper and R. E. Grant, of the National Museum of Natural History, in their work on the silicified Permian faunas of west Texas (Cooper and Whittington, 1965).

The first large-scale acid etching of Kentucky Ordovician limestones was done by R. B. Neuman of the U.S. Geological Survey in the early 1960's. In 1965, E. L. Yochelson of the U.S. Geological Survey and I sampled numerous Ordovician localities in the inner Blue Grass region of Kentucky to determine the extent and quality of the silicification of the Ordovician fossils of the area. The results of these preliminary samplings indicated that large numbers of whole well-silicified fossils could be obtained from the Ordovician rocks of Kentucky. From 1966 through 1972 the bulk of the 36,000 pounds of rock was collected and processed in the laboratory.

After identifying a bed containing silicified fossils in the field one has to pry out the largest blocks of limestone possible to insure a maximum number of whole specimens for study. After the Ordovician blocks were collected, they were wrapped in newspaper, placed in burlap sacks, and shipped to the laboratory by motor freight as broken rock. After the blocks of limestone arrived at the laboratory, the first step in processing them was to wash and weigh them. After weighing, the underside of the blocks were coated with an acid-proof resin so that upon etching in acid the blocks would only etch from the top down and the sides in. If a block were also to etch from the bottom up eventually a central core of limestone would remain, resting on fragile silicified fossils below; such a core could collapse and crush the fossils below it.

Once the resin was dry, the blocks of limestone were placed in acid-impervious vats of appropriate size on a screen made of Monal Metal or plastic. The screen allowed clay- and sand-sized particles to be washed through it; as fossils etched free from the matrix they collected on the screen and could be removed en masse by lifting the screen from the vat. Ordinarily the screen was placed on top of 1-inch-thick granite slabs so that the fine insoluble particles released by the etching would not bury the base of the limestone block and stop the etching process. Once the block of limestone was on the screen and granite slabs, the block was covered with water and enough acid was added to create about a 10-percent solution of commercial-grade hydrochloric (muriatic) acid.

Most of the acid etching was done with commercial-grade hydrochloric acid, because it is relatively cheap and can be readily obtained. However, the smaller collections and a sample (usually 25 pounds) of larger collections were etched in commercial-grade glacial acetic acid to preserve the fossils composed of calcium phosphate. For the first 14,097 pounds of rock etched, we used 2,416 American gallons of acid (2,137 gallons of hydrochloric acid and 279 gallons of acetic acid); this gives an average yield of about 6 pounds of rock per gallon of full-strength acid.

Once the limestone matrix was etched away, the screen on which the free silicified fossils rested was removed from the vat. Sometimes it was necessary to slide plexiglass or masonite under the screen to prevent it from collapsing from the weight of the silicified fossils and crushing some of the specimens. After a time it became standard practice to place the plexiglass or masonite under the screen before etching of the block began. If there were a significant component of clay-sized particles in the block being etched, these tended to coat the surface being etched and inhibit or stop the etching process. The clay was difficult to remove without damaging specimens already partially freed from the matrix. Sometimes the clay particles could be successfully removed with careful scraping or brushing or with a gentle spray of water. Blocks with a significant clay or silt content were difficult to prepare and took considerably longer to etch to completion than did blocks which lacked these particle sizes.

After the matrix was completely etched away, the screen with the silicified fossils was removed from the acid vat, and residual acid on the specimens washed away. This was done in a tank of slowly running water in which the specimens and the screen were completely immersed; ordinarily collections were left washing in the tank overnight. One could readily determine if all of the residual acid had been washed away by the odor of the sample, by an olive-green color which developed on drying specimens which still had residual hydrochloric acid, or by the growth of calcium acetate crystals on specimens etched in acetic acid. Once all of the residual acid was washed away, the screen with the silicified specimens was allowed to dry; ordinarily our specimens were air dried, but various types of heated compartments can be constructed to speed the drying process. It is critically important that specimens be completely dried before they are picked and sorted or handled in any way. The specimens are far stronger and weigh less when dry than when wet.

Sometimes when a screen was removed from a vat after dissolution of the matrix, the specimens would be covered or buried in sediment of fine particle size. This clay- and silt-size sediment must be removed before drying the specimens; otherwise the sediment would harden around the specimens and it would not be possible to remove them from the screen. The easiest and quickest way to remove this fine sediment was to slowly wash it through the screen with a gentle spray or stream of water, taking care that the stream of water was not so strong as to damage the specimens.

The length of time it takes to acid etch a sample is a function of the type of acid being used, the size of the block being etched, and the amount of clay and silt in the sample. Hydrochloric acid is cheaper and works more rapidly than does acetic or monochloracetic acid, but it destroys the phosphatic fossils. Formic acid combines the best features of the above acids, but is more expensive than acetic acid, and is highly corrosive to flesh; great care must be taken in handling formic acid. The smaller the block being etched, the greater its surface area to its volume and the faster it will etch. However, the smaller the block the fewer specimens it will contain and all those along the broken edges of the block will not be whole. As mentioned above, sediment of fine particle size will adhere to the surface being etched and inhibit or completely prevent the acid from reaching the calcium carbonate. When effervescence stops, because the acid in the vat has been used up, it is not sufficient to simply add more acid. Calcium chloride buildup in the solution (or impurities in commercial-grade acids) will eventually prevent the reaction. After the acid has been used up it is necessary to siphon off the brine and then add fresh water and acid.

Once the sample is dry, the insoluble residue must be removed from the screen. For fossils which are too large to be handled with a camel's-hair brush, it is best to use a pair of tweezers made from watch spring, which allow a gentle but firm hold at their tips. At the time the specimens are picked from the screen it is also best to sort them biologically. At this point it may also be desirable to harden the fossils with a solution of an acetone-soluble resin. Hardening decreases the fragility of the specimens; it is accomplished by dipping the specimens into the solution, placing them on a paper towel, and allowing them to air dry. To reduce the acetone fumes, this procedure is best done in a chemical hood. The procedures should be used with very fragile material, but many specimens, if handled carefully, do not require hardening. A point to consider is that hardening of the fossils sometimes produces a surface sheen that makes them difficult to photograph.

Throughout the acid-etching process one is dealing with potentially injurious chemicals and care must be taken to have the basic safety equipment of any chemical laboratory: it is absolutely essential to have adequate ventilation for the etching and hardening processes, to have and use safety goggles and rubber aprons and gloves, and to have and maintain a shower with a strong stream of water in the laboratory.

LOCALITY REGISTER

Although fossils were collected from nearly 1,100 localities, this register includes information on only the 317 localities from which the specimens described in the paleontological sections of this report were collected. The 317 localities occur in 55 quadrangles; most of these are in the State of Kentucky, although some of them span the Kentucky-Ohio border, and three quadrangles are entirely in the State of Indiana (fig. 3).

The localities are arranged sequentially by the collection number assigned to each in the U.S. Geological Survey register of Cambrian and Ordovician localities (-CO). This sequence is also approximately the order in which the collections were made between 1961 and 1972. The letter D before a collection number indicates that this number is entered in the U.S. Geological Survey Cambrian and Ordovician locality register kept in Denver, Colo. All other collections are entered in the USGS Cambrian and Ordovician locality register kept in Washington, D.C. An asterisk after a collection number indicates that the locality is published on a 1:24,000-scale geologic quadrangle map of the area where the collection was made.

I have indicated each locality geographically and with a set of coordinates. The coordinates are given in millimeters, measured first east and then north from the lower left corner of the 1:24,000 quadrangle map on which the locality occurs. Thus, locality 4072–CO is 153 mm east of the southwest corner of the Tyrone, Ky., quadrangle and 99 mm north of the 153 mm mark. In addition to the locality information, the following data are provided for each collection: the formation or member from which the collection was made, any available data on the stratigraphic position of the collection within the formation or section being collected, whether or not the collection was silicified, the weight (where known) of each silicified collection, and the name of the quadrangle in which the collection was made. A number of the collections are from measured sections that have been designated by names and numbers; where such data are available they are listed. The names and numbers of all measured sections are kept at the USGS offices in Lexington, Ky.

Collection number -----4072–CO*.
Geographic location ----Proceed east 0.75 mi from Milner, Ky., and turn right (southwest) on Shryock Ferry Road. Continue down Shryock Ferry road about 1 mi. to top of section .
Coordinates -----------153 mm east, 99 mm north (base of section at 134 mm east, 87 mm north).
Formation ------------Grier Limestone Member, Lexington Limestone.
Stratigraphic position --154 ft above the base of the Curdsville Limestone Member, Lexington Limestone.
Silicified --------------Yes
Quadrangle name ------Tyrone, Ky.
Section name ---------Tyrone A.
Section number --------89.

Collection number -----4073–CO*.
Geographic location ----The same as for 4072–CO.
Coordinates ----------- Do.
Formation ------------Grier Limestone Member, Lexington Limestone.
Stratigraphic position --148 ft above the base of the Curdsville Limestone Member, Lexington Limestone.
Silicified --------------Yes (1,160 lbs).
Quadrangle -----------Tyrone, Ky.
Section name ----------Tyrone A.
Section number --------89.

Collection number -----4075–CO*.
Geographic location ----The same as for 4072–CO.
Coordinates ----------- Do.
Formation ------------Grier Limestone Member, Lexington Limestone.
Stratigraphic position --133 ft above the base of the Curdsville Limestone Member, Lexington Limestone.
Silicified --------------Yes.
Quadrangle -----------Tyrone, Ky.
Section name ----------Tyrone A.
Section number --------89.

Collection number -----4122–CO*.
Geographical location --The same as for 4072–CO.
Coordinates -----------134 mm east; 87 mm north.
Formation ------------Curdsville Limestone Member, Lexington Limestone.
Stratigraphic position --16 ft above the base of the Curdsville Limestone Member, Lexington Limestone.
Silicified --------------Yes.
Quadrangle -----------Tyrone, Ky.
Section name ----------Tyrone A.
Section number --------89.

Collection number -----4123–CO*.
Geographic location ----The same as for 4072–CO.
Coordinates -----------The same as for 4122–CO.
Formation ------------Curdsville Limestone Member, Lexington Limestone.
Stratigraphic position --12 ft above the base of the Curdsville Limestone Member, Lexington Limestone.
Silicified --------------Yes.

Quadrangle ------------Tyrone, Ky.
Section name ----------Tyrone A.
Section number --------89.

Collection number -----4124-CO.
Geographic location ----From east side of Blackburn Memorial Bridge crossing of Kentucky River take first road north toward Kentucky Utilities Plant; section in railroad and road exposures.
Coordinates -----------108 mm east, 197 mm north (road exposures).
Formation ------------Logana Member, Lexington Limestone.
Stratigraphic position --12 ft above base of Logana Member, Lexington Limestone
Silicified --------------Yes.
Quadrangle ------------Tyrone, Ky.
Section name ----------Tyrone C.
Section number --------174.

Collection number -----4125-CO.
Geographic location ----The same as for 4124-CO.
Coordinates ----------- Do.
Formation ------------Logana Member, Lexington Limestone.
Stratigraphic position --7 ft above base of Logana Member, Lexington Limestone.
Silicified --------------Yes.
Quadrangle ------------Tyrone, Ky.
Section name ----------Tyrone C.
Section number --------174.

Collection number -----4178-CO*.
Geographic location ----Road and creek exposures across the Kentucky River from the termination of Kentucky Route 595.
Coordinates -----------36 mm east, 274 mm north (base of section at 54 mm east, 246 mm north).
Formation ------------Sulphur Well Member, Lexington Limestone.
Stratigraphic position --188 ft above the base of the section.
Quadrangle name ------Valley View, Ky.
Section name ----------Valley View B (Hunters Ferry Road).
Section number --------34.

Collection number -----4179-CO*.
Geographic location ----The same as for 4178-CO.
Coordinates ----------- Do.
Formation ------------Sulphur Well Member, Lexington Limestone.
Stratigraphic position --187 ft above the base of the section.
Quadrangle name ------Valley View, Ky.
Section name ----------Valley View B (Hunters Ferry Road).
Section number --------34.

Collection number -----4180-CO*.
Geographic location ----The same as for 4178-CO.
Coordinates ----------- Do.
Formation ------------Sulphur Well Member, Lexington Limestone.
Stratigraphic position --186 ft above the base of the section.
Quadrangle name ------Valley View, Ky.
Section name ----------Valley View B (Hunters Ferry Road).
Section number --------34.

Collection number -----4184-CO*.
Geographic location ----The same as for 4178-CO.
Coordinates ----------- Do.
Formation ------------Brannon Member, Lexington Limestone.
Stratigraphic position --180 ft above the base of the section.
Quadrangle name ------Valley View, Ky.
Section name ----------Valley View B (Hunters Ferry Road).
Section number --------34.

Collection number -----4191-CO*.
Geographic location ----The same as for 4178-CO.
Coordinates -----------54 mm east, 262 mm north.
Formation ------------Grier Limestone Member, Lexington Limestone.
Stratigraphic position --104 ft above the base of the section.
Silicified --------------Yes.
Quadrangle name ------Valley View, Ky.
Section name ----------Valley View B (Hunters Ferry Road).
Section number --------34.

Collection number -----4194-CO*.
Geographic location ----Kentucky Route 52, 0.75 mi south of crossing with Taylor Fork.
Coordinates -----------220 mm east, 400 mm north.
Formation ------------Back Bed, Tate Member, Ashlock Formation.
Silicified --------------Yes.
Quadrangle name ------Richmond South, Ky.

Collection number -----4195-CO*.
Geographic location ----U.S. Route 25 crossing of Dog Branch of Silver Creek, 3.7 mi south of junction of U.S. Routes 25 and 421.
Coordinates -----------362 mm east, 36 mm north.
Formation ------------Stingy Creek Member, Ashlock Formation.
Stratigraphic position --Near base of Stingy Creek Member.
Silicified --------------Yes.
Quadrangle name ------Richmond South, Ky.
Section name ----------Dog Branch Section.

Collection number -----4197-CO*.
Geographic location ----Roadcut on Kentucky Route 52 near crossing of Old Town Branch, 0.5 mi northeast of Caleast, Ky.
Coordinates -----------182 mm east, 327 mm north,
Formation ------------Calloway Creek Limestone.
Stratigraphic position --40 ft above the top of the Garrard Siltstone.
Silicified --------------Yes.
Quadrangle name ------Richmond South, Ky.

Collection number -----4208-CO.
Geographic location ----U.S. Route 150 along west bluff of Beech Fork northwest of Fredericktown, Ky.

Coordinates ....Base of section at 81 mm east; 61 mm north.
Formation ....Upper tongue of the Grant Lake Formation.
Stratigraphic position ..133 ft below the base of the Brassfield Dolomite (Silurian).
Silicified ....Yes.
Quadrangle ....Maud, Ky.

Collection number .....4209–CO.
Geographic location ....The same as for 4208–CO.
Coordinates .... Do.
Formation ....Tate Member, Ashlock Formation.
Stratigraphic position ..158 ft below the base of the Brassfield Formation (Silurian).
Silicified ....Yes.
Quadrangle ....Maud, Ky.

Collection number .....4210–CO.
Geographic location ....The same as for 4208–CO.
Coordinates .... Do.
Formation ....Tate Member, Ashlock Formation.
Stratigraphic position ..167 ft below base of the Brassfield Dolomite (Silurian).
Silicified ....Yes.
Quadrangle ....Maud, Ky.

Collection number .....4211–CO.
Geographic location ....Kentucky Route 605 3 mi south of junction with U.S. Route 150.
Coordinates ....356 mm east, 520 mm north.
Formation ....Upper part of Grant Lake Limestone.
Stratigraphic position ..99 ft below the base of the Brassfield Formation (Silurian).
Silicified ....Yes.
Quadrangle ....Loretto, Ky.

Collection number .....4213–CO*.
Geographic location ....Creek exposure 0.55 mi south of Kentucky Route 169, 1.35 mi east of Nicholasville, Ky.
Coordinates ....322 mm east, 23 mm north.
Formation ....Curdsville Limestone Member, Lexington Limestone.
Stratigraphic position ..3 ft below Curdsville Limestone Member-Logana Member contact.
Quadrangle name .....Nicholasville, Ky.

Collection number .....4464–CO*.
Geographic location ....1.2 mi east and 1 mi south of the northwest corner of the Union City quadrangle, Kentucky.
Coordinates ....83 mm east, 513 mm north.
Formation ....Back Bed, Tate Member, Ashlock Formation.
Silicified .... Yes.
Quadrangle name ......Union City, Ky.

Collection number .....4465–CO*.
Geographic location ....1.3 mi north and 3.1 mi west of the southeast corner of the Union City quadrangle, Kentucky.
Coordinates ....248 mm east, 87 mm north.
Formation ....Preachersville Member, Drakes Formation.
Quadrangle name ......Union City, Ky.

Collection number .....4466–CO.
Geographic location ....7,200 ft south and 9,700 ft east of the northwest corner of the Union City quadrangle, Kentucky.
Coordinates ....124.5 mm east, 485 mm north.
Formation ....Reba Member, Ashlock Formation.
Quadrangle ....Union City, Ky.

Collection number .....4467–CO*.
Geographic location ....0.4 mi east and 0.85 mi south of the northwest corner of the Palmer quadrangle, Kentucky.
Coordinates ....28 mm east, 517 mm north.
Formation ....Reba Member, Ashlock Formation.
Quadrangle name ......Palmer, Ky.

Collection number .....4468–CO*.
Geographic location ....2.6 mi east and 0.1 mi north of the southwest corner of the Palmer quadrangle, Kentucky.
Coordinates ....170 mm east, 4 mm north.
Formation ....Otter Creek Coral Bed, Preachersville Member, Drakes Formation.
Quadrangle name .....Palmer, Ky.

Collection number .....4491–CO*.
Geographic location ....Roadcut about 3.5 mi west of courthouse in Owingsville, Ky., on U.S. Route 60, near headwaters of Hurricane Creek.
Coordinates ....193 mm east, 98 mm north.
Formation ....Sunset Member, Bull Fork Formation.
Quadrangle name ......Owingsville, Ky.

Collection number .....4556–CO*.
Geographic location ....Buffalo Creek about 0.3 mi south of intersection of Kentucky Route 1156 and Clay Lane Road.
Coordinates ....23 mm east, 306 mm north.
Formation ....Back Bed, Tate Member, Ashlock Formation.
Silicified ....Yes.
Quadrangle name ......Richmond North, Ky.

Collection number .....4573–CO.
Geographic location ....Exposures along West Run and in old quarry about 1.3 mi west of Liberty, Ind.
Coordinates ....159 mm east, 70 mm north.
Formation ....Dillsboro Formation.
Stratigraphic position ..40 ft above base of section.
Silicified ....Yes.
Quadrangle name ......Liberty, Ind.

Collection number .....4574–CO.
Geographic location ....The same as for 4573–CO.
Coordinates .... Do.
Formation ....Dillsboro Formation.
Stratigraphic position ..42–43 ft above the base of the section.

Silicified ______________Yes.
Quadrangle name ______Liberty, Ind.

Collection number _____4575–CO.
Geographic location ____The same as for 4573–CO.
Coordinates ___________ Do.
Formation ____________Dillsboro Formation.
Stratigraphic position __Float 28–44 ft above base of section.
Silicified ______________Yes.
Quadrangle name ______Liberty, Ind.

Collection number _____4852–CO*.
Geographic location ____Section along Interstate Route 75, 1.4 mi south of Georgetown, Ky., exit.
Coordinates ___________364 mm east, 321 mm north.
Formation ____________Grier Limestone Member, Lexington Limestone.
Stratigraphic position __25 ft below the top of the Grier Limestone Member.
Silicified ______________Yes (850 lbs).
Quadrangle name ______Georgetown, Ky.
Section name __________Georgetown A.
Section number ________151.

Collection number _____4871–CO*.
Geographic location ____Road exposures between Trinity Church and Antioch Church, southwest quadrant Valley View quadrangle, Kentucky.
Coordinates ___________Base of section at 19 mm east, 176 mm north.
Formation ____________Grier Limestone Member, Lexington Limestone.
Stratigraphic position __25 ft above the base of the section.
Quadrangle name ______Valley View, Ky.[1]
Section name __________Valley View C (Antioch Church Road).
Section number ________180.

Collection number _____4872–CO*.
Geographic location ____The same as for 4871–CO.
Coordinates ___________ Do.
Formation ____________Grier Limestone Member, Lexington Limestone.
Stratigraphic position __27 ft above the base of the section.
Quadrangle name ______Valley View, Ky.
Section name __________Valley View C (Antioch Church Road).
Section number ________180.

Collection number _____4874–CO*.
Geographic location ____The same as for 4871–CO.
Coordinates ___________ Do.
Formation ____________Grier Limestone Member, Lexington Limestone.
Stratigraphic position __30 ft above the base of the section.
Quadrangle name ______Valley View, Ky.
Section name __________Valley View C (Antioch Church Road).
Section number ________180.

Collection number _____4876–CO*.
Geographic location ____The same as for 4871–CO.

[1] Collections 4871–CO–4905–CO are not listed on the map of the Valley View quadrangle, their positions are indicated on the stratigraphic section accompanying the map of the Little Hickman quadrangle, Kentucky.

Coordinates ___________ Do.
Formation ____________Grier Limestone Member, Lexington Limestone.
Stratigraphic position __35 ft above the base of the section.
Silicified ______________Yes (30 lbs).
Quadrangle name ______Valley View, Ky.
Section name __________Valley View C (Antioch Church Road).
Section number ________180.

Collection number _____4879–CO*.
Geographic location ____The same as for 4871–CO.
Coordinates ___________ Do.
Formation ____________Grier Limestone Member, Lexington Limestone.
Stratigraphic position __43–45 ft above the base of the section.
Silicified ______________Yes (200 lbs).
Quadrangle name ______Valley View, Ky.
Section name __________Valley View C (Antioch Church Road).
Section number ________180.

Collection number _____4880–CO*.
Geographic location ____The same as for 4871–CO.
Coordinates ___________ Do.
Formation ____________Grier Limestone Member, Lexington Limestone.
Stratigraphic position __47 ft above the base of the section.
Silicified ______________Yes (50 lbs).
Quadrangle name ______Valley View, Ky.
Section name __________Valley View C (Antioch Church Road).
Section number ________180.

Collection number _____4898–CO*.
Geographic location ____The same as for 4871–CO.
Coordinates ___________ Do.
Formation ____________Clays Ferry Formation.
Stratigraphic position __150 ft above the base of the section.
Quadrangle name ______Valley View, Ky.
Section name __________Valley View C (Antioch Church Road).
Section number ________180.

Collection number _____4905–CO*.
Geographic location ____The same as for 4871–CO.
Coordinates ___________ Do.
Formation ____________Clays Ferry Formation.
Stratigraphic position __Float, 190 ft above base of section.
Quadrangle name ______Valley View, Ky.
Section name __________Valley View C (Antioch Church Road).
Section number ________180.

Collection number _____4929–CO*.
Geographic location ____Road exposures 0.5 mi east and 1.6 mi south of northwest corner of Salvisa quadrangle, Kentucky.
Coordinates ___________32 mm east, 467 mm north.
Formation ____________Grier Limestone Member, Lexington Limestone.
Stratigraphic position __8 ft below the base of the Brannon Member, Lexington Limestone.
Silicified ______________Yes (20 lbs).

Quadrangle name ------Salvisa, Ky.
Section name ----------Salvisa A.
Section number --------175.

Collection number -----4940-CO*.
Geographic location ----Road exposure on west side of Kentucky River at bridge crossing of Central Kentucky Parkway, on north side of parkway.
Coordinates -----------Base of section at 186 mm east, 508 mm north.
Formation ------------Curdsville Limestone Member, Lexington Limestone.
Stratigraphic position --7 ft above the top of the Tyrone Limestone.
Silicified --------------Yes (7 lbs).
Quadrangle name ------Salvisa, Ky.
Section name ----------Salvisa B.
Section number --------176.

Collection number -----4956-CO*.
Geographic location ----The same as for 4940-CO.
Coordinates ----------- Do.
Formation ------------Grier Limestone Member, Lexington Limestone.
Stratigraphic position --137 ft above the top of the Tyrone Limestone.
Quadrangle name ------Salvisa, Ky.
Section name ----------Salvisa B.
Section number --------176.

Collection number -----4957-CO*.
Geographic location ----The same as for 4940-CO.
Coordinates ----------- Do.
Formation ------------Grier Limestone Member, Lexington Limestone.
Stratigraphic position --144 ft above the top of the Tyrone Limestone.
Quadrangle name ------Salvisa. Ky.
Section name ----------Salvisa B.
Section number --------176.

Collection number -----4959-CO*.
Geographic location ----The same as for 4940-CO.
Coordinates ----------- Do.
Formation ------------Grier Limestone Member, Lexington Limestone.
Stratigraphic position --149-152 ft above the top of the Tyrone Limestone.
Silicified --------------Yes (1,001 lbs).
Quadrangle name ------Salvisa, Ky.[2]
Section name ----------Salvisa B.
Section number --------176.

Collection number -----4963-CO*.
Geographic location ----Road exposure in east-bound lanes of Interstate Route 64, 0.5 mi east of Frankfort-Lawrenceburg, Ky., interchange.

[2] Note on the published geologic map of the Salvisa quadrangle that this collection is indicated as coming from the same section as 4929-CO; Cressman (1973; pl. 1, noted on proper placement of the collection in section 176.

Coordinates -----------Base of section at 417 mm east, 148 mm north.
Formation ------------Grier Limestone Member, Lexington Limestone.
Stratigraphic position --30 ft below the base of the Brannon Member, Lexington Limestone.
Quadrangle name ------Frankfort West, Ky.
Section name ----------Frankfort West A.
Section number --------88.

Collection number -----4964-CO*.
Geographic location ----The same as for 4963-CO.
Coordinates ----------- Do.
Formation ------------Grier Limestone Member, Lexington Limestone.
Stratigraphic position --27 ft below the base of the Brannon Member, Lexington Limestone.
Quadrangle name ------Frankfort West, Ky.
Section name ----------Frankfort West A.
Section number --------88.

Collection number -----4982-CO*.
Geographic location ----The same as for 4963-CO.
Coordinates ----------- Do.
Formation ------------Tanglewood Limestone Member, Lexington Limestone.
Stratigraphic position --32 ft above the base of the Brannon Member, Lexington Limestone.
Quadrangle name ------Frankfort West, Ky.
Section name ----------Frankfort West A.
Section number --------88.

Collection number -----4998-CO*.
Geographic location ----The same as for 4963-CO.
Coordinates ----------- Do.
Formation ------------Tanglewood Limestone Member, Lexington Limestone.
Stratigraphic position --84 ft above the base of the Brannon Member, Lexington Limestone.
Quadrangle name ------Frankfort West, Ky.
Section name ----------Frankfort West A.
Section number --------88.

Collection number -----5015-CO*.
Geographic location ----Quarry exposure 0.4 mi south of Perryville, Ky., on east side of Mitchellsburg Road, east side of Chaplin River.
Coordinates -----------191 mm east, 92 mm north.
Formation ------------Salvisa Bed, Perryville Limestone Member, Lexington Limestone.
Stratigraphic position --5 ft above base of Salvisa Bed.
Silicified --------------Yes (1,423 lbs).
Quadrangle name ------Perryville, Ky.
Section name ----------Perryville B (Perryville South).
Section number --------30B.

Collection number -----5016-CO*.
Geographic location ----The same as for 5015-CO.
Coordinates ----------- Do.
Formation ------------Cornishville Bed, Perryville Limestone Member, Lexington Limestone.

Stratigraphic position --14 ft above the base of the Salvisa Bed, Perryville Limestone Member, Lexington Limestone.
Silicified --------------Yes (7 lbs).
Quadrangle name ------Perryville, Ky.
Section name ----------Perryville B (Perryville South).
Section number --------30B.

Collection number -----5022–CO.
Geographic location ----Section in quarry and road exposures near Clear Creek, 0.2 mi east and 2.6 mi south of the northwest corner of the Keene quadrangle, Kentucky.
Coordinates -----------Base of section at 21 mm east, 326 mm north.
Formation ------------Curdsville Limestone Member, Lexington Limestone.
Stratigraphic position --Float from the lower 22 ft of the Curdsville Limestone Member.
Silicified --------------Yes (75 lbs).
Quadrangle name ------Keene, Ky.
Section name ----------Keene A.
Section number --------150.

Collection number -----5023–CO.
Geographic location ----The same as for 5022–CO.
Coordinates ----------- Do.
Formation ------------Curdsville Limestone Member, Lexington Limestone.
Stratigraphic position --30 ft above the base of the Curdsville Limestone Member.
Silicified --------------Yes (75 lbs).
Quadrangle name ------Keene, Ky.
Section name ----------Keene A.
Section number --------150.

Collection number -----5025–CO.
Geographic location ----Road exposure west from crossing of Kentucky Route 32 and the Licking River.
Coordinates -----------Base of section at 197 mm east, 499 mm north.
Formation ------------Millersburg Member, Lexington Limestone.
Stratigraphic position --4 ft above base of section.
Quadrangle name ------Moorefield, Ky.
Section name ----------Moorefield A.
Section number --------173.

Collection number -----5027–CO.
Geographic location ----The same as for 5025–CO.
Coordinates ----------- Do.
Formation ------------Millersburg Member, Lexington Limestone.
Stratigraphic position -- 18 ft above base of section.
Quadrangle name ------ Moorefield, Ky.
Section name ---------- Moorefield A.
Section number --------173.

Collection number ----- 5030–CO.
Geographic location ---- The same as for 5025–CO.
Coordinates ----------- Do.
Formation ------------Millersburg Member, Lexington Limestone.
Stratigraphic position --27 ft above base of section.
Quadrangle name ------Moorefield, Ky.
Section name ----------Moorefield A.
Section number --------173.

Collection number -----5031–CO.
Geographic location ----The same as for 5025–CO.
Coordinates ----------- Do.
Formation ------------Nicholas Bed, Tanglewood Limestone Member, Lexington Limestone.
Stratigraphic position --50 ft above base of section.
Quadrangle name ------Moorefield, Ky.
Section name ----------Moorefield A.
Section number --------173.

Collection number -----5033–CO.
Geographic location ----The same as for 5025–CO.
Coordinates ----------- Do.
Formation ------------Nicholas Bed, Tanglewood Limestone Member, Lexington Limestone.
Stratigraphic position --72 ft above base of section.
Quadrangle name ------Moorefield, Ky.
Section name ----------Moorefield A.
Section number --------173.

Collection number -----5036–CO*.
Geographic location ----Small stream exposure on Squires Road, 1.8 mi southwest of intersection with U.S. Route 421 (upstream 0.1 mi).
Coordinates -----------151 mm east, 494 mm north.
Formation ------------Devils Hollow Member, Lexington Limestone.
Stratigraphic position --60 ft above the base of the Brannon Member, Lexington Limestone.
Silicified --------------Yes (300 lbs).
Quadrangle name ------Coletown, Ky.

Collection number -----5039–CO*.
Geographic location ----Roadcut on Interstate Route 75, north of Clays Ferry Bridge crossing of Kentucky River.
Coordinates -----------80 mm east, 94 mm north.
Formation ------------Probably Preachersville Member, Drakes Formation.
Stratigraphic position --Breccia in Elk Lick Creek graben.
Quadrangle name ------Ford, Ky.
Collection number -----5058–CO.
Geographic location ----Roadcuts west of Sadieville, along Interstate Route 75, north of Eagle Creek.
Coordinates -----------Base of section at 182 mm east, 125 mm north.
Formation ------------Clays Ferry Formation.
Stratigraphic position --27–28 ft above the base of the main body of the Clays Ferry Formation.
Quadrangle name ------Sadieville, Ky.[3]

[3] Cressman (1973, pl. 2) considered this section to be a part of Sadieville A (179), which is exposed south of Eagle Creek along Interstate Route 75.

Section name ----------Sadieville B.

Collection number -----5067-CO*.
Geographic location ----Hillside pasture exposure on west side of U.S. Route 227, 0.4 mi south of intersection of Ford-Hampton Road and U.S. 227, north of Ford, Ky.
Coordinates -----------423 mm east, 187 mm north.
Formation ------------Grier Limestone Member, Lexington Limestone.
Stratigraphic position --140 ft above top of Tyrone Limestone.
Silicified --------------Yes (795 lbs).
Quadrangle name ------Ford, Ky.

Collection number -----5069-CO*.
Geographic location ----Exposures along Hanley Lane behind Old Taylor distillery.
Coordinates -----------Base of section at 142 mm east, 112 mm north.
Formation ------------Upper Curdsville Limestone Member, Lexington Limestone.
Silicified --------------Yes (40 lbs).
Quadrangle name ------Frankfort East, Ky.

Collection number -----5071-CO*.
Geographic location ----The same as for 5069-CO.
Coordinates ----------- Do.
Formation ------------Upper part of Grier Limestone Member, Lexington Limestone.
Silicified --------------Yes (10 lbs).
Quadrangle name ------Frankfort East, Ky.

Collection number -----5072-CO.
Geographic location ----Immediately behind Old Crow distillery, north bluff of Glenns Creek Road, 0.7 mi west of intersection with Hanley Lane.
Coordinates -----------107 mm east, 102 mm north.
Formation ------------Lower part of Lexington Limestone; mostly basal Curdsville Limestone Member, but with some float blocks of the Logana Member included in the sample.
Silicified --------------Yes (150 lbs).
Quadrangle name ------Frankfort East, Ky.
Section name ----------Frankfort East B.
Section number --------87.

Collection number -----5073-CO*.
Geographic location ----Northwest of Old Crow distillery, on first sharp north bend of Glenns Creek Road 0.9 mi west of intersection with Hanley Lane.
Coordinates -----------82 mm east, 111 mm north.
Formation ------------Upper part of Logana Member, Lexington Limestone.
Stratigraphic position --Just below 4 ft-thick dalmanellid coquina.
Silicified --------------Yes (496 lbs).
Quadrangle name ------Frankfort East, Ky.
Section name ----------Frankfort East B.
Section number --------87.

Collection number -----5080-CO*.
Geographic location ----First crossing of Southern Railroad tracks by unnamed road running due south from two right-angle turns in Kentucky Route 342, 1.2 mi west of Herrington Lake Spillway.
Coordinates -----------88 mm east, 158 mm north.
Formation ------------Upper part of Curdsville Limestone Member, Lexington Limestone.
Silicified --------------Yes (250 lbs).
Quadrangle name ------Wilmore, Ky.
Collection number -----5081-CO.
Geographic location ----From east side of Blackburn Memorial Bridge crossing of Kentucky River take first road north toward Kentucky utilities plant; section in railroad and road exposures.
Coordinates -----------99 mm east, 214 mm north (railroad exposures).
Formation ------------Tyrone Limestone.
Stratigraphic position --Float, 35 ft below top of Tyrone Limestone.
Silicified --------------Yes (5 lbs).

Quadrangle name ------Tyrone, Ky.
Section name ----------Tyrone C.
Section number --------174.

Collection number -----5084-CO.
Geographic location ----The same as for 5081-CO.
Coordinates -----------108 mm east, 214 mm north (railroad exposures).
Formation ------------Curdsville Limestone Member, Lexington Limestone.
Stratigraphic position --5 ft above base of Curdsville Limestone Member.
Silicified --------------Yes (12 lbs).
Quadrangle name ------Tyrone, Ky.
Section name ----------Tyrone C.
Section number --------174.

Collection number -----5086-CO.
Geographic location ----The same as for 5081-CO.
Coordinates -----------The same as for 4124-CO.
Formation ------------Logana Member, Lexington Limestone.
Stratigraphic position --18-20 ft above the base of the Logana Member.
Silicified --------------Yes (100 lbs).
Quadrangle name ------Tyrone, Ky.
Section name ----------Tyrone C.
Section number --------174.

Collection number -----5087-CO*.
Geographic location ----Small road exposure on U.S. Route 421, 0.5 mi east of U.S. Routes 60 and 421 junction.
Coordinates -----------242 mm east, 287 mm north.
Formation ------------Upper part of Devils Hollow Member, Lexington Limestone.
Silicified -------------- Yes (458 lbs).
Quadrangle name ------Frankfort East, Ky.

Collection number -----5089-CO*.

Geographic location ----Road exposure on westbound lanes of Interstate Route 64, on traffic island south side of west bound lanes.
Coordinates -----------97 mm east, 173 mm north.
Formation ------------Macedonia Bed, Grier Limestone Member, Lexington Limestone.
Silicified --------------Yes.
Quadrangle name ------Frankfort East, Ky.[4]

Collection number -----5092–CO.
Geographic location ----The same as for 5081–CO.
Coordinates -----------The same as for 4124–CO.
Formation ------------Logana Member, Lexington Limestone.
Stratigraphic position --10–12 ft above the base of the Logana Member.
Silicified --------------Yes (997 lbs).
Quadrangle name ------Tyrone, Ky.
Section name ----------Tyrone C.
Section number --------174.

Collection number -----5093–CO*.
Geographic location ----0.3 mi southwest of Kentucky River on Devils Hollow Road.
Coordinates -----------411 mm east, 318 mm north.
Formation ------------Macedonia Bed, Grier Limestone Member, Lexington Limestone.
Stratigraphic position --Float.
Silicified --------------Yes (25 lbs).
Quadrangle name ------Frankfort West, Ky.

Collection number -----5095–CO*.
Geographic location ----Road exposure on north side of westbound lanes of Interstate Route 64, about 0.5 mi east of bridge over Kentucky River.
Coordinates -----------123 mm east, 195 mm north.
Formation ------------Devils Hollow Member, Lexington Limestone.
Stratigraphic position --6–8 ft above the base of the Devils Hollow Member.
Silicified --------------Yes (542 lbs).
Quadrangle name ------Frankfort East, Ky.[5]
Section name ----------Frankfort East A.
Section number --------86.

Collection number -----5096–CO.
Geographic location ----Just before ferry crossing of Tates Creek Road and Kentucky River, take road west toward Daniel Boone YMCA Camp; collection from near top of north bluff Kentucky River, 0.4 mi southeast of YMCA Camp in abandoned railroad bed.
Coordinates -----------151 mm east, 432 mm north.
Formation ------------Grier Limestone Member, Lexington Limestone.
Silicified --------------Yes (300 lbs).
Quadrangle name ------Valley View, Ky.

Collection number -----5100–CO*.
Geographic location ----Crisman Mill Road, 0.2 mi west of Hickman Creek crossing.
Coordinates -----------411 mm east, 451 mm north.
Formation ------------Lower part of Curdsville Limestone Member, Lexington Limestone.
Silicified --------------Yes (600 lbs).
Quadrangle name ------Little Hickman, Ky.
Section name ----------Little Hickman B.

Collection number -----5101–CO.
Geographic location ----Kentucky Route 169 just west of Hickman Creek crossing.
Coordinates -----------398 mm east, 81 mm north.
Formation ------------Lower part of Curdsville Limestone Member, Lexington Limestone.
Silicified --------------Yes (799 lbs).
Quadrangle name ------Nicholasville, Ky.

Collection number -----5107–CO.
Geographic location ----Hillside exposure in farm road leading south from U.S. Route 60, just west of Keeneland racetrack collected at 900-ft contour.
Coordinates -----------43 mm east, 194 mm north.
Formation ------------Grier Limestone Member, Lexington Limestone.
Silicified --------------Yes (75 lbs).
Quadrangle name ------Lexington West, Ky.

Collection number -----5120–CO.
Geographic location ----Hill slopes on farmland 1.2 mi north-northeast of Judio, Ky. Section begins near junction of farm access road near mouth of Perry Cary Hollow and was measured northerly up hill slope, then offset south about 600 ft to outcrops near farmhouse, and then east up hill slope east of farmhouse.
Coordinates -----------Coordinates for the base of this section were measured east and then south from the northwest corner of the Blacks Ferry quadrangle. 84 mm east, 183 mm south.
Formation ------------Leipers Limestone.
Stratigraphic position --50.5 ft below the base of the Cumberland Formation.
Quadrangle name ------Blacks Ferry, Ky.
Section name ----------Judio North.
Section number --------703.

Collection number -----5135–CO.
Geographic location ----Outcrops at and near abandoned Clara Wilham Quarry, about 1.2 mi south of Dunnville, Ky. and about 500 ft east of U.S. Route 127 (Kentucky Route 35).
Coordinates -----------431 mm east, 262 mm north,
Formation ------------Reba Member, Ashlock Formation.
Quadrangle name ------Dunnville, Ky.
Section name ----------Dunnville South.
Section number --------702.

[4] On geologic quadrangle map this locality is marked on the north side of the westbound lanes.

[5] The geologic map of this quadrangle incorrectly places this collection in the Tanglewood Limestone Member, Lexington Limestone.

Collection number -----5136-CO.
Geographic location ----The same as for 5135-CO.
Coordinates ----------- Do.
Formation ------------Reba Member, Ashlock Formation.
Quadrangle name ------Dunnville, Ky.
Section name ----------Dunnville South.
Section number --------702.

Collection number -----5137-CO.
Geographic location ----Outcrops along U.S. Route 127 (Kentucky Route 35) in roadcut a few hundred feet north of junction with Kentucky Route 906 on west side of the settlement of Kidds Store, Ky.
Coordinates -----------Base of section at 78.5 mm east, 191 mm north.
Formation ------------Gilbert Member, Ashlock Formation.
Quadrangle -----------Hustonville, Ky.
Section name ----------Kidds Store.
Section number --------101.

Collection number -----5140-CO.
Geographic location ----U.S. Route 27, 0.1 mi northeast of crossing of Dix River.
Coordinates -----------42.5 mm east, 342 mm north.
Formation ------------Reba Member, Ashlock Formation.
Quadrangle name ------Lancaster, Ky.
Section name ----------Ashlock Cemetery.
Section number --------21B.

Collection number -----5141-CO.
Geographic location ----The same as for 5140-CO.
Coordinates ----------- Do.
Formation ------------Stingy Creek Member, Ashlock Formation.
Quadrangle name ------Lancaster, Ky.
Section name ----------Ashlock Cemetery.
Section number --------21B.

Collection number -----5183-CO.
Geographic location ----Roadside exposure on northbound lanes of Interstate Route 75 south of Eagle Creek.
Coordinates -----------Base of section about 181 mm east, 108 mm north.
Formation ------------Lower tongue of Clays Ferry Formation.
Stratigraphic position --4 ft above base of lower tongue of Clays Ferry Formation.
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville A.
Section number --------179.

Collection number -----5308-CO*.
Geographic location ----10,150 ft south and 8,650 ft west of the northeast corner of the Union City quadrangle.
Coordinates -----------348.5 mm east, 447.5 mm north.
Formation ------------Otter Creek Coral Bed. Preachersville Member, Drakes Formation.
Quadrangle -----------Union City, Ky.

Collection number -----5309-CO*.
Geographic location ----About 4 mi north and 1.4 mi east of southwest corner of Union City quadrangle, Kentucky.
Coordinates -----------96 mm east, 253 mm north.
Formation ------------Otter Creek Coral Bed, Preachersville Member, Drakes Formation.
Quadrangle name ------Union City, Ky.

Collection number -----5899-CO.
Geographic location ----Subsurface section cored just west of U.S. Route 27, about 0.3 mi northeast of intersection with Baker Lane.
Coordinates -----------241 mm east, 185 mm north.
Formation ------------Upper part of Curdsville Limestone Member, Lexington Limestone.
Stratigraphic position --184.4 ft below the top of the core.
Quadrangle name ------Nicholasville, Ky.
Section name ----------Nicholasville 1 (A. J. Denny Heirs).
Section number --------152.

Collection number -----6127-CO.
Geographic location ----Southernmost tributary of Landing Run, 2,000 ft east of intersection of U.S. Route 31E and Kentucky Route 46, between Balltown and Culvertown, Ky.
Coordinates -----------381 mm east, 436 mm north.
Formation ------------Rowland Member, Drakes Formation.
Silicified --------------Yes (710 lbs).
Quadrangle name ------New Haven, Ky.

Collection number -----6128-CO.
Geographic location ----Outcrop at farm pond 2,000 ft west of intersection of Mt. Horeb and Carrick Roads, 1,000 ft north of Carrick Road.
Coordinates -----------183 mm east, 387 mm north.
Formation ------------Clays Ferry Formation tongue between Millersburg Member, Lexington Limestone, below and Tanglewood Limestone Member, Lexington Limestone, above.
Stratigraphic position --5-10 ft above base of Clays Ferry Formation tongue, 15-20 ft above *Allonychia flanaganensis* Zone in the Millersburg Member, Lexington Limestone.
Silicified --------------Yes (389 lbs).
Quadrangle name ------Centerville, Ky.[6]

Collection number -----6129-CO.
Geographic location ----Lebanon Stone quarry, north side Kentucky Routes 49 and 52, 0.3 mi east intersection of Kentucky Route 327 and Kentucky Routes 49 and 52.
Coordinates -----------163 mm east, 464 mm north.

[6] On the geologic map of the Centerville quadrangle, the part of Clays Ferry Formation that intertongues with the upper part of Lexington Limestone is mapped as argillaceous limestone and shale.

Formation ------------Gilbert Member, Ashlock Formation.
Silicified --------------Yes (68 lbs).
Quadrangle name ------Lebanon West, Ky.

Collection number -----6131–CO*.
Geographic location ----Section on Kentucky Route 33, just north of bridge crossing of Mocks Branch, 2.5 miles north of Danville, Ky.
Coordinates -----------405 mm east, 307 mm north.
Formation ------------Upper part of Curdsville Limestone Member, Lexington Limestone.
Stratigraphic position --23 ft above the Tyrone Limestone-Lexington Limestone contact.
Silicified --------------Yes (707 lbs).
Quadrangle name ------Danville, Ky.

Collection number -----6134–CO*.
Geographic location ----Road exposures 0.2 mi west of Dix River crossing of Kentucky Route 52.
Coordinates -----------315 mm east, 78 mm north.
Formation ------------Curdsville Limestone Member, Lexington Limestone.
Stratigraphic position --Lower 3 ft of Curdsville Limestone Member.
Silicified --------------Yes (632 lbs).
Quadrangle name ------Bryantsville, Ky.
Section name ----------Bryantsville D.

Collection number -----6135–CO*.
Geographic location ----The same as for 6134–CO.
Coordinates ----------- Do.
Formation ------------Curdsville Limestone Member, Lexington Limestone.
Stratigraphic position --23 ft above the Tyrone Limestone Lexington Limestone contact.
Silicified --------------Yes (371 lbs).
Quadrangle name ------Bryantsville, Ky.
Section name ----------Bryantsville D.

Collection number -----6136–CO*.
Geographic location ----Roadcut on Kentucky Route 52, 1.45 mi east of junction with U.S. Route 150; 0.15 mi east crossing of Kentucky Route 52 and Balls Branch Run.
Coordinates -----------74 mm east, 35 mm north.
Formation ------------Faulconer Bed, Perryville Limestone Member, Lexington Limestone.
Stratigraphic position --Basal 3–4 ft of Perryville Limestone Member, immediately above the Tanglewood Limestone Member, Lexington Limestone.
Silicified --------------Yes (562 lbs).
Quadrangle name ------Bryantsville, Ky.[7]
Section name ----------Bryantsville B.

Collection number -----6137–CO*.
Geographic location ----The same as for 6136–CO.

[7] The Faulconer Bed of the Perryville is not indicated on the geologic map of the Bryantsville quadrangle because it is too thin to map. It is present and as much as 4 ft thick in the southwest quadrant of the quadrangle.

Coordinates ----------- Do.
Formation ------------Salvisa Bed, Perryville Limestone Member, Lexington Limestone.
Stratigraphic position --8 ft above the Perryville Limestone Member-Tanglewood Limestone Member contact.
Silicified --------------Yes (105 lbs).
Quadrangle name ------Bryantsville, Ky.
Section name ----------Bryantsville B.

Collection number -----6138–CO*.
Geographic location ----The same as for 6136–CO.
Coordinates ----------- Do.
Formation ------------Cornishville Bed, Perryville Limestone Member, Lexington Limestone.
Stratigraphic position --16 ft above the Perryville Limestone Member-Tanglewood Limestone Member contact.
Silicified --------------Yes (138 lbs).
Quadrangle name ------Bryantsville, Ky.
Section name ----------Bryantsville B.

Collection number -----6139–CO.
Geographic location ----South bank of Salt Creek, 900 ft upstream from covered bridge on Enochsburg-Oldenburg, (Indiana) Road.
Coordinates -----------328 mm east, 378 mm north.
Formation ------------Upper part of Dillsboro Formation.
Silicified --------------Yes (573 lbs).
Quadrangle name ------New Point, Ind.

Collection number -----6140–CO.
Geographic location ----North bank of Salt Creek, 0.4 mi upstream from covered bridge on Enochsburg-Oldenburg (Indiana) Road.
Coordinates -----------315 mm east, 380 mm north.
Formation ------------Upper part of Dillsboro Formation.
Silicified --------------Yes (271 lbs).
Quadrangle name ------New Point, Ind.

Collection number -----6141–CO.
Geographic location ----South bank of Salt Creek, 50 ft upstream from covered bridge on Enochsburg-Oldenburg (Indiana) Road.
Coordinates -----------336 mm east, 385 mm north.
Formation ------------Upper part of Dillsboro Formation.
Silicified --------------Yes (98 lbs).
Quadrangle name ------New Point, Ind.

Collection number -----6142–CO*.
Geographic location ----Road exposure on east side of Kentucky Route 982, 0.4 mi south of junction of Kentucky Routes 32, 36, and 982 in Cynthiana, Ky. (across highway from River View Mission Church and Liggett and Myers tobacco warehouse).
Coordinates -----------290 mm east, 39 mm north.
Formation ------------Lower tongue of Clays Ferry Formation.

Stratigraphic position ..18–20 ft above the base of the section.
Silicified ....Yes (353 lbs).
Quadrangle name ......Cynthiana, Ky.

Collection number .....6143–CO*.
Geographic location ....The same as for 6142–CO.
Coordinates .... Do.
Formation ....Upper tongue of Clays Ferry Formation (separated from lower tongue of Clays Ferry Formation from which collection 6142–CO was made by a tongue of Millersburg Member of Lexington Limestone).
Stratigraphic position ..30–35 ft above the base of the section.
Silicified ....Yes (488 lbs).
Quadrangle name ......Cynthiana, Ky.

Collection number .....6144–CO*.
Geographic location ....The same as for 6142–CO.
Coordinates .... Do.
Formation ....Base of upper tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position ..24 ft above the base of the section.
Silicified ....Yes (286 lbs).
Quadrangle name ......Cynthiana, Ky.

Collection number .....6145–CO*.
Geographic location ....Kentucky Route 8, 1 mi south of Carntown, Ky.
Coordinates ....28 mm east, 326 mm north.
Formation ....Point Pleasant tongue, Clays Ferry Formation.
Stratigraphic position ..About 50 ft below the base of the Kope Formation.
Silicified ....Yes (141 lbs).
Quadrangle name ......Moscow, Ohio-Ky.

Collection number .....6146–CO*.
Geographic location ....Section in streamlet immediately north of U.S. Route 52, 0.25 mi west of the crossing of Route 52 and Patterson Run; 2.1 mi west of intersection of Route 52 and Ohio Route 133.
Coordinates ....3.5 mm east, 187 mm north.
Formation ....Point Pleasant tongue, Clays Ferry Formation.
Stratigraphic position ..30–40 ft below the base of the Kope Formation.
Silicified ....Yes (169 lbs).
Quadrangle name ......Felicity, Ohio-Ky.

Collection number .....6211–CO.
Geographic location ....Section on east side of Bear Creek Road immediately north of intersection with U.S. Route 52, east of Chilo, Ohio.
Coordinates ....Base of section at 329 mm east, 233 mm north.
Formation ....Basal few feet of Kope Formation.
Quadrangle name ......Moscow, Ohio-Ky.

Section name ....Bear Creek.

Collection number .....6282–CO*.
Geographic location ....Northwest side of Interstate Route 75, Erlanger, Ky., interchange.
Coordinates ....41 mm east, 125 mm north.
Formation ....Bellevue Tongue of Grant Lake Limestone.
Quadrangle name ......Covington, Ohio-Ky.

Collection number .....6283–CO*.
Geographic location ....The same as for 6282–CO.
Coordinates .... Do.
Formation ....Upper part of Fairview Formation.
Quadrangle name ......Covington, Ohio-Ky.

Collection number .....6284–CO*.
Geographic location ....The same as for 6282–CO.
Coordinates .... Do.
Formation ....Upper part of Fairview Formation.
Quadrangle name ......Covington, Ohio-Ky.

Collection number .....6286–CO*.
Geographic location ....West side of Erlanger Road 4,000 ft north of collection 6282.
Coordinates ....41 mm east, 174 mm north.
Formation ....Upper part of Fairview Formation.
Quadrangle ....Covington, Ohio-Ky.

Collection number .....6288–CO*.
Geographic location ....The same as for 6286–CO.
Coordinates .... Do.
Formation ....Upper part of Fairview Formation.
Quadrangle name ......Covington, Ohio-Ky.

Collection number .....6289–CO*.
Geographic location ....The same as for 6286–CO.
Coordinates .... Do.
Formation ....Upper part of Fairview Formation.
Quadrangle name ......Covington, Ohio-Ky.

Collection number .....6290–CO*.
Geographic location ....The same as for 6286–CO.
Coordinates .... Do.
Formation ....Upper part of Fairview Formation.
Quadrangle ....Covington, Ohio-Ky.

Collection number .....6291–CO*.
Geographic location ....The same as for 6286–CO.
Coordinates ....The same as for 6286–CO.
Formation ....Upper part of Fairview Formation.
Quadrangle ....Covington, Ohio-Ky.

Collection number .....6292-CO*.
Geographic location ....The same as for 6286–CO.
Coordinates .... Do.
Formation ....Upper part of Fairview Formation.
Quadrangle ....Covington, Ohio-Ky.

Collection number .....6409–CO.
Geographic location ....Hillside exposure south of Kinnard Cemetery. along unnamed road which runs from Paint Lick Creek to Kentucky Route 52, 1.2 mi north of Paint Lick, Ky.

Coordinates ----------- 367 mm east, 30 mm north.
Formation ------------ Calloway Creek Limestone.
Stratigraphic position -- Upper 5 ft of Calloway Creek Limestone, 10 ft below the Back Bed, Tate Member, Ashlock Formation.
Silicified -------------- Yes (140 lbs).
Quadrangle name ------ Kirksville, Ky.
Section name ---------- Kinnard Cemetery.
Section number -------- 35.

Collection number ----- 6410–CO.
Geographic location ---- The same as for 6409–CO.
Coordinates ----------- Do.
Formation ------------ Basal part of Back Bed, Tate Member, Ashlock Formation.
Stratigraphic position -- 10 ft above 6409–CO.
Silicified -------------- Yes (75 lbs).
Quadrangle ----------- Kirksville, Ky.
Section name ---------- Kinnard Cemetery.
Section number -------- 35.

Collection number ----- 6411–CO*.
Geographic location ---- U.S. Route 27, 0.1 mi northeast of crossing of the Dix River.
Coordinates ----------- 42.5 mm east, 342 mm north.
Formation ------------ Gilbert Member, Ashlock Formation.
Stratigraphic position -- 5 ft above the base of the Gilbert Member.
Silicified -------------- Yes (236 lbs).
Quadrangle name ------ Lancaster, Ky.
Section name ---------- Ashlock Cemetery.
Section number -------- 21B.

Collection number ----- 6412–CO*.
Geographic location ---- The same as for 6411–CO.
Coordinates ----------- Do.
Formation ------------ Gilbert Member, Ashlock Formation.
Stratigraphic position -- 11.5 ft above the base of the Gilbert Member.
Silicified -------------- Yes (558 lbs).
Quadrangle name ------ Lancaster, Ky.
Section name ---------- Ashlock Cemetery.
Section number -------- 21B.

Collection number ----- 6413–CO*.
Geographic location ---- U.S. Route 27, 1.1 mi north of junction with Kentucky Route 52, north of Lancaster, Ky.
Coordinates ----------- 160 mm east, 45 mm north.
Formation ------------ Top of Calloway Creek Limestone.
Silicified -------------- Yes (421 lbs).
Quadrangle name ------ Buckeye, Ky.

Collection number ----- 6414–CO.
Geographic location ---- Exposures on Kentucky Route 21, 0.9 mi south of the junction of Walnut Meadow Branch and Paint Lick Creek.
Coordinates ----------- 18 mm east, 372 mm north.
Formation ------------ Gilbert Member, Ashlock Formation.
Stratigraphic position -- 1-2-ft silicified zone at the top of Gilbert Member.
Silicified -------------- Yes (840 lbs).
Quadrangle name ------ Berea, Ky.

Collection number ----- 6416–CO.
Geographic location ---- Road exposures on Interstate Route 75, just north of crossing of Kentucky Route 169.
Coordinates ----------- 206 mm east, 57 mm north.
Formation ------------ Grant Lake Limestone.
Stratigraphic position -- 25–30 ft below the top of the exposure.
Silicified -------------- Yes (339 lbs).
Quadrangle name ------ Richmond North, Ky.
Section name ---------- Arlington West.
Section number -------- 98A.

Collection number ----- 6417–CO.
Geographic location ---- South entrance L and N Railroad tunnel, 0.35 mi north of Boonesboro, Ky.
Coordinates ----------- 361 mm east, 572 mm north.
Formation ------------ Tanglewood Limestone Member, Lexington Limestone.
Stratigraphic position -- Float, tunnel fill.
Quadrangle name ------ Richmond North, Ky.

Collection number ----- 6418–CO.
Geographic location ---- Kentucky Route 52, 1.5 mi west of Reeds Crossing, Ky.
Coordinates ----------- 7 mm east, 536 mm north.
Formation ------------ Top of Reba Member, Ashlock Formation.
Silicified -------------- Yes (141 lbs).
Quadrangle name ------ Moberly, Ky.
Section name ---------- Lake Reba.
Section number -------- 37.

Collection number ----- 6419–CO*.
Geographic location ---- 1.4 mi east of Wilmore, Ky. 500 ft north of main road.
Coordinates ----------- 420 mm east, 534 mm north.
Formation ------------ Lower part of Logana Member, Lexington Limestone.
Silicified -------------- Yes (329 lbs).
Quadrangle name ------ Wilmore, Ky.

Collection number ----- 6699–CO.
Geographic location ---- The same as for 6211–CO.
Coordinates ----------- Do.
Formation ------------ Point Pleasant tongue, Clays Ferry Formation.
Stratigraphic position -- Float from top 15 ft of the Point Pleasant tongue, Clays Ferry Formation.
Quadrangle name ------ Moscow, Ohio-Ky.
Section name ---------- Bear Creek.

Collection number ----- 6803–CO.
Geographic location ---- Exposure on Kentucky Route 11, 1 mi north of Concord, Ky.
Coordinates ----------- 357 mm east, 362 mm north.
Formation ------------ Upper part of Grant Lake Limestone.
Quadrangle name ------ Sherburne, Ky.

Collection number -----6909-CO*.
Geographic location ----Road exposure on U.S. Route 27 just north of junction with Kentucky Route 318, northwest of Falmouth, Ky.
Coordinates -----------Base of section at 98.5 mm east; 158 mm north.
Formation ------------Point Pleasant Tongue, Clays Ferry Formation.
Stratigraphic position --Lower 20 ft of section below the flow roll beds.
Silicified --------------Yes (338 lbs).
Quadrangle name ------Falmouth, Ky.
Section name ----------Falmouth A.
Section number --------195.

Collection number -----6915-CO*.
Geographic location ----Boyle County quarry, west side of U.S. Route 68, 1.3 mi northeast of Perryville, Ky.
Coordinates -----------217 mm east, 176 mm north.
Formation ------------Salvisa Bed, Perryville Limestone Member, Lexington Limestone.
Stratigraphic position --Basal 2 ft of the Salvisa Bed, 42 ft above the contact of the Tanglewood Limestone Member and the Perryville Limestone Member. Collected from northwest wall of quarry.
Silicified --------------Yes (532 lbs).
Quadrangle name ------Perryville, Ky.
Section name ----------Perryville A (Perryville North).
Section number --------30A.

Collection number -----6916-CO*.
Geographic location ----The same as for 6915-CO.
Coordinates ----------- Do.
Formations -----------Salvisa Bed, Perryville Limestone Member, Lexington Limestone.
Stratigraphic position --The same as for 6915-CO, but collected from east wall of quarry.
Silicified --------------Yes (236 lbs).
Quadrangle name ------Perryville, Ky.
Section name ----------Perryville A (Perryville North).
Section number --------30A.

Collection number -----6945-CO.
Geographic location ----East side of Kentucky River, opposite Boonesboro Beach on Ford–Boonesboro Road.
Coordinates -----------414 mm east, 112 mm north.
Formation ------------Clays Ferry Formation.
Stratigraphic position --17 ft above main body of Tanglewood Limestone Member, Lexington Limestone.
Silicified --------------Yes (33 lbs).
Quadrangle name ------Ford, Ky.
Section name ----------Ford–Boonesboro Road Section.

Collection number -----6990-CO*.
Geographic location ----West side of U.S. Route 27, 1,700 ft from highway, 0.9 mi south of Lair, Ky.
Coordinates -----------245 mm east, 369 mm north.
Formation ------------Top of Tongue of Clays Ferry Formation which lies between lower part of Millersburg Member tongue, Lexington Limestone, and an upper tongue of Tanglewood Limestone Member, Lexington Limestone.
Stratigraphic position --60 ft above top of Grier Limestone Member, Lexington Limestone.
Silicified --------------Yes (20 lbs).
Quadrangle name ------Shawhan, Ky.
Section name ----------Section at White Farm.

Collection number -----7039-CO*.
Geographic location ----0.7 mi southeast of junction of Kentucky Route 974 and Dry Fork Road, on Dry Fork Road. Section begins in valley of East Fork of Fourmile Creek in the Tanglewood Limestone Member, Lexington Limestone just below the *Allonychia flanaganensis* Zone of Millersburg Member, Lexington Limestone. The main part of the section is north of East Fork, along Dry Fork Road above the 823-ft elevation mark.
Coordinates -----------Base of section at 394 mm east; 268 mm north.
Formation ------------Lowermost tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position --15 ft above *Allonychia flanaganensis* horizon.
Quadrangle name ------Winchester, Ky.
Section name ----------Winchester A (Dry Fork Road).
Section number --------1004.

Collection number -----7040-CO*.
Geographic location ----The same as for 7039-CO.
Coordinates ----------- Do.
Formation ------------Lowermost tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position --16 ft above *Allonychia flanaganensis* horizon.
Quadrangle name ------Winchester, Ky.
Section name ----------Winchester A (Dry Fork Road).
Section number --------1004.

Collection number -----7041-CO*.
Geographic location ----The same as for 7039-CO.
Coordinates ----------- Do.
Formation ------------Lowermost tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position --17 ft above *Allonychia flanaganensis* horizon.
Quadrangle name ------Winchester, Ky.
Section name ----------Winchester A (Dry Fork Road).
Section number --------1004.

Collection number -----7043-CO*.
Geographic location ----The same as for 7039-CO.
Coordinates ----------- Do.
Formation ------------Tongue of Clays Ferry Formation.

Stratigraphic position __22 ft above *Allonychia flanaganensis* horizon.
Quadrangle name ______Winchester, Ky.
Section name __________Winchester A (Dry Fork Road).
Section number ________1004.

Collection number _____7044–CO*.
Geographic location ____The same as for 7039–CO.
Coordinates ___________ Do.
Formation ____________Tongue of Clays Ferry Formation.
Stratigraphic position __25 ft above *Allonychia flanaganensis* horizon.
Quadrangle name ______Winchester, Ky.
Section name __________Winchester A (Dry Fork Road).
Section number ________1004.

Collection number _____7045–CO*.
Geographic location ____The same as for 7039–CO.
Coordinates ___________ Do.
Formation ____________Tongue of Clays Ferry Formation.
Stratigraphic position __27 ft above *Allonychia flanaganensis* horizon.
Quadrangle name ______Winchester, Ky.
Section name __________Winchester A (Dry Fork Road).
Section number ________1004.

Collection number _____7046–CO*.
Geographic location ____The same as for 7039–CO.
Coordinates ___________ Do.
Formation ____________Tongue of Clays Ferry Formation.
Stratigraphic position __30 ft above *Allonychia flanaganensis* horizon.
Quadrangle name ______Winchester, Ky.
Section name __________Winchester A (Dry Fork Road).
Section number ________1004.

Collection number _____7047–CO*.
Geographic location ____The same as for 7039–CO.
Coordinates ___________ Do.
Formation ____________Second tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position __33 ft above *Allonychia flanaganensis* horizon.
Quadrangle name ______Winchester, Ky.
Section name __________Winchester A (Dry Fork Road).
Section number ________1004.

Collection number _____7049–CO*.
Geographic location ____The same as for 7039–CO.
Coordinates ___________ Do.
Formation ____________Second tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position __37 ft above *Allonychia flanaganensis*
Qaudrangle name ______Winchester, Ky.
Section name __________Winchester A (Dry Fork Road).
Section number ________1004.

Collection number _____7050–CO*.
Geographic location ____The same as for 7039–CO.
Coordinates ___________ Do.
Formation ____________Second tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position __39 ft above *Allonychia flanaganensis.*
Quadrangle name ______Winchester, Ky.
Section name __________Winchester A (Dry Fork Road).
Section number ________1004.

Collection number _____7051–CO*.
Geographic location ____The same as for 7039–CO.
Coordinates ___________ Do.
Formation ____________Second tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position __42–47 ft above *Allonychia flanaganensis.*
Quadrangle name ______Winchester, Ky.
Section name __________Winchester A (Dry Fork Road).
Section number ________1004.

Collection number _____7053–CO*.
Geographic location ____The same as for 7039–CO.
Coordinates ___________ Do.
Formation ____________Second tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position __43 ft above *Allonychia flanaganensis.*
Quadrangle name ______Winchester, Ky.
Section name __________Winchester A (Dry Fork Road).
Section number ________1004.

Collection number _____7054–CO*.
Geographic location ____The same as for 7039–CO.
Coordinates ___________ Do.
Formation ____________Second tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position __44 ft above *Allonychia flanaganensis.*
Quadrangle name ______Winchester, Ky.
Section name __________Winchester A (Dry Fork Road).
Section number ________1004.

Collection number _____7055–CO*.
Geographic location ____The same as for 7039–CO.
Coordinates ___________ Do.
Formation ____________Second tongue of Millersburg Member, Lexington Limestone.
Stratigraphic location __47 ft above *Allonychia flanaganensis.*
Quadrangle name ______Winchester, Ky.
Section name __________Winchester A (Dry Fork Road).
Section number ________1004.

Collection number _____7056–CO*.
Geographic location ____The same as for 7039–CO.
Coordinates ___________ Do.
Formation ____________Second tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position __48 ft above *Allonychia flanaganensis.*
Quadrangle name ______Winchester, Ky.
Section name __________Winchester A (Dry Fork Road).
Section number ________1004.

Collection number _____7057–CO*.
Geographic location ____The same as for 7039–CO.
Coordinates ___________ Do.
Formation ____________Second tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position __49–52 ft above *Allonychia flanaganensis.*
Quadrangle name ______Winchester, Ky.
Section name __________Winchester A (Dry Fork Road).
Section number ________1004.

Collection number _____7058–CO*.
Geographic location ____The same as for 7039–CO.
Coordinates ___________ Do.

Formation ------------Second tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position --54–57 ft above *Allonychia flanaganensis*.
Quadrangle name ------Winchester, Ky.
Section name ----------Winchester A (Dry Fork Road).
Section number --------1004.

Collection number -----7059–CO*.
Geographic location ----The same as for 7039–CO.
Coordinates ----------- Do.
Formation ------------Second tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position --54 ft above *Allonychia flanaganensis*.
Quadrangle name ------Winchester, Ky.
Section name ----------Winchester A (Dry Fork Road).
Section number --------1004.

Collection number -----7060–CO*.
Geographic location ----The same as for 7039–CO.
Coordinates ----------- Do.
Formation ------------Second tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position --57 ft above *Allonychia flanaganensis*.
Quadrangle name ------Winchester, Ky.
Section name ----------Winchester A (Dry Fork Road).
Section number --------1004.

Collection number -----7061–CO*.
Geographic location ----The same as for 7039–CO.
Coordinates ----------- Do.
Formation ------------Second tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position --58 ft above *Allonychia flanaganensis*.
Quadrangle name ------Winchester, Ky.
Section name ----------Winchester A (Dry Fork Road).
Section number --------1004.

Collection number -----7062–CO*.
Geographic location ----The same as for 7039–CO.
Coordinates ----------- Do.
Formation ------------Middle Tongue of Tanglewood Limestone Member, Lexington Limestone.
Stratigraphic position --62 ft above *Allonychia flanaganensis*.
Quadrangle name ------Winchester, Ky.
Section name ----------Winchester A (Dry Fork Road).
Section number --------1004.

Collection number -----7066–CO*.
Geographic location ----The same as for 7039–CO.
Coordinates ----------- Do.
Formation ------------Third tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position --70–72 ft above *Allonychia flanaganensis*.
Quadrangle name ------Winchester, Ky.
Section name ----------Winchester A (Dry Fork Road).
Section number --------1004.

Collection number -----7068–CO*.
Geographic location ----The same as for 7039–CO.
Coordinates ----------- Do.
Formation ------------Third tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position --75 ft above *Allonychia flanaganensis*.
Quadrangle name ------Winchester, Ky.
Section name ----------Winchester A (Dry Fork Road).
Section number --------1004.

Collection number -----7071–CO*.
Geographic location ----The same as for 7039–CO.
Coordinates ----------- Do.
Formation ------------Upper tongue of Tanglewood Limestone Member, Lexington Limestone.
Stratigraphic position --79 ft above *Allonychia flanaganensis*.
Quadrangle name ------Winchester, Ky.
Section name ----------Winchester A (Dry Fork Road).
Section number --------1004.

Collection number -----7072–CO*.
Geographic location ----The same as for 7039–CO.
Coordinates ----------- Do.
Formation ------------Uppermost tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position --83 ft above *Allonychia flanaganensis*.
Quadrangle name ------Winchester, Ky.
Section name ----------Winchester A (Dry Fork Road).
Section number --------1004.

Collection number -----7079–CO*.
Geographic location ----The same as for 7039–CO.
Coordinates ----------- Do.
Formation ------------Lowermost tongue of Millersburg Member, Lexington Limestone.
Stratigraphic position --18–21 ft above *Allonychia flanaganensis*.
Silicified --------------Yes (156 lbs).
Quadrangle name ------Winchester, Ky.
Section name ----------Winchester A (Dry Fork Road).
Section number --------1004.

Collection number -----7097–CO*.
Geographic location ----South bluff of Kentucky River, 0.6 mi west of junction with Twomile Creek.
Coordinates -----------9 mm east, 36 mm north.
Formation ------------Millersburg Member, Lexington Limestone, in bed of Tanglewood Limestone Member lithology.
Stratigraphic position --44 ft below occurrence of abundant *Sowerbyella* in overlying Clays Ferry Formation.
Silicified --------------Yes (57 lbs).
Quadrangle name ------Winchester, Ky.

Collection number -----7310–CO.
Geographic location ----Outcrop 1,700 ft east of Kentucky Route 89, 1.5 mi southeast of Winchester, Ky.
Coordinates -----------413 mm east, 497 mm north.
Formation ------------Strodes Creek Member, Lexington Limestone.
Quadrangle name ------Winchester, Ky.

Collection number ------7312–CO.
Geographic location ----Outcrop 1,700 ft east of Kentucky Route 89, 1.5 mi southeast of Winchester, Ky.
Coordinates ------------413 mm east, 497 mm north.
Formation --------------Strodes Creek Member, Lexington Limestone.
Quadrangle name --------Winchester, Ky.

Collection number ------7313–CO.
Geographic location ----The same as for 7312–CO.
Coordinates ------------Do.
Formation --------------Strodes Creek Member, Lexington Limestone.
Qaudrangle name --------Winchester, Ky.

Collection number ------7314–CO.
Geographic location ----Roadcuts along Maple Street, U.S. Route 227, northern outskirts of Winchester, Ky.
Coordinates ------------Base of section at 268 mm east, 567 mm north.
Formation --------------Millersburg Member, Lexington Limestone.
Stratigraphic position --2.5 ft above base of section.
Quadrangle name --------Winchester, Ky.
Section name -----------Locality B (Black and Cuppels, 1973).

Collection number ------7317–CO.
Geographic position ----The same as for 7314–CO.
Coordinates ------------Do.
Formation --------------Strodes Creek Member, Lexington Limestone.
Stratigraphic position --10 ft above base of section.
Quadrangle name --------Winchester, Ky.
Section name -----------Locality B (Black and Cuppels, 1973).

Collection number ------7318–CO.
Geographic location ----The same as for 7314–CO.
Coordinates ------------Do.
Formation --------------Strodes Creek Member, Lexington Limestone.
Stratigraphic position --11 ft above base of section.
Quadrangle name --------Winchester, Ky.
Section name -----------Locality B (Black and Cuppels, 1973).

Collection number ------7319–CO.
Geographic location ----The same as for 7314–CO.
Coordinates ------------Do.
Formation --------------Millersburg Member, Lexington Limestone.
Stratigraphic position --13 ft above base of section.
Quadrangle name --------Winchester, Ky.
Section name -----------Locality B (Black and Cuppels, 1973).

Collection number ------7321–CO.
Geographic location ----The same as for 7314–CO.
Coordinates ------------Do.
Formation --------------Millersburg Member, Lexington Limestone.
Stratigraphic position --21 ft above base of section.
Quadrangle name --------Winchester, Ky.
Section name -----------Locality B (Black and Cuppels, 1973).

Collection number ------7322–CO.
Geographic location ----The same as for 7314–CO.
Coordinates ------------Do.
Formation --------------Millersburg Member, Lexington Limestone.
Stratigraphic position --32 ft above base of section.
Quadrangle name --------Winchester, Ky.
Section name -----------Locality B (Black and Cuppels, 1973).

Collection number ------7324–CO*.
Geographic location ----Exposure on U.S. Route 227 (Maple Street, Winchester, Ky., extended) 0.6 mi north of Interstate Route 64.
Coordinates ------------266 mm east, 93 mm north.
Formation --------------Strodes Creek Member, Lexington Limestone.
Quadrangle name --------Austerlitz, Ky.

Collection number ------7325–CO*.
Geographic location ----The same as for 7324–CO.
Coordinates ------------Do.
Formation --------------Strodes Creek Member, Lexington Limestone.
Quadrangle name --------Austerlitz, Ky.

Collection number ------7327–CO*.
Geographic location ----Exposure on U.S. Route 227 (Maple Street, Winchester, Ky., extended) 2.6 mi north of Interstate Route 64.
Coordinates ------------270 mm east, 221 mm north.
Formation --------------Strodes Creek Member, Lexington Limestone.
Quadrangle name --------Austerlitz, Ky.

Collection number ------7328–CO*.
Geographic location ----The same as for 7327–CO.
Coordinates ------------Do.
Formation --------------Strodes Creek Member, Lexington Limestone.
Quadrangle name --------Austerlitz, Ky.

Collection number ------7330–CO*.
Geographic location ----Outcrops on U.S. Route 227 from crossing of Strodes Creek to 0.8 mi southeast of crossing.
Coordinates ------------Top of section at 268.5 mm east, 422 mm north.
Formation --------------Millersburg Member, Lexington Limestone.
Stratigraphic position --93 ft above base of section.
Quadrangle name --------Austerlitz, Ky.
Section name -----------Type section, Strodes Creek Member.

Collection number ------7332–CO*.
Geographic location ----The same as for 7330–CO.
Coordinates ------------Do.

Formation ------------Millersburg Member, Lexington Limestone.
Stratigraphic position --76 ft above base of section.
Quadrangle name ------Austerlitz, Ky.
Section name ----------Type section, Strodes Creek Member.

Collection number -----7333–CO*.
Geographic location ----The same as for 7330–CO.
Coordinates ----------- Do.
Formation ------------Tongue of Clays Ferry Formation.
Stratigraphic position --71 ft above base of section.
Quadrangle name ------Austerlitz, Ky.
Section name ----------Type section, Strodes Creek Member.

Collection number -----7334–CO*.
Geographic location ----The same as for 7330–CO.
Coordinates ----------- Do.
Formation ------------Millersburg Member, Lexington Limestone.
Stratigraphic position --66 ft above base of section.
Quadrangle name ------Austerlitz, Ky.
Section name ----------Type section, Strodes Creek Member.

Collection number -----7335–CO*.
Geographic location ----The same as for 7330–CO.
Coordinates ----------- Do.
Formation ------------Tongue of Clays Ferry Formation.
Stratigraphic position --61 ft above base of section.
Quadrangle name ------Austerlitz, Ky.
Section name ----------Type section, Strodes Creek Member.

Collection number -----7336–CO*.
Geographic location ----The same as for 7330–CO.
Coordinates ----------- Do.
Formation ------------Millersburg Member, Lexington Limestone.
Stratigraphic position --32 ft above base of section in *Allonychia flanaganensis* Zone.
Quadrangle name ------Austerlitz, Ky.
Section name ----------Type section, Strodes Creek Member.

Collection number -----7337–CO*.
Geographic location ----The same as for 7330–CO.
Coordinates ----------- Do.
Formation ------------Tanglewood Limestone Member, Lexington Limestone.
Stratigraphic position --22 ft above base of section.
Quadrangle name ------Austerlitz, Ky.
Section name ----------Type section, Strodes Creek Member.

Collection number -----7343–CO*.[8]

Collection number -----7344–CO*.
Geographic location ----East side U.S. Route 27, 900 ft from highway, 0.4 mi north of Lair, Ky.
Coordinates -----------246 mm east, 439 mm north.
Formation ------------Near top of lower tongue of Millersburg Member, Lexington Limestone.
Silicified --------------Yes (7.5 lbs).
Quadrangle name ------Shawhan, Ky.

[8] This collection number was applied to a recollection of 6900–CO and all information which applies to 6990–CO also applies to 7343–CO.

Collection number -----7345–CO*.
Geographic location ----The same as for 6142–CO.
Coordinates ----------- Do.
Formation ------------Lower tongue of Clays Ferry Formation.
Stratigraphic position --20–22 ft above the base of the section.
Silicified --------------Yes (10 lbs).
Quadrangle name ------Cynthiana, Ky.

Collection number -----7348–CO*.
Geographic location ----4,300 ft east, 6,300 ft south of the northwest corner of the Shawhan Quadrangle.
Coordinates -----------54 mm east, 493 mm north.
Formation ------------Tongue of Clays Ferry Formation underlain by tongue of Millersburg Member, Lexington Limestone, and overlain by a tongue of Tanglewood Limestone Member, Lexington Limestone.
Stratigraphic position --Float, 4 ft above 810-ft contour.
Silicified --------------Yes (181 lbs).
Quadrangle name ------Shawhan, Ky.

Collection number -----7349–CO*.
Geographic location ----The same as for 7348–CO.
Coordinates ----------- Do.
Formation ------------ Do.
Stratigraphic position --Float, 5 ft above 810-ft contour.
Silicified --------------Yes (210 lbs).
Quadrangle name ------Shawhan, Ky.

Collection number -----7350–CO*.
Geographic location ----The same as for 7348–CO.
Coordinates ----------- Do.
Formation ------------ Do.
Stratigraphic position --Float, 6 ft above 810-ft contour.
Silicified --------------Yes (84 lbs).
Quadrangle name ------Shawhan, Ky.

Collection number -----7353–CO*.
Geographic location ----1 mi east northeast junction of Cook Road and Lair Road in stock pond.
Coordinates -----------428 mm east, 471 mm north.
Formation ------------Lower tongue of Millersburg Member, Lexington Limestone.
Silicified --------------Yes (354 lbs).
Quadrangle name ------Shawhan, Ky.

Collection number -----7448–CO.
Geographic location ----Section along road to U.S. Route 25, 0.4 miles west of Sadieville, Ky.
Coordinates -----------Base of section at 295 mm east, 63 mm north.
Formation ------------Clays Ferry Formation tongue.
Stratigraphic position --1 ft above base of section.
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7450–CO.
Geographic location ----The same as for 7448–CO.
Coordinates ----------- Do.

Formation ------------Clays Ferry Formation tongue.
Stratigraphic position --5 ft above the base of the section.
Silicified --------------Yes (50 lbs).
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7452-CO*.
Geographic location ----The same as for 7448-CO.
Coordinates ----------- Do.
Formation ------------Clays Ferry Formation tongue.
Stratigraphic position --10 ft above the base of the section.
Silicified --------------Yes (43 lbs).
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7454-CO.
Geographic location ----The same as for 7448-CO.
Coordinates ----------- Do.
Formation ------------Millersburg Member, Lexington Limestone.
Stratigraphic position --20 ft above the base of the section.
Silicified --------------Yes (70 lbs).
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7455-CO.
Geographic location ----The same as for 7448-CO.
Coordinates ----------- Do.
Formation ------------Millersburg Member, Lexington Limestone.
Stratigraphic position --22 ft above the base of the section.
Silicified --------------Yes (45 lbs).
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7456-CO.
Geographic location ----The same as for 7448-CO.
Coordinates ----------- Do.
Formation ------------Millersburg Member, Lexington Limestone.
Stratigraphic position --30 ft above the base of the section.
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7457-CO.
Geographic location ----The same as for 7448-CO.
Coordinates ----------- Do.
Formation ------------Millersburg Member, Lexington Limestone.
Stratigraphic position --32 ft above the base of the section.
Silicified --------------Yes (52 lbs).
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7458-CO.
Geographic location ----The same as for 7448-CO.
Coordinates ----------- Do.
Formation ------------Clays Ferry Formation tongue.
Stratigraphic position --35 ft above the base of the section.
Silicified --------------Yes (16 lbs).
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7459-CO.
Geographic location ----The same as for 7448-CO.
Coordinates ----------- Do.
Formation ------------Clays Ferry Formation tongue.
Stratigrapic position --50 ft above the base of the section.
Silicified --------------Yes.
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7460-CO.
Geographic location ----The same as for 7448-CO.
Coordinates ----------- Do.
Formation ------------Clays Ferry Formation tongue.
Stratigraphic position --55 ft above the base of the section.
Silicified --------------Yes.
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7461-CO.
Geographic location ----The same as for 7448-CO.
Coordinates ----------- Do.
Formation ------------Clays Ferry Formation tongue.
Stratigraphic position --50-55 ft above the base of the section.
Silicified --------------Yes (60 lbs).
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7462-CO.
Geographic location ----The same as for 7448-CO.
Coordinates ----------- Do.
Formation ------------Clays Ferry Formation Tongue.
Stratigraphic position --57 ft above the base of the section.
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7467-CO.
Geographic location ----The same as for 7448-CO.
Coordinates ----------- Do.
Formation ------------Tanglewood Limestone Member, Lexington Limestone.
Stratigraphic position --77 ft above the base of the section.
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7468-CO.
Geographic location ----The same as for 7448-CO.
Coordinates ----------- Do.
Formation ------------Clays Ferry Formation.
Stratigraphic position --82 ft above the base of the section.
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number ----- 7471–CO.
Geographic location ---- The same as for 7448–CO.
Coordinates ----------- Do.
Formation ------------ Clays Ferry Formation.
Stratigraphic position -- 97 ft above the base of the section.
Quadrangle name ------ Sadieville, Ky.
Section name ---------- Sadieville C.
Section number -------- 192.

