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IN MEMORIAM

C. M. Goethe
(1875-1966)

Lloyd G. Grinnell
(1894-1966)

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No separate index is included for the volume. Each number is indexed separately. Contents of volume is listed in the beginning of the volume.

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SOME LATE CENOZOIC CIRRIPEDS FROM VENEZUELA AND FLORIDA

By

NORMAN E. WEISBORD

Department of Geology
The Florida State University

1965

Paleontological Research Institution
Ithaca, New York, U.S.A.

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SOME LATE CENOZOIC CIRRIPEDS FROM VENEZUELA AND FLORIDA

Norman E. Weisbord
Department of Geology
The Florida State University

ABSTRACT

Nine species of barnacles from northern Venezuela, and four species of barnacles from northern Florida are described, compared, and illustrated. The Venezuelan barnacles occur in the Cabo Blanco group, and eight of them are Pliocene and one Pleistocene. The Floridan barnacles occur in the Choctawhatchee formation at Jackson Bluff and are late Miocene in age.

Discussed briefly are the "interlaminate figures" displayed in the walls of barnacles; the designation of "right" and "left" for the valves of the operculum; and a method of recovering opercular valves entombed in the shell.

The citations in the Bibliography deal primarily with barnacles in the Order Thoracica.

INTRODUCTION

The barnacles (Class Cirripedia: Family Balanidae) described in this paper[1] were collected in 1955 and 1956 from the Cabo Blanco group in northern Venezuela, and in 1963 and 1964 from the Choctawhatchee formation in northern Florida.

The thickness of the Cabo Blanco group at Cabo Blanco, Venezuela, is approximately 708 meters (2,323 feet). The lowest formation of the group is known as Las Pailas and has a thickness of 375 meters (1,230 feet). This formation is unfossiliferous, but based on position and lithologic correlation it is inferred to be middle Tertiary in age. The formations above the Las Pailas, in ascending sequence, are the Playa Grande, the Mare, and the Abisinia. These are highly fossiliferous in one place or another, and, based on the Mollusca, the Playa Grande and Mare formations are believed to have been laid down in early Pliocene time, and the Abisinia in the Pleistocene. One of the barnacles, *Balanus* sp. indet. aff. *B. trigonus* Darwin, is from the Abisinia formation and the other eight species are from the Mare or Playa Grande formations.

The Choctawhatchee formation at Jackson Bluff in Leon County, Florida, is about 20 feet (6 meters) thick and is highly fossiliferous throughout. Based on the survival of 20 per cent of the Mollusca to Recent time, the Choctawhatchee formation has been assigned a late Miocene age. The four species of barnacles collected from the Choctawhatchee formation at Jackson Bluff are new.

The types and figured specimens of this work have been deposited in the Paleontological Research Institution, Ithaca, New York, U.S.A. Dupli-

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[1] The support given for this work by the National Science Foundation through its Research Grant GB-1676, awarded October 1963, is gratefully acknowledged.

cate specimens are stored in the Department of Geology, Florida State University, Tallahassee, Florida, U.S.A.

ACKNOWLEDGMENTS

I wish to express my sincere appreciation to Arnold Ross of the University of Florida for his thorough and critical reading of the entire manuscript, and for deferring to me the publication of the chapter on the Floridan barnacles, which unbeknown to each other we were working on independently and concurrently. I want to thank John Kenneth Osmond of the Geology Department of Florida State University for attempting to date the Abisinia formation of Venezuela by the ionium disequilibrium method of age determination. His footnote (4) of this paper is but a distillate of the considerable thought and effort that went into the analyses. I am indebted to R. Tucker Abbott and Robert Robertson and to Horace G. Richards of the Academy of Natural Sciences of Philadelphia for allowing me to study the Academy's collections of Recent and fossil barnacles. I am similarly grateful to Donald F. Squires and Fenner P. Chace, Jr. of the United State National Museum for extending to me the privilege of examining the Museum's collection of Cirripedia which contains the types described in 1916 by the late Henry A. Pilsbry. The interest in this work and the help rendered by Katherine V. W. Palmer of the Paleontological Research Institution, is gratefully acknowledged. Most of the photographs were taken and processed by Gerrit Mulders of Tallahassee, and some by Hal F. Riehle, formerly of Florida State University.

THE *LAME HYPODERMIQUE* OR INTERLAMINATE FIGURE

It has been demonstrated by Alessandri (1895), Gruvel (1905), Davadie-Suaudeau (1952, 1964), Cornwall (1956-1962), and Harding (1963), that many species of balanomorph cirripeds with tubular parietes exhibit a characteristic pattern of shell structure in the walls, and that this pattern is unique for each particular species. A polished section of a paries, ground parallel with the base of the shell, reveals that there is an individual design in the shell substance between the walls, this design or pattern emerging from the inner wall and extending toward the outer wall by way of the avenue or interspace between the parietal pores. The pattern has been termed the *lame hypodermique* by Gruvel and Davadie-Suaudeau and anglicized to interlaminate figure by Cornwall. A description of the *lame hypodermique* was given by Mme. Davadie-Suaudeau (1952, p. 41) as follows:

> The aspect of these figures is always the same: they are constituted of an axial stem, which at its extremity sends out lateral prolongations, the whole forming at the base of the stem a mass which, under the microscope, is whitish or yellowish, and of variable form: round, or ovoid, or again elongated and pointed. If the polished section is sufficiently fine for permitting a clear observation of the lateral prolongations of the interlaminate figures, one observes that the form and arrangement of them are characteristic for each species. Thus the prolongations can be more or less proximate; they vary in lengh and thickness, and may or may not be terminated by a rounded surface. [Translation].

The part of the interlaminate figure traversing the interspace between the parietal pores is generally linear, and in plan view often appears as a simple lamina or septum separating, or forming the sides of the parietal tubes. The main part of the figure which leads into the septum is built up of successive layers of shell material to produce the sides or walls of the parietal tubes, and if these layers, one on top of the other, are sharply defined, they appear in cross section as a bilaterally digitate trunk, with the number of digitations or prolongations in a column corresponding to the number of shell layers. Interlaminate figures may persist from the base of a paries to the sheath. However, in some species the interlaminate figure is best displayed near the base, in others near the sheath, and in still others somewhere between. In many sections I have discerned no figure but this may be due to faulty technique. As stated by Cornwall, the figures may be seen to much better advantage by applying a liquid on the polished surface, and for viewing and photographing the sections I wetted the surface with benzyl alchohol which is a relatively nonviscous glycerine recommended by Cornwall.

Paleontologists have long relied on the characters of the shell, of the orifice, of the sheath, of the basis or calyx, and especially of the opercular valves to identify barnacles, but thanks to the contributions of Davadie-Suaudeau, Cornwall, and Harding, the importance of the interlaminate figure as a significant taxonomic feature, has been re-emphasized. It is probably true that the interlaminate figure of the parietes (or alae) are in themselves so diagnostic that determinations can be made on the figures alone, particularly if the grinding and polishing is performed as exquisitely as in Dr. Davadie's latest work (1964) on the fossil balanids of Europe and Africa. Nevertheless it is also true that interlaminate figures of different species may be similar, and in such examples it is difficult to ascertain whether the species is the same as, or different than another by this criterion alone. There is no doubt that the pattern of the interlaminate figure is important in taxonomy, but this feature is only one of a number of characters that must be considered in classification.

Most of the species I collected in Venezuela and Florida were sectioned to bring out the interlaminate figure but the results at best were middling. If available, an entire shell was held in my fingers and ground, base down, on coarser to finer abrasives until the interlaminate figure was revealed. I found I could also hold individual paries or fragments in my fingers and grind them down also. However, if the fragment was too small, I heated Lakeside No. 70, a thermoplastic cement, to 300°F. on a glass slide, embedded the fragment in the melt, allowed the cement to harden, and ground down the embedded fragment. The abrasive was silicon carbide grain, a product by Carborundum, in sizes 100, 220, 320, and 400. This was sprinkled with water on 4″ x 4″ glass plates ¼″ thick, and the sectioning process effected by pressure and rotation from the hand.

"RIGHT" AND "LEFT" VALVES OF THE OPERCULUM

The designation of the right or left valves of the operculum depends on the orientation of the shell and the preference of the observer. Darwin suggested that the right and left sides of the barnacle shell be determined with the carina forward and the orifice up. The observer looking down into the orifice might thus call the valves on the right-hand side the right scutum, and the tergum attached to that, the right tergum. Darwin seldom, if ever, used "right" and "left" in describing opercular valves, and these terms were rarely mentioned by Pilsbry. Withers, however, in 1910, employed the designations right and left in describing the opercula of New Zealand barnacles, and in the orientation he followed the suggestion of Darwin: carina forward, orifice up. Nilsson-Cantell, on the other hand, designated right and left with the carina *toward* the observer, and, looking down on the orifice, the tergum and its attached scutum on the right-hand side were spoken of as "right". G. C. Martin (1904), in his excellent description and illustrations of *Balanus concavus* Bronn, from the Miocene of Maryland, had the "right" scutum attached to the "left" tergum when viewing the valves with the carina toward the observer, and the "right" tergum attached to the "left" scutum with the carina of the shell forward, or away from the observer. It is seen then that the terms "right" and "left" have not been standardized, and relate to the orientation of the shell as preferred by a particular author. In this work I follow Nilsson-Cantell and others in speaking of the "right" tergum and attached "right" scutum as lying in the right-hand side of the orifice with the carina of the shell pointed toward me and with the orifice up.

RECOVERING OPERCULAR VALVES ENTOMBED IN THE SHELL

As fossil barnacle shells are generally filled with sediment it is often impossible to determine by superficial inspection whether or not the operculum is buried in the shell cavity. In casting about for a method of removing the debris from the interior of the shell without destroying the contained fossil material, it was suggested to me by Carl Oman, a graduate student in geology at Florida State University, that I try using the same ultrasonic cleaner that is used in the laboratory for cleaning micro- and megafossils. This I did, with considerable success, albeit frequently at the expense of shattering the shell of the barnacle. If the debris within the shell is loosely cemented or relatively soft, the sonic vibrations will loosen it into discrete fragments of rock and organic remains which may be readily separated from the wash. These same vibrations will disarticulate the shell of the barnacle along sutures or contacts of the plates but generally does no harm to smaller shelly organisms of unitized construction such as single valves of the operculum.

The trade name of the cleaner used is the "Sonogen", manufactured by the Branson Ultrasonic Corp., Stamford, Connecticut. The metal inner container of this apparatus is half filled with water, and into the container is placed, so that it floats, a half-filled glass beaker of water with the barnacle in it. The intensity of the vibration is regulated by a tuning knob and is registered on a small generator lamp. The length of time required for separation varies but can be gauged visually. Often a few minutes operation is sufficient. The clay is decanted from the beaker, and the residue, funneled through filter paper, is then allowed to dry for examination under the microscope.

CIRRIPEDS FROM VENEZUELA

LOCALITIES

The Venezuelan cirripeds[2] described in this paper were collected in the Cabo Blanco area, which is situated along the coast of the Caribbean Sea some 19 kilometers or so by road north of Caracas. All of the specimens except one (which is a Recent shell) were found in the Cabo Blanco group which consists of the following formations:[3]

---

[2] The Cirripedia is the fifth class of invertebrates described by the writer from the late Ceonozoic deposits of northern Venezuela. The other classes were the Gastropoda (Weisbord, 1962), the Pelecypoda (1964a), and the Scaphopoda and the Polychaetia (1964b).

[3] For details see Weisbord, 1957.

Formation		*Age*	*Thickness (meters)*
Abisinia		Pleistocene	13 max.
		Disconformity	
Mare		Lower Pliocene	19 max.
		Local unconformity	
Playa Grande	Maiquetía member		68+
	Catia member		156-233
		Angular unconformity	
Las Pailas		Middle Tertiary	375+

The localities and formations in which the barnacles occur are listed below. The letter preceding the locality description is the same as that prefixing the number given to each species from that locality. The localities are shown on the geologic map accompanying the writier's account (1957) of the geology of the Cabo Blanco area. On that map, field stations are marked by the letter "W", and some of the localities listed below refer to those stations:

A. Beach, at Playa Grande Yachting Club, Distrito Federal. Recent.
D. Eastern edge of Playa Grande village at W-30. Abisinia formation.
G. Hillside above west bank of Quebrada Mare Abajo near W-14. Mare formation.
H. Fifteen meters south of axis of Punta Gorda anticline at W-25. Mare formation.
I. Hillside above west bank of Quebrada Mare Abajo at W-13. Lower Mare formation.
J. Small stream 100 meters west of Quebrada Mare Abajo and 125 meters west-southwest of the intersection of Quebrada Mare Abajo and the coast road. Lower Mare formation.
K. Bluff 125 meters west of the intersection of the Playa Grande Yachting Club road and coast road, and about 95 meters due south of the shoreline. Playa Grande formation (Catia member).
L. South side of Playa Grande road about 220 meters west of W-15. Playa Grande formation (Catia member).
M. W-15, south side of Playa Grande road 40 meters southeast of its intersection with the Playa Grande Yachting Club road. Playa Grande formation (Catia member.)
N. Near W-21 and to the south of that station in stream flowing along the strike of the north flank of the Litoral anticline. Playa Grande formation (Catia member).
O. Dip slope 100 meters west of Costa fault and 130 meters south of shoreline at W-22. Playa Grande formation (Catia member).
R. Quebrada Las Bruscas at W-26, approximately 125 meters upstream from junction with Quebrada Las Pailas. Playa Grande formation (Maiquetía member).
S. Near *Lithothamnium* reef at W-23, north flank of Punta Gorda anticline. Playa Grande formation (Maiquetía member).

T. Stream 250 meters south-southwest of the mouth of Quebrada Las Pailas and 255 meters east-northeast of wireless station. Mare formation.

U. South side of coast road at east end of the village of Catia La Mar. Playa Grande formation (Catia formation).

LIST OF CIRRIPEDS FROM THE CABO BLANCO AREA

The cirripeds collected in the Cabo Blanco area, and the formations in which they occur, are listed below. Formational names are abbreviated thusly: Re=Recent; Ab=Abisinia formation; PGm=Playa Grande formation (Maiquetía member); and PGc=Playa Grande formation (Catia member).

Species	*Formation*
Balanus (Megabalanus) tintinnabulum antillensis Pilsbry	Re; Ma; PGc
Balanus (Megabalanus) venezuelensis Weisbord, n. sp.	PGc
Balanus (Balanus) laguairensis Weisbord, n. sp.	PGc; Ma
Balanus sp. indet. aff. B. trigonus Darwin	Ab
Balanus (Balanus) caribensis Weisbord, n. sp.	PGc; Ma
Balanus (Balanus) caboblanquensis Weisbord, n. sp.	Ma; PGm
Balanus (Balanus) playagrandensis Weisbord, n. sp.	PGm; PGc
Balanus (Balanus) concavus Bronn, Nilsson-Cantell	Ma; PGm?
Balanus (Balanus) species	PGc

ANALYSIS OF THE INVERTEBRATES OF THE CABO BLANCO GROUP

In the following tables all of the invertebrates of the Cabo Blanco group thus far studied by the writer are enumerated by class to show the total number and per cent of the species found in a given formation that have survived to Recent time. As there is a judgment factor involved in determining whether a fossil species is identical with, or distinct from its living counterpart, the number of fossil species that has survived to the present is represented in the tables as a minimum-to-maximum figure. Applying Lyell's percentage method of subdividing the Cenozoic into epochs, and complementing that with the stratigraphy of the Cabo Blanco group, it is believed that the Abisinia formation is Pleistocene[4] in age, and that the Mare and Playa Grande formations are early Pliocene in age.

[4] Other evidence which tends to support the view that the Abisinia formation is Pleistocene (rather than Holocene) in age has been obtained by John Kenneth Osmond, associate professor of geology at Florida State University. Dr. Osmond has analyzed, by the ionium disequilibrium method, a number of specimens of the gastropod *Mazatlanica aciculata* (Lamarck), which is the most abundant of the mollusks in the Abisinia formation, and finds that their isotopic ratios suggest an age for the material in excess of 300,000 years. Dr. Osmond's memorandum, dated 5 May 1964, summarized the results of the work as follows:

Venezuelan snail

The dating of this material is based on two assumptions: (Continued p. 12)

Table 1. Invertebrates of the Abisinia formation

Class	*Total number of species*	*Number of Recent species*	*Per cent of Recent species*
Gastropoda	34	26-31	76-88
Pelecypoda	18	15-16	83-90
Scaphopoda	—	—	—
Polychaetia	1	1	100
Cirripedia	1	1	100
Total	54	43-51	80-94

Table 2. Invertebrates of the Mare formation

Class	*Total number of species*	*Number of Recent species*	*Per cent of Recent species*
Gastropoda	142	23-48	16-34
Pelecypoda	82	32-38	39-46
Scaphopoda	8	4	50
Polychaetia	2	1	50
Cirripedia	5	1-2	20-40
Total	239	61-93	25-40

Table 3. Invertebrates of the Playa Grande formation (Maiquetía member)

Class	*Total number of species*	*Number of Recent species*	*Per cent of Recent species*
Gastropoda	81	7-22	9-28
Pelecypoda	53	23-31	43-58
Scaphopoda	6	3	50
Polychaetia	1	0	—
Cirripedia	3	0-1	0-33
Total	144	33-57	23-40

Table 4. Invertebrates of the Playa Grande formation (Catia member)

Class	*Total number of species*	*Number of Recent species*	*Per cent of Recent species*
Gastropoda	3	0-1	0-33
Pelecypoda	26	8-10	31-40
Scaphopoda	2	1	50
Polychaetia	3	0-1	0-33
Cirripedia	6	1	16
Total	40	9-14	23-35

1) Initial disequilibrium derived from isotopic abundances of U and Th in sea water.

2) No loss or gain of radioelements from shell material after burial.

Sea water derived disequilibria are used for coral dating, but whether snails exhibit similar disequilibria has not been demonstrated. These snails looked as if they had suffered some leaching. So both assumptions are open to question.

Nevertheless the isotopic ratios look reasonably consistent and suggest an age for the material in excess of 300,000 years.

Data: Thorium 2.0 1.0 p.p.m.
Uranium 3.0 0.1 p.p.m.
Th230/U234 Ratio: 1.10 .10
U234/U238 Ratio: 1.15 .10

SYSTEMATIC DESCRIPTIONS

CIRRIPEDIA

BALANIDAE

Balanus (Megabalanus) tintinnabulum antillensis Pilsbry

Pl. 1, figs. 1-13; Pl. 2, figs. 1-8

Balanus tintinnabulum antillensis Pilsbry, 1916, U.S. Nat. Mus., Bull. 93, pp. 63-65, pl. 13, figs. 1-2e; Pilsbry, 1927, K. Zool. Genootsch., Natura Artes Magistra, vol. 25, p. 38, fig. 3; Pilsbry, 1939, Nilsson-Cantell, Capita Zoologica, vol. 8, pt. 4, pp. 3,4; Pilsbry, T. A., and A. Stephenson, 1952, Jour. Ecol., vol. 40, No. 1, p. 57; Pilsbry, 1953, Acad. Nat. Sci. Philadelphia, Proc., vol. 105, pp. 24-25, pl. 2, figs. 4-4c.

Balanus (*Megabalanus*) *tintinnabulum antillensis* Pilsbry, 1928, Nilsson-Cantell, Ann. Mag. Nat. Hist., ser. 10, vol. 2, pp. 31-32, fig. 15.

Shell of moderate size, subtubular, tubulo-conical, or conical in shape. Orifice relatively large, one-half to four-fifths the length of the base, broadly and subangularly ovate, sharply narrowed at the carinal end. Carina a little more angular and generally a little higher than the other compartments, the sides of the shell steeply sloping. Externally, the parietes are smoothish to somewhat gnarled, or striped longitudinally, or provided with weak irregular longitudinal folds. In the interior, the walls of the parietes are usually smooth above and longitudinally ribbed only near the base, but on at least one fossil specimen (I589d) the ribs are strongly developed up to the sheath, with the lower part of the ribs bearing fine longitudinal filaments. Sheath-plates smooth. Within the walls of the parietes the longitudinal tubes are fairly large, the tube-ends at the base rectangular and numbering 63 on the single Recent shell collected. The radii are relatively broad at the orifice, and their summits are more or less parallel with the base. The walls of the radii are provided with regular horizontal tubules, and the edges of the radii are crenate or denticulate. The summits of the alae are also roughly parallel with the base. The basis is subcircular in outline, flattish to concave to undulatory, porose, marked by narrow swirling ribbons radiating outward from an off-center nucleus. Some of the fossil specimens still retain a rose, violet, or purple color, the colors striped longitudinally on the parietes, but fairly uniform and darker, if present at all, on the radii. Sometimes, however, the radii are lighter even on the most rosaceous specimens. On one fossil shell (K589a) the parietes are sculptured externally by narrow longitudinal ribs which are nodulous and crossed by fairly numerous concentric stripes of violet. The Recent shell is deep violet on the parietes, colorless on the radii.

The interlaminate figure of the fossil specimens is a short, bilaterally digitate trunk divided into two more or less equal halves by a longitudinal aisle of "plain" shell material. The figures extend from the inner wall toward the parietal pores and terminate at the base of the pore itself or in the interspace between the pores at about the level of the base. The figures are white or paler than the shell material surrounding them. The long axis of the figure is normal to the wall, but where growth of the shell has been restricted, as in a cluster, the figures are oblique.

The scutum is triangular, with a straight occludent margin, a straight tergal margin, a flexuous basal margin having a subrounded to subangular basi-tergal corner, and a simple apex. Externally there is a low rounded ridge extending from the apex to the basi-tergal corner, and in front of the ridge there is a broad shallow radial depression widening toward the basal margin; behind the ridge the tergal arch is gentle to subrostrate. The outer surface is sculptured by prominent flexuous folds whose contours conform with that of the basal margin, and on a scutum with an occludent margin 9 mm. in length there are about 23 such folds. From about the middle to the base, every other fold is raised as it envelops the occludent margin. All of the scuta are weathered or corroded in varying degree, and no longitudinal striae crimping the folds can be observed, though from the appearance of one scutum (I589b), the presence on fresh examples of such striae, widely spaced, is suggested. On the interior, the articular ridge is heavy, broad, and somewhat reflexed, and the articular ridge is deep. The adductor ridge is blunt and massive, and is confluent with the articular ridge. The adductor muscle impression is fairly large, more or less oval, and somewhat oblique. The impression of the lateral depressor muscle is subovate and fairly small and deep.

The tergum resumbles a slightly curved asymmetric arrowhead, with the carinal margin gently curved and the scutal margin shallowly concave. The longitudinal furrow on the outer surface is slitlike on the operculum above the spur, and open as it leads into the spur. The furrow divides the tergum into unequal halves, with the carinal wing having about double the width of the scutal wing. The apex of the tergum is broken away on all specimens but it is inferred, from the configuration below, to be simple and pointed. The basal margin on the scutal side of the spur forms a straight line whereas that of the carinal side is a little sinuous. The external surface is sculptured by thickened concentric lamellae or folds which are slanted toward the apex. These folds bow downward at the furrow toward the spur, and terminate as triangular barbs at the edge of the scutal margin. The scutal margin is broadly inflected or rostrate, the rostration forming substantially a right angle with the exterior surface of the valve. The spur enlarges gradually to its base where it is broadest. Internally, the articular ridge is moderately narrow and prominent, and the adjacent articular furrow is subparallel and deep. As the terga are corroded or broken, the character of the crests for the depressor muscles is obscured.

Dimensions.—Shell: specimen H589a, carino-rostral diameter 19 mm., height 15 mm., length of orifice 13 mm.; specimen H589b, thickness of wall at mid-section of shell 1.4 mm.; specimen U589, carino-rostral diameter 22 mm., height 21 mm., length of orifice 13 mm.; specimen G589, carino-rostral diameter 23 mm., height 26 mm., length of orifice 12 mm.; specimen G589a, carino-rostral diameter 18 mm., height 19 mm., length of orifice 9.5 mm.; specimen T589a, carino-rostral diameter 13 mm., height 12 mm., length of orifice 7:5 mm.; specimen I589a, carino-rostral diameter at base 6 mm., diameter at middle 7.5 mm., height 13 mm., length of orifice 4 mm., width or orifice 4 mm.; specimen I589d, carino-rostral diameter 10 mm., height 10 mm., length of orifice 8 mm.; specimen J589a, carino-rostral diameter 18 mm., height 16 mm., length of orifice 8 mm.; specimen K589a (fragment with two lateral compartments), height 24 mm., width 14 mm.; specimen A588a, carino-rostral diameter 9 mm., height 6.5 mm., length of orifice 4 mm., width of orifice 3.3 mm.

Scutum: specimen I589b, width across basal margin 6.2 mm., length along occludent margin 7.8 mm., length of outer ridge 6.5 mm.; specimen I589c, width across basal margin 4.5 mm., length along occludent margin 5.9 mm., length of outer ridge 4.8 mm.; specimen T589b, width across basal margin 7.3 mm., length along occludent margin (reconstructed) 8.8 mm., length of outer ridge (reconstructed) 7.5 mm.

Tergum: specimen L592a, width across basal margin (reconstructed) 5.5 mm., length from apex to base of spur 8 mm., length of spur below basal margin 2 mm., width at base of spur 1 mm.; specimen M589a, width across basal margin (reconstructed) 14 mm., length of spur below basal margin 3 mm., width at base of spur 2.1 mm.; specimen T589c (broken), length 5 mm., width across middle 3.8 mm.

Localities.—Recent, on beach at Playa Grande Yachting Club, Distrito Federal. One dead shell. Upper Mare formation, in stream 250 meters south-southwest of the mouth of Quebrada Las Pailas. One shell and numerous fragments; three scuta; one tergum. Mare formation near W-14 on hillside above west bank of Quebrada Mare Abajo. Eight shells. Mare formation at W-25, south flank of Punta Gorda anticline. Four adult shells. Lower Mare formation at W-13, on hillside above west bank of Quebrada Mare Abajo. Five shells and numerous fragments; four scuta. Lower Mare formation, in small stream 100 meters west of Quebrada Mare Abajo. One shell and several fragments. Playa Grande formation (Catia member), about 220 meters west of W-15. One tergum. Playa Grande formation (Catia member) at W-15, south side of Playa Grande road 40 meters southeast of its intersection with the Playa Grande Yachting Club road. One tergum. Playa Grande formation (Catia member), south side of coast road at east end of Catia La Mar. One adult shell. Playa Grande formation (Catia member), in bluff 125 meters west of the intersection of the Playa Grande Yachting Club road and coast road. One tergum; one complete shell; one large fragment (K589a) with two lateral compartments remaining. Specimen K589a is exactly like the variant of *B. t. antillensis* from the east coast of Florida illustrated by Pilsbry (1953) in his figure 4 of plate 2, right-hand specimen. Playa Grande formation (Catia member) near W-21. Two shells attached to *Ostrea verspertina venezuelana* Weisbord (1964, pp. 187-190, pl. 24, figs. 5-11).

Remarks.—The shell and opercular valves of the Venezuelan fossil cannot be distinguished from the type (ANSP No. 2083) and other Recent specimens of *B. t. antillensis* Pilsbry in the Academy of Natural Sciences of Philadelphia. I have not seen an illustration of the interlaminate figure of *B. t. antillensis,* but the section of a Recent shell of *B. t. antillensis* from off Fort Lauderdale, Florida, sent to me by Arnold Ross, shows the interlaminate figure to be virtually the same as that of the Venezuelan fossil.

Range and distribution.—Although *Balanus tintinnabulum antillensis* Pilsbry has been conveyed to alien waters, the native Recent form occurs in Florida (Fort Pierce, Fort Lauderdale, and Ocean Ridge), Cuba, Curaçao, the islands of Centinela and Coche in Venezuela, and doubtfully from Rio de Janeiro, Brazil. This is the first report of the subspecies as a fossil (lower Pliocene) but there is some possibility that the form identified by Nilsson-Cantell (1939a, p. 6) as *B. tintinnabulum* (Linnaeus) from east of Santa Fé, north of Cerro de Santa Ana in the Paraguaná Peninsula, Venezuela, in "horizontal marly limestone about 30-50 meters above sea-level" is also the subspecies *antillensis.* Nilsson-Cantell refrained from committing himself on the subspecific identification of the Paraguaná *B. tintinnabulum* as the opercular valves were lacking.

Balanus (Megabalanus) venezuelensis, new species Pl. 2, figs. 9-12

Shell whitish, low, cylindrico-conical, with steeply sloping sides, an angular, nearly vertical carinal end, a subangular and slightly convex rostral end, and a subcircular to suboval base. Orifice large, four-fifths the length of the base, distinctly diamond-shaped, the rims of the orifice longer and more acutely converging toward the carina than toward the rostrum. Externally, the parietes are smoothish to moderately gnarled or irregularly folded longitudinally. Internally, the walls are slightly ribbed near the base, but the upper part of the walls, as well as the sheath-plates, are smooth. The longitudinal tubules within the parietes are relatively small and elongate-oval or ovate in cross section. The radii are broad and thick, and level at the summit. The tubules within the walls of the radii show through the outer wall as narrow horizontal ribbons. The edges of the radii are strongly crenated, and on the free edge the crenations are vertically striate. The summits of the alae are more or less parallel with the base. The basis is flattish to undulatory and is constructed of narrow septate tubules radiating outward and curving slightly from a center which is located nearer one side of the basis than the other. There are some 73 such tubules at the periphery of the paratype (O593b) which has a carino-rostral diameter of 12 mm. Within the shell the contacts of plates and septa are not tightly joined but are slightly separated or gaping.

The interlaminate figure of the carinal paries, sectioned a millimeter or two above the basis of the paratype (O593c), is a stubby, bilaterally digitate trunk extending from the inner wall to the base of the interspace between the parietal pores. One or two of the digitate trunks at the front end of the carina are nearly solid, but away from the front the trunks bifurcate to form two double lineate branches which traverse the interspace between the parietal pores, loop around the outer rim of the pore, and then descend to unite with or form the branch of the adjacent trunk. In series the pattern is a succession of U's with double limbs looped around the parietal pores. Whether this pattern is the same on the lateral parietes is not known as I was able to obtain the interlaminate figure on one shell and on only a part of that.

No opercular valves were found.

Dimensions.—Holotype (O593a), carino-rostral diameter 17 mm.; height 12 mm.; length of orifice 13 mm.; maximum width of orifice 7 mm.

The holotype is the largest specimen of a cluster embedded in tan sandy limestone. Paratype (O593b), carino-rostral diameter 12 mm.; height 11 mm.; length of orifice approximately 8 mm.; maximum width of orifice 4 mm. This shell was chiseled out of the cluster mentioned above. Paratype (O593c), carino-rostral diameter 16 mm.; height approximately 7 mm.; length of orifice 12 mm.; maximum width of orifice 5.5 mm.

Type locality.—Playa Grande formation (Catia member) at W-22, on dip slope 100 meters west of Costa fault. At least 15 shells with others attached base to base, the whole cemented in sandy limestone.

Remarks.—The large and elongated diamond-shaped orifice and the chain of "U"-looped interlaminate figures are the distinguishing characters of this species. Superficially, the shell seems to fall in the race of *B. tintinnabulum* (Linnaeus) which ranges from Oligocene to Recent. None of the subspecies of that form possesses the elongated diamond-shaped orifice of the Venezuelan shell here named *Balanus venezuelensis,* n. sp.

Balanus (Balanus) laguairensis, n. sp. Pl. 3, figs. 1-10

Shell relatively small, sturdy, and asymmetrically conical. The carinal end is subangular, with a steep, sometimes nearly vertical slope; the rostral end is gently rounded and slightly convex; and the walls of the lateral compartments are steeply sloping and more or less straight-sided. The orifice is ovate to subtrigonal, somewhat toothed, sharply convergent at the carinal end, and one-fourth to two-fifths the length of the base. The parietes are sculptured externally by strong, irregular, and often branching longitudinal folds. Generally there are four or five principal folds on the carina and rostrum, three or four on the lateral parietes, and one on each of the carinolaterals, the last sometimes single and broad but sometimes bifurcate or trifurcate basalward. Internally, the parietes are traversed by prominent, slightly wavy, longitudinal ribs ascending from the base to the sheath. The sheath is evenly ovate, and the sheath plates are sculptured by fine, regular, slightly raised concentric laminae, of which there may be 18 to 20 on a plate 1.5 mm. in height. The lateral radii are moderately broad and oblique at the summit, but all of the others are narrow. The alae are slightly protuberant. The tube-ends at the base of the compartments are small and subrectangular, and on one specimen with a carino-rostral diameter of 7.5 mm. there are approximately 59 of them. The basis is thin, slightly concave to strongly undulatory, and, depending on the situs of attachment, subcircular to irregularly oval in outline. The basis is formed of alternating narrow stripes of hyaline and white shell material radiating and curving slightly outward from off center to the periphery.

The interlaminate figure is not clear but seems to consist of longitudinal, horizontally digitate stalks extending from the inner wall, continuing as septa in the spaces between the parietal pores, and becoming obsolescent before reaching the outer wall.

No opercular valves associated with the shell were recovered.

Dimensions.—Holotype (U590a), carino-rostral diameter 7.1 mm.; height at carinal end 4 mm.; length of orifice 2.2 mm.; maximum width of orifice 1.7 mm. Paratype (M590a), carino-rostral diameter 8 mm.; height at carinal end 6.8 mm.; length of orifice 2 mm.; maximum width of orifice 1.7 mm. Paratype (M590b), section of paries, thickness of wall at carina excluding sheath 1.2 mm. Paratype (M590c), section of paries, thickness of wall near sheath 1.5 mm. Paratype (I588a), carino-rostral diameter 7 mm.; height 4 mm.; length of orifice 3 mm.; maximum width of orifice 2 mm. Paratype (I590a), carino-rostral diameter 7 mm.; height at carinal end 5 mm.; length of orifice 1.7 mm.; maximum width of orifice 0.9 mm.

Type locality.—Playa Grande formation (Catia member), south side of coast road at east end of the village of Catia La Mar. One shell, the holotype.

Other localities.—Playa Grande formation (Catia member), south side of Playa Grande road 40 meters southeast of its intersection with the Playa Grande Yachting Club road. Eight shells, three of them attached to *Lyropecten arnoldi* Aguerrevere, and 12 fragments. Lower Mare formation at W-13, hillside above west bank of Quebrada Mare Abajo. Thirteen shells or their bases attached to *Ostrea vespertina venezuelana* Weisbord. Mare formation near W-14, hillside above west bank of Quebrada Mare Abajo. Four shells and six fragments. Upper Mare formation, 115 meters south-southwest of the crossing of Quebrada Mare Abajo and coast road, and 90 meters southwest of W-12. Two fragments, one of the carina, the other of a lateral compartment; attached to the latter is the serpulid polychaete *Spirorbis venezuelensis* Weisbord (1964b, pp. 166-167, pl. 19, figs. 7-10; pl. 20, figs. 6-7).

Comparisons.—The shell of this species closely resembles the paratypes of *Balanus calidus* Pilsbry (1916, pp. 118-120, pl. 25, figs. 1-1c) collected by the *Albatross* at station 2372. *B. calidus* lives in the Caribbean Sea, the Gulf of Mexico, and the Western Atlantic as far north as Beaufort, North Carolina. As a fossil it has been reported by Nilsson-Cantell (1939a, pp. 6,7) from a late Cenozoic marl in the Goajira Peninsula, Colombia. Though the shell of the Venezuelan fossil resembles the shell of the living *B. calidus*, the interlaminate figure of *B. calidus* (see Cornwall, 1958, pp. 82,84, fig. 33) is distinct from that of *B. laguairensis*, n. sp. in that it is shaped like a dumbbell, with oval, bilaterally digitate ends connected by a linear septum which lies in the interspaces between the parietal pores. The interlaminate figure of *B. laguairensis* is not well revealed on my specimens, but it can be seen that it is not dumbbell-shaped.

Balanus (Balanus) sp. indet. aff. **B. trigonus** Darwin Pl. 4, figs. 1,2

The following description is based on a single broken shell with only the carinal end and a part of the basis remaining. The shell is relatively small, high conical, with steeply sloping sides and thick walls. From a short distance above the base to the apex, the parietal tubes are filled solidly by calcium carbonate, but near the base the tubes are open. The orifice is large and sharply angulate carinally, but as the rest of it is broken away its entire configuration is not known though there is the suggestion that it is trigonal and almost equilateral. At the base, the shell is subcircular in outline. The basis is abnormally thickened by a calcareous deposit but seems to be constructed of ribbons radiating outward from off center. Externally, the parietes are sculptured by low, slightly irregular longitudinal folds; internally, the parietes are longitudinally ribbed, the ribs (about 11 in number on the carina) wavy, and extending upward to terminate at the base of the sheath. The sheath plate of the carina is marked by 10 or 11 narrow concentric fillets which tend to become lamellar, slightly elevated, and upswept at the edges; the lower margin of the carinal sheath plate is cemented to the wall of the shell, and there is no space between the lower edge of the sheath and the inner wall. The radii and alae are broad, and smoothish externally, and the edges of the radii are denticulate.

Dimensions.—Specimen D588a, height 5.3 mm.

Locality.—Abisinia formation at W-30, eastern edge of Playa Grande village. One broken shell.

Remarks.—It is not possible to identify this single broken shell with any assurance though the solidly filled parietal tubes and the large trigonal orifice suggest affinity to *Balanus trigonus* Darwin. Recent specimens of *B. trigonus* from the Western Atlantic are generally more depressed, and the longitudinal ribs on the exterior finer than on the Venezuelan fossil, but *B. trigonus* is a variable shell, and the most diagnostic character is the longitudinally pitted scutum. No opercular valves were recovered from the shell, and as the single specimen is imperfect and broken, a paries was not sectioned to reveal the interlaminate figure which on *B. trigonus* "shows a pattern projecting into, or forming the rib" (Cornwall 1958, p. 81, figs. 46-49).

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Range and distribution.—Balanus trigonus Darwin is a cosmopolitan species ranging in age from Miocene to Recent. The living *B. trigonus* has been found at depths ranging from near shore to 3,000 meters, and inhabits the Eastern Atlantic (from the Azores and Madeira along the west coast of Africa to South Africa), the Red Sea, the Western Atlantic (from Florida, the Gulf of Mexico, and the West Indies to Argentina), the Eastern Pacific (from California to Peru), the Western Pacific (Japan and the Philippines), and in the waters of Indonesia, Australia, New Zealand, and the Friendly Islands (Tongatabu). In Venezuela the living shell occurs at La Guaira, Coche, Margarita, and at Carúpano in the State of Sucre. The fossil shell here discussed is from the Abisinia formation of Pleistocene age. Pleistocene specimens have also been collected on Cedros, Magdalena, Santa Margarita, and Maria Magdalena Islands off the west coast of Mexico (Ross 1962). In the Miocene the species has been reported by Kolosváry (1955,1959) from Mt. Mecsek in Hungary, by

Withers (1953) from the Cojímar formation of Cuba, and by Ross (1964) from the Yorktown formation of Virginia, U.S.A.

Balanus (Balanus) caribensis, n. sp.

Pl. 4, figs. 3-10; Pl. 5, figs. 1-4; Pl. 7, figs. 5-9.

Shell fairly small, moderately sturdy, conical to tubulo-conical (the latter molar-like in profile), and suboval at the base. Compartments six, the carina nearly vertical, the rostrum generally somewhat convex, the sides steeply sloping. Orifice diamond-shaped, somewhat more acute carinally than rostrally, prominently toothed at the rim, the length varying from approximately two-fifths to four-fifths that of the base. Externally, the parietes are smoothish or slightly gnarled but sometimes they are faintly and irregularly ridged longitudinally; the sutures of the parietes are closely crenate horizontally, the crenations bearing generally vertical microscopic striae. The parietal tubes are moderately large and rectangular in cross section, and on specimen N591a, with a diameter of 6.6 mm., there are about 52 of them. The radii are wide, usually smooth on the outer surface, denticulate at the edges, and oblique at the summit. The alae are also decidedly oblique at the summit. Internally, the compartments are longitudinally ribbed, the ribs ascending toward, and sometimes continuing under the free lower margin of the sheath. The sheath plates are robust and are marked in the middle by faint concentric laminae; on some specimens these laminae are obsolescent but on others they are moderately prominent. The basis is thin, undulatory to concave, and, though not clearly visible on any of the specimens, seems to be constructed of flattened radiating ribbons of alternating shell density.

The scutum is a flattish triangular valve, with straight occludent and tergal margins and a hardly curved basal margin. The tergal margin is only a little longer than the cord across the basal margin. Taking the average of three scuta, the apical angle is about 34 degrees, the basi-occludent angle about 50 degrees. The outer surface is sculptured by subequal nonflexuous concentric lirae paralleling the base and extending upward from the basal margin to the apex where they become obsolescent or are absent. On one scutum there is a vague suggestion that on unweathered valves the concentric lirae may be traversed by faint radial striae. The tergal margin is narrow and reflected over an angle of about 100 degrees to form a rostration. Internally, the articular ridge is prominent, and is reflexed toward the tergal margin along the upper half of its length, the lower half continuing to near the basal margin as a sharp elevation. The adductor ridge is high and narrow and is more or less parallel with the occludent margin. The depression between the articular and adductor ridges is triangular; the furrow between the adductor ridge and occludent margin is broadly linear; and the furrow between the articular ridge and tergal margin is narrowly linear. The impression made by the adductor muscle is indistinct but seems to be elongate-oval, and it lies on the side of the adductor furrow facing the occludent margin. The cavity for the lateral depressor muscle lies in the basi-tergal corner, and is small, deep, and oval.

The tergum is thin-shelled, and in outline resembles a broad, slightly curved, asymmetrical arrowhead. The valve has a flattish outer surface, a gently curved carinal margin, a straight scutal margin, and a pointed apex turned slightly toward the scutal margin. Externally, and leading into the spur, there is a narrow triangular segment widening basalward, and this segment, which has little or no relief on the single tergum recovered, is bounded on each side by a faint, hardly impressed line. The basal margin on the carinal side of the spur is broadly and deeply embayed, and the low regular concentric riblets ornamenting the surface of the valve follow the contour of the embayment. The spur proper is broken away, but the upward continuation is marked by faint, somewhat irregular striae bowed asymmetrically downward. The narrower scutal wing of the tergum is sculptured by coarser riblets, oblique above, bowed upward below. The scutal margin is narrowly rostrate, the rostration forming an angle of about 90 degrees with the surface. Internally, the articular ridge is subangularly arcuate, the upper part more prominent but narrower than the lower. On the apical area below the beak there are five thin laminae or ridges, the lowermost one forming a vertical wall. The crests for the depressor muscles cannot be seen.

Some 20 sections or so of different parietes were made but only one yielded a fair interlaminate figure. This is a white, fairly broad and straight, bilaterally digitate trunk running from near the inner wall to midway between the parietal pores about level with their lower edge. From here the figure narrows and continues through the interspace of the parietal pores toward the outer wall either with short digitations or as a plain septal bar to about level with the top of the parietal pores. The parietal pores on two sections are surrounded by a broad subrectangular to suboval halo of shell material that is lighter in tone and denser than that of the spaces between the pores.

Dimensions.—Shell: holotype (K589b), carino-rostral diameter at base 9 mm., height 8 mm., length of orifice 7.5 mm., max. width of orifice 5.5 mm.; paratypes: specimen K591a, thickness of wall 1.6 mm.; specimen M591g, thickness of wall at base of sheath 2.2 mm.; specimen M591h, thickness of wall midway between sheath and base 0.5 mm.; specimen M591a, carinolateral diameter at base 5 mm., height 5.5 mm., length of orifice 4 mm., max. width of orifice 2.5 mm.; specimen M591f, lateral compartment, height 8 mm.; specimen M591b, carino-rostral diameter at base 7.1 mm., height at carinal end 5.3 mm., length of orifice 3 mm., max. width of orifice 2.2 mm; specimen N591a, shell broken away at base, maximum diameter 6.6 mm., length of orifice 3.1 mm., max. width of orifice 2.2 mm. Scutal valves: measurements of three scuta are the following:

	Length in mm.			*Angles*		
Specimen	*Occl. Marg.*	*Terg. Marg.*	*Bas. Marg.*	*Apical*	*Basi-Occl.*	*Basi-Terg.*
T591a	5.8	3.6	3.8	34°	50°	96°
M591c	5	3.3	3.4	33°	46°	101°
M591d	4	3.1	2.7	37°	52°	91°

Tergum: specimen M591e, width across basal margin 2.5 mm., length from apex to embayment of basal margin on carinal side of spur 2.1 mm., length along scutal margin 2.9 mm.

Type locality.—Playa Grande formation (Catia member), in bluff 125 meters west of the intersection of the Playa Grande Yachting Club road and coast road. Two shells.

Other localities.—Playa Grande formation (Catia member) at W-15, south side of Playa Grande road, 40 meters southeast of its intersection with Playa Grande Yachting Club road. Forty-one shells and fragments; two scuta; one tergum. Playa Grande formation (Catia member), south side of Playa Grande road about 220 meters west of W-15. On shell fragment consisting of the carinolateral and lateral compartments. Playa Grande formation (Catia member) near W-21 in stream bed along the strike of the north flank of the Litoral anticline. One shell. Upper Mare formation, in stream 250 meters south-southwest of the mouth of Quebrada Las Pailas. One scutum.

Comparisons.—Insofar as the shell and operculum are concerned, the new species is strongly reminiscent of *B. venustus modestus* (Darwin), a Recent barnacle, probably from the West Indies. However, the interlaminate figure of *B. venustus modestus*, as shown by Harding (1962, pp. 287-289, pl. 8c), consists of a series of "V"s, with the base of the "V" lying near the inner wall and the limbs virgating therefrom and touching the base of the parietal pores. The interlaminate figure of *B. caribensis,* n. sp., on the other hand, is a simple, bilaterally digitate trunk something like that, for example, of *B. tintinnabulum californicus* Pilsbry (see Cornwall, 1958, p. 83, fig. 8). The shell and operculum of *B. t. californicus,* are distinct from *B. caribensis.* This similarity of certain diagnostic features and the dissimilarity of other equally diagnostic features between two species point up the necessity of utilizing all visible taxonomic characters—the shell, the orifice, the sheath, the basis, the operculum, the interlaminate figure—to determine the identity of a particular barnacle. There must be a reasonable similarity in all of the essential parts of a barnacle to be considered the same species as another.

Balanus (Balanus) caboblanquensis, n. sp. Pl. 5, figs. 5-12; Pl. 6, figs. 1-2

Shell small, low conical, with a flat, subcircular to suboval base. Orifice diamond-shaped, acute carinally, toothed around the rim, generally a little over half the length of the basis. Sides of shell straight except the carina which is concave immediately below the orifice. Compartments six, all of them broad save the carino-laterals which are narrow. Parietes smooth and whitish but marked by longitudinal hyaline lines, corresponding with, and caused by the parietal septa being visible externally through the outer layer of the walls. There is generally one such hyaline line down the middle of each of the carino-lateral parietes (with often a faint one along either edge), 11 of them on the carina and laterals, and 16 or 17 of them on the rostrum. The striped appearance of the parietes results from the contrast between the hyaline septa and the whiteness of the shell material. The radii are narrow, smooth externally, acutely oblique at the summit, and minutely denticulate at the edge. The alae are protuberant, much less oblique at the summit, and coarsely crenated at the suture. Internally, the parietes are ribbed, the ribs running from the base upward and under the plates of the sheath, the sheath plates themselves marked by about six fine, raised, concentric laminae. The tube-ends at the base of the compartments are large and rectangular, and on one specimen measuring 5.7 mm. in diameter at the base, there are about 55 of them around the periphery. The basis is thin and permeated by pores though the pores do not generally extend to the center. From the center (which is not in the middle of the basis but nearer one side) there radiate outward in curved bands the same narrow stripes of shell material that constitute the parietes.

The scutum is triangular, has a flat outer surface, straight occludent and tergal margins, a hardly flexuous basal margin, and a rounded basi-tergal corner. The apical angle is roughly 30 degrees, and the basi-occludent angle roughly 52 degrees. Externally, the scuta are sculptured by faint concentric growth striae which run parallel with the basal margin; at widely spaced intervals a stria becomes enlarged and forms a raised ridgelet as it envelopes and terminates at the occludent margin. On a valve having a length of 2.5 mm. along the scutal margin there may be eight such raised ridgelets from the base upward for two-thirds the total length. No vertical striae have been observed. Internally, the articular ridge is prominent, elevated, lamellar, and slightly reflexed above, but is low and blunt along the continuation below. The adductor ridge, which is subparallel with the occludent margin but some distance from it, is also moderately prominent; however, it is lower than the articular ridge and terminates well before the basal margin. The scar of the adductor muscle cannot be seen. In the articular furrow there is a small shallow subtriangular cavity at the basi-tergal angle for the lateral depressor muscle.

The tergum is slightly undulatory on the outer surface by virtue of the broad, shallow radial depression on the carinal area, and the slightly deeper depression of the segment leading into the spur. The basal margin is deeply embayed on the carinal side of the spur and is narrowly and deeply notched on the scutal side of the spur. The scutal margin is straight and the carinal margin somewhat humpbacked. The outer surface is marked by faint, widely spaced, concentric growth laminae, those on the carinal area following the contour of the basal margin, the ones on the spur bowed a little downward; the laminae on the narrow scutal area are somewhat more prominent, and form tiny elbows or protuberances as they envelop and terminate at the occludent margin. The spur is relatively broad, with a vertical scutal side and a subangularly rounded and oblique basal end. Internally, the articular ridge is subangularly curved, and is higher and thinner above than it is below. On left valves of the terga the articular furrow is relatively broad and widens basalward. Within the furrow there is a low ridgelike elevation emerging from the basi-scutal corner of the spur, and this ridge (which is the obverse of the spur depression) continues up the furrow or curves toward the articular ridge. On right valves the articular furrow is deep and linear, and there is no ridge within it as on the right tergum. The crests for the depressor muscles, of which there may be as many as six, lie in the basi-carinal corner of the valve, and extend upward for a short distance. The apex is sculptured by two or three obliquely curved lamellae.

Two specimens were sectioned, one close to the basis and the other a short distance above the basis, but no recognizable interlaminate figure was revealed. As all examples of this species are small and fragile they were embedded, for sectioning, in the thermopastic cement known as "Lakeside No. 70", and this proved a satisfactory medium for holding the shell during grinding. Also, because of its transparency, details of structure can be seen even though the cement permeates the pore spaces.

Dimensions.—Shell: holotype (G594a), carino-rostral diameter 5.2 mm.; height at carinal end 1.9 mm.; length of orifice 2.4 mm. The length of the orifice compared with that of the base along the carino-rostral axis on six other specimens is listed below:

Length of orifice (mm.)	*Length of base (mm.)*	*Ratio (%)*
2.5	5.5	45
3.3	6.6	50
2.8	5.2	54
3.0	5.5	54
2.3	4.1	56
2.2	4.1	54

Scutum: paratype (G594b), length along occludent margin 2.5 mm.; paratype (G594c), length along occludent margin 2.6 mm. Tergum: paratype (G594d), length from apex to base of spur 1.65 mm.; paratype (G594e), length from apex to base of spur 1.65 mm.; paratype (G594f), length from apex to embayment of basal margin 0.8 mm. Compartment: paratype (G594g), height 2.1 mm.; width 2.9 mm.

Type locality.—Mare formation near G-14, on hillside above west bank of Quebrada Mare Abajo. Twenty-one specimens, most of them with the opercular valves entombed in the shell cavity.

Other localities.—Playa Grande formation (Maiquetía member), north bank of Quebrada Las Pailas, about 180 meters east of the intersection of the Bruscas and Mare Abajo faults. Fourteen specimens. Playa Grande formation (Maiquetía member) at W-26, in Quebrada las Bruscas approximately 125 meters upstream from its junction with Quebrada Las Pailas. Three shells.

Comparisons.—This species is close to certain variants of *B. improvisus assimilis* Darwin (1854, pp. 250-253). Darwin differentiated his *B. improvisus assimilis* from his *B. improvisus improvisus* by the occurrence on *B. i. assimilis* of "longitudinal white hyaline lines" but came to the conclusion that this did not constitute a specific distinction. His description of *B. i. assimilis* therefore was included with that of *B. improvisus s. s.* Pilsbry (1916, p. 84) also united *B. i. assimilis* with *B. improvisus improvisus,* and his illustrations show that the basal margin of the tergum on the carinal side of the spur is straight or truncate. In contrast, the basal margin of the Venezuelan fossil is definitely and consistently embayed, and is thus distinct from that of *B. improvisus improvisus* as interpreted by Pilsbry. However, Darwin also stated that although "the basal margin is generally straight on opposite sides of the spur . . . sometimes on the carinal side it is a little hollowed out". This "hollowing out" or embayment of the basal margin on the carinal side of the spur is always present on the Venezuelan terga, and the shell material is always regularly striped by longitudinal hyaline lines. Darwin did not indicate whether the few tergal valves that were embayed belonged to the hyaline-striped shell, but it is clear from his illustration (pl. 6, fig. 1c) that the tergum of *B. improvisus improvisus* is not the same as that of the Venezuelan fossil under discussion. In view of this, and in view of the fact that Darwin did not mention, nor did Pilsbry illustrate a ridge within the articular furrow of the right tergum, it seems best to consider the Venezuelan form as new.

Balanus (Balanus) playagrandensis, n. sp. Pl. 6, figs. 3-10; Pl. 7, figs. 1-4

The tergum resembles an asymmetric arrowhead, with a shallowly arcuate carinal margin and a hardly concave to nearly straight scutal margin; the basal margin is partially broken away but seems to be straight from the basi-carinal corner to before the middle, and then, to judge from the external markings, slightly embayed to the spur; the spur proper and the lower portion of the scutal segment are missing. The valve is flat externally except for the well-defined spur segment which is feebly depressed. The outer surface is divided into four radial segments: the spur segment, the marginal segment on the scutal side of the spur, the carinal segment on the opposite side of the spur, and the marginal segment adjacent to that. The outer surface is sculptured by sinuous concentric riblets, these varying in prominence and contour on the different segments of the valve: on the spur segment they are light, and bowed down shallowly toward the spur; on the scutal segment they are prominent, more or less horizontally disposed, and, as they envelop and terminate at the scutal margin, they form minute protuberances; on the carinal segment next to the spur the markings are sublaminar and gently arcuate; and on the carinal segment next to the margin, the concentric riblets are again faint and bowed slightly downward. The margino-carinal segment is also traversed by radial lineations, those on the lower half representing the reflections, from the interior, of the crests for the depressor muscle, but those on the upper half constituting part of the shell layer. Internally, the articular ridge is fairly sharp, and terminates halfway down the valve. The apical area is thickened and is sculptured by four obliquely curved lamellae. The beak is subrounded at the tip. The crests for the depressor muscle are moderately strong, five or six in number, and extend upward some distance from the basi-carinal corner before becoming obsolescent.

The scutum is triangular, with a nearly flat outer surface except along the tergal margin where there is a low narrow rise. The tergal and occludent margins are straight, the basal margin hardly flexuous, and with a notch in the basi-tergal corner at the cavity of the lateral depressor muscle. The apical angle is about 33 degrees, the basi-occludent angle about 44 degrees. Externally, the scutum is sculptured by subregular concentric ridges or laminae which form small protuberances as they envelop and terminate at the occludent margin. In certain light, the concentric ridges are seen to be traversed locally by microscopic radii. Internally, the upper half of the articular ridge is high, lamellar, and a little reflexed, the lower continuation low and blunt and terminating near the basal margin. The adductor ridge is prominent, inclined toward the articular ridge, more or less parallel with the occludent margin. On the side of the adductor ridge facing the occludent margin there is a large lenticular scar or depression of the adductor muscle. The cavity for the lateral depressor muscle is deep and subtrigonal, widening into a notch in the basi-tergal corner. On the lower half of the valve the concentric ridges of the surface are reflected through to the interior.

The shell, in which the opercular valves described above were entombed, was destroyed in the process of separation by the ultrasonic vibrator, and the diagnosis which follows is based on those fragments and on other individuals belonging to this species. The shell is small, compact and sturdy, low conical, and suboval at the base. Compartments six, the rostrum slightly convex, the carina and laterals generally straight-sided. Orifice angularly ovate or diamond-shaped, toothed, acute carinally, and about half the length of the long axis of the basis. The thickness of the walls increases rapidly toward the basis, and at the basis the parietal tubes are relatively large and subrectangular: on one specimen 6.5 mm. in length there are about 49 parietal tubes. Externally, the parietes are generally smooth, though occasionally they may be concentrically lineated or bear faint longitudinal rugae. Within, the compartments are strongly ribbed, the ribs continuous with the septa in the wall, extending upward toward and often under the plates of the sheath. The sheath plates themselves are sculptured by fine, fairly numerous, slightly elevated concentric laminae. The radii are relatively narrow, angulate at the summit, strongly crenate at the edge. The alae tend to stand out, are only slightly oblique at the summit, and are coarsely crenate at the suture. The basis is undulatory-concave, marked by low subregular ridges diverging from well off center to the periphery. At the periphery the basis is two-walled and septate, but inward toward the center the walls meet to form a single membrane or layer though the septa are still visible as hyaline lines between the ridging.

The interlaminate figure is white and dendritic. The figure consists of a central stem extending from the inner wall of the paries to a point about midway between and level with the base of the parietal pores. Leading into the stem on both sides are short white horizontal lines of which there are six in number in the column on either side of the stem in specimen K591a.

Dimensions.—Holotype (R591a), diameter at base 7 mm.; altitude 5 mm.; approximate length of orifice 3 mm. Paratype (R591b), a right tergum, length from apex to basal margin 2.25 mm.; width across basal margin 2.1 mm. Paratype (R591c), a left tergum, length from apex to basal margin 1.75 mm.; width across middle 1.3 mm. Paratype (R591d), right scutum of pair, length along occludent margin 3.2 mm.; length along tergal margin 2.4 mm.; width across basal margin 2.2 mm. Paratype (R591e), left scutum of same pair as R591d, same dimensions. Paratype (R591f), a worn shell, carino-rostral diameter 5 mm.; height at carinal end 3.2 mm.; length on orifice 2.5 mm. Paratype (R591g), carina and carinolateral compartments, width 5 mm.; height 4 mm.

Type locality.—Playa Grande formation (Maiquetía member) at W-26 in Quebrada Las Bruscas approximately 125 meters upstream from its junction with Quebrada Las Pailas. Two terga, two scuta, three imperfect shells, and fragments.

Other localities.—Playa Grande formation (Catia member), in bluff 125 meters west of the intersection of the Playa Grande Yachting Club road and coast road. One shell and one fragment. Playa Grande formation (Catia member) near W-21. About 20 shells or bases cemented to *Ostrea vespertina venezuelana* Weisbord (1964a, pp. 187-190, pl. 24, figs. 5-11).

Comparisons.—The shell of this species is not unlike that of *B. improvisus* Darwin, and the interlaminate figure not unlike that of *B. eburneus* Gould (see Cornwall, 1958, p. 84, fig. 10) and *B. psittacus* (Molina) as shown by Cornwall (1956, p. 648, fig. d). However, the tergum of *B. improvisus* is not radially striate on the margino-carinal segment as it is on the Venezuelan fossil, and the shells of *B. eburneus* and *B. psittacus,* as well as their opercula, are dissimilar to those of *B. playagrandensis,* n. sp.

Balanus (Balanus) concavus Bronn, Nilsson-Cantell

1888. *Balanus* sp. Schepman, *In* Martin, Bericht über eine Reise nach Nederlandisch West-Indien und darauf gegrundete Studien, II, p. 228.

1913. *Balanus* sp. Schepman, Ernst, Ministerio de Obras Públicas (Venezuela), Rev. Técnica, año 3, No. 34, p. 692. [Translation in Spanish of the above].

1939. *Balanus concavus* Bronn, Nilsson-Cantell, Capita Zoologica, vol. 8, pt. 4, pp. 3,5,6.

Although I did not find this particular species of barnacle, the type locality is known to me, and I have collected a rich invertebrate fauna from it. Martin's original *Balanus* sp. of Schepman is believed to occur in the Mare formation at my stations W-13 or W-14 (see Weisbord 1957, Geologic Sketch Map) on the hillside rising above the west bank of Quebrada Mare Abajo. According to Nilsson-Cantell, the *Balanus* sp. of Schepman is represented by a single specimen which is in the collection of the Geological State Museum in Leiden, The Netherlands. This specimen was examined by Nilsson-Cantell and determined by him to belong to the race of *Balanus concavus* Bronn. A subspecific identification was not possible as the opercular valves were lacking. Another locality in the Cabo Blanco area where this species is said to occur by Nilsson-Cantell is "Punta Gorda, East of Cabo Blanco, La Guaira, 19. VIII. 1936; one specimen in horizontal, shell-bearing, marly sediments of a marine cliff, about 4-5 m above sea level." This specimen was collected by P. Wagenaar Hummelinck during a trip to the north coast of South America in 1936 and 1937 and was deposited in the Geologisch-Mineralogisch Instituut in Utrecht, The Netherlands. From my field work in 1955 and 1956, I think it likely that the Punta Gorda location is close to my stations W-23 and W-25 (see Weisbord 1957). However, as the axis of the Punta Gorda fault-anticline is presumed to run between stations W-23 and W-25, and as there is a considerable amount of obscuring talus material on the slope, I cannot be certain whether the shell in question was obtained from the Maiquetía member of the Playa Grande formation or from the wedge of Mare formation lying above the Maiquetía member on the south side of the Punta Gorda anticline.

Following is Nilsson-Cantell's discussion of the shell referred by him to *Balanus concavus* Bronn:

> The major port of the fossil Balanus specimens in this collection may be considered as belonging to *Bal. concavus,* found fossilized in America and Europe before. This species contains several recent and fossil subspecies which are rather difficult to identify, even in recent material with opercular valves and internal parts present. Some specimens (the largest measuring 20 mm. in carino-rostral diameter) from Carirubana, Paraguaná, with small ribs on the walls, agree somewhat with Pilsbry's fig. 3, pl. 21, 1916 of *Bal. concavus glyptopoma,* found in the Miocene of Virginia and (Pilsbry, 1918) in the Panama Canal Zone. According to Pilsbry (1918), however, this subspecies differs, by the closely septate parietal tubes, so much from *Bal. concavus,* that he considers the subspecies *glyptoma* as a distinct species. It was impossible to make out the structure of the pariental tubes in the material, because they were filled up during calcination. For this reason I put the specimens to *Bal. concavus.* Some specimens from Rio Hacha, La Goajira, may also belong to this species. They have the wall only slightly, sometimes even rather indistinctly roughened longitudinally.

Localities.—In addition to the occurrence at Quebrada Mare Abajo and at the Punta Gorda anticline, *Balanus concavus* Bronn has been reported by Nilsson-Cantell at the following localities: "North of Carirubana, Paraguaná, 17. II. 1937; some specimens on an *Ostrea* shell in the *Ostrea*-zone of a marine cliff of horizontal, shell-bearing marl, about 10 m above seal-level." This locality is in Venezuela. "Northeast of Rio Hacha, La Goajira, 20. I. 1937; several specimens in horizontal, shell-bearing marl of a low, marine cliff, about 1-½ m above sea level; one specimen on *Pecten.*—About 1 km S.S.E. of Rio Hacha, La Goajira, 18. I. 1937; several specimens in horizontal, shell-bearing marl, about 5-10 m above sea level; some specimens on *Pecten* and *Ostrea.*" The two last-named localities are in Colombia.

Range and distribution.—Nilsson-Cantell's *Balanus concavus* occurs in the Pliocene of Venezuela and in the late Tertiary or Pleistocene of Colombia. It is not yet known if the Venezuelan form is identical with the *Balanus concavus* of Bronn which has been reported from the Oligocene to Pleistocene of Italy, the Miocene of Hungary, the Pliocene of England and Portugal, and the late Tertiary of northern Africa.

Balanus species Pl. 7, figs. 10, 11

The following description pertains to a single right scutum obtained from the residue of a washed sample. The shell to which the valve belongs is not known. The scutum in question is small, sturdy, and triangular, with a straight occludent margin, a slightly flexuous basal margin, which is barely notched in the basi-tergal corner, and a straight, pointed beak. The outer surface is flat except at the apex where it is a little concave. The sculpture consists of closely spaced concentric riblets which follow the contour of the basal margin and are decussated by numerous regular radii. The radii are short, low, and broad, are separated by narrow, shallowly incised interspaces, and appear to be absent in the deep intercostal spaces of the concentric riblets. There are approximately 40 concentric riblets on the surface from the base to the beak (toward which they gradually diminish in size), and every other riblet, from the basal margin to a little above the middle, completely envelops the occludent margin; alternate riblets do not envelop the occludent margin but terminate there against the adjacent larger riblet. The radii crossing the concentric riblets are pronounced on the apical area where they crenulate the suface but are more lightly developed below and become obsolescent on the tergal rostration. Externally, the furrow between the tergal margin and articular rostration is deep and narrow. Internally, the articular ridge is prominent, high, and a little reflexed, and its length is nearly three-quarters that of the tergal margin; the edge of the tergal platform under the articular ridge is notched at the base of the articular ridge. The adductor ridge is strong, swollen, somewhat arcuate, and short. The pit for the adductor muscle is deep and oval. The pit for the lateral depressor muscle is large and triangular, widening and shallowing at the basi-tergal corner. Just above the basi-occludent corner there is another prominent lenticular pit produced by the reflexion of the inner edge of the occludent margin. Between the adductor ridge and the depressor pit there is a narrow, obtuse, diverging ridge, one side of which forms the wall of the lateral depressor muscle, the other separated from the adductor ridge by a shallow depression. The tergal margin is somewhat sinuous, strongly reflected below to form a platform on which are continued the concentric riblets of the outer face of the valve.

Dimensions.—Specimen K590a, a right scutum: length of occludent margin 5 mm.; width across basal margin 3 mm.

Locality.—Playa Grande formation (Catia member), in bluff 125 meters west of the intersection of the Playa Grande Yachting Club road and coast road and about 95 meters due south of the shoreline. One scutum.

Comparisons.—This scutum, though generally similar to that of a number of species, is specifically characterized by the swollen and arcuate adductor ridge; by the prominent notch on the inner edge of the tergal platform just below the end of the articular ridge; by the slight indentation of the basal margin at the pit for the lateral depressor muscle; by the deep lenticular pit just above the basi-occludent corner; and by the low divergent ridges between the adductor ridge and the pit for the lateral depressor muscle. The scutum of the late Cenozoic *B. calidus* Pilsbry is the nearest of any I have seen, though that has a much smaller and deeper and more oval pit for the lateral depressor muscle, and only a hardly visible scar for the adductor muscle.

The possibility that the scutum here described may represent the opercular valve of *B. laguairensis*, n. sp. described in this paper, or of the "*Balanus concavus* Bronn" from the Mare formation described by Nilsson-Cantell (1939a, pp. 3,5,6) cannot be dismissed, but until opercula-bearing shells of those species are found the true identity of the present scutum must remain in abeyance.

CIRRIPEDS FROM FLORIDA

LOCALITY

The barnacles here described from Florida were collected from the Choctawhatchee formation at Jackson Bluff in Leon County. Jackson Bluff forms a nearly vertical scarp on the southeast bank of the Ochlockonee River and is located in the southwest corner of Section 16, Township 1 South, Range 4 West, roughly a mile or so west of Bloxham and about 24 miles, by state highway 20, west of Tallahassee. The Choctawhatchee formation is exposed over an area of several acres at the top of the bluff a short distance downstream from the dam at Lake Talquin and has a thickness of 20 feet or so. The Choctawhatchee section at Jackson Bluff is so richly fossiliferous, and the fossils are so well preserved and easy to collect, that this small area is considered one of the important upper Miocene localities in the Gulf Coast province of the United States. Of the various phyla represented, the Mollusca are by far the most abundant, and those were described by Mansfield in 1930[5] and 1932[6]. However, certain other classes of organisms, among them the Cirripedia, have been largely neglected, and the writer, having undertaken the description of some late Cenozoic barnacles from Venezuela, decided to broaden that work by including in the present paper the diagnoses and illustrations of four species of barnacles from the Choctawhatchee formation at Jackson Bluff. In 1963

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[5] Mansfield, W. C., 1930. *Miocene gastropods and scaphopods of the Choctawhatchee formation of Florida.* Florida State Geol. Sur., Bull. No. 3, 185 pp., 21 pls.

[6] Mansfield, W. C., 1932. *Miocene pelecypods of the Choctawhatchee formation of Florida.* Florida State Geol. Sur., Bull. No. 8, 233 pp., 34 pls.

and early in 1964 a number of trips were made to Jackson Bluff for the specific purpose of collecting barnacles, and though they are not overly abundant, I was able to obtain a number of specimens thanks to the help of Paul F. Huddlestun, a graduate student in the Dept. of Geology at Florida State University. Both the Choctawhatchee and the underlying Hawthorn formations are exposed at Jackson Bluff, and I am indebted to my colleague, Lyman D. Toulmin, for providing me with the description of the two formations, which is as follows:

Geologic Section at Jackson Bluff

		Feet
Choctawhatchee formation		
Cancellaria zone		
7.	Sand, light gray, medium-grained, quartz, packed with shells of mollusks, small corals, barnacles. Exposed in borrow pit.	5+
Ecphora zone		
6.	Marl (calcareous clay), weathered reddish brown, quartz granules, glauconite, uneven-grained, packed with mollusk shells. Exposed at top of bluff.	10+
	Disconformity	
Hawthorn formation		
5.	Clay (Fuller's earth), greenish brown, shaly.	3
4.	Sand, like bed 2.	2
3.	Clay (Fuller's earth), greenish brown, shaly, with sand	3
2.	Sand, light greenish gray, massive, fine- to medium-grained, quartz, many fossil prints (mollusks).	4
1.	Limestone, grayish white, massive, very sandy (medium-grained quartz), fossil prints. Contains at the top very irregular solution-resistant masses of calcareous standstone up to 3 feet long, and 6 feet below the top grades downward into sand, white, medium-grained, quartz. The lower part of this sand is undercut by the current, and consists of bright blue fine-grained quartz with manatee rib bones. Below the blue sand is a shelf of limestone, white, very sandy (coarse-grained quartz), rare *Pecten* prints. The lower limestone of bed 1 varies in thickness with the sand.	
	Total exposed thickness of bed 1 to water level at lowest stage of river.	21

The name *Cancellaria* zone (bed 7) was proposed by Mansfield[7] in 1929 to designate the soft fossiliferous sand at the top of the Choctawhatchee formation at Jackson Bluff containing the guide fossil *Cancellaria propevenusta* Mansfield. According to Huddlestun, *Cancellaria propevenusta* also occurs rarely in the lowermost strata of the Choctawhatchee formation at Jackson Bluff, but the term *Cancellaria* zone is still generally used to denote the top member of the Choctawhatchee formation at Jack-

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[7] [In] Cooke, C. Wythe, and Mossom, Stuart, 1929. *Geology of Florida.* Florida Geol. Sur., Twentieth Ann. Rept., p. 140.

son Bluff and elsewhere. It may be added that in the Jackson Bluff area, the Choctawhatchee formation is overlain unconformably by loose unfossiliferous Quaternary sand and silt.

The name *Ecphora* zone (bed 6), from the guide fossil *Ecphora quadricostata umbilicata* (Wagner), is a modification by Mansfield (1929) of the term "*Ecphora* bed" used by Dall and Harris[8] for a bed at Alum Bluff on the Apalachicola River. At Alum Bluff the "*Echpora* bed" is the upper fossiliferous bed unconformably overlying the Chipola formation. It is 15 to 25 feet thick and consists of fossiliferous sandy clay which is bluish where unweathered. According to Mansfield the *Ecphora* zone, or bed 6 of Jackson Bluff, is the equivalent of the *Ecphora* bed at the top of Alum Bluff. At Jackson Bluff the lowest several feet of the *Ecphora* zone consist of a bluish, tough, highly fossiliferous clay, and this clay disconformably overlies the soft, greenish brown clay of the Hawthorn formation. The contact is clearly visible in a drainage ditch leading to the edge of the bluff. Upward, the *Ecphora* zone becomes somewhat sandier and not so tough, and finally there is a transition to the soft sand of the *Cancellaria* zone.

Based on the mollusks, the Choctawhatchee beds at Jackson Bluff are late Miocene in age. Mansfield described 192 species of Mollusca from Jackson Bluff: 80 gastropods, 5 scaphopods, and 107 pelecypods. Of the 80 gastropods 16 are living; of the 5 scaphopods 1 is living; and of the 107 pelecypods 20-22 are living. On these figures, 20 per cent of the Choctawhatchee mollusks at Jackson Bluff have survived to Recent time. The four species of barnacles described in this paper are new and do not lend themselves to age determination. They are late Cenozoic in affinity and do not discredit the evidence of the mollusks which in Lyell's calendar points to a late Miocene age.

SYSTEMATIC DESCRIPTIONS

CIRRIPEDIA

BELANIDAE

Balanus (Balanus) talquinensis, new species Pl. 8, figs. 1-13; Pl. 9, figs. 1-6

Shell large, steeply conical to tubulo-conical, subcircular to suboval at the base. Carina subangular on the exterior, sharply angular within, nearly

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[8] 1892. *The Neocene of North America.* [In] *Correlation papers. Neocene.* U. S. Geol. Sur., Bull., No. 84, p. 124.

vertical, rising to a sharply pointed apex higher than that of all the other compartments. Rostrum moderately convex, often humpbacked in profile, its elevation the lowest of the compartments. Orifice trigonal to pentagonally ovate, acute carinally, subtruncate rostrally, deeply toothed, four-tenths to seven-tenths the length of the base. Parietes smoothish to gently gnarled to very coarsely roughened to irregularly ribbed longitudinally, the surface sometimes marked by oblique and divers allomorphic ridges formed by attachment to mollusks and other shells; concentric growth lines are numerous and prominent, and under a lens on slightly weathered exteriors, crowded longitudinal striations representing the parietal tubes are visible. The radii are subequal in width, extend down to the basis, and are sharply oblique at the summit forming an angle of about 45 to 50 degrees with the horizontal; the summit or free edge is finely denticulate, the crenations becoming larger and stronger at the sutures where the interlocking ridges are themselves sculptured by numerous vertical striae; the exterior of the radii is marked by regularly spaced horizontal or slightly oblique lineations, but the walls are solidly filled. The alae stand out prominently and are also acutely oblique at the summit which is thin. Internally, the compartments are closely ribbed longitudinally, the ribs corresponding with the septa of the parietal tubes; where the inner wall is weathered the ribs are seen to be composed of minor longitudinal filaments which in cross section impart a bilaterally digitate structure. The parietal tubes ascend toward the sheath, and near the basis are rectangular to oval in cross section. The sheath plates, though sometimes relatively smooth, are sculptured by concentric lamellae slanted shingle-like toward the apex, the lamellae gradually becoming closer upward, and numbering 30 or more on a carinal sheath plate measuring 16 mm. in height. The basis is thin, and either somewhat concave or wedge-shaped to form a calyx; it is composed of numerous septate tubules radiating and swirling outward from a nucleus which is well off center. The shell substance is thin to thick, the thick shells prevalent in the tough lower clays, the thin ones occurring in the soft upper sands. The color is dull gray or cream, the former, with somewhat darker radii, occurring mostly in the lower clays, the lighter cream-colored ones occurring generally in the upper sands. The opercula from the barnacles with thick shells are smaller than those with thin shells of the same size. It has also been observed that the concentric lamellae of the sheath plates are generally more pronounced on the thick, dull gray shells than on the thinner cream-colored shells. A relatively thick, cream-colored shell, suffused with pale pink below the orifice, is found in lesser abundance in both the lower and upper zones of the Choctawhatchee formation at Jackson Bluff.

The scutum is triangular, with a straight occludent margin, a sharply angulate basi-occludent corner, a shallowly arcuate basal margin, a rounded to obliquely truncated basi-tergal corner, a slightly sinuous tergal margin, and a simple, sharply pointed beak. The outer surface is flat except in the apical area where it is slightly concave. Externally, the valve is sculptured by regularly disposed concentric laminae on which are superposed numerous prominent radial riblets; at the intercepts of the radial riblets with the summit of the concentric laminae small beads or nodules are present. Between the larger concentric laminae are fine concentric growth striae. As the laminae envelop the occludent margin they are raised into oblique ridges producing a ropy structure along the occludent edge. The laminae are also raised into low ridges at the tergal margin which itself is reflected into a platform on which the ridges terminate. Internally, the articular ridge is a thickened slanting slab extending down about three-quarters the length of the tergal margin. The adductor ridge is an elevated sloping wall extending somwhat beyond the termination of the articular ridge and then continuing somewhat arcuately as a low ridge to near the basal margin. Both the articular and adductor ridges are roughened by shell growth, and diverge from the apex at an acute angle. The pit for the adductor muscle is large, shallow, and broadly ovate in outline. The pit for the lateral depressor muscle is fairly deep, large, rhomdoidal in outline, and bounded by a prominent ridge. Just above the basi-occludent corner there is another pit or excavation of narrowly lenticular form. The scuta are white or dark gray depending on the color of the shell. On the exterior of the white scuta there is a radial stripe of pale lavender extending a short distance down from the beak near the tergal margin.

The tergum resembles a curved asymmetric arrowhead, with a strongly arcuate carinal margin, a concave scutal margin, and a simple pointed beak turned toward the scutal margin. The basal margin on the scutal side of the spur is deeply embayed, but on the carinal side it is hardly concave to subtruncate. The longitudinal furrow on the outer surface is narrow and shallow but broadens in the spur. The furrow divides the tergum into unequal halves, the carinal wing nearly double the width of the scutal wing. The spur is large and prominent, and its maximum width is two-sevenths that of the valve; the base of the spur is truncate and the carinal side nearly straight except for a minute bulge a short distance above the basal corner; the scutal side of the spur is slightly convex but there is a marked contraction just above the base. On large terga, the base of the spur is serrated by small projections, and on the scutal edge of the base there is a rather pronounced slit. On small terga, the serrations may be absent, though the slit, in an incipient stage of development, is usually present. Externally, the tergum is sculptured by widely spaced lamellae, the lamellae generally flattened but sometimes a little raised near the base, and having the same contour as that of the respective basal margins. Internally, the articular ridge is fairly broad and prominent, arcuate in its course, and diminishing in height as it enters the basi-scutal corner. The crests for the depressor muscle are long and well developed. The beak is marked by curved laminae, and the body of the tergum is roughened by longitudinal growths of shell.

The interlaminate figure is a digitate trunk divided by a narrow aisle of plain shell material. The aisle extends from near the inner wall of the paries to the septum between the parietal pores, and, extending out from each side of the aisle, are short horizontal bars. These bars impart a digitate or dendritic effect and there are five or six of them on each side of the aisle.

Dimensions.—The steeply conical to tubulo-conical shells described above have the following dimensions: holotype (JBC-1f), shell, carino-rostral diameter at base 21 mm., height at carinal end 24 mm., height at rostral end 22 mm., length of orifice 13 mm., max. width of orifice 6.5 mm.; paratypes—Specimen JBC-1g, shell, carino-rostral diameter at base 22 mm., height at carinal end 12 mm., height at rostral end 21 mm., length of orifice 10 mm., max. width of orifice 7 mm. Specimen JBC-1h, shell, carino-rostral diameter at base 19 mm., height at carinal end 20 mm., height at rostral end 27 mm., length of orifice 12 mm., max. width of orifice 8 mm. Specimen JBC-1i, shell, thickness of wall 1.2 mm. Specimen JBC-1a, right scutum, length of occludent margin 12.3 mm., width across basal margin 8.7 mm. Specimen JBC-1b, left scutum, length along occuldent margin 9 mm., width across basal margin 6.2 mm. Specimen JBC-1c, right tergum, length from beak to base of spur 9.7 mm., width across basal margin 5.6 mm. Specimen JBC-1d, left tergum, length from beak to base of spur 10.2 mm., width across basal margin 6.6 mm. Specimen JBC-1e, shell, width of wall of rostrum near base 1.2 mm. The largest shell found was from the *Ecphora* zone, and measures as follows:

carino-rostral diameter at base 43 mm.; height at carinal end 40 mm.; height at rostral end 38 mm.; length of orifice 22 mm.; max. width of orifice 11.5 mm.

Remarks.—Associated with the asymmetrically conical to tubulo-conical shells described under *B. talquinensis*, n. sp. are a number of thinner, more regularly conical, and longitudinally striped shells that seem to me to be variants of this same species. These conical shells have steeply sloping sides and a subcircular base. The carina, which is the highest compartment, may be nearly vertical, and rises to a sharply pointed apex; the rostrum, which is the lowest compartment (due to the slant of the orifice), is also steeply sloping, though it may be a little convex at the orifice, and is broadly triangular at the summit. The orifice is subtrigonal to pentagonally ovate, acute carinally, subtruncate rostrally, and deeply toothed, and its length is up to three-fifths that of the base. The parietes are relatively smooth on the outer surface but are striped subsurficially by narrow radial bands alternating in shell density. Not infrequently the parietes have taken on certain markings allomorphically derived from the invertebrate shell on which the barnacle was growing. Additionally, concentric growth striae or laminae are also present. The radii are subequal in width, they narrow sharply down to the base, and are decidedly oblique at the summit, the summit forming an angle of 45 to 50 degrees with the horizontal. The summit or free edge is finely denticulate, but the sutural edge, and the parietal suture with which it interlocks, is regularly and coarsely crenate, the crenations themselves bearing numerous vertical striae. The exterior surface of the radii is sometimes sculptureless but more often is marked by faint subequal horizontal lineations, though the walls of the radii are solid and tubeless. The alae stand out prominently and are also acutely oblique at the summit which is thin and nearly smooth. Internally, the compartments are closely ribbed longitudinally, the ribs coinciding with the septa between the parietal tubes, the septa compounded of several longitudinal filaments which in cross section are seen to be bilaterally digitate. The sheath plates are sculptured by flattened lamellae slanted upward, and on a sheath plate 6 mm. in height there are about 26 such lamellae. At the base, the parietal tubes are closely spaced and more or less rectangular in section, and, on a specimen 15 mm. in diameter there are 102 such tubes. The basis is thin, cup-shaped to undulatory, consisting of vermicular ribbons radiating outward to the periphery from a nucleus which is somewhat off center. The periphery of the inner surface of the basis bears rectangular pores leading to the parietal tubes. A number of the shells are radially striped and concentrically banded in light lavender on a cream-colored ground. Others from the lower, *Ecphora,* zone are dull gray or dull gray and light tan. Conical variants from the upper, *Cancellaria,* zone are cream-colored. The opercular valves and interlaminate figures are virtually the same as in the asymmetrically conical and tubulo-conical forms.

The dimensions of the conical forms described above are as follows: Paratypes—Specimen JBC-2f, shell from which the opercular valves JBC-2a-d were recovered and from which the basis (JBC-2e) was removed, carino-rostral diameter 15.5 mm., height at carinal end 15.5 mm., height at rostral end 14.5 mm. Specimen JBC-2g, shell, carino-rostral diameter at base 20 mm., height at carinal end 21.5 mm., height at rostral end 15 mm., length of orifice 8.5 mm., max. width of orifice (eroded) 7 mm. Specimen JBC-2h, shell, carino-rostral diameter at base 25 mm., height at carinal end (tip broken away) 20 mm., height at rostral end 20 mm., length of orifice 12 mm., max. width of orifice 7 mm. Specimens JBC-2a,b, right and left scuta of pair, length along occludent margin 7.2 mm., width across basal margin of single vaive 5.5 mm. Specimens JBC-2c,d, right and left terga of pair, length from beak to base of spur 6 mm., width across basal margin of single valve 4.1 mm. Specimen JBC-2e, basis detached from JBC-f, maximum diameter 15.5 mm.

The barnacle *Balanus talquinensis,* n. sp. was found loose as well as attached to various mollusks. Among the latter were *Turritella etiwanensis* (Tuomey and Holmes), *Cancellaria tabulata* Gardner and Aldrich, *Pecten ochlockoneensis* Mansfield, *Chlamys comparilis* (Tuomey and Holmes), *Chione ulocyma* Dall, and *Chione erosa* Dall.

Although the asymmetric and tubulo-conical shells seem to differ from the more regularly conical forms, I am persuaded that the differences are superficial and are due to individual variation rather than to specific or genetic constitution. The reasons for so thinking are that there is a gradation of external characters in a large series; that both the opercular valves (even to the lavender ray on the white scutal valves) and the interlaminate figures are very much alike; and that the various forms occur together in the same locality and throughout the same stratigraphic interval.

Comparisons.—Certain of the coarsely ridged specimens of *B. talquinensis,* n. sp. are similar to *B. concavus proteus* Conrad (see Ross, 1964, pp. 486-488, pl. 71, fig. 20; text fig. 2) from the Miocene of Virginia, whereas other specimens of *B. talquinensis* resemble *B. concavus chesa-*

peakensis Pilsbry (1916, pp. 103-104, pl. 22, figs. 1-1c) from the Miocene of Maryland. I have examined the types of *B. c. proteus* and *B. c. chesapeakensis* at the Academy of Natural Sciences of Philadelphia and find that one significant difference is that the alae of *B. c. proteus* are, as stated by Ross, subhorizontal, whereas on *B. talquinensis* the summits of the alae are acutely oblique. As for *B. c. chesapeakensis,* in which the opercular valves are similar to those of *B. talquinensis,* one difference lies in the radii: in *B. talquinensis* the radii are scored by distinct though surficial horizontal linations, but in *B. c. chesapeakensis* such lineation is hardly apparent. Furthermore, the radii of *B. c. chesapeakensis* are, in Pilsbry's words, "sunken and slitlike in the lower part". As for the operculum, the basal margin on the scutal side of the spur is deeply embayed on the right tergum of *B. talquinensis* but nearly straight on the same valve of the type of *B. c. chesapeakensis.*

The smoother, more conical variant of *B. talquinensis* strongly resembles the shell of certain Recent specimens of *Balanus concavus mexicanus* Henry (1941, pp. 100-102, pl. 13 [16], figs. 1-5) occurring along the west coast of Mexico, but the scutum of *B. c. mexicanus* is less strongly striate radially than that of *B. talquinensis,* and the spur of *B. c. mexicanus* is shorter and more rounded at the base than on *B. talquinensis,* and lacks the groove or split at the basi-scutal corner which characterizes *B. talquinensis.*

The conical *B. talquinensis* is also reminiscent of *Balanus concavus pacificus* Pilsbry (1916, pp. 104-108, pl. 23, figs. 1-2c) but *B. c. pacificus* is a more depressed shell, the radii are not nearly so oblique at the summit, the orifice is not so prominently toothed, and the pit for the lateral depressor muscle of the scutum is narrower, more lenticular, and deeper than on *B. talquinensis.*

Balanus (Balanus) leonensis, new species Pl. 9, figs. 7,8; Pl. 10, figs. 1-11

Shell small, sturdy, conical, and strongly ribbed. Compartments rather steeply sloping but flared slightly at the base, the base subcircular in outline, and scalloped at the periphery by the projection of the ribs. Orifice pentagonally ovate, acute carinally, subtruncate rostrally, its length about one-third that of the carino-rostral diameter at the base. Parietes strongly costate longitudinally, the costae or ribs crossed by prominent, fairly regular concentric lirae of which there are 34 or so on a paries with a height of 11 mm. Each of the carinolateral compartments bears but one radial (longitudinal) rib, the carina three, the laterals three or four unequal ones, and the rostrum four, with a minor intercalated riblet near the base. The major ribs are high, rounded at the crest, subregular to irregular on the type but somewhat vermicular on other specimens. The concentric lirae are closely spaced, their interspaces linear and shallowly incised. The radii are narrow and extremely oblique (about 80 degrees with the horizontal) at the summit, the summit joining the adjacent paries about halfway down from the latter's apex. The radii are darker in tone than the parietes, are denticulate along the summit or free edge, and are more strongly crenulate at the suture with which it interlocks. The horizontal crenations of the suture are provided with numerous microscopic vertical striae. The alae are broader than the radii at the orifice but their summits are not so oblique. The basis is relatively flat and thin, and is made up of alternating ribbons of hyaline and denser shell material, the ribbons radiating to the periphery from a nucleus which is located to one side of the basis. In the interior, the compartments are coarsely ribbed longitudinally, the ribs coinciding with the septa between the parietal tubes and ascending toward, but becoming obsolescent at the free, basal margin of the sheath. In cross section the ribs are bilaterally digitate. The parietal tubes are subrectangular at the base where there are approximately 90 of them on the type (which has a diameter of 16.5 mm.). The sheath plates are smooth except those of the carinolateral compartments which are marked by low narrow horizontal ridges numbering 18 or so on a plate 4.5 mm. in height. The ridges are widely spaced below but become progressively closer toward the apex. In contrast, all of the other sheath plates are smooth.

The interlaminate figure is a relatively long wedgelike, subrectangular or suboval bilaterally digitate trunk protruding from the inner wall to the septum between the parietal pores, the digitations ending at about the level of the base of the pores.

The scutum, as represented by a valve with the lower half broken away, is triangular and has straight occludent and tergal margins. The outer surface is flat except at the apical area where it is slightly concave. The exterior is sculptured by concentric, somewhat flexuous laminae which are slightly raised and slanted toward the basal margin, and are traversed by weak, relatively widely spaced radial lineations. Alternate laminae are somewhat elevated as they envelop the occludent margin; after crossing the disk, the concentric laminae become longitudinally oblique in the tergal furrow and on the back of the articular ridge. In the interior, the articular ridge is simple, moderately high, and slightly reflexed. The adductor ridge is not developed in the upper half of the valve and if it is at all present below, it is assumed to be inconspicuous.

The tergum, as represented by some fragments, has a slightly concave scutal margin, a shallowly arcuate carinal margin, and a simple beak. On the exterior, the furrow leading into the spur is narrow, moderately deep, and sharply defined at the edges. The spur itself has not been seen. The outer surface of the tergum is sculptured by faint, concentric, slightly flexuous fillets with little relief, bowed down in the furrow, and forming tiny denticulations as they envelop the scutal margin. In the interior, the articular ridge is strong, shallowly crescentic, flattened on the crest, and located relatively near the tergal margin. On the apex there are five or six slightly curved laminae. The crests for the depressor muscles are long and narrow, and there are five of them on the type.

Dimensions.—Before the holotype was broken to remove the opercular valves the shell measured 16.5 mm. across the base, 9.5 mm. in height at the carina, and 5 mm. in length of orifice. Components of the type have the following measurements: specimen JBC-3a (lateral compartments and part of carina), diameter 15 mm., height at carinal end 9.5 mm.; specimen JBC-3b (rostrum), width 10 mm.; height about 10 mm.; specimen JBC-3c (carinolateral compartment), width at base 2.6 mm., height 9 mm.; specimen JBC-3d (upper half of right scutum) length along occludent margin as is 2 mm.; specimen JBC-3e (right tergum) length along incomplete carinal side 3.1 mm.; specimen JBC-3f (broken left tergum), length of valve as is 1.7 mm.; paratype (JBC-3g), maximum thickness of wall at base of sheath, including rib projection 2.4 mm.; paratype (JBC-3h), thickness of shell wall just above base, including rib projection 2.5 mm.

Remarks.—The diagnostic characters of the shell of *B. leonensis,* n. sp. are the extremely oblique summits of the radii, and the faint horizontal ridges on only the carino-lateral sheath plates: all of the other sheath plates are smooth. The few specimens found were from the *Ecphora* zone of the Choctawhatchee formation at Jackson Bluff.

Comparisons.—The shell of *B. leonensis,* n. sp. resembles that of the strongly costate form of the Miocene to Recent *B. crenatus* Bruguière but may be differentiated by the strongly oblique summits of the radii. Also, the tergum of *B. leonensis* has a channeled furrow or fasciole leading into the spur, whereas there is no furrow on the tergum of *B. crenatus.* The interlaminate figure of *B. leonensis* is like that of the Miocene to Recent

B. trigonus Darwin, but both the shell and opercular valves are distinct, the summit of the radii being much more oblique on *B. leonensis,* and the scutum of *B. leonensis* lacking the longitudinal rows of little pits.

Balanus (Balanus) ochlockoneensis, new species

Pl. 11, figs. 1-7; Pl. 12, figs. 1-4;

Shell small, sturdy, conical, and strongly ribbed longitudinally, the projection of the ribs forming rounded scallops on the periphery of the shell at the base. The six compartments are steeply and regularly sloping, the carinal end subangular, the rostral end hardly rounded. The orifice is toothed, pentagonally ovate, acute carinally, subtruncate to truncate rostrally, and roughly one-third the long diameter of the base in length. The parietes are sculptured externally by strong irregular radial ribs crossed by low regular concentric growth ridges, the growth ridges separated by linear, slightly impressed interspaces. The carinolateral compartments are narrower than the others, and bear but one broad rib which is generally bifurcate or trifurcate at the base; on the carina and rostrum there are about six unequal ribs, the broader ones of which are bipartite or tripartite on the lower half; on the lateral compartments there are four to six ribs, and the larger of these are also divided basalward. The ribs are gently rounded at the crest, and they are separated by narrowly incised interspaces. The radii are moderately oblique and finely denticulate at the summit, more coarsely crenulate at the sutures with which they interlock, the sutures themselves also strongly and closely crenulate horizontally. The outer surface of the radii is smoothish but on some specimens there are faint horizontal lineations crossed by longitudinal striations. The alae are rather strongly oblique and slightly arched at the summit which is thin and smooth. The basis is subcircular, thin, somewhat concave to undulatory, made up of fine flattened tubules which appear in plan as narrow alternating ribbons radiating outward from a nucleus which is located subcentrally or off to one side; on the outer surface the basis is marked by extremely faint concentric lineations. The compartments, in the interior, are irregularly ribbed longitudinally, the ribs ascending toward but not reaching the sheath. The ribs are part of and superposed on the septa between the parietal tubes, and where the epidermis is worn off, it is seen that the ribs are built up of a number of layers of shell material. The sheath plates are sharply delimited, are freely dependent at the lower margin, and are sculptured by fairly regular concentric laminae which are raised slightly and slanted toward the apex.

The interlaminate figure is a bilaterally digitate trunk with four to six short digitations on each side. The figure protrudes from the inner wall and continues to form the septum between the parietal pores. The septum or wall is thus a continuation of the figure.

The scutum is triangular and concave. It has a straight occludent margin, a straightish tergal margin, a truncate to hardly flexuous basal margin, and a subangular basi-tergal corner. The outer surface is sculptured by faint concentric laminae which are crossed by weak radial striations. At regular intervals the concentric laminae are raised somewhat, and as these envelop the occludent margin they form elevated serrations of which there are nine or more on a margin 2.5 mm. in length. In the interior, the articular ridge is moderately high, slightly reflected toward the tergal margin, and a little over half the length of the tergal margin. The adductor ridge is low and moderately prominent, and extends from a little above a point opposite the termination of the articular ridge to near the basal margin. From slightly below a point opposite the base of the articular ridge, the adductor ridge splays off like a wishbone to produce a subsidiary ridge which forms the side of the pit for the lateral depressor muscle. Between these latter ridges there is a fairly prominent oval depression. The impression of the adductor muscle is large, shallow, and more or less oval. The pit for the lateral depressor muscle is small and subtriangular. Both scutal valves are light tan and are faintly flushed within, on the lower half, by a tinge of pale lavender; on the exterior, the tergal half of the valves is suffused a pale lavender, the hue sharply delimited along a line near the tergal margin, and then becoming evanescent near the middle of the valve.

Only a fragment of the tergum was recovered. This reveals that on the outer surface the spur fasciole has little or no relief, and that in the interior, the five crests for the depressor muscle are long, narrow, and closely spaced.

Dimensions.—Holotype (JBC-4b), shell, carino-rostral diameter at base 14 mm.; height at carinal end 8 mm.; length of orifice 4.5 mm. Paratypes: specimen JBC-4a, shell, carino-rostral diameter at base 8.5 mm., height at carinal end 3.8 mm., length of orifice 2.5 mm.; specimen JBC-4c, shell, carino-rostral diameter at base 10 mm., height at carinal end 7 mm., length of orifice 3.5 mm.; specimen JBC-4d, shell, carino-rostral diameter at base 11.3 mm., height at carinal end 7 mm., length of orifice 4.6 mm., thickness of wall at base (including rib projection) 1 mm.; specimens JBC-4f1-2, scutal valves of pair, length of occludent margin 2.5 mm., width across basal margin of single valve 1.7 mm.; specimen JBC-4f3, fragment of tergum, width 0.9 mm.; specimen JBC-4f4, lateral compartment, height 3.9 mm., width 2.6 mm. [*Note*: specimens JBC-4f1-4 were obtained by breaking up a shell attached to *Chlamys comparilis* (Tuomey and Holmes)]; specimen JBC-4g, shell with basis intact, carino-rostral diameter 10.5 mm., height at carinal end 7.5 mm., length of orifice 3 mm.

Remarks.—This barnacle was found separately as well as adherent to the following pelecypods: *Pecten ochlockoneensis* Mansfield, *Chlamys comparilis* (Tuomey and Holmes), and *Anomia simplex* d'Orbigny. The species is not abundant, and thus far has been found only in the lower (*Ecphora*) member of the Choctawhatchee section at Jackson Bluff.

Comparisons.—Though superficially similar, this species is differentiated from *B. leonensis,* n. sp. by the occurrence of concentric laminae on all of the sheath plates, and by the absence of a channeled furrow or fasciole leading into the spur of the tergum. *B. ochlockoneensis,* n. sp. also resembles *B. withersi* Pilsbry (1930, pp. 429-431, text figs. 1a-c, pl. 36, figs. 1-27) from the Miocene of New Jersey, but among other differences, the scutum of *B. withersi* has heavier concentric ribs than *B. ochlockonensis* and is more sharply angulate at the basi-tergal corner than the Jackson Bluff species.

Balanus (Balanus) bloxhamensis, new species Pl. 12, figs. 5,6

Shell small, moderately sturdy, tubulo-conical to low conical, and subcircular at the base. The carinal end is erect, slightly concave at the orifice, and a little shorter in height than the rostral end; the rostral end is somewhat convex or humpbacked, and the lateral compartments are steeply sloping. The orifice is pentagonally ovate, moderately acute carinally, subrounded rostrally, a little compressed on the carinolateral walls, and toothed at the rim; the length of the orifice is roughly seven-tenths the long diameter of the base. The parietes are slightly gnarled, and marked by concentric growth lines or fine longitudinal wrinkles or both. Of the six compartments the carinolaterals are the narrowest. The radii are cut into a deep "V" at the summit, and from the base of the "V" to the base of the shell the radii are divided by a narrow slit; on either side of the slit the radii are narrow and sculptured by a few strong longitudinal ridges; the rostral or hinder edge of the summit "V" is beveled, and the beveled edge as well as the edges of the radii along the medial slit are crenulate. The alae stand out rather prominently, are fairly thick, and are dog-legged at the summit, with that part of the summit adjoining the paries being short and nearly horizontal, and then descending sharply and obliquely; the oblique edge of the alae is scored by several vertical grooves between which are numerous horizontal microscopic striae. On the holotype the borders of the radii and the oblique edge of the alae are dull gray in contrast with the creamy color of the rest of the shell. The parietal tubes are small, septate, and for the most part filled. In the interior, the compartments are longitudinally ribbed, the ribs ascending from the base toward the sheath. The sheath plates are sculptured by sharp closely spaced concentric laminae, and the sutures between the sheath plates are not tightly joined but are slightly agape. The basis is thin, lamellar, somewhat concave to undulatory, and made up of narrow septate, alternating white and hyaline ribbons radiating outward from a somewhat off-centered nucleus.

The opercular valves have not been seen. And, as only two specimens were collected, no attempt was made to section the walls for the interlaminate figure.

Dimensions.—Holotype (JBC-5b), carino-rostral diameter of shell at base 7:5 mm.; height at carinal end 5.3 mm.; height at rostral end 7.4 mm.; length of orifice 5 mm. Paratype (JBC-5d), diameter at base 6 mm.; height 3.5 mm.; length of orifice 4 mm.

Remarks.—The "V"-shaped cut at the summit of the radii, the longitudinal slit dividing the radii, and the vertical ridges traversing the radii, are the distinctive characters of the shell.

Comparisons.—Superficially the new species seems to be akin to the smooth-shelled form of *B. crenatus* Bruguière, a cosmopolitan Miocene to Recent barnacle. *B. crenatus,* lacks the "V"-shaped cut at the summit of the radii and the longitudinal slit down the middle of the radii, though the shell itself and the vertical ridges on the radii are similar.

The holotype of *B. bloxhamensis,* n. sp. was dropped and broken some time after it was photographed. Fortunately the photograph is an acceptable likness of the shell when whole, and the fragments of the type have been placed together in a vial.

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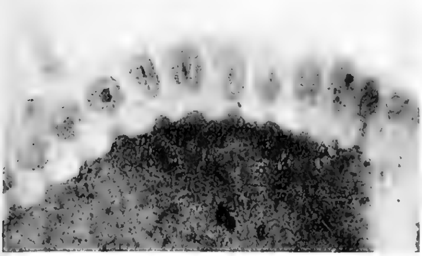

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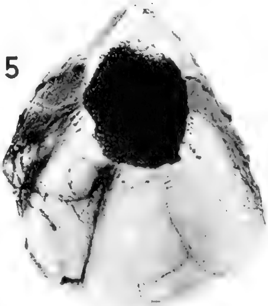

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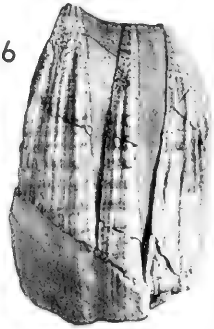

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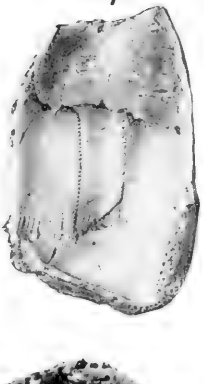

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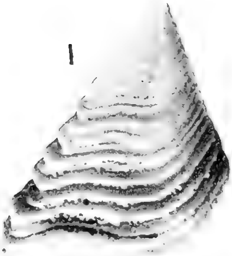
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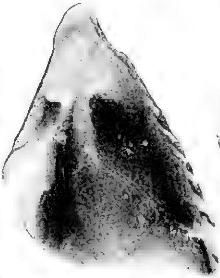
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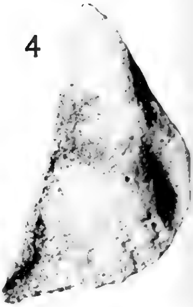
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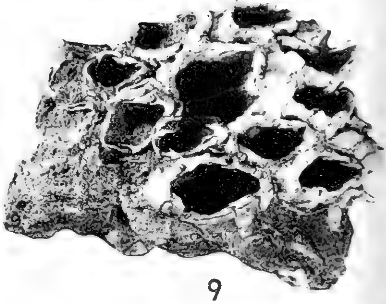
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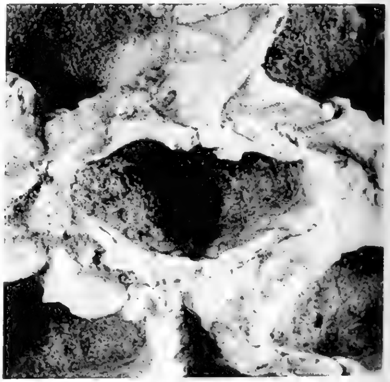
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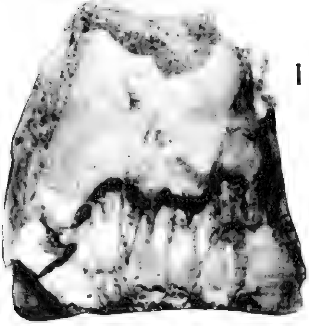
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1-8. **Balanus (Megabalanus) tintinnabulum antillensis** Pilsbry . 13

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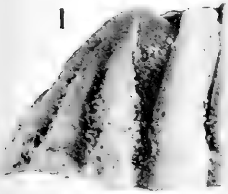

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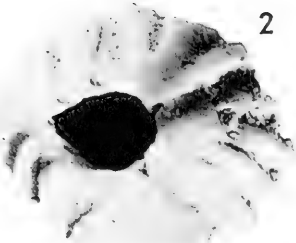

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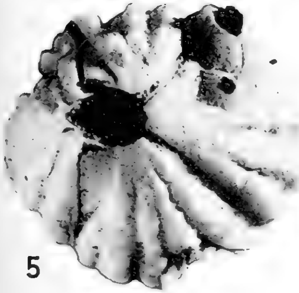

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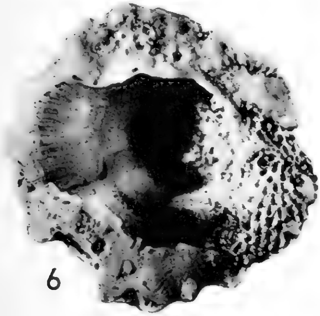

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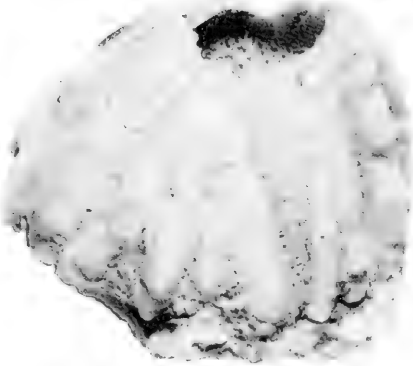

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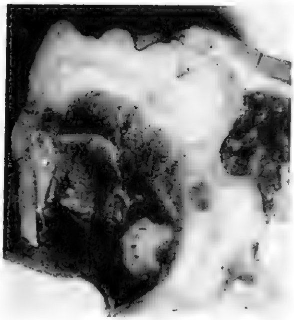

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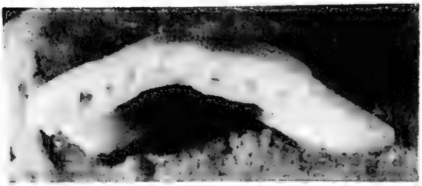

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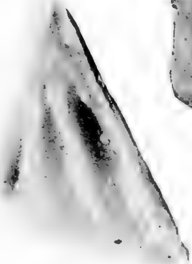

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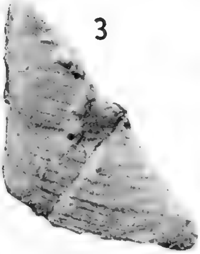

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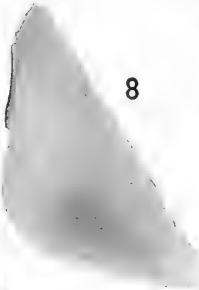

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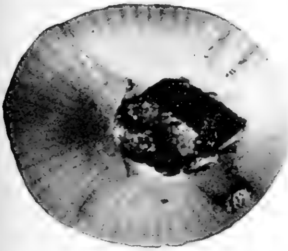

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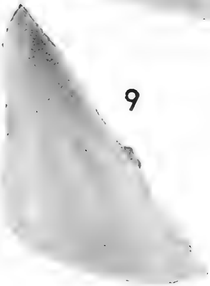

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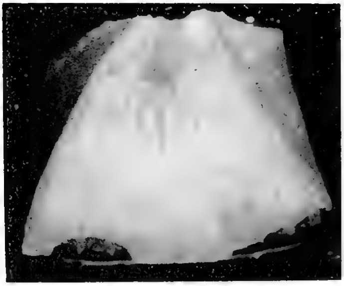

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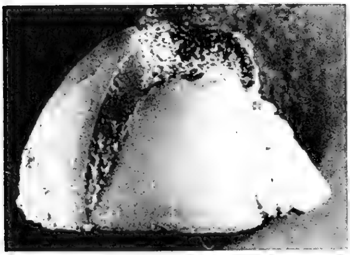

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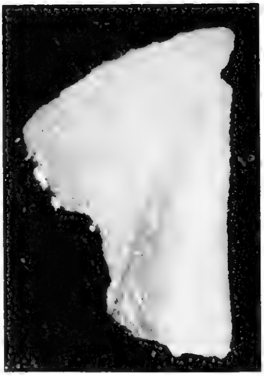

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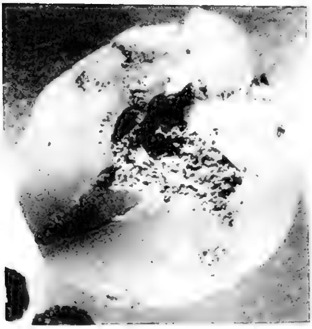

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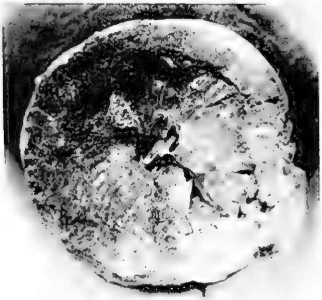

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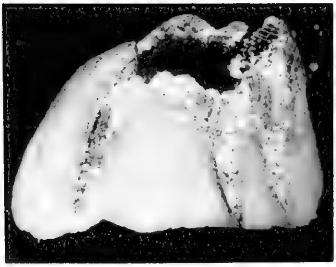

EXPLANATION OF PLATE 6

Figure		Page
1,2.	**Balanus (Balanus) caboblanquensis** Weisbord, n. sp.	26

Paratype (G594g), 27362 PRI. Interior and exterior of lateral compartment. Height 2.1 mm.; width 2.9 mm. Mare formation.