Collection number -----7472–CO.
Geographic location ----The same as for 7448–CO.
Coordinates ----------- Do.
Formation ------------Clays Ferry Formation.
Stratigraphic position --100 ft above the base of the section.
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7475–CO.
Geographic location ----The same as for 7448–CO.
Coordinates ----------- Do.
Formation ------------Clays Ferry Formation.
Stratigraphic position --115 ft above the base of the section.
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7477–CO.
Geographic location ----The same as for 7448–CO.
Coordinates ----------- Do.
Formation ------------Clays Ferry Formation.
Stratigraphic position --142 ft above the base of the section.
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7478–CO.
Geographic location ----The same as for 7448–CO.
Coordinates ----------- Do.
Formation ------------Clays Ferry Formation.
Stratigraphic position --145–148 ft above the base of the section.
Quadrangle name ------Sadieville, Ky.
Section name ----------Sadieville C.
Section number --------192.

Collection number -----7702–CO*.
Geographic location ----Railroad cut southeast from Agawam station, 1.5 mi south of Ruckerville, Ky.
Coordinates -----------Base of section at 142 mm east, 176.5 mm north.
Formation ------------Grant Lake Limestone.
Stratigraphic position --51.4 ft above base of section.
Quadrangle name ------Hedges, Ky.
Section name ----------Agawam South.
Section number --------26.

Collection number -----7703–CO*.
Geographic location ----The same as for 7702–CO.
Coordinates ----------- Do.
Formation ------------Grant Lake Limestone.
Stratigraphic position -- 41.6 ft above the base of the section.
Silicified --------------Yes.
Quadrangle name ------Hedges, Ky.
Section name ----------Agawam South.
Section number --------26.

Collection number -----7704–CO*.
Geographic location ----The same as for 7702–CO.
Coordinates ----------- Do.
Formation ------------Grant Lake Limestone.
Stratigraphic position --38.9 ft above the base of the section.
Silicified --------------Yes.
Quadrangle name ------Hedges, Ky.
Section name ----------Agawam South.
Section number --------26.

Collection number -----7705–CO*.
Geographic location ----The same as for 7702–CO.
Coordinates ----------- Do.
Formation ------------Grant Lake Limestone.
Stratigraphic position --27.2 ft above the base of the section.
Quadrangle name ------Hedges, Ky.
Section name ----------Agawam South.
Section number --------26.

Collection number -----7706–CO*.
Geographic location ----The same as for 7702–CO.
Coordinates ----------- Do.
Formation ------------Grant Lake Limestone.
Stratigraphic position --21.8 ft above the base of the section.
Quadrangle name ------Hedges, Ky.
Section name ----------Agawam South.
Section number --------26.

Collection number -----7707–CO*.
Geographic location ----The same as for 7702–CO.
Coordinates ----------- Do.
Formation ------------Grant Lake Limestone.
Stratigraphic position --8.3 ft above the base of the section.
Quadrangle name ------Hedges, Ky.
Section name ----------Agawam South.
Section number --------26.

Collection number -----7708–CO*.
Geographic postion ----The same as for 7702–CO.
Coordinates ----------- Do.
Formation ------------Grant Lake Limestone.
Stratigraphic position --7.9 ft above the base of the section.
Quadrangle name ------Hedges, Ky.
Section name ----------Agawam South.
Section number --------26.

Collection number -----7782–CO.
Geographic location ----The same as for 5081–CO.
Coordinates ----------- Do.
Formation ------------Curdsville Limestone Member, Lexington Limestone.
Stratigraphic position --Lower 5 ft of Curdsville Limestone Member.
Silicified --------------Yes (655 lbs).
Quadrangle name ------Tyrone, Ky.
Section name ----------Tyrone C.
Section number --------174.

Collection number -----7784–CO.
Geographic location ----U.S. Route 27, 0.3 mi southeast of crossing of Kentucky River Bridge on south side of road.
Coordinates -----------41 mm east, 75 mm north.
Formation ------------Curdsville Limestone Member, Lexington Limestone.
Stratigraphic position --Basal 2 ft of Curdsville Limestone Member.
Silicified --------------Yes (788 lbs).
Quadrangle name ------Little Hickman, Ky.

Collection number -----7785–CO.
Geographic location ----The same as for 7784–CO.
Coordinates ----------- Do.
Formation ------------Curdsville Limestone Member, Lexington Limestone.
Stratigraphic position --11–12 ft above the base of Curdsville Limestone Member.
Silicified --------------Yes (359 lbs).
Quadrangle name ------Little Hickman, Ky.

Collection number -----7789–CO.
Geographic location ----Eastbound lanes of Interstate Route 64 (both north and south sides), 0.8 mi east of Kentucky River bridge crossing.
Coordinates -----------The same as for 5095–CO.
Formation ------------Upper part of Devils Hollow Member, Lexington Limestone.
Silicified --------------Yes (422 lbs).
Quadrangle name ------Frankfort East, Ky.
Section name ----------Frankfort East A.
Section number --------86.

Collection number -----7790–CO.
Geographic location ----Jones Lane Branch Road, 0.85 mi northwest of junction with Watkinsville Road; west side of Jones Lane Branch Road.
Coordinates -----------10.5 mm east, 552 mm north.
Formation ------------Millersburg Member, Lexington Limestone.
Silicified --------------Yes (172 lbs).
Quadrangle name ------Midway, Ky.

Collection number -----7791–CO.
Geographic location ----The same as for 4940–CO.
Coordinates ----------- Do.
Formation ------------Lower part of Logana Member, Lexington Limestone.
Stratigraphic position --35 ft above Tyrone Limestone-Lexington Limestone contact.
Silicified --------------Yes (427 lbs).
Quadrangle name ------Salvisa, Ky.
Section name ----------Salvisa B.
Section number --------176.

Collection number -----7792–CO.
Geographic location ----The same as for 5067–CO.
Coordinates -----------The same as for 5067–CO.
Formation ------------Grier Limestone Member, Lexington Limestone.
Stratigraphic position --170 ft above the top of the Tyrone Limestone.
Silicified --------------Yes (169 lbs).
Quadrangle name ------Ford, Ky.

Collection number -----7793–CO.
Geographic location ----U.S. Route 227, 0.2 mi south of road to Boonesboro Beach.
Coordinates -----------400 mm east, 82.5 mm north.
Formation ------------Tongue of Tanglewood Limestone Member, Lexington Limestone, overlain and underlain by Clays Ferry Formation.
Stratigraphic position --15 ft below abundant *Sowerbyella* in Clays Ferry Formation.
Quadrangle name ------Ford, Ky.

Collection number -----7805–CO.
Geographic location ----The same as for 6211–CO.
Coordinates ----------- Do.
Formation ------------Uppermost part of Point Pleasant Tongue, Clay Ferry Formation.
Quadrangle name ------Moscow, Ohio–Ky.
Section name ----------Bear Creek.

Collection number -----7806–CO.
Geographic location ----The same as for 6211–CO.
Formation ------------Point Pleasant Tongue, Clays Ferry Formation.
Stratigraphic position --5 ft below top of Point Pleasant Tongue, Clays Ferry Formation.
Quadrangle name ------Moscow, Ohio-Ky.
Section name ----------Bear Creek.

Collection number -----7809–CO.
Geographic location ----75 ft south of junction Kentucky Route 388 and U.S. Route 227.
Coordinates -----------384 mm east, 113 mm north.
Formation ------------Tanglewood Limestone Member, Lexington Limestone.
Stratigraphic position --First bed above Brannon Member-Tanglewood Limestone Member contact.
Silicified --------------Yes (205 lbs).
Quadrangle name ------Ford, Ky.
Section name ----------Boonesboro Beach.

Collection number -----7812–CO.
Geographic location ----Farm pond 250 ft west of U.S. Route 27, 500 ft south of junction of U.S. Routes 27 and 62.
Coordinates -----------220 mm east, 548 mm north.
Formation ------------Clays Ferry Formation.
Silicified --------------Yes (170 lbs).
Quadrangle name ------Shawhan, Ky.

Collection number -----7834–CO.
Geographic location ----U.S. Route 50 1.6 miles east of Versailles, Ind.
Coordinates -----------86.5 mm east, 297 mm north.
Formation ------------Uppermost part of Dillsboro Formation.
Silicified --------------Yes (242 lbs).
Quadrangle name ------Milan, Ind.

Collection number -----7836-CO.
Geographic location ----Section on U.S. Route 27, 1 mi south of intersection with road to Camp Nelson National Cemetery.
Coordinates -----------Top of section at 60 mm east, 113.5 mm north.
Formation ------------Upper part of Camp Nelson Limestone.
Silicified --------------Yes (217 lbs).
Quadrangle name ------Little Hickman, Ky.
Section name ----------Type section Camp Nelson Limestone.

Collection number -----7875-CO.
Geographic location ----Exposures along road up from Kentucky River lock number 7 to High Bridge, Ky. and junction with Kentucky Route 29; 1,000 ft west of high-level railroad bridge over Kentucky River. Base of section taken at U-shaped bend in road, between two pillars on road leading to dam at lock number 7.
Coordinates -----------Base of section at 97.5 mm east, 347 mm north.
Formation ------------Camp Nelson Limestone.
Stratigraphic position --60.5 ft above base of section.
Silicified --------------Yes (100 lbs).
Quadrangle name ------Wilmore, Ky.
Section name ----------High Bridge.

Collection number -----7936-CO*.
Geographic location ----The same as for 7702-CO.
Coordinates ----------- Do.
Formation ------------Grant Lake Limestone.
Silicified --------------Yes.
Quadrangle name ------Hedges, Ky.
Section name ----------Agawam South.
Section number --------26.

Collection number -----7937-CO*.
Geographic location ----The same as for 7702-CO.
Coordinates ----------- Do.
Formation ------------Grant Lake Limestone.
Silicified --------------Yes.
Quadrangle name ------Hedges, Ky.
Section name ----------Agawam South.
Section number --------26.

Collection number -----7978-CO.
Geographic location ----Exposures along Moffett Road, 0.5 mi west of Kenton, Ky.
Coordinates -----------Base of section at 118.5, mm east, 547 mm north.
Formation ------------Kope Formation.
Stratigraphic position --40-43 ft above Point Pleasant Tongue of Clays Ferry Formation-Kope Formation contact.
Quadrangle name ------De Mossville, Ky.
Section name ----------Moffett Road.

Collection number -----7984-CO.
Geographic location ----The same as for 7978-CO.
Coordinates ----------- Do.
Formation ------------Kope Formation.
Stratigraphic position --57 ft above Point Pleasant Tongue of Clays Ferry Formation-Kope Formation contact.
Quadrangle name ------De Mossville, Ky.
Section name ----------Moffett Road.

Collection number -----8068-CO.
Geographic location ----The same as for 7978-CO.
Coordinates ----------- Do.
Formation ------------Point Pleasant Tongue, Clays Ferry Formation.
Stratigraphic position --2-3 ft above the base of the section.
Silicified --------------Yes (150 lbs).
Quadrangle name ------De Mossville, Ky.
Section name ----------Moffett Road.

Collection number -----D-1106-CO*.
Geographic location ----Kentucky Route 35, 0.3 mi southeast of crossing with Elkhorn Creek.
Coordinates -----------Base of section at 115 mm east, 281 mm north.
Formation ------------Macedonia Bed, Grier Limestone Member, Lexington Limestone.
Stratigraphic position --20 ft above the base of the section.
Quadrangle name ------Switzer, Ky.
Section name ----------Switzer A.
Section number --------61.

Collection number -----D-1115-CO*.
Geographic location ----The same as for D-1106-CO.
Coordinates ----------- Do.
Formation ------------Grier Limestone Member, Lexington Limestone.
Stratigraphic position --78 ft above the base of the section.
Quadrangle name ------Switzer, Ky.
Section name ----------Switzer A.
Section number --------61.

Collection number -----D-1117-CO*.
Geographic location ----The same as for D-1106-CO.
Coordinates ----------- Do.
Formation ------------Grier Limestone Member, Lexington Limestone.
Stratigraphic position --85 ft above the base of the section.
Quadrangle name ------Switzer, Ky.
Section name ----------Switzer A.
Section number --------61.

Collection number -----D-1119-CO*.
Geographic location ----The same as for D-1106-CO.
Coordinates ----------- Do.
Formation ------------Stamping Ground Member, Lexington Limestone.
Stratigraphic position --105 ft above the base of the section.
Quadrangle name ------Switzer, Ky.
Section name ----------Switzer A.
Section number --------61.

Collection number -----D-1120-CO*.
Geographic location ----The same as for D-1106-CO.
Coordinates ----------- Do.

Formation ____________Base of Stamping Ground Member, Lexington Limestone.
Stratigraphic position __101 ft above the base of the section.
Quadrangle name ______Switzer, Ky.
Section name __________Switzer A.
Section number ________61.

Collection number _____D-1121-CO*.
Geographic location ____The same as for D-1106-CO.
Coordinates ___________ Do.
Formation ____________Stamping Ground Member, Lexington Limestone.
Stratigraphic position __111 ft above the base of the section.
Quadrangle name ______Switzer, Ky.
Section name __________Switzer A.
Section number ________61.

Collection number _____D-1122-CO*.
Geographic location ____The same as for D-1106-CO.
Coordinates ___________ Do.
Formation ____________Stamping Ground Member, Lexington Limestone.
Stratigraphic position __120 ft above the base of the section.
Quadrangle name ______Switzer, Ky.
Section name __________Switzer A.
Section number ________61.

Collection number _____D-1123-CO*.
Geographic location ____The same as for D-1106-CO.
Coordinates ___________ Do.
Formation ____________Stamping Ground Member, Lexington Limestone.
Stratigraphic position __118 ft above the base of the section.
Quadrangle name ______Switzer, Ky.
Section name __________Switzer A.
Section number ________61.

Collection number _____D-1125-CO*.
Geographic location ____The same as for D-1106-CO.
Coordinates ___________ Do.
Formation ____________Tanglewood Limestone Member, Lexington Limestone.
Stratigraphic position __140 ft above the base of the section.
Quadrangle name ______Switzer, Ky.
Section name __________Switzer A.
Section number ________61.

Collection number _____D-1129-CO*.
Geographic location ____The same as for D-1106-CO.
Coordinates ___________ Do.
Formation ____________Millersburg Member, Lexington Limestone.
Stratigraphic position __175 ft above the base of the section.
Quadrangle name ______Switzer, Ky.
Section name __________Switzer A.
Section number ________61.

Collection number _____D-1132-CO*.
Geographic location ____The same as for D-1106-CO.
Coordinates ___________ Do.
Formation ____________Nicholas Bed, Tanglewood Limestone Member, Lexington Limestone.
Stratigraphic position __195 ft. above the base of the section.
Quadrangle name ______Switzer, Ky.
Section name __________Switzer A.
Section number ________61.

Collection number _____D-1169-CO*.
Geographic location ____Old road to lower Clays Ferry, Ky., Bridge, section beginning about 1,750 ft west of the high bridge piers for the new Interstate Route 75 bridge crossing of the Kentucky River.
Coordinates ___________Base of section at 132 mm east, 31 mm north.
Formation ____________Clays Ferry Formation.
Stratigraphic position __8 ft above top of Tanglewood Limestone Member, Lexington Limestone.
Quadrangle name ______Ford, Ky.
Section name __________Clays Ferry (lower part); Ford A.
Section number ________22B.

Collection number _____D-1170-CO*.
Geographic location ____The same as for D-1169-CO.
Coordinates ___________ Do.
Formation ____________Clays Ferry Formation.
Stratigraphic position __10 ft above top of Tanglewood Limestone Member, Lexingon Limestone.
Quadrangle name ______Ford, Ky.
Section name __________Clays Ferry (lower part); Ford A.
Section number ________22B.

Collection number _____D-1171-CO*.
Geographic location ____The same as for D-1169-CO.
Coordinates ___________ Do.
Formation ____________Clays Ferry Formation.
Stratigraphic position __15 ft above top of Tanglewood Limestone Member, Lexington Limestone.
Quadrangle name ______Ford, Ky.
Section name __________Clays Ferry (lower part); Ford A.
Section number ________22B.

Collection number _____D-1172-CO*.
Geographic location ____The same as for D-1169-CO.
Coordinates ___________ Do.
Formation ____________Clays Ferry Formation.
Stratigraphic position __24 ft above top of Tanglewood Limestone Member, Lexington Limestone.
Silicified ______________Yes (109 lbs).
Quadrangle name ______Ford, Ky.
Section name __________Clays Ferry (lower part); Ford A.
Section number ________22B.

Collection number _____D-1173-CO*.
Geographic location ____The same as for D-1169-CO.
Coordinates ___________ Do.
Formation ____________Clays Ferry Formation.
Stratigraphic position __30 ft above top of Tanglewood Limestone Member, Lexington Limestone.
Quadrangle name ______Ford, Ky.

Section name ----------Clays Ferry (lower part); Ford A.
Section number --------22B.

Collection number -----D-1174-CO*.
Geographic location ----The same as for D-1169-CO.
Coordinates ----------- Do.
Formation ------------Clays Ferry Formation.
Stratigraphic position --38 ft above top of Tanglewood Limestone Member, Lexington Limestone.
Quadrangle name ------Ford, Ky.
Section name ----------Clays Ferry (lower part); Ford A.
Section number --------22B.

Collection number -----D-1178-CO*.
Geographic location ----The same as for D-1169-CO.
Coordinates ----------- Do.
Formation ------------Clays Ferry Formation.
Stratigraphic position --56 ft above top of Tanglewood Limestone Member, Lexington Limestone.
Quadrangle name ------Ford, Ky.
Section name ----------Clays Ferry (lower part); Ford A.
Section number --------22B.

Collection number -----D-1179-CO*.
Geographic location ----The same as for D-1169-CO.
Coordinates -----------The same as for D-1169-CO.
Formation ------------Clay Ferry Formation.
Stratigraphic position --74 ft above top of Tanglewood Limestone Member, Lexington Limestone.
Quadrangle name ------Ford, Ky.
Section name ----------Clays Ferry (lower part); Ford A.
Section number --------22B.

Collection number -----D-1180-CO*.
Geographic location ----The same as for D-1169-CO.
Coordinates ----------- Do.
Formation ------------Clays Ferry Formation.
Stratigraphic position --76 ft above top of Tanglewood Limestone Member, Lexington Limestone.
Quadrangle name ------Ford, Ky.
Section name ----------Clays Ferry (lower part); Ford A.
Section number --------22B.

Collection number -----D-1196-CO*.
Geographic location ----Eastbound lanes of Interstate Route 64 from Kentucky River bridge crossing to end of exposures.
Coordinates -----------Base of section at 88 mm east, 164 mm north.
Formation ------------Top of Logana Member, Lexington Limestone.
Stratigraphic position --50 ft above top of Tyrone Limestone.
Silicified --------------Yes (250 lbs).
Quadrangle name ------Frankfort East, Ky.
Section name ----------Frankfort East A.
Section number --------86.

Collection number -----D-1200-CO*.
Geographic location ----Westbound lanes of Interstate Route 64, exposures beginning about 0.5 mi east of bridge crossing of Kentucky River.
Coordinates -----------Base of collected section at 112.5 mm east, 188 mm north.
Formation ------------Tanglewood Limestone Member, Lexington Limestone.
Stratigraphic position --205 ft above top of Tyrone Limestone.
Quadrangle name ------Frankfort East, Ky.
Section name ----------Frankfort East A.
Section number --------86.

Collection number -----D-1204-CO*.
Geographic location ----The same as for D-1200-CO.
Coordinates ----------- Do.
Formation ------------Tanglewood Limestone Member, Lexington Limestone.
Stratigraphic position --230 ft above top of Tyrone Limestone.
Quadrangle name ------Frankfort East, Ky.
Section name ----------Frankfort East A.
Section number --------86.

Collection number -----D-1207-CO*.
Geographic location ----The same as for D-1200-CO.
Coordinates ----------- Do.
Formation ------------Devils Hollow Member, Lexington Limestone.
Stratigraphic position --256 ft above top of Tyrone Limestone.
Quadrangle name ------Frankfort East, Ky.
Section name ----------Frankfort East A.
Section number --------86.

Collection number -----D-1239-CO*.
Geographic location ----Road exposure running parallel to Mason County and Lewis County boundary line in the northeast corner of the Orangeburg quadrangle and the southeast corner of the Maysville East quadrangle.
Coordinates -----------Base of section at 425 mm east, 559 mm north in the Orangeburg quadrangle.
Formation ------------Bull Fork Formation.
Stratigraphic position --7-13 ft above base of Bull Fork Formation.
Quadrangle name ------Orangeburg, Ky.
Section name ----------County Line.

Collection number -----D-1241-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.
Stratigraphic position --11 ft above base of Bull Fork Formation.
Quadrangle name ------Orangeburg, Ky.
Section name ----------County Line.

Collection number -----D-1243-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.

Stratigraphic position --22 ft above base of Bull Fork Formation.
Quadrangle name ------Orangeburg, Ky.
Section name ----------County Line.

Collection number -----D-1244-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.
Stratigraphic position --23 ft above base of Bull Fork Formation.
Quadrangle name ------Orangeburg, Ky.
Section name ----------County Line.

Collection number -----D-1246-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.
Stratigraphic position --28-35 ft above base of Bull Fork Formation.
Quadrangle name ------Orangeburg, Ky.
Section name ----------County Line.

Collection number -----D-1247-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.
Stratigraphic position --36 ft above base of Bull Fork Formation.
Quadrangle name ------ Orangeburg, Ky.
Section name ----------County Line.

Collection number -----D-1248-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.
Stratigraphic position --38 ft above base of Bull Fork Formation.
Quadrangle name ------Orangeburg, Ky.
Section name ----------County Line.

Collection number -----D-1250-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.
Stratigraphic position --56-61 ft above base of Bull Fork Formation.
Quadrangle name ------Orangeburg, Ky.
Section name ----------County Line.

Collection number -----D-1251-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.
Stratigraphic position --Float at 56-61 ft above base of Bull Fork Formation.
Quadrangle name ------Orangeburg, Ky.
Section name ----------County Line.

Collection number -----D-1252-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.

Stratigraphic position --71 ft above base of Bull Fork Formation.
Quadrangle name ------Orangeburg, Ky.
Section name ----------County Line.

Collection number -----D-1253-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.
Stratigraphic postion --91 ft above base of Bull Fork Formation.
Quadrangle name ------Orangeburg, Ky.
Section name ----------County Line.

Collection number -----D-1254-CO*
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.
Stratigraphic position --101-106 ft above base of Bull Fork Formation.
Quadrangle name ------Orangeburg, Ky.
Section name ----------County Line.

Collection number -----D-1255-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.
Stratigraphic position --96-111 ft above base of Bull Fork Formation.
Quadrangle name ------Orangeburg, Ky.
Section name ----------County Line.

Collection number -----D-1256-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.
Stratgraphic position --106-111 ft above base of Bull Fork Formation.
Quadrangle name ------Orangeburg, Ky.
Section name ----------County Line.

Collection number -----D-1258-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.
Stratigraphic position --144 ft above base of Bull Fork Formation.
Quadrangle name ------Orangeburg, Ky.
Section name ----------County Line.

Collection number -----D-1259-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.
Stratigraphic position --149-154 ft above base of Bull Fork Formation.
Quadrangle name ------Maysville East, Ohio-Ky.
Section name ----------County Line.

Collection number -----D-1260-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.

Stratigraphic position --169 ft above base of Bull Fork Formation.
Quadrangle name ------Maysville East, Ohio-Ky.
Section name ----------County Line.

Collection number -----D-1263-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.
Stratigraphic position --189–194 ft above base of Bull Fork Formation.
Quadrangle name ------Maysville East, Ohio-Ky.
Section name ----------County Line.

Collection number -----D-1265-CO*.
Geographic location ----The same as for D-1239-CO.
Coordinates ----------- Do.
Formation ------------Bull Fork Formation.
Stratigraphic position --126–131 ft above base of Bull Fork Formation.
Quadrangle name ------Orangeburg, Ky.
Section name ----------County Line.

Collection number -----D-1267-CO.
Geographic location ----The same as for 4208-CO.
Coordinates ----------- Do.
Formation ------------Tate Member, Ashlock Formation.
Stratigraphic position --10 ft above base of the section.
Quadrangle name ------Maud, Ky.
Section name ----------Fredericktown.

Collection number -----D-1273-CO.
Geographic location ----The same as for 4208-CO.
Coordinates ----------- Do.
Formation ------------Gilbert Member, Ashlock Formation.
Stratigraphic position --47 ft above the base of the section.
Quadrangle name ------Maud, Ky.
Section name ----------Fredericktown.

Collection number -----D-1276-CO.
Geographic location ----The same as for 4208-CO.
Coordinates ----------- Do.
Formation ------------Upper tongue of Grant Lake Limestone.
Stratigraphic position --73 ft above the base of the section.
Quadrangle name ------Maud, Ky.
Section name ----------Fredericktown.

Collection number -----D-1277-CO.
Geographic location ----The same as for 4208-CO.
Coordinates ----------- Do.
Formation ------------Upper tongue of Grant Lake Limestone.
Stratigraphic position --81 ft above the base of the section.
Quadrangle name ------Maud, Ky.
Section name ----------Fredericktown.

Collection number -----D-1280-CO.
Geographic location ----The same as for 4208-CO.
Coordinates ----------- Do.
Formation ------------Upper tongue of Grant Lake Limestone.
Stratigraphic position --97 ft above the base of the section.
Quadrangle name ------Maud, Ky.
Section name ----------Fredericktown.

Collection number -----D-1288-CO.
Geographic location ----The same as for 4208-CO.
Coordinates ----------- Do.
Formation ------------Bardstown Member, Drakes Formation.
Stratigraphic position --167 ft above the base of the section.
Quadrangle name ------Maud, Ky.
Section name ----------Fredericktown.

Collection number -----D-1289-CO.
Geographic location ----The same as for 4208-CO.
Coordinates ----------- Do.
Formation ------------Top of Bardstown Member, Drakes Formation.
Stratigraphic position --175 ft above base of section.
Quadrangle name ------Maud, Ky.
Section name ----------Fredericktown.

Collection number -----D-1292-CO.
Geographic location ----The same as for 4208-CO.
Coordinates ----------- Do.
Formation ------------Bardstown Member, Drakes Formation.
Stratigraphic position --156 ft above the base of the section.
Quadrangle name ------Maud, Ky.
Section name ----------Fredericktown.

Collection number -----D-1295-CO.
Geographic location ----1.7 mi southeast of Gratz, Ky. on Kentucky Route 355 (north bluff of Clements Bottom).
Coordinates -----------Base of section at 280 mm east, 416 mm north.
Formation ------------Grier Limestone Member, Lexington Limestone.
Stratigraphic position --21 ft above the base of the section.
Quadrangle name ------Gratz, Ky.
Section name ----------Gratz A.
Section number --------62.

Collection number -----D-1301-CO.
Geographic location ----The same as for D-1295-CO.
Coordinates ----------- Do.
Formation ------------Grier Limestone Member, Lexington Limestone.
Stratigraphic position --32 ft above the base of the section.
Quadrangle name ------Gratz, Ky.
Section name ----------Gratz A.
Section number --------62.

Collection number -----D-1309-CO.
Geographic location ----The same as for D-1295-CO.
Coordinates ----------- Do.
Formation ------------Possibly Grier Limestone Member, Lexington Limestone, or tongue of Clays Ferry Formation.
Stratigraphic position --70 ft above the base of the section.
Quadrangle name ------Gratz, Ky.
Section name ----------Gratz A.
Section number --------62.

Collection number -----D-1310-CO.
Geographic location ----The same as for D-1295-CO.
Coordinates ----------- Do.
Formation ------------Either Grier Limestone Member, Lexington Limestone or tongue of Clays Ferry Formation.
Stratigraphic position --75–76 ft above the base of the section.
Quadrangle name ------Gratz, Ky.
Section name ----------Gratz A.
Section number --------62.

Collection number -----D-1312-CO.
Geographic location ----The same as for D-1295-CO.
Coordinates ----------- Do.
Formation ------------Millersburg Member, Lexington Limestone.
Stratigraphic position --120 ft above the base of the section.
Quadrangle name ------Gratz, Ky.
Section name ----------Gratz A.
Section number --------62.

Collection number -----D-1314-CO*.
Geographic location ----Section along Kentucky Route 1449, beginning about 0.7 mi south of junction with Kentucky Route 10. Section extends along Route 1449 from southwest corner of the Maysville East quadrangle to the northwest corner of the Orangeburg quadrangle.
Coordinates -----------Base of section at 114.5 mm east, 12 mm north in the Maysville East quadrangle.
Formation ------------Kope Formation.
Stratigraphic position --46 ft above the base of the section.
Quadrangle name ------Maysville East, Ohio-Kentucky.
Section name ----------Sleepy Hollow, Sleepy Hollow is the name applied to the eastern tributary of Kennedy Creek. The name Sleepy Hollow is also applied to the valley immediately west of Kennedy Creek Valley. The Sleepy Hollow referred to here is the eastern tributary of Kennedy Creek.

Collection number -----D-1327-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Upper part of Fairview Formation.
Stratigraphic position --122 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1330-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Basal part of Grant Lake Limestone.
Stratigraphic position --132 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1332-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Lower part of Grant Lake Limestone..
Stratigraphic position --135 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1333-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Grant Lake Limestone.
Stratigraphic position --138 ft above the base of the section. (float).
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1334-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Lower part of Grant Lake Limestone.
Stratigraphic position --138 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1335-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Lower part of Grant Lake Limestone.
Stratigraphic position --139 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1336-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Grant Lake Limestone.
Stratigraphic position --140 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1337-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Grant Lake Limestone.
Stratigraphic position --141 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1338-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Lower part of Grant Lake Limestone.
Stratigraphic position --142 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1339-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Lower part of Grant Lake Limestone.

Stratigraphic position --152 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1340-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Lower part of Grant Lake Limestone.
Stratigraphic position --146 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1341-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Lower part of Grant Lake Limestone.
Stratigraphic position --165 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1342-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Lower part of Grant Lake Limestone.
Stratigraphic position --176 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-Co.

Collection number -----D-1343-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Lower part of Grant Lake Limestone.
Stratigraphic position --183 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1344-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Upper part of Grant Lake Limestone.
Stratigraphic position --201 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1345-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Upper part of Grant Lake Limestone.
Stratigraphic position --218 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1346-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Upper part of Grant Lake Limestone.
Stratigraphic position --224 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1347-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Upper part of Grant Lake Limestone.
Stratigraphic position --225-230 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1348-CO*.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Uppermost part of Grant Lake Limestone.
Stratigraphic position --235 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1349-CO.
Geographic location ----The same as for D-1314-CO.
Coordinates ----------- Do.
Formation ------------Grant Lake Limestone.
Stratigraphic position --140-143 ft above the base of the section.
Quadrangle name ------Orangeburg, Ky.
Section name ----------See D-1314-CO.

Collection number -----D-1365-CO*.
Geographic location ----Section in roadcut on Interstate Route 75 beginning 0.4 mi south of bridge over Kentucky River.
Coordinates -----------Base of section at 150.5 mm east, 574 mm north.
Formation ------------Calloway Creek Limestone.
Stratigraphic position --56-61 ft above base of Calloway Creek Limestone.
Quadrangle name ------Richmond North, Ky.
Section name ----------Type section Calloway Creek Limestone (Weir, Greene, and Simmons, 1965).

Collection number -----D-1367-CO*.
Geographic location ----The same as for D-1365-CO.
Coordinates ----------- Do.
Formation ------------Calloway Creek Limestone.
Stratigraphic position --73-94 ft above base of Calloway Creek Limestone.
Quadrangle name ------Richmond North, Ky.
Section name ----------The same as for D-1365-CO.

Collection number -----D-1368-CO*.
Geographic location ----The same as for D-1365-CO.
Coordinates ----------- Do.
Formation ------------Calloway Creek Limestone.
Stratigraphic position --94-107 ft above base of Calloway Creek Limestone.
Quadrangle name ------Richmond North, Ky.
Section name ----------The same as for D-1365-CO.

Collection number -----D-1369-CO*.
Geographic location ----The same as for D-1365-CO.
Coordinates ----------- Do.
Formation ------------Calloway Creek Limestone.
Stratigraphic position --107-124 ft above base of Calloway Creek Limestone.
Quadrangle name ------Richmond North, Ky.
Section name ----------The same as for D-1365-CO.

Collection number -----D-1370E-CO*.
Geographic location ----17,300 ft north and 14,950 ft west of the southeast corner of the Richmond North quadrangle.
Coordinates -----------269.5 mm east, 222 mm north.
Formation ------------Otter Creek Coral Bed, Preachersville Member, Drakes Formation.
Stratigraphic position --80 ft below the top of the Drakes Formation.
Quadrangle name ------Richmond North, Ky.

Collection number -----D-1629-CO.
Geographic location ----The same as for 4871-CO.
Coordinates ----------- Do.
Formation ------------Grier Limestone Member, Lexington Limestone.
Stratigraphic position --46 feet above the base of the section.
Quadrangle name ------Valley View, Ky.
Section name ----------Valley View C (Antioch Church Road).
Section number --------180.

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The Brachiopod Genus *Platystrophia*

By LEONARD P. ALBERSTADT

CONTRIBUTIONS TO THE ORDOVICIAN PALEONTOLOGY OF KENTUCKY AND NEARBY STATES

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1066–B

Prepared in cooperation with the Commonwealth of Kentucky, University of Kentucky, Kentucky Geological Survey

Discussion of the stratigraphic and geographic distribution of Platystrophia *and the description of eight species*

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1979

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SYSTEM OF MEASUREMENT UNITS

The investigations underlying this series of reports were made over a period of years, and distances and stratigraphic measurements appear fairly uniformly in English units. Measurements of fossil specimens, on the other hand, follow the long-standing convention of appearing in metric units. Because of the dates of the investigations and the amount of resulting data, the English measurements have been retained. Conversions to metric units may be made by using the following conversion table.

To convert English unit:	To metric unit:	Multiply by:
Mile (mi)	Kilometer (km)	1.61
Foot (ft)	Meter (m)	.305

THE BRACHIOPOD GENUS *PLATYSTROPHIA*

By LEONARD P. ALBERSTADT[1]

ABSTRACT

The brachiopod genus *Platystrophia* is one of the most conspicuous taxa in the Ordovician strata of Kentucky; it can be divided into four easily recognizable nontaxonomic groups, referred to as (1) the *ponderosa* group, (2) the *colbiensis-elegantula* group, (3) the *annieana* group, and (4) the *laticosta-cypha* group. The species within the *colbiensis-elegantula* group are confined to the Lexington Limestone and Clays Ferry Formation. Species in the *ponderosa*, *annieana*, and *laticosta-cypha* groups occur in the overlying Calloway Creek, Fairview, Ashlock, Grant Lake, Bull Fork, and Drakes Formations.

All the species of *Platystrophia* from Kentucky are members of the "triplicate" group of Cumings (1903). The stratigraphic positions of these species are generally consistent with McEwan's (1919) phylogenetic interpretation of the "triplicate" group; the only exception is her interpretation that *P. laticosta* was ancestral to *P. cypha*. The reported stratigraphic positions of these two species in Kentucky do not lend support to this sequential history.

The stratigraphic distribution and morphology of the various species in Kentucky suggest that the Richmondian species are more closely related to the underlying species (Edenian and Maysvillian forms) than they are to those in western and arctic faunas. The various species of *Platystrophia* from Anticosti Island, Quebec; from northern Canada; and from Iowa, Idaho, Texas, Wyoming, and Oklahoma, are distinctly different from those in the Cincinnati, Ohio, region. This difference makes Upper Ordovician brachiopod biostratigraphic correlations difficult, and furthermore makes the rocks of the Cincinnati, Ohio, region less effective as the standard for the Upper Ordovician of North America.

INTRODUCTION

The brachiopod genus *Platystrophia* is one of the most conspicuous taxa in the Middle and Upper Ordovician formations of Kentucky. Its abundance and ease of recognition have been used by various workers over the years to help define some of the formations. The difficulties that arise from such a procedure have been discussed by others (Weiss, 1961) and will not be elaborated here.

James (1881), Cumings (1903), Shaler (1876), Foreste (1909a, 1909b, 1910), McEwan (1919), and Caster, Dalve, and Pope (1961) are some of the workers who have studied *Platystrophia* from this region, and their work has greatly influenced our understanding of the genus, although the work of McEwan (1919) is undoubtedly the "standard" reference for the genus. Unfortunately her species differentiations are based primarily on external characters and details of the interiors are lacking.

Platystrophia is a highly variable genus for which many species and subspecies have been proposed, as McEwan's study well illustrates. However, serious question exists as to the validity of all of the proposed taxa, and a thorough reevaluation is in order.

Although it is difficult to confidently assign all specimens from Kentucky to a previously defined species or subspecies, suites of specimens with more than 25 complete individuals can be properly assigned in most cases. I have avoided erecting any new taxa on the basis of this work, because the genus needs careful reevaluation; and collections other than those from Kentucky must be considered. Such a reevaluation is not the purpose here; rather, it is to determine the stratigraphic occurrences and the morphological variability of the several species as they are represented in these collections from Kentucky, in hopes of increasing our understanding of the biostratigraphy of the Ordovician of Kentucky.

The species of *Platystrophia* from Kentucky described in this paper form four easily recognizable nontaxonomic groups. These informal groups are designated (1) the *ponderosa* group, (2) the *colbiensis-elegantula* group, (3) the *annieana* group, and (4) the *laticosta-cypha* group. Most of the specimens are referred to established species within

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these groups. The species described herein are assigned to groups as follows: (1) *ponderosa* group: *Platystrophia ponderosa*; (2) *annieana* group: *Platystrophia annieana, P. acutilirata, P.* cf. *P. foerstei;* (3) *colbiensis-elegantula* group: *P. colbiensis, P. elegantula;* (4) *laticosta-cypha* group: *P. laticosta, P. cypha.*

Characteristics most commonly used in differentiating species of *Platystrophia* are (1) hinge-line width, (2) shell thickness (dorsal to ventral dimension of articulated specimens), (3) ratio of thickness to width, (4) number of plications in sinus, on fold, and on flanks, (5) size and shape of plications and furrows, (6) size of specimen at maturity, (7) height of fold and depth of sinus, (8) position and method of addition of plications, and (9) appearance of cardinal extremities. As evidenced from the literature and from studies of the specimens in these collections all of the above-mentioned features show some degree of intraspecific variation. Also, that a great deal of interspecific overlap exists appears undoubted; this is one reason a reevaluation of the genus is needed.

A good example of such interspecific overlap is the similarity of *Platystrophia laticosta, P. cypha,* and specimens commonly referred by other workers to *P. unicostata* and *P. crassa.* This overlap is particularly true of small and medium-sized specimens.

McEwan (1919, p. 432) pointed out that the difference between *P. laticosta* and *P. cypha* is one of degree. Mature and old specimens of *P. crassa* have a gibbosity that is slightly more pronounced than that of *P. laticosta* or *P. cypha,* but overall great similarity exists among all three species.

P. colbiensis, P. elegantula, and smaller individuals of other species, particularly *P. annieana* and *P. ponderosa,* also exhibit similarities. Species differentiation of small and medium sized specimens is difficult. As an example compare the following: figures 8 and 9 (*P. annieana*) on plate 3, figure 3 (*P. colbiensis*) on plate 5, and figures 55 and 60, (*P. elegantula*) on plate 5. Species distinctions are much easier when large numbers of specimens are available so that complete growth series can be assembled and variations better evaluated. However, large suites of specimens commonly contain several distinctly atypical individuals. Such specimens commonly have a different appearance because of variations in overall shell shape, and the number and shape of plications, particularly in the number of plications on the fold. Figures 29, 30, 32, and 33 on plate 4 illustrate this point. All the above-mentioned specimens on plate 4 are from the same collection, and all are referred to *P. ponderosa.* The specimen shown in figure 29 has fewer and more angular plications than that of figure 32, which has many more plications distributed slightly unevenly across the shell. The specimen shown in figure 33, plate 4, has "typical" plications on its flanks but a fold with seven plications compared to four plications in most specimens of *P. ponderosa.* Figures 37 and 38 on plate 5 are the best examples showing the differences that can occur in the number of fold plications in a single collection; figure 37 has two large angular plications and figure 38 has six uniformly developed plications. The best illustration of variations in flank plications is shown by figures 43 and 44 on plate 5. These are specimens from a small collection and are tentatively referred to *P. cypha;* plate 5, figure 43, has 15 to 16 flank plications and plate 5, figure 44, has 10 flank plications. Such variation has long been recognized in *Platystrophia* of the Ohio Valley, and until appropriate statistical studies are done to help define the species, their biostratigraphic value will be limited.

ACKNOWLEDGMENTS

I want to express my sincere appreciation to Alwyn Williams, P. M. Sheehan, R. Peter Richards, John Pojeta, and J. K. Pope for reading the manuscript and making suggestions for its improvement. Many of their suggestions were followed, but any shortcomings or misinterpretations in this report are mine alone.

STRATIGRAPHIC DISTRIBUTION

The vertical distributions of species of *Platystrophia* as determined from the Kentucky collections are shown in figure 1. The most conspicuous aspect of these distributions is the restriction of the *elegantula-colbiensis* group to the Lexington Limestone and Clays Ferry Formation, and the occurrence in the overlying Calloway Creek, Fairview, Ashlock, Grant Lake, Bull Fork, and Drakes Formations of members of the *ponderosa* group, *annieana* group, and *laticosta-cypha* group. In addition, two other aspects of the stratigraphic distribution may be meaningful. First, the lowermost appearance of the *laticosta-cypha* group is near the base of the Ashlock Formation-Grant Lake Limestone. Second, *P. annieana* appears to be restricted to the uppermost part of the Ordovician; the Drakes and Bull Fork Formations.

The nonoverlapping occurrence of the *elegantula-colbiensis* group and the *ponderosa, annieana,* and

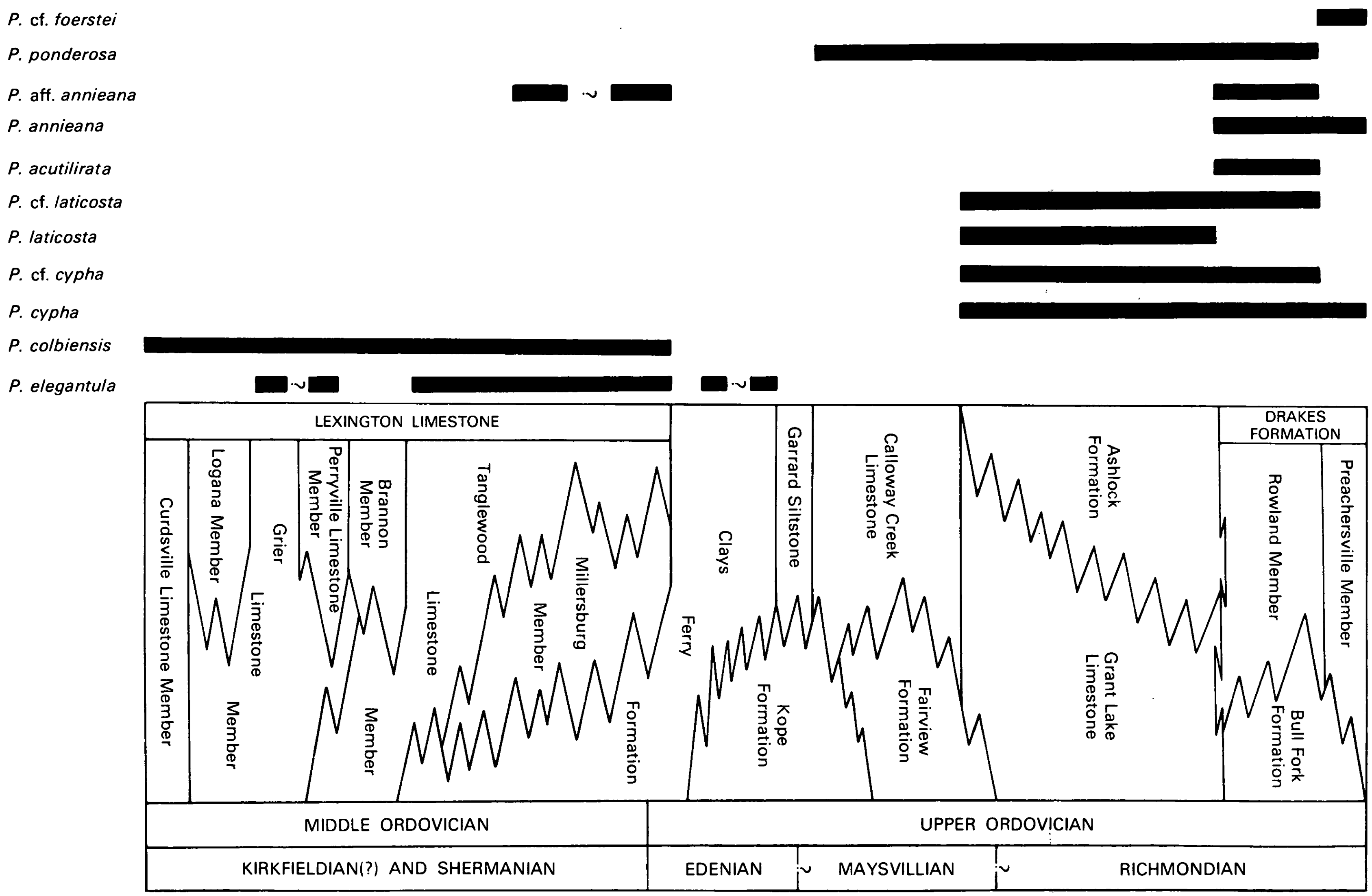

FIGURE 1.—General lithostratigraphic framework of the Ordovician strata in Kentucky and the vertical distribution of the brachiopod species. The position of the Middle-Upper Ordovician boundary is taken from Sweet and Bergström (1971).

laticosta-cypha groups may be of importance in interpreting the phylogenetic history of species of *Platystrophia.* It is interesting to note that the termination of the *elegantula-colbiensis* group and the beginning of the *ponderosa* group is separated by the Garrard Siltstone. Such stratigraphic evidence should be considered in any interpretation that Late Ordovician species in Kentucky were derived from either of these two Middle Ordovician species.

All of the specimens in the Kentucky collections fall within the "triplicate" group of Cumings (1903). Figure 2 is a modified version of the phylogeny of the triplicate subgroup as interpreted by McEwan (1919), showing the low-fold subgroup well established in the Shermanian, and characterized by such species as *P. elegantula, colbiensis,* and *amoena.* The low-fold subgroup gave rise to the *ponderosa* subgroup shortly after the beginning of the Maysvillian; during late Maysvillian and early Richmondian time the low-fold subgroup gave rise to the high-fold subgroup of *laticosta-unicostata-cypha.* The concepts underlying McEwan's phylogeny are based on interpretations of orthogenesis, racial development, and the "biogenic law," some of which are not as absolute as once thought.

According to McEwan (1919) the distinction of the low-fold, high-fold, and *ponderosa* subgroups is based on hinge-line width, thickness of articulated specimen, nature of the fold, and overall size. The low- and high-fold subgroups have long hinge lines relative to their thickness and have a similar ontogenetic development. However, in late neanic development, members of the high-fold subgroup depart markedly from those of the low-fold subgroup in developing a high, compressed fold and weak lateral fold plications. Species that develop to a large size (30–35 mm average) with a hinge line shorter than or approximately equal to the shell width are referred to the *ponderosa* subgroup.

The modified phylogenetic diagram of McEwan (fig. 2 herein) contains most of the species found in the Kentucky collections and described in this paper. They are incorporated into the diagram at their approximate stratigraphic position as reported by McEwan (1919). Note the similarity between this modified diagram of McEwan's and the stratigraphic occurrences of these species as determined from a study of the Kentucky material (fig. 1). With the exception of the specimens referred to in this paper as *P.* cf. *P. foerstei* and *P.* aff. *P. annieana* the stratigraphic distribution of the Kentucky species is in general agreement with the superpositional occurrence required by McEwan's phylogenetic scheme.

The validity and utility of McEwan's phylogenetic scheme has been questioned and undoubtedly needs revision (Williams, 1963). In discussing the Ordovician brachiopods of the Bala District of Wales, Williams pointed out that, according to McEwan's interpretation, a homogeneous sample of *Platystrophia* cf. *P. sublimis* Öpik would be assigned to three species based on the number and mode of origin of the costae (Williams' term) within the sulcus. The same association is found in the rocks of Kohtla, Estonia, where Williams (1963) cited Öpik and described two species based on the presence of either two or three costae (Williams' term) in the ventral sulcus (Williams, 1963).

It is not unreasonable to expect that McEwan's phylogenetic proposals need revision, based as it is on faunas now known to have a history of complex mixings and migrations. Whether the plication patterns can help unravel the details of the evolution of *Platystrophia* remains to be seen.

I have not attempted to make any specific phylogenetic interpretations based on my work with the Kentucky specimens. With the exception of the *laticosta-unicostata-cypha* line, McEwan gave little indication of the ancestor-descendant relationships among the various triplicate species of the genus. In general, she pointed out that many of the species from the Richmondian are remarkably similar in appearance to those in the Trentonian (Shermanian?), and that great care is needed to differentiate them. In the Kentucky collections, with the exception of small specimens of *P. ponderosa* and *annieana,* there is little difficulty in differentiating Richmondian species from the two common Shermanian species, *P. colbiensis* and *P. elegantula.* I agree with McEwan's observation that specimens from the Richmondian appear to have fewer flank plications than those from the Shermanian.

McEwan (1919) stated that little in the morphology of *P. ponderosa* indicates its ancestry except the lowfold growth pattern of the early growth stages. This suggests the derivation of *P. ponderosa* from some member of the low-fold subgroup. She further speculated that *P. ponderosa* may be polyphyletic. It is my belief, however, that the presence of a "cruralium-like" structure in almost all brachial valves of this species negates the idea of a polyphyletic origin, unless one is willing to entertain the idea of a multiple development of this structure. Such a conclusion is not warranted at this time.

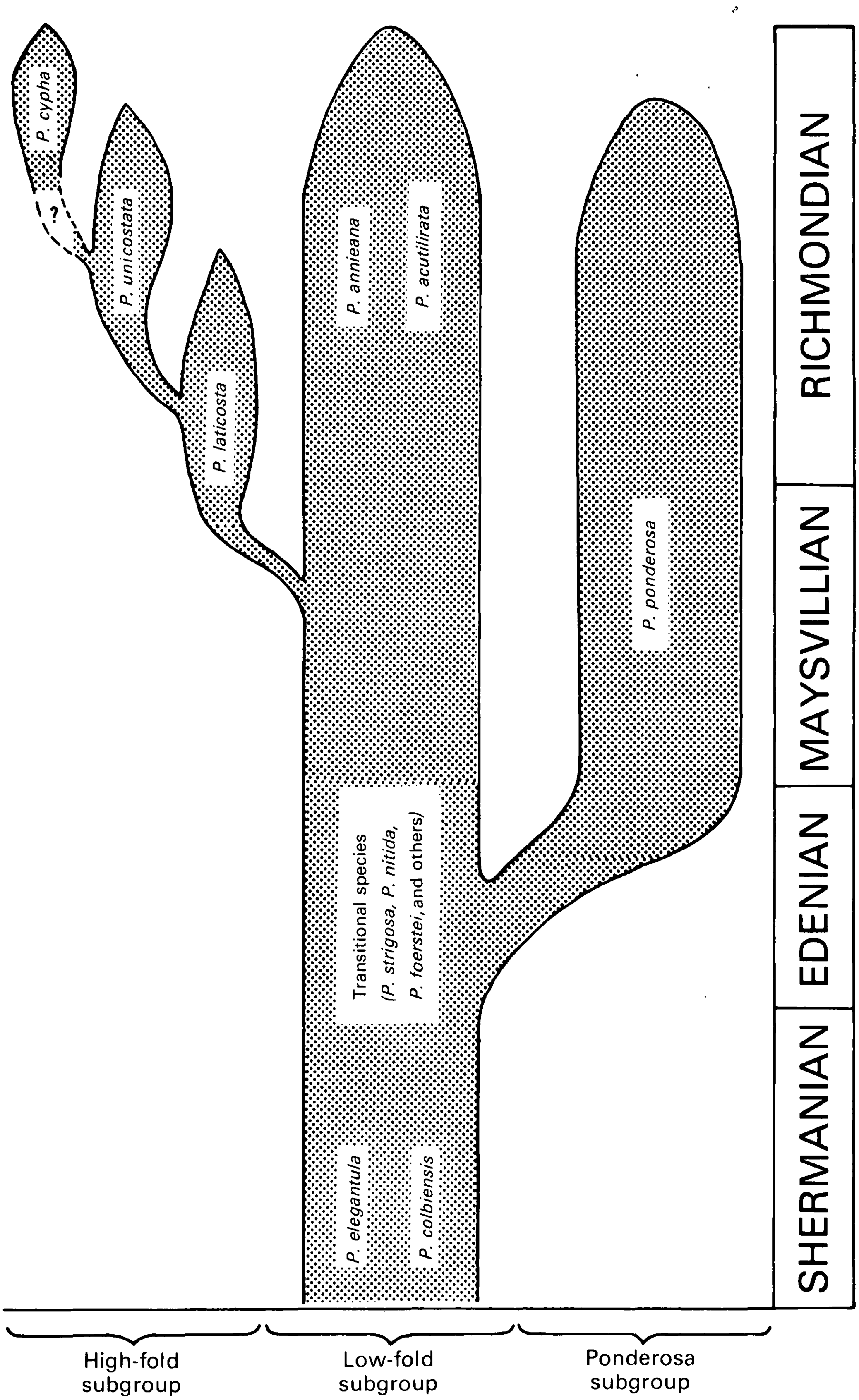

FIGURE 2.—Phylogeny of the triplicate subgroup (modified from McEwan, 1919).

The stratigraphic occurrence of *Platystrophia* species as determined from the Kentucky collections is generally consistent with the phylogenetic history of the triplicate group as presented by McEwan (1919). However, her interpretation that within the high-fold subgroup, *P. laticosta* was ancestral to *P. unicostata* (which in turn gave rise to *P. cypha*) is not entirely compatible with the stratigraphic occurrence of the species in Kentucky. *P. laticosta* and *P. cypha* seem to appear at about the same stratigraphic horizon (fig. 1).

The overall morphology and stratigraphic distribution of *Platystrophia* species in the Middle and Upper Ordovician rocks of Kentucky indicates that the Richmondian species are more closely related to underlying Edenian-Maysvillian forms of the Ohio Valley region rather than to species of the western and arctic faunas of North America. Species in the Drakes and Bull Fork Formations commonly range into the underlying units, exceptions being *P. annieana* and *P. acutilirata.* The interpreted phylogeny of the *Platystrophia laticosta-cypha* line helps accentuate the fact that Richmondian Platystrophias have more Edenian-Maysvillian affinities than some of the other brachiopods. The range of *P. ponderosa* also suggests such a conclusion.

The boundary between the Middle and Upper Ordovician is interpreted to be somewhere in the upper part of the Lexington Limestone (fig. 1). The lower part of the Clays Ferry is believed to be equivalent to the upper part of the Lexington Limestone (Black, Cressman, and MacQuown, 1965). *Platystrophia elegantula* and *Platystrophia colbiensis* occur in many parts of the Lexington and the Clays Ferry. However, they do not appear to be sufficiently restricted stratigraphically to be considered valid taxa for interpreting the Middle Ordovician (Shermanian).

All of the species of *Platystrophia* in the overlying lithostratigraphic units can be used as an assemblage to characterize the Upper Ordovician (Edenian, Maysvillian, and Richmondian Stages?). With the exception of *P. annieana,* none of them appears to have the necessary stratigraphic restriction or the morphological distinctness to use them as stadial markers. However, the association of *P. annieana, P. ponderosa,* and *P. cypha* can be used to characterize the upper part of the Upper Ordovician (Richmondian), although *P. ponderosa* is not reported from the Preachersville Member of the Drakes Formation. Other evidence suggests that *P. ponderosa* does not range above the lower part of the Richmondian in western Ohio and Indiana (John Pope, written commun., 1975).

GEOGRAPHIC DISTRIBUTIONS AND RELATIONS TO OTHER FAUNAS

The many species and morphological variants of *Platystrophia* are a conspicuous part of the brachiopod faunas of Ordovician rocks of Kentucky and nearby States, and are probably nowhere better developed than in this region. However, there still exist significant uncertainties about the evolutionary history of Late Ordovician brachiopod faunas, particularly the Richmondian faunas of the Ohio Valley. Many of the questions regarding this history were initially raised by Twenhofel (1928) in his study of Upper Ordovician and Silurian rocks of Anticosti Island. Macomber (1970) presented an excellent summary of this problem as well as additional data suggesting the likelihood that the Richmondian brachiopod faunas in the type area of the Ohio Valley are mixtures of Edenian-Maysvillian descendants and migrants from western and "arctic" faunas. He rightly pointed out that such a situation reduces the effectiveness of the Ohio Valley as a standard for the Upper Ordovician.

ORDOVICIAN FAUNAL MIGRATIONS

Much work has been done recently to indicate that from Middle Ordovician through Late Ordovician time the North American continent was subjected to various faunal migrations. For example, Macomber (1972) pointed out the almost simultaneous occurrence of the same species of *Heterorthis* in Wales and eastern North America, owing to "overflow" from a flood of *Heterorthis* in the Upper Longvillian of Britain. Cooper (1956) referred to a migration in describing the Porterfieldian Stage in the southern Appalachians. The Porterfieldian is characterized by "a prolific and exotic fauna that floods into the Appalachians and blots out and absorbs the Lincolnshire fauna" (Cooper, 1956, p. 8).

Williams (1973) stated that faunal interchange between European and North American realms began during middle Caradocian time and that by Ashgillian time (Richmondian) a cosmopolitan fauna had emerged. Based on present correlations, this middle Caradocian interchange is appreciably later than the Porterfieldian "flooding" described by Cooper (1956). The middle Ashgillian faunal alinement resulted in the North American province being primarily a western and midcontinent province, but in eastern North America being European in its overall taxonomic composition.

Undoubtedly these migrations and interchanges have greatly influenced biostratigraphic interpretations of Middle and Upper Ordovician rocks of North America. Detailed studies of North American conodonts (Bergström and Sweet, 1966, Sweet and Bergstrom, 1971; Schopf, 1966; Sweet and others, 1970) and the gradual recognition that the type Richmondian is a mixed assemblage (Macomber, 1970) helped immensely in clarifying certain troublesome correlations of Edenian, Maysvillian, and Richmondian rocks of the Western United States with the type area of the Ohio Valley.

PLATYSTROPHIA MIGRATIONS

The *Platystrophia* of the Ohio Valley form part of this "mixed" assemblage brought about by the migration of different taxa into the region throughout Maysvillian and Richmondian time, probably from western and northern sources from what is commonly referred to as the "arctic" fauna.

The earliest reported occurrence of *Platystrophia* is from the Leningrad district of Russia and is probably Arenigian in age (Neuman, 1964).

The consensus is that the appearance of *Platystrophia* in Britain is due to its westerly spread from the Baltic provinces (MacGregor, 1961; Whittington and Williams, 1955). Whittington and Williams (1955) described many of the brachiopods, including *Platystrophia*, in the Derfel Limestone (lower Caradocian, Costonian) of North Wales as "exotics," probably Russian. MacGregor (1961) reported the same species of *Platystrophia* from the upper Llandeilian of Wales. Bates (1968) described the same species from the *Nemagraptus gracilis* zone of Anglesey (middle-upper Llandeilian). However, several other species of *Platystrophia* (*P. scotica* and *P. caelata*) of Caradocian Age have been described from Britain (Williams, 1962; 1974).

Neuman (1963, 1964, and 1968) described *Platystrophia* from sediments associated with volcanic rocks around ancient volcanic islands in Maine and Newfoundland. Those from Maine (Shin Brook Formation (Arenigian to Llanvirnian?)) are similar to *P. precedens* McEwan (1919) and *P. precedens major* Williams (in Whittington and Williams, 1955). Overall the Shin Brook fauna is most like the Arenigian of the Baltic region (Neuman, 1964). Neuman (1964, 1968) believed that the volcanic islands served as steppingstones for faunal migrations in a general east-to-west direction, thus allowing the European species to migrate westward to North America.

The two species of *Platystrophia* from Anticosti Island (Ellis Bay Formation) described by Twenhofel (1928) resemble externally some of the species from the Ohio Valley. However, on Anticosti, the *P. ponderosa, P. laticosta, P. crassa, P. cypha,* and *P. annieana* forms so characteristic of the type Cincinnatian are completely absent. Twenhofel (1928) assigned a post-Richmondian to pre-Silurian age to the Ellis Bay primarily because it lacks certain faunal similarities with the type areas of the midcontinent. More recent studies by Bolton (1971) suggest that the Ellis Bay is probably Richmondian, although some conflicting opinion remains.

The age of the Ellis Bay Formation is not important as such; it is important to substantiate the fact that the few *Platystrophia* species from Anticosti Island are more like the western forms and much younger than those reported by Neuman from adjacent areas of Maine and Newfoundland.

Twenhofel's (1928) studies of the Anticosti Island faunas led him to believe that a westward-trending current during the Ordovician enabled a westward spread of species from a North Atlantic source, but prevented a concentrated eastward spread of North American faunas. This he believed explained the absence in the Anticosti succession of certain prominent Richmondian midcontinent taxa such as the numerous species of *Platystrophia.*

This explanation of current directions was made with the belief that the North American and European continents were positioned in the Ordovician as they are now. More recent geophysical evidence and new data on Ordovician brachiopod distributions indicate that the European and North American continents were much closer together (Williams, 1969), but separated by a narrow seaway (Proto-Atlantic?). According to Williams (1969), the North American side was dominated by an easterly flowing current and the European-African side by a westerly current. This Williams believed to be the pattern that best explained the distributions and first occurrences of certain Ordovician brachiopod genera. However, superimposed on this model are the various sedimentary facies, which certainly must be considered along with circulation patterns in any explanation of faunal provinces and the distribution of taxa.

NORTH AMERICAN PLATYSTROPHIAS OUTSIDE THE OHIO VALLEY

In addition to the prolific *Platystrophia* fauna of the Ohio Valley, various other species of this genus have been described from the midcontinent and western areas of North America. The following discussion is by no means an exhaustive presentation, but only a brief summary of those species pertinent to substantiate the uniqueness of the Ohio Valley fauna and its possible origin. The speculations regarding this origin should be viewed as only the present state of thinking of some of the workers who have addressed themselves to this problem. Undoubtedly other viewpoints are possible, and much additional evidence is needed to clarify the history of these faunas.

Wang (1949) described a single species, *P. equiconvexa*, from the Maquoketa Shale of Iowa. Ross (1959) considered the only species in the Saturday Mountain Formation to resemble *P. equiconvexa* Wang more than any other known species of the genus. Howe (1966) described a new species, *P. prayi*, from the Aleman Limestone (Montaya Group) of the Trans-Pecos region of Texas. The specimens reported by Macomber (1970) from the Bighorn Dolomite of Wyoming are referred to *P. equiconvexa* Wang and *P. prayi* Howe, although Macomber pointed out that the latter is very similar to *P. regularis globata* Twenhofel from the Ellis Bay Formation on Anticosti Island. He suggested that the Ellis Bay species evolved from the western form. The fauna on Anticosti Island contains *P. camerata* Twenhofel and *P. regularis* Shaler. Alberstadt (1973) described three new species from the Viola Limestone of Oklahoma, all of which are clearly distinct from previously described forms. Ludvigsen (1975) reported an unnamed species of *Platystrophia* from the Whittaker Formation (Shermanian-Maysvillian?) from western and northern Canada.

All these more recent brachiopod studies show that the *Platystrophia* species of the northern and western areas of North America are distinctly different from the highly variable forms found in the Ohio Valley. It is not presently possible to tell which, if any, were ancestral to the Richmondian forms of the Ohio Valley. With the exception of the species in southern Oklahoma (Alberstadt, 1973), strong homogeneity marks the occurrences of *Platystrophia* from Iowa, Anticosti Island, Wyoming, Idaho, and Trans-Pecos Texas.

PROVINCIALISM

Evidence that Late Ordovician brachiopod faunas were provincial in their distribution is unmistakable; such provincialism is now recognized as partly responsible for past difficulties in correlating Upper Ordovician rocks throughout North America. Howe (1973) maintained that part of the reason for this provincial aspect was variation between sedimentary basins. One can only speculate as to the reasons for the development of such isolated or semi-isolated sedimentary basins during part of the Late Ordovician followed by a sudden influx of outside species near the end of the Late Ordovician. Two phenomena of the Ordovician bear directly on this question of provinciality. First, it has been proposed that the Proto-Atlantic gradually closed during the Ordovician, bringing European and North American faunal provinces closer together and helping to break down faunal barriers and to permit mixing. Various paleontological studies seem to support this general conclusion by showing that faunal distinctness was substantially reduced during the Ordovician (Williams, 1973), culminating in the more cosmopolitan faunas of the Silurian.

Second, the discovery of Late Ordovician glaciation has led some workers to suggest that sea level was lowered sufficiently to subject the shallow-water epicontinental faunas to unique stress conditions, resulting in the extinction of many forms (Sheehan, 1973). Although Sheehan's work is aimed at understanding the faunal changeover from the Ordovician to the Silurian, it seems reasonable to believe that such glaciations and the resultant strong climatic zonation helped maintain endemism.

It is also possible that marked differences between the Ohio Valley species and those from the "surrounding" regions of North America represent different environmental realms in a manner similar to that proposed by Ross and Ingham (1970) to explain the occurrences of Whiterockian (Middle Ordovician) trilobites in the Northern Hemisphere. According to these workers, the composition of the fauna is as much related to paleoenvironment as to time, and they proposed that faunal differences reflect the overall different conditions of the interior continental platforms and the bordering continental margins (miogeosyncline to eugeosyncline). Ross (1975) presented a summary showing that this general setting existed for western and central North America during much of the Ordovician. The shallow carbonate banks of the midcontinent could have restricted circulation, which may partly account for faunal differences across the platform-shelf transect. Using this model, then, the different assemblages of *Platystrophia* from Oklahoma, Texas, Idaho, Wyoming, and Canada may represent a marginal shelf-like paleotectonic setting much different from the midcontinent carbonate platform setting of the Ohio Valley.

SYSTEMATIC PALEONTOLOGY

I have followed the classification of the Treatise on Invertebrate Paleontology (Part H; Williams and others, 1965); therefore, suprageneric details are not repeated here.

Genus PLATYSTROPHIA King, 1850

Diagnosis.—Subquadrate to spiriferoid in outline; hinge line straight, equal to or greater than midwidth. Strongly biconvex; prominent plications, fold plications commonly accentuated and larger than flank plications; plications smooth or pustulose. Muscle field in pedicle valve well impressed; elongate, extends almost to middle of valve. Adductor scars in brachial valve moderately impressed, ellipsoidal to narrowly elongate in shape, some curved slightly; posterior scars better impressed than anterior ones. Notothyrial cavity deep and commonly narrow; low bladelike cardinal process; brachiophores well developed, bases strongly to weakly convergent.

Platystrophia colbiensis Foerste

Plate 5, figures 1–36; plate 7, figures 36–38, 40, 41

Platystrophia colbiensis Foerste, 1910, Denison Univ. Sci. Lab. Bull., v. 16, p. 55, pl. 4, figs. 2A, B.

Platystrophia colbiensis Foerste. McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 414, pl. 44, figs. 8–11.

Platystrophia colbiensis var. *mutata* Foerste. McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 414–415, pl. 44, fig. 12.

Species small to medium size for genus (table 1); subrectangular in outline with right angle cardinal extremities in most, in some rounded; hinge line straight and slightly less than maximum width (which occurs at middle lateral position), anterolateral margins evenly curved, anterior margin slightly curved or straight. Lateral profile equi-biconvex with even curvature from posterior to anterior; pedicle valve slightly flatter in some. Typical specimen has four plications on fold and three in sulcus (table 1); six to nine plications on flanks. Plications well defined, V-shaped profile with straight steep sides, rounded tops. Growth lines absent in most specimens.

Brachial valve interarea orthocline, curved; beak slightly incurved to erect. Notothyrium triangular, open. Floor of cavity curved and sloping steeply toward anterior; part of floor formed by the curved lateral margins of the brachiophore bases (pl. 5, figs. 34–36). Brachiophores thin, well defined, diverging, distinct upward curvature. Sockets deep, triangular slits (pl. 5, fig. 34) in some, pit-like in most. Cardinal process a thin low ridge. Posterior adductor scars well to moderately impressed (pl. 5, figs. 26–30), some absent (pl. 5, figs. 34, 35), elongate ellipsoidal in outline with straight to moderately curved sides and distinctly pointed anterior ends (pl. 5, figs. 26–30). Anterior scars absent or very poorly defined in all specimens. Interior of valve crenulated throughout; crenulations are reflections of external plications (pl. 5, figs. 26–30, 34, 35).

Pedicle valve interarea apsacline, slightly curved; beak erect. Teeth triangular; dental plates thin, descending straight to floor of valve and joining margins of ellipsoidal to oval-shaped muscle field (pl. 5, figs. 32, 33). Field extends approximately one-third to one-half length of valve. Field elevated slightly above floor and defined by thin rims; some specimens with faint reflections of external plications. Interior of valve crenulated throughout.

Discussion.—*Platystrophia colbiensis* is most like *P. elegantula* in size and general morphology. *P. colbiensis* is most easily distinguished from *P. elegantula* by its longer hinge line and slightly larger size at maturity. Figures 3 and 4 are scatter diagrams comparing several measured parameters of these two species. See the discussion of *P. elegantula* for additional statements of these two species.

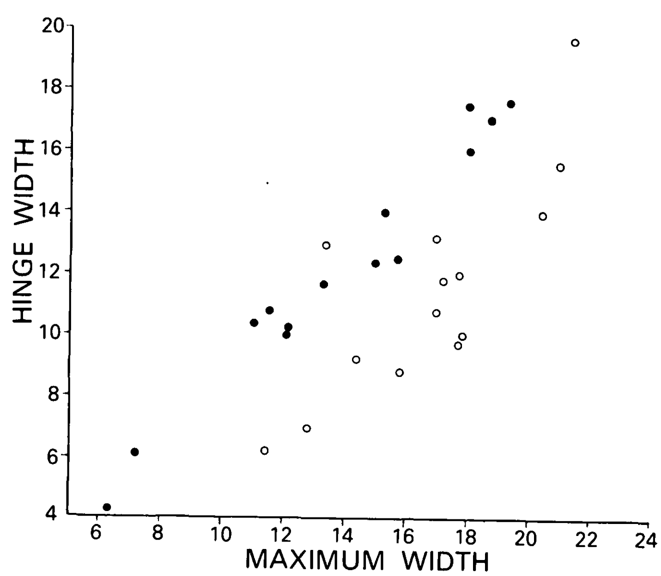

FIGURE 3.—Scatter diagram showing the relationship between the maximum width and width at the hinge line of specimens of *P. elegantula* and *P. colbiensis*. The specimens of *P. elegantula* (open circles) are from the Tanglewood Limestone Member of the Lexington Limestone (USGS colln. D1204–CO and 4982–CO; USNM 189575 and 189576). The specimens of *P. colbiensis* (solid circles) are from the Clays Ferry Formation; (USGS colln. 7812–CO; USNM 189574). All measurements are in millimeters.

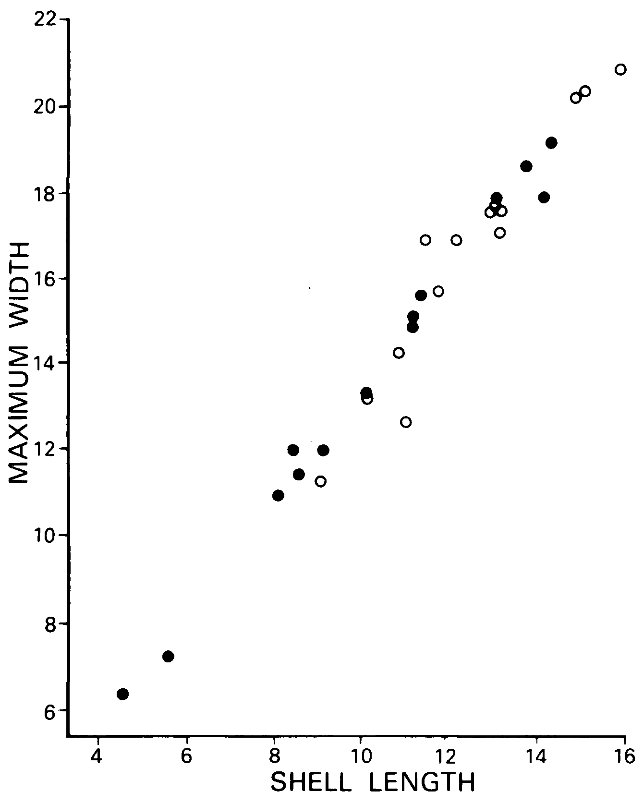

FIGURE 4.—Scatter diagram showing the relationship between the maximum width and shell length of specimens of *Platystrophia elegantula* and *P. colbiensis*. The specimens of *P. elegantula* (open circles) are from the Tanglewood Limestone Member of the Lexington Limestone (USGS colln. D1204–CO and 4982–CO; USNM 189575 and 189576). The specimens of *P. colbiensis* (solid circles) are from the Clays Ferry Formation (USGS colln. 7812–CO USNM 189574). All measurements are in millimeters.

Occurrence and stratigraphic distribution.—*Platystrophia colbiensis* Foerste is the most abundant species of the genus occurring in the Middle Ordovician of Kentucky. Numerous specimens occur in the Lexington Limestone, particularly the Millersburg and Perryville Limestone Members, and the Clays Ferry Formation.

Platystrophia colbiensis occurs in the following USGS collections: 4178–CO to 4180–CO, 4940–CO, 5015–CO, 5016–CO, 5071–CO, 6128–CO, 6138–CO, 6142–CO to 6144–CO, 6990?–CO, 7044?–CO, 7049?–CO, 7050?–CO, 7051–CO, 7056?–CO, 7057–CO, 7079–CO, 7310?–CO, 7314?–CO, 7327–CO, 7328?–CO, 7332–CO, 7335–CO, 7343 CO, 7344–CO, 7348–CO, 7349–CO, 7353–CO, 7812–CO, D1367?–CO, D1172?–CO, D1173–CO.

Platystrophia elegantula McEwan

Plate 5, figures 54–65, 70, 71; plate 7, figure 39

Platystrophia elegantula McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 410–411, pl. 43, figs. 44–47.

Platystrophia elegantula var. *triplicata* McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 411, pl. 43, fig. 48.

Playstrophia elegantula var. *amplisulcata* McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 411–412, pl. 43, fig. 49.

Species small for the genus (tables 2 and 3): ellipsoidal in outline with cardinal extremities obtusely rounded (pl. 5, figs. 56, 57, 61, 62); hinge line straight and two-thirds as wide as the maximum shell width (which occurs slightly anterior of the middle) (pl. 5, figs. 56, 61). Lateral margins rounded and leading evenly into a rounded anterior margin. Lateral profile biconvex with brachial valve slightly thicker (pl. 5, fig. 60); pedicle valve typically flatter across middle than brachial valve. Beak of pedicle valve extends slightly more to posterior than brachial beak. Plications on fold range from 4 to 6 (measurements, tables 2, and 3), from 3 to 5 in sulcus; plications on flanks range from 7 to 12. Plications low and rounded. Growth lines absent.

Brachial valve interarea anacline, curved. Notothyrium open, triangular; cardinal process low ridge

TABLE 1.—*Measurements, in millimeters, and number of plications in a suite of specimens of* Platystrophia colbiensis *Foerste, Clays Ferry Formation, Shawhan quadrangle, Kentucky*

[USGS collection 7812–CO; all specimens cataloged as USNM 189574. Collected from east side of U.S. Highway 27 just south of junction with U.S. Highway 62. Leaders (---) indicate not countable]

Length	Hinge width	Mid-width	Thickness	Plications on fold	Plications in sulcus	Plications on flank
4.5	4.3	6.3	2.8	--	--	--
5.5	6.1	7.2	3.6	4	3	8
8.0	10.4	11.0	4.5	4	3	7
8.5	10.7	11.5	5.9	4	3	7
8.3	10.0	12.1	6.2	4	3	6
9.0	10.2	12.1	5.8	4	3	7
10.0	11.7	13.3	12.9	4	3	8
11.0	12.3	15.0	8.8	4	3	8
11.0	14.0	15.2	9.3	4	3	7
11.2	12.5	15.7	7.9	4	3	7
12.9	16.0	18.0	10.2	4	3	9
14.0	17.5	18.0	12.0	4	3	8
14.1	17.6	19.3	12.6	4	3	8
13.5	17.1	18.7	13.6	4	3	8

that extends entire length of cavity; cavity floor elevated above valve floor and sloping anteriorly. Brachiophores thick with prominent shelf on inner face. Sockets deep. Posterior adductor scars faintly preserved as small oval impressions in a few specimens; most specimens lack observable scars. Interior of valve faintly crenulated.

Pedicle valve interarea anacline. Delthyrium triangular and open; cavity walls sloping outward. Dental plates moderately thin, join margins of muscle field; field small, ellipsoidal with straight sides, extends only about one-third length of valve. Interior of valve crenulated in anterior two-thirds of valve.

Discussion.—Platystrophia elegantula has some easily recognizable characteristics that differentiate it from *P. colbiensis*, the only other small species in the Kentucky collections. (See figs. 3, 4 for a comparison of *P. elegantula* and *P. colbiensis.*) *P. elegantula* is characterized by its regular ellipsoidal to almost oval outline, its short hinge line, and the variation shown by the number of plications on the fold, in the sulcus, and on the flanks (tables 2, 3). Internally *P. elegantula* is differentiated from *P. colbiensis* by the presence of only faint internal crenulations—compared to the prominent crenulations in *P. colbiensis.*

Occurrence and stratigraphic distribution.—Platystrophia elegantula McEwan is not an abundant species in the Kentucky collections. It occurs most abundantly in the upper parts of the Lexington Limestone, particularly in the Millersburg and Tanglewood Limestone Members. Specimens that are questionably referred to *P. elegantula* (because of too few specimens and poor preservation) also occur in the Perryville Limestone Member of the Lexington Limestone and the Clays Ferry Formation. *Platystrophia elegantula* occurs in the following USGS collections: 4898–CO, 4982–CO, D1204–CO.

Platystrophia acutilirata (Conrad)

Plate 6, figures 50–54; plate 7, figures 1–3

Delthyris acutilirata Conrad, 1842, Acad. Natl. Sci. Philadelphia Jour. v. 8, p. 260, pl. 14, fig. 15. (fide McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 424).

Orthis (Platystrophia) biforata var. *acutilirata* Conrad. Meek, 1873, Ohio Geol. Survey, Repts., v. 1, pt. 2, p. 119–121, pl. 10, figs. 5a–g.

Platystrophia acutilirata (Conrad). McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 424–425, pl. 45, figs. 20–21.

Platystrophia acutilirata var. *prolongata* Foerste, 1910, Denison Univ. Sci. Lab. Bull., v. 16, p. 67, pl. 3, figs. 8a–b.

Platystrophia acutilirata var. *inflata*, Foerste, 1910, Denison Univ. Sci. Lab. Bull., v. 16, p. 67, pl. 4, fig. 8.

Platystrophia acutilirata var. *senex* Cumings. McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 426, pl. 45, fig. 23.

TABLE 2.—*Measurements, in millimeters, and numbers of plications in a suite of specimens of* Platystrophia elegantula *McEwan, Tanglewood Limestone Member of the Lexington Limestone, Frankfort East quadrangle, Kentucky*

[USGS collection D1204–CO; all specimens cataloged as a suite as USNM 189575. Collected from 229 ft above the top of the Tyrone Limestone along Interstate Highway 64 East, at the Kentucky River crossing (Frankfort East A Section). Leaders (---) indicate not measureable]

Length	Maximum width	Hinge width	Thickness	Plications on fold	Plications in sulcus	Plications on flank
9.0	11.4	6.2	5.5	6	5	8
10.9	12.8	7.0	7.0	5	4	7
11.6	15.8	8.9	8.8	5	4	8
13.0	17.7	12.0	10.8	6	5	8
13.0	17.2	11.8	11.4	5	4	8
14.9	20.5	---	10.2	6	5	7
12.9	17.8	10.0	10.5	5	4	8

TABLE 3.—*Measurements, in millimeters, and numbers of plications in a suite of specimens of* Platystrophia elegantula *McEwan, Tanglewood Limestone Member of the Lexington Limestone, Frankfort West quadrangle, Kentucky*

[USGS collection 4982–CO; all specimens cataloged as USNM 189576. Collected from 32 ft above the base of the Brannon Member of the Lexington Limestone along Interstate Highway 64, west of the Kentucky River Bridge crossing (Frankfort West A Section). Leaders (---) indicate not measurable]

Length	Maximum width	Hinge width	Thickness	Plications on fold	Plications in sulcus	Plications on flank
10.0	13.3	13.0	6.6	6	5	8
10.7	14.4	9.2	7.7	4	3	8–9
11.3	17.0	13.2	9.2	5	4	9
12.0	17.0	10.8	9.5	5	4	9
14.2	---	10.5	9.8	6	5	7
12.8	17.7	9.7	9.6	4	3	12
13.1	---	14.0	9.3	6	5	9
14.0	---	15.2	10.9	5	4	10
14.7	20.4	14.0	13.0	6	5	10
15.7	21.0	15.6	13.5	5	4	9

Species moderate size for the genus. (The measurements for the most complete specimen are: length, 19.2 mm; hinge width, 28.7 mm; thickness, 18.0 mm.) Subrectangular in outline with cardinal extremities slightly acute. Hinge line straight and marks widest part of shell. Lateral margins straight to slightly curved, anterior margin straight. Brachial and pedicle valves evenly convex in lateral profile, brachial valve slightly thicker. Little increase in fold height from posterior to anterior; 4 plications on fold, 3 in sulcus, 12–14 on flanks. Fold and sulcus plications larger than flank plications; flank plications low and well rounded, fold and sulcus plications more angular. Brachial valve interarea anacline, pedicle valve interarea apsacline. Brachial and pedicle beaks slightly incurved.