3-10.	**Balanus (Balanus) playagrandensis** Weisbord, n. sp.	29

Figs. 3-5, holotype (R591a), 27363 PRI. Views of side, orifice, and basis. Diameter at base 7 mm.; height 5 mm.; approx. length of orifice 3 mm. Figs. 6,7, paratype (R591b), 27364 PRI. Exterior and interior of right tergum. Length 2.25 mm.; width across basal margin 2.1 mm. Figs. 8,9, paratype (R591c), 27365 PRI. Exterior and interior of left tergum (broken). Width across middle 1.3 mm. Fig. 10, paratype (R591f), 27366 PRI. Lateral view of shell. Diameter at base 5 mm.; height 3.2 mm.; length of orifice 2.5 mm.; max. width of orifice 1.5 mm. All of the above (figs. 3-10) are from the Playa Grande formation (Maiquetía member).

EXPLANATION OF PLATE 7

Figure Page

1-4. **Balanus (Balanus) playagrandensis** Weisbord, n. sp. 29

Figs. 1,2, paratype (R591g), 27367 PRI. Interior and exterior of carinal half of shell. Width 5 mm.; height 4 mm. Figs. 3,4, detached scutal valves of pair. Fig. 3, paratype (R591d), 27368 PRI. Exterior of right scutum. Fig. 4, paratype (R591e), 27369 PRI. Interior of left scutum. Length along scutal margin of pair 3.2 mm.; width across basal margin of individual valve 2.2 mm. Playa Grande formation (Maiquetía member).

5-9. **Balanus (Balanus) caribensis** Weisbord, n. sp. 23

Figs. 5-7, paratype (M591b), 27370 PRI. Views of side, apex, and basis. Diameter 7.1 mm.; height 5.3 mm.; approx. length of orifice 3 mm. The diamond shape of the orifice has been destroyed by breakage around the rim. Fig. 8, paratype (N591a), 27371 PRI. Apical view. Diameter 6.6 mm.; height 3.7 mm.; length of orifice 3.1 mm.; max. width of orifice 2.2 mm. Fig. 9, paratype (K591a), 27372 PRI. Section above base showing interlaminate figure. Playa Grande formation (Catia member).

10,11. **Balanus** species 33

Specimen K590a, 27373 PRI. Exterior and interior of right scutum. Length along occludent margin 5 mm.; width across basal margin 3 mm. Playa Grande formation (Catia member).

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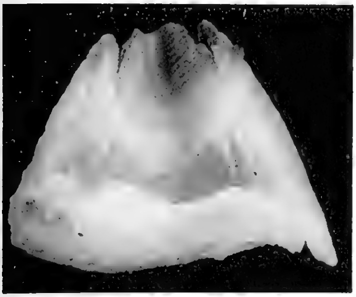

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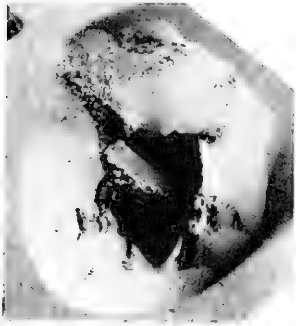

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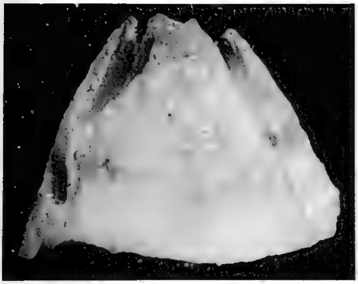

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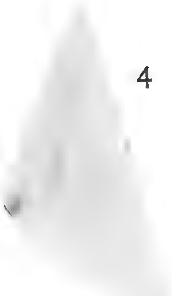

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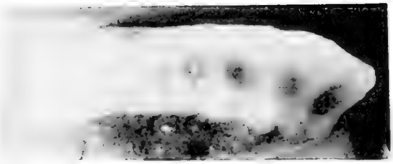

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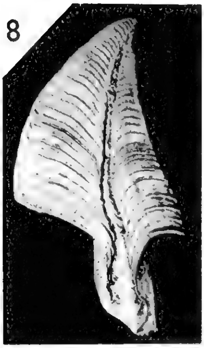

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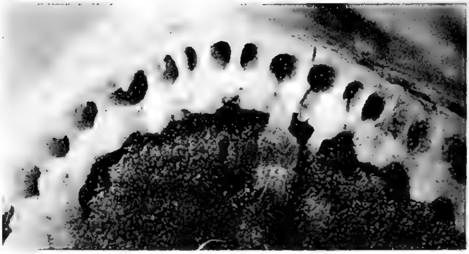

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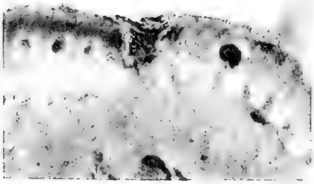

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1-13.	**Balanus (Balanus) talquinensis** Weisbord, n. sp.	37

Fig. 1, holotype (JBC-1f), 27374 PRI. Lateral view of shell. Diameter 21 mm.; height 24 mm.; length of orifice 13 mm. Paratypes: Fig. 2 (JBC-1h), 27375 PRI. Lateral view of shell. Diameter 19 mm.; height 20 mm.; length of orifice 12 mm. Fig. 3 (JBC-1g), 27376 PRI. Lateral view of shell attached to *Turritella etiwanensis* (Tuomey and Holmes). Diameter 22 mm.; height 12 mm.; length of orifice 10 mm. Fig. 4 (JBC-1a), 27377 PRI. Exterior of right scutum. Length along occludent margin 12.3 mm. Fig. 5 (JBC-2a), 27378 PRI. Exterior of right scutum. Length along occludent margin 7.2 mm. Fig. 6 (JBC-1b), 27379 PRI. Interior of left scutum. Length along occludent margin 9 mm. Fig. 7 (JBC-2b), 27380 PRI. Interior of left scutum. Length along occludent margin 7.2 mm. Fig. 8 (JBC-1c), 27381 PRI. Exterior of right tergum. Length 9.7 mm. Fig. 9 (JBC-2c), 27382 PRI. Exterior of right tergum. Length 6 mm. Fig. 10 (JBC-1d), 27383 PRI. Interior of left tergum. Length 10.2 mm. Fig. 11 (JBC-2d), 27384 PRI. Interior of left tergum. Length 6 mm. Fig. 12 (JBC-1e), 27385 PRI. Interlaminate figure of section above base. Fig. 13 (JBC-1i), 27386 PRI. Interlaminate figure of section above base.

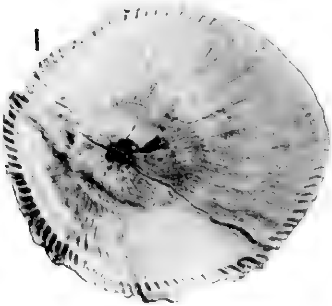
EXPLANATION OF PLATE 9

Figure		Page
1-6.	**Balanus (Balanus) talquinensis** Weisbord, n. sp.	37

Paratypes: Fig. 1 (JBC-2e), 27387 PRI. Interior surface of basis. Long diameter 15.5 mm. Figs. 2,3 (JBC-2f), 27388 PRI. Outer and inner views of rostrum and adjoining compartment. Height 14.5 mm. Fig. 4 (JBC-2g), 27389 PRI. Lateral view of shell. Diameter 20 mm.; height 21.5 mm.; length of orifice 8.5 mm. Fig. 5 (JBC-2h), 27390 PRI. Lateral view of shell. Diameter 25 mm.; height 20 mm.; length of orifice 12 mm. Fig. 6 (JBC-2i), 27391 PRI. Interlaminate figure of section above base.

Figure		Page
7,8.	**Balanus (Balanus) leonensis** Weisbord, n. sp.	43

Holotype (JBC-3a), 27392 PRI. Exterior and interior of lateral compartments and part of carina. Length 15 mm.; height 9.5 mm.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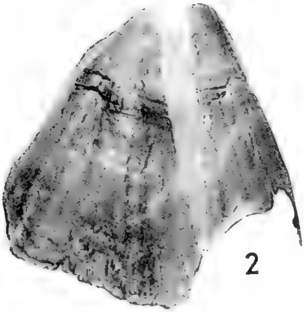
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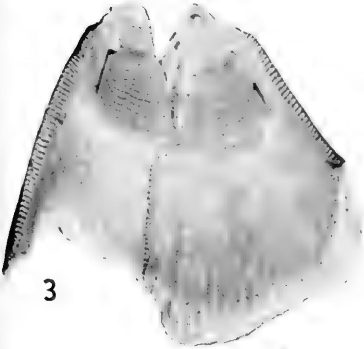
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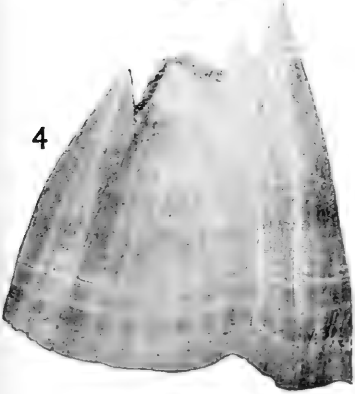
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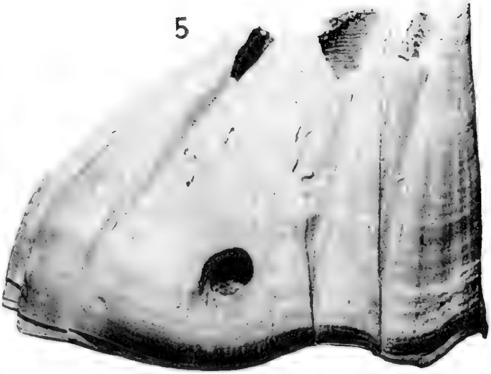
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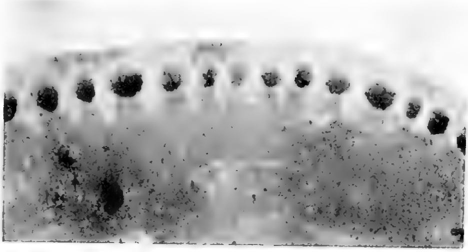
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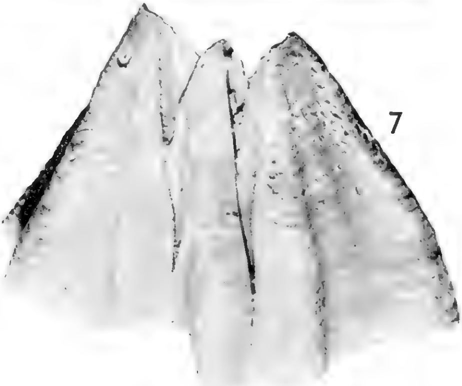
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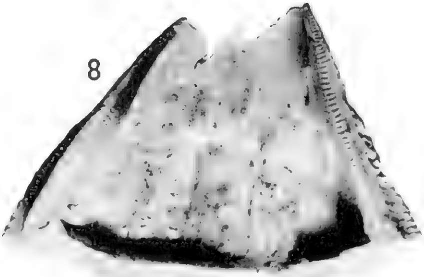
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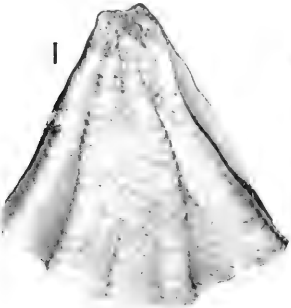

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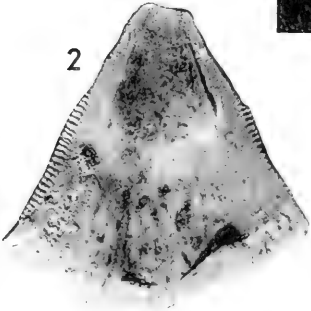

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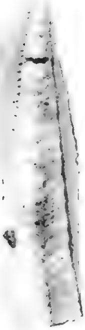

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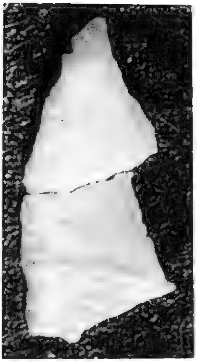

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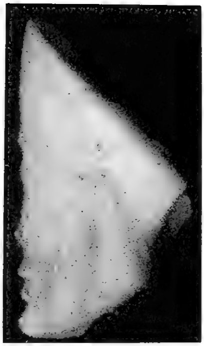

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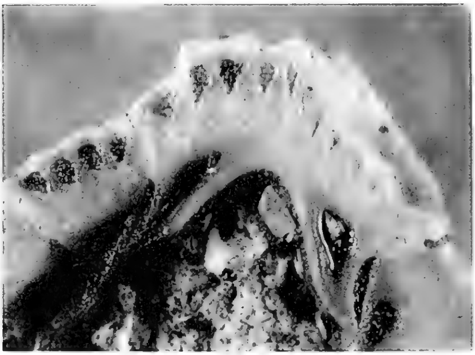

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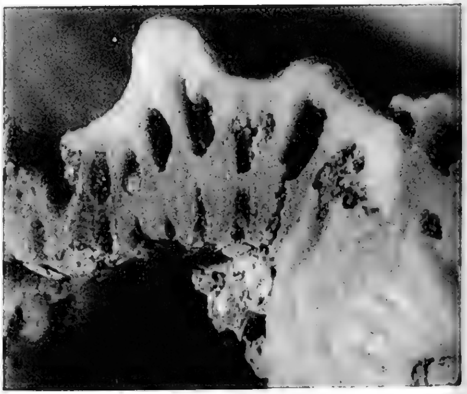

Explanation of Plate 10

Figure Page

1-11. Balanus (Balanus) leonensis Weisbord, n. sp. 43

Figs. 1-9, components of holotype. Figs. 1,2 (JBC-3b), 27393 PRI. Exterior and interior of rostrum. Width 10 mm.; height 10 mm. Figs. 3,4 (JBC-3c), 27394 PRI. Exterior and interior of carino-lateral compartment. Width at base 6 mm.; height 9 mm. Figs. 5,6 (JBC-3e), 27395 PRI. Exterior and interior of broken right tergum. Length along carinal side of fragment 3.1 mm. Figs. 7,8 (JBC-3d), 27396 PRI. Exterior and interior of right scutum, broken at base. Length along occludent margin 2 mm. Fig. 9 (JBC-3f), 27397 PRI. Exterior of incomplete left tergum. Length 1.7 mm. Paratypes: Fig. 10 (JBC-3g), 27398 PRI. Interlaminate figure of section above base. Fig. 11 (JBC-3h), 27399 PRI. Interlaminate figure of section above base.

EXPLANATION OF PLATE 11

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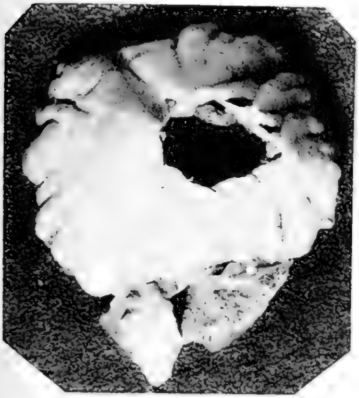
1-7.	**Balanus (Balanus) ochlockoneensis** Weisbord, n. sp.	46

Fig. 1, holotype (JBC-4b), 27400 PRI. Lateral view of shell. Diameter 14 mm.; height 8 mm.; length of orifice 4.5 mm. Fig. 2, paratype (JBC-4c), 27401 PRI. Lateral view of shell. Diameter 10 mm.; height 7 mm.; length of orifice 3.5 mm. Figs. 3,4, paratype (JBC-4d), 27402 PRI. Shell, with base sectioned to reveal interlaminate figure. Fig. 3, view of interior. Diameter of shell at base 11.3 mm.; height at carinal end 7 mm.; length of orifice 4.6 mm. Fig. 4, interlaminate figure of section at base. Fig. 5, paratype (JBC-4a), 27403 PRI. Apical view of shell. Diameter 8.5 mm.; height 3.8 mm.; length of orifice 2.5 mm. Figs. 6,7, paratype (JBC-4fl-2), 27404 PRI. Exterior and interior of paired scutal valves. Length of occludent margin 2.5 mm. The enlargement of fig. 5 is greater than that of fig. 6, but the specimens are the same.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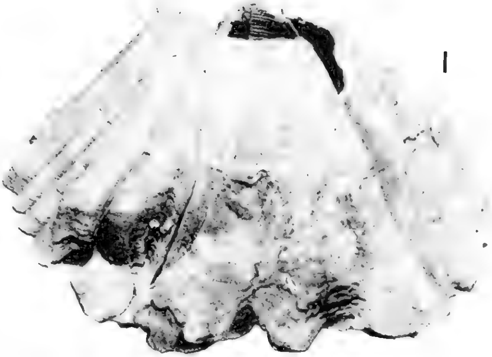
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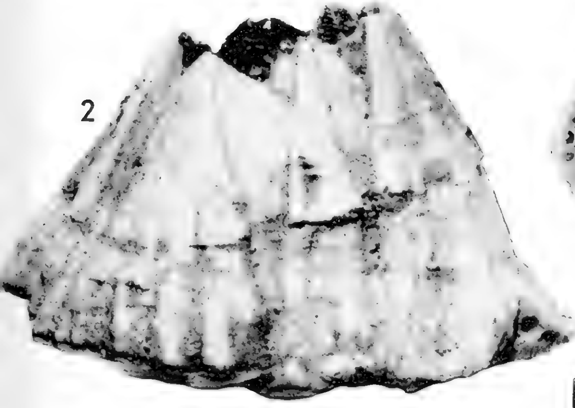
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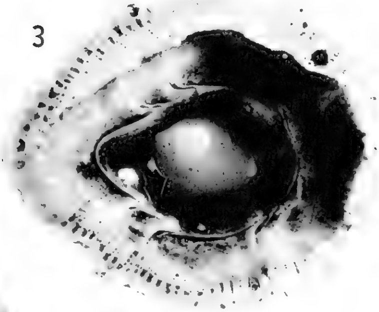
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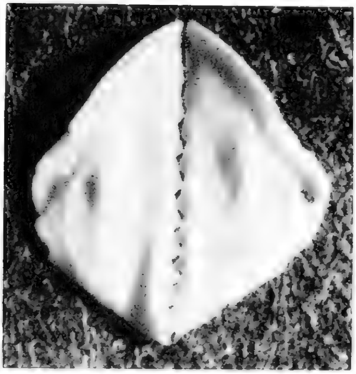
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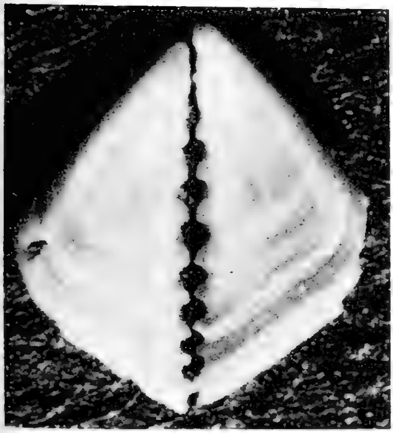
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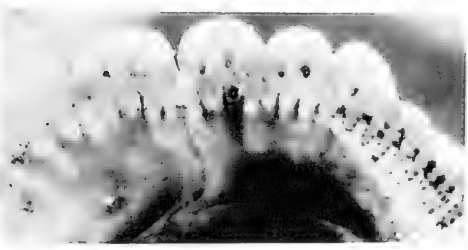
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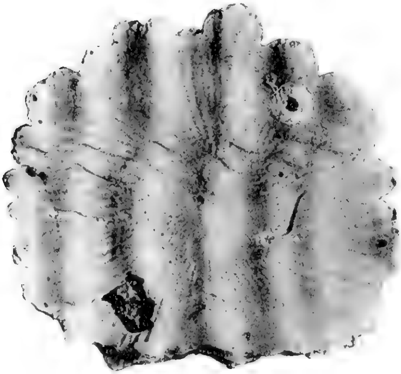

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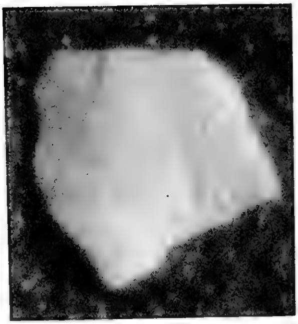

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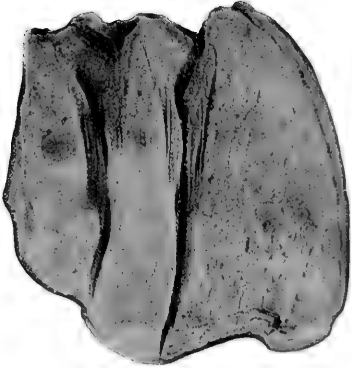

EXPLANATION OF PLATE 12

Figure Page

1-4. **Balanus (Balanus) ochlockoneensis** Weisbord, n. sp. . . 46

Fig. 1, paratype (JBC-4g), 27405 PRI. External view of basis. The shell to which the basis is attached measures 10.5 mm. at the base, 7.5 mm. in height, and 3 mm. in lnegth of orifice. Figs. 2,3, paratype (JBC-4f4), 27406 PRI. Exterior and interior of lateral compartment. Height 3.9 mm.; width 2.6 mm. Fig. 4, paratype (JBC-4f3), 27407 PRI. Interior of fragment of right tergum. Width of fragment 0.9 mm.

5,6. **Balanus (Balanus) bloxhamensis** Weisbord, n. sp. 48

Holotype (JBC-5b), 27408 PRI. Lateral view of shell. Diameter 7.5 mm.; height 5.3 mm.; length of orifice 5 mm.

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THE DISTRIBUTION OF FORAMINIFERA IN THE EASTERN ROSS SEA, AMUNDSEN SEA, AND BELLINGSHAUSEN SEA, ANTARCTICA

By

CHARLES E. PFLUM

1966

Paleontological Research Institution
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THE DISTRIBUTION OF FORAMINIFERA IN THE EASTERN ROSS SEA, AMUNDSEN SEA, AND BELLINGSHAUSEN SEA, ANTARCTICA

Charles E. Pflum

ABSTRACT

This study deals with the Foraminifera found in 17 cores taken by the U. S. Navy Oceanographic Office during its Deep Freeze 61 project. These cores were from the eastern Ross Sea, Amundsen Sea, and Bellingshausen Sea. One hundred-four species of Foraminifera were identified and nine species were given letter designations. These species are included in 55 genera.

Temperature, salinity, and depth were investigated as possible ecologic controls. Because temperature and salinity have only minor variations over the area, these parameters do not seem to have an important effect upon the reproduction and population of the Foraminifera in this study. Three assemblages were designated according to depth. These assemblages were at the depths of: 210-515 meters, 604-1134 meters, and 1765-3545 meters.

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INTRODUCTION

PURPOSE

The purpose of this study is to examine the distribution of Foraminifera found in 17 cores taken by the United States Navy as part of the Deep Freeze 61 project and to determine the effect, if possible, of the ecologic factors of depth, temperature, and salinity on the foraminiferal assemblages. A secondary purpose is to verify the existence of any currents that control distribution as proposed by William M. McKnight (1962).

LOCATION

The core samples selected for this foraminiferal study are from water depths ranging from 210 to 3,545 meters. Ten core samples are from the eastern Ross Sea, four from the Amundsen Sea, and three from the

Bellingshausen Sea. These sample locations are shown as the solid dots in Figure 2. The numbers are those assigned to the surface sample of each Phleger core by the Sedimentology Research Laboratory at Florida State University and are also the station numbers used in this study. Subsurface samples are indicated by the depth in the core after the station number. These core samples are cross-referenced to the United States Navy Oceanographic Office stations in Table 1.

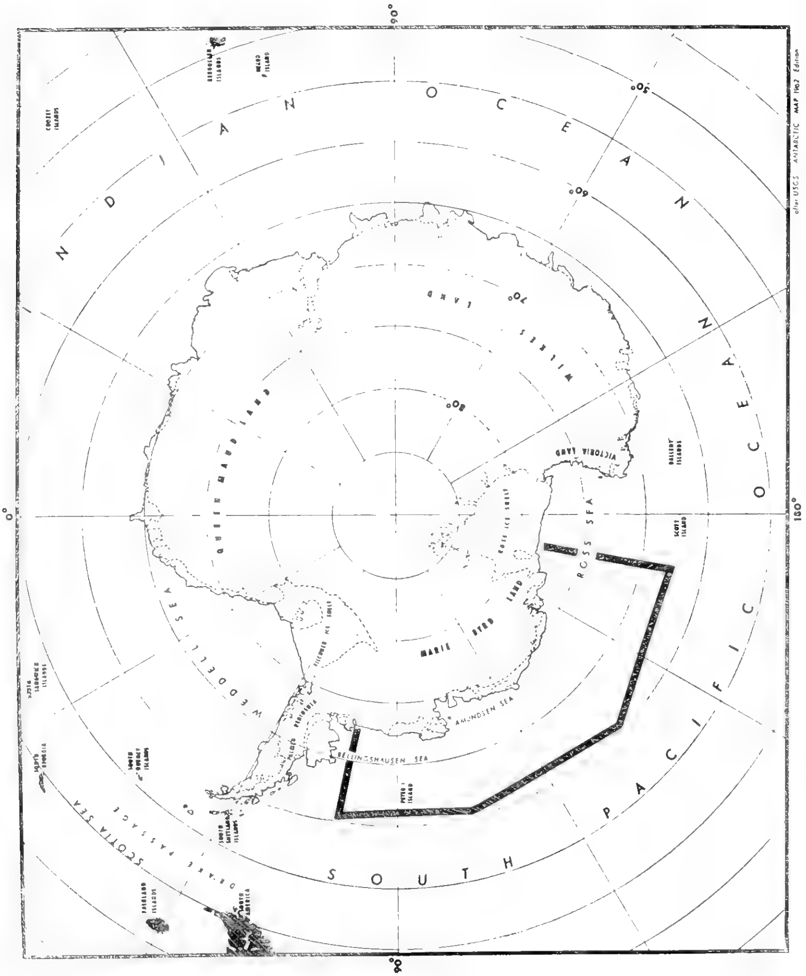

Figure 1. General Sample Area.

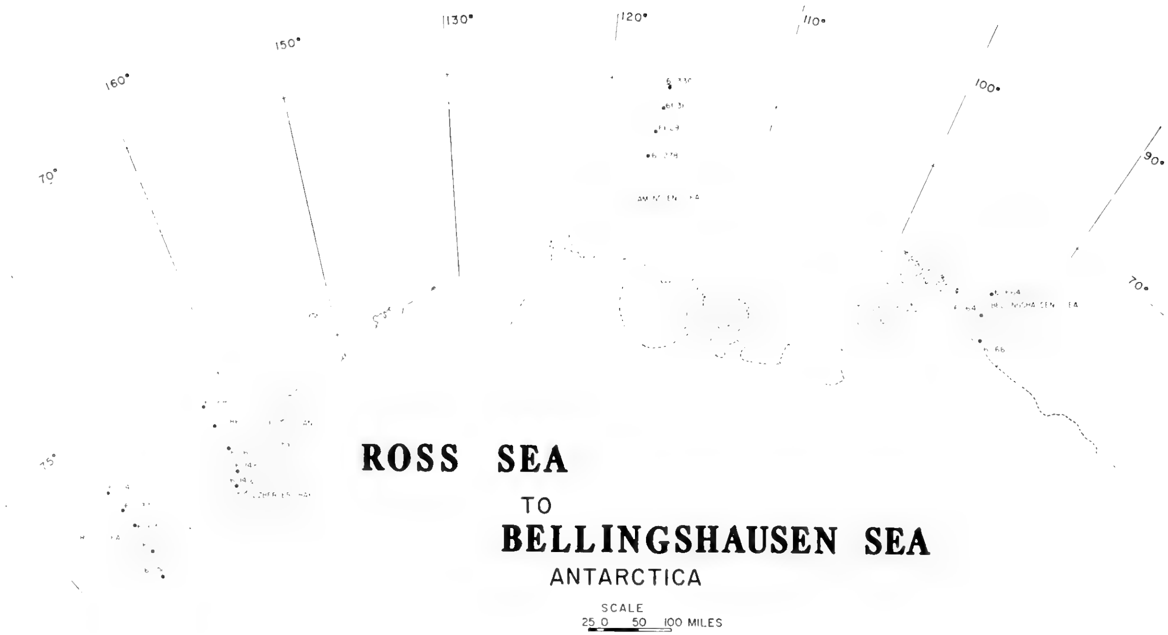

Figure 2. Sample Locations.
(solid dots)

PREVIOUS WORK IN THE AREA

Most of the previous work on the Foraminifera of the Antarctic area has been connected with the large expeditions into the area. Among these were The Challenger Expedition, 1872-76; The Deutsche Sud-Polar Expedition, 1901-03; The Scotia Expedition, 1903-04; The Terra Nova Expedition, 1910; The Australasian Antarctic Expedition, 1911-14; The British and New Zealand Antarctic Research Expedition, 1929-31; Bay of Whales, Ross Sea, 1936; and Deep Freeze IV, 1958-59. McKnight (1962) described the investigations prior to his Deep Freeze IV work adequately and, therefore, they will not be summarized further here.

The Deep Freeze IV material studied by McKnight was from 28 cores, most of which were from the western Ross Sea area. He studied five factors of ecology: depth, temperature, salinity, sediment type, and geographic location. He also considered surface and bottom currents in general. He found that water depth, temperature, salinity, and sediment type (with exception of standard deviation) had little effect on the distribution of the Foraminifera in his study area. Standard deviation proved to be important in 10 of 20 statistically tested species of Foraminifera. He believed that the standard deviation of the sediment was controlled by the currents. McKnight postulated a subsurface current in the Ross Sea running clockwise and parallel to Victoria Land. He believed the current removed planktonic Foraminifera from a channel parallel to the Ross Ice Shelf barrier and Victoria Land.

METHODS OF STUDY

SAMPLE COLLECTION

The cores used in this study were collected by the *USS STATEN ISLAND* for the United States Navy Oceanographic Office during its Operation Deep Freeze 61 (1960-61). This was the seventh consecutive United States Expedition in support of Antarctic research. The cores were Phleger cores in clear plastic liners.

Cores were selected in a pattern of traverses perpendicular to the shoreline, where possible, in order to include both shallow and deep water locations. This pattern of traverses also allowed an investigation of McKnight's postulation of a bottom current in front of the Ross Ice Shelf.

LABORATORY PROCEDURE

The cores, varying in length from 12 to 101 centimeters, were split and sampled at 30 centimeter intervals. The dry weight of each sample was recorded. The sample was washed over a .062 mm. sieve to remove particles smaller than this size. The particles larger than .062 mm. were placed in perchloroethylene in order to concentrate the Foraminifera by flotation. The residue was examined and any Foraminifera that did not float were picked out and placed with those already separated.

Although some samples contained no Foraminifera, other samples contained several tens of thousands. For this reason the total concentrations of Foraminifera were split so as to contain at least 300 Foraminifera (Bandy, 1954) in order to get a more workable count of the abundant forms. The total concentration was examined for any rare forms that may have been missed in the splitting process. The microsplitter used was a handmade wooden cone with an aperture in the bottom. The aperture was divided equally by a razor blade that divided the total concentration into two statistically equal fractions. Further splitting was necessary for some samples. The specimens were examined under a binocular microscope and then placed on sixty-block group slides for identification and counting.

IDENTIFICATION OF SPECIES

The foraminiferal indentifications were made from written descriptions and figured specimens in publications dealing with Recent Foraminifera. Some specimens could not be identified to the specific level and these were identified to the generic level and a letter designation assigned to them. In addition, the author used specimens identified by McKnight and deposited with the Department of Geology, Florida State University for comparison. The identifications were checked by L. D. Toulmin. Hypotypes of the species identified in this study are on file in the Geology Department, Florida State University.

QUANTITATIVE METHODS

In order to indicate the abundance of species in the sediment and for comparison to McKnight's study, the author has used the foraminiferal number; this is the number of specimens occurring in one gram of sediment. This method is generally thought to be one means of measuring rates of sedimentation. In an area where deposition is chiefly by ice rafting, such as the Antarctic or Arctic areas, this figure can be misleading as an indicator of rates of sedimentation. For example, one sample may consist of a clayey sand but a sample nearby may, for the most part, be made up of one pebble. If the living population is approximately equal in both locations, the sample with the pebble will have a lower count per gram than the sand sample. This would be interpreted as a faster rate of sedimentation for the pebbly sample which may not be the case. It is true that this method is misleading with respect to abundance of species, but it appears to be more useful and more reliable than the method using percentage of total population.

No preservation or protein staining techniques were carried out on board the *USS STATEN ISLAND.* Because of this, there is no information available concerning the living assemblage.

DISCUSSION OF ENVIRONMENTAL FACTORS

Because all of the cores in the present study are south of the Antarctic Convergence there is little change in temperature and salinity in the water column. For this reason these ecologic factors are discussed in general for all three areas involved in this report.

There is a slight seasonal variation in temperature and salinity in all areas of this study. In the winter, these factors are essentially isothermal and isohaline at all levels of the water column. In the summer there is a slight increase in temperature and decrease in salinity due to summer heating and ice melting.

TEMPERATURE

As stated in Navy TR-105 (U. S. Navy Ocean. Office, 1962), there is a complex layering of the Pacific-Antarctic water types. As was found in past studies of the Antarctic water column, the temperature variations measured in Deep Freeze 61 were small. The bottom temperatures varied between —1.88°C. and +0.99°C. The average bottom temperature was —0.94°C. The author believes an average figure for bottom temperature is sufficient to work with in regard to benthonic Foraminifera in this study. The surface temperatures were uniform throughout with a low of —1.77°C. and a high of—1.18°C. The average surface temperature was—1.47°C. It is doubtful if the distribution of planktonic Foraminifera is affected by the small temperature variations.

SALINITY

The variations in salinity for the stations used in this study were small. The extremes in bottom salinities were 34.71 0/00 to 34.29 0/00. The surface variation was from 34.00 0/00 to 33.12 0/00. The small variation in bottom salinities would have little effect on the ecology of the benthonic fauna. The planktonic fauna is probably not affected by the surface variation.

DEPTH

There appears to be three assemblages that can be related to depth in this study. One assemblage has species most abundant at depths less than 515 meters; this the author designates as Shelf Assemblage I (210-515 meters). The second assemblage has species more abundant at depths ranging between 604 and 1,134 meters; this is designated Shelf Assemblage II. The third assemblage is at depths ranging between 1,765 and 3,545 meters; this is the Slope Assemblage. No samples were from depths between 1,134 and 1,765 meters. Stations 61-041, 61-188, and 61-278 were exceptions to the Slope Assemblage. These stations were adjacent to the shelf but in water depths greater than 1,765 meters. The samples from these stations contained a mixture of Shelf and Slope Assemblages. It is interesting to note that 64% of the species found in the Slope Assemblage are calcareous. In the Shelf Assemblages, 50% are calcareous and many of these are represented by one specimen.

Uchio (1960a) recognized depth assemblage boundaries at 850 and 2,000 meters in the Lutzow-Holm Bay area (30°—50°E). A comparison of Uchio's study and the present study shows some similarities.

Shelf Assemblage I (10 samples, 210-515 meters).—This assemblage has the following species in four or more samples. They are listed by frequency of occurrence in the samples.

	Samples
Angulogerina angulosa	9
Haplophragmoides canariensis	6
Alveolophragmium wiesneri	5
Cassidella davisi	5
Ehrenbergina glabra	5
Hormosina ovicula gracillis	5
Nonion germanicus	5
Psammosiphonella discreta	5
Angulogerina earlandi	4
Cassidulina crassa	4
Hormosina ovicula	4
Lagena gracilis	4
Nonion sp.	4
Parafissurina lata	4
Reophax nodulosus	4
Trochammina conica	4
Verneuilina minuta	4

Trochammina antarctica, Textularia antarctica, and *Textularia tenuissima* were about equally distributed between the two Shelf Assemblages. These are included on the Shelf Assemblage II list because they were in more samples there.

Shelf Assemblage II (*11 samples, 604-1,134 meters*).—Those species occurring in four or more samples are:

	Samples
Textularia tennissima	6
Trochammina antarctica	6
T. grisea	5
T. wiesneri	5
Textularia antarctica	4

Slope Assemblage (*18 samples, 1,765-3,545 meters*).—Many of the species (those marked by an asterisk below) placed in this Assemblage were found in samples on the Shelf also but were more abundant at these depths. This indicates those species should be used as depth indicators only when found in the presence of other deep forms or in the absence of shallow water forms.

Those species occurring in three or more samples below 1,765 meters are:

	Samples
**Epistominella exigua*	8
**Eponides weddellensis*	7
**Cassidulina subglobosa*	5
**Cyclammina pusilla*	4
Eponides tener	4
Alveolophragmium subglobosum	3
Bolivina pseudoplicata	3
**Oolina globosa*	3
**Uvigerina asperula*	3

Angulogerina angulosa was found in three samples but it is believed these were displaced from the shelf. *Cyclammina pusilla* may be represented by some displaced specimens in sample 61-188.

The author considers these Foraminifera to be indicative of the separate assemblages.

Shelf Assemblage I (*210-515 meters*).—*Angulogerina angulosa, Haplophragmoides canariensis, Psammosiphonella discreta, Alveolophragmium wiesneri,* and *Ehrenbergina glabra.*

Shelf Assemblage II (*604-1,134 meters*).—*Textularia antarctica, T. tenuissima, Trochammina antarctica, T. grisea,* and *T. wiesneri.*

Slope Assemblage (*1,765-3,545 meters*).—*Epistominella exigua, Eponides weddellensis,* and *E. tener.*

One important similarity appears in the depth assemblages of McKnight, Uchio, and the present study. Although all of the assemblage depths overlap, Foraminifera noted as occurring consistently in water less than 850 meters deep in these studies are: *Angulogerina anglosa, Adercotryma glomeratum, Textularia tenuissima, T. antarctica, Trochammina antarctica, Patellina corrugata, Ehrenbergina glabra, Cibicides refulgens, Haplophragmoides canariensis,* and *Lagena feildeniana.*

Convection of currents is important for reproduction of Foraminifera (Sverdrup, *et. al.,* 1946, p. 790). The currents renew nutrients important to biologic processes. These currents possibly cause the patchy occurrence of some species of Foraminifera.

The data of this study show that depth has an effect on only a few species. It is possible that depth in combination with a particular current could be a control for the distribution of Foraminifera. More information on the intricate current systems in the Antarctic area is needed to determine the ecologic controls for that area.

DISCUSSION OF DATA

GENERAL

In this study 104 species of Foraminifera were identified. Nine additional species were identified to genus and given a letter designation. These species compose 55 genera, many of which are typical of the cold, deeper water of the oceans. It is believed several species are restricted to the Antarctic waters.

At least 10 species found in this study are also found in the Arctic areas studied by Green (1960) and Wagner (1962). Höglund (1947) listed at least 16 species from Gullmar Fjord and the Skagerak common to the Antarctic. However, it appears that the Antarctic waters support a much larger fauna. The most logical explanation for this is that the geographic location of Antarctica allows many more currents and water types to circulate around it than is possible in the Arctic area. These currents and water types supply more nutrients and can thus support the larger fauna.

The planktonic Foraminifera are discussed briefly. They represent a minor aspect of this study. The benthonic Foraminifera as indicators of the bottom environment are treated at greater length.

PLANKTONIC FORAMINIFERA

The planktonic Foraminifera in this study are composed of four species belonging to two genera. *Globigerina bulloides, G. conglomerata, G. pachyderma,* and *Orbulina porosa* represent the total planktonic population. *G. pachyderma* was the most abundant form and *G. conglomerata* was more abundant than *G. bulloides*. *Orbulina porosa* was represented by one specimen in sample 61-311. This may be a radiolarian. Because only one specimen was available, it was not checked with acid to determine if the test was calcium carbonate or silica. The author includes it here as a foraminifer reserving the right to change his opinion. *G. pachyderma* was present in all but 11 samples; most of these came from the western traverse in the Ross Sea. It has a foraminiferal number range of 1,136 to .06. The higher numbers encountered, for the planktonic forms, were found in the Amundsen Sea samples from relatively deep water. The foraminiferal numbers for the planktonic forms were usually low in the samples from the shelf area.

G. pachyderma may well be a benthonic form, especially in the adult stages. Bé (1960) studied *G. pachyderma* in Arctic sediments and believed this species to be the only *Globigerina* in that area. He decided the tiny forms found in the plankton tow nets were not *G. bulloides* or *G. eggeri* as described by many workers. By removing the last chamber of *G. pachyderma*, Bé noticed that the remainder of the test had a resemblance to *G. bulloides* and *G. eggeri*. Furthermore, no *G. eggeri* or *G. bulloides* specimens were found in the sediments but *G. pachyderma* specimens were. Therefore, the forms that appear to be *G. eggeri* and *G. bulloides* in the tow nets must be *G. pachyderma*. This may be true in some of the cases in the Antarctic area as well as the Arctic.

Although there are several forms of *Globigerina* found in the Antarctic area, it is possible that many of the *G. bulloides* found in plankton tows are really juvenile forms of *G. pachyderma*. As the individual *G. pachyderma* grows it becomes heavier and sinks, becoming a benthonic form in its adult stages.

In spite of this theory, *G. pachyderma* is considered to be planktonic in this study in order to make comparison with McKnight's study where it was treated as a planktonic form.

Because the temperatures are nearly isothermal and salinities nearly isohaline, the author doubts if these two factors control the population of the planktonic forms. However, it is possible there is a difference in planktonic reproduction and population near the ice shelf where, in the summer, there may be quantities of fresh water supplied by melting ice. It should be noted (Fig. 5) that most of the samples from stations 61-001, 61-012, 61-031, 61-037, and 61-041 have no or few planktonic forms. The samples from Sulzberger Bay and west of Guest Island show higher planktonic numbers. In this area there is not an extensive ice shelf as in the traverse to the west in front of the Ross Ice Shelf.

BENTHONIC FORAMINIFERA

EASTERN ROSS SEA

In this area, where 10 cores were studied, 92 species belonging to 47 genera were found. Forty-seven species were calcareous. It is interesting to note that 51 species and 32 genera were restricted to this area. The most common benthonic genera were *Reophax, Textularia, Trochammina, Cassidulina,* and *Angulogerina.* These were present in all but a few cores.

The most common species in this area were: *Cassidulina subglobosa, Eponides weddellensis, Cibicides refulgens, Ehrenbergina glabra, Reophax nodulosus, R. distans, R. pilulifer, R. spiculifer, Trochammina antarctica, T. conica, T. glabra, T. grisea, T. wiesneri, Textularia antarctica, T. tenuissima, Verneuilina minuta, Angulogerina angulosa, Recurvoides contortus, Miliammina oblonga, M. lata, Alveolophragmium subglobosum, A. wiesneri, Hormosina ovicula gracilis,* and *Haplophragmoides canariensis.*

Most trends found by McKnight also hold true for the area of the present study. As in McKnight's study, the samples in the eastern Ross Sea show a decrease in the number of foraminiferal species with increased water depth and distance from land. Contrary to McKnight's study is the fact that there is a general decrease in the abundance of individuals with increasing distance from land. This is true in all cases except at stations 61-031 and 61-142 which have lower foraminiferal numbers than do the stations on either side. This decrease seaward may indicate that the relative rate of sedimentation is greater away from shore or ice shelf barrier. This is to be expected at stations 61-041 and 61-188 as they are at the base of the steep continental slope or scarp. At these two stations there may be a near constant rain of sediment either being washed off the shelf into the deeper water or from icebergs passing over. Also, samples 61-041 and 61-188 have many species that are more abundant in the samples on the shelf in shallower water. Sample 61-188 had few Foraminifera but most of those present were found on the shelf. It is difficult to explain the general decrease of foraminiferal numbers in the other samples however. One possibility may be a faster melting rate of the ice as it moves into more open water therefore dropping more sediment on the outer stations.

McKnight postulated a clockwise current in the Ross Sea in a channel paralleling the Ross Ice Shelf and Victoria Land. He believed this to be a surface and bottom current responsible for two distinct populations in the surface samples of his study. He also believed the *Globigerina* were re-

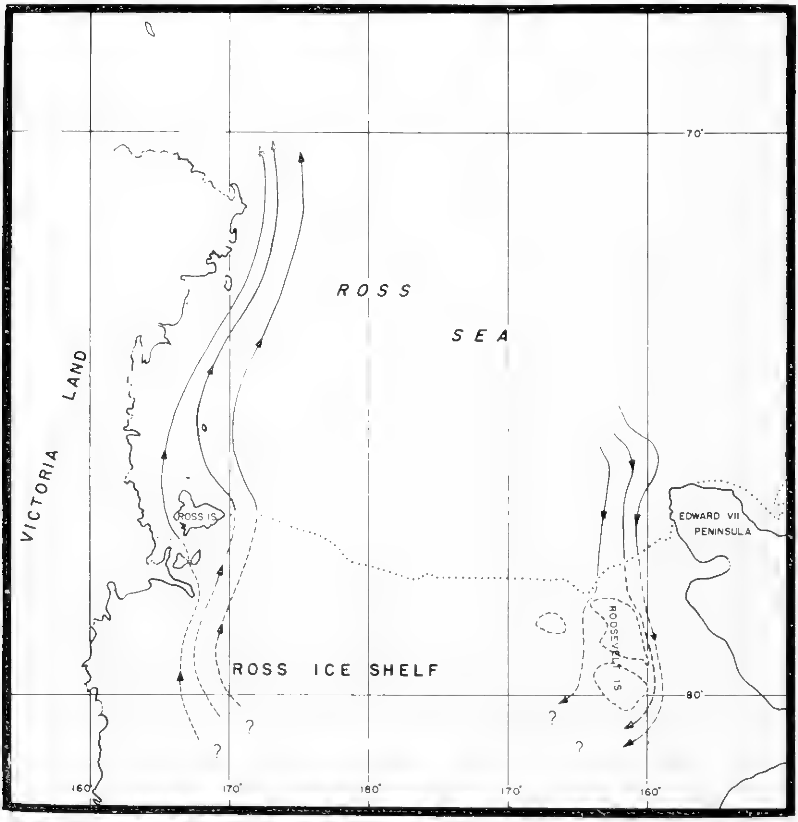

Figure 3. Proposed Ross Sea Current.

moved from the channel by this surface and bottom current. Investigations by the U. S. Navy Oceanographic Office (1962) have shown there is a clockwise current in the Ross Sea. In regard to the bottom current they say:

> It is suggested that the water of the eastern Ross Sea flows southward against the Ross Ice Shelf, where the near-surface water is deflected to the west and the deeper water flows under the shelf, possibly around the southern tip of Roosevelt Island, and emerges well to the west.

In light of the Oceanographic Office's suggestion that the water near the bottom goes under the ice shelf, the author believes the Foraminifera may be removed by this current and swept under the shelf instead of in front of it as suggested by McKnight. To the west, where the current emerges from under the ice, it may possibly remove the planktonic forms from that area as McKnight suggested. As this current reaches the tip of Victoria Land, it meets the Antarctic Circumpolar Current, is slowed down and the Foraminifera settle. This could be over a station where McKnight found high planktonic foraminiferal numbers.

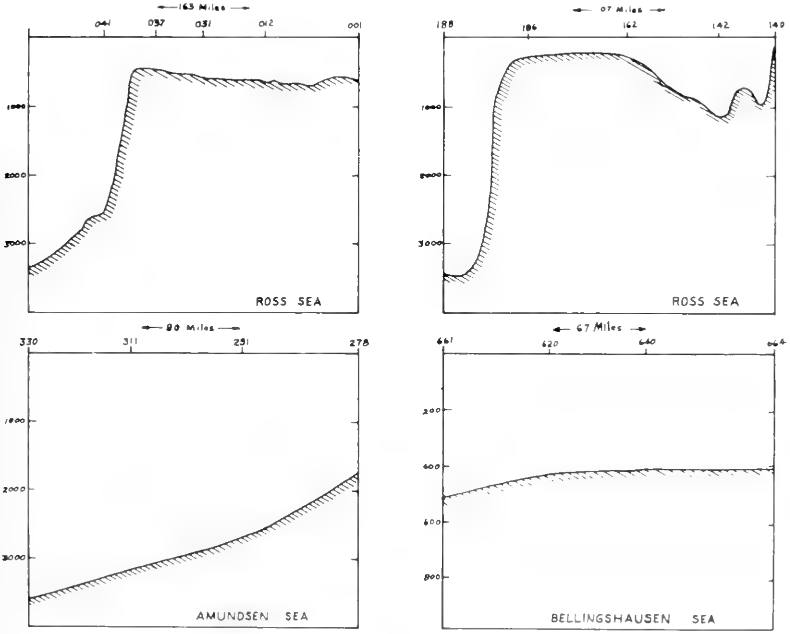

Figure 4. Bottom Profiles Along Selected Traverses.
[Bellingshausen Sea profile by author; other adapted from Navy TR-105 (1962)].

AMUNDSEN SEA

In the Amundsen Sea, the four cores investigated for Foraminifera are from below 1,765 meters and approximately 250 miles from the Antarctic shore. As shown in the profile (Fig. 4), the depth increases seaward with a decrease in gradient near station 61-291. In these cores, 32 species belonging to 22 genera were found. The most common genera were: *Eponides, Bolivina, Eggerella, Oolina, Pyrgo, Angulogerina, Bulimina,* and *Epistominella.* Only two arenaceous genera were found in this series of cores.

Surface Samples.—Eight genera and 13 species are restricted to the surface samples of the Amundsen Sea. The most common of which are *Eponides tener, Gyroidina neosoldani,* and *Pyrgo murrhina.* Calcareous forms predominate in these samples with only two arenaceous species, *Eggerella bradyi* and *Textularia catenata,* being present. Where present they occurred in higher numbers than many of the individual calcareous species also in that core.

The surface samples indicate a decrease in the number of species and abundance of individuals at the greater depths. For example, *Epistominella exigua* decreases in frequency from 129 (sample 61-278) to 0 (sample 61-330) with increasing water depths. If *E. exigua* were restricted to the particular depth where sample 61-278 was taken, the high frequency there could be explained easily. It is apparent from the foraminiferal number chart, however, that *E. exigua* is not restricted to any one depth, therefore, another process must be responsible for this distribution. This will be discussed later.

Subsurface Samples.—In only four cases were there species present at depth in the core that were not present in the surface samples. In the subsurface samples the foraminiferal numbers were low. The most common species at 30 centimeters were *Epistominella exigua* and *Eponides weddellensis. Cassidulina subglobosa, Bolivina pseudoplicata,* and *Angulogerina angulosa* occurred in lesser numbers. At the 60 centimeter level only three species, *Cassidulina subglobosa, Eponides weddellensis,* and *Oolina globosa* were present. These three species were present at three stations: *Cassidulina subglobosa* at 61-278 (60 cm.) and 61-291 (60 cm.) and *Eponides weddellensis* and *Oolina globosa* at 61-311 (60 cm.). At the 90 centimeter level in the cores only two benthonic species, *Eponides weddellensis* and *Epistominella exigua,* occurred. Both of these species were present in samples 61-291 (90 cm.) and 61-311 (90 cm.).

In the cores from the Amundsen Sea, the foraminiferal numbers diminish with distance from land and with increased core depth. In this area, the trend is indicated by both planktonic forms and calcareous and arenaceous benthonic forms. There is one reversal of this trend between samples 61-291 and 61-311. Here the *Globigerina pachyderma* number increases to 646 in sample 61-311 from 393 in sample 61-291. This trend leads the author to believe there has been a change in the rate of sedimentation with a more rapid rate on the outer slope today, or there has been a change in foraminiferal populations.

Several explanations are possible. One is a water mass change between these stations. Antarctic Deep Water has been divided into three types (U. S. Navy Ocean. Office, 1962). These are Upper Deep Water, Lower Deep Water, and Bottom Water. The Amundsen Sea samples are identified with the latter two zones. Lower Deep Water is defined as having temperatures greater than 0.5 C and a maximum salinity greater than 34.7 0/00. To be identified as Bottom Water, the water must have a temperature of less than O.5 C and a salinity of less than 34.7 0/00. Station 61-278 (Table 2) has water characteristics which place it in the zone of Lower Deep Water and stations 61-291, 61-311, and 61-330 have water characteristics that place them in the zone of Bottom Water. This may account for the differences in distribution if the Foraminifera prove to be sensitive to such minute changes. This theory may be queried however, since the planktonic numbers (assuming *Globigerina pachyderma* is planktonic) diminish as do the benthonic numbers.

Another possibility may be a faster rate of sedimentation. In the Pleistocene, the ice shelves of the Antarctic continent may have extended much farther seaward. This would cause the past rate of sedimentation to be greater over the outer stations than the present rate. If this were so, it could account for the decrease in the foraminiferal numbers with core depth. This could also account for the numerous sand layers (Table 4) found below 30 centimeters in the outer three cores. The question then concerns station 61-278, which does not have many sand layers at depth and is the station closest to shore.

It is doubtful that there is a faster rate of sedimentation caused by ice rafting over the outer stations at the present time. Most of the samples in the Amundsen Sea were taken through pack ice. The sedimentation from this pack ice is probably low since this is mostly frozen sea water and is not derived from the continent.

A faster rate of sedimentation on the outer slopes of the continent may result from turbidity or density currents. The gradient between stations 61-278 and 61-330 is approximately 65 feet per mile but a steeper gradient of approximately 134 feet per mile exists between stations 61-278 and 61-291, the next core seaward. This slope, with probable steeper slopes toward shore, and the rather concentrated deposition on the shelf and upper slope areas are conducive to turbidity or density currents.

Dr. J. K. Osmond, Department of Geology, Florida State University, has informed the author that data on rates of sedimentation of the specific cores are not available. More cores are needed adjacent to the traverse to determine whether or not this more rapid sedimentation was caused by turbidity currents.

BELLINGSHAUSEN SEA

Three cores taken east of Thurston Island were selected for foraminiferal analysis. All of these were from the shelf in water less than 515 meters deep. Only the surface samples have several species present. The species found in all of the surface samples were *Alveolophragmium wiesneri, Cyclammina pusilla, Hormosina ovicula, H. ovicula gracilis, Psammosiphonella discreta, Psammosphaera fusca, Textularia antarctica,* and *T. tenuissima.* All of these are arenaceous. They are not present in the two subsurface samples 61-670 (30 cm.) and 61-676 (60 cm.). *Angulogerina angulosa* was the only calcareous foraminifer common in this area. It was present in four of the five samples and had a foraminiferal number of 32.3 in sample 61-664.

It should be noticed that the deficiency of arenaceous forms with increased core depth is not limited to the Bellingshausen Sea samples. This is also true of the Ross Sea, including McKnight's area, and the Amundsen Sea samples. The author does not believe a late migration into these areas by arenaceous forms is a satisfactory explanation. The author believes there is a disintegration, either mechanical or chemical, of the arenaceous tests soon after burial. This disintegration is, for the most part, completed by the time new sediment builds to 30 centimeters.

CONCLUSIONS

The purpose of this study has been to investigate the distribution of Foraminifera found in 17 cores taken by the United States Navy as part of the Deep Freeze 61 project. The author investigated the ecologic factors

Figure 5. Distribution of Foraminiferal Numbers.

DISTRIBUTION OF FORAMINIFERAL NUMBERS

Sample 61-	336	330	206	200	194	188	329	323	317	311	309	303	297	291	041	290	284	278	154	148	142	018	012	011	007	001	036	034	031	661	037	676	670	664	640	166	162	186	140
Sonic Depth (meters, uncorrected)	3545	3545	3402	3402	3402	3402	3150	3150	3150	3150	2685	2685	2685	2685	2561	1765	1765	1765	1134	1134	1134	668	668	640	640	640	604	604	604	515	460	410	410	410	410	274	274	265	210
Globigerina bulloides											09							37.6																		03			44
G. conglomerata										15.2	09		2 14	48 9			90	230																		51	07	19	
G. pachyderma	09		24	16.4			53	.33	15 3	646	1 10	89	203	393		164	2.94	1136	80	938	1 88	.06		.15		.29					.32		20	226	1.29	5 33	448	1 90	1.22
Orbulina porosa										1.26																													
Alveolophragmium subglobosum	09					.20									.10						.13																		
Cyclammina pusilla	29	14				1.11									3.88					.15	.27									.19				2.42	103				
Epistominella exigua	09						18			101	18		25	28.2			90	129	.48			.03												.81		.18		12	6.32
Cassidulina subglobosa		14										30				.23	.22	25.0	3.06	45														161		2.0	.74	.40	4.88
Cibicides subhaidingerii		.14																12 5																		33	.29		1.22
Eponides tenera		.28							.15					144				20.8																					
Pullenia bulloides		14																																					
Uvigerina asperula		43								8.86				2.96								.09												81		.03	3.82		.11
Cyclammina orbicularis						40																																	
Hormosina normani						10																																	
Psammosphaera fusca						.20																								.58				1.61	1.03			.08	
P. parva						10																	.24								.19				.26			.04	
Eponides weddellensis							35	.11		13.9	.18		25	14.8				50.0	1.93	90		.31		1 20							.19			31.4		.95	.15	.51	15.3
Oolina globosa								.11						1.44				4 16																		07	.29	.08	.22
Eggerella bradyi										1.26								8.32																.81					
Gyroidina neosoldanii										2.53																													
Lagena striata										1.26																												.04	
Textularia catenata										3.80																										21			
Bolivina psuedoplicata														144			22	125																					
Ellipsolagena cucullata														144																									
Fissurina kerguelenensis														144																						03			.11
Lagena orbignyana var. B														144																									
Fissurina sp. A														1.44																									
Pullenia subcarinata														1.44																									
Pyrgo depressa														144																									
P. murrhyne														144				8.32																					
Sigmoilina edwardsi acuta														144																									
Uvigerina brunnensis														440																							.51		
Ammomarginulina ensis															42																								
Angulogerina angulosa															10		.22	33.4	.16											39	.32	.40	.10	32.3		3.07	14.9	13.8	4 88
Haplophragmoides rotulatum															.52																								
Hormosina ovicula															.21								61			59				58				.81	1.29		.15		
Pelosphaera cornuta															.21																								
Recurvoides contortus															21								.36								71								
Reophax distans															.21						.40		.97						.33		.25							.16	
R. nodulosus															.10						.27									.39	.12				26		.15		
Saccorhiza ramosa															42						.54																.29		
Textularia tenuissima															10				.16		.27		1.57		.22	2.90			.89	1.74	51			3.22	.52			.32	
Involutina anguillae															.10						.27																		
Bulimina marginata																		12.5			.13													4.84		.03			
B. gibba																		12.5														.19							
Lagena orbignyana var. A																		4.16																					
Nonion germanicus																		4 16	.48			.06		.22							45					.21	1 32	.95	.55
Parafissurina subcarinata																		8.32													.06					.07		.04	
Pyrgo sp.																		4.16																					
Triloculina tricarinata																		4.16																					.22
Cassidella davisi																		4.16	.16	.30														3.22		.28	.22	.08	.66
Cassidulina carinata																			.48	.15																.47			1 66
Cassidulinoides parkerianus																			.16																	.03		.04	
Ehrenbergina glabra																			.16												.19					1.80	.95	.51	1.11
Nonionella bradyi																			.48																	.15		.04	1.11
Trochammina antarctica																			.16		.13		73	.07		2.99			.99	1.16	.12				.26			40	
T. grisea																			16			.03	1 93			2.69			44		25								
T. wiesneri																			.16		.13		.61			1.19			.11	1.35					.26				
Dentalina sp.																				.15																			
Ammomarginulina foliaceus																					.13				.22														
Haplophragmoides sp. A																					.13																		
Haplophragmoides subtrullissatma																					.54																		
Hyperammina elongata																					.13																		
Miliammina oblonga																					.13		1.45													.15			
Reophax spiculifer																					.13								.11								.15		
Textularia antarctica																					.40		.61			4.19			.22	.77	.25			2.42	.52				
Trochammina conica																					3.63		.24						.33	4.45	.77				4.64		.51		
T. glabra																					.13					.29				2.51									
Verneuilina minuta																					.13		.12			.29				.39	.06			.81				.04	
Angulogerina earlandi																						.03		07												.07	.74	12	.11
Cassidulina crassa																						.03														.66	.44	5.19	.55
Adercotryma glomeratum																							12			29								.81	.77			.12	
Alveolophragmium wiesneri																							85	07					22	1.16	.19			2.42	1.29			.36	
Haplophragmoides canariensis																							85							445	1 09			2.42	1.03		.37	.24	
Hormosina ovicula gracilis																							24			1.19				.58	.19			.81	.26			04	
Hyperammina malovensis																							.24								.12								
Miliammina lata																							.24			1.19											.07		
Psammosiphonella discreta																							1.93							2.13	4.49			4.84	9.81		.15		
Reophax pilulifer																							.12			.59				.19	.45			.81					
Miliammina arenacea																										1 49				77									
Jaculella acuta																														.19	.12				.77				
Reophax dentaliniformis																														.19	12				26				
Cibicides refulgens																															.45					.36		.16	.22
Lagena laevis																															.06					.03			
L. laureata																															.06					.03		.16	
Nonionella sp.																															.06						.07		1.55
Oculosiphon linearis																															.32				.26				
Parafissurina lata																															06					.25		.19	.33
Reophax difflugiformis																															.06								
Trochammina intermedia																															.06								
Lagena fieldiana																																		1.61			22	04	
L. gracilis																																		.81		.03	.07	04	
Angulogerina angulosa asperrima																																				18	.66	47	
Nonion sp.																																				.15	07	.08	.11
Cornuspira involvens																																				03			.11
Fissurina cf. trigono-marginata																																							.11
Glandulina antarctica																																				.03			
Lagena hispida																																				.07			
L. melo																																				.03			.11
L. psuedocatenulata																																				.11			
L. subacuticosta																																				.03	07		
Oolina apiculata																																				.03	15	04	
Quinqueloculina sp.																																				.03			
Robertina wiesneri																																				.03			
Triloculina cf. rotunda																																				44			1 44
Lagena costata																																					15		
Lenticulina sp.																																					.15		
Fissurina alveolata																																						.32	
Parafissurina dorbignyana																																						.04	
Reophax subfusiformis																																						.04	
Tholosina vesicularis																																						.08	
Hippocrepinella alba																																							.11
Patellina corrugata																																							.22

of depth, temperature, and salinity as related to this distribution. The secondary purpose was to investigate the existence of a current that controls distribution as proposed by William M. McKnight, Jr. The author's major conclusions of this study are:

1. Temperature and salinity had negligible influence on distribution in the area studied and depth had a more important influence.
2. Three assemblages may be related to depth. They are: Shelf Assemblage I (210-515 meters); Shelf Assemblage II (604-1,134 meters); and the Slope Assemblage (1,765-3,545 meters).
3. McKnight's postulation of a current sweeping planktonic forms from a channel may be correct in part. There does not seem to be a bottom current paralleling the Ross Ice Shelf but rather a current that flows under the Shelf.
4. A water-mass change or turbidity currents could cause an apparent change in the rates of sedimentation on the slope.
5. A disintegration, either mechanical or chemical, is responsible for a deficiency of arenaceous forms with increased core depth apparent throughout most of the cores.

ANNOTATED SYNONYMY

The species are listed in taxonomic order. Geographic and depth distributions are stated for some species. The Foraminiferal Number Chart (Fig. 5) gives the sample occurrence and frequency of each species.

Foraminifera figured by McKnight (1962) are not refigured in this study. The reader is referred to McKnight's article for those illustrations. The taxonomy of this work has been patterned after Cushman (1948). Loeblich's and Tappan's treatise (1964) was not available when the synonymy was written.

Family **ASTRORHIZIDAE**

Oculosiphon cf. **O. linearis** (Brady) Pl. 14, fig. 8

Rhabdammina linearis Brady, 1879, p. 37, pl. iii, figs. 10, 11; Brady, 1884, p. 269, pl. XXII, figs. 1-6.
Oculosiphon linearis (Brady), Avnimelech, 1952, p. 65.

A section was made of one specimen to investigate the central chamber. Brady's specimens all came from much deeper water than the specimens of the present study. This species is restricted to depths of less than 460 meters.

Pelosphaera cornuta Heron-Allen and Earland Pl. 14, fig. 10

Pelosphaera cornuta Heron-Allen and Earland, 1929, (1932), p. 255, pl. ii, figs. 12-15; Earland, 1933, p. 61, pl. VII, figs. 24-7; Parr, 1950, p. 265, pl. IV, fig. 8.

This species has a conical process, or neck, projecting from the central chamber. It is believed the figured specimen originally had another process, but it may have been broken in the cleaning process.

Psammosiphonella discreta (Brady) Pl. 13, fig. 5

Rhabdammina discreta Brady, 1879, (1881), p. 48; Brady, 1884, p. 268, pl. XXII, figs. 7-10.

Psammosiphonella discreta (Brady), Avnimelech, 1952, p. 65.

Every specimen of this species seemed to be a fragment of a larger individual, and, therefore, the foraminiferal numbers may not be correct. The relative abundance of the species is shown by the numbers. The species is restricted to depths less than 668 meters in the eastern Ross Sea and Bellingshausen Sea.

Family **RHIZAMMINIDAE**

Hippocrepinella alba Heron-Allen and Earland Pl. 14, fig. 9

Hippocrepinella alba Heron-Allen and Earland, 1932, p. 259, pl. 1, figs. 16-18; Earland, 1933, p. 71, pl. 7, figs. 10-12; Earland, 1934, p. 73; Rhumbler, 1935, p. 155, pl. 2, figs. 43, 44; Höglund, 1947, p. 45, pl. 1, figs. 11-13, text-fig. 17, p. 56.

This species may be more common than it appears in the Deep Freeze 61 material. The test is so thin that it may be broken in the process of washing out the clay, therefore, lost to any investigation. Only one complete specimen was found.

Family **SACCAMMINIDAE**

Subfamily **PSAMMOSPHAERINAE**

Psammosphaera fusca Schulze

Psammosphaera fusca Schulze, 1875, p. 113; Brady, 1884, p. 249, pl. XVIII, fig. 1: Wiesner, 1931, p. 79, pl. IV, figs. 32-33; Heron-Allen and Earland, 1932, p. 327, pl. VIII, figs. 1-4; Parr, 1950, p. 256; McKnight, 1962, p. 99, pl. 9, fig. 3.

As McKnight reported, depth seems to have little effect on the distribution of this species. It was found between 265 and 3,402 meters in the present study.

Psammosphaera parva Flint

Psammosphaera parva Flint, 1899, p. 268; McKnight, 1962, p. 99, pl. 9, fig. 4.

This species was found in the same depth range as *P. fusca* in the Deep Freeze 61 samples.

Subfamily **WEBBINELLINAE**

Tholosina vesicularis (Brady) Pl. 14, fig. 12

Placopsilina vesicularis Brady, 1879, p. 51, pl. v, fig. 2; Brady, 1884, p. 316, pl. XXXV, figs. 18, 19.
Tholosina vesicularis (Brady), Rhumbler, 1903, p. 227, fig. 53; Heron-Allen and Earland, 1932, p. 331.

This sessile form was found at station 61-186 at 265 meters. The species is represented by two individuals on one pebble. Heron-Allen and Earland stated that this species often occurs in enormous numbers in the Falkland Island area.

Family **HYPERAMMINIDAE**

Subfamily **HYPERAMMININAE**

Hyperammina elongata Brady Pl. 13, fig. 7

Hyperammina elongata Brady, 1878, p. 433, pl. XX, fig. 2a,b; Brady, 1884, p. 257, pl. XXIII, fig. 8.

Hyperammina malovensis Heron-Allen and Earland Pl. 13, fig. 6

Hyperammina malovensis Heron-Allen and Earland, 1932, p. 333, pl. VIII, figs. 12-14.

A section was made of one specimen from sample 61-012. This section showed one end plugged as mentioned by Heron-Allen and Earland in their description. This species was found in two samples with a frequency of .24 in 61-012.

Jaculella acuta Brady

Jaculella acuta Brady, 1879, p. 35, pl. iii, figs. 12, 13; Brady, 1884, p. 255, pl. XXII, figs. 14-18; McKnight, 1962, p. 99, pl. 9, fig. 5.

Because this species occurred in fragments, the foraminiferal numbers may be erroneous. The species is less common than in the area studied by McKnight. It is restricted to water less than 515 meters deep in the present study.

Subfamily **DENDROPHRYINAE**

Saccorhiza ramosa (Brady) Pl. 13, fig. 4

Hyperammina ramosa Brady, 1879, p. 32, pl. iii, figs. 14, 15; Brady, 1884, p. 261, pl. XXIII.
Saccorhiza ramosa (Brady), Eimer and Fickert, 1899, p. 670; Heron-Allen and Earland, 1932, p. 325; Earland, 1934, p. 75.

This species does not seem to be so common as Brady found it to be. Heron-Allen and Earland found a few fragments at one station. Earland found it to be generally distributed throughout the Bellingshausen Sea down to 5,029 meters. The species was found in only three samples of the present study. All of these are from the eastern Ross Sea to a depth of 2,561 meters. This depth was at station 61-041 where the species could have washed in. The other cores, 61-142 and 61-162, were from the shelf.

Family **REOPHACIDAE**

Subfamily **REOPHACINAE**

Reophax dentaliniformis Brady

Reophax dentaliniformis Brady, 1884, p. 293, pl. XXX, fig. 21-22; Heron-Allen and Earland, 1922, T. N., p. 94; Parr, 1950, p. 266; McKnight, 1962, p. 100, pl. 9, fig. 7.

The depth range of this species as reported by McKnight and by Parr is similar to that recorded in this study. An exception reported by Parr is the occurrence on the Antarctica continental slope where it may easily have been deposited from the continental shelf.

Reophax difflugiformis Brady Pl. 14, fig. 11

Reophax difflugiformis Brady, 1879, p. 51, pl. IV, figs. 3a, b; Brady, 1884, p. 289, pl. XXX, figs. 2-4 (non 1-5).
Proteonina difflugiformis (Brady), Cushman, 1918, p. 47, pl. XXI, figs. 1, 2.

This species was observed in one sample of the Deep Freeze 61 material. Loeblich and Tappan (1955) considered *Proteonina* a synonym of *Reophax.*

Reophax distans Brady

Reophax distans Brady, 1884, p. 296, pl. XXXI, figs. 18-22; Wiesner, 1931, p. 90, pl. IV, figs. 104-105; Earland, 1934, p. 83; Chapman and Parr, 1937, p. 147; Parr, 1950, p. 266; McKnight, 1962, p. 100, pl. 9, fig. 8.

Every specimen of this species was broken except one. Therefore, the foraminiferal numbers may be in error. They do give an indication of relative abundance, however. All of the specimens except two were found on the continental shelf. These, from sample 61-041, may have washed over the edge of the steep shelf break in this area. This may well be the case with Parr's specimens also. His one deep station where this species is found seems to be just seaward of the shelf break.

Reophax nodulosus Brady

Reophax nodulosus Brady, 1884, p. 294, pl. XXXI, figs. 1-9; Wiesner, 1931, p. 91, pl. IX, fig. 108; Parr, 1950, p. 267; McKnight, 1962, p. 100, pl. 9, fig. 10.

Based on previous reports, this species has a wide geographic distribution in the Antarctic area. My specimens were typical and ranged in depth from 274 to 2,561 meters. The species was present in samples from the eastern Ross Sea and the Bellingshausen Sea.

Reophax pilulifer Brady

Reophax pilulifera Brady, 1884, p. 292, pl. XXX, figs. 18-20.
Reophax pilulifer (Brady), Heron-Allen and Earland, 1922, p. 93; Earland, 1934, p. 80, pl. ii, figs. 10, 36; Parr, 1950, p. 267; McKnight, 1962, p. 101, pl. 9, fig. 11.

Earland found this species to be widely distributed. He found it to depths of 5,029 meters. In the present study it was found only at depths of less than 668 meters. It has a maximum frequency of .81 in sample 61-664.

Reophax spiculifer Brady

Reophax spiculifera Brady, 1879, p. 54, pl. IV, figs. 10, 11; Brady, 1884, p. 295, pl. XXXI, figs. 16-17.
Reophax spiculifer (Brady), Wiesner, 1931, p. 91, pl. IX, fig. 113; Parr, 1950, p. 269; McKnight, 1962, p. 101, pl. 9, fig. 12.

This species was rare but equally distributed in three samples. Its depth range was 274 to 1,134 meters. McKnight reported this species from off Queen Maud Land in 1,670 meters of water. All of Parr's specimens were from relatively shallow water.

Reophax subfusiformis Earland Pl. 13, fig. 3

Reophax subfusiformis Earland, 1933, p. 74, pl. ii, figs. 16-19; Höglund, 1947, p. 82, pl. 9, figs. 1-4; pl. 26, figs. 1-36; pl. 27, figs. 1-19; text-figs. 43-50.

Höglund's excellent study of the variations developed by this species leaves little doubt that the one specimen found in sample 61-186 is this species. Parr reported this species from 219 meters. Earland found it down to 4,517 meters, and in this study it was found at 265 meters.

Hormosina ovicula Brady

Hormosina ovicula Brady, 1879, p. 61, pl. iv, fig. 6; Brady, 1884, p. 327, pl. XXXIX, figs. 7-9; Wiesner, 1931, p. 92, pl. XI, figs. 125-6; Earland, 1934, p. 85, pl. III, fig. 1.

This species is widely distributed over the shelf of the Antarctic area. It was not abundant at any of the Deep Freeze 61 stations.

Hormosina ovicula gracilis Earland

Reophax distans var. *gracilis* Earland, 1933, p. 76, fig. 21.
Hormosina ovicula var. *gracilis* (Earland), Earland, 1934, p. 85, pl. III; McKnight, 1962, p. 100, pl. 9, fig. 6.

This form was separated from *H. ovicula* because of its smaller size.

It is restricted to water less than 668 meters deep. It was found to be rare at all locations.

Hormosina normani Brady Pl. 13, fig. 2

Hormosina normani Brady, 1879, p. 52; Brady, 1884, p. 329, pl. XXXIX, figs. 19-23; Parr, p. 270, pl. iv, fig. 22.

This species was observed in sample 61-188. It is represented by a single typical large specimen.

Family **LITUOLIDAE**

Subfamily **HAPLOPHRAGMIINAE**

Adercotryma glomeratum (Brady)

Lituola glomerata Brady, 1878, p. 433, pl. 20, fig. 1.
Haplophragmoides glomeratus (Brady), Earland, 1936, p. 35, n. 72.
Adercotryma glomeratum (Brady), Loeblich and Tappan, 1952, p. 141; McKnight, 1962, p. 102, pl. 9, fig. 15.

This species ranged in depth from 668 meters to 265 meters. It was most abundant in sample 61-664 at 410 meters. It was also found by Chapman, Earland, Parr, Wiesner, and McKnight. McKnight found nearly the same maximum abundance at a similar depth.

Alveolophragmium subglobosum (G. O. Sars)

Lituola subglobosa G. O. Sars, 1872, p. 253.
Haplophragmium latidorsatum Brady, 1884, p. 307, pl. XXXIV, figs. 7, 8, 10.
Haplophragmoides subglobosum (G. O. Sars), Cushman, 1910, p. 105.
Labrospira subglobosum (G. O. Sars), Höglund, 1947, p. 144.
Alveolophragmium subglobosum (G. O. Sars), Barker, 1960, pl. 34, figs. 7, 8, 10; McKnight, 1962, p. 102, pl. 10, figs. 16a, b.

Typical specimens of this species were found in four samples. In sample 61-188, specimens with both types of apertures (Earland, 1935) were present. The species had a depth range of 1,134 to 3,545 meters. It is thought to have a deep and wide distribution.

Alveolophragmium wiesneri (Parr) Pl. 14, figs. 14a, b

Trochammina trullissata Brady (*non T. trullissata* Brady, 1879), 1884, (*pars*), p. 342, pl. XL, figs. 14, 15 (*non* 13-16).
Haplophragmoides trullissata (Brady), Cushman, 1910, p. 100, text-fig. 148.
Labrospira wiesneri Parr, 1950, p. 272, pl. IV, figs. 25, 26.
Alveolophragmium wiesneri (Parr), Loeblich and Tappan, 1953, p. 9; (?) McKnight, 1962, p. 102, pl. 10, figs. 17a, b.

This species was found restricted to much shallower water than in McKnight's study. The Deep Freeze 61 specimens ranged in depth from 265 to 668 meters. These figures agree much more closely with Parr's figures (219-437 meters) than with McKnight's (384-2,995 meters).

McKnight's figure of *A. wiesneri* shows the aperture a slit at the base of the last chamber instead of above the base of the chamber as described by Parr.

Ammomarginulina ensis Wiesner

Ammomarginulina ensis Wiesner, 1931, p. 97; Earland, 1933, p. 82, pl. III, figs. 1-4; McKnight, 1962, p. 103, pl. 10, fig. 18.

This species was rare in the Deep Freeze 61 samples. It was present in but one sample (61-041) where it had a frequency of .42.

Ammomarginulina foliaceus (Brady) Pl. 14, figs. 13a, b

Haplophragmium foliaceus Brady, 1879, p. 50, Brady, 1884, p. 304, pl. XXXIII, figs. 20-25.
Ammobaculites foliaceus (Brady), Cushman, 1918, (1920), p. 64, pl. XIII, figs. 1, 2; Earland, 1934, p. 93.
Ammomarginulina foliaceus (Brady), Cushman, 1933, pl. 10, figs. 6a, b.

This thin, delicate species was found in two samples at depths of 640 meters and 668 meters. Both are from the eastern Ross Sea.

Haplophragmoides sp. A Pl. 13, figs. 1a, b

Represented by one specimen, this large species was assigned to *Haplophragmoides* because of the aperture at the base of the last chamber and the single arenaceous wall. The specimen is smoothly finished, and each succeeding chamber is lighter in color than the previous one. It was present in sample 61-142 at 1,134 meters.

Haplophragmoides canariensis (d'Orbigny)

Nonionina canariensis d'Orbigny, 1839, p. 128, pl. ii, figs. 33-34.
Haplophragmium canariense (d'Orbigny), Brady, 1884, p. 310, pl. XXXV, figs. 1-5.
Haplophragmoides canariensis (d'Orbigny), Wiesner, 1931, p. 95, pl. II; Chapman and Parr, 1937, p. 139; Parr, 1950, p. 270; McKnight, 1962, p. 103, pl. 10, fig. 20.

This species is restricted to depths of less than 668 meters in the Deep Freeze 61 samples. Its greatest frequency was between 410 and 515 meters.

Haplophragmoides cf. **H. rotulatus** (Brady)

Haplophragmoides rotulatum Brady, 1879, etc., (1881), p. 50; Brady, 1884, p. 306, pl. XXXIV, figs. 5, 6; McKnight, 1962, p. 103, pl. 10, figs. 21a, b.

Five specimens were found in sample 61-041. Two were damaged but still comparable to those of McKnight.

Haplophragmoides subtrullissatus Parr Pl. 15, figs. 19a, b.

Haplophragmoides subtrullissatus Parr, 1950, p. 271, pl. iv, figs. 27a, b.

The Deep Freeze 61 specimens are somewhat different than Parr's figure. They have a large proloculus and seem to be the megalospheric form of Parr's species.

Recurvoides contortus Earland

Haplophragmoides scitula Wiesner, 1931, p. 96, pl. XII, fig. 141.
Haplophragmoides scitulum (Wiesner), Earland, 1933, p. 112, pl. III, figs. 11, 12.
Recurvoides contortus Earland, 1934, p. 91, pl. X, fig. 7-19; Chapman and Parr, 1937, p. 138, pl. IX, fig. 34; Parr, 1950, p. 273; McKnight, 1962, p. 103, pl. 10, fig. 22.

All specimens of the species were in samples from the eastern Ross Sea. The species has a depth range of 460 to 2,561 meters.

Subfamily **LITUOLINAE**

Cyclammina orbicularis Brady

Cyclammina orbicularis Brady, 1884, p. 353, pl. XXXVII, figs. 17-19; Wiesner, 1931, p. 97, pl. XIII, fig. 149; Earland, 1936, p. 39, pl. I, figs. 27-8; McKnight, 1962, p. 104, pl. 10, fig. 23.

Four specimens were found in one sample (61-188) at a depth of 3,402 meters.

Cyclammina pusilla Brady

Cyclammina pusilla Brady, 1884, p. 353, pl. XXXVII, figs. 20-23; Wiesner, 1931, p. 97, pl. XIII, fig. 151; Earland, 1936, p. 39, pl. I, figs. 25-6; Parr, 1950, p. 273; McKnight, 1962, p. 104, pl. 11, figs. 24a, b.

This species ranges in depth from 410 to 3,545 meters and was found in all three areas of investigation. This is a widespread form in the Antarctic, as stated by Parr and McKnight. Its greatest abundance is in sample 61-664 with a foraminiferal number of 2.42.

Family **TEXTULARIIDAE**

Subfamily **TEXTULARIINAE**

Textularia antarctica (Wiesner)

Bolivina punctata var. *arenacea* Heron-Allen and Earland, 1922, p. 133, pl. IV, figs. 21-2.
Pseudobolivina antarctica Wiesner, 1931, p. 99, pl. XXI, figs. 257-8, pl. XXIII, stereo-figs. 21-2.
Textularia antarctica (Wiesner), Earland, 1934, p. 116, pl. IV; McKnight, 1962, p. 104, pl. 11, fig. 25.

This species is restricted to water less than 1,134 meters deep in the eastern Ross Sea and the Bellingshausen Sea. It is widely distributed in the Antarctic area.

Textularia catenata Cushman Pl. 15, figs. 16a, b

Textularia catenata Cushman, 1911, p. 23, figs. 39, 40; Earland, 1934, p. 115, pl. IV, figs. 44-47; McKnight, 1962, p. 201, pl. 11, fig. 26.

Specimens of this species are typical in their coarse arenaceous construction. Earland reported this form from 3,638 to 4,773 meters. In this study, seven specimens were found in the eastern Ross Sea at a depth of 274 meters, 30 centimeters below the surface. Three specimens were found in the Amundsen Sea at a depth of 3,150 meters. These were from the surface sample 61-311.

Textularia tenuissima Earland

Textularia elegans Lacroix, 1932, p. 8, fig. 4, 6.
Textularia tenuissima Earland, 1933, p. 95, pl. III, figs. 21-30; Earland, 1934, p. 115; Chapman and Parr, 1937, p. 151, pl. X, fig. 43; Höglund, 1947, p. 176, pl. 13, fig. 1; text-figs. 154-5, 161. Parr, 1950, p. 276; McKnight, 1962, p. 105, pl. 11, fig. 27.

This species has wide distribution. Earland reported it from all his areas and at all depths. He mentioned having an exceptionally long and slender "variety" in his most southern samples. In the present study, this type was present at three stations—61-142, 61-001, 61-640.

Family **VERNEUILINIDAE**

Verneuilina minuta Wiesner

Verneuilina minuta Wiesner, 1931, p. 99, pl. 13, fig. 155; Earland, 1934, p. 119, pl. V, figs. 22-26; McKnight, 1962, p. 105, pl. 11, fig. 28.

All of the samples, except one, in which this species was found were between the depths of 265 and 668 meters. The one exception, from 1,134 meters, is from a location (61-142) in which the specimen could have been washed in. This species was most abundant at station 61-664 with a frequency of .81 per gram.

Family **VALVULINIDAE**

Subfamily **EGGERELLINAE**

Eggerella bradyi (Cushman)

Verneuilina pygmaea Brady, 1884, p. 385, pl. XLVII, fig. 6.
Verneuilina bradyi Cushman, 1911, p. 54.
Eggerella bradyi (Cushman), Cushman, 1933, p. 33; McKnight, 1962, p. 105, pl. 11, fig. 29.

This species was rare in the Deep Freeze 61 samples. Sample 61-278, however, had a foraminiferal number of 8.32.

Family **SILICINIDAE**

Subfamily **INVOLUTININAE**

Involutina angiullae (Höglund) Pl. 16, fig. 21

?Ammodiscus incertus Brady (part), 1884, (not d'Orbigny) p. 330, pl. XXXVIII, figs. 1, 3; McKnight, 1962, p. 101, pl. 9, fig. 13.

Ammodiscus angiullae Höglund, 1947, p. 128, pl. 28, fig. 8; pl. 29, fig. 4; text-figs. 101, 105, 109.

Involutina angiullae (Höglund), Loeblich and Tappan, 1954, pp. 21-2; Barker, 1960, p. 78, pl. XXXVIII, figs. 1, 3.

This species was rare in the Deep Freeze 61 samples between 1,134 and 2,561 meters.

Subfamily **RZEHAKININAE**

Miliammina arenacea (Chapman)

Miliolina oblonga (Montagu) var. *arenacea* Chapman, 1916, p. 59.

Miliolina oblonga var. *arenacea* Chapman, Heron-Allen and Earland, 1922, p. 66.

Miliammina oblonga Heron-Allen and Earland, 1929, pp. 41-42.

Miliammina arenacea (Chapman), Earland, 1934, p. 110; Parr, 1950, p. 253; McKnight, 1962, p. 106, pl. 11, figs. 31a, b.

Although reported as common in the Antarctic area, this species was observed in only two cores in the present study. One core was from the eastern Ross Sea and one from the Bellingshausen Sea.

Miliammina lata Heron-Allen and Earland

Miliolina agglutinans Chapman, 1916, p. 58, pl. I, fig. 6.

Miliammina lata Heron-Allen and Earland, 1929, p. 253, pl. I, figs. 13-17; Earland, 1933, p. 93, pl. III, fig. 17; Earland, 1934, p. 111; Parr, 1950, p. 253, pl. III, fig. 4; McKnight, 1962, p. 106, pl. 11, figs. 32a, b.

The specimens from Deep Freeze 61 samples are found in a depth range of 274 to 668 meters. Earland and Parr mentioned that *M. lata* is not present in many samples with *M. arenacea*. In my samples they were found together in one of three samples.

Miliammina oblonga Heron-Allen and Earland

Miliammina oblonga Heron-Allen and Earland, 1929, p. 41; MacFadyen, 1933, p. 92; Earland, 1934, p. 111; McKnight, 1962, p. 106, pl. 11, fig. 33a, b.

This species was found in the eastern Ross Sea samples only. It ranges from depths of 274 to 1,134 meters. This is close to what McKnight found.

Family **MILIOLIDAE**

Quinqueloculina sp. A Pl. 15, figs. 17a, b

The one specimen found was damaged, and identification with a named species was not attempted. It was found at 274 meters in the eastern Ross Sea.

Sigmoilina edwardsi acuta Chapman and Parr Pl. 15, figs. 18a, b

Sigmoilina edwardsi (Schlumberger) var. *acuta* Chapman and Parr, 1937, p. 132, pl. IX, fig. 33.

This form compares with Chapman and Parr's single figure and description fairly well. The aperture is similar to *S. edwardsi*, and the periphery is compressed and acute as described by Chapman and Parr. The form was found at station 61-291 at a depth of 2,685 meters.

Triloculina tricarinata d'Orbigny

Triloculina tricarinata d'Orbigny, 1826, p. 299; Chapman and Parr, 1937, p. 134; Parr, 1950, p. 294; McKnight, 1962, p. 107, pl. 12, fig. 39.
Miliolina tricarinata Brady, 1884, p. 165, pl. III, fig. 17; Heron-Allen and Earland, 1922, p. 66.

This species was found in two Deep Freeze 61 samples. At station 61-278 it had a frequency of 4.16 per gram. Its depth range was 210 to 1,765 meters. The position of the bifid tooth is variable.

Triloculina rotunda d'Orbigny

Triloculina rotunda d'Orbigny, 1826, p. 299; McKnight, 1962, p. 107, pl. 12, figs. 38a, b.

This species compares favorably with McKnight's although it is not so large.

Pyrgo sp. A Pl. 15, figs. 15a, b

One specimen represents this species in the Deep Freeze 61 samples. It was damaged so that identification with a named species was not considered possible.

Pyrgo depressa (d'Orbigny)

Biloculina depressa d'Orbigny, 1826, p. 298.
Pyrgo depressa Earland, 1934, p. 46; Chapman and Parr, 1937, p. 135; Parr, 1950, p. 297; McKnight, 1962, p. 108, pl. 13, fig. 43.

Parr found this species to be a shallow-water form at 13 stations. McKnight reported it to have a depth range of 274 to 805 meters. In this study it was found at a depth of 2,685 meters only.

Pyrgo murrhina (Schwager)

Biloculina murrhina Schwager, 1866, p. 203, pl. IV; Wiesner, 1931, p. 110, pl. XVII, fig. 195.
Pyrgo murrhyna [*sic*] (Schwager), Chapman and Parr, 1937, p. 136; Parr, 1950, p. 297; McKnight, 1962, p. 108, pl. 13, fig. 44.

Based on previous reports, the depth range for this species is 384 to 3,410 meters in the Antarctic area. It was found in two Deep Freeze 61 samples. The depth range is 1,765 to 2,685 meters with a maximum abundance of 8.32 at 1,765 meters.

Family **OPHTHALMIDIIDAE**

Subfamily **CORNUSPIRINAE**

Cornuspira involvens (Reuss) Pl. 16, figs. 22a, b

Operculina involvens Reuss, 1849, p. 370, pl. xlv, fig. 20.
Cornuspira involvens (Reuss), Reuss, 1863, p. 39, pl. i, fig. 2.

This species was found in two shelf samples to a depth of 274 meters.

Family **TROCHAMMINIDAE**

Subfamily **TROCHAMMININAE**

Trochammina antarctica Parr

Trochammina antarctica Parr, 1950, p. 280, pl. V, figs. 2-4; McKnight, 1962, p. 110, pl. 14, figs. 52a, b.

This species seems to be widely distributed in the Antarctic area. My specimens came from 10 samples at depths of 265 to 1,134 meters. McKnight found this species between 164 and 2,995 meters. Parr's specimens were found at depths of less than 640 meters.

Trochammina conica Earland

Trochammina conica Earland, 1935, p. 104, pl. III; McKnight, 1962, p. 109, pl. 13, figs. 49a, b.

This common Antarctic form was found restricted to depths less than 1,134 meters. It had a maximum foraminiferal number of 4.64 at station 61-640 at a depth of 410 meters.

Trochammina glabra Heron-Allen and Earland

Trochammina glabra Heron-Allen and Earland, 1932, p. 344; McKnight, 1962, p. 110, pl. 13, figs. 50a, b.

All of my specimens are typical. They were found in three samples, two from the eastern Ross Sea and one from the Bellingshausen Sea. The species had a maximum frequency of 2.51 at station 61-661 at a depth of 515 meters.

Trochammina grisea Earland

Trochammina grisea Earland, 1935, p. 104, pl. III; McKnight, 1962, p. 110, pl. 14, figs. 51a, b.

This species was found between the depths of 460 and 1,134 meters. It was most common at station 61-001 with a frequency of 2.69 per gram.

Trochammina intermedia Rhumbler Pl. 16, figs. 23a, b

?Trochammina squamata Heron-Allen and Earland, 1913a, p. 50.
Trochammina squamata intermedia Rhumbler, 1938, p. 186, figs. 27a, b.
Trochammina intermedia Rhumbler, Höglund, 1947, p. 206, pl. 16, fig. 1, text-fig. 188.

Höglund stated that:

> The most distinctive feature in this species is the pronounced crescentric shape of the youngest chambers in the last spiral whorl and the almost entirely closed umbilicus.

The Deep Freeze 61 material produced one such specimen that also fits Rhumbler's description. It was found at station 61-037 in 460 meters of water.

Trochammina wiesneri Parr Pl. 16, figs. 24a, b

Trochammina wiesneri Parr, 1950, p. 279, pl. v, fig. 14.

This distinctive form with an enlarged last chamber was found at 11 stations. It is closely related to *T. antarctica* and is approximately equal in abundance at stations where they are found together. Their depth ranges are similar also.

Family **LAGENIDAE**

Subfamily **NODOSARIINAE**

Dentalina sp. A Pl. 16, fig. 20

This species is represented by one broken specimen from sample 61-148 (30 cm.).

Lenticulina sp. A Pl. 16, figs. 25a, b

One specimen was observed in sample 61-162 at a depth of 274 meters.

Lagena costata (Williamson) Pl. 16, fig. 26

Entosolenia costata Williamson 1858, p. 9, pl. I, fig. 18.
Lagena costata (Williamson), Heron-Allen and Earland, 1932, p. 369, pl. X, fig. 9; McKnight, 1962, p. 114, pl. 16, fig. 75.

This species was observed in one sample. Heron-Allen and Earland (1932) stated that this species is one of the most abundant Lagenae in the Falkland Island area.

Lagena feildeniana Brady

Lagena feildeneana Brady, 1878, p. 434; Brady, 1884, p. 469, pl. LVIII, fig. 38-9; McKnight, 1962, p. 114, pl. 16, fig. 77.

Never abundant, this species was found in three samples. Two were from the eastern Ross Sea and one from the Bellingshausen Sea. This species appears to be widespread in the Antarctic waters.

Lagena gracilis Williamson Pl. 16, fig. 27

Lagena gracilis Williamson, 1848, p. 13, pl. i, fig. 5; Brady, 1884, p. 464, pl. LVIII, figs. 2, 3, 7-10, 22-24; Heron-Allen and Earland, 1932, p. 366.

Found in four samples, this species has its greatest abundance in sample 61-664. The depth of this sample is 410 meters.

Lagena hispida Reuss Pl. 16, fig. 28

Lagena hispida Reuss, 1858, p. 434; Reuss, 1862, p. 335, pl. VI, figs. 77-9; Brady, 1884, p. 459, pl. LVII, figs. 1-4; pl. LIX, figs. 2-5; Heron-Allen and Earland, 1932, p. 364, pl. X, figs. 7, 8.

This species has been reported in the Falkland Island area by Heron-Allen and Earland. The outer layer has been destroyed on the two specimens obtained from Deep Freeze 61 samples.

Lagena laevis (Montagu) Pl. 16, fig. 29

Vermiculum laeve Montagu, 1803, p. 524.
Lagena semistriata Brady, 1884, pl. LVII, fig. 17.
Lagena laevis Barker, 1960, p. 118, pl. LVII, fig. 17; McKnight, 1962, p. 115, pl. 16, fig. 82.

This species was rare in the area studied.

Lagena laureata Heron-Allen and Earland Pl. 16, fig. 30

Lagena laureata Heron-Allen and Earland, 1932, p. 382, pl. XI, figs. 37-40.
Lagena orbignyana (Sequenza), McKnight, p. 116, pl. VIII, fig. 86.

This seems to be the same foraminifer that McKnight called *L. orbignyana* (Sequenza). It more closely resembles *L. laureata.* It is rare at all stations. Its maximum frequency was .16 in sample 61-186.

Lagena melo (d'Orbigny)

Oolina melo d'Orbigny, 1839, p. 19.
Lagena melo Heron-Allen and Earland, 1932, p. 370, pl. X, fig. 25-27; Parr, 1950, p. 303; McKnight, 1962, p. 115, pl. 16, fig. 83.

This species was observed in two samples, both in less than 274 meters of water.

Lagena orbignyana form A Pl. 17, fig. 32

This species was observed in sample 61-278 from the Amundsen Sea at a depth of 1,765 meters.

Lagena orbignyana form B Pl. 17, fig. 33

One specimen was observed in the Amundsen Sea sample 61-291 from a depth of 2,685 meters.

Lagena pseudocatenulata Chapman and Parr Pl. 17, fig. 34

Lagena catenulata Reuss (*non Entosolenia squamosa* var. *catenulata* Williamson), 1863, p. 332, pl. VI, figs. 75, 76; Heron-Allen and Earland, 1922, p. 152, pl. V, figs. 16-18.
Lagena pseudocatenulata Chapman and Parr, 1937, p. 65, pl. VII, fig. 6.

Four specimens of this species were observed in one sample from the eastern Ross Sea.

Lagena striata (d'Orbigny) Pl. 17, fig. 31

Oolina striata d'Orbigny, 1839, p. 21, pl. V, fig. 12.
Lagena vulgaris var. *substriata* Williamson, 1858, p. 7, fig. 14.
Lagena striata Brady, 1884, p. 460, pl. LVII, figs. 19, 22, 24, 28.

This species is represented by two specimens from two samples. One of these samples (61-311) was from a depth of 3,150 meters; the other (61-186) from 265 meters.

Lagena subacuticosta Parr

Lagena sulcata Parker and Jones, 1865, p. 351.
Lagena acuticosta Brady, 1884, p. 464; Wiesner, 1931, p. 117.
Lagena subacuticosta Parr, 1950, p. 302, pl. VIII, fig. 3; McKnight, 1962, p. 116, pl. 16, fig. 89.
Lagena apiopleura Loeblich and Tappan, 1953, p. 59.

This species is widespread. Parr reported it from the Antarctic, Kerguelen Islands, Macquarie Island, and Tasmania. McKnight reported it from the Ross Sea, Weddell Sea, and off Queen Maud Land. In the present study, it was observed in samples from the eastern Ross Sea near Guest Island.

Oolina apiculata Reuss Pl. 17, fig. 35

Oolina apiculata Reuss, 1851, p. 22, pl. 2, fig. 1; Barker, 1960, p. 115, pl. LVI, figs. 15, 16.
Lagena apiculata (Reuss), Reuss, 1862, p. 319, pl. i, figs. 4-8, 10, 11; Brady, 1884, p. 453, pl. LVI, figs. 15, 16; Earland, 1934, p. 142, pl. VI, fig. 36; McKnight, 1962, p. 113, pl. 15, fig. 71.

The author has followed Barker in using the original nomenclature for this species. It was observed in three samples, all from less than 274 meters in the eastern Ross Sea.

Oolina globosa (Montagu) Pl. 17, fig. 36

Vermiculum globosum Montagu, 1803, p. 523.
Lagena globosa (Montagu), Brady, 1884, p. 452, pl. LVI, fig. 2; McKnight, 1962, p. 114, pl. 16, fig. 80.
Oolina globosa (Montagu), Parr, 1950, p. 302; Barker, 1960, pl. 56, fig. 2.

This species was found to a depth of 3,150 meters. It was found in seven samples. It was most abundant in sample 61-278 with a foraminiferal number of 4.16.

Fissurina sp. A Pl. 17, figs. 38a, b

This form was observed in the Amundsen Sea sample 61-291.

Fissurina alveolata (Brady) Pl. 17, figs. 40a, b

Lagena alveolata Brady, 1884, p. 487, pl. LX, figs. 30, 32; Earland, 1934, p. 141.
Fissurina alveolata (Brady), Parr, 1950, p. 307.

Parr's classification of the lagenid Foraminifera is used in this study.

Fissurina kerguelenensis Parr Pl. 17, fig. 37

Lagena staphyllearia Brady, 1884, p. 474, pl. LIX, figs. 8-11.
Fissurina kerguelenensis Parr, 1950, p. 305, pl. VIII, fig. 7; Green, 1960, p. 75; Wagner, 1962, Table 1.
Entosolenia kerguelenensis (Parr), McKnight, 1962, p. 121, pl. 19, fig. 116.

This species is widespread throughout both the Arctic and Antarctic. Green and Wagner both reported it from the Arctic. Parr and McKnight reported it from the Antarctic. It was represented in cores from the eastern Ross Sea and Amundsen Sea in the present study.

Fissurina cf. **F. trigonomarginata** (Parker and Jones) Pl. 17, figs. 41a, b

Lagena trigono-marginata Parker and Jones, 1865, p. 348, pl. XVIII, figs. 1a, b; Brady, 1884, p. 482, pl. LXI, figs. 12, 13; McKnight, 1962, p. 113, pl. 15, figs. 69a, b.

This species is similar to that figured by Brady and McKnight. This specimen is not so inflated as Brady's but similar to McKnight's. This one specimen was found in sample 61-140 at 210 meters.

Family **POLYMORPHINIDAE**

Subfamily **POLYMORPHININAE**

Glandulina antarctica Parr

Glandulina rotundata Wiesner, 1931, p. 115.
Glandulina laevigata Wiesner, 1931, p. 115.
Glandulina antarctica Parr, 1950, p. 334, pl. XII, fig. 8, 9a, b; McKnight, 1962, p. 117, pl. 17, fig. 92a, b.

This species is represented by one specimen from sample 61-166 (30 cm.) in the eastern Ross Sea.

Family **NONIONIDAE**

Nonion sp. A Pl. 17, figs. 42a, b

This species resembles *Atrononion,* but the supplementary chambers are missing. The sutures are limbate over the central part of each specimen and may be mistaken for chambers. The last chamber has an extension or flap over the umbilicus. The species was found in four samples but was never abundant.

Nonion germanicus (Ehrenberg)

Nonionina germanicum Ehrenberg, 1840, p. 23, pl. 2, fig. 1.
Nonion germanicum (Ehrenberg), Cushman, 1939, p. 22, pl. V, figs. 31, 32.
Nonion germanicus (Ehrenberg), Parr, 1950, p. 370; McKnight, 1962, p. 118, pl. 17, figs. 97a, b.

The depth range for this species was between 210 and 1,765 meters. The depth range given by Parr was between 193 and 1,718 meters. Parr reported it rare at each station it was observed and McKnight reported it to have a frequency of 8.3 at one station. The highest frequency in this study was 4.16.

Nonionella sp. A

This species is similar to McKnight's *Nonionella* sp. A, but it does not have the flattened last chamber.

Nonionella bradii (Chapman)

Nonionina (?) *scapha* Brady, 1884, p. 730, pl. CIX, fig. 6.
Nonionina scapha var. *bradii* Chapman, 1916, p. 71, pl. V, fig. 42.
Nonionella bradii Chapman, Parr, 1950, p. 371; McKnight, 1962, p. 118, pl. 17, figs. 99a, b.

This species was found to be more common in depths less than 274 meters. All the specimens were from the eastern Ross Sea.

Family **BULIMINIDAE**

Subfamily **TURRILININAE**

Robertina wiesneri Parr Pl. 17, figs. 39a, b

Robertina wiesneri Parr, 1950, p. 369, pl. XV, fig. 9a, b.

This species compares well with Parr's description. It has fewer whorls and larger chambers than *R. arctica.* In this study, it was found to be rare at a depth of 274 meters in one sample. Parr's station depths are comparable.

Bulimina gibba Fornasini

Bulimina elegans Brady, 1884, p. 398, pl. L, fig. 1-4.
Bulimina gibba Fornasini, 1901, p. 378; McKnight, 1962, p. 119, pl. 18, fig. 105.
Bulimina fusiformis Fornasini, 1901, p. 377.
Bulimina baccata Cushman and Parker, 1940, p. 14, pl. 3, figs. 1-6.