Discussion.—This species is rare in the Kentucky collections; only about five specimens were identified.

The one outstanding external feature about *P. acutilirata* is the conspicuous difference between the size of the plications on the fold and sulcus and those on the flanks. No interiors were present in the collections, and thus no conclusions can be made regarding internal characteristics.

The two varieties, *P. acutilirata prolongata* Foerste and *P. acutilirata senex* Cumings, are regarded here as intraspecific variants of *P. acutilirata,* and no useful purpose is served by designating them separate taxa. McEwan stated (1919, p. 426) that both varieties are commonly found associated with typical *P. acutilirata* specimens.

The specimens of *P. acutilirata* studied by McEwan (1919) are like those occurring in the Kentucky collections except for a difference in outline. McEwan's specimens have a much longer hinge line which makes the cardinal extremities extremely acute (pl. 7, fig. 1). The specimens from Kentucky are more subquadrate in outline. (Compare pl. 6, fig. 50 with pl. 7, fig. 1.)

Occurrence and stratigraphic distribution.—This species is rare in Kentucky and is found only in the Bull Fork Formation. *Platystrophia acutilirata* occurs in USGS collection 5309–CO.

Platystrophia annieana Foerste

Plate 3, figures 1–45; plate 4, figures 1–15, plate 5, figures 37, 38; plate 7, figures 4–8

Platystrophia annieana Foerste, 1910, Denison Univ. Sci. Lab. Bull., v. 16, pl. 6, fig. 14.

Platystrophia annieana Foerste. McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 423, pl. 46, figs. 20–24.

Species medium to large for the genus (measurements, table 4); subquadrate to subrectangular in outline; cardinal extremities vary from slightly rounded to right angle to acute. Lateral margins more typically curved leading smoothly into curved anterior margin. Biconvex in lateral profile with brachial valve slightly deeper, some specimens almost twice as deep; rate of curvature decreases in anterior half of shell and is distinctly less than in posterior half (pl. 3, figs. 37–45). Most specimens have 4 plications on fold and 3 in sulcus; flanks have 6 to 11. Plications broad with well-rounded tops, interplication troughs well rounded also; plications tend to "flare out" in anterior parts of shell. Growth lines absent in most specimens.

Brachial interarea orthocline to slightly anacline, curved and about one-half as long as pedicle interarea. Notothyrium open, triangular. Cavity deep, some elevated high above valve floor. Inner faces of brachiophores concave with inward-projecting ledges along lower parts, helping to form floor of cavity. Cardinal process a low ridge that extends full length of cavity, slightly thicker anteriorly. Brachiophores thick, curved upward and outward, pointed. Sockets triangular pits, poorly defined in most. Inside of valve crenulated throughout. Posterior adductor scars circular in outline (pl. 4, fig. 3), anterior scars somewhat triangular with gently curved margins (pl. 4, fig. 3).

Pedicle interarea apsacline, curved. Delthyrium triangular, open; walls of cavity sloping slightly outward. Dental plates thin to thick, join margins of ellipsoidal muscle field; field extends about one-fourth length of valve and defined by thin to moderately thick rim. Interior of valve crenulated.

Discussion.—The largest specimens of this species slightly resemble intermediate-size specimens of *P. ponderosa.* However, *P. annieana* is easily differentiated from *P. ponderosa* by its smaller size (tables 4, 9), slightly more subrectangular outline compared to a more quadrate outline in *P. ponderosa.* Internally, *P. annieana* lacks a cruralium-like structure so characteristic of the brachial valves of *P. ponderosa.* Compare the brachial interiors of *P. annieana* (pl. 4, figs. 1–3 and 13, 14) and *P. ponderosa* (pl. 2, figs. 15–19).

The specimens studied by McEwan (1919) agree in overall size, outline, and convexity with those in the Kentucky collections. The one noticeable difference is that some of the Kentucky specimens have lower, much broader, and therefore less numerous plications than McEwan's specimens. Low broad plications like this are identical to those occurring in *P. laticosta.* The difference in number of plications is indicated somewhat by tables 4 and 5, although the size of the sample of McEwan's specimens is much smaller than the suite from Kentucky. The average number of flank plications in the specimens studied by McEwan (table 5) is 10.5; the average number for the Kentucky specimens (table 4) is 8.

Occurrences and stratigraphic distribution.—*Platystrophia annieana* Foerste is an abundant species in the uppermost part of the Kentucky Ordovician. Almost all of the large collections in the area are from the Preachersville Member of the Drakes

TABLE 4.—*Measurements in millimeters, and numbers of plications in a suite of specimens of* Platystrophia annieana *Foerste, Dillsboro Formation, Milan quadrangle, Indiana*

[USGS collection 7834-CO; all specimens cataloged as USNM 189577. Collected from section along U.S. Highway 50 east of Versailles, Ind. Leaders (---) indicate not countable]

Length	Hinge width	Mid-width	Thickness	Plication on fold	Plications in sulcus	Plications on flank
9.0	9.2	12.6	7.2	--	--	--
10.3	12.9	15.1	9.3	5	4	9
11.4	11.7	15.0	9.0	5	4	7
8.5	14.5	12.7	6.5	4	3	9
10.0	11.0	9.3	13.4	4	3	7
11.3	12.1	15.6	8.9	5	4	7
11.7	10.6	15.0	9.9	4	3	7
12.9	11.4	15.2	9.6	4	3	6
11.9	13.8	16.2	10.1	4	3	7
12.8	13.1	17.1	10.5	4	3	8
13.4	12.0	17.8	11.0	4	3	7
11.9	12.0	16.0	10.0	4	3	6
11.7	15.0	17.2	9.9	4	3	7
13.0	16.2	18.3	12.4	4	3	9
14.4	15.8	20.5	12.7	4	3	7
13.0	13.8	18.0	11.4	4	3	8
13.7	15.5	19.8	12.2	4	3	7
13.2	15.2	18.3	11.4	4	3	9
12.6	16.0	18.7	11.7	4	3	6
13.5	15.3	18.6	12.0	4	3	7
13.8	18.5	20.6	12.8	4	3	8
13.5	22.2	20.4	13.7	4	3	11
14.0	20.6	20.9	12.7	4	3	9
15.7	16.3	20.8	13.3	4	3	8
14.4	20.3	21.0	12.0	4	3	9
16.0	19.3	23.4	15.0	5	4	11
16.3	17.8	21.8	13.7	5	4	8
17.3	20.0	23.3	13.7	4	3	7
15.5	20.5	22.0	12.5	4	3	10
16.9	20.3	23.8	17.8	4	3	9
18.0	27.1	26.7	16.2	4	3	6
18.5	28.3	27.3	18.9	4	3	9
20.3	29.0	30.0	20.1	6	5	9

TABLE 5.—*Measurements, in millimeters, and numbers of plications of* Platystrophia annieana *from specimens studied by McEwan (1919), and deposited in the U.S. National Museum*

[Leaders (---) indicate not measurable]

Length	Hinge width	Mid-width	Thickness	Plications in fold/sulcus	Plications on flanks (average)	Catalog number (USNM)
19.2	28.7	25.6	18.0	4/3	11	65664
17.8	32.0	27.5	15.0	6/5	12	65664
17.8	29.3	26.0	14.8	4/3	13	65651
16.8	23.9	23.8	15.5	4/3	8	65651
16.9	30.4	25.0	15.2	4/3	10	39041
16.3	25.0	---	18.2	4/3	9	39041

Formation in Kentucky and from Dillsboro Formation of Indiana. Well-preserved specimens and large suites also occur in the lower parts of the Drakes. This species is conspicuously absent from all of the underlying formations. However, one collection from the Millersburg Member of the Lexington Limestone contains specimens that are very similar to specimens of *P. annieana* identified by McEwan. A typical specimen from this Millersburg suite is figured on plate 7 (figs. 34, 35). Figures of *P. annieana* identified by McEwan are also shown on plate 7 (figs. 4–8) for comparison. *Platystrophia annieana* occurs in the following USGS collections: 4468–CO, 5308–CO, 6139–CO, 6140–CO, D1370e–CO, 7834–CO.

Platystrophia laticosta (Meek)

Plate 5, figures 45–49; plate 6, figures 1–13, 19–28; plate 7, figures 17–21

Orthis laticostata James, 1871, Catalog Lower Silurian Fossils, Cincinnati Group, p. 10 (fide F. B. Meek, 1873, Ohio Geol. Survey Repts., v. 1, pt. 2 (Paleontology), p. 116).

Orthis (Platystrophia) biforata var. *laticosta* Meek, 1873, Ohio Geol. Survey Repts., v. 1, pt. 2 (Paleontology), p. 116, pl. 10, fig. 4.

Platystrophia laticosta (Meek). Foerste, 1903, Am. Geologist, v. 31, p. 334.

Platystrophia unicostata Cumings, 1903, Am. Jour. Sci., 4th ser., v. 15, p. 28–29, pl. 31, fig. 15.

Platystrophia laticosta Cumings. Foerste, 1910, Denison Univ. Sci. Lab. Bull., v. 16, pl. 3, figs. 1, 2.

Platystrophia laticosta (Meek). McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 432–433, pl. 48, figs. 11–13.

Platystrophia unicostata Cumings. McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 433–434, pl. 48, figs. 4–7.

Platystrophia unicostata var. *crassiformis* McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 434, pl. 48, figs. 8–10.

Subquadrate to rectangular in outline; rounded cardinal extremities, right angled to obtuse in some. Hinge line straight and shorter than mid-width. Fold and sulcus well developed and having an anterior 'thrust" when viewed laterally; prominence of fold accentuated by high, straight-sided marginal plications that descend to the flanks of the valve. In some specimens fold is elevated high above flanks of valve (pl. 5, fig. 50) with flanks sloping steeply to cardinal extremities; in some specimens extremities concave. Plications are pronounced, sharply angular (pl. 6, figs. 25–27). Fold with four plications in most specimens and three in sulcus; some specimens having prominent plication in sulcus (pl. 5, fig. 51). In lateral view curvature from posterior to anterior rather straight in both valves (pl. 5, fig. 49); lateral commissure rectimarginate, anterior commissure strongly uniplicate. Pedicle and brachial beaks erect to suberect, a few strongly incurved. Flanks with six to eight angular plications.

No interiors of either brachial or pedicle valves.

Discussion.—The entire range of forms normally referred to by most workers as either *Platystrophia laticosta, P. unicostata,* or *P. cypha* comprises a highly variable group having numerous intermediates that are sometimes difficult to identify with any degree of confidence. McEwan (1919) clearly intimated the presence of such intermediates and variations by erecting several varieties of *P. unicostata* and *P. cypha* and by such statements as (1919, p. 432), "The chief distinction between *Platystrophia laticosta* and *P. cypha* is one of degree" and (1919, p. 433), "*Platystrophia unicostata* is connected with *Platystrophia laticosta* by all degrees of variants."

None of these species is abundantly present in the Kentucky collections; approximately 10 specimens were identified from 2 or 3 localities and stratigraphic intervals. It is difficult to properly evaluate intermediates, ranges of variation, and degrees of overlap from such limited data. Nevertheless, granting that clear demarcation among these three "species" is difficult, I have chosen to refer to members of this group as either *P. laticosta* or *P. cypha.* I interpret *P. unicostata* to be synonomous with *P. laticosta.* This interpretation is made because *P. laticosta* and *P. unicostata* are more similar in outline and profile and have approximately the same numbers of plications in the sulcus, on the fold, and on the flanks. *P. cypha* has a rectangular outline with an elongated hinge line and pronounced elevation of the fold. *P. cypha* is the only one with a marked concavity to the flanks of the pedicle valve.

I have examined specimens of all three species studied by McEwan (1919) and deposited in the United States National Museum. *P. laticosta* and *P. unicostata* are more similar to each other than either is to *P. cypha.* The data presented in tables 6–8 give some indication of these similarities and differences. The outstanding difference that distinguishes *P. cypha* from *P. laticosta* and *P. unicostata* is the number of plications on the flanks of the shell. The plications on *P. laticosta* and *P. unicostata* tend to be broader with long gentle slopes; those on *P. cypha* tend not to be as angular and are closer together (pl. 7, figs. 28 and 29).

Occurrence and stratigraphic distribution.—*Platystrophia laticosta* is about as abundant as *P. cypha* in the Kentucky collection, occurring mostly in the Ashlock Formation, although specimens questionably referred to *P. laticosta* are also found in the Bull Fork Formation and Grant Lake Limestone. *Platystrophia laticosta* occurs in the following USGS collections: 5135–CO, 5136–CO, 5140–CO, D1244–CO, D1253?–CO, D1288–CO, D1289–CO, D1367–CO.

Platystrophia cypha (James)

Plate 5, figures 39, 40, 43, 44, 50, 52; plate 6, figures 14–18, 29–32; plate 7, figures 22–29

Orthis (Platystrophia) cypha James, 1874, Cincinnati Quart. Jour. Sci., v. 1, p. 20, not figured (fide McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 435).

TABLE 6.—*Measurements, in millimeters, and numbers of plications of* Platystrophia laticosta, *from specimens studied by McEwan (1919) and deposited in the U.S. National Museum*

Length	Hinge width	Mid-width	Thickness	Plications in fold/sulcus	Plications on flank (average)	Catalog number (USNM)
20.6	34.6	28.2	29.6	4/3	5	50946
21.2	37.0	29.9	27.5	4/3	8	50946
18.2	28.1	27.5	18.1	4/3	6	50946
18.8	32.5	26.8	16.4	4/3	8	50946
20.0	31.9	27.9	22.8	4/3	6	50946
18.2	30.6	26.7	17.2	4/3	6	48605
20.4	32.3	30.2	19.0	4/3	7	48605
16.9	26.0	24.0	15.5	4/3	8	48605

TABLE 7.—*Measurements, in millimeters, and numbers of plications of* Platystrophia cypha, *from specimens studied by McEwan (1919) and deposited in the U.S. National Museum*

[Leaders (---) indicate not measurable]

Length	Hinge width	Mid-width	Thickness	Plications in fold/sulcus	Plications on flank (average)	Catalog number (USNM)
19.0	34.4	29.6	14.9	4/3	15	66001
17.1	31.9	26.0	17.4	4/3	8	66001
18.2	34.4	27.2	20.9	4/3	11	66001
17.0	30.6	24.1	16.5	4/3	12	66001
19.0	32.1	28.9	19.1	6/5	10	66001
15.6	28.4	23.0	17.8	4/3	8	66001
18.0	32.9	20.0	---	---	10	66001
17.1	29.5	23.4	25.6	4/3	11	66009
16.0	31.9	25.0	16.0	4/3	9	66009
18.7	32.8	24.9	19.5	4/3	10	66009
15.0	27.9	22.4	14.4	4/3	9	66009
16.3	28.9	24.2	18.5	4/3	10	66009
16.7	25.3	25.8	17.5	4/3	6	66009
16.1	25.2	22.4	15.7	4/3	6	66009

TABLE 8.—*Measurements, in millimeters, and numbers of plications of* Platystrophia unicostata, *from specimens studied by McEwan (1919) and deposited in the U.S. National Museum*

Length	Hinge width	Mid-width	Thickness	Plications in fold/sulcus	Plications on flank (average)	Catalog number (USNM)
16.9	26.0	22.3	19.0	4/3	6	65969
17.8	26.8	22.4	18.3	3/2	7	65969
19.7	27.7	21.0	17.4	4/3	6	65970
18.4	26.2	25.2	20.5	4/3	6	39037
23.0	32.1	26.9	24.4	4/3	6	39037
22.4	33.5	27.6	20.2	4/3	6	39037
18.6	27.9	25.4	20.8	3/2	6	39037
23.2	30.4	23.8	22.3	2/1	7	65968
19.7	29.0	25.0	21.4	3/2	6	65968
19.4	28.9	26.7	18.8	3/2	5	65968
15.0	24.5	21.2	19.1	2/1	5	65968
18.5	26.8	24.1	18.2	4/3	7	65968
21.5	27.6	25.6	18.2	4/3	6	65968

Platystrophia cypha Cumings. Foerste, 1910, Denison Univ. Sci Lab. Bull., v. 16, p. 61, pl. 4, fig. 10a, b; 12 pl. 5, fig. 11.

Platystrophia cypha (James). McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 435–436, pl. 47, figs. 22–25; pl. 48, figs. 14–16.

Platystrophia cypha var. *tumida* McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 436–437, pl. 48, figs. 17–20.

Platystrophia cypha var. *arcta* McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 437, pl. 48, figs. 1–3.

Platystrophia cypha var. *bellatula* McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 438, pl. 47, figs. 28–30.

Moderate size for genus (best preserved specimen: length, 16.0 mm; hinge width, 26.8 mm; midwidth, 23.7 mm; thickness, 16.1 mm; cardinal extremities acute to right angle. Hinge line the widest part, lateral margins straight, anterior margin straight. Lateral profile unequally biconvex with brachial valve about twice as deep; fold rises steadily from posterior to highest anterior extremity. Fold has four plications, two middle ones prominent with two lateral ones only poorly to moderately developed; six to seven plications on flank. Sulcus deep, bordered on each side by two prominent highly elevated plications. Flank of pedicle valve distinctly concave with asymmetrical plications; plication slopes facing cardinal extremities twice as long as opposite slopes. Flanks of brachial valve slightly convex, uneven plications.

No interiors preserved.

Discussion.—As pointed out in the discussion of *P. laticosta*, all degrees of intermediates exist between *P. cypha, P. unicostata,* and *P. laticosta,* which makes interpretation of these species difficult. I have studied many of the types designated by McEwan (1919) and deposited in the U.S. National Museum. In addition to the similarities between *P. cypha, P. unicostata,* and *P. laticosta,* certain specimens designated by McEwan as *P. clarksvillensis* are nearly identical to some designated as *P. cypha.* I have tried to show this similarity by figuring several of McEwan's specimens (pl. 7, figs. 30–33) of *P. clarksvillensis.* Also, McEwan (1919, p. 422) claimed that *P. clarksvillensis* "bears a marked resemblance to *Platystrophia laticosta.*" In my opinion just as much similarity exists between *P. cypha* and *P. clarksvillensis* as between *P. cypha* and *P. laticosta.* Such degrees of variation and similarities point up the need for a complete reevaluation of the genus, as well as the difficulty of specific designations.

Occurrence and stratigraphic distribution.—*Platystrophia cypha* occurs in a scattering of collections throughout the upper part of the Upper Ordovician in the Ashlock Formation, Grant Lake Limestone, and Bull Fork Formation and the Preachersville Member of the Drakes Formation. *Platystrophia cypha* occurs in the following USGS collections: 4466–CO, 6418–CO, D1248?–CO, D1253–CO, D1280–CO, D1370e–CO.

Platystrophia ponderosa Foerste

Plate 1, figures 1–21; plate 2, figures 1–27; plate 4, figures 16, 18–33

Platystrophia ponderosa Foerste, 1909a, Denison Univ. Sci. Lab. Bull., v. 14, p. 225, pl. 4, fig. 14.

Platystrophia ponderosa Foerste, 1912, Ohio Naturalist, v. 12, p. 453, pl. 22, fig. 11 (fide McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 427).

Platystrophia ponderosa Foerste. McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 427–428; pl. 49, figs. 1–5; pl. 50, figs. 4–7; pl. 51, figs. 1–5; pl. 52, figs. 1–3, 7–10.

Platystrophia ponderosa var. *auburnensis* Foerste. McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 428, pl. 49, figs. 9–12.

Platystrophia ponderosa var. *arnheimensis* McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 428, pl. 51, figs. 6–8.

Species large for the genus (measurements, table 9). Shell thick in mature specimens. Quadrate to subquadrate in outline; cardinal extremities at a right angle in most specimens but slightly acute or "spiriferoid" in others, some small specimens obtuse. Pedicle sulcus and brachial fold prominent, shallow to moderately deep. Most specimens with four plications on fold and three in sulcus (table 9, range of variation); six to eight plications on flanks. Plications broad with gently rounded tops. Hinge line straight and approximately the widest part (measurements, table 9). Lateral profile evenly biconvex with thickest part in or near middle; rate of curvature from posterior to anterior nearly equal in both valves. Lateral commissure rectimarginate, anterior commissure uniplicate. Growth lines weak or absent. Brachial and pedicle interareas slightly curved; pedicle interarea apsacline and slightly longer than anacline brachial interarea. Brachial beak slightly incurved, pedicle beak suberect.

Delthyrium triangular, open, moderately deep; walls slightly farther apart at base of cavity than at top. Dental plates thin in small specimens, thick in large specimens; anterior margins of plates descend straight to floor of valve, some slope to posterior. Plates join margins of muscle field; field elliptical in outline and extends about one-third length of valve (pl. 2, fig. 24). Faint rim around field in small and medium-sized specimens; rim more pronounced in larger specimens (pl. 2, fig. 22). Margins of field parallel, diverging slightly in some specimens. Adductor scars not visible or poorly developed in most specimens. Faint groove along base of each dental plate might be adjustor scar.

TABLE 9.—*Measurements of several dimensions (in millimeters) and numbers of plications in a suite of* Platystrophia ponderosa *Foerste from a single collection (USGS colln. 4556–CO; USNM 189578) from the Back Bed, Tate Member of the Ashlock Formation in the Richmond North quadrangle, Kentucky*

Length	Hinge width	Mid-width	Thickness	Plications on fold	Plications in sulcus
20.9	27.8	25.7	17.3	4	3
20.2	25.2	24.5	15.0	4	3
27.7	29.4	33.5	24.6	4	3
29.1	34.5	37.0	20.7	4	3
32.5	33.7	37.1	26.9	4	3
33.7	35.0	36.5	31.0	4	4
26.0	30.5	31.0	24.0	4	3
27.5	28.5	31.5	23.5	5	4
27.2	35.3	34.0	22.9	5	4
24.8	33.3	32.3	20.4	4	3
28.4	34.0	33.8	22.0	4	3
28.4	30.7	33.3	23.5	4	3
25.6	31.5	33.0	19.0	4	3
28.8	35.7	35.8	24.0	4	3
29.6	36.5	35.3	27.3	6	5
28.0	34.5	32.5	23.2	4	3
28.5	32.0	35.6	24.5	4	3
20.4	27.6	27.3	15.8	4	3
20.5	30.7	27.7	17.0	4	3
24.8	32.4	29.8	18.3	5	4
23.0	22.4	21.8	18.3	4	3
19.3	23.8	25.4	15.2	4	3
28.2	29.1	33.6	24.8	4	3
28.7	24.3	33.2	24.4	6	5
29.5	36.1	35.2	24.9	4	3
23.0	30.4	37.7	27.5	4	4
27.5	30.0	30.7	27.0	5	4
17.0	19.2	20.0	12.0	5	4
19.4	25.0	23.8	14.5	4	3
20.7	27.5	26.5	15.4	4	3
30.9	38.7	37.2	26.3	4	3
27.8	37.8	36.0	24.5	4	3
26.0	31.0	31.4	19.6	6	5
23.7	31.8	29.6	18.3	5	4

Notothyrium open, triangular; floor of cavity steeply sloping to anterior. Cardinal process a thin blade about one-fifth as high as cavity is deep. Inner faces of brachiophores have variable slope, most slope inward and join a median ridge to form a cruralium-like structure (pl. 2, figs. 17–19). Brachiophores thick, moderately deep sockets positioned on outer face at hinge line. Underside of brachiophores strongly curved to the posterior, many with keel-like ridge. Posterior adductors oval in outline, more deeply impressed and larger than anterior adductors (pl. 2, fig. 27). Anterior adductors somewhat triangular and straight sided. Faint median ridge extends from anterior margin of notocavity to anterior margin of muscle field, joins with a more pronounced ridge that is a reflection of external plication. Interior of valve crenulated.

Discussion.—*Platystrophia ponderosa* is the most abundant species of the genus in the Kentucky collections. Unlike many of the other species, specimens of *P. ponderosa* are easier to identify because of their distinctively large size, quadrate outline, and presence of a cruralium-like structure in the brachial valve. Not all the brachial valves, however, have the cruralium-like structure developed to the same degree as is shown on plate 2, figures 17–21. Figures 15 and 16 on plate 2 show the differences in the appearance of this structure, although in both specimens it is unmistakably present. The presence of such a structure in small specimens is not as obvious, but indications of it do occur in some. Figure 21 on plate 2 is an enlarged view of a specimen 2–3 mm wide, in which the inward-sloping brachiophore bases and the median ridge are clearly visible.

The variable appearance of the cruralium is due to the difference in the degree of slope of the brachiophore bases and the degree to which the undersides of the brachiophores curve toward the posterior. Some of the brachiophore bases are distinct plates (pl. 2, figs. 18 and 19), but others are not as well developed and the undersides of the brachiophores have a distinct posterior curvature (plate 2, fig. 17).

Many specimens are represented by large broken fragments of *Platystrophia ponderosa* with only the beak regions preserved (pl. 4, figs. 24–27). Nevertheless, these fragments have characteristics such as a robust shell, cruralium-like appearance of the brachial valve, and long muscle-scar region of the pedicle valve, which make it relatively easy to identify them as *P. ponderosa*.

Platystrophia annieana is the only other species in the Kentucky collection that approaches the size of *P. ponderosa,* although none of the largest specimens is nearly as large as full-sized *P. ponderosa.* Also, the brachial valves of *P. annieana* lack the cruralium-like structure so prominent in *P. ponderosa. P. annieana* is more rectangular in outline compared to the more quadrate outline of *P. ponderosa.*

Occurrence and stratigraphic distribution.—In the Upper Ordovician of Kentucky, *Platystrophia ponderosa* is probably the most widely distributed and most easily recognizable species of the genus. It is well represented in the Calloway Creek, Fairview, Ashlock, Grant Lake, Bull Fork, and Drakes Formations, but it is not found in the Preachersville Member of the Drakes (the uppermost Ordovician strata in Kentucky). *Platystrophia ponderosa* occurs in the following USGS collections: 4194–CO, 4195–CO, 4208–CO to 4211–CO, 4464–CO, 4467–CO, 4556–CO, 5039–CO, 5120–CO, 5137?–CO, 5141–CO, 6127–CO, 6284–CO, 6409?–CO, 6410–CO to 6412–CO, 6414–CO, 6416–CO, 7702?–CO, 7703–CO, 7704–CO, 7705?–CO, 7706–CO, 7707–CO, 7708?–CO, 7936?–CO, 7937–CO, D1239–CO, D1241?–CO, D1244–CO, D1247–CO, D1267–CO, D1273–CO, D1276–CO, D1277–CO, D1327–CO, D1333–CO, D1334–CO, D1336–CO to D1341–CO, D1344–CO, D1345?–CO, D1347–CO, D1349–CO, D1365–CO, D1367–CO to D1369–CO.

Platystrophia cf. P. foerstei McEwan

Plate 6, figures 33–41

Platystrophia foerstei McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 420–421, pl. 46, figs. 9–12.

Platystrophia foerstei var. *ampla* McEwan, 1919, U.S. Natl. Mus. Proc., v. 56, p. 421, pl. 46, figs. 13–16.

Species moderate size for genus; measurements for the two most complete specimens are as follows:

Length (mm)	Mid-width (mm)	Hinge width (mm)	Thickness (mm)
15.7	23.0	17.0	14.0
15.0	20.2	15.9	14.4

Subquadrate in outline with cardinal extremities distinctly rounded. Hinge line straight and shorter than maximum width, which is at mid-line; lateral margins rounded, anterior margin fairly straight. In lateral view, brachial and pedicle valves evenly rounded from posterior to anterior; brachial valve slightly thicker. Brachial interarea curved and orthocline, pedicle interarea curved and apsacline; both beaks erect. Lateral commissure rectimarginate, anterior commissure uniplicate. Brachial fold with 4–6 plications, flanks with 10 or 11; fold moderate in height, increases slightly toward anterior.

No interiors in collections.

Discussion.—Fewer than 10 articulated specimens are present in the Kentucky collections; all from the same sample. All are about the same size and outline but several incomplete specimens are considerably thinner than the figured (pl. 6, figs. 33–41) and measured specimens. *Platystrophia* cf. *P. foerstei* occurs in the following USGS collection D1347–CO.

Platystrophia sp.

Plate 6, figures 42–46

Discussion.—The specimen figured on plate 6, figures 42–46 occurs about 150 feet above the base of the Tate Member of the Ashlock Formation in a small collection of broken and articulated specimens. The other specimens in the suite are not nearly so bulbous but are like the specimens figured on plate 6, figures 1–13; they are referred to *Platystrophia laticosta.* The specimen figured here (figs. 42–46) resembles externally *Platystrophia precursor* Foerste, but because it is the only specimen in a suite that is predominantly *Platystrophia laticosta,* a specific designation seems unjustified. According to McEwan (1919), *P. precursor* Foerste is a Middle Ordovician (Trentonian) species in Kentucky occurring in the Cynthiana Limestone. The specimen figured here is from the Ashlock Formation, which is considered to be Upper Ordovician (Maysvillian). *Platystrophia* sp. occurs in USGS collection D1292–CO.

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Plates 1–6 are of species occurring in the Ordovician rocks of Kentucky and deposited in the collections of the United States National Museum. Plate 7 is primarily a selection of specimens of the species studied by McEwan (1919) and are presented for general comparison with the ones from Kentucky. Several of the specimens on plate 7, however, are from the Ordovician Kentucky collections of the U.S.G.S.

PLATES 1-7

Contact photographs of the plates in this report are available, at cost from the U.S. Geological Survey Library, Federal Center, Denver, Colorado 80225

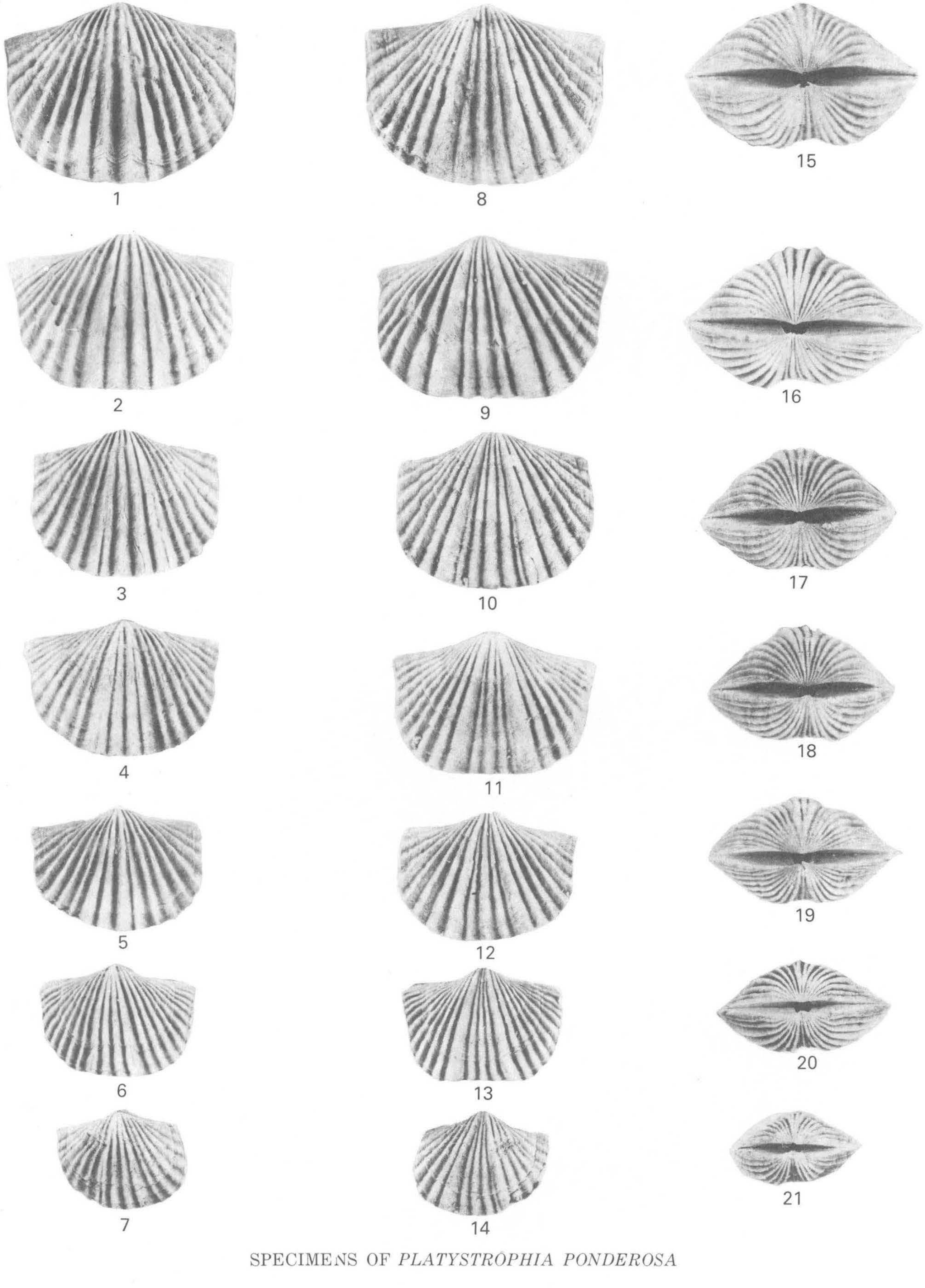
PLATE 1

[All figures × 1.1. Figures 1–21 are from USGS collection 4556–CO]

FIGURES 1–7. *Platystrophia ponderosa* Foerste (p. B16).
Figures 1–7 are a growth series showing the brachial exteriors
1. Figured specimen USNM 189449.
2. Figured specimen USNM 189450.
3. Figured specimen USNM 189451.
4. Figured specimen USNM 189452.
5. Figured specimen USNM 189453.
6. Figured specimen USNM 189454.
7. Figured specimen USNM 189455.

8–14. *Platystrophia ponderosa* Foerste (p. B16).
Figures 8–14 are a growth series showing the pedicle exteriors
8. Figured specimen USNM 189449.
9. Figured specimen USNM 189450.
10. Figured specimen USNM 189451.
11. Figured specimen USNM 189452.
12. Figured specimen USNM 189453.
13. Figured specimen USNM 189454.
14. Figured specimen USNM 189455.

15–21. *Platystrophia ponderosa* Foerste (p. B16).
Figures 15–21 are a growth series showing the posterior view
15. Figured specimen USNM 189449.
16. Figured specimen USNM 189450.
17. Figured specimen USNM 189451.
18. Figured specimen USNM 189452.
19. Figured specimen USNM 189453.
20. Figured specimen USNM 189454.
21. Figured specimen USNM 189455.



SPECIMENS OF *PLATYSTROPHIA PONDEROSA*

PLATE 2

[Figures 1-14 and 22-27 are from USGS collection 4556-CO. Figures 15-17 and 19 are from USGS collection 7834-CO]

FIGURES 1-7. *Platystrophia ponderosa* Foerste (p. B16).

Figures 1-7 are a growth series showing the lateral views (× 1.1).

1. Figured specimen USNM 189449.
2. Figured specimen USNM 189450.
3. Figured specimen USNM 189451.
4. Figured specimen USNM 189452.
5. Figured specimen USNM 189453.
6. Figured specimen USNM 189454.
7. Figured specimen USNM 189455.

8-14. *Platystrophia ponderosa* Foerste (p. B16).

Figures 8-14 are a growth series showing the anterior views (× 1.1).

8. Figured specimen USNM 189449.
9. Figured specimen USNM 189450.
10. Figured specimen USNM 189451.
11. Figured specimen USNM 189452.
12. Figured specimen USNM 189453.
13. Figured specimen USNM 189454.
14. Figured specimen USNM 189455.

15. *Platystrophia ponderosa* Foerste (p. B16).

Enlarged view (× 8) of cardinalia showing the brachiophore bases elevated above the floor of the valve and positioned on a ridge to form a cruralium like structure. Specimen tilted. Figured specimen USNM 189456.

16. *Platystrophia ponderosa* Foerste (p. B16).

Figured specimen USNM 189457; (× 8). Enlarged view of cardinalia showing a slight elevation of the brachiophore bases on a poorly defined ridge. Specimen tilted.

17-19. *Platystrophia ponderosa* Foerste (p. B16).

Specimens showing the various appearances of the cardinalia in which the bases of the brachiophores are elevated on a ridge to form a cruralium-like structure. All specimens are tilted (× 1.1).

17. Figured specimen USNM 189458.
18. Figured specimen USNM 189459; USGS colln. 6411-CO.
19. Figured specimen USNM 189460.

20, 21. *Platystrophia ponderosa* Foerste (p. B16).

Small valves showing the appearance of the early stages of the formation of the cruralium-like structure. In specimen 20 the bases of brachiophores extend to the floor of the valve and apparently a central ridge is not formed. In specimen 21 the central ridge is present and the brachiophore bases are tilted toward it. Both specimens (× 3.5).

20. Figured specimen USNM 189461; USGS colln. 4908-CO.
21. Figured specimen USNM 189462; USGS colln. 4908-CO.

22-24. *Platystrophia ponderosa* Foerste (p. B16).

View of pedicle interior of three valves of different size and shell thickness. Specimen 22 has the thickest shell and, therefore, the poorest delineation of plications in the posterior part. Specimen 24 is the smallest and thinnest and the plications are reflected on the inside to a greater degree than in specimen 22. All figures × 1.1.

22. Figured specimen USNM 189463.
23. Figured specimen USNM 189464.
24. Figured specimen USNM 189536.

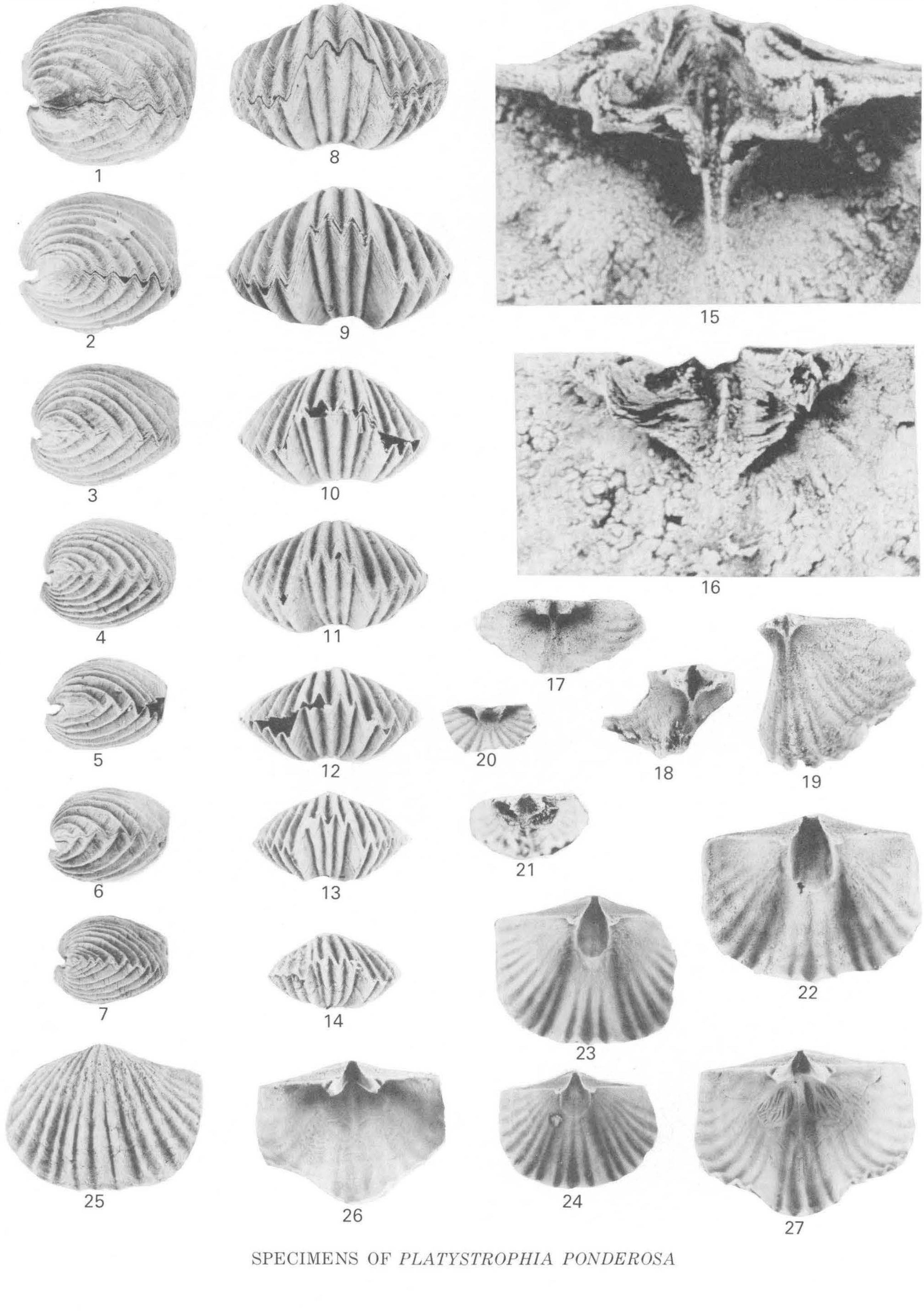
25. *Platystrophia ponderosa* Foerste (p. B16).

View of brachial exterior of a specimen in which the cardinal extremities are distinctly different. The right cardinal extremity is right angled; the left extremity is evenly rounded. Figured specimen USNM 189465. (× 1.1).

26, 27. *Platystrophia ponderosa* Foerste (p. B16).

View of brachial interior showing muscle field. Specimen in figure 26 not tilted; photograph taken normal to line of commissure. Specimen in figure 27 is one of largest; tilted to show the posterior scars better. Both figures × 1.1.

26. Figured specimen USNM 189466.
27. Figured specimen USNM 189467.



SPECIMENS OF *PLATYSTROPHIA PONDEROSA*

PLATE 3

[All figures × 1.1. All figured specimens are from USGS collection 7834–CO]

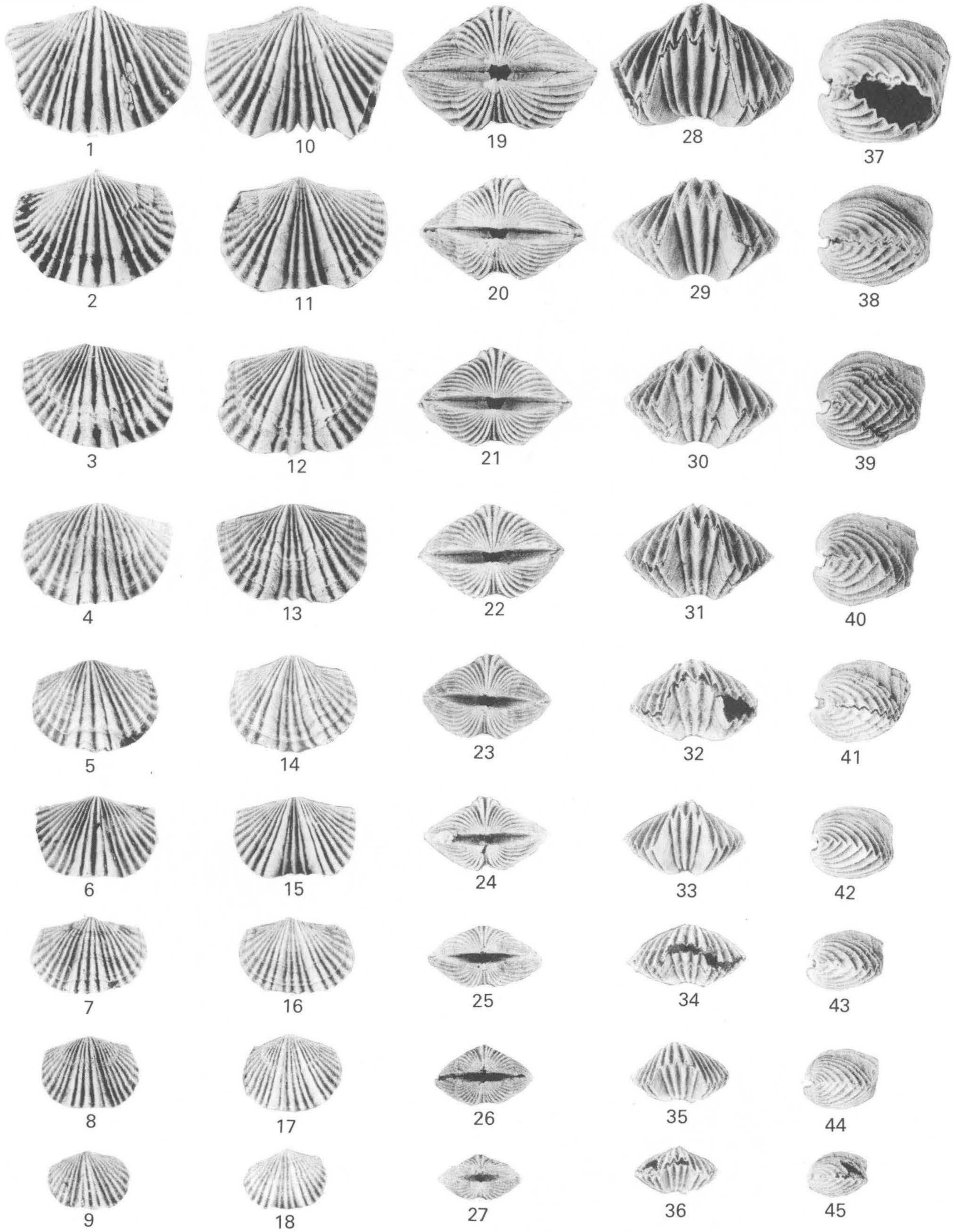
FIGURES 1–9. *Platystrophia annieana* Foerste (p. B12).
Growth series showing brachial exteriors.
1. Figured specimen USNM 189468.
2. Figured specimen USNM 189469.
3. Figured specimen USNM 189470.
4. Figured specimen USNM 189471.
5. Figured specimen USNM 189472.
6. Figured specimen USNM 189473.
7. Figured specimen USNM 189474.
8. Figured specimen USNM 189475.
9. Figured specimen USNM 189476.

10–18. *Platystrophia annieana* Foerste (p. B12).
Growth series showing pedicle exteriors.
10. Figured specimen USNM 189468.
11. Figured specimen USNM 189469.
12. Figured specimen USNM 189470.
13. Figured specimen USNM 189471.
14. Figured specimen USNM 189472.
15. Figured specimen USNM 189473.
16. Figured specimen USNM 189474.
17. Figured specimen USNM 189475.
18. Figured specimen USNM 189476.

19–27. *Platystrophia annieana* Foerste (p. B12).
Growth series showing posterior views.
19. Figured specimen USNM 189468.
20. Figured specimen USNM 189469.
21. Figured specimen USNM 189470.
22. Figured specimen USNM 189471.
23. Figured specimen USNM 189472.
24. Figured specimen USNM 189473.
25. Figured specimen USNM 189474.
26. Figured specimen USNM 189475.
27. Figured specimen USNM 189476.

28–36. *Platystrophia annieana* Foerste (p. B12).
Growth series showing the anterior views.
28. Figured specimen USNM 189468.
29. Figured specimen USNM 189469.
30. Figured specimen USNM 189470.
31. Figured specimen USNM 189471.
32. Figured specimen USNM 189472.
33. Figured specimen USNM 189473.
34. Figured specimen USNM 189474.
35. Figured specimen USNM 189475.
36. Figured specimen USNM 189476.

37–45. *Platystrophia annieana* Foerste (p. B12).
Growth series showing the lateral views.
37. Figured specimen USNM 189468.
38. Figured specimen USNM 189469.
39. Figured specimen USNM 189470.
40. Figured specimen USNM 189471.
41. Figured specimen USNM 189472.
42. Figured specimen USNM 189473.
43. Figured specimen USNM 189474.
44. Figured specimen USNM 189475.
45. Figured specimen USNM 189476.



SPECIMENS OF *PLATYSTROPHIA ANNIEANA*

PLATE 4

[All figures × 1.1. Figures 1–5 are from USGS collection 7834–CO. Figures 6–10, 15 are from USGS collection 6140–CO. Figures 11–14, 17 are from USGS collection number 6139–CO]

FIGURES 1, 2. *Platystrophia annieana* Foerste (p. B12).
Brachial interior. Figure 1 taken normal to line of commissure. Figure 2 tilted to show faint posterior adductor scars.
1. Figured specimen USNM 189477.
2. Figured specimen USNM 189477.

3. *Platystrophia annieana* Foerste (p. B12).
View of brachial interior showing nature of muscle field. Specimen tilted. Figured specimen USNM 189478.

4. *Platystrophia annieana* Foerste (p. B12).
View of pedicle interior. Figure is normal to line of commissure.
Figured specimen USNM 189479.

5. *Platystrophia annieana* Foerste (p. B12).
View of pedicle interior of specimen with rounded cardinal extremities. This specimen has a distinctly different outline than the normal *P. annieana* with the elongated hinge line. Figured specimen USNM 189480.

6–10. *Platystrophia annieana* Foerste (p. B12).
Brachial exterior, pedicle exterior, posterior, anterior, and lateral views. Figured specimen USNM 189481.

11. *Platystrophia annieana* Foerste (p. B12).
View of pedicle interior of an intermediate-size specimen. Figure normal to line of commissure. Figured specimen USNM 189482.

12. *Platystrophia annieana* Foerste (p. B12).
View of pedicle interior of a small specimen. Figure normal to line of commissure. Figured specimen USNM 189483.

13. *Platystrophia annieana* Foerste (p. B12).
View of brachial interior; specimen tilted to show posterior adductor scars. Figured specimen USNM 189484.

14. *Platystrophia annieana* Foerste (p. B12).
View of brachial interior; specimen tilted to show posterior adductor scars. Figured specimen USNM 189485.

15. *Platystrophia annieana* Foerste (p. B12).
View of brachial exterior. Figured specimen USNM 189486.

16. *Platystrophia ponderosa* Foerste (p. B12).
View of pedicle interior of a short-hinge line form. Figured specimen USNM 189487; USGS colln. 6411–CO.

17. *Platystrophia* cf. *P. annieana* Foerste (p. B12).
View of pedicle interior. Figure normal to line of commissure.
Figured specimen USNM 189488.

18–20. *Platystrophia ponderosa* Foerste (p. B16).
Brachial interior of three immature specimens. All tilted to show muscle scars.
18. Figured specimen USNM 189489; USGS colln. 4556–CO.
19. Figured specimen USNM 189490; USGS colln. 4556–CO.
20. Figured specimen USNM 189491; USGS colln. 4210–CO.

21–23. *Platystrophia ponderosa* Foerste (p. B16).
Pedicle interior of three small specimens. All figures taken normal to line of commissure.
21. Figured specimen USNM 189492; USGS colln. 6411–CO.
22. Figured specimen USNM 189493; USGS colln. 4556–CO.
23. Figured specimen USNM 189494; USGS colln. 4556–CO.

24–28. *Platystrophia ponderosa* Foerste (p. B16).
Normal appearance of brachial and pedicle valves preserved as fragments. Many of the collections contain fragmented specimens still recognizable as *P. ponderosa*. This is due to the thick shell material around the beak region.
24. Figured specimen USNM 189495; USGS colln. 6409–CO.
25. Figured specimen USNM 189496; USGS colln. 6412–CO.
26. Figured specimen USNM 189497; USGS colln. 6410–CO.
27. Figured specimen USNM 189498; USGS colln. 6410–CO.
28. Figured specimen USNM 189499; USGS colln. 6412–CO.

29. *Platystrophia ponderosa* Foerste (p. B16).

Pedicle exterior of a specimen with broad plications. Compare this specimen to figure 30 in which the plications are more numerous and closer together. Both specimens are from the same suite. Figured specimen USNM 189500; USGS colln. 6416–CO.

30. *Platystrophia ponderosa* Foerste (p. B16).

Pedicle exterior showing a typical plication pattern. Figured specimen USNM 189501; USGS colln. 6416–CO.

31. *Platystrophia ponderosa* Foerste (p. B16).

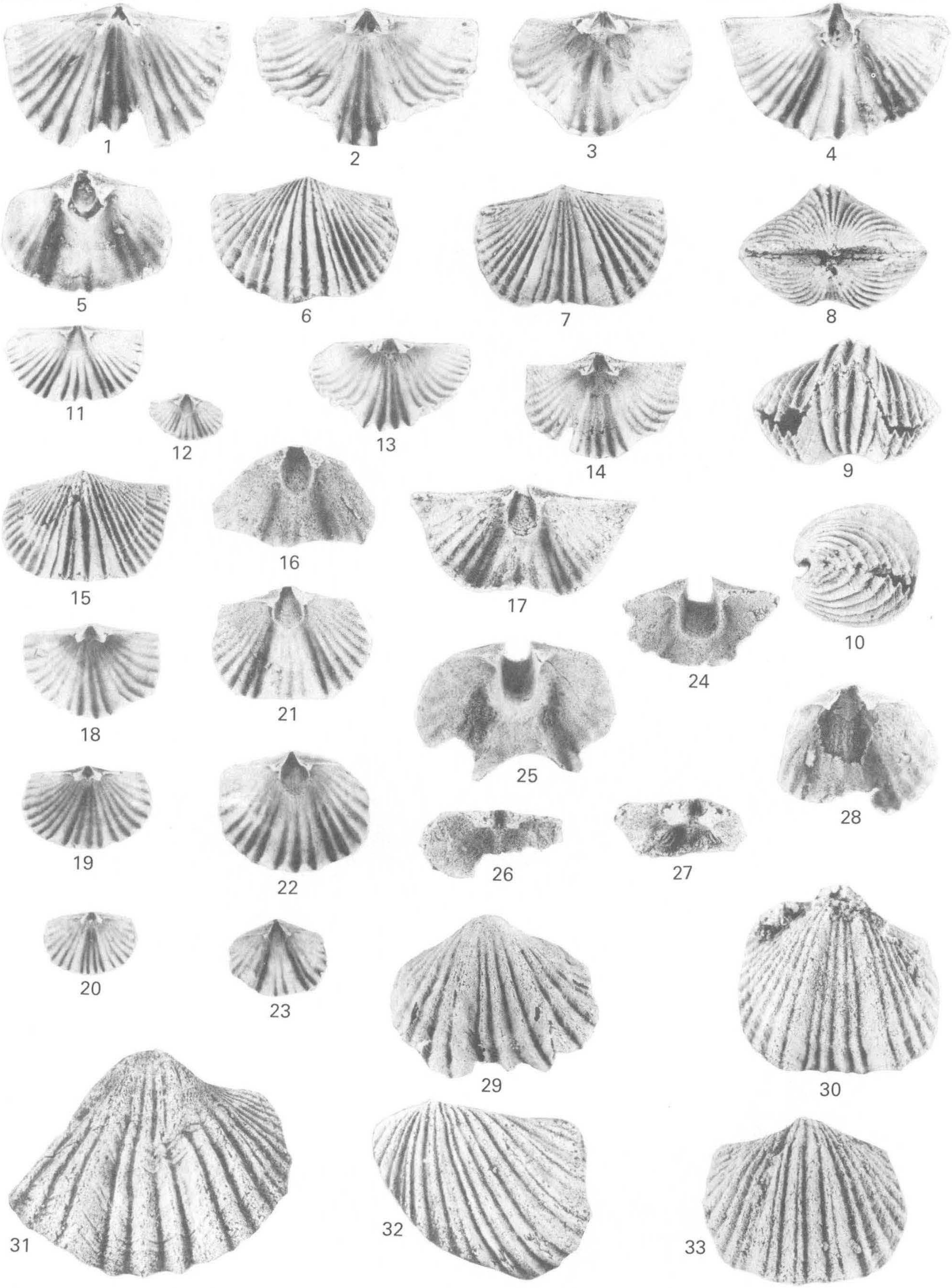
Pedicle exterior of a specimen in which a "scar" appears across several of the plications suggesting that some damage occurred which was later repaired by the individual. Figured specimen USNM 189502; USGS colln. 6416–CO.

32. *Platystrophia ponderosa* Foerste (p. B16).

Brachial exterior of a specimen having a peculiar plication pattern. Note that the three plications in the region of the cardinal extremity have a distinct "cleft" running from the hinge line to the lateral margin. Figured specimen USNM 189503; USGS colln. 6416–CO.

33. *Platystrophia ponderosa* Foerste (p. B16).

Brachial exterior of a specimen with seven plications on the fold. Figured specimen USNM 189504; USGS colln. 6416–CO.



SPECIMENS OF *PLATYSTROPHIA ANNIEANA* AND *PLATYSTROPHIA PONDEROSA*

PLATE 5

[All figures × 1.2. Figures 1–30 are from USGS collection 7353–CO. Figures 31–36 are from USGS collection 7812–CO]

FIGURES 1–5. *Platystrophia colbiensis* Foerste (p. B9).
Brachial views of a growth series.
1. Figured specimen USNM 189505.
2. Figured specimen USNM 189506.
3. Figured specimen USNM 189507.
4. Figured specimen USNM 189508.
5. Figured specimen USNM 189509.

6–10. *Platystrophia colbiensis* Foerste (p. B9).
Pedicle views of a growth series.
6. Figured specimen USNM 189505.
7. Figured specimen USNM 189506.
8. Figured specimen USNM 189507.
9. Figured specimen USNM 189508.
10. Figured specimen USNM 189509.

11–15. *Platystrophia colbiensis* Foerste (p. B9).
Anterior views of a growth series.
11. Figured specimen USNM 189505.
12. Figured specimen USNM 189506.
13. Figured specimen USNM 189507.
14. Figured specimen USNM 189508.
15. Figured specimen USNM 189509.

16–20. *Platystrophia colbiensis* Foerste (p. B9).
Posterior views of a growth series.
16. Figured specimen USNM 189505.
17. Figured specimen USNM 189506.
18. Figured specimen USNM 189507.
19. Figured specimen USNM 189508.
20. Figured specimen USNM 189509.

21–25. *Platystrophia colbiensis* Foerste (p. B9).
Lateral views of a growth series.
21. Figured specimen USNM 189505.
22. Figured specimen USNM 189506.
23. Figured specimen USNM 189507.
24. Figured specimen USNM 189508.
25. Figured specimen USNM 189509.

26–30. *Platystrophia colbiensis* Foerste (p. B9).
Brachial interiors of several valves of different sizes. All tilted slightly to the posterior.
26. Figured specimen USNM 189510.
27. Figured specimen USNM 189511.
28. Figured specimen USNM 189512.
29. Figured specimen USNM 189513.
30. Figured specimen USNM 189514

31. *Platystrophia colbiensis* Foerste (p. B9).
Brachial exterior. Figured specimen USNM 189515.

32, 33. *Platystrophia colbiensis* Foerste (p. B9).
Pedicle interiors.
32. Figured specimen USNM 189516.
33. Figured specimen USNM 189517.

34–36. *Platystrophia colbiensis* Foerste (p. B9).
Brachial interiors. Figure 34 is normal to line of commissure; figures 35 and 36 are tilted to the posterior.
34. Figured specimen USNM 189518.
35. Figured specimen USNM 189518.
36. Figured specimen USNM 189519.

37. *Platystrophia annieana* Foerste (p. B12).
Brachial exterior of a specimen with two large plications on the fold and more numerous smaller plications on the flanks. This is an atypical specimen of *P. annieana.* Figured specimen USNM 189520; USGS colln. 6139–CO.

38. *Platystrophia annieana* Foerste (p. B12).
Brachial exterior of a specimen with six plications on the fold; plications on flanks are same size. Compare this figure with figure 37; both specimens are from the same suite. Figured specimen USNM 189521; USGS colln. 6139–CO.

39, 40, 50. *Platystrophia cypha* (James) (p. B15).
Pedicle exterior, brachial exterior, anterior views. Figured specimen USNM 189522; USGS colln. 4060–CO.

41. *Platystrophia* cf. *P. laticosta* (Meek) (p. B14).
Pedicle exterior of a small specimen with one plication in the sulcus like that found in specimens referred by some to *P. unicostata.* Figured specimen USNM 189523; USGS colln. 6418–CO.

42. *Platystrophia* cf. *P. laticosta* (Meek) (p. B14).
Brachial exterior of a medium-sized specimen having two large inner plications on the fold and two smaller marginal fold plications. Figured specimen USNM 189524; USGS colln. 6418–CO.

43. *Platystrophia cypha* (James) (p. B15).
Pedicle exterior of a small specimen showing a greater than normal number of plications along the flanks. Compare this with figure 44, which is a specimen of about the same size but with a typical number of flank plications for *P. cypha.* Figured specimen USNM 189525; USGS colln. 4060–CO.

44, 52. *Platystrophia cypha* (James) (p. B15).
Small specimen. Pedicle exterior, anterior views. Figured specimen USNM 189526; USGS colln. 4060–CO.

45–49. *Platystrophia laticosta* (Meek) (p. B14).
Pedicle exterior, brachial exterior, posterior, anterior, lateral views. Figured specimen USNM 189527. USGS colln. 4067–CO.

51, 53. *Platystrophia* cf. *P. laticosta* (Meek) (p. B14).
Anterior view and brachial exterior of a slightly crushed specimen. Figured specimen USNM 189528; USGS colln. 4060–CO.

54. *Platystrophia elegantula* McEwan (p. B10).
Brachial interior. Figure normal to line of commissure. Figured specimen USNM 189529; USGS colln. 5015–CO.

55. *Platystrophia elegantula* McEwan (p. B10).
Pedicle interior. Figure normal to line of commissure. Figured specimen USNM 189530; USGS colln. 5015–CO.

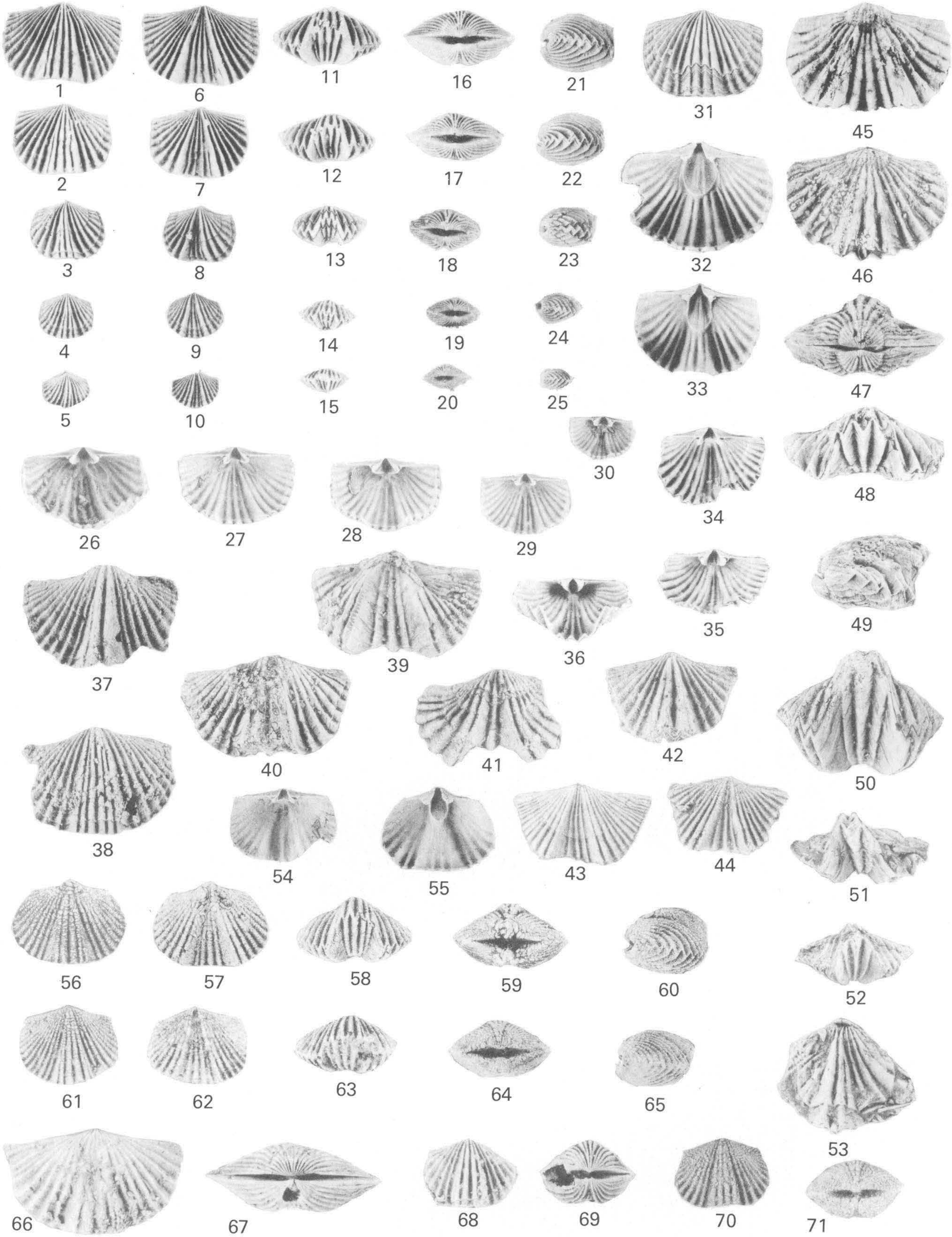
56–60. *Platystrophia elegantula* McEwan (p. B10).
Brachial exterior, pedicle exterior, anterior, posterior, lateral views. Figured specimen USNM 189531; USGS colln. D1204–CO.

61–65. *Platystrophia elegantula* McEwan (p. B10).
Brachial exterior, pedicle exterior, anterior, posterior, lateral views. This specimen is from a different stratigraphic section than the specimen figured in 56–60. Figured specimen USNM 189532.

66, 67. *Platystrophia* aff. *P. annieana* Foerste (p. B12).
Brachial exterior, posterior views. Figured specimen USNM 189533; USGS colln. 7066–CO.

68, 69. *Platystrophia* cf. *P. colbiensis* Foerste (p. B9).
Brachial exterior, posterior views. Figured specimen USNM 189534; USGS colln. 7079–CO.

70, 71. *Platystrophia elegantula* McEwan (p. B10).
Brachial exterior, posterior views. Figured specimen USNM 189535; USGS colln. 4982–CO.



SPECIMENS OF *PLATYSTROPHIA COLBIENSIS*, *PLATYSTROPHIA ANNIEANA*, *PLATYSTROPHIA CYPHA*, *PLATYSTROPHIA LATICOSTA*, *PLATYSTROPHIA* CF. *P. LATICOSTA*, *PLATYSTROPHIA ELEGANTULA*, *PLATYSTROPHIA* CF. *P. ANNIEANA*, AND *PLATYSTROPHIA* CF. *P. COLBIENSIS*

PLATE 6

[All figures × 1.1 unless otherwise noted]

FIGURES 1–5. *Platystrophia laticosta* (Meek) (p. B14).
Brachial exterior, pedicle exterior, posterior, anterior, and lateral views. Figured specimen USNM 189537; USGS colln. D1363–CO.

6, 7. *Platystrophia laticosta* (Meek) (p. B14).
Brachial exterior. Figured specimen USNM 189538. USGS colln. 6284–CO.

8–10. *Platystrophia laticosta* (Meek) (p. B14).
Brachial exterior, pedicle exterior, anterior view. Figured specimen USNM 189539; USGS colln. D1363–CO.

11–13. *Platystrophia laticosta* (Meek) (p. B14).
Brachial exterior, pedicle exterior, anterior view of a small specimen. Figured specimen USNM 189540; USGS colln. D1363–CO.

14–18. *Platystrophia cypha* (James) (p. B15).
Brachial exterior, pedicle exterior, posterior, lateral, and anterior views. Figured specimen USNM 189541. USGS colln. D1250–CO.

19–21. *Platystrophia laticosta* (Meek) (p. B14).
Brachial exterior, pedicle exterior, anterior view. This specimen is characterized by broad, low-angle plications and occurs in the same suite of specimens as figures 6, 7, 25, 26, 27, and 28. Figured specimen USNM 189542; USGS colln. 6284–CO.

22–24. *Platystrophia laticosta* (Meek) (p. B14).
Brachial exterior, pedicle exterior, anterior view. Figured specimen USNM 189543; USGS colln. 4545–CO.

25–28. *Platystrophia laticosta* (Meek) (p. B14).
Brachial exterior, pedicle exterior, anterior, and lateral views. Figured specimen USNM 189544; USGS colln. 6284–CO.

29, 30. *Platystrophia cypha* (James) (p. B15).
View of brachial interior showing muscle scars; specimen tilted. View of brachial interior; photograph taken normal to plane of commissure. Figured specimen USNM 189545; USGS colln. 4067–CO.

31. *Platystrophia cypha* (James) (p. B15).
View of pedicle interior; photograph taken normal to plane of commissure. Figured specimen USNM 189546; (× 1.) USGS colln. 4067–CO.

32. *Platystrophia cypha* (James) (p. B15).
Pedicle interior. Figured specimen USNM 189547; (× 1) USGS colln. 4067–CO.

33–37. *Platystrophia* cf. *P. foerstei* McEwan (p. B18).
Brachial exterior, pedicle exterior, posterior view, anterior view, and lateral view. Figured specimen USNM 189548; USGS colln. D1370–CO.

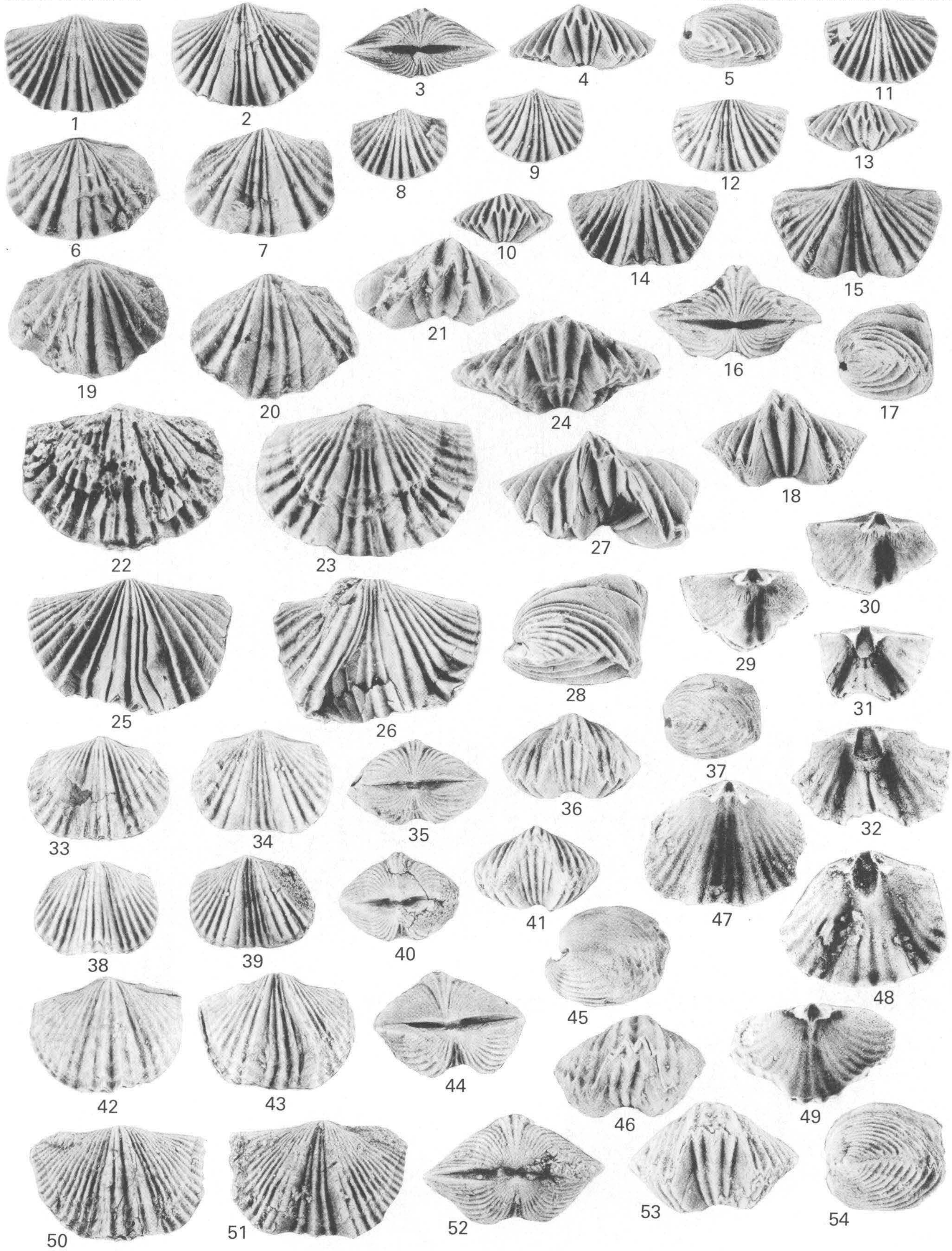
38–41. *Platystrophia* cf. *P. foerstei* McEwan (p. B18).
Brachial exterior, pedicle exterior, posterior view, lateral view. Figured specimen USNM 189549; USGS colln. D1370–CO.

42–46. *Platystrophia* sp. (p. B18).
Brachial exterior, pedicle exterior, posterior view, lateral view, and anterior view. Figured specimen USNM 189550; USGS colln. D1292–CO.

47, 49. *Platystrophia ponderosa* Foerste (p. B16).
Brachial interior; photograph taken normal to plane of commissure. Brachial interior; specimen tilted to show inward-sloping brachiophore bases and the formation of the cruralium-like structure. Figured specimen USNM 189551; USGS colln. 4195–CO. This specimen is a short-hinge-line form commonly designated *P. ponderosa* var. *auburnensis* Foerste.

48. *Platystrophia ponderosa* Foerste (p. B16).
Pedicle interior of a short-hinge-line form commonly referred to *P. ponderosa* var. *auburnensis* Foerste. Figured specimen USNM 189552; USGS colln. 4195–CO.

50–54. *Platystrophia acutilirata* (Conrad) (p. B11).
Brachial exterior, pedicle exterior, posterior view, anterior view, and lateral view. Figured specimen USNM 189553; USGS colln. 5309–CO.



SPECIMENS OF *PLATYSTROPHIA LATICOSTA*, *PLATYSTROPHIA CYPHA*, *PLATYSTROPHIA* CF. *P. FOERSTEI*, *PLATYSTROPHIA* SP., *PLATYSTROPHIA PONDEROSA*, AND *PLATYSTROPHIA ACUTILIRATA*

PLATE 7

[All figures × 1.1 unless otherwise noted]

FIGURES 1, 3. *Platystrophia acutilirata* (Conrad) (p. B11).
Brachial exterior, posterior view of a specimen studied by McEwan (1919) from the Whitewater Formation near Richmond, Ind. Figured specimen USNM 189554.

2. *Platystrophia acutilirata* (Conrad) (p. B11).
Pedicle exterior of a specimen studied by McEwan (1919) from the Whitewater Formation near Richmond, Ind. Figured specimen USNM 189555.

4–6. *Platystrophia annieana* Foerste (p. B12).
Brachial exterior, anterior view, lateral view of a specimen studied by McEwan (1919) from the "Richmond Group" near Waynesville, Ohio. Figured specimen USNM 189556 (× 1.2).

7, 8. *Platystrophia annieana* Foerste (p. B12).
Lateral view, anterior view of a specimen studied by McEwan (1919) from the "Richmond Group" near Waynesville, Ohio. This specimen is not as thick as the one shown in figures 4–6. Figured specimen USNM 189557 (× 1.2).

9–12. *Platystrophia unicostata* Cumings (p. B14).
Pedicle exterior, anterior view, posterior view, lateral view of a specimen studied by McEwan (1919) from the "Maysville Group" 2.5 miles north of Lebanon, Ky. Figured specimen USNM 189558.

13, 14. *Platystrophia unicostata* Cumings (p. B14).
Brachial exterior, anterior view of a specimen studied by McEwan (1919) from the "Maysville Group" near Madison, Ind. Figured specimen USNM 189559. Note the presence of only one plication in the sulcus. This is the single attribute that is supposed to distinguish this species from all others.

15, 16. *Platystrophia unicostata* Cumings (p. B14).
Brachial exterior, anterior view of a specimen studied by McEwan (1919) from the "Maysville Group" near Madison, Ind. Figured specimen USNM 189560.

17–19. *Platystrophia laticosta* (Meek) (p. B14).
Brachial exterior, anterior view, lateral view of a specimen studied by McEwan (1919) from the "Maysville Group" ("Bellevue Formation?") in Oldham County, Ky. Figured specimen USNM 189561.

20–21. *Platystrophia laticosta* (Meek) (p. B14).
Anterior view, lateral view of a specimen studied by McEwan (1919) from the "Maysville Group" ("Bellevue Formation?") in Oldham County, Ky. Figured specimen USNM 189562.

22, 23, 27. *Platystrophia cypha* (James) (p. B15).
Brachial view, lateral view, anterior view of a specimen studied by McEwan (1919) from the Arnheim Formation near Waynesville, Ohio. Figured specimen USNM 189563.

24, 25. *Platystrophia cypha* (James) (p. B15).
Brachial exterior, anterior view of a specimen studied by McEwan (1919) from the Arnheim Formation near Waynesville, Ohio. Figured specimen USNM 189564.

26. *Platystrophia cypha* (James) (p. B15).
Brachial exterior of a specimen studied by McEwan (1919) from the Arnheim Formation near Waynesville, Ohio. Figured specimen USNM 189565.

28. *Platystrophia cypha* (James) (p. B15).
Brachial exterior of a specimen studied by McEwan (1919) from the Arnheim Formation near Waynesville, Ohio. Figured specimen USNM 189566.

29. *Platystrophia cypha* (James) (p. B15).
Pedicle exterior of a specimen studied by McEwan (1919) from the "Arnheim" Formation 1 mile east of Seatonville, Ky. Figured specimen USNM 189567.

30. *Platystrophia clarksvillensis* Foerste (p. B16).
Brachial exterior of a specimen studied by McEwan (1919) from the Waynesville Shale near Oregonia, Ohio. Figured specimen USNM 189568.

31. *Platystrophia clarksvillensis* Foerste (p. B16).
Anterior view of a specimen studied by McEwan (1919) from the Waynesville Shale near Waynesville, Ohio. Figured specimen USNM 189569.

32, 33. *Platystrophia clarksvillensis* Foerste (p. B16).
Brachial exterior, anterior view of a specimen studied by McEwan (1919) from the Waynesville Shale near Waynesville, Ohio. Figured specimen USNM 189570.

34, 35. *Platystrophia* cf. *P. annieana* Foerste (p. B14).
Pedicle exterior, posterior views. Figured specimen USNM 189571; USGS colln. 7066–CO.

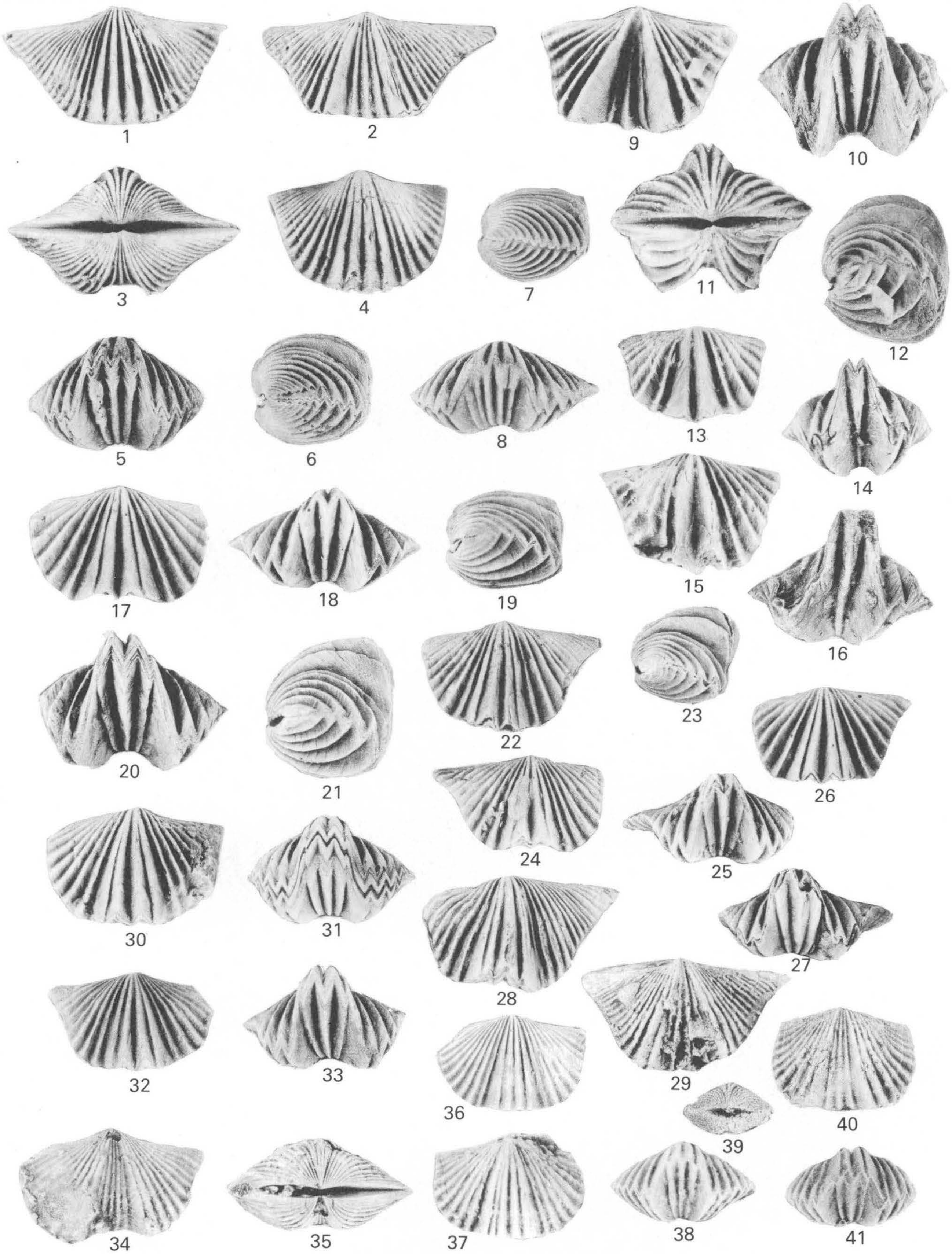
36, 38. *Platystrophia colbiensis* Foerste (p. B9).
Brachial exterior, anterior views of rather large specimen of the species. Figured specimen USNM 189572; USGS colln. 7319–CO.