Specimens were found at 1,765 meters and 410 meters.

Bulimina marginata d'Orbigny Pl. 17, fig. 43

Bulimina marginata d'Orbigny, 1826, p. 269; Höglund, 1947, p. 227, pl. 20, figs. 1, 2; pl. 22, fig. 1; text-fig. 205-218.
Bulimina aculeata d'Orbigny, 1826, p. 269, pl. 11, fig. 128; Brady, 1884, p. 406, pl. LI, fig. 7-9; Parr, 1950, p. 337; McKnight, 1962, p. 119, pl. 18, fig. 104.

The author followed Höglund in his belief that *B. aculeata* is one of many "varieties" of *B. marginata.* Some specimens are spinose and others have few spines. The arrangement of the spines follows no set pattern on any single specimen. On one whorl the spines may be arranged neatly around the lower periphery, but in the next whorl the spines would be at all angles. This species had an abundance of 12.5 at station 61-278 at a depth of 1,765 meters.

Subfamily **CASSIDELLINAE**

Cassidella davisi (Chapman and Parr)

Virgulina schreibersiana Brady, 1884, p. 414, pl. 52, figs. 1, 2.
Virgulina davisi Chapman and Parr, 1937, p. 88, pl. VIII, fig. 15; McKnight, 1962, p. 122, pl. 19, fig. 122.
Cassidella davisi (Chapman and Parr), Thalmann, 1955, p. 875.

According to Bandy and Kolpack (1963), the genus *Virgulina* d'Orbigny, 1826, is a homonym, having been used by Bory de Saint Vincent in 1823 for a trematode worm. *Cassidella* Thalmann, 1952 is the first available name for this foraminifer.

Bolivina pseudoplicata Heron-Allen and Earland Pl. 18, figs. 44a, b

Bolivina plicata Brady, 1870, p. 302, pl. xii, figs. 7a, b.
Bolivina pseudo-plicata Heron-Allen and Earland, 1930, p. 81, pl. iii, figs. 36-40; Heron-Allen and Earland, 1932, p. 355, pl. IX, figs. 9-11.
Bolivina plicatella Cushman, 1930, p. 46, pl. viii, fig. 10.

This distinctive species was found in three samples. It was abundant in sample 61-278 with a foraminiferal number of 125.

Subfamily **UVIGERININAE**

Uvigerina asperula Czjzek Pl. 18, fig. 51

Uvigerina asperula Czjzek, 1848, p. 146, pl. xiii, figs. 14, 15; Cushman, 1910, 1911, 1913, p. 101, pl. xliii, fig. I; Barker, 1960, p. 156, pl. LXXV.

This spinose form is distributed at all depths. It was present in eight samples and had a foraminiferal number of 8.86 in sample 61-311.

Uvigerina brunnensis Karrer Pl. 18, fig. 53

Uvigerina brunnensis Karrer, 1877, p. 385, pl. 166, fig. 49.

This species had a foraminiferal number of 4.4 at station 61-291 at a depth of 2,685 meters.

Angulogerina angulosa (Williamson) Pl. 18, fig. 48

Uvigerina angulosa Williamson, 1858, p. 67, pl. V, fig. 140.
Angulogerina angulosa Cushman, 1927, p. 69, pl. xiv, fig. 22.

This species was common in many of the more shallow samples. It was also common in the surface sample 61-278, although in the next sample, 30 centimeters below, it is rare. It is suspected that the surface sample contains forms washed from the shelf.

Angulogerina angulosa asperrima Chapman and Parr Pl. 18, fig. 52

Angulogerina angulosa (Williamson), var. *asperrima* Chapman and Parr, 1937, p. 97, pl. VIII, fig. 20.

This spinose form of *A. angulosa* was restricted to samples with depths of 265 to 274 meters. All of these samples were in the same general area off Guest Island. Chapman and Parr found this species in 328 fathoms (approximately 600 meters).

Angulogerina earlandi Parr

Uvigerina angulosa Heron-Allen and Earland (*non* Williamson), 1932, p. 397, pl. xii, figs. 32-39.
Angulogerina angulosa Chapman and Parr (*non Uvigerina angulosa* Williamson), 1937, p. 97.
Angulogerina earlandi Parr, 1950, p. 341, pl. XII, fig. 21; McKnight, 1962, p. 123, pl. 20, fig. 125a, b.

This species was found in six samples of the Deep Freeze 61 material. In none was it abundant. It is more abundant in four samples that had a depth range of 210 to 274 meters.

Family **ELLIPSOIDINIDAE**

Ellipsolagena cucullata Chapman and Parr Pl. 18, fig. 46

Ellipsolagena cucullata Chapman and Parr, 1937, p. 98, pl. VIII, figs. 21a, b.

One specimen from sample 61-291 represents this species. Chapman and Parr reported the species from a depth of 220 fathoms (approximately 400 meters). In this study, the species was found at 2,685 meters.

Parafissurina dorbignyana (Wiesner)

Lagena orbignyana Chapman, 1916, p. 66, pl. IV, fig. 29.
Ellipsolagena dorbignyana Wiesner, 1931, p. 127, pl. XXIV, fig. P.
Parafissurina valida Parr, 1950, p. 320, pl. X, fig. 21.
Parafissurina dorbignyana (Wiesner), McKnight, 1962, p. 124, pl. 20, fig. 127.

My specimen closely resembles Wiesner's figure.

Parafissurina lata (Wiesner) Pl. 18, fig. 45

Ellipsolagena lata Wiesner, 1931, p. 126, pl. XXIV, stereo-figs. k, 1.
Parafissurina lata (Wiesner), Parr, 1950, p. 315, pl. IX, fig. 17.

This species is represented in four samples, all from the eastern Ross Sea.

Parafissurina subcarinata Parr

Parafissurina subcarinata Parr, 1950, p. 318, pl. X, fig. 9a-c; McKnight, 1962, p. 124, pl. 20, fig. 129.

In the Deep Freeze 61 samples, this species shows a depth range of 265 to 1,765 meters as compared to McKnight's range of 365 to 2,620 meters.

Family **ROTALIIDAE**

Subfamily **DISCORBINAE**

Patellina corrugata Williamson

Patellina corrugata Williamson, 1858, p. 46, pl. 3, figs. 86-89; Heron-Allen and Earland, 1932, p. 406; Chapman and Parr, 1937, p. 102; Barker, 1960, p. 178; McKnight, 1962, p. 124, pl. 20, fig. 131a, b.
Patellina antarctica Parr, 1950, p. 352, pl. XIII, figs. 19-21.

My specimens compare closely with those of McKnight on file with the Geology Department at Florida State University. My specimens do not have the "thin, wide, marginal keel" of Parr's species.

Gyroidina neosoldanii Brotzen

Rotalia soldanii Brady, 1884, p. 706, pl. CVII, fig. 6, 7; Earland, 1934, p. 189.
Gyroidina neosoldanii Brotzen, 1936, p. 158; McKnight, 1962, p. 125, pl. 21, fig. 135a, b, c.
Gyroidina soldanii Parr, 1950, p. 360.

I have followed McKnight in using Brotzen's specific name here although my specimens are somewhat smaller than McKnight's.

Subfamily **ROTALIINAE**

Eponides tener (Brady)

Truncatulina tenera Brady, 1884, p. 665, pl. XCV, fig. 11.
Eponides tenera Cushman, 1954, p. 359; McKnight, 1962, p. 126, pl. 21, fig. 136a, b.
Pseudoeponides tenera Parker, 1954, p. 530.

This species is restricted to a depth range of 1,765 to 3,545 meters in the Deep Freeze 61 material in the Amundsen Sea.

Eponides weddellensis Earland

Eponides weddellensis Earland, 1936, p. 57, fig. 65-67; McKnight, 1962, p. 126, pl. 21, figs. 137a, b.

Although found in several samples at different depths, this species seems to be more abundant in two depth ranges. The first is between 460 and 2,100 meters; the second between 1,765 and 3,150 meters.

Family **CASSIDULINIDAE**

Subfamily **CASSIDULININAE**

Cassidulina carinata Silvestri ? Pl. 18, figs. 50a, b

Cassidulina laevigata var. *carinata* Silvestri, 1896, p. 104.
Cassidulina carinata Silvestri ?, Barker, 1960, p. 110, pl. LIV, figs. 2,3.

The Deep Freeze 61 specimens have distinct chambers but do not have the large keel Silvestri's figures show, otherwise they are closely similar to Silvestri's and Brady's figures. They ranged in depth from 210 to 1,134 meters.

Cassidulina crassa d'Orbigny

Cassidulina crassa d'Orbigny, 1839, p. 56, pl. 7, fig. 18-20; Wiesner, 1931, p. 131, pl. XXI, fig. 259; Heron-Allen and Earland, 1932, p. 357, pl. IX, figs. 26-33; Parr, 1950, p. 343; McKnight, 1962, p. 126, pl. 21, fig. 138.

My specimens are similar to McKnight's although the range in size is large in the Deep Freeze 61 material. Four of five samples are from depths less than 410 meters. The species has a foraminiferal number of 5.19 in sample 61-186.

Cassidulina subglobosa Brady

Cassidulina subglobosa Brady, 1879, (1881), p. 60; Brady, 1884, p. 430, pl. LIV, fig. 17; Heron-Allen and Earland, 1932, p. 359.

This species is close to *C. islandica* Norvang except for the last chamber. The last chamber of *C. islandica* seems to be higher, making it stand out farther in a side view. The Deep Freeze 61 specimens have low last chambers and are small. The specimens had a depth range of 210 to 3,545 meters, but they were most abundant at approximately 300 and 1,700 meters.

Cassidulinoides parkerianus (Brady)

Cassidulina parkerianus Brady, 1884, p. 432, pl. LIV, figs. 11-16; Heron-Allen and Earland, 1932, p. 359, pl. IX, figs. 22-25.
Cassidulinoides parkerianus (Brady), Thalmann, 1932, p. 302; Parr, 1950, p. 344, pl. XII, fig. 25; McKnight, 1962, p. 127, pl. 22, fig. 141.

Most abundant in sample 61-154, this species proved to be rare in the Deep Freeze 61 material. All specimens were found in cores taken from the eastern Ross Sea.

Epistominella exigua (Brady) Pl. 18, figs. 47a, b

Pulvinulina exigua Brady, 1884, p. 696, pl. CIII, figs. 13-14.
Epistominella exigua Husezima and Maruhasi, Parker, 1954, p. 533.

This species was present in 14 Deep Freeze 61 samples. Five of these were from the eastern Ross Sea. The species was abundant in sample 61-278 with a foraminiferal number of 129. Brady found this species to exceed 1,000 fathoms (1,800 meters) in 25 to 34 stations. McKnight did not observe this species in the Deep Freeze IV material.

Subfamily **EHRENBERGININAE**

Ehrenbergina glabra Heron-Allen and Earland

Ehrenbergina hystrix Brady var. *glabra* Heron-Allen and Earland, 1922, p. 140, pl. V, figs. 1-6; Wiesner, 1931, p. 132, pl. XXII; Earland, 1934, p. 139.
Ehrenbergina glabra Heron-Allen and Earland, Chapman and Parr, 1937, p. 84; Parr, 1950, p. 344; McKnight, 1962, p. 127, pl. 22, fig. 142a, b.

This species is most abundant in the shallower stations. All specimens except one were from samples with depths of less than 460 meters. This agrees well with Uchio's (1960a) findings. McKnight found this species between 165 to 2,620 meters. It is common in four Deep Freeze 61 samples.

Family **CHILOSTOMELLIDAE**

Subfamily **ALLOMORPHINELLINAE**

Pullenia bulloides (d'Orbigny)

Sphaeroidina bulloides d'Orbigny, 1826, p. 267.
Pullenia bulloides (d'Orbigny), Cushman and Todd, 1943, p. 13; Parr, 1950, p. 346; McKnight, 1962, p. 128, pl. 22, figs. 143a, b.

This species is represented in Deep Freeze 61 material by one specimen. It was found at a depth of 3,545 meters. This is deeper than McKnight's or Parr's stations.

Pullenia subcarinata (d'Orbigny)

Nonionina subcarinata d'Orbigny, 1839, p. 28, pl. 5, figs. 23, 24.
Nonionina quinqueloba Reuss, 1851, p. 47, pl. V, fig. 31a, b.
Pullenia quinqueloba Brady, 1884, p. 617, pl. LXXXIV, figs. 14, 15.
Pullenia subcarinata Heron-Allen and Earland, 1932, p. 403, pl. XIII, figs. 14-18; Earland, 1934, p. 179. Parr, 1950, p. 347; McKnight, 1962, p. 128, pl. 22, figs. 144a, b.

Heron-Allen and Earland stated that *P. quinqueloba* (Reuss) must be regarded as a synonym of *P. subcarinata* (d'Orbigny). My specimen is a five-chambered *quinqueloba* type which Heron-Allen and Earland observed occurring with the six-chambered type of D'Orbigny.

Family **GLOBIGERINIDAE**

Subfamily **GLOBIGERININAE**

Globigerina bulloides d'Orbigny

Globigerina bulloides d'Orbigny, 1826, p. 277; Brady, 1884, p. 593, pl. LXXIX, figs. 3-7; Parr, 1950, p. 365; McKnight, 1962, p. 128, pl. 22, figs. 145a, b.

All the specimens of *G. bulloides* in the Deep Freeze 61 samples are small. Bé believed (1960) the specimens identified as *G. bulloides* by many workers in Arctic studies are small forms of *G. pachyderma.* Only specimens with a large aperture are included here. All other are placed with *G. pachyderma.*

Globigerina conglomerata Schwager

Globigerina conglomerata Schwager, 1866, p. 255, pl. VII, fig. 113; Cushman, 1927, p. 172; Parr, 1950, p. 366; Barker, 1960, pl. LXXXI, fig. 1; McKnight, 1962, p. 128, pl. 22, fig. 146a, b; Chapman and Parr, 1937, p. 111.

Globigerina dutertrei Brady (*non* d'Orbigny), 1884, p. 601, pl. LXXXI, figs. 1a-c; Heron-Allen and Earland, 1932, p. 399, pl. XIII, figs. 1-4.

I included *G. dutertrei* under *G. conglomerata* because of their similarity and the fact that the *conglomerata* form was more common in the samples where both were present. It had a frequency of 230 per gram in sample 61-278.

Globigerina pachyderma (Ehrenberg)

Aristerospira pachyderma Ehrenberg, 1873, p. 386, pl. 1, fig. 4.

Globigerina pachyderma (Ehrenberg), Heron-Allen and Earland, 1932, p. 401, pl. XIII, fig. 9-13; Chapman and Parr, 1937, p. 112; Parr, 1950, p. 366; Barker, 1960, pl. CXIV, fig. 19; McKnight, 1962, p. 129, pl. 22, fig. 147a, b.

This common cold-water species was distributed throughout most of the Deep Freeze 61 material. It reached a frequency of 1,136 per gram of sediment in sample 61-278.

Subfamily **ORBULININAE**

Orbulina porosa (Terquem) Pl. 18, fig. 49

Globulina porosa Terquem, 1858, p. 633.

Orbulina liasica Terquem, 1862, p. 432, pl. V, fig. 4.

Orbulina porosa (Terquem), Brady, 1884, p. 611, pl. LXXXI, fig. 27.

This species was reported to be rare by Brady. It was found only in Deep Freeze 61 sample 61-311 at 3,150 meters. This may be a radiolarian.

Family **ANOMALINIDAE**

Subfamily **CIBICIDINAE**

Cibicides refulgens Montfort

Cibicides refulgens Montfort, 1808-10, p. 122; Barker, 1960, pl. XCII, figs. 7-9; McKnight, 1962, p. 129, pl. 23, fig. 150a, b.
Truncatulina refulgens (Montfort), Heron-Allen and Earland, 1922, p. 207.

McKnight said that this species was the most common form of *Cibicides* in the Antarctic area, but in the Deep Freeze 61 material it was found in only four samples, all from the eastern Ross Sea.

Cibicides subhaidingerii Parr

Truncatulina haidingerii Brady, 1884, p. 663, pl. XCV, fig. 7.
Cibicides subhaidingerii Parr, 1950, p. 364, pl. XV, fig. 7; McKnight, 1962, p. 130, pl. 123, fig. 151a, b.

This species had a frequency of 12.5 in sample 61-278. Some of the specimens may have washed down from the shelf.

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APPENDIX

TABLE 1. SAMPLE LOCATIONS

FSU	OCEAN. OFF.	LATITUDE	LONGITUDE	DEPTH(m)
		Ross Sea		
61-001	SI-2	78-08 S	162-51 W	640
30 cm.				
60 cm.				
61-012	SI-3	77-24 S	162-06 W	668
30 cm.				
61-031	SI-4	76-57 S	162-21 W	604
30 cm.				
60 cm.				
61-037	SI-5	76-32 S	162-30 W	460
61-041	SI-6	76-05 S	162-45 W	2561
61-140	SI-31	77-16 S	152-22 W	210
61-142	SI-30	77-00 S	151-48 W	1134

30 cm.				
60 cm.				
61-162	SI-29	76-30 S	151-39 W	274
30 cm.				
61-186	SI-28	75-58 S	151-58 W	265
61-188	SI-27	75-31 S	152-08 W	3402
30 cm.				
60 cm.				
90 cm.				
		Amundsen Sea		
61-278	SI-42	71-30 S	117-10 W	1765
30 cm.				
60 cm.				
61-291	SI-43	70-59 S	116-56 W	2685
30 cm.				
60 cm.				
90 cm.				
61-311	SI-44	70-30 S	116-39 W	3150
30 cm.				
60 cm.				
90 cm.				
61-330	SI-45	70-03 S	116-30 W	3545
30 cm.				
		Bellingshausen Sea		
61-640	SI-67	72-14 S	92-45 W	410
61-661	SI-70	72-41 S	91-55 W	515
61-664	SI-71	71-45 S	92-54 W	410
30 cm.				
60 cm.				

TABLE 2. WATER CHARACTERISTICS

FSU	OCEAN. OFF.	SALINITY, 0/00		TEMPERATURE, C°	
		BOTTOM*	SURFACE	BOTTOM*	SURFACE
		Ross Sea			
61-001	SI-2	34.53	34.28	—1.83	—1.26
61-012	SI-3	34.51	34.30	—1.87	—1.31
61-031	SI-4	34.53	34.26	—1.88	—1.25
61-037	SI-5	34.54	34.27	—1.24	—1.31
61-041	SI-6	34.71	34.26	+0.77	—1.26
61-140	SI-31	34.29	34.11	—1.17	—1.32
61-142	SI-30	34.41	34.19	—1.54	—1.18
61-162	SI-29	34.34	34.28	—1.70	—1.74
61-186	SI-28	34.35	34.03	—1.66	—1.44
61-188	SI-27	34.70	34.00	+0.45	—1.51
		Amundsen Sea			
61-278	SI-42	34.71	34.00	+0.69	—1.63
61-291	SI-43	34.70	33.93	+0.43	—1.70
61-311	SI-44	34.70	33.84	+0.38	—1.60
61-330	SI-45	34.69	33.78	+0.39	—1.77
		Bellingshausen Sea			
61-640	SI-67	34.59	33.12	+0.55	—1.47
61-661	SI-70	34.67	33.48	+0.99	—1.55
61-664	SI-71	34.61	33.71	+0.71	—1.77

*In some cases the temperature and salinity readings are not the actual bottom readings as the floor was not always reached. The data for the bottom salinity and temperature are for the deepest standard depths obtained for that sample.

TABLE 3. FORAMINIFERAL NUMBERS

FSU SAMPLE NO.	TOTAL FORAMINIFERAL NUMBERS	PLANKTONIC FORAMINIFERAL NUMBERS	BENTHONIC FORAMINIFERAL NUMBERS	NUMBER OF SPECIES
Ross Sea				
61-001	20.46	.29	20.17	14
30 cm.	.44	0	.44	2
60 cm.	1.80	.15	1.65	6
61-012	14.16	0	14.16	20
30 cm.	.69	.06	.63	8
61-031	3.66	0	3.66	9
30 cm.	0	0	0	0
60 cm.	0	0	0	0
61-037	12.84	.32	12.52	32
61-041	6.40	0	6.40	13
61-140	44.98	1.66	43.32	28
61-142	10.09	1.88	8.21	21
30 cm.	11.50	9.37	2.13	7
60 cm.	9.01	.80	8.21	15
61-162	32.58	4.56	28.02	31
30 cm.	18.40	5.84	12.56	39
61-186	28.42	2.10	26.32	38
61-188	2.23	0	2.23	6
30 cm.	0	0	.0	0
60 cm.	16.41	16.41	0	1
90 cm.	.24	.24	0	1
Amundsen Sea				
61-278	1871.54	1403.66	467.88	21
30 cm.	5.44	3.85	1.59	6
60 cm.	1.87	1.64	.23	2
61-291	508.40	442.24	66.16	17
30 cm.	22.95	22.45	.50	4
60 cm.	1.19	.89	.30	2
90 cm.	1.65	1.28	.37	5
61-311	702.52	662.02	40.50	10
30 cm.	15.42	15.27	.15	2
60 cm.	.55	.33	.22	3
90 cm.	1.06	.53	.53	3
61-330	1.13	0	1.13	5
30 cm.	.56	.09	.47	4
Bellingshausen Sea				
61-640	26.58	1.29	25.29	19
61-661	23.40	0	23.40	20
61-664	390.32	225.80	164.52	23
30 cm.	.30	.20	.10	2
60 cm.	.60	0	.60	2

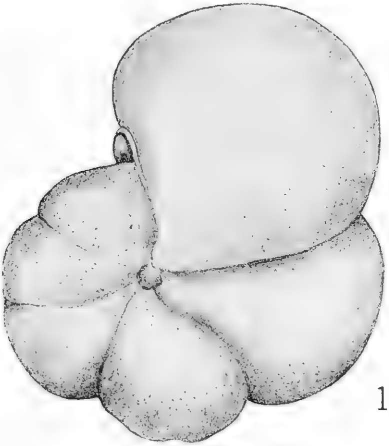
TABLE 4. CORE DESCRIPTION—DEEP FREEZE 61 CORES

DESCRIPTION	USN	FSU	INTERVAL (cm.)
Clay, silty; dark grey	SI-2	001	0-11
Clay, silty; brown			11-41
Clay, sandy with pebbles; brown			41-57
Clay, silty; brown	SI-3	012	0- 7
Clay, silty; mottled black and brown			7-12
Clay, gravelly; brown			12-17
Clay, silty; brown			17-29
Clay, sandy and pebbly; brown			29-38
Clay, silty; dark brown			38-45
Clay, silty; olive	SI-4	031	0- 8
Clay, silty; mottled brown and dark grey			8-18
Sand, clayey; grey			18-31
Clay, silty; grey			31-40
Clay, sandy; brown	SI-5	037	0- 5
Gravel, clayey; brown			5- 8
Clay, sandy; brown			8-10
Clay, silty; mottled grey and black			10-23
Clay, silty; brown	SI-6	041	0-23
Gravel, clayey and sandy; brown	SI-31	140	0-12
Clay, silty; olive	SI-30	142	0-67
Gravel, clayey			67-73
Clay, gravelly; olive	SI-29	162	0- 6
Gravel, clayey; black (bottom 2 cm.)			6-11
Clay, silty; olive			11-19
Clay, gravelly; olive			19-43
Clay, gravelly; mottled olive-dark grey	SI-28	186	0-12.5
Clay, silty; brown	SI-27	188	0-11
Sand; brown			11-13
Clay, silty; brown			13-56
Clay, sandy; yellow brown			56-58
Clay, silty; brown			58-77
Clay, silty; grey			77-104.5
Clay, globigerina ooze; brown	SI-42	278	0- 6
Sand, coarse, (lapillae?); brown and black			6-10
Clay; brown, globigerina ooze, pebbly			10-70
Clay, globigerina ooze with thin sand layers; brown	SI-43	291	0-57
Globigerina ooze, sandy; brown			57-63
Same as top 57 cm.			63-88
Clay, silty; dark grey			88-104
Clay, silty with globigerinas (sand layers at 33, 34, 51, 54 cms.); brown	SI-44	311	0-59
Sand, thin layers of fine grained; and clay, silty; brown			59-65
Clay, silty with fine sand layers at 82, 91, 93.5 cms.; grey-brown			65-96
Clay, silty with globigerina sand layers at 31, 32 cms.; brown	SI-45	330	0-52
Clay, pebbly and sandy; olive	SI-67	640	0-22.5
Sand, clayey and gravelly; olive	SI-70	661	0-15.5
Clay, sandy and gravelly; brown grading down to grey	SI-71	664	0-58

PLATES

EXPLANATION OF PLATE 13

Figure		Page
1.	**Haplophragmoides** sp. A. a. Side view; b. Apertural view; 94 mm. diameter, 54 mm. thick.	173
2.	**Hormosina normani** Brady 1.73 mm. wide, 3.6 mm. long.	172
3.	**Reophax subfusiformis** Earland 1.26 mm. wide, 2.88 mm. long.	171
4.	**Saccorhiza ramosa** (Brady) Tube, 40 mm. wide, 1.88 mm. long	169
5.	**Psammosiphonella discreta** (Brady) .97 mm. wide, 4.14 mm. long	168
6.	**Hyperammina malovensis** Heron-Allen and Earland .25 mm. wide, 1.94 mm. long	169
7.	**Hyperammina elongata** Brady .29 mm. wide, 2.81 mm. long	169



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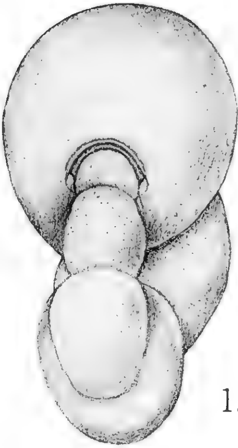

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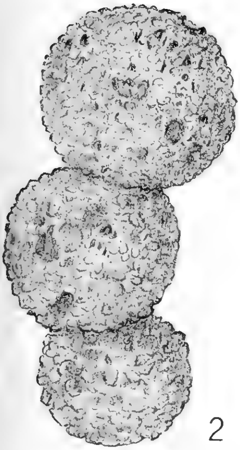

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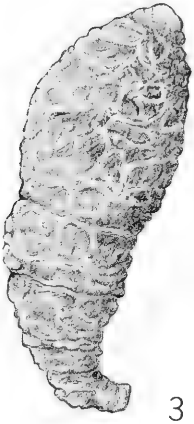

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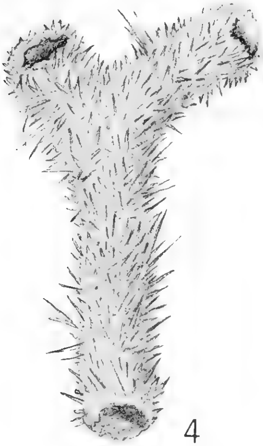

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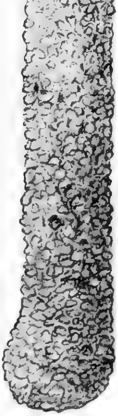

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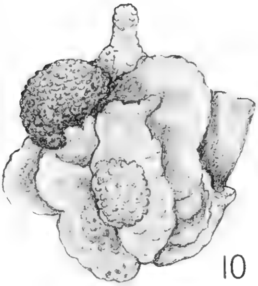

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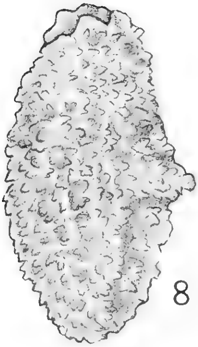

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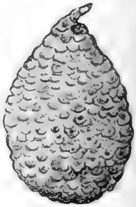

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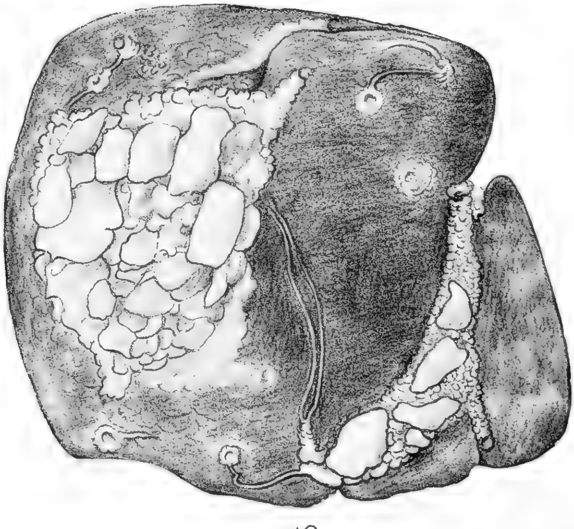

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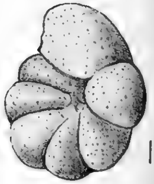

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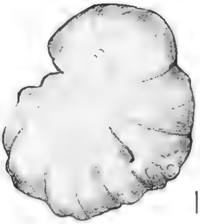

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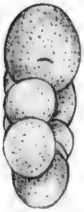

14a

EXPLANATION OF PLATE 14

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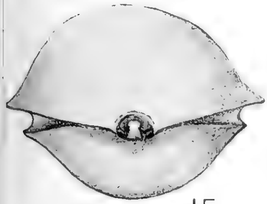
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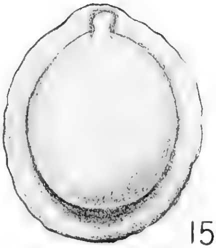
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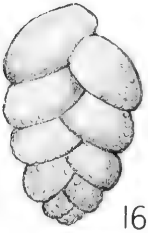
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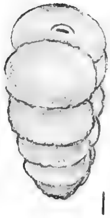
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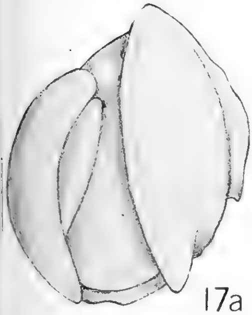
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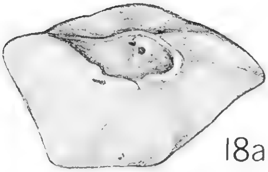
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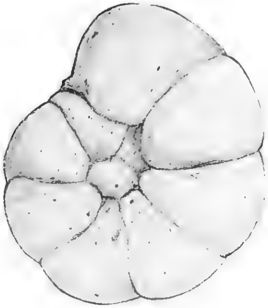
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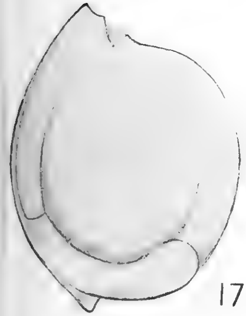
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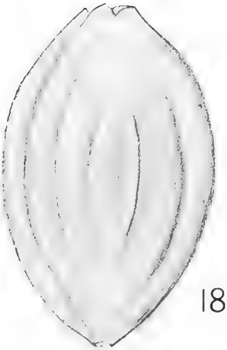
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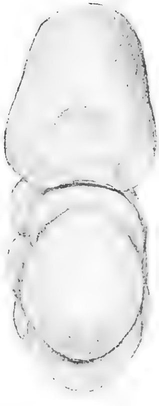
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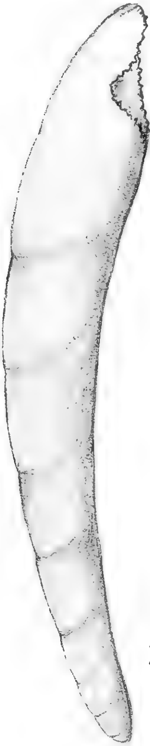

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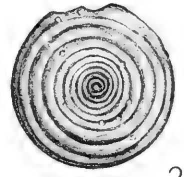

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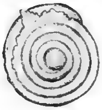

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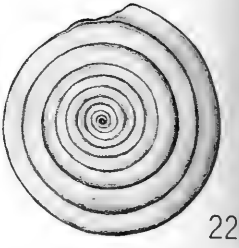

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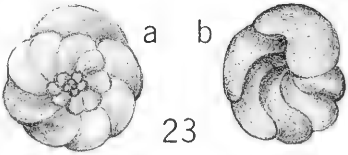

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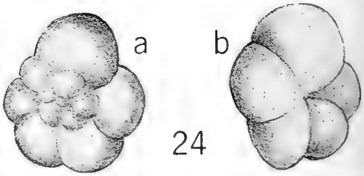

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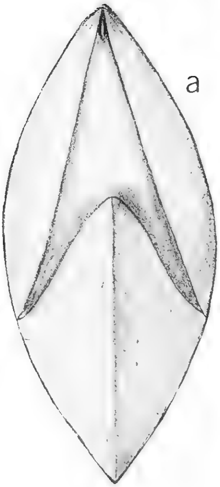
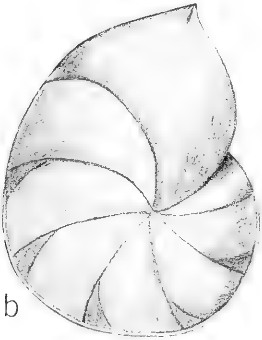

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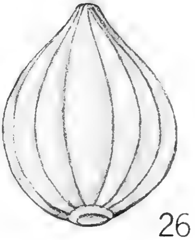

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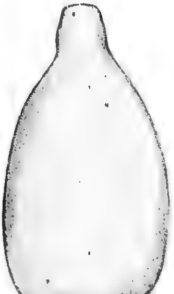

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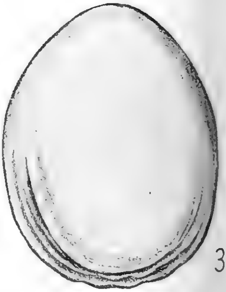

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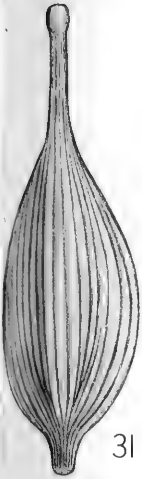

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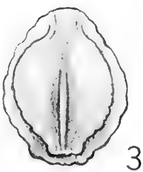

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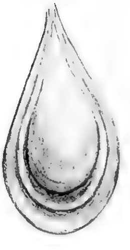

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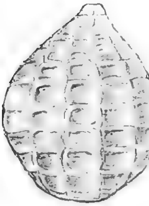

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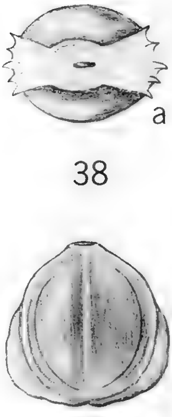

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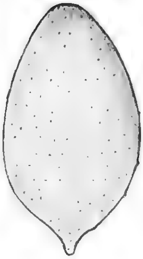

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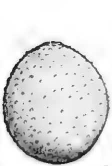

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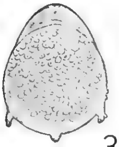

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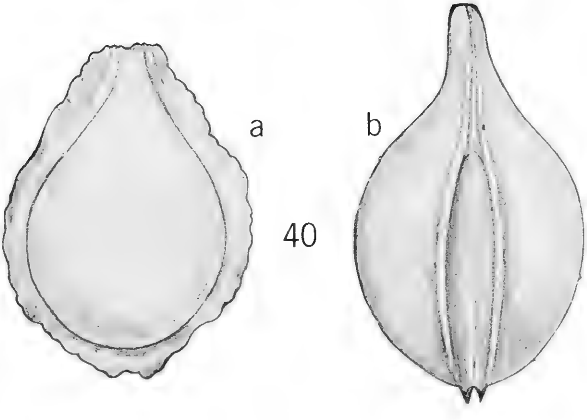

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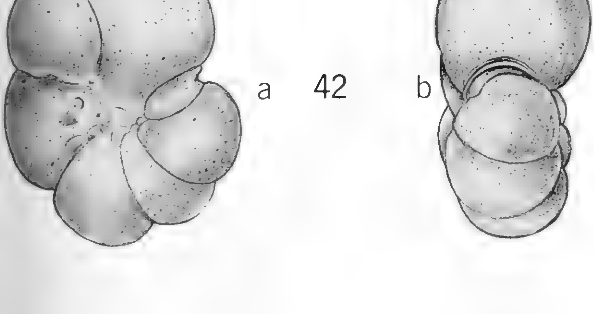

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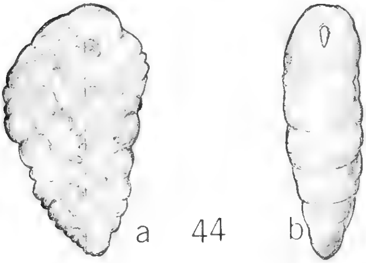

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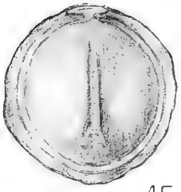
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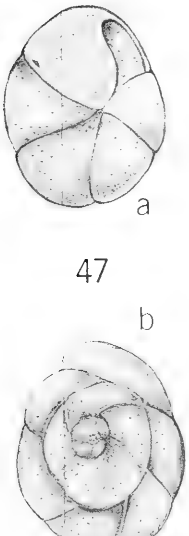

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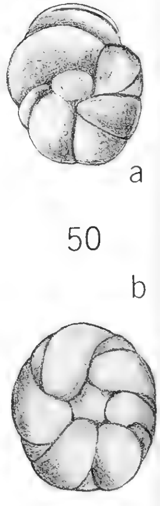

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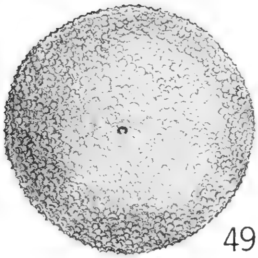
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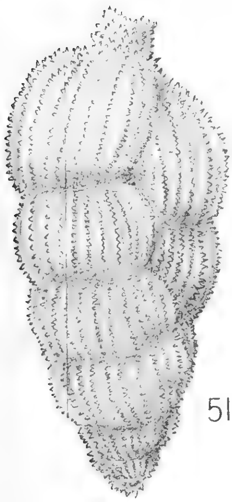
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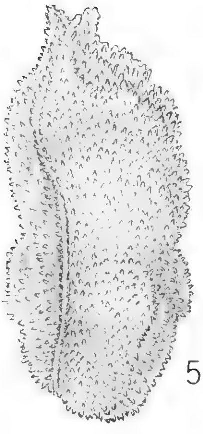
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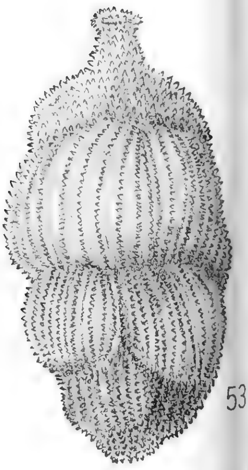
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THE LINNAEAN OLIVES

By

Axel A. Olsson and S. Peter Dance

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THE LINNAEAN OLIVES

Axel A. Olsson[1] and S. Peter Dance[2]

INTRODUCTION

The current identifications of the three Linnaean Olives, assigned originally to *Voluta*, have long been in dispute because of their brief description and confused synonymy cited in both the 10th (1758) and 12th (1767) editions of the *Systema Naturae.* A proper understanding of these species is important, as each species is the type of a group at the generic or subgeneric level, the *Voluta oliva* of the genus *Oliva* itself. The purpose of this note is to establish the identification of these three species through a more critical study of the specimens in the Linnaean collection and the selection of a lectotype for each. As discussed by Hanley (1855), the Linnaean collection of shells did not pass directly into the possession of The Linnean Society of London but remained for some time in the hands of Sir James Smith, the noted botanist, who purchased the collection from Linnaeus's heirs in Sweden. During this period, the zoological part of the collection suffered from neglect while some specimens may have been misplaced and others added. The criteria adopted for the recognition of original or authentic material or its association with other pertinent data will be discussed by the junior author in a separate paper dealing with the whole Linnaean collection. Of primary consideration in the determination of original specimens are the shells marked in ink with the number corresponding to their enumeration in the Systema or in boxes so marked with the provision that the marked specimens fit the species description in the 10th or 12th edition of the Systema with sufficient accuracy.

In both editions of the Systema, Linnaeus often supplemented his description of a species with references to figures in the works of earlier and contemporary authors; illustrations which in many cases depicted shells of more than one species. Reliance on these figures offer a choice of interpretation and, therefore, the only sure guide in the identification of such Linnaean species are the original specimens in the collection and an understanding interpretation of their description in the 10th edition. It should be understood, that the Latin of Linnaeus is that of a botanist, and the meaning of some words and phrases should be translated with that in mind.

---

[1] Honorary Research Associate, Smithsonian Institution; Research Associate, Paleontological Research Institution and of the Academy of Natural Sciences of Philadelphia.

[2] Zoology Department, British Museum (Natural History).

The first review of the shells of Linnaeus was made by Sylvanus Hanley, published in book form in 1855, and bears the title "Ipsa Linnaei Conchylia or Shells of Linnaeus determined from his manuscripts and collection". This work by an eminent conchologist served to establish the identification of most of the Linnaean species but some have remained uncertain for one reason or other. For any worker dealing with Linnaean species, this work of Hanley is indispensable. Of more recent date, the Linnaean mollusks were again reviewed by Henry Dodge in a series of papers published by the American Museum of Natural History in New York. This later work remains incomplete and was based on film and photographs furnished by The Linnean Society and not on any direct examination of the shells by the author.

ACKNOWLEDGMENTS

The senior author is grateful to the authorities of the British Museum (Natural History) for extensive privileges in working with their collections and especially to Mr. N. Tebble in charge of Recent Mollusks, and to Mr. C. P. Nuttall of the Paleontological Department. We are also indebted in this instance to Dr. J. P. E. Morrison of the United States National Museum for help and skill in comparing our photographs of *Oliva oliva* (Linnaeus) with the Recent species of *Oliva* in the National Museum collection. The Linnean Society of London kindly allowed us to examine and photograph the material on which this paper is based.

SYSTEMATICS

(1) **Voluta porphyria** Linnaeus Pl. 19, figs. 1, 1a

1758. Systema Naturae, ed. 10, p. 729, No. 349
1767. " " , ed. 12, p. 1187, No. 398

Concerning this species, Hanley noted that the *Oliva porphyria* and *O. erythrostoma* of Lamarck and later authors are confused in the synonymy of Linnaeus. The figures in Rumphius (1705, 1741) and Regenfuss (1758) are illustrations of *O. erythrostoma:* the figures in Gualtieri (1742) and D'Argenville (1742) of *O. porphyria.* It is well to note that the name "Porphyre" had been given to the Panama Tent Olive long before Linnaeus's time, the shell because of its beautiful markings and size being a marked favorite amongst collectors. The term "Porphyria" is commonly translated to signify a purple color as for instance stated in Favanne's edition of Dezallier d'Argenville (1780, vol. 2, p. 821), "c'est sans doute à ses vives couleurs marron qu'elle doit celui de Porphyre". There is also the possibility that the name was given first in allusion to the tentlike markings bearing a resemblance to the angular outlines of crystals in the polished surface of an igneous rock such as porphyry, graphic granite.[3]

The description of *Voluta porphyria* in the 10th edition of the Systema, although brief and concise, is fully sufficient for an accurate identification of the species. In this description, we have the significant expression, *"labro medio retuso"* which refers to a curious inswing or curvature of the margin of the outer lip so that in a profile view its edge is seen to be slightly concave in its middle section (fig. 1, Pl. 19). This feature of the outer lip of the Panama Tent Olive is especially characteristic and is seen in no other species of the genus. In his mention of this feature, Linnaeus set this species apart from all others, and it further attests to his remarkable gift of observation and close discrimination of characters of importance. To our knowledge, no other author dealing with this species noticed this important differential character. The term *"retuso"* in Linnaeus's description must be translated with its usual meaning in botany as a notch or inflexion in the middle (as a retuse leaf illustrated well by the terminal lobe of the leaf of *Liriodendron*). In the 12th edition the description of *V. porphyria* is further enlarged with the term "in *forma castrorum*" which directly refers to the surface pattern of triangular or peaked markings resembling the tents of an armed camp or fortification.

In Panama, the *Oliva porphyria* is largely restricted to the waters around the Pearl Islands in the Gulf of Panama, although the species has a general distribution throughout the whole of the Panamic-Pacific faunal province from the Galapagos Islands to the Gulf of California. To consolidate the identification of the species we have selected as lectotype the largest of the three specimens segregated by Hanley (1855). We also designate Isla Pedro Gonzales in the Pearl Islands as type locality for the species.

(II) **Voluta oliva** Linnaeus Pl. 19, figs. 2, 2a

1758. Systema Naturae, ed. 10, p. 729, No. 350
1767. " " , ed. 12, p. 1188, No. 399

The tray of *Voluta oliva* has five specimens. Four of them represent the species commonly known as *Oliva maura* Lamarck showing glossy lus-

---

[3] From Webster's Dictionary. "Porphyry, a rock consisting of feldspar crystals embedded in a compact dark red or purple groundmass. It is found in Egypt and was much used by the Romans".

ter and good color; it is assumed that these four specimens are not originals but had been added to the collection before it was acquired by The Linnean Society as suggested by Hanley. The remaining or fourth specimen is marked with the number 350 on the back and is considered as original and as such, we have selected it as the lectotype of *Voluta oliva* Linnaeus. Its description follows: The shell is relatively small for the genus (length 29 mm.), narrowly cylindrical in form and of uniform diameter throughout, except at the ends, the outer lip straight, with no angulation at the shoulder level. Sutures are grooved or channelled and terminate at the aperture in simple, unthickened margins. The color of the surface is a dull white with a few blotches of black in no fixed arrangement. The plaits and lirations along the parietal wall and pillar are similar to those seen on most species of *Oliva.*

The salient characters of the shell are as follows:

1. Its small size as compared to the average in the genus.
2. Its low, conic spire (different from that of *O. maura* which has a depressed or sunken spire).
3. Its simple sutures throughout (again different from *O. maura* in which the sutural margins at the lip termination are raised and thickened).
4. Form and spacing of the pillar plaits (in close agreement with *Oliva ispidula* of authors).
5. White color with a few black blotches following no set pattern.

A careful study of the large series of *Oliva* in the collection of the United States National Museum at Washington, D. C., led to the identification of the Linnaean shell with the small form of *Oliva ispidula* of authors common in the Philippines, and it seems likely that the Linnaean shell came from that general region. For this comparative study, the senior author is indebted to Dr. J. P. E. Morrison of the National Museum for his help and interest in this problem. We, therefore, designate; Zamboanga, Mindanao, Philippines, as the type locality for *Oliva oliva* (Linnaeus).

(III) **Voluta ispidula** Linnaeus Pl. 19, fig. 3

1758. Systema Naturae, ed. 10, p. 730, No. 351
1767. " " , ed. 12, p. 1158, No. 400

In the box of *Voluta ispidula,* there are three specimens which had been glued on the same tablet. The smallest specimens, originally placed on the left side, is a small *Olivella* of unknown affinity; the second or middle specimen is a poorly preserved *Agaronia* (either *testacea* or *hiatula*) ; the third and largest specimen is a fossil *Agaronia* and is marked on the back with the number 351. All three specimens are considered as original; the larger one, marked with the Linnaean number 351, we have selected as the lectotype of *Voluta ispidula* Linnaeus.

The original description of *V. ispidula* in the 10th edition of the *Systema Naturae,* by itself, hardly permits a positive identification of the species, but it does mention *"spira prominente"* which fits the marked specimen. In this connection, Hanley's remarks are worth quoting—"for a fossil, which has much the general aspect of *O. hiatula* (which species has the most prominent spire . . .), but which the late Mr. G. B. Sowerby informed me was the *O. plicaria* of Lamarck, is marked for the species in the collection". Sowerby had, therefore, recognized the marked specimen in the Linnaean collection as the fossil species *O. plicaria.*

Positive identification of the marked specimen depended upon the removal of the glue covering the aperture so that the pillar plaits could be seen. After removal of the glue, the shell was easily identified as *Oliva plicaria* of Lamarck (1811), a common fossil in the Burdigalian Miocene of southwestern France. For assistance in this identification, we wish to thank Mr. C. P. Nuttall. We desiginate, as type locality, Burdigalian Miocene, Saucats, Gironde, France.

SUMMARY

I. *Voluta porphyria* Linnaeus *Oliva porphyria* (Linnaeus)

The original description in the 10th edition, and somewhat further supplemented in the 12th edition, is fully sufficient for a definite identification of *Voluta porphyria* with the Panama Tent Olive along tradional lines. For type locality, we select Isla Pedro Gonzales in the Archipiélago de las Perlas (Pearl Islands) in the Gulf of Panama.

II. *Voluta oliva* Linnaeus *Oliva oliva* (Linnaeus)
(Syn. *Oliva ispidula* of authors not of Linnaeus)

Oliva oliva is the type of the genus *Oliva* Bruguière, 1789, by tautonomy and monotypy. At first a genus without mention of species, established fully by Lamarck, 1799.

The name *Oliva oliva* (Linnaeus) replaces that of *Oliva ispidula* of most authors, not of Linnaeus, a common Indo-Pacific species.

For type locality we select Zamboanga, Mindanao, Philippine Islands.

III. *Voluta ispidula* Linnaeus *Agaronia ispidula* (Linnaeus)
(syn. *Oliva plicaria* Lamarck, 1811) A Miocene fossil.

Ispidula Gray, 1847 becomes a direct synonym of *Agaronia* Gray, 1839.

For type locality we select, Burdigalian Miocene; Saucats, Gironde, France.

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PLATES

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Linnaean Olives

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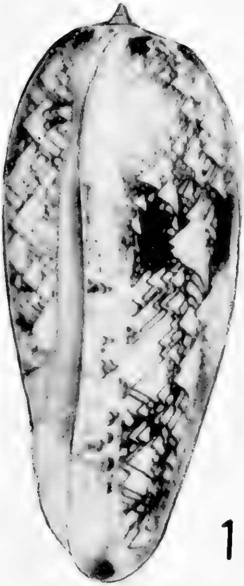
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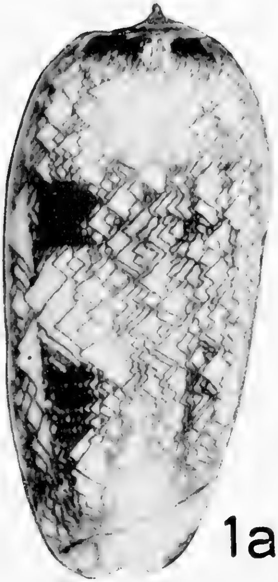
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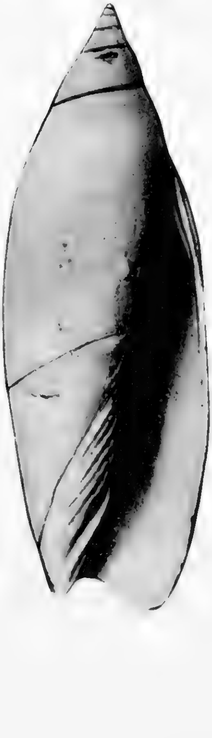
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ADDITIONAL COMMENTS ON THE FORAMINIFERAL GENUS CAMERINA

By

W. Storrs Cole

1966

Paleontological Research Institution
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ADDITIONAL COMMENTS ON THE FORAMINIFERAL GENUS CAMERINA*

W. Storrs Cole
Cornell University

ABSTRACT

Camerina Bruguière, 1792, was suppressed (ICZN, 1945, Op. 192) in favor of its junior synonym *Nummulites* Lamarck, 1801, after 18 years of indecision by the Commission on Zoological Nomenclature. This ruling, based on use and convenience, was unjustified and should not be accepted. Analysis of the pattern and elements of the test of certain camerinids with undivided median chambers demonstrates that these species cannot be assigned to "form" genera with definite stratigraphic ranges but belong to *Camerina* which has a stratigraphic range from Paleocene to Recent (Cole, 1960).

INTRODUCTION

The dictum that the foraminiferal genus *Nummulites* Lamarck, 1801 (type species: *Camerina laevigata* Bruguière, 1792) [=*Camerina* Bruguière, 1792 (type species: *C. laevigata*)] has a stratigraphic range restricted to the lower Tertiary (Paleocene through the Oligocene) occurs frequently in the geologic literature. Gignoux (1955, p. 467), for example, stated, "It is convenient to combine all the lower Tertiary formations in a single group. This Paleogene or Nummulitic system will be characterized first by the presence of *Nummulites,* almost limited to this period. . . ." Thus, the assumption must be made that this foraminiferal genus has been analyzed so completely that it not only can be identified with certainty, but also that there is agreement concerning its stratigraphic range and geographic distribution.

The type species of *Camerina* (=*Nummulites*) is well known, and other species have been recognized which have an external shape and internal structure similar to that of *C. laevigata*. However, there are numerous other species which superficially appear not to conform. Many other generic designations have been proposed for such deviators. Although most of these generic names have been abandoned, a few have gained acceptance. The genus *Operculina* d'Orbigny, 1826, is an example. Carpenter (1862, p. 248) stated, ". . . the difference between *Operculina* and *Nummulina*

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*The cost of the printed plates has been contributed by the Gurley Foundation for Paleontology of the Geological Sciences Department of Cornell University. Grateful acknowledgment is made to Dr. Hans G. Kugler and Dr. L. Hottinger of the Natural History Museum of Basel, Switzerland, for providing me with European specimens (locs. 9, 10, 12, 14-16, 24).

(=*Camerina* of this article) come to rest only on the general form of the spire and the conspicuousness of its convolutions,—characters which seem by no means sufficient for the separation of the former as a genus distinct from the latter."

The genus *Operculinoides* Hanzawa, 1935 (p. 18), type species, *Nummulites* (*Nummulina*) *willcoxi* Heilprin, 1882, was erected for "foraminifera found in North, South, and Central America (which) show peculiar characteristics intermediate between typical *Operculina* and *Camerina* or *Assilina*." Vaughan and Cole (1936, p. 489) accepted *Operculinoides* as did Barker (1939, p. 308). However, Barker wrote, "I am not yet convinced as to the advisability of splitting up the group into so many genera, as in all cases forms can be found intergrading from one so-called genus into another . . . thus leaving much to the discrimination and personal opinion of individual workers."

Mrs. de Cizancourt (1948, p. 11) suggested that *Operculina* and *Operculinoides* should be regarded as subgenera of *Camerina*. Cole (1953, p. 32) retained and defended *Operculina* and *Operculinoides* as valid genera. Smout (1954, p. 76) wrote, "*Operculinoides* (Hanzawa, 1935) is often taken as complanate and partly involute, but the type species, *O. wilcoxi,* is a typical Nummulite."

Later Cole (1959, p. 352) stated, "As there is complete gradation in a single species from *Operculinoides* to *Operculina,* it is apparent that only one genus can be recognized." In 1960 Cole (p. 196) concluded, ". . . there are no structural differences which may be used to distinguish between *Camerina, Planocamerinoides* (=*Assilina* of authors), *Operculina, Operculinoides, Ranikothalia,* and *Paraspiroclypeus.* These genera have been defined in terms of intergradational features which are specific rather than generic differences."

In 1964 in the "Treatise of Invertebrate Paleontology" Cole (p. 644) stated, "In the past, many generic names have been erected for nummulitids with undivided median chambers, based on the assumption that the type of coiling (involute or evolute), the number of coils, height of the coils, shape of the chambers, character of the spiral wall, and strength of the marginal cord are structures of constant nature within groups of species and accordingly useable for defining genera. These structures can be used to distinguish species from one another, even though they vary within limits between specimens of the same species. Thus, the structures mentioned are characteristic of species, not genera."

Hanzawa and Urata (1964, p. 2-4) and Hanzawa (1965, p. 241-242) urged that many of the genera which Cole had placed in the synonymy of *Camerina* be retained as valid. Arni (1963, p. 21-27) on the other hand retained certain of these generic names (*Assilina* and *Operculina*) but reduced others (*Operculinella* and *Ranikothalia*) to subgeneric rank under *Camerina* (=his *Nummulites*). Moreover, Arni (1963, p. 26) introduced another subgenus, *Chordoperculinoides,* as an additional subdivision of *Camerina.*

Van der Vlerk (1955, p. 72) recognized that "One of the most discouraging tasks of a geologist is the reading of papers on systematic paleontology. . . . The cause of his disappointment is the extreme disagreement in viewpoint among different paleontologists." Although camerinids with undivided median chambers can be separated easily from all other kinds of Foraminifera by the basic arrangement of the chambers, the presence of a marginal cord, and the complex canal system, the subdivision of this group into genera, subgenera, and species at the present time is a matter of subjective interpretation.

The question, therefore, is whether it is logical to subdivide camerinids with undivided median chambers into several smaller components (genera and subgenera) by such characteristics as the strength of the marginal cord, the degree of development of the alar projections, involute or evolute coiling, and similar arrangements of the basic elements of the test. If such subdivision is attempted, the definition of each subdivision (genus or subgenus) must be based upon relative or comparative statements as the same basic structures must be used in defining each subdivision.

Any definition in which relative or comparative terminology is used is open to subjective interpretation even by experienced observers. Moreover, there are different opinions concerning the importance of slight modifications of individual structural elements of the test. For example, it has long been accepted that the septal filaments in *Camerina* may be variously arranged (straight and radial, meandrine, reticulate, and otherwise). Hanzawa and Urata (1964, p. 7) stated concerning a new species *"Nummulites" ushi-*

bukensis, "As seen in the transverse sections of this form, its ultimate and penultimate whorls are usually compressed laterally as being seen in the later whorls of *Operculinoides* (refer to Hanzawa 1962, p. 163; Barker, 1939), but the anastomosing septal prolongations never occur in the latter genus so far as the writers are aware."

Must one assume, therefore, that this species would have been assigned to *Operculinoides* if anastomosing septal filaments had not been present? Although anastomosing septal filaments have not been observed in *Camerina willcoxi,* the type of *Operculinoides,* they do occur in the American species *Camerina panamensis* (Pl. 27, fig. 5), a species which consistently has been referred as *Operculinoides.* However, if the criterion used by Hanzawa and Urata (1964, p. 7) for assigning "N." *ushibukensis* to *Camerina* (their *Nummulites*) is used, the American species *"Operculinoides" panamensis* must be transferred to *Camerina.*

Texts (Sigal, 1952, *in* Piveteau, p. 250) list *Assilina* d'Orbigny, 1839, as a valid genus with a stratigraphic range from Paleocene to the upper Eocene. This genus is characterized as being evolute with the septal filaments not continuous across the earlier whorls, and alar prolongations are not developed. Specimens (Pl. 21, figs. 1-4, 6; Pl. 27, fig. 2) from the Miocene and from the Pleistocene (Pl. 22, fig. 7) of the Indo-Pacific region are illustrated (for additional illustrations see: Cole, 1959, pl. 28, figs. 1-11, 15; pl. 29, figs. 3-10, 12, 15; pl. 30, figs. 2-8; pl. 31, figs. 5-7; 1961, pl. 14, figs. 1-17, 20-24; pl. 15, figs. 2-11) which conform to the definition of *Assilina.* Yet, such specimens have been assigned to *Operculinoides* or *Operculina.*

These illustrations point to the fact that the genera of camerinids with undivided chambers have been defined in such a manner that they can not be recognized with certainty. Cole (1960, references pp. 198, 199) after extensive analysis of many species finally concluded that only the genus, *Camerina,* should be recognized.

There are clear admissions in the literature which demonstrate that authors are willing to accept generic names that are defined in relative terms. Drooger (1960, p. 314) in arguing for the retention of *Ranikothalia* wrote, "Cole (1953, p. 10) is perfectly right in stating that the difference between *Ranikothalia* and other nummulitic genera is one of degree. However, though possibly not different by a completely new structure, the absence of a general morphological intergradation between species of the *Ranikothalia* group and those of *Nummulites* and *Operculina* is considered a sufficient basis for generic separation." Cole (1961*b,* p. 380-383) in commenting upon the difficulties of defining genera in relative terms wrote (p. 382), "It is easier to recognize species such as *Camerina catenula* (Cushman and Jarvis) (Cole, 1958*b,* p. 270) than to decide to which genus this species should be referred if multiple generic names for camerinids with undivided median chambers are maintained."

Hanzawa and Urata (1964, p. 4) wrote, "Since Foraminifera, even the larger forms, are protozoa and are much more simple than metazoa in structure, sometimes it is fairly difficult to find any decided gap which defines any systematic taxon in a given group which is presumably of common phylogenetic origin, because all the forms in this group are similar in general structure. . . ." Elsewhere (p. 3) they wrote, ". . . the domain of variability of *Operculina* d'Orbigny is larger than that of *Nummulites* Lamarck. We must never overlook these generic characters given by nature, although it may be sometimes difficult to detect them."

If I interpret Hanzawa and Urata correctly, they admit that camerinids with undivided median chambers have the same structure, but minor variability of structure may be used, however difficult it is to detect, to define genera. If the same structures are present, it is more logical to consider that such structures define a genus, and variation in the structures delimits species.

Genera must be defined on distinct, readily recognizable structures unique to the genus. Species are defined on the variability which may occur in the basic structures, for example, a strongly developed marginal cord versus a weakly developed marginal cord. Specimens within a species may intergrade, and species may intergrade. Genera should be distinct and not intergrade. In other words, each genus must be based on the addition or subtraction of one of the basic structural elements which characterize the genus, for example, the subdivision of the median chambers by chamberlets which characterize *Heterostegina.*

Two genera of camerinids with undivided median chambers in addition to *Camerina* are thought to be valid. The Upper Cretaceous genus *Sulcoperculina* Thalmann, 1938, has a slightly asymmetrical test, and the marginal cord is invaginated and composed of radial plates. The Paleocene genus *Miscellanea* Pfender, 1935, has a coarsely perforate marginal sheet and spiral wall composed of closely spaced pillars. The marginal cord is not sharply differentiated from the spiral sheet.

The specific names of American species used as examples in this discourse have been reviewed by Cole (1958*b;* 1964*b,* p. 141). The specific names of the European specimens have not been analyzed critically, therefore, certain of these may be proven eventually either to be preoccupied or synonyms.

LOCALITIES OF THE FIGURED SPECIMENS

East Indies

Borneo

Locality

1. Djaing Langit, Tabalong District; A. Tobler, collector; through the courtesy of the late T. Wayland Vaughan (references: Douvillé, 1905, p. 448; Cole, 1959, p. 351).
2. Tidoengsche Landen (Seboekoe District) courtesy of the late Mrs. Helen Jeanne Plummer.

Sumatra

3. Pladjoe; courtesy of I. M. van der Vlerk.

Cuba

4. Cut on the Carretera Central under the railroad bridge at Central San Antonio, 2 kilometers west of Madruga, Havana Province (Palmer sta. 757); courtesy of the late Mrs. D. K. Palmer (references: Palmer, 1934, p. 239; Cole, 1953, pl. 3, figs. 8, 11).
5. 2 kilometers south from Km. post 5.5 on the Cardenas-Varadero Road, thence 800 meters northwest to trail, thence 400 meters west, Matanzas Province; courtesy of the late Mrs. D. K. Palmer (references: D. K. Palmer, 1934, p. 261; Cole, 1958*b,* p. 276).

England

6. Bracklesham, Sussex; donated by the late G. D. Harris (reference: Cole, 1953, pl. 2, fig. 10).
7. Alum Bay, Isle of Wight; donated by the late G. D. Harris.

Eniwetok Atoll

8. Bore hole F-1 at a depth of 910-920 feet, cutting sample (reference: Cole, 1957*c*).

France

9. Berdoulou (Gan) near Pau.
10. Cahurt (Ste. Marie de Gosse).
11. Cuise La Motte, near Compiegne; purchased from Ward's Natural Science Establishment.
12. Gibret.
13. Goustouge (Aude); purchased from Ward's Natural Science Establishment.
14. Latone.
15. Mont Cayla (Aude); zone of *Alveolina pasticillata* Schwager.
16. Montéraud; zone of *Alveolina ellipsoidalis* Schwager.

Italy

17. Gravella, second layer from top of hill; courtesy of the late T. Wayland Vaughan.

Panama Canal Zone

18. Second stream northwest of end of Armour Trail, about 60 meters above mouth, Barro Colorado Island; 54*l*, W. P. Woodring, collector, 1954 (references: Cole, 1957*a*; 1964*b*; Woodring, 1958, p. 35).
19. Core hole SL-84, Gatun Lake area, 3.6 miles north-northwest of Frijoles, on the divide between Quebrada Juan Gallegos and Quebrada La Chinilla at a depth of 74 feet; T. F. Thompson, collector (reference: Cole, 1949, p. 269).

Philippine Islands

20. Albatross station D 5142, latitude 6° 06′ 10″ N., longitude 121° 02′ 40″ E., at a depth of 21 fathoms; courtesy of U.S. National Museum (reference: Cole, 1959, p. 361).

Ryukyu Islands

21. Station IS-F 310*a*-56, Ishigaki-shima, Yaeyama-guntō; deposit of gray sandy clay exposed in the north bank of the east branch of the Nagura-gwa about 2.45 miles from the mouth of the river (references: Cole, 1959, p. 356; 1961*a*, p. 118; Foster, 1965, p. A51).

Spain

22. Halfway between Gombreny and Pobla de Lillet.

St. Lucia, Windward Islands, West Indies

23. La Titance, Lavouette (sta. 6138); P. H. Martin-Kaye, collector (reference: Cole, 1961*b*, p. 378).

Switzerland

24. Gufler, strata 4-8.

United States

Florida

25. 4.5 miles west of Williston, Levy County; W. S. Cole, collector (reference: Cole, 1958*b*, p. 273).

Mississippi

26. Road below National Cemetery, Vicksburg; C. W. Cooke, collector (reference: Vaughan and Cole, 1936, p. 491; Cole, 1961*c*, p. 144).

CAMERINA VERSUS NUMMULITES

Cushman (1927, p. 53) in "An outline of a re-classification of the Foraminifera" correctly reinstated *Camerina* Bruguière, 1792, for *Nummulites* Lamarck, 1801. Galloway (1928, p. 47) accepted *Camerina* as a senior synonym of *Nummulites.* In the interval between 1927 and 1945 three widely used texts on the classification of the Foraminifera were published. These were by Cushman (1928) with four revisions, the last of which appeared in 1948, Galloway (1933), and Glaessner (1945). *Camerina* was accepted in all of these texts. Moreover, *Camerina* was used and reestablished by numerous workers among whom may be mentioned Vaughan (1929), Umbgrove (1931), Doornink (1932), Caudri (1934), D. K. Palmer (1934), M. G. Rutten (1935), Gravell and Hanna (1935), and Cole (1941).

Soon after Cushman reestablished *Camerina* Chapman (12 December 1928) submitted to the International Commission on

Zoological Nomenclature a request to suspend the rule of priority on *Camerina.* The subsequent history of the arguments for and against the suspension of the rule of priority is completely and fairly documented by Hemming (1945, Opinion 192). On 2 January 1945, nearly 18 years after priority had been invoked correctly to recognize *Camerina,* this generic name was suppressed in favor of its junior synonym *Nummulites.*

If the International Commission had not been divided on the advisability of conserving *Nummulites* and had acted with promptness, the decision would have been accepted although certain workers might have believed that this particular suspension of the rules was unjustified and unwise. However, after this long interval of indecision in which *Camerina* was used widely, the workers who had followed the basic rule of nomenclature were presented with a *fait accompli* pressured by persons who were more concerned with stratigraphic implications rather than with orderly nomenclature procedures.

Although Vaughan was aware that the decision had been made to suppress *Camerina* in favor of *Nummulites* he stated in his last published article (1945, p. 23) ". . . *Camerina,* of which *Nummulites* is a synonym." Moreover, in a letter (dated 30 September 1947) to me he stated in positive terms his complete opposition to this decision. In 1953 (p. 31, footnote 3) I not only retained the generic name *Camerina* ". . . notwithstanding the recent substitution of *Nummulites* for *Camerina* (see Opinion 192, International Commission on Zoological Nomenclature, 1945) as *Nummulites* is without question a junior synonym of *Camerina,*" but also stated clearly the view of Vaughan.

Cushman wrote me (letter date 30 January 1948) at the time he was preparing the final revision of his text on Foraminifera that he had retained ". . . *Camerina* and Camerinidae in spite of the decision which does not seem to me to be very worthwhile."

Inasmuch as this decision was based entirely on use and convenience, it violated the basic rule of priority. Moreover, by the time the opinion was rendered *Camerina* had been accepted by many workers. Commissioner Cabrera (*in* Hemming, 1945, p. 147) wrote, "If we suspend the rules for *Nummulites,* we open a door for constant transgression of law, as many other names in Palaeontology are in the same position; and if we do so for fossil genera, the same thing must be done for living genera."

Decisions of this kind based upon use and convenience can not anticipate that new data may become available which will completely nullify the "use and convenience" of retaining an obvious junior synonym. Such is the case of *"Nummulites"* inasmuch as this kind of Foraminifera does not characterize the sequence of rocks from the Paleocene through the Oligocene throughout the world. In fact, if the revised definition (Cole, 1960) of this genus is accepted, *Camerina* ranges from Paleocene to Recent.

If the law of priority had not been suspended, *Camerina,* already accepted by many workers in the 18 years which elapsed, would have been recognized generally, and the generic name *Nummulites* with an imprecise stratigraphic connotation would have been submerged. The genus could have been restudied in an objective manner without the pressure to maintain *Nummulites* as a lower Tertiary genus for stratigraphic or historic purposes.

Admittedly, if the generic name *Camerina* is accepted as suggested here, many widely used specific names will have to be changed. I find no objection to this. Nomenclature should be dynamic and subject to change as new concepts are developed. In fact, this would be entirely salutory as a complete review of the species, previously assigned to several "form" or artificial genera, would have to be reviewed. Thereby, some order might be made from the chaos which exists at present.

At the present time errors, oversights, and incorrect interpretations continue to multiply. It is time, in fact long past the time, when consideration should be given to defining genera in such definite terms that these genera can be recognized. Once this is done, nomenclature will be objective, not subjective, as it now is.

ILLUSTRATIONS OF VARIATION IN SPECIES

If a sufficient number of specimens are available from a given locality, the individual tests can be arranged in an intergrading series. Tests at either end of such a series may be so superficially different in appearance that without the intermediate specimens two species could be recognized (Pl. 20, fig. 12, left end). However, with abundant specimens so arranged in a comparative series it is impossible to select any point at which the series may be interrupted.

Cole and Ponton (1930, p. 37) described a species under the name *"Operculinella dia"* from the Marianna limestone (Oligocene) of Florida. This species occurred at its type locality with *Lepidocyclina (Lepidocyclina) mantelli* (Morton). Later, Vaughan and Cole (1936, p. 490) described from the Byram marl (Oligocene) of Mississippi *"Operculinoides vicksburgensis"* which occurred in association with *L. (Lepidocylina) supera* (Conrad).

Thus, *Operculinella dia* and *L. mantelli* were assumed to be distinct species restricted to the Marianna limestone, whereas *Operculinoides vicksburgensis* and *L. supera* were supposed to be characteristic of the Byram marl.

Cole (1957*b*, p. 38) restudied *L. mantelli* and *L. supera* concluding that *L. supera* could not be distinguished from *L. mantelli*, therefore *L. supera* was a junior synonym of *L. mantelli*. In 1958*b* Cole (p. 270) suggested that several species of American Oligocene camerinids should be combined under *Operculinoides dia*. Finally, after additional study of variability in species of *Camerina* Cole (1964*b*, p. 141) concluded that *Operculinoides dia* was in turn a synonym of *Camerina panamensis* (Cushman) (1918, p. 98).

The specimens (Pl. 20, figs. 5, 9) are topotypes of *"Operculinoides vicksburgensis"* similar to the uncut specimen (Pl. 20, fig. 12, first specimen on the left, lower row). These illustrations should be compared with topotypes of *"Operculinella dia"* (Cole, 1964, pl. 14, figs. 1, 11). These two sets of transverse and median sections are identical.

If the specimens (Pl. 20, figs. 4, 6) which are also topotypes of *"Operculinoides vicksburgensis"* and similar to the uncut specimens (Pl. 20, fig. 12, first specimen on the left, upper row) are compared with similar sections of *Operculinoides semmesi* Vaughan and Cole (1936, pl. 37, figs. 10-13), it will be observed that these sets are identical. In addition the specimens (Pl. 20, figs. 4, 6) should be compared with *Operculinoides muiri* Barker (1939, pl. 14, fig. 4; pl. 20, fig. 1; pl. 22, fig. 1; Cole, 1945, pl. 5, figs. 7, 8).

Barker (1939, p. 313) in his comments on *"O. muiri"* stated, "The nearest described species seems to be *O. vicksburgensis*

Vaughan and Cole, but *O. muiri* is considerably thicker than that species . . . and rather more closely coiled." Under the description of Mexican specimens which Barker (1939, p. 318) referred to "*O. vicksburgensis*" he stated, "Occurs generally in association with *O. muiri*." Thus, the association of *O. vicksburgensis* with other supposedly valid species is established at two different localities.

If the specimens (Pl. 20, figs. 3, 7), also topotypes of *O. vicksburgensis* and similar to the uncut specimens (Pl. 20, fig. 12, right end), are compared with the best illustrations (Vaughan and Cole, 1936, pl. 36, figs. 5, 6) accompanying the type description of this species, it will be observed that these specimens are similar.

By selecting three sites in a series of specimens (Pl. 20, fig. 12) from a single locality three species at a minimum can be recognized. All of these specimens have the same fundamental arrangement of the chambers and the same structures. Admittedly, some are larger (Pl. 20, fig. 7) than others (Pl. 20, fig. 8), some are thicker (Pl. 20, fig. 6) than others (Pl. 20, fig. 8), and some are more tightly coiled (Pl. 20, fig. 4), whereas others are more loosely coiled (Pl. 20, figs. 3, 5). All of these, however, are relative and gradational features from specimen to specimen.

Should three or more species separated on relative and comparative intergrading structures be recognized from this single population, or should all of these specimens be assigned to a single species? I recognize only one species.

This decision is based first on the evidence which may be observed by the study of numerous specimens from a given locality arranged in a series, and secondly on the biology of species of Foraminifera. They have both an asexual and sexual mode of propagation. In sexual reproduction gametes fuse to produce the zygotes. The gamets are not necessarily from one individual but may come from different individuals. If one assumes that there are more than one species in a population such as this, then one must assume that the gametes of one species will not unite with those of another species, otherwise each species would not retain its individual characteristics.

In the population under discussion all the specimens are essentially the same. The differences between individual specimens are those of degree, not kind, and if a sufficient number of specimens are analyzed there is complete intergradation. Therefore, it is doubtful if the gametes from one individual would repel those from another. If the gametes from individuals, regardless of the relative differences between these two reproducing individuals, fuse, only one species is present in such a population.

In my opinion this population (Pl. 20, fig. 12) represents one in which cross-fertilization would occur as I can not conceive of gametes from specimens so similar to each other repelling one another. If this occurred, only one species is present as the comparative series (Pl. 20, fig. 12) indicates.

The ecological situation in which populations lived must be evaluated also. One may assume that this population lived under optimum conditions. The tests are numerous, well developed, and run the gamut in size and shape which might be expected in specimens of species with this kind of test development.

Moreover, specimens similar to those illustrated as figures 3, 7, Plate 20, and on the right end of figure 12, Plate 20, are the most abundant. The specimens illustrated on the extreme left end of figure 12, Plate 20, are less abundant.

Under other ecological conditions one might find different frequencies. Thus, the type population of *"Operculinella dia"* is composed largely of thin individuals, none of which attain the maximum diameter of type *"O. vicksburgensis."* The type locality for *"Operculinella dia"* is a limestone, whereas that of *"Operculinoides vicksburgensis"* is a calcareous clay. Cole (1958*a*, p. 191, 195) commented previously upon the influence of ecological conditions on the development of the tests of camerinids, and how varying ecological conditions might produce specimens of the same species which superficially had a different appearance. Ecological variants might, and have been thought, to be distinct species.

Specimens (Pl. 20, figs. 1, 2) from locality 18 (Panama) were identified first as *Operculinoides panamensis* (Cushman) (Cole, 1957*a*, p. 314). These specimens are identical with certain topotypes of *"Operculinoides vicksburgensis"* (compare Pl. 20, figs. 1, 2 with figs. 3, 7). Other specimens (Cole, 1946*b*, pl. 14, figs. 4, 7, 12) from locality 18 (Panama) are similar to topotype specimens of *"Oper-*

culinella dia" and specimens (Pl. 20, figs. 5, 8, 10) from the type locality of *"O." vicksburgensis.*

Cole (1958*b,* p. 263) suggested that *"O." panamensis* and *"O." dia* were distinct species which could be recognized by the degree of recurvature of the chamber walls as viewed in median section. As more thin sections became available, Cole (1964*b,* p. 141) revised this opinion and assigned *"Operculinella dia"* to the synonymy of *Camerina panamensis* (Cushman).

If this analysis is correct, there is only one recognizable species of *Camerina* in the American Oligocene. The numerous specific names which have been given (see: synonymy under *"Operculinoides" dia* in Cole, 1958*b,* p. 270) to specimens of the Oligocene species *C. panamensis* (Cushman) are all synonyms.

The Tertiary to Recent species *Camerina ammonoides* has been analyzed in the same manner (Cole, 1959; 1961*a*). This kind of specific analysis has not been accepted (Smout and Eames, 1969, p. 109). Whereas, Cole recognized one variable species in the populations he analyzed, Smout and Eames decided, at least, four species could be identified.

Two additional specimens (Pl. 21, fig. 6; Pl. 27, fig. 2) are illustrated. One (Pl. 21, fig. 6) is an evolute specimen, the other (Pl. 27, fig. 2) is an involute specimen. Both are without alar prolongations. Other involute specimens from this same sample have marked alar prolongations, and there is complete intergradation from specimen to specimen in the series.

If superficial form is the criterion, three species should be recognized in this population: 1) involute with alar prolongations, 2) involute without alar prolongations, and 3) evolute without alar prolongations. Between these three extremes there are other specimens with intermediate characters, and the entire population from a single sample can be arranged into an intergrading series of individuals.

BASIS FOR DEFINING GENERA

The series concept of analyzing a species by studying the variation of specimens from a single locality at which numerous, well-preserved specimens can be obtained, and then integrating specimens from other localities, into the original series can be useful in developing definitions of genera. In generic analysis as many species as possible from numerous different geographic areas and stratigraphic horizons must be studied. In generic analysis the emphasis is placed on the species arranged in a series rather than upon the individual specimens.

KIND OF COILING

Hanzawa (1965, p. 242) emphasized in defining *Operculinoides* that, "the whorls of this genus are closely coiled in the early growth stage and loosely coiled in the gerontic stage." This kind of development, however, has been used also to define *Operculina* (Pl. 27, fig. 4). If the increase of the height of the chambers of the final volution is one of major criterion by which *Operculinoides* and *Operculina* can be distinguished from *Camerina,* such an increase, if consistent, might be a generic characteristic.

The type species of *Operculinoides, O. willcoxi* (Heilprin) contains individuals in which the chambers do not increase in height (Pl. 27, fig. 1; Cole, 1958*b,* pl. 33, fig. 12), whereas other specimens of this species have the chambers of the final volution increasing in height (Cole, 1958*b,* p. 33, fig. 9). A similar pattern has been observed in *Camerina panamensis* (Cushman) (Pl. 20, figs. 3-5).

Eames, *et al.* (1960, p. 448) recognized *Palaeonummulites* Schubert, 1908, type species *Nummulina pristina* Brady, 1874, as a valid genus of which *Operculinella* Yabe, 1918, and *Operculinoides* Hanzawa, 1935, are synonyms. Cole (1961*b,* p. 378) on the other hand maintained that *Palaeonummulites* was a synonym of *Camerina.* Eames, *et al.* (1962, p. 23, 50) developed in more detail the concept that *Palaeonummulites* was a valid genus and gave excellent illustrations of *Nummulites vascus* (Eames, *et al.,* 1962, pl. 1, figs. A, B) and *Palaeonummulites cumingi* (pl. 1, figs. C, D). Cole (1959, p. 361) considered that *"Amphistegina cumingii"* Carpenter was a synonym of *Camerina venosa* (Fichtel and Moll) and still maintains this position.

Palaeonummulites as defined by Eames, *et al.* (1962, p. 23) included "miniature *Nummulites*-like forms, involute, of small size, with a very small megalospheric nucleoconch, with very little difference in size between the two generations, with or without a tendency to flare in old age. . . ."

Camerina cojimarensis (D. K. Palmer) of the American Miocene has megalospheric specimens with a diameter of 2.7 to 5.5 mm., but the microspheric specimens have diameters from 9 to 12 mm. (Cole, 1961*b*, p. 379), otherwise this species conforms to the definition given of *Palaeonummulites*. To which genus should such a species be assigned? There is a considerable size difference between individuals of the two generations.

Some individuals (Pl. 22, fig. 4) of *C. cojimarensis* are entirely similar in coiling and other arrangements to specimens traditionally assigned to *Camerina*, whereas others (Pl. 22, fig. 5) conform to the pattern of *Operculinella*. This same variation occurs in *Camerina venosa* (Cole, 1959, pl. 29, figs. 1, 2, 11, 13, 14). If a population contained only specimens without the enlarged flange, these specimens could be assigned either to *Camerina* or to *Palaeonummulites*. But, the assignment to *Palaeonummulites* would depend on the occurrence of individuals in a population with a marked flange.

In numerous populations which I have examined, specimens with a marked flange are often rare, whereas specimens without a flange are numerous. *C. willcoxi* normally is without a flange (Pl. 20, fig. 11), but individuals (Pl. 22, fig. 3) occur which have a decided flange. Smout (1954, p. 76) stated, ". . . *O. wilcoxi* is a typical Nummulite." I agree that this species should be assigned to *Camerina*, but as genera are defined at present this species could be as well referred to *Palaeonummulites*.

Hanzawa and Urata (1964, p. 6) named a new species *Nummulites ushibukensis*, stating, ". . . its ultimate and penultimate whorls are usually compressed laterally as being seen in the later whorls of *Operculinoides* . . . but the anastomosing septal prolongations never occur in the latter genus so far as the writers are aware." Anastomosing septal prolongations (Pl. 27, fig. 5) do occur in species such as *Camerina* (formerly *Operculinoides*) *panamensis*.

Doornink (1932, pl. 6, fig. 10) identified specimens as *Nummulites irregularis* Desh. and Schaub (1961, pl. 6, fig. 4) identified specimens as *Nummulites vonderschmitti tenuis* Schaub which are entirely similar in development to "*Operculinoides*" *willcoxi*. Many other examples could be cited.

The question is to which genus should such species be assigned? If they are to be transferred from *Camerina* to *Operculinoides* or *Palaeonummulites,* where does one draw the line and on what criteria? Should some specimens (Pl. 20, fig. 4) be assigned to *Camerina,* and other specimens (Pl. 20, figs. 3, 5) be identified as *Operculinoides*? The only satisfactory answer to such questions is that only one genus *Camerina* should be recognized. I maintain that such characteristics as the increase in the height of the chambers is a specific or even an individual one and can not be used to define a genus.

SIZE

Camerina pengaronensis (Verbeek) from the Tertiary *b* (Eocene) of the Eniwetok drill holes (Cole, 1957*c,* p. 753) has megalospheric individuals with a diameter of 3 to 4 mm., but the microspheric specimens recovered had a diameter of about 6 mm. There is in this species a slighter size difference between specimens of the two generations than in *C. cojimarensis.* The distance across the embryonic chambers of *C. pengaronensis* varies from 230 to 320 μ. This same distance in *C. cojimarensis* varies from 160 to 220 μ. Average specimens of *C. willcoxi* from Florida have embryonic chambers with a diameter of 200 to 250 μ (Cole, 1958*b,* p. 274), well within the range of those of *C. pengaronensis.*

Many other examples could be cited wherein size differences could not be used to define genera. The use of such relative differences has been discussed already in this connection (Cole, 1961*b,* p. 381). As *Palaeonummulites* is defined, many species could be referred either to *Palaeonummulites* or to *Camerina* depending on the viewpoint and interpretation of the worker.

TRANSVERSE SECTIONS

The median sections of *Assilina* (Pl. 23, figs. 3, 4; Pl. 24, fig. 6) are entirely similar to those of *Camerina* (Pl. 23, figs. 6, 7). Detail of the wall of *Assilina* (Pl. 24, figs. 3, 5) is identical to that of *Camerina* (Pl. 24, fig. 4). Thus, *Assilina,* if it is a valid genus, must be distinguished from *Camerina* by other criteria than the characteristics of the median section. *Assilina* has been defined as, ". . . chambers numerous, low, evolute and septal filaments not transgressing upon earlier whorls, but the chamber wall (spiral lamina) may be partly involute; pillars often present.—Paleocene to Upper Eocene" (Glaessner, 1945, p. 175).

Cole (1954, p. 574) described from Tertiary *f* sediments of the Bikini drill holes a species which he named *Operculinoides bikiniensis*. The median sections (Pl. 23, fig. 1; Pl. 27, fig. 7) represent this species but were obtained from the Eniwetok drill holes (Cole, 1957*c*, p. 755). Median sections of specimens from the Bikini drill holes are illustrated by Cole (1954, pl. 204, figs. 21, 22) and are the same.

Median sections of *"O." bikiniensis* (Pl. 23, fig. 1) are entirely similar to those prepared from a well-known European species of *Assilina* (Pl. 23, figs. 3, 4).

Two transverse sections (Cole, 1954, pl. 204, figs. 20, 21) of *"O." bikiniensis* from the Bikini drill holes were given, and several additional sections of specimens were prepared for this article of which three (Pl. 21, figs. 1-4) are illustrated. For comparison on Plate 21 there are transverse sections of *Assilina pustulosa* (figs. 5, 7), *A. placentula* (Pl. 21, fig. 8) and *A. exponens* (figs. 9, 11-13). In addition Miocene specimens of *"Operculina" ammonoides* (Pl. 21, fig. 6; Pl. 27, fig. 2) and an American *Camerina* (Pl. 21, fig. 10) are illustrated. An additional transverse section (Pl. 23, fig. 2) of *A. pustulosa* is shown on another plate.

The transverse sections of *"O." bikiniensis* (Pl. 21, figs. 1-4) have the same arrangement and development as do those of typical European *Assilina* (Pl. 21, figs. 5, 7-13). Therefore, should *Operculinoides bikiniensis* be transferred to the genus *Assilina?* If such an assignment is correct, the stratigraphic range of *Assilina* would extend into the Miocene, at least.

The transverse section of *Camerina* (Pl. 21, fig. 10) shows the alar prolongations extend to the center of the test. The specimens of typical European *Assilina* do not possess these alar prolongations (Pl. 21, figs. 5, 7-13). Therefore, the question may be asked—can *Assilina* be distinguished from *Camerina* by this one characteristic?

Transverse sections of specimens referred to *"Operculina" ammonoides* (Pl. 21, fig. 6; Pl. 27, fig. 2; Cole, 1959, pl. 29, figs. 3-7, 9, 12; 1961*a*, pl. 15, figs. 2-7, 9-11) are similar to specimens traditionally referred to *Operculina* (Pl. 22, figs. 1, 2; Cole, 1961*a*, pl. 16, figs. 2-6) which does not have alar prolongations which extend to the center of the test. However, specimens of *Assilina spira* (Pl. 22, figs. 9, 10) and *A. praespira* also do not have alar prolongations which extend to the center of the test.

Certain species *"Operculinoides" bikiniensis* (Pl. 21, figs. 1-4), *"Assilina" pustulosa* (Pl. 21, figs. 6, 7; Pl. 23, fig. 2), *"A." placentula* (Pl. 21, fig. 8), *"A." exponens* (Pl. 21, figs. 9, 11-13), *"A." leymeriei* (Pl. 25, fig. 2), *"Operculina" ammonoidea* (Pl. 22, fig. 1) and *"Operculina" heberti* (Pl. 22, fig. 2) which lack alar prolongations have the initial whorls covered by the spiral sheet which forms a continuous sequence of layers one upon the other at the center of the test.

In other species certain specimens do not have the spiral sheet continuous to the center of test (Pl. 21, fig. 6; Cole, 1959, pl. 28, fig. 7; Pl. 21, fig. 9). Other specimens from the same samples have the spiral sheet overlapping, at least, the next preceding whorl (Pl. 22, fig. 10).

Thus, the arrangement of the spiral sheet in *"Assilina" spira* (Pl. 22, fig. 9) is similar to that of Miocene and Tertiary specimens referred to *Camerina ammonoides*.

SEPTAL FILAMENTS

Specimens in which the alar prolongations extend to the center of the test normally have septal filaments which are continuous to the center of the test (Pl. 27, fig. 5), whereas specimens in which the alar prolongations are not developed do not have spiral filaments which extend to the center of the test (Pl. 22, figs. 6, 7).

The pattern of the septal filaments and the development of alar prolongations depends on whether the test is involute, partially involute or evolute. In species, such as *Camerina ammonoides*, specimens run the gamut from involute to evolute. All of these specimens are similar in all other aspects, such as the strength of development of the marginal cord, size of embryonic chambers, curvature of chamber wall and the like.

Therefore, the conclusion may be made that the alar prolongations and pattern of the septal filaments are not generic characteristics and in certain cases can not be used even to define a species. These are arrangements which vary with the specimen.

Moreover, if the pattern of the septal filaments were to be used as a generic characteristic, specimens with reticulate septal filaments (Pl. 25, fig. 6), for example, should be referred to a distinct genus, and likewise any other slight modification must become an indicator of a new genus. Use of such critera would indeed result in a multiplication of generic names.

MARGINAL CORD

The marginal cord (Pl. 26; Pl. 27, figs. 3, 6) is a distinct structure of camerinids, but its development is variable. Species traditionally assigned to *Camerina* have marginal cords of variable development (Pl. 21, fig. 10; Pl. 26, fig. 3; Cole, 1953, pl. 2, figs. 8-10). Moreover, the marginal cord often has a difference in strength of development between individuals of the megalospheric and microspheric kinds (Pl. 26, figs. 1, 6; Cole, 1953, pl. 2, fig. 4; pl. 3, figs. 10, 11).

Species which have been assigned to *Assilina* (Pl. 22, figs. 8-10; Pl. 21, figs. 5, 7-9, 11-13; Pl. 26, figs. 2, 4, 5, 7, 8) have marginal cords which are as variable in development as those in species assigned to *Camerina*.

The development of the spiral sheet viewed in transverse sections of certain American species (Cole and Herrick, 1953, pl. 2, figs. 1, 2) is entirely similar to that of certain European specimens (Pl. 22, figs. 8, 9; Pl. 26, figs. 2, 8).

American specimens (Pl. 23, fig. 5; Pl. 24, fig. 1; Vaughan and Cole, 1941, pl. 6, figs. 3, 3a) with a strongly developed marginal cord have a fissured spiral wall. This fissured kind of spiral wall develops in other species, including those still living (Pl. 24, fig. 2), in which the marginal cord is less strongly developed. Other specimens (Pl. 24, figs. 3-5) have spiral walls in which a radial structure is developed. However, species in which some specimens have a fissured spiral wall (Pl. 24, fig. 1) contain other specimens (Cole, 1960, pl. 26, fig. 1) in which the spiral wall shows a pronounced radial structure. Although the spiral wall, viewed in median section, reflects the kind of marginal cord, its appearance depends on the plane of the section as well as the strength of development of the marginal cord.

The genus *Ranikothalia* Caudri, 1944, is based in part on species with a strongly developed marginal cord, a fissured spiral wall, and a coarsely perforated spiral sheet. This genus has been assumed to be restricted to the Paleocene and lower Eocene.

Although the strength and development of the marginal cord is often an excellent specific character, this structural element of the test is too variable to be used as a generic characteristic, thus *Ranikothalia* is defined on elements of the test which characterize species.

LATERAL CHAMBERS VERSUS VACUOLES

The generic name *Paraspiroclypeus,* type species *Camerina chawneri* D. K. Palmer, 1934, was proposed by Hanzawa (1937, p. 116) for species of camerinids with undivided median chambers, but which had ". . . the spiral laminae . . . subdivided into several layers so as to leave some empty spaces between them, the interspaces being subdivided into chambers by anastomosing vertical partitions." Hanzawa (1937, p. 117) stated, "The subdivision of the interspaces between layers of spiral laminae into chamberlets reminds us of those of the genus *Spiroclypeus.*"

Cole (1958*b,* p. 276, pl. 34, figs. 1, 5, 8, 10, 11) prepared and published additional illustrations of *Camerina chawneri.* Later, Cole (1960, p. 189) concluded "*Paraspiroclypeus* with vacuoles in the spiral wall as its distinguishing structure is not a valid genus. The vacuoles are a specific characteristic, not a generic one." Hanzawa and Urata (1964, p. 3) restated that the structure in the specimens ". . . differs from vacuoles. . . . and consist of vermicular chambers."

Two additional preparations (Pl. 25, figs. 7, 10) of *Camerina chawneri* were prepared, and a restudy was made of other preparations (Pl. 25, fig. 1). Specimens which had been identified by Van der Vlerk as *Spiroclypeus leupoldi* were prepared for comparison (Pl. 25, figs. 3, 4). A microspheric specimen (Pl. 25, fig. 9) of *Spiroclypeus* is illustrated for comparison with the microspheric specimen (Pl. 25, fig. 7) of *Camerina chawneri.*

In addition two species of *Camerina* (Pl. 25, figs. 6, 8) are illustrated. Figure 6, Plate 25 illustrates a broken specimen of *Camerina laevigata,* a species with so-called subreticulate septal filaments. These subreticulate septal filaments are well developed on the lower left and upper parts of the specimen. The spiral sheet occupies the central part of the illustration, and the undivided median chambers of a partial whorl appear on the right hand side. The transverse section (Pl. 25, fig. 8) is from a specimen identified as *C. planulata* which has so-called meandrine septal filaments.

Comparison of these illustrations (Pl. 25, figs. 7, 10) demonstrates that the cavities in *Camerina chawneri* are different in arrangement and development. The cavities in *Camerina laevigata* and in *C. planulata* develop between the spiral sheet, not within the spiral sheet which is shown well in the central part of the microspheric specimen (Pl. 25, fig. 7) of *Camerina chawneri.*

The lateral chambers of *Spiroclypeus* are developed similar to those of *Lepidocyclina.* The surface of the test is covered by a sequence of pits with intervening raised ridges. Each of these meshwork surfaces is in turn eventually covered by a calcareous deposit, thus leaving a sequence of cavities which commonly are in alignment as viewed in transverse sections (Pl. 25, fig. 3). During the life of the individual these cavities are occupied by protoplasm and communication is maintained through a sequence of stolons.

Sections (Pl. 25, fig. 4; Cole and Bridge, 1953, pl. 3, fig. 4) of *Spiroclypeus* made parallel to, but above the median plane, always show a regular polygonal meshwork of open areas bounded by intervening narrow walls. In similar sections of *Camerina chawneri* (Pl. 25, fig. 1) there are irregularly spaced pits (the more or less circular spots which have the appearance of small bubbles of air in the upper part of the illustration).

In both the transverse sections (Pl. 25, figs. 7, 10) and the median section (Pl. 25, fig. 1) of *Camerina chawneri* the vacuoles do not have any regularity in alignment, size, or shape. Moreover, these vacuoles are better developed in the outer layers of the spiral sheet, particularly where it is the thickest.

Figure 5, Plate 25 shows a part of the transverse section of *Camerina panamensis.* Several vacuoles are present in the spiral sheet in the central area of this specimen. Although these vacuoles are small and infrequent, they are the same as the more numerous vacuoles in the spiral sheet of *Camerina chawneri.*

Therefore, the conclusion was reached that this kind of opening does not represent lateral chambers as developed in *Spiroclypeus, Lepidocyclina,* and other larger Foraminifera. *Camerina chawneri,* however, can be reasonably assigned to *Camerina* as defined here. The vacuoles, thus, would be considered a specific feature.

Finally, it should be emphasized that microspheric individuals of *Camerina chawneri,* a Cuban Miocene species, may have a diameter of as much as 22.0 mm. The tests are extremely thin and the surface of the test is normally smooth.

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PLATES

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3-10 12. Locality 26 (Oligocene, Mississippi).

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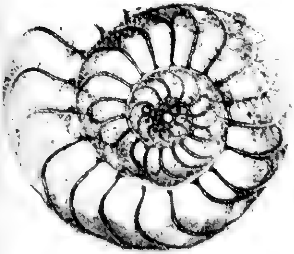
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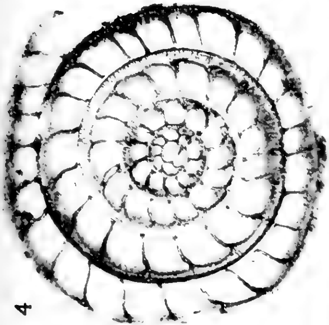
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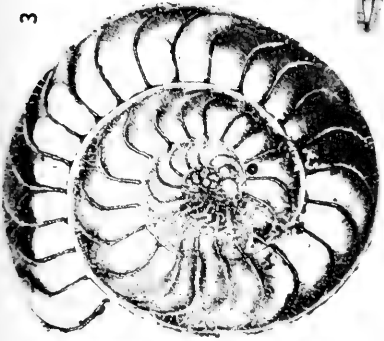
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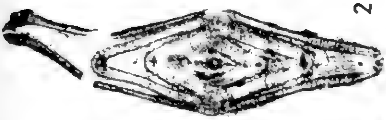
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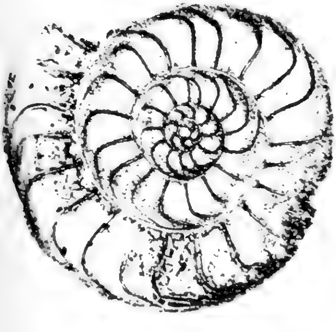
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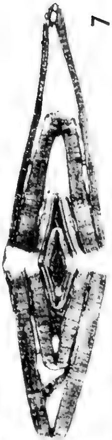
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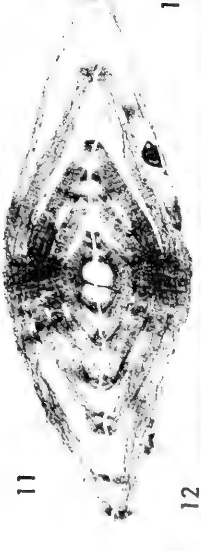
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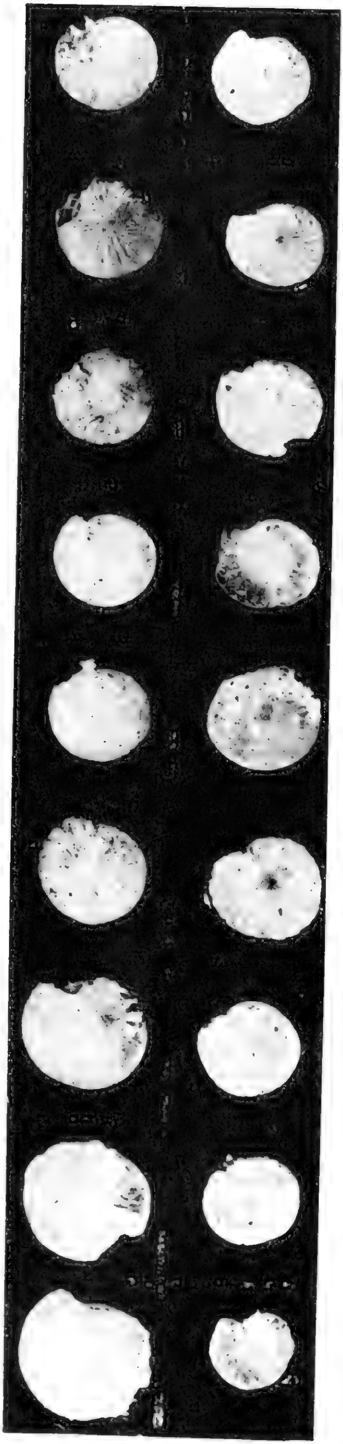
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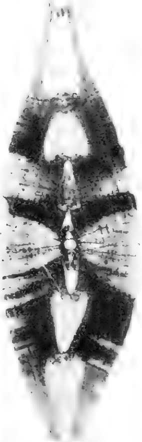
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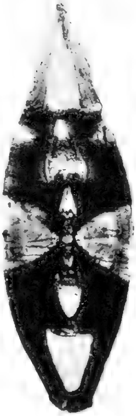
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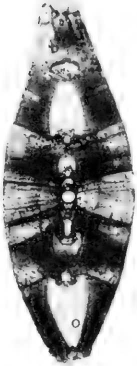
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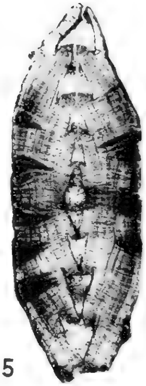
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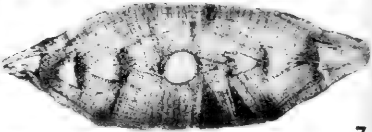
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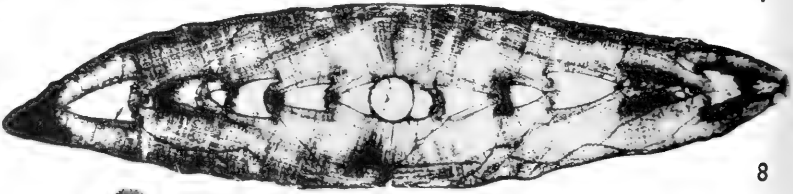
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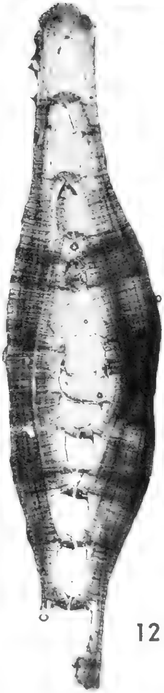
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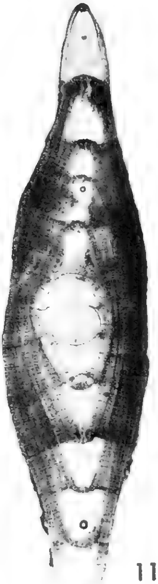
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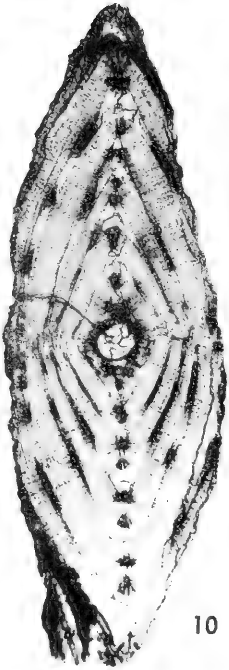
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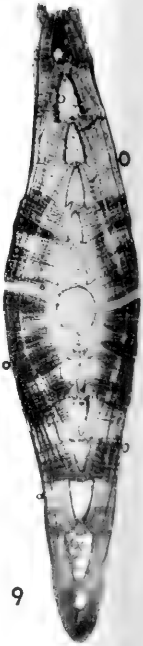
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EXPLANATION OF PLATE 21

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9, 13. Locality 10 (Middle Eocene, France).
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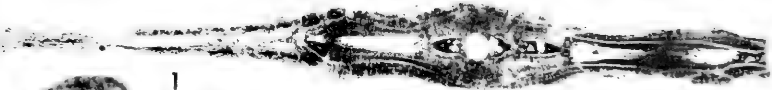
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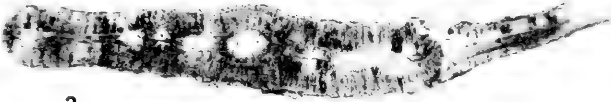
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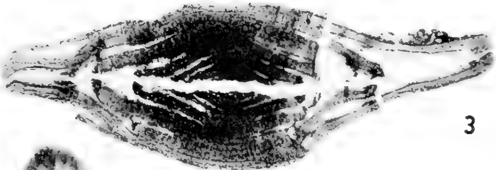
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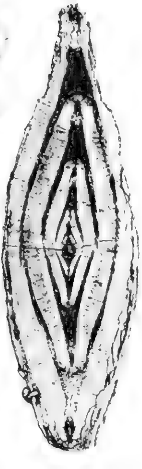
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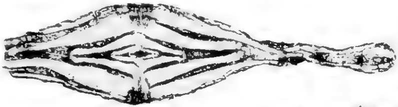
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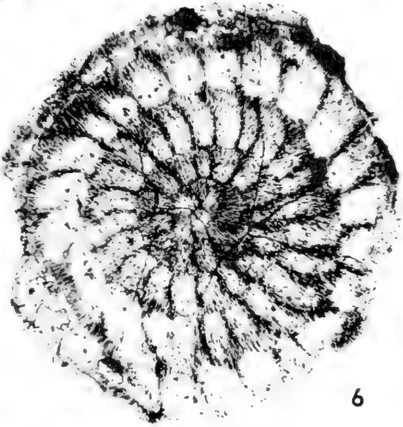
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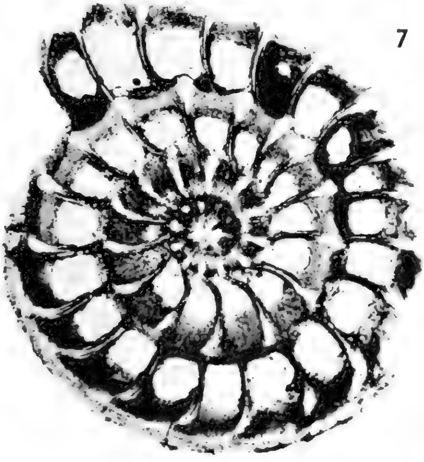
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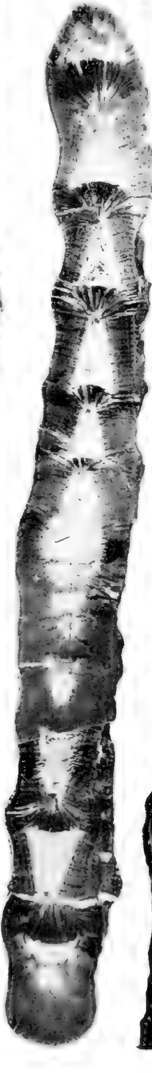
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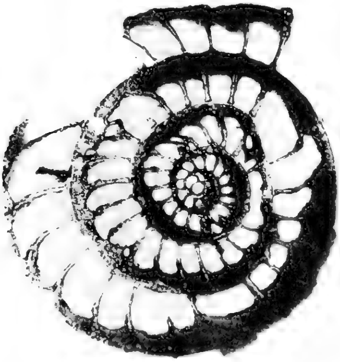

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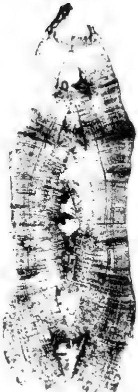

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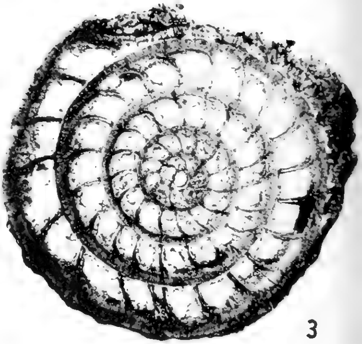

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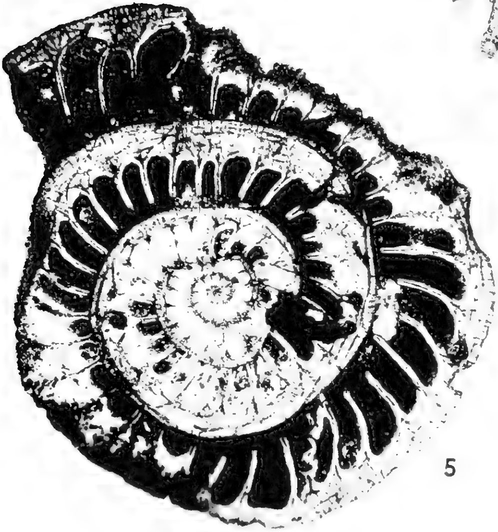

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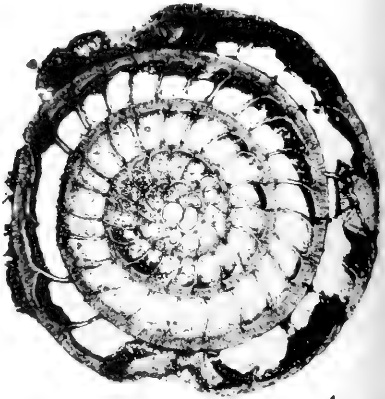

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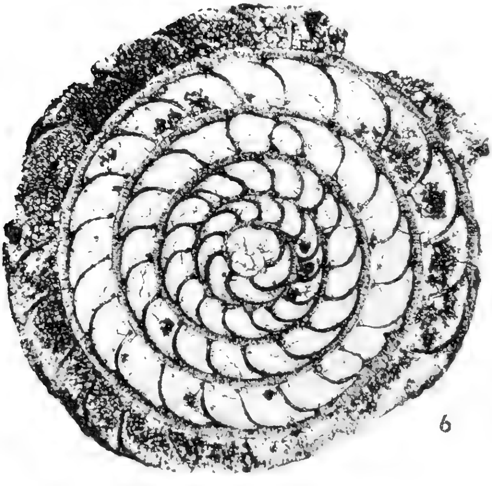

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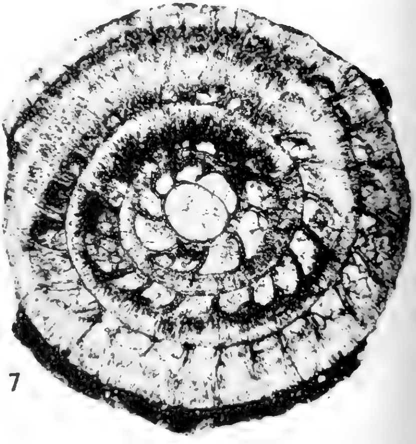

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5.	**Camerina catenula** (Cushman and Jarvis) Median section of a microspheric specimen; topotype of *"Operculina bermudezi"* D. K. Palmer.	248
6.	**Camerina striatoreticula** (L. Rutten) Median section.	245
7.	**Camerina atacica** (Leymerie)	245

1. Locality 8 (Tertiary *f*, Eniwetok atoll).

2-4. Locality 16 (Paleocene, France)

5. Locality 4 (Paleocene, Cuba).

6. Locality 19 (Upper Eocene, Panama Canal Zone).

7. Locality 13 (Middle Eocene, France).

EXPLANATION OF PLATE 24

All figures, x 40, except 3, x 20, and 6, x 12.5.

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	Part of the median section, Pl. 23, fig. 5, to illustrate detail of the spiral wall.	
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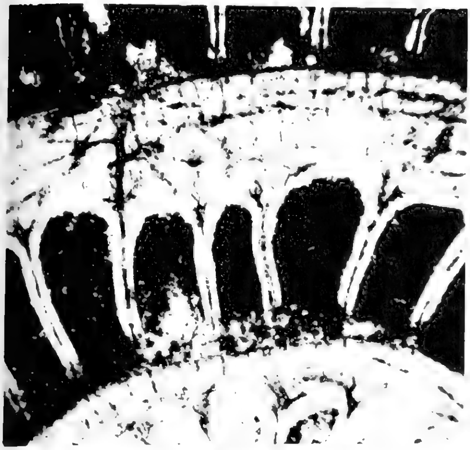
3.	**Camerina spira** (de Roissy)	245, 248
4.	**Camerina atacica** (Leymerie)	245, 248
	Part of the median section, Pl. 23, fig. 7.	
5, 6.	**Camerina placentula** (Deshayes)	245, 248
	5. Part of the median section, this Plate, fig. 6, enlarged to illustrate details of the spiral wall.	

1. Locality 4 (Paleocene, Cuba).
2. Locality 20 (Recent, Philippine Islands).
3. Locality 10 (Middle Eocene, France).
4. Locality 13 (Middle Eocene, France).

5, 6. Locality 9 (Lower Eocene, France).



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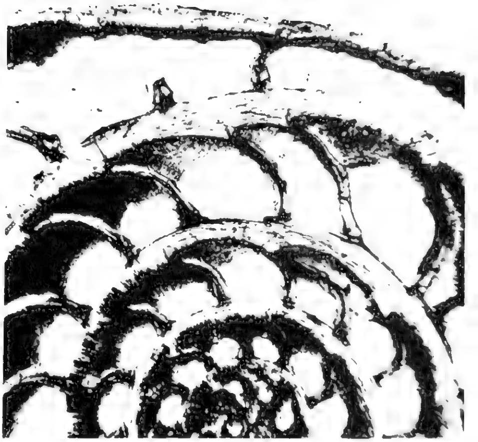

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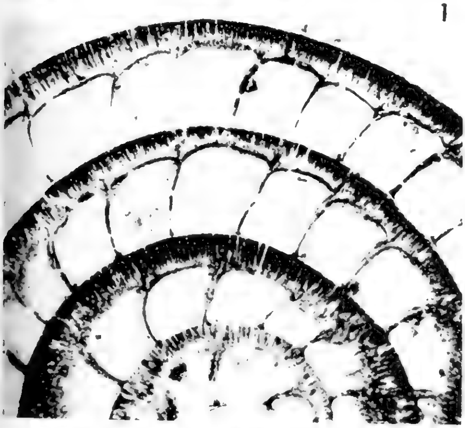

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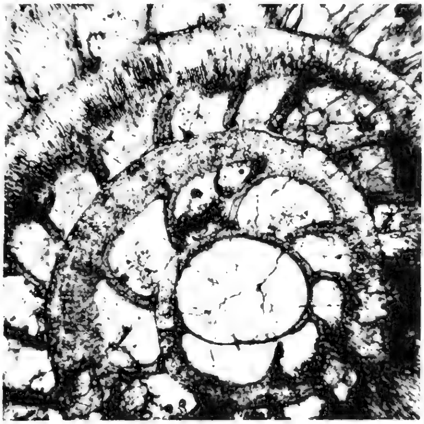

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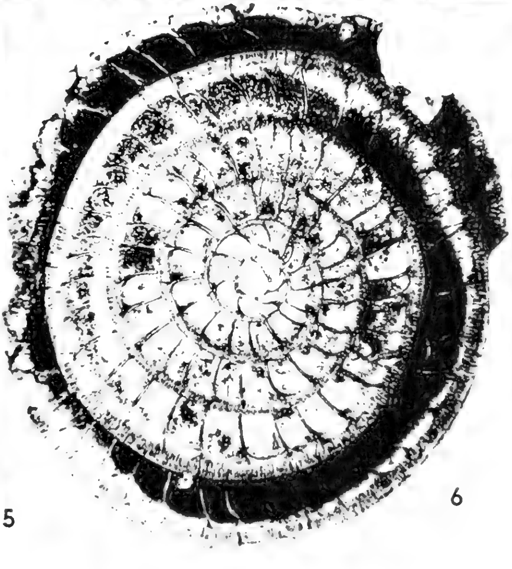

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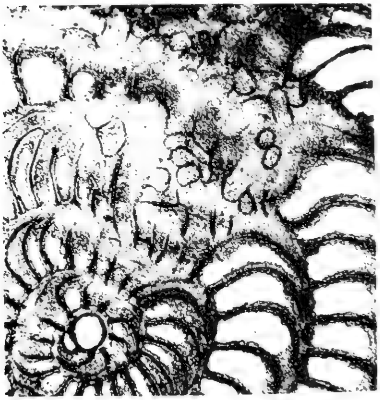

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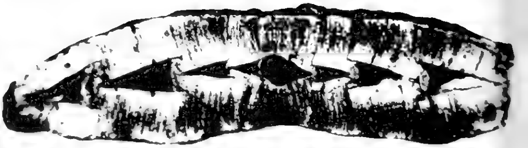

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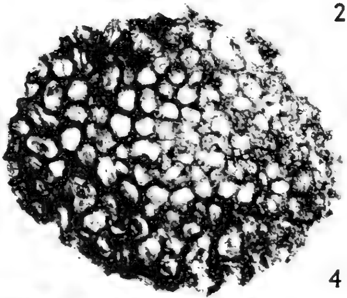

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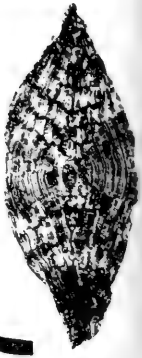

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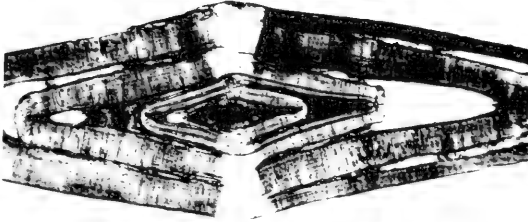

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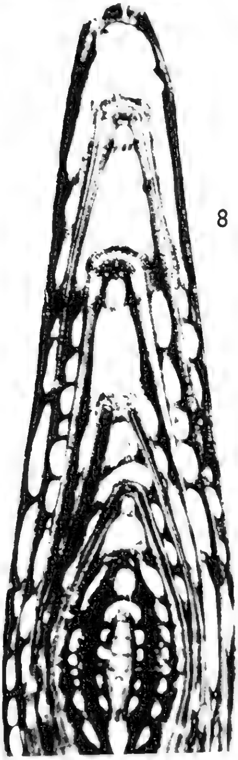

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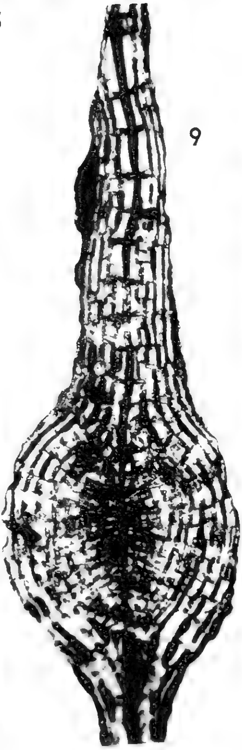

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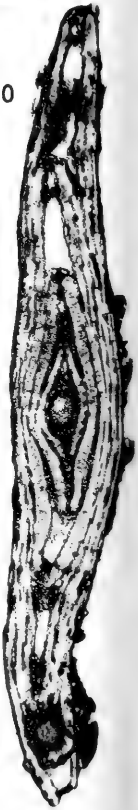

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EXPLANATION OF PLATE 25

All figures, x 20, except 5, x 40, and 6, x 15.

Figure Page

1, 7, 10. **Camerina chawneri** D. K. Palmer 249, 250

1. Part of the median section, pl. 34, figs. 10, 11 (Cole, 1958) to illustrate irregularly developed vacuoles in the wall of the spiral sheet; 7, part of a transverse section of a microscopic specimen to illustrate irregular developed vacuoles in the wall of spiral sheet; 10, transverse section of a megalospheric specimen to illustrate that vacuoles do not occur in the spiral wall of the initial volutions.

2. **Camerina leymeriei** (d'Archiac and Haime) 247

Transverse section.

3, 4. **Spiroclypeus leupoldi** van der Vlerk 249, 250

3. Transverse section to illustrate the lateral chambers arranged in regular tiers; 4, section parallel to, but above the median plane, to illustrate the pattern of the lateral chambers.

5. **Camerina panamensis** (Cushman) 250

Part of the transverse section, Pl. 20, fig. 7, to illustrate the structure of the spiral sheet and the development of small, irregular vacuoles.

6. **Camerina laevigata** Bruguière 248-250

Natural median section to show the spiral sheet (central area), anastomosing septal filaments (lower left and upper part), and the undivided chambers of the median plane (right).

8. **Camerina planulata** (Lamarck) 249

Part of a transverse section of a microspheric specimen with reticulate septal filaments so arranged that lateral chambers seem to be present.

9. **Spiroclypeus leupoldi** van der Vlerk 249

Transverse section of a microspheric specimen with numerous, well-developed lateral chambers.

1, 7, 10. Locality 5 (Miocene, Cuba).
2. Locality 15 (Paleocene, France).
3, 4. Locality 3 (Tertiary *e*, Sumatra).
5. Locality 26 (Oligocene, Mississippi).
6. Locality 7 (Middle Eocene, England).
8. Locality 11 (Lower Eocene, France).
9. Locality 2 (Tertiary *e*, Borneo).

Explanation of Plate 26

All figures, x 40, parts of transverse sections
to illustrate development of the marginal cord.

Figure Page

1, 6. **Camerina catenula** (Cushman and Jarvis) 248

1, 6. See Cole, 1953, pl. 3, fig. 8; pl. 3, fig. 11, for complete transverse sections of these specimens.

2. **Camerina praespira** (H. Douvillé) 248

Same specimen illustrated as fig. 8, Pl. 22.

3. **Camerina variolaria** (Lamarck) 248

See also Cole, 1953, pl. 2, fig. 10.

4. **Camerina placentula** (Deshayes) 248

Compare with fig. 8, pl. 21.

5. **Camerina exponens** (J. de C. Sowerby) 248

Same specimen illustrated as fig. 12, Pl. 21.

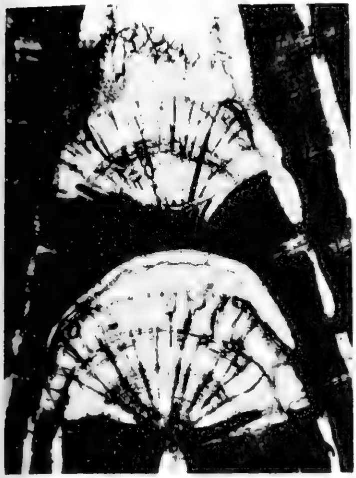
7. **Camerina pustulosa** (Doncieux) 248

Same specimen illustrated as fig. 7, Pl. 21.

8. **Camerina spira** (de Roissy) 248

Same specimen illustrated as fig. 9, Pl. 22.

1. 6. Locality 4 (Paleocene, Cuba).
2. Locality 22 (Middle Eocene, Spain).
3. Locality 6 (Upper Eocene, England).
4. Locality 24 (Lower Eocene, Switzerland).
5. Locality 12 (Middle Eocene, France).
7. Locality 16 (Paleocene, France).
8. Locality 10 (Middle Eocene, France).



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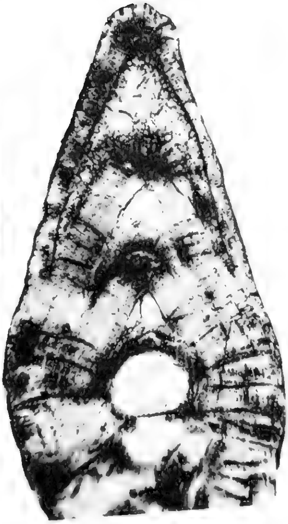

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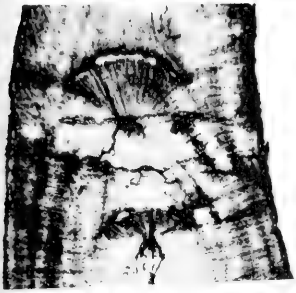

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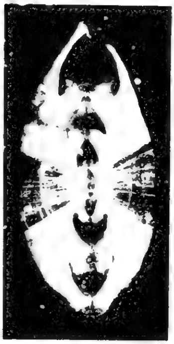

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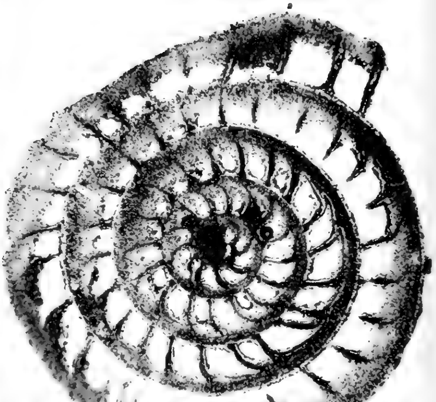

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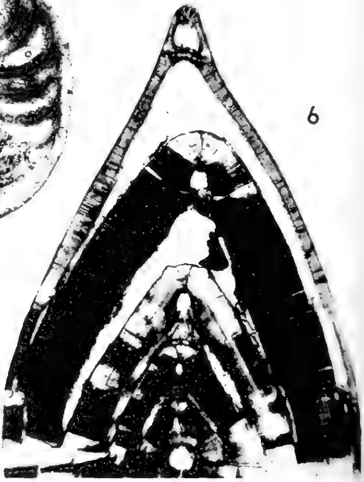

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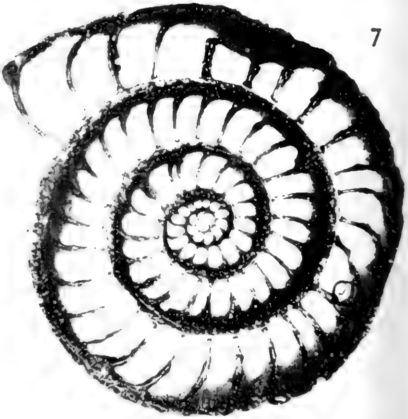

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EXPLANATION OF PLATE 27

Figures 1, 2, 7, x 20; 3, 5, 6, x 40; 4, x 12.5.

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	Median section of specimen whose final chambers do not increase notably in height.	
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3.	**Camerina chawneri** (D. K. Palmer)	248
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4.	**Camerina heberti** (Munier-Chalmas)	243
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5.	**Camerina panamensis** (Cushman)	232, 244, 247
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6.	**Camerina venosa** (Fichtel and Moll)	248
	Part of a transverse section to illustrate the marginal cord.	
7.	**Camerina bikiniensis** (Cole)	246
	Median section in which there is a slight increase in the height of the chambers.	

1. Locality 25 (Upper Eocene, Florida).
2. Locality 1 (Tertiary *c*, Borneo).
3. Locality 5 (Miocene, Cuba).
4. Locality 14 (Paleocene, France).
5. Locality 26 (Oligocene, Mississippi).
6. Locality 20 (Recent, Philippine Islands).
7. Locality 8 (Tertiary *f*, Eniwetok Atoll).

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CONODONTS FROM THE LEXINGTON LIMESTONE (MIDDLE ORDOVICIAN) OF KENTUCKY AND ITS LATERAL EQUIVALENTS IN OHIO AND INDIANA

BY

STIG M. BERGSTRÖM
AND
WALTER C. SWEET

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CONODONTS FROM THE LEXINGTON LIMESTONE (MIDDLE ORDOVICIAN) OF KENTUCKY, AND ITS LATERAL EQUIVALENTS IN OHIO AND INDIANA

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ABSTRACT

Seventy conodont form-species, grouped in 32 single or multielement species of 24 genera, are described from the Lexington limestone of Kentucky and its lateral equivalents in Ohio and Indiana. The distribution of nearly 250,000 conodont elements indicates that the Lexington and its equivalents correlate with the uppermost Rockland, Kirkfield, Shoreham, Denmark, and lower Cobourg of New York and southern Ontario, and with the upper Decorah, Galena, Dubuque, and lower Maquoketa of Iowa and Minnesota.

Lexington limestone sections are compiled by logging vertical fluctuations in relative abundance of *Phragmodus undatus,* which dominates the Lexington interval in Kentucky, Ohio, and Indiana. Comparison of a master log of relative abundance of *Phragmodus undatus* with a similar log showing vertical distribution of this species in Wilderness and Barneveld rocks of New York and Ontario reveals remarkable similarity, and it is concluded that typical Eden strata in Ohio (=Kope formation) are largely Barneveld in age.

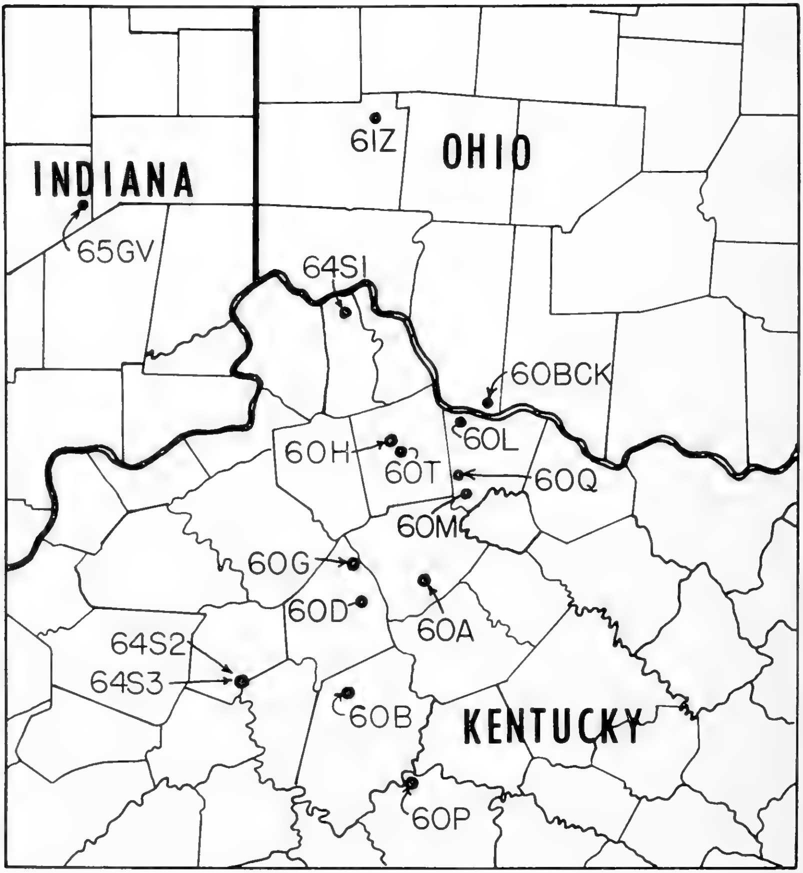
Combination of form-species into multielement species thought to represent a single biologic apparatus sheds new light on evolutionary development in well-known conodont species. One new genus *(Rhodesognathus)* and three new species *(Bryantodina? staufferi, Plectodina? posterocostata, Rhipidognathus discreta)* are described.

INTRODUCTION

This report is the third in a series designed to elucidate the nature, distribution, and stratigraphic significance of conodonts in the Ordovician rocks of southwestern Ohio and adjacent parts of Kentucky and Indiana. In previous reports (Sweet, *et al.,* 1959; Pulse and Sweet, 1960) conodonts were described from the Eden (or Kope), Fairview, and McMillan formations; in this paper, we consider the large and varied faunas of the Lexington limestone, which underlies and is partly equivalent laterally to the Eden (or Kope) and Clays Ferry formations in Kentucky, Ohio, and Indiana.

Our knowledge of Lexington conodonts is based on the study of nearly 250,000 discrete elements, collected from 13 surface sections in Kentucky, one in Ohio, and from two long cores that penetrate the Kope and Lexington formations. One of the latter was drilled just south of Middletown (Butler County) Ohio; the other was drilled near New Point (Decatur County) Indiana. The location of these sections is shown in Text-figure 1; their thickness is given in

Table 1, which also includes information on the number of samples taken at each section. Ten of the 13 Kentucky sections were sampled in September, 1960; the Ohio section and the Middletown core were measured, described, and sampled in 1960 (the latter by Claude C. Rust); the three remaining Kentucky surface sections were described and sampled in June and July of 1964; and the New Point, Indiana, core was processed in the spring and summer of 1965.



Text-fig. 1. Location of Lexington limestone sections yielding the conodonts described in this report. The northern and southernmost sections, 61Z and 60P, are 112 miles apart. Sections are located more precisely in Appendix A.

Table 1.--Sample and Collection Data, Lexington Sections
(See Figure 1 and Appendix A for location of sections)

Section		Thickness (feet)			
No.	Name	Sub-Lex.	Lex.	Supra-Lex.	No. Samples
60A	Cynthiana, Kentucky	---	49.0	---	35
60B	Greendale Sta., Ky.	---	13.5	---	8
60BCK	Bear Creek, Ohio	---	82.0	56.0	49
60D	Rogers Gap, Kentucky	---	---	20.0	12
60G	Sadieville W., Ky.	---	?39.0	?63.0	40
60H	Menzie, Kentucky	---	57.5	---	16
60L	Carntown, Kentucky	---	75.0	43.0	39
60M	Milford, Kentucky	---	17.5	13.5	19
60P	Clays Ferry, Ky.	---	153.0	84.5	129
60Q	Willow Creek, Ky.	---	16.0	---	10
60T	Falmouth, Kentucky	---	73.5	11.5	34
61Z	Middletown Core, O.	57.0	254.0	384.0	202
64S1	Banklick Creek, Ky.	---	36.0	---	11
64S2	Frankfort East, Ky.	10.0	307.0	---	80
64S3	Frankfort West, Ky.	---	95.0	7.0	31
65GV	New Point Core, Ind.	22.0	62.0	865.0	146

The nearly 250,000 conodont elements that form the basis for this report were collected from acid residues of 861 limestone samples. The samples were collected at 2.5 - 3-foot intervals in all 16 sections through the Lexington limestone and overlying rocks. In the laboratory, these samples were crushed, screened, and washed, and 200, 300, or 500 grams of each were digested in 15-percent acetic acid. Insoluble residues were washed through 100-mesh screens to remove clay and silt and were further concentrated magnetically or through differential settling in tetrabromoethane. Conodont elements were picked from most of the concentrated insoluble residues with a wet brush and arrayed on standard micropaleontological slides. In a few concentrated residues, the number of conodont elements was exceptionally large, and we collected only the least abundantly represented forms. All others in these large samples were identified and tabulated but not picked.

ACKNOWLEDGMENTS

During our study of Lexington conodonts we had much help, all of which is gratefully acknowledged. Mr. Claude C. Rust, of The Ohio State University, assisted in sampling sections in Kentucky

and assembled nearly all the collections from the Middletown (Ohio) core. Professor John K. Pope, of Miami University (Ohio), and Dr. Earle Cressman of the U.S. Geological Survey, directed us to Lexington sections in Kentucky and Ohio and provided descriptions of these sections. Dr. Henry H. Gray of the Indiana Geological Survey made the New Point, Indiana, core available to us for study.

Our views on conodont taxonomy have been strengthened and improved through discussions with Dr. T. J. M. Schopf, of the Marine Biological Laboratory, Woods Hole, Massachusetts; Dr. Gerald F. Webers, of the University of Minnesota; and Dr. Maurits Lindström, of Lund University, Sweden. Field and laboratory expenses and costs of the senior author's first year in the United States were largely met by a grant from the Ohio State University Council on Research, and similarly generous grants from the Swedish Research Council and the Royal Physiographic Society of Lund enabled the senior author to spend an additional three months at The Ohio State University in 1964, during which time this report was largely completed.

LITHOSTRATIGRAPHY

In north-central Kentucky and adjacent parts of Ohio (Text-figure 1), the "birdseye" limestone of the Tyrone formation is succeeded by 250-300 feet of limestone and shaly limestone, which, in turn, grades upward and in part laterally into shalier strata of the Clays Ferry and Kope (formerly Eden) formations (Weiss and Sweet, 1964; Black, Cressman, and MacQuown, 1965; Weir and Greene, 1965). For more than 80 years, it has been assumed that the post-Tyrone, pre-Kope succession is entirely Trentonian in age; and, since 1906, this succession has been consistently divided into two formations, a lower Lexington and an upper Cynthiana. There has never been complete agreement as to the content of either formation or about the stratigraphic level of the contact between them, for each formation is a complex of lithic and faunal facies that intertongue laterally and intergrade vertically with one another. Perplexity as to the interrelationship of these facies is plainly expressed in the more than two dozen names that are available for various beds and members in the Lexington-Cynthiana succession, and discussion of these units is hampered by the fact that most of them have never been adequately defined in lithic terms, nor have all of them been traced and mapped.

Members of the U.S. Geological Survey, working in cooperation with the Kentucky Geological Survey, are now engaged in systematic mapping of the Lexington-Cynthiana succession and its lateral equivalents in north-central Kentucky. In connection with this mapping program, rocks in the Lexington-Cynthiana interval have been re-grouped, formation boundaries have been re-defined, and a number of newly named lithic units have been established. This work is current and has recently been reported in detail (Black and MacQuown, 1965; Black, Cressman, and MacQuown, 1965), so we do not attempt to review it here. However, we should note that we agree with U.S. Geological Survey personnel that all the strata between the Tyrone formation and the Clays Ferry or Kope (=Eden) formations represent a single, variable lithostratigraphic unit, for which the name Lexington limestone is freest from positive objection. Consequently, in this report we use the term Lexington limestone (or formation) for all the post-Tyrone, pre-Kope and pre-Clays Ferry carbonates in north-central Kentucky and adjacent Ohio and Indiana. We should emphasize that the Lexington limestone is not a time-stratigraphic unit as Paleozoic formations in the North American Midcontinent have often been assumed to be. Its boundaries are clearly diachronous.

Four long, widely spaced sections (designated 60P, 61Z, 64S2, and 65GV in this report) provide a key to the regional development of the Lexington limestone and its lateral equivalents. These same sections have also served as the bases for establishing a conodont succession in this part of the Ordovician section. Detailed descriptions of all these sections are, or soon will be, available in other places, hence they are not repeated here. A few general remarks about each section are appropriate so that the conodonts described in later pages of this report can be understood in broad stratigraphic context.

Virtually the entire Lexington limestone is exposed under the bridge and in roadcuts along both lanes of Kentucky-U.S. Interstate Highway 64 east of the Kentucky River, in the Frankfort East 7.5-minute quadrangle, Franklin County, Kentucky. This section (64S2 of this report; described on pages C11-C14 of Black, Cressman, and MacQuown, 1965) is no more than a mile north of the Old Crow Distillery section (Miller, 1905), in Woodford County, Kentucky, which has long been considered typical of the Lexington. In these sections, the Lexington consists of about 310 feet of thin- to thick-bedded, mostly medium- to coarse-grained brownish- to yellowish-gray biogenic limestone interbedded with stringers and partings of gray shale and siltstone of greatly subordinate thickness. Most of the limestones are phosphatic, but the phosphate content appears to increase upward in the section. Some intervals, primarily in the upper half of the formation, are prominently cross-bedded, and a unit distinguished by conspicuous convolute bedding (Brannon member of previous workers) occurs about 100 feet below the top of the formation. In these sections, the Lexington is underlain by thick-bedded, gray lithographic limestone of the Tyrone formation, and overlain by interbedded shale and tabular limestone included by U.S. Geological Survey personnel in the Clays Ferry formation. The basal contact, with the subjacent Tyrone, is sharp and distinct, and is probably unconformable; the upper contact, with the Clays Ferry, is clearly gradational.

At Clays Ferry, Madison County, Kentucky, more than 120 feet of Lexington limestone is exposed in a faulted section (60P of this report) immediately south of the Kentucky River. The base of the Lexington is not exposed in this section, but carbonates similar to those of the typical sections in Franklin and Woodford counties are succeeded gradationally by a well-exposed sequence of shale and thin-bedded, micrograined limestone, included in the Clays Ferry formation by U.S. Geological Survey personnel. From regional tracing of these rocks (Black and MacQuown, 1965; Black, Cressman, and MacQuown, 1965) and from the biostratigraphic work summarized in this report, it is clear that at least the lower 40 feet of the Clays Ferry formation in this section is equivalent to the upper 40 feet of the Lexington limestone in its type sections. Our report on Lexington limestone conodonts, as a consequence, includes discussion of the conodonts in the lower 40 feet of the Clays Ferry formation in the Clays Ferry, Kentucky, section.

A 695-foot core, drilled just south of Middletown (Butler County) Ohio, penetrates all of the Kope formation, a complete sequence of strata occupying the interval of the Lexington limestone of Kentucky, and the upper 38 feet of the subjacent Tyrone formation. We have used this long, fossiliferous section (61Z in this report) as the base for compiling information on the sequence of Lexington conodonts, but we do not mean to imply that strata in the Lexington interval are entirely identifiable with those exposed in typical Lexington sections in Kentucky. In the Middletown Core section, the place of the Lexington is occupied by 254 feet of shales and limestones, only the lower 88 feet of which are identifiable lithologically with the typical Lexington. These thick-bedded, pinkish-tan, medium-grained Lexington limestones are succeeded stratigraphically by 20 feet of dark olive-gray calcareous shale and siltstone containing a few 2-inch to 2-foot limestone beds; 67 feet of dark carbonaceous shale containing a few thin gray-brown medium-grained fossiliferous limestones; 25 feet of olive-gray shale with thin hard dark siltstone interbeds; and 54 feet of gray shale interbedded with thin medium-grained sparingly fossiliferous limestones. Rocks in the latter unit grade upward into the thick gray-green calcareous shales and subordinate medium- to coarse-grained limestones of the Kope formation. The hard, dark, silty shales in the Lexington interval of the Middletown Core section have commonly been designated "Utica" by drillers in the eastern Midcontinent, but this term is not appropriate for the entire succession of strata in the Lexington interval. Consequently, in this report we refer to these strata as occupying the "Lexington interval," without intending to imply that they are identifiable with typical Lexington carbonates. Conodonts indicate that these strata and the lower 65 feet of the superjacent Kope formation are the lateral correlatives of the Lexington formation in Franklin and Woodford counties, Kentucky.

A 949-foot core, which penetrates the entire Cincinnatian (Upper Ordovician) section, the complete Lexington interval, and the upper 22 feet of the subjacent Tyrone formation, was drilled by the Indiana Geological Survey near New Point (Decatur County), Indiana. The section penetrated by this core (65GV in this report) is grossly similar to that displayed by the Middletown, Ohio, core, but there are some outstanding differences. Typical Tyrone limestones at the base of the New Point, Indiana, core are succeeded by about 62 feet of coarse-grained, fossil-fragmental limestones identifiable as Lexington; 196 feet of hard, dark, silty, carbonaceous shale of the type commonly identified by drillers as "Utica;" and by about 670 feet of gray-green shale and medium- to coarse-grained biogenic limestone of the several types typical of outcropping Cincinnatian formations. We have thus far been successful in extracting conodonts only from strata below and above the "Utica" in the New Point, Indiana, core. These indicate that the base of the "Lexington interval" is comparable to a point about 54 feet above the base of the same interval in the Middletown, Ohio, core; and that the top of the "Utica" correlates provisionally with a point about 370 feet above the base of the Middletown, Ohio, core. The "Lexington interval" in the New Point, Indiana, core seems to be slightly more than 50 feet thinner than in Franklin and Woodford counties, Kentucky, and Butler County, Ohio, and, except for 62 feet of Lexington-like limestone at the base, apparently consists almost entirely of hard, silty, brownish-gray shale.

From the remarks in preceding paragraphs, it is clear that the upper part of the typical Lexington limestone of Franklin and Woodford counties, Kentucky, is replaced southeastward (towards Clays Ferry, Kentucky) by shalier rocks of the Clays Ferry formation; and that the bulk of the formation grades north and northwestward into hard, dark, carbonaceous "Utica-like" shales and the gray-green shales and subordinate biogenic limestone of the Kope (or Eden) formation. We include collections from all these facies in our report on Lexington limestone conodonts.

THE CONODONT FAUNAS

As indicated in Table 2, we have collected 243,878 discrete conodont elements from the Lexington limestone, its lateral equivalents, and immediately superjacent strata of the Kope and Clays Ferry formations. This large collection of discrete elements is readily divisible into 70 morphologic groups, or form-species, most of which have been adequately described and are well illustrated in recent reports on Ordovician conodont faunas. All of the discrete conodont elements in our Lexington-Kope collection are amber in color, most of them are well preserved, and virtually all of them are specifically identifiable. Many specimens lack the tips of process denticles and processes, and basal funnels and their fillings are rare. We have collected only a few whole representatives of the fragile elements re-

Table 2. The Lexington Conodont Fauna

Species	Constituent Form-Species	Number of Specimens	Percent of Total Collection
Acodus mutatus	Distacodus procerus Acodus mutatus	32 4	0.0147
*Acontiodus alveolaris	Acontiodus alveolaris	2	0.0008
**Amorphognathus ordovicica	Amorphognathus ordovicica Ambalodus triangularis	6074 3922	4.0987
*Belodina compressa	Belodina compressa Eobelodina fornicala	187 44	0.0947
*Belodina sp. cf. B. inornata	Belodina sp. cf. B. inornata	19	0.0078
*Bryantodina? abrupta	Ozarkodina? abrupta prioniodina-like element	279 76	0.1455
Bryantodina? staufferi	bryantodina-like element ozarkodina-like element ?trichonodella-like element	30 16 3	0.0201
*Cyrtoniodus flexuosus	Cordylodus flexuosus prioniodina-like element	9657 500	4.1911
Cyrtoniodus, sp. nov.	Cyrtoniodus, sp. nov.	5	0.0021
*Distacodus falcatus	Distacodus falcatus	17	0.0070
*Drepanodus suberectus	Drepanodus suberectus Oistodus inclinatus Drepanodus homocurvatus	592 973 6106	3.1454
*"Fibrous conodonts"		112	0.0459
**Holodontus superbus	Holodontus superbus	91	0.0373
**Icriodella superba	Icriodella superba Sagittodontus robustus Sagittodontus dentatus Rhynchognathodus divaricatus Rhynchognathodus typicus	2200 1173 248 538 544	1.9284
Oistodus venustus	Oistodus venustus	19	0.0078
*Oulodus oregonia	Cordylodus excavatus Oulodus casteri Prioniodina oregonia	3356 1203 2166	2.7575
*Ozarkodina? obliqua	Prioniodina robusta Ozarkodina obliqua dichognathus-like element	102 48 35	0.0759
*Ozarkodina polita	Ozarkodina polita	6170	2.6268
*Ozarkodina tenuis	Ozarkodina tenuis	7900	3.2393
*Panderodus gracilis	Panderodus compressus Panderodus gracilis	485 1082	0.6425
*Panderodus panderi	Panderodus panderi	44	0.0180
**Periodon grandis	falodus-like element periodon-like element prioniodina-like element ligonodina-like element	41 50 12 2	0.0430
*Phragmodus undatus	Phragmodus undatus Dichognathus brevis Dichognathus typica Oistodus abundans	79575 18916 18932 25327	58.5333

Table 2 (continued)

*Plectodina aculeata	Cordylodus aculeatus Trichonodella recurva Zygognathus illustris	98 90 29	0.0889
*Plectodina furcata	Cordylodus delicatus Trichonodella angulata Zygognathus mira Prioniodina furcata	16859 12139 6385 5380	16.7145
Plectodina? posterocostata	hibbardella-like element trichonodella-like element zygognathus-like element cordylodus-like element	5 8 6 12	0.0126
*Polyplacognathus ramosa	Polyplacognathus ramosa Polyplacognathus bilobata	171 18	0.0775
*Rhipidognathus discreta	ozarkodina-like element prioniodina-like element trichonodella-like element	151 55	0.1029
**Rhodesognathus elegans	Ambalodus elegans Ambalodus pulcher	600 553	0.4727
**Scandodus sp. cf. S. dissimilaris	S. sp. cf. S. dissimilaris	5	0.0021
**Scolopodus insculptus	Scolopodus insculptus	32	0.0131
Synprioniodina sp. cf. S. forsenta	S. sp. cf. S. forsenta	48	0.0197
**Tetraprioniodus delicatus	Ligonodina delicata Hibbardella gracilis (incl. Keislognathus simplex) Tetraprioniodus superbus	603 1204 433	0.9184

* Characteristic of North American Midcontinent Province

**Characteristic of "European" Conodont Fauna

ferable to *Icriodella, Amorphognathus,* and *Polyplacognathus.* These latter features suggest that the elements experienced some attrition before lithification of the rocks that enclose them, but we do not believe that there was much sorting, for most of our samples yielded specimens of a wide variety of sizes and shapes.

MULTIELEMENT SPECIES

Assembly of our Lexington-Kope-Clays Ferry conodont collections took several years. During this time, it gradually became apparent to us that certain groups of form-species are almost invariable associates; we found that it was often possible to predict with uncanny accuracy the ultimate composition of a collection after just the first few specimens had been sorted from the residue. At first we interpreted these groups as faunal associates; ultimately the number of these groups grew so large that we came to regard them as representatives of "natural" or "biologic" species.

Our decision to treat several groups of form-species as representatives of a single biologic species is based on several considerations. First, close study of the constituents of each group reveals similarities, or identities, in size, color, and secondary structural features such as denticulation, attachment-surface morphology, and ornamentation. Second, compilation of information with respect to stratigraphic distribution indicates that components of these groups have similar, or identical, ranges. Third, both section-by-section and composite frequency statistics indicate that components of these form-species groups occur together throughout their range in constant proportions that are expressible in small whole numbers and make good biologic "sense." Finally, a survey of the literature and our extensive reference collections indicates that most faunas from other localities that contain one of the members of a form-species group also contain the others.

As a consequence of the observations just summarized, we have combined the 70 form-species listed in the center column of Table 2 into 32 taxa, at least 23 of which we regard as "natural" or biologic species. Twenty of the species named in the left-hand column of Table 2 are represented by composite, or multielement, apparatuses; three *(Holodontus superbus, Ozarkodina polita,* and *O. tenuis)* apparently formed elements of only one morphologic type. The remaining nine species contain elements of only one structural type. They are represented by so few specimens that we are unable to judge if they are the only elements of a biologic species or whether they are merely components of a more elaborate, multielement apparatus. We suspect that the latter is true for at least some of them.

Recognition of multielement conodont species depends on large collections, systematically made and statistically analyzed. The taxonomic philosophy involved is not new, nor is it novel in the interpretation of collections of discrete conodont elements. It is clear that most contemporary students of conodonts *(e.g.,* Lindström, 1964; Walliser, 1964; Schopf, 1966; Webers, 1966) regard a multielement specific taxonomy as a real and immediate goal, for the recognition of such species has many biologic and stratigraphic advantages. Through recognition of multielement species, it is possible to chart the course of evolutionary development in many common species that have previously been difficult of analysis, and it is likewise possible to divide these lineages horizontally into species that promise to be useful stratigraphically. That is, some elements in each evolving stock are conservative and changed little, if at all, in that stock's history. Consequently, most of the form-species to which they have been referred have greatly extended stratigraphic ranges. Other structures in multielement species evolved more rapidly, and these are especially useful in assessing the developmental history of the entire apparatus as well as in dividing a group of long-ranging form-species into successions of distinctive taxa, each with a somewhat shorter vertical range.

Recognition of multielement conodont species also creates problems in that it has an obvious and profound effect on generic taxnomy. Eventually, we feel, it will be necessary to redefine and probably to revise considerably our concepts of most conodont genera. In the pages that follow, we discuss a number of conodont genera, but we have addressed ourselves to the problem of emendation in only a few instances, for we believe that combination of new and described form-species into multielement taxa must precede redefinition of most generic units. As a consequence of this conservative view, we suspect that many of the multielement species we recognize in this report will ultimately be reassigned on the generic level.

THE MIDCONTINENT FAUNA

"Fibrous conodonts" and the 18 species single-starred in Table 2 account for about 92.5 percent of our Lexington-Kope-Clays Ferry collections. Although many of its members are known from scattered occurrences in northwestern Europe, the fauna represented by these species is apparently North American in its origin and principal development. In short, it is the "North American Midcontinent Fauna" of Sweet, *et al.* (1959).

In Kentucky and adjacent parts of Ohio and Indiana, as in New York and southern Ontario, the type area of the Trenton group (Schopf, 1966), the Midcontinent fauna is dominated by *Phragmodus undatus, Plectodina furcata, Cyrtoniodus flexuosus,* and *Ozarkodina tenuis*. Collectively, these species account for about 82 percent of our Lexington-Kope-Clays Ferry collections, and for about 71 percent of the collections assembled by Schopf (1966) from the Trenton group of New York and southern Ontario.

In Iowa and Minnesota, *Phragmodus undatus* dominates the Midcontinent fauna only in the Decorah shale; it is much less abundant in the superjacent Cummingsville member of the Galena formation; is absent or only sparsely represented in the upper Galena (=Stewartville member), and Dubuque formations; and reappears in abundance in the lower third of the Maquoketa formation (Glenister, 1957; Ethington, 1959; Webers, 1966). Above the Decorah, *Cyrtoniodus flexuosus, Ozarkodina concinna* (which is similar to *O. tenuis), Panderodus gracilis,* and *Plectodina furcata* are the dominant elements of the Midcontinent fauna, and *Belodina compressa* is a more significant component than in the Cincinnati Region.

The composition of the Midcontinent fauna north and west of the Iowa and Minnesota sections described by Glenister (1957), Ethington (1959), and Webers (1966), is not well known, but scattered collections we have seen from Nevada and California, as well as those described from Colorado (Sweet, 1955), Wyoming (Amsden and Miller, 1942; Stone and Furnish, 1959; Cygan and Koucky, 1963), the Dakotas (Furnish, Barragy, and Miller, 1936; Carlson, 1960), and Manitoba (Ethington and Furnish, 1959, 1960), suggest that early parts of the section are dominated by "fibrous conodonts" and later ones by representatives of *Panderodus* and *Belodina. Phragmodus undatus* is apparently rare or absent in the western and northern midcontinent, as it is between the top of the Cummingsville member of the Galena formation and the base of the Maquoketa formation in Iowa and Minnesota.

From the observations just summarized, it is clear that the North American midcontinental fauna is not developed in the same way throughout the vast region in which its components are known. Indeed, the distribution of its elements outlines three intergradational subprovinces. That is, except for brief westward spreads in early Lexington time and later in early Maquoketa time, that part of the Midcontinent fauna dominated by *Phragmodus undatus* seems to have been restricted largely to the elliptical area stretching southwestward from southern Ontario and New York to the Cincinnati Region of Ohio, Kentucky, and Indiana. Fortunately, this subprovince includes the reference sections for the Trentonian stages and the three Cincinnatian stages. A second subprovince, characterized by *Ozarkodina polita, Oulodus oregonia,* and *Rhipidognathus discreta,* appears best developed in the Nashville-Ozark region, although some elements of this fauna also occur with abundant *Panderodus* and *Belodina* in a third subprovince that apparently includes much of the Midcontinent west and north of the Cincinnati Region.

The vertical fluctuations in relative abundance of *Phragmodus undatus* and *Panderodus-Belodina* that have enabled us to correlate our Lexington-Kope-Clays Ferry sections with one another and with Trentonian sections collected by Schopf (1966) indicate that during Lexington and later time there was free communication between subprovincial elements of the Midcontinent fauna and that the boundaries between the three subprovinces just outlined shifted repeatedly. We do not know what combination of environmental features was responsible for the obvious regionation of the Midcontinent fauna, but we suspect that both water temperature and depth played a significant role.

THE EUROPEAN FAUNA

About 7.5 percent of our Lexington-Kope-Clays Ferry collections and 4.5 percent of Schopf's Trentonian collections are referable to the eight conodont species double-starred in Table 2. Collectively, these species represent a fauna that is best known from, and was apparently most fully developed in, northwestern Europe. This is the "Anglo-Scandinavian-Appalachian fauna" of Sweet, *et al.* (1959), a cumbersome name for which we now prefer the shorter denomination, European fauna.

The European fauna, as we understand it, includes at least the eight species named in Table 2 but is dominated by *Amorphognathus ordovicica, Icriodella superba,* and *Periodon grandis.* It appears fairly abruptly in the Cincinnati Region between 75 and 85 feet above the base of our composite Lexington-Kope-Clays Ferry section (Text-fig. 4), and at least some elements of it are known as high as the basal Richmondian ("Arnheim") of Indiana (McClish, 1965). *Periodon grandis* makes a similarly abrupt debut in Iowa and Minnesota at the base of the Galena formation (Ethington, 1959; Webers, 1966), but *Amorphognathus ordovicica* and *Icriodella superba* do not appear until much higher in the section, in the uppermost Galena (=Stewartville member) and in the Dubuque formation, respectively.

Amorphognathus ordovicica, Icriodella superba, and *Tetraprioniodus delicatus* occur in the Rockland formation of New York and southern Ontario (Schopf, 1966), which we believe to be largely if not entirely, pre-Lexington in age. In New York and Ontario, the European fauna does not appear in force until the mid-Shoreham, at a level equivalent to a point about 148 feet above the base of our composite Lexington-Kope-Clays Ferry section. Above this level in the type Trentonian, the European fauna is represented by at least some of its characteristic components to the top of the Cobourg formation.

We suspect that the same regionation we noted in the North American Midcontinent fauna also exists in the European fauna, but present evidence is insufficient to outline subprovinces in detail. It is interesting to note that certain elements of this fauna appear to have preceded others as the European fauna invaded the North American Midcontinent Province. All elements of the European fauna appear at about the same level in Lexington sections, but *Periodon* is present to the east and southeast in strata that are certainly pre-Lexington in age (Pratt Ferry of Alabama; "Martinsburg" of New Jersey; slaty black shales in Maine). Apparently *Periodon grandis* invaded the Upper Mississippi Valley region well in advance of *Amorphognathus, Icriodella,* and *Tetraprioniodus.*

CONODONT BIOSTRATIGRAPHY

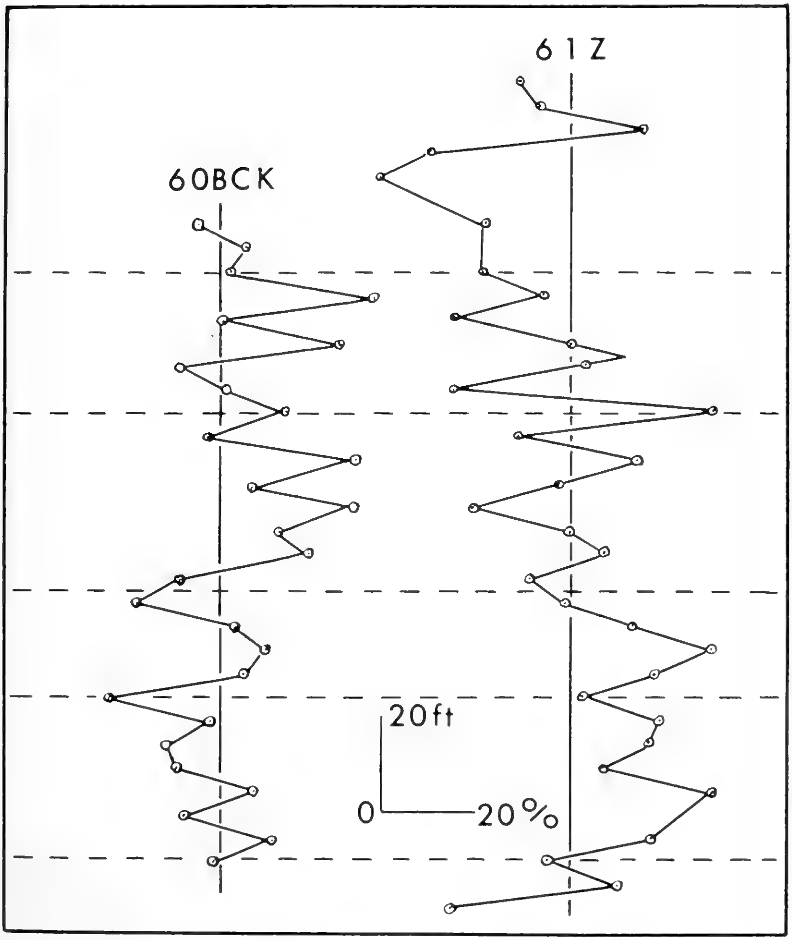
Early in our studies of Lexington conodonts it became apparent that the large and varied fauna described on subsequent pages appeared first at or near the base of the Lexington and its equivalents and persisted with little change in form or composition through the Lexington into younger rocks. All but a few Lexington species continue upward through rocks of Maysvillian and Richmondian age and the apparent distinctions between Edenian, Maysvillian, and Richmondian faunas reported in previous studies (Sweet, *et al.,* 1959; Sweet, 1959; Pulse and Sweet, 1960; Sweet and Rust, 1962; Branson, Mehl, and Branson, 1951) result largely from vertical fluctuations in the relative abundance of species that appeared in the Cincinnati Region early in Lexington time.

Because virtually all the conodont species represented in the Lexington have ranges that exceed the thickness of our sampled sections, we have experienced considerable difficulty in correlating these sections and in dividing them into biostratigraphic units that are persistent and useful either in or beyond the boundaries of the Cincinnati Region. These difficulties are compounded in that at least two distinct, long-ranging conodont faunas made repeated contributions to the conodont sequence in the Cincinnati Region and elsewhere, with the result that lateral changes in composition of the overall fauna of the Lexington and younger rocks are greater than, or mimic, vertical ones in some parts of the section.

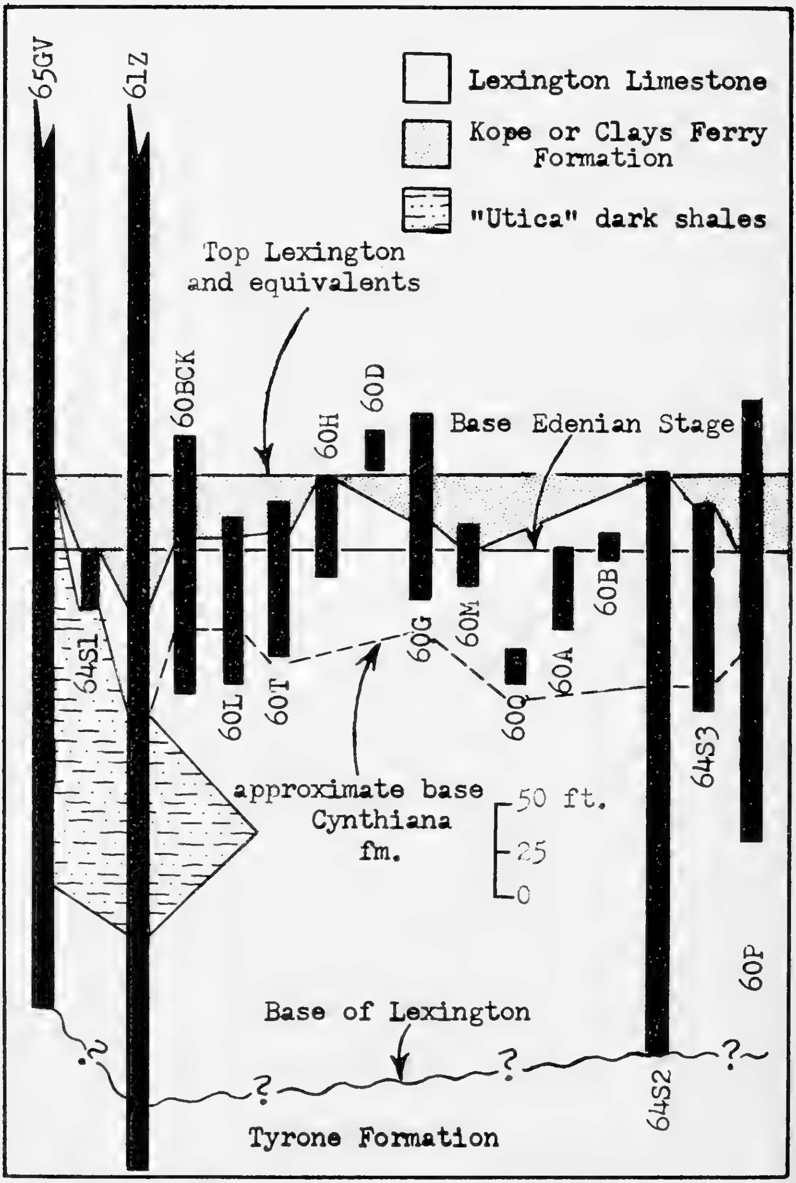
To synthesize a regionally useful conodont biostratigraphy, we have thus far been unable to use methods that depend on the total stratigraphic range of species. Instead, we have had to rely on a procedure that is thus far unique in conodont biostratigraphy but which permits us to correlate Lexington and younger rocks with what appears to be reasonable reliability. The procedure to which we refer is common in palynological studies and relies heavily on a graphic analysis of vertical changes in the relative abundance of *Phragmodus undatus*, the dominant species in our collections from virtually every Lexington section. Because most of our conclusions with respect to the distribution of Lexington conodont species depend on the framework provided by abundance analysis of *Phragmodus undatus*, we feel that the method and its underlying assumptions merit expanded discussion.

RELATIVE-ABUNDANCE ANALYSIS

Representatives of *Phragmodus undatus* (which includes conodont elements previously referred to the form-species *Phragmodus undatus, Dichognathus brevis, D. typica,* and *Oistodus abundans)* are present in collections from almost every level in the Lexington limestone and its lateral equivalents; only a few of our samples from this interval lack them and in many they account for more than 50 percent of the total collection. There are conspicuous fluctuations in the relative abundance of this species from level to level in all of the Lexington sections we have studied, and these fluctuations appear to be generally unrelated to the gross lithologic character of the rocks in any section. Because of the latter observation, we conclude that changes in relative abundance of *Phragmodus undatus* were effected by changes in environmental conditions that left little obvious impress on the rock sequence. It is reasonable to assume that the environmental changes, whatever their nature, were basin-wide and that at least the major fluctuations in relative abundance of *Phragmodus undatus* were essentially contemporaneous events in all parts of the Cincinnati Region.



Text-fig. 2. Relative-abundance logs of *Phragmodus undatus* for sections 60BCK and 61Z. The center line of each log is 50 percent and dashed horizontal lines bracket comparable intervals in each section.



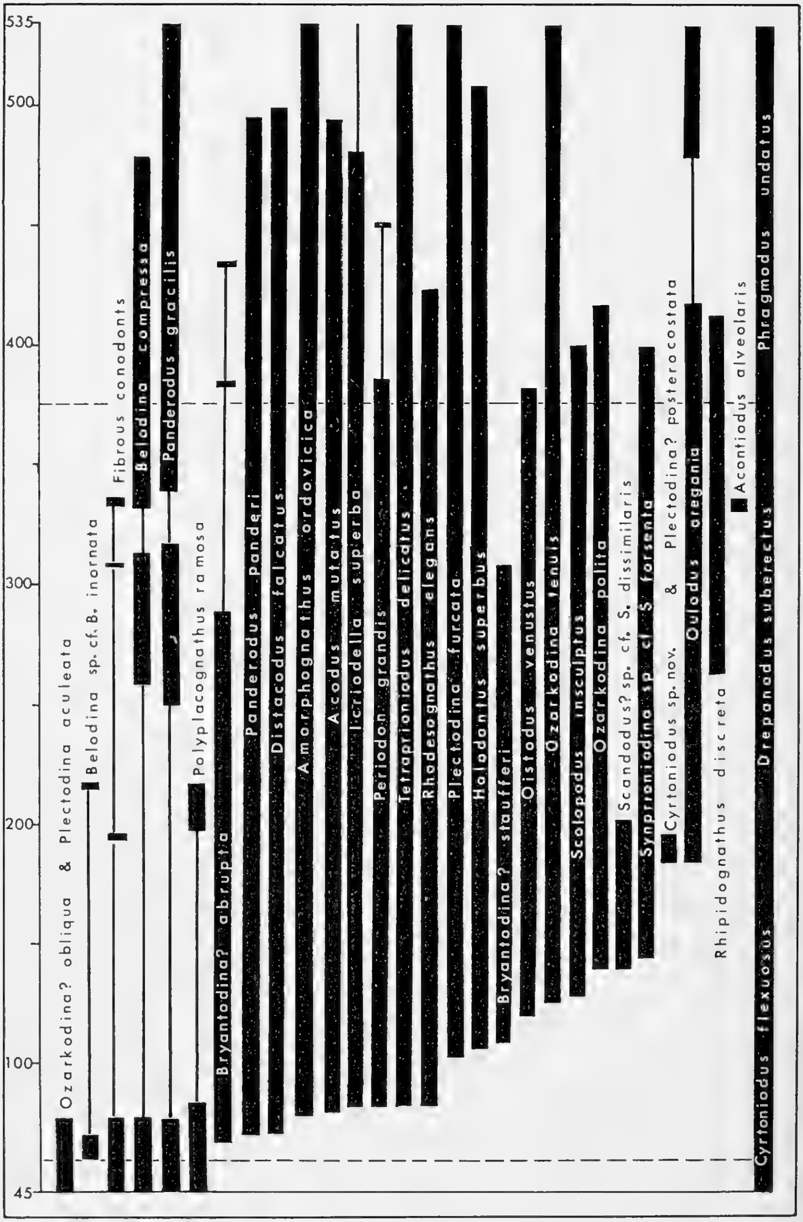
Text-fig. 3. Correlation of Lexington limestone sections yielding the conodonts described in this report. Sections were correlated by matching relative-abundance logs of *Phragmodus undatus,* as described in the text.

On the basis of these assumptions, we determined the relative abundance of *Phragmodus undatus* in each sample in every Lexington, Kope, and Clays Ferry section, and in samples taken at three- to five-foot intervals through the entire length of the Middletown, Ohio, and New Point, Indiana, cores. Using the percentage figures thus obtained, we constructed logs of relative abundance for each of our systematically sampled sections. Two of these logs, reproduced at much smaller scale, are compared in Text-figure 2; the complete array, together with others developed for younger sections, will be included in a more extensive report on Ordovician conodont biostratigraphy to be issued later (Sweet and Kohut, in preparation).

As can be seen in Text-figure 2, correspondence in the shape of the two logs is close. Major changes in the relative abundance of *Phragmodus undatus* are reflected at the same levels in both of them, and about the same degree of comparability, or even greater comparability, is exhibited between logs for all of our Lexington, Kope, and Clays Ferry sections. Comparison of these logs is rendered simpler by the fact that the sequence studied appears to be of essentially the same thickness throughout the Cincinnati Region.

Relative-abundance logs of all our Lexington sections were arrayed and visually correlated, with the results depicted schematically in Text-figure 3. Following this, we projected tabulated information with respect to the distribution and frequency of other conodont species in each section to the appropriate level in the Middletown, Ohio, core, which was selected as the base for compilation because of its length, continuity, and productivity of conodonts. Completion of this procedure resulted in a composite Lexington-Kope-Clays Ferry section, from which we have constructed the much simpler composite distribution chart shown in Text-figure 4 which served as a check on the accuracy of our initial correlation of the *Phragmodus undatus* abundance logs. Our local correlation diagram (Text-figure 3) and our conodont distribution diagram (Text-figure 4) are based on an internally consistent biostratigraphic framework that avoids many of the errors implicit in stating distribution in terms of lithostratigraphic units or in terms of a biostratigraphic frame of reference determined from analysis of another group of organisms.

After compiling all our Lexington sections into a single, composite



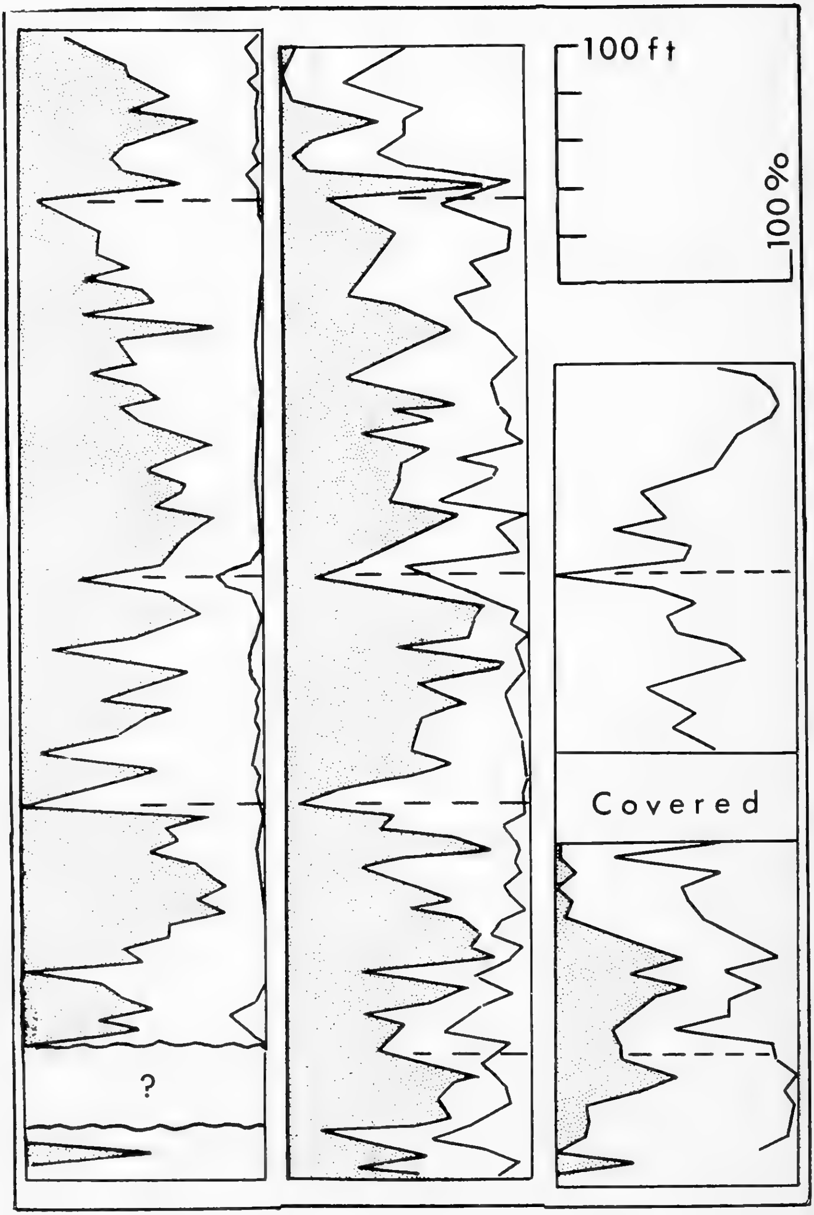
Text-fig. 4. Vertical distribution of Lexington limestone conodont species. The Lexington and its lateral equivalents occupy the interval between the dashed horizonal lines. The chart is composite in that information with respect to range has been projected into a single section (61Z) from 16 sections correlated by matching relative-abundance logs of *Phragmodus undatus,* as described in the text. Scale at left indicates feet above base of section 61Z.

section, we constructed a "master log" showing vertical fluctuations in the relative abundance of *Phragmodus undatus* for the Cincinnati Region as a whole. Following this, but using essentially the same techniques, we compiled Trenton group sections in New York and southern Ontario, using data on the vertical distribution and relative frequency of *Phragmodus undatus* reported by Schopf (1966). Although there was initially little reason to expect that master frequency logs of Lexington and Trenton group *Phragmodus undatus* would be comparable in detail, comparison of the two (Text-figure 5) reveals close correspondence in the sequence and shape of major frequency peaks. Furthermore, the vertical distribution of nearly all other elements of the faunas compared is closely similar in the two areas (we show only a log of *Panderodus-Belodina* in Text-figure 5). Finally, the close comparability of these two master logs indicates that the composite sections are of essentially the same thickness, even though their areas of outcrop are separated by several hundred miles.

Phragmodus undatus is abundant in Iowa and Minnesota only in the Decorah shale and in the immediately superjacent Cummingsville member of the Galena formation (Webers, 1966). Above the Cummingsville, the Galena fauna is dominated by *Panderodus* and *Belodina,* which represent the subprovincial fauna characteristic of the western and northern Midcontinent Province. Using frequency data supplied by Dr. Webers, we constructed a master log for the Upper Mississippi Valley sections he studied (Text-figure 5). The part of this log representing *Phragmodus undatus* is much shorter than the two with which it is compared in Text-figure 5, but we believe it supports correlations indicated by the relative-frequency log of the *Panderodus-Belodina* fauna and by the distribution of other elements not shown in either log. Point-by-point comparison of the Minnesota log with those for Trenton group and Lexington conodonts indicates that the Upper Mississippi Valley section is only four-fifths as thick as the two with which it is compared in Text-figure 5. Consequently, as explained in the legend of Text-figure 5, we have increased the scale of the Minnesota log to provide better visual comparison.

ZONATION

It was our original hope that compilation of all the sections men-



Text-fig. 5. Relative-abundance logs of *Phragmodus undatus* (stippled) and *Panderodus gracilis-Belodina compressa* for Lexington limestone of Ohio, Kentucky, and Indiana (on the left), the Trenton group of New York (in the center), and Middle Ordovician rocks in Minnesota (on the right). For the *Phragmodus undatus* logs, 100% is to the right; for *Panderodus-Belodina* logs, 100% is to the left. All logs have the same vertical scale, but the Minnesota logs are enlarged because initial comparison indicated that the section represented is only four-fifths as thick as the two with which it is compared. Dashed horizontal lines bracket major units.

tioned in the preceding discussion would yield a record that we could divide into zones distinctive enough to be useful stratigraphically in at least that part of eastern North America to which we have devoted most of our attention. This is not the case.

We discern no clear-cut zonal boundaries in Text-fig. 4; however, it is clear in that figure that there is a gradual change in fauna between about 76 and 125 feet above the base of our composite Lexington-Kope section. Part of this change is the result of the rather abrupt appearance of the "European fauna" between 75 and 85 feet and part of it results from the introduction of new Midcontinent-fauna species, some of which we believe developed from older species that occur below 75 feet in our composite section.

Above 125 feet in our composite Lexington-Kope section (Text-figure 4), the conodont fauna is a mixture of evolved Midcontinent species and typical European forms, and vertical distinctions in faunal composition result largely from fluctuations in the relative abundance of elements in both the Midcontinent and European components of this fauna. Such a fauna persisted with little detectable change to the top of the "Arnheim formation" which is well above the interval shown in Text-figure 4 and has long been considered the basal unit of the Richmond group. At the top of the "Arnheim" the European component of the fauna disappears.

Between 139 and 409 feet above the base of our composite Lexington-Kope section (Text-figure 4), representatives of *Ozarkodina polita*, *Oulodus oregonia*, and *Rhipidognathus discreta* constitute a small, but distinctive part of the Lexington-Kope fauna. These species represent a subprovincial element within the more widely distributed North American Midcontinent fauna which is best developed and longest in range in an area that includes the present Nashville Basin and the east flanks of the Ozarks. The appearance of these species between 139 and 409 feet in our composite section apparently represents the first of several northward invasions of that subprovincial fauna and distinguishes a distinctive biostratigraphic unit in the Lexington and lower Kope formations.

From these brief remarks about the Lexington-Kope-Clays Ferry conodont fauna, and from our earlier discussion of the Midcontinent and European conodont faunas as a whole, it is clear that the Cincinnati Region was repeatedly invaded in the Middle and Upper

Ordovician by the three subprovincial elements of the Midcontinent fauna and by the aggregation of species we term the European fauna. As a consequence, the Lexington, Kope, and Clays Ferry formations can be divided into several locally recognizable biostratigraphic units. These units have only a limited stratigraphic utility in the Cincinnati Region, and it is certain that they lose character and merge with others of similarly limited usefulness laterally. Thus we do not propose names for these biostratigraphic units, and we have not attempted to correlate them beyond the Cincinnati Region.

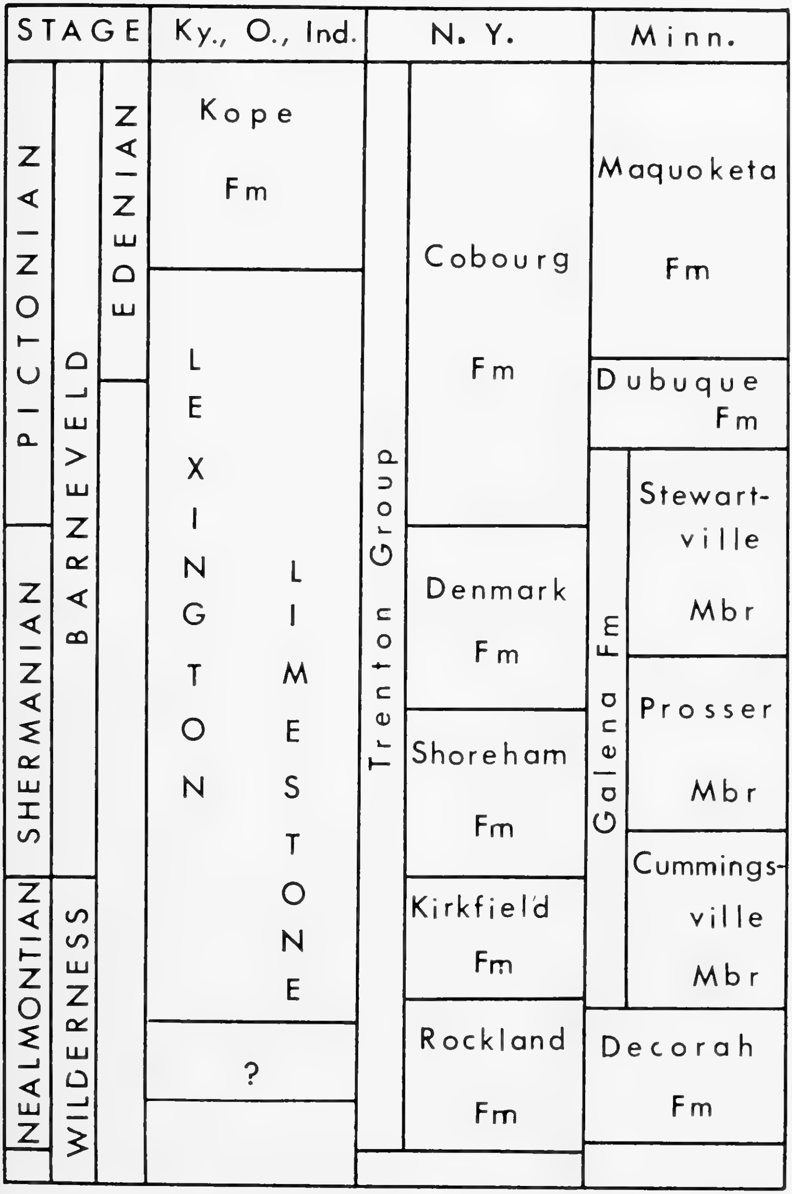
CORRELATIONS

As we noted earlier in this report, we have been successful in correlating our Lexington, Kope, and Clays Ferry sections only through application of relative-abundance analysis of *Phragmodus undatus*. We believe that extension of this procedure to the Upper Mississippi Valley and to the type area of the Trenton group has been similarly successful. Consequently, the following remarks on correlation depend almost entirely on the results of this type of analysis.

In Text-figure 5 we indicate our conclusions with respect to correlation of Lexington-Kope-Clays Ferry, Minnesota Ordovician, and Trenton group sections, and in Text-figure 6 we summarize the correlations indicated by a comparison of the master frequency logs shown in Text-figure 5. We are satisfied that we can demonstrate close correlation between the three sections shown in Text-figure 5 and Text-figure 6, hence we confine our discussion of North American correlations to these three sections.

CORRELATION WITH THE TRENTON GROUP OF NEW YORK AND ONTARIO

Correlation of the logs of Text-figure 5 indicates that the Lexington limestone is the temporal equivalent of the uppermost Rockland, Kirkfield, Shoreham, Denmark, and lower Cobourg "formations" of New York and southern Ontario. If one follows Kay's (1960) most recent classification of these strata, our correlations suggest that the Lexington limestone includes strata of the Nealmontian, Shermanian, and lower Pictonian stages. Cooper (1956) and Fisher (1962) assigned the Rockland and Kirkfield "formations"



Text-fig. 6. Correlation of the Lexington limestone of Kentucky, Ohio, and Indiana, with the Trenton group of New York and Ordovician strata in Minnesota. Chart is drawn to same vertical scale as logs of Text-fig. 5 and correlations shown are those implied by the matched logs of Text-fig. 5.

to the Wilderness Stage and Fisher (1962) included the Shoreham, Denmark, and Cobourg "formations" in the Barneveld Stage. If their classification is followed, the lower 70 feet of the Lexington belongs in the Wilderness Stage and the upper part in the Barneveld Stage.

MIDDLE AND UPPER ORDOVICIAN STADIAL CLASSIFICATION

In all current classifications of the Middle and Upper Ordovician rocks of North America, the three stages of the Cincinnatian Series (Edenian, Maysvillian, and Richmondian) are shown to succeed the Pictonian (Kay, 1960) or Barneveld (Fisher, 1962) without gap or overlap. Our correlations, based entirely on conodonts and the several assumptions explained in a previous chapter, suggest that this is not the case.

By definition, the base of the Edenian Stage is the base of the Kope (=Eden) formation in Cincinnati, Ohio. The base of the Kope is not exposed in Eden Park, Cincinnati, but it is exposed in a section near Latonia, Kentucky, (64S1 of this report) just a few miles south. This contact is 334 feet above the base of our composite Lexington-Kope section. Interpreted strictly, the top of the Barneveld Stage is the top of the Cobourg formation in the section exposed along West Canada Creek near Trenton (or Barneveld), New York. According to our correlations, the Cobourg top in this section is equivalent to a point 426 feet above the base of our composite Lexington-Kope section, or 92 feet above the base of the Edenian Stage. Fisher (1962) clearly included in the Barneveld even higher Cobourgian strata than are present along West Canada Creek, and the highest of these we can correlate with confidence are in Schopf's (1966) section on Atwater Creek, New York. The highest Cobourg in that section projects to a point 471 feet above the base of our composite Lexington-Kope section, or 137 feet above the base of the Edenian Stage. This indicates that the lower 137 feet of the Kope formation is Barneveld in age, or, conversely, that the upper 137 feet of the Barneveld is Edenian in age. In short, it is clear that the Barneveld and Edenian stages overlap, and that we can not regard them as mutually exclusive, but successive, units in a continent-wide classification of the North American Ordovician System.

It is even more obvious that the Edenian Stage does not succeed the Pictonian Stage of Kay (1960) which includes the Cobourg formation, the overlying Deer River and Atwater Creek formations, and their many lateral equivalents. Because the Pictonian Stage includes rocks above the Cobourg, it is plain that its upper boundary must be at a point much higher than the top of the Cobourg, which is at least 471 feet in our composite section. We have no information on the distribution of conodonts above the Cobourg in New York. However, the New York and Ohio-Kentucky-Indiana sections seem to be of closely comparable thickness and at their type sections the Deer River and Atwater Creek formations are each about 70 feet thick (Kay, 1937). If 140 feet is added to the top of the Cobourg, it seems possible that the top of Kay's Pictonian Stage is about 611 feet above the base of our composite Lexington-Kope section. Such a point is well above the top of Text-figure 6. Indeed it is 50 feet above the projected base of the type Maysville Stage. This indicates to us that the Pictonian Stage not only embraces the Edenian Stage completely but might even include younger rocks (Maysville) as well.

It would be premature to suggest a revised stadial classification of Middle and Upper Ordovician rocks based solely on the studies reported here, even though these studies offer strong evidence that the present classification is not a satisfactory one. It is pertinent to note that the Kirkfield-Shoreham boundary in New York and Ontario separates rocks distinguished by strikingly different faunas (Cooper, 1956; Whittington, 1959; Ross, 1964; Schopf, 1966), and this boundary apparently falls within the interval 76 to 125 feet above the base of our composite section in which a considerable change takes place in the Lexington conodont fauna. Thus, as Schopf (1966) noted, this seems to be the best level at which to place the boundary between two major biostratigraphic units, and it is the level at which Kay (1960) drew the boundary between the Nealmontian and Shermanian stages and the one at which Cooper (1956) and Fisher (1962) placed the boundary between the Wilderness and Barneveld stages. Based on a consideration of conodonts alone, we are inclined to include all the rocks above the Kirkfield and below the top of the lower Richmondian "Arnheim" of Indiana and Ohio, and the temporal equivalents of all these strata, in a single stage, for which there is currently no name. Such a stage should have its reference section in an area of uniformly fossiliferous strata, and the most desirable such area may well be in the Cincinnati Region of Kentucky, Ohio, and Indiana.

CORRELATION WITH THE ORDOVICIAN OF SOUTHERN MINNESOTA

Our conclusions with respect to the correlation between Lexington-Kope sections and the Middle Ordovician rocks of southern Minnesota are summarized in the correlation chart of Text-figure 6, which is based primarily on the master frequency logs compared in Text-figure 5. In the Minnesota frequency log of Text-figure 5 it can be seen that *Phragmodus undatus* is present in abundance only in the 112-foot interval between the uppermost Platteville and the top of the Cummingsville member of the Galena formation. The log depicting this distribution is not obviously similar to the part of our master Lexington-Kope log with which we have equated it because we believe there to be an unconformity between the Lexington and subjacent Tyrone. The Minnesota *Phragmodus undatus*-log is closely comparable to the corresponding segment of the adjacent Trenton-group log, especially if one accepts our conclusion that the rate of sedimentation was 1.25 times greater in New York than in Minnesota.

Correlation of the Minnesota section with the Trenton group suggested by comparison of *Phragmodus undatus* logs is made even more convincing by the close similarity of logs showing vertical fluctuations in the relative abundance of *Panderodus gracilis* and *Belodina compressa,* which we interpret as representatives of the western and northern element of the Midcontinent fauna. The correlations we show are also supported by the fact that the gradual faunal change we recognize between 76 and 125 feet above the base of our composite Lexington-Kope section occurs in the lower Cummingsville of Minnesota, in a part of that section which correlates exactly with the sections with which it is compared in Text-figure 5.

EXTRA-NORTH AMERICAN CORRELATIONS

Extra-North American conodont faunas of Late Middle and Early Upper Ordovician age have been described only from Europe, where they are particularly well known in Wales. In Wales only a few thin intervals in an extensive stratigraphic succession have produced conodonts and described sections are mostly not thick enough to produce the long series of collections requisite to quantitative analysis. Such sections are available in Scandinavia and they yield conodonts in abundance. Conodonts from the latter sections are mostly undescribed. They have so little in common with presumably contemporaneous American faunas that neither quantitative nor qualitative comparisons now yield much information on correlation. Consequently, our remarks on extra-North American correlations are brief, entirely qualitative, and refer almost exclusively to the Caradocian succession in Wales.

According to our correlations, the Lexington-Kope succession belongs in the upper Wilderness and Barneveld stages, and there is ample evidence that these stages (together with older and younger rocks) are entirely within the British Caradoc Series. Unfortunately, the Caradoc conodont succession is incompletely known; that is, conodonts have yet to be recovered from strata of the Costonian, Harnagian, or Soudleyan stages, which constitute the lower third of the Caradoc Series, nor have conodonts been reported from Actonian, Onnian, or Pusgillian strata, which collectively form the upper third of the Caradoc. All Caradoc conodont faunas thus far described came from thin Mid-Caradoc limestones in the upper Longvillian and Marshbrookian stages (Bergström, 1964).

Welsh Mid-Caradocian faunas are discussed by Bergström (1964), who noted that faunas from the upper Longvillian Brun Pig, Gelli-grin, and Pen-y-garnedd limestones, and that of the Marshbrookian Crug limestone, are closely related. These faunas (Table 3) apparently consist of three major elements: (1) a group of species including *Cordylodus? spurius, Cyrtoniodus flexuosus, Drepanodus suberectus, Ozarkodina polita, Panderodus gracilis,* and *Plectodina furcata,* all characteristic of, and best known from, various parts of the North American Midcontinent Province; (2) an element consisting of *Acodus similaris, Acontiodus* sp., two unnamed species of *Oistodus,* and *Prioniodus? variabilis,* all known best in Baltic Ordovician faunas; and (3) a group composed of *Amorphognathus complicata, A. ordovicica, Holodontus superbus, Icriodella superba, Rhodesognathus elegans, Scolopodus insculptus,* and *Tetraprioniodus delicatus,* which we regard as characteristic of the "European

Table 3.—Distribution of Conodont Species in Welsh Mid-Caradocian Limestones

SPECIES	Brun Pig Limestone	Gelli-grin Limestone	Pen-y-garnedd Limestone	Crug Limestone	Lexington Limestone
Midcontinent Fauna					
?Bryantodina? sp.	---	X	---	---	---
Cordylodus? spurius	---	---	X	X	---
Cyrtoniodus flexuosus	X	X	---	X	X
Drepanodus suberectus	X	X	---	X	X
Ozarkodina polita	---	---	---	X	X
Panderodus gracilis	X	X	X	?	X
?Panderodus similaris	---	X	X	---	---
Plectodina furcata	X	X	X	X	X
European Fauna					
Amorphognathus complicata	---	---	X	---	---
A. ordovicica	X	X	X	X	X
Holodontus superbus	X	X	---	---	X
Icriodella superba	X	X	X	X	X
Rhodesognathus elegans	X	X	X	X	X
Scolopodus insculptus	---	X	X	---	X
Tetraprioniodus delicatus	X	X	X	X	X
Baltic Fauna					
Acodus similaris	---	---	X	X	---
Acontiodus sp.	X	---	---	---	---
?Drepanodus? altipes?	X	X	X	---	---
Oistodus? sp. Lindström	---	---	---	X	---
O. n. sp. Lindström	---	---	---	X	---
Prioniodus? variabilis	---	---	---	X	---
Faunal Affinities Unknown					
Cordylodus n. sp. Lindström	---	---	---	X	---
Hindeodella? sp. Lindstrom	---	---	---	X	---
Oistodus venustus	X	X	X	---	X
Ozarkodina pseudotypica	---	---	---	X	---
Spathognathodus pseudofissilis	---	---	---	X	---

fauna," but which also has a wide distribution in eastern North America. An additional group of species, mostly rare and listed separately in Table 3, can not now be related to any of these faunal elements.

The "Baltic" element of the Welsh faunas is not known to be represented in the North American Midcontinent Province, and *Phragmodus undatus*, which dominates Lexington-Kope and Trenton group strata, apparently does not occur in Wales. Otherwise, Lexington-Kope and Welsh Mid-Caradoc faunas are generally similar. This overall similarity in common elements does not necessarily indicate that the Lexington-Kope sequence is equivalent in age to Welsh Longvillian and Marshbrookian strata, for most of the common species are apparently long-ranging forms in both Wales and eastern North America. It is tempting to conclude that the presence of *Plectodina furcata* in both Welsh Mid-Caradocian and North American Midcontinent faunas indicates at least partial contemporaneity, for *P. furcata* makes its American debut in the Lexington limestone. The fact that Trenton group and Lexington-Kope strata are distinguished by a "flood" of the "European" elements characteristic of Welsh Mid-Caradocian limestones might also be taken as additional evidence of broadly similar age. If Wales was the center of distribution for the "European fauna," that fauna may begin in older beds there than in North America and elements of it *(e.g., Amorphognathus ordovicica, Scolopodus insculptus)* are known to persist into high Upper Ordovician and Lower Silurian strata in northwest Europe, well above their known range in North America.

Caradocian conodonts known from Scandinavia (Bergström, 1962; Hamar, 1964) are clearly older than those known from Wales, and they have little in common with the Lexington-Kope faunas described here. It is pointless to compare our American faunas with those known from Scandinavia. It is of interest that *Holodontus superbus* and *Tetraprioniodus delicatus* (which seem to be restricted to the Middle and Upper Caradoc), together with *Icriodella* cf. *superba* and *Rhodesognathus elegans* (which range into the Ashgill), appear first in Sweden in rocks broadly equivalent to those in the Longvillian-Marshbrookian interval in Britain. Ultimately the distribution of this group of species may be of considerable importance in intercontinental correlation of Caradoc strata; at the present we can not evalute its significance.

In the upper part of the *Diplograptus multidens* zone and in the

Dicranograptus clingani zone of Sweden, representatives of *Icriodella* and *Rhodesognathus* are associated with numerous *Periodon grandis,* and in even younger rocks a few undescribed specimens reminiscent of *Phragmodus undatus* and a somewhat larger number of *Belodina compressa* have been discovered. The distribution of the species represented by these specimens is not yet known in detail for the Swedish Upper Ordovician. They are rare in these strata, and we doubt that it will ever be possible to tie Swedish and eastern North American sections together by the type of analysis we have used in effecting detailed correlation between Lexington-Kope, Trenton group, and Upper Mississippi Valley Ordovician sections.

SYSTEMATIC DESCRIPTIONS

In the descriptions that follow we orient our conodont elements and describe them in terms that are reasonably standard and should be understandable to students of this group. Our terminology differs from that employed in Part W of the *Treatise on Invertebrate Paleontology* (Hass, *et al.*, 1962), for we especially abjure terms that seem to identify conodont elements with the teeth or jaws of vertebrates *(e.g.,* tooth, jaw, oral, aboral, pulp cavity, fang, ramus).

Description of multielement species has caused us some difficulty, for there is as yet no standard way to describe the morphologically diverse elements of what we interpret as a single biologic species. Most of the elements of these species have been described previously as form-genera and we feel that discussion of them is intelligible if we refer to them as cordylodus-like or trichonodella-like elements of the apparatus in which they occur. We have avoided the use of such expressions as "cordylodid" or "trichonodellid" (in place of cordylodus-like or trichonodella-like), for these contractions convey the impression that we refer to members of the nonexistent families Cordylodidae and Trichonodellidae. The terms "cordylodoid" and "trichonodelloid" are free from positive objection, but they are not particularly euphonious in all combinations.

All the conodonts described in the following pages are part of the Micropaleontological collections of The Ohio State University. The composition of the Lexington collections is indicated in Appendix B which also includes the reference numbers of our collections. Types and figured specimens are stored in the Orton Museum of Geology at The Ohio State University and their catalog numbers are prefixed with the abbreviation "OSU."

Genus **ACODUS** Pander, 1856

1856. *Acodus* Pander, Monographie der Fossilen Fische des Silurischen Systems der Russisch-Baltischen Gouvernements, p. 21.

Pander's description of *Acodus erectus,* type species of the form-genus *Acodus,* is brief and contains few useful details. The present repository of its types is unknown. In addition, the species has not been recognized in any other fauna and even its exact age is unknown, although its types were probably derived from Lower Ordovician rocks. Thus we have no information about the faunal associates of *A. erectus,* and we cannot reconstruct the biologic apparatus of which this element may have been a component.

There are no major differences in general appearance between *Acodus erectus* and the suberectus-element of *Drepanodus suberectus,* and the lateral costa of the former, which has been regarded as the principal biocharacter of *Acodus,* is a feature of somewhat questionable taxonomic significance. Until additional representatives of *A. erectus* are available for study it would be premature to discuss the status of the species or of the genus of which it is typical.

We have only a few specimens that fit Pander's broad diagnosis of *Acodus,* and these elements are obviously part of an apparatus that also includes form-species previously referred to *Acontiodus* (or *Distacodus*). We do not know whether this assembly of elements represents a species that is closely related to *Acodus erectus.* We include the following species in *Acodus* because at least one of its components matches the classical definition of that genus, and opinion has been divided about the form-generic assignment of the other. This species may well represent an undescribed genus.

Range (of the form-genus).—Lower Ordovician to Middle Silurian.

Type species.—*Acodus erectus* Pander, 1856.

Acodus mutatus (Branson and Mehl) Pl. 35, figs. 7-9

1933. *Belodus* (?) *mutatus* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 126, pl. 10, fig. 17.

1959. *Acodus inornatus* Ethington, Jour. Paleont., vol. 33, p. 268, pl. 39, fig. 11.
1959. *Distacodus procerus* Ethington, *idem,* p. 275, pl. 39, fig. 8.
1962. *Acodus inornatus* Ethington, Ethington and Furnish, Jour. Paleont., vol 36, pp. 1259, 1260.
1962. *Distacodus procerus* Ethington, Ethington and Furnish, *idem,* p. 1265.
1964. *Acodus* ("*Belodus* (?)") *mutatus* (Branson and Mehl), Bergström, Acta Univ. Lundensis, sec. II, No. 3, pp. 9-10, text-fig. 2.
1966. *Acodus inornatus* Ethington, Schopf, New York State Mus., Bull. 405, p. 31, pl. 5, fig. 20; text-fig. 7a.
1966. *Distacodus procerus* Ethington, Schopf, *idem,* p. 51, pl. 5, fig. 1; text-fig. 7b.
1966. *Acodus mutatus* (Branson and Mehl), Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 21, pl. 3, figs. 5, 6.

Representatives of the form-species *Acodus mutatus* (Branson and Mehl) (=*Acodus inornatus* Ethington) and *Distacodus* (or *Acontiodus*) *procerus* Ethington are not common in our Lexington limestone collections, but they are sufficiently well represented to indicate that the two form-species have a similar stratigraphic range, are of essentially identical size and appearance, and intergrade morphologically. For these reasons, we do not hesitate to combine these two form-species into a single taxon, the oldest name for which is *Acodus mutatus* (Branson and Mehl).

Ethington's description and illustration of *Distacodus procerus* and of *Acodus inornatus,* are sufficient to indicate that the elements at hand are conspecific. Study of Lexington limestone and Kope specimens shows that the upper edge of the base in both form-species becomes progressively more bladelike, and the posteriorly situated lateral costae become gradually more distinct, in growth stages that are larger than the ones represented by the type specimens.

In Lexington elements identified with the form-species *Distacodus procerus,* there is some variation in degree of development of the lateral costae and a few representatives of this form-species are distinctly asymmetric with respect to placement of these structures. In this respect, they may be said to grade morphologically toward *Acodus inornatus,* with which we here combine them.

As Bergström (1964) suggested, and as has since been confirmed by examination of the pertinent types, the oldest available name for this species is *Belodus* (?) *mutatus* Branson and Mehl. The lectotype of this species (Bergström, 1964, text-fig. 2) is a large robust specimen; in all other respects, it is so closely similar to the more delicate Galena specimens on which Ethington based *Acodus* *inornatus* that we do not see how the two form-species can be distinguished.

Occurrence.—Our collections contain 32 representatives of "*Distacodus procerus*" and 4 of "*Acodus mutatus*," and the distribution of these indicates an over-all range of the composite species, *Acodus mutatus,* from 79 to 495 feet above the base of our compiled Lexington-Kope section. *Acodus mutatus* has a wide geographic distribution: it is known from the Galena and Maquoketa formations of Iowa and Minnesota, from the Lexington and Kope formations of Ohio and Kentucky, from the Trenton group of New York and southern Ontario. It has been identified in undescribed U. S. Geological Survey collections (1087CO) from Middle or Upper Ordovician rocks in the Monitor Range, Nevada. The species has also been reported (but not figured) from the Silurian of the Spanish Sahara and may also occur in the Brassfield formation (Silurian) of Ohio.

Repository.—Micropaleontological collections, The Ohio State University. Reference slides 61Z-200, 242, 259, 275, 284, 297, 471, 483, 502, 564, 567, 570, 587, 616; 64S1-7; 64S2-13, 14. Figured specimens, OSU 27407, 27408.

Genus **ACONTIODUS** Pander, 1856

1856. *Acontiodus* Pander, Monographie der Fossilen Fische des Silurischen Systems der Russisch-Baltischen Gouvernements, p. 28.

As is the case with all the simple conodont genera erected by Pander, *Acontiodus* was based on discrete conodont elements that were probably derived from beds in the lower part of the Baltic Lower Ordovician. *A. latus* Pander, type species of the form-genus, is a distinctive form. In several ways, it exhibits a superficial similarity to the oistodus-delta-element of *O. lanceolatus* Pander, the type species of *Oistodus.*

Although *Acontiodus latus* has not been reported as a component of any fauna other than the one described by Pander, the senior author recently recovered several conodonts from a single Arenigian sample that agree so closely with Pander's figures of *A. latus* that identity is obvious. These elements, which were derived from strata just below a shale in the zone of *Phyllograptus densus* (=lower part of zone of *Didymograptus nitidus*) in south-central Sweden, occur with *"Falodus" carinatus* (Pander), *Oepikodus smithensis* Lindström, *Prioniodus elegans* Pander, *Scolopodus rex* Lindström, *Tetraprioniodus* cf. *robustus* Lindström, and *Scandodus furnishi* Lindström. Unfortunately the few specimens in this sample do not permit us to draw valid conclusions as to the composition of the *A. latus* apparatus, but they do establish the age of the species.

In our Lexington-Kope collections, conodont elements similar to the type species of *Acontiodus* are rare and are clearly conspecific with *A. alveolaris* Stauffer, 1935b. The compostion of the species of which *A. alveolaris* may have been a component is unknown, but it is probable that *A. falcatus* (Ethington, *non* Hadding) was part of the same apparatus. The material available to us does not provide much information on the nature of *Acontiodus*. It is referred to *Acontiodus* solely on the basis of form, but it may well represent an undescribed genus.

Range (of the form-genus).—Lower to Upper Ordovician.

Type species.—*Acontiodus latus* Pander, 1856.

Acontiodus alveolaris Stauffer Pl. 35, figs. 16-19

1935. *Acontiodus alveolaris* Stauffer, Jour. Paleont., vol. 9, pp. 601, 602, pl. 74, fig. 44.
1944. *Acontiodus,* n. sp. Branson, Univ. of Missouri Studies, vol. 19, pp. 89, 90, pl. 13, figs. 12, 13 (not pl. 13, figs. 9, 10, which are *Acontiodus falcatus* Ethington).
1959. *Acontiodus alveolaris* Stauffer, Ethington, Jour. Paleont., vol. 33, p. 268, pl. 39, figs. 23, 24.
1965. *Acontiodus alveolaris* Stauffer. Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 22, pl. 3, fig. 3.

We have two representatives of this distinctive species in our Lexington limestone collections. Both agree in all essential characters with the types of *Acontiodus alveolaris* Stauffer, and we do not hesitate to refer them to that species. Study of these specimens indicates that the conical basal cavity is deep and that it extends to the point of maximum cusp curvature.

The specimen identified as *Acontiodus alveolaris* by Ethington (1959, pl. 39, figs. 23, 24) is similar to our Lexington elements, but it appears to lack a groove on the posterior cusp margin. Whether this feature is of taxonomic significance cannot be decided on the basis of the material available.

The two specimens at hand are insufficient to allow us to recognize possible associates of this form-species. *Acontiodus aveolaris* is similar to *Acontiodus falcatus* (Ethington, *non* Hadding), and the two form-species occur together in at least part of their range. It may also be worthwhile to note that *Acontiodus alveolaris* appears in the Lexington limestone in the same interval in which the somewhat better-represented *Distacodus falcatus* and *Panderodus panderi* reach their greatest abundance.

Occurrence.—Lexington limestone, 331 and 334 feet above the base of our composite section. One representative occurs in section 64S1 (Banklick Creek); the other was derived from section 60M (Milford, Kentucky).

Acontiodus alveolaris is also known from single occurrences in the lowermost Decorah of Minnesota (Stauffer, 1935b), the Prosser of Iowa (Ethington, 1959), and the Kimmswick of Missouri (Branson, 1944). Webers (1966) described the species from the Ordovician of Minnesota, where it ranges from the upper beds of the Glenwood to the upper part of the Dubuque formation. There are undescribed representatives of this species in our collections from the uppermost part of the Kope formation near Maysville, Kentucky; from the Decorah (=Barnhart) formation just north of Eureka (St. Louis County), Missouri; from the Kimmswick formation just north of Barnhart (Jefferson County), Missouri; and from the Pecatonica member of the Platteville formation at McGregor, Iowa.

Repository.—Micropaleontological collections, The Ohio State University, reference slides 60M3-8, 64S1-10; figured specimen, OSU 27409.

Genus **AMORPHOGNATHUS** Branson and Mehl, 1933

1933. *Amorphognathus* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 126.
1933. *Ambalodus* Branson and Mehl, *idem*, p. 127.

Walliser (1964) noted that representatives of the form-genera *Amorphognathus* and *Ambalodus* occur regularly together in the oldest of the faunas he studied. He suggested that these elements are components of the same "Conodonten-Apparat." Our experience with large collections from diverse Middle and Upper Ordovician strata leads us to support Walliser's suggestion. Amorphognathus-like and ambalodus-like elements invariably occur together in all these collections, have fairly constant proportions to one another, have a common stratigraphic and geographic distribution, and have obvious similarities in general appearance and structure.

Amorphognathus and *Ambalodus* are both based on species whose types are discrete conodont elements from the Thebes sandstone member of the Orchard Creek ("Maquoketa") shale, at Ozora, Missouri. We have studied the types of both genera and thousands of specimens conspecific with them. These studies have convinced us that elements referable to *Amorphognathus ordovicica* and *Ambalodus triangularis* represent the same biologic apparatus. Consequently, we combine these two species into a single taxon, *Amorphognathus ordovicica*, and suggest that the scope of *Amorphognathus* be broadened to embrace multielement species that included paired ambalodus-like elements and unpaired amorphognathus-like elements of "blade" and "non-blade" types, respectively. Both of the form-species here united in multielement *Amorphognathus ordovicica*, as well as the distinctive "blade" and "non-blade" types of amorphognathus-like elements, have been thoroughly discussed in the recent literature (Sweet, *et al.*, 1959; Pulse and Sweet, 1960; Bergström, 1962; Bergström, 1964), and we have nothing to add to the details presented in those discussions.

Range.—Upper Lower Ordovician through Upper Ordovician. Walliser (1964) reported both *Amorphognathus* and *Ambalodus* from strata in the Carnic Alps that may be lowermost Silurian in age but are not necessarily so. Associated conodonts have a distinctly Ordovician aspect and further studies of the vertical distribution of conodonts near the Ordovician-Silurian boundary in well-dated sections are necessary before the age of Walliser's material can be definitely established.

Type species. — *Amorphognathus ordovicica* Branson and Mehl, 1933.

Amorphognathus ordovicica Branson and Mehl Pl. 28, figs. 1-8

1933. *Amorphognathus ordovicica* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 127, pl. 10, fig. 38.

1933. *Ambalodus triangularis* Branson and Mehl, *idem*, pp. 127, 128, pl. 10, figs. 35-37.

1940. *Dichognathus protexus* Stauffer, Jour. Paleont., vol. 14, p. 422, pl. 59, figs. 45, 46.

1941. *Amorphognathus ordovicica* Branson and Mehl, Graves and Ellison, Univ.

Missouri School Mines and Metallurgy, Bull., Tech. Ser., vol. 14, pp. 5, 7, pl. 3, figs. 32, 36-38.

1941. *Ambalodus triangularis* Branson and Mehl, Graves and Ellison, *idem,* pp. 5, 7, pl. 3, figs. 29, 33-35.

1944. *Amorphognathus ordovicica* Branson and Mehl, Branson and Mehl, *in* Shimer and Shrock, p. 237.

1944. *Ambolodus triangularis* Branson and Mehl, Branson and Mehl, *idem,* p. 237, pl. 93, figs. 7-8.

1944. *Amorphognathus ordovicica* Branson and Mehl. Branson, Univ. Missouri Studies, vol. 19, p. 95.

1944. *Ambalodus triangularis* Branson and Mehl, Branson, *idem,* p. 95.

1953. *Amorphognathus ordovicicus* Branson and Mehl, Rhodes, Phil. Trans. Roy. Soc. London, Ser. B, vol. 237, p. 283, pl. 20, figs. 47-49.

1953. *Ambolodus triangularis* Branson and Mehl, Rhodes, *idem,* p. 280, pl. 20, figs. 28-31.

1953. *Balognathus expansus* Rhodes, *idem,* p. 285, pl. 20, figs. 50-53, 57.

1955. *Amorphognathus ordovicicus* Branson and Mehl, Rhodes, Quart. Jour. Geol. Soc. London, vol. 111, p. 123, pl. 9, fig. 4.

1955. *Ambalodus triangularis* Branson and Mehl, Rhodes, *idem,* pp. 122, 123, pl. 7, figs. 9-14.

1955. *Amorphognathus duftonus* Rhodes, *idem,* p. 123, pl. 9, figs. 1, 3, 5, 8.

1957. *Amorphognathus adunca* Glenister, Jour. Paleont., vol. 31, p. 723, pl. 88, figs. 23, 24.

1957. *Ambalodus triangularis* Branson and Mehl, Glenister, *idem,* p. 722, pl. 88, figs. 20, 21.

1957. *Amorphognathus ramosa* (Stauffer), Glenister, *idem,* p. 724, pl. 88, fig. 27.

1959. *Amorphognathus ordovicica* Branson and Mehl, Stone and Furnish, Jour. Paleont., vol. 33, p. 220, pl. 32, fig. 12.

1959. *Ambalodus triangularis* Branson and Mehl, Stone and Furnish, *idem,* p. 219, pl. 32, fig. 3.

1959. *Amorphognathus* aff. *A. duftona* Rhodes, Ethington, Jour. Paleont., vol. 33, p. 270, pl. 40, fig. 11.