37. *Platystrophia colbiensis* Foerste (p. B9).
Brachial exterior of a large specimen of this species occurring in the same suite as the specimen figured in 36 and 38. Compare these specimens with the figures of *P. colbiensis* studied by McEwan (1919) from the Catheys Limestone (Trentonian) of Tennessee. Figured specimen USNM 189573. USGS colln. 7319–CO.

39. *Platystrophia elegantula* McEwan (p. B10).
Posterior view of a specimen studied by McEwan (1919) from either the Bigby Limestone (Trentonian) of Tennessee or the Trenton Group at Ellisburg, N.Y. Figured specimen USNM 189574.

40. *Platystrophia colbiensis* Foerste (p. B9).
Pedicle exterior of a specimen studied by McEwan (1919) from the Catheys Limestone (Trentonian) in Nashville, Tenn. Figured specimen USNM 189575.

41. *Platystrophia colbiensis* Foerste (p. B9).
Anterior view of a specimen studied by McEwan (1919) from the Catheys Limestone (Trentonian) near Edgefield Junction, Tenn. Figured specimen USNM 189576.



SPECIMENS OF *PLATYSTROPHIA ACUTILIRATA*, *PLATYSTROPHIA ANNIEANA*, *PLATYSTROPHIA UNICOSTATA*, *PLATYSTROPHIA LATICOSTA*, *PLATYSTROPHIA CYPHA*, *PLATYSTROPHIA CLARKSVILLENSIS*, *PLATYSTROPHIA* CF. *P. ANNIEANA*, *PLATYSTROPHIA ELEGANTULA*, AND *PLATYSTROPHIA COLBIENSIS*

Middle and Late Ordovician Plectambonitacean, Rhynchonellacean, Syntrophiacean, Trimerellacean, and Atrypacean Brachiopods

By HERBERT J. HOWE

CONTRIBUTIONS TO THE ORDOVICIAN PALEONTOLOGY OF KENTUCKY AND NEARBY STATES

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1066–C

Prepared in cooperation with the Commonwealth of Kentucky, University of Kentucky, Kentucky Geological Survey

Descriptions and illustrations of 14 species of Ordovician brachiopods

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SYSTEM OF MEASUREMENT UNITS

The investigations underlying this series of reports were made over a period of years, and distances and stratigraphic measurements appear fairly uniformly in English units. Measurements of fossil specimens, on the other hand, follow the long-standing convention of appearing in metric units. Because of the dates of the investigations and the amount of resulting data, the English measurements have been retained. Conversions to metric units may be made by using the following conversion table.

To convert English unit:	To metric unit:	Multiply by:
Mile (mi)	Kilometer (km)	1.61
Foot (ft)	Meter (m)	.305

CONTRIBUTIONS TO THE ORDOVICIAN PALEONTOLOGY OF KENTUCKY AND NEARBY STATES

MIDDLE AND LATE ORDOVICIAN PLECTAMBONITACEAN, RHYNCHONELLACEAN, SYNTROPHIACEAN, TRIMERELLACEAN, AND ATRYPACEAN BRACHIOPODS

By HERBERT J. HOWE[1]

ABSTRACT

Middle and Upper Ordovician strata in Kentucky yielded a large silicified brachiopod fauna representing the superfamilies Plectambonitacea, Rhynchonellacea, Syntrophiacea, and Trimerellacea. Fourteen species from eight genera are described: *Sowerbyella curdsvillensis* (Foerste), *S. grierensis* Howe n. sp., *Sowerbyella* sp., *S. rugosa* (Meek), *Thaerodonta clarksvillensis* (Foerste), *Rhynchotrema dentatum* (Hall), *R. increbescens* (Hall), *Rostricellula minuta* Cooper, *Lepidocyclus? capax* (Conrad), *Orthorhynchula linneyi* (James), *O. sublinneyi* Howe n. sp., *Camerella bella* Fenton, *C.* sp. aff. *C. immatura* Cooper, and *Elliptoglossa?* sp. An atrypid species, probably an aberrant *Zygospira*, is also described.

INTRODUCTION

The purpose of this paper is to describe the plectambonitacean, rhynchonellacean, syntrophiacean, and trimerellacean brachiopods from Middle and Upper Ordovician strata in Kentucky. The U.S. Geological Survey material at hand consists of more than 8,500 specimens representing 14 species and 8 genera.

All figured specimens have been deposited in the U.S. National Museum (USNM) in Washington, D.C. Photographed fossils were stained with india ink and then whitened with ammonium chloride. Statistics, tables, and scattergrams have been used in some samples to show basic variations in diagnostic characters. In normally distributed samples, reduced major axes have been estimated from a method by Imbrie (1956). Measurements include length and width, thickness, height of fold (and corresponding depth of sulcus), and fold width.

ACKNOWLEDGMENTS

I am indebted to the U.S. Geological Survey for permission to study the Survey's large collection of Middle and Late Ordovician brachiopods from Kentucky; to G. Arthur Cooper for permission to examine pertinent specimens in the U.S. National Museum; and to Norman D. Newell for permission to examine Hall's type lot of *Rhynchotrema increbescens*, which is reposited in the American Museum of Natural History. I owe special thanks to John Pojeta of the U.S. Geological Survey for responding to numerous requests for assistance and information.

SYSTEMATIC PALEONTOLOGY

Superfamily PLECTAMBONITACEA Jones nom. transl. Cooper and Williams

Family SOWERBYELLIDAE Öpik

Genus SOWERBYELLA Jones, 1928; emended Wang, 1949; Howe, 1972

Sowerbyella curdsvillensis (Foerste) 1912

Plate 1, figures 6–16

Plectambonites curdsvillensis Foerste, 1912; p. 122, pl. 10, figs. 15A, B.

Plectambonites punctostriatus Mather, 1917; p. 38, pl. 1, figs. 15–17.

Sowerbyella punctostriata (Mather). Cooper, 1944, p. 335, pl. 128, figs. 44–49.

Sowerbyella curdsvillensis (Foerste). Cooper, 1956, p. 780, pl. 201A, figs. 1–13.

Sowerbyella punctostriata (Mather). Cooper, 1956, p. 792, pl. 205C, figs. 9–25; pl. 206D, figs. 14, 15.

Sowerbyella curdsvillensis (Foerste). Howe, 1972, p. 442, pl. 1, fig. 9.

Sowerbyella punctostriata (Mather). Howe, 1972, p. 442, pl. 1, fig. 12.

Description.—Shell large for the genus; width nearly twice the length; cardinal extremities acute to right-angular; anterior margin broadly rounded. Ornamentation unevenly costellate and faintly beaded; one to five finer costellae grouped between slightly larger ones. Region adjacent to posterior margin displaying weak oblique wrinkles in occasional specimens.

[1] Purdue University, Lafayette, Ind.

Pedicle valve moderately convex in lateral profile; umbonal region gently inflated. Interior of pedicle valve finely papillose. Teeth small. Adjustor-diductor muscle field wide, extending to about midlength; diductors strongly diverging in front of short median septum; paired adductor scars deeply incised into callus deposits of delthyrial floor.

Brachial valve concave in lateral profile. Inner surface marked by fine papillose elevations. Adductor muscle field large, subcircular in outline, reaching beyond the middle of the valve; inner scars bordered by moderately elevated septa; occasional specimens displaying low median septum. Brachiophores large, strongly divergent, and ending in points; cardinal process strongly elevated ventrally. Interarea short, anacline.

Remarks.—*S. curdsvillensis* suggests the genus *Thaerodonta* in its large size and the deeply incised adductor scars on the delthyrial floor. However, it lacks the diagnostic dorsal lateral septa, accessory teeth, and hinge denticulations of that genus. Papillose ornamentation occasionally extends into the cardinal area of the brachial valve, but the papillae do not correspond with the dorsal denticles of Thaerodonta nor do any of the many specimens at hand show any fossettes along the ventral hinge.

Comparison.—*S. curdsvillensis* is most like a form that has been widely recognized in the lower part of the Trenton Group of New York and Ontario and in the Midwest as *S. punctostriata* (Mather). According to Cooper (1956), *S. curdsvillensis* and *S. punctostriata* are sufficiently similar to be possible ecads of a single species, but he felt that larger collections than those available to him would be necessary to demonstrate this. He distinguished the two forms on the basis of *S. punctostriata* exhibiting (1) lesser concavity and generally thinner valves, (2) a shallower brachial valve, (3) greater development of oblique wrinkling, (4) fairly late development of a thickened subperipheral rim, (5) lesser thickening of all internal features, and (6) a greater tendency to auriculate cardinal extremities. Mather (1917) emphasized the subperipheral rim and thickening of interior features in *S. curdsvillensis* as the major points of difference. Study of large suites of *S. curdsvillensis* in the USGS collections from Kentucky revealed wide variations in the amount of thickening of internal structures, the prominence of the subperipheral rim, shell thickness, acuteness of the cardinal extremities, and the concavity of the brachial valve. In view of these variations, the oblique wrinkling in *S. punctostriata* appears to be the only basis for distinguishing the two forms. Both show beaded costellae.

S. curdsvillenis is similar to *Thaerodonta clarksvillensis* in size and in growth pattern of length to width (fig. 1), but that form has accessory denticulations along the hinge, accessory teeth, and lateral septa dividing the dorsal muscle field.

Distribution and material.—This species is one of the most common brachiopods in the Curdsville Limestone Member of the Lexington Limestone. Approximately 1,400 disarticulated valves, many of which are partially broken, were recovered from the following USGS localities: 4122–CO, 4123–CO, 4124–CO, 4125–CO, 4213–CO, 4940–CO, 5022–CO, 5069–CO, 5084–CO, 6131–CO, and 6135–CO.

Dimensions.—Measurements and growth patterns of length to width are given in figure 1 for comparison with respesentatives of *Thaerodonta clarksvillensis*.

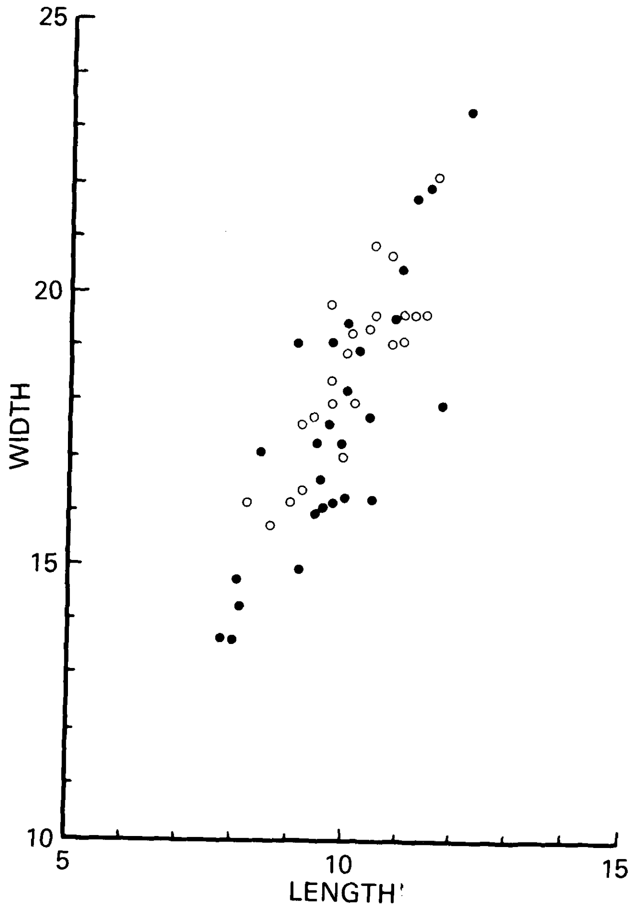

FIGURE 1.—Scatter diagram of length-width in millimeters (brachial valve) of *Sowerbyella curdsvillensis* (Foerste) (open circles) from the Curdsville Limestone Member of the Lexington Limestone, USGS locs. 5101–CO and 7785–CO; and *Thaerodonta clarksvillensis* (Foerste) (solid circles) from Richmondian beds at Waynesville, Ohio, USNM 40460.

Sowerbyella grierensis Howe, n. sp.

Plate 1, figures 1–5

Description.—Shell of medium size for the genus; adult specimens averaging about 12 mm in width; width nearly twice the length. Cardinal extremities acute to right angular; lateral margins sloping inward; anterior margin broadly rounded to somewhat truncate. Surface ornamented by costellae of nearly equal size; pedicle valve displaying finely beaded costellae; brachial valve occasionally bearing small oblique wrinkles adjacent to hinge.

Pedicle valve moderately convex in lateral profile; umbo somewhat swollen; flanks gently convex to flat. Ventral interarea moderately long, pseudodeltidium absent or rudimentary. Interior of pedicle valve: teeth small; delthyrial floor thickened with callus deposits into which small adductor pits are incised. Adjustor-diductor field large, subflabellate, reaching to about midlength, and diverging in front of a short median ridge.

Brachial valve gently concave in lateral profile and having maximum concavity at about the middle. Dorsal interior displaying slightly diverging septa, which reach greatest elevation just anterior to middle; anterior slope of crest steep and papillose. Medial region marked by weak ridge. Adductor muscle field long, extending to midlength; impressions about equal in size and bordered laterally by nearly straight margins. Inner surface finely papillose.

Distribution and material.—This species is found in the Grier Limestone Member of the Lexington Limestone. Four USGS localities (4871–CO, 4872–CO, 4876–CO, and 4956–CO) yielded 119 disarticulated valves.

Types.—Holotype, USNM 208592, a pedicle valve from the Grier Limestone Member of the Lexington Limestone. USGS loc. 4956–CO; length 7.4 mm, width 13.0 mm. Paratype, USNM 208589, a dorsal valve, USGS loc. 4956–CO; length 5.5 mm, width 10.4 mm. Paratype, USNM 208590, a pedicle valve, USGS loc. 4956–CO, length 6.7 mm, width 12.2 mm. Paratype, USNM 208591, a dorsal valve, USGS loc. 4956–CO, length 6.7 mm, width 12.3 mm. Paratype, USNM 208593, a dorsal valve, USGS loc. 4956–CO, length 7.4 mm, width 14.4 mm.

Remarks.—*S. grierensis* is closely related to a group of Shermanian *Sowerbyella* that includes *S. curdsvillensis* (Foerste), *S. eximia* Cooper, and *S. monilifera* Cooper. All of these forms display beaded ornamentation, incised adductor scars in the ventral valve, and with the exception of *S. grierensis,* all are large for the genus. *S. grierensis* most closely suggests *S. curdsvillensis,* but it is much smaller and more delicate than the latter and the costellae are more equally developed. Also, the outer margins of the dorsal muscle field are nearly straight in contrast to the rounded borders of *S. curdsvillensis.* The trivial name, *grierensis,* alludes to its occurrence in the Grier Limestone Member of the Lexington Limestone.

Sowerbyella rugosa (Meek)

Plate 1, figures 17–20

Leptaena rugosa Meek, 1873, p. 72, pl. 5, figs. 3f, g, h.

Sowerbyella rugosa (Meek). Cooper, 1944, p. 335, pl. 128, figs. 41–43.

Sowerbyella rugosus (Meek). Caster and others, 1961, pl. 2, figs. 14–16.

Sowerbyella rugosa (Meek). Howe, 1972, pl. 1, figs. 4–7.

Remarks.—Study of large suites of *S. rugosa* in the collections at the U. S. National Museum shows a number of diagnostic features for this species, namely: rugose surface exteriors, oblique wrinkling along the posterior margins of both valves, acute cardinal extremities, and a well-defined dorsal median septum. The U.S. Geological Survey collections from the Kope Formation contain specimens that are smaller than most of those examined in the National Museum, but in other aspects they are characteristic of the species. Occasional specimens in both the National Museum and the Kentucky material show slightly elevated dorsal lateral septa somewhat suggestive of *Thaerodonta.*

Material.—The USGS collection consists of 37 specimens from the Kope Formation, loc. 7978–CO.

Comparison.—*S. rugosa* suggests *Thaerodonta aspera* Wang in its rugose exterior, but it lacks the accessory teeth, hinge denticulations, and elevated dorsal lateral septa of that species.

Figured specimens.—USNM 208596 and 208597, respectively, a pedicle valve and complete specimen, from Kope Formation, USGS loc. 7978–CO; and USNM 170730, dorsal valve, from Kope Formation outcrop behind the Newport Shopping Center on U.S. Highway 27, Newport, Ky.

Sowerbyella sp.

Plate 2, figures 1–13

Description.—Outline semielliptical, wider than long; cardinal extremities acute to obtuse. Surface unevenly multicostellate, consisting of one to four finer costellae separated by somewhat larger ones.

Pedicle valve moderately convex in lateral profile. Interarea long, apsacline. Ventral interior papillose. Muscle field elongate forming strongly bilobed outline anteriorly. Adductor scars deeply incised into adventitious deposits on delthyrial floor;

diductor scars large, separated posteriorly by short septum. Hinge showing incipient fossettes on occasional specimens. Pseudodeltidium absent or rudimentary.

Brachial valve moderately concave at the umbo becoming gently concave laterally and anteriorly. Occasional specimens, including juveniles, show incipient denticles along cardinal margins. Dorsal muscle field transversely subelliptical, extending about two-thirds the length of the valve. Medial septa slightly divergent, merging anteriorly with an elevated platform that is thickened and spinose. Inner and outer adductor scars about equal in size. Median septum weak, occasionally well defined. Brachiophores long, bladelike, ending in sharp points. Inner surface finely papillose.

Remarks.—A number of specimens of *Sowerbyella* sp. show incipient denticles on the brachial valve and corresponding fossettes on the pedicle. This morphology presages the much stronger accessory denticulations observed in the Late Ordovician genus *Thaerodonta.* None of the brachial valves show elevated lateral septa in the dorsal muscle field and only one of the ventral interiors develops accessory teeth such as in *Thaerodonta. Sowerbyella* sp. appears to be a connecting link between the late Shermanian species of the genus, which are large and have delthyrial thickening and incised ventral adductors, and the genus *Thaerodonta,* characterized by hinge denticulations, strong accessory teeth, and dorsal lateral septa.

Comparison.—*Sowerbyella* sp. is most like *S. rugosa,* another Edenian species, but it differs in lacking the strongly lamellose exterior and oblique wrinkling of that form. *Sowerbyella* sp. is also similar to the Richmondian species, *Thaerodonta clarksvillensis,* but the latter is larger (fig. 2) and has hinge denticulations and elevated lateral septa.

Material.—More than 200 disarticulated valves, the majority of which are brachial valves, were recovered from the Point Pleasant Tongue of the Clays Ferry Formation at USGS loc. 8068–CO. An additional 55 specimens came from Clays Ferry locs. 4905–CO, 5058–CO, 7472–CO, and 7478–CO. A number of coquinoid limestone slabs display large numbers of disarticulated valves and fragments.

Dimensions.—Growth patterns of length to width are given in figure 2 for comparison with representatives of *Thaerodonta clarksvillensis,* the succeeding sowerbyellid species in the stratigraphic section.

Figured specimens.—USNM 208600, 208601, two brachial valves, from Clays Ferry Formation, USGS loc. 5058–CO; USNM 208602, a complete specimen from Clays Ferry Formation, USGS loc. 4905–CO; and USNM 208603–208608, from Point Pleasant Tongue of Clays Ferry Formation, USGS loc. 8068–CO.

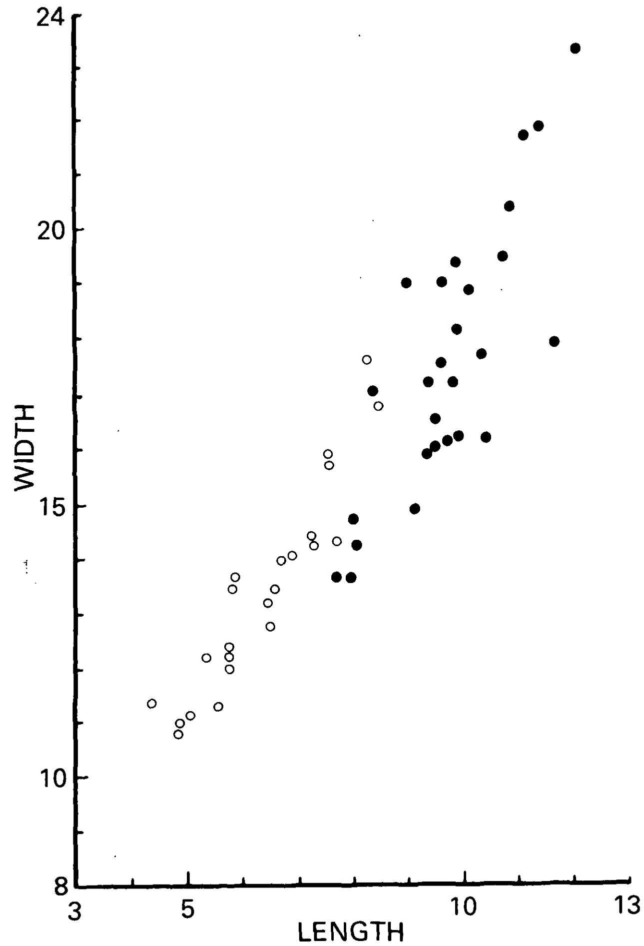

FIGURE 2.—Scatter diagram of length-width in millimeters (brachial valve) of *Sowerbyella* sp. (open circles) from the Point Pleasant Tongue of the Clays Ferry Formation, USGS loc. 8068–CO; and *Thaerodonta clarksvillensis* (solid circles) from Richmondian sedimentary rocks at Waynesville, Ohio, USNM 40460.

Genus THAERODONTA Wang, 1949, amended Howe, 1972

Thaerodonta clarksvillensis (Foerste)

Plate 2, figures 14–17

Plectambonites rugosa-clarksvillensis Foerste, 1912, p. 127, pl. 1, figs. 7A–C, pl. 10, figs. 7A–D.

Sowerbyella clarksvillensis (Foerste). Cooper, 1944, p. 335, pl. 128, figs. 39–40.

Sowerbyella rugosus clarksvillensis (Foerste). Caster and others, 1961, pl. 7, figs. 25 and 26?.

Thaerodonta clarksvillensis (Foerste). Howe, 1972, pl. 1, figs. 1–3.

Description.—Shell of medium size for the genus; length about sixth-tenths the width; hinge usually forming the greatest width; cardinal extremities acute to obtuse; anterior margin rounded to slightly truncate. Surface unequally multicostellate; occasionally lamellose in anterior part of shell.

Pedicle interior: apex of delthyrial floor filled with callus deposits into which small adductor scars are deeply incised; adjustor-diductor muscle field large, reaching beyond midlength and diverging in front of median septum; adjustors and diductors about equal in size. Teeth small, supported by advancing dental plates. Hinge fossettes large, ranging from four to eight in most specimens, and situated on cardinal flanks.

Brachial interior: cardinalia displaying short brachiophores that end in points; cardinal process strongly elevated. Adductor muscle field marked by two pairs of septa, the outer pair being weaker than the inner ones. Hinge flanks marked by denticles corresponding in position to the ventral fossettes.

Comparison.—This species suggests *S. curdsvillensis* in shape and in size (fig. 1 and table 1), but it differs from the Shermanian form in having dorsal lateral septa and hinge-like denticulations. *Thaerodonta clarksvillensis* is similar to *Sowerbyella rugosa* in many aspects but differs from the Edenian species in having a normally smooth exterior, hinge-line denticulations, and somewhat less width relative to length. Also, posterior wrinkling is not as common or as pronounced as is found in *Sowerbyella rugosa. Thaerodonta clarksvillensis* most closely resembles *T. recedens* (Sardeson) from the Maquoketa Shale of Iowa and Minnesota in size, shape, weakness of accessory teeth in the ventral valve, and weakness of lateral septa in the dorsal muscle field. The Ohio Valley form has fewer and distinctly weaker hinge-line denticulations. The differences may reflect geographic separation of populations of the same species.

TABLE 1.—*Measurements (in millimeters) of length and width of species of* Sowerbyella *and* Thaerodonta

Species	I	II	III	IV
Number (N)	24	26	23	24
Length (L) (mean)	10.6	9.73	6.4	10.53
Observed range, L	8.2–11.7	7.7–12.2	4.3–8.5	8.2–12.2
Width (W) (mean)	18.60	17.58	13.40	16.98
Observed range, W	15.7–22.1	13.6–23.3	10.8–17.6	14.2–20.0

I. *Sowerbyella curdsvillensis* (Foerste), from the Curdsville Limestone Member of the Lexington Limestone, USGS locs. 5101–CO and 7785–CO.
II. *Thaerodonta clarksvillensis* (Foerste), from Richmondian strata at Waynesville, Ohio, USNM 40460.
III. *Sowerbyella* sp., from Point Pleasant Tongue of Clays Ferry Formation, USGS loc. 8068–CO.
IV. *Thaerodonta recedens* (Sardeson), from Maquoketa Shale, near Spring Valley, Minn., USNM collection.

Superfamily RHYNCHONELLACEA Gray
Family RHYNCHOTREMATIDAE Schuchert nom. transl. Cooper
Genus RHYNCHOTREMA Hall,
1860; emended Wang, 1949; Cooper, 1956;
Howe, 1965

Rhynchotrema dentatum (Hall)

Plate 7, figures 21, 22

Atrypa dentata Hall, 1847, p. 148, pl. 33, figs. 14a–c.
Rhynchonella dentata (Hall). Meek, 1873, p. 121, pl. 11, figs. 3a–d.
Rhynchotrema dentatum arnheimensis Foerste, 1909a, p. 227, pl. 4, fig. 12.
Rhynchotrema dentatum arnheimensis Foerste, 1910, p. 27, pl. 3, fig. 13.
Rhynchotrema dentata (Hall). Foerste, 1910, p. 29, pl. 2, fig. 16, pl. 3, fig. 12.
Rhynchotrema dentatum arnheimensis Foerste. Bassler, 1932, pl. 24, figs. 5–8.
Rhynchotrema dentatum (Hall). Cooper, 1944, p. 309, pl. 118, figs. 11–13.
Rhynchotrema dentatum (Hall). Wilson, 1948, pl. 19, figs. 23–25.
Rhynchotrema dentatum (Hall). Wilson, 1949, pl. 19, figs. 23–25.
Rhynchotrema dentatum (Hall). Caster and others, 1961, pl. 5, figs. 19–23.
Rhynchotrema dentatum (Hall). Howe, 1965, pl. 134, figs. 4, 13.
Rhynchotrema dentatum (Hall). Howe, 1969, pl. 155, figs. 1–8; pl. 156, fig. 25.

Remarks.—Three USGS localities (D1248–CO, D1247–CO, and D1246–CO) in the Bull Fork Formation (Richmondian) yielded nine specimens, all of which are partially exposed on bedding surfaces of limestone samples. These specimens conform to the shape and size variation displayed in the large collections of *R. dentatum* from Ohio and Indiana, which are reposited in the U.S. National Museum. They also conform to the large numbers of specimens recovered by Howe (1969) from the "Arnheim" Formation and basal calcarenites of the overlying Fernvale Formation in Tennessee. This species is a common and diagnostic faunal element of Richmondian beds in Ohio and Indiana (Caster and others, 1961).

Figured specimens.—USNM 208689 (pl. 7, fig. 21), from the Bull Fork Formation (Richmondian), USGS loc. D1247–CO; USNM 208690 (pl. 7, fig. 22), from the Bull Fork Formation, USGS loc. D1246–CO.

Rhynchotrema increbescens (Hall)

Plate 3, figures 1–30

Atrypa increbescens Hall, 1847, p. 146, pl. 33, figs. 13c–d (lectotype designated by Wang, 1949, p. 11).
Rhynchonella (Rhynchotrema) increbescens (Hall). Hall, 1860, p. 66.
Trematospira (?) *quadriplicata* Miller, 1875, p. 60, figs. 6, 7.

Rhynchotrema inaequivalve (Castelnau). Foerste, 1909b, p. 314, pl. 7, figs. 10A–C.
Rhynchotrema inaequivalve (Castelnau). Miller, 1913, pl. 6, fig. 3.
Rhynchotrema kentuckiense Fenton and Fenton, 1924, p. 67, pl. 1, figs. 4, 5; 18–22.
Rhynchotrema kentuckiense varians Fenton and Fenton, 1924, p. 68, pl. 1, figs. 1–3.
Rhynchotrema mercerense Fenton and Fenton, 1924, p. 69, pl. 2, figs. 17–21.
Rhynchotrema increbescens (Hall). Bassler, 1932, pl. 18, figs. 7, 8.
Rhynchotrema increbescens (Hall). Cooper, 1944, p. 309, pl. 118, figs. 14–16.
Rhynchotrema kentuckiense Fenton and Fenton. Cooper, 1956, p. 629, pl. 130, A, figs. 1–5.
Rhynchotrema increbescens (Hall). Cooper, 1956, pl. 138, A, figs. 1–5.
Rhynchotrema increbescens (Hall). Wilson, 1949, pl. 9, figs. 5–9.
Rhynchotrema quadriplicata (Miller). Howe, 1965, pl. 134, figs. 3, 11, 12, 14.
Rhynchotrema sp., Howe, 1965, pl. 134, figs. 2, 10.
Rhynchotrema increbescens (Hall). Alberstadt, 1973, p. 51, pl. 7, figs. 6, 7.
Rhynchotrema increbescens (Hall). Schmidt, 1965, fig. 422, 3a–c.

Description.—Shell of average size for the genus; width and length about equal. Lateral profile unequally biconvex, the brachial valve having the greater depth. Outline subtriangular to subelliptical; anterolateral margins rounded in outline; anterior commissure strongly uniplicate with the depth of the sulcus averaging more than one-half of the total thickness of the shell. Surface multicostate, numbering about 14 to 20 costae (table 2), of which 4 occur on the fold and 3 in the sulcus. Surface crossed by closely spaced zig-zag lamellae, which become especially conspicuous near the anterior commissure.

Pedicle valve moderately convex in lateral profile, having the greatest convexity at about the middle. Beak elevated and suberect; umbo swollen, merging anteriorly with a progressively widening sulcus that occupies somewhat more than one-half the width of the valve at the front. Ventral flanks gently inflated. Interior of pedicle valve: delthyrium triangular and open or partially closed by rudimentary deltidial plates; beak occasionally resorbed to form a small apical foramen. Delthyrial floor large, occupied by scar of pedicle attachment. Teeth strong, supported by thin dental plates; umbonal cavities small and commonly reduced by shell thickening. Ventral muscle field large and flabellate in outline in mature specimens, occasionally subquadrate in juveniles; adductor scars small, incised, truncate at the back and tapering anteriorly; diductor scars large, expanding anteriorly to enclose the adductor impressions; adjustor scars situated at lateral margin of field, occasionally attaining the width of the diductors (fig. 3).

Brachial valve strongly convex in lateral profile, the greatest depth occurring at about the middle. Umbo broadly swollen, merging anteriorly with a fold that becomes prominent at the front; flanks inflated. Interior of brachial valve: hinge plates divided, thick, gently concave and supporting short crura; cardinal process bladelike and dividing narrow notothyrial cavity; shaft low to strongly swollen and elevated. Adductor muscle field oval in outline, the posterior and anterior pair about equal in size.

Dimensions.—Growth patterns of length to width, length to thickness, thickness to height of fold, and width to fold width are given in figures 4–7 for comparison with *R. wisconsinense* from the Decorah Formation in Minnesota.

Distribution.—*Rhynchotrema increbescens* is one of the most abundant brachiopods in late Middle Ordovician rocks in Kentucky. USGS samples yield more than 5,000 specimens from the following stratigraphic members (arranged in order of decreasing age): 240 specimens (about 90 percent disarticulated and partially broken) from the Curdsville Limestone Member of the Lexington Limestone; USGS locs. 4123–CO, 4213–CO, 5023–CO, 5080–CO, 5100–CO, 5101–CO, 7782–CO, 7784–CO, and 7785–CO. Approximately 500 specimens (about 65 percent disarticulated and partially broken) from the Grier Limestone Member of the Lexington Limestone; USGS locs. 4072–CO, 4073–CO, 4075–CO, 4852–CO, 4874–CO, 4876–CO, 4879–CO, and 4957–CO. Approximately 4,300 specimens (more than half articulated juveniles) from the upper part of the Grier Limestone and the Perryville Limestone Members of the Lexington Limestone. About 40 articulated specimens from the Brannon Member of the Lexington Limestone and 245 specimens from the Tanglewood Limestone Member of the Lexington Limestone; USGS locs. D1119–CO, D1120–CO, D1121–CO, D1123–CO, 4982–CO, 7790–CO, and 7809–CO.

Discussion.—Considerable confusion has surrounded the genus *Rhynchotrema* Hall. *Rhynchotrema increbescens* (Hall) is the type species, although Hall (1860, p. 68) described the characters of the genus from three specimens now assigned to *Lepidocyclus manniensis* (Foerste). Wang (1949) designated a specimen that was figured by Hall (1847, pl. 33, fig. 13c–d) as lectotype of *R. increbescens*. Through the courtesy of Norman D. Newell, I was able to examine the type lot, which is

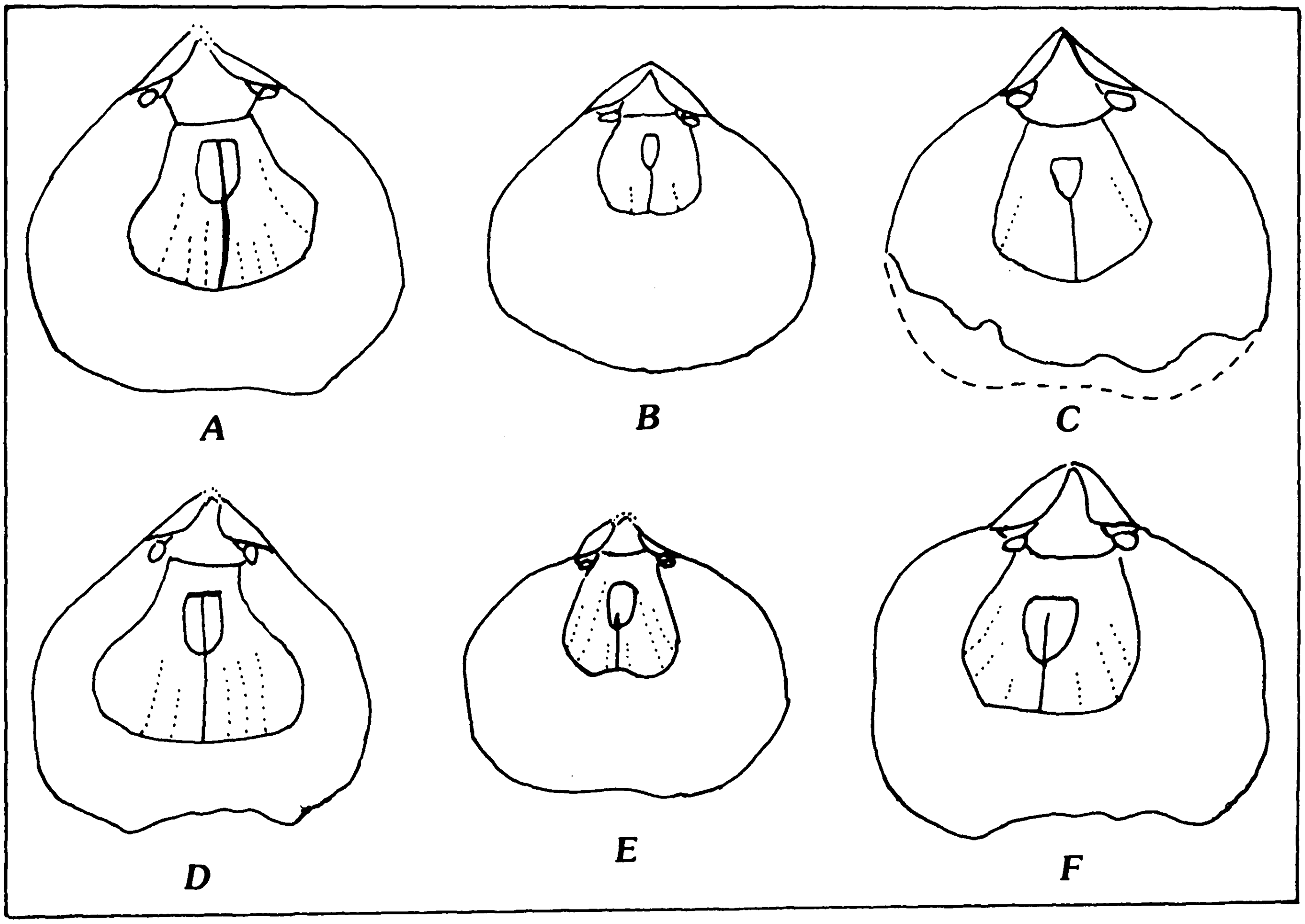

FIGURE 3.—Interior views of *Rhynchotrema increbescens* (Hall) showing variations in pedicle musculature, × 4, USNM 208635A–F, respectively, from the Perryville Limestone Member of the Lexington Limestone, USGS loc. 5015–CO.

reposited in the American Museau of Natural History. A total of seven specimens are in the type collection (instead of four as reported by Cooper, 1956). Except for one specimen, which may be a different species, the Hall specimens conform to the size and shape exhibited by the Lexington members; thus, they appear to be conspecific (figs. 4 and 5).

Comparison.—*R. increbescens* is similar to *R. wisconsinense* Fenton and Fenton in size, and only slight differences in shape are noted. *R. increbescens* is somewhat narrower and not as thick relative to length, and it has a somewhat larger fold and sulcus (figs. 4–7). Surface ornamentation is the major difference between the two species. *R. wisconsinense* is more costate (table 2), and its surface lamellae are much more conspicuous.

TABLE 2.—*Number of costae (brachial valve) in species of* Rhynchotrema

[μ—range of means; C.L.—confidence level]

Species	I	II
Number (N)	28	45
Mean	17.37	21.09
Observed range	14–20	17–24
Standard deviation	1.486	1.743
μ (95 percent C.L.)	16.9–17.86	20.65–21.53
μ (99 percent C.L.)	16.69–18.07	20.46–21.72

I. *Rhynchotrema increbescens* (Hall) from the Salvisa Bed of the Perryville Limestone Member of the Lexington Limestone, USGS loc. 5015–CO.
II. *R. wisconsinense* Fenton and Fenton, from the Ion Dolomite Member of the Decorah Formation, roadcut exposure, 1¼ mi east of U.S. Highway 52, south edge of Cannon Falls, Minn., USNM 179571, collected by O. C. Cole.

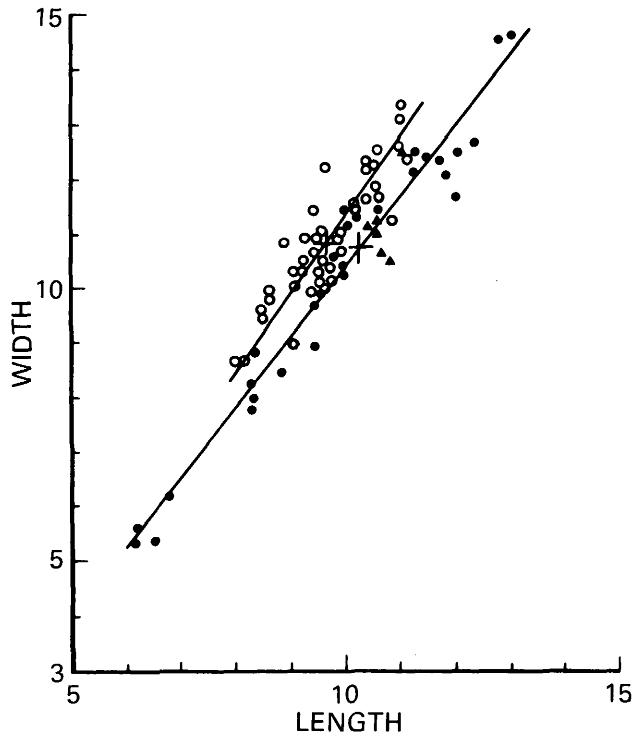

FIGURE 4.—Scatter diagram and reduced major axes of length-width in millimeters of *Rhynchotrema increbescens* (solid circles) from the Perryville Limestone Member of the Lexington Limestone, USGS loc. 5015–CO; *R. wisconsinense* Fenton and Fenton (open circles) from the Ion Dolomite Member of the Decorah Formation, county road exposure, 1¼ mi east of U.S. Highway 52, south edge of Cannon Falls, Minn., USNM 179571, collected by O. C. Cole. *R. increbescens* from Trenton Group, Middleville, N. Y. (type lot AMNH 707/1 shown in solid triangles). + marks means of dimensions.

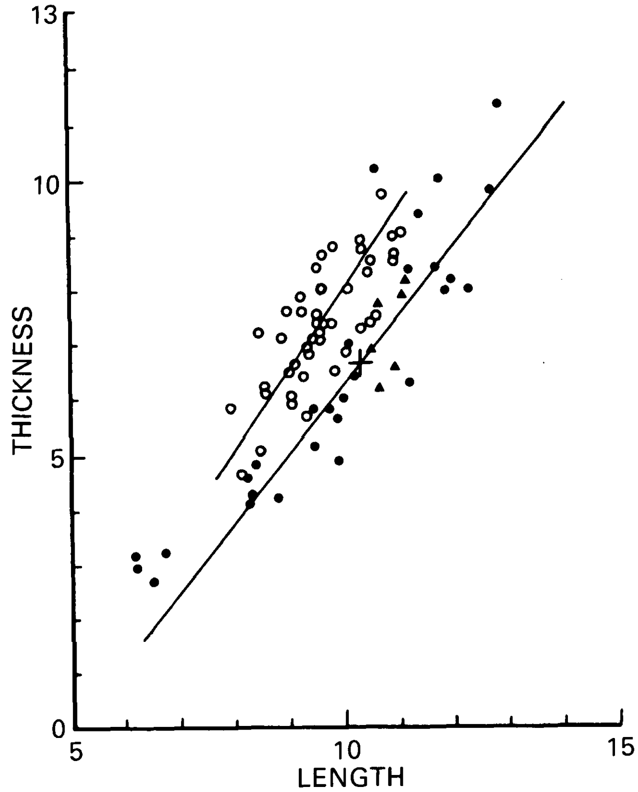

FIGURE 5.—Scatter diagram and reduced major axes of length-thickness in millimeters of *Rhynchotrema increbescens* (solid circles) from the Perryville Limestone Member of the Lexington Limestone, USGS loc. 5015–CO; *R. wisconsinense* Fenton and Fenton (open circles) from the Ion Dolomite Member of the Decorah Formation, county road exposure, 1¼ mi east of U.S. Highway 52, south edge of Cannon Falls, Minn. Collected by O. C. Cole. *R. increbescens* from Trenton Group, Middleville, N.Y. (type lot AMNH 707/1 shown in solid triangles). + marks means of dimensions.

Genus ROSTRICELLULA Ulrich and Cooper, 1942
Rostricellula minuta Cooper, 1956

Plate 7, figures 9–12

Rostricellula ? minuta Cooper, 1956, Cooper, p. 640, pl. 137, A, figs. 1–6.

Remarks.—This species, which Cooper tentatively assigned to the genus *Rostricellula,* is found only sparingly in the Logana Member of the Lexington Limestone. The USGS collections include six dorsal valves from loc. D1196–CO and a small complete specimen from loc. 5073–CO. They show a more triangular outline than the types of the species from the Hermitage Formation in Tennessee, but the small size, high fold, and deep sulcus marked by a single costa are diagnostic features. The fold is strongly elevated at the front and bears two strong, angular costae. The flanks display seven to nine costae. The nonimbricate ornamentation and absence of a cardinal process indicate relationship to *Rostricellula.*

Figured specimens.—USNM 208691 (pl. 7, fig. 9), from 0.5 ft from the top of the Logana Member of the Lexington Limestone, USGS loc. D1196–CO length 6.8 mm, width 7.2 mm, USNM 208692 (pl. 7, figs. 10–12), from the upper part of the Logana Member of the Lexington Limestone, USGS loc. 5073–CO; length 5.1 mm, width 5.1 mm.

Family LEPIDOCYCLIDAE Cooper
Genus LEPIDOCYCLUS Wang, 1949; emended Howe, 1965
Lepidocyclus? capax (Conrad)

Plate 4, figures 1–10

Atrypa capax Conrad, 1842, p. 264, pl. 14, fig. 21.

Atrypa increbescens Hall, 1847, p. 146, pl. 33, figs. 13t–y.

Rhynchonella capax (Conrad). Meek, 1873, p. 123, pl. 11, figs. 2a–f.

Rhynchonella perlamellosa Whitfield, 1882, Whitfield, p. 265, pl. 12, figs. 23–25.

Rhynchotrema capax (Conrad). Hall and Clarke, 1894a, p. 825, pl. 42, figs. 11, 12, 16 (not figs. 13, 14, 15).

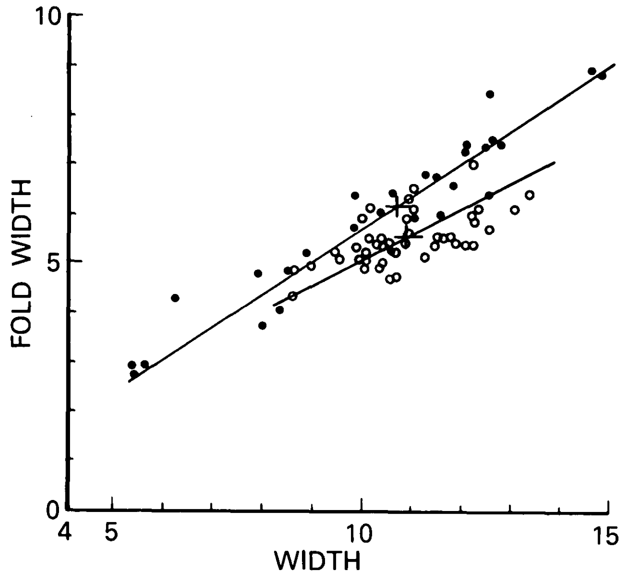

FIGURE 6.—Scatter diagram and reduced major axes of width-fold width in millimeters of *Rhynchotrema increbescens* (solid circles) from the Perryville Limestone Member of the Lexington Limestone, USGS loc. 5015–CO and *R. wisconsinense* Fenton and Fenton (open circles) from the Ion Dolomite Member of the Decorah Formation, exposure on county road, 1¼ mi east of U.S. Highway 52, south edge of Cannon Falls, Minn.; USNM 179571, collected by O. C. Cole. + marks means of dimensions.

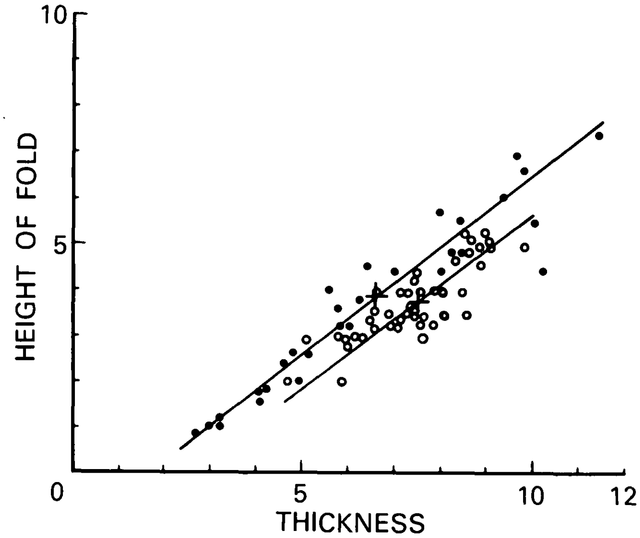

FIGURE 7.—Scatter diagram and reduced major axes of thickness-height of fold in millimeters of *Rhynchotrema increbescens* (solid circles) from the Perryville Limestone Member of the Lexington Limestone, USGS loc. 5015–CO and *R. wisconsinense* Fenton and Fenton (open circles) from the Ion Dolomite Member of the Decorah Formation, exposure on county road, 1¼ mi east of U.S. Highway 52, south edge of Cannon Falls, Minn.; USNM 179571, collected by O. C. Cole. + marks means of dimensions.

Rhynchotrema capax (Conrad). Hall and Clarke, 1894b, p. 183, pl. 56, figs. 14, 15, 22, 23 (not figs. 16, 17, 18, 20, 21).

Rhynchotrema capax (Conrad). Winchell and Schuchert, 1895, p. 462, pl. 34, figs. 30–33.

Rhynchotrema capax (Conrad). Cooper, 1944, p. 309, pl. 118, figs. 7–10.

Rhynchotrema capax (Conrad). Caster and others, 1961, pl. 5, figs. 7–10.

Rhynchotrema perlamellosum (Whitfield). Cooper, 1944, p. 309, pl. 118, figs. 29–30.

Lepidocyclus perlamellosus (Whitfield). Wang, 1949, p. 14, pl. 6A, figs. 1–5.

Lepidocyclus? capax (Conrad). Howe, 1965, pl. 134, figs. 15, 16, 20; 1966, p. 263, pl. 31, figs. 15–20; 1967b, p. 850, pl. 104, figs. 1–5, 11–14, 23; pl. 105, fig. 10; 1969, p. 1341, pl. 156, figs. 1–14.

Lepidocyclus? sp. Howe, 1965, pl. 134, fig. 20.

Lepidocyclus capax (Conrad). Alberstadt, 1973, p. 53, pl. 6, figs. 1–3.

Remarks.—This species is one of the most widespread and diagnostic brachiopods in Upper Ordovician rocks of North America. It is particularly common in Richmondian rocks of the Ohio Valley and in correlative strata in Texas, Oklahoma, Missouri, and Tennessee. It is less common in the Maquoketa Shale of Iowa and the Ely Springs Dolomite of Nevada. A larger form, identified as *L. gigas* by Macomber (1970), from the Bighorn Dolomite in Wyoming appears to differ from *L. capax* only in its much larger size. Specimens from the "Arnheim" Formation of Tennessee are smaller than those in the Ohio Valley and they average nearly three more costae per valve. The Oklahoma representatives of the species are larger and slightly less costate than the norm for the Ohio Valley. These differences probably reflect the geographic separation of the populations.

Rhynchotrema increbescens suggests *L. capax* in many aspects, and it is probably directly ancestral to the Late Ordovician species. Internally, both forms display a flabellate muscle field in the ventral valve, a delthyrium which is open or only partially closed by rudimentary deltidial plates, and a large delthyrial cavity which is wholly occupied by the scar of the pedicle attachment. Moreover, occasional specimens of *L. capax* exhibit *Rhynchotrema*-like dental plates that are not completely obscured by shell thickening. Externally, the two forms are very similar except for the smaller size of *R. increbescens* and its moderately elevated ventral beak. *L. capax* occupies a position that is intermediate between *Lepidocyclus* and *Rhynchotrema* because of its open delthyrium and large pedicle callist.

Material.—Three USGS localities (D1259–CO, D1260–CO, and D1263–CO) in the Bull Fork Formation yielded 11 specimens. An additional 74 specimens were recovered from six localities in the Dillsboro Formation of Indiana—6139–CO, 6140–CO, 6141–CO, 4573–CO, 4574–CO, and 4575–CO.

Figured specimens.—USNM 208649, from Bull Fork Formation, USGS loc. D1259–CO; USNM 208650–53, from Dillsboro Formation, USGS loc. 6139–CO; and USNM 208654 and 208655, from Richmondian roadcut, U.S. Highway 50, 3.1 mi east of Versailles, Ind.

Family ORTHORHYNCHULIDAE Cooper
Genus ORTHORHYNCHULA Hall and Clarke, 1893
Orthorhynchula linneyi (James), 1881

Plate 4, figures 11–18; plate 5, figure 7; plate 6, figures 1–15; plate 7, figures 1–4.

Orthis? linneyi James, 1881, p. 41.
Orthis linneyi James. Nettleroth, 1889, p. 41, pl. 34, figs. 7–13.
Orthorhynchula linneyi (James). Hall and Clarke, 1894a, p. 181, pl. 56, figs. 10–13.
Orthorhynchula linneyi (James). Foerste, 1910, p. 24, pl. 3, fig. 10.
Orthorhynchula linneyi (James). Schuchert and Cooper, 1932, pl. 16, figs. 12, 17, 28–30.
Orthorhynchula linneyi (James). Cooper, 1944, p. 309, pl. 117, figs. 41–47; (1956) pl. 128, F, figs. 32–36.
Orthorhynchula linneyi (James). Wilson, 1949, pl. 18, figs. 6–9.
Orthorhynchula linneyi (James). Caster and others, 1961, pl. 3, figs. 32, 33.
Orthorhynchula linneyi (James). Schmidt, 1965, fig. 425, 3a–c.

Description.—Shell subtriangular to occasionally subelliptical in outline; apical angle slightly more than 90°; sides broadly rounded; valves subequal in depth, the brachial valve deeper and showing greatest width at the middle; width somewhat exceeding length; hinge line short, averaging somewhat less than half of the shell width. Surface costate, ornamented with 3 costae in sulcus, 4 on the fold, and 7 to 13 on the flanks.

Pedicle valve gently to moderately convex in in lateral profile, displaying the greatest convexity between the umbo and the middle of the valve. Umbo swollen with moderately steep sides; flanks gently inflated. Sulcus originating in front of umbo and forming a mesial depression that increases in width to about one-half the shell width at the front. Interarea of pedicle valve short but well defined, averaging somewhat less than one-half the shell width; delthyrium large, open, with small apical foramen usually present through beak resorption.

Brachial valve moderately to strongly convex in lateral profile, displaying the greatest curvature in the posterior half. Umbo inflated, merging anteriorly with a fold which bears four costae, the lateral pair of which are weaker and lower than the median costae; fold becoming moderately elevated at the front and occupying about one-half the valve width. Flanks moderately convex. Dorsal interarea smaller than the ventral one and varying from about four-tenths to one-half the valve width.

Interior: Teeth large, supported by short dental plates that may become obscured by adventitious deposits in gerontic forms. Ventral muscle field typically quadrate in outline and occupying from one-third to one-half the valve length; adductor impressions gently forming a linear track in the anterior one-half to two-thirds of the muscle field; diductor scars moderately impressed, elongate; adjustor scars commonly indistinguishable from diductors; when defined, adjustors occupy the sides of the muscle field and are shorter than the diductors. Dorsal muscle field extending to about the middle of the valve and divided medially by a low ridge extending from the notothryial platform; adductor scars unequal in size, the posterior pair the larger. Dorsal hinge plates deeply concave and bordered by long crura, which are extended anteriorly. Cardinal process directed posteriorly, supported by main shaft, which is most commonly bilobid on the myophore; accessory ridges commonly produce a multilobate form to the myophore. Diductor impressions extending from the posterior face of the myophore and along the sides of the cardinal shaft.

Dimensions.—Growth patterns of length to width, length to thickness, thickness to height of fold, and width to fold width are given in figures 9–12 for comparison with *Orthorhynchula sublinneyi* from the Devils Hollow Member of the Lexington Limestone.

Distribution.—*Orthorhynchula linneyi* is one of the most common brachiopods found in the Calloway Creek Limestone (Maysvillian) of Kentucky. The Calloway Creek material at hand consists of approximately 1,250 specimens from USGS locs. 6409–CO and 6413–CO. Nearly all of the specimens are disarticulated and partially to extensively fragmented. The overlying Ashlock Formation yielded only three pedicle valves from USGS loc. 6411–CO.

Comparison.—The Maysvillian species is very similar to its ancestral form, *O. sublinneyi* n. sp., in size and in growth patterns of length to width, length to thickness, thickness to height of fold, and width to fold width (figs. 9–12). The scattergrams suggest that *O. linneyi* is somewhat narrower in outline, more globose in lateral profile, and slightly narrower in its fold. Because the differences are small and sample preservation precluded normally

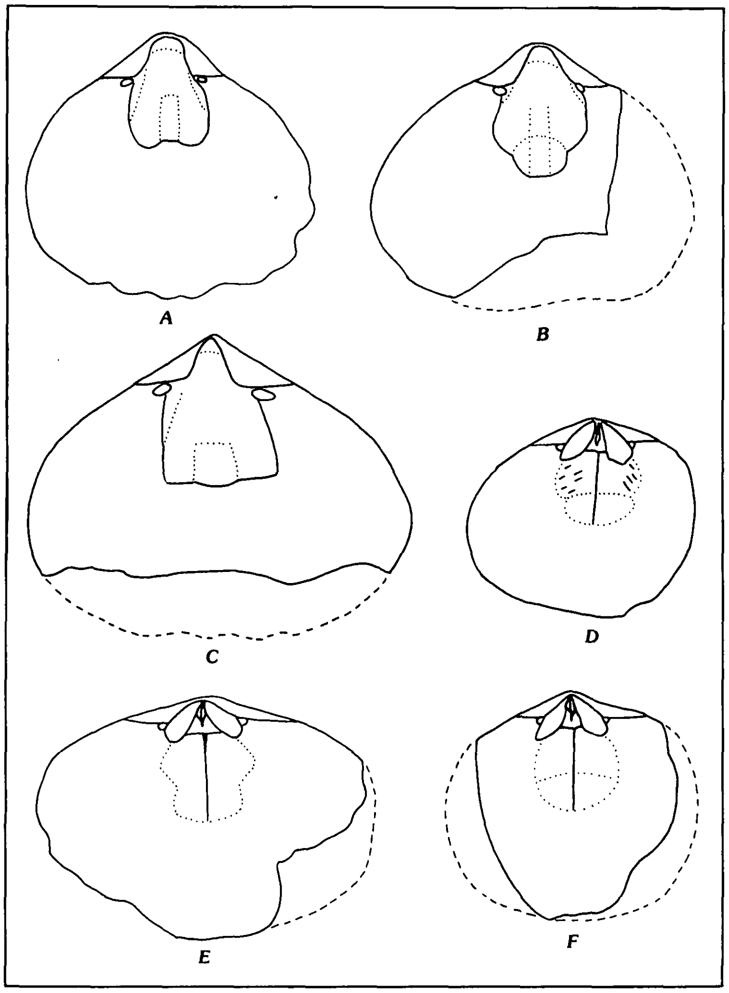

FIGURE 8.—Interior views of *Orthorhynchula linneyi* showing variations in musculature, × 2; *A*, *B*, *C*, pedicle valves, USNM 208663, 208664, and 208696; *D*, *E*, *F*, brachial valves, USNM 208700, 208704, and 208703. From the Calloway Creek Limestone (Maysvillian), USGS loc. 6409–CO.

distributed data for all of the parameters, it is not clear whether these differences are significant. *O. linneyi* is significantly less costate than *O. sublinneyi* (averaging only 22 costae compared to 28 in the latter, table 3), and it has a more consistently subtriangular outline instead of the common subelliptical form of the Lexington Limestone species. The fold is characterized by four costae, whereas in *O. sublinneyi* fold costation is much more variable, ranging from three to as many as eight costae. Only rare specimens of *O. linneyi* show three costae and none in the collections have more than four. In about four-fifths of the specimens examined the lateral costae on the fold are distinctly less elevated than the central pair. A similar pattern occurs in the majority of *O. sublinneyi* bearing four costae on the fold.

Discussion.—This species was first described by James (1881) from specimens collected by W. M. Linney from the "upper part of the Cincinnati Group" in Boyle County, Ky. Although James did not include any illustrations or precise stratigraphic and geographic data, his description conforms to the Maysvillian form, *O. linneyi,* rather than to forms from the Lexington Limestone previously noted in the literature as *O. linneyi* but described herein as *O. sublinneyi.* James' description is as follows:

Shell sub-oval in outline, breadth and length about as 4 to 3; cardinal line less than half the broadest part of the shell; regularly and evenly rounded margin from the terminations of the cardinal line to the front; cardinal area short and confined to the ventral valve. Umbone of the ventral valve prominent, shell curving sharply to the beak which projects beyond that of the other valve and is incurved; a mesial sinus commencing near the beak, narrow and shallow at

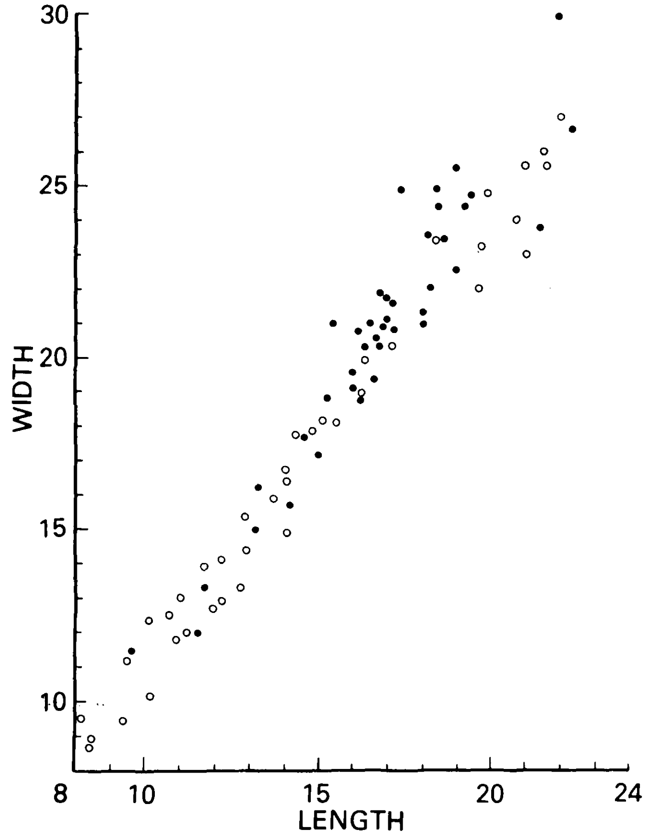

FIGURE 9.—Scatter diagram of length-width in millimeters of *Orthorhynchula linneyi* (open circles) from the Calloway Creek Limestone, USGS loc. 6409–CO and *O. sublinneyi* Howe n. sp. (solid circles) from the Devils Hollow Member of the Lexington Limestone, USGS locs. 5036–CO and 5095–CO.

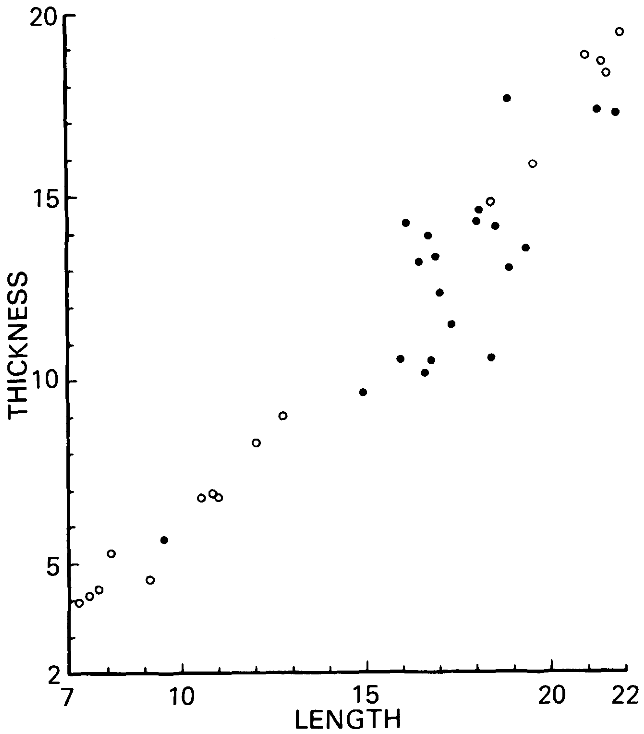

FIGURE 10.—Scatter diagram of length-thickness in millimeters of *Orthorhynchula linneyi* (open circles) from the Calloway Creek Limestone, USGS loc. 6409–CO; and *O. sublinneyi* Howe (solid circles) from the Devils Hollow Member of the Lexington Limestone, USGS locs. 5036–CO and 5095–CO.

first, but widening and deeping to the front margin; deltidium triagonal, and rather broad. Beak of the dorsal valve projecting very little, if any, beyond the cardinal line, and but slightly incurved; a mesial elevation commencing rather low at the umbone, but becoming prominent near and at the front; front margin quite sinuous, caused by the mesial sinus of the ventral valve, and the prominent mesial sinus on the dorsal valve. Each valve covered by about 23 rather coarse, simple plications, three of which are in the sinus, and the same number on the mesial elevation.

Nettleroth (1889, pl. 34, figs. 7–13) illustrated additional specimens of *O. linneyi,* which were collected by W. M. Linney from "shales of the Hudson River or Cincinnati Group, near Danville, Kentucky." His figures show the less costate Maysvillian species rather than the earlier form, *O. sublinneyi,* from the Lexington Limestone.

Members of *Orthorhynchula* are characterized by long crura, strongly concave hinge plates in the dorsal valve, an orthoid-like cardinal process, a ventral quadrate muscle field, and a small but well-defined pedicle interarea. Schuchert and Cooper (1932, p. 226) transferred *Porambonites ottawaensis* Billings, a Trentonian species from Ontario, to *Orthorhynchula* because it possessed an interarea on the pedicle valve and a divided hinge plate with concave crural supports. Later, Cooper (1956, p. 627) reassessed the types of *P. ottawaensis* and compared additional material with the interiors of *O. linneyi.* He concluded that the two forms have

TABLE 3.—*Number of costae (brachial valve) in species of* Orthorhynchula

[μ—range of means; C.L.—confidence level]

Species	I	II
Number (N)	20	20
Mean	22.80	28.25
Observed range	19–31	23–38
Standard deviation	2.75	3.36
μ (95 percent C.L.)	21.52–24.08	26.68–29.82
μ (99 percent C.L.)	19.94–25.66	26.10–30.40

I. *Orthorhynchula linneyi* (James), from upper 5 ft of Calloway Creek Limestone (Maysvillian), USGS loc. 6409–CO.
II. *O. sublinneyi* Howe, n. sp., from the Devils Hollow Member of the Lexington Limestone, USGS locs. 5036–CO and 5095–CO.

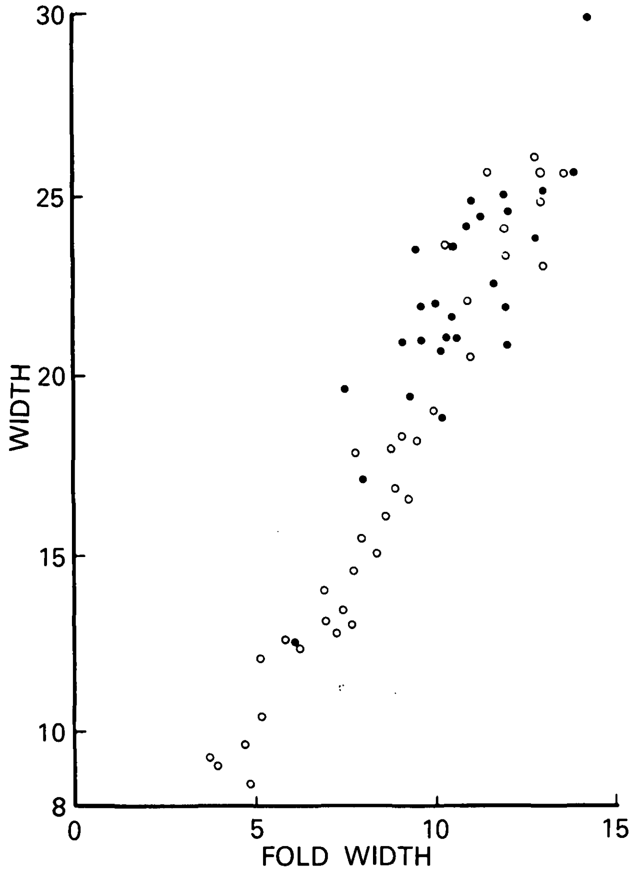

FIGURE 11.—Scatter diagram of width-fold width in millimeters of *Orthorhynchula linneyi* (open circles) from the Calloway Creek Limestone, USGS loc. 6409–CO; and *O. sublinneyi* (solid circles) from the Devils Hollow Member of the Lexington Limestone, USGS locs. 5036–CO and 5095–CO.

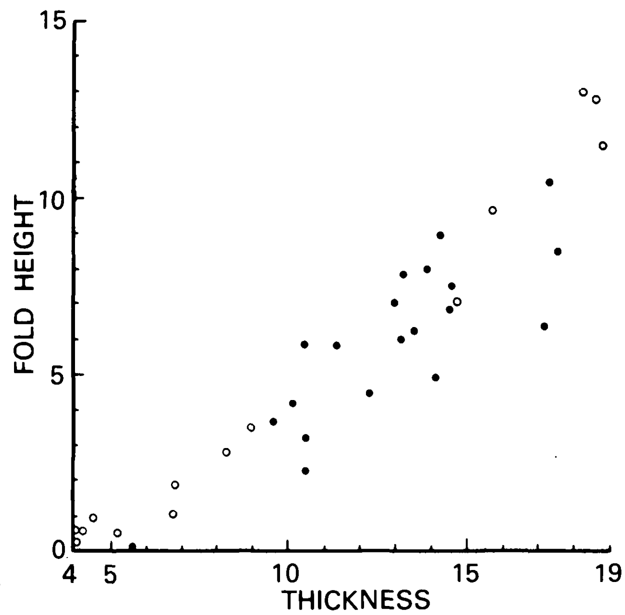

FIGURE 12.—Scatter diagram of thickness-height in millimeters of fold of *Orthorhynchula linneyi* (open circles) from the Calloway Creek Limestone, USGS loc. 6409–CO; and *O. sublinneyi* (solid circles) from the Devils Hollow Member of the Lexington Limestone, USGS locs. 5036–CO and 5095–CO.

little in common except for their interareas and, as a consequence, he established a new genus, *Drepanorhyncha,* based on the Billings species. According to Cooper, the concave hinge plates of *Drepanorhyncha* lie obliquely facing one another rather than directly outward as in *Orthorhynchula.* Additionally, he attributed generic significance to the long dental plates and absence of a cardinal process in his genus. Further study is needed to determine the ventral muscle pattern in *Drepanorhyncha.* In *O. linneyi,* the type species of *Orthorhynchula,* the diductors show variations in outline ranging from the typical quadrate pattern with angular corners to lobate forms with rounded margins. (Contrast *C* with *A* and *B* in fig. 8.)

Orthorhynchula sublinneyi Howe, n. sp.

Plate 4, figures 19–31; plate 5, figures 1–6, 8–15

Description.—Large, transversely subelliptical to subtriangular in outline; posterolateral margins widely divergent, lateral margins rounded, front margin nearly straight. Lateral profile unequally biconvex, the brachial valve being deeper. Surface multicostate, from 19 to 38 costae; sulcus and fold commonly bearing 3 and 4 costae, respectively, but variations include 2 to 6 in the sulcus and 3 to 8 on the fold.

Pedicle valve broadly convex in lateral profile; sulcus originating at the umbo, and increasing in width and depth anteriorly, where it attains nearly one-half the valve width at the front. Flanks of ventral valve gently swollen. Pedicle interarea apsacline and curved in lateral profile; short but well defined, and varying from four-tenths to about one-half the shell width. Interior of pedicle valve: delthryium large, triangular, open; beak occasionally resorbed, forming an apical foramen; delthryial cavity deep; teeth stout, supported by short, receding dental plates; umbonal cavities small, shallow, and commonly obscured by adventitious deposits in adult specimens. Muscle field quadrate in outline, occasionally lobate (fig. 13), and occupying one-third to one-half the length of the valve; adductor scars small, forming a linear track in the front half of the muscle field; adjustors small, typically shorter than the diductors, but occasionally reaching the front margin; diductor scars large, elongate, forming angular to rounded anterolateral margins.

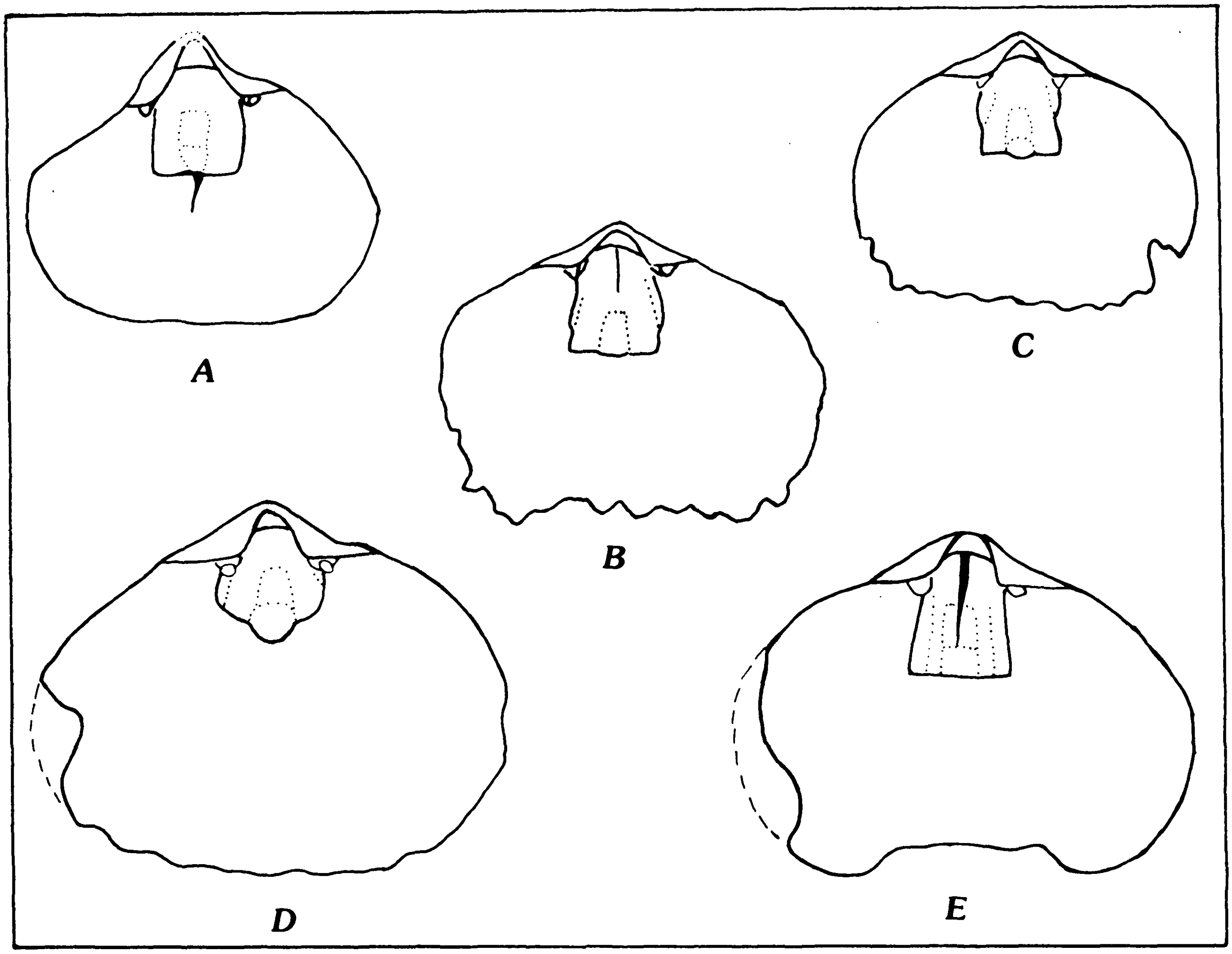

FIGURE 13.—Interior views of *Orthorhynchula sublinneyi* showing variations in ventral musculature. *A*, × 4, USNM 208684, from USGS loc. 6916–CO; *B–E*, USNM 208683, 208680, 208682, 208681, respectively, from USGS loc. 5036–CO. Solid outline is the muscle field; stippled outline is the actual muscle scars.

Brachial valve moderately convex in lateral profile; flanks broadly inflated; fold originating at the umbo and occupying nearly one-half the shell width at the anterior commissure. Dorsal interarea smaller than the ventral one, poorly defined in some specimens. Interior of brachial valve: cardinal process bladelike and serrated posteriorly on the myophore, shaft low to strongly elevated and thickened, commonly becoming bilobid or even trilobid posteriorly; accessory ridges to the main shaft effecting a multilobate appearance to the myophore when present. Hinge plates strongly concave, bearing long crura that taper to points at the ends. Dorsal muscle field ovate in outline, separated mesially by a well-defined septum; anterior scars much smaller than posterior pair.

Dimensions.—Growth patterns of length to width, length to thickness, thickness to height of fold, and width to fold width are given in figures 9–12 for comparison with *O. linneyi,* its descendent species, from the Calloway Creek Limestone (Maysvillian).

Distribution.—*O. sublinneyi* is an important brachiopod of the Perryville Limestone, Devils Hollow, and Millersburg Members of the Lexington Limestone. The Perryville collection consists of approximately 450 specimens, mostly disarticulated and partially broken, from USGS locs. 6915–CO and 6916–CO. The Devils Hollow material contains more than a thousand specimens recovered from USGS locs. 5036–CO, 5087–CO, 5095–CO, and 7789–CO. Nearly all of these specimens are disarticulated and are partially to extensively broken. Three Millersburg specimens were collected from USGS loc. 7051–CO.

Types.—Holotype, USNM 208667 (pl. 4, figs. 24–26), from the Devils Hollow Member of the Lexington Limestone, USGS loc. 5095–CO; length 20.7 mm; width 25.0 mm; and thickness 16.8 mm. Paratype, USNM 208668 (pl. 4, figs. 28–30), from USGS loc. 5095–CO; length 22.0 mm; width 30.0 mm; and thickness 16.7 mm. Paratype, USNM 208666 (pl. 4, figs. 21–23), from USGS loc. 5095–CO; length 15.0 mm; width 17.3 mm; and thickness 9.5 mm. Paratype, USNM 208665 (pl. 4, figs. 19, 20), from USGS loc. 5095–CO; length 10.0 mm; width 11.7 mm; and thickness 5.5 mm.

Discussion.—Foerste (1910) extended the range of *O. linneyi* to include forms that he observed in the "Cynthiana Formation" of Kentucky. However, these older specimens now assignable to the Perryville Limestone, Devils Hollow, and Millersburg Members of the Lexington Limestone show greater variation in shell outline, ranging from a predominantly transversely subelliptical outline to subtriangular. *O. linneyi* displays a more consistent subtriangular shape. Also, *O. sublinneyi* is significantly more costate (table 3), and costate ornamentation on the fold and sulcus is more variable, varying from three to as many as eight on the fold and two to six in the sulcus.

The ventral muscle field is characterized by elongate diductors that typically form an angular outline in front of the adjustor scars (fig. 13). Variants display rounded anterolateral margins that are sometimes shorter than the front margin of the adductor track. Two adductor scars can be differentiated in some specimens—a longer rectangular impression situated posteriorly and a smaller, oval, rectangular, or chordate scar in front. The adjustor scars are typically shorter than the diductor scars, but gradations to the same length are noted in occasional specimens. (Contrast fig. 13, *C* and *E*.) In the dorsal muscle field the anterior adductor pair are much smaller than the posterior scars (fig. 14).

The cardinal process of *O. sublinneyi* is especially variable, ranging from a low nearly indistinct ridge to one that is strongly elevated and thickened until it nearly fills the notothryial cavity between the hinge plates. (Contrast figs. 8 and 9 of pl. 5.) The myophore varies from a flattened and serrated shelf to a bilobid structure characterized by a deep fissure along the shaft. Occasionally, the shaft protrudes upward as a thin partition dividing the myophore surface into two parts.

Superfamily SYNTROPHIACEA Schuchert and Cooper
Family CAMERELLIDAE Hall and Clarke
Genus CAMERELLA Billings, 1859

Camerella bella Fenton

Plate 7, figures 23–28

Camerella bella Fenton, 1928, p. 136, pl. 3, figs. 1–12.
Camerella bella Fenton. Cooper, 1956, p. 563, pl. 112, C, figs. 8–15.

Remarks.—Approximately 150 disarticulated valves, nearly all of which are partially to extensively broken, were recovered from the Camp Nelson Limestone (USGS loc. 7836–CO). The coarsely silicified specimens show costation that is limited to the anterior half of the valves, a well-defined dorsal fold and corresponding ventral sulcus, and flanks marked by four coarse costae. The fold originates between the umbo and the middle of the valve and becomes moderately elevated at the front margin. The valves are unequally convex in lateral profile. The brachial valve has the greater depth. Internal features include a small cruralium that is narrow and supported by a short septum, and a large spondylium that is supported by a septum reaching to midlength or beyond. Overall, these features conform most closely to *C. bella* Fenton, a species having fairly large size for the genus and partial plicate surface ornamentation.

Distribution.—Cooper (1956, p. 564) recorded and described this species from the Plattin Group (Macy Formation) in Missouri and the Carters Limestone in Tennessee.

Figured specimens.—USNM 208692 (pl. 7, figs. 23, 28), from the Camp Nelson Formation, USGS loc. 7836–CO; USNM 208693 (pl. 7, figs. 24, 27), from USGS loc. 7836–CO; and USNM 208694 (pl. 7, figs. 25, 26) from USGS loc. 7836–CO.

Camerella sp. aff. C. immatura Cooper

Plate 7, figures 17–20

Camerella immatura Cooper, 1956, p. 570, pl. 110, A, figs. 1–5.

Remarks.—Two localities in the Curdsville Limestone Member of the Lexington Limestone (USGS 7782–CO and 7784–CO) yielded 11 poorly preserved specimens for study. Their small size, noncostate exterior, and outline suggest the holotype of *C. immatura* Cooper from the Chatham Hill Formation of Cooper (1956) in Virginia. Cooper's holotype is somewhat different in that it shows a shallow fold and sulcus anteriorly and a narrowly uniplicate anterior commissure. The noncostate ornamentation and small size of the Kentucky specimens also suggest

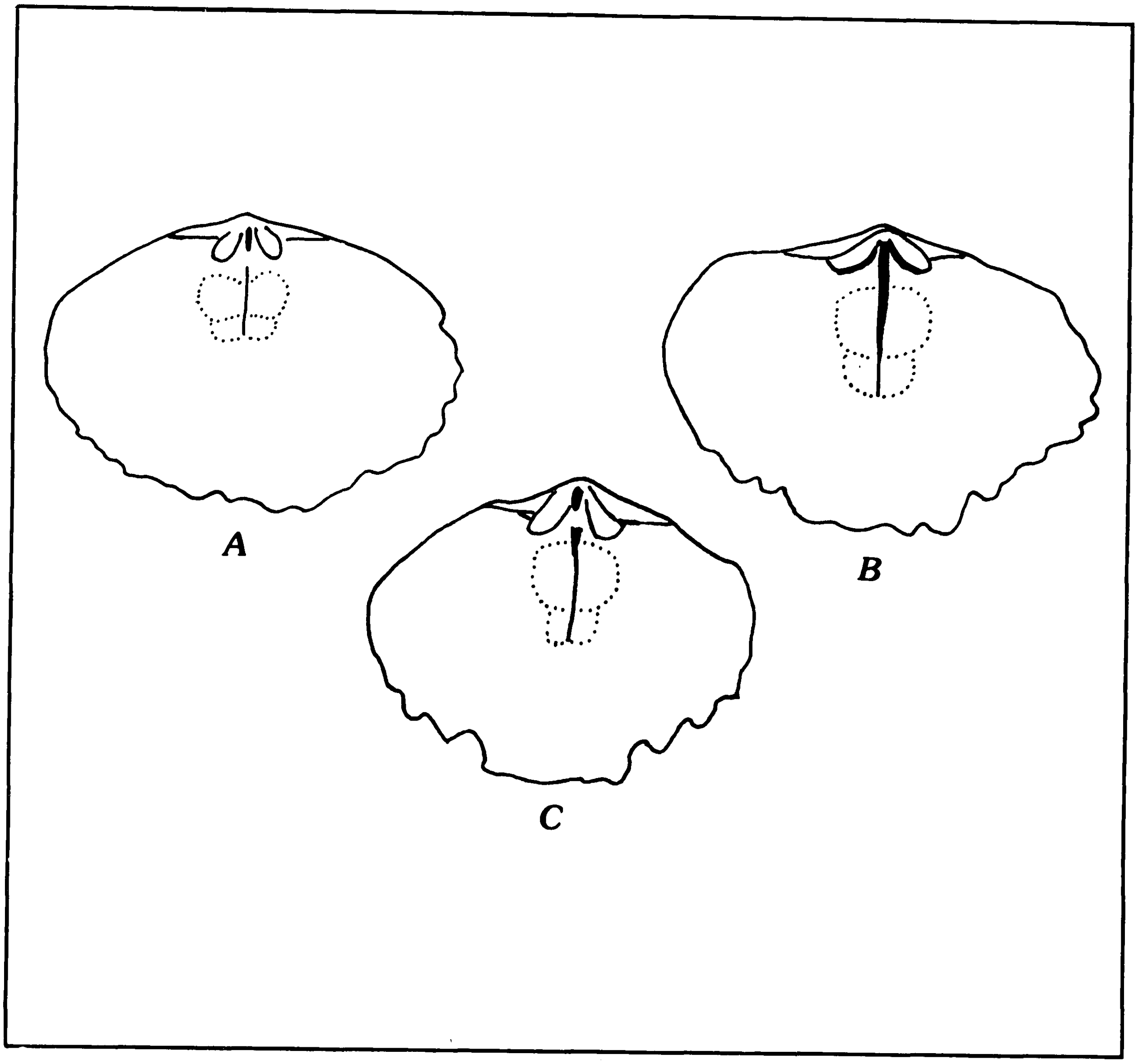

FIGURE 14.—Interior views of *Orthorhynchula sublinneyi* showing variations in dorsal musculature. *A*, USNM 208678A, × 4; *B*, USNM 208678B, × 3; *C*, USNM 208678C, × 3; All from the Devils Hollow Member of the Lexington Limestone, USGS loc. 5036–CO. Stippled outline is the actual muscle scars.

C. nuda Cooper, but a low fold and shallow sulcus in that species produces a moderately long uniplication along the anterior commissure; two or three faint costae are developed on its flanks and three in the sulcus.

Figured specimens.—USNM 208697 (pl. 7, figs. 17–20), from the lower part of the Curdsville Limestone Member of the Lexington Limestone, USGS loc. 7784–CO.

Superfamily TRIMERELLACEA Schuchert
Genus ELLIPTOGLOSSA Cooper, 1956

Elliptoglossa? sp.

Plate 7, figures 5–8

Remarks.—Two USGS localities (D1200–CO and 7805–CO) from the Tanglewood Limestone Member of the Lexington Limestone yielded several fragments of an inarticulate brachiopod. According to G. A. Cooper (written commun., 1974) the inarticulate appears to be his genus *Elliptoglossa*. The surface ornamentation and shape suggest species of that genus, but the assignment is only tentative because the muscle scar patterns are different. It does not have the muscle platforms of *Lingulops* but otherwise the interiors are similar.

Figured specimens.—USNM 208686 (pl. 7, figs. 5, 7) from the Tanglewood Limestone Member of the Lexington Limestone, USGS loc. D1200-CO and USNM 208687 and 208688 (pl. 7, figs. 6, 8), two interior views, from the Lexington Limestone, USGS loc. 7805-CO.

Superfamily ATRYPACEA Schuchert
Family ATRYPIDAE Gill
Genus ZYGOSPIRA Hall, 1862

Zygospira? sp.

Plate 7, figures 13–16

Remarks.—A single well-preserved specimen of *Zygospira?* sp. was found in a Lexington Limestone collection from USGS locality 5015-CO. Its small size, biconvex profile, costation, and rostrate pedicle beak are suggestive of the genus *Zygospira*, but its outline and shape cannot be compared with any known species of that genus.

The flanks of both valves are moderately inflated. The outline is subovate with the length being greater than the width. The valves are moderately biconvex in lateral profile displaying the maximum depth at midlength. Surface ornamentation consists of 13 costae on both ventral and dorsal valves.

Figured specimen.—USNM 208685 (pl. 7, figs. 13–16), from the Perryville Limestone Member of the Lexington Limestone, USGS loc. 5015-CO; length 5.0 mm, width 6.4 mm, and thickness 4.7 mm.

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PLATES 1-7

Contact photographs of the plates in this report are available, at cost, from U.S. Geological Survey Library, Federal Center, Denver, Colorado 80225

PLATE 1

[All figures × 3 except fig. 20, × 4]

FIGURES 1–5. *Sowerbyella grierensis* Howe, n. sp. (p. C3).

From the Grier Limestone Member of Lexington Limestone; USGS loc. 4956–CO.

1. Interior of brachial valve, paratype, USNM 208589.
2. Interior of pedicle valve, paratype, USNM 208590.
3. Exterior view of brachial valve, paratype, USNM 208591.
4. Exterior view of pedicle valve, holotype, USNM 208592.
5. Interior of brachial valve, paratype, USNM 208593.

6–16. *Sowerbyella curdsvillensis* (Foerste) (p. C1).

From the Curdsville Limestone Member of the Lexington Limestone.

6, 7. Exteriors of two brachial valves, USNM 208575, USNM 208576, respectively, from USGS loc. 5081–CO.

8. Exterior of pedicle valve USNM 208577; USGS loc. 4124–CO.

9, 10. Two brachial valves, US[illegible] 208578, 208579, respectively; USGS loc. 4124–CO.

11. Interior of brachial valve, USNM 208580; USGS loc. 4124–CO.

12. Interior of pedicle valve, showing deeply incised adductor scars; USNM 208581; USGS loc. 4124–CO.

13. Dorsal interior of juvenile, showing papillose ornamentation; USNM 208582; USGS loc. 4124–CO.

14. Ventral interior showing musculature; USNM 208583; USGS loc. 4124–CO.

15. Interior of brachial valve, displaying cardinalia; USNM 208584; USGS loc. 4122–CO.

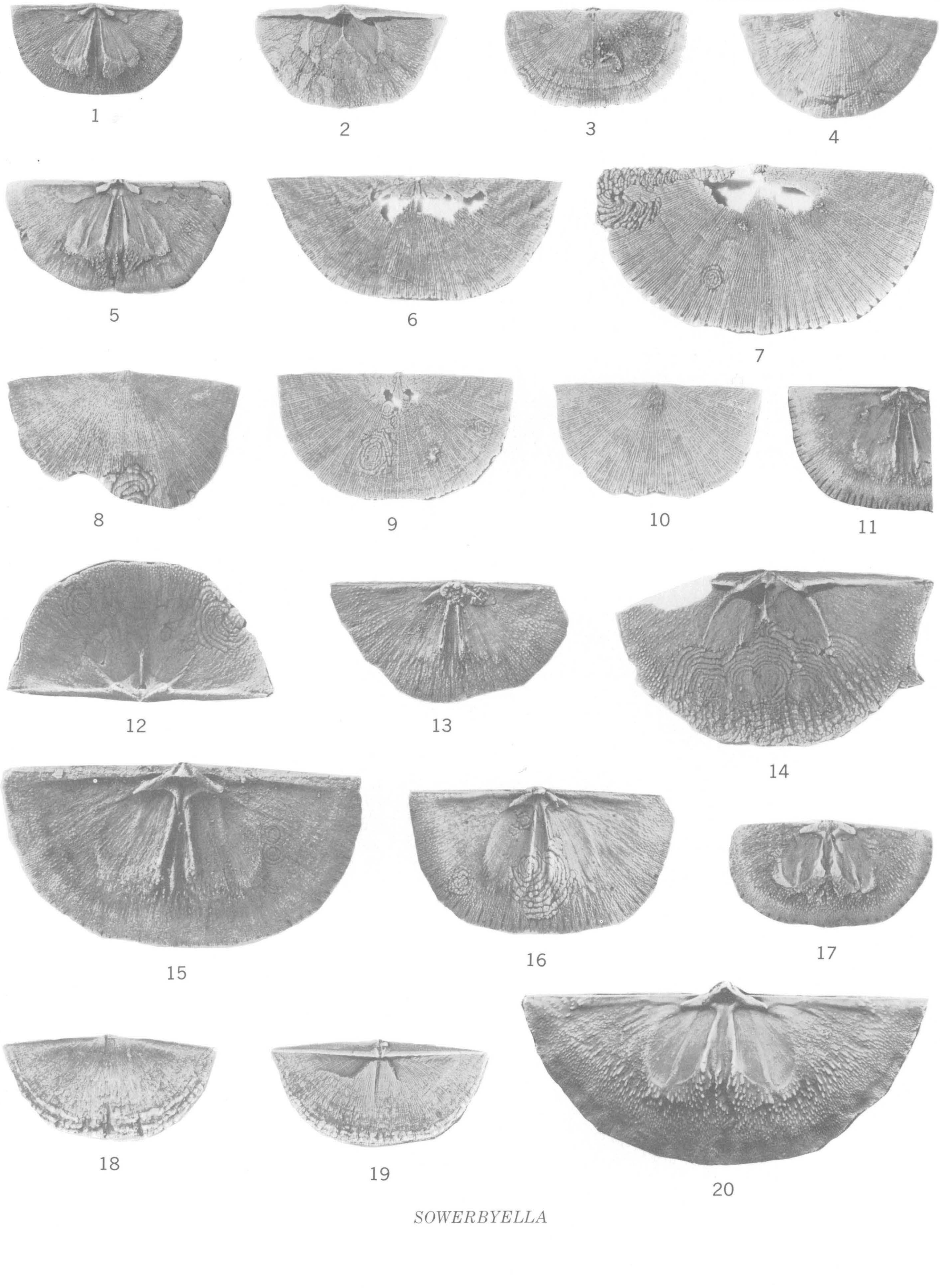
16. Brachial interior, USNM 208585; USGS loc. 4124–CO.

17–20. *Sowerbyella rugosa* (Meek) (p. C3).

17. Dorsal interior, displaying slightly elevated lateral septa in muscle field; USNM 208596; from Kope Formation, USGS loc. 7978–CO.

18, 19. Ventral and dorsal views, respectively, of complete specimen, showing lamellose ornamentation; from Kope Formation, USGS loc. 7978–CO. USNM 208597.

20. Interior of brachial valve, showing papillose ornamentation on cardinal flanks; USNM 170730; from Kope Formation, Newport Shopping Center on U.S. Highway 27, Newport, Ky.



SOWERBYELLA

PLATE 2

FIGURES 1–13. *Sowerbyella* sp. (p. C3).

From the Clays Ferry Formation.

1. Interior of brachial valve, × 3, USNM 208600, USGS loc. 5058–CO.

2, 3. Interior of brachial valve, × 3, × 6, USNM 208601, USGS loc. 5058–CO.

4. Dorsal view of complete specimen, × 3, USNM 208602, USGS loc. 4905–CO.

From Point Pleasant Tongue of Clays Ferry Formation, USGS loc. 8068–CO.

5, 8. External and internal views of dorsal valve, × 3, × 6, respectively, USNM 208603. Note incipient denticles on cardinal flanks.

6, 10. External and internal views of dorsal valve, × 3, USNM 208604.

7, 9. External and internal views of brachial valve, × 3, USNM 208605.

11. Pedicle interior, × 3, showing incipient fossettes along hinge, USNM 208606.

12. Brachial interior of juvenile, displaying several incipient denticles along hinge, × 3, USNM 208607.

13. Pedicle interior, showing rudimentary accessory teeth, × 5, USNM 208608.

14–17. *Thaerodonta clarksvillensis* (Foerste) (p. C4).

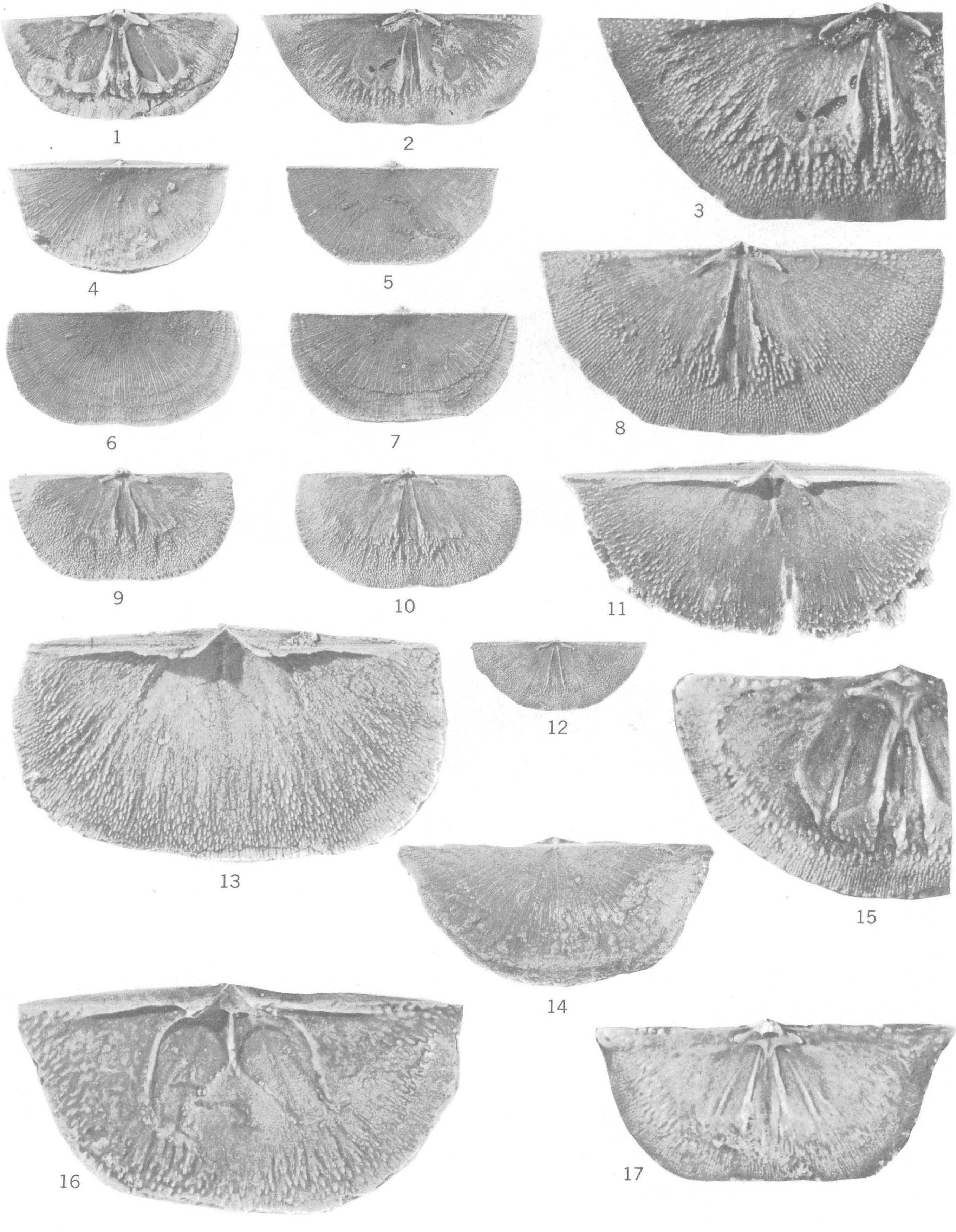
From the Bull Fork Formation, USGS loc. D1254–CO.

14. Exterior of brachial valve, × 3, USNM 208616.

15. Enlarged view of brachial interior, displaying hinge-line denticles, × 5, USNM 208617.

16. Pedicle interior, displaying fossettes, × 4.5, USNM 208618.

17. Interior of brachial valve, × 4.5, USNM 208619. Note lateral septa dividing adductor muscle field.



SOWERBYELLA AND *THAERODONTA*

PLATE 3

FIGURES 1–30. *Rhynchotrema increbescens* (Hall) (p. C5).

All figures from the Perryville Limestone Member of the Lexington Limestone, USGS loc. 5015–CO, unless noted.

1–4. Dorsal, ventral, side, and end views, × 2.5, of young adult, USNM 208623.

5, 6, 11, 12. Dorsal views of early growth series, × 3, USNM 208624–208627, respectively.

7–10. Dorsal, ventral, side, and end views, × 2.5, of young adult, USNM 208628.

13–17. Dorsal, ventral, side, end, and top views, × 2.25, of subtriangular form, USNM 208629.

18. Brachial view of subellipital member, × 2.25, USNM 208630.

19. Brachial view, × 2.25, USNM 208631.

20. Ventral interior of juvenile, showing dental plates, × 2.25, USNM 208632.

21. Ventral interior of late juvenile, × 3, showing large open delthyrium and rudimentary interarea, USNM 208633.

22. Ventral interior, displaying quadrate muscle field, × 3, USNM 208634.

23. Ventral interior, showing flabellate muscle field, × 3, USNM 208635a.

24. Ventral interior, displaying dental plates, × 3, USNM 208635c.

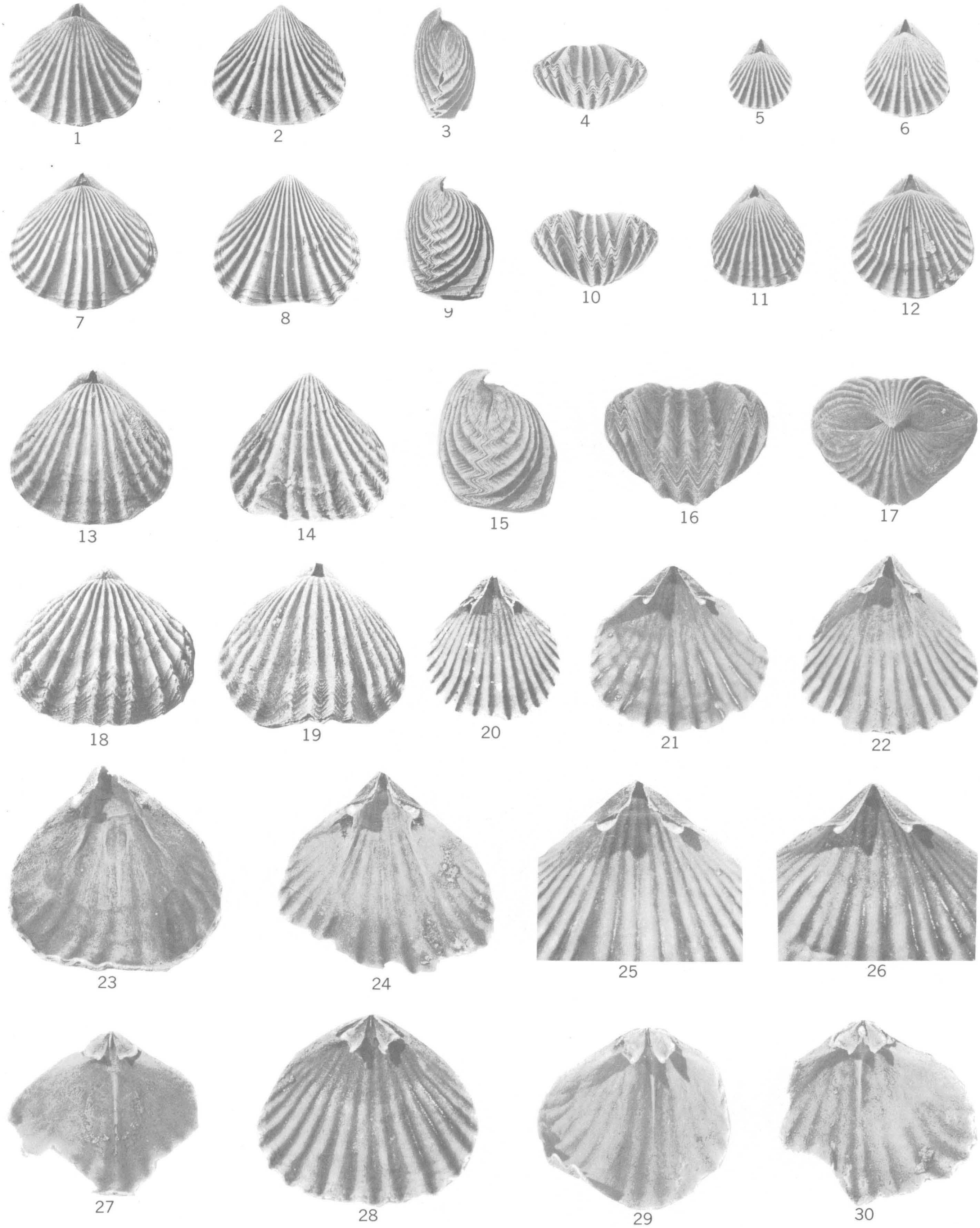
25. Enlarged view of ventral interior, × 4.5, showing rudimentary deltidial plates, USNM 208637.

26. Enlarged view of ventral interior, × 4.5, showing dental plates supporting delthyrial opening, USNM 208638.

27, 30. Two dorsal interiors, × 3, USNM 208639, 208640, from the Tanglewood Limestone Member of the Lexington Limestone, USGS loc. 5016–CO.

28. Interior of brachial valve, showing cardinalia, × 4.5, USNM 208641.

29. Brachial interior, × 3, USNM 208642. Contrast thin cardinal septum with swollen septum of figure 30.



RHYNCHOTREMA

PLATE 4

[All figures × 1.5]

FIGURES 1–10. *Lepidocyclus*? *capax* (Conrad) (p. C8).

1, 2, 5. Dorsal, ventral and side views, from the Bull Fork Formation, USNM 208649, USGS loc. D1259–CO.

3, 4. Ventral and dorsal views of young adult, USNM 208650, from Dillsboro Formation, USGS loc. 6139–CO.

6, 10. Pedicle interior and side view of globose specimen, USNM 208654, 208655, respectively, from Richmondian outcrop along U.S. Highwy 50, 3.1 miles east of Versailles, Ind.

7–9. Two dorsal interiors and a pedicle interior, USNM 208651, 208652, 208653, respectively, from Dillsboro Formation, USGS loc. 6139–CO.

11–18. *Orthorhynchula linneyi* (James) (p. C10).

From the Calloway Creek Limestone (Maysvillian), USGS loc. 6409–CO.

11, 12. Dorsal and side views of juvenile, USNM 208657.

13, 14. Dorsal and end views of young adult, USNM 208658.

15. Side view of adult, USNM 208659.

16–18. Dorsal, end, and ventral views, respectively, of adult, USNM 208660.

19–31. *Orthorhynchula sublinneyi* Howe, n. sp. (p. C13).

From the upper part of the Devils Hollow Member of the Lexington Limestone, USGS loc. 5095–CO unless noted.

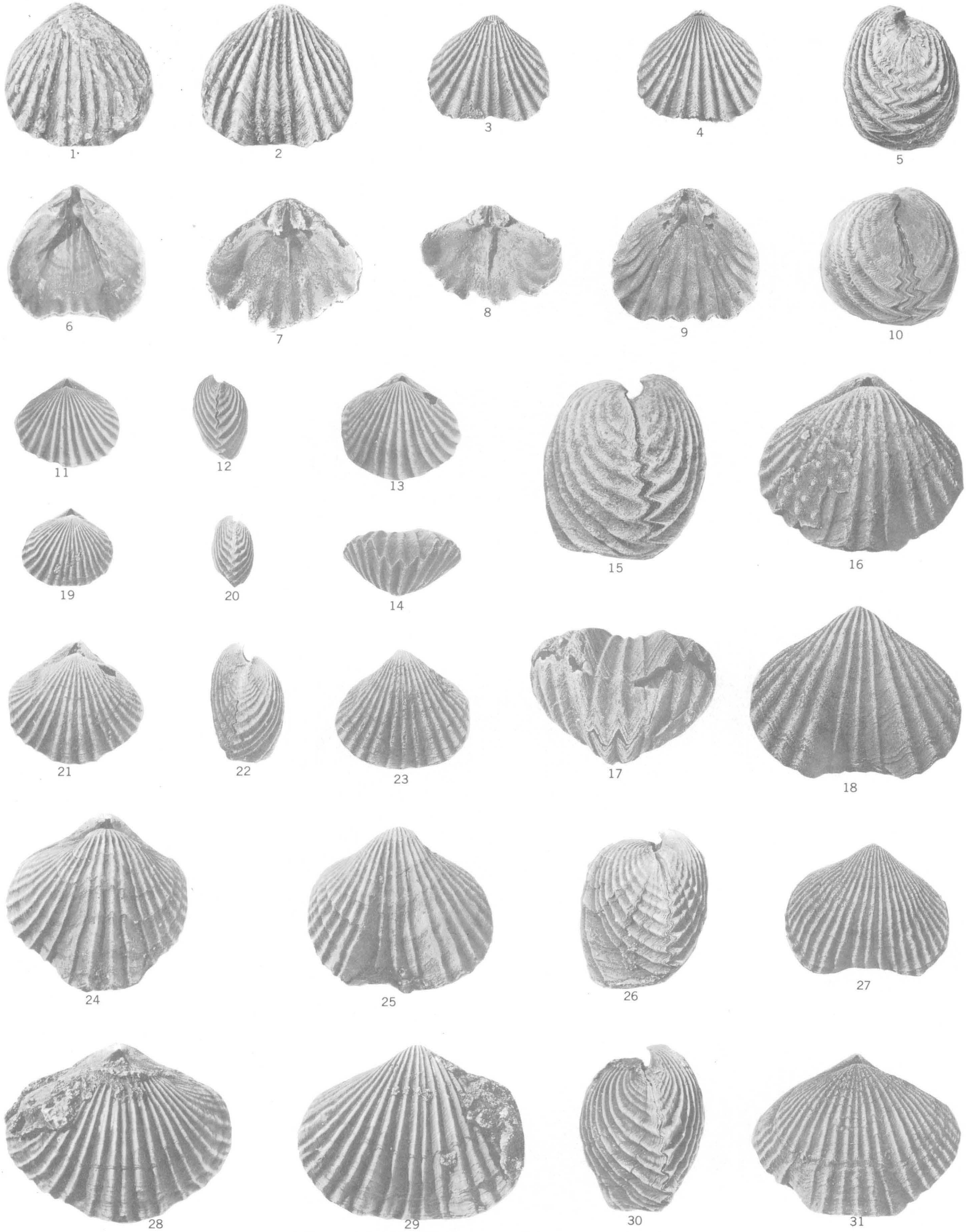
19, 20. Dorsal and side views of juvenile, USNM 208665.

21–23. Dorsal, side, and ventral views, respectively, of young adult, USNM 208666.

24–26. Dorsal, ventral, and side views, respectively, USNM 208667.

28–30. Dorsal, ventral, and side views, respectively, showing elliptical outline, USNM 208668.

27, 31. Pedicle exterior and dorsal view of complete specimen, USNM 208669, 208670, respectively, from the Devils Hollow Member of the Lexington Limestone, USGS loc. 5036–CO.



LEPIDOCYCLUS? AND *ORTHORHYNCHULA*

PLATE 5

FIGURES 1–6, 8–15. *Orthorhynchula sublinneyi* Howe, n. sp. (p. C13).

1, 2. Interior of brachial valve, × 3, and × 6, respectively, USNM 208671, from the Perryville Limestone Member of the Lexington Limestone, USGS loc. 6916–CO.

3. Interior of brachial valve, × 3, USNM 208677, from the Devils Hollow Member of the Lexington Limestone, USGS loc. 5036–CO.

4, 5. Interior of brachial valve, × 3 and × 6, respectively, USNM 208672, USGS loc. 6916–CO.

6, 8, 9. Interiors of three dorsal valves, showing variations in cardinal process, × 6, USNM 208673, 208674, and 208675, respectively, USGS loc. 6916–CO.

10. Enlarged view of pedicle interior, × 4, USNM 208679, USGS loc. 5036–CO.

11. Brachial interior, displaying dorsal musculature, × 3, USNM 208678, USGS loc. 5036–CO.

12. Pedicle interior, × 3, USNM 208680, USGS loc. 5036–CO.

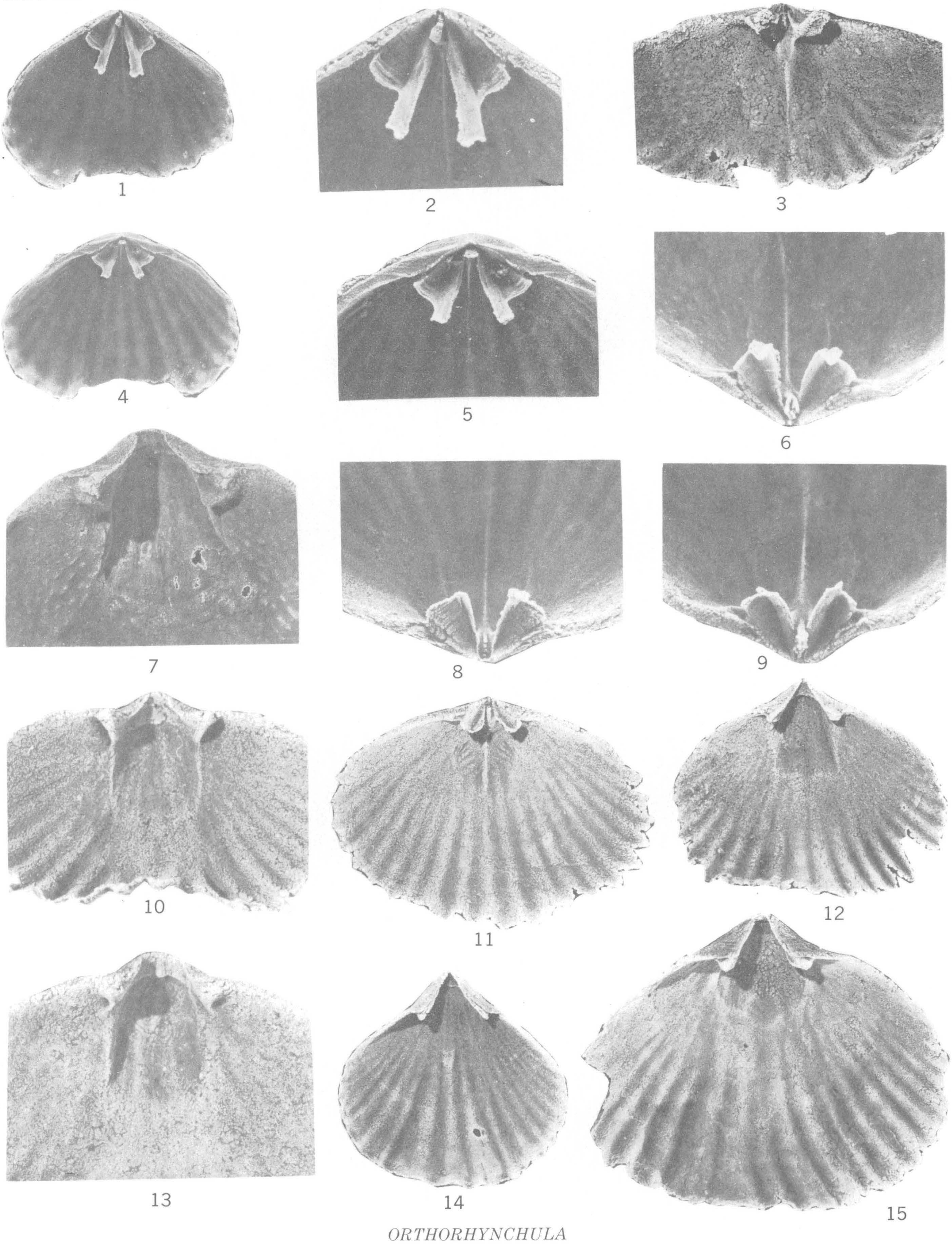
13. Enlarged view of pedicle interior, showing musculature, × 4, USNM 208681, USGS loc. 5036–CO.

14. Interior of pedicle valve, × 3, USNM 208676, USGS loc. 6916–CO.

15. Interior of pedicle valve, × 3, USNM 208682, USGS loc. 5036–CO.

7. *Orthorhynchula linneyi* (James) (p. C10).

7. Interior of pedicle valve, showing thick adventitious deposits obscuring dental plates, × 3, USNM 208661, from the Calloway Creek Limestone, USGS loc. 6409–CO.



ORTHORHYNCHULA

PLATE 6

FIGURES 1–15. *Orthorhynchula linneyi* (James) (p. C10).

From the Calloway Creek Limestone (Maysvillian), USGS loc. 6409–CO.

1, 2. Enlarged views of ventral musculature, × 3 and × 6, respectively, USNM 208663.

3, 6. Enlarged views of ventral musculature, × 3 and × 4, respectively, USNM 208664.

4. Interior of pedicle valve showing quadrate muscle field, × 3, USNM 208696.

5, 8. Enlarged views of dorsal cardinalia, × 3 and × 6, respectively, USNM 208695.

7. View of cardinalia and notothyrial platform, × 4, USNM 208697. Note diverging crural plates.

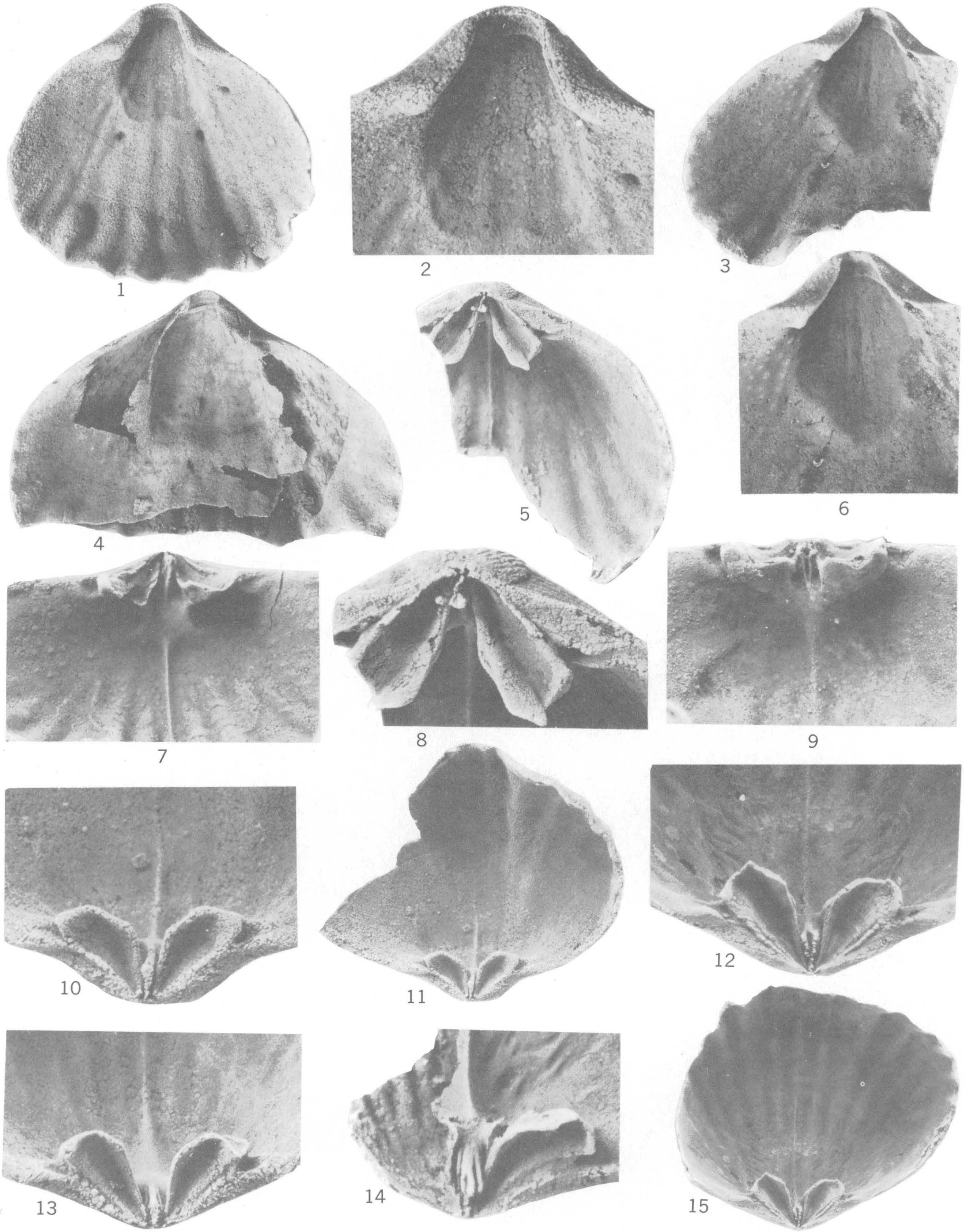
9. Oblique view of cardinalia and notothyrial platform, × 4, USNM 208698. Crural plates obscured by shell thickening.

10, 11. Interior of brachial valve displaying simple bladelike cardinal process, × 6 and × 3, respectively, USNM 208699.

12, 15. Dorsal interior showing bilobid cardinal process and myophore, × 6 and × 3, respectively, USNM 208700.

13. Brachial interior showing trilobate process, × 6, USNM 208701.

14. Interior of brachial valve, × 6, USNM 208702. Note accessory ridges forming a quadrilobate myophore.



ORTHORHYNCHULA

PLATE 7

FIGURES 1–4. *Orthorhynchula linneyi* (James) (p. C10).

1–4. Brachial, pedicle, side, and end views of juvenile, × 3, USNM 208662, from the Calloway Creek Limestone, USGS loc. 6409–CO.

5–8. *Elliptoglossa*? sp. (p. C16).

5, 7. Interior and exterior views, × 8, USNM 208686, USGS loc. D1200–CO, from the Tanglewood Limestone Member of the Lexington Limestone.

6, 8. Interior views of two valves, × 8, USNM 208687 and 208688, respectively, from USGS loc. 7805–CO.

9–12. *Rostricellula minuta* Cooper (p. C8).

9. Pedicle view, × 4, USNM 208691, 0.5 ft from top of the Logana Member of the Lexington Limestone, USGS loc. D1196–CO.

10–12. Side, anterior, and brachial views, × 4, USNM 208692, from the Logana Member of the Lexington Limestone, USGS loc. 5073–CO.

13–16. *Zygospira*? sp. (p. C17).

13–16. Dorsal, ventral, side and top views, × 4, USNM 208685, from the Perryville Limestone Member of the Lexington Limestone, USGS loc. 5015–CO.

17–20. *Camerella* sp. aff. *C. immatura* Cooper (p. C15).

17–20. Ventral, dorsal, side, and anterior views, × 4, USNM 208697, from the lower part of the Curdsville Limestone Member of the Lexington Limestone, USGS loc. 7784–CO.

21–22. *Rhynchotrema dentatum* (Hall) (p. C5).

21. Brachial valve, × 3, USNM 208689, from the Bull Fork Formation (Richmondian), USGS loc. D1247–CO.

22. Brachial view of complete specimen, × 3, from the Bull Fork Formation, USGS loc. D1246–CO, USNM 208690.

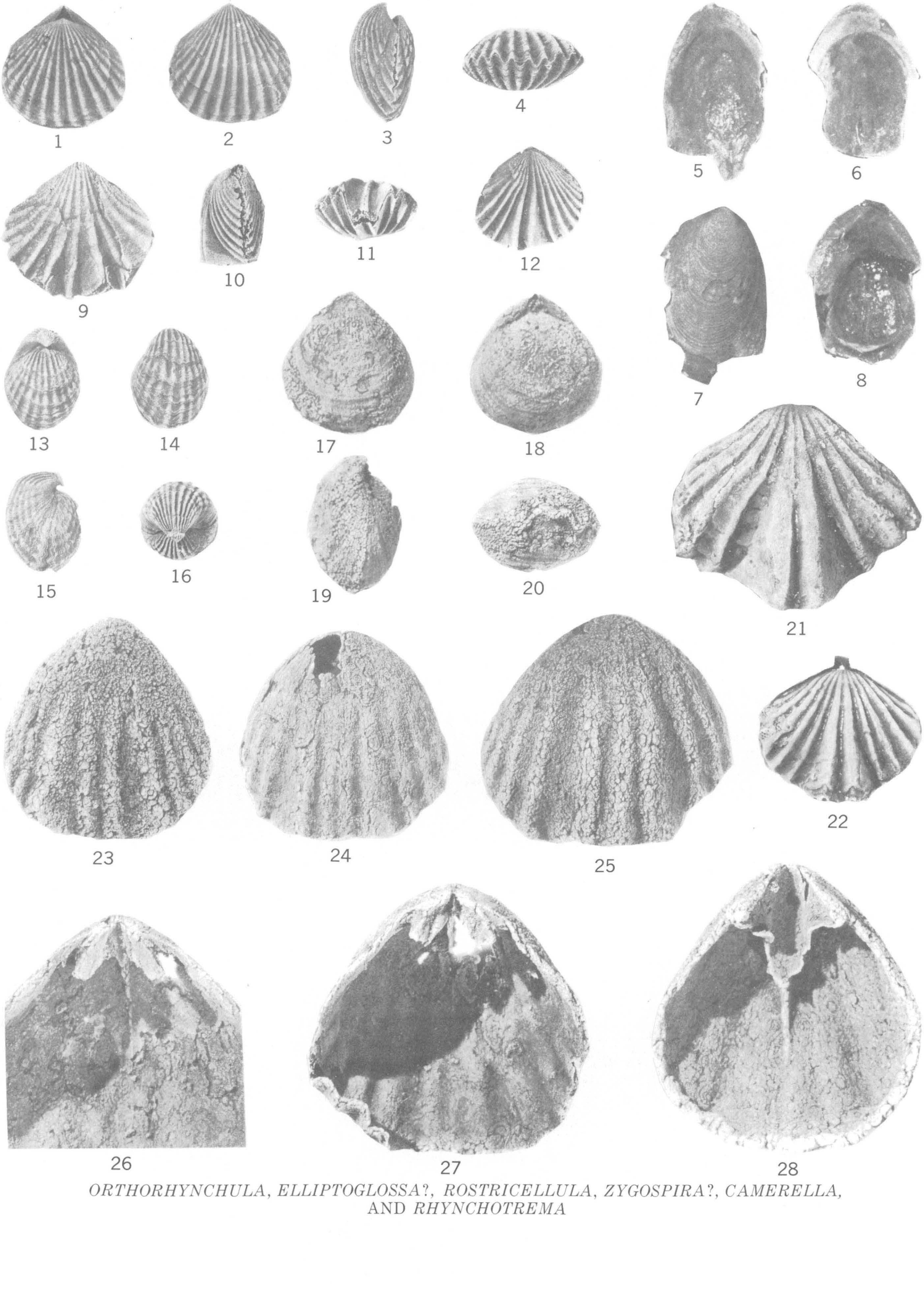
23–28. *Camerella bella* Fenton (p. C15).

From the Camp Nelson Limestone, USGS loc. 7836–CO.

23, 28. Exterior and interior views of pedicle valve, × 3 and × 4, Respectively, USNM 208692.

24, 27. Exterior and interior views of brachial valve, × 3 and × 4, respectively, USNM 208693.

25, 26. Exterior and interior views of brachial valve, × 3 and × 4, respectively, USNM 208694.



ORTHORHYNCHULA, *ELLIPTOGLOSSA*?, *ROSTRICELLULA*, *ZYGOSPIRA*?, *CAMERELLA*, AND *RHYNCHOTREMA*

Additional Trilobites from the Ordovician of Kentucky

By REUBEN JAMES ROSS, JR.

CONTRIBUTIONS TO THE ORDOVICIAN PALEONTOLOGY OF KENTUCKY AND NEARBY STATES

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1066-D

Prepared in cooperation with the
Commonwealth of Kentucky
University of Kentucky,
Kentucky Geological Survey

Species of the trilobites *Triarthus, Decorproetus, Isotelus, Gravicalymene, Platylichas, Primaspis,* and *Acidaspis,* are described from Orvodician strata of Kentucky

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1979

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ILLUSTRATIONS

SYSTEM OF MEASUREMENT UNITS

The investigations underlying this series of reports were made over a period of years, and distances and stratigraphic measurements appear fairly uniformly in English units. Measurements of fossil specimens, on the other hand, follow the longstanding convention of appearing in metric units. Because of the dates of the investigations and the amount of resulting data, the English measurements have been retained. Conversions to metric units may be made by using the following conversion table:

To convert English unit:	To metric unit:	Multiply by:
Mile (mi)	Kilometer (km)	1.61
Foot (ft)	Meter (m)	.305

ADDITIONAL TRILOBITES FROM THE ORDOVICIAN OF KENTUCKY

By REUBEN JAMES ROSS, JR.

ABSTRACT

Trilobites collected from Ordovician limestones in Kentucky supplement earlier collections reported by Ross in 1967. Included are olenids, proetids, asaphids, calymenids, lichids, and odontopleurids. A remarkable specimen of *Primaspis* shows traces of the ventral appendages crudely silicified.

INTRODUCTION

Preparation of large samples of Ordovician limestones from Kentucky for silicified brachiopods and pelecypods has also provided a limited number of trilobites. These supplement the few trilobites previously reported (Ross, 1967).

The generic assemblage of trilobites from the Ordovician rocks of Kentucky resemble those of the Caradocian of England, Scandinavia, and to a lesser extent Bohemia. The genera described and illustrated here include *Triarthrus, Decoroproetus, Isotelus, Gravicalymene, Flexicalymene, Platylichas, Primaspis,* and *Acidaspis.*

These genera do not all occur in the same stratigraphic units. Care should be taken to ally each genus and species with the stratigraphic interval to which it belongs. Collections and localities are indicated so that the reader may refer to the stratigraphic summary.

Most collections were made under the direction of John Pojeta. However, two collections not made by U.S. Geological Survey personnel have yielded important material. S. M. Warshauer and J. M. Warn of the University of Cincinnati found exceptionally fine specimens of *Triarthrus* that are not silicified. A new species, *Gravicalymene truncatus,* is represented by unsilicified specimens collected by D. M. Lorenz, of the University of California, Los Angeles.

The genus *Cryptolithus* was found in six collections, but because only fragments of fringes were present, no effort was made to describe or illustrate the specimens. The six collections are:

5073 CO—Logana Member, Lexington Limestone—Frankfort East quadrangle.

5092 CO—Logana Member, Lexington Limestone—Tyrone quadrangle.

7791 CO—Logana Member, Lexington Limestone—Salvisa quadrangle.

7793 CO—Tanglewood Limestone Member, Lexington Limestone—Ford quadrangle.

6211 CO—Kope Formation, lowermost beds—Moscow quadrangle.

7806 CO—Point Pleasant Tongue of the Clays Ferry Formation—Moscow quadrangle.

Six species are given letter designations rather than being named formally. The two species of *Acidaspis* are represented by one cranidium and one pygidium each—hardly an adequate sample on which to base a species. The species of *Decoroproetus* and *Primaspis* are represented by enough specimens to indicate that they belong to four different species but by too few to be sure that one or more previously described species are not synonyms.

Museum numbers are abbreviated as follows:

AMNH—American Museum of Natural History
NYSM—New York State Museum
UCM—University of Cincinnati Museum
USNM—U.S. National Museum

ACKNOWLEDGMENTS

Niles Eldredge of the American Museum of Natural History loaned specimens of *Triarthrus becki* and *Primaspis trentonensis* described and illustrated by James Hall (1847). Specimens on the basis of which Ruedemann (1926) revised *Triarthrus becki* and *T. eatoni* were furnished by Donald W. Fisher of the New York State Museum at Albany, who also provided the loan of specimens of *Primaspis eatoni* from the Trenton Group.

DESCRIPTIONS OF TRILOBITES

Class TRILOBITA Walch, 1771
Order PTYCHOPARIIDA Swinnerton, 1915
Superfamily OLENACEA Burmeister, 1843
Family OLENIDAE Burmeister, 1843

Genus TRIARTHRUS Green, 1832

Ruedemann (1926, p. 115–121) compared and revised the two common North American species *Triarthrus becki* Green and *Triarthrus eatoni* Hall and emphasized the stratigraphic significance of their taxonomic differences. Examination of the specimens illustrated by Ruedemann (1926, pl. 21, figs. 7, 8, 12) and by Hall (1847, pl. 64, figs. 2b, c) confirms these differences.

The specimens described herein are assigned to *Triarthrus eatoni* rather than being assigned to a new species. All these Kentucky specimens from the Kope Formation are beautifully preserved, retaining their original convexity, whereas the specimens available to me from the Utica Shale are flattened. Such differences as exist between the Utica and the Kope specimens are probably caused more by preservation than by biology.

In describing these olenid specimens I have tempered the terminology of Henningsmoen (1957, p. 12–14) with that of Harrington, Moore, and Stubblefield (1959, p. O117–O126).

Triarthrus eatoni (Hall)

Plate 1, figures 1–13

Triarthrus eatoni (Hall) Ruedemann, 1926, New York State Mus. Bull., no. 272, part 2, p. 115–121, pl. 21, figs. 7–9.

The beautiful little specimens of *Triarthrus eatoni* collected by S. M. Warshauer and J. M. Warn are all enrolled and preserve the convexity that is usually lost by flattening in shale. The average sagittal length of cephala is a little more than 3 mm.

Cephalon is 1.5 times as wide as long, without genal angles or spines. Except at occipital ring, border is continuously subtubular, of almost uniform width, and bounded by shallow furrow. Preglabellar field lacking. Cephalic axis constitutes 0.9 sagittal length of cephalon; glabellar length (sag) exceeds 0.7 length of cephalon, and length (sag) of occipital ring is 0.2 sagittal length of cephalic axis.

Glabellar outline is bluntly rounded in front; axial furrows only approximately parallel because glabella is widest at lateral lobe 2*p*. Sagittal length of cephalic axis 1.1 times greatest width of glabella. Length of glabella equals 0.86 its greatest width. Anterior width (tr) of occipital ring is 0.93 greatest width of glabella.

Posterior courses of facial sutures divergent convex; length of cranidium more than 0.7 width (tr) at posterior margin. Width (tr) of fixigena immediately behind palpebral lobe is 0.21 greatest width of glabella; width of fixigena at posterior border equals 0.36 greatest width of glabella. Anteriorly facial sutures cross border diagonally inward meeting at median suture.

Thorax composed of 14 segments. Like occipital ring, each bears median tubercle. Axis constitutes slightly more than one-third thoracic width. Pleurae slope steeply ventrolaterally. Tip of each pleura blunt, flattened, with lateral projection (pl. 1, figs. 3, 13), which produces a tight fit against doublure of cephalon. Pleural furrows deep, terminating distally at the lateral projection.

Pygidium small; in every specimen, border is enrolled against cephalon so that its characters are partly hidden. However, it seems that at least the front three segments of the pygidium bear the same lateral projections as the tips of the thoracic segments. Axis composed of four rings and minute, transverse terminal piece.

Illustrated specimens.—UCM 40633a–e.

Occurrence.—Kope Formation, 23 ft above contact with underlying Point Pleasant Tongue of Clays Ferry Formation. North side of 12 Mile Creek, 75 ft east of bridge (Twelve Mile Road) across creek, Laurel 7½-minute quadrangle, Kentucky. Collected by John M. Warn and Steven M. Warshauer.

Discussion.—*Triarthrus parchaensis* Harrington and Leanza and *T. rectifrons* Harrington both possess a preglabellar field discrete from anterior border and in both the glabella is much broader than in *T. eatoni*. *T. gachalensis* Harrington and Leanza has a much wider glabella and narrower cephalon. None of the Early Ordovician species from Argentina (Harrington and Leanza, 1957, p. 115–119) is very similar to *Triarthrus eatoni* from the Kope Formation. *Triarthrus convergens* Whittard (1961, p. 190–191, pl. XXIV, figs. 16–18) has a broader glabella and acute genal angles. According to Cooper (1953, p. 9, pl. 2, figs. 7–10), *Triarthrus* (*Porterfieldia*) *caecigenus* Raymond has only 11 thoracic segments and 7 axial rings on the pygidium as well as somewhat different features of the cephalon.

A comparison of the specimens from the Kope with those collected by Hall from the Trenton at Middleville, N. Y., (Hall, 1847, p. 237, pl. LXIV, fig. 2; Ruedemann, 1926, p. 119–121) shows not only that the cephalic axis is wider and shorter in the Trenton species but also that it bears abbreviated glabellar furrows 3*p* that do not intersect the dorsal furrows; this anterior pair of furrows is virtually lacking in the Kentucky specimens. In the few specimens on which furrows 3*p* do appear they are visible only as faint traces—but the traces extend to the dorsal furrow.

Glabellar proportions of the Kope specimens agree exactly with those of specimens of comparable size in the Columbia University collections from the Utica Shale of Rome, N. Y. Those specimens are now considered to belong to *Triarthrus eatoni*. Such seeming differences as exist in proportions of the cephalon are readily explained by mode of preservation.

Superfamily PROETACEA Salter, 1864
Family PROETIDAE Salter, 1864
Genus DECOROPROETUS Pribyl, 1946

Decoroproetus Pribyl. Owens, 1973a, Norsk Geol. Tiddskr. v. 53, p. 134.

Decoroproetus Pribyl. Owens, 1973b, British Ordovician and Silurian Proetidae (Trilobita). Palaeontographical Soc., pub. no. 535, p. 41.

Proetidella Bancroft. Ross, 1967, U.S. Geol. Survey Prof. Paper 583–B, p. B6–B7.

Species previously assigned to *Proetidella* (Ross, 1967) must be redesignated *Decoroproetus* following the excellent revisions of Owens (1970, 1973a, 1973b).

Previously *Decoroproetus* (as *Proetidella*) has been reported in the Grier and Tanglewood Limestone Members of the Lexington Limestone and in the Clays Ferry Formation. Here it is recorded in the Perryville Limestone Member of the Lexington as well as at another locality in the Clays Ferry Formation.

Decoroproetus sp. x
Plate 2, figures 1–6

In the collection (USGS colln. 6143 CO) from the Clays Ferry of the Cynthiana quadrangle are 22 partly enrolled silicified specimens of *Decoroproetus*. All are incomplete. Most are composed of the hypostoma, glabella, thoracic axis, and pygidial axis. Four specimens retain most of one or both librigenae, but in three others only the silicified border and doublure of a librigena remains. No complete pygidium remains.

Cephalon essentially semicircular in outline if the genal spines are disregarded. The spines extend backward as far as the third thoracic segment. Glabella widest between palpebral lobes and at occipital ring; width exceeds 0.9 sagittal glabella length including occipital ring. The width of glabella slightly more than one-third the width of cephalon. Glabellar outline constricted between fronts of palpebral lobes and rounded at anterior end. Occipital ring a flattened band set off by distinct occipital furrow. Occipital furrow curves forward sagittally and at junction with axial furrow. Occipital lobes are faint swellings adjacent to the axial furrows. Length (sag) of anterior border is less than 0.2 glabellar length. Length (exsag) of eyes is 0.45 glabellar length but length (exsag) of slender palpebral lobes is less than 0.3 glabellar length.

Hypostoma is strongly and narrowly convex, widest at anterior wings; width at wings only slightly less than sagittal length. Width of middle body two-thirds sagittal length. Middle body indistinctly divided into large anterior and short (sag) lobe by a pair of diagonal creases rather than maculae. Behind anterior wings, subtubular border surrounds hypostoma and is set off by a distinct border furrow. The anterior edge of the hypostoma lies beneath the rounded front of the glabella. The rounded posterior margin of the hypostoma extends to the middle of the occipital ring.

There are 10 segments in the thorax and 6 rings in the pygidial axis, plus a narrowly rounded terminal piece. Pleural furrows on the thorax are straight and extend outward from the axial furrow at least as far as the pleural lobe is flat; all tips of pleurae are broken.

The outlines of three pygidia are crudely indicated by partial silicification of border and doublure, but not a single specimen retains the pleural field. The outline seems to be broadly parabolic and about 2½ times as wide (tr) as long (sag). Length of axis is 0.85 length (sag) of pygidium.

Illustrated specimens.—USNM 206836, 206837.

Occurrence.—USGS collection 6143 CO, Upper tongue of Clays Ferry, 30–35 ft above base of section, roadcut on east side of Kentucky Highways 32 and 36, Cynthiana quadrangle, Kentucky.

Discussion.—Comparison with previously described species is hampered by the erratic nature of silicification. Such features as are preserved are similar to those of *Decoroproetus fearnsidesi* (Bancroft) from lower Caradocian of Shropshire, as described by Dean (1963, p. 243–246); the glabellar outline, occipital lobes, dimensions of the preglabellar field, and outline of the pygidium are similar to those of the English species, but definition of the anterior border is poorer than in *D. fearnsidesi*.

D. subornatus (Cooper and Kindle, 1936, p. 364–365, pl. 42, figs. 16, 24) is based on a pygidium and fragmentary cranidium; reasonable comparison cannot be made with that species from Quebec.

Decoroproetus marri Dean (1962, p. 124–126, pl. 17, figs. 5, 8) possesses a more bluntly rounded glabellar outline, a longer (sag) preglabellar field, and a more prominent and narrower anterior border than the Kentucky specimens. Owens (1973b, p. 44–45) placed *D. marri* in synonymy with *D. calvus* (Whittard). Illustrations of the type and other specimens of *D. calvus* (Owens, 1973b, pl. 8, figs. 1a, 1b, 7) show that the preglabellar field is more convex (sigmoidal) in sagittal profile than in the specimens from Kentucky.

Owens (1973a, table 3) summarized the diagnostic features of Scandinavian species of *Decoroproetus*. Inasmuch as *D*. sp. x possesses a constricted glabellar outline, lacks glabellar furrows, and has a straight longitudinal profile of the preglabellar field, it is best compared with *D. gyratus* Owens (1970, p. 316, 319–20, fig. 6A, B, D). The Scandinavian species has a longer (sag) preglabellar field and a less well defined border.

Decoroproetus sp. x differs from all British species (Owens, 1973b) with unfurrowed glabellae in having a flat rather than sigmoidal (sag) preglabellar field, a distinct flat-topped border defined proximally by a break in slope, narrowly rounded frontal lobe of glabella, and gentle constriction of the glabella.

Decoroproetus has also been described from the "Confinis" Flags (Tripp, 1962, p. 13, pl. II, fig. 15) and from the Upper Stinchar Limestone (Tripp, 1967, p. 52–53, pl. II, figs. 13–17) of the Girvan District, southwest Scotland. The specimens from the "Confinis" Flags are too incomplete for comparison; both of the two species from the Upper Stinchar Limestone have a much longer (sag) preglabellar field and one has a longer (sag) pygidial axis than the species from the Clays Ferry. The two Scottish formations were correlated by Williams (1962, p. 58–62) with the Porterfieldian of Cooper.

In Kentucky, a few specimens of *Decoroproetus* (under the name of *Proetidella*) were reported and illustrated (Ross, 1967, p. B6–B7) from the Lexington Limestone and the Clays Ferry Formation. The cranidium from the Millersburg Member of the Lexington Limestone (*P*. sp. 3, Ross, 1967, pl. 2, fig. 15) may be conspecific with the species described here, but none of the pygidia can be compared with the present incomplete material.

Decoroproetus sp. 2

Plate 2, figures 7–16

Proetidella sp. 2. Ross, 1967, U.S. Geol. Survey Prof. Paper 583–B, p. B7, pl. 2, fig. 14.

Four fragments of cranidia included in sample, three of which are only the preglabellar field and border; the fourth is only the posterior third of a glabella. Nine librigenae are fairly well preserved. No hypostoma is confidently assigned to this species. Of the six pygidia only two are worthy of illustration.

Librigenae bear long (exsag) eyes above smooth surface that slopes gently to anterior border furrow. Narrow anterior border gently convex. Anterior and posterior border furrows intersect at acute angle and continue as single furrow onto dorsal surface of genal spine.

Pygidium broadly parabolic in outline, its length (sag) equaling 0.62 its width (tr). Axis robust, tapering, bluntly rounded at posterior end. Length of axis approximately 0.8 length (sag) of pygidium; anterior width (tr) of axis about 0.4 greatest pygidial width (tr). Axis composed of seven rings and terminal piece in largest specimen (pl. 2, figs. 7–9) but of six rings plus terminal piece in a slightly smaller pygidium (pl. 2, figs. 10–12). Axial furrow distinct but shallowing at confluence around end of axis. Three pairs of interpleural furrows almost reach margin, but only the anterior two pairs are readily discernible. Six pairs of pleural furrows traverse pleural field to approach margin but posterior two pairs very faint. Discrete border and border furrow lacking; pleural region distally concave immediately inside the margin.

Occurrence.—USGS collection 5015 CO, Perryville Limestone Member of Lexington Limestone, 5 ft above base of Salvisa Bed. In quarry 0.4 mi south of Perryville. Kentucky coordinates, north zone: E. 2,232,250 ft, N. 478,400 ft. Perryville quadrangle, Kentucky.

Illustrated specimens.—USNM 206838–206841 inclusive.

Discussion.—The difference in number of axial rings on the two illustrated pygidia might be considered the basis for distinguishing two species. Without a larger sample, no measure of variability is practical. In other respects the pygidia seem most similar to that designated as *Proetidella* sp. 2 (Ross, 1967, p. B7, pl. 2, fig. 14) from the Tanglewood Limestone Member of the Lexington Limestone in the Switzer quadrangle, Kentucky. It is unfortunately impossible to make a meaningful comparison with the pygidia of *Decoroproetus* sp. x described here.

Superfamily ASAPHACEA Burmeister, 1843
Family ASAPHIDAE Burmeister, 1843
Subfamily ISOTELINAE Angelin, 1854

Genus ISOTELUS DeKay, 1824

No genus is more widely represented in the collections from Kentucky than *Isotelus*. Unfortunately, only fragments remain in the great majority of the collections, making identification as to species impossible. The genus is present in 22 collections. These are 6139 CO, 6145 CO, 6146 CO, 6412 CO, 6414 CO, 6418 CO, 7458 CO, 6909 CO, 6916 CO, 6915 CO, 7471 CO, 7079 CO, 7454 CO, 7834 CO, 6136 CO, 5067 CO, 6417 CO, 7456 CO, 7457 CO, 7448 CO, 4852 CO, 7792 CO and 5015 CO. The best silicified preservation is in collection 5015 CO; this collection also showed the best silicification of a group of collections treated in a previous study (Ross, 1967).

Isotelus gigas DeKay

Plate 1, figures 14, 15

Isotelus gigas DeKay. Ross, 1967, U.S. Geol. Survey Prof. Paper 583–B, p. B3, B6, pl. 1. pl. 2, figs. 1–4.

Henningsmoen (1975, p. 196, fig. 13) in a review of methods of trilobite ecdysis reported the discovery of a specimen of *Isotelus* in which the median suture between the librigenae was obsolete; his specimen was from the Trenton Group of New York.

In the material from USGS collection 5015 CO prepared since 1966 are two examples of librigenae yoked together (pl. 1, figs. 14, 15). In both, the median suture is merely a slit extending 5 mm back from the front margin; otherwise the doublure is continuous. Specimens smaller than these two have librigenae separated by the median suture. Probably, when the animal reached such a size that the cephalon was approximately 60 mm long, it was able to withdraw from its carapace without splitting the cheeks apart.

Illustrated specimens.—USNM 206844, 206845.

Megalaspid(?) pygidium

Plate 1, figures 16–18

A single pygidium without associated cephalic parts has been collected from the Camp Nelson Limestone. Asaphid pygidia of this generalized type are almost impossible to identify as to genus without supporting information. This specimen may belong to a megalaspid. Future collectors may discover the needed cephalic evidence.

Illustrated specimen.—USNM 206846.

Occurrence.—Camp Nelson Limestone, USGS collection 7875 CO, Wilmore quadrangle, Kentucky.

Order PHACOPIDA Salter, 1864
Family ENCRINURIDAE Angelin, 1854

Cybelinid cranidium

Plate 2, figure 20

A fragmentary cranidium, possibly belonging to the genus *Paracybeloides*, is illustrated as a matter of record. The specimen is a silicified cast of the ventral side of the carapace. No cybelinid pygidium was found associated.

Illustrated specimen.—USNM 206842.

Occurrence.—USGS collection 6419 CO, lower part of Logana Member of Lexington Limestone, Wilmore quadrangle, Kentucky.

Family CALYMENIDAE Burmeister

Genus GRAVICALYMENE Shirley 1936

The importance of the genus *Gravicalymene* in the Middle Ordovician of Kentucky has been reviewed by Ross (1967, p. B8–B9). Collection 7984 CO includes a species assigned to *Gravicalymene;* however, it is so distinctive that it might be the basis of a new genus or might be assigned to *Diacalymene*.

The lateral glabellar lobes 3*p* are very small. The front of the glabella is transversely rectilinear; the width (tr) at the front is at least as wide as the width of the glabella at lobes 3*p*. The preglabellar furrow is extremely deep and undercuts the front of the glabella. The anterior border is flat topped and has the kind of lateral profile associated by Shirley (1936, fig. 2; pl. XXIX, figs. 19–23 with *Diacalymene*. I have found no description of a species with the truncated anterior glabella.

The thickness of the carapace suggests that comparison with internal casts could be very difficult and misleading.

A correction in my previous interpretation of pygidial segmentation (Ross, 1967, p. B9) is in order. In all species of *Gravicalymene* described from Kentucky—including *G. truncatus* n. sp.—the first four rings of the pygidial axis are distinct. On the pleural regions there are five pairs of pleural furrows but only four pairs of interpleural furrows. Because the fundamental segmentation of the pygidium is shown by the interpleural furrows (Harrington, 1959, p. O73), the front four rings should be considered axial rings. The terminal piece therefore bears two faint furrows and in some specimens an indistinct dimple. The fifth pleural furrow belongs to the front faint ring in the terminal piece.

Gravicalymene hagani Ross

Plate 2, figures 18, 19; plate 3, figures 1–9

Gravicalymene hagani Ross, 1967, U.S. Geol. Survey Prof. Paper 583–B, p. B9–B10, pl. 3, figs. 1–12.

In the new material for USGS collection 5015 CO many beautifully silicified parts of *Gravicalymene hagani* are preserved. Four cranidia of different sizes, a hypostoma, and the tip of a thoracic segment are illustrated partly as a matter of record and partly to supplement the previous description.

Hypostoma typical for the family Calymenidae. The specimen illustrated in plate 3, figure 5 shows the anterior downward flexure to fit the rostral plate along the connective suture and the deep elongate pits on the ventral surface that correspond to the anterior wing processes on the inner dorsal side. The middle body is 1.5 times as long as wide. Length (sag) of anterior lobe about 0.70 length of middle body.

Left side of a thoracic segment is illustrated to show the smooth facet on the outside and the vincular stop on the front edge near the tip.

The insides of two cranidia show the fossular apodemes (pl. 3, figs. 4, 9). In larger, possibly gerontic, specimens the fossula seems to extend so deeply into the apodeme that a canal is present into the inner side of the integumen. This feature may be the result of some vagary of silicification or maybe an original feature; if the latter, it would indicate a connection with the dorsal surface for purposes about which we can only speculate.

Illustrated specimens.—USNM 206847–206852 inclusive.

Occurrence.—Perryville Limestone Member, Lexington Limestone, USGS collection 5015 CO.

Gravicalymene truncatus n. sp.

Plate 3, figures 11–20

This species is characterized by the transversely truncated anterior end of the glabella, small lateral lobes 3*p*, and deep preglabellar furrow. Outline of glabella would be bellshaped if anterior end were not truncated.

The cephalon approximately semicircular in outline and its height only slightly less than its sagittal length. Length (sag) of glabella including occipital ring almost 0.75 length of cranidium. Length (sag) of occipital ring equals 0.2 length of glabella including ring. Width (tr) at frontal lobe equals width at lateral lobes 3*p* and 0.6 width (tr) at lobes 1*p*. Greatest width of glabella at lobes 1*p* equals 1.0–1.2 times glabellar length including occipital ring.

Palpebral lobes centered opposite glabellar lobes 2*p*. Width (tr) of fixed cheeks at palpebral lobes only 0.4 width of glabella at lobes 2*p*.

Anterior border elevated, higher than wide (sag). Dorsal surface somewhat flattened and sloping backward. Anterior face of margin steeply inclined downward and backward. Border furrow extremely deep; in one specimen undercutting front of glabella, in another vertically sided. Furrow widest sagittally. Combined width (sag) of border and border furrow equals 0.25 length of glabella including occipital ring.

Length (exsag) of lateral lobes 3*p* only 0.09 length (sag) of glabella including occipital ring.

Hypostoma not known.

Thorax composed of 13 segments of which the tips are flattened and rounded from front to back.

The pygidium strongly convex of a generalized design common to all Kentucky species of *Gravicalymene*. Sagittal length of pygidium equals 0.6 its greatest width. Length of axis 0.9 pygidial length and 0.75 its own width (tr). Width of axis (tr) about 0.4 width of pygidium. Axis consists of four well-defined anterior rings and terminal piece; terminal piece takes up almost half the sagittal length of axis. Terminal piece bears two faint transverse furrows delimiting two weak rings. A small median dimple may be present on some specimens in the back half of the terminal piece. Five pairs of pleural furrows but only four pairs of interpleural furrows present in pleural regions.

Illustrated specimens.—USNM 206853–206855 inclusive.

Occurrence.—USGS collection 7984 CO, Kope Formation, 57 ft 1 in. above Point Pleasant—Kope contact, Moffett Road section, Demossville quadrangle, Kentucky.

Discussion.—Although the glabella of a species like *Gravicalymene praecox* (Bancroft) may be no wider (tr) at the frontal lobe than at lobes 3*p*, in no species described to date is the front of the glabella so abruptly terminated. One is inclined to think the specimen deformed until he find others that are similar. The anterior truncation of the glabella, smallness of glabellar lobes 3*p*, enormously high anterior border, and deep border furrow distinguish this species.

Genus FLEXICALYMENE Shirley, 1936

Flexicalymene sp.

Plate 3, figure 10

A single fragmentary cranidium in the new collections is assignable to *Flexicalymene*. It is illustrated as a matter of record.

Illustrated specimen.—USNM 206856.

Occurrence.—Gilbert Member of Ashlock Formation, USGS Collection 6129 CO.

Order LICHIDA Moore
Family LICHIDAE Hawle and Corda, 1847
Subfamily HOMOLICHINAE Phleger

Genus PLATYLICHAS Gurich, 1901

Because a pygidium is lacking, the assignment of specimens described here to a genus is uncertain. However, the association of a fragmentary hypostome with the middle body wider than long and bounded posteriorly by a furrow rules out assignment to *Lichas* as shown by Tripp (1957, fig. 4). The posterior courses of longitudinal and axial furrows are similar to those of *Platylichas halli* (Foerste) from the Cincinnatian of Ohio and of *Platylichas laxatus* (McCoy) as illustrated by Warburg (1939, pl. 12, figs. 2, 3, 5, 6, 10), from the *Chasmops* beds. The axial furrow runs almost straight from the front of the palpebral lobe to the inner end of the occipital lobe; the posterior "hooked" end of the longitudinal furrow is connected by a short, shallow furrow to the axial and occipital furrows also at the inner end of the occipital lobe.

A case might be made for assigning this species to *Metopolichas*, but in all illustrations of *M. hubneri* (Eichwald) (the type species) and *M. verrucosus* Eichwald the axial furrow is shown intersecting the occipital furrow on the outer side of the occipital lobe, and no connecting furrow from the end of the longitudinal furrow is present.

As noted by Tripp (1957, p. 116) a theoretical evolutionary sequence was proposed for *Platylichas* by Öpik (1937, p. 55–62) involving in particular migration of the posterior end of the axial furrow. The Kentucky specimens represent an early step in Öpik's scheme.

Platylichas is present in Caradocian deposits (Yugorskiy horizon) of southern Vaigach Island and northern Pay-Khoy peninsula north of the Urals (Bondarev and others, 1968). The genus is reported by Jaanusson (1964, p. 30) from the Caradocian (Viruan) Skagen Formation of Västergotland, Sweden. *Platylichas* is also to be found in the Caradocian strata of Lithuania (Modlinski, 1967). In Wales it is reported from Caradocian and Ashgillian strata (Whittington, 1962). Lesperance (1968) has recorded *Platylichas* at Percé, Quebec, from beds of either Caradocian or Ashgillian age.

Platylichas halli (Foerste)

Plate 4, figures 1–7

Lichas halli Foerste, 1888, Denison Univ. Sci. Lab. Bull., v. 3, p. 118–120, pl. XIII, fig. 4.

This species is represented by six fragmentary cranidia and one partial hypostoma.

Greatest width of glabella positioned slightly posterior to anterior pits, although width at the occipital ring is essentially its equal. Glabella is narrowest immediately in front of occipital furrow; there its width (tr) is less than half the greatest width. At its intersection with the occipital furrow each axial furrow is essentially tangent to the inner end of the occipital lobe; each axial furrow runs forward and outward in a nearly straight course to the front of the palpebral furrow; it then curves inward and downward to the anterior pit. From the anterior pit each longitudinal furrow continues the course of the axial furrow, curves inward and backward. At a distance in front of the occipital furrow equal to one-eighth the sagittal glabellar length each longitudinal furrow curves abruptly outward to assume a "hooked" course. The length (exsag) of composite lateral lobes thus defined is approximately six-tenths the sagittal glabellar length. Composite lobes moderately inflated. Frontal and median lobes less inflated than composite lobes. Frontal lobe slopes evenly forward to very narrow (sag) border. On a transverse line through the greatest width of glabella the width of median lobe is slightly more than half the width of each composite lobe.

The hooked posterior end of each longitudinal furrow is connected by a short, shallow furrow to the intersection of axial and occipital furrows. Occipital lobes lie entirely outside this intersection; the distance (tr) between inner ends of occipital lobes is a little less than half the width (tr) of the glabella at the occipital ring. The length (exsag) of arcuate palpebral lobe between one-fourth and one-third the length (sag) of glabella. The palpebral furrow is confluent with the axial furrow for a short distance posterior to the anterior pit; as a result each palpebral rim is connected by an eye ridge to the anterior pit.

The single associated hypostoma lacks a posterior border and is incompletely silicified. The maculae serve to divide the subrectangular middle body, which is wider (tr) than long (sag) in a ratio of 5.5:4, into anterior and posterior lobes; the sagittal length of the anterior lobe is three times that of the posterior lobe.

Librigenae, thorax, and pygidium not known.

Illustrated specimens.—USNM 206857–206859.

Occurrence.—USGS collection. 7343 CO (lithology of Millersburg Member of Lexington Limestone). At top of tongue of Clays Ferry Formation, 0.9 mi south of Lair, Ky. Kentucky coordinates, North zone: E.1,983,700 ft; N.302,000 ft, Shawhan quadrangle, Kentucky. USGS collection 4959 CO. Upper part of Grier Limestone Member of Lexington Limestone, 149–152 ft above Tyrone-Lexington contact. Central Kentucky Parkway. (Blue Grass Parkway), north side at top of bluff. Kentucky coordinates, North zone: E. 1,835,050 ft; N. 173,600 ft, Salvisa quadrangle, Kentucky.

Discussion.—In Platylichas bottniensis (Wiman) (Warburg, 1939, pl. 10) the posterior axial and longitudinal furrows intersect in front of the occipital furrow and in this regard differ from those of *P. halli.* The cranidium of *P. laxatus* (McCoy) (Warburg, 1939, pl. 12, figs. 2, 3, 5, 6, 9, 10; Dean, 1963, p. 235–237, pl. 43, figs. 1, 2, 5, 8–12) is much wider (tr) along the posterior border, has larger palpebral lobes, a narrower glabella, and shorter composite glabella lobes than the specimens from Kentucky. Whittington and Williams (1955, p. 424, pl. 40, figs. 113, 114, 117) described an indeterminate species from the Derfel Limestone of the Arenig District Wales, which is very similar in outline of glabella and proportions of frontal lobe but differs in the outline of composite glabellar lobes. Another Welsh species, *P. nodulosus* (McCoy) (Whittington, 1962, pl. VII, figs. 1–8; 1968, p. 100–101, pl. XXXI, figs. 5, 6, 8–11) is very similar to the Kentucky species in cranidial features, differing in having a narrower (tr) middle lobe of the glabella and a wider (sag) anterior border. The median glabellar lobe of *P. glenos* Whittington (1962, p. 28, pl. VII, fig. 15; pl. VIII, figs. 3–5) is even narrower and its convexity in lateral view is greater than in the Kentucky species.

A cranidium designated *P.* cf. *laxatus* (McCoy) by Dean (1962, p. 121, pl. 17, fig. 1) has a narrower glabella than *P. halli*; the composite lobes of the glabella are not terminated posteriorly by as pronouncedly "hooked" longitudinal furrows and the median lobe of the glabella is narrower than in *P. halli.*

Although the type specimen of *Platylichas halli* (Foerste) is not available for comparison, it is more than likely that we are dealing with this or a remarkably similar species. Foerste (1888, p. 120) commented that the type specimen had come from the "Cincinnati Group" in Clermont County, Ohio. Bassler (1915, p. 35) interpreted this to mean "Maysville (Corryville)". The species range may easily include Edenian as well as Maysvillian equivalents.

Ancigin (1973, p. 106–107, pl. XV, figs. 11, 12, 13, 15, 16) has described *Platylichas micus* from the uppermost Arenigian strata from the west side of the southern Urals. The widest part of the glabella is across the compound lobes, and the palpebral furrow is discrete from the axial furrow in this Russian species; in both respects it differs from *P. halli.*

Order ODONTOPLEURIDA Whittington, 1959
Family ODONTOPLEURIDAE Burmeister, 1843
Subfamily ODONTOPLEURINAE Burmeister, 1843
Genus PRIMASPIS Richter and Richter, 1917

Primaspis trentonensis (Hall)

Plate 4, figures 8–14

Acidaspis trentonensis Hall, 1847, p. 240, pl. 64, figs. 4a–f.
Leonaspis trentonensis? (Hall). Whittington, 1941, Jour. Paleontology, v. 15, p. 501–502, pl. 74, figs. 31–34.
Primaspis trentonensis (Hall). Whittington, 1956b, Harvard Coll. Bull. Mus. Comp. Zoology, v. 114, no. 5, p. 203.

The concept of *Primaspis trentonensis* as revised by Whittington (1941, p. 502–503, pl. 74, figs. 31–37; 1956b, p. 203) included three specimens from two different localities. The present examination of specimens from Kentucky suggests that Whittington's hypodigm includes two different species.

The holotype (AMNH 853/2), an enrolled specimen from exposures on the Bay of Quinte, near Belleville, Ontario, is illustrated in plate 4, figures 8–11. The specimen has been somewhat abraded. The posterior margin of the occipital ring has been damaged and may have borne a median tubercle, which is now missing. Behind the occipital furrow a transverse row of five coarse tubercles decorates the axial part of the occipital ring. Each lateral lobe of the occipital ring is low and bounded proximally by a furrow, which may be deep more because of zeolous preparation than from its natural state. The occipital furrow between the lateral occipital lobe and the posterior of the genal region is very shallow.

The pygidium has only two pairs of spines anterior to the major spines and two posterior pairs between the major spines. One of these posterior pairs is rooted in the bases of the major spines.