1959. *Ambalodus triangularis* Branson and Mehl, Ethington, *idem,* p. 269, pl. 40, fig. 12.

1959. *Amorphognathus* cf. *ordovicica* Branson and Mehl, Lindström, Micropaleont., vol. 5, p. 436, pl. 2, figs. 12-17.

1959. *Amorphognathus,* n. sp., Lindström, *idem,* pp. 437, 438, pl. 2, figs. 18, 19.

1959. *Ambalodus triangularis* Branson and Mehl, Lindström, *idem,* pp. 435, 436, pl. 2, figs. 1-11.

1959. *Amorphognathus* sp., Sweet, *et al.,* Jour. Paleont., vol. 33, pp. 1040, 1041, pl. 133, figs. 1, 2.

1959. *Ambalodus triangularis* Branson and Mehl, Sweet, *et al., idem,* p. 1040, pl. 133, fig. 4.

1960. *Amorphognathus ordovicica* Branson and Mehl, Pulse and Sweet, Jour. Paleont., vol. 34, pp. 248, 249, pl. 37, figs. 13, 15.

1960. *Ambalodus triangularis* Branson and Mehl, Pulse and Sweet, *idem,* p. 248, pl. 35, fig. 16.

1964. *Amorphognathus ordovicica* Branson and Mehl, Bergström, Acta Univ. Lundensis, sec. II, No. 3, pp. 15-17, text-fig. 5.

1964. *Ambalodus triangularis* Branson and Mehl, Bergström, *idem,* pp. 9, 10, 48, 50, 52, 56, 58, 59, 62.

?1964. *Amorphognathus,* n. sp., Walliser, Abh. Hess. L.-Amt. Bodenforsch., vol. 41, p. 27, pl. 4, fig. 1; pl. 10, figs. 25-27.

?1964. *Ambalodus triangularis* Branson and Mehl, Walliser, *idem,* p. 27, pl. 4, fig. 2; pl. 11, figs. 4-9.

1965. *Ambalodus triangularis* Branson and Mehl, Barnett, Micropaleont., vol. 11, p. 68, pl. 2, fig. 8.

?1965. *Amorphognathus* sp., Barnett, *idem,* p. 68, pl. 2, fig. 20.

1966. *Amorphognathus ordovicica* Branson and Mehl, Schopf, New York State Mus., Bull. 405, p. 40, pl. 3, figs. 1-7.

1966. *Ambalodus triangularis* Branson and Mehl, Schopf, *idem,* p. 39, pl. 4, figs. 1-5.

1966. *Amorphognathus ordovicica* Branson and Mehl, Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 22, pl. 13, figs. 16, 17.

Our Lexington-Kope collections contain 6074 mostly fragmentary representatives of the form-species *Amorphognathus ordovicica* and 3922 discrete elements referable to the form-species *Ambalodus triangularis.* Representatives of both form-species are invariably present in every collection large enough to include more than a few specimens of either. This common association is apparently true at every locality from which either form-species has been reported. As noted in our generic discussion, we regard the form-species *Amorphognathus ordovicica* and *Ambalodus triangularis* as parts of the biologic species *Amorphognathus ordovicica.*

Both of the form-species we include in *Amorphognathus ordovicica* have been thoroughly described in the recent literature and study of our large collections adds little to a knowledge of the structure or morphology of either. We should note that representatives of the "blade" and "non-blade" types of the form-species *Amorphognathus ordovicica* are apparently about equally abundant in our collections, although it is difficult to determine which form is represented by the numerous fragmentary processes we have. Typical representatives of each form-type have been described and illustrated recently by Bergström (1964).

Although we have 6074 fragmentary representatives of the form-species *Amorphognathus ordovicica,* we doubt that this figure is statistically significant. These elements are fragile and tend to break into three or four pieces: whole specimens are rare in our collections. It is probable that the form-species *Ambalodus triangularis* (of which we have nearly 4,000 specimens) is about twice as abundant as *A. ordovicica.* If this is so, we suggest that the smallest number of elements in a single individual of the composite species was 6: 1 each of the unpaired blade- and non-blade type of *A. ordovicica,* and four *Ambalodus triangularis.*

We have also noted that representatives of *Amorphognathus ordovicica* are most abundant in those parts of the section that contain appreciable thicknesses of shale. We do not suggest an association between this species and shale, but the relationship may indicate that the species developed best in the deeper, quieter water environment indicated in our sections (but not necessarily in others) by an increased volume of shale.

Occurrence. — *Amorphognathus ordovicica* ranges from 76 to 626 feet above the base of our composite Lexington-Kope section. It has been reported from the superjacent Fairview formation (Pulse and Sweet, 1960), and we have recovered a few representatives of the species from rocks of probable lower Richmondian age ("Arnheim") in the New Point, Indiana, core (section 65GV of this report). The synonymy at the head of this discussion indicates the widespread occurrence of *Amorphognathus ordovicica* and the known extent of its stratigraphic range.

Repository. — Micropaleontological collections, The Ohio State University. Reference slides from all sections included in this study (see Appendix B). Figured specimens, OSU 27410, 27411, 27412.

Genus **BELODINA** Ethington, 1959

1959. *Belodina* Ethington, Jour. Paleont., vol. 33, p. 271.
1959. *Eobelodina* Sweet, *et al.*, Jour. Paleont., vol. 33, p. 1050.

Ethington (1959) proposed *Belodina* for conodont species, formerly assigned to *Belodus*, which bear bladelike, crowded, or fused denticles on the posterior margin of the deeply excavated cusp, the base of which is expanded upward to form a prominent "heel" posterior to the denticle series.

Prior to 1959, most species of *Belodina* were assigned to *Belodus* Pander, the characters of which are obscure and the types of which are lost. Lindström (1964) expressed the opinion, which we share, that the type species of *Belodus* is probably a *Cordylodus*. It is unlikely that elements representing *Belodina* were available to Pander, for his collections were largely from Lower Ordovician strata and recent studies suggest that *Belodina* is restricted to the Upper Ordovician in the Baltic area. Thus we see no reason to confuse *Belodina* with *Belodus* (as was done by Hass, *et al.*, 1962), regardless of what the type species of the latter may eventually turn out to be.

We have studied hundreds of typical belodinas and they form a distinct group that is readily distinguished from all conodonts except those referred to *Eobelodina* Sweet, *et al.*, 1959. Eobelodinas are not common in any of the faunas we have studied, but they are almost invariably associated with *Belodina*, which they also resemble in nearly every structural particular. We believe this association and structural similarity indicate close relationship; indeed, it is our conclusion that both belodina- and eobelodina-like elements were parts of the same biologic apparatus and that the scope of *Belodina* should be broadened to include eobelodina-like elements.

It should be noted that not all faunas that yield typical belodinas contain eobelodina-like elements. Thus, although we believe that elements of both types were components of some species of *Belodina*, we do not mean to imply that both were necessarily present in every species of *Belodina*. For example, we have no evidence that there was an eobelodina-like element in *Belodina alabamensis* Sweet and Bergström, from the Middle Ordovician Pratt Ferry formation of Alabama, nor does any such element occur in association with the ones we refer to *B.* cf. *B. inornata* (Branson and Mehl) on a later page of this report. Actually, eobelodina-like elements may have developed only in *Belodina compressa* which includes *Eobelodina fornicala* (Stauffer), the type and only known species of *Eobelodina*.

Range. — Middle and Upper Ordovician. Best known from North America, but undescribed specimens have been collected recently from European Upper Ordovician strata.

Type species. — *Belodina compressa* (Branson and Mehl, 1933) (=*Belodus grandis* Stauffer, 1935b, which Ethington (1959) designated type of *Belodina*).

Belodina compressa (Branson and Mehl) Pl. 31, figs. 12-19

1933. *Belodus compressus* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 114, pl. 9, figs. 15, 16.
1935. *Belodus grandis* Stauffer, Jour. Paleont., vol. 9, pp. 603, 604, pl. 72, figs. 46, 47, 49, 53, 54, 57.
1935. *Belodus wykoffensis* Stauffer, *idem,* p. 604, pl. 72, figs. 51, 52, 55, 58, 59.
1935. *Oistodus fornicalus* Stauffer, *idem,* p. 610, pl. 75, figs. 3-6.
1936. *Belodus compressus* Branson and Mehl, Furnish, Barragy, and Miller, Am. Assoc. Petrol. Geol., Bull., vol. 20, p. 1334, pl. 1, fig. 10; pl. 2, fig. 13.
1944. *Belodus compressus* Branson and Mehl, Branson and Mehl, *in* Shimer and Shrock, pp. 79, 80, pl. 11, figs. 36, 37.
1944. *Belodus compressus* Branson and Mehl, Branson, Univ. Missouri Studies, vol. 19, pp. 81, 89, pl. 12, figs. 9, 10.
?1957. *Belodus dispansus* Glenister, Jour. Paleont., vol. 31, pp. 729, 730, pl. 88, figs. 14, 15.

1959. *Belodina compressa* (Branson and Mehl), Stone and Furnish, Jour. Paleont., vol. 33, p. 220, pl. 31, fig. 14.
?1959. *Belodina dispansa* (Glenister), Stone and Furnish, *idem,* p. 220, pl. 31, fig. 11.
1959. *Belodina compressa* (Branson and Mehl), Sweet, *et al.,* Jour. Paleont., vol. 33, p. 1042, pl. 133, figs. 12, 15.
1959. *Eobelodina fornicala* (Stauffer), Sweet, *et al., idem,* p. 1050, 1051, pl. 133, fig. 11.
1959. *Belodina grandis* (Stauffer), Ethington, Jour. Paleont., vol. 33, p. 272, pl. 40, fig. 14.
1959. *Belodina wykoffensis* (Stauffer), Ethington, *idem,* p. 272, pl. 40, fig. 16.
?1959. *Belodina* aff. *B. dispansa* (Glenister), Ethington, *idem,* p. 272, pl. 40, fig. 15.
?1959. *Belodina dispansa* (Glenister), Ethington and Furnish, Jour. Paleont., vol. 33, p. 542, pl. 73, figs. 12, 13.
1960. *Belodina compressa* (Branson and Mehl), Carlson, North Dakota Geol. Sur., Bull. 35, p. 71, pl. 2, fig. 19.
1960. *Belodina grandis* (Stauffer), Carlson, *idem,* tab. II.
?1960. *Oistodus fornicalis (sic)* Stauffer, Carlson, *idem,* p. 77, pl. 2, fig. 18.
1960. *Belodina inclinata* (Branson and Mehl) ?, Pulse and Sweet, Jour. Paleont., vol. 34, p. 250, pl. 37, figs. 10, 11.
?1960. *Belodina leithi* Ethington and Furnish, Jour. Paleont., vol. 34, p. 269, pl. 38, fig. 12.
1962. *Belodina grandis* (Stauffer), Sweet and Bergström, Jour. Paleont., vol. 36, p. 1224, pl. 170, figs. 16, 17.
1963. *Belodus compressus* Branson and Mehl, Cygan and Koucky, Guidebook, First Joint Field Conf., Wyo. Geol. Assoc.-Billings Geol. Soc., Northern Powder River Basin, pp. 33, 34, pl. 1, fig. 11.
1965. *Belodina compressa* (Branson and Mehl), Barnett, Micropaleont., vol. 11, p. 68, pl. 1, fig. 30.
?1965. *Belodina* cf. *B. dispansa* (Glenister), Barnett, *idem,* p. 68.
1966. *Belodina compressa* (Branson and Mehl), Schopf, New York State Mus., Bull. 405, p. 41, pl. 1, figs. 1, 3, 4, 6.
?1966. *Belodina dispansa* (Glenister), Schopf, *idem,* p. 43, pl. 1, fig. 7.
1966. *Eobelodina fornicala* (Stauffer), Schopf, *idem,* p. 55, pl. 1, fig. 16.
1966. *Belodina compressa* (Branson and Mehl), Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 24, pl. 6, figs. 2, 6, 7, 13, 15.

Conodont elements referable to *Belodina compressa* (in which we include a variety of variously named form-species) and *Eobelodina fornicala* are almost invariably associated in North American Middle and Upper Ordovician rocks, have a common stratigraphic range, and share a number of distinctive biocharacters. We believe they represent a single biologic species, for which *Belodina compressa* (Branson and Mehl) is the oldest valid name.

Our Lexington and Kope collections contain 187 representatives of the form-species *Belodina compressa,* and 44 specimens referable to *Eobelodina fornicala.* Both form-species are distinctive, long-ranging, and have been fully described (under various names) in the recent literature (Ethington, 1959; Sweet, *et al.,* 1959; Sweet and

Bergström, 1962). We see no need to redescribe either of the form-species we include in *Belodina compressa,* but comments on the variation and nomenclature of the typical, multidenticulate form are appropriate.

As we have noted elsewhere (Sweet, *et al.,* 1959; Sweet and Bergström, 1962), we see no objective way to distinguish the types of *Belodina compressa* (Branson and Mehl) from those of *B. grandis* (Stauffer). Further, we can not agree with Stauffer (1935b) or Ethington (1959) that significant differences separate the form-species *B. grandis* (Stauffer) and *B. wykoffensis* (Stauffer). To be sure, we can recognize different growth stages of forms identical with both *B. grandis* and *B. wykoffensis* in the material at hand and could readily divide most of it into these form-groups. Those of *B. grandis* type are somewhat more elongate than those of *B. wykoffensis* type, and most of them have six or seven (rather than four or five) denticles on the concave margin of the cusp. There are many specimens that are intermediate between these two extremes in both characters, and the two form groups have essentially the same stratigraphic range. For these reasons, we regard *B. grandis* and *B. wykoffensis* as the extremes in a somewhat variable species, for which the name *Belodus compressus* Branson and Mehl is the oldest available denomination.

Although we have studied the types of *Belodina compressa* (Branson and Mehl), *B. grandis* (Stauffer), and *B. wykoffensis* (Stauffer), we have not seen those of either *B. dispansa* (Glenister) or *B. leithi* Ethington and Furnish. Kope collections at The Ohio State University contain a few belodinas strikingly similar to the figured types of both species and we do not hesitate to group those specimens with representatives of *B. compressa* that occur in the same, or stratigraphically adjacent, collections. *B. dispansa,* in our view, probably represents early growth stages of *B. compressa,* and *B. leithi* can be distinguished from the forms described as *B. wykoffensis* by Stauffer and Ethington only in that the five denticles of the concave margin increase slightly in length anteriorly. Because our representatives of these species are identical in all other respects with conodont elements clearly referable to *B. compressa* (Branson and Mehl), we group them with that species.

We can add nothing to the description of elements previously identified as *Eobelodina fornicala* (Stauffer) from study of the 44 specimens at hand. It should be noted that the "*Oistodus fornicalus*" described by Graves and Ellison (1941) from the Fort Peña formation of Texas represents *Oistodus venustus*, a species that is not in any way related to *Belodina compressa*.

Occurrence. — *Belodina compressa* (including *Eobelodina fornicala*) ranges from 48 to 565 feet above the base of our composite Lexington-Kope section. The species is represented in collections from all our Lexington sections except 60A (Cynthiana, Kentucky), 60H (Menzie, Kentucky), and 64S3 (Frankfort West, Kentucky). As the synonymy indicates, *Belodina compressa* is widespread geographically in North America and has a long stratigraphic range. The lowest reported occurrence of the two form-species we unite in *Belodina compressa* is in the Pratt Ferry formation of Alabama (Sweet and Bergström, 1962); it occurs in the Glenwood shale of Minnesota (Webers, 1966) and the Chaumont formation of New York and southern Ontario (Schopf, 1966); and typical representatives of this taxon range upward into rocks of lower Maysvillian age in Ohio (Pulse and Sweet, 1960). In this connection, it is also of interest to note that one of us (Bergström) has collected conodont elements that are similar to, if not identical with, *Belodina compressa* from Ashgillian strata in south-central Sweden. These elements are the first typical representatives of *Belodina* to be recorded from Europe.

Repository. — Micropaleontological collections, The Ohio State University. The 187 representatives of the form-species *Belodina compressa* are included in reference slides from sections 60BCK, 60D, 60G, 60L, 60M, 60P, 60Q, 60T, 61Z, 64S1, 64S2. The 44 specimens representing the form-species *Eobelodina fornicala* are in reference slides from sections 60B, 60BCK, 60G, 60L, 60M, 60P, 61Z, 64S1, 64S2. Figured specimens, OSU 27413, 27414, 27415.

Belodina sp. cf. **B. inornata** (Branson and Mehl) Pl. 32, figs. 6-8

cf. 1933. *Belodus inornatus* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 115, pl. 9, fig. 18.

The conodont elements here described as *Belodina* sp. cf. *B. inornata* Branson and Mehl are bilaterally symmetrical to markedly asymmetric units with a large asymmetrically subconical basal cavity that is triangular in lateral view and both highest and widest posteriorly. The concave margin of each element is denticulate and its posterior end is developed into a low "heel." The smallest specimens in our collections have six essentially erect denticles on the concave margin of the cusp; larger specimens have only three to four denticles in this position, for during ontogeny anterior denticles of the concave margin were gradually overgrown by, and thus included in, the posterior margin of the cusp.

Sides of the element are longitudinally striated, and the nondenticulate portion of each is constricted near mid-height by a broad longitudinal groove. In symmetrical units, this groove is inconspicuous but developed about equally on each side; in asymmetric elements the groove is distinctly more prominent on one side than the other and in some specimens the raised or longitudinally swollen areas subjacent to it are developed as costae. There is little apparent regularity in the development of these costae and we attribute no taxonomic significance to them.

The basal cavity is similar in lateral outline to that of other species of *Belodina*, and it is incompletely divided into narrow upper, and more swollen lower, portions by the same longitudinal grooves that ornament the surface on each side. These segments of the basal cavity communicate with one another. They are not isolated by inward confluence of the lateral grooves as they appear to be in *B. compressa*, type species of *Belodina*.

Remarks. — The conodont elements included under this name represent a species that is internally somewhat variable, but distinctive and readily separated from *Belodina compressa*, with which it occurs in the upper part of its range. The species represented by these elements may be the one for which Branson and Mehl (1933) coined the name *Belodus inornatus*, but we can not be certain of this because *B. inornatus* is based on a single specimen from which we can learn little about the range of specific variation. In aggregate, the specimens available to us exhibit many of the distinctive features of *B. inornatus*, and the holotype of that species may represent a massive late growth stage of elements like those at hand. On the other hand, the holotype of *B. inornatus* apparently lacks a "heel," and has a shelflike lateral projection immediately beneath the denticle series. All our specimens have a "heel" and none develops the shelflike projection of the holotype. Thus to indicate the relationship between our specimens and the type of *B. inornatus*, as well as to express our uncertainty about the holotype of that species, we use open nomenclature rather than propose a new name that may ultimately prove synonymous with *Belodina inornata* (Branson and Mehl).

Occurrence. — The 19 representatives of *Belodina* sp. cf. *B. inornata* in our Lexington limestone collections were derived from the lower portion of the Middletown Core (section 61Z) and an equivalent interval in the Frankfort East, Kentucky, section (64S2). As indicated in Text-figure 4 these occurrences define a Lexington limestone range between 58 and 70 feet above the base of our composite section. The holotype of *Belodina inornata* is from the Plattin formation, at Warrenton, Missouri, but Branson and Mehl (1933, p. 115) also mentioned similar specimens from the Thebes sandstone at an unspecified Missouri locality.

Repository. — Micropaleontological collections, The Ohio State University. Reference slides 61Z-637, 480; 64S2-7. Figured specimen, OSU 27416.

Genus **BRYANTODINA** Stauffer, 1935

1935. *Bryantodina* Stauffer, Geol. Soc. America, Bull., vol. 46, p. 131.

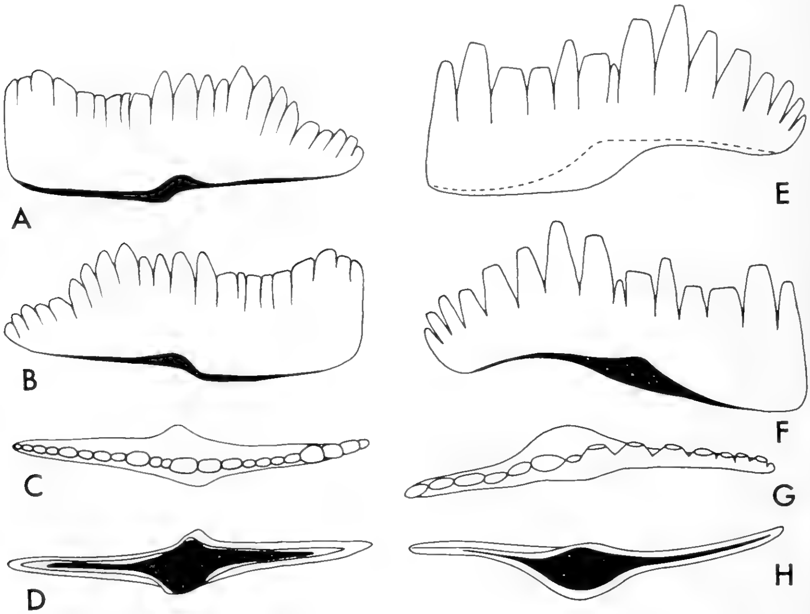
Range. — After examination of the types of *Bryantodina typicalis* Stauffer (type species of *Bryantodina)* and *Spathognathodus primus* (Branson and Mehl) (Text-figure 7); and after comparison of these with the neotype of *Ctenognathus murchisoni* illustrated by Gross (1957) and with Silurian to Triassic representatives of many other species commonly referred to the form-genus *Spathognathodus*, we conclude that *Bryantodina*, not *Spathognathodus*, is the oldest valid name for the form-genus in which all these conodonts belong. Thus inclusive, *Bryantodina* ranges from the Lower Ordovician (Lindström, 1960) to the Middle Triassic (Tatge, 1956), and may extend as high as the Cretaceous (Diebel, 1956). This great range suggests that bryantodina-like elements occupied a conservative but consistently important function in conodont species representing many different stocks.

Type species. — *Bryantodina typicalis* Stauffer, 1935.

Bryantodina? abrupta (Branson and Mehl) Pl. 30, figs. 9-12; Text-fig. 8A-D

1933. *Ozarkodina* (?) *abrupta* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 100, pl. 6, fig. 11.
1944. *Bryantodina*, n. sp. Branson, Univ. Missouri Studies, vol. 19, p. 90, pl. 13, figs. 34-36.
1966. *Bryantodina abrupta* (Branson and Mehl), Schopf, New York State Mus., Bull. 405, p. 44, pl. 4, figs. 13, 14.
1966. *Rhipidognathus paucidentata* Branson, Mehl, and Branson, Schopf, *idem*, p. 72, pl. 2, fig. 21.

Bryantodina-like elements of *Bryantodina*? *abrupta* are straight, unbowed, laterally compressed, and bladelike, consisting of a long, high, massive anterior process and a low, short, posterior process. The upper edge of the anterior process bears a series of four to eight short, straight denticles that are robust, slightly compressed laterally, blunt-pointed, and laterally confluent for most of their length. Most of the denticles on the anterior process are of about the same length; the two anteriormost ones tend to be slightly longer than the others



Text-fig. 7. A-D. *Bryantodina prima* (Branson and Mehl), type species of *Spathodus* Branson and Mehl. Camera lucida drawing, X25, of Univ. Missouri specimen C151-5 (illustrated by Branson and Mehl, 1933, pl. 3, fig. 25). E-H. *Bryantodina typicalis* Stauffer, type species of *Bryantodina* Stauffer, 1935. Camera lucida drawing, X 85, of holotype (figured by Stauffer, 1935a, pl. 10, fig. 23).

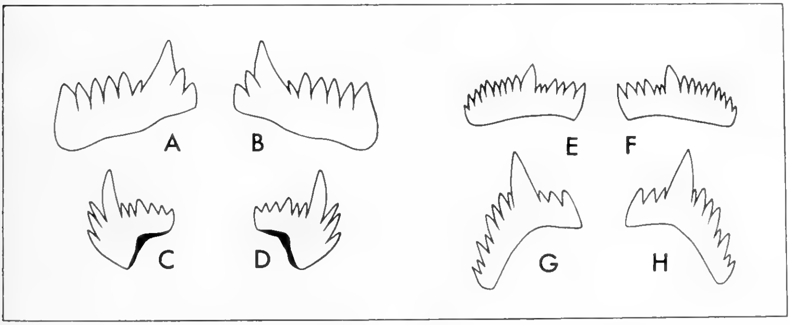
and the denticle immediately in front of the cusp is distinctly smaller than others on the anterior process in many specimens.

Posterior to the denticles of the anterior process is a strongly reclined cusp that is slightly compressed laterally and has convex lateral faces. The short posterior process bears two or three reclined, laterally confluent denticles, which decrease in size and length posteriorly. The denticle immediately posterior to the cusp tends to be suppressed during growth and is ultimately incorporated in the cusp base. No such tendency for "overgrowth" has been observed at any other site on either process.

The under side of the element is longitudinally excavated for its full length. Beneath the anterior process, the basal cavity is shallow and narrow; below the cusp, its walls flare laterally and the enclosed cavity is more capacious. Posterior to the cusp, the basal cavity is narrow and shallow, but it can be traced to the extremity of the short process.

The sides of both the anterior and posterior process are smooth and faintly convex in most specimens. In large specimens, there is a marked constriction in one side along the upper edge of the sheath and a somewhat less conspicuous constriction in the same position on the opposite side.

The prioniodina-like elements we include in *Bryantodina? abrupta* are arched, faintly bowed, individually asymmetric, and consist of a laterally compressed, erect to slightly recurved cusp and short an-



Text-fig. 8. A-D. *Bryantodina? abrupta* (Branson and Mehl). E-H. *Bryantodina? staufferi, sp. nov.* Diagrammatic lateral views of bryantodina-like (A,B; E,F) and prioniodina-like (C,D; G,H) elements of these species, X 30.

terior and posterior processes, the longitudinal axes of which are about at right angles to one another. The anterior process bears three to four erect to proclined, laterally compressed denticles that are discrete and sharp pointed distally, but confluent laterally, and which increase in width and length toward the cusp. The posterior process, which is about half as high as the anterior process, bears three to four low erect denticles of subequal size, which are discrete for their full length.

The under side of the prioniodina-like elements is excavated to the extremities of both processes. The basal cavity is most capacious beneath the cusp; its sheath flares slightly toward the concave (or inner) side of the element and more conspicuously toward the convex (or outer) side.

Remarks. — The bryantodina- and especially the prioniodina-like forms we include in this species are similar in plan and overall development to comparable elements in *Rhipidognathus discreta, sp. nov.* That species, however, also includes subsymmetrical trichonodella-like elements, as does *R. symmetrica,* the type species of *Rhipidognathus.* Primarily for this reason, then, we refer the Lexington-Kope species to *Bryantodina* rather than *Rhipidognathus.* Our generic assignment is supported because the holotype of *Ozarkodina? abrupta* Branson and Mehl is clearly referable to the form-genus *Bryantodina.* On the other hand, Webers (1966) indicated that *Bryantodina typicalis* Stauffer, type species of *Bryantodina,* may have included hibbardella-like elements (as well as prioniodina-like structures) and no hibbardella-like forms occur with the elements we include in the species at hand. Thus, we indicate a residual uncertainty by including this species only tentatively in *Bryantodina.*

Occurrence. — The two form-variants we include in *Bryantodina? abrupta* are almost invariably associated in our Lexington limestone collections and range from 65 to 289 feet above the base of our composite Lexington-Kope section. Single occurrences are also represented 383 and 432 feet above the base of that section, indicating a total known range in Kentucky, Ohio, and Indiana, of 65-432 feet in our composite section. Bryantodina-like elements of *B.? abrupta* are known from the Joachim and Kimmswick formations of Missouri, and both have been reported from New York and Ontario (Schopf, 1966), where they occur in the Kirkfield and (rarely) in the lower Cobourg formations.

Repository. — Micropaleontological collections, The Ohio State University. Reference slides from sections 60BCK, 60D, 60P, 60Q, 60T, 61Z, 64S2, and 64S3 contain 279 bryantodina-like elements and 76 prioniodina-like forms, which suggests the two may have occurred together in the simple ratio of 4:1. Figured specimens, OSU 27417, 27418.

Bryantodina? staufferi Bergström and Sweet, sp. nov. ?Pl. 33, figs. 10, 11; Pl. 34, figs. 1, 2, 3, 4; Text-fig. 8E-H

This new species is based on 46 discrete specimens, 30 of which represent the form-genus *Bryantodina* and 16 the form-genus *Ozarkodina*. Three additional specimens that belong in the form-genus *Trichonodella* may also be structural components of this species, but we are not certain about them and do not include them among the types of *Bryantodina? staufferi.*

Bryantodina-like elements are virtually straight, unbowed, and have subequal anterior and posterior processes surmounted by laterally compressed, apically discrete, sharp-pointed denticles. The eight or more erect to faintly reclined denticles of the anterior process increase regularly in height toward the cusp, which is conspicuously reclined and is the longest denticle of the series. The five to seven reclined denticles of the posterior process are shortest near the cusp and at the posterior extremity; thus they form a series that is arcuate in lateral view and has its crest near process mid-length.

The basal margin of the bryantodina-like elements is faintly sinuous in lateral aspect as a result of the fact that the undenticulated portion of the posterior process is not so wide as the corresponding part of the anterior process. Center of basal cavity is an asymmetrically subconical pit beneath the cusp, with an apex that is directed somewhat anteriorly and projects to mid-height of the undenticulated segment of the blade. Walls of subapical pit flare faintly and about equally to each side, somewhat posterior to the cusp on one side and slightly anterior to it on the other. Under side of both processes excavated by a shallow groove with inconspicuously flaring walls which is continuous with the subapical pit. This groove is shallower beneath the anterior process than beneath the posterior, but extends to the extremities of both.

Ozarkodina-like elements are similar to the bryantodina-like forms of *Bryantodina*? *staufferi*. They differ from these elements only in being arched (rather than straight), somewhat bowed, and in having a cusp that is somewhat longer and wider basally.

The three trichonodella-like elements that may have been components of *Bryantodina*? *staufferi* (Pl. 33, figs. 10, 11) are arched, posteriorly bowed, symmetrical to subsymmetrical elements with two compressed bladelike processes, the axes of which intersect the cusp axis at about 45°. The cusp, which is at the junction of the lateral processes, is erect to slightly reclined, sharp pointed, and is the longest of the denticles. Denticles of the lateral processes are compressed, laterally confluent, apically discrete, and sharp pointed. The basal cavity is low and narrow, but extends as a faint groove to the process extremities; beneath the cusp its sheath expands slightly toward both the posterior and anterior sides of the element, but no discernible posterior process is formed.

Discussion. — The bryantodina-like and ozarkodina-like elements of *Bryantodina*? *staufferi* are reminiscent of the Crug limestone specimens described as *Ctenognathus pseudofissilis* and *Ozarkodina pseudotypica* by Lindström (1959). The Welsh specimens are robust, conspicuously bowed, and have a posterior process that is shorter than the anterior process. Further, Lindström's collections apparently did not include trichonodella-like elements of the type we describe above, and which may belong in *B.*? *staufferi*.

Bryantodina- and ozarkodina-like elements in *B.? staufferi* are also somewhat similar to comparable structures in *Rhipidognathus discreta* and *R. symmetrica,* but they lack the subapical boss characteristic of all elements in those species.

We assign the new species only provisionally to *Bryantodina* because the structure and composition of *B. typicalis,* its type species, are still not certainly known. Webers (1966) suggested that *B. typicalis* may have included hibbardella-like elements, and structures of this type are apparently absent in *B.*? *staufferi*. Bryantodina-like elements in *B.*? *staufferi* are generally similar to those of *B. typicalis,* and this suggests at least a broad relationship between the two species.

Occurrence.—Bryantodina? staufferi ranges from 106 to 305 feet above the base of our composite Lexington-Kope section. No component of this species has been reported from any other locality.

Repository.—Micropaleontological collections, The Ohio State University. Reference slides 60L2-2, 60L3-1; 60PJ-64, 60PJ92; 60Q1-1, 60Q1-5; 60T3-1; 61Z-491, 509, 512, 513; 64S2-13, 14, 17, 32, 33, 37, 39, 46, 47, 48. Syntypes, OSU 27420, 27421. Figured trichonodella-like element, OSU 27419.

Genus **CYRTONIODUS** Stauffer, 1935

1935. *Cyrtoniodus* Stauffer, Geol. Soc. America, Bull., vol. 46, p. 140.

In a conodont taxonomy based strictly on single-element morphology, there is little reason to recognize both *Cordylodus* Pander, 1856, and *Cyrtoniodus* Stauffer, 1935, and several recent authors (Lindström, 1955a; Sweet, *et al.,* 1959) have suggested that the latter is synonymous with the former. In a natural classification, there is ample reason to regard the two categories as distinct, even if their type form-species are subjectively indistinguishable at the generic level.

Pander (1856) based *Cordylodus* on two types of conodont elements from the Lower Ordovician of Estonia, which he named *C. angulatus* and *C. rotundatus.* Subsequent studies (Lindström, 1955a; Furnish, 1938; Sando, 1958) indicate that these two form-species are Lower Ordovician associates in both Sweden and North America, and we believe they were parts of the same biologic apparatus, *C. rotundatus.* A similar pair of cordylodus-like elements, described as *C. spinatus* and *C. ramosus,* has been recovered from the Middle Ordovician of Sweden, Scotland, and North America (Hadding, 1913; Lindström, 1955b, 1964; Lamont and Lindström, 1957; Kay, 1962; Sweet and Bergström, 1962). We agree with Lindström (1964) that these elements also represent a single biologic species, *C. ramosus.* As noted by Lindström (1964) *C. ramosus* represents an even more elaborate apparatus than *C. rotundatus,* for it includes ligonodina-like and roundya-like elements in addition to two form-species of cordylodus-like elements. We regard these differences as significant only on the specific level, for it has been our observation that development in other conodont stocks also tends to produce more elaborate apparatuses in time.

The type form-species of *Cyrtoniodus, C. complicatus* Stauffer, includes cordylodus-like elements, but they lack the "inverted" basal cavity that is prominent in typical species of *Cordylodus,* their basal sheath expands broadly beneath the cusp, and their process denticles tend to be shorter and more approximate than those of typical *Cordylodus.* We would regard these distinctions as significant on only the specific level if it were not that the assembly of the form-species of which *Cyrtoniodus complicatus* is evidently a part includes only cordylodus-like elements and very closely related ligonodina- or prioniodina-like structures. In this respect, it appears that we are dealing with a stock that is much removed from, or completely unrelated to, *Cordylodus.* Because this stock includes the type form-species of *Cyrtoniodus,* it is appropriate to retain that name for it.

Range.—Cyrtoniodus, as just interpreted, is apparently restricted to Middle and Upper Ordovician strata. It is common in Midcontinent faunas in North America, but scattered occurrences are known in Great Britain. In addition, *Neoprioniodus planus* Walliser, 1964, is almost certainly a *Cyrtoniodus,* and we suspect that the rocks from which it was collected are largely Upper Ordovician in age, rather than Lower Silurian.

Type species.—Cyrtoniodus flexuosus (Branson and Mehl, 1933).

Cyrtoniodus flexuosus (Branson and Mehl) Pl. 32, figs. 9-11

?1932. *Euprioniodina crassa* Stauffer, Jour. Paleont., vol. 6, p. 262, pl. 40, fig. 24.
1933. *Prioniodus? flexuosus* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 130, pl. 10, fig. 16.
1935. *Cyrtoniodus complicatus* Stauffer, Geol. Soc. America, Bull., vol. 46, p. 140, pl. 11, figs. 44, 46, 48, 49, 50, 51.
1935. *Stereoconus gracilis* Branson and Mehl (part), Stauffer, *idem,* p. 153, pl. 12, fig. 32.
1935. *Plectodina glenwoodensis* Stauffer, *idem,* p. 152, pl. 11, figs. 38, 39.
1935. *Subcordylodus paratus* Stauffer, *idem,* p. 154, pl. 10, fig. 48.
1935. *Cyrtoniodus apicalis* Stauffer, Jour. Paleont., vol. 9, p. 604, pl. 73, figs. 1, 10, 43, 45.
1935. *Cyrtoniodus complicatus* Stauffer, Stauffer, *idem,* p. 604, pl. 73, figs. 9, 11-13, 15-16, 18-20, 25, 27, 32, 38, 41-42, 47.
1935. *Subcordylodus* sp. Stauffer, *idem,* p. 618, pl. 73, fig. 21.
1936. *Prioniodus?* sp. Furnish, Barragy, and Miller, Amer. Assoc. Petrol. Geol. Bull., vol. 20, p. 1334, pl. 2, fig. 20.
1941. *Cordylodus?* sp. Graves and Ellison, Missouri Univ. School Mines and Metallurgy, Bull., Tech. Ser., vol. 14, p. 5, pl. 8, fig. 15.

1944. *Cyrtoniodus complicatus* Stauffer, Branson and Mehl, *in* Shimer and Shrock, p. 240, pl. 93, fig. 68.
1953. *Cyrtoniodus complicatus* Stauffer, Rhodes, Phil. Trans. Roy. Soc. London, ser. B, v. 237, p. 302, pl. 22, figs. 193-196.
1953. *Cordylodus spurius* Branson and Mehl, Rhodes, *idem,* p. 301, pl. 21, fig. 133.
1957. *Cyrtoniodus complicatus* Stauffer, Glenister, Jour. Paleont., vol. 31, p. 732, pl. 88, fig. 16.
1959. *Cyrtoniodus complicatus* Stauffer, Stone and Furnish, Jour Paleont., vol. 33, pp. 221, 222, pl. 31, fig. 9.
1959. *Cyrtoniodus complicatus* Stauffer, Ethington, Jour. Paleont., vol. 33, p. 274, pl. 40, fig. 7.
1959. *Cyrtoniodus complicatus* Stauffer, Ethington and Furnish, Jour Paleont., vol. 33, p. 541, pl. 73, fig. 4.
1959. *Cordylodus flexuosus* (Branson and Mehl), Sweet, *et al.,* Jour. Paleont., vol. 33, p. 1045, pl. 132, fig. 13.
1959. *Cordylodus* cf. *spurius* Branson and Mehl, Lindström, Micropaleont., vol. 5, p. 438, pl. 4, fig. 21.
1960. *Cyrtoniodus complicatus* Stauffer, Ethington and Furnish, Jour. Paleont., vol. 34, p. 270 (not figured).
1960. *Cyrtoniodus sinclairi* Ethington and Furnish, *idem,* pp. 270, 271, pl. 38, fig. 16.
1960. *Cordylodus flexuosus* (Branson and Mehl), Pulse and Sweet, Jour. Paleont., vol. 34, pp. 251, 252, pl. 36, figs. 4, 7.
1964. *Cordylodus flexuosus* (Branson and Mehl), Bergström, Acta Univ. Lundensis, sec. II, No. 3, pp. 17-18.
1965. *Cordylodus flexuosus* (Branson and Mehl), Barnett, Micropaleont., vol. 11, p. 69, pl. 1, fig. 4; pl. 2, fig. 3.
?1965. *Cordylodus* cf. *C. glenwoodensis* (Stauffer), Barnett, *idem,* p. 69, pl. 1, fig. 22.
1966. *Cordylodus flexuosus* (Branson and Mehl), Schopf, New York State Mus., Bull. 405, p. 47, pl. 2, fig. 20.
1966. *Cordylodus flexuosus* (Branson and Mehl), Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 25, pl. 8, fig. 8.

This species, to which we refer 10,197 Lexington-Kope conodont elements, has had varied treatment in the literature and, as indicated in the synonymy, has been described under many names. We have compared the types of *Prioniodus? flexuosus* Branson and Mehl and *Cyrtoniodus complicatus* Stauffer and are convinced that they represent the same form-species. We are likewise convinced that the types of *Plectodina glenwoodensis* Stauffer, *Subcordylodus paratus* Stauffer, and *Cyrtoniodus apicalis* Stauffer are objectively indistinguishable from those of *Cyrtoniodus complicatus* Stauffer, which we regard as a junior subjective synonym of *Prioniodus? flexuosus* Branson and Mehl. We are not certain that *Prioniodus? flexuosus* Branson and Mehl is the oldest name for this species. In 1932 Stauffer described a species from the "Decorah Shale" of Kansas, which he termed *Euprioniodina crassa.* His description and illustration of this species are unfortunately inconclusive, and its type specimens have apparently been lost. No such doubt attaches to the types of *Prioniodus? flexuosus* Branson and Mehl, and we employ that name for the species under consideration.

Because there are several differences between Ordovician species of *Cordylodus* and the assembly of elements here referred to *Prioniodus? flexuosus* Branson and Mehl, we do not now believe that it can properly be included in *Cordylodus* Pander. *Prioniodus? flexuosus* includes the type species of *Cyrtoniodus* Stauffer, and that name has been employed heretofore only for form-species of cordylodus-type. Thus we include *Prioniodus? flexuosus* Branson and Mehl in *Cyrtoniodus* Stauffer and broaden the scope of that genus to include prioniodina- or ligonodina-like elements.

Typical representatives of *Cyrtoniodus flexuosus* (Branson and Mehl) are pick-shaped, compound, individually asymmetric conodont elements, with a prominent laterally compressed anterior cusp and an arched posterior process surmounted by closely appressed denticles of minor size. In some of these forms, the unit is bowed; in others it is essentially straight. In all of them there is a capacious basal cavity that extends the full length of the underside of the element and a conspicuous downwardly directed anterior anticusp.

More than 500 of the elements we include in *Cyrtoniodus flexuosus* bear one to several discrete, laterally compressed denticles on the upper edge of the anticusp, or anterior process, and the length and degree of development of this denticulated process are clearly associated with the relative size of the element. That is, all our specimens exhibiting anterior denticulation are relatively large forms, representing robust (or late) growth stages. We have assembled an almost complete series of transitions from forms lacking anterior denticles to those with a conspicuously denticulated anterior process. Thus we include both cordylodus- and prioniodina-type elements in *Cyrtoniodus flexuosus* (Branson and Mehl).

Occurrence.—Cyrtoniodus flexuosus is ubiquitous in Ohio Valley Middle and Upper Ordovician sections, where it has a known range from the base of the Lexington limestone (58 feet above the base of our composite section) into strata in the lower part of the Richmondian Whitewater formation (McClish, 1965). In New York and adjacent parts of southern Ontario and Quebec, *Cyrtoniodus flexuosus* ranges from at least as low as the Chaumont formation to the top of the Cobourg (Schopf, 1966), and in the Upper Mississippi Valley the species is known from the upper beds of the Glenwood shale through the Elgin member of the Maquoketa formation (Webers, 1966). We regard this species as typical of the North American Midcontinent conodont fauna, for its distribution is essentially like that of *Phragmodus undatus*, the index to that fauna.

Repository.—Micropaleontological collections, The Ohio State University. Representatives of *Cyrtoniodus flexuosus* occur in virtually every reference slide from all Lexington-Kope sections included in this study (see Appendix B). Prioniodina-like elements included in this species occur only in slides from sections 60A, 60B, 60G, 60H, 60L, 60M, 60P, 60T, 64S2, and 64S3, at least parts of which are dominated by robust elements referable to a variety of species. Figured specimens, OSU 27422, 27423.

Cyrtoniodus, sp. nov. Pl. 32, figs. 12-14

1966. *Cordylodus* n. sp. Schopf, New York State Mus., Bull. 405, p. 48, pl. 2, fig. 16.

The five conodont elements we describe as *Cyrtoniodus, sp. nov.* are similar in having an erect, sharp-pointed cusp and an arched, bowed posterior process with smooth sides and discrete, erect to slightly reclined, laterally compressed denticles. Below the posterior process, the attachment cavity is a low narrow groove; posterior to the cusp axis this groove expands to form a slightly more capacious cavity with an inwardly flaring wall, then continues as an inconspicuous slitlike groove almost to the bluntly rounded antero-basal corner of the element.

In some respects, *Cyrtoniodus, sp. nov.* resembles the Plattin limestone specimen described as *Cordylodus spurius* by Branson and Mehl (1933), but direct comparison of our specimens with the type of *C. spurius* indicates that they are not conspecific. Representatives of *Cyrtoniodus, sp. nov.* are also similar to *Cyrtoniodus flexuosus* in the shape of the posterior process and cusp, in denticulation, and also, to some extent, in development of the basal cavity. The principal difference between the two form-species is the shape of the antero-basal corner, which is bluntly rounded in our new species, but acute or "pick-like" in *C. flexuosus.*

Representatives of *Cyrtoniodus, sp. nov.* were derived from the same part of the Lexington-Kope section as those described as *Plectodina*? *posterocostata.* We have so few specimens of either species that we are unable to determine if this common occurrence represents a faunal association or whether the two were originally components of the same biologic apparatus.

Occurrence. — *Cyrtoniodus, sp. nov.* ranges from 183 to 195 feet above the base of our composite Lexington-Kope section.

Repository. — Micropaleontological collections, The Ohio State University. Reference slides 61Z-510, 512. Figured specimen, OSU 27424.

Genus **DISTACODUS** Hinde, 1879

1856. *Machairodus* Pander (*non* Kaup, 1853), Monographie der Fossilen Fische des Silurischen Systems der Russisch-Baltischen Gouvernements, p. 22.
1879. *Distacodus* Hinde, Quart. Jour. Geol. Soc. London, vol. 35, p. 357.

Pander's figures (1856, pl. 1, figs. 22a,b,c) of the type form-species of *Distacodus, Machairodus incurvus* Pander, suggest that it is generally similar to the "suberectus"-element of *Drepanodus suberectus,* from which it differs primarily in having lateral costae (or carinae). The significance of this difference is difficult to evaluate, for Pander's figures may be somewhat generalized and *D. incurvus* has never been reported by anyone other than Pander. It is possible that *D. incurvus* (Pander) is the "suberectus"-like element of an assembly similar to the one we include in *Drepanodus suberectus* and these two species may be congeneric. No information is available to us about the apparatus of which the form-species *D. incurvus* may once have been a part and, therefore, we are unable to define *Distacodus* as a "natural" taxonomic unit. We interpret the genus here in the same formal way advocated by Pander (1856) and Lindström (1955a).

Elements fitting Pander's description of *Distacodus* are rare in North American Midcontinent Middle and Upper Ordovician rocks. In our Lexington-Kope collections only one species, *D. falcatus* Stauffer, is referable to the genus and this form constitutes an insignificant part (0.0070%) of those collections. Hence we have no indication that *D. falcatus* is associated with any other element in the faunas described, nor could we demonstrate that it was the only structure secreted by the conodont animal.

Range. — Lower Ordovician to Middle Silurian.

Type species. — *Machairodus incurvus* Pander, 1856.

Distacodus falcatus Stauffer Pl. 35, figs. 10-13

1935. *Distacodus falcatus* Stauffer, Geol. Soc. America, Bull., vol. 46, p. 142, pl. 12, fig. 16.
1935. *Distacodus falcatus* Stauffer, Stauffer, Jour. Paleont., vol. 9, p. 605, pl. 74, fig. 30.
1959. *Distacodus falcatus* Stauffer, Ethington, Jour. Paleont., vol. 33, p. 275, pl. 39, fig. 9.
1960. *Panderodus robustus* (Branson, Mehl, and Branson), Pulse and Sweet, Jour. Paleont., vol. 34, pp. 256, 257, pl. 35, fig. 5.
?1962. *Distacodus? falcatus* Stauffer, Bergström, Arkiv Min. Geol., vol. 3, pp. 38, 39, pl. 1, fig. 15.
?1963. *Scolopodus cornuformis* Sergeeva, Paleont. Jour., Akad. Nauk S.S.S.R., 1963, No. 2, pp. 93-95, pl. 7, figs 1-3.
1966. *Distacodus falcatus* Stauffer, Schopf, New York State Mus., Bull. 405, p. 51, pl. 5, fig. 27.
1966. *Distacodus falcatus* Stauffer, Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 27, pl. 3, fig. 4.

We have 17 representatives of this species from the Lexington and Kope formations that agree completely with the type specimen in morphology and are clearly the same as specimens from Iowa and Minnesota referred to this species by Ethington (1959) and Webers (1966). *Scolopodus cornuformis* Sergeeva and *Distacodus*? *falcatus* of Bergström are similar in overall shape and may represent the same category of form-species as *Distacodus falcatus*, but the nature of the relationship between these forms is not clear at the present time.

Occurrence. — *Distacodus falcatus* ranges from 70 to 499 feet above the base of our composite Lexington-Kope section, although it is not a common form at any level in any section we have studied. In Minnesota, the species occurs in the Glenwood shale and ranges upward into the Dubuque formation (Webers, 1966), and in New York, Ontario, and Quebec, it is represented in the Denmark and Cobourg formations (Schopf, 1966).

Repository. — Micropaleontological collections, The Ohio State University. Reference slides 60L10-1; 60M13-3; 60P7-1, 10, 16; 61Z-196, 284; 64S1-7, 10, 11; 64S2-7, 47; 64S3-13, 33. Figured specimens, OSU 27425, 27426.

Genus **DREPANODUS** Pander, 1856

1856. *Drepanodus* Pander, Monographie der Fossilen Fische des Silurischen Systems der Russisch-Baltischen Gouvernements, p. 20.

Drepanodus arcuatus Pander, type species of *Drepanodus*, is abundantly represented in many Lower Ordovician faunas of the Baltic area (Lindström, 1955a; Sergeeva, 1962), and a study of specimens in the material described by Lindström and in other collections available to us, suggests that *D. arcuatus* included simple conodont elements exclusively. The composition of the *D. arcuatus* assembly is unknown at present, but there are strong indications that it lacked elements comparable to the suberectus- and inclinatus-like structures we include in *Drepanodus suberectus.*

In our Lexington-Kope collections, several thousand simple cones obviously represent a single biologic apparatus that was composed of three types of elements; two of these are drepanodus-like and a third is oistodus-like. The multielement species represented by this assembly of elements differs considerably from *Drepanodus arcuatus*, but the significance of the differences can not be evaluated until all the components of *D. arcuatus* are known in detail. The two drepanodus-like elements of the Lexington-Kope species are similar in many ways to known elements of *D. arcuatus*, and our species is included in *Drepanodus* for this reason.

Range (of the form-genus).—Upper Cambrian to Lower Devonian.

Type species.—*Drepanodus arcuatus* Pander, 1856.

Drepanodus suberectus (Branson and Mehl) Pl. 35, figs. 22-27

?1930. *Distacodus arcuatus* Stauffer, Jour. Paleont., vol. 4, p. 123, pl. 10, fig. 2.

?1932. *Distacodus arcuatus* Stauffer, Stauffer, Jour. Paleont., vol. 6, p. 258. [This name, proposed in 1930, is the oldest available for conodonts herein referred to *Drepanodus suberectus*. On transfer to *Drepanodus,* it is a junior homonym of *D. arcuatus* Pander, 1856.]

1933. *Oistodus suberectus* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 111, pl. 9, fig. 7.

1933. *Oistodus inclinatus,* Branson and Mehl, *idem,* p. 110, pl. 9, fig. 8.

1933. *Oistodus curvatus* Branson and Mehl, *idem,* pp. 110, 111, pl. 9, figs. 4, 10, 12.

1935. *Oistodus inclinatus* Branson and Mehl, Stauffer, Geol. Soc. America, Bull., vol. 46, pp. 147, 159, pl. 12, fig. 21.

1935. *Oistodus inclinatus* Branson and Mehl, Stauffer, Jour. Paleont., vol. 9, pp. 610, 611, pl. 74, fig. 41; pl. 75, figs. 9, 14.

1935. *Oistodus abundans* Branson and Mehl, Stauffer, *idem,* p. 609, pl. 75,

figs. 7, 11, 12 [not pl. 75, fig. 2, which = *Oistodus pseudoabundans* Schopf, 1966.]
?1935. *Oistodus brevis* Stauffer, *idem,* p. 609, pl. 74, fig. 32.
1935. *Oistodus curvatus* Branson and Mehl, Stauffer, *idem,* p. 609, pl. 74, figs. 12, 39.
?1935. *Oistodus erectus* Stauffer, *idem,* pp. 609, 610, pl. 74, fig. 50.
1935. *Oistodus excelsus* Stauffer, *idem,* p. 610, pl. 74, fig. 43.
1955. *Drepanodus suberectus* (Branson and Mehl), Lindström, Geol. Fören. (Stockholm), Förhandl., bd. 76, p. 568, pl. 2, figs. 21, 22.
1955. *Drepanodus homocurvatus* Lindström, *idem,* p. 563, pl. 2, figs. 23, 24, 39.
1959. *Oistodus excelsus* Stauffer, Stone and Furnish, Jour. Paleont., vol. 33, p. 224, pl. 31, fig. 5.
1959. *Oistodus excelsus* Stauffer, Ethington, Jour. Paleont., vol. 33, p. 282, pl. 39, fig. 20.
1959. *Oistodus excelsus* Stauffer, Sweet, *et al.,* Jour. Paleont., vol. 33, p. 1053, pl. 130, fig. 5.
1960. *Oistodus excelsus* Stauffer, Ethington and Furnish, Jour. Paleont., vol. 34, p. 271.
1960. *Oistodus inclinatus* Branson and Mehl, Pulse and Sweet, Jour. Paleont., vol. 34, p. 255, pl. 35, figs. 10, 12. [Includes significant synonymy through November, 1959.]
1960. *Drepanodus suberectus* (Branson and Mehl), Carlson, North Dakota Geol. Sur., Bull. 35, pl. 2, fig. 10; tab. II.
1962. *Oistodus excelsus* Stauffer, Bergström, Arkiv Min. Geol., bd. 3, No. 1, p. 44, pl. 2, figs. 18, 19.
1962. *Drepanodus suberectus* (Branson and Mehl), Sweet and Bergström, Jour. Paleont., vol. 36, p. 1226, pl. 169, fig. 8. [Includes significant synonymy through 1961.]
1964. *Drepanodus homocurvatus* Lindström, Hamar, Norsk Geol. Tidsskr., bd. 44, p. 264, pl. 2, figs. 3, 4; text-fig. 6, no. 3b.
1964. *Oistodus excelsus* Stauffer, Bergström, Acta Univ. Lundensis, sec. II, No. 3, p. 44, text-fig. 21A.
1965. *Drepanodus suberectus* (Branson and Mehl), Barnett, Micropaleont., vol. 11, p. 70, pl. 1, fig. 29; pl. 2, fig. 22.
1965. *Drepanodus homocurvatus* Lindström, Barnett, *idem,* p. 70, pl. 1, fig. 15; pl. 2, fig. 5.
1965. *Oistodus inclinatus* Branson and Mehl, Barnett, *idem,* p. 71, pl. 1, fig. 8; pl. 2, fig. 7.
1966. *Drepanodus amoenus* Lindström, Schopf, New York State Mus., Bull. 405, p. 54, pl. 5, fig. 12.
1966. *Drepanodus planus* Lindström, Schopf, *idem,* p. 54, pl. 5, fig. 21.
1966. *Drepanodus suberectus* (Branson and Mehl), Schopf, *idem,* p. 54, pl. 5, fig. 25.
1966. *Drepanodus* sp. cf. *D. homocurvatus* Lindström, Schopf, *idem,* p. 55, pl. 5, figs. 11, 14, 15.
1966. *Oistodus inclinatus* Branson and Mehl, Schopf, *idem,* p. 60, pl. 5, fig. 10.
1966. *Drepanodus suberectus* (Branson and Mehl), Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 29, pl. 6, figs. 9, 11, 14, 16.

The form-species *Drepanodus homocurvatus* Lindström (=*Oistodus curvatus* Branson and Mehl), *Drepanodus suberectus* (Branson and Mehl), and *Oistodus inclinatus* Branson and Mehl, are represented in our Lexington conodont collections by 6,106, 592, and 973 specimens, respectively. Representatives of these species occur together in virtually every sample that contains any one of them, and all have the same overall stratigraphic range in the sections we have studied. In addition, conodont elements referable to these three species are of similar size and color: commonly, they are the largest conodont elements in any collection. For all these reasons, we believe these form-species should be united in a single taxon, the oldest available name for which appears to be *Drepanodus suberectus* (Branson and Mehl).

Conodont elements referable to the form-species *Drepanodus homocurvatus* Lindström and *D. suberectus* (Branson and Mehl) exhibit a broad range of variability, and we interpret the groups represented to be completely intergradational. Variation is expressed in shape and development of the basal cavity, in curvature, and in cross-sectional shape. We have been unable to divide either form-species into subordinate groups that maintain stability in any combination of these characters.

The form-species *Oistodus inclinatus* includes large simple cones with a long, inwardly bowed bladelike cusp, the posterior margin of which joins the keeled upper edge of the short base to form a sharp angle of 35° to 45°. The cusp has bladelike anterior and posterior edges, is smooth and broadly convex on its outer side, and is distinguished by a broad median carina on the inner side. The basal cavity is shallow; its sheath flares slightly on the outer side and broadly inward on the inner side. On the outer side, the basal margin is semicircular in lateral view; on the inner side it is distinctly sigmoidal in outline, flaring outward broadly at the proximal end of the median cusp carina and curving abruptly inward and anteriorly just before it reaches the antero-basal corner of the element. Lexington representatives of this form-species have been compared directly with the types of both *Oistodus inclinatus* Branson and Mehl and *Oistodus excelsus* Stauffer. All these specimens clearly belong in the same form-species.

Our tallies indicate that representatives of the form-species *Drepanodus homocurvatus* are about four times more abundant than the total of *Oistodus inclinatus* and *Drepanodus suberectus*. Because all three form-species include individually asymmetric elements, we suggest that each representative of the biologic species *Drepanodus suberectus* included no fewer than two representatives of *Oistodus inclinatus,* two of *Drepanodus suberectus,* and 16 of *Drepanodus* *homocurvatus*. About the same relationship is suggested by the tabulations reported by Webers (364:509:2364) for conodont elements of this group but not by those included in Schopf's (1966) study of Trenton group conodonts. In the latter study, representatives of *Drepanodus suberectus* are distributed among more than three form-species, but the totals in the groups we recognize are 187:530:3233.

Occurrence. — Representatives of *Drepanodus suberectus* occur in practically every sample in our Lexington collections and were recovered from every section we studied. The species ranges from the base to the top of our composite section, and all three elements have been identified in Ohio Valley Ordovician sections as high as the base of the Silurian. The species has a similarly extensive range in Middle and Upper Ordovician sections in Iowa and Minnesota (Glenister, 1957; Ethington, 1959; Webers, 1966), where it ranges from at least as low as the base of the Glenwood shale to the top of the Maquoketa formation. Schopf (1966) indicated a range from upper Chaumont through Cobourg for all three form-species. *Drepanodus homocurvatus* and *D. suberectus* have both been reported from rocks that are older than the Chaumont and Glenwood (*e.g.*, lowermost Ordovician of Sweden and the Pratt Ferry formation of Alabama: Lindström, 1955a; Sweet and Bergström, 1962), but all these assemblages lack *Oistodus inclinatus*. This may mean that elements with *D. homocurvatus* and *D. suberectus* in these older strata are homeomorphs of younger elements of similar architecture, which occur in a multielement species containing the form-species *Oistodus inclinatus*.

Repository. — Micropaleontological collections, The Ohio State University. Reference slides from all sections included in this study (see Appendix B). Figured specimens, OSU 27427, 27428, 27429.

"FIBROUS CONODONTS"

The large Lexington limestone collections we have assembled include 112 "fibrous conodont-elements," representing the form-genera *Curtognathus, Polycaulodus, Microcoelodus, Ptiloconus, Trucherognathus,* and probably *Stereoconus*. We do not describe or figure any of these specimens because we believe our collection is far too small to provide the detail necessary to an understanding of these forms. We include a mention of them largely to complete the record of their occurrence.

Occurrence. — "Fibrous conodonts" are consistently present in the lower 76 feet of our composite Lexington-Kope section, and isolated specimens occur 194, 308, 333, and 337 feet above the base of that section. The specimens in the last three samples listed constitute the youngest known record of "fibrous" forms. The elements referred to "fibrous" form-species by Branson, Mehl, and Branson (1951) and by Stone and Furnish (1959) do not represent this curious group.

Repository. — Micropaleontological collections, The Ohio State University. "Fibrous conodonts" occur in the following samples: 60L6-5; 60M3-7; 60T7-1; 61Z-501, 622, 629, 637, 644, 645, 649, 650; 64S2-6, 7, 8, 9.

Genus **HOLODONTUS** Rhodes, 1953

1953. *Holodontus* Rhodes, Phil. Trans. Roy. Soc. London, Ser. B, No. 647, vol. 237, p. 303.

The characters of *Holodontus* are reviewed by Bergström (1964), who noted that *Tvaerenognathus* Bergström, 1962, is clearly a junior subjective synonym. *Holodontus* is also closely related in form to *Goniodontus* Ethington, 1959, and we are not certain that the two genera are distinct. The range of variation in the type form-species of *Goniodontus, G. superbus,* is not well known because few representatives of it have been collected. In addition, undescribed Upper Ordovician faunas from Sweden and Great Britain contain distinctive, but undescribed, conodont elements that appear to represent an advanced form-species of *Goniodontus.* These specimens are different from *Holodontus superbus,* and, at least for the present, we refer them to *Goniodontus* rather than *Holodontus.*

Despite the fact that we have identified representatives of *Holodontus* in several Ordovician faunas from Europe and North America, we have no evidence that it is invariably associated with any other element. Thus the form-species referred to this genus may have been the only structures in the biologic apparatus. We should point out, that elements referable to *Holodontus* are not common, and we have no reliable data with regard to their numeric relations to other form-species. The genus is commonly represented in faunas that contain representatives of *Tetraprioniodus* and *Amorphognathus* and it is clearly a member of the so-called European fauna.

Range. — Llandeilian and Caradocian in northwestern Europe; Barneveldian in eastern North America. The oldest representatives of *Holodontus* known to us are from the Upper Llandeilian of Sweden and from presumably contemporaneous strata in Wales (Bergström, 1964).

Type species. — *Holodontus superbus* Rhodes, 1953.

Holodontus superbus Rhodes Pl. 29, figs. 12, 13

1953. *Holodontus superbus* Rhodes, Phil. Trans. Roy. Soc. London, Ser. B, No. 647, vol. 237, p. 304, pl. 2, figs. 125-127.
1964. *Holodontus superbus* Rhodes, Bergström, Acta Univ. Lundensis, Sec. II, No. 3, pp. 26, 27, text-fig. 11.
1966. *Holodontus superbus* Rhodes, Schopf, New York State Mus., Bull. 405, p. 58, pl. 4, figs. 16, 17; text-fig. 6f.

Our Lexington-Kope collections include 91 conodont elements that we regard as conspecific with *Holodontus superbus* Rhodes. All these specimens are fragmentary, but we have compared them directly with topotypes of Rhodes' species and have observed no significant differences. All our specimens are of about the same size and apparently represent the same growth stage, hence they offer no information about early or late growth stages, which are currently unknown.

As one of us (Bergström) recently noted (1964), *Holodontus superbus* is closely related to Llandeilian and lower Caradocian *H. ordovicicus* (Bergström) and to *Goniodontus superbus* Ethington. It is apparently distinguished from *H. ordovicicus*, in having fewer apical denticles and a shorter and less distinctly denticulated anterior process. Only a few specimens of *Goniodontus superbus* are known, but all of them appear to have just one apical denticle (rather than the two or three of *Holodontus superbus*). In addition, the short anterior process of *Goniodontus superbus* is undenticulated in the type specimen. It is an open question whether these small differences should be considered significant on the generic level and justify the separation of *Goniodontus* and *Holodontus*.

Occurrence. — *Holodontus superbus* ranges from 105 to 501 feet above the base of our composite Lexington-Kope section. As noted in the generic discussion, it is a representative of the European fauna. Its apparent absence from Upper Mississippi Valley sections, which also yield few representatives of *Amorphognathus ordovicica* and which completely lack *Rhodesognathus,* may suggest a relationship between species of these genera. *Holodontus superbus* ranges from the upper Shoreham through the Denmark and into the upper Cobourg formation of New York (Schopf, 1966) but is best known from northwestern Europe, where it has been recorded from the Gelli-grin and Brun Pig limestones of Wales (Rhodes, 1953; Bergström, 1964). The senior author also has undescribed representatives of *H. superbus* from the Balclatchie mudstones of the Girvan area, Scotland.

Repository.—Micropaleontological collections The Ohio State University. Reference slides from sections 60BCK, 60G, 60H, 60L, 60M, 60T, 61Z, 64S1, 64S3 (see Appendix B). Figured specimen, OSU 27430.

Genus **ICRIODELLA** Rhodes, 1953

1953. *Icriodella* Rhodes, Phil. Trans. Roy Soc. London, Ser. B, vol. 237, p. 287.

The form-genus *Icriodella* includes elongate, platform-like conodont elements with anterior and posterior processes and poorly developed lateral processes. The anterior process bears two parallel rows of short stubby denticles; the posterior process bears a single denticle row; and the under side of the entire element is widely excavated.

Study of many conodont faunas from Middle and Upper Ordovician rocks in North America and northwestern Europe demonstrates that the form-species *Icriodella superba* is almost invariably associated with the form-species *Sagittodontus dentatus, S. robustus, Rhynchognathodus divaricatus,* and *R. typicus.* Although these elements differ from one another in form, they exhibit many similiarities in secondary structural features and they have the same stratigraphic and geographic distribution. As a result, we conclude that all these elements represent the same biologic species, *I. superba,* and that the genus *Icriodella* includes not only icriodella-like elements but also the other complex conodont elements just mentioned.

Lindström (1964) regarded *Icriodella* as a junior synonym of *Icriodina* Branson and Branson, 1947 but noted that the types of the latter are fragmentary. We have also studied Branson and Branson's types and we have seen more nearly complete specimens from the type strata (Brassfield limestone). From these studies we conclude that *Icriodina* is based on broken processes of platform-like conodonts that may be referable to either *Icriodella* or *Hadrognathus* Walliser, 1964, or to both. These two genera occur in the Brassfield limestone and we know of no certain way to distinguish fragmentary representatives with assurance. Consequently, we regard the types of *Icriodina* as too incomplete to be generically determinable, and *Icriodina* as a *nomen dubium.*

Scyphiodus Stauffer, 1935b, is based on a number of fragmentary platform-like elements from the Decorah shale of Minnesota. More nearly complete topotypes in our reference collections indicate that the type species, *Scyphiodus primus,* is similar in several respects to the icriodella-like element of *Icriodella superba.* It differs from these elements, in having three, rather than two, denticle rows on the anterior process, and in having no lateral processes. Furthermore, no rhynchognathodus-like or sagittodontus-like elements are associated with *Scyphiodus* in the type strata. Thus we believe *Scyphiodus* to be a distinct genus that is probably not closely related to *Icriodella.* It may have developed from bladelike forms like those commonly referred to *Bryantodina* or *Ozarkodina.*

Range. — *Icriodella* is common and widely distributed in Middle Ordovician strata, but it also occurs in both the Upper Ordovician and the Lower Silurian. The oldest icriodella-like element known to us is from the Fort Peña formation of Texas, the conodont fauna of which is being described by Mrs. Lael E. Bradshaw. The youngest known occurrence of *Icriodella* is in the Brassfield limestone (Lower Silurian) of Kentucky, Ohio, and Indiana.

Type species. — *Icriodella superba* Rhodes, 1953.

Icriodella superba Rhodes Pl. 29, figs. 1-11

1953. *Icriodella superba* Rhodes, Phil. Trans. Roy. Soc. London, Ser. B, vol. 237, p. 288, pl. 20, figs. 54, 58, 62, 63, 65, 78.
1953. *Icriodella superba* var. *acuta* Rhodes, *idem,* p. 288, pl. 20, figs. 59, 60, 64, 66, 71-73, 77.
1953. *Icriodella deforma* Rhodes, *idem,* p. 286, pl. 20, figs. 68-70.
1953. *Icriodella elongata* Rhodes, *idem,* p. 287, pl. 20, figs. 79-81.
1953. *Icriodella plana* Rhodes, *idem,* p. 287, pl. 20, figs. 67, 74, 76.
1953. *Sagittodontus robustus* Rhodes, *idem,* p. 311, pl. 21, figs. 141, 142.
1953. *Trichonodella divaricata* Rhodes, *idem,* p. 313, pl. 21, figs. 145, 146.

1959. *Icriodella superba* Rhodes, Lindström, Micropaleont., vol. 5, p. 440, pl. 4, figs. 10-16.
1959. *Acodus robustus* (Rhodes), Lindström, *idem*, pp. 433-435, pl. 4, figs. 22-27.
1959. *Roundya* sp., Lindström, *idem*, p. 448, pl. 3, figs. 31, 32, 33.
1959. *Icriodella acuta* Rhodes, Ethington, Jour. Paleont., vol. 33, pp. 279, 280, pl. 41, fig. 6.
1959. *Sagittodontus robustus* Rhodes, Ethington, *idem*, pp. 287, 288, pl. 39, fig. 12.
1959. *Sagittodontus dentatus* Ethington, *idem*, p. 287, pl. 39, fig. 13.
1959. *Rhynchognathus aborodentata* Ethington, *idem*, pp. 286, 287, pl. 41, figs. 1, 2.
1959. *Rhynchognathus typica* Ethington, *idem*, p. 286, pl. 41, figs. 3, 4.
1959. *Sagittodontus dentatus* Ethington, Sweet, *et al.*, Jour. Paleont., vol. 33, pp. 1062, 1063, pl. 131, figs. 7, 8.
?1964. *Acodus robustus* (Rhodes), Hamar, Norsk Geol. Tidsskr., bd. 44, p. 255, pl. 1, figs. 23, 24; text-fig. 4, No. 2.
1964. *Sagittodontus dentatus* Ethington, Bergström, Acta Univ. Lundensis, Sec. II, No. 3, pp. 45, 51, 57, 63.
1964. *Sagittodontus robustus* Rhodes, Bergström, *idem*, pp. 51, 53, 57, 59, 63.
1964. *Icriodella superba* Rhodes, Bergström, *idem*, pp. 56, 59, 62.
1964. *Rhynchognathodus divaricatus* (Rhodes), Bergström, *idem*, pp. 36, 37, 51, 56, 59, 63, text-fig. 18.
1964. *Rhynchognathodus typica* (Ethington), Bergström, *idem*, pp. 37, 51, 56, 63.
1965. *Icriodella superba* Rhodes, Barnett, Micropaleont., vol. 11, pp. 70, 71, pl. 2, fig. 16.
1965. *Sagittodontus* cf. *S. dentatus* Ethington, Barnett, *idem*, p. 73, pl. 2, fig. 18.
1965. *Sagittodontous robustus* Rhodes, Barnett, *idem*, p. 73, pl. 2, figs. 24, 27.
1966. *Icriodella superba* Rhodes, Schopf, New York State Mus., Bull. 405, p. 58, pl. 3, figs. 17, 22, 23.
1966. *Rhynchognathodus divaricatus* (Rhodes), Schopf, *idem*, p. 73, pl. 3, fig. 15.
1966. *Rhynchognathodus typicus* (Ethington), Schopf, *idem*, p. 74, pl. 3, figs. 18, 19.
1966. *Sagittodontus dentatus* Ethington, Schopf, *idem*, p. 77, pl. 4, fig. 24.
1966. *Sagittodontus robustus* Rhodes, Schopf, *idem*, p. 78, pl. 5, fig. 31.
1966. *Icriodella superba* Rhodes, Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 31, pl. 13, figs. 3-9.

Conodont elements representing five form-species of the form-genera *Icriodella*, *Sagittodontus*, and *Rhynchognathodus* are common associates in parts of the Lexington and Kope formations, and we believe that they represent a single biologic species. The oldest available name for this species is *Icriodella superba* Rhodes, and we include all these elements in that species. As thus conceived, *Icriodella superba* Rhodes includes the type species of all three of the form-genera *(Icriodella, Sagittodontus, Rhynchognathodus)* we include in it, although these names may continue to serve a useful purpose in describing the structural units of other assemblages — which may or may not be referable to *Icriodella*.

The form-species we include in *Icriodella superba* are listed in Table 4, where we also indicate the frequency of each element in both our Lexington-Kope collections and those assembled from Middle and Upper Ordovician rocks in Minnesota by Webers (1966).

Table 4.--Element Frequency in Icriodella superba

Form-species	Lexington-Kope		Minnesota		Totals	
Icriodella superba	2200	4.1	227	4.1	2427	4.1
Sagittodontus robustus	1173	2.1	172	3.1	1345	2.2
S. dentatus	248	0.5	37	0.6	285	0.5
Rhynchognathodus typicus	544	1.0	60	1.1	604	1.0
R. divaricatus	538	1.0	56	1.0	594	1.0

In Table 4 we also show the simple proportions between the various elements of this assembly in both the Ohio Valley area and that of the Upper Mississippi Valley. In most respects, it is clear that the two collections are similar. Our Lexington-Kope collections differ primarily from Webers' in being about 10 times larger. Because all the elements in this assembly are individually asymmetric, the smallest number in a single animal would have been 34 (4 each of *Rhynchognathodus divaricatus* and *R. typicus,* 2 *Sagittodontus dentatus,* 8 *S. robustus,* and 16 *Icriodella superba.)* The actual number may have been some smaller than this, for icriodella-like elements commonly fragment readily and both parts are easily identifiable. Thus the number of icriodella-like elements in a single animal may have been as few as eight, and the total number as low as 26.

All five form-species we include in *Icriodella superba* are well known morphologically either from their original or from subsequent descriptions (Rhodes, 1953; Ethington, 1959) and we see no need to repeat those descriptions here. Each element of the assembly exhibits some variation, but we have not discovered trends or tendencies in our material to substantiate the recognition of more than one species. All elements are similar in being deeply excavated, thin-walled, and built on a plan that is essentially a hollow three-sided pyramid. The simplest form in this plexus is *Sagittodontus robustus,* a hollow three-sided pyramid; denticles on two or three of these margins produce the two species of *Rhynchognathodus,* and development of two of these margins into denticulated processes results in *Icriodella,* the element that is least obviously a member of the assembly structurally.

Occurrence.—*Icriodella superba* ranges from 81 to 480 feet above the base of our composite Lexington-Kope section. Above this level we have no record of the species until the basal Richmond ("Arnheim"), where it occurs in abundance in Indiana (McClish, 1965; section 65GV of this report.) All five of the form-species here included in *Icriodella superba* occur together in Iowa and Minnesota (Ethington, 1959; Webers, 1966), where the species ranges from the middle to the upper part of the Dubuque formation. In New York, Ontario, and Quebec, *Icriodella superba* appears first at the base of the Rockland formation and ranges upward into the upper Cobourg (Schopf, 1966), whereas in Wales all elements referred to *Icriodella superba* are present in the Gelli-grin, Pen-y-garnedd, and Brun Pig limestones (of Longvillian age), and most of them have been reported from the Crug limestone (of Marshbrookian age) (Lindström, 1959; Bergström, 1964) and the Birdshill limestone (of lower Ashgillian age) (Bergström, 1964).

Repository.—Micropaleontological collections, The Ohio State University. Reference slides from all sections but 60A, 60G, 60H (see Appendix B). Figured specimens, OSU 27431, 27432, 27433, 27434, 27435.

Genus **OISTODUS** Pander, 1856

1856. *Oistodus* Pander, Monographie der Fossilen Fische des Silurischen Systems der Russisch-Baltischen Gouvernements, p. 27.

Pander based his genus *Oistodus* on simple conodont elements from the Baltic Lower Ordovician, but his generic diagnosis, which is broad and vague, permitted inclusion of a wide variety of forms in the genus. In 1955, Lindström redefined *Oistodus* and particularly stressed the acute angle between the posterior margin of the cusp and the upper margin of the base. This redefinition considerably restricted the scope of the form-genus and it has been widely accepted during the past decade.

Recently, Lindström (1964, p. 82) pointed out that *Oistodus lanceolatus* Pander, 1856, type species of *Oistodus,* is a multielement species that includes oistodus, cladognathodus-, and roundya-like elements. Thus *O. lanceolatus,* which may also have included other elements, is basically different from most, if not all, the species previously referred to *Oistodus,* including the Lexington-Kope specimens we include in *O. venustus* Stauffer. *O. venustus* is rare and all its components may not have been recognized; even so, there is no indication that it included the several types of elements present in *O. lanceolatus*. This difference is undoubtedly significant and *O. lanceolatus* and *O. venustus* are probably not at all closely related. Like most form-species included in *Oistodus, O. venustus* is imperfectly known and we are reluctant to establish a new genus for it. The form-species is here referred to *Oistodus* pending revision of this complex group of species; ultimately, we suspect, *O. venustus* should probably be included in some other genus, for which a new name will perhaps be needed.

Oistodus venustus Stauffer Pl. 35, figs. 20, 21

1935. *Oistodus venustus* Stauffer, Geol. Soc. America, Bull., vol. 46, pp. 146, 159, pl. 12, fig. 12.
1953. *Oistodus abundans* Branson and Mehl, Rhodes, Phil. Trans. Roy. Soc. London, Ser. B, vol. 237, p. 294, pl. 21, figs. 91, 92.
1962. *Oistodus venustus* Stauffer, Sweet and Bergström, Jour. Paleont., vol. 36, p. 1232, pl. 168, figs. 10, 11 (includes synonymy through 1961).
1964. *Oistodus venustus* Stauffer, Hamar, Norsk Geol. Tidsskr., bd. 44, p. 269, pl. 3, figs. 3-6, 9, 11; text-fig. 6, No. 10.
1966. *Oistodus venustus* Stauffer, Schopf, New York State Mus., Bull. 405, p. 62, pl. 5, fig. 19.
1966. *Oistodus venustus* Stauffer, Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 34, pl. 2, figs. 18, 19.

Nineteen specimens in our Lexington-Kope collections are referable to the form-species *Oistodus venustus* Stauffer. We have recently discussed and described this form-species (Sweet and Bergström, 1962), and the few specimens at hand add only to our knowledge of its occurrence and stratigraphic distribution.

We are unable to determine from the material available to us whether elements identified as *Oistodus venustus* were the only hard parts of the conodont species they represent, or whether they were minor constitutents of a composite apparatus. Lexington-Kope occurrences suggest a relationship to *Periodon,* but we have only a few representatives of either taxon and the association suggested is not borne out by examination of other faunas. For example, elements indistinguishable from the type of *Oistodus venustus* occur in the Llandeilo, Castell, Gelli-grin, Pen-y-garnedd, and Brun Pig limestones of Wales (Rhodes, 1953; Bergström, 1964), but these strata apparently lack *Periodon*. It may well be that *Oistodus venustus* was merely a faunal associate of *Periodon,* not part of the same biologic apparatus. Or, *O. venustus* may include a variety of indistinguishable (or undistinguished) homeomorphs, some of which were parts of a species that also included periodon-like elements.

Occurrence. — *Oistodus venustus* ranges from 120 to 383 feet above the base of our composite Lexington-Kope section. The synonymy at the head of this discussion includes information about known North American occurrences: Welsh occurrences are summarized by Bergström (1964).

Repository. — Micropaleontological collections, The Ohio State University. Reference slides 60H3-1; 60L3-1; 60L10-1; 61Z-313, 383, 481, 493, 501, 546, 575; 64S1-1. Figured specimen, OSU 27436.

Genus **OULODUS** Branson and Mehl, 1933

Emend. Bergström and Sweet, herein

1933. *Oulodus* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 116.
1935. *Gyrognathus* Stauffer, Geol. Soc. America, Bull., vol. 46, p. 144.

Emended diagnosis. — A genus of multielement conodonts, in which early species developed oulodus- and cordylodus-like elements and derivative species added a variety of prioniodina-like structures to the apparatus.

Discussion. — All the elements we include in *Oulodus* are well known (Branson and Mehl, 1933; Sweet, *et al.*, 1959; Pulse and Sweet, 1960) and there is no need to describe them all again here. It is sufficient to note that we recognize four multielement species of *Oulodus*, *O. mediocris* Branson and Mehl, *O. serratus* (Stauffer), *O. oregonia* (Branson, Mehl, and Branson), and *O. velicuspis* (Pulse and Sweet). The first two of these species include only cordylodus- and oulodus-like elements, whereas the latter two (which are also younger than the former pair) developed cordylodus-, oulodus-, and prioniodina-like structures. We discuss all these species in connection with our description of *Oulodus oregonia*, which is the only one we recognize in our Lexington, Kope, and Clays Ferry collections.

Range. — Middle and Upper Ordovician. *Oulodus* is known at present only from North America.

Type species. — *Oulodus mediocris* Branson and Mehl, 1933.

Oulodus oregonia (Branson, Mehl, and Branson) Pl. 32, figs. 20, 21 Pl. 33, fig. 5; Pl. 34, figs. 13-16; Text-fig. 9G-L

1951. *Prioniodina oregonia* Branson, Mehl, and Branson, Jour. Paleont., vol. 25, pp. 15, 16, pl. 3, fig. 18; pl. 4, figs. 28-32.
1951. *Oulodus* sp., Branson, Mehl, and Branson, *idem,* pl. 3, fig. 12.
1959. *Microcoelodus sweeti* Stone and Furnish, Jour. Paleont., vol. 33, p. 224, pl. 31, fig. 18.
1959. *Cordylodus plattinensis* Branson and Mehl, Stone and Furnish, *idem,* p. 221, pl. 32, fig. 10.
1959. *Oulodus mediocris* Branson and Mehl, Stone and Furnish, *idem,* pp. 224, 225, pl. 32, figs. 4, 5.
1959. *Plectodina dilata* Stauffer, Ethington and Furnish, Jour. Paleont., vol. 33, p. 544, pl. 73, fig. 10.
?1959. *Oulodus rohneri* Ethington and Furnish, *idem,* p. 544, pl. 73, figs. 17, 18.
1959. *Prioniodina? oregonia* Branson, Mehl, and Branson, Ethington and Furnish, *idem,* p. 545, pl. 73, fig. 15.
1959. *Cordylodus excavatus* Sweet, *et al.,* Jour. Paleont., vol. 33, pp. 1045, 1046, pl. 132, fig. 16.
1959. *Oulodus mediocris* Branson and Mehl?, Sweet, *et al., idem,* pp. 1054, 1055, pl. 133, fig. 5.
1959. *Prioniodina oregonia* Branson, Mehl, and Branson, Sweet, *et al., idem,* pp. 1060, 1061, pl. 132, fig. 18; pl. 133, fig. 9.
1959. *Prioniodina rotunda* Sweet, *et al., idem,* p. 1061, pl. 131, fig. 12; pl. 133, fig. 8.
1960. *Plectodina dilata* Stauffer, Ethington and Furnish, Jour. Paleont., vol. 34, p. 272, pl. 38, fig. 7.
1960. *Oulodus?* sp., Ethington and Furnish, *idem,* p. 271, pl. 38, fig. 15.
1960. *Cordylodus excavatus* Sweet, *et al.,* Pulse and Sweet, Jour. Paleont., vol. 34, p. 251, pl. 35, figs. 11, 15.
1960. *Oulodus casteri* Pulse and Sweet, *idem,* p. 255, pl. 36, figs. 1, 8, 12.
1960. *Prioniodina rotunda* Sweet, *et al.,* Pulse and Sweet, *idem,* p. 259, pl. 36, figs. 14, 16, 18.

In our Lexington-Kope collections, and in those assembled from the Maysvillian Fairview and McMillan formations by Pulse and Sweet (1960), the form-species *Prioniodina oregonia, Cordylodus excavatus,* and *Oulodus casteri* almost invariably occur together and have a closely similar stratigraphic range. Representatives of these form-species are also commonly of about the same size and color and they have many morphologic similarities. For these reasons, we believe they are collectively the representatives of a single apparatus and we describe them here as one conodont species, *Oulodus oregonia* (Branson, Mehl, and Branson).

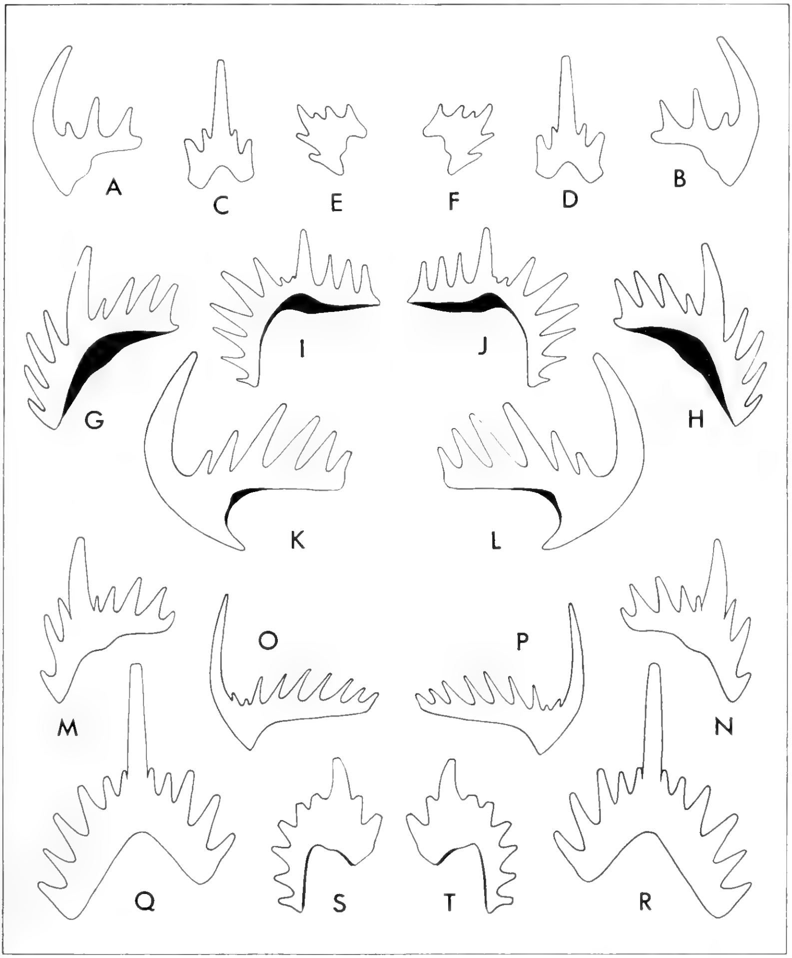
Cordylodus-like elements of *Oulodus oregonia* are morphologically indistinguishable from older forms referable to *Cordylodus serratus* Stauffer and *Cordylodus concinnus* Branson and Mehl. All these form-species are distinguished by a robust cusp and a straight to slightly bowed posterior process surmounted by reclined denticles that show a distinct tendency to be discrete at all stages of growth. In early growth stages, the cusp has an inflated biconvex cross-section with an indistinct posterior costa and an anterior costa that is deflected somewhat laterally and widens slightly at the antero-basal corner. In intermediate and later growth stages, the cusp develops a longitudinal posterior channel and the deflected anterior costa becomes progressively less and less distinct. In the largest individuals known (of the type previously referred to *Cordylodus excavatus* Sweet, *et al.*, 1959) the cusp is heart-shaped in cross-section and its sides are symmetrically biconvex.

Denticles of the posterior process of cordylodus-like elements are laterally compressed, reclined, and discrete in small specimens; in successively larger forms, these denticles become peglike and their cross-section approaches circularity. In all stages of growth, posterior denticles are discrete and tend to be separated from the cusp by a space, although a few small denticles may occur in this interval. The basal cavity is shallow and broad beneath the posterior process and expands beneath the cusp to form a subconical space that is enclosed by a sheath which flares about equally to both sides. In lateral view, the basal margin is straight beneath the posterior process and tends to form a smooth curve beneath the subapical cavity to its junction with the antero-basal corner of the element. In some variants, this latter segment of the basal margin is interrupted near mid-length by a broadly convex spatulate projection.

Oulodus-like elements of *Oulodus oregonia* have been referred to *O. casteri* Pulse and Sweet, 1960, but they are morphologically indistinguishable from *O. mediocris* Branson and Mehl, 1933, type species of *Oulodus*. The latter species is from the Plattin formation of Missouri and is not known to occur with representatives of *Prioniodina oregonia*. We believe the latter to be part of the apparatus here described. All of our Lexington-Kope oulodus-elements have a long cusp that is suberect to distinctly recurved posteriorly and subequal lateral processes surmounted by discrete denticles that curve slightly toward the cusp distally. In some specimens, proximal portions of the lateral processes are in essentially the same plane; in others, one process curves gracefully to the anterior and is deflected downward distally; in a third group, one process projects abruptly anteriorly from its junction with the cusp, and the plane including it is essentially normal to the one defined by the other lateral process.

The three syntypes of *Oulodus casteri* Pulse and Sweet (1960, pl. 36, figs. 1, 8, 12) represent the same variant groups.

Small, fragile oulodus-like elements, presumably juveniles, have a laterally compressed cusp; larger, more robust specimens, repre-



Text-fig. 9. A-F. *Plectodina aculeata* (Stauffer), X30. G-L. *Oulodus oregonia* (Branson, Mehl, and Branson), X20. M-T. *Plectodina furcata* (Hinde), X30. Diagrammatic views of the cordylodus-like (A,B; K,L; O,P), trichonodella-like (C,D; Q,R), zygognathus-like (E,F; S,T), oulodus-like (I,J), and prioniodina-like (G,H; M,N) elements of these species.

senting later growth stages, have less conspicuously compressed cusps or ones that are essentially circular in cross-section. The attachment surface is deeply excavated and the excavation continues to the process extremities.

Prioniodina-like elements of *Oulodus oregonia* have been described under many names (*Prioniodina oregonia* by Branson, Mehl, and Branson, 1951; *Microcoelodus sweeti* by Stone and Furnish, 1959; *Prioniodina rotunda* by Sweet, *et al.*, 1959, and Pulse and Sweet, 1960). There is no need to repeat those descriptions here. This form-species is distinguished from others by its capacious basal cavity, its spaced, peglike denticles, and by its cusp which is strongly bent postero-laterally. Within the form-species thus broadly defined, we can distinguish two principal variants. In one, the anterior process is distinctly shorter than the posterior process and the cusp tends to be flattened antero-posteriorly; in the second, anterior and posterior processes are subequal in length and the cusp is subcircular in cross-section even in early stages of growth. These two groups are about equally represented in our collections and they tend to intergrade.

Discussion. — Our collections include 2166 representatives of the form-species *Prioniodina oregonia*, 3356 specimens representing *Cordylodus excavatus*, and 1203 oulodus-like elements. These figures suggest a complete biologic apparatus included 14 elements: two oulodus-like elements, four prioniodina-like elements, and eight cordylodus-like elements.

Oulodus oregonia is undoubtedly a close relative of both *O. mediocris* Branson and Mehl (which includes *Cordylodus concinnus*), and *O. serratus* (Stauffer) [which includes *Oulodus primus* (Stauffer)]. It differs most conspicuously from these older species in possession of well-developed prioniodina-like elements. *O. mediocris* and *O. serratus* were almost certainly geographically isolated contemporaries, and the former might well be regarded a subspecies of the latter. They differ primarily in structure of their respective oulodus-like elements. The form-species *Oulodus mediocris* has a well-defined basal cavity that extends to the process extremities; the corresponding part of *O. primus* (a component of *O. serratus*) is shallowly excavated and the undersides of its processes are essentially flat.

Prioniodina velicuspis Pulse and Sweet (1960) is closely related morphologically to one of the two form-groups we include in the form-species *Prioniodina oregonia* which suggests that development of the stock *O. mediocris-O. oregonia* resulted in the Maysvillian in a short-lived species, *O. velicuspis* (Pulse and Sweet). The latter species has associated with it both corylodus-like elements (described as *Cordylodus excavatus* by Pulse and Sweet) and prioniodina-like elements (described as *P. rotunda* by Pulse and Sweet). These interpretations suggest that cordylodus- and oulodus-like elements were conservative structures in this developmental line and that specific novelty is expressed by variations in structure of the prioniodina-like elements.

Occurrence. — *Oulodus oregonia* (Branson, Mehl, and Branson) ranges from 183 to 416 feet above the base of our composite Lexington-Kope-Clays Ferry section, and occurs again in lesser numbers in the interval between 479 and 628 feet above the base of that section. In the latter interval, we have also recognized a few representatives of the form-species *Prioniodina velicuspis*, and it is probable that at least some of the cordylodus-, oulodus-, and prioniodina-like elements found in these samples were parts of the composite species *Oulodus velicuspis* (Pulse and Sweet). Solution of this problem is deferred, pending a complete synthesis of Lexington-Cincinnatian conodont stratigraphy (Sweet and Kohut, in preparation).

Repository. — Micropaleontological collections, The Ohio State University. Reference slides from all sections considered in this report (see Appendix B). Figured specimens, OSU 27437, 27438, 27439, 27440.

Genus **OZARKODINA** Branson and Mehl, 1933

1933. *Ozarkodina* Branson and Mehl, Univ. Missouri Studies, vol. 8, No. 1, p. 51.

Ozarkodina typica, type species of the form-genus *Ozarkodina,* is based on three fragmentary conodont-elements from the Middle Silurian Bainbridge formation of Missouri (Branson and Mehl, 1933). These fragmentary specimens are not like the host of Ordovician forms commonly referred to *Ozarkodina,* nor are their relations to other elements clear from Branson and Mehl's description of the Bainbridge fauna. Consequently, there will always be doubt as to the nature and content of *Ozarkodina* until the Bainbridge fauna is restudied.

Walliser (1964) referred 260 discrete elements from the Silurian and Lower Devonian of the Carnic Alps to two subspecies of *Ozarkodina typica* Branson and Mehl. In addition, he noted that these elements occur regularly with others identified as *Trichonodella symmetrica* (Branson and Mehl), *Plectospathodus flexuosus* Branson and Mehl, *Neoprioniodus bicurvatus* (Branson and Mehl), *Hindeodella priscilla* Stauffer, and *Spathognathodus steinhornensis* Ziegler. He included them as components of an assemblage informally designated "Conodonten-Apparat J." Like those of *Ozarkodina typica,* the types of *T. symmetrica, P. flexuosus,* and *N. bicurvatus* are from the Bainbridge of Missouri which has also yielded representatives of *Spathognathodus* and *Hindeodella.* Thus it is possible that the type form-species of *Ozarkodina* was part of a multielement biologic species that included trichonodella-, plectospathodus-, and neoprioniodus-like elements and which may have included spathognathodus-, and hindeodella-like structures as well. If this is so, our concept of *Ozarkodina* will require considerable emendation, and it is likely that a majority of the species now referred to that genus solely on the basis of form will be excluded.

Revision of *Ozarkodina,* suggested by Walliser's studies, is beyond the scope of this paper. Pending such a revision we follow custom in referring two apparently single-element Lexington-Kope species to *Ozarkodina,* and we also include it it a third species which is clearly a multielement apparatus. We suspect that ozarkodina-like elements occur in several genera, and that the ones here included in *Ozarkodina* will ultimately be removed to some other genus.

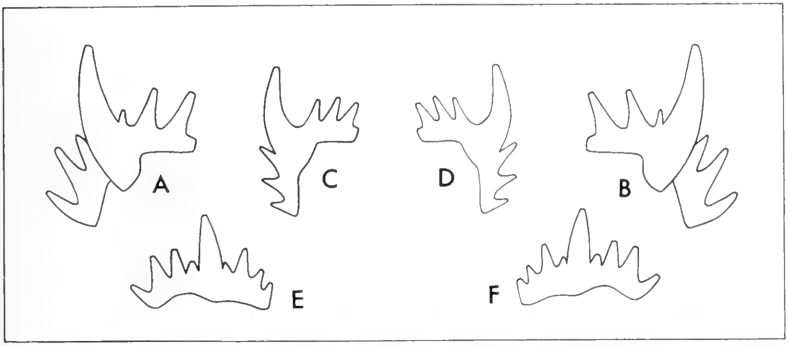
Range (of the form-genus).—Middle Ordovician through Middle Triassic.

Type species.—*Ozarkodina typica* Branson and Mehl, 1933.

Ozarkodina? obliqua (Stauffer) Pl. 33, figs. 6-9; Pl. 34, figs. 7-8; Text-fig. 10A-F

1930. *Prioniodus? obliquus* Stauffer, Jour. Paleont., vol. 4, p. 123, pl. 10, figs. 3,4.
1930. *Prioniodus cornutus* Stauffer, *idem,* p. 127, pl. 10, fig. 15.

1930. *Euprioniodina futilis* Stauffer, *idem*, p. 126, pl. 10, fig. 10.
1930. *Eupriomiodina robusta* Stauffer, *idem*, p. 123, pl. 10, fig. 1.
1930. *Prioniodus cultellatus* Stauffer, *idem*, p. 126, pl. 10, fig. 11.
1932. *Prioniodus obliquus* Stauffer, Stauffer, Jour. Paleont., vol. 6, p. 259.
1932. *Prioniodus cultellatus* Stauffer, Stauffer, *idem*, pp. 259, 260, pl. 40, figs. 8, 9.
1932. *Eupriomiodina robusta* Stauffer, Stauffer, *idem*, pp. 258, 262, 263, pl. 40, fig. 25.
1933. *Pteroconus tortus* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 112, pl. 8, fig. 33.
1935. *Ozarkodina concinna* Stauffer (part), Geol. Soc. America, Bull., vol. 46, p. 148, pl. 10, fig. 45 (not figs. 41, 46).
1935. *Eupriomiodina robusta* Stauffer, Stauffer, *idem*, pp. 144, 159, pl. 11, fig. 29.
1935. *Eupriomiodina dubia* Stauffer, Jour. Paleont., vol. 9, pp. 605, 606, pl. 72, fig. 23.
1935. *Microcoelodus obliquus* (Stauffer), Stauffer, *idem*, p. 608, pl. 73, figs. 53, 56.
1935. *Pteroconus robustus* (Stauffer), Stauffer, *idem*, p. 617, pl. 75, figs. 15-17, 20, 21.
1935. *Dichognathus variabilis* Stauffer (part), *idem*, pp. 604, 605, pl. 74, fig. 8 (not pl. 73, figs. 14, 24, 30, 31, 34-37, 40, 44, 50, 59).
?1935. *Dichognathus* sp., Stauffer, *idem*, p. 605, pl. 75, fig. 10.
1936. *Pteroconus* aff. *P. robustus* (Stauffer), Furnish, Barragy, and Miller, Am. Assoc. Petrol. Geol., Bull., vol. 20, p. 1334, pl. 2, fig 11.
1944. *Pteroconus tortus* Branson and Mehl, Branson, Univ. Missouri Studies, vol. 19, pp. 80, 82, pl. 11, fig. 59.
1955. *Ptiloconus tortus* (Branson and Mehl), Sweet, Jour. Paleont., vol. 29, p. 246, pl. 28, fig. 11.
1966. *Prioniodina robusta* (Stauffer), Schopf, New York State Mus., Bull. 405, p. 72, pl. 2, fig. 19.
1966. *Ozarkodina obliqua* (Stauffer), Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 36, pl. 10, figs. 1-7, 9.



Text-fig. 10. *Ozarkodina? obliqua* (Stauffer), X30. Diagrammatic lateral views of dichognathus-like (A,B), prioniodina-like (C,D), and ozarkodina-like (E,F) elements of this species.

Webers (1966) recently combined the form-species *Prioniodina* (or *Ptiloconus*) *robusta* (Stauffer) and *Ozarkodina obliqua* (Stauffer) with distinctive, but unnamed dichognathus-like elements in a multielement species that he termed *Ozarkodina obliqua* (Stauffer). Our Lexington-Kope collections contain 185 discrete elements representing these form-species, and we here refer them to the multielement species conceived by Webers, albeit with some reservations.

Prioniodina-like elements of *Ozarkodina*? *obliqua,* which have been described previously as *Euprioniodina* (or *Pteroconus*) *robusta* (Stauffer, 1930, 1935) and *Pteroconus* (or *Ptiloconus*) *tortus* (Branson and Mehl, 1933; Sweet, 1955), are by far the best known and most distinctive of the elements Webers included in *O. obliqua.* In these elements, anterior and posterior processes join beneath the cusp to enclose an angle of about 90°; the cusp is laterally compressed and sharp-edged in early and intermediate stages but becomes more nearly circular in transverse section in late growth stages. The anterior process is shorter than the posterior process, but both bear discrete denticles that are laterally compressed in early stages and peglike in later stages. The entire element is excavated basally; a subconical pit beneath the cusp is continuous with grooves that extend to the process extremities.

Ozarkodina-like elements, described previously as *Prioniodus* (or *Microcoelodus*) *obliquus* (Stauffer, 1930, 1935b) have a short cusp, an anterior process that is somewhat shorter than the posterior process, and a deep basal excavation. Process denticles are laterally compressed in small specimens but discrete and peglike in larger ones. Some of these ozarkodinas are unbowed and only moderately arched; others are prominently arched and tend to develop a distinctly sigmoidal, oulodus-like curvature.

Dichognathus-like elements of this species are similar to those commonly identified as *D. brevis* Branson and Mehl. They are distinguished from those elements by their more robust construction and their denticulation, which, like that of ozarkodina- and prioniodina-like elements, tends to become peglike in advanced growth stages.

Discussion.—The common association of the three types of elements just mentioned in both the Upper Mississippi Valley Ordovician and the lower part of the Lexington limestone of the Ohio

Valley region certainly suggests that they are closely related. A common pattern of denticulation, similar size, comparable color, and similarity in construction of basal cavity further suggests that these elements were originally parts of the same biologic apparatus. We agree with Webers (1966) that these elements ought to be associated in a single multielement species. The association of elements is not like that indicated by Walliser (1964) for *Ozarkodina typica*, nor is this species like forms referred on subsequent pages to *O. polita* and *O. tenuis*. All are referred to *Ozarkodina*, for they all contain ozarkodina-like elements and we are not sure of the scope of the genus.

Occurrence.—Our collections contain 102 specimens referable to *Prioniodina robusta* (Stauffer); 49 referable to the form-species *Ozarkodina obliqua* (Stauffer); and 35 representatives of *Dichognathus* that appear to be associated morphologically with the first two form-species mentioned. In aggregate, these specimens indicate that *Ozarkodina*? *obliqua* (Stauffer), ranges from 58 to 76 feet above the base of our composite Lexington-Kope section. In Minnesota, the species ranges to the top of the Decorah formation (Webers, 1966), which we believe is represented by a point just a few feet above the base of our composite Lexington-Kope section. In New York and southern Ontario, *Ozarkodina*? *obliqua* ranges from the Lowville into the Kirkfield formation (Schopf, 1966) and is known in abundance from the Verulam and Bobcageon formations. All these units are probably of about the same age.

Repository.—Micropaleontological collections, The Ohio State University. Reference slides 61Z-627, 629, 635; 64S2-6, 7, 8, 9. Figured specimens, OSU 27441, 27442, 27443.

Ozarkodina polita (Hinde) Pl. 31, figs. 6-11

1879. *Prioniodus? politus* Hinde, Quart. Jour. Geol. Soc. London, vol. 35, p. 358, pl. 15, fig. 11.
1923. *Prioniodus politus* Hinde, Parks and Fritz, Ont. Dept. Mines, 31st Ann. Rept., vol. 31, p. 37, pl. 6, fig. 27.
1928. *Bryantodus politus* (Hinde), Holmes, U.S. Nat. Mus. Proc., vol. 72, art 5, No. 2701, p. 7, pl. 5, fig. 16.
1933. *Ozarkodina* (?) *polita* (Hinde), Branson and Mehl, Univ. Missouri Studies, vol. 8, pp. 155, 156, pl. 12, fig. 16.
1933. *Ozarkodina* (?) *equilatera* Branson and Mehl, *idem*, p. 118, pl. 10, fig. 7
?1959. *Ozarkodina rhodesi* Lindström, Micropaleont., vol. 5, p. 441, pl. 1, figs. 1-9; text-fig. 3:6.

1960. *Aphelognathus irregularis* Pulse and Sweet, Jour. Paleont., vol. 34, pp. 249, 250, pl. 36, figs. 15, 17.

Our Lexington-Kope collections contain 6170 ozarkodinas that represent *Ozarkodina polita* (Hinde). This species has been thoroughly diagnosed and described (as *Aphelognathus irregularis*) in the recent literature (Pulse and Sweet, 1960), and it would be superfluous to repeat either diagnosis or description here. It should be noted that many of our specimens are more nearly complete than those available to Pulse and Sweet. From study of these specimens, it is now evident that the posterior process of *O. polita* is only slightly shorter than the anterior process and may bear as many as nine denticles on its upper margin.

Our collections include a virtually complete series of growth stages of *Ozarkodina polita* and, as is evident in figures 6-11, Plate 31, the difference between early and late stages of this species is considerable. Small specimens, representing early growth stages of *O. polita,* are delicate and similar to elements representing the same stages of *O. tenuis*. They differ from early-stage elements of the latter species, in that the basal cavity appears to have no well-defined tip below the cusp base. Such a feature is prominently displayed in all our representatives of *O. tenuis*.

Advanced growth-stage elements of *Ozarkodina polita* are robust and at least four times larger than early-stage elements. The larger elements have rounded denticles that are blunt apically and confluent laterally for much of their length. In addition, denticles immediately anterior to the cusp are suppressed and overgrown by the cusp base in late stage elements. Indeed, this "gap" in the denticle row is one of the more conspicuous and constant features of *O. polita*. The basal cavity in late-stage elements is capacious, a result of a strong lateral flare of the cavity walls below the cusp.

Discussion.—Through the courtesy of Dr. R. H. Bate and the Trustees of the British Museum (Nat. Hist.), we have had the opportunity to study Hinde's Ordovician conodont types. On the occasion of this study, it became apparent that the type of *Ozarkodina polita* (Hinde) is indistinguishable from that of *Aphelognathus irregularis* Pulse and Sweet, and similar, as well, to the type of *Ozarkodina* (?) *equilatera* Branson and Mehl, derived by them from the Plattin formation of Missouri. We believe that *O. rhodesi*

Lindström, from the Crug limestone of Wales, is probably based on elements that are objectively indistinguishable from the types of *O. polita;* we have not had the opportunity to study a complete sequence of growth stages of this species. For this reason we include it only tentatively in the list of synonyms of *O. polita*.