The two specimens (NYSM 9773, 9774) of *Primaspis* (pl. 4, figs. 12–14) from the Trenton Group at Trenton Falls, N. Y. (Whittington, 1941, pl. 74, figs. 35, 36, 37) have a different ornamentation of the occipital ring. A large median tubercle is present; other tubercles are evenly distributed behind the occipital furrow but increase in size to a transverse row behind the large median tubercle along the margin of the occipital ring. There are two pairs of pygidial border spines in front of the major pair and two posterior pairs, both of which are discrete from the major spines.

Three specimens, to be sure, can hardly be a sufficient sample on which to base two species, but we are faced with the fact that *Primaspis trentonensis*

(Hall) is based on one of them. The other two specimens differ in features that are of species rank. Additional collections should be made and studied.

Primaspis sp. x

Plate 5, figures 1–14; plate 6, figures 1, 2

This species is represented in three collections—USGS collections 6143 CO, 6990 CO, and 7343 CO. An unfortunate amount of variation occurs between specimens, even between those from the same collection, in regard to details of ornament. These differences are caused almost entirely by different degrees of silicification. It is paradoxical that a single partial trilobite. (pl. 5, figs. 1, 2) whose dorsal surface preserves almost no fine ornament is the only known specimen to retain silicified casts of usually evanescent appendages.

In general, cranidial features, including the tuberculate surface ornamentation, are similar to those of *P. evoluta* (Törnquist) as described and illustrated by Bruton (1966), p. 4–7, pl. 1, figs. 3, 5, 6), although slight differences in proportions do exist.

Excluding genal spines the width (tr) of cephalon is approximately 2.5 times its length (sag). Similarly, the width (tr) of the cranidium at the posterior border is 2.0 times the cranidial length (sag). At the palpebral lobes, the width (tr) is about 1.3 times the sagittal length of the cranidium. The anterior width (tr) between antennal notches is almost 1.1 times the cranidial length (sag).

The width (tr) of the glabella at lateral lobe 1*p* is essentially equal to the glabellar length (sag) including occipital ring. At lobe 2*p*, it is almost 0.9 and at lobe 3*p*, almost 0.6 of the glabellar length (sag). Lobe 1*p* semiovoid, pointed anterolaterally; lobe 2*p* about half as long (exsag), semiovoid, but pointed posteroproximally. Lobe 3*p* very small, almost rectangular, narrow, directed anterolaterally. Anterior lobe of glabella slightly expanded. Occipital furrow deepest behind lateral glabellar lobe 1*p*. Occipital ring occupies almost one-third sagittal length of glabella; width (tr) of occipital ring at posterior border equals 0.8 glabellar length including occipital ring. Axial furrows poorly defined anteriorly but become deeply entrenched at distal end of glabellar furrow 3*p*, then run backward and outward around front third of lobes 1*p* and converge sharply to intersect occipital furrow, then diverge markedly around occipital lobes to cross posterior border. Lateral furrows 1*p* and 2*p* are deepest close to the longitudinal furrow. Longitudinal furrows arise faintly from proximal ends of 3*p* running almost straight backward to the occipital furrow, which they join in diverging downward into a deep pit behind lobe 1*p;* they then run almost straight upward and backward halfway across the occipital ring to delimit the proximal sides of occipital lobes.

The occipital ring is divided into an anterior tuberculate half and a raised, smooth, bordering posterior half. A median tubercle is present on the posterior half. Laterally the tuberculate surface extends to the longitudinal furrows; the swollen occipital lobes are a part of the posterior portion of the occipital ring.

On a line through the eye centers, each fixed cheek is a little lower than lateral glabellar lobes 1*p*; the width (tr) on that line is slightly less than the greatest width of lobe 1*p*.

Facial sutures follow raised sutural ridges. Anteriorly the sutures converge slightly in dorsal view and cross the dorsal side of the border above the antennal notch to the outer margin; from there the sutures converge sharply in a curving course downward and backward across the narrowly rolled doublure inside the antennal notch. As a result, the notch is entirely on the free cheek. In ventral view a connective suture runs almost straight between facial sutures and separates an extremely narrow (sag) rostral plate from the remainder of the doublure; in anterior view the connective suture appears somewhat sinuous. The posterior edge of the rostral plate is concave in outline to fit the curved front of the hypostoma. The posterior facial sutures diverge at about 160° to the border furrow, then curve sharply to cross the posterior border immediately within the base of the genal spine.

Each librigena bears a small bulbous eye above a genal platform which slopes approximately 45°. The prominent rolled border, set off by a deep furrow, bears 14 small tubercles along its ventral surface. The length of genal spine is about equal to the distance from axial furrow to facial suture at the posterior border.

The hypostoma is of low convexity; its length about three-fourths its width. Anterior wings flexed dorsally to fit contour of antennal notch on doublure. Lateral notch shallow. Shoulder angular, moderately swollen. Border furrow shallow. Maculae not evident, perhaps because of poor preservation.

Thorax composed of 10 segments, each bearing a strong axial ring, principal pleural ridge, and principal pleural spine. The anterior ridge bears a neat row of tubercles, commonly six, and extends into an anterior pleural spine. Tubercles are also sparsely present on the axial ring.

Exclusive of marginal spines the width (tr) of the pygidium is twice its length (sag). The axis is composed of two rings and terminal piece. The anterior axial ring is confluent with a large pair of diverging, essentially horizontal major spines. From the thickened border four pairs of smaller spines protrude, two pairs ahead of the large pair and two pairs behind. The bases of all spines are discrete.

Appendages.—On the ventral side of a single specimen (pl. 5, fig. 2) crude silicified casts of appendages are preserved. Silicification is too coarse to show the number of segments in each appendage. The specimen does show a pair of slender legs(?) for each segment of the thorax. Although one cannot determine any details of appendages under the cephalon it seems probable that they were different from thoracic appendages. With a modicum of imagination, one can visualize an anterior pair of mitten-shaped appendages (pl. 5, fig. 2, beneath the hypostoma. These modified appendages may have aided in the food-gathering process.

Michael E. Taylor (oral and written commun., 1973) has called my attention to a somewhat similar arrangement of appendages on the modern isopod crustacean *Serolis*.

Illustrated specimens.—USNM 206860–206864 inclusive.

Occurrence.—Clays Ferry Formation, USGS collection 6143 CO, Cynthiana quadrangle; USGS collections 6990 CO, 7343 CO, and 7812 CO Shawhan quadrangle, Kentucky.

Discussion.—I have tentatively assigned to *Primaspis* sp. x the only specimen found in collection 6990 CO; this is a delicate, almost complete trilobite, but silicification of the pygidium is incomplete (pl. 5, figs. 10–14). The major spines of the pygidium are not differentially enlarged and the anterior and posterior spines are little more than tubercles around the margin. Whether the underdevelopment of the pygidial spines is an artifact of poor silicification or an original feature cannot be known until additional specimens are available from the same locality.

Primaspis sp. x bears a strong resemblance to *P. evoluta* Törnquist (Bruton, 1966, p. 4–7, pl. 1, figs. 1–9) from the Boda Limestone of Sweden. The cranidium of the Kentucky species tends to be wider, but this might be related to the smaller size of specimens. The major spines of the pygidium are discrete from minor spines between them; in *P. evoluta* there are three pairs of spines between the major ones and one of these is rooted in the major spines. *P. bestorpensis* Bruton possesses three more pairs of pygidial spines than *P.* sp. x and *P. multispinosa* Bruton has at least five more pairs.

Primaspis primordialis (Barrande) differs in having paired occipital spines on the glabella. In *P. ascitus* Whittington (1956b, p. 199–205, pl. 1, 2) the surface ornamentation is more densely tuberculate, the posterior border of the cranidium including the back of the occipital ring is tuberculate rather than smooth, and the pygidial spines number six pairs of which one is based on the major spines.

All of the species of *Primaspis* described by Whittard (1961, p. 199–204, pl. XXVII) differ from *P.* sp. x either in number of pygidial spines or proportions of the cranidial features. In *P. whitei* there are 17 spines on the ventral border of the free cheeks, wider fixed cheeks, and 2 more pairs of pygidial spines. *Primaspis simulatrix* has more elongate glabellar lobes 1*p*, and a pygidium with many more spines. *P. rorringtonensis* differs in its very densely spaced tubercles on the surface.

Primaspis semievoluta Reed (Dean, 1962, p. 122, pl. 17, figs. 3, 13) has narrower fixed cheeks, but like *P. halli* has a total of five pairs of pygidial spines.

Primaspis harnagensis (Bancroft) (Dean, 1963, p. 237–238, pl. 44, figs. 1, 4, 6, 8) has longer (exsag) glabellar lobes 1*p*, and narrower (tr) fixed cheeks than *P.* sp. x; there are four pairs of pygidial spines in front of the major pair. *P. caractaci* (Salter) possesses one more posterior pair of pygidial spines (Dean, 1963, p. 240).

Bruton (1968a, p. 13–14, pl. 2, fig. 5) noted that *P. peregrina* (Barrande) "has a smooth posterior margin of the occipital ring" and may be the only previously described species to share this feature with the specimens from Kentucky.

Primaspis sp. y

Plate 6, figures 3–16

This species is represented by 3 fragmentary cranidia, 2 librigenae, 10 incomplete pygidia, and 2 fragments of thoracic segments from collection 5015 CO, and 2 fragmentary cranidia, 4 librigenae, 5 incomplete pygidia, and numerous fragments of thoracic segments from collection 6915 CO.

The proportions of the cranidia of this species are almost identical to those of *Primaspis* sp. x, but a few significant differences exist, even though none of the cranidia is fully mature. The surface of the occipital ring in *Primaspis* sp. y is tuberculate over its entire surface; the large median tubercle is positioned high on the posterior part.

On the librigenae, 13 large tubercles or short spines ornament the ventral side of the border.

Six pairs of marginal spines ornament the pygidium. The major spines diverge initially at an angle of 30°; a very short distance behind the pygidial margin they curve inward so that their tips converge at an angle less than 15° without meeting. Three pairs of anterior spines decrease in size forward. Of the two pairs of posterior spines the median pair is the larger; the second smaller pair is rooted in the base of the major pair of spines.

Illustrated specimens.—USNM 206865–206870 inclusive.

Occurrence.—Salvisa Bed of Perryville Limestone Member of Lexington Limestone, USGS collection 6915 CO, USGS collection 5015 CO.

Discussion.—*Primaspis* sp. y differs from *P.* sp. x in lacking a smooth posterior border of the occipital ring. But the most striking difference is in the pygidium. In *P.* sp. y the major spines diverge at 60°, and they maintain that angle throughout their length; there are only two rather than three pairs of anterior border spines and both posterior pairs of spines are discrete from the major spines.

Primaspis sp. y differs significantly from *P. ascitus* Whittington only in the direction of recurving of the major pygidial spines and in the size of the posterior spines that arise from the bases of the major spines. Whittington (1956b, p. 205) noted that the number of anterior border spines in *P. ascitus* is reduced with an increase in pygidial size from a sagittal length of 0.9 to 1.35 mm. In *Primaspis* sp. y a series of pygidia shows no change in number of border spines although the sagittal length, exclusive of the articulating half ring, ranges from 0.75 to 1.5 mm. The close resemblance to *P. ascitus* suggests that the Salvisa Bed may be correlative with the lower part of the Martinsburg Shale north of Harrisonburg, Va.

Primaspis semievoluta has one fewer pair of pygidial spines than does *P.* sp. y and *P. harnagensis;* there are four rather than three pairs in front of the major spines. *P. evoluta* has two pairs of anterior and three pairs of posterior spines.

Associated with the small specimens assigned to *Primaspis* sp. y in collection 5015 CO are a large cranidium and pygidium (pl. 6, figs. 17–19, 21–23), which may be mature specimens of the same species. They are tentatively designated as *Acidaspis* sp. a, however.

Genus ACIDASPIS Murchison, 1839

Acidaspis? sp. a

Plate 6, figures 17–19, 21–23

A large cranidium and part of a large pygidium are associated with *Primaspis* sp. y in USGS collection 5015 CO. Because of the number of border spines it is unlikely that the pygidium could belong to *Primaspis* sp. y; it resembles more closely pygidia of *Acidaspis.* The cranidium lacks the enormous occipital spine of *Acidaspis,* although the obtusely pointed extension of the occipital ring can be interpreted as such a spine. This cranidium may be a large mature specimen belonging to *Primaspis* sp. y. Until additional material is discovered, the correct generic and specific assignment of these two specimens is uncertain.

Sagittal length of cranidium is 6 mm, more than twice that of any cranidium here assigned to *Primaspis* sp. y. Cranidial length (sag) equals 0.6 width (tr) at posterior margin and 0.7 width at palpebral lobes. Length (sag) of glabella including occipital ring is 0.94 sagittal length of cranidium but length of glabella excluding occipital ring only 0.6 cranidial length. Length (sag) of occipital ring about 0.6 length of glabella in front of ring. Longitudinal furrows and occipital furrow shallow and broad, devoid of tuberculation. Middle lobe of glabella narrower (tr) than lateral lobe 1*p* and only slightly wider than greatest width (tr) of fixed cheek. Width (tr) of glabella at lobes 1*p* equals 1.5 sagittal length of glabella excluding occipital ring and 0.7 transverse width of cranidium between palpebral lobes.

Narrow distinct dorsal furrows curve inward around lobes 1*p* to join occipital furrow. A very short, shallow crescentic furrow branches from longitudinal furrow to indent the inner side of lobes 1*p*; this feature previously described only for *Acidaspis aviensis* Bruton (1968b, p. 300, fig. 12). Lateral furrows 1*p* and 2*p* subparallel and deep, clearly defining 2*p*. Furrow 3*p* very faint so that 3*p* is poorly defined and barely separated from frontal lobe. Three pairs of posterior border spines, of which the outer pair is rooted in the inner side of the major spines.

Illustrated specimens.—USNM 206871, 206872.

Occurrence.—Salvisa Bed of Perryville Limestone Member of Lexington Limestone, USGS collection 5015 CO.

Discussion.—The sagittal length of the occipital ring is longer (relative to the width of the ring) than in known species of *Primaspis.* The peculiar indenting of the inner side of glabellar lobe 1*p* is shared by *Acidaspis* sp. b described here. However, in *A.* sp. b, the indenting furrow seems to be a continuation adaxially of furrow 1*p*, whereas in sp. a it may be a minute indistinct anterolateral branch of the longitudinal furrow. Other species of *Acidaspis* may exhibit this feature, although it seems to have gone unnoticed in previous descriptions; it appears to be present in *A. grayi* Barrande (Bruton, 1968a, pl. 5, figs. 4, 6).

Acidaspis sp. b

Plate 6, figures 20, 24–26

The following description is based on a damaged silicified cranidium and a fragmentary silicified pygidium.

As in other species of *Acidaspis*, the axial lobe of the cranidium is composed of a short wide glabella and an occipital ring dominated by a huge median spine. The occipital furrow is shallow medially; it curves back across the longitudinal furrows and around the posterior ends of lateral glabellar lobes 1*p* to reach the axial furrows. Axial furrows are shallow but distinct in bounding the glabella; from their junction with the occipital furrow behind the lateral lobes 1*p*, they diverge to bound the occipital ring, turning straight back at the border furrow to cross the margin. At the posterior margin the width (tr) of the occipital ring is 1.3 times the sagittal length of the glabella.

The glabella is widest at lateral lobes 1*p*. The sagittal glabellar length is 0.7 width (tr) at lobes 1*p*, 0.9 width (tr) at lobes 2*p*, and 1.22 times width (tr) at lobes 3*p*. Each lateral lobe 1*p* is broadly elliptical and only moderately inflated; length (exsag) is half the sagittal length of glabella. The length (exsag) of lobe 2*p* slightly overlaps lobe 1*p* and is one-third the glabellar length.

Lobe 3*p* is minute; its width (tr) exceeds its length (exsag), which is only 0.13 the sagittal glabellar length. The longitudinal furrow does not alter lobe 3*p*, but originates in the proximal end of furrow 2*p*, from whence it runs back shallowly to meet the occipital furrow; from the junction a short sharply incised furrow curves inward and backward about halfway across the occipital ring. This short furrow might be considered the terminus of the longitudinal furrow. It partially defines a small occipital lobe.

Palpebral lobes are short (exsag), semierect, and positioned opposite the occipital furrow. The palpebral rims and furrows are confluent forward with the eye ridges, which converge to the anterior border furrow, where they terminate against the frontal lobe of the glabella. Anteriorly the facial sutures converge to the border furrow (but not as much as the eye ridges), and cross the border to the front margin where a connective suture parallels the margin. The course on the doublure is not known. Posteriorly the suture runs downward almost to the border furrow, turns laterally parallel to the furrow, and then crosses furrow and border at an angle; the width (tr) of cranidium at the border is 1.6 times the sagittal length of the glabella.

The fragmentary pygidium excluding spines seems to have been about four times as wide as long. The axis must have been composed of two rings and a terminal piece, all crudely defined. The anterior ring is linked by a raised ridge with a pair of coarse marginal spines. Six smaller pairs are arranged three in front of and three between the major spines; the inner pair adjacent to the major spines is based indistinctly on the larger spines.

Illustrated specimens.—USNM 206873, 206874.

Occurrence.—USGS collection 7343 CO. Top of tongue of Clays Ferry Formation 0.9 mi south of Lair; Kentucky coordinates: E. 1,983,700 ft, N. 302,000 ft, Shawhan quadrangle, Kentucky.

Discussion.—The single silicified cranidium described here is almost identical in proportions to that illustrated by Ross (1967, pl. 5, fig. 20); the only difference is the seeming absence of lateral glabellar lobe 3*p* in the previously illustrated specimen. Whether the contrast between limestone and silicified preservation could account for this difference is doubtful, but possible.

The peculiar indenting of glabellar lobe 1*p* adjacent to the longitudinal furrow has been previously discussed, under *Acidaspis* sp. a.

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PLATES 1-6

Contact photographs of the plates in this report are available, at cost from U.S. Geological Survey Library, Federal Center, Denver, Colorado 80225

PLATE 1

[All illustrations are stereophotographs except figures 14 and 15]

FIGURES 1–13. *Triarthrus eatoni* (Hall) (p. D2).

Kope Formation, Laurel 7½-minute quadrangle, Kentucky, All figures × 5.

- 1–3. Complete individual, enrolled. Relative to cephalon, dorsal, anterior, and lateral views. UCM 40633a.
- 4–6. Complete individual, enrolled. Relative to cephalon, dorsal, anterior, and lateral views. UCM 40633b.
- 7–9. Complete individual, enrolled. Relative to cephalon, dorsal, anterior, and lateral views. UCM 40633d.
- 10–12. Complete individual, enrolled. Relative to cephalon, dorsal, anterior, and lateral views. UCM 40633e.
- 13. Partly enrolled individual on pleural tips showing lateral projections that fit snugly against doublure of cephalon. UCM 40633c.

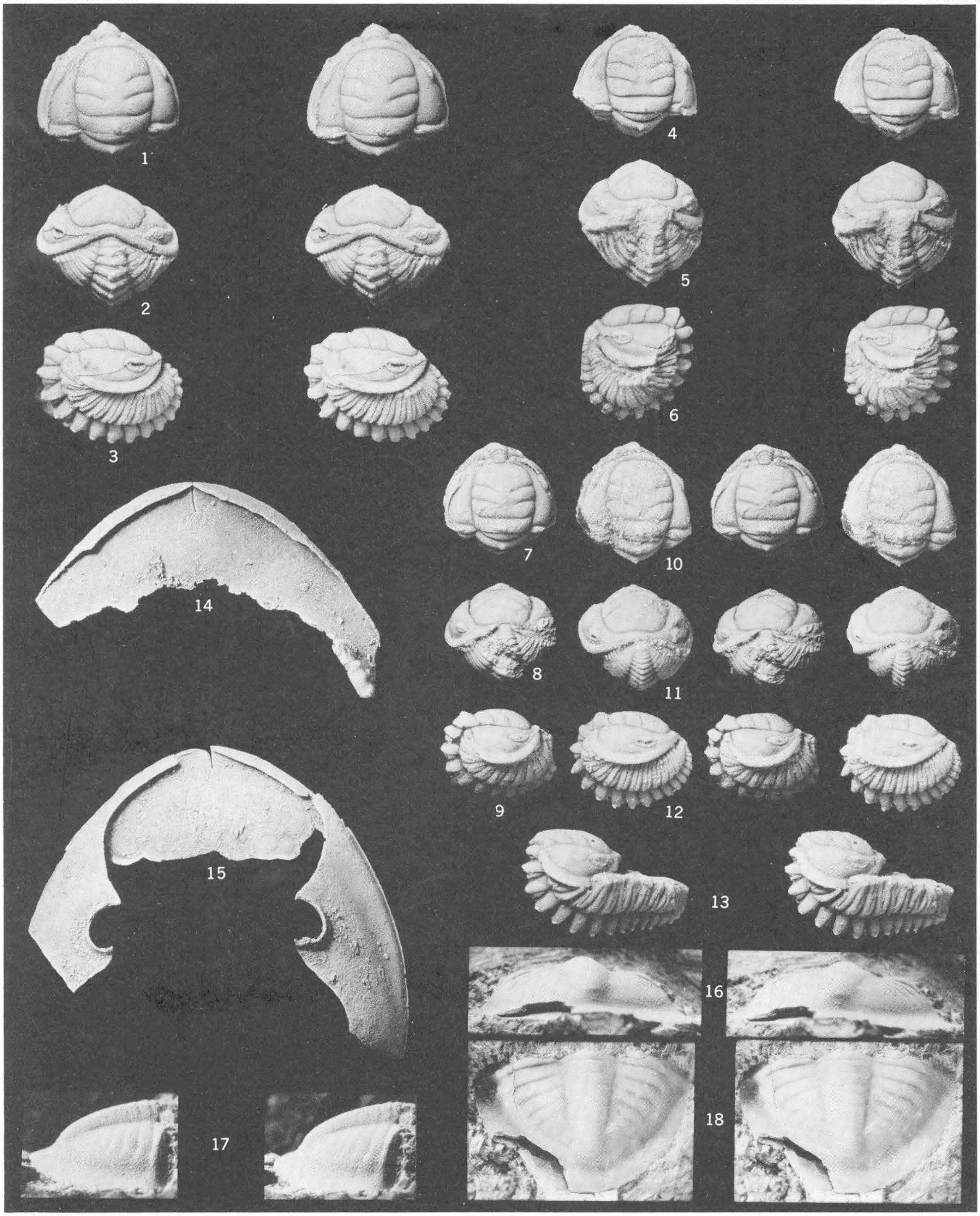
14, 15. *Isotelus gigas* DeKay (p. D5).

USGS colln. 5015 CO, Perryville, Ky. Dorsal views of yoked doublure of free cheeks. Median suture no longer functional. USNM 206844, 206845 (× 1).

16, 17, 18. Megalaspid(?) pygidium (p. D5).

Posterior, lateral, and dorsal views, (× 3).

USNM 206846. Camp Nelson Limestone, USGS colln. 7875 CO.



TRIARTHRUS, *ISOTELUS*, MEGALASPID(?)

PLATE 2

[All figures are stereophotographs]

FIGURES 1–6. *Decoroproetus* sp. x (p. D3).

Two partly enrolled individuals, only partly silicified. USGS colln. 6143 CO, Clays Ferry Formation, Cynthiana quadrangle, Kentucky.

1–3. Specimen preserving preglabellar field anterior border, thoracic and pygidial axis (× 5), USNM 206836.

4–6. Specimen preserving part of genal spine; hypostoma in place (× 4), USNM 206837.

7–16. *Decoroproetus* sp. 2 (p. D4).

USGS colln. 5015, Perryville Limestone Member of Lexington Limestone Perryville quadrangle, Kentucky. All figures (× 4).

7–9. Pygidium, dorsal, posterior, and lateral views, USNM 206838.

10–12. Pygidium, lateral, dorsal, and posterior views, USNM 206839.

13, 14. Librigena, dorsal and ventral views, USNM 206840.

15, 16. Librigena, ventral and dorsal views, USNM 206841.

17. Pygidium undetermined, not described.

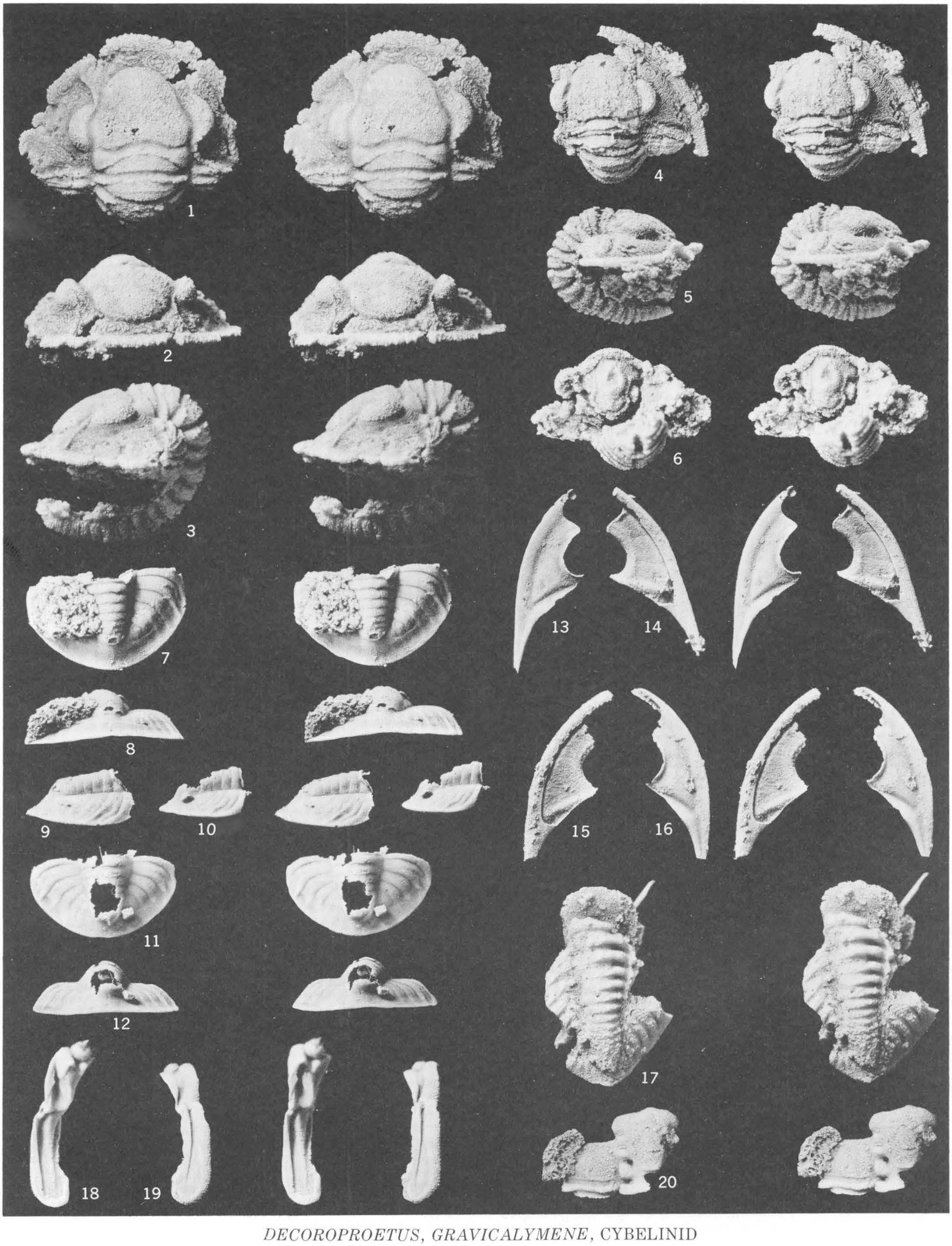
USGS colln. 6419 CO, Logana Member of Lexington Limestone, Wilmore quadrangle, Kentucky. USNM 206843.

18, 19. *Gravicalymene hagani* Ross (p. D5):

Thoracic segment showing construction of pleural tip (× 3), USGS colln. 5015 CO. USNM 206849. Note smooth facet and vincular stop.

20. Cybelinid cranidium (p. D5).

Dorsal view (× 2). USNM 206842. USGS colln. 6419 CO, Logana Member of Lexington Limestone, Wilmore quadrangle, Kentucky.



DECOROPROETUS, *GRAVICALYMENE*, CYBELINID

PLATE 3

[All figures are stereophotographs]

FIGURES 1–9. *Gravicalymene hagani* Ross (p. D5).

USGS colln. 5015 CO. Perryville Limestone Member of Lexington Limestone.

1–3. Cranidium, inmature, dorsal, anterior, and lateral views (× 4). USNM 206847.

4. Cranidium, large (possibly gerontic), showing apodemes for attachment of hypostoma. Ventral view (× 2). USNM 206850.

5. Hypostoma, ventral view (× 5). USNM 206852.

6–8. Cranidium, mature, lateral, dorsal, and anterior views (× 2). USNM 206848.

9. Cranidium, ventral view (× 2), showing apodemes for attachment of hypostoma. USNM 206851.

10. *Flexicalymene* sp. (p. D6).

Partial cranidium, dorsal view (× 5). USNM 206856. USGS colln. 6129 CO., Ashlock Formation.

11–20. *Gravicalymene truncatus* n. sp. (p. D6).

USGS colln. 7984 CO, Kope Formation, Moffett Road section, Demossville quadrangle, Kentucky.

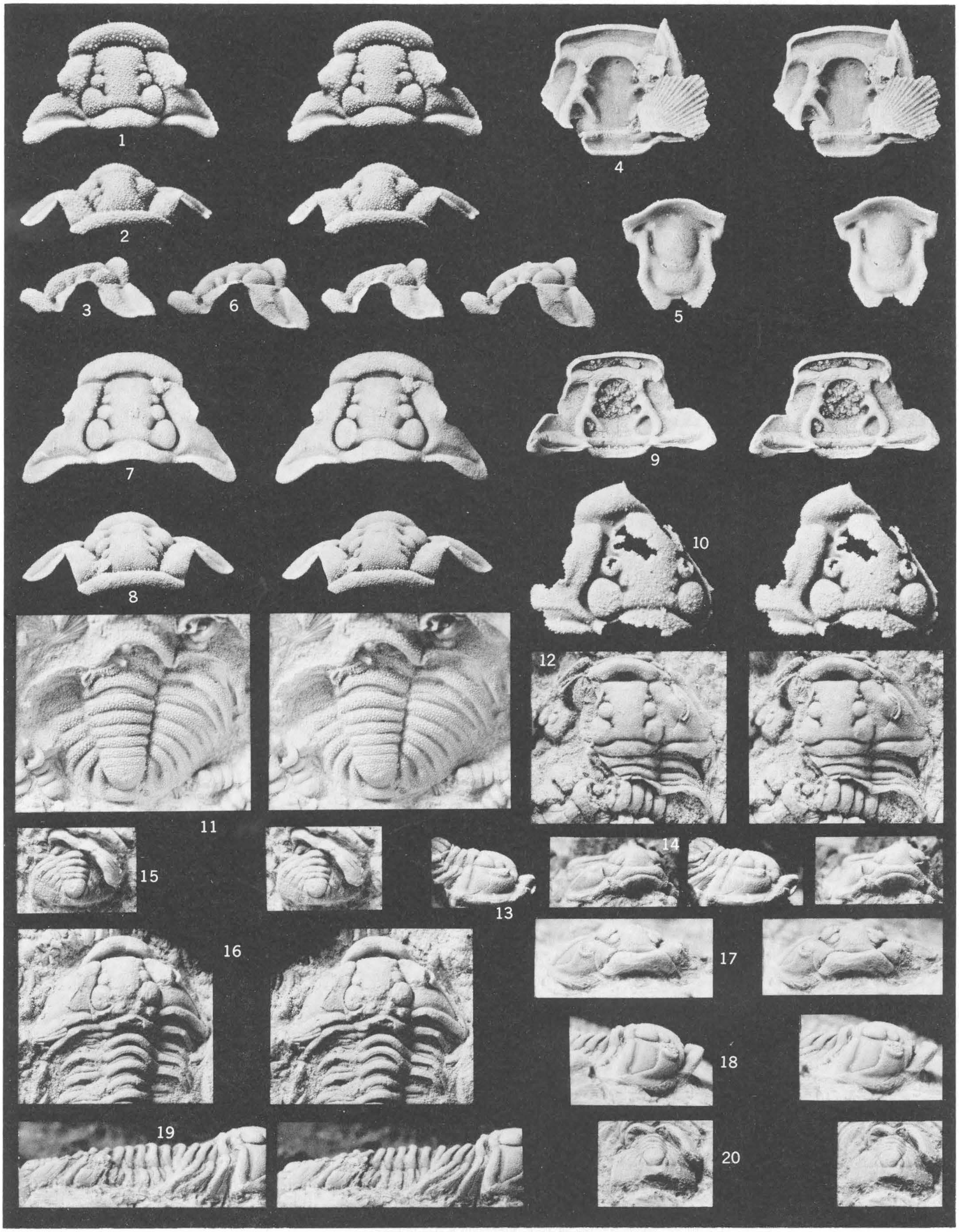
11. Large associated pygidium, paratype, dorsal view (× 3). USNM 206853.

12–14. Partial cephalon, paratype, dorsal, lateral, and anterior views (× 4). USNM 206855.

15, 20. Pygidium, dorsal and posterior views (× 3). Same pygidium shown on left in figure 19. USNM 206854 (same no. as figs. 16 and 19).

16–18. Cephalon and anterior part of thorax (same shown in fig. 19), holotype, dorsal, anterior, and lateral views (× 3). USNM 206854.

19. Thorax, lateral view of holotype, same specimen as in figures 15–18, 20. USNM 206854.



GRAVICALYMENE, FLEXICALYMENE

PLATE 4

[All figures are stereophotographs]

FIGURES 1–7. *Platylichas halli* (Foerste) (p. D7).

USGS colln. 7343 CO. Tongue of Clays Ferry Formation, Shawhan quadrangle, Kentucky.

1. Hypostoma, ventral view (× 5), of a partially silicified specimen. USNM 206857.

2–4. Cranidium, dorsal, lateral, and anterior views (× 3). USNM 206858.

5–7. Cranidium, dorsal, anterior, and lateral views (× 2). USNM 206859.

8–11. *Primaspis trentonensis* (Hall) (p. D8).

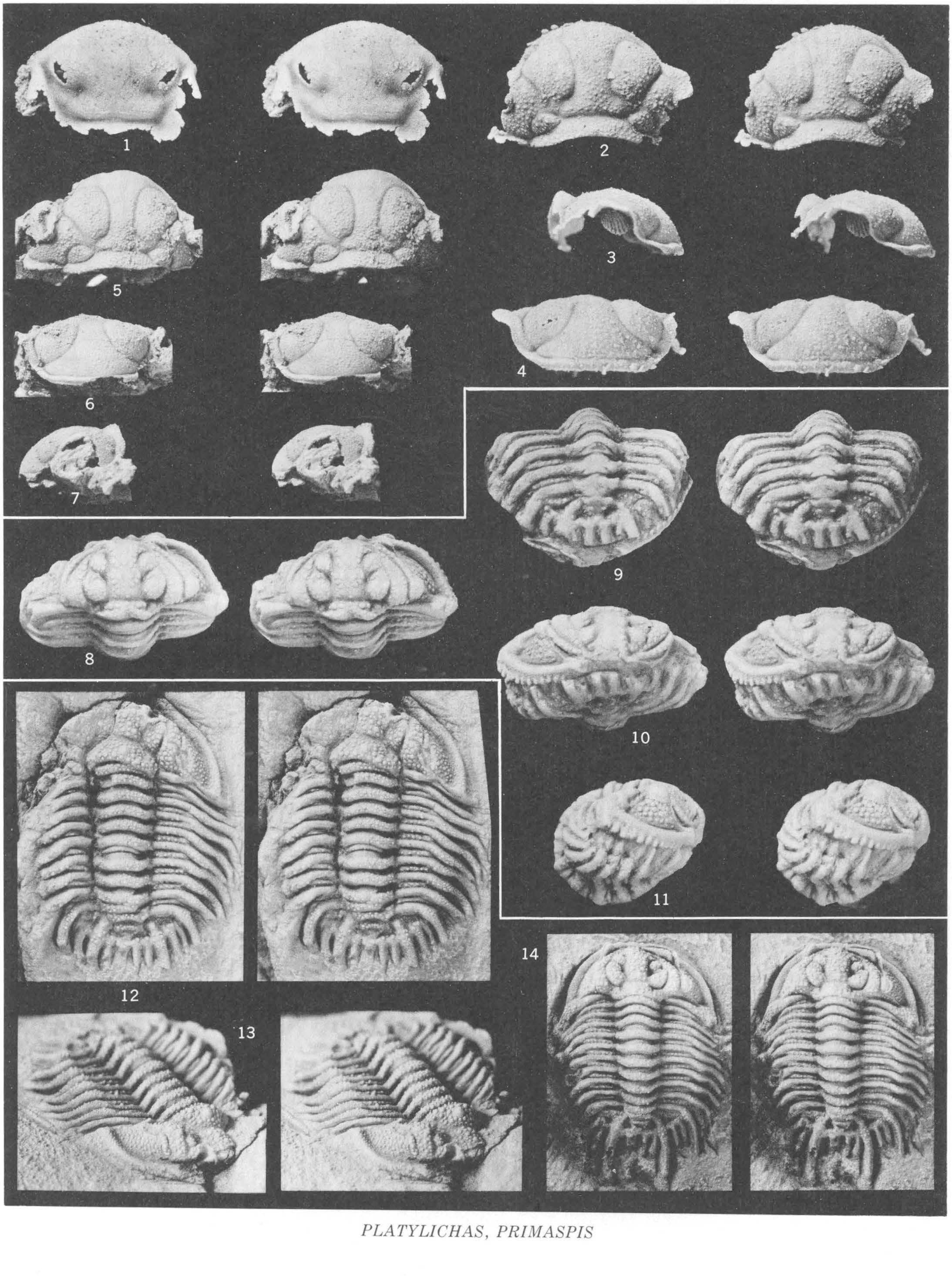
Holotype, illustrated by Hall (1847, pl. 64, fig. 4) and by Whittington (1941, pl. 74, figs. 31–34). Enrolled individual, views relative to cephalon are dorsal, ventral, anterior and lateral (× 6). AMNH 853/2. Bay of Quinte, Ontario.

12–14. *Primaspis "trentonensis"* (p. D8).

Trenton Group near Trenton Falls, N.Y., (× 5). Previously illustrated by Whittington (1941, pl. 74, figs. 35–37) but not same species as Hall's holotype.

12, 13. Individual showing ornament of occipital ring and arrangement of pygidial spines. NYSM 9774.

14. Individual demonstrating cephalic features. NYSM 9773.



PLATYLICHAS, PRIMASPIS

PLATE 5

[All figures are stereophotographs]

FIGURES 1–14. *Primaspis* sp. x (p. D9).

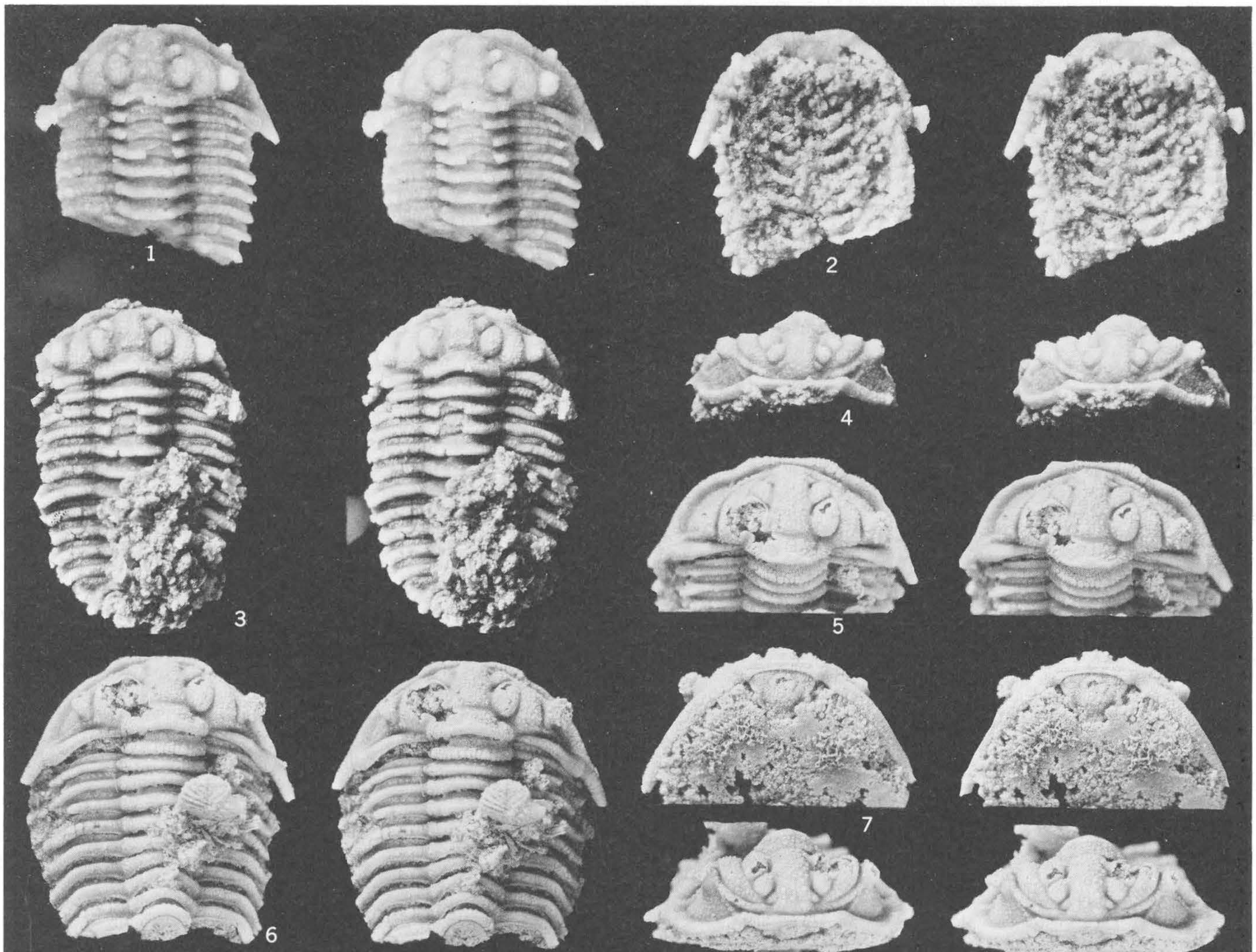
Clays Ferry Formation, Cynthiana and Shawhan quadrangles, Kentucky.

1, 2. Cephalon and partial thorax with silicified casts of appendages crudely preserved on ventral side (× 7). USNM 206860. USGS colln. 6143 CO.

3, 4. Nearly complete individual. Dorsal and anterior views (× 7). USNM 206861. USGS colln. 6143 CO.

5–9. Partial specimen, lacking posterior thorax and pygidium. Views of dorsal cephalon, thorax, ventral cephalon and hypostoma, anterior cephalon, and lateral (× 5). USNM 206863. USGS colln. 7343 CO.

10–14. Complete individual (× 5). USNM 206862. USGS colln. 6990 CO. Stumps of appendages may be partly preserved on ventral side in figure 11. Compare pygidium in figure 12 with that in plate 6, figure 1.



PRIMASPIS

PLATE 6

[All figures are stereophotographs]

FIGURES 1–2. *Primaspis* sp. x (p. D9).
Thorax and pygidium showing fine ornament. Dorsal and lateral views (× 5). USNM 206864. USGS colln. 7343 CO.

3–16. *Primaspis* sp. y (p. D10).
Salvisa Bed of Perryville Limestone Member of Lexington Limestone, USGS colln. 6915 CO, except figs. 13, 14.

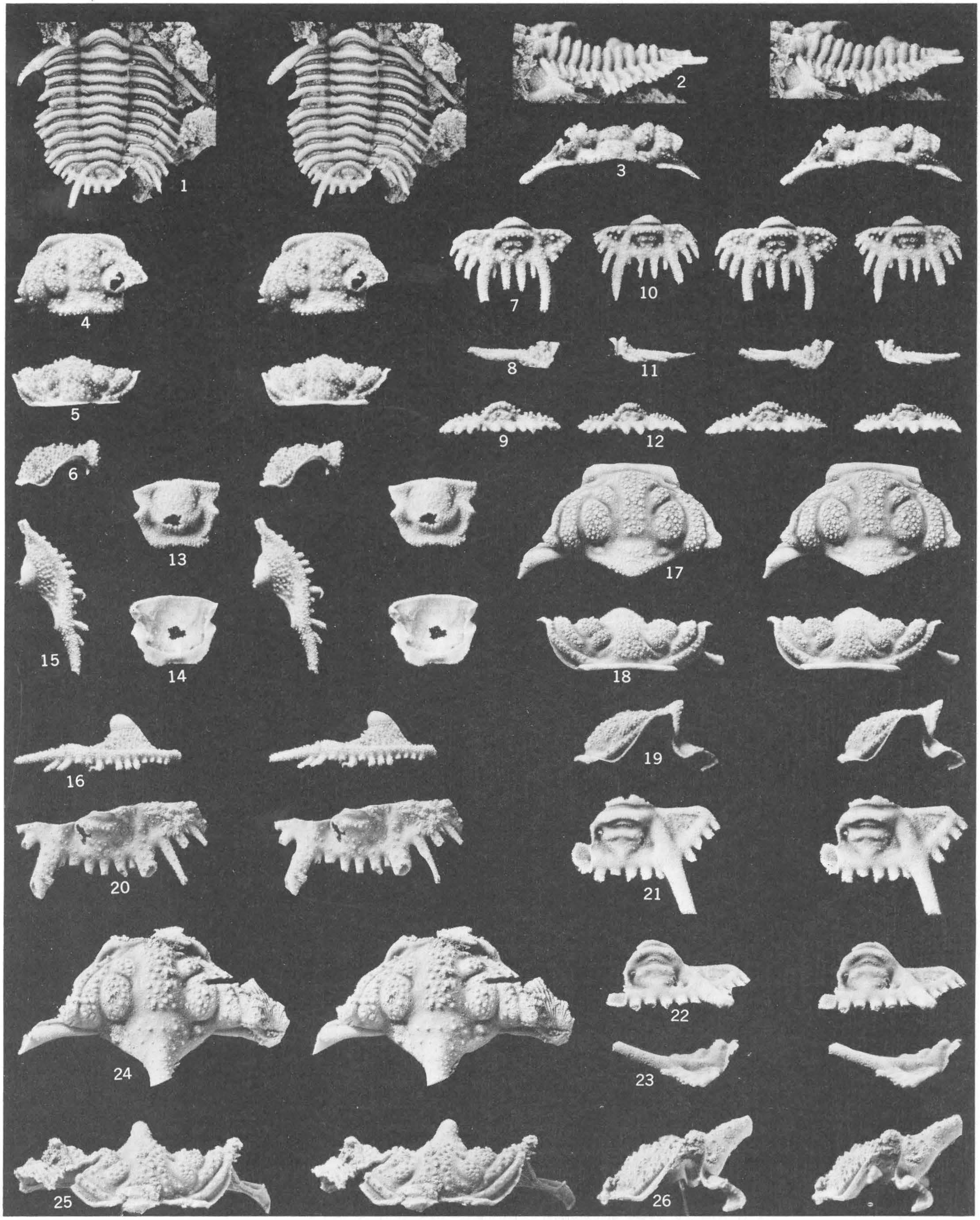
- 3. Posterior part of cranidium, dorsal view showing full width (tr) at posterior border and occipital lobes (× 6). USNM 206865.
- 4–6. Cranidium lacking posterior part of fixed cheeks. Dorsal, anterior, and lateral views (× 7). USNM 206866.
- 7–9. Pygidium, dorsal, lateral, and posterior views (× 7). USNM 206868.
- 10–12. Pygidium, dorsal, lateral, and posterior views (× 7). USNM 206869.
- 13, 14. Hypostoma, ventral and dorsal views (× 7). USNM 206870. USGS colln. 5015 CO.
- 15, 16. Librigena, dorsal and lateral views (× 7). USNM 206867.

17–19, 21–23. *Acidaspis*? sp. a (p. D11).
USGS colln. 5015 CO, Salvisa Bed of Perryville Limestone Member of Lexington Limestone.

- 17–19. Cranidium; dorsal, anterior, and lateral views (× 4). USNM 206871.
- 21–23. Pygidium, lacking left pleural region and tips of all spines. Dorsal, posterior, and lateral views (× 4). USNM 206872.

20, 24–26. *Acidaspis* sp. b. (p. D12).
USGS colln. 7343 CO. Tongue of Clays Ferry Formation.

- 20. Pygidium, poorly preserved; dorsal view (× 3). USNM 206874.
- 24–26. Cranidium, dorsal, anterior, and lateral views (× 3). USNM 206873.



PRIMASPIS, ACIDASPIS

Edrioasteroids (Echinodermata)

By BRUCE M. BELL

CONTRIBUTIONS TO THE ORDOVICIAN PALEONTOLOGY OF KENTUCKY AND NEARBY STATES

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1066-E

Prepared in cooperation with the
Commonwealth of Kentucky,
University of Kentucky,
Kentucky Geological Survey

Descriptions and illustrations of six species,
with comments on their morphology and distribution

CONTENTS

ILLUSTRATIONS

CONVERSION FACTORS

The investigations underlying this series of reports were made over a period of years, and distances and stratigraphic measurements appear fairly uniformly in English units. Measurements of fossil specimens, on the other hand, follow the longstanding convention of appearing in metric units. Because of the dates of the investigations and the amount of resulting data, the English measurements have been retained. Conversions to metric units may be made by using the following conversion table:

To convert English unit:	To metric unit:	Multiply by:
Mile (mi)	Kilometer (km)	1.61
Foot (ft)	Meter (m)	.305

EDRIOASTEROIDS (ECHINODERMATA)

By BRUCE M. BELL[1]

ABSTRACT

Seven edrioasteroids that belong to six species are described. The new material revises the known geographic and stratigraphic ranges of the species and provides the first known specimen on which the entire attachment structure of *Edrioaster* is preserved. No new taxa are described.

INTRODUCTION

Seven edrioasteroids were found during this investigation of the Ordovician of Kentucky and nearby States. Five are silicified through replacement of the calcareous plates by beekite; they were recovered from acid residues. Silicification has obliterated most sutures but has preserved the thecal shape. The other two specimens retain the primary calcareous composition of the plates. They were isolated from the bulk samples in the field and were not acidized.

The seven specimens represent six known species. The specimens extend the range of their respective taxa. Moreover, one specimen shows a rare intraspecific variation, and another preserves an attachment structure previously quite poorly known.

SYSTEMATIC PALEONTOLOGY

Phylum ECHINODERMATA Bruguiere
Class EDRIOASTEROIDEA Billings, 1858
Order ISOROPHIDA Bell, 1976
Suborder LEBETODISCINA Bell, 1976
Family CARNEYELLIDAE Bell, 1976
Genus CARNEYELLA Foerste, 1917

Carneyella pilea (Hall, 1866)

Figure 1; plate 1, figures 1-3

Carneyella pilea has a domal theca averaging 16 mm in diameter in adults; it has three central primary oral plates and one large hydropore oral; the hydropore slit is in the right-posterior part of the oral area formed by the two proximal coverplates of the posterior side of ambulacrum V, the large hydropore oral, and the right edge of the large posterior primary oral; the ambulacra form low rounded ridges and are curved (I–IV, contrasolarly; V, solarly); ambulacral terminations are confined to interambulacral areas; the ambulacral tunnel is low and wide; the ambulacral floorplates are uniserial and imbricate proximally; ambulacral coverplates are biserial and of moderate thickness; a coverplate passageway system connects the thecal cavity directly to the exterior of the theca; the passageways are oblique and their external foramina elliptical; the interambulacrals are squamose and imbricate; the anal structure is a periproct; the peripheral rim plates are geniculate; theca prosopon includes small nodes sparsely scattered over the interambulacrals and rim plates, and small perradial ridges on the ambulacral coverplates.

Discussion.—Figure 1 shows USNM specimen 170362 from USGS locality 6699–CO, Point Pleasant Tongue of the Clays Ferry Formation.

This specimen retains the calcareous composition of its plates. It appears to have been attached directly to a

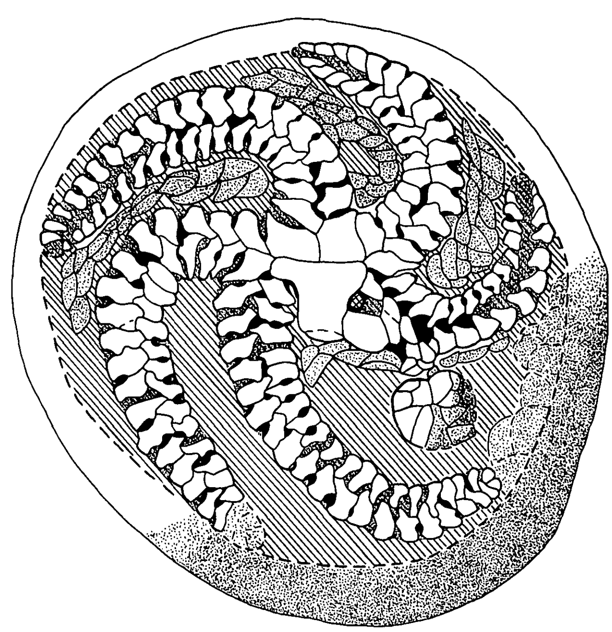


FIGURE 1.—*Carneyella pilea* (Hall, 1866). USNM 170362. Oral surface, X 3.5.

[1]New York State Museum and Science Service. Published by permission of the Director, New York State Museum and Science Service, Journal Series No. 155.

hardground substrate. The theca is nearly complete except for the interambulacral area, in which most plates are disrupted or missing. Many of the distal plates of the peripheral rim are hidden or absent. The exterior surface of the theca has been deeply etched, which has removed the surface detail and in some areas obscured plate boundaries.

USNM 170362 seems to be a typical adult *Carneyella pilea* except for ambulacrum V, which is reversed and curves contrasolarly. It appears that ambulacrum V has a small aborted branch which extends from the posterior side adjacent to the anal area. It is possible that this represents the primary axis of ambulacrum V, which stopped growing, whereas the secondary branch continued to lengthen and curve contrasolarly. It is also possible that this specimen is one of the extremely rare variants in which a primary ambulacrum has a reverse curvature.

The direction of ambulacral curvature is generally constant at the generic level in edrioasteroids, and thus it is employed as a primary taxobasis. However, it is not a sole determinant, for a suite of characters comprise the taxobases of a species. The anomalous ambulacrum found in USNM 170362 does not exclude the specimen from *Carneyella pilea;* all other features bespeak *C. pilea.*

This specimen is among the oldest known representatives of this species, which is most common in the later Ordovician.

Family LEBETODISCIDAE Bell, 1976
Genus CYSTASTER Hall, 1871
Cystaster stellatus (Hall, 1866)
Figure 2; plate 1, figures 5, 6

Cystaster stellatus has a small discoidal theca; adult thecal diameters are commonly 7 to 8 mm; three large primary orals are flanked laterally only by two pairs of shared coverplates; the hydropore is along the proximal part of the posterior side of ambulacrum V and is encompassed by the two proximal coverplates of the posterior side of ambulacrum V and two large interambulacrals, one interambulacral being larger than the other and having a prominent sickle-shaped ridge; the straight ambulacra are relatively broad; the ambulacral tunnel is high and narrow; the uniserial floorplates imbricate proximally; the thick, wide ambulacral coverplates form a biseries; a coverplate passageway system connects the thecal cavity directly to the exterior of the theca; the passageways are nearly vertical, and their external foramina are elongate; the interambulacral plates are squamose and imbricate; the anal structure is a periproct; the peripheral rim plates are squamose; large, rounded, irregular nodes cover the interambulacral and rim plates.

Discussion.—Figure 2 shows USNM specimen 206294 from USGS locality 6699–CO, Pt. Pleasant Tongue of the Clays Ferry Formation (7.4 mm axial by 6.8 mm transverse diameter).

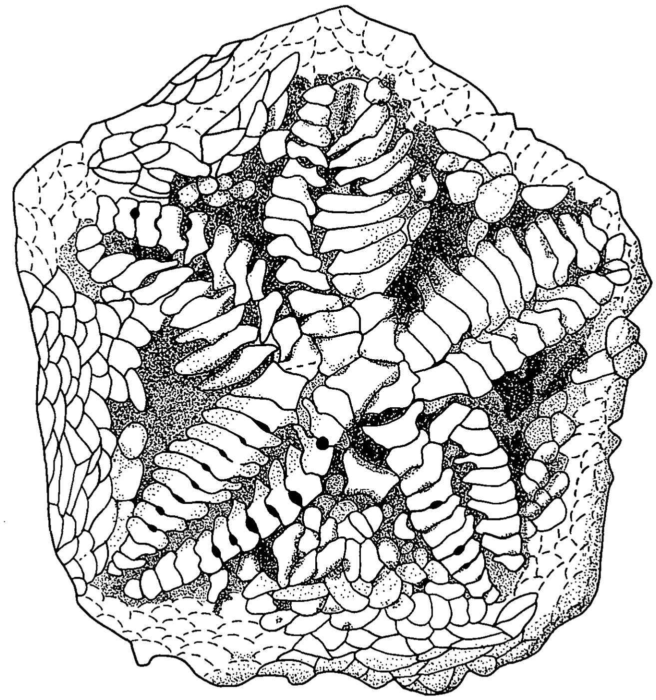


FIGURE 2.—*Cystaster stellatus* (Hall, 1866). USNM 206294. Oral surface, X 6.

This specimen is preserved retaining the primary calcareous composition of its plates. The theca is nearly complete. The interambulacrals are collapsed and partially disrupted, as is the periproct. The central sector of ambulacrum III is displaced somewhat to the left. The larger, posterior interambulacral plate of the hydropore structure is displaced toward the anus. This displacement exposes the stone canal passageway. The theca has been extensively etched, which exposes subsurficial views of the plates, particularly the ambulacral coverplates.

USNM 206294 is a typical *Cystaster stellatus.* It is one of oldest known specimens of the species, which is most common in the Cincinnatian Series.

Family LEBETODISCIDAE Bell, 1976
Genus STREPTASTER Hall, 1872
Streptaster vorticellatus (Hall, 1866)
Plate 1, figure 4

Streptaster vorticellatus has a domal theca that averages 15 mm in diameter and is totally dominated by the exceptionally high ambulacra. Three large primary orals are flanked by two pairs of lateral shared coverplates and several secondary oral plates; the hydropore opens along the proximal part of the posterior side of ambulacrum V; the hydropore structure comprises the second and third proximal coverplates of the posterior side of ambulacrum V and one large bulbous interambulacral. The ambulacra are all curved contrasolarly and dominate the theca; and the ambulacral tunnel is extremely high and narrow. The uniserial floorplates imbricate proximally; the coverplates are massive and so high that they are columnar; movable spines are mounted in basins atop the coverplates. The coverplate passageway system connects the thecal cavity directly to the thecal exterior through the vertical passageways. The external foramina are unusually elongate; the interambulacrals are squamose and imbricate; the anal structure is a periproct; the peripheral rim plates are geniculate; the rim and interambulacral plates are covered with large, rounded, irregular nodes.

Discussion.—Plate 1, figure 4, shows USNM specimen 206295, from USGS locality 7790–CO, Millersburg Member of the Lexington Limestone (11.2 mm axial by 10.4 mm transverse diameter).

The specimen is silicified and preserves only the peripheral rim, the ambulacra, and the oral area. It is clear that the ambulacra are all curved in a contrasolar direction, but it is difficult to identify individual ambulacra; therefore, the specimen may be improperly oriented in the plate.

Ambulacral disposition and the columnar coverplates favor placement of this individual in the genus *Streptaster*. That genus is believed to be monotypic, and thus the specimen apparently belongs to the type species *Streptaster vorticellatus*. This is the oldest known specimen of *Streptaster;* all other specimens come from the Cincinnatian Series.

Suborder ISOROPHINA Bell, 1976
Family ISOROPHIDAE Bell, 1976
Genus ISOROPHUS Foerste, 1917

Isorophus cincinnatiensis (Roemer, 1851)

Figure 3; plate 2, figures 1–3

Isorophus cincinnatiensis has a domal theca that is commonly 20 to 25 mm in diameter; the four large central primary orals are flanked by two pairs of lateral shared coverplates, one large hydropore oral, and five or more secondary oral plates; the slitlike hydropore is in the right-posterior part of the oral area. Five plates constitute the hydropore structure--the hydropore oral, the right edge of the large right-posterior primary oral, the right-posterior shared coverplate, and the first two primary posterior coverplates of ambulacrum V. The structure is integrated with the central oral rise. Ambulacra are curved (I–IV, contrasolarly; V, solarly); they are of moderate width and taper gradually distally. The floorplates are uniserial, and contiguous floorplates abut one another along vertical sutures; the ambulacral coverplates form a double alternating biseries of pairs—large primary and distinctly smaller secondary plates. Secondary coverplates rarely reach the external adradial suture line; interambulacrals are squamose and imbricate, interambulacral areas are of moderate size in proportion to thecal diameter. The valvular anal structure is formed by an inner and outer circlet of alternating large triangular plates; the plates of the peripheral rim are geniculate; the thecal plates are smooth.

Discussion.—Figure 3*A* and plate 2, figures 1–2, show USNM specimen 206296 from USGS locality 4929–CO, Grier Limestone Member of the Lexington Limestone, 8 ft below the base of the Brannon Member of the Lexington Limestone (6.6 mm axial by 6.5 mm transverse diameter).

This silicified edrioasteroid is attached to a brachiopod (*Rafinesquina* sp.) in which silicification has produced large beekite rings. The edrioasteroid is nearly complete; only interambulacral 1 and part of 3 have missing plates. The specimen is only partially depressed. Most sutures have been obliterated.

Figure 3*B* and plate 2, figure 3, show USNM specimen 206297 from USGS locality 7454–CO, Millersburg Member of the Lexington Limestone (5.1 mm axial by 5.4 mm transverse diameter).

Silicification of this specimen has obscured detail. The individual has been separated from its attachment site and the theca has been depressed, thereby accentuating the relative elevation of the ambulacral-oral structures.

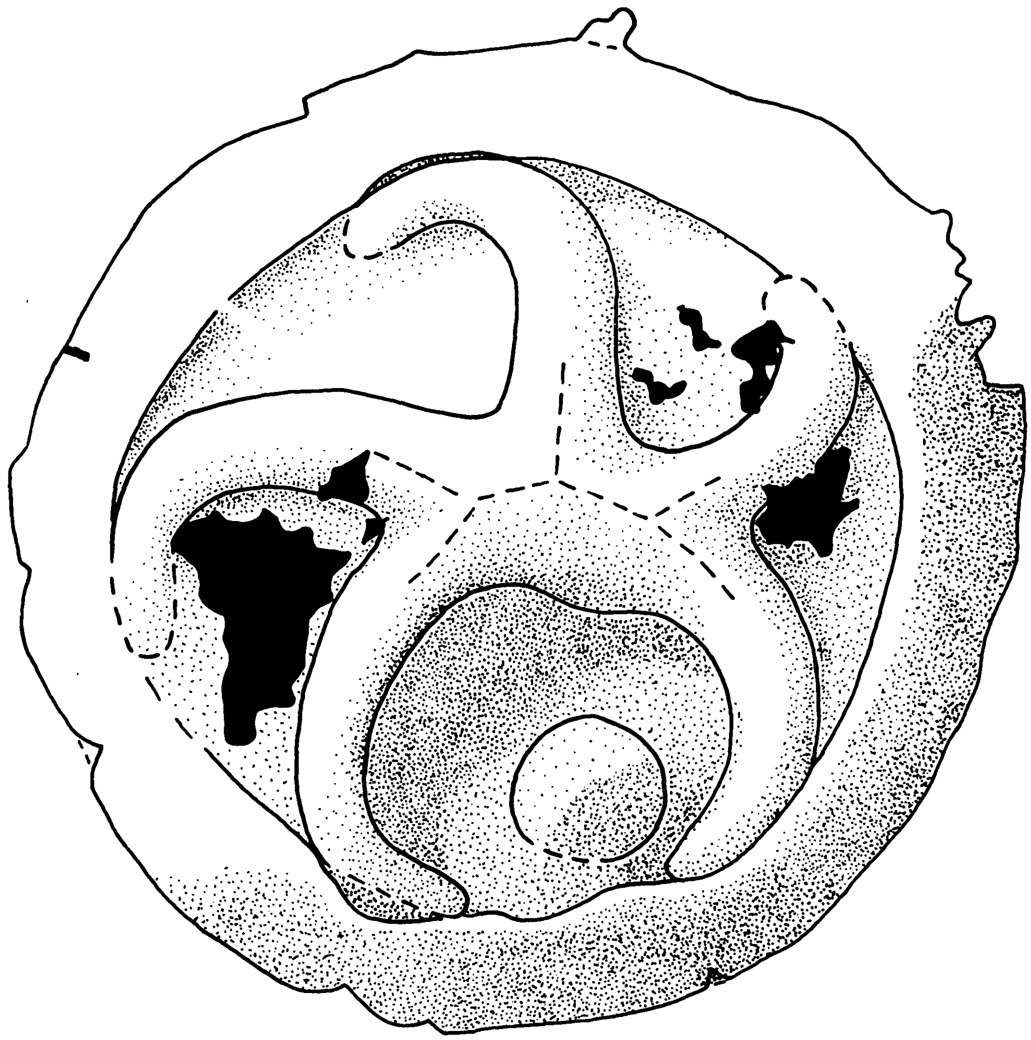
USNM 206296 and 206297 are both poorly preserved and cannot be assigned with assurance to any species. However, those features that can be recognized all suggest *Isorophus*, and it is likely that both specimens belong to the type species, *I. cincinnatiensis*, in that it is the most common species of the genus and is also the only one reported from equivalent horizons. Features suggesting this assignment include the curvature, length, width, and elevation of the ambulacra, the proportionally large size of the oral area, the valvular anal structure, and the apparent shape and position of the hydropore structure.

Order EDRIOASTERIDA Bell, 1976
Family EDRIOASTERIDAE Billings, 1858
Genus EDRIOASTER Billings, 1858

Edrioaster bigsbyi (Billings, 1857)

Plate 2, figures 4, 5

Edrioaster bigsbyi has a subgloboid theca with an invaginated base; adults are commonly 40 to 45 mm in diameter; the oral covering plates are similar to the ambulacral coverplates; the hydropore is in the posterior part of the oral area; the slitlike opening is elongate normal to the suture line between the two oral plates, which it penetrates. The ambulacra are curved (I–IV, contrasolarly; V, solarly); curvature is initiated above the am-



A

FIGURE 3.—*Isorophus* cf. *I. cincinnatiensis* (Roemer, 1851). *A*, USNM 206296, oral surface, X 6. *B*, USNM 206297, oral surface, X 7. Dashed lines represent likely sutures.

bitus. The biserial ambulacral floorplates house a sutural passageway system that connects the thecal cavity to the ambulacral tunnel. The ambulacral coverplates are biserial and sit on top of the floorplates without intrathecal extensions. Interambulacral plates are large, polygonal, and tessellate; the anal structure is a periproct; the margin of the oral surface is a flexible polyplated membrane that extends from the distal edge of the basal invagination of the theca down to the substrate; the exterior surfaces of the theca plates are nodose.

Discussion.—Plate 2, figures 4–5, shows USNM specimen 206298 from USGS locality 5022–CO, Curdsville Limestone Member of the Lexington Limestone (34.9 mm axial by 35.5 mm transverse diameter by 14 mm high).

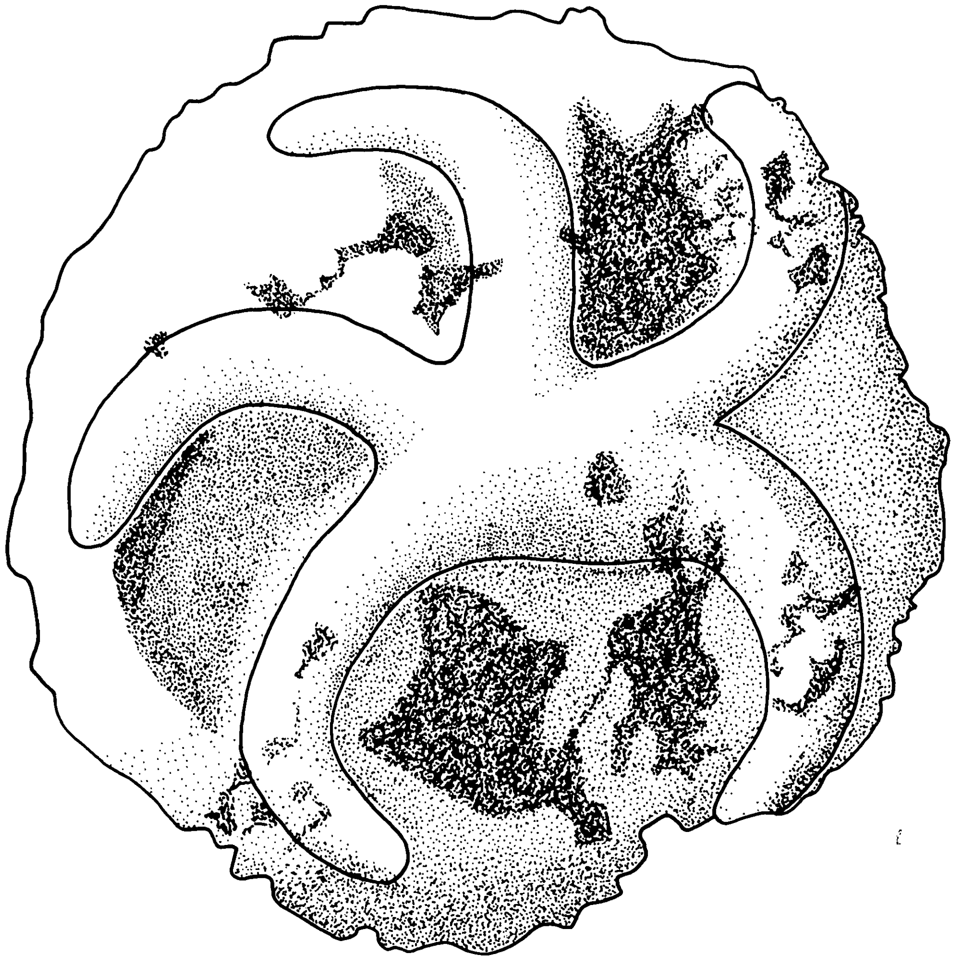
This specimen is fragmentary. Most of the plates of the upper oral surface are gone, and those of the lower side of the theca are hidden by matrix. However, the distal parts of all the ambulacra are preserved near or just below the ambitus. Moreover, most of the upper oral surface parts of ambulacra I and V and interambulacra 4 and 5 are preserved. The theca apparently remained inflated after burial, and the thecal cavity is filled with crystalline calcite. This filling demonstrates the size and shape of the specimen even though most of the upper oral surface is missing.

The ambulacral structure and disposition clearly establish that this specimen is an *Edrioaster.* Its large size and lack of any unusual features suggest it is a member of the type species, *E. bigsbyi.* This individual extends the geographic range of the species, which previously was known only in Ontario and Michigan.

Edrioaster priscus (Miller and Gurley, 1894)

Figure 4; plate 2, figures 6–9

Edrioaster priscus is very similar to *E. bigsbyi* but is thought to be smaller (commonly 15 to 19 mm in diameter), to have smooth exterior surfaces on its plates, and



B

FIGURE 3.—Continued.

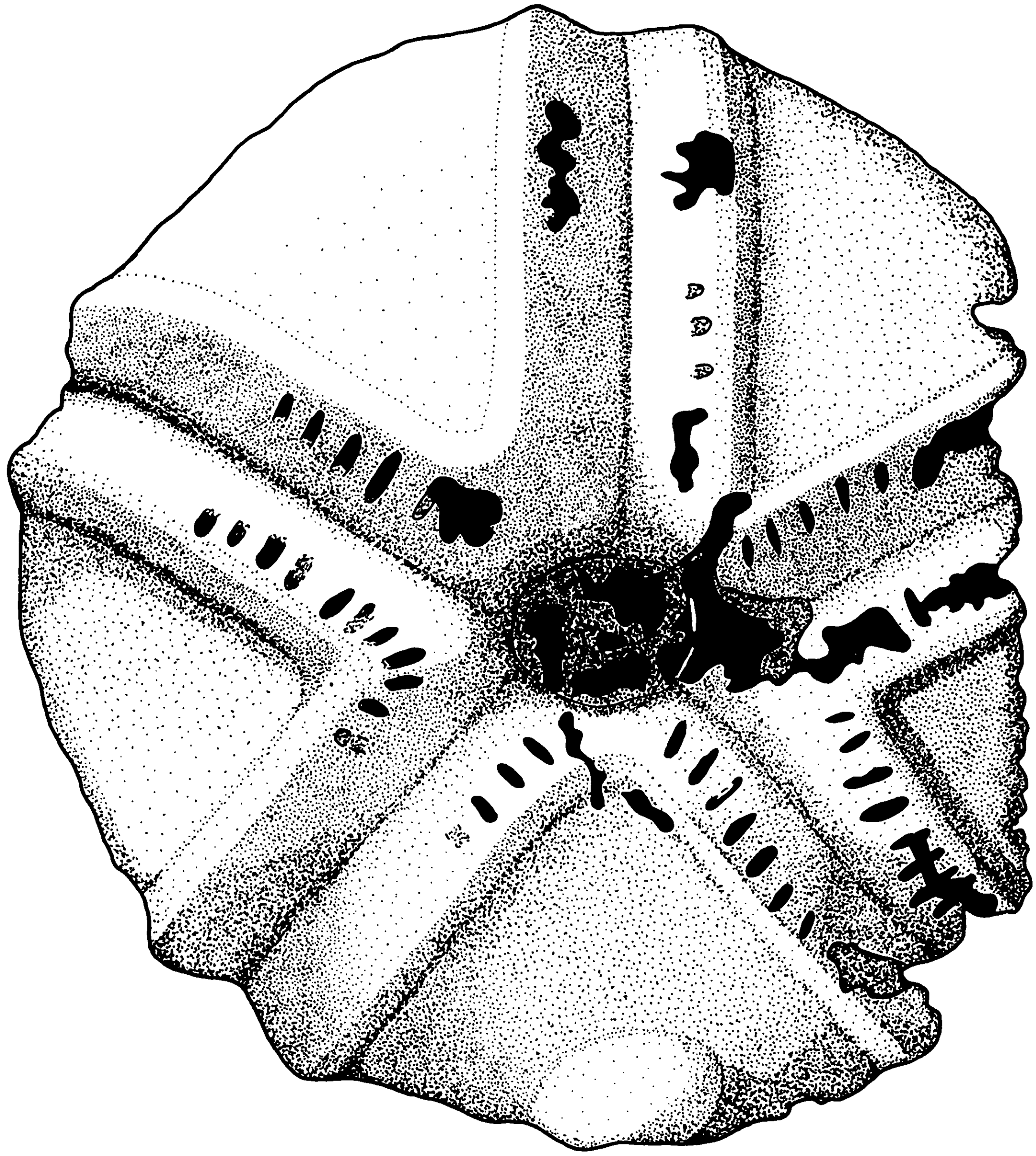
to have ambulacral curvature initiated below the ambitus of the theca.

Discussion.—Figure 4 and plate 2, figures 6–9, show USNM specimen 206299, from USGS locality 5072–CO, basal Curdsville Limestone Member of the Lexington Limestone (18.8 mm axial by 17.6 mm transverse diameter).

Silification of this specimen has obliterated most sutures. However, the theca remains inflated and preserves the shapes of individual structures. The right quarter of the theca is missing, as are all of the oral and ambulacral coverplates. Other structures are intact.

USNM 206299 clearly is an *Edrioaster priscus*. (*E. priscus* is recognized only with question. Specimens assigned to this species may be young *E. bigsbyi*. A complete discussion of this problem may be found in Bell (1974). The specimen reveals not only the thecal shape, ambulacral disposition, anal periproct, and hydropore structure, but also preserves some of the ambulacral passageway structures of the biserial floorplates.

This specimen provides the only clear look at the attachment structure of *Edrioaster* (fig. 4*B*). Other specimens have demonstrated the existence of a polyplated, flexible membrane that extended downward from the distal plates of the oral surface; these plates form the inner edge of the invaginated base of the theca. Until now, only small segments of this membrane have been observed. In this specimen the flexible collar is triangular in shape. This may reflect the shape of the object to which the animal was attached, or perhaps it is due to a slight constriction of the ring after it was pulled from its attachment area. The distal edge of the membrane appears to be slightly curled under. Silification has obliterated the boundaries between the tiny platelets that constitute the structure. The specimen also suggests the presence of a sole across the base of the triangular collar. This membrane probably was not plated and may have acted as a sucker. If so, attachment may have been by suction rather than by fleshy connection between the polyplated membrane and the substrate. An *Edrioaster* might have been able to release itself from its resting site, in contrast with all Isorophida, which are thought to have been permanently anchored to the substrate.



A

FIGURE 4.—*Edrioaster priscus* (Miller and Gurley, 1894). USNM 206299. *A*, Upper oral surface, X 4. *B*, Lower side of theca with attachment structure, X 4.

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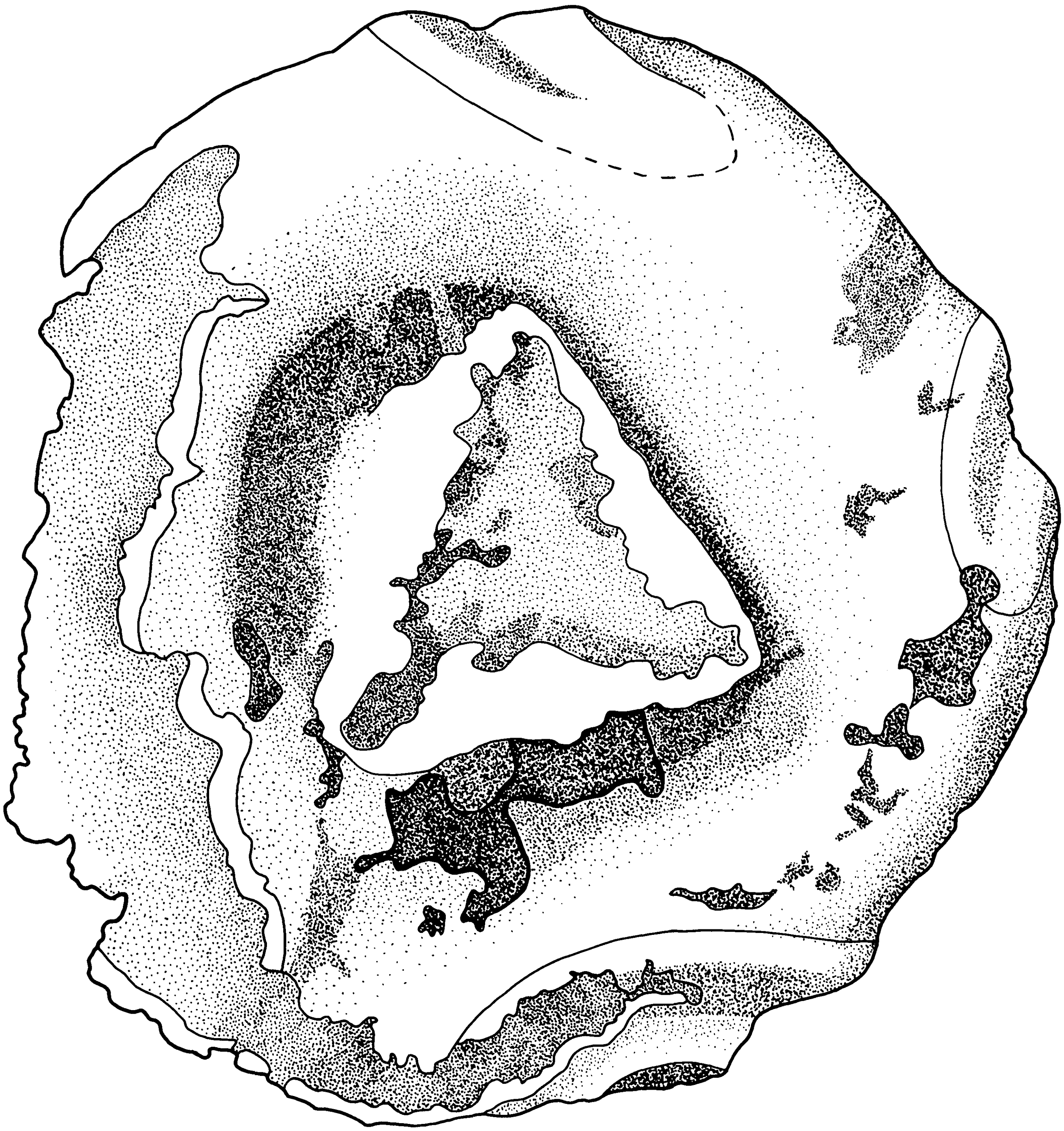

B

FIGURE 4.—Continued.