Occurrence.—Ozarkodina polita (Hinde) ranges from 140 to 416 feet above the base of our composite Lexington-Kope section. It is known from even younger strata in the Cincinnati Region (Pulse and Sweet, 1960) and probably occurs at least as high as the lower Richmondian "Arnheim" formation (McClish, 1965).

Repository.—Micropaleontological collections, The Ohio State University. Reference slides from all sections considered in this report (see Appendix B). Figured specimens, OSU 27444, 27445, 27446, 27447, 27448, 27449.

Ozarkodina tenuis Branson and Mehl Pl. 31, figs. 1-5

1933. *Ozarkodina tenuis* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 128, pl. 10, figs. 19-21, 23.

1941. *Ozarkodina tenuis* Branson and Mehl, Graves and Ellison, Univ. Missouri, School Mines and Metallurgy, Bull., Tech. Ser., vol. 14, pp. 6, 7, pl. 3, figs. 3, 6.

1953. *Ozarkodina tenuis* Branson and Mehl, Rhodes, Phil. Trans. Roy. Soc. London, Ser. B, vol. 237, p. 320, pl. 22, figs. 187, 197-200.

1959. *Ozarkodina robusta* Stauffer, Sweet, *et al.,* Jour. Paleont., vol. 33, pp. 1055, 1056, pl. 132, figs. 19, 20; pl. 133, fig. 14.

1960. *Ozarkodina robusta* Stauffer, Pulse and Sweet, Jour. Paleont., vol. 34, p. 256, pl. 35, figs. 18, 19.

1965. *Ozarkodina robusta* Stauffer, Barnett, Micropaleont., vol. 11, p. 71, pl. 1, fig. 23; pl. 2, fig. 21.

1966. *Ozarkodina* sp. cf. *O. tenuis* Branson and Mehl, Schopf, New York State Mus., Bull. 405, p. 63, pl. 2, figs. 11-13.

We have about 7900 ozarkodinas that appear to be conspecific with the types of *Ozarkodina tenuis* Branson and Mehl. The original description of this species, based on material from the Maquoketa formation of Missouri, mentions all its important characters and little needs to be added here. We have specimens that represent several growth stages, and these provide information on the ontogenetic development of *Ozarkodina tenuis* that merits reporting.

The smallest recognizable specimens (Pl. 31, fig. 1), evidently representing an early growth stage, are thin and delicate and have denticles that are strongly compressed laterally, sharp pointed apically, and not notably confluent basally. The basal cavity extends beneath the entire under side of the processes but is deepest, and its sheath flares most laterally, beneath the cusp; its uppermost part is developed as a tip which is situated below the center of the cusp base. In even these early growth stages, most specimens tend to have a slightly twisted posterior process, and this feature becomes more prominent in more advanced stages.

In the course of ontogeny, the elements increased progressively in size and robustness. Denticles became more rounded and grew together for at least part of their length. The basal cavity became more capacious, a tendency that is particularly evident below the cusp, where one of the cavity walls tends to flare out more laterally than the other. Many late-stage elements are exceedingly robust and have a large basal cavity. The denticles of these elements are blunt distally, confluent for most of their length, and in many specimens denticles adjacent to the cusp have been incorporated into its base. As noted by Branson and Mehl (1933, p. 128), there is otherwise no distinct tendency for suppression of denticles in *Ozarkodina tenuis,* particularly not immediately anterior to the cusp as in *O. polita.*

Ozarkodina tenuis is similar in form to the several ozarkodinas described by Stauffer (1935a, 1935b) from the Glenwood and Decorah formations of Minnesota. There are slight, but evidently constant, differences in denticulation, shape of basal cavity, and general development of processes, between the forms at hand, his species, and presumably conspecific forms from Iowa (Glenister, 1957; Ethington, 1959). All the Upper Mississippi Valley specimens are strikingly alike and they constitute a well-defined form-group that differs in some respects from typical species of *Ozarkodina* such as *O. typica.* We do not know if the differences between our specimens and those from the Upper Mississippi Valley reflect expectable geographic variation, or if variations in their biocharacters are features of taxonomic significance at the species level; further study of large collections is needed to solve that problem. *Ozarkodina tenuis* is the oldest name available for these species, should they be judged conspecific, and because our specimens are close to the types of that species there is no question as to their identity.

Occurrence.—Ozarkodina tenuis ranges from 126 to 628 feet above the base of our composite Lexington-Kope section. It has a comparable stratigraphic range in New York and Ontario (Schopf, 1966) and its types were derived from the Missouri Maquoketa, which undoubtedly represents at least part of the interval bracketed by Kentucky, Ohio, and Indiana occurrences.

Repository.—Micropaleontological collections, The Ohio State University. Reference slides from all sections considered in this report (see Appendix B). Figured specimens, OSU 27450, 27451, 27452, 27453, 27454.

Genus **PANDERODUS** Ethington, 1959

1959. *Panderodus* Ethington, Jour. Paleont., vol. 33, p. 284.

Numerous form-species have been assigned to *Panderodus* (or *Paltodus*) in the past, but the genus needs thorough revision, as we have noted previously (Sweet and Bergström, 1962). The collections at hand do not provide the basis for such a revision, but, together with all the others we have seen, they indicate that most of the form-species referred to *Panderodus* are closely related morphologically and at least some of them were multielement species that included only panderodus-like elements. Thus *Panderodus,* as commonly interpreted, may have a sound biologic basis, even though many of the numerous form-species referred to it may ultimately be combined into multielement species.

The panderodus-like specimens in our Lexington-Kope collections represent two species. *Panderodus gracilis* is a multielement species, whereas *P. panderi* may have had only one somewhat variable element in its apparatus. *Panderodus* is a common associate of *Belodina,* which it resembles in some particulars, and the two genera are especially distinctive of the western and northern Midcontinent Province fauna in North America.

Range.—Middle Ordovician to Middle Devonian.

Type species.—Paltodus unicostatus Branson and Mehl, 1933.

Panderodus gracilis (Branson and Mehl) Pl. 35, figs. 1-6

1933. *Paltodus gracilis* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 108, pl. 8, figs. 20, 21.

1933. *Paltodus compressus* Branson and Mehl, *idem,* p. 109, pl. 8, fig. 19 (the figured specimen is here designated lectotype of the form-species).

1935. *Paltodus compressus* Branson and Mehl, Stauffer, Geol. Soc. America, Bull., vol. 46, pp. 150, 159, pl. 12, figs. 17, 26.

1935. *Paltodus cornutus* Stauffer, Jour. Paleont., vol. 9, p. 612, pl. 74, figs. 1, 2, 11, 13-15.

1935. *Paltodus elegans* Stauffer, *idem,* pp. 612, 613, pl. 74, figs. 4, 7.

1935. *Paltodus striatus* Stauffer, *idem,* p. 613, pl. 74, figs. 3, 16.

1936. *Paltodus compressus* Branson and Mehl, Furnish, Barragy, and Miller, Am. Assoc. Petrol. Geol., Bull., vol. 20, p. 1334, pl. 2, fig. 5.

?1936. *Paltodus gracilis* Branson and Mehl, Furnish, Barragy, and Miller, *idem,* p. 1334, pl. 1, fig. 3.

1940. *Paltodus cornutus* Stauffer, Stauffer, Jour. Paleont., vol. 14, p. 427, pl. 60, fig. 10.

1940. *Paltodus striatus* Stauffer, Stauffer, *idem,* p. 428, pl. 60, figs. 5, 12, 13, 17.

1941. *Paltodus gracilis* Branson and Mehl, Graves and Ellison, Univ. Missouri School Mines and Metallurgy, Bull., Tech. Ser., vol. 14, pp. 6, 7, pl. 3, fig. 10 *(not* pl. 2, fig. 5 or pl. 3, figs. 4, 22).

1943. *Paltodus compressus* Branson and Mehl, Branson and Mehl, Jour. Paleont., vol. 17, p. 386, pl. 64, fig. 6.

1943. *Paltodus gracilis* Branson and Mehl, Branson and Mehl, *idem,* p. 386, pl. 64, figs. 7, 8.

1944. *Paltodus gracilis* Branson and Mehl, Branson, Univ. Missouri Studies, vol. 19, pp. 80, 82, pl. 12, figs. 20, 23.

1944. *Paltodus elegans* Stauffer, Branson, *idem,* pp. 81, 89, pl. 12, figs. 25, 26.

1951. *Paltodus gracilis* Branson and Mehl, Branson, Mehl, and Branson, Jour. Paleont., vol. 25, p. 6, pl. 1, figs. 1-8.

1953. *Paltodus equicostatus* Rhodes, Phil. Trans. Roy. Soc. London, Ser. B, vol. 237, p. 297, pl. 21, figs. 106-109; pl. 22, figs. 162, 165.

1957. *Paltodus gracilis* Branson and Mehl, Glenister, Jour. Paleont., vol. 31, p. 728, pl. 85, figs. 2-5.

1957. *Paltodus striatus* Stauffer, Glenister, *idem,* p. 729, pl. 85, fig. 6.

1957. *Paltodus feulneri* Glenister, *idem,* p. 728, pl. 85, fig. 11.

1957. *Paltodus unicostatus* Branson and Mehl, Glenister, *idem,* p. 729, pl. 85, fig. 1.

1959. *Panderodus gracilis* (Branson and Mehl), Stone and Furnish, Jour. Paleont., vol. 33, p. 225, pl. 31, fig. 2.

1959. *Panderodus gracilis* (Branson and Mehl), Ethington, Jour. Paleont., vol. 33, p. 285, pl. 39, fig. 1.

1959. *Panderodus compressus* (Branson and Mehl), Ethington, *idem,* p. 284, pl. 39, fig. 4.

1959. *Panderodus feulneri* (Glenister), Ethington, *idem,* pp. 284, 285, pl. 39, fig 2.

?1959. *Panderodus gracilis* (Branson and Mehl), Ethington and Furnish, Jour. Paleont., vol. 33, p. 541 (not figured).

1959. *Panderodus compressus* (Branson and Mehl), Ethington and Furnish, *idem,* p. 541, pl. 73, fig. 8.

1959. *Panderodus gracilis* (Branson and Mehl), Sweet, *et al.,* Jour. Paleont., vol. 33, p. 1056, pl. 131, fig. 1.

1959. *Panderodus unicostatus* (Branson and Mehl), Sweet, *et al., idem,* p. 1057, pl. 131, fig. 3.

?1960. *Panderodus gracilis* (Branson and Mehl), Ethington and Furnish, Jour. Paleont., vol. 34, p. 272, (not figured).

?1960. *Panderodus compressus* (Branson and Mehl), Ethington and Furnish, *idem,* p. 272 (not figured).

1960. *Panderodus gracilis* (Branson and Mehl), Pulse and Sweet, Jour. Paleont., vol. 34, p. 256, pl. 35, figs. 3, 6.

?1960. *Panderodus gracilis* (Branson and Mehl), Carlson, North Dakota Geol. Survey, Bull. 35, tab. II (not figured).

?1960. *Panderodus compressus* (Branson and Mehl), Carlson, *idem,* tab. II (not figured).
1961. *Panderodus gracilis* (Branson and Mehl), Wolska, Acta Paleont. Polonica, vol. 6, p. 353, pl. 4, figs. 2a, b.
1961. *Panderodus unicostatus* (Branson and Mehl), Wolska, *idem,* p. 353, pl. 4, figs. 3a, b.
1962. *Panderodus gracilis* (Branson and Mehl), Sweet and Bergström, Jour. Paleont., vol. 36, p. 1233, text-fig. 1H.
1963. *Paltodus equicostatus* Rhodes, Cygan and Koucky, Guidebook, First Joint Field Conf., Wyoming Geol. Assoc.-Billings Geol. Soc., Northern Powder River Basin, p. 34, pl. 1, fig. 5.
1964. *Panderodus gracilis* (Branson and Mehl), Bergström, Acta Univ. Lundensis, sec. II, No. 3, p. 32, text-fig. 16.
?1964. *Panderodus gracilis* (Branson and Mehl), Hamar, Norsk Geol. Tidsskr., bd. 44, pp. 271, 272, pl. 1, figs. 25, 26, text-fig. 6, 2a-b.
1965. *Panderodus compressus* (Branson and Mehl), Barnett, Micropaleont., vol. 11, p. 72, pl. 1, fig. 28.
1965. *Panderodus gracilis* (Branson and Mehl), Barnett, *idem,* p. 72, pl. 1, fig. 32.
?1965. *Panderodus* cf. *P. acostatus* (Branson and Branson), Barnett, *idem,* p. 72, pl. 1, fig. 19; pl. 2, fig. 17.
1966. *Panderodus compressus* (Branson and Mehl), Schopf, New York State Mus., Bull. 405, p. 65, pl. 5, fig. 23.
1966. *Panderodus feulneri* (Glenister), Schopf, *idem,* p. 66, pl. 5, fig. 30.
1966. *Panderodus compressus* (Branson and Mehl), Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 38, pl. 2, figs. 10, 11.
1966. *Panderodus feulneri* (Glenister), Webers, *idem,* p. 38, pl. 3, figs. 1, 2.
1966. *Panderodus gracilis* (Branson and Mehl), Webers, *idem,* p. 39, pl. 3, figs. 10-12.

The form-species *Panderodus gracilis* (Branson and Mehl) [in which we include forms previously identified as *P. elegans* (Stauffer), *P. striatus* (Stauffer), and *P. equicostatus* (Rhodes)], and *Panderodus compressus* (Branson and Mehl) [in which we include forms previously identified as *P. cornutus* (Stauffer) and *P. feulneri* (Glenister)] are represented in our Lexington limestone and Kope collections by 1082 and 485 specimens, respectively. Because these two form-species occur together in our collections in the ratio of about 2:1, have essentially the same stratigraphic range in the sections with which we are familiar and elsewhere, and because the two form-species are almost invariably associated throughout their known geographic extent, we regard them as components of a single biologic species. Both form-species include asymmetric elements only, hence the smallest number of elements in one animal would have been two *P. compressus* and four *P. gracilis.*

Elements we include in the form-species *Panderodus gracilis* are all similar to the Plattin limestone types in that they are slender, have a moderately curved cusp with rounded anterior margin, and lateral faces marked by at least one costa on each side. All have the deep basal cavity characteristic of *Panderodus*. There is considerble variation of this general pattern exhibited by the 1082 specimens we include in this form-species: for the most part, variation is noted in placement and degree of development of the lateral costae and in cusp curvature. It is clear that these elements developed at various distances from the plane of bilateral symmetry, and we attribute both variable biocharacters to this variation in placement.

The form-species *Panderodus compressus,* in which we include 485 Lexington-Kope specimens, is characterized by a moderately curved cusp that is strongly compressed laterally and has more or less sharp anterior and posterior margins. One side of the cusp is evenly convex and lacks costae or carinae; the other face bears a longitudinal groove near the posterior margin. The basal cavity is narrow and deep, and extends to a point about two-thirds the height of the cusp.

Panderodus compressus is readily distinguished from most other form-species included in *Panderodus* by its lack of lateral sculpture, at least in young and intermediate growth stages. *P. cornutus* (Stauffer) is similar in cusp curvature, in having sides with subdued sculpture, and in shape of basal cavity. We see no objective way to distinguish that form-species from *P. compressus. P. feulneri* (Glenister) differs superficially from the generally smaller specimens included in typical *P. compressus* in development of a pattern of subdued costae laterally. We regard this feature as a late growth-stage development in *P. compressus,* for our collections contain a complete sequence of growth stages in which the transition from *P. compressus* to *P. feulneri* can readily be traced.

Panderodus compressus is also somewhat similar morphologically to the paratypes of *Paltodus acostatus* figured by Branson and Branson (1947) on their plate 82, figures 1-5. These specimens (which are not conspecific with the holotype of the form-species *P. acostatus*) differ from the ones at hand in having a basal cavity that extends almost to the cusp apex, rather than to a point just two-thirds its height.

We also include in the biologic species *Panderodus gracilis* a number of elements similar to those referred to *Paltodus unicostatus*

Branson and Mehl by Glenister (1957) and Sweet, *et al.* (1959). These are delicate specimens, gracefully recurved, with a twisted cusp that bears a conspicuous antero-lateral costa on one face but is smooth except for a longitudinal groove near the posterior margin on the opposed face. We regard these specimens as extremes in development of the *P. gracilis* type but do not mean to imply that the Silurian species with which others have identified them is synonymous with *P. gracilis*. That is, *P. unicostatus* Branson and Mehl was based on an unspecified number of syntypes, two of which were figured (Branson and Mehl, 1933, pl. 3, fig. 3). These specimens, from the Bainbridge limestone of Missouri, have a posterior margin that is more rounded and a cusp that is far less twisted and more regularly recurved than in the majority of our otherwise similar specimens. The Bainbridge specimens, in addition, approach bilateral symmetry (except for the lateral costa), whereas our specimens are conspicuously asymmetric.

Occurrence.—Representatives of the two species here united in *Panderodus gracilis* occur in samples from all our Lexington-Kope-Clays Ferrys sections except 60B, 60D, 60H, 60Q, 60T. The species ranges from 58 to 601 feet above the base of our composite Lexington-Kope section, from the Glenwood through the Maquoketa of Iowa and Minnesota (Webers, 1966; Glenister, 1957), and from the Chaumont through the Cobourg in New York, southern Ontario, and Quebec (Schopf, 1966). Relationship between this species, as we conceive it, and the many form-species of *Panderodus* described from Richmond group strata in Kentucky and Indiana by Branson, Mehl, and Branson (1951) is not yet clear.

Repository.—Micropaleontological collections, The Ohio State University. Reference slides from sections 60BCK, 60G, 60L, 60P, 61Z, 64S1, 64S2, and 64S3. Figured specimens, OSU 27455, 27456, 27457.

Panderodus panderi (Stauffer) Pl. 35, figs. 14, 15; Text-fig. 11

1940. *Paltodus panderi* Stauffer, Jour. Paleont., vol. 14, p. 427, pl. 60, figs. 8, 9.
1957. *Paltodus panderi* Stauffer, Glenister, Jour. Paleont., vol. 31, pp. 728, 729, pl. 85, figs. 8, 9.
1959. *Panderodus panderi* (Stauffer), Ethington, Jour. Paleont., vol. 33, p. 285, pl. 39, fig. 5.
1959. *Panderodus panderi* (Stauffer), Stone and Furnish, Jour. Paleont., vol. 33, p. 226, pl. 31, fig. 4.

1959. *Panderodus panderi* (Stauffer) Ethington and Furnish, Jour. Paleont., vol. 33, p. 541, pl. 73, fig. 9.

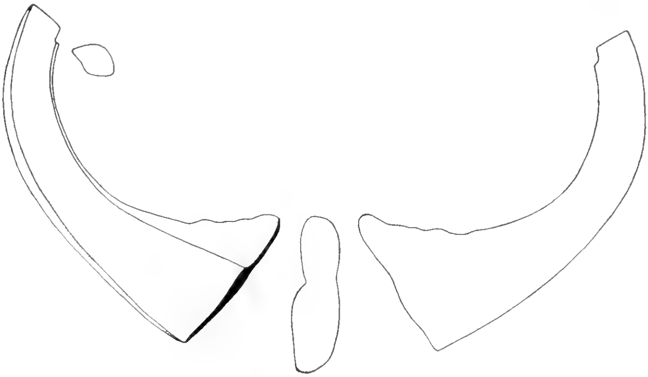
?1960. *Panderodus panderi* (Stauffer), Ethington and Furnish, Jour. Paleont., vol. 34, pp. 267, 272 (not figured).

?1966. *Panderodus striatus* (Stauffer), Schopf, New York State Mus., Bull. 405, p. 66, pl. 5, figs. 22, 24.

1966. *Panderodus panderi* (Stauffer), Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 39, pl. 2, figs. 1, 2, 3, 6.

This rare species, of which we have only 44 Lexington-Kope representatives, is based on specimens from a mixture of Ordovician and Devonian conodonts derived from a residual clay of probable Cretaceous age in Minnesota (Stauffer, 1940). The species was fully diagnosed by Stauffer and has subsequently been carefully reconsidered by Glenister (1957) and Webers (1966). Our specimens are similar to those described by these authors, hence there is no need to describe them here.

Like other *Panderodus* species, *P. panderi* is somewhat variable in development and arrangement of costae. Sharp recurvature of the cusp, a posterior costa on each face, and the distinctive architecture of the base are all characters that plainly distinguish *P. panderi* from the other species of the genus. We have examined the holotype of this species (Text-figure 11) and find it asymmetric, with an antero-lateral costa that extends the full length of the cusp. The same feature distinguishes the paratype figured by Stauffer (1940, pl. 3, fig. 9). Our specimens, like Glenister's Maquoketa one, lack an



Text-fig. 11. Holotype of *Panderodus panderi* (Stauffer), X75. Lateral views and cross-sections; dotted line outlines basal cavity.

antero-lateral costa, although some have a short central costa along the anterior margin at the bend of the cusp. Study of a comparatively large assemblage of these elements in our reference collections from the Dubuque formation of Iowa and Minnesota suggests that the anterior margin of *Panderodus panderi* may develop in a variety of ways. For this reason, we regard our specimens as conspecific with *P. panderi* even though they do not agree with the holotype in every detail.

Occurrence.—Panderodus panderi ranges from 70 to 495 feet above the base of our composite Lexington-Kope section. Minnesota representatives range from the Glenwood shale to the top of the Galena limestone (Webers, 1966), and Glenister (1957), recorded the species from all five members of the Maquoketa formation in Iowa, and from Minnesota localities. Schopf (1966) may have this species in rocks of Wilderness and Barneveld age in New York, Ontario, and Quebec, and representatives of *P. panderi* are also known from the Bighorn of Wyoming (Stone and Furnish, 1959) and the Stony Mountain and Shammattawa of Manitoba (Ethington and Furnish, 1959, 1960).

Repository.—Micropaleontological collections, The Ohio State University. Specimens are in reference slides numbered 60L10-1; 60PB-18, 60P7-17; 61Z-200, 208, 227, 288, 309, 384, 480, 505; 64S2-7, 32, 52, 53; 64S3-9, 10, 16, 17, 37, 38. Figured specimen, OSU 27458.

Genus **PERIODON** Hadding, 1913

Emend. Bergström and Sweet, herein

1913. *Periodon* Hadding, Lunds Univ. Årsskr., N. F., Afd. 2, bd. 9, No. 15, p. 33.
1941. *Loxognathus* Graves and Ellison, Univ. Missouri School Mines and Metallurgy, Bull., Tech. Ser., vol. 14, p. 12.
1955. *Falodus* Lindström, Geol. Fören. (Stockholm), Förhandl., bd. 76, h. 4 (1954), p. 568.

Emended diagnosis.—Periodon embraces multielement conodont species that include cordylodus-, ligonodina-, cladognathodus-, roundya-, prioniodina-, and falodus-like conodont elements.

The cordylodus-, ligonodina-, cladognathodus-, and roundya-like elements of *Periodon* are all similar in having a slender, recurved, anterior cusp and a bladelike, multidenticulate posterior process that is commonly twisted and may reach considerable length. The underside of this process is excavated anteriorly; posteriorly, the attachment surface of most specimens is prominently "inverted." The upper edge of the process bears numerous laterally compressed denticles which are pointed, basally confluent, and apically free. Denticles next to the cusp are small; more posteriorly, denticles are successively larger and some rival or exceed the cusp in size; still more posteriorly, average denticle size decreases and a crude hindeodelloid pattern may develop. In cordylodus-like elements, the cusp base may be prolonged as a short anticusp, the anterior edge of which may be weakly denticulate; or, in ligonodina-, cladognathodus-, and roundya-like elements, the base may be provided with one or two short denticulate lateral processes.

Prioniodina-like elements are arched, bladelike, multidenticulate units, excavated beneath, with a prominent central cusp and laterally compressed, apically pointed, basally confluent denticles along the upper edge of the processes.

Ligonodina-like elements are basically like prioniodina-like forms, but the anterior process is directed outward rather than inward. Lindström (1964) regarded such elements as oulodus-like in fundamental structure.

Falodus-like structures are essentially simple conodont elements with a well-developed base and a recurved cusp that is denticulate along the anterior edge.

Range.—Lower to Upper Ordovician; widespread, but rarely abundant.

Type species.—Periodon aculeatus Hadding, 1913.

Discussion.—Periodon is based on shale-embedded upper Llandeilian conodonts from southernmost Sweden (Hadding, 1913; Lindström, 1955b). For many years little was known about the genus, but during the past decade much new information about it has been published (Lindström, 1955b, 1964; Sweet and Bergström, 1962; Schopf, 1966; Webers, 1966). Sweet and Bergström (1962) and Lindström (1964) noted that typical periodon-elements include several form-variants, and a similar conclusion was reached independently by Schopf (1966). None of these authors included structures other than periodon-like elements (and their variants) in species of *Periodon*.

Periodon occurs in several of the described and undescribed faunas available to us, but it is abundant in only a few of them. After a thorough study of our material, and the types of every structurally related form-species, we have concluded that species of the biologic genus *Periodon* included not only cordylodus-, cladognathodus-, and roundya-like elements, but also prioniodina-, ligonodina-, and falodus-like elements. The same array of structures is recognizable in the three species we currently believe to be distinct, that is in *P. flabellum* (Lindström, 1955a), *P. aculeatus* Hadding, 1913, and *P. grandis* (Ethington, 1959).

Many of the elements we include in the three species of *Periodon* we recognize have previously been described as independent form-species. Thus, *P. flabellum* includes *Trichonodella flabellum* Lindström, 1955a, *Prioniodina*? *deflexa* Lindström, 1955a (cf. Lindström, 1964), "*Falodus prodentatus* (Graves and Ellison, 1941)" of Lindström 1955a, and probably *Prioniodina inflata* Lindström, 1955a. *Periodon aculeatus* includes *P. aculeatus* Hadding, 1913, *Loxognathus flabellata* Graves and Ellison, 1941, *Ozarkodina macrodentata* Graves and Ellison, 1941, *Oistodus prodentatus* Graves and Ellison, 1941, and *Ligonodina tortilis* Sweet and Bergström, 1962. *Periodon grandis* (Ethington), which is represented in our Lexington-Kope collections, includes *Eoligonodina magna* Ethington, 1959, *Loxognathus grandis* Ethington, 1959, *Trichonodella insolita* Ethington, 1959, "*Falodus prodentatus* (Graves and Ellison, 1941)" of Ethington (1959), and "*Ozarkodina macrodentata* (Graves and Ellison, 1941)" of Ethington (1959) (=*Prioniodina araea* Webers, 1966).

The type form-species of both *Falodus* Lindström, 1955a, and *Loxognathus* Graves and Ellison, 1941, are here interpreted to be parts of the same biologic apparatus as *P. aculeatus*, the type form-species of *Periodon*. Thus both *Falodus* and *Loxognathus* are regarded as junior subjective synonyms of *Periodon*.

Periodon grandis (Ethington) Pl. 30, figs. 1-8

1944. *Oistodus breviconus* Branson and Mehl, Branson, Univ. Missouri Studies, vol. 19, p. 89, pl. 13, figs. 7, 8.
1944. *Subcordylodus* n. sp., Branson, *idem,* p. 89, pl. 13, fig. 19.

1959. *Eoligonodina magna* Ethington, Jour. Paleont., vol. 33, p. 277, pl. 40, figs. 3, 4.
1959. *Falodus prodentatus* (Graves and Ellison), Ethington, *idem,* pp. 277, 278, pl. 39, fig. 18.
1959. *Loxognathus grandis* Ethington, *idem,* p. 281, pl. 40, fig. 6.
1959. *Ozarkodina macrodentata* Graves and Ellison, Ethington, *idem,* p. 284, pl. 41, fig. 14.
1959. *Trichonodella insolita* Ethington, *idem,* pp. 289, 290, pl. 41, fig. 9.
1962. *"Falodus prodentatus"* (Graves and Ellison), Sweet and Bergström, Jour. Paleont., vol. 36, p. 1228, text-fig. 2C.
1966. *Periodon aculeatus* Hadding, Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 57, pl. 12, fig. 16.
1966. *Prioniodina araea* Webers, *idem,* p. 58, pl. 12, fig. 13.
1966. *Falodus prodentatus* (Graves and Ellison), Webers, *idem,* p. 56, pl. 12, figs. 6, 7.
1966. *Ligonodina tortilis* Sweet and Bergström, Webers, *idem,* p. 57, pl. 12, fig. 16.
1966. *Prioniodina macrodentata* (Graves and Ellison), Schopf, New York State Mus., Bull. 405, p. 70, pl. 4, figs. 27, 28.
1966. *Periodon aculeatus* Hadding, Schopf, *idem,* p. 67, pl. 3, figs. 10, 12-14, 16.
1966. *Falodus prodentatus* (Graves and Ellison), Schopf, *idem,* p. 56, p.l3, fig. 11.
1966. *Ligonodina tortilis* Sweet and Bergström, Schopf, *idem,* p. 59, pl. 4, figs. 22, 23, 26.

Periodon grandis is not common in our Lexington-Kope collections, but we have a few representatives of it and have seen hundreds of others in faunas from related strata. As is evident from the synonymy at the head of this discussion, we include in *P. grandis* cordylodus-, cladognathodus-, roundya-, prioniodina-, ligonodina-, and falodus-like elements. The first three of these are represented in our collections by a total of 50 discrete specimens; the next two by about 14; and the falodus-like element by 41.

Cordylodus-, cladognathodus-, and roundya-like elements of *Periodon grandis* were thoroughly described by Ethington (1959) as *Eoligonodina magna, Loxognathus grandis,* and *Trichonodella insolita,* respectively, and our specimens agree completely with the Galena conodonts on which he based his diagnoses. Consequently, there is no need to describe our limited material. It should be noted, that periodon-like elements of *P. grandis* are similar in overall shape and in most morphologic features to the corresponding structures of *P. aculeatus. Eoligonodina magna*-type forms are distinguished from similar components of *P. aculeatus* by a somewhat larger number of small denticles between cusp and principal posterior denticle; by generally shorter and more slender denticles in the posterior process; and by a somewhat more prominently developed anticusp below the cusp base.

Prioniodina-like elements of *Periodon grandis* have recently been described as *Prioniodina araca* by Webers (1966) and our limited material adds nothing to his complete diagnosis. These elements and the ligonodina-like forms of *P. grandis* are similar to *Prioniodina macrodentata* and *Ligonodina tortilis,* the prioniodina-, and ligonodina-like components of *P. aculeatus.* They differ from the corresponding structures of *P. aculeatus* primarily in having a more evenly rounded, more elongate cusp that is not so broad basally and which lacks conspicuous flangelike margins or distinct longitudinal carinae.

The falodus-like component of *Periodon grandis* is its most characteristic and diagnostic structure. We have previously pointed out (Sweet and Bergström, 1962, p. 1228, text-fig. 2C) that this structure differs from *Falodus prodentatus,* the corresponding element of *P. aculeatus,* in having a large, subtriangular base, an essentially straight basal margin, and anterior denticles that are closely appressed to the anterior margin of the cusp rather than being developed on a more or less conspicuous anterior process. In some specimens, anterior denticulation is inconspicuous; indeed, in a few, like the one referred to *Oistodus breviconus* by Branson (1944), anterior denticles are lacking altogether. The latter specimens are not conspecific (or even congeneric) with the Plattin elements on which Branson and Mehl (1933) based *O. breviconus*—those specimens belong in *Oistodus abundans,* which we believe is part of a multielement species named *Phragmodus undatus.*

Occurrence.—Periodon grandis ranges from 82 to 450 feet above the base of our composite Lexington-Kope section. In New York and Ontario, the species first appears in the Rockland and ranges through the Cobourg formation (Schopf, 1966), whereas in Minnesota and Iowa it makes its debut in the basal Cummingsville and ranges to the top of the Dubuque formation (Ethington, 1959; Webers, 1966). *P. grandis* is also represented in the Kimmswick limestone of Missouri (Branson, 1944), and has been recovered from the middle Caradocian of Sweden.

Repository.—Micropaleontological collections, The Ohio State University. Reference slides 60BCK-1; 60H1-7; 60L3-1; 61Z-309, 383, 384, 390, 398, 439, 463, 480, 491, 493, 497, 500, 501, 502, 503, 509, 510, 512, 513, 518, 531, 541, 542, 543, 546, 555, 561, 575, 580, 613; 64S1-4; 64S2-17, 36, 42; 65GV-360. Figured specimens, OSU 27459, 27460, 27461, 27462.

Genus **PHRAGMODUS** Branson and Mehl, 1933

Emend., Bergström and Sweet, herein

1933. *Phragmodus* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 98.
?1933. *Dichognathus* Branson and Mehl, *idem,* p. 35.

Emended diagnosis.—*Phragmodus* is a multielement conodont genus composed basically of paired phragmodus-, and dichognathus-like elements but developing paired oistodus-like elements in some advanced species.

Phragmodus-like elements, which invariably dominate in known species, are symmetric structures, excavated beneath, with an arched multidenticulate posterior process and a proclined to reclined cusp that is continued downward as an undenticulated anticusp. At the crest of the arch, the posterior process is surmounted by at least one prominent denticle that rivals the cusp in size; this denticle, fundamental to recognition of phragmodus-like elements, is commonly (but not invariably) separated from the cusp by smaller denticles, and may be followed by a posterior process of considerable length with crude hindeodelloid denticulation.

Dichognathus-like elements are asymmetric, bladelike structures, excavated beneath, and with denticulated inner-lateral and posterior processes that are continuous with more or less well-defined costae on the cusp. The anterior edge of the cusp is not denticulated nor is it produced into a distinct process.

Oistodus-like elements, developed in some *Phragmodus* species, are basally excavated, laterally compressed simple cones, in which the posterior margin of the cusp and the upper margin of the base join to form an acute angle.

Range.—Middle and Upper Ordovician. Known primarily from North America, but one of us (Bergström) collected the elements of a typical *Phragmodus* assemblage from the Upper Ordovician Boda limestone of Sweden. Forms reported from Norway (Hamar, 1964) are not indigenous.

Type species.—*Phragmodus primus* Branson and Mehl, 1933.

Discussion.—We recognize only four species of *Phragmodus* as we have diagnosed it. In addition to *P. primus* Branson and Mehl, the type species, these are *P. inflexus* Stauffer, *P. cognitus* Stauffer, and *P. undatus* Branson and Mehl.

Phragmodus inflexus Stauffer is apparently the oldest known species of *Phragmodus* and, in our view, it is also the most primitive. It is represented in the McLish formation of Oklahoma, the Dutchtown formation of Missouri, the Glenwood shale of Minnesota, and the Castell limestone of Wales. Central to this species are the phragmodus-like elements described as *P. inflexus* and *P. singularis* by Stauffer (1935a), but the assembly of elements referable to the multielement species also includes forms referred by Stauffer to *Subcordylodus elongatus, S. sinuatus,* and *Dichognathus pecularis,* as well as most of the Glenwood shale conodonts he identified with *Dichognathus typica* Branson and Mehl (Webers, 1966). The species is essentially distinguished by the primitive development of the phragmodus-like elements (some, like those Stauffer included in *Subcordylodus,* are only slightly arched), and in that the dichognathus-like elements bear a single small denticle anterior to the cusp. Collections of *P. inflexus* from the Glenwood shale of Minnesota (Webers, 1966) contain about twice as many phragmodus-like elements as dichognathus-like forms. Because all elements are paired and three distinct form-groups are recognizable in the phragmodus-assembly, we suggest that the smallest number of elements in a single representative of *P. inflexus* was 18; six dichognathus-like elements and 12 phragmodus-like forms.

In Minnesota, rocks with *Phragmodus inflexus* are succeeded by strata yielding *Phragmodus cognitus* Stauffer, a multielement species embracing conodonts formerly referred to the form-species *Phragmodus cognitus* Stauffer (part) and *Dichognathus brevis* Branson and Mehl, and perhaps including the simple cones recently described as *Oistodus pseudoabundans* by Schopf (1966). This species is distinguished from somewhat similar *Phragmodus undatus* Branson and Mehl in that all elements are shallowly excavated basally and by the limited variability of the dichognathus-like forms. In Minnesota collections of *P. cognitus* described by Webers (1966) phragmodus-like elements are approximately three times more abundant than those of dichognathus or oistodus type, which suggests to us that the smallest number of elements in a single representative of *Phrag-*

modus cognitus was 10: two oistodus-like elements, two dichognathus-like elements, and six phragmodus-like elements.

Phragmodus undatus Branson and Mehl, which appears later than *P. cognitus* in Minnesota Ordovician sections, ranges upward at least to the base of the Richmondian Whitewater formation in Ohio and Indiana (McClish, 1965) and dominates Middle and Upper Ordovician conodont faunas in the eastern Midcontinent of North America. This distinctive species includes conodonts previously referred to form-species described by Branson and Mehl as *Phragmodus undatus, Dichognathus brevis, D. typica,* and *Oistodus abundans. P. undatus* is readily distinguished from *P. cognitus,* the only species with which it might be confused, in that the assembly includes two dichognathus-like elements and all elements have a capacious basal cavity. In our collections of *Phragmodus undatus,* and in those assembled from the Trenton group of New York, Ontario, and Quebec, by Schopf (1966) phragmodus-like elements are twice as abundant as dichognathus-like elements and three times more abundant than oistodus-like elements. This suggests that the smallest number of elements in a single representative of *P. undatus* was 22: four oistodus-like elements, six dichognathus-like elements, and 12 phragmodus-like elements. Webers' (1966) much smaller collections from Minnesota suggest a ratio of 1:1:2 for oistodus-: dichognathus-: phragmodus-like elements in *P. undatus,* which gives a somewhat different model for this species.

Phragmodus primus Branson and Mehl, although type species of the genus, is unfortunately its most poorly known species. The Joachim limestone phragmodus-like elements on which it is based are similar to the Plattin forms later included in *Phragmodus undatus* by Branson and Mehl, but the only dichognathus-like element in the reported Joachim fauna is *D. decipiens* Branson and Mehl, which is difficult to distinguish from similar elements included by Webers in the multielement species *Ozarkodina obliqua* (Stauffer). If *Phragmodus primus* consists only of phragmodus-, and *Dichognathus decipiens*-like elements, it is similar to *P. cognitus* Stauffer, and the latter should be regarded as a synonym of *P. primus.* The type specimen of *P. primus* is fragmentary and we have no information on the nature of its basal cavity. Marked restriction in development of this structure is a distinctive feature of *P. cognitus,* which may also include oistodus-like elements. Thus we suggest that both *P. primus* and *P. cognitus* be recognized until larger collections of the former species are assembled for comparison.

Phragmodus undatus Branson and Mehl Pl. 28, figs. 13-20

1933. *Phragmodus undatus* Branson and Mehl, Univ. Missouri Studies, vol. 8, pp. 115, 116, pl. 8, figs. 22-26.
1933. *Dichognathus brevis* Branson and Mehl, *idem*, p. 113, pl. 9, figs. 24-26.
1933. *Dichognathus typica* Branson and Mehl, *idem*, pp. 113, 114, pl. 9, figs. 27-29.
1933. *Oistodus abundans* Branson and Mehl, *idem*, p. 109, pl. 9, figs. 11, 17.
1933. *Oistodus breviconus* Branson and Mehl, *idem*, p. 109, pl. 9, figs. 13, 14.
1960. *Phragmodus undatus* Branson and Mehl, Pulse and Sweet, Jour. Paleont., vol. 34, pp. 257, 258, pl. 37, figs. 4, 16, 18, 19; text-fig. 2A-E (includes synonymy through November, 1959).
1960. *Dichognathus brevis* Branson and Mehl, Pulse and Sweet, *idem*, p. 252, pl. 35, figs. 9, 14 (includes synonymy through November, 1959).
1960. *Dichognathus typica* Branson and Mehl, Pulse and Sweet, *idem*, p. 252, pl. 37, figs. 6, 14 (includes synonymy through November, 1959).
1960. *Oistodus abundans* Branson and Mehl, Pulse and Sweet, *idem*, p. 254, pl. 35, figs. 1, 8 (includes synonymy through November, 1959).
1960. *Phragmodus undatus* Branson and Mehl, Ethington and Furnish, Jour. Paleont., vol. 34, p. 272, pl. 38, fig. 4.
?1960. *Dichognathus typica* Branson and Mehl, Ethington, and Furnish, *idem*, p. 271.
1960. *Phragmodus undatus* Branson and Mehl, Carlson, North Dakota Geol. Sur., Bull. 35, p. 70, pl. 2, figs. 5?, 14.
?1960. *Dichognathus typica* Branson and Mehl, Carlson, *idem*, tab. II (not figured).
1964. *Phragmodus undatus* Branson and Mehl, Hamar, Norsk Geol. Tidsskr., bd. 44, p. 274, pl. 3, fig. 12.
1964. *Dichognathus typica* Branson and Mehl, Hamar, *idem*, pp. 262, 263, pl. 3, fig. 10.
1965. *Phragmodus undatus* Branson and Mehl, Barnett, Micropaleont., vol. 11, p. 72, pl. 1, figs. 16, 18, 26; pl. 2, fig. 2.
1965. *Dichognathus attenuata* Branson and Mehl, Barnett, *idem*, p. 69, pl. 1, fig. 6.
1965. *Dichognathus brevis* Branson and Mehl, Barnett, *idem*, p. 69, pl. 1, fig. 11; pl. 2, fig. 19.
1965. *Dichognathus extensa* Branson and Mehl, Barnett, *idem*, p. 70, pl. 1, fig. 10.
1965. *Dichognathus typica* Branson and Mehl, Barnett, *idem*, p. 70, pl. 1, fig. 9; pl. 2, fig. 4.
1965. *Oistodus abundans* Branson and Mehl, Barnett, *idem*, p. 71, pl. 1, fig. 31; pl. 2, fig. 10.
1966. *Phragmodus undatus* Branson and Mehl, Schopf, New York State Mus., Bull. 405, p. 68, pl. 1, figs. 22, 23, 29.
1966. *Dichognathus brevis* Branson and Mehl, Schopf, *idem*, p. 49, pl. 1, fig. 15.
1966. *Dichognathus typica* Branson and Mehl, Schopf, *idem*, p. 49, pl. 1, fig. 17.
1966. *Oistodus abundans* Branson and Mehl, Schopf, *idem*, p. 59, pl. 1, figs. 10, 14; text-fig. 7f.
1966. *Phragmodus undatus* Branson and Mehl, Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 41, pl. 10, figs. 10, 11, 13, 15.

Specimens cited in the following references are not components of *Phragmodus undatus*, although they have been identified with, or regarded as synonyms of, one of the form-species we include in this species.

1933. *Dichognathus extensa* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 114, pl. 9, fig. 21 (the type specimen is an *Ozarkodina*).
1941. *Phragmodus undatus* Branson and Mehl (part), Graves and Ellison, Univ. Missouri School Mines and Metallurgy, Bull., Tech. Ser., vol. 14, p. 6, pl. 2, figs. 2, 9, 10, 26 (= *Periodon aculeatus* Hadding) (pl. 3, figs. 7, 8 = *Phragmodus undatus).*
1943. *Phragmodus undatus* Branson and Mehl, Branson and Mehl, Jour. Paleont., vol. 17, pp. 386, 387, pl. 64, figs. 4, 5.
1944. *Oistodus breviconus* Branson and Mehl, Branson, Univ. Missouri Studies, vol. 19, p. 89, pl. 13, figs. 7, 9 (specimen is a falodus-like element).
1953. *Dichognathus* cf. *D. typica* Branson and Mehl, Rhodes, Phil. Trans. Roy. Soc. London, Ser. B, vol. 237, p. 317, pl. 22, figs. 178-180(=*Prioniodus* n. sp. aff. *P. variabilis* Bergström).
1953. *Oistodus breviconus* Branson and Mehl, Rhodes, *idem,* p. 294, pl. 21, figs. 95, 96 (=*Oistodus*? n. sp.).
1962. *Dichognathus typica* Branson and Mehl, Bergström, Arkiv Min. Geol., vol. 3, p. 37, pl. 5, fig. 6 (=?*Prioniodus*? *variabilis* Bergström).

Our Lexington-Kope collections contain 142,750 discrete elements referable to *Phragmodus undatus*, in which we include not only phragmodus-like elements but also those previously included in *Dichognathus brevis, D. typica,* and *Oistodus abundans.* Each of these elements has been thoroughly described in the recent literature (Sweet, *et al.,* 1959; Pulse and Sweet, 1960) and we see no reason to repeat those descriptions here.

The phragmodus-like elements at hand, like those from the superjacent Eden and Maysville strata, can be divided into three groups on the basis of cusp ornamentation. One group includes forms with anterior and posterior cusp costae and, in a few, a weakly developed outer lateral costa. A second includes specimens with anterior, posterior, and two lateral costae; and a third contains subsymmetrical elements with a posterior costa and two anteriorly situated lateral costae, the basal extensions of which flare laterally and forward as distinct (but short) wings. Representatives of the first two groups, which differ somewhat in content from those distinguished by Sweet, *et al.* (1959), are about equally abundant in our large collections and four or five times more numerous than representatives of the subsymmetrical "winged" group.

Although we do not believe that any taxonomic significance should be attached to the three form-groups we recognize in the phragmodus-like elements of *Phragmodus undatus,* it is interesting that exactly the same groups can be distinguished in large collections of *Phragmodus cognitus* and *Phragmodus inflexus,* and they are likewise developed (although somewhat differently) in *Periodon aculeatus* Hadding. In the latter, cusp costae tend to develop into denticulate processes and the form-groups have been described as distinct species of several different form-genera (*e.g., Loxognathus, Periodon, Eoligonodina,* and *Trichonodella*).

With respect to other elements in the assembly here described, the form-species *Oistodus breviconus* Branson and Mehl is herein regarded as synonymous with the form-species *Oistodus abundans,* which we include in the assembly that constitutes *Phragmodus undatus.* One of the types of *O. breviconus* (Branson and Mehl, 1933, pl. 9, fig. 13) is a broken specimen that clearly falls within the range of variation of *O. abundans;* the other (pl. 9, fig. 14) is apparently an aberrant *O. abundans* exhibiting a cusp that was broken during the animal's lifetime and later re-formed.

Of the 142,750 elements here included in *Phragmodus undatus,* 79,575 are phragmodus-like; 18,916 represent *Dichognathus brevis;* 18,932 are referable to *D. typica;* and 25,327 belong in the form-species *Oistodus abundans.* This indicates a ratio of oistodus-, to dichognathus-, to phragmodus-like elements of 1:1.5:3.1, and suggests that the smallest number of elements in a single individual was four oistodus-like elements, six dichognathus-like elements, and 12 phragmodus-like elements, a total of 22 discrete structures. This further suggests that, because subsymmetrically costate phragmodus-like elements are only a fifth as abundant as representatives of the other two form-groups we have distinguished, each individual contained two subsymmetric phragmodus-like elements and five each of the other ornament-groups on each side of the plane of bilateral symmetry.

Occurrence.—Representatives of *Phragmodus undatus* are present in virtually every sample from every Lexington limestone section we have studied, as they are in samples from younger strata as high as the base of the Richmondian Whitewater formation. The species is not so well represented or so long-ranging in undescribed Nashville Basin Ordovician sections. It appears to decrease in relative abundance in sections west of a line joining the type areas of the Trenton group and the Lexington, Kope, Maysville, and Richmond formations. The species occurs in abundance in Minnesota only from the middle of the Platteville formation to the top of the lower (Cummingsville) member of the Galena limestone (Webers, 1966), and is absent above that level. In Iowa, Ethington (1959) recorded *Phragmodus undatus* in the Prosser and Dubuque members of the Galena limestone, and Glenister (1957) reported it from all five members of the immediately superjacent Maquoketa formation.

We are not convinced that typical *Phragmodus undatus* has been recorded from extra-North American sections, even though elements reminiscent of *D. typica* have been reported from Germany (Sannemann, 1955), and undoubted representatives of the form-species *P. undatus* and *Dichognathus typica* have been reported from Norway (Hamar, 1964). The German specimens may well be referable to *Prioniodus,* and the Norwegian elements are so unlike others in Hamar's Middle Ordovician fauna that we suspect they were inadvertently introduced during laboratory preparation of his samples.

Repository.—Micropaleontological collections, The Ohio State University. Reference slides from all sections described in this report (see Appendix B). Figured specimens, OSU 27463, 27464, 27465, 27466.

Genus **PLECTODINA** Stauffer, 1935

1935. *Plectodina* Stauffer, Geol. Soc. America, Bull., vol. 46, p. 152.

Three of our Lexington-Kope species include cordylodus-like, trichonodella-like (or hibbardella-), and zygognathus-like elements, and one of them has prioniodina-like structures. We are confident that all three represent multielement species and there is no doubt about the trivial names that should be used for them. There is some question as to the generic reference of these species. The synonymies at the head of the following systematic descriptions indicate that the elements we include in these three species have previously been referred to 16 form-genera.

Of the 16 form-genera mentioned in the following three synonymies only *Cordylodus, Subcordylodus, Trichonodella, Zygognathus, Eoligonodina,* and *Plectodina* merit serious consideration as generic receptacles for the three species here considered. For some time we favored reference to *Cordylodus* because all three species include many cordylodus-like elements. However, none of the multielement species closely resembles multielement *Cordylodus angulatus* Pander or *C. ramosus* (Hadding), which we describe in our discussion of *Cyrtoniodus*, nor do we see how any of the three species to which we refer could have developed from typical Lower Ordovican and Lower Middle Ordovician species of *Cordylodus*. Reference of these three species to *Cordylodus*, then, would be merely expedient, and we reject it because it would suggest a relationship we now believe to be nonexistent.

The type form-species of *Subcordylodus*, *S. elongatus* Stauffer, 1935, is grossly similar to the cordylodus-like elements of two of the three species here considered. Webers (1966) showed that *S. elongatus* is a component of *Phragmodus inflexus* Stauffer, a multielement species that also includes phragmodus-, and dichognathus-like elements. *Subcordylodus*, as a consequence, is a junior subjective synonym of *Phragmodus* Branson and Mehl, 1933, which includes complex species different in composition from the ones here considered.

The type species of *Trichonodella*, *Zygognathus*, *Eoligonodina*, and *Plectodina* are all parts of multielement species from the North American Middle and Upper Ordovician and they were undoubtedly parts of multielement species that are congeneric with at least two of the three species discussed here. All these names are valid, but *Plectodina* is the oldest. Consequently, we refer the following three species to *Plectodina*.

Reference of the following three species to *Plectodina* automatically broadens the scope of that genus and it will ultimately have to be revised and emended. We do not undertake these tasks for *Plectodina* almost certainly includes species that are not represented in our Lexington-Kope collections and a revision of the genus should include consideration of those taxa.

Range.—Middle and Upper Ordovician.

Type species.—*Plectodina aculeata* (Stauffer, 1930).

Plectodina aculeata (Stauffer) Pl. 32, figs. 15, 16; Pl. 33, figs. 22, 23; Pl. 34, figs. 5, 6; Text-fig. 9A-F

1930. *Prioniodus aculeatus* Stauffer, Jour. Paleont., vol. 4, p. 126, pl. 10, fig. 12.
1930. *Prioniodus calcaratus* Stauffer, *idem*, pp. 126, 127, pl. 10, fig. 13.
1930. *Prioniodus cristulus* Stauffer, *idem*, p. 128, pl. 10, fig. 19.

?1930. *Subprioniodus latus* Stauffer, *idem,* pp. 124, 126, pl. 10, fig. 9.

1931. *Prioniodus aculeatus* Stauffer, Harris, *in* Decker and Merritt, Oklahoma Geol. Sur., Bull. 55, pp 40, 63, 72, 94, 95, pl. 11, fig. 3.

1932. *Prioniodus aculeatus* Stauffer, Stauffer, Jour. Paleont., vol. 6, pp. 258, 259, pl. 40, fig. 2.

1933. *Cordylodus plattinensis* Branson and Mehl, Univ. Missouri Studies, vol. 8, pp. 116, 117, pl. 8, figs. 34, 36.

1933. *Trichognathus recurva* Branson and Mehl, *idem,* p. 119, pl. 10, fig. 6.

1933. *Trichognathus erecta* Branson and Mehl, *idem,* p. 118, pl. 10, fig. 5.

1935. *Trichognathus deformis* Stauffer, Geol. Soc. America, Bull., vol. 46, pp. 155, 156, pl. 12, fig. 3.

1935. *Trichognathus barbarus* Stauffer, *idem,* p. 155, pl. 12, fig. 11.

1935. *Trichognathus illustris* Stauffer, *idem,* p. 156, pl. 12, fig. 4.

1935. *Trichognathus recurvus* Branson and Mehl, Stauffer, *idem,* p. 156, pl. 12, figs. 1, 2.

1935. *Trichognathus inopinatus* Stauffer, *idem,* p. 156, pl. 12, figs. 5, 6.

1935. *Belodus lineatus* Stauffer, *idem,* p. 131, pl. 12, fig. 13.

1935. *Plectodina dilata* Stauffer, *idem,* p. 152, pl. 11, figs. 43, 47.

1935. *Subcordylodus rectilinetaus* Stauffer, *idem,* p. 154, pl. 11, figs. 30, 32.

1935. *Dichognathus variabilis* Stauffer (part), Jour. Paleont., vol. 9, pp. 604, 605, pl. 73, fig. 59 (*non* pl. 73, figs. 14, 24, 30. 31, 34-37, 40, 44, 50; pl. 75, fig. 8).

1935. *Prioniodus cristulus* Stauffer (part), Stauffer, *idem,* p. 616, pl. 73, fig. 49 (*not* figs. 48, 57, 58).

1935. *Trichognathus minnesotensis* Stauffer, *idem,* p. 619, pl. 71, figs. 45, 50.

1935. *Trichognathus symmetricus* Stauffer (*non* Branson and Mehl, 1933), *idem,* p. 620, pl. 75, figs. 25, 26.

1935. *Trichognathus recurvus* Branson and Mehl, Stauffer, *idem,* pp. 619, 620, pl. 71, figs. 20, 27, 39, 41, 47; pl. 72, figs. 48, 56; pl. 75, fig. 22.

1935. *Plectodina dilata* Stauffer, Stauffer, *idem,* p. 613, pl. 73, fig. 51.

1935. *Subprioniodus hamatus* Stauffer, *idem,* p. 618, pl. 73, fig. 55.

1935. *Subcordylodus rectilineatus* Stauffer, Stauffer, *idem,* p. 618, pl. 73, figs. 7, 23, 33 (*non* figs. 28, 29, 39, which = *Cordylodus serratus*).

?1936. *Cordylodus plattinensis* Branson and Mehl, Furnish, Barragy, and Miller, Amer. Assoc. Petrol. Geol., Bull., vol. 20, p. 1334, pl. 1, fig. 5.

?1936. *Cordylodus concinnus* Branson and Mehl, Furnish, Barragy, and Miller, *idem,* pl. 1, fig. 6.

1936. *Trichognathus* cf. *T. barbarus* Stauffer, Furnish, Barragy, and Miller, *idem,* pl. 1, fig. 1.

1941. *Cordylodus plattinensis* Branson and Mehl, Graves and Ellison, Univ. Missouri School Mines and Metallurgy, Bull., Tech. Ser., vol. 14, pp. 5, 7, pl. 2, fig. 8 (?); pl. 3, fig. 11.

1955. *Trichonodella deformis* (Stauffer), Sweet, Jour. Paleont., vol. 29, p. 257, pl. 29, fig. 6.

1955. *Cordylodus plattinensis* Branson and Mehl, Sweet, *idem,* p. 253, pl. 29, fig. 15.

1955. *Trichonodella recurva* (Branson and Mehl), Sweet, *idem,* p. 258, pl. 29, figs. 1, 2.

?1955. *Trichonodella pumila* (Branson and Mehl), Sweet, *idem,* p. 257, pl. 29, figs. 3, 14.

?1960. *Cordylodus plattinensis* Branson and Mehl, Carlson, North Dakota Geol. Sur., Bull. 35, pp. 69, 70, pl. 2, figs. 1, 9.

1963. *Trichonodella recurva* (Branson and Mehl), Cygan and Koucky, Guidebook First Joint Field Conf., Wyoming Geol. Assoc.-Billings Geol. Soc., Northern Powder River Basin, pl. 1, fig. 13 (not fig. 12).

1966. *Trichonodella recurva* (Branson and Mehl), Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 48, pl. 8, figs. 3, 5-7.
1966. *Zygognathus illustris* (Stauffer), Webers, *idem,* p. 61, pl. 9, figs. 7, 8.
1966. *Cordylodus aculeatus* (Stauffer), Webers, *idem,* p. 61, pl. 8, figs. 13, 14; pl. 9, figs. 4, 6.

The form-species *Cordylodus aculeatus* (Stauffer), *Trichonodella recurva* (Branson and Mehl), and *Zygognathus illustris* (Stauffer) are common associates in the Middle Ordovician rocks of eastern North America and we are of the opinion that they represent parts of a single biologic apparatus. Each element in this apparatus has been described under at least two different names; the oldest one is *Prioniodus aculeatus* Stauffer, 1930, and the trivial name in this binomen must prevail for the multielement species we recognize. Our reasons for referring this species to *Plectodina* are stated in the generic discussion.

Cordylodus-like elements of *Plectodina aculeata* are bowed, individually asymmetric structures consisting of an erect to distally reclined cusp and a long posterior process which bears low, reclined, laterally compressed denticles of subequal size that tend to be discrete only at their apices. The cusp is laterally compressed, but the plane that contains its sharp anterior and posterior edges tends to be almost normal to the one defined by the posterior process and its denticles. The laterally deflected anterior edge of the cusp is produced downward and posteriorly as a distinct anticusp, on the distal extremity of which one or two short, sharp-pointed denticles are developed in about half of our specimens. A deep subconical cavity beneath the cusp, and sheathed grooves that extend to the extremities of the posterior process and anticusp, enclose the attachment surface. The sheath of the subapical cavity flares moderately toward the inner side of the element, and the mid-portion of its lower margin is marked by a bluntly spatulate lappet that tends to become more distinct in advanced growth stages.

Trichonodella-like elements are individually symmetrical or slightly to markedly asymmetrical structures characterized by a stoutly recurved subcentral cusp; subequal lateral processes that join beneath the cusp to enclose an angle of about 60°; and a relatively short posterior process formed by a backward elongation of the cusp base. The three or four denticles on each of the lateral processes tend to be discrete, sharp-pointed, erect to slightly recurved distally, and antero-posteriorly compressed in specimens representing early growth stages. In later growth stages, both process denticles and cusp become more nearly circular in transverse section and peglike in structure. In specimens representing early growth stages, the upper margin of the short posterior process is sharp and angular; in individuals representing later stages the upper edge of this process is broadly rounded or distinctly channeled longitudinally. At all stages of growth, but especially in later ones, the posterior process may bear a few low, nodelike denticles. The cusp base is penetrated by a deep subconical cavity and the under sides of all three processes are excavated to about a third their height by grooves that extend to process extremities.

Zygognathus-like elements are similar morphologically to trichonodella-like elements, of which they are clearly highly asymmetric extremes. In these forms, one lateral process, which is deflected directly posteriorly, becomes somewhat longer than the other (which may be deflected slightly to the anterior), and bears four or five discrete, peglike denticles. The shorter process characteristically develops only two denticles, one near its distal extremity and another close to the cusp. We note that during ontogeny the angular upper edge of the posterior process of these elements gradually becomes broadly rounded, as does that of the comparable process in trichonodella-like elements. None of our zygognathus-like elements develops a channeled or denticulated posterior process.

Discussion. — Cordylodus-like elements of multielement *Plectodina aculeata* have been made types of nine form-species: *Prioniodus aculeatus, P. calcaratus, P. cristulus, Subprioniodus latus, Belodus lineatus, Plectodina dilata, Subcordylodus rectilineatus,* and *Subprioniodus hamatus* (all of Stauffer), and *Cordylodus plattinensis* Branson and Mehl. Although the multiplicity of names available for these elements suggests a variability that is more apparent than real, it does emphasize the ubiquitous occurrence of these structures in Ordovician strata of the eastern Midcontinent. We have examined the types of all the form-species enumerated above and find them to be closely similar; the principal differences among them are largely attributable to differences in the stage of growth represented by their types.

Trichonodella-like elements of *Plectodina aculeata* are types of at least six form-species: *Trichonodella recurva* (Branson and Mehl), *T. erecta* (Branson and Mehl), *T. barbara* (Stauffer), *T. inopinata* (Stauffer), *T. minnesotensis* (Stauffer), and *T. symmetrica* (Stauffer). We have examined the types of all these form-species and have assembled large collections of topotypes. From study of the types and topotypes, we are convinced that all represent a single somewhat variable structural unit that is distinguished from closely similar ones in younger apparatuses primarily by its peglike denticulation and the common (but not invariable) presence of nodelike denticles on the posterior process, even in small specimens representing early growth stages.

Zygognathus-like elements of *Plectodina aculeata* have been referred to at least two form-species: *Zygognathus deformis* (Stauffer), and *Z. illustris* (Stauffer). They are distinguished from the form-species *Z. mira* (Branson and Mehl) primarily by their peglike denticles and by a more pronounced separation between posterior process and posteriorly deflected lateral process.

Occurrence.—Our collections contain 98 representatives of the form-species *Cordylodus aculeatus,* 90 of the form-species *Trichonodella recurva,* and 29 of the form-species *Zygognathus illustris.* Together, these elements indicate a range for multielement *Plectodina aculeata* of 0 to 76 feet above the base of our composite Lexington-Kope section. In Minnesota, this species ranges to the top of the Decorah formation (Webers, 1966). We have all the elements of this species in our collections from the Barnhart (=Decorah) formation of Missouri, and these strata are probably equivalent to the ones from which Branson and Mehl (1933) derived the types of the form-species *Trichonodella recurva, T. erecta,* and *Cordylodus plattinensis* (=*C. aculeatus* (Stauffer)).

Repository.—Micropaleontological collections, The Ohio State University. Reference slides 61Z-637 (36 spm.), 61Z-630 (1 spm.), 61Z-629 (9 spm.), 61Z-627 (4 spm.), 61Z-625 (1 spm.); 64S2-6 (17 spm.), 64S2-7 (116 spm.), 64S2-8 (13 spm.), and 64S2-9 (21 spm.). Figured specimens, OSU 27467, 27468, 27477.

Plectodina furcata (Hinde) Pl. 32, figs. 17-19; Pl. 33, figs. 1-4; 14-21; Pl. 34, figs. 9-12; Text-fig. 9M-T

1879. *Prioniodus furcatus* Hinde, Quart. Jour. Geol. Soc. London, vol. 35, p. 358, pl. 15, fig. 13.

1923. *Prioniodus furcatus* Hinde, Park and Fritz, Ontario Dept. Mines, 31st Ann. Rept., vol. 31, p. 37, pl. 6, fig. 25.

1928. *Euprioniodina? furcata* (Hinde), Holmes, U.S. Nat. Mus., Proc., vol. 72, art. 5, No. 2701, p. 10, pl. 5, fig. 23.

1933. *Dichognathus furcata* (Hinde), Bransom and Mehl, Univ. Missouri Studies, vol. 8, p. 155, pl. 12, fig. 15.

1933. *Cordylodus? delicatus* Branson and Mehl, *idem,* p. 129, pl. 10, figs. 14, 15.

1933. *Phragmodus mirus* Branson and Mehl, *idem,* p. 123, pl. 10, fig. 12.

1933. *Trichognathus tenuis* Branson and Mehl, *idem,* p. 131, pl. 10, fig. 18.

1941. *Cordylodus? delicatus* Branson and Mehl, Graves and Ellison, Univ. Missouri School Mines and Metallurgy, Bull., Tech. Ser., vol. 14, pp. 5, 7, pl. 3, fig. 23.

1944. *Subcordylodus delicatus* (Branson and Mehl), Branson, Univ. Missouri Studies, vol. 19, p. 89, pl. 13, figs. 17, 18.

1953. *Cordylodus elongatus* Rhodes, Phil. Trans. Roy. Soc. London, Ser. B, vol. 237, pp. 299, 300, pl. 21, figs. 114-118.

1953. *Gyrognathus? superbus* Rhodes (part), *idem,* p. 319, pl. 20, figs. 43-45; pl. 21, fig. 132.

1953. *Cordylodus geniculatus* Rhodes, *idem,* p. 300, pl. 21, fig. 113.

1957. *Cordylodus? delicatus* Branson and Mehl, Glenister, Jour. Paleont., vol. 31, pp. 731, 732, pl. 88, fig. 5.

1957. *Ozarkodina delecta* Stauffer, Glenister, *idem,* p. 735, pl. 88, figs. 8, 9.

1957. *Trichonodella flexa* Rhodes, Glenister, *idem,* p. 734, pl. 88, fig. 13.

1959. *Gyrognathus elongata* Rhodes, Ethington, Jour. Paleont., vol. 33, p. 279, pl. 40, fig. 13.

1959. *Ozarkodina delecta* Stauffer, Ethington, *idem,* pp. 283, 284, pl. 41, fig. 17.

1959. *Subcordylodus delicatus* (Branson and Mehl), Ethington, *idem,* p. 288, pl. 41, fig. 13.

1959. *Trichonodella exacta* Ethington, *idem,* p. 290, pl. 41, figs. 10, 11.

1959. *Trichonodella flexa* Rhodes, Ethington, *idem,* p. 290, pl. 41, figs. 7, 8.

1959. *Gyrognathus elongata* Rhodes, Stone and Furnish, Jour. Paleont., vol. 33, p. 223, pl. 32, fig. 9.

1959. *Ozarkodina? delecta* Stauffer, Stone and Furnish, *idem,* p. 225, pl. 32, figs. 1, 2.

1959. *Trichonodella barbara* (Stauffer), Stone and Furnish, *idem,* p. 227, pl. 32, fig. 15.

1959. *Trichonodella recurva* (Branson and Mehl), Stone and Furnish, *idem,* p. 227, pl. 32, fig. 14.

?1959. *Eoligonodina richmondensis* Branson, Mehl, and Branson, Ethington and Furnish, Jour. Paleont., vol. 33, p. 543, pl. 73, fig. 1.

?1959. *Cordylodus robustus* Ethington and Furnish, *idem,* p. 543, pl. 73, fig. 11.

?1959. *Gyrognathus elongata* Rhodes, Ethington and Furnish, *idem,* p. 543, pl. 73, fig. 14.

1959. *Cordylodus delicatus* Branson and Mehl, Sweet, *et al.,* Jour. Paleont., vol. 33, pp. 1044, 1045, pl. 132, figs. 12, 14, 17.

1959. *Prioniodina delecta* (Stauffer), Sweet, *et al., idem,* pp. 1060, 1061, pl. 131, fig. 1.

1959. *Trichonodella angulata* Sweet, *et al., idem,* p. 1064, pl. 131, figs. 9, 13.

1959. *Trichonodella subundulata* Sweet, *et al., idem,* p. 1065, pl. 131, figs. 2, 5, 10.

1959. *Trichonodella tenuis* (Branson and Mehl), Sweet, *et al., idem,* p. 1065, pl. 132, figs. 10, 15.

1959. *Zygognathus deformis* (Stauffer), Sweet, *et al., idem,* pp. 1066, 1067, pl. 132, figs. 1, 5.

1959. *Cordylodus* cf. *spurius* Branson and Mehl, Lindström, Micropaleont., vol. 5, p. 438, pl. 4, figs. 19-21.

1959. *Prioniodina pulcherrima* Lindström, *idem*, pp. 442, 443, pl. 3, figs. 28-30.
?1959. *Trichonodella parabolica* Lindström, *idem*, p. 450, pl. 1, figs. 18-22.
1959. *Zygognathus crugensis* Lindström, *idem*, p. 451, pl. 1, figs. 11-15; text-fig. 3:5.
1960. *Subcordylodus delicatus* (Branson and Mehl), Ethington and Furnish, Jour. Paleont., vol. 34, pp. 268, 273.
1960. *Trichonodella* cf. *T. flexa* Rhodes, Ethington and Furnish, *idem*, p. 273.
1960. *Trichonodella* spp., Ethington and Furnish, *idem*, p. 273, pl. 38, figs. 5, 6.
?1960. *Prioniodina?* sp. Ethington and Furnish, *idem*, p. 272, pl. 38, fig. 14.
1960. *Cordylodus delicatus* Branson and Mehl, Pulse and Sweet, Jour. Paleont., vol. 34, p. 251, pl. 36, figs. 4, 7.
1960. *Prioniodina delecta* (Stauffer), Pulse and Sweet, *idem*, pp. 258, 259, pl. 36, figs. 10, 11.
1960. *Trichonodella angulata* Sweet, *et al.*, Pulse and Sweet, *idem*, p. 260, pl. 37, figs. 2, 7.
1960. *Trichonodella subundulata* Sweet, *et al.*, Pulse and Sweet, *idem*, p. 261, pl. 37, figs. 17, 20.
1960. *Trichonodella tenuis* (Branson and Mehl), Pulse and Sweet, *idem*, p. 261, pl. 37, figs. 3, 8.
1960. *Zygognathus deformis* (Stauffer), Pulse and Sweet, *idem*, p. 261, pl. 37, figs. 1, 5.
1964. *Cordylodus delicatus* Branson and Mehl, Bergström, Acta Univ. Lundensis, Sec. II, no. 3, pp. 18-21, text-figs. 6,7.
1964. *Trichonodella subundulata* Sweet, *et al.*?, Bergström, *idem*, pp. 40, 63.
1964. *Zygognathus deformis* (Stauffer), Bergström, *idem*, pp. 40, 41.
1964. *Prioniodina delecta* (Stauffer), Bergström, *idem*, pp. 32-34.
1965. *Cordylodus delicatus* Branson and Mehl, Barnett, Micropaleont., vol. 11, p. 69, pl. 1, fig. 20; pl. 2, fig. 1.
1965. *Prioniodina delecta* (Stauffer), Barnett, *idem*, p. 73, pl. 1, fig. 27.
1965. *Trichonodella* cf. *T. angulata* Sweet, *et al.*, Barnett, *idem*, p. 74, pl. 1, fig. 24.
1965. *Trichonodella recurva* (Branson and Mehl), Barnett, *idem*, p. 75, pl. 1, fig. 25; pl. 2, fig. 26.
?1965. *Trichonodella* sp., Barnett, *idem*, p. 74, pl. 2, fig. 14.
1965. *Zygognathus deformis* (Stauffer), Barnett, *idem*, p. 75, pl. 1, fig. 5; pl. 2, fig. 23.
1966. *Cordylodus delicatus* Branson and Mehl, Schopf, New York State Mus., Bull. 405, p. 45, pl. 2, figs. 22, 23, ?24, 25-27.
1966. *Prioniodina pulcherrima* Lindström, Schopf, *idem*, p. 71, pl. 2, figs. 17, 18.
1966. *Trichonodella flexa* Rhodes, Schopf, *idem*, p. 80, pl. 2, figs. 5, 6, 10.
1966. *Trichonodella recurva* (Branson and Mehl), Schopf, *idem*, p. 81, pl. 2, figs. 14, 15.
1966. *Zygognathus deformis* (Stauffer), Schopf, *idem*, p. 83, pl. 4, figs. 25, 29, 34.
1966. *Cordylodus delicatus* Branson and Mehl?, Webers, Minnesota Geol. Sur., Spec. Bul. SP-4, p. 59, pl. 10, fig. 16.
1966. *Zygognathus elongata* (Rhodes), Webers, *idem*, p. 59, pl. 12, fig. 1.
1966. *Prioniodina pulcherrima* Lindström, Webers, *idem*, p. 60, pl. 12, figs. 9, 11.
1966. *Trichonodella flexa* Rhodes, Webers, *idem*, p. 47, pl. 12, figs. 2-5.

The form-species *Cordylodus delicatus* Branson and Mehl, *Zygognathus mira* (Branson and Mehl), *Trichonodella angulata* Sweet, *et al.*, and *Prioniodina furcata* (Hinde) are common associates in Ordovician rocks of the North American Midcontinent. They have been reported under various names in nearly every recent description of upper Middle and Upper Ordovician conodonts. These form-species are also well represented in our Lexington-Kope collections, in which they are second in abundance (40,763 specimens) only to *Phragmodus undatus,* which dominates the fauna. Elements of all these form-species are closely related in form, size, color, mode of denticulation, and range. We believe they represent parts of a single biologic apparatus, *Plectodina furcata* (Hinde).

Cordylodus-like, trichonodella-like, and zygognathus-like elements of *Plectodina furcata* are similar to comparable structures in *Plectodina aculeata* (Stauffer), from which we have been unable to distinguish them by consistent use of any single morphologic criterion. It is our impression, however, that process denticles of all elements of *P. furcata* tend to be laterally compressed and confluent, whereas those of *P. aculeata* tend to be discrete and peglike in at least advanced stages of growth. In addition, we note that antero-lateral denticles in cordylodus-like elements and posterior denticles in trichonodella-like elements develop only in large specimens of *P. furcata,* whereas even juvenile stages bear such structures in comparable elements of *P. aculeata.* The principal difference between *P. furcata* and *P. aculeata* is the development of prioniodina-like elements in the former and the apparent absence of such structures in the latter.

Prioniodina-like elements of *Plectodina furcata* have been described in several recent reports as *Ozarkodina* (or *Prioniodina) delecta* Stauffer and *Prioniodina pulcherrima* Lindström (Glenister, 1957; Ethington, 1959; Sweet, *et al.,* 1959; Lindström, 1959; Webers, 1966; Schopf, 1966). These descriptions are adequate for recognition of this element of *P. furcata* (Hinde) and we need not elaborate on them here. Through the kindness of Dr. R. H. Bate and the Trustees of the British Museum (Natural History) we have been able to study the type of *Prioniodus furcatus* Hinde and we find this specimen objectively indistinguishable from forms described recently as *Prioniodina delecta* and *P. pulcherrima.*

The type of *Prioniodus furcatus* Hinde is a large, shale-embedded prioniodina with two denticulated, laterally compressed processes and a robust cusp at their junction. The posterior process is straight and bears about nine slightly reclined, basally confluent denticles that are slightly compressed laterally. The anterior process is about the same length as the posterior one, with which it makes an angle of about 90°; in the somewhat distorted type, this process is directed straight downward. Along the upper margin of the anterior process there are about seven denticles, which are confluent for most of their length but otherwise similar to those of the posterior process. The exposed side of the processes is smooth except for a faint longitudinal carina along the posterior process, slightly below the base of the denticle row. The cusp is stout, sharp-edged, about three times as long as wide, and strongly compressed laterally. It has a conspicuous tendency to incorporate denticles basally; the unusual width of the cusp is at least in part due to the fact that it has included two posterior-process denticles and one anterior-process denticle in its base. Because the holotype is shale-embedded, we cannot determine the shape of the basal cavity. It appears to have been large, but there is no indication that it flared conspicuously anteriorly.

Representatives of *Prioniodina furcata* in our Lexington-Kope collections are not all the same. All of them have a cusp that is strongly compressed laterally and slightly recurved, and process denticles that are similarly compressed and laterally confluent. Except for a tendency to incorporate process denticles in the cusp base, large specimens are similar to small ones, which suggests to us that there was little modification in form during ontogeny in these elements.

Discussion. — *Plectodina furcata* (Hinde) is obviously related intimately to *P. aculeata* (Stauffer) which precedes it stratigraphically. We believe that development of *P. furcata* from *P. aculeata* involved addition of prioniodina-like elements to the apparatus and gradual suppression of the tendency for denticles to develop anterolaterally in cordylodus-like elements and posteriorly in trichonodella-like elements.

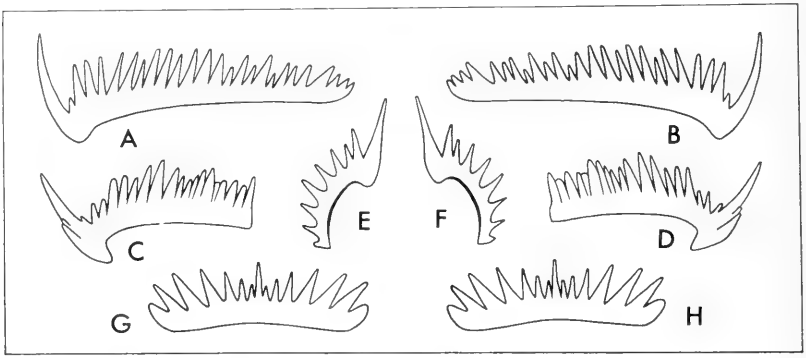
Our Lexington-Kope collections include 16,859 cordylodus-like elements, 12,139 trichonodella-like elements, 6,385 zygognathus-like elements, and 5,380 prioniodina-like elements of *Plectodina furcata* (Hinde). This suggests that the complete biologic apparatus consisted of no fewer than 14 elements: two prioniodina-like elements, two zygognathus-like elements, four trichonodella-like elements, and six cordylodus-like elements.

Occurrence. — *Plectodina furcata* (Hinde) ranges from 101 feet above the base, to the top of our composite Lexington-Kope section. It is well represented in the superjacent Fairview and McMillan formations of the typical Maysville (Pulse and Sweet, 1960), and it may occur in undescribed Richmond faunas as well (McClish, 1965). In Minnesota, *P. furcata* appears in the mid-Cummingsville (Webers, 1966) and ranges through the Dubuque formation into the overlying Maquoketa. Iowa Maquoketa collections described by Glenister (1957) and undescribed collections from the same strata at The Ohio State University, establish the presence of *P. furcata* (or a very closely allied species) to the top of the Iowa Ordovician. Schopf (1966) reported the species in the Denmark and Cobourg formations of New York and Ontario. Element-assemblages comparable to those we include in *P. furcata* have also been reported (Bergström, 1964) from the Gelli-grin, Brun Pig, and Crug limestones of Wales, which may be of about the same age as the interval that yields *Plectodina furcata* in eastern North America.

Repository. — Micropaleontological collections, The Ohio State University. Reference slides from all sections considered in this report (see appendix B). Figured specimens, OSU 27469, 27470, 27471, 27472, 27473, 27474, 27475, 27476, 27478, 27479.

Plectodina? posterocostata Bergström and Sweet, sp. nov. Pl. 32, figs. 1-5; Pl. 33, figs. 12, 13; Pl. 34, figs. 17, 18; Text-fig. 12A-H

1944. *Oulodus?*, n. sp., Branson, Univ. Missouri Studies, vol. 19, p. 89, pl. 13, figs. 14, 15.



Text-fig. 12. *Plectodina? posterocostata, sp. nov.,* X30. Diagrammatic views of cordylodus-like (A,B), hibbardella-like (C,D), zygognathus-like (E,F), and trichonodella-like (G,H) elements of this new species.

Diagnosis and description. — A multielement conodont species including cordylodus-, hibbardella-, zygognathus-, and asymmetric trichonodella-like elements.

Hibbardella-like elements have a long, suberect to slightly reclined cusp that is slightly compressed laterally and has sharp anterior and posterior edges and convex lateral faces. Short lateral processes are symmetrically developed on either side of the cusp. These processes are strongly compressed antero-posteriorly; each bears two erect, apically pointed denticles, the outer of which is longer and larger than the one immediately adjacent to the cusp. The posterior process is long, conspicuously arched, strongly compressed laterally, and has smooth sides. Viewed from above, this process is straight immediately posterior to the cusp; beyond this, it is distinctly sinuous. The upper edge of the posterior process bears 20 or more reclined, compressed denticles that are basally confluent and apically discrete, and increase in length and width from the extremities to process mid-length. The under side of the element is excavated. The cavity is a slightly indented groove beneath the posterior process but a somewhat more capacious cavity beneath the cusp and proximal parts of the processes; it is nowhere conspicuously developed.

Cordylodus-like elements have an erect cusp with sharp anterior edge, faintly convex sides, and a posterior face that is flat or faintly channeled longitudinally. The antero-basal corner of the cusp in these elements is acute, not bluntly rounded; it does not form a distinct anticusp. The posterior process is long, slightly arched, faintly bowed, distally twisted, and surmounted by at least 12 (to as many as 25) reclined denticles that are of subequal width and length. The under side of the entire element is excavated. Beneath the posterior process this basal excavation is a shallow groove with thin, fragile walls; beneath the cusp, the excavation is a subconical pit with an acuminate apex and sheathed walls that flare only faintly to the sides.

Zygognathus-like elements have a short, elongate, slightly reclined cusp that is pointed apically, strongly compressed laterally, and has sharp anterior and posterior margins. Each side of the cusp bears an inconspicuous subcentral costa that is discernible the full length of the cusp. Together, cusp edges and costae give a cross-section that is subrhomboidal. The cusp base is extended into a short, distinct posterior process that is undenticulated and strongly compressed laterally. Its upper edge is continuous with the posterior edge of the cusp. Antero-laterally, there is a short lateral process that bears a single denticle which rivals or exceeds the cusp in width and length. The proximal edge of this slightly compressed denticle is continuous with the anterior edge of the cusp. On the opposite side of the cusp is a slender postero-lateral process that is slender, gracefully curved posteriorly, and at least three times as long as the antero-lateral process. The upper edge of the postero-lateral process bears at least four slightly compressed discrete denticles that are sharp pointed and oval in cross-section. The under side of the element is excavated: beneath the processes this cavity is comparatively broad and shallow; beneath the cusp it is more capacious and forms a subconical pit with an acuminate apex.

Trichonodella-like elements are all slightly asymmetric and consist of a compressed, bladelike cusp that is slightly recurved and situated at the apex of a low arch formed by two long antero-posteriorly compressed lateral processes. The six or more denticles on the lateral processes increase in width and length toward the process extremities and tend to incline away from the cusp. The short posterior process is an extension of the cusp base: its upper edge is angular and bears no denticles. The under side of the element is marked by a deep subconical cavity beneath the cusp and shallow grooves that extend about halfway to the extremities of the lateral processes.

Discussion. — We have only 36 representatives of this distinctive species. These are sufficient to recognize it as a previously unnamed taxon, but not numerous enough to provide us any information on ontogenetic development or arrangement in the apparatus they represent. Of these 36 elements, 5 are hibbardellas, 8 are asymmetric trichonodellas, 6 represent zygognathus-like forms, and 12 are cordylodus-like.

In composition of the apparatus, this new species is generally similar to the two others we refer to *Plectodina,* but elements of the apparatus are different in mode of denticulation, color, and general appearance from those of either *P. aculeata* or *P. furcata.* In addition, the new species contains hibbardella-like elements, which are lacking in the other species of *Plectodina* we recognize. For all these reasons, we refer the new species only tentatively to *Plectodina.*

We do not compare this new species with other forms because we are not aware of any previously described conodonts that are even closely similar to *Plectodina? posterocostata.* It is interesting to note that one of the four form-species we include in *P.? posterocostata* is known from the Kimmswick limestone of Missouri (Branson, 1944), which suggests that this new species may be of potential stratigraphic significance.

Occurrence.—Plectodina? posterocostata ranges from 183 to 195 feet above the base of our composite Lexington-Kope section. The only other recorded occurrence of the species is an unspecified level in the Kimmswick limestone of Missouri (Branson, 1944).

Repository. — Micropaleontological collections, The Ohio State University. Reference slides in which representatives of *Plectodina? posterocostata* occur are numbered 61Z-500, 501, 502, 505, 510, 512; 64S2-8? Syntypes, OSU 27480, 27481, 27482, 27483.

Genus **POLYPLACOGNATHUS** Stauffer, 1935

Emend. Bergström and Sweet, herein

1935. *Polyplacognathus* Stauffer, Jour. Paleont., vol. 9, p. 615.

Emended diagnosis. — *Polyplacognathus* is a multielement conodont genus composed of two principal types of platform-like conodont elements. One element, of modified amorphognathus-type, is more or less star-shaped in superior view and consists of about six lobes or processes of varying length that diverge from a point in the center of the unit. Most of these lobes are broad and flat, but one or more may be alate. The under side of the lobes is excavated, but the basal cavity is restricted to narrow furrows that typically give way to central ridges or keels distally. The upper side of all processes bears a central row of subequal denticles without a distinct cusp; in addition, irregular rows of smaller denticles, nodes, and ridges occur at the sides of the central denticle rows in some species.

The second component of *Polyplacognathus,* a modified ambalodus-like element, is Y-shaped and has three processes similar in appearance to those of the amorphognathus-like element. There may be a low cusp at the junction of the three processes.

Range. — Middle Ordovician (Porterfield, Wilderness, Barneveld stages). Species of *Polyplacognathus* are widely distributed in North America and probable representatives of the genus also occur in Scandinavia and Wales.

Type species. — *Polyplacognathus ramosa* Stauffer, 1935.

Discussion. — The two form-components of *Polyplacognathus* occur together throughout the known stratigraphic and geographic range of the genus. In each assemblage known, we believe that these two elements represent the same biologic species. There is no indication that the assemblage included any other elements.

The relationship between *Polyplacognathus* and *Amorphognathus* has been dealt with recently by Sweet and Bergström (1962, p. 1235). Although that discussion concerned only the amorphognathus-like element of *Polyplacognathus,* we should emphasize that the same features of denticulation and attachment-surface morphology characterize the ambalodus-like element. Further, the ambalodus-like element of *Polyplacognathus* tends to be more platform-like and to have better-developed lateral processes than the comparable structure in multielement *Amorphognathus.*

In the Middle Ordovician of Scandinavia, Wales, and the southern Appalachians, a group of platform-like conodont elements combines form-similarity to *Polyplacognathus ramosa* with a basal cavity that, in some specimens, is widened almost to the same extent as in typical species of *Amorphognathus.* In at least some species of this group there are also considerable differences between sinistral and dextral representatives of the ambalodus-like element. This group of species, which includes *P. elongata* (Bergström), *P. ringerikensis* Hamar, and several undescribed species, is currently difficult to classify. It appears to stand closer to *Polyplacognathus* than *Amorphognathus.*

Polyplacognathus ramosa Stauffer Pl. 28, figs. 9-12

1935. *Polyplacognathus ramosus* Stauffer, Jour. Paleont., vol. 9, p. 615, pl. 75, figs. 23, 28-31, 37.
1935. *Ancyrognathus*? sp. b, Stauffer, *idem,* p. 602, pl. 75, figs. 60, 61.
?1935. *Ancyrognathus*? sp. a, Stauffer, *idem,* p. 602, pl. 75, fig. 24.

1935. *Polyplacognathus expansus* Stauffer, *idem*, p. 615, pl. 75, figs. 27, 33.
?1935. *Polyplacognathus* sp. a, Stauffer, *idem*, pp. 615, 616, pl. 74, figs. 32, 36, 38, 43, 49, 62, 63.
?1935. *Polyplacognathus* sp. b, Stauffer, *idem*, p. 616, pl. 72, figs. 8, 11, 12, 16; pl. 72, figs. 39, 42, 44, 47.
?1935. *Polygnathus?* sp., Stauffer, *idem*, p. 615, pl. 75, fig. 53.
1944. *Amorphognathus ramosa* (Stauffer), Branson, Univ. Missouri Studies, vol. 19, p. 81, pl. 12, figs. 33-36.
1944. *Amorphognathus ramosa* (Stauffer), Branson and Mehl, *in* Shimer and Shrock, p. 237, pl. 93, figs. 5, 6.
1955. *Amorphognathus ramosa* (Stauffer), Sweet, Jour. Paleont., vol. 29, p. 248, pl. 29, figs. 9, 10, 11, 17, 23, 25.
1955. *Amorphognathus lingualis* Sweet, *idem*, pp. 248, 249, pl. 29, fig. 24.
1962. *Polyplacognathus ramosa* Stauffer, Sweet and Bergström, Jour. Paleont., vol. 36, pp. 1235-1237, text-figs. 3F, 3G.
1965. *Polyplacognathus ramosa* Stauffer, Barnett, Micropaleont., vol. 11, p. 72, pl. 1, fig. 13.
1966. *Polyplacognathus ramosa* Stauffer, Schopf, New York State Mus., Bull. 405, p. 70, pl. 1, figs. 19-21.
1966. *Polyplacognathus bilobata* Schopf, *idem*, p. 69, pl. 1, figs. 24-28.
1966. *Polyplacognathus ramosa* Stauffer, Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 43, pl. 11, figs. 7, 8, 10.

This distinctive species includes two morphologic types, each of which has been described separately in most previous studies. One, which is typified by the types of the form-species *Polyplacognathus ramosa* Stauffer and may be regarded as an amorphognathus-like element, is represented in our Lexington collections by 171 mostly fragmentary specimens. The other, based on fragments and described originally as "*Ancyrognathus?* sp. b" by Stauffer (1935b), may be considered a modified ambalodus-like element. We have only 18 fragmentary representatives of the latter form-species.

The two form-species that we include in *Polyplacognathus ramosa* Stauffer occur together throughout their known stratigraphic and geographic range. They are fully described in the recent literature (Schopf, 1966; Webers, 1966) on the basis of much larger collections than are available to us; hence we include only illustrations of typical Lexington specimens in this report.

Occurrence.—*Polyplacognathus ramosa* Stauffer ranges from 46 to 215 feet above the base of our composite Lexington-Kope section. In Minnesota, the species appears first in the Glenwood shale, ranges through the Platteville formation, and appears again in the upper part of the Decorah formation (Webers, 1966). In New York, Ontario, and Quebec, *P. ramosa* ranges from the upper Rockland to the mid-Shoreham, and a single specimen is known from the lower

Cobourg of Galloo Island, near Watertown, New York (Schopf, 1966). The species is abundantly represented in the Coburn limestone of Pennsylvania (Schopf, 1966), and smaller collections are known from the Jacksonburg limestone of New Jersey and Pennsylvania (Barnett, 1965), the Kimmswick limestone of Missouri (Branson, 1944), and the Harding sandstone of Colorado (Sweet, 1955). Unlike *Amorphognathus ordovicica,* which it somewhat resembles, *Polyplacognathus ramosa* has not yet been recorded from extra-North American localities.

Repository. — Micropaleontological collections, The Ohio State University. Specimens are in reference slides numbered 61Z-480, 493, 497, 613-622, 624, 649; 64S2-7, 11. Figured specimens, OSU 27484, 27485.

Genus **RHIPIDOGNATHUS** Branson, Mehl, and Branson, 1951

1951. *Rhipidognathus* Branson, Mehl, and Branson, Jour. Paleont., vol. 25, p. 10.

Rhipidognathus includes multielement conodont species represented by shallowly excavated bryantodina-like, ozarkodina-like, (or prioniodina-like), and trichonodella-like elements, the process denticles of which are numerous and laterally compressed. In some species, these denticles are laterally confluent and apically discrete, and there is no observed tendency for them to be overgrown as elements increase in size; in other species, denticles formed in early growth stages are overgrown during development to form distinct "germ denticles," distinguished by axial concentrations of "white matter." In known species a short segment of the lower edge of the outer (or anterior) side of all elements tends to develop into a distinct downwardly directed boss beneath the cusp; on the inner (or posterior) side, these elements develop a ridgelike swelling just above the margin of the base.

Range. — Middle and Upper Ordovician of eastern North America.

Type species. — *Rhipidognathus symmetrica* Branson, Mehl, and Branson, 1951 (in which we also include *R. paucidentata, R. curvata,* and *R. spuria* of the same authors).

Discussion. — Perhaps with an eye to the future, the founders of this genus allowed it greater morphologic breadth than any of the numerous other conodont genera they established. From the first they included in it elements that might just as well have been referred to the form-genera *Trichonodella (e.g., Rhipidognathus symmetrica), Ozarkodina (e.g., Rhipidognathus curvata)* and *Prioniodina (R. paucidentata)*. They followed fixed practice however, in regarding each form-variant as a distinct form-species.

We conclude that each biologic species of *Rhipidognathus* includes some or all of the elements recognized as form-species by Branson, Mehl, and Branson. On this basis, we distinguish two element-groups that we refer to this genus. *Rhipidognathus discreta, sp. nov.*, which characterizes the "Cynthiana" interval of the Lexington limestone, is similar to Richmondian *R. symmetrica,* the type species, in including bryantodina-like, ozarkodina-like, and trichonodella-like elements and in developing a boss beneath the cusp on the outer (or anterior) face. *R. discreta* includes robust elements whose denticles are not conspicuously compressed and in which we have observed no consistent or constant tendency for formation of "germ-denticles." *Rhipidognathus symmetrica* characterizes strata in the upper part of the Richmond group in the Ohio River Valley region but apparently has a more extended range in Ordovician strata southwestward toward the Nashville region of Tennessee. Elements representative of this species, the youngest known, are separated by their extreme fragility, the profuse denticulation of their processes, and the fact that juvenile denticles are completely overgrown by the lamellae that form late-stage denticles.

Although it sheds considerable light on the content and development of *Rhipidognatus,* the material at hand provides little information on the origin of this distinctive genus. The most numerous elements in both the species we recognize are clearly referable to the form-genus *Bryantodina* (or *Ozarkodina)*, and we suspect that the origins of *Rhipidognathus* are to be found in that complex of species.

Rhipidognathus discreta Bergström and Sweet, sp. nov. Pl. 30, figs. 13-20

Our Lexington collections contain 201 conodont elements that are clearly referable to *Rhipidognathus* but appear to represent an undescribed species of that genus. Of these elements, 151 are bryantodina- (or ozarkodina-) like forms; 55 are prioniodina-like; and 45 represent trichonodella- (or zygognathus-) like structural units.

Bryantodina-like (or ozarkodina-like) elements of *Rhipidognathus discreta* are arched, less commonly straight; faintly bowed; and have an erect cusp and two processes of subequal length bearing laterally confluent denticles that are sharp pointed, apically discrete, and elliptical in cross-section. The five to seven denticles of the anterior process increase gradually in length (but not in width) toward the cusp, and we have noted an apparently irregular tendency for the anteriormost denticle of this series to be overgrown by the anterior margin of the cusp during development. The five to seven denticles of the posterior process are of subequal length, less than half as long as the cusp, and discrete for their full length at all stages of growth. The posteriormost denticle of this series is overgrown by the posterior margin of the cusp during development in some specimens. Inner and outer sides of these elements are smooth in early and intermediate growth stages; in late stages the sides (especially the outer one) become distinctly swollen at mid-height. In early and intermediate growth stages, the basal cavity consists of a conical subapical pit continuous anteriorly and posteriorly with shallow grooves that extend along the under sides of the processes to their extremities. The sheath of this cavity tends to flare most prominently on the outer (or convex) side of the element beneath the cusp.

Prioniodina-like elements of *Rhipidognathus discreta* are distinctly arched and bowed, with a slender, erect cusp and bladelike processes of subequal length. Both processes are surmounted by narrow sharp-pointed denticles, which are discrete for their full length above the bar and decrease in length from the cusp toward the termini of both processes. The outer side of the element is essentially smooth but is marked by faint striae that are parallel to the long dimensions of the cusp and process denticles. Between the base of the denticles and the upper edge of the basal cavity, the inner side of the element develops a prominent ridgelike swelling which is terminated below by an abrupt constriction at the upper edge of the basal sheath. The basal cavity consists of a subapical pit with sheath walls that flare prominently outward and less conspicuously inward, and narrow grooves that extend from the subapical pit to the ends of the processes. In robust specimens, representing late growth stages, the flaring basal sheath is produced outward and downward to form a stout, spatulate subapical boss on the outer side of the element.

Trichonodella-like elements include both bilaterally symmetrical and distinctly asymmetrical (or zygognathus-like) form-variants. These elements are similar in discreteness and shape of denticles, shape and striation of sides, and basal cavity development to the prioniodina-like elements just described, and we have observed nearly all stages in transition between these two form categories. As in prioniodina-like elements, the spatulate subapical boss, distinctive of the outer side of all elements in typical *Rhipidognathus*, is a late growth-stage development. Its place in the smallest of our specimens is occupied only by the outwardly flaring sheath of the basal cavity.

The number of elements referable to each of the morphologic categories just described indicates that a single individual of this species developed one symmetrical (trichonodella-like) element and two asymmetrical (zygognathus-like), two prioniodina-like, and eight ozarkodina-like (or bryantodina-like) elements.

Discussion.—*Rhipidognathus discreta* is clearly related to *R. symmetrica*, and it is also similar in several respects to the species we describe as *Bryantodina*? *abrupta* and *B.*? *staufferi*. From the latter species it differs primarily in larger size, in bearing denticles that tend to be discrete for their full length, in developing a distinct ridge at mid-height on the inner side and a conspicuous boss on the outer side at maturity, and including trichonodella-like elements. From the former *(R. symmetrica)* the new species differs in having denticles that tend to be discrete in early and intermediate stages and are elliptical in section at all stages of growth. In *R. symmetrica* processes are fragile and bladelike at all stages of growth and during late stages of development denticles are completely fused laterally except at their apices.

We regard *Rhipidognathus discreta* as a species intermediate between *Bryantodina*? *staufferi* and *R. symmetrica*, and its intermediate position in the Ordovician section of the Cincinnati Region supports this view. We are not certain whether *R. symmetrica* developed from *R. discreta*, which it succeeds in the Richmond group, or whether it developed from *B.*? *staufferi*. Solution of this problem probably lies in the Ordovician rocks of the Nashville area, Tennessee, in which *Rhipidognathus* is represented almost continuously from the mid-Hermitage to the base of the Silurian.

Occurrence. — *Rhipidognathus discreta* ranges from 263 to 412 feet above the base of our composite Lexington-Kope section and may be represented by a few fragmentary elements collected from the Maysvillian McMillan formation, near Maysville, Kentucky (Carpenter and Ory, 1961).

Repository. — Micropaleontological collections, The Ohio State University. Reference slides from sections 60A, 60P, 64S2, and 64S3 (see Appendix B). Figured syntypes, OSU 27486, 27487, 27488, 27489 (all from the Catheys formation of the Nashville area, Tennessee).

Genus **RHODESOGNATHUS** Bergström and Sweet, gen. nov.

Diagnosis. — A multielement conodont genus composed of paired ambalodus-like conodont elements.

The elements of *Rhodesognathus* are complex asymmetric units of modified ambalodus-type, which consist basically of three processes that diverge at different angles from a central cusp. All processes are excavated beneath and most, or all, of their lateral faces develop a conspicuous ledge that is parallel to the margin of the basal cavity. The upper margin of all processes bears laterally compressed denticles that are distinctly smaller than the cusp. The denticle row of the lateral process is continuous with the denticle immediately anterior to the cusp.

Range. — Middle and Upper Ordovician; Wales, Sweden, and eastern North America.

Type species. — *Ambalodus elegans* Rhodes, 1953.

Derivation of name. — In honor of Professor F. H. T. Rhodes, Swansea, Wales, who began modern conodont research in Great Britain.

Discussion. — The form-species *Ambalodus elegans* and *A. pulcher* are closely related morphologically, invariably occur together throughout their stratigraphic and geographic range, and are represented in our large Lexington-Kope collections and in others we have studied by approximately equal numbers of elements. For these reasons, we believe that these elements were parts of the same biologic apparatus and they are here combined into a single species, *Rhodesognathus elegans.*

In general form, in development of lateral ledges along the processes, and in the fact that the denticle row of the lateral process is connected with the denticle in front of the cusp, the elements of *Rhodesognathus* are similar to the ambalodus-like elements of *Amorphognathus ordovicica*. The latter, however, do not exhibit the variable development of the inner side of the posterior process that is conspicuous in *Rhodesognathus elegans*. Furthermore, platform-like elements play an important role in *Amorphognathus* but are apparently lacking in *Rhodesognathus*. This makes multielement species of the two genera different in composition.

In the variable appearance of the posterior process and in the presence of ledges along the processes, the components of *Rhodesognathus elegans* also show some similarity to elements such as *Prioniodus*? *variabilis* and *P.*? *alatus*. According to unpublished studies by the senior author the latter form-species belong in assemblages that differ greatly in composition from *Rhodesognathus elegans* which is apparently not closely related in composition to any multielement species thus far described. We believe these facts justify reference of the form-species *Ambalodus elegans* and *A. pulcher* to a new genus, *Rhodesognathus*.

Rhodesognathus elegans (Rhodes) Pl. 34, figs. 19-23

1953. *Ambolodus elegans* Rhodes, Phil. Trans. Roy. Soc. London, Ser. B, vol. 237, pp. 278, 279, pl. 20, figs. 21-25.
1953. *Ambolodus pulcher* Rhodes, *idem*, p. 279, pl. 20, figs. 38-41.
1953. *Ambolodus robustus* Rhodes, *idem*, pp. 279, 280, pl. 20, figs. 26, 27, 32, 33.
?1957. *Ambolodus* cf. *elegans* Rhodes, Lindström, Geol. Fören. (Stockholm) Förhandl., bd. 79, p. 172, pl. 1, fig. 21; text-fig. 2.
1959. *Ambalodus pulcher* Rhodes, Lindström, Micropaleont., vol. 5, p. 435, pl. 3, figs. 14-16.
1959. *Ambalodus elegans* Rhodes, Lindström, *idem*, p. 435, pl. 3, figs. 20-22.
1959. *Ambalodus elegans* Rhodes, Sweet, *et al.*, Jour. Paleont., vol. 33, p. 1040, pl. 132, fig. 9.
1959. *Prioniodus* n. sp., Sweet, *et al.*, *idem*, p. 1061, 1062, pl. 132, fig. 8.
1959. Genus and species indet., Sweet, *et al.*, *idem*, p. 1043, pl. 122, figs. 3.6.
1964. *Ambalodus elegans* Rhodes, Bergström, Acta Univ. Lundensis, sec. II, No. 3, pp. 11, 12, text-fig. 3.
1964. *Ambalodus pulcher* Rhodes, Bergström, *idem*, p. 11, text-fig. 4.
1965. *Ambalodus elegans* Rhodes, Barnett, Micropaleont., vol. 11, p. 67, pl. 1, fig. 3; pl. 2, fig. 6.
1965. *Ambalodus pulcher* Rhodes, Barnett, *idem*, p. 68, pl. 2, fig. 12.
1966. *Ambalodus elegans* Rhodes, Schopf, New York State Mus., Bull. 405, p. 38, pl. 3, fig. 11.
1966. *Ambalodus pulcher* Rhodes, Schopf, *idem*, p. 38, pl. 4, fig. 12.

The form-species *Ambalodus elegans* and *A. pulcher* have been fully described in the recent literature (see synonymy). The two form-species are closely related morphologically and are distinguished primarily by the fact that *A. pulcher* lacks the conspicuous ledge along the lower margin of the posterior face of the lateral process that is prominent on all the lateral faces of the processes in *A. elegans*. In *A. elegans*, the inner face of the posterior process flares laterally a short distance posterior to the cusp to produce a triangular, platform-like bulge. In one of our specimens, shown in Plate 34, figure 23, this lateral flare is produced laterally to form a conspicuous lobelike extension, the upper surface of which is nodose.

We have a virtually complete sequence of growth stages of both *Ambalodus elegans* and *A. pulcher* in our collections. Detailed comparisons of individuals representing successive stages indicates that morphologic changes during ontogeny were few and were reflected primarily in increasing robustness and, in *A. elegans,* by increased prominence of ledges along the margins of the processes.

Occurrence. — Representatives of the two form-species here combined into *Rhodesognathus elegans* (Rhodes) occur in all of our Lexington-Kope sections except 60A and 60B. Together they indicate a range from 82 to 419 feet above the base of our composite section. The species occurs in undescribed collections from the mid-Caradocian of Sweden and has been reported from the Gelli-grin, Pen-y-garnedd, Crug, Birdshill, and Brun Pig limestones of Wales (Rhodes, 1953; Lindström, 1959; Bergström, 1964). In New York and southern Ontario it ranges from mid-Kirkfield through Cobourg (Schopf, 1966). Representatives of the species are not known from Ordovician sections west of those here considered. That is, it has not been reported from the Ozark region of Missouri or from Upper Mississippi Valley sections described by Glenister (1957), Ethington (1959), or Webers (1966). The youngest known occurrence in North America of *Rhodesognathus elegans* is in lower Richmond group strata in Indiana (McClish, 1965).

Repository. — Micropaleontological collections, The Ohio State University. Reference slides from all sections but 60A and 60B (see Appendix B). These slides contain 600 representatives of *Ambalodus elegans* and 553 representatives of *Ambalodus pulcher.* Figured specimens, OSU 27490, 27491, 27492.

Genus **SCANDODUS** Lindström, 1955

1955. *Scandodus* Lindström, Geol. Fören. (Stockholm) Förhandl., bd. 76, p. 594.

Scandodus was erected for simple conodont elements from the Lower Ordovician of Sweden that have a twisted noncostate cusp. Subsequently several other Ordovician species, mostly from the Baltic area, have been referred to the same genus. The type form-species, *S. furnishi* Lindström, 1955a, is similar to many of the oistodus-like elements of *Drepanodus suberectus,* which, in turn, are scandodous-like in that the cusp is commonly more or less twisted.

After study of Swedish Arenigian faunas that contain *Scandodus furnishi,* we agree with Lindström (1964) that this form-species is close to *Drepanodus conulatus* Lindström, 1955a which occurs in the same faunas. These two elements have the same dark yellowish color and a distinctive growth-axis that is thin and nearly uniform in size along the cusp. Thus, while there are good reasons to suspect that these elements represent the same biologic species, there is no reason to believe that multielement *S. furnishi* included any other elements. These observations are preliminary but they suggest that *S. furnishi* may be closely related to *Drepanodus suberectus,* from which it differs primarily in lacking elements like those included in the form-species *Drepanodus suberectus.* In short, multielement *S. furnishi* and multielement *D. suberectus* may be congeneric, but they are certainly not conspecific.

We have only a few scandodus-like specimens in our Lexington-Kope collections. They are not much like either *S. furnishi* or the oistodus-like elements of *Drepanodus suberectus.* They are clearly related in form to other species referred to the form-genus *Scandodus,* particularly to the form-species *S. unistriatus* Sweet and Bergström, 1962. As noted in the following description of our scandodus-like elements, we suspect they might belong in a multielement species with *Scolopodus insculptus* (as *S. unistriatus* may be related to *S. varicostatus* Sweet and Bergström, 1962). If this suspicion proves correct, it is obvious that these specimens do not belong in the same genus with *Scandodus furnishi,* or in one that includes both *S. furnishi* and *Drepanodus suberectus.* We describe our specimens as *Scandodus* sp. cf. *S. dissimilaris* (Branson and Mehl), but in making this assignment it is emphasized that we interpret *Scandodus* as a form-genus of twisted simple cones that may belong naturally in several different biologic assemblies.