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PLATES 1 and 2

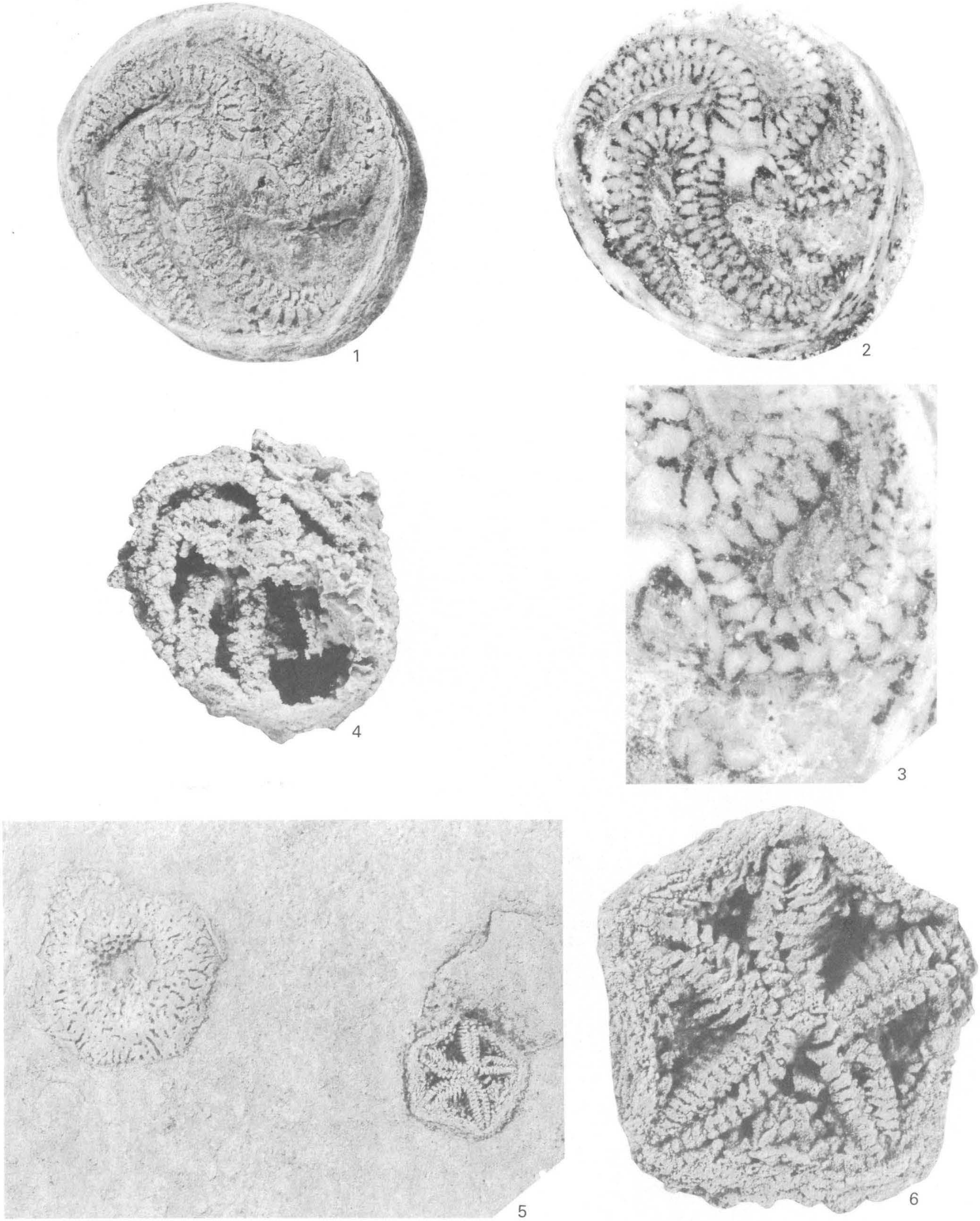
Contact photographs of the plates in this report are available,
at cost, from U.S. Geological Survey Library, Federal Center,
Denver, Colorado 80225

PLATE 1

FIGURES 1–3. *Carneyella pilea* (Hall). (p. E1).
USNM 170362.
1. Oral surface, whitened with ammonium chloride, X 6.
2. Oral surface, in xylene, X 6.
3. Ambulacrum V and adjacent areas, in xylene, X 12.

4. *Streptaster* cf. *S. vorticellatus* (Hall). (p. E2).
USNM 206295. Oral surface whitened with ammonium chloride, X 5.

5, 6. *Cystaster stellatus* (Hall). (p. E2).
USNM 206294.
5. Crinoid base and edrioasteroid attached to hardground substrate; ambulacrum III of the edrioasteroid points toward the crinoid base; whitened with ammonium chloride, X 3.
6. Oral surface, whitened with ammonium chloride, X 10.



CARNEYELLA, *STREPTASTER*, AND *CYSTASTER*

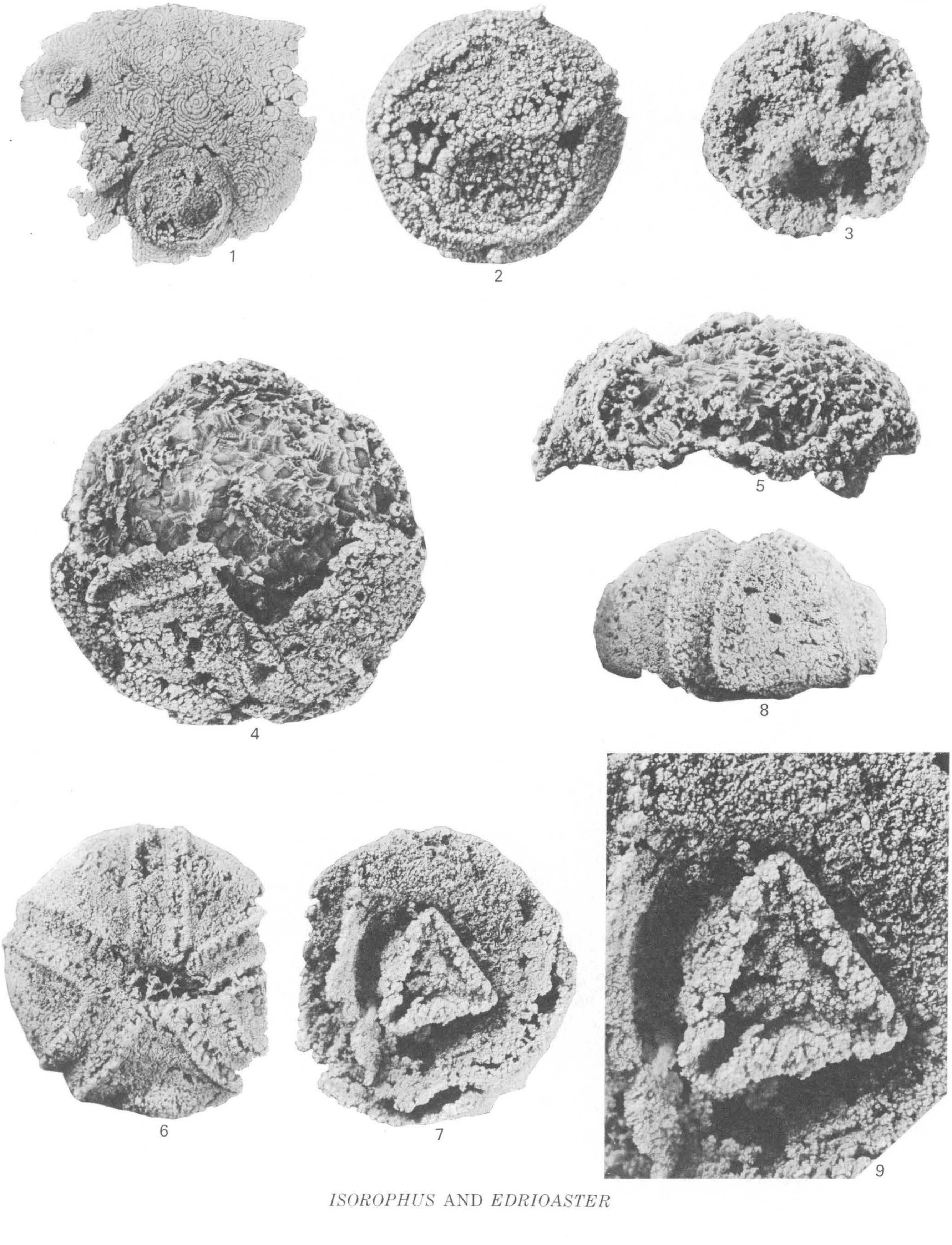
PLATE 2

FIGURES 1, 2. *Isorophus* cf. *I. cincinnatiensis* (Roemer). (p. E 3).
USNM 206296.
1. The specimen attached to a brachiopod, *Rafinesquina* sp., the anterior of the edrioasteroid pointed west-northwest, whitened with ammonium chloride, X 3.
2. Oral surface, whitened with ammonium chloride, X 7.

3. *Isorophus* cf. *I. cincinnatiensis* (Roemer) (p. E 3).
USNM 206297. Oral surface whitened with ammonium chloride, X 8.

4, 5. *Edrioaster bigsbyi* (Billings) (p. E 3)
USNM 206298.
4. Oral surface, whitened with ammonium chloride, X 2.
5. Lateral view, whitened with ammonium chloride, X 2.

6–9. *Edrioaster priscus* (Miller and Gurley) (p. E 4).
USNM 206299.
6. Oral surface, whitened with ammonium chloride, X 3.
7. Lower side of theca, whitened with ammonium chloride, X 3.
8. Lateral view, whitened with ammonium chloride, X 3.
9. Flexible attachment ring, whitened with ammonium chloride, X 6.



ISOROPHUS AND *EDRIOASTER*

Asteroidea (Echinodermata)

By J. W. BRANSTRATOR

CONTRIBUTIONS TO THE ORDOVICIAN PALEONTOLOGY OF KENTUCKY AND NEARBY STATES

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1066-F

Prepared in cooperation with the
Commonwealth of Kentucky,
University of Kentucky,
Kentucky Geological Survey

Systematics and paleoecology of four species, with comments on two species of uncertain systematic position

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1979

CONTENTS

ILLUSTRATIONS

SYSTEM OF MEASUREMENT UNITS

The investigations underlying this series of reports were made over a period of years, and distances and stratigraphic measurements appear fairly uniformly in English units. Measurements of fossil specimens, on the other hand, follow the long-standing convention of appearing in metric units. Because of the dates of the investigations and the amount of resulting data, the English measurements have been retained. Conversions to metric units may be made by using the following conversion table:

To convert English unit:	To metric unit:	Multiply by:
Mile (mi)	Kilometer (km)	1.61
Foot (ft)	Meter (m)	.305

ASTEROIDEA (ECHINODERMATA)

By J. W. BRANSTRATOR [1]

ABSTRACT

Specimens belonging to the stelleroid genera *Promopalaeaster, Lanthanaster*, and *Stenaster* have been obtained from Kentucky's Middle and Upper Ordovician rocks. *Promopalaeaster speciosus* (Meek) is a subjective senior synonym of *P. prenuntius* Schuchert. Lectotype and paralectotype specimens are designated from the syntypes of *Palaeaster finei* Ulrich and *Mesopalaeaster proavitus* Schuchert; both type suites are composed of immature specimens of *Promopalaeaster finei* (Ulrich) n. comb. By subjective synonomy, *Mesopalaeaster intermedius* (Schuchert) n. comb. replaces *Lanthanaster cruciformis* as the type species of *Lanthanaster* Branstrator. The generic affinities of "*Hudsonaster milleri*" Schuchert and "*Mesopalaeaster? dubius*" (Miller and Dyer) Schuchert cannot be determined from available materials.

INTRODUCTION

Verrill (1914, p. 17) noted that a particular difficulty in the determination of genera and species of starfishes is that many do not attain their adult or diagnostic characteristics until of considerable size. Thus, young individuals of a species may appear to belong to different species, or even different genera, unless they can be compared with individuals in a growth series. I have attempted to piece together growth series for the fossil starfish species known from North America. This report deals with the results as applied to specimens from Kentucky.

Most asteroid specimens from the later Ordovician strata in Kentucky belong to species, described previously, from Cincinnati and southwestern Ohio. Geographic and lithostratigraphic data accompanying the type and supplementary specimen material from Ohio are usually poor, however. Kentucky's earlier Ordovician rocks have no time-equivalent strata exposed in the classic collecting sites in adjacent states. Some specimens from these earlier rocks belong to species described from ostensibly time-equivalent and lithologically similar strata in southeastern Canada and the British Isles. Although commonly coarsely recrystallized or disarranged during preservation, new specimens of *Promopalaeaster finei, Lanthanaster intermedius*, and *Stenaster obtusus* from Kentucky are most valuable because of the fine lithostratigraphic control with which they were collected. These specimens shed light on the succession and paleoecology of species originally described from elsewhere.

Museum's from which specimens were borrowed have their names abbreviated as follows: U.S. National Museum of Natural History—USNM; Museum of Comparative Zoology, Harvard University—MCZ; University of Kentucky—UK; Yale University Peabody Museum—YPM; American Museum of Natural History—AMNH; Field Museum of Natural History—FM; University of Michigan, Museum of Paleontology—UM; and University of Cincinnati, Geology Museum—UC.

ACKNOWLEDGMENTS

John Pojeta provided silicified and nonsilicified specimens collected as part of the U.S. Geological Survey–Kentucky Geological Survey Cooperative mapping program. F. J. Collier lent type and supplementary specimens from the National Museum of Natural History. Porter M. Kier and Thomas Phalan, also of USNM, provided assistance and advice in utilizing the collections of that institution. Norman D. Newell and Roger Batten supplied specimens from the American Museum of Natural History. Eugene S. Richardson, Jr., and Matthew H. Nitecki provided specimens and collection data from the Field Museum of Natural History. John K. Pope of Miami University and Lois Campbell of the University of Kentucky lent important specimens. Robert Kesling arranged for a loan of a specimen from the University of Michigan Museum of Paleontol-

[1] Earlham College, Richmond, Ind.

ogy. Richard A. Davis allowed the author to borrow and curate many specimens from the University of Cincinnati Geology Museum. Kenneth E. Caster provided consultation and invaluable library resources. Frederic Hotchkiss and John Pojeta offered additional data and helpful criticism. The Joseph Moore Museum at Earlham College provided research facilities for the completion of this project.

TERMINOLOGY

Spencer and Wright (1966, p. 28–30) provided a useful glossary of morphological terms applied to asterozoans. Their terminology is used herein, with exceptions and additions as follows: **Brachium** is used interchangeably with **arm. Odontophore** refers only to one of the ossicles functionally involved in the operation of the mouth frame. This particular ossicle is seldom visible on the external skeletal surface of fossil specimens, and many authors incorrectly refer to any unpaired, exposed axillary inferomarginal as an odontophore. **Perradial** indicates a feature on or near a vertical plane that would longitudinally bisect each brachium. **Abradial** indicates a position relatively away from this plane.

Brachial length (R) is commonly used to denote size in stelleroids. It is the mean distance between the geometric center of the disc and each arm tip. Only an approximate value for this parameter is possible for most fossil specimens because they are commonly fragmental or distorted from their living proportions.

Systematic Paleontology

Family PROMOPALAEASTERIDAE Schuchert, 1914
Genus PROMOPALAEASTER Schuchert, 1914

Palaeaster [*part*], 1868–1914.
Mesopalaeaster Schuchert [*part*], 1914, p. 24–25; [*part*], 1915, p. 74–77.
Promopalaeaster Schuchert [*part*], 1914, p. 5–6, 33–34; [*part*], 1915, p. 102–106.
Spencer [*part*], 1916, p. 91–92.
Spencer and Wright [*part*], 1966, p. 53.
Anorthaster Schuchert, 1914, p. 5–6, 11–12; 1915, p. 125–126.
Spencer and Wright, 1966, p. 53.

Diagnosis.—Asteroids with all external ossicle surfaces having numerous, prominent spine-base pustules, each pustule carrying or having carried, a single articulating spine; paxillae never present. All primary columns of ossicles prominent throughout life. Intermarginal and adradial ossicles arranged in longitudinal columns as well as transverse rows. More prominent transverse rows of intermarginals alternate with less prominent ones. Podial pores abradial to ambulacral ossicle bodies at junctions of ambulacral and adambulacral ossicle columns. Proximal podial cupules quadriserial; distal podial cupules biserial.

Type species.—*Palaeaster speciosus* Meek (1872); by original designation of Schuchert (1914) as "*Palaeaster granulosus* Meek" [=*Palaeaster speciosus* Meek].

Promopalaeaster speciosus (Meek, 1872)
Plate 1, figures 1–3

Palaeaster granulosus? Hall. Meek, 1872, p. 227; 1873, p. 60–61, pl. 4, figs. 3a–c.
Palaeaster speciosus? Meek, 1872, p. 227; 1873, p. 60–61, pl. 4, figs. 3a–c.
Promopalaeaster prenuntius Schuchert, 1915, p. 107–108, pl. 13, fig. 3; pl. 15, fig. 5.
Promopalaeaster speciosus (Meek). Schuchert, 1914, p. 34; 1915, p. 109-112, pl. 14, figs. 3–4; pl. 15, figs. 1–4.
Spencer and Wright, 1966, p. 53.

Diagnosis.—*Promopalaeaster* with intermarginal, but not adradial accessory ossicles arranged in alternately prominent transverse rows. Intermarginals and adradials tumid and nearly as massive as adjacent ossicles of primary columns; not substantially excavated on ossicle margins.

Materials and occurrence.—The holotype MCZ 22, Dyer Colln.) is from Cincinnati, Ohio. No additional stratigraphic or locality data accompany the specimen or are included in Meek's description. Schuchert (1915, p. 110–111) states unequivocally that the specimen was collected "in the Maysvillian at Cincinnati, Ohio." Although no specific reason exists to doubt this information, its authenticity cannot be documented, and it must be regarded as an inference on Schuchert's part.

Promopalaeaster prenuntius Schuchert (1915, 107–108) is a subjective synonym of *P. speciosus*. It was described from its holotype (UK 403), which was found in a coarse calcarenite in the Lexington Limestone (Middle Ordovician part) near Frankfort, Ky. A brachial fragment of another individual (YPM 3405) came from the same area and is similarly preserved. Natural molds of eight poorly preserved individuals in a calcarenitic slab (AMNH 1100) labeled "Hudson River Group [Upper Ordovician], near Rome, New York" considerably extend the geographic range of *P. speciosus*.

Description.—Known specimens of *P. speciosus* range in size from $R=20$ mm (Rome, N.Y. specimen) to $R=44$ mm (the holotype). Both Kentucky specimens have brachial lengths near 35 mm.

Dorsal and ventral aspects are available from the *P. speciosus* holotype (pl. 1, figs. 1*A–C*). The specimen is composed of two, nearly complete, adjacent brachia, which meet at their bases in an acute angle. Each arm tapers slowly to a broadly acuminate tip.

One open ambulacral groove is clear of matrix and shows details of ambulacral ossicle structure and arrangement.

Each ambulacral ossicle possesses a prominent ventral carina. Perradial nodes (pl. 1, fig. 1*C*) on the ventral carina are also prominent, and form deep ambulacral channels for the lengths of the brachia. The ventral carinae on the distal half of each brachium are straight and define two columns of podial cupules in the ambulacral groove. On the proximal portion of each brachium the ventral ambulacral carinae lie alternately diagonally on the ambulacral ossicles and form four longitudinal columns of cupules. Dentition, or hinge structure, marks abutting surfaces between opposite ambulacral ossicles of adjacent columns. Contact with the adjacent adambulacral ossicle is by means of a prominent abradial flange on the ventral carina of each ambulacral ossicle. Most of the ossicle body of each ambulacral ossicle overlies the proximal portion of the next more distal ossicle.

The intermarginal ossicles of *P. speciosus* are arranged in longitudinal columns as well as diagonally transverse rows. Close examination reveals that these rows are composed of ossicles in two size groups. A row of small ossicles intercalates between each row of larger ossicles (pl. 1, fig. 1*A*), and one of these paired series occurs for each inferomarginal and corresponding superomarginal on the lateral surface of an arm. This biserial intermarginal condition is common to all promopalaeasterids, but the intermarginals of *P. speciosus* are relatively more massive and carried many more spines than those of other promopalaeasterid species.

Like the intermarginals, the adradial ossicles of this species are relatively massive and carried many more spines than similar ossicles of other promopalaeasterids. Abradial adradials of *P. speciosus* are at least as prominent as adjacent superomarginals (pl. 1, figs. 1*A–B*). The adradials are excavated only slightly at their margins for the accommodation of dermal papulae. Furthermore, the paired subseries arrangement common to the adradials of other promopalaeasterids and the intermarginals of all promopalaeasterids does not occur in this species.

Discussion.—The Kentucky specimens of *P. speciosus*, from the Lexington Limestone, are probably older than the holotype and New York specimens, as much of the Lexington Limestone is Middle Ordovician and the New York specimens are Late Ordovician in age. Schuchert (1915, p. 107) assumed the holotype of his *P. prenuntius* to be disstinct from *P. speciosus* because of its "smaller size, less pustulose ornamentation of the plates, and lower position in the geological column." These are not tenable criteria for species differentiation among asteroids.

Overall size, arm length, disc width, number of ossicles in a particular brachial column, number of intercalating ossicles in a brachial column, and number of intercalating columns—all increase with maturity in asteroids. The "pustulose ornamentation" referred to by Schuchert in distinguishing *P. prenuntius* from *P. speciosus* is simply an indication of overall spinosity of an individual. Spinosity varies intraspecifically in asteroids and, in fact, increases with size in some genera (Rasmussen, 1965). Hence, the morphological characteristics used by Schuchert to distinguish *P. prenuntius* from *P. speciosus* may be useful in describing individuals, but they should be avoided in species characterization, unless the maturity of the examined specimens can be determined by comparison with other individuals in a growth series. Without substantiating morphological evidence, the stratigraphic occurrence criterion Schuchert used to distinguish his new species is meaningless.

The holotype, UK 403, presents a ventral aspect that reveals details of ambulacral ossicle structure. Quadriserial podial cupules occupy less of the arm lengths in this less mature specimen than they do in the larger *P. speciosus* holotype. An overturned arm tip (pl. 1, fig. 2) reveals that the specimen possesses the adradial ossicle condition unique to this species of *Promopalaeaster*.

The Lexington Limestone specimens show the fenestrate nature of the ossicles. The coarse calcarenitic matrix imposed some distortion to the ossicle surfaces, but has allowed differential weathering of replaced stereom and stromal canal filling. Spines (pl. 1, fig. 3) and ossicles of these early asteroids had internal microstructures similar to those of modern echinoderms.

Paleoecology.—Where matrix is available with specimens of *P. speciosus* (all but the holotype), it is calcarenite, rather than the fossiliferous calcilutite found with the other species of the genus. The internal ampullae, the primary organs of respiration in modern asteroids, were connected remotely to the external podia in the promopalaeasterids. This imposed a respiratory inefficiency on this system in these early forms (Branstrator, 1975). Furthermore, the alternate organs of respiration in asteroids, dermal papulae, were not well developed in this species. *P. speciosus* probably inhabited relatively high energy, oxygen-rich areas.

Promopalaeaster finei (Ulrich, 1879) n. comb.

Plate 1, figures 4–9; plate 2, figures 1–6

Palaeaster finei Ulrich, 1879, p. 19, pl. 7, figs. 15a–b.
Mesopalaeaster finei (Ulrich). Schuchert, 1914, p. 25; 1915, p. 81–82, pl. 7, fig. 5; pl. 9, fig. 5.
Mesopalaeaster proavitus Schuchert, 1915, p. 83–84.

Diagnosis.—*Promopalaeaster* with intermarginal and adradial accessory ossicles arranged in alternately prominent transverse rows. Intermarginal and adradial ossicles less massive than adjacent ossicles in primary columns; substantially excavated on ossicle margins.

Materials and occurrence.—The syntype material of *Palaeaster finei* Ulrich, 1879 (USNM 60604) is from the Upper Ordovician "Eden Shale" (=Kope Formation) in eastern Cincinnati, Ohio. The lectotype is herein designated as the specimen figured on plate 2, figure 1 of this report; it has been circled on its slab by this author to distinguish it from other syntypes, which become paralectotypes. Ulrich's original suite may have included YPM 14779, but because this is uncertain I am excluding these latter specimens from paralectotype designation.

William H. White, Jr., of Milford, Ohio, found a number of small specimens (UC 40371–40383) in the Kope Formation at the junction of Beechmont and Elstun Avenues in eastern Cincinnati. USNM 236052 is from USGS locality 6419–CO (Logana Member of the Lexington Limestone). The syntypes of *Mesopalaeaster proavitus* Schuchert (1915) (FM 54069, Walker Colln.) are from the "Eden Shale" (=Kope Formation) at Covington, Ky. The largest specimen (pl. 1, fig. 4) in the suite is herein designated as the lectotype of Schuchert's *M. proavitus;* the remainder of the syntype specimens become paralectotypes (pl. 1, fig. 5). *M. proavitus* material has not been figured previously. UM 6230 came from Cincinnati, but its stratigraphic occurrence is unknown. UC 40758, Winnes Colln. (pl. 1, fig. 9), is from an undetermined stratum near Augusta, Ky. Two coarsely silicified specimens, USNM 236051 and 236050 (pl. 2, fig. 5), are known from USGS locality 6134–CO (Clays Ferry Formation). AMNH 1196 and USNM 92613 are from undetermined strata in Cincinnati, Ohio, and Covington, Ky., respectively. Finally, USNM 236049 is from USGS locality 6803–CO (Grier Limestone Member of the Lexington Limestone).

Description.—The specimens listed after the type material above are in order of increasing size. They range from $R=2$ mm (UC 40378), through the juvenile *P. finei* lectotype with $R=9$ mm, to USNM 236049 with a brachial length greater than 40 mm. The generic and specific diagnoses serve to distinguish *P. finei* from other Kentucky asteroids.

The numerous specimens of various sizes make available some important information on skeletal ontogeny in this promopalaeasterid. The nonadaxial relationship between the axial and extraxial skelton is apparent from the smallest of juvenile growth stages; there are always more adambulacral ossicles than inferomarginal ossicles in adjacent columns (pl. 1, figs. 5, 7; pl. 2, figs. 1, 2*B*, 3*B*, 4, 6*A*)—this characteristic is useful in distinguishing all growth stages of this genus from those of *Mesopalaeaster,* which always has 1–to–1 ratio of ossicles in adjacent adambulacral and inferomarginal columns. Adoral carinae are absent in small individuals (pl. 2, fig. 6*A*), but develop in specimens over 20 mm (pl. 2, fig. 2*B*). Unpaired axillaries become isolated from the ambitus by radial length 6 mm (pl. 2, fig. 6*A*), and become progressively more isolated throughout growth (pl. 2, fig. 2*B,* lower axil). The youngest specimens (less than 3 mm) do not have adradial or intermarginal accessory ossicles, but both kinds of ossicles are present by $R=5$ mm and increase in number throughout growth (pl. 2, figs. 6*B–D,* 2*A,* 3*A;* pl. 1, figs. 4, 6, 8, 9). Mature specimens of *Mesopalaeaster* developed no more than two or three columns of intermarginal ossicles (pl. 3, fig. 4); juvenile *Promopalaeaster* are difficult to distinguish from this latter genus when only dorsal aspects are available.

Paleoecology.—This species appears to have been adapted to a less oxygenated habitat than *P. speciosus.* Quadriserial podia occupied more of the brachial lengths in *P. finei.* Individuals of all sizes possessed numerous large papulae protruding through pores in the dorsal and lateral wall; these were necessary to supplement podial respiration. All specimens of *P. finei* are in, or appear to have come from, a calcilutite or mixed calcilutite-calcarenite matrix suggestive of quieter waters than the calcarenite matrix of *P. speciosus.*

Family SCHUCHERTIIDAE Schuchert, 1915

Genus LANTHANASTER Branstrator, 1972

Lanthanaster Intermedius (Schuchert, 1915) n. comb.

Plate 3, figures 1–3

Mesopalaeaster intermedius Schuchert, 1915, p. 79–81, pl. 9, fig. 4.
Lanthanaster cruciformis Branstrator, 1972, p. 66–69, pl. 1.

Diagnosis.—Stelleroid possessing only ambulacral, adambulacral, and inferomarginal primary ossicles in the brachia. Dorsal skeleton of small cruciform ossicles, each surmounted by a single articulating spine. Ambulacral ossicles dorsoventrally flattened except for a high ventral carina. Ampullar pores at junctions of ambulacral and adambulacral columns. Few short, broad spines on low spine-base pustules on inferomarginals and large, deltoid ventral interbrachials. Madreporite on ventral surface.

Materials and occurrence.—The holotype (FM 9575, Faber Colln.) is from rocks of Maysvillian Age at Cincinnati, Ohio. The holotype of the synonymous species *Lanthanaster cruciformis* Branstrator (1972), UC 6433, is also from Maysvillian-Age rocks in Cincinnati. Another Cincinnati specimen (USNM 92608) came from the Kope Formation. Silicified fragments of at least five small individuals (USNM 236053) have been etched from the upper part of the Clays Ferry Formation at USGS locality 6143-CO.

Description.—The holotype (pl. 3, fig. 1) is fragmental and shows portions of the ventral surfaces of two brachia. Its brachial length is nearly 14 mm. The more mature University of Cincinnati specimen possesses all five brachia, shows both dorsal and ventral surfaces, and is more than twice the size of the holotype. The other known specimens are smaller and less well preserved than either of these.

The University of Cincinnati specimen best shows the cruciform dorsal ossicles and dorsal (pl. 3, fig. 2*B*) and ventral (pl. 3, fig. 2*A*) spines. No spines are preserved with the holotype, nor are any cruciform dorsal ossicles apparent. The Kentucky specimens (pl. 3, figs. 3*A–C*) are too coarsely recrystallized to preserve well either of these characteristics.

The madreporites of the Kentucky specimens (pl. 3, fig. 3*B*) are more tumid than that of the University of Cincinnati specimen (pl. 3, fig. 2*A*), but this may be an ontogenetic difference. Other than this difference, the newly recognized Ohio and Kentucky specimens confirm my earlier description of this species (Branstrator, 1972, p. 66–68). Schuchert's supposition (1915, p. 81) that the hidden dorsal surface of his specimen, was similar to that of *Mesopalaeaster* was an error.

Discussion.—Schuchert (1915, p. 80) believed his species to be an intermediate form between the species he included in *Hudsonaster* and *Mesopalaeaster*. The single, large, marginal, ventral interbrachial ossicle (characteristic of *Hudsonaster*), the wide ambulacral groove (a feature he believed common to *Promopalaeaster* species), and the ambulacral ossicles of a form "known in *Mesopalaeaster*" make a paradoxical combination best reconciled (to Schuchert's thinking) by the supposition that his new species was an evolutionarily intermediate form. The axillary intermarginals, while single as in *Hudsonaster*, are not otherwise similar to those of that genus. *Lanthanaster* axillary intermarginals are deltoid, possess few, scattered spine-base pustules, and are widest orad of their midlength; *Hudsonaster* axillaries are sagittate, have many, crowded spine-base pustules, and are widest distal to their midlength. Had Schuchert known of the distinctive dorsal ossicles and of the ventral madreporite in the species that his specimen represented, he would not have placed it in *Mesopalaeaster*.

I did not recognize Schuchert's error in placing his specimen among the *Mesopalaeaster* prior to my description of *Lanthanaster cruciformis*. I have subsequently examined Schuchert's holotype and found that it must be included in the same species as the specimen I described. Schuchert's trivial name has priority, but the species does not belong in *Mesopalaeaster* or any genus erected prior to *Lanthanaster*.

Paleoecology.—Until the ecological significance of the ventral madreporite is known, it will be difficult to determine the paleoecology of *Lanthanaster*. The Kentucky specimens are from a unit reported to be representative of outer infralittoral (Cressman and Karklins, 1970, p. 21). The cruciform ossicles provided a fenestrated dorsal surface, probably as an aid to papular respiration—a necessity in an infralittoral habitat.

Family STENASTERIDAE Schuchert, 1914
Genus STENASTER Billings, 1858
Stenaster obtusus (Forbes, 1848)

Plate 2, figures 7, 8

Uraster obtusus Forbes, 1848, p. 463; 1849, p. 2, pl. 1, fig. 3.
Stenaster salteri Billings, 1858, p. 78, pl. 10, fig. 1a. Schuchert, 1915, p. 165–166, p. 32, fig. 1.
Stenaster obtusus (Forbes). Stürtz, 1886, p. 152; Spencer, 1914, p. 23, pl. 1, figs. 6–7; Schuchert, 1915, p. 167; Spencer, 1927, p. 356–359, pl. 23, figs. 1–9; pl. 24, fig. 10; Fedotov, 1936, p. 10–17, pl. 1, figs. 3–6; Spencer and Wright, 1966, p. 82, text figs. 70, 2a–d.

Diagnosis.—Only ambulacral and adambulacral primary ossicles in the brachial skeleton. Dorsal skeleton of minute granules originally invested in an integument, but commonly not apparent in fossils. A deep groove between opposite pairs of dorsoventrally thick ambulacral ossicles accommodated the radial vessels.

Materials and occurrence.—The holotype is a mold in a mudstone of Caradocian Age from Waterford, Ireland. Spencer (1927, pl. 23, fig. 8) illustrated a cast of the specimen. He also included in the species specimens from the Cardocian of Bala, Wales, the Ashgillian of Scotland, and North American specimens referred to *Stenaster salteri* Billings by Schuchert (1915, p. 165–166). Most North American specimens come from Ontario, where *S. obtusus* is common in the Hull Limestone (Middle Ordovician) at the Kirkfield quarries. In addition, Marshall Kay found a well-preserved specimen in the Long Point Limestone (Middle Ordovician), Newfoundland. Fedotov (1936) reported it from two Middle Ordovician localities in Kazakhstan (U.S.S.R.).

Three coarsely silicified brachial fragments of *Stenaster cf. S. obtusus* (USNM 263054) have been etched from the Curdsville Limestone Member of the Lexington Limestone at USGS locality 5101–CO. Schuchert (1915, p. 166) reported that Ulrich obtained four isolated brachial fragments from the same rock unit near Curdsville, Ky.

Description.—Beekite has replaced the calcitic stereom in the USNM 263054 specimens, but the diagnostic characteristics of the primary ossicles are apparent (pl. 2, fig. 8). Only ambulacral and adambulacral ossicles are present, and the deep groove that accommodated the radial vessels is apparent.

The typical asteroid dorsal skeleton of massive primary and intercalated ossicles is absent in *Stenaster*. The dorsal integument was ossified by small elongate granules (Ruedemann, 1916, p. 54) that are commonly not apparent in fossils. A specimen (UC 36426) from Kirkfield, Ontario, retains some of these granules (pl. 2, fig. 7), but they are not apparent on the Kentucky specimens owing to poor preservation.

The Curdsville Limestone Member of the Lexington from which the Kentucky specimens were extracted is reported to have been a calcarenite deposited in littoral and infralittoral zones (Cressman and Karklins, 1970, p. 18). The Welsh specimen is also preserved in a calcarenite. The peculiar disarrangement of individuals in the rich faunas associated with the Kirkfield, Ontario, and the Scottish specimens suggest that they were swept some distance and then buried as the results of storms.

Species inquirenda

Plate 3, figures 5–8

Several asteroid specimens of indeterminable affinities are known from Kentucky rocks and deserve mention because they have been designated holotypes of species or have been mentioned in the literature.

The holotype of "*Hudsonaster milleri*" Schuchert (1915), UK 1344, shows its ventral surface and is preserved in a recrystallized calcarenite of the lower part of the Lexington Limestone in Fayette County, Ky. Parts of four brachia remain, although preservation is poor and taxonomically significant details have been obscured. The large axial inferomarginals (pl. 3, fig. 5), which did not function as odontophores, suggest that Schuchert's generic placement of the specimen was incorrect because axillary inferomarginals are odontophores in *Hudsonaster*.

Schuchert (1915, p. 60) conditionally placed a coarsely silicified specimen (YPM 13178) found at Curdsville, Ky., in *Hudsonaster narrawayi* (Hudson), 1912 [=*Protopalaeaster narrawayi* Hudson] because it posseses a smaller disc, a stouter appearance, and smaller axillary ossicles than other specimens of that species known to him. The specimen (pl. 3, figs. 6*A*–*B*) has a few adradial and intermarginal ossicles on its dorsal surface, however, which suggests that it is a developmental form of *Promopalaeaster*. The suite of young *P. finei* donated to University of Cincinnati by William H. White, Jr., shows such a hudsonasterid-like stage in the very early postlarval development of that species.

Schuchert (1915, p. 62) reported a specimen (USNM 60617, Ulrich Colln.) of "*Hudsonaster incomptus*" from the "Maysville formation" south of Covington, Ky. The specimen is disarranged and abraded, however, and generic determination is impossible.

A specimen (MCZ 25) from the "river quarries" (Point Pleasant Tongue of the Clays Ferry Formation) at Ludlow, Ky., was designated the holotype of "*Palaeaster ?dubius*" Miller and Dyer (1878). More of this specimen (pl. 3, fig. 7) has been rendered from its matrix since its original description, but still no diagnostic characters can be seen. It appears to be an asteroid and therefore distinct from a poorly preserved oegophiurid (YPM 11771) from the same quarries. The oegophiurid specimen (pl. 3, fig. 8) has unusually long mouth-angle ossicles, distinct tori, and long narrow ambulacral ossicles.

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PLATES 1–3

Contact photographs of the plates in this report are available, at cost, from U.S. Geological Survey Library, Federal Center, Denver, Colorado 80225

PLATE 1

FIGURE 1. *Promopalaeaster speciosus* (Meek). Unknown horizon, Cincinnati, Ohio; MCZ 22, holotype. *A*, Arm, dorsolateral aspect, arrow 1 points ossicle of smaller intermarginal subseries; arrow 2 points ossicle of larger intermarginal subseries, × 8 (p. F2). *B*, Theca, dorsal aspect × 2 (p. F2). *C*, Theca, ventral aspect, arrow points to perradial node × 2 (p. F2).

2. *Promopalaestar speciosus* (Meek). Lexington Limestone, near Frankfort, Ky.; UK 403 (holotype of *P. prenuntius* Schuchert). Ventral aspect with one brachial tip (arrow) overturned, × 1.5 (p. F2).

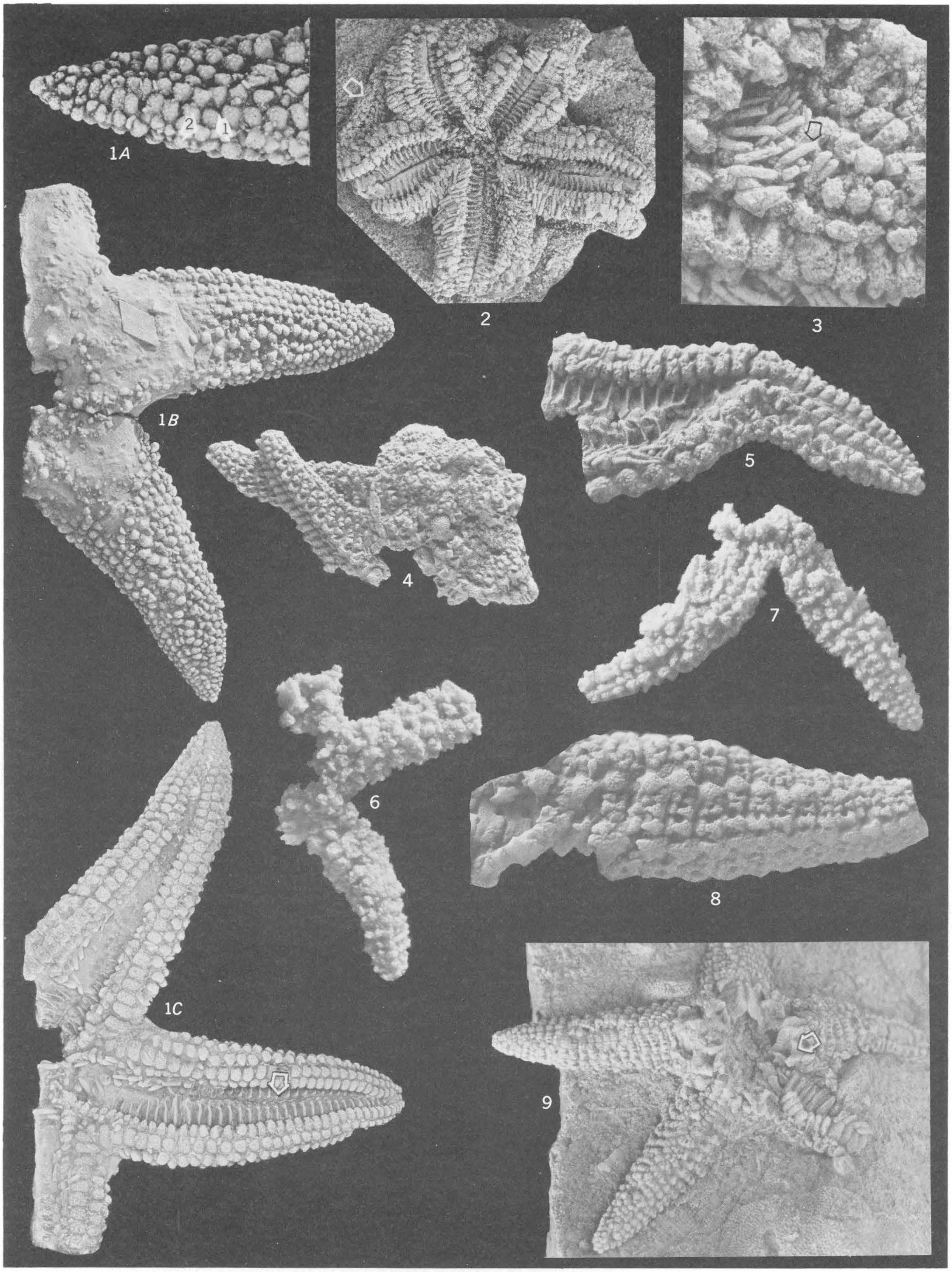
3. *Promopalaeaster speciosus* (Meek). Lexington Limestone, near Frankfort, Ky.; YPM 3405. Arm, ventrolateral aspect showing relic structure of spine stereom (arrow), × 9 (p. F2).

4,5. *Promopalaester finei* (Ulrich) n. comb. Kope Formation, Covington, Ky.; FM 54069. 4, Lectotype of *Mesopalaeaster proavitus* Schuchert, × 3 (p. F4). 5, Paralectotype in ventral aspect, × 6 (p. F4).

6,7. *Promopalaeaster finei* (Ulrich) n. comb. Logana Member of Lexington Limestone, USGS locality 6419–CO; USNM 236052. 6, Dorsal aspect of larger fragment, × 4 (p. F4). 7, Ventral aspect of smaller fragment, × 4 (p. F4).

8. *Promopalaeaster finei* (Ulrich) n. comb. Unknown horizon, Cincinnati, Ohio; UM 6230. Brachium, dorsolateral aspect showing relative prominence of dorsal primary and secondary ossicles. Note biserial arrangement of adradials and intermarginals, × 5 (p. F4).

9. *Promopalaeaster finei* (Ulrich) n. comb. Unknown horizon, near Augusta, Ky.; UC 40758. Theca, dorsal aspect with exposed buccal frame showing internal odontophores (arrow on one), × 2 (p. F4).



PROMOPALAEASTER

PLATE 2

FIGURE 1. *Promopalaeaster finei* (Ulrich) n. comb. Kope Formation, Cincinnati, Ohio; USNM 60604, lectotype. Ventral aspect of disarticulated juvenile, × 6 (p. F4).

2. *Promopalaeaster finei* (Ulrich) n. comb. Unknown horizon, Cincinnati, Ohio; AMNH 1196, (largest specimen in suite). *A*, Dorsal aspect, × 2.4 (p. F4). *B*, Ventral aspect, arrow points to adoral carina, × 2.5 (p. F4).

3. *Promopalaeaster finei* (Ulrich) n. comb. Clays Ferry Formation, USGS locality 6143–CO; USNM 236050. *A*, Theca, dorsal aspect. (Most ossicles removed by preparational acidization; interossicle fillings remain.) × 2 (p. F4). *B*, Oral area, × 4 (p. F4).

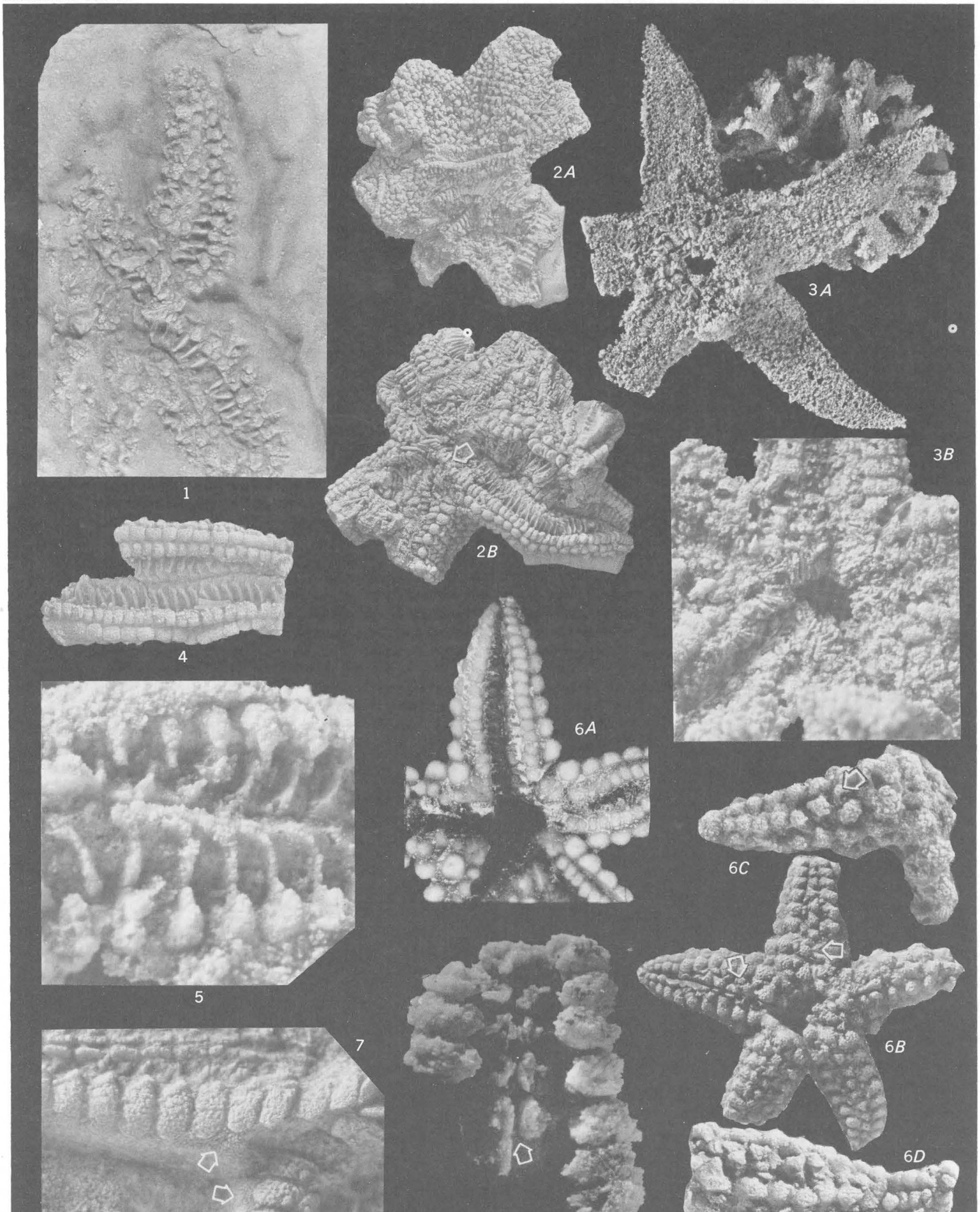
4. *Promopalaeaster finei* (Ulrich) n. comb. Unknown horizon, Covington, Ky.; USNM 92613. Brachial fragment, ventral aspect. Note tendency toward quadriserial podial cupules on proximal (left) end, × 2 (p. F4).

5. *Promopalaeaster finei* (Ulrich) n. comb. Clays Ferry Formation, USGS locality 6143–CO; USNM 236051. Brachium, ventral aspect, × 11 (p. F4).

6. *Promopalaeaster finei* (Ulrich) n. comb. Kope Formation, Cincinnati, Ohio. *A*, A brachium and disc, ventral aspect (photographed in xylol). UC 40371, × 7 (p. F4). *B*, Theca, dorsal aspect. (Arrows point developing adradials.) UC 40371, × 5 (p. F4). *C*, Brachium, dorsal aspect. (Arrow points early adradial.) UC 40381, × 10 (p. F4). *D*, Brachium, dorsal view (Arrow points intermarginals.) UC 40382, × 6 (p. F4).

7. *Stenaster obtusus* (Forbes). Hull Limestone, Kirkfield, Ontario; UC 36426. Interbrachial area, ventrolateral aspect. (Arrows point granular ossicles of lateral integument.) Note deep furrow between opposing ambulacral ossicles, × 6 (p. F5).

8. *Stenaster cf. S. obtusus* (Forbes). Curdsville Limestone Member of Lexington Limestone, USGS locality 5101–CO; USNM 263054. Brachial fragment, ventral aspect. (Arrow points deep radial furrow.) × 6 (p. F6).



PROMOPALAEASTER, STENASTER

PLATE 3

FIGURE 1. *Lanthanaster intermedius* (Schuchert) n. comb. Maysvillian Age (horizon unknown), Cincinnati, Ohio; FM 9575, holotype. Ventral aspect, × 3 (p. F4).

2. *Lanthanaster intermedius* (Schuchert) n. comb. Maysvillian Age (horizon unknown), Cincinnati, Ohio; UC 6433 (holotype of *Lanthanaster cruciformis* Branstrator). *A*, Theca, ventral aspect. (Arrow points madreporite.) × 1.5 (p. F4). *B*, Theca, dorsal aspect, × 1.5 (p. F4).

3. *Lanthanaster intermedius* (Schuchert) n. comb. Clays Ferry Formation, USGS locality 6143-CO; USNM 236053. *A*, Brachium, dorsal aspect, × 8 (p. F4). *B*, Theca, ventral aspect. (Arrowpoints madreporite) × 2.5 (p. F4). *C*, Theca, dorsal aspect, × 2.5 (p. F4).

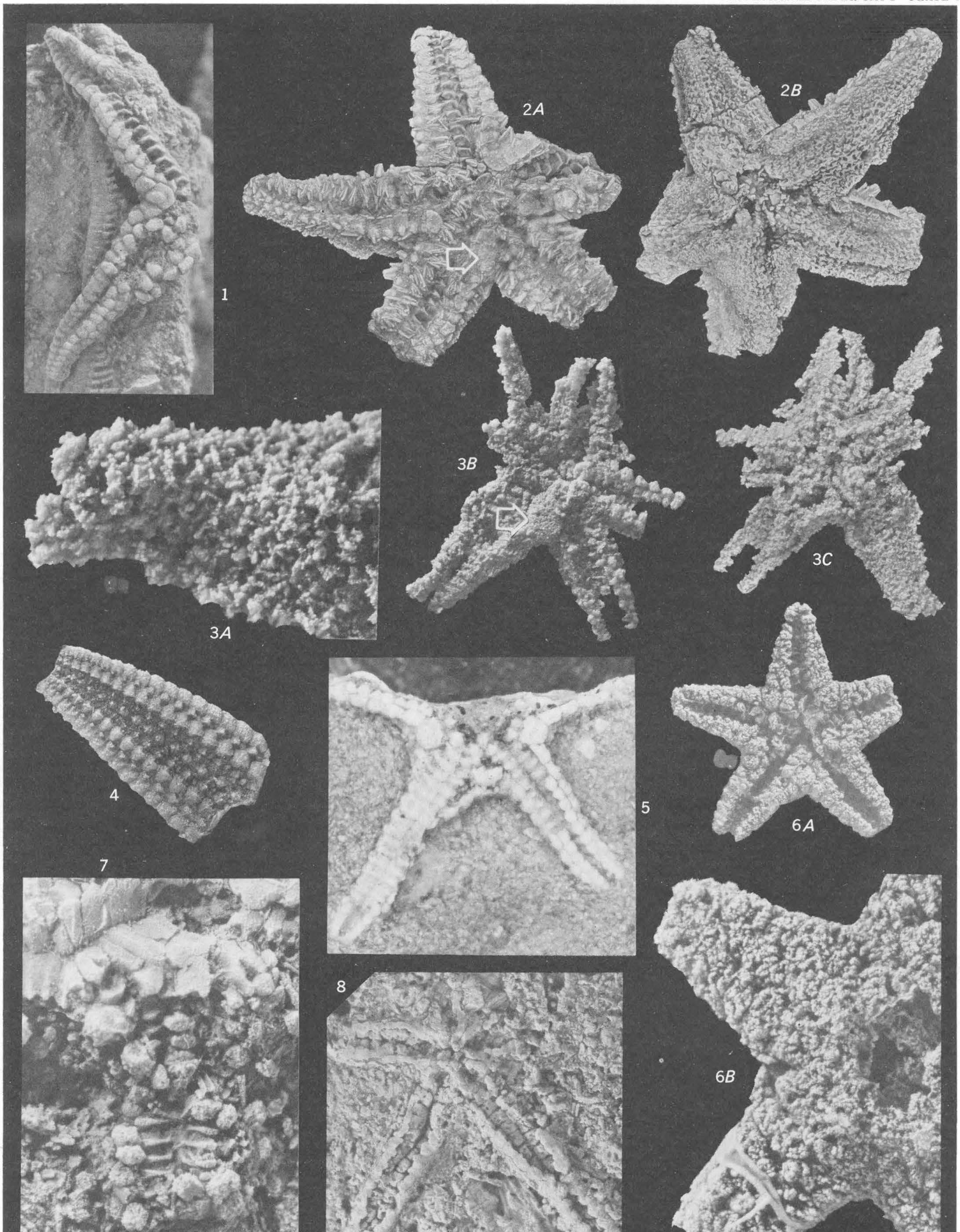
4. *Mesopalaeaster shafferi* (Hall). Maysvillian Age (horizon unknown), Cincinnati, Ohio; USNM 60621. Brachium, dorsal aspect, × 2.5 (p. F4).

5. "*Hudsonaster milleri*" Schuchert. Lexington Limestone, Fayette County, Ky.; UK 1344. Theca, ventral aspect (photographed in xylol), × 4 (p. F6).

6. "*Hudsonaster narrawayi*" (Hudson) *fide* Schuchert. Unknown horizon, near Curdsville, Ky.; YPM 13178. *A*, Theca, ventral aspect, × 3.5 (p. F6). *B*, Brachia and disc, dorsal aspect (note adradial columns), × 7 (p. F6).

7. "*Palaeaster ?dubius*" Miller and Dyer. Point Pleasant Tongue of Clays Ferry Formation, Ludlow, Ky.; MCZ 25. Fragmented and eroded theca, ventral aspect, × 10 (p. F6).

8. Oegophiurid. Point Pleasant Tongue of Clays Ferry Formation, Ludlow, Ky.; YPM 11771. Theca, ventral aspect, × 6 (p. F6).



LANTHANASTER, *MESOPALAEASTER*, SPECIES INQUIRENDA

Conodonts and Conodont Biostratigraphy of Post-Tyrone Ordovician Rocks of the Cincinnati Region

By WALTER C. SWEET

CONTRIBUTIONS TO THE ORDOVICIAN PALEONTOLOGY OF KENTUCKY AND NEARBY STATES

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SYSTEM OF MEASUREMENT UNITS

The investigations underlying this series of reports were made over a period of years, and distances and stratigraphic measurements appear fairly uniformly in English units. Measurements of fossil specimens, on the other hand, follow the long-standing convention of appearing in metric units. Because of the dates of the investigations and the amount of resulting data, the English measurements have been retained. Conversions to metric units may be made by using the following conversion table:

To convert English unit:	To metric unit:	Multiply by:
Mile (mi)	Kilometer (km)	1.61
Foot (ft)	Meter (m)	.305

CONODONTS AND CONODONT BIOSTRATIGRAPHY OF POST-TYRONE ORDOVICIAN ROCKS OF THE CINCINNATI REGION

By WALTER C. SWEET [1]

ABSTRACT

Conodonts representing 35 species of 20 genera have been collected from post-Tyrone Ordovician rocks at 51 localities in the Cincinnati region of north-central Kentucky and adjacent parts of Ohio and Indiana. Most species are long-ranging components of the conodont fauna of the North American Midcontinent Province. Logs charting vertical fluctuations in relative abundance of common midcontinent species are used to correlate short sections and combine them into synthetic composites for four districts of the Cincinnati region. A regional correlation chart is derived from correlation of the four district composites, as is a composite range table that summarizes all available information on stratigraphic distribution of conodonts in post-Tyrone Ordovician rocks of the Cincinnati region. Taxonomy of all the conodonts represented is reviewed and updated.

INTRODUCTION

Conodonts are abundantly represented in Ordovician rocks of the Cincinnati Region,[2] from the base of the Lexington Limestone upward to the top of the Cincinnatian Series. The first conodonts to be described from Ordovician rocks of the Cincinnati region are apparently the ones figured by James (1884), although Grinnell (1877) and Ulrich (1878) speculated on the conodont affinities of some scolecodonts they collected from rocks of the same area. Branson and Branson (1942) noted that conodonts are present throughout the Cincinnatian in Kentucky and adjacent States, but they provided no descriptions or illustrations of their specimens.

Extensive studies of conodonts from the Ordovician of the Cincinnati region began in 1951, when Branson, Mehl, and Branson published descriptions and illustrations of typical Richmondian forms from Kentucky and Indiana. Subsequently (Sweet and others, 1959; Pulse and Sweet, 1960; Bergström and Sweet, 1966; Kohut and Sweet, 1968), the entire complex of conodont species characteristic of Lexington and younger Ordovician strata has been described, in at least preliminary form, and the faunas represented by these species are now among the best known from any part of the Ordovician anywhere in the world.

Descriptions and interpretations of Cincinnati region Ordovician conodonts have been completed and published piecemeal over a period of more than 25 years. Except for understanding based on material assembled by Branson, Mehl, and Branson (1951), current knowledge of Cincinnati region Ordovician conodonts is founded almost entirely on collections at The Ohio State University that now include more than 418,000 identified and cataloged specimens. As collections have grown in size and have come to represent more and more of the interval between the base of the Lexington Limestone and the top of the Cincinnatian Series, and as additional sections have been sampled to provide ever wider geographic coverage within the Cincinnati region, our taxonomic and stratigraphic concepts have also evolved. Early reports (Branson and others, 1951; Sweet and others, 1959; Pulse and Sweet, 1960) were made in a stratigraphic context inherited from turn-of-the-century studies largely in the environs of the city of Cincinnati and in a form-taxonomic framework that was generally acceptable at the time. Later studies (Bergström and Sweet, 1966; Kohut and Sweet, 1968) had the advantage of at least preliminary information from modern stratigraphic work on, and mapping of, Ordovician rocks in the Cincinnati re-

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[2] As used in this and previous reports on Ordovician conodonts and stratigraphy, the designation, *Cincinnati region*, refers to the entire area of Ordovician exposure in southwest Ohio and adjacent parts of Indiana and Kentucky. The Cincinnati region is the stippled area of figure 1.

gion, and were also set in the context of an evolving multi-element taxonomy for conodonts. Although advances between 1951 and 1966 were important to a detailed understanding of Ordovician conodonts and history in the Cincinnati region, an unfortunate consequence of the evolution in stratigraphic and taxonomic concepts has been that earlier descriptions, as well as the statements on stratigraphic range that accompany them, are difficult to interpret accurately in present-day taxonomic or stratigraphic terms. Consequently, it is the principal purpose of this report to summarize and to bring up to date information on the taxonomy and stratigraphic distribution of Ordovician conodonts from the Cincinnati region. It is hoped that this summary will be more useful to stratigraphers and paleontologists than are the scattered reports, both published and unpublished, on which it is based.

SAMPLE MATERIAL

Present knowledge of the geographic and stratigraphic distribution of Ordovician conodonts in the Cincinnati region is based on a collection of 418,144 identified conodont-elements, assembled from 2,358 300- to 500-gram samples, which have been collected from sections at 51 sites (fig. 1 and "Locality Register"). A majority of the specimens were derived from the acid-insoluble residues of limestone samples, but about 20,000 of them were collected from shale samples, which had been disaggregated and washed through 100-mesh screens. At present, all of the collections are kept in the Micropaleontological Laboratories of the Department of Geology and Mineralogy, The Ohio State University.

More than 90 percent of the samples and specimens were collected and prepared by students and faculty at The Ohio State University in connection with long-range biostratigraphic studies of the Ordovician rocks of the Cincinnati region. About 27,000 specimens, however, derived from 266 samples that were collected at 10 localities in Kentucky, were submitted for study by various members of the U.S. Geological Survey. The latter specimens are now included in permanent collections at The Ohio State University, but they are in distinctly numbered slides and are filed separately from the bulk of the collections, which are identified by distinctive Ohio State University sample- and catalog-number designations of the general 74XY–000 type.

It should be noted that non-type bulk collections of conodonts from the "Eden Formation" of the Cincinnati region (Sweet and others, 1959) are not included in tabulations reported in the preceding paragraph, nor are most of the localities from which those conodonts were derived listed in the "Locality Register." "Eden" bulk collections were destroyed by an untrained museum assistant, who, however, was careful to preserve the types of all taxa described and illustrated by Sweet and others in their report of 1959. Large collections have subsequently been derived from rocks of Edenian Age, but most of them are from different sections from the ones listed in Sweet and others (1959).

ACKNOWLEDGMENTS

Many of the conclusions and most of the speculation in this report are the writer's responsibility. However, the material on which this report is based has been assembled by a number of persons, to all of whom sincere appreciation is expressed. Earl Warner, Jr., of Lafayette, La., Lorna C. Wilkie, of Washington, D.C., and Caroline A. Turco, of Ridgefield Park, N.J., collected conodonts from Edenian rocks and did much of the original interpretive work. Richard R. Pulse, now of Denver, Colo., made extensive collections from Maysvillian rocks; and Richard F. McClish of New Orleans, La., measured and collected many conodonts from sections of Richmondian strata. Claude C. Rust, of Houston, Tex., prepared samples from the Middletown Core (OSU section 61Z), helped develop the relative-abundance-analysis technique, and assisted in the field as many samples from the Lexington Limestone were collected. Joseph J. Kohut, now of Portland, Oreg., substantially augmented our collections of Richmondian conodonts, tabulated and described them, and developed an imaginative and useful technique for statistical analysis of the taxa represented in our entire collection. Anita G. Harris, of Washington, D.C., prepared material from the Ohio Brush Creek locality (OSU section 62DA), and Howard Harper, Jr., of Cambridge, Mass., and Dennis Zlatkin, of Springdale, Ohio, sampled, described, and collected conodonts from the upper part of Cominco American Core C–38 (OSU section 70ZA).

A special debt is owed Stig M. Bergström, of The Ohio State University, who has participated in all but the earliest studies of Cincinnati region conodonts. Dr. Bergström did much of the fieldwork, processed most of the samples, and shared equally in the job of picking conodonts from Lexington Limestone residues. He has been generous in discussing special problems and in cooperatively preparing many reports on conodonts from the Cincinnati region. His help in reading and suggesting improve-

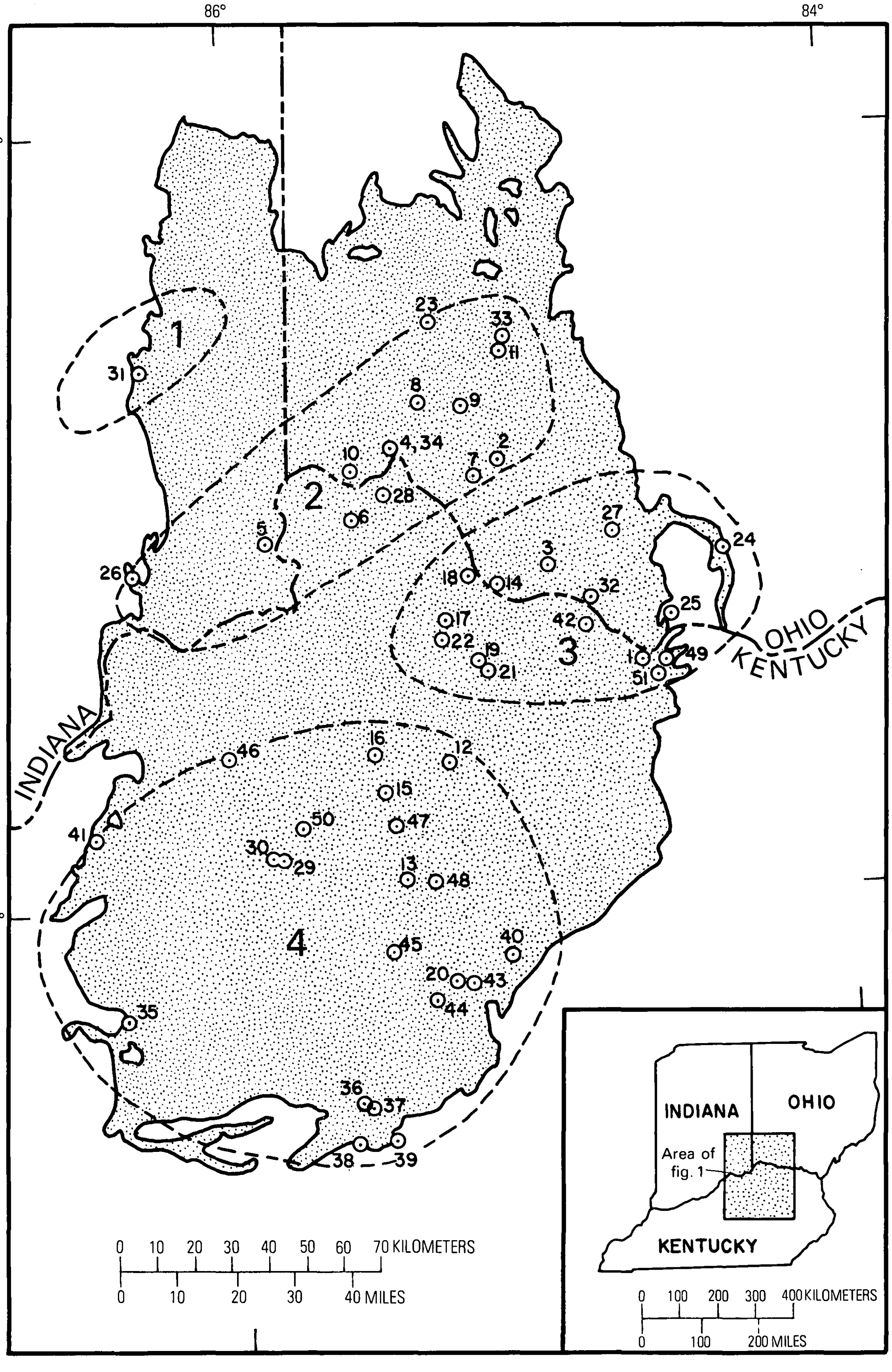

FIGURE 1.—Index map of the Cincinnati region (patterned) showing location of sections (numbered, circled dots) from which post-Tyrone Ordovician conodonts have been collected. Sections are more fully identified in "Locality Register," beginning page G22. Sets of sections enclosed by dashed lines are combined to produce the logs of figure 2.

ments to the text of the present report is warmly acknowledged.

It is also a pleasure to acknowledge the help received from various members of the U.S. Geological Survey involved in mapping Ordovician bedrock in the Cincinnati region. Earle Cressman, Gordon Wier, Douglas Black, John Peck, and Warren Peterson have been particularly generous with their time in the field, and have submitted samples from sections that have greatly increased our knowledge of the distribution of Cincinnati region Ordovician conodonts.

We also acknowledge a considerable debt to Malcolm P. Weiss, now of Northern Illinois University, DeKalb, Ill., with whom we worked very closely during much of the time we were developing our collections and our knowledge of the rocks and fossils of the Cincinnati region.

THE CONODONT FAUNAS

In 1959, Sweet and others concluded that conodont collections from Edenian rocks of the Cincinnati region included representatives of the faunas of two distinct provinces, a warm-temperate North American Midcontinent Province, and a cold-temperate Anglo-Scandinavian-Appalachian Province. Intermingling in the Cincinnati region of conodonts characteristic of these two provinces was interpreted to be a result of periodic shifting of the interprovincial boundary, permitting occasional immigration of certain Anglo-Scandinavian-Appalachian species into waters of the North American Midcontinent Province.

Pulse and Sweet (1960) recognized that species of Anglo-Scandinavian-Appalachian affinities were also periodic contributors to the Maysvillian conodont faunas of the Cincinnati region, and they noted the appearance in rocks of Early Maysvillian Age of the northern Cincinnati region of a group of robust elements of *Aphelognathus* and *Oulodus* that are obviously related to more delicate forms characteristic of the North American Midcontinent Province. The provincial affinities of species represented by the robust Maysvillian elements were not determined, but it was tentatively suggested that they might be the local results of peculiar ecologic conditions. Following Sweet and others (1959), Pulse and Sweet (1960) also recognized that Richmondian rocks contain many conodonts that seem unrelated to either the North American Midcontinent or Anglo-Scandinavian-Appalachian elements of Edenian and Maysvillian faunas. Some of the species represented by elements of Richmondian aspect appear in Maysvillian rocks, and Pulse and Sweet suggested that they might represent the initial migration into the Cincinnati region of a third fauna, which made its principal contribution to that of the Cincinnati region in Richmondian time.

Bergström and Sweet (1966) concluded from their study of conodonts from the Lexington Limestone and its lateral equivalents that their collections included representatives of both the North American Midcontinent Province and the Anglo-Scandinavian-Appalachian Province. They proposed, however, that the designation, European Province, was a less cumbersome term than Anglo-Scandinavian-Appalachian, and noted (p. 283) that "* * * the North American midcontinental fauna is not developed in the same way throughout the vast region in which its components are known." That is, they pointed out that *Phragmodus* and *Plectodina* are the midcontinent genera most characteristic of the eastern part of the North American Midcontinent Province; that *Panderodus* and *Belodina* seem to be the most characteristic genera of midcontinent faunas in Iowa, Minnesota, and areas north and west of those States; and that *Aphelognathus, Oulodus*, and *Rhipidognathus* characterize a third subprovince that is best developed in the Nashville-Ozark region.

Kohut and Sweet (1968) also recognized European and midcontinent components in conodont faunas reconstructed from specimens they collected from rocks of Late Maysvillian and Richmondian Age in the Cincinnati region. They noted, however, that European faunal elements are not represented in Richmondian strata above the top of the "Arnheim" Formation, and they introduced the informal designations "northern fauna" for the subprovincial midcontinent fauna dominated by *Phragmodus* and *Plectodina*, and "southern fauna" for the subprovincial midcontinent fauna distinguished by the conodonts referred in this report to *Aphelognathus, Oulodus*, and *Rhipidognathus*. Elements of the southern fauna were also shown to be associated in abundance with rocks whose lithic and structural features indicate deposition in very shallow water environments.

Seddon and Sweet (1971) distinguished between "indigenous," "interior," and "European" components of the Ordovician conodont faunas of the Cincinnati region. The indigenous and interior faunas were regarded as subprovincial components of the North American midcontinent fauna. The former included the northern and southern faunas of Kohut and Sweet (1968); the latter was a name applied to the subprovincial midcontinent fauna dominated by *Panderodus* and *Belodina* and first recognized by Bergström and Sweet (1966).

In this report, the name "North Atlantic Province" is used for the region characterized in the Ordovician by the conodont fauna termed Anglo-Scandinavian-Appalachian by Sweet and others (1959) and Pulse and Sweet (1960), or European by Bergström and Sweet (1966), Kohut and Sweet (1968), and Seddon and Sweet (1971). This substitution of names follows the practice of Bergström (1971a, 1971b, among other reports), who has written extensively about the conodont faunas of the North Atlantic Province. The designation North American Midcontinent Province (or Midcontinent Province) is still adequate for the region dominated in the Ordovician by conodonts referable to *Phragmodus, Plectodina, Oulodus, Aphelognathus, Rhipidognathus, Panderodus,* and *Belodina,* but it is also appropriate to recognize, at least informally, that composition of the midcontinent conodont fauna varied from place to place, and from time to time, within the province. Consequently, it is possible to distinguish an "exterior" subprovince, in which the characteristic conodont genera were *Phragmodus* and *Plectodina,* and an "interior" subprovince, in which the indigenous conodont fauna was dominated by certain species of *Panderodus* and *Belodina.* For much of Middle and Late Ordovician time, the exterior subprovince included the Trenton type area of southern Ontario and adjacent New York, the Appalachians west of the Saltville fault, the Cincinnati region, the Nashville Basin of Tennessee, the Ozarks, the Batesville district of northeastern Arkansas, the Arbuckle Mountains of Oklahoma, and the Marathon district of Texas. The interior subprovince included a vast area west and north of the exterior subprovince. Faunas of interior-subprovince type are known from sections in northeast Iowa and adjacent Minnesota, Wisconsin, and Illinois, and from the Dakotas, southern Manitoba, Wyoming, Kansas, Nebraska, Colorado, California and Nevada. Additionally, the Ozarks and the Batesville district of northeast Arkansas came to be dominated by faunal elements of the interior subprovince in the Late Ordovician, at a time when there was also a conspicuous influx of such conodonts into the eastern segment of the exterior subprovince. It should be noted that, for that part of the Ordovician considered in this report, Barnes, Rexroad, and Miller (1973) also recognized two divisions of the Midcontinent Province, which they termed eastern and western subprovinces. These correspond to the exterior and interior subprovinces of this report.

MIDCONTINENT FAUNAL ELEMENTS

In that part of the Ordovician represented by the stratigraphic succession considered in this report, the Cincinnati region was apparently situated about 100 miles west of what is now the east edge of the North American Midcontinent Province. Consequently, the bulk of the conodonts recovered from Lexington and younger Ordovician rocks of the Cincinnati region are referable to species characteristic of the exterior subprovince of the North American Midcontinent Province. From time to time, however, immigrants from either the North Atlantic Province or the interior subprovince of the Midcontinent Province made contributions to the fauna of the Cincinnati region. Thus, about 8 percent of the conodonts in our collections represent immigrant species from the North Atlantic Province, and another 1 percent of our specimens is referable to *Panderodus gracilis, P.* sp. aff. *P. panderi, P. angularis, P. staufferi,* and various species of *Belodina,* which we regard as typical of the interior subprovince of the North American Midcontinent Province.

On the basis of their geographic and stratigraphic distribution, midcontinent elements of Cincinnati region Ordovician conodont faunas can be separated into two groups. One, characterized by *Phragmodus undatus* and *Plectodina furcata,* is dominant in the north half of the Cincinnati region through virtually all of the stratigraphic interval considered here; whereas, the other, typified by various species of *Aphelognathus, Oulodus,* and *Rhipidognathus,* is best and most continuously developed in the south half of the Cincinnati region. It now appears probable, from data summarized by Seddon and Sweet (1971), that the northern element of the indigenous fauna of the exterior subprovince flourished in waters above the deeper depositional sites in the Cincinnati region and that the southern element was adapted to waters over the more shallowly submerged depositional sites. As noted in the section on biostratigraphy in this report, extensive use has been made of areal and vertical fluctuations in the relative abundance of the northern and southern elements of the indigenous fauna of the exterior subprovince to effect correlations between the 51 sections from which we have collected conodonts in the Cincinnati region.

Specimens assignable to *Panderodus* and *Belodina,* which we regard as indexes to the fauna of the interior subprovince of the Midcontinent Province, are minor but consistent components of conodont collections from the base of the Lexington Limestone to a level about 85 feet above the base of the Maysvillian Stage. The upper 125 feet of the Maysvillian Stage lacks interior faunal elements, but they reappear in force at the base of the Richmondian Stage and are conspicuous constituents of all our collections above that level to the top of the Cincinnatian Series. It is suspected that the absence of interior faunal elements in rocks of late Maysvillian age indicates that no direct marine connection was open between the Cincinnati region and more interior areas of the continent at that time. Perhaps it was during this interval that the unconformity separating the Dubuque Formation and Maquoketa Shale of the Upper Mississippi Valley was formed.

NORTH ATLANTIC FAUNAL ELEMENTS

Immigrants from the North Atlantic Province into the exterior subprovince of the North American Midcontinent Province include: *Amorphognathus ordovicicus*, *A. superbus*, *A. tvaerensis*, *Icriodella superba*, *Paroistodus*? *mutatus*, *Periodon grandis*, *Protopanderodus* n. sp. cf. *P. insculptus*, *P.* sp. cf. *P. dissimilaris*, and *Rhodesognathus elegans*. Of these nine species, only four are represented in any abundance in the Cincinnati region. These are *Icriodella superba* and the three species of *Amorphognathus*. Collectively, however, the North Atlantic contingent of immigrants ranges from 40 to 785 feet above the base of the Lexington Limestone; that is, from a level in rocks of the Kirkfieldian Stage to one about 30 feet above the base of the Richmondian Stage.

Amorphognathus and *Icriodella*, the two North Atlantic conodont genera most abundantly represented in the Cincinnati region, differ conspicuously in their distribution. *Icriodella* is the North Atlantic form most prominently represented in samples dominated by elements of the southern component of the indigenous midcontinent fauna, whereas *Amorphognathus* is the genus most prominently represented in samples dominated by elements of the northern component of that fauna.

Seddon and Sweet (1971) interpreted these distributional vagaries to mean that *Icriodella* inhabited a depth zone that was closer to the surface of the water body than was the one inhabited by *Amorphognathus*. However, in assembling the data for this report, it was noted that in only 88 (or 14 percent) of the 613 samples containing specimens of *Icriodella* and (or) *Amorphognathus* do the two occur together. Through much of the Edenian Stage in the north half of the Cincinnati region, *Amorphognathus* is the only North Atlantic genus represented, and the same is true in the Maysville area. *Icriodella* is, indeed, more abundantly and continuously represented in the southern Cincinnati region than in the northern part, but even there only 9 of the 135 samples that yield North Atlantic elements include specimens of both *Icriodella* and *Amorphognathus*. If Seddon's and Sweet's (1971) conclusion about these conodonts was correct, both should be represented in the northern Cincinnati region, even though it might be expected that *Icriodella*, the shallower water form, would occur by itself in the southern part of that region. From the data reported here, however, it appears that *Icriodella* was, indeed, adapted to a shallower water environment than *Amorphognathus;* or, more precisely, that *Icriodella* inhabited water over the more shallowly submerged depositional sites, whereas *Amorphognathus* flourished in water over the more deeply submerged depositional sites, at least in the Midcontinent Province. (In the Balto-Scandic area, however, representatives of *Amorphognathus* are common in some rocks that are demonstrably of very shallow water origin (S. M. Bergström, oral commun., 1974).)

The fact that a few specimens of *Amorphognathus* do occur with elements of *Rhipidognathus* in several samples from the southern Cincinnati region suggests that *Amorphognathus* was occasionally able to invade the shallowly submerged areas favored by *Icriodella*. And this, in turn, suggests that species of the two genera may have occupied the same depth zone, but in deeper water and shallower water environments, respectively.

The stratigraphic distribution of North Atlantic faunal elements in the Ordovician succession of the Cincinnati region has been helpful in correlating that succession with the sequence in the type area of the Trenton Group (Sweet and Bergström, 1971), and with the sequence of conodont zones established by Bergström (1971a) for rocks in the North Atlantic Province. Conodonts of North Atlantic affinities are of less value for correlation within the Cincinnati region, as indicated in the next section of this report.

BIOSTRATIGRAPHY

ASSEMBLING THE RECORD

Long continuous sections are rare in the area of Ordovician exposure in the Cincinnati region, and assembling short, scattered sections into a chronologically meaningful composite has been difficult and time consuming. Further, we have had to rely on methods that differ substantially from those ordinarily used in building a biostratigraphic framework. Consequently, the procedures employed to develop the four composite sections of figure 2 merit extended description and discussion.

Early in the study of Ordovician conodonts from the Cincinnati region it was noted (Sweet and others, 1959; Pulse and Sweet, 1960) that at least two provincially distinct conodont faunas made periodic contributions to the fauna of the Cincinnati region, and that there were substantial lateral and vertical variations in the composition of the indigenous fauna itself. The latter variations, expressed vertically by fluctuations in the relative abundance of long-ranging components of the indigenous fauna and laterally by the gradual appearance of different species, were not understood at first, but have come to be of prime importance in building the biostratigraphic framework depicted in figure 2.

In an abstract of 1965, Sweet, Bergström, and Rust commented on the potential utility of relative-abundance analysis in effecting a conodont biostratigraphy for Ordovician rocks of the Cincinnati region, and the methods they discussed were described more fully by Bergström and Sweet in 1966. Briefly, it was noted that the conodont species most abundantly and commonly represented in Lexington and younger Ordovician rocks of the Cincinnati region range from the bottom to the top of individual sections, but vary in their relative abundance from level to level in these sections in a seemingly systematic way. Because logs showing these vertical fluctuations in abundance are strikingly similar from section to section and appear to be related in only a general way to concordant variations in measured lithic features, it was concluded that correlation in time could be effected by matching relative-abundance logs for at least adjacent sections, particularly if it were assumed that the fluctuations were related to basin-wide changes in water-body conditions. Factors controlling vertical and lateral variations in relative abundance were unknown, however, and this inhibited full acceptance of the correlations made in 1966.

In 1968, Kohut and Sweet distinguished between northern and southern elements of the indigenous Richmondian conodont fauna and pointed out that transition from the area dominated by the former to that dominated by the latter is accompanied by lithic features that indicate progressively shallower water. This suggestion that lateral changes in composition of the indigenous conodont fauna were related to changes in water depth was subsequently amplified by Seddon and Sweet (1971), who proposed a general ecologic model for conodonts, in which it was postulated that these animals were pelagic and that species or groups of species were segregated by depth in somewhat the same manner that obtains for living chaetognaths. According to the Seddon-Sweet model, the diverse conodont fauna of the northern Cincinnati region changed character southward into progressively shallower water largely through the loss of deeper water species as the upper limits of their life zones "dragged bottom." Fluctuations with the passage of time in the distribution of relatively deeper and relatively shallower water areas would then produce variations in the relative abundance of deeper and shallower water conodonts that fell to and accumulated on the bottom at a particular depositional site. In short, the relative abundance of any conodont species that was confined in its lifetime to a restricted depth zone should provide, at any particular level in the stratigraphic record, at least a crude measure of the relative water depth at the depositional site. Further, vertical abundance variations in a section should be measures of changes in water depth at that site with the passage of time. Because it seems unlikely that a change in depth sufficient to influence the relative abundance of a particular species in a measurably significant way could have been confined to just a single depositional site, the conclusion of Bergström and Sweet (1966) that pattern similarities in relative-abundance logs for sections throughout the Cincinnati region imply time-correlative basin-wide changes in water-body conditions still seems valid.