Scandodus sp. cf. **S. dissimilaris** (Branson and Mehl) Pl. 34, figs. 24, 25; Text-fig. 13D

1933. *Phragmodus dissimilaris* Branson and Mehl (part), Univ. Missouri Studies, vol. 8, pp. 123, 124, pl. 10, fig. 29 (not unfigured cotype C95-4, which = *Scolopodus insculptus* (Branson and Mehl)).

1965. *Paltodus dissimilaris* (Branson and Mehl), Schopf, New York State Mus., Bull. 405, p. 64, pl. 3, figs. 24, 25.

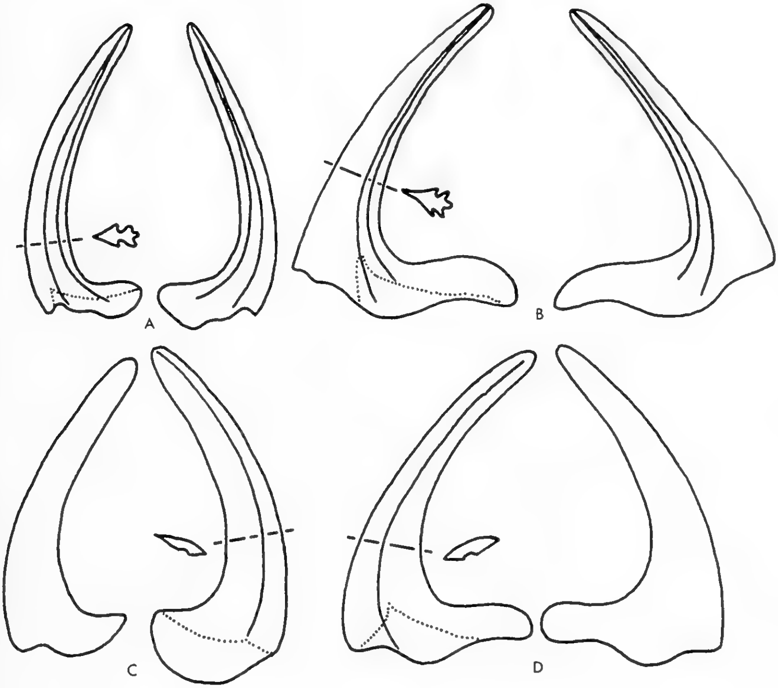
Branson and Mehl included in *Phragmodus dissimilaris* two different types of conodont elements. The only syntype illustrated, herein designated lectotype of the species, is a *Scandodus;* the unillustrated syntype is an asymmetric *Scolopodus insculptus*.

Based on its lectotype and Lexington material at hand, the form-species *Scandodus dissimilaris* (Branson and Mehl) is similar to *Scandodus unistriatus* Sweet and Bergström (1962) from the Pratt Ferry formation of Alabama, and it may have developed directly from that form. It is distinguished from *S. unistriatus,* in having a base that is conspicuously elongated posteriorly and a distinct flange on its upper edge.

As we note in Text-figure 13, the features that distinguish *S. dissimilaris* and *S. unistriatus* probably arose gradually and in a way similar to the development of *Scolopodus insculptus* from *S. varicostatus* Sweet and Bergström, 1962. For this reason, intermediate forms, like the one shown in Text-figure 13D, are difficult to classify. The base of this specimen is longer posteriorly than that of typical *S. unistriatus,* and it appears to have had a low keel on the upper edge of the base. We believe it to be a primitive *S. dissimilaris*.

The phylogenetic scheme suggested above, like that recognized in *Scolopodus varicostatus-S. insculptus,* has potential stratigraphic utility. At present, only a few representatives of *Scandodous dissimilaris* are known and our conclusions as to their development can not be thoroughly tested. We indicate the intermediate position of our Lexington specimens by identifying them only as *Scandodus* sp. cf. *S. dissimilaris*.

Occurrence. — Lexington limestone. Five specimens indicate a range of 140 to 202 feet above the base of our composite reference



Text-fig. 13. *Scandodus? dissimilaris* (Branson and Mehl) and *Scolopodus insculptus* (Branson and Mehl) compared with *Scandodus unistriatus* Sweet and Bergström and *Scolopodus varicostatus* Sweet and Bergström. A. *Scolopodus varicostatus* Sweet and Bergström; topotype from Pratt Ferry formation of Alabama, X30. B. *Scolopodus insculptus* (Branson and Mehl), OSU 27494, X25. C. *Scandodus unistriatus* Sweet and Bergström; topotype from Pratt Ferry formation, Alabama, X30. D. *Scandodus? dissimilaris* (Branson and Mehl); reconstruction of type specimen figured by Branson and Mehl (1933), X30.

section. The type of *Scandodus dissimilaris* is from the Thebes sandstone, at Ozora, Missouri, and the only other recorded occurrences of the species are in the Denmark formation of New York (Schopf, 1966). In all three areas from which it has been reported the species occurs with *Scolopodus insculptus* (Branson and Mehl) and the two may represent the same natural species. Our collections are far too limited to test this hypothesis.

Repository. — Micropaleontological collections, The Ohio State University. Reference slides 61Z-493, 497, 509, 555. Figured specimen, OSU 27493.

Genus **SCOLOPODUS** Pander, 1856

1856. *Scolopodus* Pander, Monographie der Fossilen Fische des Silurischen Systems der Russisch-Baltischen Gouvernements, p. 25.

Scolopodus is based on simple conodont elements from the Lower Ordovician of Estonia. The type form-species, S. *sublaevis* Pander, is a multicostate, suberect simple cone that is ovate in cross-section. To the best of our knowledge this form-species has not been identified in collections other than Pander's and the repository of his collections is unknown. Consequently the only information about this species is contained in Pander's short description and figures. From these it is impossible to reconstruct an assemblage of which S. *sublaevis* might have been part.

Many simple cones have been referred to *Scolopodus* since 1856 and Lindström's (1955a) redefinition of the genus has been widely accepted in the last decade. As currently interpreted, *Scolopodus* is a form-genus and includes many species that are probably not closely related.

Scolopodus-like simple cones are rare in our collections and all appear to represent the same form-species, *Scolopodus insculptus*. In all probability this species bore only simple elements, but these include both symmetrical and asymmetrical types. Other than that they are multicostate, these elements show little similarity to S. *sublaevis*, and we are not entirely convinced that there is any close relationship between the latter and our specimens. We are reluctant to establish another conodont genus as long as the assemblage of S. *sublaevis* is unknown and our material is, therefore, referred to the form-genus *Scolopodus*, which we interpret broadly.

Range. — Lower Ordovician through Lower Devonian.

Type species. — *Scolopodus sublaevis* Pander, 1856.

Scolopodus insculptus (Branson and Mehl) Pl. 34, figs. 26, 27; Text-fig. 13B

1933. *Phragmodus insculptus* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 124, pl. 10, figs. 32-34.

1933. *Phragmodus dissimilaris* Branson and Mehl (part), *idem*, pp. 123, 124, unfig. syntype C95-4 (*not* syntype figured on pl. 10, fig. 29, which is lectotype of *Scandodus dissimilaris* (Branson and Mehl)).

1941. *Phragmodus insculptus* Branson and Mehl, Graves and Ellison, Univ. Missouri School Mines and Metallurgy, Bull., Tech. Ser., vol. 14, p. 6, pl. 3, fig. 1.

1941. *Phragmodus dissimilaris* Branson and Mehl, Graves and Ellison, *idem,* pp. 6, 7, pl. 3, fig. 9.
1953. *Phragmodus insculptus* Branson and Mehl, Rhodes, Phil. Trans. Roy. Soc. London, Ser. B, vol. 237, p. 310, pl. 21, figs. 136, 153, 154.
1955. *Phragmodus insculptus* Branson and Mehl, Rhodes, Quart. Jour. Geol. Soc. London, vol. 111, p. 136, pl. 10, fig. 17.
1959. *Distacodus insculptus* (Branson and Mehl), Ethington, Jour. Paleont., vol. 33, pp. 275, 276, pl. 39, fig. 10.
1959. *Scolopodus insculptus* (Branson and Mehl), Sweet, *et al.,* Jour. Paleont., vol. 33, p. 1063, pl. 130, fig. 6.
1960. *Distacodus insculptus* (Branson and Mehl), Carlson, North Dakota Geol. Sur., Bull. 35, p. 71, pl. 2, fig. 20.
1964. *Scolopodus insculptus* (Branson and Mehl), Bergström, Acta Univ. Lundensis, Sec. II, No. 3, pp. 53, 57, 63.
1966. *Scolopodus insculptus* (Branson and Mehl), Schopf, New York State Mus., Bull. 405, p. 78, pl. 3, figs. 20, 21.
1966. *Scolopodus insculptus* (Branson and Mehl), Webers, Minnesota Geol. Sur., Spec. Pub. SP-4, p. 46, pl. 12, figs. 14, 15.

We have only 32 representatives of this species in our Lexington limestone collections, and Schopf (1966) reported only a few more than this from the Trenton group of New York, Ontario, and Quebec. Most of our specimens are fragmentary, but all are clearly referable to *Scolopodus insculptus* (Branson and Mehl), a distinctive species that has been thoroughly discussed in the recent literature (*e.g.,* Ethington, 1959; Sweet, *et al.,* 1959).

Among described species of *Scolopodus, S. insculptus* is most closely related in form to *S. varicostatus* Sweet and Bergström from the Pratt Ferry formation of Alabama. *S. insculptus* is readily distinguished from *S. varicostatus* in that the upper margin of the base is elongated posteriorly and its upper edge is produced into a conspicuous keel or flange in the former and not in the latter. The antero-basal corner of *S. varicostatus* is deeply notched, whereas that of *S. insculptus* is, as a rule, less deeply invaginated. Further, the basal third of the anterior margin is almost invariably produced into a conspicuous flangelike keel in *S. insculptus;* this structure is lacking in most representatives of *S. varicostatus,* although a few we have seen develop a narrow structure of this type antero-basally.

The succession of forms available suggests that *Scolopodus insculptus* developed more or less directly from *S. varicostatus* through progressive posterior elongation of the base and gradual development of flanges posteriorly and antero-basally. This development is shown graphically in Text-figure 13. It is interesting that essentially the same array of symmetrical and asymmetrical form-groups is to be found in *Scolopodus insculptus* as in *S. varicostatus*. The type of *S. insculptus* is an essentially symmetrical specimen that corresponds to the symmetrical *Scolopodus varicostatus* group illustrated by Sweet and Bergström (1962) in their text-fig. 1K. One of the syntypes of *Phragmodus dissimilaris* Branson and Mehl (C95-4 in the University of Missouri collections) is a markedly asymmetrical edition of *Scolopodus insculptus* and corresponds to the *S. varicostatus* shown by Sweet and Bergström (1962) in their text-fig. 1C. For that reason, this syntype is here included in *S. insculptus* (the other one is chosen as lectotype of *Scandodus dissimilaris* (Branson and Mehl)).

Occurrence.—Scolopodus insculptus ranges from 137 to 400 feet above the base of our composite Lexington-Kope section, but it is not common at any level in this section. The species is somewhat more abundantly represented in the Stewartville and Dubuque members of the Galena formation in Iowa and Minnesota (Ethington, 1959; Webers, 1966), and ranges from the mid-portion of the Shoreham formation of New York into the upper part of the Cobourg formation in that area (Schopf, 1966). The types of this species are from the Thebes sandstone of Missouri, and references included in our synonymy indicate a wide distribution in northwestern Europe.

Repository.—Micropaleontological collections, The Ohio State University. Specimens are in reference slides numbered 60BCK-52.5, 82, 126; 60L8-17, 10-1, 10-3; 60M3-8; 60P7-14; 60T9-1; 61Z-398, 480, 497, 543, 546, 555, 558; 64S1-4, 5; 64S3-33. Figured specimen, OSU 27494.

Genus **SYNPRIONIODINA** Bassler, 1925

Synprioniodina sp. cf. **S. forsenta** Stauffer Pl. 33, fig. 24

cf. 1940. *Synprioniodina forsenta* Stauffer, Jour. Paleont., vol. 14, pp. 432-435, pl. 59, figs. 31-33, 38-41.

In this form-species we include complex, individually asymmetric conodont elements of inverted-V shape which consist of two laterally compressed processes that lie in the same plane but enclose an angle of about 90° in lateral view. The longest of the two processes, here regarded as posterior, may be five times or more longer than high and is strongly compressed laterally. Its upper edge bears a large number of laterally compressed, apically pointed denticles that are somewhat confluent basally and may vary considerably in size. In most of our specimens these denticles are arranged in a hindeodelloid manner; that is, several small denticles alternate with single, far larger ones at more or less regular intervals.

The second process, here regarded as anterior, may be about half as long as the posterior process, but it is otherwise of essentially the same structure. It is situated in essentially the same vertical plane as the posterior process in most specimens, although in a few it is flexed laterally from the plane of the posterior process. The upper edge of the anterior process bears a few subequal, laterally compressed, basally confluent, apically pointed denticles. The sides of both processes are smooth.

At the junction of the two processes there is a long, laterally compressed, apically pointed cusp, which is proclined and has sharp anterior and posterior edges. In most of our specimens the cusp is in the same plane as the processes; in a few, it is flexed toward the same side as the anterior process.

The under side of the element is excavated to the extremities of the processes. The basal cavity is narrow and not deep except below the cusp, where it penetrates more deeply than in other parts of the processes. We also note a tendency toward increased height of basal cavity below the bases of the larger denticles of both processes.

Discussion.—The specimens at hand are reminiscent of those on which Stauffer (1940) based *Synprioniodina forsenta*. The only substantive differences between our specimens and Stauffer's appear to be that our forms have a somewhat deeper basal cavity along the processes than the Minnesota specimens; and our Lexington elements have a basal sheath that is slightly less posteriorly flexed beneath the cusp and a more obvious hindeodelloid pattern of denticulation than the types of *Synprioniodina forsenta*. These differences may not be particularly important systematically, but these are the first synprioniodina-like elements reported from the Ordovician, and we are not able to assess the specific significance of the variations just noted. Furthermore, the age of the types of *S. forsenta* is unknown—they were derived from a clay containing a mixture of Ordovician and Devonian conodonts. Thus we merely compare our specimens with *S. forsenta* Stauffer.

Occurrence.—*Synprioniodina forsenta* has been reported previously only from a mixed fauna of Ordovician and Devonian conodonts in Minnesota (Stauffer, 1940). Our report is the first to record elements like this in place. Our collections include only 48 specimens referable to *S.* sp. cf. *S. forsenta* and these indicate a range from 143 to 398 feet above the base of our composite Lexington-Kope section. This range is not like that of any of the other species we recognize, nor does the form here described resemble others in the Lexington or Kope faunas. Thus we suspect it was the only element in the conodont apparatus it represents.

Repository. — Micropaleontological collections, The Ohio State University. Specimens are in reference slides numbered 60H1-13; 60L1-1, 2-2, 3-1; 61Z-297, 463, 493, 500-502, 505, 508, 511, 512, 552; 64S1-11; 64S2-53; 64S3-37. Figured specimen, OSU 27495.

Genus **TETRAPRIONIODUS** Lindström, 1955

1955. *Tetraprioniodus* Lindström, Geol. Fören. (Stockholm) Förhandl., vol. 76, p. 596.

The assembly of ligonodina-like, hibbardella-like, and tetraprioniodus-like elements that we describe as *Tetraprioniodus delicatus* (Branson and Mehl) was recognized as a multielement species by Schopf (1966), who termed it *Rosagnathus delicata* (Branson and Mehl). We agree with Schopf that these elements represent a single species and that the oldest name for it appeared in the binomen *Phragmodus delicatus* Branson and Mehl, 1933. The generic assignment of this species is uncertain and our decision to refer it to *Tetraprioniodus* (rather than *Rosagnathus)* requires some explanation.

Rosagnathus Rhodes, 1955, was based on specimens that were undoubtedly parts of a multielement species closely related to the one we describe as *Tetraprioniodus delicatus.* Even before his description of *Rosagnathus* was published, Rhodes (1955) noted the striking similarity between its type species *(R. superba)* and the Swedish Arenigian specimen on which Lindström (1955a) had based *Tetraprioniodus robustus.* Because of this similarity, Rhodes suggested that *Rosagnathus* be considered a junior subjective synonym of *Tetraprioniodus.*

We have no information about the composition of Lower Ordovician *Tetraprioniodus robustus* Lindström, but it is fairly certain that it was part of a multielement species that was at least grossly similar to *Rosagnathus superba* and the one we term *Tetraprioniodus delicatus.* The latter two species include ligonodina-like elements and no such structures are known to be associated with typical *T. robustus.* This might be taken to indicate that *Tetraprioniodus* and *Rosagnathus* can be distinguished by the absence of ligonodina-like elements in the former and their presence in the latter. On the other hand, new structural elements appear in the history of other stocks that we regard as genera *(e.g., Phragmodus, Plectodina),* and this could have been the case during the evolution of *Tetraprioniodus.* Consequently, we refer the species described by Schopf (1966) as *Rosagnathus delicata* (and *R. superba* Rhodes) to *Tetraprioniodus,* thereby assigning only specific significance to their ligonodina-like components.

Range. — Lower Ordovician to Lower Silurian.

Type species. — *Tetraprioniodus robustus* Lindström, 1955a.

Tetraprioniodus delicatus (Branson and Mehl) Pl. 29, figs. 14-22

1933. *Phragmodus delicatus* Branson and Mehl, Univ. Missouri Studies, vol. 8, p. 123, pl. 10, fig. 22.

Not 1941. *Phragmodus delicatus* Branson and Mehl, Graves and Ellison, Univ. Missouri School Mines and Metallurgy, Bull., Tech. Ser., vol. 14, p. 6, pl. 3, figs. 12, 13 (=*Tetraprioniodus superbus* (Rhodes) and *Keislognathus?* sp., respectively).

1953. *Ligonodina elongata* Rhodes, Phil. Trans. Roy. Soc. London, Ser. B, vol. 237, p. 305, pl. 21, figs. 130, 131.

1953. *Ligonodina extensa* Rhodes, *idem,* p. 306, pl. 21, figs. 128, 129.

1953. *Trichonodella gracilis* Rhodes, *idem,* p. 314, pl. 21, figs. 144, 147-150.

1953. *Holodontus* sp. Rhodes, *idem,* p. 304.

1957. *Roundya inclinata* (Rhodes), Glenister, Jour. Paleont., vol. 31, pp. 733, 734, pl. 88, fig. 19.

1957. *Cordylodus primus* Branson and Mehl, Glenister, *idem,* p. 732, pl. 88, fig. 18.

1959. *Keislognathus* sp. Stone and Furnish, Jour. Paleont., vol. 33, p. 223, pl. 32, fig. 6.

?1959. *Tetraprioniodus superbus* (Rhodes), Stone and Furnish, *idem,* p. 227, pl. 32, fig. 13.

1959. *Eoligonodina elongata* (Rhodes), Ethington, Jour. Paleont., vol. 33, p. 277, pl. 40, fig. 5.

1959. *Keislognathus simplex* Ethington, *idem,* p. 280, pl. 40, fig. 9, 10.

1959. *Tetraprioniodus parvus* Ethington, *idem,* pp. 288, 289, pl. 40, fig. 8.

1959. *Trichonodella inclinata* Rhodes, Ethington, *idem,* p. 290, pl. 41, fig. 6.

1959. *Ligonodina elongata* Rhodes, Lindström, Micropaleont., vol. 5, p. 440, pl. 3, figs. 26, 27.

1959. *Roundya* cf. *gracilis* (Rhodes), Lindström, *idem,* pp. 446-448, pl. 4, figs. 28-31.
1959. *Trapezognathus?* sp. Lindström, *idem,* p. 448, pl. 3, figs. 23-25.
1959. *Eoligonodina elongata* (Rhodes), Sweet, *et al.,* Jour. Paleont., vol. 33, p. 1051, pl. 132, fig. 4.
1959. *Keislognathus gracilis* Rhodes, Sweet, *et al., idem,* pp. 1051, 1052, pl. 132, fig. 11.
?1960. *Keislognathus gracilis* Rhodes, Pulse and Sweet, Jour. Paleont., vol. 34, p. 254, pl. 36, fig. 3 (A fragmentary tetraprioniodus-like element).
1960. *Tetraprioniodus superbus* (Rhodes), Pulse and Sweet, *idem,* p. 260, pl. 36, fig. 2.
cf. 1961. *Keislognathus gracilis* Rhodes, Wolska, Acta Paleont. Polonica, vol. 6, p. 350, pl. 2, figs. 2, 3.
cf. 1962. *Ligonodina elongata* Rhodes, Bergström, Arkiv Min. Geol., vol. 3, pp. 43, 44, pl. 5, figs. 14, 15, 17, 18.
1964. *Hibbardella? gracilis* (Rhodes), Bergström, Acta Univ. Lundensis, Sec. II, No. 3, pp. 24, 25.
1964. *Ligonodina delicata* (Branson and Mehl), Bergström, *idem,* pp. 28, 29, text-fig. 12.
1965. *Eoligonodina elongata* (Rhodes), Barnett, Micropaleont., vol. 11, p. 70, pl. 2, fig. 28.
?1965. *Tetraprioniodus superbus* (Rhodes), Barnett, *idem,* p. 74, pl. 2, fig. 15.
?1965. *Trichonodella* cf. *T. divaricata* Rhodes, Barnett, *idem,* p. 74, pl. 2, fig. 9.
1965. *Trichonodella* cf. *T. gracilis* Rhodes, Barnett, *idem,* pp. 74, 75, pl. 2, fig. 25.
1966. *Rosagnathus delicata* (Branson and Mehl), Schopf, New York State Mus., Bull. 405, p. 76, pl. 4, figs. 6-10, 15.
1966. *Ligonodina delicata* (Branson and Mehl), Webers, Minnesota Geol Sur., Spec. Pub. SP-4, p. 32, pl. 13, figs. 10, 11, 13-15.

We have 2240 minute conodont elements in our Lexington and Kope collections that exhibit many similarities in structure and occur together throughout their range in proportions that seem too constant to be the results of chance. Consequently, we regard all these conodonts as representatives of a single species, the oldest name for which is *Phragmodus delicatus* Branson and Mehl. Of the conodont elements we include in this species, 603 represent the form-genus *Ligonodina* (or *Eoligonodina);* 1204 are symmetrical and asymmetrical elements of the form-genus *Hibbardella;* and 433 have four denticulate processes, hence belong in the form-genus *Tetraprioniodus.* Each of the form-species we include in *Tetraprioniodus delicatus* (Branson and Mehl) has had a varied taxonomic and nomenclatural history and we discuss them separately.

Ligonodina-like elements of *Tetraprioniodus delicatus* include conodonts described previously as *Phragmodus delicatus* (Branson and Mehl, 1933), *Ligonodina* (or *Eoligonodina) elongata* (Rhodes, 1953; Ethington, 1959; Lindström, 1959; Sweet, *et al.,* 1959; Bergström, 1962, 1964; Barnett, 1965), *Ligonodina extensa* (Rhodes, 1953), and *Cordylodus primus* (Glenister, 1957; *not* Branson and Mehl, 1933). The specimens described under these names are excavated basally and all have a proclined to erect cusp, a relatively long posterior process surmounted by denticles arranged in hindeodelloid fashion, and a laterally deflected anterior process bearing one or a few slender denticles, the axes of which are essentially parallel to the cusp. Additional details on morphology, together with remarks on nomenclature, are given by Bergström (1964, pp. 28, 29).

Hibbardella-like elements of *Tetraprioniodus delicatus* include conodonts referred in the past to *Trichonodella* (or *Roundya* or *Hibbardella) gracilis* (Rhodes, 1953; Lindström, 1959; Bergström, 1964), *Roundya inclinata* (Glenister, 1957; Ethington, 1959; *not* Rhodes, 1953), *Keislognathus simplex* (Ethington, 1959), and *K. gracilis* (Sweet, *et al.*, 1959; Pulse and Sweet, 1960; *not* Rhodes, 1955). All are small, basally excavated, and have a proclined to suberect cusp, a lateral process on each side, and a long, delicate posterior process surmounted by denticles arranged in hindeodelloid fashion. About a third (400) of our Lexington-Kope specimens are nearly bilaterally symmetrical; the remaining two-thirds (804) are asymmetric in that one of the lateral processes is situated somewhat more anteriorly than the other. These elements are similar to the types of the form-species *Keislognathus gracilis* Rhodes and *Hibbardella? diminuta* (Rhodes), which we believe to be symmetric and asymmetric form-variants of a single species. That species has fewer denticles on the lateral processes than the one represented by our Lexington and Kope elements and probably occurs with a slightly different assembly of elements than does the form-species under discussion.

The tetraprioniodus-like elements we include in *Tetraprioniodus delicatus* (Branson and Mehl) are like those referred to the form-species *Tetraprioniodus parvus* by Ethington (1959). These small elements are excavated basally, have a proclined to suberect cusp, a short anterior process, a lateral process on each side, and a long, delicate posterior process surmounted by denticles arranged in hindeodelloid manner. They represent a form-species closely similar to *Tetraprioniodus superbus* (Rhodes, 1955) but are distinguished from that species primarily in that the latter tends to develop a few large, closely spaced denticles in the proximal portions of the lateral processes. These denticles are more or less parallel to, and in some specimens appressed to, the cusp (Rhodes, 1955, pl. 7, fig. 1). In most specimens of *T. superbus* there is also a furrow-like depression in the cusp base immediately posterior to the large denticles of the lateral processes. None of these features is prominently developed in the 433 specimens at hand.

Elements of all the form-species just enumerated are closely similar in size, in basal cavity development, in denticulation pattern, and in color. Further, ligonodina-like, hibbardella-like, and tetraprioniodus-like elements occur in the ratio of 12:6:4, which we believe represents the smallest number of elements borne by a single representative of this multielement species.

Occurrence. — *Tetraprioniodus delicatus* (Branson and Mehl) ranges from 82 to 601 feet above the base of our composite Lexington-Kope section. The highest known occurrence of the species in the Cincinnati Region is in basal Richmond group ("Arnheim") rocks in Indiana (McClish, 1965). The species is represented in the uppermost Stewartville, and in the Dubuque members of the Galena limestone in Minnesota (Webers, 1966), and it has been recorded from the Stewartville, Dubuque, and basal Maquoketa of Iowa (Ethington, 1959; Glenister, 1957). Schopf (1966) reported that the species ranges from the Rockland formation through the Cobourg formation of New York and adjacent areas, and Barnett (1965) described it from the Jacksonburg limestone of New Jersey. In Wales, *Tetraprioniodus delicatus* is known from the Gelli-grin, Pen-y-garnedd, Brun Pig, Crug, and Birdshill limestones (Bergström, 1964), and it occurs in a number of as yet undescribed Scandinavian faunas.

Repository. — Micropaleontological collections, The Ohio State University. Reference slides from all sections but 60 D (see Appendix B). Figured specimens, OSU 27496, 27497, 27498, 27499, 27500.

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APPENDIX A

LOCALITY REGISTER

(See Text-fig. 1 for locations; Table 1 for thicknesses)

O.S.U. File Designation	Locality	Description
60A	Cynthiana (Harrison Co.), 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, Ky. 7.5′ quadrangle.
60B	Greendale Station (Fayette Co.), Ky.	Cut along Southern Railroad right-of-way about 4 mi. north of Lexington, Kentucky, and 1,000 ft. south of intersection of Spurr Road and railroad tracks. Possibly type section of Greendale member of Cynthiana formation.
60BCK	Bear Creek (Clermont Co.), 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 of Washington Twp., Clermont, Co., Ohio.
60D	Rogers Gap (Scott Co.), Ky.	Cuts along Southern Railroad right-of-way, about 1 mi. south of Rogers Gap, Kentucky. SW¼ SW¼ east central rectangle, Delaplain, Ky. 7.5′ quadrangle. May be type Rogers Gap member of Cynthiana formation.
60G	Sadieville West (Scott Co.), Ky.	Weathered road cuts on east and west sides of Kentucky-U.S. Highway 25, 1.65 mi. west of Sadieville, Kentucky. SW¼ south central rectangle, Sadieville, Ky. 7.5′ quadrangle.
60H	Menzie (Pendleton Co.), Ky.	Cut along L. & N. Railroad right-of-way, 0.25 mi. north of Menzie, Ky. NE¼ northwest rectangle, Falmouth, Ky. 7.5′ quadrangle.
60L	Carntown (Bracken Co.), Ky.	Abandoned quarry adjacent to Kentucky route 8 at Carntown, Ky. SW¼ northwest rectangle, Moscow, Ohio-Ky. 7.5′ quadrangle.

60M	Milford (Bracken Co.), Ky.	Abandoned quarry on east side of Kentucky Route 539, 0.15 mi. south-southeast of its junction with Kentucky Route 19, directly east of, but across North Fork of Licking River from, Milford, Ky. NW¼ east central rectangle, Claysville, Ky. 7.5′ quadrangle.
60P	Clays Ferry (Madison Co.), Ky.	Weathered cuts along Clays Ferry Road (old Ky.-U.S. Highway 25) on southeast side of Kentucky River. SE¼ southwest rectangle, Ford, Ky. 7.5′ quadrangle. Section begins in Kentucky River fault zone and extends upward in downthrown block.
60Q	Willow Creek (Bracken Co.), Ky.	Natural exposure in floor and walls of Willow Creek valley, upward from point Kentucky Route 539 crosses the creek and 1.1 mi. west-northwest of Milford, Ky. SE¼ north central rectangle, Claysville, Ky. 7.5′ quadrangle.
60T	Falmouth (Pendleton Co.), Ky.	Three road cuts on northeast and southwest sides of Ky.-U.S. Highway 27, beginning 0.25 mi. southeast of city limits of Falmouth, Ky. NW¼ south central rectangle, Falmouth, Ky., 7.5′ quadrangle.
61Z	Middletown (Butler Co.), Ohio	2.25-inch core drilled in 1957 by Texas Eastern Transmission Corp. on farm of Mr. Valentine Apple, SW¼ sec. 19, Lemon Twp., Butler Co., Ohio. (Numbered 860 in files of Ohio Geological Survey, where core is kept.)
64S1	Banklick Creek (Kenton Co.), 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.
64S2	Frankfort East (Franklin Co.), Ky.	Road cuts along eastbound and westbound lanes of Kentucky-U.S. Interstate Highway 64 east of the Kentucky River and about a mile south of Frankfort, Ky.
64S3	Frankfort West (Franklin Co.), Ky.	Road cuts along eastbound and westbound lanes of Kentucky-U.S. Interstate Highway 64 west of the Kentucky River and about a mile west of 64S2.
65GV	New Point (Decatur Co.), Ind.	2.25-inch 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 this road and Indiana-U.S. Interstate Highway 74, 0.5 mi. north of New Point, Indiana.

APPENDIX B

Distribution and Frequency of Conodonts by Section and Bed

In the tables that follow, Lexington-Kope-Clays Ferry conodonts are listed in columns, the numbers of which refer to the numbered species in the following list. Names preceded by an asterisk are not included in the tables of Appendix B; information with respect to the distribution of these species is included in the systematic section of this report. Column one of Appendix B lists the section number; column two the bed designation in that section; column three indicates the position of the bed in feet above the base of the composite, or reference, section. Figures in subsequent columns indicate the number of discrete elements referable to the species whose number appears at the head of the column.

Lexington-Kope-Clays Ferry Conodont Species

*1. *Acodus mutatus* (Branson and Mehl)
*2. *Acontiodus alveolaris* Stauffer
3. *Amorphognathus ordovicica* Branson and Mehl
4. *Belodina compressa* (Branson and Mehl)
*5. *Belodina* sp. cf. *B. inornata* (Branson and Mehl)
6. *Bryantodina? abrupta* (Branson and Mehl)
*7. *Bryantodina? staufferi* Bergström and Sweet, *sp. nov.*
8. *Cyrtoniodus flexuosus* (Branson and Mehl)
*9. *Cyrtoniodus, sp. nov.*
*10. *Distacodus falcatus* Stauffer
11. *Drepanodus suberectus* (Branson and Mehl)
*12. "Fibrous" conodonts
13. *Holodontus superbus* Rhodes
14. *Icriodella superba* Rhodes
*15. *Oistodus venustus* Stauffer
16. *Oulodus oregonia* (Branson, Mehl, and Branson)
*17. *Ozarkodina? obliqua* (Stauffer)
18. *Ozarkodina polita* (Hinde)
19. *Ozarkodina tenuis* Branson and Mehl
20. *Panderodus gracilis* (Branson and Mehl)
*21. *Panderodus panderi* (Stauffer)
*22. *Periodon grandis* (Ethington)
23. *Phragmodus undatus* Branson and Mehl
*24. *Plectodina aculeata* (Stauffer)
25. *Plectodina furcata* (Hinde)
*26. *Plectodina? posterocostata* Bergström and Sweet, *sp. nov.*
*27. *Polyplacognathus ramosa* Stauffer
28. *Rhipidognathus discreta* Bergström and Sweet, *sp. nov.*
29. *Rhodesognathus elegans* (Rhodes)
*30. *Scandodus?* sp. cf. *S.? dissimilaris* (Branson and Mehl)
*31. *Scolopodus insculptus* (Branson and Mehl)
*32. *Synprioniodina* sp. cf. *S. forsenta* Stauffer
33. *Tetraprioniodus delicatus* (Branson and Mehl)

SECTION AND BED			CONODONT SPECIES															
Sec.	Bed	Ref. Sec.	3	4	6	8	11	13	14	16	18	19	20	23	25	28	29	33
60A	2-1	296	2			30	1			5	11	1		16	49			
	2-2	297								1	3				1			
	2-3	298				6				2	8			3	9			
	2-4	299								4	4	3			11			
	2-5	300				13				2	5				15			
	2-6	301	2			15				6	7	1		1	11			
	3-2	303				7	2			51	37			1	28	2		
	3-4	305				3				3	2			4	1	3		
	4-1	306	7			19	2			13	19	9		31	71	3		
	4-2	307	12			14				12	7	8		13	36			
	4-3	308	6			19	2			18	9	5		13	31	2		1
	4-4	309	13			34	10			14	25	19		101	122	4		1
	4-5	310	1			3	23			2	1	4		7	17			
	4-6	311	5			7				6	6	3		8	16			
	4-7	312	12			30	6			13	20	9		55	93	5		1
	5-1	313	7			4				4	3	4		11	15			
	5-2	314	50			53	12			16	35	26		121	191	4		5
	5-3	315	21			34				29	26	7		67	68	1		2
	5-4	316	6			13				5	9	2		29	42	3		
	6-1	318	1			6				10	15	2		3	16	21		
	7-1	320	2			67				17	26	54		18	185	9		
	7-2	321	9			47	2			22	24	29		17	144	9		1
	8-1	323	3			7				12	4			9	33	5		
	8-2	324	3			7				3	3	2		9	38	3		
	8-3	325	4			22	3			25	17				38	8		
	8-4	326	12			35	3			22	14			5	113	14		
	8-5	327				1				1					5	6		
	8-6	328				3	2			12	8	1			23	11		
	8-7	329				1				1					6	4		
	9-1	330	1			5				11	6			4	13	2		
	9-3	332				15	4			27	15	4			15			
	9-4	333				16	9			14	10	8		1	38	9		
	9-5	334	2			8	12			23	24	10		11	120	3		
	9-6	335				6	3			16	12	3		6	47	4		
	9-7	336	1			19	4			9	11	6		9	55	14		
60B	1-1	332	3			5				4	12	2		16	41			
	1-2	333								6	5			11	13			
	1-3	334	29			56	2		1	47	35	34		83	145			1
	2-1	336	4			9				17	5	5		8	34			
	2-3	338	5			12				31	7	3		4	32			
	2-5	340				7				20	8	10		1	18			
	2-7	342	1			5				14	4	7		3	17			
	2-9	344	3			19	1			16	6	1		29	52			
60BCK	1	261		1	2	17	3		14	14	10	24		222	64		1	1
	3	263				8	1		3		1	7		78	28			
	5	265	2		5	45	10		18	18	7	36		361	108			
	7	267				30			1			3		51	17			
	11	271				6	2			4		6		121	47			
	13.5	273		1	1	42	12		3	12	12	49		359	115		2	
	15.5	275				21	7		4	18	23	23		140	79			
	17.5	277				12	8		1	14	16	10		183	92		4	1
	19.5	279				364	85		15	122	103	357		3200	1085		145	10
	21.5	281				48	8			13	23	42		227	141		16	
	23.5	283	3			154	40			29	43	169		2532	750		13	14
	26	286	16			118	36	2		26	32	102		882	368		6	13
	28.5	288	1			1				2				6	8			
	33	293	299			66	126			96	246	284		2514	513		1	51
	35	295	186				6			26	32	24		394	107			6
	37	297	14							19	5	1		18	10			
	41	301	14			2				7	3	1		44	9			
	43	303	161			92	12		8	10	35	234		1911	336			48
	45	305	44				1				1	1			4			
	47	307	23			18	12		1	4	4	27		238	89			3
	52.5	312	9			5				8	4	4		80	35			
	54.5	314	6			75	47			13	19	76		930	308			24
	56.5	316	5				27			5	4	27		512	125		1	12
	59	319	220			110	100			79	25	78		410	460			20
	61.5	321	22			33	14			24		70		386	191			11
	63.5	323								1		1		1	3			
	65.5	325	2			4	2			2	1	6		125	23			1

Sec.	Bed	Ref. Sec.	3	4	6	8	11	13	14	16	18	19	20	23	25	28	29	33
60BCK	67.5	327	2			17	19			19		32		525	86			5
	70.5	330	58			10	1			8	6	13		103	12			2
	73	333	3	1		14	17			2	2	22		349	41			1
	76	336	1				4			1				22	3			
	78	338	2	1		12	12			1		26		515	26		1	2
	82	342	11	5			32					5	2	214	13		1	
	83	343	13			2	7			1		1	1	25	10			
	88	348	55			37	33			12		60	7	2715	149		8	60
	91	351	58	1		8	28			4		4		158	30			3
	94	354				2	2						6	129	13			2
	97	357	11	1		6	9					8	2	424	44		2	8
	99.5	359	7	2		7	9					10		89	35			
	103.5	363	6	10		13	20						1	307	53			
	105.5	365	7	2		4	9					3		87	24			1
	107.5	367	1			2	3					1		58	14			
	109	369	81	6		11	18					5		99	32		1	2
	113	373	5	1		7	2					5		447	53			
	115	375	4	5		6	3					7		135	30			
	120	380	11	7		2	2					5		42	9			
	126	386	42	2		27	19						8	1494	66		3	22
	129	389	4	7		1	18					8		300	44		1	2
	131	391	8			1				3				1	4			
	134	394	10				11					9		143	30			5
	138	398		1			7						2	136	52			2
60D	1-1	379					2			1	1			8	1			
	2-1	381	1			3	7			1		4		43	10			
	2-3	383	3	1	1	1	4			5	1	2		10	6			
	2-4	384				4	2		1	9	11	7		75	38			
	2-5	385				1								7				
	2-7	387		2		5	4			1		5		41	13			
	3-1	389	4	1		8	6			2		2		28	11			
	3-3	391	3	2		1	5			1		1		40	8			
	3-5	393					1					1		18	1			
	3-7	395	1	1			7					5		45	5			
	3-9	397	1							1				14	3			
	3-11	399	4	1		1	3					1		26	5		1	
60G	1-1	311				12	4			3	10	3		75	26			
	1-5	315				20				12	4	14		39	63			
	2-1	316				8	3			4		3		22	5			
	2-3	318				4				1	5	5			5			
	2-5	320	1			6	9			16	2	2		43	5			
	3-1	324				6				26	7			7	22			
	3-3	326	4			52	70	1		12	4	99		527	179		1	23
	3-5	328	2			11	10			3	4	19		110	64			1
	4-3	331	16			31	17			8	11	50		342	82			6
	4-5	333	9			9	2			12	7	6		22	15			
	5-1	334	32			21	1			11	10	11		84	47			
	5-3	336								14	3	1		4	6			
	5-10	343	11			17				13	7			4	24			
	5-13	346	1			2				16	6	1			8			
	6-2	348								1	1				1			
	6-3	349	1			1	1			5	1	1			5			
	6-4	350	3			4	1			5	4	8		34	29			1
	7-1	351								6	3	1		4	3			
	7-7	357		1		6	18					11		178	30			1
	7-10	360	4			20	47			5	1	14		421	98			
	7-13	363	12	6		29	58			5			1	398	76			
	7-16	366	1			2	1					1		4	4			
	7-19	369	7	1		23	25			9	2	14		325	60			1
	7-22	372	1			41	43	1		5			29	4829	194		1	4
	8-1	373	8	1		69	77			26		31	2	4322	324			18
	8-5	377	9			39	62	1		27		35	2	3104	142		2	33
	8-11	383	2			8	5			22	5	10		128	29			
	9-3	387	1			5	19			16	2	19		269	54			
	10-1	391	16			90	61	1		33	12	69	3	2062	384			18
	11-1	395	18	1		125	58	1		50	21	84		1927	470			4
	11-5	398	7	3		15	13			10	5	8	1	190	40			
	12-5	404	6	3		45	85			4		50	1	1425	204		1	1
	13-1	406	4	2		7	24			7	3	6		50	15			
	13-3	408	1	3		7	18			1	4			25	23			
60H	1-1	323				4	3			16	5	5		41	9		2	
	1-3	325				13	4			4	8	24		260	51			4

Sec.	Bed	Ref. Sec.	3	4	6	8	11	13	14	16	18	19	20	23	25	28	29	33
60H	1-7	329	1			26	17	1		11	7	45		681	116		12	5
	1-9	331				2	3				1	9		66	5			
	1-11	333				2	5			4	1	4		54	7			1
	1-13	335	3			60	27			18	22	76		698	189		12	
	2-2	338	44			3	2			16	4	4		31	11			
	3-1	340	34			9	16			10	6	15		358	36		1	8
	3-3	342	201			29	9			36	46	31		659	111			7
	3-7	346	2			1					2	3		8	4			
	3-9	348	13			6	1				9	17		85	17			2
	3-13	352	9			1	1			5	2	2		16	4			2
	5-1	374	48			8	4			16	6	7		44	34			
60L	1-1	266		1		72	16		41	12				1039	204		4	
	2-2	277		1		123	44			12	24	62		2335	467		38	22
	3-1	279	1	2		336	81		2	38	79	376		5891	1303		209	52
	3-3	281				115	31			18	21	76		664	255		30	5
	3-5	283				19				6	10	19		224	78		3	
	3-7	285				44	46			20	13	51		1082	137		5	
	4-1	287		1		22	7			9	4	14		320	76		1	
	4-3	289	5			10	15	1		3	5	25		140	95		2	4
	4-5	291	2			20	26			3	9	45		375	83			2
	4-7	293	25			17	10			10	6	7		123	51			1
	4-9	294	48			22	21		1	16	13	25		172	72		4	12
	4-11	296	225			71	4	1		197	66	9		221	138			
	4-13	297	85			13	5			20	19	8		106	40			1
	5-1	298	114			43	8			24	30	5		591	90			33
	5-3	300	3			1				2		1		8	5			
	5-5	302	11			13	14	2		1	26	18		186	57			6
	6-1	305	5											2				
	6-3	306				1	1							5	1			1
	6-5	308	25			126	62	3		7	11	155		1862	184		1	40
	6-7	310	54							2	1			3				
	6-11	314	7			4	15			2	2	13		82	23			
	7-1	316	3			21	18	2		6	4	15		258	67			3
	7-3	318	54				33	1		7	2	21		270	158		5	7
	7-5	320				62								1				
	7-9	322	9			8	10			8	2	9		104	33			
	8-1	324					1					1		11	3			
	8-3	326	13			33	23		1	10	12	18		349	122		1	3
	8-5	328	2			4	12			11	2	5		15	9			
	8-7	330					4			1		3		1				
	8-9	332	4				4					1		4	2			
	8-11	334	4	1		2	57					4		83	7			
	8-13	336		1		3	13					1		21	3			
	8-15	338	21	2		8	72			3		6		263	27			1
	8-17	340	4			5	55			1		7	5	587	28			1
	9-2	342	2			1	4			2		1		31	5			
	9-6	346	3			7	10			4		12		156	24			4
	10-1	348	35	6		4	56	2	1			7	51	2401	38		3	87
	10-3	350	6	5		4	33			1		15	6	235	27			4
60M	1-1	317	6			30	6			3	3	19		196	49			6
	1-3	319	30			38				29	24	1		2	96			
	2-1	321	15			45	2			12	12	22		81	108			
	2-3	323	20			17	10			29	20	26		92	55			
	2-5	325	100			67	13			27	21	80		424	171		1	2
	3-1	327				4	9			3	1	1		372	14			
	3-2	328				7	6			1	2	6		58	13			
	3-3	329	6			17	56		1	11	1	11		582	91			
	3-5	331	59			31	5			17	23	31		170	72			2
	3-6	332					3					1		5	1			
	3-7	333	106			64	8	1		81	24	50		243	170			8
	3-8	334	5	13		30	63			27				169	93			
	3-9	335	20			14	11		1	15	17	14		122	69			2
	3-10	336					1							7				
	3-12	338				1	2			3	1	2		50	10			
	4-1	340	5	8		6	29			2		8		250	28			2
	4-3	342	8	1		1	59			6	1	6		61	20			
	4-5	346					1					2		37				
	4-7	348	7			3	5			7		6	1	1155	31			3
	4-9	350										2	1	14				
60P	J-0	182				2	1		2					71	1			
	J-4	186				1	7				1	1	2	51	2			
	J-8	190					5				1	1	2	101	1			

Sec.	Bed	Ref. Sec.	3	4	6	8	11	13	14	16	18	19	20	23	25	28	29	33
60P	J-12	194					1				10		1	65	4			
	J-16	198				11	8				16	2		189	25			
	J-20	202				20	65		1		4	10	5	572	65			
	J-24	206					5					2		63	3			
	J-28	210				8			1		1	11		8	28			
	J-32	214			3	64	6		29		1	69		292	287			1
	J-36	218				6	5				1	6	5	30	21			
	J-40	222					10		1		5	4		10	30			
	J-44	226				8	9					19	2	2	24			
	J-48	230				21	8		4	5	14	10	5	42	115			
	J-52	234				11	14		1	1	1	13	7	71	73			
	J-56	238				52	24		4		24	26		100	170			
	J-60	242				48	4		2	6	1	20	10	91	292			
	J-64	246			5	14	3			12		25	5	31	87			
	J-68	250				10				4	3	17	5	12	27			
	J-72	254				1					2	5		3	12			
	J-76	258				24	17		1		1	26	14	5	121			
	J-80	262			1	7	5		1			5	5	4	14			
	J-84	266				63	25			2		34	109	6	395			
	J-88	270				12	8			3		3	5	3	12			
	J-92	274				37				22	41	10	2	9	185	1		
	J-95	277				9	25	1	1	5	5	8	1	49	34			
	B-2	280				3	9			4	5	22		122	83			
	B-4	282				7				4	1	5	1	22	15			
	B-6	284													1			
	B-8	286				16	1			11	7	12		25	59			
	B-12	290				1	2			2	4	2		9	12			
	B-14	292				120	7		4	340	170			103	398			
	B-16	294				7			2	2	8			1	22			
	B-18	296				26	3		2	5	18	28		12	131			
	B-20	298				41	3			9	25	21		29	182			
	B-22	300				1			1	1	1	2		1	6			
	BW-2	305				31	18			29	21	4		17	123			
	BW-4	307				3	2			9	5	1		4	15			
	BW-6	309				13	6			21	11	5		2	55			
	BW-8	311				12	8		1	31	18			3	76			
	BW-10	313				43	14		7	32	53	23		32	171	1		
	BW-12	315				54	18		10	25	83	7		62	220			
	BW-14	317				32	12		3	36	43	10		20	142			
	BW-16	319				69	10		9	110	88	27		77	325			2
	BW-18	321				38	1			20	29	23		13	197	1		
	BW-20	323				18				14	28	2		7	95	2		
	BW-22	325				12				20	27	6		5	147			
	BW-24	327				12	1			12	13	4		9	45			
	BW-26	329				33	10		2	4	3	35		43	126			
	BW-28	331				22	2			3	17	10		18	83			
	BW-30	333				9	1			32	16	2		1	29	3		
	BW-32	335				26	3			54	36	12		41	125			
	1-1	338				2				97	24	1			35			1
	1-2	339				7	1			37	26	4			26			1
	2-1	340				3	1				1	1		2	10		1	
	2-2	341				3	1			3	2	2		5	8			
	2-3	342	1			8	2			12	7	3		21	26			
	2-4	343				10	2			2	9	5		19	31			2
	2-5	344				28	4			38	29	14		8	77			1
	2-6	345				2	1			10	10	2		3	25			
	2-7	346				4				1	2	4		1	14			
	2-8	347									1	5		8	3			
	2-9	348				57				43	52	33		22	267			
	3-1	349				1				4	3				5			
	3-2	350													1			
	3-3	351					1			7	4			1	8			1
	3-4	352				12				1	3	5		8	44	1		
	3-5	353													2			
	3-6	354				6	1			6	13	1			21			1
	3-7	355				70	7			13	20	40		461	308			
	3-8	356				4				6	6	1		3	20			1
	3-10	358				15				13	8	3		5	44		1	
	4-5*	359								1								
	4-1	360								1					1			
	4-2	361				2				4	7			2	17			
	4-3	362				9	1				13	6		12	48			
	4-4	363				7	3			4	21	15		22	38	3		
	4-5	364												1	1			
	4-6	365										1		1	1			

Sec.	Bed	Ref. Sec.	3	4	6	8	11	13	14	16	18	19	20	23	25	28	29	33
60P	4-7	366								3	4	1		1	6	1		
	5-1	367				1				27	13	1			23			
	5-2	368				3	1			13	7				28			
	5-4	370				4				10	9				21			
	5-5	371				1	1			8	2			1	7			
	5-6	372				1				6	3				16			
	5-7	373				1				57	11				14			
	5-8	374				11	5			32	7	3			48			
	5-9	375				12	2			18	5				12			
	5-10	376				6	1			15	1	2		4	22			
	5-11	377				1	4			12	8			3	21			
	6-5"	378								3					1			
	6-1	379				1				14	2				7			
	6-2	380				3	3			8	5	1		1	19			
	6-3	381				47	3			24	24	11		40	73			1
	6-4	382				1	7			7	1			2	9			
	6-5	383				14	11			14	10	3			28			
	6-6	384				9	3			9	7	10		14	26			
	6-7	385		1		6	4			1	10	6		4	38			
	7-5"	386				19	2			4	4			8	41			
	7-1	387				7					4	4	1	12	20			
	7-2	388				8	6			12	15	6	1	14	42			
	7-3	389				5	14			3	5	4	1	48	39			
	7-4	390				11	7			2	10			15	38			
	7-5	391				21	11			5	14	3		158	98			
	7-6	392				16	11			2	9	8		24	41			
	7-7	393				17	18			8	3	6	1	21	53			
	7-8	394				12	13			2	8	8		44	38			
	7-9	395				11	7			1	5	2		4	17			
	7-10	396				6	6			1	2	2		16	21		1	
	7-12	398		1		5	5			5	7	3	1	58	38			
	7-13	399				18	18			10	6	8	4	94	48			
	7-14	400	1			24	1			9	6	15		168	99			
	7-15	401		1		14	23			6	11	3		76	43			
	7-16	402				14	7			4		3		62	41			
	7-17	403		2		21	21			23	35	6	2	362	122			
	7-18	404				9	7			9	18	4	2	229	56			
	7-19	405	2			17	16			21	15	7		472	81			
	7-20	406	2	1		6	6			8	3	5		52	37			
	7-21	407	1	3		10	21			5	3	7		65	29			
	7-22	408				13	7			3	2	6		26	5			
	7-23	409				18	11			24	20	18	1	172	67			
	7-24	410				1	8			1	4	3		29	16			
	7-25	411				13	3			6	15	19		364	61			1
	7-26	412				21	20			33	14	3		304	75	1		1
	8-2	414	1			34	5			12	11	12		226	111			
	8-3	415				23	14			34	12	8		92	65			
	8-4	416	2			15	25			13	21	10		269	86			
60Q	1-1	266				43			45	7	56	21		944	136			
	1-3	268			2	12			9	7	13	9		159	41			
	1-5	270			1	14				4	13	1		191	56		1	
	2-1	272				11				11	9	15		368	85		2	
	2-3	274				28				16	9	9		144	68			
	2-5	276				28				10	24	10		811	159		8	4
	2-7	278								33				1270	249		5	2
	2-9	280		1						17				147	96		4	
	2-11	282								54				24	50			
60T	1-1	281			4	10	7		77	29	16	14		252	64			
	2-14	295				3	1			9		7		141	31		2	1
	2-16	297				16	7			6	8	28		393	68		3	1
	2-18	299	12			58	21			10	7	50		614	125		6	4
	2-20	301	1			47	23			2	4	54		1097	211		3	1
	3-1	305				121	13			10	24	100		815	490			
	3-3	307				38	4			15	35	107		513	275			1
	3-5	309				35	6			4	23	39		253	166			1
	3-9	313				114	20			18	41	117		706	493			5
	4-1	316	9			2				9	3			13	10			1
	4-3	318	133			68	13			50	44	57		190	252			33
	4-5	320	24			59	60			15	4	13		196	231			
	5-1	321	60			26	1			39	32	12		87	85			2
	5-2	322	73			29	1		1	35	34	9		112	83			1
	6-1	323	139			27	4			51	35	22		241	104			2
	6-3	325	105			61	14			59	41	14		1271	336			4

Sec.	Bed	Ref. Sec.	3	4	6	8	11	13	14	16	18	19	20	23	25	28	29	33
60T	6-5	327	220			67	12	1	1	58	56	31		1713	411			32
	6-7	329	16			30	22			9	13	38		433	91			4
	6-9	331	52			6				18	4	3		47	17			5
	7-1	337	14			3	2			7	1	6		13	5			
	7-3	339	48	6		72	78			64		54		117	344			18
	7-5	341	3			1				7	1	1		11	11			1
	7-7	343	21			21	38			45	33	21		51	146			
	8-1	345	10			24	33			10	2	20		231	105			1
	8-3	347	11			4	19			3	1	6		103	11			
	8-5	349	1			2	14					1		120	8			1
	9-1	351	39	1		6	83					25		239	57		2	1
	9-3	353	14			2	4					1		12	4			
	9-5	355	2			1						1		98	4			
	9-7	357				1	2					2		111	6			
	9-9	359	1			1	2							52	1			
612	647	48		1			13							31				
	637	58		1		1	17						3					
	630	65			4		1							7				
	629	66					1							2				
	628	67				1								5				
	627	68											3	11				
	626	69					1						1	4				
	625	70			2									7				
	624	71											2	27				
	622	73		9	5		33						2	265				
	621	74					1							9				
	620	75					2							3				
	619	76					16							25				
	618	77					7							67				
	617	78					8							21				
	616	79					1							1				
	615	80	2				21							24				
	614	81					19		6					2				
	613	82	1				23		71					58			1	1
	612	83					12		3					29				
	611	84							1					3				
	607	88					1											
	600	95	2				1		6					12			1	2
	595	100	3											2				
	592	103					1							7				2
	590	105	30				13	2	37					197	1		3	34
	587	108	22				9	3	10					116			1	2
	583	112	5				11							407				6
	580	115	2		1		3							51				2
	578	117	40				31	2	2					459				11
	575	120	1				16		17				1	448	1		1	1
	570	125	1				5							120				2
	567	128					20							134				
	564	131	1				5						4	29				2
	561	134	1				8						1	114				
	558	137	1				9						3	52				
	555	140	1				8				1			26				
	552	143	3				35						2	148			3	
	546	149	7				12		1			1	1	110			1	4
	542	153	2				16		1				1	306			2	3
	538	157	1				2											
	535	160					2		5									
	531	164	1				1		2					3	1		5	1
	523	172					7		9					42	1			
	518	177	1			1			1					8	3			4
	514	181					1							1				
	513	182	40		8	3	43		213				2	124	10		33	29
	512	183	98		17	2	139	2	625				2	372	31		116	129
	511	184	2			1	2		14				1	35			11	6
	510	185	198		44	6	141		442	2	2	12	1	308	29		33	
	509	186	11		8	3	50		130			4		92	4		16	6
	508	187	34		7	2	68		223			5		101	9		22	6
	505	190			7	6	50	1	149	1		7	21	535	45		21	18
	502	193			8	5	16		35			11	5	308	33		9	11
	501	194	3		8	3	19		222			1	1	315	19		88	19
	500	195			+		1		49			1	1	99	13		6	6
	499	196			1									15			4	
	493	202	43		8	9	74		252	4		5	15	390	25		9	12
	491	204				1	3	1	5			3		14	1		2	

Sec.	Bed	Ref. Sec.	3	4	6	8	11	13	14	16	18	19	20	23	25	28	29	33
61Z	194	501	33			4	19	1		2		10	20	71	33			4
	192	503	14			8	9			2		8	14	36	59			5
	189	506	1				9					7	25	41	25			2
	185	510	3			9	11					18	20	115	43			1
	183	512	2			1	8					3	15	40	10			1
	173	522	17				2			2		6	17	51	31			4
	171	524	1							1		3	7	26	4			
	168	527												5				
	164	531	12			27	27			4		37	10	158	106			1
	162	533												2				
	157	538	9			6	11			1		4	9	48	19			3
	153	542	9			4	1			1		8	4	78	24			1
	150	545	4			2	1					5	13	21	11			
	146	549	25			12	20			3		17	29	333	56			13
	140	555	3			3	4					1	34	84	18			1
	137	559	2			10	8					4	38	80	29			3
	130	565	36	1		33	50			6		30	38	590	102			22
	124	571												10				
	120	575	2			5	4					4	4	18	15			
	115	580				1	2			3		9		6	10			
	110	585				1	6					2		18	6			
	107.5	587	1			3	11					7		75	26			
	104.5	590				1	1					5		2	9			
	101	594	2			2	6			2		3		16	11			
	98	597	1			2	7			2		4		21	11			
	95	600	6				3			23		2		1	6			
	94	601	6			1	13			2		5	1	31	19			1
	90	605				3	6			8		9		35	11			1
	85	610				1	4							4	2			
	80.5	615	1			1	1			3		1		5	3			
	78	617	4			3	8			1		4		35	11			
	76	619	2				1			11				1	4			
	74	621	2			2				3		2		5	1			
	72	623	1			1	2			5		1		1	5			
	70.1	626	6			1	3			7		1		16	6			
	68.5	627				1	3			3		1		11				
	67	629				2	1			1		1		4	6			
64S1	1	303	3			7	7					11		252	36			10
	2	305	11			5	9			2		3		78	13			
	3	309	28			3	2					6		126	10		1	10
	4	312	155			16	54	7	10	16	11	20		2276	95			107
	5	316	222			9	30	2	10	1[illegible]	4	1	1	251	47			8
	6	319	23			5	4					2		39	13			3
	7	322	14			7	46	1	1			16		601	51			45
	8	325	249			47	46		1	10	1	11		982	264		1	4
	9	329	201			15	117	1	1	32	12	34		405	140			1
	10	331	63			30	40			12		14		2553	178			32
	11	334	122	3		14	28		1			5		952	35			10
64S2	6	67					14											
	7	70		15	107	3	41					15	65	107				
	8	73		3	34	2	12						7	156				
	9	76	1	8	27		17						4	238				
	10	90			1									1				
	11	101	5				10					2		99	2		3	
	12	103					7							112			23	4
	13	106	1				5		8					305			1	
	14	110					1		9					61			1	
	15	116				1	2		20					28	4			
	16	119	1			1	3		88					326	2			
	17	122				3	16		68					192	8		10	4
	18	126	1			3	5		20			3	1	338	12			
	19	129					3		22					430	5			1
	20	132	2				9		1					41				
	21	135			1	1	4					4		66	2			
	22	138				6	21		27			14	2	1478	45			
	23	141				1	12		21			1		296	3			
	24	145			16	1	26		24			4		586	11			
	25	147			6	2	5					3		168	7			
	26	149			2	1	5					3		248	8			
	27	153				1	7					4	1	144	4			
	29	158				2	17					6	10	263	21			
	30	160				2	5					5	1	223	22			
	31	163				4	14					14	9	295	48			

Sec.	Bed	Ref. Sec.	3	4	6	8	11	13	14	16	18	19	20	23	25	28	29	33
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	483	212	1			1	8		58	2		3	3	199	25		5	2
	481	214	30			7	72		317	6		5	6	380	34		3	15
	480	215	52				102	5	673	18		8	18	613	73		18	37
	475	220	3			1	2		1			2		26	2		2	3
	471	224	2				4							4	1		1	1
	467	228	2		1		4	1				3		24	2			6
	463	232	99		1	7	53	7	28			16		742	31		25	66
	457	238	1											4				
	447	248	1									1		5				
	443	252											1	1	2			
	439	256	2									1		6				
	433	262	9									1		10				
	429	266	3											3	2			
	425	270												11				1
	419	276	2			1	1					1		8	1			1
	415	280				1	1							33				1
	410	285	7											17	4			
	405	290										1		7				1
	401	294	14			1	3					4		81	1		1	
	398	297	63			2	30					9		257	27			30
	397	298												6				
	395	300	18			2	2							33	4			2
	393	302	9			3	1					1		46	5			1
	391	304	39			1	4							52	4		1	4
	390	305	60	1		6	10					3		292	12			16
	388	307	6			4	1			1		2		37	3			
	387	308	1			1						2		135	3			1
	386	309	19			1	1					2		115	6			5
	385	310	36	1			13	1	1			4		321	5			16
	384	311	222	22		4	57	14	1			1	3	1358	11			101
	383	312	196				44		1			15		330	37			6
	379	316	12				3					1		26	1			1
	372	323	88				6					2		101	6			1
	369	326	2			4	1					4		77	11			1
	365	330	78			5	26	1				10		432	36		13	9
	361	334	33			1	5					1		58	9		3	
	360	335	7				1					1		12	5			
	358	337	72									1		49	6			
	354	341	2				1							5				
	350	345											1	12				3
	343	352	53			1	9	1				2		54	1		2	4
	340	355	35				7					3		44	4			2
	338	357								1				4				
	334	361	15				4	1						12	1			1
	327	368	6	2			3					1		26	1			1
	322	373	47			4	14					1		153	27		2	1
	317	378	382	1		23	26	2				26	2	279	89		5	11
	313	382	68			2	16					6	3	140	18		4	23
	309	386	35	1			1					2	1	17	7			4
	305	390	47				2					5		73	10			2
	297	398	220			9	10					10		280	38		26	13
	288	407	341	2		19	8	3			1	34	1	68	75			15
	284	411	86			5	1	1				4		24	14			7
	281	414	1	1								5		30	5			
	275	420	89			8	51					15	50	557	36		1	31
	270	425	55	1		3	9					7	2	114	11			4
	268	427	33			3	1					3		63	4			5
	263	432	207	5	1	19	42	1				12	23	504	72			37
	259	436	34			3	4		1			3	6	194	12			7
	248	447	61			1	11		1			5		119	16			4
	246	449	91			7	19					11	9	333	29			4
	242	453	75	2		9	13					8	4	254	30			6
	240	455	11	1		3	18					6		373	16			2
	236	459	1										1	1				
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	211	484	3				1	1						8	5			
	208	487	11				12			1		8	17	110	14			5
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	32	348	3			11	10			11	9			47	35			
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	34	354	4				7			4		1		78	16			1
	35	356	8			7	13		1	2		6	1	912	52		1	2
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	37	359	8			18	19	1	2	4		24	12	1490	68		2	10
	38	362	27			13	23			1		24		405	64			

PLATES

The plates were prepared by the senior author, using facilities provided by the Paleontological Institute, Lund University, Sweden. The figures have not been retouched, but conodonts were lightly coated before they were photographed. The cost of reproduction of plates and text-figures has been met by a grant from special funds of The Department of Geology, The Ohio State University and of the Paleontological Institute, Lund University, Sweden.

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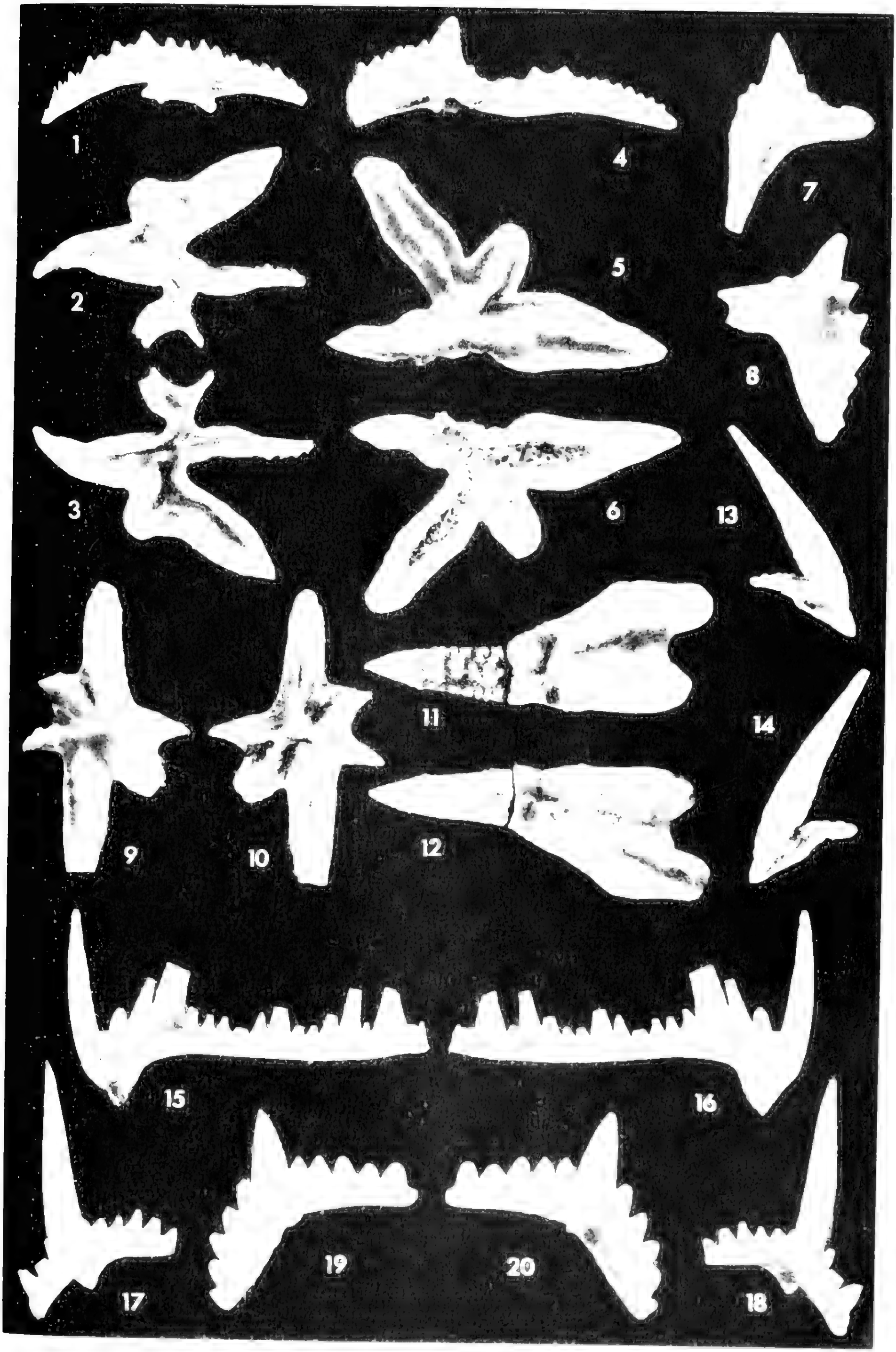
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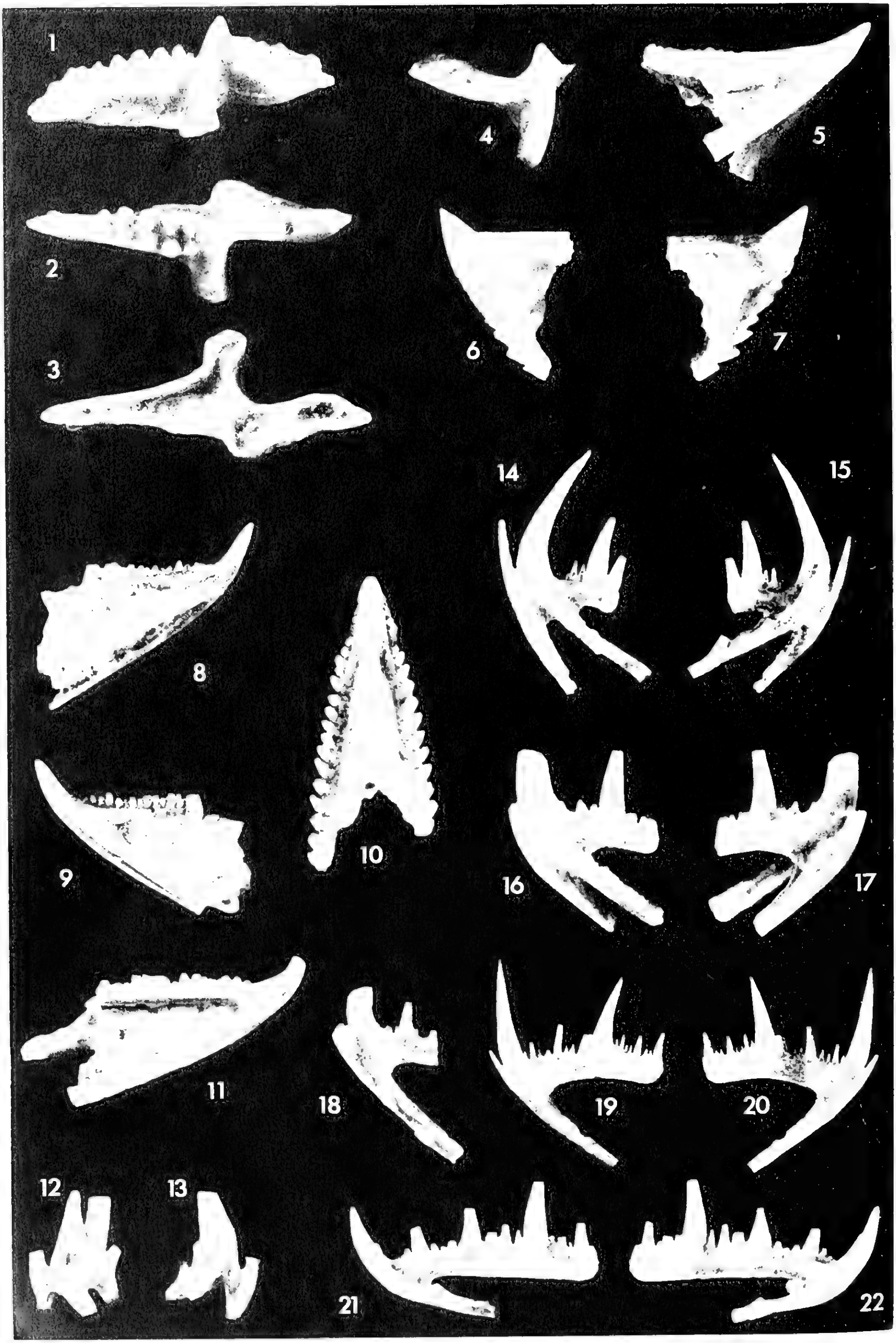
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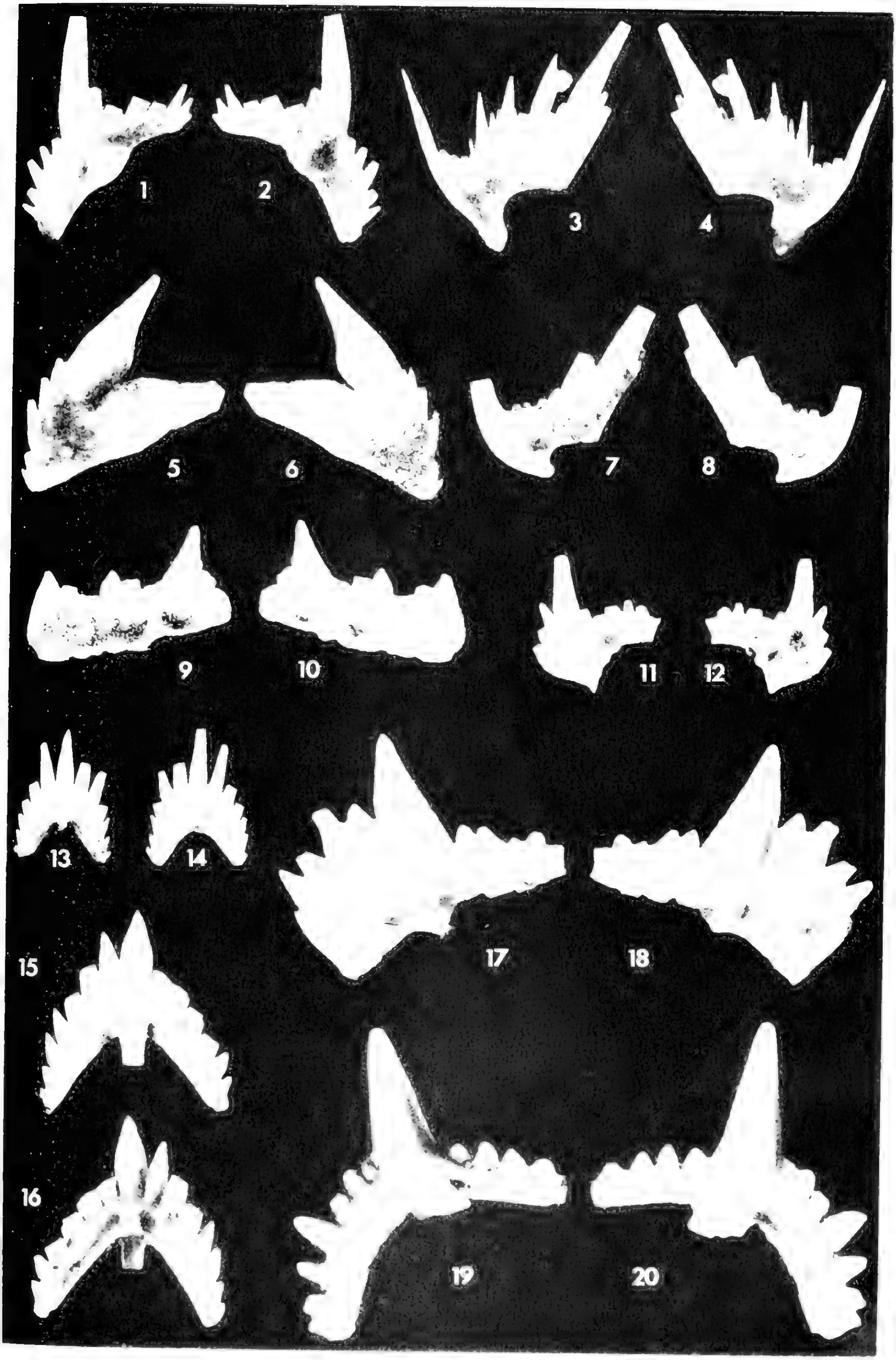
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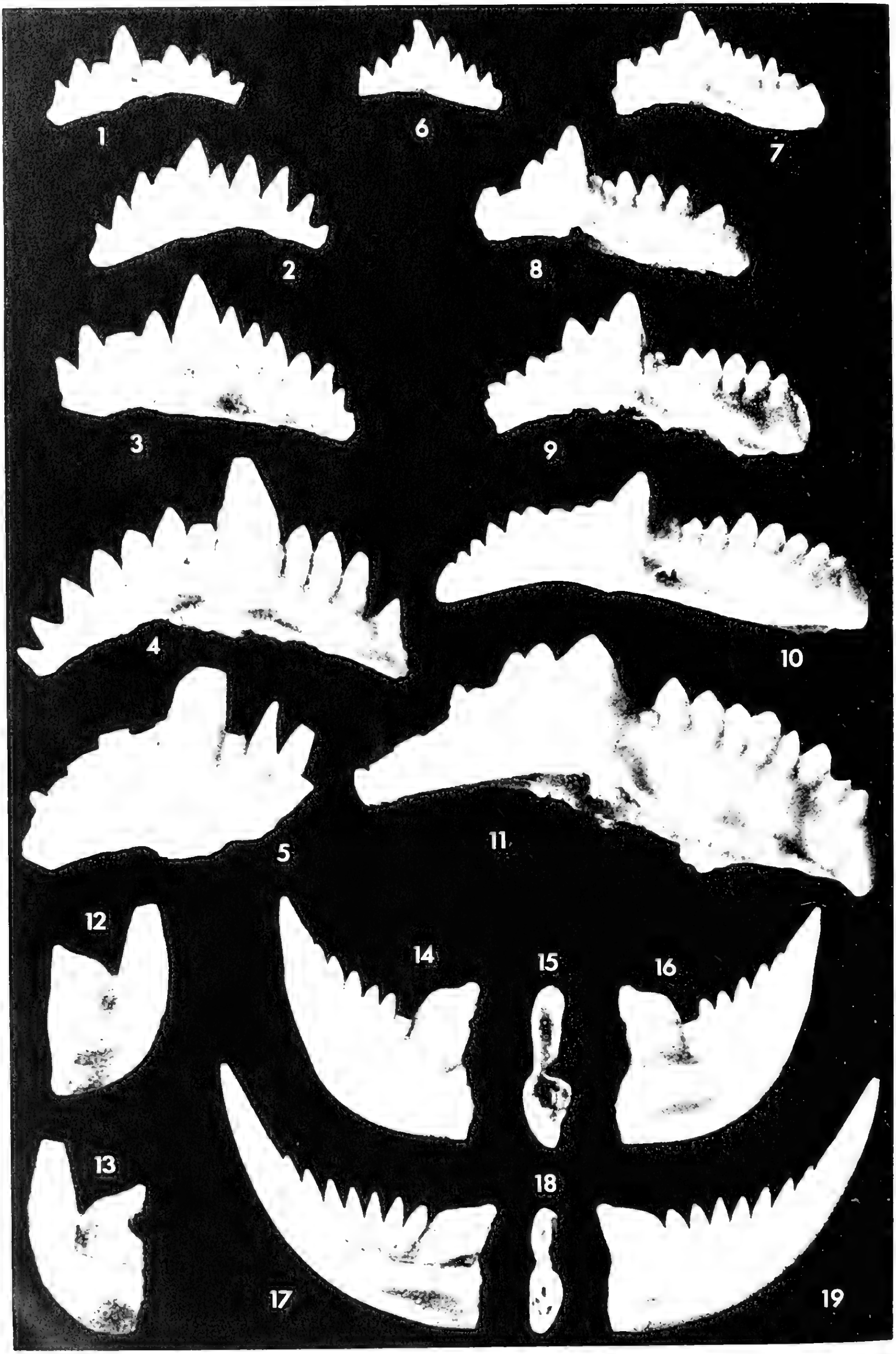
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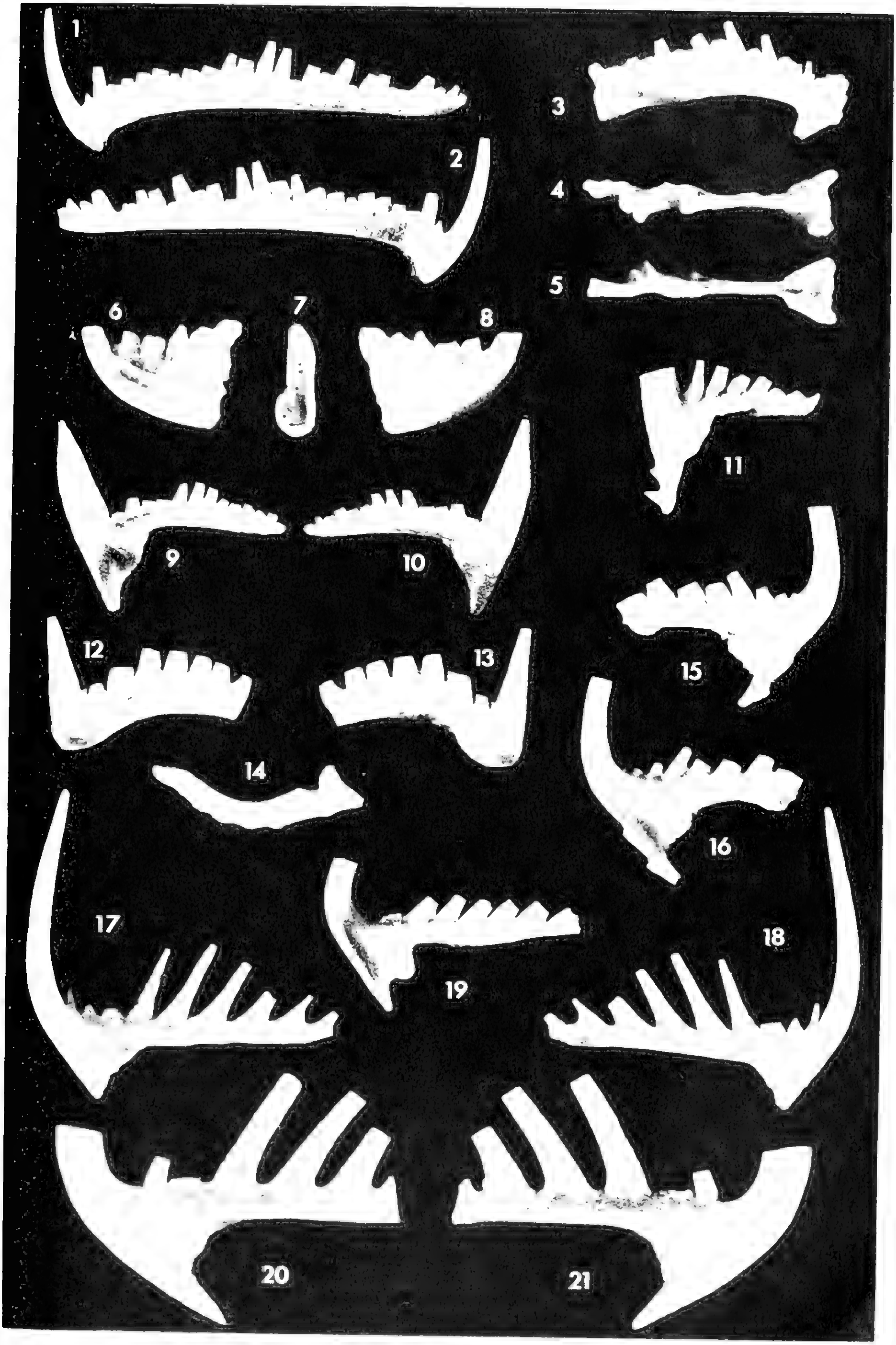
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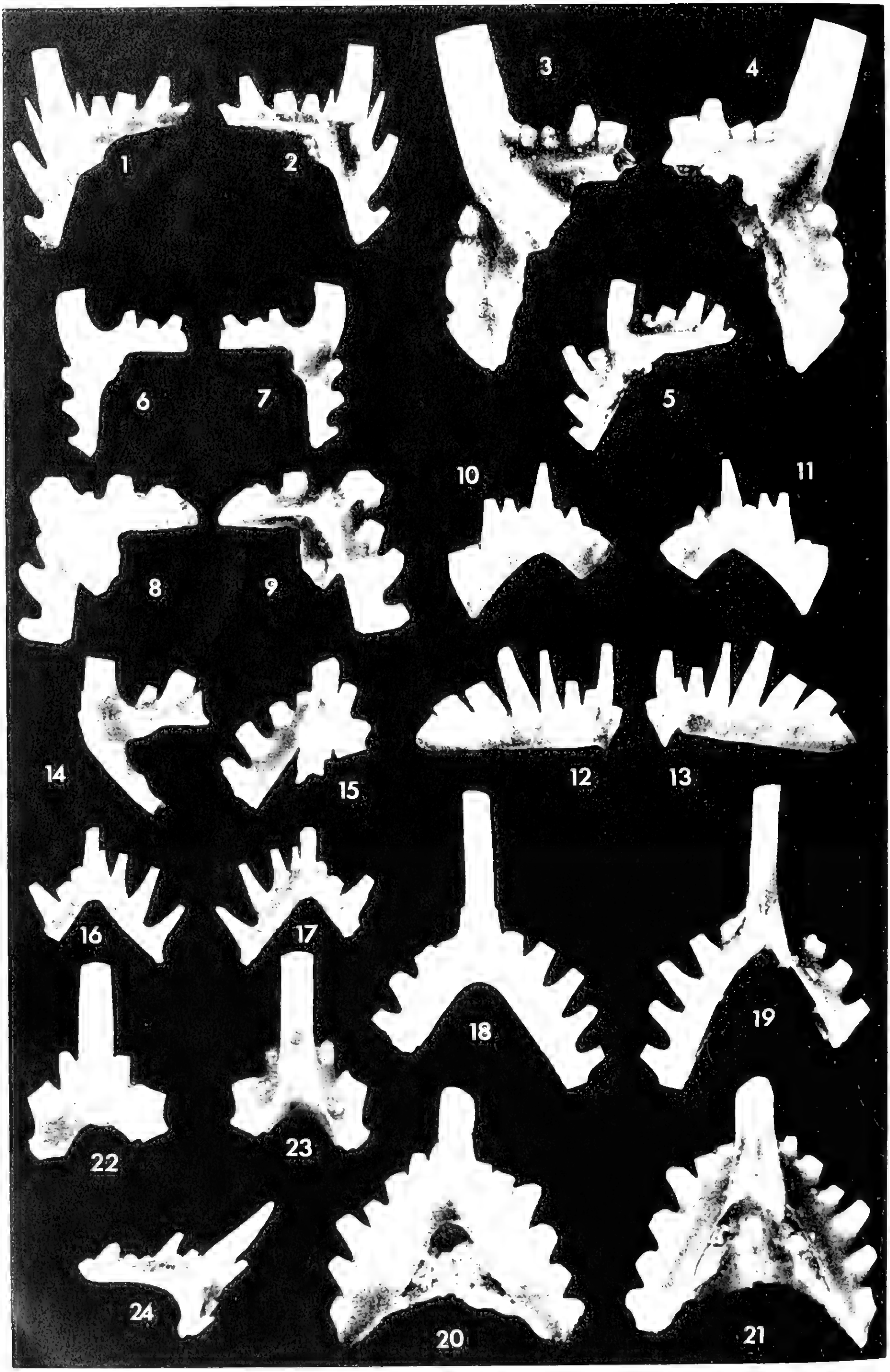
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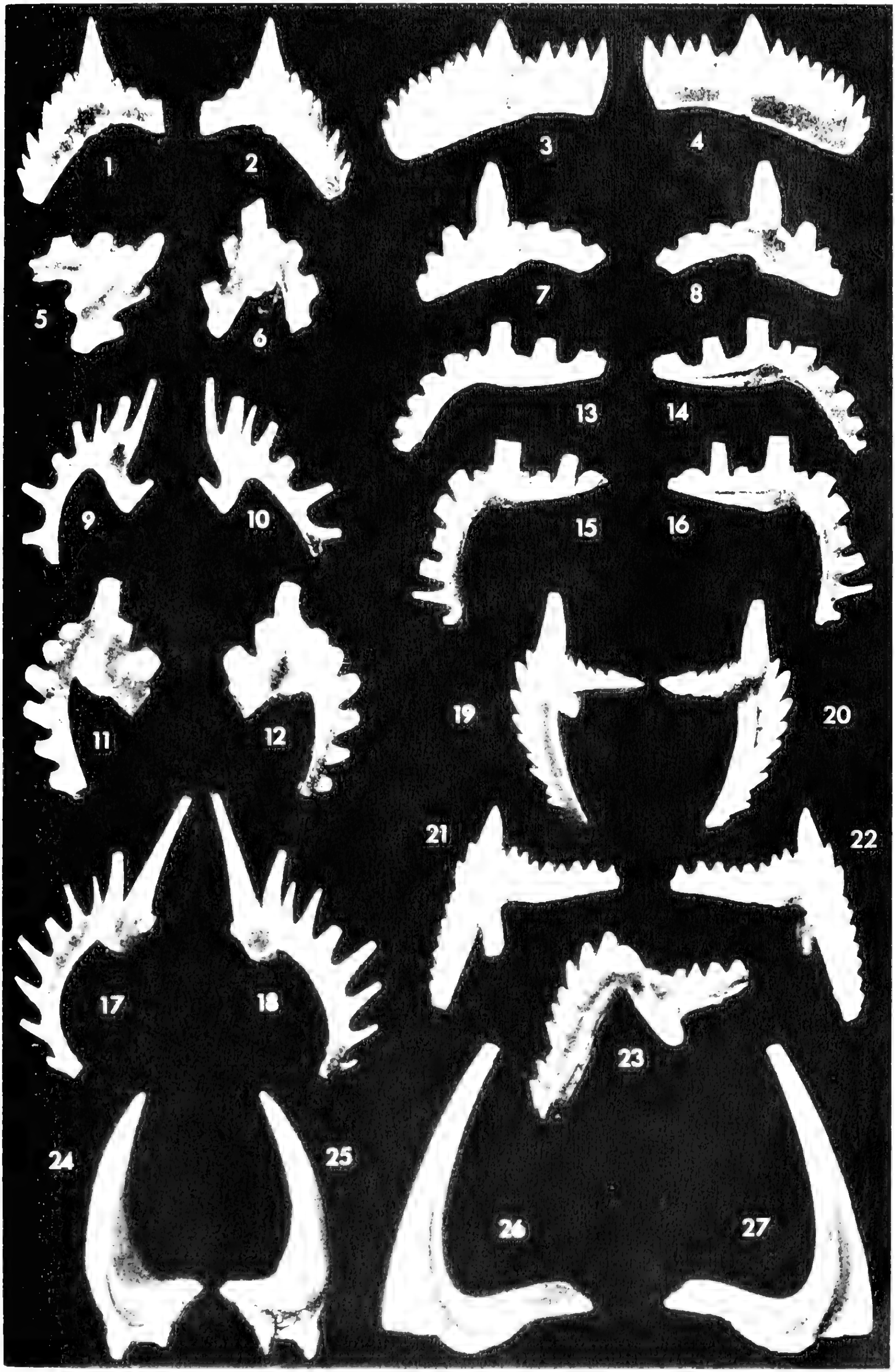
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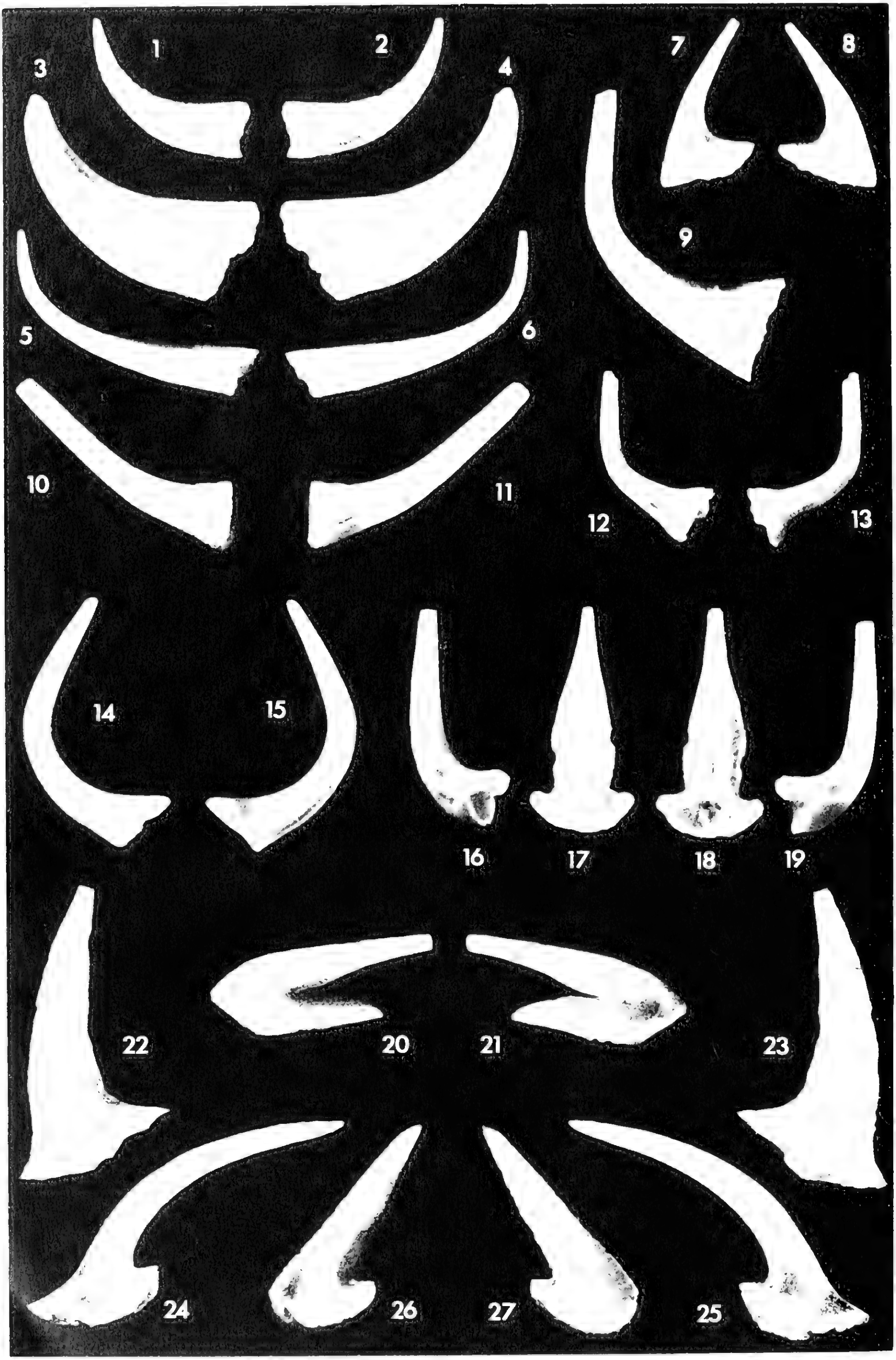
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ARENACEOUS FORAMINIFERA FROM THE WALDRON SHALE (NIAGARAN) OF SOUTHEAST INDIANA

By

WILLIAM A. MCCLELLAN

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ARENACEOUS FORAMINIFERA FROM THE WALDRON SHALE (NIAGARAN) OF SOUTHEAST INDIANA

WILLIAM A. MCCLELLAN
University of Cincinnati*

ABSTRACT

A large and diversified Foraminifera fauna has beeen collected from the Waldron shale of Niagaran age in southeast Indiana and northern Kentucky. A total of 16 genera and 33 species representing three families, Astrorhizidae, Saccamminidae, and Ammodiscidae, was recovered from 11 localities. Of these one new genus, *Sorostomasphaera,* and seven new species are recognized: *Stegnammina contorta, Hemisphaerammina casteri, Metamorphina imbricata, Sorostomasphaera waldronensis, Webbinelloidea hattini, W. globulosa,* and *W. ventriquetra.* Several species are recorded from the Silurian for the first time. *Hyperammina constricta* and *H. casteri* were previously known only from the Mississippian, and *Webbinelloidea hemispherica* from the Devonian. *Hemisphaerammina bradyi* was previously known only as a Recent form.

The Waldron shale fauna can be differentiated from certain other Silurian formations on the basis of the foraminiferal assemblages and relative abundance of certain groups. The present fauna is dominated by the Saccamminidae whereas lower Silurian assemblages are characterized by the abundance of the family Ammodiscidae.

INTRODUCTION

PURPOSE

The present investigation is concerned with the arenaceous Foraminifera occurring in the Waldron shale of southeastern Indiana and northern Kentucky (Middle Silurian: Niagaran series). To study the geographic development of the fauna, samples were taken from ten sites along the outcrop belt of the Waldron in southeastern Indiana and from one locality in northern Kentucky (see Text-figure 1). All 11 localities were extensively sampled and measured, supplementary collections being made at those outcrops exhibiting a diversified lithology.

In addition to extending knowledge of Silurian Foraminifera, particular attention has been paid to their distribution in the Waldron shale. Previous work has largely ignored the stratigraphic aspects, having been usually confined both areally and vertically. Here it is attempted to establish the nature of the faunal assemblages and their ecology, believing that this knowledge can serve as a basis for correlation and environmental studies of related strata.

PREVIOUS WORK

Past American workers have mainly concentrated their studies of Silurian Foraminifera on the limestones of three different areas. The earliest work was done in the Oklahoma-Kansas area by Moreman (1930, 1933) who described a large fauna from Ordovician and Silurian limestones (Arbuckle, Viola, and Chimney Hill limestone, and the Haragan

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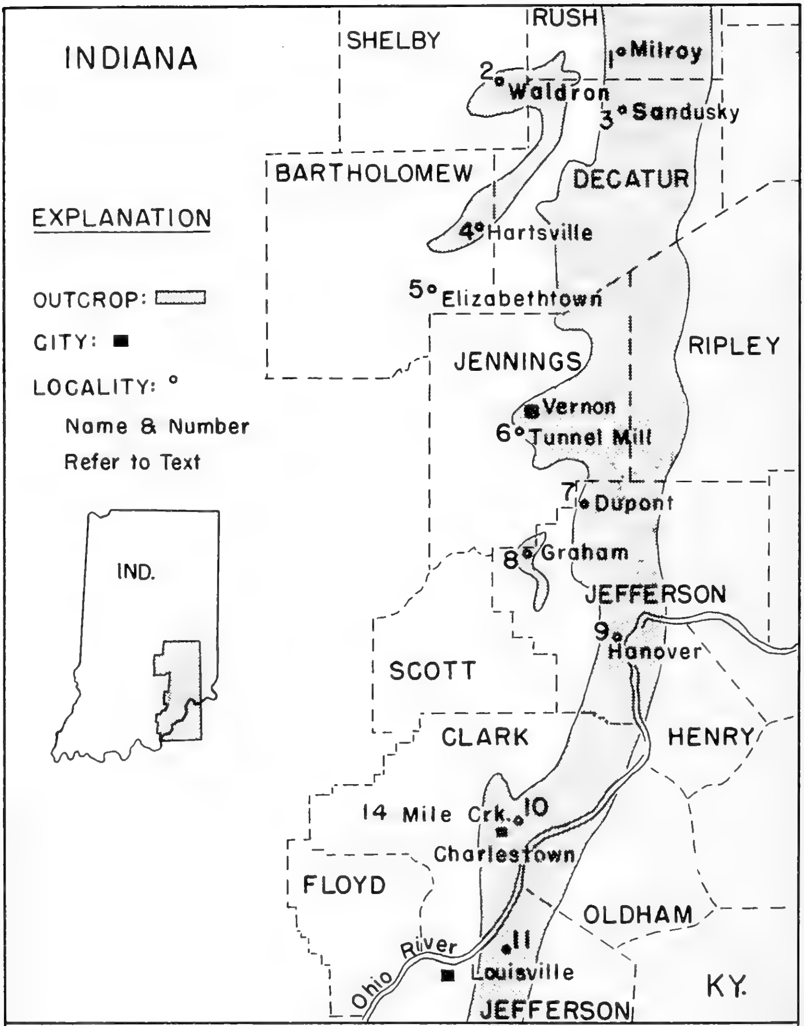

Figure 1: Map of southeastern Indiana and northern Kentucky, showing collecting localities and outcrop of the Waldron Shale.

and Woodford formations). Also from this area were studies by Ireland (1939) on the Silurian and Devonian and by Miller (1956) who attempted to show the index value of Silurian Foraminifera. In the Illinois Basin work (1961) on the Brassfield limestone is the first attempt at establish-stones of Indiana and Ohio have received most of the attention. Mound's work (1961) on the Brassfield limestone is the first attempt at estabishing distributions of the fauna. Other work by Stewart and Priddy (1941), Stewart and Lampe (1947), Raymond (1955), Summerson (1958), and Browne and Schott (1963) were concerned mainly with the taxonomic composition of this fauna. Hattin (1960) did the only previous work on Waldron Foraminifera; his main concern was with populations and ontogenies at three selected localities in southeastern Indiana.

DEPOSITION OF TYPES

All type specimens have been placed in the collections of the Geology Museum, Department of Geology, University of Cincinnati. The abbreviation U.C. has been used with the museum catalog numbers.

ACKNOWLEDGMENTS

The initiation of this study was undertaken at the suggestion of K. E. Caster, Department of Geology, University of Cincinnati, who also encouraged and helpfully criticized the work to its completion. To him the writer is greatly indebted. Dr. D. E. Hattin of the Department of Geology, Indiana University, was most generous with specimens of his work in the same area as well as plates of his type specimens. He also made many helpful suggestions in the paleontological problems encountered with the fauna.

Mrs. Ruth Browne of Louisville, Kentucky, read the manuscript and made helpful suggestions for which the writer is grateful.

The writer is indebted to Charles R. Ringer of the Indiana Geological Survey for recommendations of photographic techniques, and to Ronald L. Parsley, Department of Geology, University of Cincinnati, for many suggestions in photography.

The United States National Museum, The Ohio State University Museum, and Indiana University Museum were generous with the loan of numerous type specimens. Funds to defray the cost of photography and plate production were provided by the Nevin M. Fenneman Fund of the Department of Geology, University of Cincinnati.

STRATIGRAPHY

The Waldron shale has long been famous for its invertebrate fauna. It was first mentioned in the literature by James Hall (1862, pp. 195-228), who described some fossils sent to him from shale beds near Waldron, Indiana. Hall identified the fossils as Niagaran in age (p. 203) and compared them to the Niagaran fauna of New York. For the next 20 years fossil collectors and geologists referred to these blue-gray shales as the Waldron beds, and they became renowned for their diversified and well-preserved fauna.

Elrod (1883, p. 111), in discussing the calcareous shales of Niagaran age in southeastern Indiana, designated the blue-gray fossiliferous upper beds as the "Waldron shale formation". His purpose was to distinguish these shales from lower Niagaran shales which represented the upper part of the Osgood formation as it is presently known. Later Foerste (1897, p. 215) classed the Waldron shale with the underlying Osgood formation and Laurel limestone, and the overlying Louisville limestone as the Niagaran series of Indiana. This classification has continued to the present.

Originally the Waldron shale was recognized only in southeastern Indiana and in the vicinity of Louisville, Kentucky. Hall (1862, p. 228) compared the Waldron to similar fossiliferous beds in Tennessee. However, direct correlation remained undone until Foerste's work in 1935. He proposed the name "Massie clay shale" for Waldron equivalents near Cedarville, Ohio, (p. 153) and extended the Waldron through western Kentucky and into Tennessee southwest of Nashville at Iron City (p. 177) where it had been called the Newsom shale. Thus the Waldron shale outcrops in a band from Greene County, Ohio, westward to Waldron, Indiana, then south through Louisville, Kentucky, and western Tennessee where it is last represented in Lewis and Perry counties (see Text-figure 1).

In the subsurface extension of the formation westward and northward in Indiana, the Waldron changes to an argillaceous and sometimes dolomitic limestone. In the past it has been correlated with the lower part of the Mississinewa shale of northern Indiana (Esary and Bieberman, 1948, p. 7), and thence with the upper part of the Rochester shale of New York where 34 species of the Indiana fauna occur. Pinsak and Shaver (1964, p. 30) restudied these formations and placed the Waldron below the Mississinewa (see Text-figure 2). They traced the former in the subsurface to Illinois, calling it the Waldron formation because it changes from a

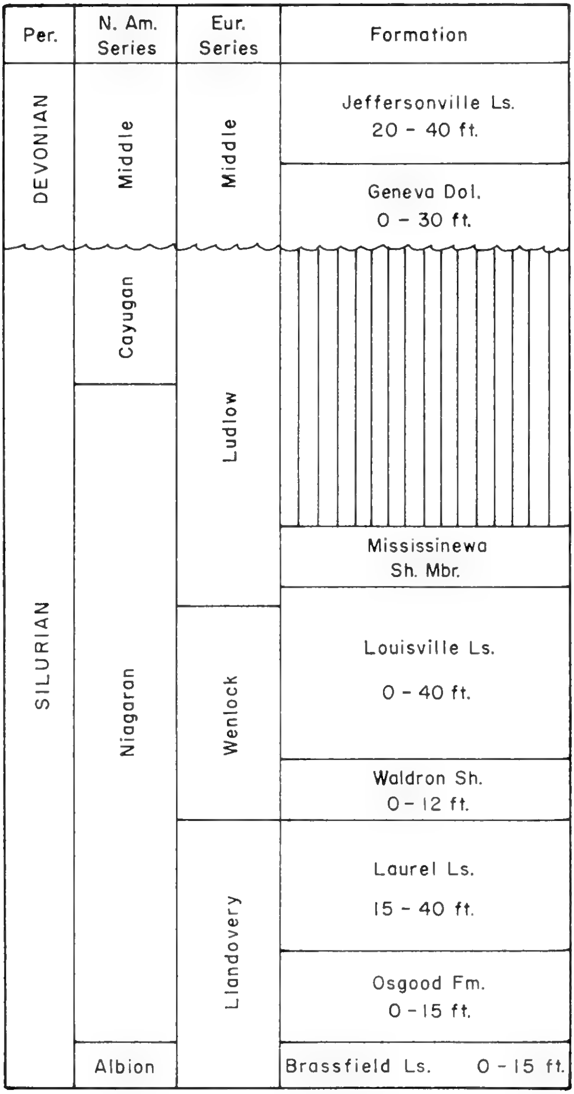

Figure 2: Stratigraphic Column of Silurian Rocks in Southeastern Indiana.

shale to consistent argillaceous limestone. Furthermore they consider it to be of Wenlock age and lying an average 60 feet below the Mississinewa (Ludlow).