The Seddon-Sweet depth-stratification model for conodonts is adequate as a general framework within which to interpret vertical and lateral fluctuations in relative abundance of species common throughout the Cincinnati region, but it needs elaboration to account for lateral changes in taxonomic composition of the indigenous fauna. That is, *Phragmodus undatus* Branson and Mehl and *Plectodina furcata* (Hinde) are the dominant members of the indigenous conodont fauna in the northern part of the Cincinnati region from the base of the Lexington Limestone almost to the top of the Cincinnatian Series. Southward, *P. furcata* becomes relatively more abundant, but the two species are still important components of the indigenous fauna. However, species of *Aphelognathus*, *Oulodus*, and ultimately *Rhipidognathus*, which are rare or absent in the northern Cincinnati region until very late in the Ordovician, are conspicuously long ranging and abundantly represented components of the indigenous fauna in the relatively shallower water deposits of the southern Cincinnati region. If, as the evidence

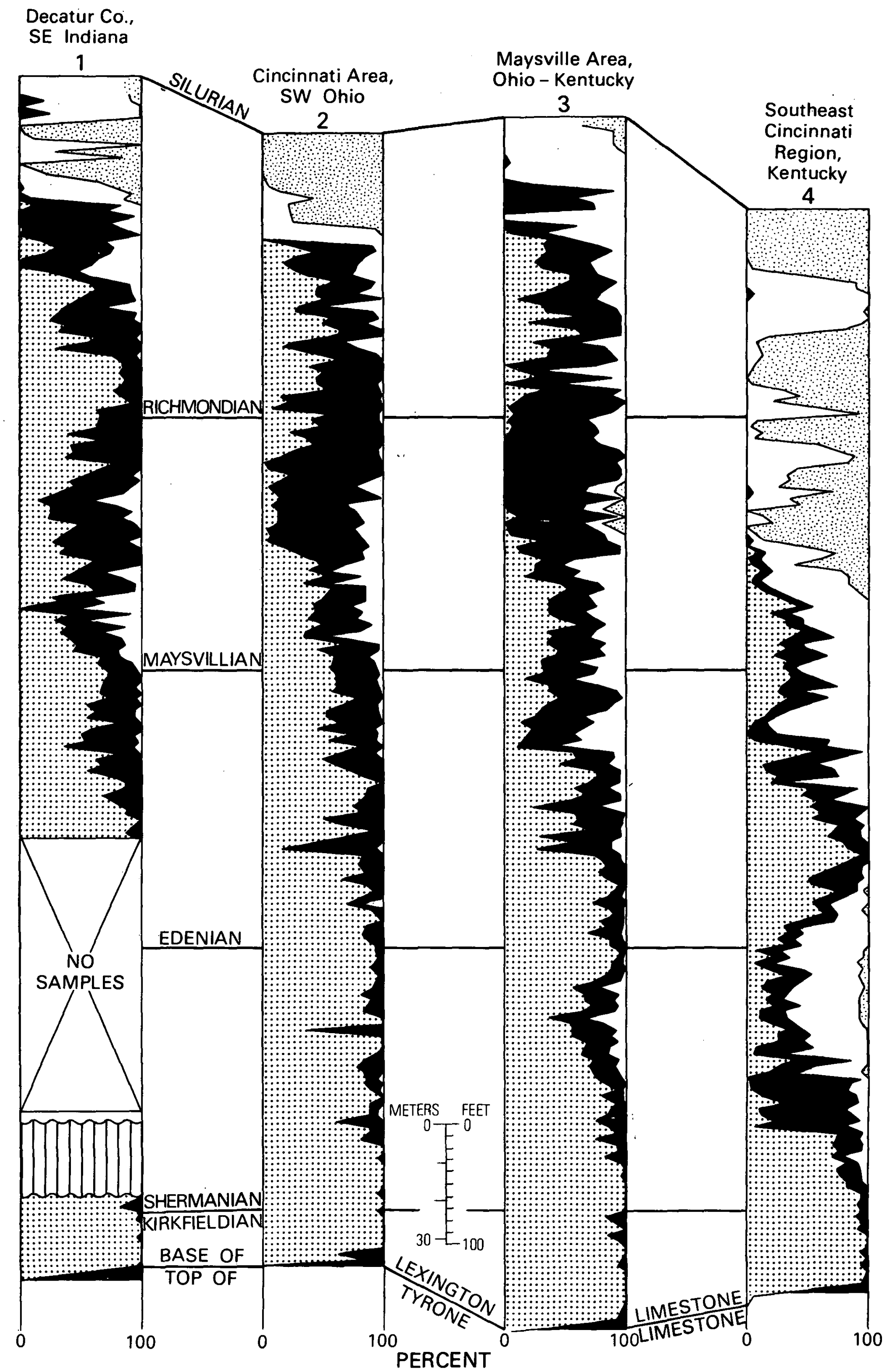

FIGURE 2.—Composite logs showing the relative abundances of *Phragmodus undatus* (coarse dots), *Plectodina* (black), *Aphelognathus* + *Oulodus* (white), and *Rhipidognathus* (fine dots) in post-Tyrone Ordovician rocks, in the four districts of the Cincinnati region enclosed in dashed lines in figure 1.

suggests, species of these latter genera inhabited water that was relatively shallower than that to which *Phragmodus* and *Plectodina* were adapted, and if water depth were the only control on their distribution, we should expect from the depth-stratification model that *Aphelognathus, Oulodus,* and *Rhipidognathus* would be represented in nearly every sample throughout the Cincinnati region. That is, as inhabitants of the shallowest water life-zone, they should have been parts of the conodont infall at every depositional site in the Cincinnati region, regardless of the absolute water depth. This is clearly not true, as is shown graphically in figure 2. Consequently, we must apparently distinguish not only between the inhabitants of various depth-zones, but also between different species that may have inhabited the same depth zone in areas of deeper or shallower water. Perhaps some of these species were benthic or nekto-benthic in habitat, as suggested by Barnes and Fåhraeus (1975).

In the more deeply submerged parts of the Cincinnati region, it appears that *Plectodina furcata* was the shallower and *Phragmodus undatus* the deeper water species; but in more shallowly submerged areas, *P. undatus* declines in relative abundance and *P. furcata* gradually gives way to *Aphelognathus politus*, which is closely related to *P. furcata* and apparently flourished in the same depth zone in shoal-water environments. In rocks that represent these shoal-water environments, specimens of *Oulodus* are also more abundant than in rocks that represent accumulation in deeper water. However, the relation of *Oulodus* to *Aphelognathus* and *Plectodina* is not clear: it may be more closely related to certain "fibrous" conodonts, as Sweet and Schönlaub (1975) have recently suggested, and the distribution of that group in rocks of pre-Lexington age very strongly suggests adaptation to very shallow water.

Rhipidognathus, as Kohut and Sweet (1968) noted, is most abundantly represented in calcareous or dolomitic mudstones that are mudcracked, ripple-marked, and may have been deposited in very shallow water environments—perhaps on intertidal mudflats. The migration of *Rhipidognathus* into the northern part of the Cincinnati region in late Cincinnatian time is clearly associated with the northward translation of such environments.

On the premise that fluctuations in the relative abundance of conodont species in the indigenous fauna of the Cincinnati region reflect basin-wide, but systematic, variations in bathymetry, but recognizing that the indigenous fauna also changes in taxonomic composition from shallower to deeper water areas, information from the 51 sections listed in the "Locality Register" has been compiled into the four areal composite sections of figure 2, rather than into a single composite, which would be too generalized to show conditions in any particular part of the Cincinnati region.

The composite log for the southeast Cincinnati region (fig. 2) includes information from all the sections in the southernmost of the areas enclosed in dashed lines in figure 1. In assembling this log, information from localities 20 and 43 (OSU sections 60P and 73SA) was first combined with additional information from locality 20 (USGS sections CF, CF-CHIEF, and CF-WEIR), for these sections collectively represent an essentially complete and continuous record in one place (Clays Ferry, Ky.) of the stratigraphic interval from low in the Lexington Limestone to the top of the Calloway Creek Limestone. To this initial "Clays Ferry composite" information was then added from locality 40 (OSU section 66KK), which is not physically continuous with the Clays Ferry composite, but begins stratigraphically at about the top of that composite section and is situated only a few miles away from it (fig. 1). From information on stratigraphic thickness and conodont frequency in all these sections, a single log (or "Clays Ferry-Agawam composite") was then constructed to show vertical fluctuations in the relative abundance of the several components of the indigenous conodont fauna of that area. Similar logs were then prepared for all the other, mostly shorter, sections of the southern Cincinnati region indicated in figure 1. These logs were compared with the "Clays Ferry-Agawam composite," and congruence of pattern, which is striking in most cases, was taken to indicate correlation. After correlation of all sections in the southern area with the "Clays Ferry-Agawam composite," a new composite frequency log was compiled, based on all available information from sections in the southern area. That log is on the right side of figure 2.

The log of figure 2 headed "Maysville area, Ohio-Kentucky" summarizes data on conodont distribution in a group of 15 sections in the east-central Cincinnati region. These sections are enclosed in a dashed line in figure 1 and are described in the Locality Register." The composite log for the Maysville area was compiled in a manner similar to that used in building the southern Cincinnati region composite. In the Maysville area, however, we compiled the initial composite by combining information from localities 42 and 1 (OSU sections 70ZA and 58A), which are close together geographically and which overlap appreciably stratigraphically. To this "Minerva-Maysville composite," data were then added from locality 25 (OSU section 63AA), which is about 10 miles east of Maysville but begins at about the same stratigraphic level as the top of the Maysville section (OSU section 58A) and continues upward to the top of the Ordovician. With the relative-abundance log for the "Minerva-Maysville-Isaacs Creek composite," logs for all the other sections shown to be parts of the "Maysville composite" in figure 1 were then compared and correlated. Ultimately, from a combination of information from all these sections, the composite frequency log for the Maysville area shown in figure 2 was constructed.

The composite frequency log for the Cincinnati area of southwest Ohio and adjacent parts of Indiana and Kentucky is the second log from the left in figure 2, and is based on information from the 14 sections enclosed by a dashed line in the north-central part of the Cincinnati region in figure 1. The initial composite was constructed from information obtained at localities 23, 34, and 26, which are respectively OSU sections 61Z (a 626-ft core drilled at Middletown, Ohio), 66KE (type section of the Maysvillian Stage, in near-downtown Cincinnati, Ohio), and 63AB (a long section of upper Maysvillian and Richmondian strata near China, Ind). These sections are more widely separated geographically than are those on which initial composites for the southern and Maysville areas were based, but they overlap stratigraphically, show closely similar patterns on relative-abundance logs, and display essentially the same sequences of lithofacies in the intervals of overlap. To this initial composite, information from other sections in the Cincinnati area was added to yield the composite log shown in figure 2.

The frequency log in figure 2 for Decatur County, Ind., is not a composite. As indicated in figure 1, this log is based on information from a single section, OSU 65GV (locality 31), which is a long core drilled by the Indiana Geological Survey and generously made available for conodont studies.

After the four regional composites just discussed were constructed, the correlations indicated in figure 2 were effected by alining the logs vertically so that events indicated by major fluctuations in the data logged were matched horizontally. In detail, the logs are noisy and out of phase at many levels. However, it is submitted that the degree to which major fluctuations in frequency and faunal composition are reflected laterally is indicative of relationships between these logs that must be more than coincidental.

Stadial boundaries indicated in figure 2 are drawn at the levels indicated by the positions of contacts in the composite log for the Cincinnati area of southwest Ohio. The base of the Maysvillian Stage, for example, is fixed by tradition at the base of the Fairview Formation in the city of Cincinnati, hence is drawn in figure 2 at the level of the Fairview base in OSU section 66KE (locality 34), which may be regarded as the Fairview type section. The base of what has become the Richmondian Stage was fixed by Orton in 1873 at the top of the *"Orthis lynx* beds" in a section in the Little Miami River valley that is very close to OSU section 58L (locality 11). Consequently, we draw the base of the Richmondian Stage in figure 2 at the level of the top of the *"Orthis lynx* beds" (=*Platystrophia ponderosa* beds) in OSU section 58L, which is part of the Cincinnati area composite. The base of the Kope Formation is no longer exposed in the city of Cincinnati, but it defines the base of the Edenian Stage and is about 230 feet below the base of the Fairview in Cincinnati (Ford, 1967). Hence the base of the Edenian Stage, and of the Cincinnatian Series, is drawn 230 feet below the base of the Fairview in OSU section 66KE (locality 34), which is also part of the Cincinnati area composite section.

Assembly of the areal composites and the correlations shown in figure 2 are based on the assumption that no large-scale or systematic variations occur within presumably contemporaneous units from place to place in the Cincinnati region. The assumption itself is based on the observation that the rock sequence throughout the Cincinnati region consists of essentially the same array of lithic types, arranged spatially in about the same stratigraphic order. Thus, although depositional rate may have varied with time, concomitant with differences in accumulation rate across the Cincinnati region, it seems unlikely that these differences were ever very great, and as data points in the logs are 5 feet apart, contemporaneous accumulation-rate differences are probably averaged out over the thickness of formations or of the logs themselves. Further, the congruence in pattern, or signature, between the logs themselves is regarded as a forceful and graphic argument for accepting the assumption that the thickness of units regarded as contemporary varies little from place to place in the Cincinnati region.

THE COMPOSITE SECTION

Conodonts from Lexington and younger Ordovician strata in the Cincinnati region are referable to 35 specific taxa and one collective category identified only as "fibrous conodonts." These 36 entities are listed alphabetically in table 1, along with their ranges in the four areal composite sections of figure 2. The right-hand column, "Composite," summarizes the known ranges for the entire Cincinnati region. In the composite, the base, or "0" point, is the base of the Lexington Limestone in the Maysville area, and the top, or "1040" point, is the top of the Cincinnatian Series in the New Point, Ind., core (OSU section 65GV; locality 31 in "Locality Register"). It is emphasized that ranges listed are merely the lowest and highest levels at which the taxa listed have been recognized: they are not intended to suggest that the species in question is continuously represented throughout the interval given by the range figures. Current concepts of the taxa identified by name in table 1 are given in the section of this report titled "Taxonomic Remarks."

For purposes of reference, it may be useful to note that the base of the Edenian Stage, and thus of the Cincinnatian Series, is at 315 feet in the composite section; that of the Maysvillian Stage is at 545 feet; and that of the Richmondian Stage is at 755 feet. In table 1 it is apparent, however, that neither the base nor the top of the range of any conodont species coincides with any of these boundaries. Consequently, none of the Cincinnatian stages can be characterized specifically by any conodont species. Six species (*Amorphognathus tvaerensis*, *Aphelognathus kimmswickensis*, *Belodina monitorensis*, *Plectodina aculeata*, *Polyplacognathus ramosus*, and *Protopanderodus* sp. cf. *P. dissimilaris*) are restricted to rocks of pre-Edenian age in the Cincinnati region, and these and five others (*Bryantodina abrupta*, *Oulodus subundulatus*, *Paroistodus*? *mutatus*, *Periodon grandis*, and *Synprioniodina*? *forsenta*) are locally restricted to pre-Maysvillian strata. Fibrous conodonts and an additional six species (*Amorphognathus superbus*, *Belodina compressa*, *Oulodus oregonia*, *Panderodus* sp. aff. *P. panderi*, *Rhodesognathus elegans*, and *Staufferella falcata*) are confined locally to pre-

TABLE 1.—*Composite and district ranges of post-Tyrone Ordovician conodonts*

[Range in feet above base of composite section; dashed lines indicate not present]

Species	Section				
	Southern	Maysville	Cincinnati	Indiana	Composite
Amorphognathus ordovicicus	---	---	585–740	585–785	585–785
superbus	205–560	210–580	210–575	410–580	205–580
tvaerensis	40–180	60–180	75–200	60–185	40–200
Aphelognathus kimmswickensis	0	---	---	44	0–44
politus	125–875	200–1,000	135–960	655–1,025	125–1,025
Belodina compressa	20–485	0–510	45–565	50–535	0–565
monitorensis	30–50	0	55	---	0–55
profunda	830–865	915–985	800–960	900–1,015	800–1,015
Bryantodina abrupta	30–475	5–465	60–430	95–110	5–475
staufferi	70–225	200–210	180–200	60–410	60–410
Cyrtoniodus sinclairi	820–865	875–975	760–895	875–1,040	820–1,040
Drepanoistodus suberectus	30–865	0–995	45–910	50–1,040	0–1,040
Fibrous conodonts	20–555	0–275	55–190	30–45	0–555
Icriodella superba	70–470	45–760	80–725	60–645	45–760
Oulodus oregonia	410–645	410–655	480–655	485–635	410–655
robustus	550–875	635–1,000	660–945	810–895	550–1,000
subundulatus	140–385	165–405	180–355	115?	115?, 140–405
ulrichi	830–870	805–990	850–900	885–1,025	805–1,025
Panderodus angularis	835–870	---	915–955	955	835–955
gracilis	20–880	0–1,000	55–970	30–995	0–1,000
sp. aff. *P. panderi*	30–365	---	185–560	55–425	30–560
staufferi	825–870	990	915–955	950–975	825–990
Paroistodus? *mutatus*	70–80	210–430	75–495	55–490	55–495
Periodon grandis	85–160	130–360	80–385	65–450	65–450
Phragmodus undatus	30–365	0–910	45–900	50–990	0–990
Plectodina aculeata	20–40	0–20	55–65	50–65	0–65
furcata	55–645	55–1,000	100–900	80–1,020	55–1,020
? *undulata*	630–880	675–1,000	850–955	900–1,015	630–1,015
Polyplacognathus ramosus	25–65	15–35	70–210	55–60	15–210
Protopanderodus sp. cf. *P. dissimilaris*	---	---	135–200	---	135–200
sp. cf. *P. insculptus*	340	105–355	135–295	80–780	105–780
Rhipidognathus rowlandensis	600–805	---	---	---	600–805
symmetricus	215–890	635–1,000	915–960	940–1,025	215–1,025
Rhodesognathus elegans	40–315	135–390	80–665	60–700	40–700
Staufferella falcata	325–580	85–585	410–555	550	85–585
Synprioniodina? *forsenta*	240	195–350	140–395	---	140–395

Richmondian rocks. Five species (*Belodina profunda, Cyrtoniodus sinclairi, Oulodus ulrichi, Panderodus angularis,* and *P. staufferi*) are known in the Cincinnati region only from Richmondian strata, and locally these species are of considerable significance biostratigraphically (Kohut and Sweet, 1968). However, all the latter species are typical components of conodont faunas of the interior subprovince of the Midcontinent Province, and they may well make their debuts there in rocks of pre-Richmondian age.

CONODONT ZONES

When systematic studies of conodonts from Ordovician rocks in the Cincinnati region began it was hoped that a sequence of zones could be delineated, which would be useful not only in effecting detailed local correlations but also in recognizing the equivalents of these rocks elsewhere in North America and the world. This goal has been only partly achieved. Nevertheless, local correlations have been effected in other ways than zonal "matching," and the regional and international equivalents of the rocks of the Cincinnati region can be broadly identified within the framework of a zonal scheme worked out in the North Atlantic Province by Bergström (1971a).

Rocks 40 to 200 feet above the base of the composite section for the Cincinnati region yield representatives of *Amorphognathus tvaerensis* Bergström; hence, they represent at least the upper part of the *A. tvaerensis* Zone (Bergström, 1971a). Between 205 and approximately 580 feet above the base of the composite section, strata of the Cincinnati region yield specimens of *Amorphognathus superbus* (Rhodes), which evolved from *A. tvaerensis* and defines the *A. superbus* Zone in Bergström's zonal scheme.

Specimens of *Amorphognathus* from rocks 585 to 785 feet above the base of the composite section are assigned to *A. ordovicicus* Branson and Mehl, although the holodontiform elements that are distinctive of this species have not been recovered from the Cincinnati region. These specimens are probably representatives of *A. ordovicicus,* however, because Bergström (1971a) has shown convincingly that that species evolved from *A. superbus,* and the specimens in question are from samples above the level at which very advanced representatives of *A. superbus* have been positively identified. If identification of these specimens with *A. ordovicicus* is correct, the rocks from which they were derived represent the *A. ordovicicus* Zone in Bergström's North Atlantic Province zonal succession.

Bergström (1971a, 1971b) has discussed the relationship between the three zones identified, zones in the standard graptolite sequence, and the stages and series into which they are grouped in the North Atlantic Province. It is sufficient here to note that the *A. superbus/A. ordovicicus* zonal boundary may approximate the Caradocian-Ashgillian Series boundary of the British standard sequence and that this level is likely to be within the lower 40 feet of the Maysvillian Stage of the standard Cincinnatian sequence of North America.

Sweet and others (1971) described a sequence of conodont faunas that could be reconstructed from collections derived from sections of Middle and Upper Ordovician rocks at various places in the North American Midcontinent Province. These faunas are readily distinguished from one another, but it could not be concluded with assurance that they represent an unbroken sequence, and they characterize rock successions of greatly different thickness and areal extent. Consequently, rocks yielding representatives of these faunas were not formally described as zones, and it does not seem useful to do so now. It may be noted, however, that rocks distinguished by elements of Fauna 8 of Sweet and others (1971) occupy the lower 55 feet of the composite section of this report; that strata between 55 and 200 feet above the base of the composite section yield representatives of Fauna 9; that Fauna 10 is represented in rocks 200 to 410 feet above the base of the composite; that *Oulodus oregonia* (in the sense of this report), which is the index to Fauna 11, characterizes an interval 410 to 655 feet above the base of the composite section; and that species characteristic of Fauna 12 are represented in at least modest abundance from 800 to 1,040 feet above the base of the same composite section. Rocks between 655 and 800 feet above the base of the composite section lack conodonts that are restricted to any of the several faunas described by Sweet and others (1971). Figure 2 shows that this latter interval is marked by pronounced shallowing at all depositional sites in the Cincinnati region, and by the first major spread of *Rhipidognathus* in this area. As mentioned previously, this interval is also characterized by complete disappearance from the Cincinnati region of *Panderodus* and *Belodina,* which are regarded as typical of the interior subprovince of the North American Midcontinent Province. As characteristic components of Fauna 12 of Sweet and others (1971) are interior-subprovince faunal elements, it seems reasonable to conclude that during the latter half of Maysvillian time, the Cincinnati region was not in open communication with the interior subprovince, and that it may well have been during this interval that broad uplift and erosion produced the unconformity that separates, for example, the Dubuque Formation and Maquoketa Shale of the Upper Mississippi Valley.

CORRELATIONS

Correlation of sections within the Cincinnati region has been effected by comparison of relative-abundance logs, in the manner described in a previous section of this report. These correlations are translated into a more general diagram in figure 3. It is difficult to show in a single two-dimensional chart all the relations between the many named facies in the Ordovician of the Cincinnati region. However, figure 3 summarizes the arrangement of major post-Tyrone lithic units indicated by the distribution of conodonts along the general southeast-to-northwest line on which the logs of figure 2 are arrayed.

No attempt is made here to interpret the arrangement of stratigraphic units displayed in figure 3 historically. However, it may be appropriate to note that, from at least the midpart of the Lexington Limestone upward, facies along the right side of figure 3, beneath the heading "N.-central Kentucky," appear to have accumulated in water that was relatively shallower and more agitated than was the water in which contemporaneous facies shown in the left side of the diagram were deposited.

Conodont-based correlation of the Lexington Limestone and younger Ordovician rocks of the Cincinnati region with strata in the type area of the

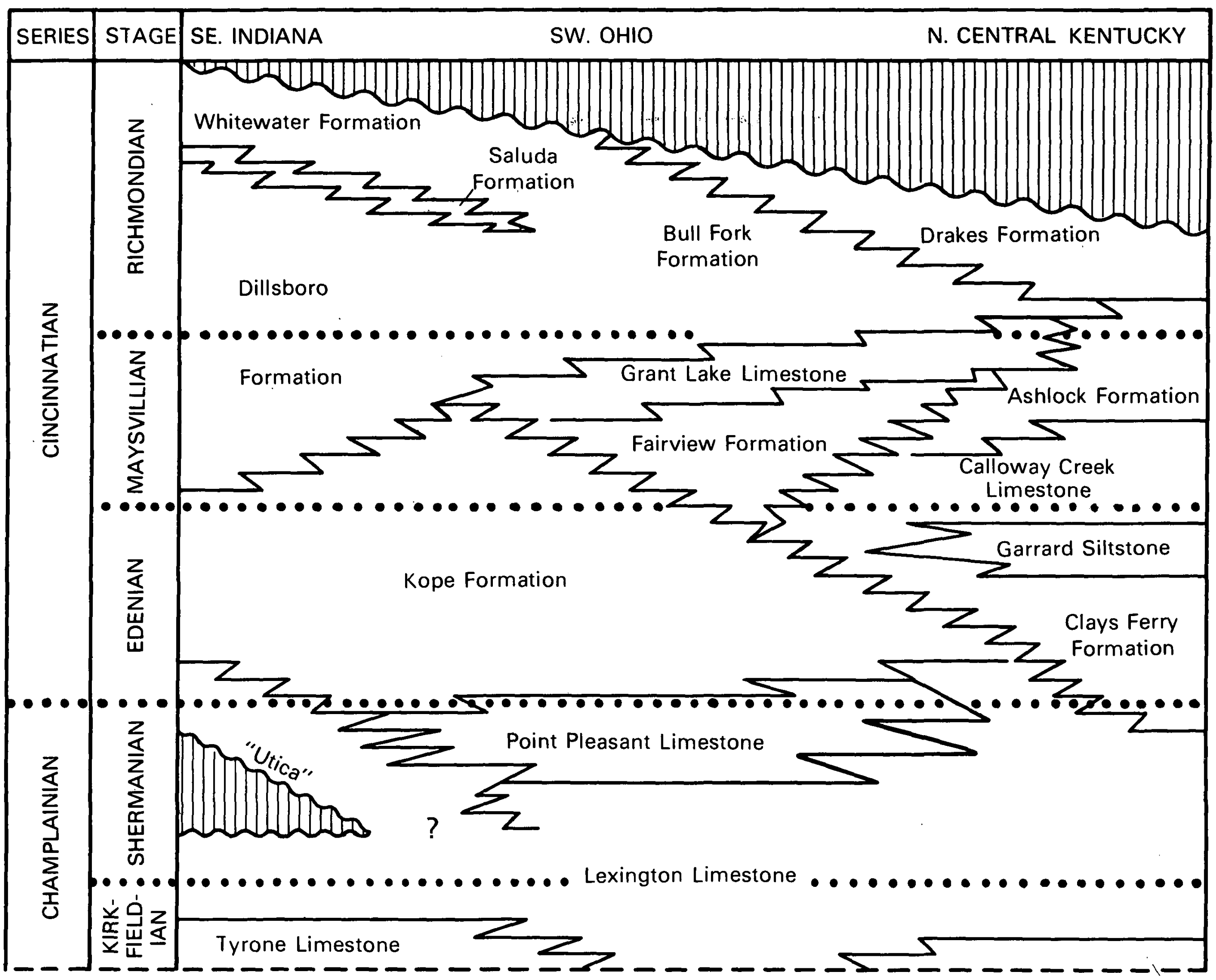

FIGURE 3.—Correlation of post-Tyrone Ordovician rocks of the Cincinnati region, as suggested by the distribution of conodonts in the sections whose locations are shown in figure 1.

Trenton Group was effected by Sweet and Bergström (1971), who have reported their procedures and conclusions elsewhere. Their correlations indicate that the base of the typical Edenian Stage and the top of the typical Shermanian Stage are at essentially the same biostratigraphic level. As a consequence of those correlations, they suggested that the top of the Champlainian Series (the North American Middle Ordovician) be defined by the base of the Cincinnatian Series, which, by convention, is the base of the Edenian Stage at its type locality. They also noted that a substantial part of the Trenton Group, long thought to be entirely pre-Cincinnatian in age, is, in fact, laterally equivalent to rocks of Edenian and early Maysvillian age. To recognize this equivalence, they suggested that the Cobourgian Stage be dropped from the standard sequence of time-stratigraphic units for North American Ordovician rocks, and that the term "Trenton" be used only in the combination "Trenton Group" to distinguish a major body of rock in New York and adjacent Ontario—not in a time-stratigraphic sense, as has been customary for many years.

According to Bergström (1971a, 1971b) the upper boundary of the *Amorphognathus tvaerensis* Zone, which is about 200 feet above the base of the composite section for the Cincinnati region, is probably in the upper part of the *Diplograptus multidens* graptolite zone; the *A. superbus* Zone 200 to 580 feet above the base of the composite, includes strata elsewhere that are assignable to the upper *D. multidens,* the *Dicranograptus clingani,* and the lower *Pleurograptus linearis* graptolite zones; and the *A. ordovicicus* Zone, above 585 feet in the composite, includes equivalents of the upper *Pleurograptus linearis,* the *Dicellograptus complanatus,* and, presumably, the *D. anceps* graptolite zones. Thus, at least broadly, rocks between the base of the Lexington Limestone and a level 30 to 40 feet above the base of the Maysvillian Stage are of Caradocian Age; and rocks above 585 feet in the composite section are Ashgillian.

TAXONOMIC REMARKS

As collections have grown and experience with multielement taxonomy has enlarged, concepts of the species and genera of conodonts represented in Ordovician rocks of the Cincinnati region have also changed. Thus, concepts currently represented by the names used in preceding sections of this report and in table 1 are indicated in the following paragraphs. As will be apparent, several taxa need additional study, and others can be revised on the basis of existing information. Systematic treatments of the latter category are not included, however, for this is intended to be a synoptic report, or status summary, on Cincinnati region Ordovician conodonts, not a complete systematic catalog.

Amorphognathus ordovicicus Branson and Mehl, 1933

The current concept of this species is that of Bergström (1971a), who recognized that elements of the sort referred to the form-species *Goniodontus superbus* Ethington, 1959, are the diagnostic components of the skeletal apparatus of *A. ordovicicus.* Holodontiform elements of this type have not yet been collected from Ordovician rocks in the Cincinnati region. However, we do have very advanced specimens of *A. superbus,* the evolutionary predecessor of *A. ordovicicus,* from rocks in the lower 30 feet of the Maysvillian Stage, and numerous specimens of the other skeletal components of an *Amorphognathus* have been recovered from rocks well above that level. Thus specimens of *Amorphognathus* from above 585 feet in the composite section have been arbitrarily assigned to *A. ordovicicus* and in table 1, the species is shown to range as high as 785 feet above the base of the composite section.

Amorphognathus superbus (Rhodes, 1953)

Bergström's (1971a) concept of this species is followed. The apparatus is distinguished by elements of the type previously identified as *Holodontus superbus* Rhodes (1953). Elements of the latter type are quite small, and they are not numerous in collections from the Cincinnati region. However, enough of them occur to indicate that *A. superbus* ranges from 205 to about 580 feet above the base of the composite section (table 1).

Amorphognathus tvaerensis Bergström, 1962

Representatives of *Amorphognathus* from samples below 200 feet in the composite section are assigned to this species, which is characterized by its distinctive amorphognathiform elements (Bergström, 1971a, pl. 2, fig. 10; Sweet and others, 1971, pl. 1, fig. 24). In the Cincinnati region, *A. tvaerensis* ranges from 40 to 200 feet above the base of the composite section.

Aphelognathus kimmswickensis Sweet, Thompson, and Satterfield, 1975

In two samples (OSU 65GV–0.5 and 70ZA–665) in the lower 44 feet of the composite section, a large number of distinctive aphelognathiform elements are associated with an array of ramiform and prioniodiniform elements like those on which Sweet, Thompson, and Satterfield (1975) based *A. kimmswickensis.* All these specimens are here assigned to *A. kimmswickensis,* which is based on material from the Kimmswick Limestone of Missouri.

Aphelognathus politus (Hinde, 1879)

Bergström and Sweet (1966) regarded robust ozarkodiniform elements with a prominent gap in the denticle profile just anterior to the cusp as representatives of a single-element species, *Ozarkodina polita* (Hinde). Subsequently (Sweet and others, 1971), after comparisons with the type material of *Aphelognathus grandis* Branson, Mehl, and Branson (1951), the species was transferred to *Aphelognathus.* Further, in the reexamination of collections that preceded preparation of this report, it has been noted that elements assignable to *A. politus* are especially characteristic of collections from the southern Cincinnati region, where they occur with robust ramiform and prioniodiniform elements that were previously regarded as components of the *Plectodina furcata* apparatus. It now seems likely that *P. furcata* and *A. politus* had skeletal apparatuses of closely similar architecture, which differed most prominently in the conformation of their ozarkodiniform elements. Thus, in samples that contain the ozarkodiniform elements of both species, it is difficult or impossible to determine which ramiform and prioniodiniform elements should be assigned to which species. In samples that contain only *politus*-type ozarkodiniform elements, however, associated ramiform and prioniodiniform elements do differ somewhat from those typical of *Plectodina furcata.* That is, they are not only more robust than those of *P. furcata,* but their cusps also tend to develop lateral flanges; the antero-basal corner of their cyrtoniodiform elements tends to be produced into a denticulate anterior process; and their cordylodiform elements tend to develop the inwardly deflected, denticulated anterior process that Branson, Mehl, and Branson (1951) regarded as characteristic of the form-genus *Eoligonodina.*

Aphelognathus politus, as characterized in the preceding paragraph, ranges from 125 to 1,025 feet above the base of the composite section. Distribution in the Cincinnati region suggests that *A. politus* inhabited essentially the same depth zone as *Plectodina furcata* but that it replaced *P. furcata* in the shallower water environments of the southern Cincinnati region. Because of the obviously close relationship between *A. politus* and *P. furcata,* it may well be that assignment to different genera is overly artificial. A separate assignment is retained, however, pending completion of a thorough study of phylogenies in the *Plectodina-Aphelognathus-Oulodus* complex of species.

Belodina compressa (Branson and Mehl, 1933)

The current concept of this species is the same as that of Bergström and Sweet (1966, p. 312–315, Pl. 31, figs. 12–19). The skeletal apparatus was composed of two belodiniform elements (*Belodus grandis* and *B. wykoffensis* of Stauffer, 1935b) and an oistodiform element (*Oistodus fornicalus* Stauffer, 1935b; or *Eobelodina fornicala* (Stauffer) of Sweet and others, 1959). *Belodina compressa* is regarded as a member of the fauna of the interior subprovince of the Midcontinent Province, and it ranges from the base to a level 565 feet above the base of the composite section.

Belodina monitorensis Ethington and Schumacher, 1969

The lower Lexington specimens described as *Belodina* sp. cf. *B. inornata* (Branson and Mehl) by Bergström and Sweet (1966, p. 315–317, pl. 32, figs. 6–8) are herein assigned to *Belodina monitorensis,* which was established by Ethington and Schumacher (1969) for material from the Copenhagen Formation of Nevada. The skeletal apparatus of this species consists of three morphologically distinct elements. Two are prominently costate along the convex margin and differ primarily in degree of longitudinal curvature. The third element, which may be homologous with the oistodiform component of *B. compressa,* is strongly curved, distinctly bowed, marginally acostate, and does not develop the basal notch and midlateral groove of the other two elements of the assembly. In the Cincinnati region, *B. monitorensis* ranges from the base to 55 feet above the base of the composite section.

Belodina profunda (Branson and Mehl, 1933)

Collections from Richmondian rocks of the Cincinnatian type area include a few specimens that appear to represent this form-taxon. These specimens were described and illustrated by Kohut and Sweet (1968), and no additional material has been collected. Specimens like this probably were components of skeletal apparatuses that were at least broadly similar to those of *B. compressa* and *B. monitorensis,* but the material at hand does not justify recognition or description of such an assembly. It might be noted, however, that elements identified as *B. profunda, B. ornata,* and *B. inornata* have the same stratigraphic range in Ordovician rocks of the Batesville district, Ark. (Craig, 1968), and these three form-species together may represent the apparatus of a single multielement species. Forms identified as *B. profunda* range from 800 to 1,015 feet above the base of the Cincinnati region composite section.

Bryantodina abrupta (Branson and Mehl, 1933)

Bergström and Sweet (1966) used this name for a multielement species whose skeletal apparatus was known to contain only bryantodiniform and prioniodiniform elements. A distinctive assembly of ramiform elements having a stratigraphic range very similar to that of *B. abrupta*, was assigned to *Plectodina*? *posterocostata* Bergström and Sweet, 1966, and a few distinctive cyrtoniodiform elements that occur in the same stratigraphic interval were described as *Cyrtoniodus* sp. nov. Although none of these elements is abundantly represented in the collections at hand, it may be noted that, collectively, they form an assembly that is strikingly similar to that of multielement *B. typicalis* Stauffer, 1935a, and various species of *Plectodina, Aphelognathus, Oulodus,* and *Ozarkodina*. Thus, in this summary the concept of the skeletal architecture of *Bryantodina abrupta* has been broadened to include all the specimens described as *Plectodina*? *posterocostata* and *Cyrtoniodus* sp. nov., by Bergström and Sweet (1966). Roscoe (1973) noted a similar association in samples from the Middle Ordovician of the Lake Champlain district. *B. abrupta* ranges from 5 to 475 feet above the base of the composite section, but the species is not abundantly represented at any level in the Cincinnati region.

Bryantodina staufferi Bergström and Sweet, 1966

Current collections contain only a few more specimens of this distinctive species than were available to Bergström and Sweet (1966) when they prepared the original diagnosis and illustrations of it. These new specimens indicate that the trichonodelliform elements tentatively associated with *B. staufferi* by Bergström and Sweet (1966) were surely parts of its skeletal apparatus, which also included fragile hindeodelliform elements that are morphologically gradational with the prioniodiniform ones originally included. *B. staufferi* ranges from 60 to 410 feet above the base of the composite section.

Cyrtoniodus sinclairi Ethington and Furnish, 1960

The concept of this form-species followed here is that of Ethington and Furnish (1960) and Kohut and Sweet (1968), who originally reported it from rocks of the Cincinnati region. These distinctive elements are suspected to have been components of the apparatus of an *Aphelognathus* or *Oulodus* species, but a conclusion on this matter will not be possible until a major study of conodonts from rocks of the western midcontinent is completed. Elements identified as *C. sinclairi* range from 820 to 1,040 feet above the base of the Cincinnati region composite section.

Drepanoistodus suberectus (Branson and Mehl, 1933)

The current concept of this species is the same as that expressed by Bergström and Sweet (1966, p. 330–333; pl. 35, figs. 22–27), but the species is referred to *Drepanoistodus* Lindström, 1971, rather than to *Drepanodus* Pander (1856). The three coniform elements of this distinctive and apparently cosmopolitan species occur in virtually every sample in the collections from Decatur County, Ind., the Cincinnati area, and the Maysville area of the Cincinnati region. In the southern Cincinnati region, however, *D. suberectus* is abundantly represented only below the level at which *Rhipidognathus* appears in force (fig. 2), and elements of this species are absent or rare in the uppermost parts of composite sections in the northern Cincinnati region, which are also dominated by *Rhipidognathus*. The cosmopolitan occurrence of *D. suberectus* is interpreted to indicate that it inhabited near-surface waters. However, the absence or greatly diminished abundance of *D. suberectus* elements in rocks dominated by specimens of *Rhipidognathus* may indicate that its optimum habitat was an offshore, open-water environment, rather than the nearer shore, very shallow water environment apparently favored by *Rhipidognathus*.

"Fibrous" conodonts

In this category are included conodont elements of a variety of morphologic types, which are distinguished by their robust construction, peglike denticulation, fibrous fracture, and minor content of "white matter." Almost certainly, these elements were components of several multielement apparatuses and the entire category they represent merits detailed study and revision. Such a study must be based on much larger collections than the ones at hand, however. Hence, all elements of fibrous habitus are grouped together here. They clearly represent species that were most abundant and most widely distributed in very shallow water, nearshore environments. Fibrous conodonts are represented sporadically in collections from Lexington and younger Ordovician strata, from the base of the Lexington to a level 555 feet above the base of the composite section. They are the principal components, however, of pre-Lexington conodont faunas in the Cincinnati region.

Icriodella superba Rhodes, 1953

The complete skeletal apparatus of this species was described and illustrated by Bergström and Sweet (1966, p. 337–340; pl. 29, figs. 1–11), and the current concept of it remains the same as theirs. *I. superba* was interpreted as a member of the fauna of the North Atlantic (or European) Province by Bergström and Sweet, and the dominance of *I. superba* elements over those of other North Atlantic species in the relatively shallower water rocks of the southern Cincinnati region led Seddon and Sweet (1971) to conclude that *I. superba* inhabited a shallower depth-zone than *Amorphognathus*, the other major North Atlantic component in Ordovician rocks of the Cincinnati region. However, the distributional data presented by Seddon and Sweet might also be interpreted to mean that *Icriodella* and *Amorphognathus* inhabited essentially the same depth-zone, but that *Icriodella* was relatively more abundant than *Amorphognathus* in the nearer shore environments in which rocks of the southern Cincinnati region were deposited.

Oulodus oregonia (Branson, Mehl, and Branson, 1951)

Bergström and Sweet (1966) united under this name a distinctive assembly of prioniodiniform, cordylodiform, and oulodiform elements, to which they later added (Sweet and Bergström, 1972) some of the trichonodelliform and zygognathiform elements they had previously referred to *Plectodina furcata* (Hinde). Currently, then, the skeletal apparatus of this species is thought to have been composed of a complete symmetry-transition series of trichonodelliform, zygognathiform, and cordylodiform elements; an oulodiform element; a prioniodiniform element with a short anterior process, which may be homologized with the neoprioniodiform element of younger prioniodinacean skeletal apparatuses; and a prioniodiniform element with subequal anterior and posterior processes. A full description of this species, as presently conceived, is included in a general study of Ordovician and Silurian species of *Oulodus* by Sweet and Schönlaub (1975). It should be noted here, however, that the species to which Bergström and Sweet referred in 1966 is the one herein named *Oulodus subundulatus* (Sweet and others, 1959). That is, it now seems certain that, although elements indistinguishable from those named *Prioniodina oregonia* by Branson, Mehl, and Branson (1951) have a long stratigraphic range in the Cincinnati region, the type specimen of that form-species (and thus the namegiver of multielement *O. oregonia*) was part of an apparatus in which the neoprioniodiform element was the distinctive form named *Prioniodina velicuspis* by Pulse and Sweet (1960)—not the slender-cusped neoprioniodiform element included by Bergström and Sweet. In short, the skeletal apparatus of the species named *Oulodus oregonia* in this report is distinguished by its broad-cusped neoprioniodiform element, which is the element Pulse and Sweet (1960, p. 259–260, Pl. 36, figs. 5, 13) named *Prioniodina velicuspis*.

Oulodus oregonia is very useful as a guide to rocks of middle Edenian to middle Maysvillian Age in the southern part of the Cincinnati region. The species ranges from 410 to 655 feet above the base of the composite section.

Oulodus robustus (Branson, Mehl, and Branson, 1951)

Kohut and Sweet (1968, p. 1471, pl. 185, figs. 12, 14, 15, 17, 24) described the essentially complete apparatus of this species as *Plectodina robusta*, but they failed to note that oulodiform elements associated in the same samples with representatives of this species are clearly parts of the same skeletal apparatus. Such elements (referred to *Oulodus oregonia* by Kohut and Sweet) are here included in the apparatus, and the species is thereby transferred from *Plectodina* to *Oulodus*. The complete apparatus, as now interpreted, is illustrated by Sweet and Schönlaub (1975). *O. robustus* ranges from the base of the Maysvillian Stage to a level very near the top of the Richmondian Stage in the Cincinnati region (from 550 to 1,000 feet above the base of the composite section).

Oulodus subundulatus (Sweet and others, 1959)

As noted in a previous paragraph, the species named *Oulodus oregonia* by Bergström and Sweet (1966, p. 342–347, pl. 32, figs. 20, 21; pl. 33, fig. 5; pl. 34, figs. 13–16) requires another name because the type specimen of the namegiving prioniodiniform element was almost certainly a component of a multielement apparatus distinguished by neoprioniodiform elements of the type named *Prioniodina velicuspis* by Pulse and Sweet (1960). Sweet and Schönlaub (1975) used the trivial name *subundulatus* for this species because at least one of the cotypes of *Trichonodella subundulata* Sweet and others (1959) was undoubtedly part of the apparatus of this *Oulodus species*. As thus defined, *O. subundulatus* may be represented 115 feet above the base of our composite section but is almost continuously present in samples between 140 and 405 feet above the base of that section. *O. subundulatus* was apparently the progenitor of *O. oregonia*, and the level of transition from this species to *O. oregonia* is a very useful biostratigraphic horizon in at least the southern and Maysville districts of the Cincinnati region.

Oulodus ulrichi (Stone and Furnish, 1959)

Available collections include only a small number of specimens of the eoligonodiniform element that distinguishes this species, which was regarded by Kohut and Sweet (1968, p. 1469, pl. 185, figs. 7, 11) as a subspecies of *O. oregonia* (Branson, Mehl, and Branson, 1951). From a study of these specimens, little can be added to the discussion of Kohut and Sweet except the observation that the species is probably more closely related to *O. robustus* (Branson, Mehl, and Branson, 1951) than to *O. oregonia* and might as appropriately be regarded as a subspecies of *O. robustus*. In the composite section, *O. ulrichi* ranges from 805 to 1,025 feet above the base and is a rare but distinctive component of the Richmondian conodont fauna locally.

Panderodus angularis (Branson, Mehl, and Branson, 1951)

The description and illustration of elements characteristic of this species presented by Branson, Mehl, and Branson (1951, p. 8, pl. 1, figs. 34–39) and by Kohut and Sweet (1968, p. 1469, pl. 185, figs. 20, 23, 27) are adequate for recognition of the species, which is regarded as a Late Ordovician component of the fauna of the interior subprovince of the North American Midcontinent Province.

Panderodus gracilis (Branson and Mehl, 1933)

The concept of this species employed here is that of Bergström and Sweet (1966, p. 355–359, pl. 35, figs. 1–6) and Kohut and Sweet (1968, p. 1469–1470, pl. 185, figs. 1, 6, 9, 10, 13, 16), whose studies were based on essentially the same material. *P. gracilis*, a component of the conodont fauna of the interior subprovince, was interpreted by Seddon and Sweet (1971) as an inhabitant of a depth zone that was relatively shallower than that favored by *Belodina*, which is also characteristic of the interior subprovince.

Panderodus sp. aff. *P. panderi* (Stauffer, 1940)

Specimens discussed under this cumbersome designation are the same ones that were referred by Bergström and Sweet (1966) to *Panderodus panderi* (Stauffer), which is common, but rarely represented in abundance, in rocks of late Maysvillian and Richmondian age elsewhere in the North American Midcontinent Province, but is yet unknown in the Cincinnati region. Craig (1968) has made a detailed study of *P. panderi*, and has pointed out that typical forms differ from those of middle Maysvillian and older rocks in having an ungrooved face that is flat and inclined slightly toward the posterior. Cincinnati region specimens assigned to *P. panderi* by Bergström and Sweet (1966), on the other hand, are typically smaller and more slender, and both lateral faces are convex. Craig referred elements of the latter type to a new species, but the name he has proposed for that species and his diagnosis of it have not yet been published.

Panderodus staufferi (Branson, Mehl, and Branson, 1951)

Available collections contain only a few representatives of this single-element species, but those specimens conform closely to the types (Branson, Mehl, and Branson, 1951, p. 7, 8, pl. 1, figs. 23–27; Kohut and Sweet, 1968, p. 1470, pl. 186, figs. 4, 5). *P. staufferi*, like other species of *Panderodus*, is regarded as a component of the fauna of the interior subprovince.

Paroistodus? mutatus (Branson and Mehl, 1933)

Bergström and Sweet (1966) united acodiform and acontiodiform elements previously referred to the form-species *Belodus? mutatus* Branson and Mehl 1933; *Acodus inornatus* Ethington, 1959; and *Distacodus procerus* Ethington, 1959, as components of the skeletal apparatus of a single multielement species, for which they used the name *Acodus mutatus* (Branson and Mehl, 1933). Barnes and Poplawski (1973) suggested that the specimens Bergström and Sweet (1966) identified with *Oistodus venustus* Stauffer, 1935b, may also have been components of the *A. mutatus* apparatus, and that the species thus represented might be more properly referred to *Paroistodus* Lindström, 1971, than to *Acodus* Pander, 1856. Although it is not certain that the oistodiform elements identified with *O. venustus* by Bergström and Sweet (1966) were components of the same apparatus as elements identified as *A. mutatus*, they are included tentatively with those elements under the name *Paroistodus? mutatus* in the tabulations in this report because they have essentially the same stratigraphic range in the composite section as do elements of *A. mutatus*. It is also not certain that *Paroistodus* is the best generic assignment, for Lindström (1971) noted that the basal cavity of *Paroistodus* elements tends to become "inverted" anteriorly whereas this feature is not seen in any of the elements at hand. Possibly these elements are skeletal components of a species of an undescribed and unnamed genus.

Periodon grandis (Ethington, 1959)

The complete multielement apparatus of this North Atlantic Province species was described by Bergström and Sweet (1966, p. 363–365, pl. 30, figs. 1–8) and the concept of it remains unchanged. In the composite section, *P. grandis* ranges from 65 to 450 feet above the base, but it is not a conspicuous faunal element at any level.

Phragmodus undatus Branson and Mehl, 1933

Representatives of this multielement species dominate collections of conodonts from the Cincinnati region, where the species ranges from the base to 990 feet above the base of the composite section. The skeletal apparatus of *P. undatus* was fully described by Bergström and Sweet (1966, p. 369–372, pl. 28, figs. 13–20), and additional material collected since 1966 merely confirms their reconstruction and interpretation. Seddon and Sweet (1971) concluded that *P. undatus* inhabited a relatively deeper life-zone in Ordovician seas than did *Plectodina furcata,* the other major component of the indigenous fauna of the Cincinnati region.

Plectodina aculeata (Stauffer ,1930)

In their study of Lexington Limestone conodonts, Bergström and Sweet (1966, p. 373, pl. 32, figs. 15, 16; pl. 33, figs. 22, 23; pl. 34, figs. 5, 6; text fig. 9A–F) recognized a close association in range and a striking similarity in morphology between certain trichonodelliform, zygognathiform, and cordylodiform elements from the lower part of the Lexington, and they concluded that all these elements were once parts of the skeletal apparatus of a single species, *Plectodina aculeata* (Stauffer). Subsequently, it became apparent that the group of elements assigned to *P. aculeata* by Bergström and Sweet has the same geographic and stratigraphic distribution as the group of ozarkodiniform, prioniodiniform, and dichognathiform elements they united as *Ozarkodina? obliqua* (Stauffer, 1930). Hence, elements of both these groups have been combined and are referred collectively to *P. aculeata.* As presently conceived, the skeletal apparatus of *P. aculeata* includes not only the symmetry-transition series of elements originally included in it by Bergström and Sweet, but also the ozarkodiniform, dichognathiform, and prioniodiniform elements they assigned to *O.? obliqua* (Stauffer) (Sweet and Bergström, 1970). The base of the range of *P. aculeata* is well below that of the stratigraphic interval considered in this report, and the top of its range locally is 65 feet above the base of the composite section.

Plectodina furcata (Hinde, 1879)

Elements of this species, and those of *Phragmodus undatus,* make up the bulk of conodont collections from the Ordovician of the Cincinnati region. The concept of the skeletal architecture of the species has evolved and is now somewhat broader than was that of Bergström and Sweet (1966, p. 377–382), who were the first to recognize its occurrence in the rocks discussed in this report. Further, it has also become clear (Sweet and Bergström, 1970) that the specimens assigned to *Ozarkodina tenuis* Branson and Mehl, 1933, and *Cyrtoniodus flexuosus* (Branson and Mehl, 1933) were parts of the *P. furcata* apparatus, but that some of the other form-categories united in *P. furcata* by Bergström and Sweet (1966) and by Kohut and Sweet (1968) were interpreted so broadly as to include components of the skeletal apparatuses of various species of *Aphelognathus* and *Oulodus.* Brief discussion of these matters is clearly appropriate here so that it will be clear what is meant by *P. furcata* elsewhere in this report.

In 1969, Kohut reported that the trichonodelliform, zygognathiform, cordylodiform, and prioniodiniform elements united by Bergström and Sweet (1966) as *Plectodina furcata* (Hinde) form a recurrent group that also includes the cyrtoniodiform elements assigned to *Cyrtoniodus flexuosus* (Branson and Mehl) and the ozarkodiniform elements assigned to *Ozarkodina tenuis* Branson and Mehl by Bergström and Sweet (1966). Mutual affinities in this group were reported to be 0.93, and rank-correlations between all pairs in this group, except those containing *O. tenuis,* were significantly positive. Kohut thus expanded Bergström and Sweet's concept of *P. furcata* by including the elements they assigned to *Cyrtoniodus flexuosus;* but, despite their occurrence in the initial group, he excluded the elements they referred to *O. tenuis* because rank-correlation values were not significant.

Kohut's conclusions were appropriately conservative, but we believe that other considerations argue strongly in favor of including in *P. furcata* the ozarkodiniform elements he excluded on rank-correlation grounds. That is, comparison of the *P. furcata* apparatus with that of other prioniodont and polygnathacean apparatuses (Sweet and Bergström, 1972) suggests that the *P. furcata* apparatus is incomplete without an ozarkodiniform element, which Kohut showed to be an essentially constant member of the recurrent *P. furcata* group. Failure of this element to show significant rank-correlation with other elements of the group is attributable, we believe, to several factors. Probably the most important of these is the fact that fragments were included in many of the frequency tabulations used by Kohut and no assurance exists that some specimens were not counted twice or several times. In addition, it now seems certain that the ramiform-element plexus assigned in its entirety to *P. furcata* by Bergström and Sweet (1966) and Kohut (1969) was shared by *P. furcata, Oulodus oregonia,* and *Aphelognathus politus.* Thus frequencies of these ramiform elements used by Kohut should probably have been adjusted by removal of elements now thought to be assignable to species of *Oulodus* and *Aphelognathus.* Consequently, including in *P. furcata* the elements referred by Bergström and Sweet (1966) to *Ozarkodina tenuis,* the high level of affinity they exhibit to others of the *P. furcata* group is emphasized and the importance of rank-correlation values obtained by Kohut is minimized.

As now conceived, the skeletal apparatus of *Plectodina furcata* (Hinde) includes a symmetry-transition series of trichonodelliform, zygognathiform, and cordylodiform elements; a cyrtoniodiform element of the type assigned by Bergström and Sweet (1966) to *Cyrtoniodus flexuosus* (Branson and Mehl); a prioniodiniform element; and an ozarkodiniform element of the type described as *Ozarkodina tenuis* Branson and Mehl by Bergström and Sweet. Process denticles of all elements tend to be compressed in the plane of the process and laterally confluent, and this feature serves to distinguish them from comparable structures of various species of *Oulodus,* which are characterized by discrete, peglike denticles. In samples that contain both the ozarkodiniform elements of *P. furcata* and the aphelognathiform elements of *Aphelognathus politus,* it is difficult to distinguish between ramiform elements of the two species. In samples that have only aphelognathiform elements, however, associated ramiform components are more stoutly constructed; cusps tend to be prominently costate marginally; and cyrtoniodiform elements tend to develop downwardly directed, denticulated anterior processes.

Seddon and Sweet (1971) concluded that *Plectodina furcata* inhabited relatively shallower water than *Phragmodus undatus,* a common associate. They did not distinguish between *Plectodina* and *Aphelognathus,* however, so their conclusion also requires some modification. That is, it is now clear that *P. furcata* was replaced laterally, in the same depth-zone but in the shallower water of the southern Cincinnati region, by *Aphelognathus politus.* Thus, *P. furcata* may still be regarded as an inhabitant of a relatively shallow depth-zone, but it was probably most characteristic of the more offshore environment and the deeper water areas of the northern Cincinnati region.

Plectodina? undulata (Branson, Mehl, and Branson, 1951)

The concept of this multielement species adopted here is essentially that of Kohut and Sweet (1968, p. 1471, pl. 186, figs. 1–3, 14, 16). However, the skeletal apparatus of this species is expanded to include the robust, twisted ozarkodiniform elements that occur in the same samples but were tabulated by Kohut and Sweet as *Ozarkodina tenuis* Branson and Mehl. Some reservations are also expressed about the reference of this species to *Plectodina.* That is, the ozarkodiniform element associated with the apparatus of this species is similar to that of *P. aculeata* and *P. furcata,* but ramiform elements display discrete, peglike denticles of the sort regarded as typical of *Oulodus* and later genera of the Prioniodinacea.

The characters by which the ramiform components of the skeletal apparatus of *Plectodina? undulata* are distinguished appear for the first time in a small group of specimens from the Lexington Limestone, between 174 and 178 feet above the base of the composite section. The species is more or less continuously represented, however, only from 630 to 1,015 feet in that section, and in that interval it is commonly associated with specimens of *Oulodus robustus* and *Rhipidognathus.* Thus, *P.? undulata* is regarded as a member of the southern element of the indigenous conodont fauna of the Cincinnati region, and as an inhabitant of the very shallow water environments that prevailed in the southern Cincinnati region during much of the Middle and Late Ordovician.

Polyplacognathus ramosus Stauffer, 1935b

The concept of this species used here is the same as that given by Bergström and Sweet (1966, p. 386–388, pl. 28, figs. 9–12). The species ranges from 15 to 210 feet above the base of the composite section, is known from rocks much older than the Lexington Limestone, and is not abundantly represented at any level in any of the sections considered in this report.

Protopanderodus sp. cf. *P. dissimilaris* (Branson and Mehl, 1933)

Bergström and Sweet (1966) described five specimens from the Lexington Limestone as *Scandodus* sp. cf. *S. dissimilaris.* No additional material has been collected, but it should be noted that the specimens probably do not represent *Scandodus* Lindström, 1955, as that genus is currently interpreted (Lindström, 1971). They may well be components of the apparatus of the species listed here as *Protopanderodus* n. sp. cf. *P. insculptus*, but available material is too small to support this suggestion adequately. Consequently, we suggest the possibility that these specimens are closely related to those referred to *P.* n. sp. cf. *P. insculptus*, by transferring them, as a separate entity, from *Scandodus* to *Protopanderodus*. The five specimens in question occur in samples from an interval 135 to 200 feet above the base of the composite section.

Protopanderodus n. sp. cf. *P. insculptus* (Branson and Mehl, 1933)

Collections at hand contain only a few specimens of this distinctive species, and they are the same ones that were referred by Bergström and Sweet (1966, p. 398–400, pl. 34, figs. 26, 27) to *Scolopodus insculptus*. These specimens are not included in *Scolopodus* here, however, for Lindström (1971) has listed a number of features not recognizable in these specimens as characters of specimens he regards as typical of *Scolopodus*. Thus, at least for purposes of reference, the species is assigned to *Protopanderodus* Lindström, 1971, although a more comprehensive study of larger collections than are now available probably will result in assignment of specimens like this to a new genus. It also seems likely that specimens from the Cincinnati region differ enough from the type-specimen of *Phragmodus insculptus* Branson and Mehl, 1933, to be regarded as representatives of a different species.

Rhipidognathus rowlandensis Kohut and Sweet, 1968

The concept of this species is unchanged from that given by Kohut and Sweet (1968, p. 1472–1473, pl. 185, figs. 4, 5) and no new material has been collected. *R. rowlandensis* is an associate of *R. symmetricus symmetricus*, and a majority of the specimens in the collection are from the Rowland Member of the Drakes Formation.

Rhipidognathus symmetricus Branson, Mehl, and Branson, 1951

This species is interpreted here as it was by Kohut and Sweet (1968), who recognized two subspecies, *R. symmetricus symmetricus* Branson, Mehl, and Branson, 1951, and *R. symmetricus discretus* Bergström and Sweet, 1966. In representatives of the latter subspecies, denticles are robust, elliptical in cross section, and discrete at all stages of growth, whereas in specimens of the former subspecies, denticles are fragile, compressed, overgrown by successive lamellae, and come to be engulfed in broad bladelike structures in late growth stages. *R. symmetricus discretus* appears first and has the widest geographic distribution of the two subspecies, but the species as a whole is interpreted to have been an inhabitant of the shallowest water and nearest shore environments represented by any of the many lithic facies in the stratigraphic interval under consideration.

Rhodesognathus elegans (Rhodes, 1953)

Bergström and Sweet (1966, p. 393–394, pl. 34, figs. 19–23) concluded that the skeletal apparatus of this species was bi-elemental; that is, that it consisted of only two morphologically distinct ambalodiform elements. Roscoe (1973), however, concluded that some of the elements referred by Bergström and Sweet to the multielement species *Tetraprioniodus delicatus* (Branson and Mehl) were, in fact, components of the apparatus of *Rhodesognathus elegans* and that all of them were not assignable to *Amorphognathus* as had been concluded by Bergström (1971a). In support of his opinion, Roscoe noted that in tables given by Bergström and Sweet (1966) the ratio between representatives of *T. delicatus* and *A. ordovicicus* is 1:4 in samples that contain specimens of both *Amorphognathus* and *Rhodesognathus*, whereas it is 1:5.5 in samples that contain representatives only of *Amorphognathus*. Furthermore, Roscoe reported that several of his samples from the Glens Falls Limestone in Vermont contained numerous elements of *Rhodesognathus* and *Tetraprioniodus* but lacked amorphognathiform or prioniodiform elements that might suggest the presence of species in which a *Tetraprioniodus*-like ramiform assembly was also characteristic. Roscoe's (1973) interpretation of *Rhodesognathus elegans* is convincing, and my tabulations of Cincinnati region conodonts have been revised to reflect that interpretation. *Rhodesognathus* will be discussed more fully in a report by Roscoe and Bergström.

Staufferella falcata (Stauffer, 1935b)

In a report on conodonts from the Cape Limestone of Missouri by Sweet, Thompson, and Satterfield (1975), the elements referred by Bergström and Sweet (1966, p. 306–307, 329; pl. 35, fig. 6–16 and 10–13) and others to *Acontiodus alveolaris* Stauffer, 1935b, and *Distacodus falcatus* Stauffer, 1935b, are united as representatives of a single multielement species, for which the generic name *Staufferella* is proposed. This species is a distinctive one, but it is represented by only a few specimens in collections from the Cincinnati region, where it ranges from 85 to 585 feet above the base of the composite section.

***Synprioniodina? forsenta* Stauffer, 1940**

No further information about this form-species now exists than was available to Bergström and Sweet (1966), who first recognized it in Ordovician strata of the Cincinnati region. Elements of the sort included in this form-taxon may have been components of a multielement apparatus like the one identified as *Bryantodina staufferi*, and they range from 140 to 395 feet above the base of the composite section.

LOCALITY REGISTER

Localities are numbered serially, then identified by their Ohio State University (OSU) or U.S. Geological Survey (USGS) field designation. Figures in parentheses following field-designation numbers, indicate the approximate range (in feet) of the section in the composite section for the Cincinnati region, which is 1,040 feet thick. Locality numbers correspond to figure 1.

The Point Pleasant Limestone of figure 3 and the following locality descriptions as used by me is a body of rock between the top of the Grier Limestone Member of the Lexington Limestone and bases of the Clays Ferry or Kope Formations. Use of the name Point Pleasant in this sense is consistent with that in descriptions of Cincinnati region geologic quadrangle maps published by the U.S. Geological Survey prior to 1975, and is the usage advocated by Sweet, Harper, and Zlatkin (1974) in their description of the section at locality 42 of this report. Since 1975, however, the U.S. Geological Survey has confined the name Point Pleasant to a body of shaly carbonate rocks interpreted as a northwest-projecting tongue of the Clays Ferry Formation. Such a body includes all the rocks exposed at the type locality of the Point Pleasant, but embraces only the upper 42 feet of the 111-foot interval assigned by Sweet, Harper, and Zlatkin (1974) to the Point Pleasant Limestone at locality 42 of this report. This is not the place to debate the relative merits of these two rather different uses of the name Point Pleasant. It is sufficient to indicate the way in which the name is used in this report.

Where U.S. Geological Survey stratigraphic terminology differs from that in the following locality register, both sets of terms are used with the U.S. Geological Survey names being placed in brackets.

1. OSU–58A (400–738). Maysville (Mason County), Ky. Cuts along U.S. Highway 62–68, 1 mi south of Maysville, Ky., Maysville West 7.5-minute quadrangle. Kope and Fairview Formations and Grant Lake Limestone; 58 samples; 4,030 conodont elements.
2. OSU–58B (545–643). Stonelick Creek (Clermont County), Ohio. Natural exposures in bed and banks of valley, upstream from a point about 3 mi north of Owensville, Stonelick T., Ohio. Batavia 7.5-minute quadrangle. Fairview Formation and Grant Lake Limestone; 144 samples; 921 conodont elements.
3. OSU–58C (525–683). White Oak Creek (Brown County), Ohio. Exposures in valley of White Oak Creek and in cuts along Ohio-U.S. Highway 125, 0.75 mi west of Georgetown, Lewis T., Higginsport 7.5-minute quadrangle. Fairview Formation and Grant Lake Lime stone; 100 samples; 1,190 conodont elements.
4. OSU–58D (545–657). Bald Knob (Hamilton County), Ohio. Cuts in Cleveland Wrecking Co. storage lot, 0.5 mi southwest of junction of Western Hills viaduct and State Avenue, Cincinnati, Ohio. West Cincinnati quadrangle. Fairview Formation; 50 samples; 949 conodont elements.
5. OSU–58E (?653–?745). Rising Sun (Ohio County), Ind. Cut along U.S. Highway 56, 3.0 mi southwest of Rising Sun. Rising Sun 7.5 minute quadrangle. Kope, Fairview, and Grant lake equivalents; 65 samples; 461 conodont elements.
6. OSU–58F (607–670). Bullock Pen and Rice Creeks (Kenton County), Ky. Exposure at Narrows Road-Turkeyfoot Road intersection, 2.0 mi southeast of Erlanger, Ky., Independence 7.5-minute quadrangle. Fairview Formation; 48 samples; 470 conodont elements.
7. OSU–58G (570–660). Dry Run (Clermont County), Ohio. Exposure 1.0 mi north of U.S. Route 50, 4.5 mi southeast of Milford, Stonelick T., Goshen 7.5-minute quadrangle. Fairview Formation; 40 samples; 484 conodont elements.
8. OSU–58H (?579–?650). Sharon Woods (Hamilton County), Ohio. Exposure in Sharon Run, 0.5 mi northeast of Sharonville, Sycamore T., Glendale 7.5-minute conodont-elements.
9. OSU–58J (550–612). Grog Run (Clermont-Warren Counties), Ohio. Natural exposure beginning 3.2 mi east of Loveland, Goshen-Hamilton Tps., South Lebanon 7.5-minute quadrangle. Fairview Formation; 35 samples; 417 conodont elements.
10. OSU–58K (545–654). Rapid Run (Hamilton County), Ohio. Natural exposure beginning 2.5 mi northeast of Delhi, Delhi T., Burlington 7.5-minute quadrangle. Fairview Formation; 62 samples; 1,385 conodont elements.
11. OSU–58L (710–755). Camp Kern Run (Warren County), Ohio. Natural exposure beginning 0.3 mi west of Ft. Ancient, Washington T., Oregonia 7.5-minute quadrangle. Grant Lake Limestone; 30 samples; 1,442 conodont elements.
12. OSU–60A (275–315). Cynthiana (Harrison County), Ky. Northeast face of inactive Poindexter quarry, opposite County High School on Kentucky Route 982 (old Ky.-U.S. 27). SE¼ south-central rectangle, Cynthiana quadrangle. Type section of Cynthiana Formation of former usage, but here regarded as Point Pleasant Limestone [Clays Ferry Formation]; 35 samples; 4,364 conodont elements.

13. OSU–60B (293–305). Greendale Station (Fayette County), Ky. Cut along Southern Railroad right-of-way about 4 mi north of Lexington and 1,000 ft south of intersection of Spurr Road and railroad tracks. Lexington west 7.5-minute quadrangle. Possibly type section of Greendale Limestone Member of Cynthiana Formation of former usage, but here included in Point Pleasant Limestone [Greendale Lentil]; 8 samples; 1,096 conodont elements.
14. OSU–60BCK (Eden locality 13098) (222–359). Bear Creek (Clermont County), Ohio. East face of inactive quarry, east of mouth of Bear Creek, at junction of Ohio-U.S. Highway 52 and Ohio Route 222 southeast corner Washington T., Moscow 7.5-minute quadrangle. Point Pleasant Limestone Tongue of Clays Ferry Formation (82 ft) and Kope Formation (56 ft); 49 samples; 37,752 conodont elements.
15. OSU–60D (?–?). Rogers Gap (Scott County), Ky. Cuts along Southern Railroad right-of-way, about 1 mi south of Rogers Gap. SW¼SW¼ east-central rectangle, Delaplain 7.5-minute quadrangle. Possibly type section of Rogers Gap Member of Cynthiana Formation of former usage, but here included in Point Pleasant Limestone [Clays Ferry Formation]; 12 samples; 621 conodont elements.
16. OSU–60G (247–342). Sadieville (Scott County), Ky. Weathered cuts on east and west sides of Kentucky-U.S. Highway 25, 1.65 mi west of Sadieville. SW¼ south-central rectangle, Sadieville 7.5-minute quadrangle. Point Pleasant Limestone [Clays Ferry Formation]; 40 samples; 26,867 conodont elements.
17. OSU–60H (220–271). Menzie (Pendleton County), Ky. Cut along L. and N. Railroad right-of-way, 0.25 mi north of Menzie, Ky. NE¼ northwest rectangle, Falmouth 7.5-minute quadrangle. Point Pleasant Tongue of Clays Ferry Formation; 16 samples; 4,573 conodont elements.
18. OSU–60L (197–282). Carntown (Bracken County), Ky. Abandoned quarry adjacent to Kentucky Route 8 at Carntown. SW¼ northwest rectangle, Moscow 7.5-minute quadrangle. Point Pleasant Tongue of Clays Ferry Formation; 39 samples; 28,161 conodont elements.
19. OSU–60M (278–211). Milford (Bracken County), Ky. Abandoned quarry on east side of Kentucky Route 19, directly east of Milford across North Fork of Licking River. NW¼ east-central rectangle, Claysville 7.5-minute quadrangle. Point Pleasant Limestone [Clays Ferry Formation]; 19 samples; 4,847 conodont elements.
20. OSU–60P (102–347), USGS–CF (265–356), USGS–CF CHIEF (386–487), USGS–CF WEIR (349–487). Clays Ferry (Madison County), Ky. Weathered cuts along Clays Ferry Road (old Kentucky-U.S. Highway 25) on southeast side of Kentucky River. SE¼ southwest rectangle, Ford 7.5-minute quadrangle. Section begins in Kentucky River fault zone and extends upward in downthrown block. Lexington Limestone, Point Pleasant Limestone [Clays Ferry Formation] Clays Ferry Formation, and Garrard Siltstone; 211 samples; 29,215 conodont elements.
21. OSU–60Q (227–243). Willow Creek (Bracken County), Ky. Natural exposure in floor and walls of Willow Creek valley, upward from point at which Kentucky Route 539 crosses the creek and 1.1 mi west-northwest of Milford. SE¼ north-central rectangle, Claysville 7.5-minute quadrangle. Point Pleasant Limestone [Clays Ferry Formation]; 10 samples; 5,905 conodont elements.
22. OSU–60T (220–299). Falmouth (Pendleton County), Ky. Three road cuts on northeast and southwest sides of Kentucky-U.S. Highway 27, beginning 0.25 mi southeast of city limits of Falmouth. NW¼ south-central rectangle, Falmouth 7.5-minute quadrangle. Point Pleasant Tongue of Clays Ferry Formation; 34 samples; 21,564 conodont elements.
23. OSU–61Z (45–627). Middletown (Butler County), Ohio. 2.25-in. core drilled in 1957 by Texas Eastern Transmission Corp. on Valentine Apple Farm, SW¼ sec. 19, Lemon T. (core numbered 860 in files of Ohio Division of Geological Survey). Trenton 7.5-minute quadrangle. Lexington Limestone, "Utica" (of drillers), Point Pleasant Limestone, Kope Formation and Fairview Formation; 202 samples; 36,628 conodont elements.
24. OSU–62DA (986–1001). Ohio Brush Creek (Adams County), Ohio. Cut along north side of Ohio Route 41, immediately south of point at which Route 41 crosses Ohio Brush Creek, Oliver T., Pebbles 7.5-minute quadrangle. Preachersville Member of Drakes Formation; 4 samples; 1,143 conodont elements.
25. OSU–63AA (735–1006). Isaacs Creek (Adams County), Ohio. Natural exposure in valley walls of Isaacs Creek, Sprigg T. Section begins 1.6 mi north of city limits of Manchester, Manchester-Islands 7.5-minute quadrangle. Grant Lake Limestone, Bull Fork Formation and Preachersville Member of Drakes Formation; 32 samples; 5,135 conodont elements.
26. OSU–63AB (650–977). China (Jefferson County), Ind. Composite of two overlapping natural sections along Dry Fork, 1 mi south of China, Canaan, 7.5-minute quadrangle. Dillsboro and Whitewater Formations; 63 samples; 8,920 conodont elements.
27. OSU–63AF (735–779). Arnheim (Brown County), Ohio. Natural exposure along Straight Creek, 1 mi south of Arnheim, Franklin T., Ash Ridge 7.5 minute quadrangle. Type section of Arnheim Formation (Foerste, 1905). Grant Lake and Bull Fork facies; 12 samples; 2,090 conodont elements.
28. OSU–64S1 (280–315). Banklick Creek (Kenton County), Ky. Natural exposure along south side of Banklick Creek, 0.35 mi west of the point at which it crosses Kentucky Route 177 in Latonia, Ky., Covington 7.5-minute quadrangle. Point Pleasant Tongue of Clays Ferry Formation; 11 samples; 11,381 conodont elements.
29. OSU–64S2 (30–360). Frankfort East (Franklin County), Ky. Cuts along eastbound and westbound lanes of Kentucky-U.S. Interstate Highway I-64 east of Kentucky River and about 1 mi south of Frankfort. Frankfort East 7.5- minute quadrangle. Lexington Limestone and Point Pleasant Limestone [Clays Ferry Formation]; 80 samples; 26,019 conodont elements.
30. OSU–64S3 (225–325). Frankfort West (Franklin County), Ky. Cuts along eastbound and westbound lanes of Kentucky-U.S. Interstate Highway I-64 west of Kentucky River and about 1 mi west of OSU–64S2. Frankfort West 7.5- minute quadrangle. Lexing-

ton Limestone and Point Pleasant Limestone [Clays Ferry Formation]; 31 samples; 11,262 conodont elements.

31. OSU-65GV (30-1040). New Point (Decatur County), Ind. 2.25-in. core drilled by Indiana Geological Survey, beginning on floor of quarry 0.5 mi west of 850 East Road and 0.5 mi north of the junction of that road and Indiana-U.S. Interstate Highway I-74, 0.5 mi north of New Point. New Point 7.5-minute quadrangle. Lexington Limestone and "Utica" (of drillers), Kope, Dillsboro, and Whitewater Formation; 146 samples; 19,769 conodont elements.

32. OSU-66KB (325-531). (Eden locality 13100). Kope Hollow (Brown County), Ohio. Natural exposure in Kope Hollow, 0.4 mi east of Levanna, on Ohio-U.S. Highway 52, Russellville 7.5-minute quadrangle. Type section of Kope Formation (Weiss and Sweet, 1964); 33 samples; 12,715 conodont elements.

33. OSU-66KD (765-900). Fort Ancient North (Warren County), Ohio. Artificial exposure in three cuts along abandoned construction road just south of Ohio-U.S. Interstate Highway I-71 on west bank of Little Miami River, 1.0 mi north of Fort Ancient, Oregonia 7.5-minute quadrangle. Base of section about 10 ft above base of Orton's (1873) "Lebanon Beds," the type section of which (and of the "Richmond Group") is on the opposite bank of the Little Miami River; 35 samples; 8,501 conodont elements.

34. OSU-66KE (505-670). Clifton Avenue, Cincinnati (Hamilton County), Ohio. Natural exposure along east and southeast side of Clifton Avenue, below Bellevue Park, Cincinnati. Covington 7.5-minute quadrangle. Upper part of Kope Formation, Fairview Formation, and lower part of Grant Lake Limestone; 33 samples; 7,299 conodont elements.

35. OSU-66KF (655-850), USGS-FRED. Fredericktown (Nelson County), Ky. Cut along U.S.-Highway 150, 7.0 mi east of Bardstown Courthouse, Maud 7.5-minute quadrangle. Section begins in Tate Member of Ashlock Formation and extends upward to base of Brassfield Formation (Silurian); 40 samples (OSU-66KF), 21 samples (USGS-FRED); 2,746 conodont elements (OSU-66KF), 1,837 conodont elements (USGS-FRED).

36. OSU-66KG (615-675). Ashlock Cemetery West (Lincoln County), Ky. Natural exposure along north bank of Dix River, beginning 0.8 mi west of U.S. Highway 27, about 4 mi north of Stanford, Stanford 7.5-minute quadrangle. Ashlock Formation; 13 samples; 1,876 conodont elements.

37. OSU-66KH (640-765). Ashlock Cemetery (Lincoln County), Ky. Cuts along U.S. Highway 27 beginning at Dix River beneath bridge just west of mouth of Gilberts Creek and about 500 ft southwest of Ashlock Cemetery, about 4 mi northeast of Stanford and 1 mi west of Gilbert, Lancaster 7.5-minute quadrangle. Ashlock Formation; 24 samples; 2,039 conodont elements.

38. OSU-66KI (760-855). Rowland West (Lincoln County), Ky. Cuts along U.S. Highway 27 on outskirts of Stanford, about 1.2 mi west of Rowland, Stanford 7.5-minute quadrangle. Reba Member of Ashlock Formation and Rowland Member of Drakes Formation; 20 samples; 1,242 conodont elements.

39. OSU-66KJ (810-895). Preachersville Southeast (Lincoln County), Ky. Natural exposure in gully and cuts along Kentucky Route 38 beginning about 2 mi southeast of Preachersville, Lancaster 7.5-minute quadrangle. Preachersville Member of Drakes Formation; 18 samples; 2,961 conodont elements.

40. OSU-66KK (630-930). Agawam South (Clark County), Ky. Natural exposures and cuts along L. and N. Railroad right-of-way, about 1.5 mi south of Ruckerville and about 8 mi southeast of Winchester, Hedges 7.5-minute quadrangle. Ashlock and Drakes Formations; 49 samples; 6,611 conodont elements.

41. OSU-66KL (755-870). Middletown (Jefferson County), Ky. Cuts along Kentucky-U.S. Interstate Highway I-64 between a point 5.2 mi east and a point due south of Middletown, Fisherville 7.5-minute quadrangle. Drakes Formation; 27 samples; 2,659 conodont elements.

42. OSU-70ZA (0-642). Cominco American Core CA-38. BX wireline core drilled 1,900 ft east of Minerva (Mason County), Ky. on Tenie W. Richardson farm, Germantown 7.5-minute quadrangle. Lexington Limestone, Point Pleasant Limestone [Clays Ferry Formation], Kope, and Fairview Formations; 125 samples; 44,157 conodont elements.

43. OSU-73SA (505-625). Type section of Calloway Creek Limestone, Madison County, Ky. Cuts along Kentucky-U.S. Interstate Highway I-75, beginning 0.5 mi south of bridge over Kentucky River and continuing southward for about 2 mi to a point 0.6 mi north of the Kentucky Highway 388 overpass over I-75, Richmond North and Ford 7.5-minute quadrangles. Calloway Creek Limestone; 21 samples; 4,376 conodont elements.

44. USGS-CUZ (185-255). Cuzick (Madison County), Ky. Exposure along unnamed stream from point 3,100 ft east of Cuzick Church to point 900 ft N. 30° E. of Cuzick Church, Valley View 7.5-minute quadrangle. Lexington Limestone and Point Pleasant Limestone [Clays Ferry Formation]; 12 samples, 802 conodont elements.

45. USGS-DENNY (20-210). A. J. Denny Heirs Diamond Core Hole (Jessamine County), Ky. Nicholasville 7.5-minute quadrangle, north zone, 1,910,650 ft east, 151,450 ft north. Lexington Limestone and Point Pleasant Limestone [Clays Ferry Formation]; 29 samples; 5,644 conodont elements.

46. USGS-GA (165-355). Gratz A (Owen County), Ky. Cuts and natural exposures along Kentucky Route 355, 1.7 mi east-southeast of Gratz. Gratz 7.5-minute quadrangle. Lexington Limestone and Point Pleasant Limestone [Clays Ferry Formation]; 11 samples; 806 conodont elements.

47. USGS-G-A (?-?). Georgetown A (Fayette and Scott Counties), Ky. Cuts along Kentucky-U.S. Interstate Highway I-75, 1.4 mi south of Georgetown exit, Georgetown, 7.5 minute quadrangle. Lexington Limestone and Point Pleasant Limestone [Clays Ferry Formation]; 9 samples; 1,446 conodont elements.

48. USGS-GLENFARM (205-460). Lexington East Core Hole 1, Glen Farm. Lexington East 7.5-minute quadrangle, north zone, 1,934,000 ft east, 184,650 ft north. Lexington Limestone, Point Pleasant Limestone [Clays Ferry Formation]; 23 samples; 4,624 conodont elements.

49. USGS–CL (786–958). County Line Section (Mason and Lewis Counties), Ky. Cuts along road that roughly parallels county line in the northeast corner of the Orangeburg 7.5-minute quadrangle and the southeast corner of the Maysville East quadrangle. Bull Fork Formation; 20 samples; 1,041 conodont elements.
50. USGS–SA (155–370). Switzer A (Franklin County), Ky. Natural exposures along Kentucky Route 35 (U.S. Highway 127), on south side of Elkhorn Creek, Switzer 7.5-minute quadrangle. Lexington Limestone and Point Pleasant Limestone [Clays Ferry Formation]; 26 samples; 2,963 conodont elements.
51. USGS–SH (515–723). Sleepy Hollow (Mason County), Ky. Exposures of Kope Formation, Fairview Formation, and Grant Lake Limestone in the NW¼ of the Orangeburg 7.5-minute quadrangle and the SW¼ of the Maysville East quadrangle; 33 samples; 2,290 conodont elements.

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