The area studied here (Text-figure 1) is only that where the formation is called the Waldron shale. This is the area which has made the Waldron so famous for its invertebrate fauna. One locality in Kentucky is included because of its close relationship to the southernmost Indiana outcrops. The formation here represents a band extending from Milroy, in Rush County, south to Louisville, Kentucky, a distance of about 84 miles and is about 20 miles wide.

The Waldron shale is blue-gray on the fresh surface and weathers to gray or buff. The parting varies from fissile to blocky, the latter condition probably due to a larger percentage of carbonate present. The formation is thinnest in the north and east, being only two to three feet thick. Westward it thickens to approximately eight feet and southward it reaches a maximum of 12 feet at Louisville, Kentucky. Locally there are calcareous zones which contain most of the diversified fauna. Mineralogically the formation is composed of quartz, calcite, dolomite, pyrite, illite, kaolinite, and traces of feldspar (Heele, 1963, p. 13). Though called a shale, silt-sized particles are actually the dominant size fraction. Heele (1963, p. 8) listed weight percentages of the different size fractions. His figures for the localities of this study yielded these average weight percentages: sand=1.90%, silt=68.17%, clay=29.93%. The pyrite contained is an important constituent in this area according to Heele (p. 12) who considered it to be of two types (p. 45), authigenic and reworked authigenic.

LOCALITIES

Indiana

1. Milroy, on the east side of Little Flat Rock Creek 150 yards south of bridge at the west edge of town: NE¼ NW¼ NW¼ sec 13, T12N, R9E, Rush County. Here the Waldron is 2.5 feet thick and above the Laurel which constitutes the stream bed and is covered by Geneva dolomite.
2. Waldron, below the stone quarry on the west bank of Conn's Creek 200 yards downstream from the mouth of Deer Creek: SE¼ SW¼ NE¼ sec 6, T11N R8E, Shelby County. The Waldron here is only 3.5 feet thick in an unfossiliferous area and rests on the Laurel with the Geneva dolomite above.

3. Sandusky, in quarry ½ mile east of town on south side of road: SE¼ NE¼ NW¼ sec 12, T11N, R9E, Decatur County. Exposure of Waldron at top of quarry with 8 feet of section and supplementary section nearby of the basal 2.5 feet, highly fossiliferous. Quarry in the Laurel limestone with Geneva overlying the Waldron.

4. Hartsville, 100 yards below Anderson Falls on Fall Fork of Clifty Creek: SW¼ NE¼ SW¼ sec 12, T9N, R7E, Bartholomew County. Base of Waldron in stream bed, thickness approximately 5 feet with Geneva above.

5. Elizabethtown, in Meshberger Quarry northwest of town on a local road: NE¼ sec 6, T8N, R7E, Bartholomew County. Only the topmost 2.5 feet of the Waldron is exposed at the base of the quarry and it is overlain by the Louisville limestone.

6. Tunnel Mill, about one mile south of Vernon, west of State Highway 3 on Muscatatuck River, a stream cut tunnel by an old mill: SW¼ sec 11, T6N, R8E, Jennings County. Waldron 4.1-4.5 feet thick in tunnel with Laurel beneath and Louisville above. Several calcareous lenses, extensively sampled.

7. Dupont, on State Highway 7 just south of town, opposite north end of cemetery, in creek on west side of the road: NE¼ SE¼ SE¼ sec 9, T5N, R9E, Jefferson County. Three feet of Waldron are exposed in the creek bank overlain by Jeffersonville (?) limestone with the stream bed on the top of the Laurel.

8. One-quarter mile northeast of Graham and 3.8 miles east of Deputy, below cemetery, on Big Camp Creek: N½ SW¼ sec 13, T4N, R8E, Jefferson County. Waldron partly covered, approximately 4 feet thick with Laurel below and overlain by the Geneva.

9. Hanover, beneath small falls of creek along Cemetery Road: NE¼ SW¼ SE¼ sec 12, T3N, R9E, Jefferson County. Exposure of 2.5 feet of Waldron with Laurel limestone below and Jeffersonville (?) above.

10. Fourteen Mile Creek, north of Charlestown on State Highway 62: C SEL S¼ Grant 121, T1S, R8E, Clark County. Exposure in long roadcut with 12.5 feet of Waldron with the Laurel beneath and overlain by Louisville limestone.

Kentucky

11. Louisville, Jefferson County, on U.S. Highway 42, four miles east of the city limits. Exposure in roadcut of 12 feet of Waldron shale with Laurel below and Louisville limestone above.

FAUNA

As mentioned above, the Waldron shale contains an abundant and diversified fauna. The macrofossils occur in limestone lenses or biostromes which are local and indeterminant in extent. Complete faunal lists have been published, so only mention of some of the most common genera is made here: corals—*Zaphrentis, Favosites*; Bryozoa—*Fistulipora, Ceramopora, Fenestella*; crinoids—*Eucalyptocrinites, Macrostylocrinus;* brachiopods—*Camarotoechia, Meristina, Atrypa, Uncinulus, Leptaena, Spirifer*; gastropods—*Platyostoma*; cephalopods—*Orthoceras*; trilobites—*Calymene, Lichas, Dalmanites.* The microfauna is here presented for the first time in detail. Hattin (1960, p. 2016) listed many of the forms found in a study of three selected localities. His results are currently in preparation and should add materially to the Silurian Foraminifera as he recovered large numbers of the common species and also many rare forms.

Silurian Foraminifera have so far all been found to be arenaceous forms. The few Ordovician forms known often carry over to the Silurian and even beyond in some instances. No particular species can be considered as an index form any closer than to a series. Therefore, the stratigraphic correlations which can be made should be done on comparisons of characteristic assemblages. In this manner Mound (1961, p. 14) characterized the Brassfield limestone of southern Indiana on the dominance of the fauna by the family Ammodiscidae. Likewise the Osgood formation can be determined by the abundance of particular forms when they occur together (individuals have a greater range). During the present study the microfauna of one locality proved to be the only definitely reliable identifying feature, showing the outcrop to be an Osgood shale zone with a typical foraminiferal assemblage (Browne and Schott, 1963, Table 1).

The fauna here recovered is dominated by the family Saccamminidae and to a lesser extent by the Astrorhizidae. Because this is the same characteristic dominance as that which occurs in the Osgood formation, further consideration must be made of which forms occur and their relative abundances. The Osgood saccamminids are especially represented by many species of *Thurammina* and *Lagenammina*, members of the subfamily Saccammininae. The Waldron saccamminids are characterized by the following members of the Hemisphaeramminae: *Hemisphaerammina, Metamorphina, Colonammina,* and *Webbinelloidea.* The Osgood hemisphaeramminids are *Tholosina, Amphicervicis,* and *Metamorphina.* Therefore, the microfaunas of the Osgood and Waldron shale formations can be separated by the assemblages of Table 1.

In addition to these species the abundance of *Ammodiscus* and *Lituotuba* species in the total fauna of the Osgood is characteristic. These genera are relatively uncommon in the Waldron but *Sorosphaera* is abundant which is not the case in the Osgood.

Table 1. Waldron and Osgood Assemblages, Characteristic Species

Waldron Shale	Osgood Formation
Hemisphaerammina bradyi	*Thurammina elliptica*
Hemisphaerammina discoidea	*Thurammina slocomi*
Hemisphaerammina casteri	*Thurammina irregularis*
Sorostomasphaera waldronensis	*Tholosina acuta*
Colonammina verruca	*Tholosina corniculata*
Webbinelloidea hemispherica	*Tholosina rostrata*
Webbinelloidea hattini	*Lagenammina perryi*
Hyperammina casteri	*Lagenammina acuta*
Hyperammina constricta	*Lagenammina sphaerica*
	Hyperammina compressa
	Hyperammina conica
	Hyperammina harrisi
	Hyperammina deminutionis

The distribution of the present fauna of the Waldron in the area studied here is shown on Table 2. The symbols are based on the following scale: Rare—1 or 2 specimens; Uncommon—3 to 6 specimens; Common—7 to 15 specimens; Abundant—over 15 specimens. Table 3 shows their stratigraphic and geographic distribution in North America.

Several species recovered from the Waldron shale have not previously been recorded from rocks of Niagaran age. One, *Hemisphaerammina bradyi* Loeblich and Tappan (1957), was previously known only from the Recent. Table 4 shows the past ranges and the extensions from this study.

Table 2: Abundance and Distribution of Species in Studied Area

R=Rare, U=Uncommon, C=Common, A=Abundant

Species	Occur.	Localities										
		1	2	3	4	5	6	7	8	9	10	11
Ammodiscus exsertus	U									3		
Bathysiphon exiguus	A	2		2	1		4			2	18	
Colonammina verruca	R						1					
Hemisphaerammina bradyi	A			6	1	3	6					
Hemisphaerammina casteri	R						2					
Hemisphaerammina discoidea	U			1	2					2		
Hyperammina casteri	A	8		11			4			4	11	1
Hyperammina constricta	R						1					
Hyperammina curva	C	1		5						1	1	
Lagenammina cumberlandiae	R			1								
Lagenammina sp. A	R			1								
Lituotuba ? elongata	R										1	
Metamorphina gibbosa	C			1	2			1		2	1	
Metamorphina imbricata	C	1			1		2	4				
Metamorphina tholus	A			2		4	8			1		2
Psammonyx campbelli	R									1		
Psammosphaera cava	A			23	1	6	47		1			
Sorosphaera bicella	C			1	2		5		2			3
Sorosphaera confusa	U					1	2					
Sorosphaera osgoodensis	R						1					
Sorosphaera tricella	C			1			10					1
Sorostomasphaera waldronensis	C				2		6					
Stegnammina contorta	R						2					
Stegnammina cylindrica	U			4			2					
Stomasphaera brassfieldensis	R					1						
Thurammina arcuata	R			1			1					
Thurammina cf. T. coronata	R			1								
Thurammina jubata	R				1							
?Thurammina sp.	R					1						
Webbinelloidea globulosa	R			1			1					
Webbinelloidea hattini	U						4					2
Webbinelloidea hemispherica	C			1	1	1	5					
Webbinelloidea ventriquetra	R						2					

Table 3: Stratigraphic & Geographic Distribution of Waldron Species	Viola (Ord.), Okla.	Brassfield, Ind.	Brassfield, Mo., Ill.	Chimney Hill, Okla.	Osgood, Ind.	Osgood, Mo., Ill., Tenn.	Dayton, Ohio	Laurel, Ind., Ohio	Waldron, Ind.	Massie, Ohio	Joliet, Ill.	Bainbridge, Mo.	Henryhouse, Okla.	Devonian	Mississippian	Pennsylvanian	Permian	Jurassic	Cretaceous	Recent
Astrorhizidae																				
Bathysiphon exiguus	X	X	X	X	X	X		X	X				X							
Hyperammina casteri									X						X					
Hyperammina constricta									X						X					
Hyperammina curva		X		X	X	X			X			X		X	X					
Saccamminidae																				
Colonammina verruca				X					X											
Hemisphaerammina bradyi									X											X
Hemisphaerammina casteri									X											
Hemisphaerammina discoidea									X					X						
Lagenammina cumberlandiae					X	X			X						X					
Lagenammina sp. A									X											
Metamorphina gibbosa				X	X				X											
Metamorphina imbricata									X											
Metamorphina tholus	X				X				X						X					
Psammosphaera cava		X	X	X	X	X			X			X	X	X	X					
Sorosphaera bicella		X	X		X			X	X	X	X	X	X	X						X
Sorosphaera confusa		X				X			X											X
Sorosphaera osgoodensis		X			X	X			X	X				X						
Sorosphaera tricella		X		X	X			X	X	X		X								
Sorostomasphaera waldronensis									X											
Stegnammina contorta									X											
Stegnammina cylindrica		X	X	X	X				X					X						
Stomasphaera brassfieldensis		X							X											
Thurammina arcuata				X	X				X		X									
Thurammina cf. T. coronata					X				X			X								
Thurammina jubata									X		X									
?Thurammina sp.									X											
Webbinelloidea globulosa									X											
Webbinelloidea hattini									X											
Webbinelloidea hemispherica									X					X						
Webbinelloidea ventriquetra									X											
Ammodiscidae																				
Ammodiscus exsertus		X		X	X	X	X		X		X	X			X					X
Lituotuba? elongata					X	X			X											
Psammonyx campbelli					X				X											

Table 4. Stratigraphic Range of Species from the Waldron Shale

Species	Previous	Present
Colonammina verruca	L. Sil.	L.—M. Sil.
Hemisphaerammina bradyi	Recent	Sil., Recent
Hemisphaerammina discoidea	Devonian	M. Sil.—Dev.
Hyperammina casteri	Miss.	M. Sil.—Miss.
Hyperammina constricta	Miss.	M. Sil.—Miss.
Lituotuba? elongata	Osgood Fm.	Osgood—Waldron
Metamorphina gibbosa	L. Sil.	L.—M. Sil.
Psammonyx campbelli	Osgood Fm.	Osgood—Waldron
Stomasphaera brassfieldensis	L. Sil.	L.—M. Sil.
Webbinelloidea hemispherica	Devonian	Sil.—Dev.

PALEOECOLOGY

The composition of the Waldron shale is not sufficiently varied to allow definite comparisons of distinctive faunas and environments. The calcareous lenses which have been mentioned contain sufficient amounts of argillaceous material to make strict environmental comparisons with the shale portion usually difficult. Some comparisons can be made by the relative abundance of species in one environment or the other.

The stratigraphy of the Waldron shale indicates a deepening and "cleaning up" of conditions toward the west and northwest. In southeast Indiana conditions were probably moderately shallow marine with slow sedimentation in a low energy environment. With a dominance of silt-sized particles in the formation deposition was not too far offshore, but sufficiently distant to have had little effect from wave action and near-shore currents. Where the calcareous lenses occur may have been the paths of bottom currents which could be responsible for the decrease in mud and more optimum conditions for the survival of the micro-fauna and macro-fauna that is preserved.

Salinity of the environment was probably near normal. The presence of authigenic pyrite indicates a possibility of low pH but that could also be attributed to post depositional conditions. Further evidence of secondary changes is afforded by the increased carbonate content of the uppermost 12-18 inches of the formation. This was evident at every locality regardless of the formation's thickness, overall composition, or the overlying beds. Heele (1963, p. 17) found a relatively high percentage of dolomite present in the silt-sized fraction throughout southeast Indiana. He found that 43.53% of this size fraction was represented by quartz (8.08%), calcite (14.81%), and dolomite (20.64%). That much dolomite is probably due to secondary dolomitization and substantiates the probability of secondary carbonate enrichment in the uppermost zone as well as post depositional pyrite development. Thus the present composition of the Waldron shale does not indicate the actual conditions under which the organisms thrived during Waldron time.

A few forms appear to have a preference for different energy conditions or a distinct tolerance for varying conditions. Tables 5 and 6 list the species with their apparent preferences as determined from the rock type from which they were most often recovered and their relative abundance.

Only one, *Hyperammina constricta,* appears to have preferred a higher energy environment. It occurs in a calcareous lens at locality 6 which is only slightly argillaceous. Its only other known occurrence is in the Mississippian Rockford limestone of northern Indiana (Gutschick and Treckman, 1959, p. 237).

Metamorphina Browne (1963 *in* Browne and Schott) was commonly found in the shale samples and infrequently in calcareous zones. *Hyperammina casteri* also preferred lower energy, muddy conditions where it was often the dominant foraminifer. It is also characteristic of the shales in the Lower Mississippian. *Bathysiphon exiguus* has previously been recorded from several limestone formations but, as represented in the Waldron shale, is definitely a low energy type where it often occurs in conjunction with *Hyperammina casteri.*

One of the most tolerant forms is *Sorosphaera* Brady (1879) which is represented by several species throughout the formation in all types of conditions. The two species of *Stegnammina* Moreman (1930) can tolerate mixed energy conditions, though *S. contorta* did apparently need coarser grained material for its test. *Sorostomasphaera waldronensis* was found in varied conditions, probably preferring an argillaceous limestone where it most frequently occurred. *Psammosphaera cava* is distinctive by its high tolerance. It was recovered from samples of all energy conditions and in some instances was the only foraminifer present.

Table 5. Low Energy Environment Species

Species	Remarks
Ammodiscus exsertus	
Bathysiphon exiguus	abundant in this environment
Hemisphaerammina casteri	
Hyperammina casteri	dominant in this environment
Hyperammina curva	
Lagenammina cumberlandiae	only found here
Lagenammina sp. A	
Lituotuba? elongata	
Metamorphina gibbosa	can tolerate carbonate
Metamorphina imbricata	
Metamorphina tholus	
Psammonyx campbelli	
Thurammina arcuata	
?*Thurammina* sp.	
Webbinelloidea globulosa	

Table 6. Mixed Energy Environment Species

Species	Remarks
Colonammina verruca	
Hemisphaerammina bradyi	prefers more shaly conditions
Hemisphaerammina discoidea	prefers more carbonate
Psammosphaera cava	very tolerant
Sorosphaera bicella	
Sorosphaera confusa	
Sorosphaera osgoodensis	
Sorosphaera tricella	
Sorostomasphaera waldronensis	probably prefers argil. carb.
Stegnammina contorta	needs access to larger grains
Stegnammina cylindrica	
Stomasphaera brassfieldensis	
Thurammina cf. *T. coronata*	
Thurammina jubata	needs coarse material
Webbinelloidea hattini	only in U. Waldron
Webbinelloidea hemispherica	only in U. Waldron
Webbinelloidea ventriquetra	only in U. Waldron

SYSTEMATIC PALEONTOLOGY

Order FORAMINIFERA Eichwald, 1830

Suborder TEXTULARIINA Delage and Herouard, 1896

Superfamily **AMMODISCACEA** Reuss, 1862

Family **ASTRORHIZIDAE** Brady, 1881

Subfamily **RHIZAMMININAE** Rhumbler, 1895

Genus **BATHYSIPHON** M. Sars, 1872

1872. *Bathysiphon* M. Sars *in* Sars, Vidensk.-Selsk. Christiania, Forhandl., vol. 1871, p. 251.
1881. *Rhabdamminella* de Folin, Soc. d'Histoire Nat. Toulouse, Bull., vol. 15, p. 140 (*nom. nud.*).
1913. *Arbathysiphum* Rhumbler, Die Foraminiferen der Plankton-Expedition, Pt. 2 Systematik, vol. 3, Lief. c, p. 352 (*nom. van.*).
1932. *Hippocrepinella* Heron-Allen and Earland, Jour. Royal Micro. Soc. London, vol. 52, p. 257.
1939. *Arenosiphon* Grubbs, Jour. Paleont., vol. 13, No. 6, p. 544.
1959. *Arenosiphon* Grubbs, Cushman, *Foraminifera,* 4th ed., p. 74.
1959. *Hippocrepinella* Heron-Allen and Earland, Cushman, *ibid.*, p. 74.

Type species.—Bathysiphon filiformis M. Sars (1872, *ibid.*, p. 251).

The original description is incomplete. Cushman's redescription (1910, p. 30) is as follows: Test free, cylindrical, sometimes tapering toward one end, straight or somewhat curved, often externally constricted, but without corresponding divisions of the tubular chamber internally, wall composed of sponge spicules overlaid by a varying thickness of what appears to be siliceous cement, wall thick in comparison with the diameter of the tube.

This is a genus which is of apparently primitive nature and has survived from the Lower Cambrian to Recent. It appears to be most closely related to *Rhizammina* Brady (1879), a cosmopolitan Recent form, but is differentiated by having a nonbranching, tubular test.

Arenosiphon Grubbs (1939) was established by him (p. 544) for forms found in Silurian rocks near Chicago, Illinois. He differentiated it from other rhizamminids on the basis of its large size and use of apparently only quartz grains in forming the test. He felt that similar forms from the Silurian, previously referred to *Bathysiphon.* should also belong under *Arenosiphon.* Because his primary difference from other genera was based only on test material and not on any definite morphological features, *Arenosiphon* is considered to be congeneric with *Bathysiphon.*

The Recent Arctic and Antarctic form, *Hippocrepinella* Heron-Allen and Earland (1932), is also congeneric with *Bathysiphon.* Loeblich and Tappan (1964, p. 186) stated the similarities of these two forms.

> *Hippocrepinella* was defined as having slightly constricted apertures and a smoothly finished, transversely wrinkled wall. None of these characters serve to separate it from *Bathysiphon.* Furthermore, sectioned specimens of *Hippocrepinella* described by Heron-Allen and Earland (1932, p. 258) showed a cavity "more or less completely filled with an ingested mass of foodstuffs, principally diatoms, and it depends upon the compactness of this mass whether the test preserves its compression." This seems also to indicate congeneric status with *Bathysiphon,* since these filled sections were probably discarded waste-filled sections of the test, similar to those described in the type species of *Bathysiphon.* The "apertural constrictions" may be due to contraction of the semiflexible test when dried.

Bathysiphon exiguus Moreman Pl. 36, figs. 1-5; Pl. 40, figs. 1-5

1930. *Bathysiphon exiguus* Moreman, Jour. Paleont, vol. 4, No. 1, p. 46, pl. 6 fig. 8.

Description—Test free, cylindrical, straight; wall thin, usually finely arenaceous, well cemented; apertures at open ends of the tubular test.

Measurements—Fourteen measured specimens varied in length from 0.42 mm. to 0.94 mm. and in diameter from 0.08 mm. to 0.16 mm. Average length was 0.60 mm. and diameter 0.12 mm. Two exceptional specimens from locality 6 measured 1.04 mm. by 0.28 mm. and 0.84 mm. by 0.26 mm. respectively. Figured specimens had the following measurements:

	U. C. Number	Length	Diameter
Pl. 36, fig. 5 Pl. 40, fig. 5	37781	0.63 mm.	0.10 mm.
Pl. 36, fig. 2 Pl. 40, fig. 2	37782	0.72 mm.	0.12 mm.
Pl. 36, fig. 3 Pl. 40, fig. 3	37783	0.44 mm.	0.12 mm.
Pl. 36, fig. 1 Pl. 40, fig. 1	37784	1.04 mm.	0.28 mm.
Pl. 36, fig. 4 Pl. 40, fig. 4	37785	0.84 mm.	0.26 mm.

Occurrence—Abundant, 29 specimens; localities 1, 3, 4, 6, 9, 10: U. C. 37781 locality 10; U. C. 37784; U. C. 37785 locality 6; U. C. 37783 locality 9.

Discussion—Some broken specimens resemble *Hyperammina curva* (Moreman), 1930, a common and widespread Silurian form, if the initial part of the latter's test is missing. Hence, there is some difficulty in recognizing the proper genus for some specimens.

The two exceptional specimens mentioned above are the only ones coming from the uppermost Waldron, in a calcareous lens, at locality 6—Tunnel Mill. In addition to their large size, they have utilized coarser material and little cement in test construction which gives a rough surface texture. The test wall is thin for the size of the specimens and more delicate than those from other localities. *Bathysiphon rugosus* Ireland (1939), from the Oklahoma Silurian, resembles these two specimens and is characterized by its rough surface, coarser grains, thin wall, and somewhat constricted sides. Mound (1961, p. 36) considered it synonymous with *B. exiguus.* Browne and Schott (1963, p. 233) tentatively retained Ireland's species distinguishing their specimen from *B. exiguus* on the larger sand grains of the test. The two specimens questioned here are likewise more coarsely arenaceous, and resemble *B. rugosus* except in the constricted test of that species. They have been considered a *B. exiguus* with their variations due to the environment in which they lived. Modern species of the genus vary considerably according to their habitat, and this was probably also the case with these specimens.

Subfamily **HIPPOCREPININAE** Rhumbler, 1895

Genus **HYPERAMMINA** Brady, 1878

Emend. Conkin, 1961

1878. *Hyperammina* Brady, Ann Nat. Hist., ser. 5, vol. 1, pp. 433-434 (*fetae*).
1913. *Arhyperammum* Rhumbler, Die Foraminiferen der Plankton-Expedition, Pt. 2 Systematik, vol. 3, Lief. c, p. 351 (*nom. van.*).
1928. *Hyperamminoides* Cushman and Waters, Cushman Lab. Foram. Res. Contr., vol. 4, p. 112.
1930. *Hyperamminoides* Cushman and Waters, Cushman and Waters, Univ. Texas Bull. 3019, p. 35.
1933. *Hyperamminoides* Cushman and Waters, Galloway, *A Manual of Foraminifera,* p. 75.
1945. *Hyperamminoides* Cushman and Waters, Plummer, Univ. Texas Pub. 4401, p. 223.
1959. *Hyperamminoides* Cushman and Waters, Cushman, *Foraminifera,* 4th ed., p. 86.

Type species—Hyperammina elongata Brady (1878, *ibid.,* pl. 20, figs. 2a,b).

Conkin (1954, pp. 167, 168) discussed the relationships of *Hyperammina* Brady (1878) and *Hyperamminoides* Cushman and Waters (1928) and presented an updating of Brady's original description. Later (1961, p. 254) he formally emended the generic description. His 1954 summary (p. 167) of Brady's description follows:

> Brady considered *Hyperammina* to have: an arenaceous test, free or adherent, with an elongate, tubular, singular or branching, second chamber; aperture open or slightly constricted; interior smooth; exterior roughly or smoothly finished with test tapering toward aperture; and a proloculus of varying bulbosity and shape.

Conkin formally emended the description in 1961 (p. 254) by proposing his 1954 discussion as a generic revision with three additional features which had been introduced informally before (1954, p. 168):

> (1) the second chamber may be nontapering, may taper towards the proloculus, or in a few species taper toward both the aperture and the proloculus ("hourglass tapering"); (2) aperture may be moderately or strongly constricted; and (3) exterior may be marked by transverse constrictions of varying strength.

The above generic concept is followed herein rather than that of Loeblich and Tappan (1964, p. 190). Neither author considered *Hyperamminoides* Cushman and Waters, 1928 (type species, *H. elegans* from the Pennsylvanian of Texas) as a separate genus. Loeblich and Tappan (p. 189) placed it under *Hippocrepina* Parker (1870) on the basis of its similarly flaring test and small proloculus. Conkin (1961, p. 255) regarded *Hyperamminoides* as synonymous with *Hyperammina* because Cushman and Waters' original description of their genus was based on siliceous cement and a more tapering test, which he considered as insufficient evidence. Conkin further doubted the correctness of *Hyperamminoides* having only siliceous cement. In addition he deemed the more tapering test and small proloculus to be only of specific value.

Hyperammina casteri Conkin Pl. 36, figs. 9, 10; Pl. 40, figs. 9, 10

1961. *Hyperammina casteri* Conkin, Bull. Amer. Paleont., vol. 43, No. 196, p. 260, figs. 6, 7, pl. 20, figs. 1-18, pl. 26, figs. 7, 8.

Description—Test free, proloculus of varying shape, usually oblate to spherical, followed by straight second chamber which expands gradually from a constriction near the proloculus to a diameter greater than the proloculus; wall thick to thin, finely arenaceous, well cemented; aperture terminal on second chamber. Microspheric forms differ in having a small, pointed proloculus and a rapidly expanding second chamber giving the general appearance of an elongated cone.

Measurements—Test lengths for ten measured megalospheric forms ranged from 0.37 mm. to 0.82 mm. with an average of 0.54 mm. Proloculus diameters at apertural end ranged from 0.10 mm. to 0.26 mm., averaging 0.16 mm. Eleven measurable microspheric forms had lengths ranging from 0.32 mm. to 1.00 mm. and an average of 0.50 mm.; proloculus diameters ranged from 0.03 mm. to 0.16 mm., averaging 0.06 mm. (mode of 0.04 mm. for four specimens); apertural end diameters ranged from 0.10 mm. to 0.24 mm., averaging 0.15 mm.

Figured megalospheric form U. C. 37787 is 0.48 mm. long, 0.08 mm. at proloculus, 0.10 mm. at apertural end. Microspheric form U. C. 37786 is 0.46 mm. long, 0.04 mm. proloculus, and 0.13 mm. at apertural end.

Occurrence—Abundant, 38 specimens of which 13 were identifiable as definite microspheric forms and 20 as megalospherics; localities 1, 3, 6, 9, 10, 11—U. C. 37787 from locality 9 and U. C. 37786 from locality 3.

Discussion—Megalospheric forms of this species are somewhat similar to those of *H. glabra* Cushman and Waters (1927) from the Texas Pennsylvanian, but according to Conkin (1961, p. 261) *H. casteri* is proportionally broader, nearly three times as large in maximum diameter.

The microspheric form is distinctive in its elongated conical appearance and cannot be confused with any other species in the Lower Paleozoic.

Hyperammina constricta Gutschick and Treckman

Pl. 36, fig. 6; Pl. 40, fig. 6

1959. *Hyperammina constricta* Gutschick and Treckman, Jour. Paleont., vol. 33, No. 2, p. 237, pl. 34, figs. 17-19, text figs. 1m,n.

Description—Test free, proloculus unknown; second chamber long, slightly curved and gradually expanding, with regularly spaced constrictions; wall thin, finely arenaceous, well cemented; aperture terminal on second chamber.

Measurements—Figured hypotype U. C. 37788 has a length of 0.78 mm., maximum diameter 0.22 mm., and minimum diameter of 0.19 mm. at constriction.

Occurrence—Rare, one specimen; locality 6.

Discussion—This form is similar to *H. kentuckyensis* Conkin (1954) present in the Lower Mississippian of Kentucky and southern Indiana. It differs from that species in having regular constrictions of the second chamber. *H. kentuckyensis* has irregular constrictions and 'hourglass' tapering in the early part of the chamber. Presence of *H. constricta* extends its range down to the Silurian and into southern Indiana. Previously it has only been recognized in the type area of northern Indiana from the Rockford limestone (Lower Mississippian).

Hyperammina curva (Moreman) Pl. 36, figs. 7, 11-13; Pl. 40, figs. 7, 11-13

1930. *Bathysiphon curvus* Moreman, Jour. Paleont., vol. 4, No. 1, p. 45, pl. 5, figs. 9, 10.

1939. *Bathysiphon curvus* var. *gracilis* Ireland, Jour. Paleont., vol. 13, No. 2, p. 192, fig. A-13, 14.

1939. *Bathysiphon curvus* Moreman, Ireland, ibid., p. 193, fig. A-7.

1942. *Bathysiphon curvus* Moreman, Dunn, Jour. Paleont., vol. 16, No. 3, p. 322, pl. 42, fig. 5.

1961. *Hyperammina curva* (Moreman) Mound, Indiana Dept. Conserv., Geol. Sur., Bull. No. 23, p. 35, pl. 3, figs. 13-16.

Description—Test free, consisting of small bluntly rounded or pointed proloculus and long, gently tapering, slightly curved second chamber with no constrictions; wall thin, finely arenaceous, well cemented; aperture at terminal end of second chamber.

Measurements—Table 7 shows the dimensions of six hypotypes.

Table 7. Dimensions of *Hyperammina curva*

	U. C. Number	Length	Min. diam.	Max. diam
Pl. 36, fig. 12 Pl. 40, fig. 12	37789	0.50 mm.	0.15 mm.	0.21 mm.
Pl. 36, fig. 11 Pl. 40, fig. 11	37790	0.58 mm.	0.12 mm.	0.16 mm.
Pl. 36, fig. 7 Pl. 40, fig. 7	37791	1.02 mm.	0.20 mm.	0.26 mm.
Pl. 36, fig. 13 Pl. 40, fig. 13	37792	0.45 mm.	0.06 mm.	0.11 mm.
Unfigured	37793	0.50 mm.	0.14 mm.	0.20 mm.
Unfigured	37794	1.21 mm.	0.14 mm.	0.16 mm.

Occurrence—Common, eight specimens; localities 1, 3, 9, 10—U. C. 37789, U. C. 37790, U. C. 37793 locality 3; U. C. 37792 locality 9; U. C. 37794 locality 1.

Discussion—Moreman's original specimens have the proloculus missing and so can possibly be mistaken for *Bathysiphon* as was done. The tests do have a distinct taper characteristic of *Hyperammina* and so have been referred to that genus. Comparison of the Waldron specimens with Moreman's syntypes shows them to be the same species, and the Waldron forms have their proloculi preserved so that they may definitely be placed as a *Hyperammina* species.

Bathysiphon curvus "var." *gracilis* Ireland (1939), from the Chimney Hill limestone of Oklahoma, is distinguished by its small size. Ireland (p. 192) found no intermediate forms between his specimen measuring 0.30 mm. long and Moreman's specimens which were over 1 mm. long, therefore, he considered it a new "variety." Mound (1961, p. 35) recovered 57 specimens from the Brassfield limestone of Indiana which ranged from 0.33 mm. to 1.00 mm. The Waldron specimens also vary in size (see Table 7). Ireland's specimens are believed to be only small individuals and not a distinct form.

Family **SACCAMMINIDAE** Brady, 1884

Subfamily **PSAMMOSPHAERINAE** Haeckel, 1894

Genus **PSAMMOSPHAERA** Schulze, 1875

1875. *Psammosphaera* Schulze, Komm. Untersuch. deutsch. Meere in Kiel, Jahrssber., vol. 1872-73, p. 113 (*fetae*).
1913. *Arpsammosphaerum* Rhumbler, Die Foraminiferen der Plankton-Expedition, Pt. 2 Systematik, vol. 3, Lief. c, p. 347 (*nom. van.*).

Type species—Psammosphaera fusca Schulze (1875, *ibid.*)

Cushman (1918, p. 34) redescribed the genus as follows:

> Test free or attached, single chambered, usually spherical, no definite aperture, the pseudopodia making their way out through the interstitial openings between the elements of the test; wall of sand grains, mica flakes, sponge spicules, or other foraminiferal tests firmly cemented.

This genus is one of the most primitive foraminifers, being simple in form and known to exist from the Middle Ordovician to Recent. Due to its primitive and nonspecialized nature, *Psammosphaera* is a common constituent of arenaceous Foraminifera faunas from varied environments. It usually is one of the most common genera to be found in marine sediments ranging from limestones to siltstones. This is true in the Waldron shale where it occurs abundantly in limestone lenses, shale zones, and even in a coarse silt at the Hartsville locality. The genus has not proved to be of any value as either a stratigraphic or ecologic indicator in the present study.

Psammosphaera cava Moreman

Pl. 37, figs. 12-14; Pl. 39, figs. 1,2; Pl. 41, figs. 12-14

1930. *Psammosphaera cava* Moreman, Jour. Paleont., vol. 4, No. 1, p. 48, pl. 6, fig. 12.
1939. *Psammosphaera gracilis* Ireland, Jour. Paleont., vol. 13, No. 2, p. 194, pl. A, figs. 10, 11.
1942. *Psammosphaera conjunctiva* Dunn, Jour. Paleont., vol. 16, No. 3, p. 323, pl. 42, fig. 28.
1942. *Psammosphaera excerpta* Dunn, *ibid.*, p. 323, pl. 42, figs. 7, 8.
1942. *Psammosphaera gigantea* Dunn, *ibid.*, p. 323, pl. 42, fig. 9.
1942. *Psammosphaera minuta* Dunn, *ibid.*, p. 323, pl. 42, figs. 10-12.
1947. *Psammosphaera delicatula* Stewart and Lampe, Jour. Paleont., vol. 21, No. 6, p. 532, pl. 78, figs. 1a, b.
1947. *Psammosphaera devonica* Stewart and Lampe, *ibid.*, p. 533, pl. 78, fig. 2.

1947. *Psammosphaera discoidea* Stewart and Lampe, *ibid.*, p. 533, pl. 78, figs. 3a, b.
1947. *Psammosphaera rotunda* Stewart and Lampe, *ibid.*, p. 533, pl. 78, fig. 4.
1958. *Psammosphaera delicatula* Stewart and Lampe, Summerson, Jour. Paleont., vol. 32, No. 3, p. 549, pl. 81, fig. 4.
1958. *Psammosphaera devonica* Stewart and Lampe, Summerson, *ibid.*, p. 549, pl. 81, fig. 5.
1958. *Psammosphaera discoidea* Stewart and Lampe, Summerson, *ibid.*, p. 549, pl. 81, fig. 6.
1958. *Psammosphaera excerpta* Dunn, Summerson, *ibid.*, p. 550, pl. 81, fig. 7.
1958. *Psammosphaera gracilis* Ireland, Summerson, *ibid.*, p. 550, pl. 81, fig. 8.
1958. *Psammosphaera rotunda* Stewart and Lampe, Summerson, *ibid.*, p. 550, pl. 81, fig. 9.
1958. *Psammosphaera aspera* Summerson, *ibid.*, p. 550, pl. 81, figs. 10, 11.
1958. *Psammosphaera elongata* Summerson, *ibid.*, p. 551, pl. 81, fig. 12.

Description—Test free, spherical; wall thin to thick with outer layer of fine to coarse sand grains and an inner pseudochitinous layer, well cemented but without an excess of cement on the surface; no aperture apparent.

Measurements—Diameters of 66 measured specimens ranged from 0.17 mm. to 0.60 mm. with a modal diameter range of 0.26 mm. to 0.31 mm. (28 specimens).

	U. C. Number	Diameter
Pl. 37, fig. 12 Pl. 41, fig. 12	37795	0.31 mm.
Pl. 37, fig. 14 Pl. 41, fig. 14	37796	0.48 mm.
	U. C. Number	Diameter
Pl. 37, fig. 13 Pl. 41, fig. 13	37797	0.18 mm.

Occurrence—Abundant, 79 specimens; localities 3, 4, 5, 6, 8—U. C. 37795, U. C. 37796 locality 6; U. C. 37797 locality 4.

Discussion—Past authors have erected numerous species for Paleozoic forms of *Psammosphaera* based on grain size, wall thickness, and variations from the spherical form of test. Moreman (1930, p. 48), in erecting the species from specimens found in the Chimney Hill limestone of Oklahoma, described it thus:

> Test free, spherical; wall thin, composed mostly of fine sand grains, well cemented; aperture indefinite; color white.

The holotype had a diameter of 0.5 mm. Later workers (Ireland, 1939; Dunn, 1942; Stewart and Lampe, 1947; Summerson, 1958) differentiated many additional species on the above mentioned criteria by considering the type species description and not allowing for variances within the species. Table 8 outlines the features used to establish the species here declared synonymous with *Psammosphaera cava.*

All of the variances in grain size, wall thickness, and test size would seem to be within the expectable range of specific variation. Likewise, abnormalities of shape may readily occur in a species having such a delicate test as that of *Psammosphaera cava.* Mound (1961, p. 27) measured 130 specimens from the Brassfield limestone of southern Indiana and found the size to range from 0.10 mm. to 0.57 mm. He further stated that the other criteria on which species had been erected could all be expected in one species. Loeblich and Tappan (1964, p. 89) showed that size of sand grains utilized by a foraminifer in building its test depends on the grain sizes available to the animal, and stated that grain size should not be considered a specific character. In Ordovician forms of *Psammosphaera* Gutschick and Treckman (1959, p. 232) found that the test was susceptible to deformation by crushing resulting in frequently recurring shapes. They concluded that "there seems to be insignificant phylogenetic difference throughout the Paleozoic for this simple genus." In the present study 79 specimens were recovered which show all gradations of the several variances used for establishment of the above species. This was true within a single sample from an outcrop in several cases.

Table 8. Variances from *Psammosphaera cava* Holotype

Species	Test size	Test shape	Grain size	Wall thick.	Range & other
P. gracilis	small		finer		Sil.-Dev.
P. conjunctiva		subspher.			Sil.-Dev.
P. excerpta	small		coarse	thick	Sil.-Dev.
P. gigantea	large				Sil.
P. minuta	small				Sil.
P. delicatula	small		variable		smooth, Sil.
P. devonica					Dev. occur
P. discoidea		discoid	coarse	thick	Dev.
P. rotunda	large			thin	Dev.
P. aspera	large		variable		Dev.
P. elongata		elongate spheroid			Dev.

Much of the reason for *Psammosphaera's* susceptibility to test deformation lies in the wall structure. As seen in Plate 39, the wall is composed of an inner pseudochitinous layer of sand grains tightly cemented (only one layer thick in sectioned specimen). At several points there are openings leading to the outer surface, indicated by dark lines between sand grains, which probably represent points at which pseudopodia emerged. Such a delicate wall with a flexible inner lining could be readily deformed or fractured after the animal's death.

Psammosphaera cava appears to be most clearly related to *P. laevigata* White, from the Upper Cretaceous of Mexico, but differs in using less cement and having a rougher surface as compared to the smooth, silky appearance of the latter species. Certain individuals of *P. cava* seem to have used more cement than others and may represent a gradation from *P. laevigata.*

Genus **SOROSPHAERA** Brady, 1879

1879. *Sorosphaera* Brady, Quart. Jour. Micr. Sci., vol. 19, new ser., pp. 28-29.
1913. *Arsorosphaerum* Rhumbler, Die Foraminiferen der Plankton-Expedition, Pt. 2 Systematik, vol. 3, Lief. c, p. 347 (*nom. van.*).

Type species—Sorosphaera confusa Brady (1879, *ibid.*, pl. 4, figs. 18, 19).

Brady's original description is as follows:

> Test free, irregular; consisting of a number of convex or spheroidal chambers, either discrete or more or less embracing, irregularly crowded together. Walls thin, loosely arenaceous in texture. General aperture, none. Long diameter of large specimens, 1/6 inch (4.5 mm).

Sorosphaera is similar to *Psammosphaera* Schulze (1875) but differs in being multilocular. Single chamber fragments are indistinguishable.

Other genera have been compared to *Sorosphaera* and several placed in synonymy (Loeblich and Tappan, 1964, p. 196). *Thuramminopsis* Haeusler (1883, p. 69), from the Jurassic of Europe, differs internally. It has a network of tubes separating the chambers or a series of internal ridges and Haeusler considered it to be monothalmous with a varied external form. It does not appear to be related closely enough to be synonymous with *Sorosphaera. Arenosphaera* Shchedrina (1939), a Recent form found in the Russian Arctic, appears to be a *Sorosphaera* on the surface. The generic description also would bear out such an observation. The genus is monotypic and the type species, *Arenosphaera perforata* Shchedrina (1939, p. 96) shows variation. Part of its description states "all chambers retain a nearly spherical shape; they are connected with one another by broad round openings." *Sorosphaera* species show no openings indicating any such connection between chambers; they are of a more primitive form than *Arenosphaera* though related phylogenetically. *Danubica* Frentzen (1944, p. 325), from the Birmendorfer beds of southern

Germany, is also similar to *Sorosphaera.* In between the bulbous projections of the test which resemble chambers are small apertures, thus it is more like *Thurammina* (discussed later) than it is *Sorosphaera.*

Within the genus a problem of speciation has recently arisen. Mound (1961, p. 32) recognized four species from the Brassfield limestone of Indiana, *S. confusa* Brady, *S. osgoodensis* Stewart and Priddy, *S. bicella* Dunn, and *S. tricella* Moreman. He considered the possibility that one might be a fragment of another with more chambers because their distinguishing characteristics are the number and attitude of the chambers. *S. confusa* does appear to be distinct due to its much more tightly clustered chambers and massive nature. Hattin (personal communication) found a complete ontogenetic sequence of the genus from the Waldron shale in this same area. He considered *S. bicella*, *S. tricella*, and *S. osgoodensis* to be growth stages of the same species. The same problem occurs in *Metamorphina* Browne and Schott (1963) which is discussed under the Hemisphaeramminae. A complete sequence of growth stages was not found in this study nor were enough specimens recovered for a statistical analysis of the ontogeny of *Sorosphaera.* Therefore, species previously established on the basis of number of chambers are provisionally retained here.

Sorosphaera confusa Brady Pl. 37, fig. 6; Pl. 41, fig. 6

1879. *Sorosphaera confusa* Brady, Quart. Jour. Micr. Sci., vol. 19, new ser., pp. 28, 29, pl. 4, figs. 18, 19.

Description—Test free, multilocular, consisting of a variable number of spherical chambers connected closely in a random manner giving a massive appearance to the test; wall thin, finely arenaceous, well cemented; no aperture apparent.

Measurements—Chamber diameters of the figured hypotype U. C. 37798 are 0.31 mm., 0.34 mm., and 0.28 mm.

Occurrence—Uncommon, three specimens; localities 5, 6, U. C. 37798, locality 6.

Discussion—As mentioned in the generic diagnosis this species is characterized by the close appression of the chambers and its massive appearance. Previous to Mound's work (1961, p. 33) which recognized this form in the Brassfield limestone of Indiana, it was known only as a Recent species. Its occurrence in the Waldron shale substantiates its presence during Silurian time.

Sorosphaera bicella Dunn Pl. 37, figs. 7-9; Pl. 41, figs. 7-9

1942. *Sorosphaera bicella* Dunn, Jour. Paleont., vol. 16, No. 3, p. 325, pl. 42, figs. 17, 18.
1947. *Sorosphaera columbiense* Stewart and Lampe, Jour. Paleont., vol. 21, No. 6, p. 533, pl. 78, figs. 5a,b,c.
1958. *Sorosphaera columbiense* Stewart and Lampe, Summerson, Jour. Paleont., vol. 32, No. 3, p. 551, pl. 81, fig. 15.

Description—Test free, bilocular, chambers spherical to globular and loosely connected; wall thin, finely arenaceous, well cemented; no apparent apertures.

Measurements—Diameter of 24 measurable chambers ranged from 0.13 mm. to 0.54 mm. with an average of 0.29 mm. Dimensions of figured hypotypes are given below.

	U. C. Number	Chamber Diameters
Pl. 37, fig. 7 Pl. 41, fig. 7	37799	0.31 mm., 0.24 mm.
Pl. 37, fig. 9 Pl. 41, fig. 9	37800	0.50 mm., 0.54 mm.
Pl. 37, fig. 8 Pl. 41, fig. 8	37801	0.32 mm., 0.34 mm.

Occurrence—Common, 13 specimens; localities 3, 4, 6, 8, 11, U. C. 37799 locality 6, U. C. 37800 and U. C. 37801 locality 4.

Discussion—This species is characterized by its bilocular form. *S. columbiense* Stewart and Lampe (1947) from the Devonian of Ohio, was separated on the basis of its flattened sides on the spherical chambers. The flattening, which gives a somewhat polygonal appearance to the chambers, is probably due to deformation of the test and should not be considered a specific trait.

Sorosphaera tricella Moreman Pl. 37, fig. 10; Pl. 41, fig. 10

1930. *Sorosphaera tricella* Moreman, vol. 4, No. 1, p. 49, pl. 5, figs. 12, 14.

Description—Test free, trilocular, chambers spherical to globular and loosely connected; wall thin, finely arenaceous, well cemented; apertures not apparent.

Measurements—Diameters of 40 measurable chambers ranged from 0.14 mm. to 0.54 mm. with an average of 0.29 mm. The figured hypotype, U. C. 37802, had chamber diameters of 0.34 mm., 0.33 mm., and 0.30 mm.

Occurrence—Common, 14 specimens: localities 3, 6, 11, U. C. 37802 locality 6.

Discussion—Like *S. bicella* this form has been distinguished by its three chambers. Some authors (Grubbs, 1939, p. 544; Mound, 1961, p. 34; Browne and Schott, 1963, p. 212) believed this form may often be a broken section from a species with more chambers. In addition, the range and average diameters of the chambers in this form and *S. bicella* show a possibility that they are one.

Sorosphaera osgoodensis Stewart and Priddy Pl. 37, fig. 11; Pl. 41, fig. 11

1941. *Sorosphaera osgoodensis* Stewart and Priddy, Jour. Paleont., vol. 15, No. 4, p. 371, pl. 54, fig. 11.

1942. *Sorosphaera multicella* Dunn, Jour. Paleont., vol. 16, No. 3, p. 325, pl. 42, figs. 19a,b.

Description—Test free, multilocular, consisting of four or more subspherical chambers more or less closely joined in a single plane; wall thin, finely arenaceous, well cemented; no apertures apparent.

Measurements—Diameters of individual chambers in specimen U. C. 37803 are 0.26 mm., 0.30 mm., 0.34 mm., and 0.26 mm.

Occurrence—Rare, one specimen; locality 6.

Discussion—This form may be more common but due to the possibility of not recognizing broken specimens, it could easily be mistaken for *S. bicella* or *S. tricella.*

S. multicella Dunn (1942), from the Osgood formation of Indiana (not the Waldron as he stated because his locality number, 2001, is listed as the Osgood Quarry where there is no Waldron present), is a junior synonym of this species. Stewart and Priddy, in their discussion of the species (1941, pp. 371, 372), were aware of Dunn's *S. multicella* and considered their form to possibly be the same. Their designation has priority and Dunn's species description shows his form to be the same as their's and thus is synonymous. *S. subconfusa* Dunn (1942), from the Osgood of Missouri, has slightly more appressed chamber connections and irregular addition of each chamber. Both features are insufficient for specific differentiation.

Genus **STEGNAMMINA** Moreman, 1930

1930. *Stegnammina* Moreman, Jour. Paleont., vol. 4, No. 1, p. 49.

1930. *Raibosammina* Moreman, Jour. Paleont., vol. 4, No. 1, p. 50.

1942. *Raibosammina* Moreman, Dunn, Jour. Paleont., vol. 16, No. 3, p. 325.

1942. *Thekammina* Dunn, *ibid.*, p. 326.

1959. *Raibosammina* Moreman, Cushman, *Foraminifera,* 4th ed., p. 77.

1959. *Thekammina* Dunn, Cushman, *ibid.*, p. 76.

1961. *Thekammina* Dunn, Mound, Indiana Dept. Conser., Geol. Sur., Bull. No. 23, pp. 25, 26.

1963. *Thekammina* Dunn, Browne and Schott, Bull. Amer. Paleont., vol. **46,** No. 209, p. 210.
1963. *Raibosammina* Moreman, Browne and Schott, *ibid.*, p. 212.

Type species—Stegnammina cylindrica Moreman (1930, *ibid.*, p. 49, pl. 7, fig. 12).

The original description of Moreman (1930, p. 49) follows:

> Test free, a straight cylindrical or subcylindrical chamber; wall thin, composed of small to medium sized sand grains, well cemented; aperture indefinite.

The genus *Raibosammina* Moreman was originally differentiated from *Stegnammina* as shown by Moreman's description (1930, p. 50):

> Test free or attached, subcylindrical, straight, crooked or irregularly branched, interior of chamber not of uniform diameter; wall of unequal thickness, composed of poorly sorted sand grains; aperture not apparent.

Dunn (1942, p. 326) described a closely related form as a new genus *Thekammina* as follows:

> Test free, with walls compressed to give an angular outline, varying from a flattened triangular to a box shaped test; wall thin, composed of fine to coarse sand grains, usually poorly cemented; aperture indefinite.

Several characteristics of this genus and of *Raibosammina* are close to Moreman's *Stegnammina.* Such generic differences as were made have been considered by Loeblich and Tappan (1964, p. 196) to be only of specific value, and they have placed the latter two genera in synonymy with *Stegnammina.*

Considering the simplicity of the test such differences as angularity of the test, varying wall thickness, or contortion of the test (as in *Raibosammina*) are most likely to be of a specific level. A comparison can be made with *Sorosphaera* Brady (1879) in which similar changes in the shape of chambers constitute different species but not different genera. Likewise *Ordovicina* Eisenack (1937) shows much variance in external form among its species. In genera of simple form small differences may cause a substantial change in the test shape which may appear to be of generic significance when actually only of specific value. Therefore, this work considers that Loeblich and Tappan are probably right in thinking that *Stegnammina, Raibosammina,* and *Thekammina* are congeneric.

Raibosammina aspera Moreman presents the only possible exception. The type species of *Raibosammina, R. mica* Moreman, is referable to *Stegnammina,* but *R. aspera* is irregularly branched and may well belong in another genus. No other species of these three genera is known to branch

The revised generic description of Loeblich and Tappan (1964, p.

196) does not include several features of the synonymous genera *Raibosammina* and *Thekammina* whose descriptions are given above. The description reads:

> Test free, subcylindrical to angular, straight to curved; wall thin, agglutinated, well cemented; without definite aperture.

In order that the generic description of *Stegnammina* satisfy the characteristics of the species now included within the genus, it is necessary to formally emend the description as follows:

Test free, monothalmous, cylindrical to angular, straight to curved; wall thin to thick, agglutinated, poorly to well cemented; aperture not apparent.

Stegnammina cylindrica Moreman Pl. 36, figs. 15, 16; Pl. 40, figs. 15, 16

1930. *Stegnammina cylindrica* Moreman, Jour. Paleont., vol. 4, No. 1, p. 49, pl. 7, fig. 12.

1942. *Stegnammina cylindrica brevis* Dunn, Jour. Paleont., vol. 16, No. 3, p. 325, pl. 42, fig. 25.

Description—Test free, monothalmous, cylindrical to subcylindrical, ends slightly flattened; wall thin, finely arenaceous, well cemented; no aperture apparent.

Measurements—Table 9 shows the dimensions of the six specimens recovered.

Table 9. Dimensions of *Stegnammina cylindrica*

	U. C. Numbers	Length	Diameter
Pl. 36, fig. 15 Pl. 40, fig. 15	37804	0.35 mm.	0.17 mm.
Unfigured	37805	0.24 mm.	0.11 mm.
Pl. 36, fig. 16 Pl. 40, fig. 16	37806	0.48 mm.	0.24 mm.
Unfigured	37807	0.33 mm.	0.17 mm.
Unfigured	37807	0.41 mm.	0.22 mm.
Unfigured	37807	0.48 mm.	0.20 mm.

Occurrence—Uncommon, six specimens; localities 3, 6—U. C. 37806, U. C. 37807 locality 3; U. C. 37804, U. C. 37805 locality 6.

Discussion—The above table demonstrates the variability in size of *Stegnammina cylindrica* with the length-diameter ratio constant at 2:1 in these specimens. Mound (1961, p. 25) measured 35 specimens from the Brassfield limestone (Lower Silurian) in Indiana which ranged from 0.17 mm. to 0.50 mm. in length. He made no mention of the ratio of the length to the diameter. On the few specimens recovered here it cannot be proven that the apparent 2:1 ratio is constant for the species.

S. cylindrica brevis was described by Dunn (1942, p. 325) to vary from the type species in being only half as long. With the range of lengths that occur it is doubtful that Dunn's subspecies is valid.

Stegnammina contorta McClellan, sp. nov.

Pl. 36, figs. 17, 18a,b; Pl. 40, figs. 17, 18a,b

Description—Test free, cylindrical and twisted, ends rounded; monothalmous, chamber narrow and tubular; wall thick, moderately to coarsely arenaceous, poorly cemented; no aperture apparent.

Measurements—The holotype U.C. 37808 has a length of 0.68 mm. and diameter of 0.14 mm., wall thickness 0.055 mm. and chamber diameter 0.03 mm. seen on broken side of specimen. Paratype U. C. 37809 has length of 0.42 mm. and diameter of 0 13 mm.

Occurrence—Rare, two specimens; locality 6—Tunnel Mill near Vernon, Indiana.

Discussion—*Stegnammina mica* (Moreman), the most closely related species, is straight or slightly bent, has an interior of irregular diameter, uneven wall thickness, and utilizes one large grain in the midst of small grains in the formation of its test. In contrast the test of *S. contorta* is twisted longitudinally, the wall thickness is constant, the chamber diameter is regular, and there is no large grain included in the test. *S. cylindrica* is cylindrical to subcylindrical, has a much thinner wall, and more robust appearance.

Subfamily **SACCAMMININAE** Brady, 1884

Genus **LAGENAMMINA** Rhumbler, 1911

1911. *Lagenammina* Rhumbler, Ergebnisse der Plankton-Expedition der Humbolt-Stiftung, vol. 3, Lief. c, p. 92, 111 (*fetae*).

1858. (*Non*) *Proteonina* Williamson, Ray Soc. Publs., p. 1, [=*Proteonina* spp. of various authors].

1913. *Arlagenammum* Rhumbler, Die Foraminiferen der Plankton-Expedition, Pt. 2 Systematik, vol. 3, Lief. c, p. 348 (*nom. van.*).

Type species –*Lagenammina laguncula* Rhumbler (1911, *ibid.*, pl. 1, fig. 4).

Cushman (1918, p. 51) redescribed the genus from Recent material of the North Atlantic Ocean.

> Test free, bottle shaped, with a pseudochitinous sublayer on which are laid quite thickly, but roughly, small foreign bodies. The presence of this sublayer distinguishes this genus from *Proteonina,* which does not have such a layer.

The presence of a pseudochitinous inner layer is difficult to determine on fossil specimens unless thin sections are made. Several Silurian species of *Lagenammina* have been established on the assumption that an inner layer was present. In the same manner species of *Proteonina* Williamson (1858) have been erected on the basis that they had no such inner layer.

Proteonina Williamson was restudied by Loeblich and Tappan (1955, pp. 7, 8) who emended Williamson's diagnosis to read:

> Test elongate, fusiform in outline, consisting of a subglobular proloculus and elongate, flask-shaped later chambers, few in number; sutures somewhat obscure or slightly constricted from the exterior, nearly horizontal; wall agglutinated, with coarse particles; aperture terminal, rounded, slightly produced.

They also designated a lectotype and refigured the type species *P. fusiformis* Williamson. They considered that "Williamson's figured specimen was a three chambered form with somewhat indistinct sutures due to the coarseness of the particles in the agglutinated wall." Their conclusion was that *Proteonina* is a junior synonym of *Reophax* Montfort (1808) which has a free elongate test, few chambers with horizontal sutures, and a rounded terminal aperture on a distinct neck. Therefore, *Proteonina* is a multilocular, uniserial form, not single chambered as commonly considered, and they suppressed the name and referred single chambered species to *Saccammina* M. Sars (1869) or *Lagenammina* Rhumbler (1911).

Saccammina and *Lagenammina* can usually be differentiated on the pyriform outline and presence of a neck in the latter. Some species of both have several similar features and may represent a transition from one genus to the other.

Lagenammina cumberlandiae (Conkin) Pl. 36, fig. 19; Pl. 40, fig. 19

1961. *Proteonina cumberlandiae* Conkin, Bull. Amer. Paleont., vol. 43, No. 196, p. 248, figs. 2, 3, pl. 19, figs. 1-3, pl. 26, figs. 4, 5.

Description—Test free, monothalmous, pyriform, somewhat compressed, long neck tapers gradually from body; wall thick to thin, finely arenaceous, well cemented; aperture rounded, on end of long, tapering, tubular neck.

Measurements—Figured specimen U. C. 37810 has a diameter of 0.17 mm. through the body and diameter of 0.14 mm. at end of the neck; length is 0.40 mm.

Occurrence—Rare, one specimen; locality 3.

Discussion—Placement of this specimen under *L. cumberlandiae* is based on its close resemblance to the type externally. The presence of a pseudochitinous layer is not proven because no thin section was made, there being only one specimen. Conkin's figured thin sections (1961, pl. 26, figs. 4, 5) show a dark area which probably represents the inner layer.

Lagenammina sp. A Pl. 36, fig. 20; Pl. 40, fig. 20

Description—Test free, monothalmous, bulbous body with a short, stout, tubular neck; wall thin, medium to finely arenaceous, poorly cemented; aperture round, at end of the stout neck.

Measurements—Figured specimen U. C. 37811 is distorted so that horizontal diameter of body is 0.42 mm. and vertical diameter 0.30 mm.; length of neck 0.09 mm., neck diameter 0.12 mm.; aperture diameter 0.04 mm.

Occurrence—Rare, one damaged specimen, locality 3.

Discussion—This specimen is partially broken and distorted so that its true shape cannot be determined. It was probably spherical before being damaged. It shows many affinities to *L. bulbosa* Dunn (1942) which occurs in the Brassfield and Osgood limestones of Illinois. That species is characterized by its bulbous form, short neck, and thick wall. The present specimen has a proportionately even shorter and stouter neck and a thin, fragile wall. Hattin (personal communication) had a similar specimen from the Waldron, which he photographed and which was subsequently accidentally fractured into several pieces. Possibly this constitutes a new species but, due to poor preservation, it is not given a name here.

Genus **SOROSTOMASPHAERA** McClellan, gen. nov.

Type species—*Sorostomasphaera waldronensis* McClellan, *sp. nov.*

Description—Test free, multilocular, consisting of a variable number of globular to spherical chambers irregularly attached to each other; chambers may be loosely connected or somewhat appressed where adjoined; wall thin, finely arenaceous, well cemented; single, rounded aperture on each chamber, no openings between chambers.

The presence of an aperture distinguishes this genus from *Sorosphaera* Brady (1879). The form of the chambers and their attachment to each other is otherwise similar. The subfamily Psammosphaerinae, to which

Sorosphaera belongs, is characterized by a free test, globular form, and no aperture. Though this genus looks similar to *Sorosphaera* because of the apertures it is placed in the Saccammininae which have free tests and definite apertures.

Within the Saccammininae it is most closely related to *Stomasphaera* Mound (1961), from the Brassfield limestone of Indiana. *Stomasphaera* (described below) is monothalmous and sometimes subangular in outline, although it does vary considerably in the latter feature. *Sorostomasphaera,* as its name implies, differs by being polythalmous, and it is more consistently subspherical to spherical. Broken specimens can be identified if there is a remaining fragment, or some other evidence, of an additional chamber. Without such evidence the differentiation of single chambers from *Stomasphaera* is highly subjective. There is the possibility that *Sorostomasphaera* is merely a multilocular form of *Stomasphaera. Stomasphaera* has heretofore been reported only from the Brassfield limestone where it is relatively common. Mound (1961, p. 28) reported no evidence that any of his specimens may have been fragments of a multilocular form. Furthermore, he found nothing which could be interpreted as a form like that of *Sorostomasphaera.* The presence of *Stomasphaera* in the Waldron shale will be discussed below with its description.

Sorostomasphaera was recovered from two localities, Tunnel Mill and Hartsville. At the Hartsville locality it occurs in an argillaceous limestone zone which has a rich brachiopod fauna, apparently a zone of slightly higher energy than is characteristic of the Waldron environment. At Tunnel Mill it is present through the formation in both the typical calcareous shale and the argillaceous limestone lenses. Thus it seems to have had no particular preference for a lower energy environment over a high energy one nor for the amount of carbonate present.

Sorostomasphaera waldronensis McClellan, sp. nov.
Pl. 37, figs. 1-5; Pl. 41, figs. 1-5

Description—Test free, multilocular, consisting of up to five chambers in present material; chambers subspherical to spherical, irregularly attached either loosely or firmly joined; wall thin, finely arenaceous, well cemented; aperture circular, single on each chamber.

Measurements—Diameters of 15 measurable chambers on nine specimens ranged from 0.22 mm. to 0.32 mm. with an average of 0.28 mm. Table 10 shows the measurements of the five figured specimens.

Table 10. Dimensions of *Sorostomasphaera waldronensis*

	U. C. Number	Chamber Diameters, in mm.
Pl. 37, fig. 5	37812	0.22, 0.24, 0.24, 0.26
Pl. 41, fig. 5	holotype	
Pl. 37, fig. 1	37813	0.32
Pl. 41, fig. 1	paratype	
Pl. 37, fig. 4	37814	0.29, 0.21, 0.30, 0.30,
Pl. 41, fig. 4	paratype	indet.
Pl. 37, fig. 3	37815	0.27, indet.
Pl. 41, fig. 3	paratype	
Pl. 37, fig. 2	37816	0.32
Pl. 41, fig. 2	paratype	

Occurrence—Common, nine specimens. Holotype U. C. 37812 and paratype U. C. 37816 from locality 4—Hartsville. Paratypes U. C. 37813, U. C. 37814, U. C. 37815 from locality 6—Tunnel Mill.

Discussion—The form of this species is consistent and, as can be seen from the measurements, there is little variation in the size of the chambers among individuals. It is probably closely related to *Stomasphaera brassfieldensis* Mound (1961) which occurs earlier in Silurian time and would be ancestral. There is probably a phylogenetic line from *Psammosphaera* Schulze (1875) to *Sorostomasphaera* which parallels the one from *Psammosphaera* to *Sorosphaera* Brady (1879). First an intermediate stage of gaining an aperture was taken before branching off along a parallel line.

Genus **STOMASPHAERA** Mound, 1961

Type species—*Stomasphaera brassfieldensis* Mound, 1961, Indiana Dept. Conserv., Geol. Sur., Bull. No. 23, p. 28, pl. 2, figs. 9-13, text fig. 3.

Mound (p. 28) gave the following generic diagnosis:

> Wall rough, thick to thin, medium to coarsely arenaceous, grains poorly to well cemented; test free, subangular to spherical, most commonly subspherical or spherical; aperture single, round or oval.

Stomasphaera Mound is closely related to *Psammosphaera* and *Sorostomasphaera*. It is probably intermediate between the two and most similar to *Sorostomasphaera* (see discussion of *S. waldronensis* above).

Stomasphaera brassfieldensis Mound Pl. 37, fig. 23; Pl. 41, fig. 23

1961. *Stomasphaera brassfieldensis* Mound, Indiana Dept. Conserv., Geol. Sur. Bull. No. 23, p. 28, pl. 2, figs. 9-13, text fig. 3.

Description—Test free, monothalmous, subspherical, slightly produced in area of aperture; wall thin, medium to finely arenaceous, well cemented; aperture single, round.

Measurements—Figured specimen U. C. 37817 has a diameter of 0.30 mm.; aperture measures 0.04 mm.

Occurrence—Rare, one specimen; locality 6.

Discussion—The single specimen recovered here is finer grained and has more cement than most of Mound's specimens. The rough texture seen in the figures is due to matrix still adhering to the test surface and does not represent fragments of an additional chamber. Because there is no evidence of the test having been multilocular and it is slightly produced in the area of the aperture, it is considered to be a distinct form, not a fragment of a *Sorostomasphaera.*

Damaged specimens of *Saccammina* M. Sars (1869), in which the neck is not present, could be mistaken for *Stomasphaera,* but no specimens of that genus were recovered in this study.

Previously *Stomasphaera brassfieldensis* has been known only from the type horizon, Brassfield limestone, in southern Indiana. Its occurrence here extends its stratigraphic range to include both Albion and Niagaran time.

Genus **THURAMMINA** Brady, 1879

1879. *Thurammina* Brady, Quart. Jour. Micro. Sci., new ser., vol. 19, pp. 45-47.
1904. *Thyrammina* Rhumbler, Archiv Protistenkunde, vol. 3, p. 236 (*nom. van.*) (*fetae*).
1913. *Arthyrammum* Rhumbler, Die Foraminiferen der Plankton-Expedition, Pt. 2 Systematik, vol. 3, Lief. c, p. 347 (*nom. van.*).

Type species—Thurammina papillata Brady, (1879, *ibid.*, p. 45) sub. design., Cushman, 1910, p. 57.

Brady (1879) described three species but did not give a generic description or designate a type species. A subsequent designation of *T. papillata* was made by Cushman (1910, p. 57) who also gave a generic description.

> Test typically free, usually nearly spherical, but in some species compressed, chamber single and undivided in typical species; wall thin, composed of fine sand with more or less chitin; apertures several to many at the end of nipple-like protuberances of the surface, occasionally wanting.

There are many species of *Thurammina* occurring in the Silurian but seldom is any one form abundant. Such is the case in the Waldron shale where there are several species but they are rare and usually poorly preserved. They do not seem to be of much use as an indication of environment, having a tolerance for both carbonate or argillaceous conditions at the same locality.

Thurammina jubata Dunn Pl. 36, figs. 25a,b; Pl. 40, figs. 25a,b

1942. *Thurammina jubata* Dunn, Jour. Paleont., vol. 16, No. 3, p. 332, pl. 44, fig. 17.

Description—Test free, monothalmous, compressed, with six broad nipple-like protuberances bearing terminal apertures and arranged irregularly around the outer edge; wall medium grained, poorly cemented.

Measurements—Diameter of U C. 37818 0.48 mm. and thickness about 0.15 mm. (specimen broken) ; height of nodes 0.05 mm.

Occurrence—Rare, one specimen; locality 4.

Discussion—This species is similar to *T. compressa* Brady (1879) which is currently known only from the Recent. Dunn's description (1942, p. 332) referred the test shape to that of a "cup with a covered top." *T. compressa* is identical in all respects except the cup shape, being more like a shallow bowl with a top. The one specimen recovered from the Waldron has more of the shape of *T. compressa.* It is referred, instead, to Dunn's species on two counts: the amount of inflation of the test could vary within a species, and there is a vast difference in age.

The amount of inflation in the two species has not been proven conclusively to be sufficiently constant such that it can be confidently used as a specific trait. It is also possible that the Silurian and Recent forms are analogous rather than homologous and represent convergent evolution from similar ancestral stock. Brady (1879, p. 46), in discussing the test fragility and poor cementation of *T. compressa,* considered that the compressed nature of the test could possibly be in some measure accidental and due to its weak nature. Such test distortion has been discussed under *Psammasphaera cava.* It is believed that the present specimen's compressed nature of the test is due to external causes and it should not be considered a *T. compressa.*

Thurammina arcuata Moreman Pl. 36, fig. 24; Pl. 40, fig. 24

1930. *Thurammina arcuata* Moreman, Jour. Paleont., vol. 4, No. 1, pl. 54, pl. 6, figs. 2, 3.

Description—Test free, monothalmous, moderately inflated, arcuate to subtriangular outline; wall thick to thin, finely arenaceous, well cemented; apertures terminal on several short, broad protuberances.

Measurements—U. C. 37819 diameter of longer side 0.28 mm, diameter of shorter side 0.24 mm. Size of four apertures indeterminant.

Occurrence—Rare, two specimens; localities 3, 6—U. C. 37819 locality 3.

Discussion—This species is characterized by its short nodes which bear the apertures. Other species of *Thurammina* bear much more prominent nodes or even short tubules. Moreman's original specimens had a varying number of nodes (two to four) which could possibly represent different stages in the development of the foraminifer. Such a possibility can only be hypothesized until sufficient material can be collected to make a statistical study. The present specimens each have four nodes which are indistinct and allow no assumptions on the animal's manner of growth.

Thurammina cf. **T. coronata** Dunn Pl. 36, fig. 23; Pl. 40, fig. 23

1942. *Thurammina coronata* Dunn, Jour. Paleont., vol. 16, No. 3, p. 331, pl. 43, fig. 18.

Description—Test free, monothalmous, elongate spheroidal; wall thin, medium grained, not well cemented; apertures terminal on prominent nodes which are broad based and taper sharply, nodes are few and mostly grouped at ends of long axis of test.

Measurements—Length along broken side 0.31 mm., nodes 0.02 mm. high, U. C. 37820.

Occurrence—Rare, one specimen; locality 3.

Discussion—In Dunn's original description he described the test as "crown-shaped with one or two tubular projections at either end and more prominent projections extending upward." The one specimen recovered from locality 10 is broken and does not have a true coronet-shaped test. It does show prominent nodes at what are probably the ends as described by Dunn. These nodes are characteristic and more definite than in *T. arcuata* and less tubular than in many other *Thurammina* species. *T. jubata,* described above, has similar shaped nodes but they are differently arranged and the test is larger, with poorly cemented coarse particles.

?**Thurammina** sp. Pl. 36, fig. 22; Pl. 40, fig. 22

Description—Test free, monothalmous, subspherical; wall thick to thin, coarsely arenaceous, well cemented, apertures indefinite, probably on ends of several broad low nodes irregularly spaced on test surface.

Measurements—Greater diameter 0.60 mm. and smaller diameter 0.48 mm. of U. C. 37821.

Occurrence—Rare, one specimen; locality 8.

Discussion—This specimen is provisionally placed under *Thurammina* on the basis of the broad, low nodes. The apertures, which would be at the ends of the nodes, are not distinct and their presence is questioned, therefore, this is doubtfully a *Thurammina* species. It shows affinities for *T. papillata* Brady (1879), a cosmopolitan long-lived species, in its test shape and size and position of the nodes.

Subfamily **HEMISPHAERAMMININAE** Loeblich and Tappan, 1961

Genus **HEMISPHAERAMMINA** Loeblich and Tappan, 1957

1904. *Webbinella* Rhumbler, Archiv Protistentkunden, vol. 3, pt. 1, p. 228.
1957. *Hemisphaerammina* Loeblich, and Tappan, U. S. Nat. Mus., Bull. 215, pp. 223, 224.
1958. *Fairliella* [in part] Summerson, Jour. Paleont., vol. 32, No. 3, pp. 555, 556.

Type species—Hemisphaerammina batalleri Loeblich and Tappan (1957, *ibid.*, p. 224, pl. 72, fig. 3).

Loeblich and Tappan (1957, p. 223) described the genus as follows:

> Test attached, consisting of a single hemispherical chamber; wall agglutinated, with considerable cement; aperture not observed.

The genus is considered here in a restricted sense, including only single chambered attached forms which are not juveniles of multilocular forms. The relationship and problems of *Hemisphaerammina* to these forms are considered under the discussion of *Metamorphina* Browne and Schott (1963).

Loeblich and Tappan also considered the genus to be more characteristic of the Mesozoic and Cenozoic while *Webbinelloidea* Stewart and Lampe (1947) and *Metamorphina* represented the Paleozoic forms. Specimens found in this study which definitely represent *Hemisphaerammina* occur in conjunction with the other two genera and can readily be differentiated. Thus it would seem better to extend the range of this genus down to the Silurian and also allow for the possibility of *Webbinelloidea* and *Metamorphina* to range higher stratigraphically. Such a concept is preferred over that of considering one simple form distinct from another primarily on the basis of time.

Fairliella Summerson (1958), from the Devonian of Ohio, has five species which were originally designated, and three of them are included here as forms of *Hemisphaerammina*: *F. carmani, F. discoidea, F. lameyi.* Each of these is hemispherical in shape, monothalmous, attached, without apparent apertures, and possesses a narrow marginal flange. They fit all characteristics of *Hemisphaerammina* closely with the single exception of a discoid shape in *F. discoidea.* This species has a slightly convex ventral surface rather than planar, but such a shape could readily be due to the surface on which it was attached. The other two species of the genus described by Summerson do not have the characteristic hemispherical test outline. The type species, *F. dicantha* Summerson, has convex upper and lower surfaces and also possesses a concave side wall with a narrow sharp flange at the juncture of the other two surfaces. Such a configuration is unlike *Hemisphaerammina* and should be retained in a separate genus. *F. clitellata* is less distinct; its major difference being a saddle-shaped outline when viewed from the top instead of a circular one. For these reasons only part of *Fairliella* is transferred to *Hemisphaerammina* after careful observation of the type specimens. Loeblich and Tappan (1964, p. 202) included the entire genus under *Hemisphaerammina* but gave no reasons nor any figures of the much different *F. dicantha* and *F. clitellata.*

Hemisphaerammina bradyi Loeblich and Tappan

Pl. 37, figs. 20a,b-22; Pl. 41, figs. 20a,b-22

1957. *Hemisphaerammina bradyi* Loeblich and Tappan, U. S. Nat. Mus., Bull. 215, p. 224, pl. 72, fig. 3.

Description—Test attached, monothalmous, hemispherical, highly convex, side wall forming sharp angle at junction with ventral surface; wall 0.02-0.05 mm. thick, thinner on bottom, finely arenaceous, well cemented; no aperture apparent.

Measurements—Diameters for 14 measured specimens range from 0.24 mm. to 0.70 mm. with a mode of 0.30 mm. Heights range from 0.16 mm. to 0.49 mm., the mode being 0.25 mm. The figured hypotypes have the following dimensions:

	U. C. Number	Diameter	Height
Pl. 37, fig. 22 Pl. 41, fig. 22	37822	0.70 mm.	0.38 mm.
Pl. 37, fig. 21 Pl. 41, fig. 21	37823	0.35 mm.	0.31 mm.
Pl. 37, figs. 20a,b Pl. 41, figs. 20a,b	37824	0.29 mm.	0.25 mm.

Occurrence—Abundant, 16 specimens; localities 3, 4, 5, 6—U. C. 37822 locality 6, U. C. 37823 locality 5, U. C. 37824 locality 3.

Discussion—This species has previously been recorded only from the Recent and here it is extended back to the Silurian. The present specimens are smaller than those of Loeblich and Tappan (1957, p. 224) which ranged from 0.5 mm. to 1.4 mm. in diameter and the holotype measured 1.56 mm. Their specimens came from a depth of 30 fathoms (p. 224) and utilized large angular grains in building their test while the Waldron forms used fine material, about 0.01 mm., which may account for their smaller size.

Hemisphaerammina bradyi somewhat resembles single chambered forms of *Webbinelloidea* species described below but is much more inflated, has a thinner basal wall, and the angle of junction between the base and side walls is sharp, varying from 75 to 100 degrees.

Hemisphaerammina casteri McClellan, sp. nov.

Pl. 38, figs. 1a,b; Pl. 42, figs. 1a,b

Description—Test attached, monothalmous, hemispherical to subhemispherical, thick, irregular, wide marginal flange is characteristic; wall thick to thin, basal wall thinner, medium-grained, well cemented, bordering flange much heavier than rest of wall; no aperture apparent.

Measurements—Dimensions of holotype U. C. 37825: overall length including flange 0.59 mm. and width 0.40 mm.; exclusive of flange, length is 0.29 mm., width 0.22 mm.; and height 0.23 mm. Thickness of flange is 0.08 mm.

Occurrence—Rare, two specimens; locality 6—Tunnel Mill near Vernon, Indiana.

Discussion—This species is differentiated from most others in the genus on the basis of the heavy, broad, marginal flange. Other species have only a narrow flange or none, with one exception. *H. coronata* (Ireland, 1939), from the Chimney Hill limestone (Silurian) of Oklahoma, also has a marginal flange which is not so massive or wide and bears projecting spines. Also, the inflated portion of the test is much larger and finely arenaceous for the overall dimensions of the animal than in the present specimen.

Hemisphaerammina discoidea (Summerson)

Pl. 38, figs. 2a,b, 3; Pl. 42, figs. 2a,b, 3

1958. *Fairliella discoidea* Summerson, Jour. Paleont., vol. 32, No. 3, p. 557, pl. 82, fig. 20, text-figs. 6a,b.

1964. *Hemisphaerammina discoidea* (Summerson), Loeblich and Tappan, Treat, Invert. Paleont., Pt. C, Protista 2, vol. 1, p. 202.

Description—Test attached, monothalmous, discoidal, outline disklike to ovoid, line of the plane of contact between upper and lower surfaces linear to undulating and forming a narrow wedge-shaped flange; wall thin, of fine to medium-sized grains, moderately cemented; no apparent aperture.

Measurements—Figured specimens have the following dimensions: U. C. 37826 length 0.62 mm., width 0.49 mm., thickness 0.21 mm.; U. C. 37827 diameter 0.27 mm., thickness 0.15 mm.

Occurrence—Uncommon, four specimens; localities 3, 4, 9; U. C. 37826 locality 4, U. C. 37827 locality 3.

Discussion—The relationships of *H. discoidea* to other species within the genus is discussed above under the generic diagnosis. The presence of this species in the Waldron shale extends its stratigraphic and geographic range, previously known only from the Ohio Devonian.

Genus **COLONAMMINA** Moreman, 1930

1930. *Colonammina* Moreman, Jour. Paleont., vol. 4, No. 1, p. 55.

Type species—*Colonammina verruca* Moreman (1930, *ibid.*, p. 56, pl. 7, fig. 3).

Moreman (1930, p. 55) gave the following generic description:

> Test attached, planoconvex, circular or elliptical in outline, attached surface surrounded by a more or less flattened border; wall thin, composed of fine sand well cemented; aperture single on the convex surface.

Colonammina is similar to *Tholosina* Rhumbler (1895) also found in the Silurian of North America. The latter is differentiated on the position and number of apertures. There are always two openings, in all presently known forms, which are on short necks situated flush with, or just above, the base of the test. Loeblich and Tappan (1964, p. 205) compared *Tholosina* to *Hemisphaerammina*, and *Colonammina* is here considered to be intermediate between those genera. *Colonammina* could have easily evolved from *Hemisphaerammina* by developing the aperture and thence to the two aperture form *Tholosina.* Similar development from *Colonammina* could result in a multilocular form, such as *Ammopemphix* Loeblich (1952), from the Recent Antarctic and Arctic, whose individual chambers resemble a *Colonammina* without any neck for the single aperture.

Colonammina verruca Moreman Pl. 37, fig. 24; Pl. 41, fig. 24

1930. *Colonammina verruca* Moreman, Jour. Paleont., vol. 4, No. 1, p. 56, pl. 7, fig. 3.

Description—Test attached, monothalmous, planoconvex, subcircular in outline, border indistinct; wall thin, finely arenaceous, well cemented; single aperture in center of convex upper surface, at end of short, rapidly tapering neck.

Measurements—Diameter of figured specimen U. C. 37828, 0.27 mm.; height 0.18 mm. including neck which is 0.04 mm. long, 0.06 mm. wide at base and 0.02 mm. wide at the top.

Occurrence—Rare, one specimen; locality 6.

Discussion—*Colonammina bituba* Dunn (1942) from the Bainbridge limestone (Silurian) of Missouri differs from this form in having two apertures, not centrally located on the upper surface. The only other species is *C. conea* Moreman (1930) from the Silurian of Oklahoma. It has a strong wedge-shaped lower surface apparently due to a preference for cracks or crevasses in which it attached itself, whereas *C. verruca*, with its planar lower surface, probably attached itself in more open places.

A study of Dunn's types of *C. bituba* may show that it is a *Tholosina.*

Genus **METAMORPHINA** Browne, 1963

Type species—*Webbinella tholus* (Moreman), (1933, Jour. Paleont., vol. 7, No. 4, p. 395, pl. 47, figs. 8, 10).

The generic definition of Browne, as given in Browne and Schott (1963, p. 223), is as follows:

> Test attached, plano-convex, varying in outline from circular to oval to linear; often surrounded by a marginal flange; single chambered to multichambered; wall of fine sand grains, smooth to roughly finished with the basal wall thin and frequently missing; aperture not apparent.

They based this genus on two important differences from the genus *Webbinelloidea* Stewart and Lampe (1947): the presence of a marginal flange and a thin basal wall. *Webbinelloidea* also commonly has much larger chambers, less closely appressed walls where chambers are joined, and utilizes coarser grains and less cement in its test. This holds true even when occurring in the presence of *Metamorphina* where the latter found sufficient smaller grains which would have also been available to *Webbinelloidea.*

Loeblich and Tappan (1957, p. 223) restudied *Webbina hemisphaerica* Parker, Jones, and Brady which is the type species for *Webbinella* Rhumbler (1904) and showed that it should be placed among the calcareous genera. Thus they assigned it to the family Lituolidae. For arenaceous species of the genus single chambered forms were placed in the new genus *Hemisphaerammina* Loeblich and Tappan and multilocular forms allocated to the genus *Webbinelloidea.* As stated above, Browne and Schott did not agree with such an assignment and, therefore, erected a new genus. *Metamorphina* is used here because the studied material bears out the differences recognized by Browne and Schott. Species of *Hemisphaerammina* found in association with *Metamorphina* and *Webbinelloidea* also support the differentiation of the three genera (see descriptions of *Hemisphaerammina* species).

Metamorphina differs from *Sorosphaera* Brady (1879), type species *Sorosphaera confusa* Brady, in being closely attached, frequently having a marginal flange, and having plano-convex chambers. *Sorosphaeroidea* Stewart and Lampe (1947) has no flange, is not appressed where the chambers contact each other, and its chambers have subpolygonal outlines.

Metamorphina tholus (Moreman) Pl. 37, figs. 15-19; Pl. 41, figs. 15-19

1933. *Webbinella tholus* Moreman, Jour. Paleont., vol. 7, No. 4, p. 395, pl. 47, figs. 8, 10.
1933. *Webbinella quadripartita* Moreman, *ibid.*, p. 396, pl. 47, figs. 4, 7.
1954. *Sorosphaera geometrica* Eisenack, Senckenbergiana Lethaea, vol. 35, No. 1-2, p. 61, pl. 4, figs. 19, 20, pl. 5, figs. 2-6, text-fig. 1.
1955. *Webbinella quadripartita* Moreman, Raymond, Thesis (A. M.) Indiana Univ., p. 18, pl. 3, fig. 12.
1955. *Webbinella gibbosa* Ireland, Raymond, *ibid.*, p. 17, pl. 3, fig. 11.
1955. *Webbinella* sp. *A* Raymond, *ibid.*, p. 19, pl. 3, fig. 13.
1955. *Webbinella* sp. *B* Raymond, *ibid.*, p. 19, pl. 3, fig. 14.
1958. *Webbinella bipartita* Ireland, Summerson, Jour. Paleont., vol. 32, No. 3, p. 553, pl. 82, fig. 2.
1961. *Sorosphaera geometrica* Eisenack, Gutschick, Weiner, and Young, Jour. Paleont., vol. 35, No. 6, p. 1205, pl. 147, figs. 11-14, 16.
1963. *Metamorphina tholsus* [*sic*] (Moreman) Browne and Schott, Bull. Amer. Paleont., vol. 46, No. 209, p. 225, pl. 51, figs. 1-9.

Description—Test attached, plano-convex with low domed convexity widening to the basal plane, usually with marginal flange; chambers number from one to five in recovered material, chambers commonly in circular arrangement though sometimes linear, closely appressed forming straight boundaries between chambers, sutures well defined and depressed; wall of fine sand grains, well cemented and smooth, basal wall thin and often missing; no aperture apparent.

Measurements—Diameters of individual chambers range from 0.14 mm. to 0.37 mm. with the modal diameter of 0.21 mm.

	U. C. Number	Test length	Test width
Pl. 37, fig. 15 Pl. 41, fig. 15	37829	0.22 mm.	0.22 mm.
Pl. 37, fig. 16 Pl. 41, fig. 16		0.42 mm.	0.28 mm.
Pl. 37, fig. 17 Pl. 41, fig. 17	37831	0.56 mm.	0.50 mm.
Pl. 37, fig. 18	37832	0.62 mm.	0.58 mm.

Pl. 41, fig. 18			
Pl. 37, fig. 19	37833	0.47 mm.	0.37 mm.
Pl. 41, fig. 19			

Occurrence—Abundant, 16 specimens; localities 3, 5, 6, 9, 11—U. C. 37829, U. C. 37831 locality 6; U. C. 37832 locality 9, U. C. 37833 locality 3.

Discussion—Past authors have designated separate species for each case of a differing number of chambers. Browne and Schott (1963, p. 227) showed that the number of chambers depends on the growth stage in the same animal. They found specimens of from one to seven chambers each and one specimen with 13 chambers. Hattin (personal communication) also found a complete sequence of chambers, all with the same features, and considered this a definite ontogenetic series. In the present study, forms with one to five chambers were recovered in sufficient abundance to substantiate these previous ideas, some specimens even showing the broken surface where another chamber had been, or was in the process of being, attached.

What appears to be this species was recorded as the new species *Sorosphaera geometrica* by Eisenack (1954, p. 61) from the Baltic Lower Silurian. He differentiated it from similar multilocular American *Sorosphaera* species which have spherical chambers and a free test, "by the fundamental surface design of the chamber and the outjutting edge of the flat surface of contact." However, *Sorosphaera* differs from *Metamorphina* as stated in the generic discussion of the latter, and has no other attached species with a definitely flat basal surface.

Metamorphina gibbosa (Ireland) Pl. 38, figs. 4a,b, 5; Pl. 42, figs. 4a,b, 5

1939. *Webbinella gibbosa* Ireland, Jour. Paleont., vol. 13, p. 198, pl. B, figs. 23, 24.

1963. *Metamorphina gibbosa* (Ireland), Browne and Schott, Bull. Amer. Paleont., vol. 46, No. 209, p. 224, unfigured.

Description—Test attached, plano-convex with high domed convexity; narrow marginal flange at base of wall; bilocular, occasionally trilocular; shallow suture between chambers which are wider than long and separated by partitions; base thin and often missing; wall fine grained, well cemented, 0.04-0.05 mm. thick; no apparent aperture.

Measurements—Overall test length of four specimens varied from 0.36 mm. to 0.82 mm.; width 0.23 mm. to 0.52 mm., and height 0.14 mm. to 0.30 mm.

	U. C. Number	Chamb. length	Width	Height
Pl. 38, figs. 4a,b Pl. 42, figs. 4a,b	37834	0.18, 0.18 mm.	0.23 mm.	0.14 mm.
Pl. 38, fig. 5 Pl. 42, fig. 5	37835	0.18, 0.20, 0.17 mm.	0.24 mm.	0.22 mm.
Unfigured	37836	0.42, 0.40 mm.	0.52 mm.	0.30 mm.

Occurrence—Common, seven specimens; localities 3, 4, 9, 10. U. C. 37834 locality 3; U. C. 37835 locality 9; U. C. 37836 locality 10.

Discussion—This species differs from *M. tholus* (Moreman) in being more highly convex, having a narrow flange, and shallow sutures. Ireland (1939, p. 198) and Browne and Schott (1963, p. 224) recorded it as bilocular in form with no indications of any additional chambers that may have been broken off. The bilocular forms found in the Waldron shale conform closely to their specimens. One specimen, which has all the other characteristics of the species, has a third chamber formed at a 45° angle from the line of the first two chambers. While the occurrence of *M. gibbosa* is not abundant and only two specimens show a deviation from the bilocular form, the possibility of the species being multilocular, as is *M. tholus*, should be considered as a possible specific trait. All other species of *Metamorphina* are either strictly monothalmous or polythalmous without a set number of chambers. Therefore, it is more probable that the bilocular character is only due to insufficient material having been available, and that the two three-chambered specimens here recovered do not represent a separate species.

Metamorphina imbricata McClellan, sp. nov.

Pl. 38, figs. 14-17; Pl. 42, figs. 14-17

Description—Test attached, plano-convex with low domed convexity widening to the basal plane, thick marginal flange; multilocular, one to three chambers in present material, chambers circular in outline, successive chambers added by slightly overlapping the previous ones and forming a linear arrangement with shingled appearance; wall thick to thin, finely arenaceous, well cemented, surface smooth, basal wall as thick as sides; no aperture apparent.

Measurements—Table 11 shows the dimensions of the eight specimens recovered. The bordering flange averages 0.04 mm. in width and 0.04 mm. in thickness.

Occurrence—Common, eight specimens; localities 1, 4, 6, 7. Holotype U. C. 37839 from locality 4; paratypes U. C. 37837 locality 6 and U. C. 37838 locality 7.

Discussion—This species is differentiated from others within the genus by its thick, broad, marginal flange and mode of attachment between chambers. No other species of *Metamorphina* adds new chambers in a like manner, therefore, this appears to be a distinctive new form. In addition, the form of the marginal flange does not compare to any other, being sufficiently different to identify even a single chambered specimen.

Metamorphina imbricata appears to be most closely related to *M. tholus.* The latter species has a similar low convexity but a somewhat narrower flange and closely appressed chambers. Species of *Metamorphina* show a trend toward broader flanges and more spreading habit beginning with *M. gibbosa* which has a small flange and high convexity. The next step is *M. bipartita* (Ireland) which has one chamber less inflated, then *M. tholus* with a definite flange and more depressed test, and finally *M. imbricata* as the most advanced form presently known.

Genus **WEBBINELLOIDEA** Stewart and Lampe, 1947

1947. *Sorosphaeroidea* Stewart and Lampe, Jour. Paleont., vol. 21, No. 6, p. 534.
1947. *Webbinelloidea* Stewart and Lampe, *ibid.*, pp. 534, 535.

Type species—*Webbinelloidea similis* Stewart and Lampe (1947, *ibid.*, p. 535, pl. 79, figs. 1a,b).

The original description of Stewart and Lampe (1947, p. 534) is stated as:

> Test attached, composed of one or more plano-convex chambers, circular to oval in outline, usually with high convexity, flattened along adjoining sides; wall generally thick, smooth or rough; sand grains in most species well sorted and firmly cemented with silica which is iron stained in some specimens; aperture indefinite.

This genus resembles *Metamorphina,* discussed previously, in general habit and form but lacks the marginal flange of that genus. Single chambered specimens are similar to *Hemisphaerammina* Loeblich and Tappan (1961) but again that genus frequently has a narrow or wide bordering flange. In addition the tests of *Hemisphaerammina* form a sharp angle at the junction of the upper and lower surfaces, whereas *Webbinelloidea* is usually more obtuse at that junction.

Sorosphaeroidea Stewart and Lampe (1947) was characterized by them (p. 534) as attached, multilocular, firmly joined chambers with a polygonal outline and flattened ventral surface. They compared it to

Table 11. Dimensions of *Metamorphina imbricata* (in mm.)

	U. C. Number	Number of Chambers	Chamber Diam.	Total Length	Chamber Height
Pl. 38, fig. 14 Pl. 42, fig. 14	37837 paratype	1	0.28	—	0.08
Pl. 38, figs. 15a,b Pl. 42, figs. 15a,b	37837 paratype	1	0.38	—	0.18
Pl. 38, fig. 16 Pl. 42, fig. 16	37838 paratype	2	0.32	0.58	indet.
Pl. 38, figs. 17a,b,c Pl. 42, figs. 17a,b,c	37839 holotype	3	0.32	0.73	0.10
Unfigured	37840	2	0.37	0.56?	indet.
Unfigured	37841	2	0.30	0.43	0.16
Unfigured	37841	2	0.32	0.44	0.14
Unfigured	37842	2	0.29	0.51	0.13

Sorosphaera Brady (1879) which is not arranged so nearly in a plane nor are the chambers as closely adjoined. With further observation of the species of *Sorosphaera,* discussed on previous pages, it is seen that it too may be arranged in a planar fashion and the chamber to chamber attachment may vary from very loose to tightly compact. *Sorosphaeroidea* shows many more affinities for *Webbinelloidea.* In fact, after study of the type species of both genera, the only distinguishing character found in *Sorosphaeroidea* was the subpolygonal outline of the chambers. That single criterion is enough only for a specific variation, and as such, is the distinguishing feature of *Webbinelloidea polygonia* (Stewart and Lampe), 1947 which occurs in the Devonian of Ohio.

Webbinelloidea hemispherica Stewart and Lampe

Pl. 38, figs. 12, 13a,b; Pl. 42, figs. 12, 13a,b

1947. *Webbinelloidea hemisphaerica* Stewart and Lampe, Jour. Paleont., vol. 21, No. 6, p. 535, pl. 79, figs. 1a,b.

Description—Test attached, apparently monothalmous, hemispherical plano-convex, junction of basal wall with upper wall a rounded angle; wall thick, about 0.04 mm., and coarsely arenaceous, moderately to well cemented; no apparent aperture.

Measurements—Figured hypotype U. C. 37843 has diameter of 0.63 mm. and height of 0.28 mm., and U. C. 37844 has diameter 0.37 mm. and height 0.20 mm. Five unfigured specimens have diameters from 0.32 mm. to 0.44 mm. and heights ranging from 0.16 mm. to 0.24 mm.

Occurrence—Common, eight specimens; localities 3, ?4, 5, 6—U. C. 37843 and U. C. 37844 locality 6.

Discussion—This species appears to have only one chamber and resembles *Hemisphaerammina bradyi* Loeblich and Tappan (1961) which occurs in conjunction with it. *H. bradyi* is more highly convex and has the sharp basal angle of the test. These features are prominent enough to readily distinguish the two forms.

A closely related species, *Webbinelloidea sola* Stewart and Lampe (1947) was originally differentiated on its greater test convexity, smoother character of the wall, and better sorting of the grains. The last two features are not usually considered valid taxobases. The convexity plus the basal angle at the margin make this species more probably a *Hemisphaerammina* and not so closely related as was considered by Stewart and Lampe (1947, p. 535).

Webbinelloidea hattini McClellan, sp. nov.

Pl. 38, figs. 10, 11; Pl. 42, figs. 10, 11

Description—Test attached, one or two-chambered forms presently known, plano-convex with high conical convex upper surface, junction with basal surface a rounded angle, suture between chambers deep and prominent; rectilinear boundary between chambers; wall thick, coarsely arenaceous, moderately cemented; no apparent aperture.

Measurements—Holotype, U. C. 37845 total length 0.86 mm., width 0.58 mm., height 0.50 mm.; paratype, U. C. 37846 diameter 0.33 mm. and height 0.24 mm.

Occurrence—Uncommon, six specimens; localities 6, 11. Type specimens from locality 6—Tunnel Mill.

Discussion—Single chambered forms of this species can be differentiated from *W. hemisphaerica* on their greater convexity. *W. similis* Stewart and Lampe (1947) is also multilocular but less conical in form and the chambers are more loosely connected. *W. hattini* is based on its high, usually conical, convexity and the rectilinear boundary with the deep suture between chambers.

Webbinelloidea globulosa McClellan, sp. nov.

Pl. 38, figs. 8, 9a,b; Pl. 42, figs. 8, 9a,b

Description—Test attached, multilocular, highly convex, of two or three chambers in present material; chambers globular with one side flattened for attachment, loosely connected to each other in a single plane, no openings between chambers; wall thin, finely arenaceous, well cemented; no apparent apertures.

Measurements—Diameters of individual chambers of holotype U. C. 37847 0.23 mm., 0.26 mm., and 0.32 mm.; height 0.24 mm. Diameters of paratype U. C. 37848 0.25 mm. and 0.28 mm. with height 0.23 mm.

Occurrence—Rare, two specimens. Holotype from locality 6—Tunnel Mill, and paratype from locality 3—Sandusky.

Discussion—This species differs from all others in the genus by its pronounced globosity of the chambers. Other species are more hemispherical or subconical (*W. hattini, sp. nov.*) in overall form. *W. trilocularis* Stewart and Lampe (1947), from the Devonian of Ohio, has a similar manner of loose connection between chambers but the chambers are less inflated.

This new form is considered a *Webbinelloidea* species on the basis of its attached multilocular test. *Metamorphina,* while having a similar multilocular and attached form is characterized by a marginal flange, and also the boundaries between chambers are rectilinear. There is no evidence of a flange on *W. globulosa* as the ventral portion of the test appears to be almost a mere flattening of one side of the chambers and is not the maximum test dimension as in *Metamorphina.* Because the flattened surface of attachment is in a single plane and is consistent, without any evidence of test breakage or collapse, it is not believed to be a damaged *Sorosphaera.*

Webbinelloidea ventriquetra McClellan, sp. nov.

Pl. 38, figs. 6, 7a,b; Pl. 42, figs. 6, 7a,b

Description—Test attached, bilocular, high dorsal convexity, ventral surface of attachment formed by two planar surfaces separated by a distinct angle; the angle is 60-80° and bisects the longitudinal axis of the test; chambers joined along a rectilinear boundary with a deep dorsal suture delineating the contact; wall moderately thick, finely arenaceous, not strongly cemented; no aperture apparent.

Measurements—Holotype U. C. 37849 has an overall test length of 0.49 mm. (individual chambers 0.24 mm. and 0.25 mm.), width of 0.28 mm., and height of 0.26 mm.; wall thickness is 0.03 mm. Paratype U. C. 37850 has diameter 0.26 mm. and height 0.16 mm.

Occurrence—Rare, two specimens; locality 6—Tunnel Mill near Vernon, Indiana.

Discussion—The most distinctive feature of this species is the biplanar surface of attachment with the sharp angle separating the surfaces longitudinally. The general shape and rounded convexity also serve to distinguish it from other species within the genus. *W. globulosa* is also highly convex, but the chambers are attached loosely and the greatest chamber width is not at the base as it is in *W. ventriquetra.*

Webbinelloidea species are usually characterized in part by the rounded angle formed at the junction of the dorsal and ventral surfaces. This new species is not so characterized. It has a much sharper angle at that point, which is more like *Hemisphaerammina* (see the generic discussion of *Webbinelloidea*), but that genus is distinguished by its unilocular form (original description; Loeblich and Tappan, 1957, p. 223).

There is a possibility that this form should be referred to the genus *Metamorphina* Browne (1963), when it is compared to *M. gibbosa* (Ireland, 1939) which has been discussed previously. The comparison lies in the convexity, size and shape of the test, and thickness of the wall. It differs in having a deeper suture, biplanar basal surface, and utilization of coarser material and less cement in the test. It is also no more than bilocular, but this may be due only to a lack of material in the present study. *M. gibbosa* also was first known as bilocular until trilocular forms were found in the Waldron (see discussion of the species). The one feature which differentiates *W. ventriquetra* from *M. gibbosa,* and all other *Metamorphina* species is the lack of a basal marginal flange. The preservation of the holotype is such that if a flange, even small as in *M. gibbosa,* were present, it could be recognized. The single chambered paratype has retained its basal surface and also shows no flange. The absence of this flange is the single most distinctive feature separating *Webbinelloidea* and *Metamorphina*, hence this new species has been placed accordingly.

Ecologically *W. ventriquetra* seems not to have had a preference for a particular energy environment. It was recovered from a mixed argillaceous limestone of relatively low energy conditions. The form of the basal surface indicates that it probably attached itself to a crack in a rock surface and then followed the crack in adding chambers. Such a habit would account for the longitudinal angle on the bottom and would also indicate that the animal may not be precise in the form of its basal surface or linear arrangement of chambers.

Family **AMMODISCIDAE** Reuss, 1862

Subfamily **AMMODISCINAE** Reuss, 1862

Genus **AMMODISCUS** Reuss, 1862

1862. *Ammodiscus* Reuss, K. Akad. Wiss. Wien, math-nat., Cl. Sitzungsber., vol. 44 (1861), p. 385 (*fetae*).

1862. *Involutina* Terquem, Acad. Imp. Metz, Mem., ann. 42 (ser. 2, ann. 9), 1860-1861, p. 450.

1874. *Ammodiscus* Reuss, Borneman, Deutsche geol. Gesell., Zeitschr., vol. 26, pp. 724-731.

1913. *Arammodiscum* Rhumbler, Die Foraminiferen der Plankton-Expedition, Pt. 2 Systematik, vol. 3, Lief. c, p. 387 (*nom. van.*).

1939. *Bifurcammina* Ireland, Jour. Paleont., vol. 13, No. 2, p. 201.

1954. *Involutina* Terquem, emend. Loeblich and Tappan, Washington Acad. Sci., Jour., vol. 44, No. 10, pp. 308-310.

1959. *Involutina* Terquem, Gutschick and Treckman, Jour. Paleont., vol. 33, No. 2, p. 241.

1961. *Involutina* Terquem, Conkin, Bull. Amer. Paleont., vol. 43, No. 196, p. 285.

1961. *Involutina* Terquem, Mound, Indiana Dept. Conserv., Geol. Sur., Bull. No. 23, p. 19.

Type species—Ammodiscus infimus Borneman, (1874, *ibid.*, p. 725, pl. 28, figs. 4-7, pl. 29, fig. 8).

The generic redescription of Cushman (1910, p. 73) reads:

> Test free, spiral, composed of a proloculum and long undivided tubular second chamber, coiled regularly in one plane, wall finely arenaceous, cement usually brown, surface smooth.
>
> I have restricted *Ammodiscus* to the basis of Rhumbler, including only those species which have a truly planospiral test.

Until recently, planispirally coiled arenaceous Foraminifera were referred to the genus *Ammodiscus.* Loeblich and Tappan (1954, pp. 306-310) emended the genus and noted that Reuss had not named a type species when establishing the genus. They considered *Orbis infimus* Strickland (1846) to be the first species cited under this genus by Borneman (1874, p. 725). Hence they declared Borneman's species to be the type species by monotypy. This then made the original specimen of Strickland (*Orbis infimus*) the type for *Ammodiscus infimus*, but it was a calcareous form, and so all agglutinated forms assigned to *Ammodiscus* were removed from that genus. Loeblich and Tappan believed that Borneman included both Strickland's calcareous form and agglutinated analogies described by Terquem in 1862 in redescribing *Ammodiscus infimus.* Therefore, they referred all agglutinated forms to the genus *Involutina* Terquem (type species, *I. silicea*, 1862).

Later study by Loeblich and Tappan (1961, pp. 189-192) showed that their 1954 assumptions of Borneman's work were incorrect. Borneman's descriptions were based on original material of Terquem's *Involutina silicea* and not on that of Strickland, though he did mistakenly include *Orbis infimus* in with *Ammodiscus infimus.* Because Borneman recognized no other species in his genus, *Involutina silicea* becomes the type species by virtual monotypy. Other species identified as *Involutina* by Terquem in 1862 are calcareous planispiral forms with lateral umbilical filling and constitute that genus with the type species being *Involutina jonesi* Terquem and Piette (1862) [=*Involutina liasina*] (Jones), 1853. As corrected by Loeblich and Tappan in 1961 those agglutinated planispirally coiled species similar to *Ammodiscus infimus* Borneman are retained in *Ammodiscus* Reuss.

The basis of the genus *Bifurcammina* Ireland (1939) is the bifurcation of the test in the last coil. In at least one species, *B. conjuncta* Ireland (1939), the double tube fuses again so that there is only one aperture as in any other *Ammodiscus* species. Loeblich and Tappan (1964, p. 210) stated that such accidental bifurcation occurs among many species of *Ammodiscus* from Paleozoic to Recent. Moreman (1930, p. 59) described such bifurcating forms as questionably *Ammodiscus*. Ireland considered the form to be distinct even though it occurred associated with *Ammodiscus* in his material. On these bases *Bifurcammina* is here considered congeneric with *Ammodiscus*.

Ammodiscus exsertus Cushman Pl. 36, fig. 21; Pl. 40, fig. 21

1910. *Ammodiscus exsertus* Cushman, U. S. Nat. Mus., Bull. 71, pt. 1, pp. 75-76, text fig. 97a,b.
1942. *Ammodiscus brevitubus* Dunn, Jour. Paleont., vol. 16, No. 3, p. 339, pl. 44, fig. 24.
1959. *Involutina exsertus* (Cushman), Gutschick, and Treckman, Jour. Paleont., vol. 33, No. 2, p. 241, pl. 35, figs. 8, 9.
1961. *Involutina exserta* (Cushman), Conkin, Bull. Amer. Paleont., vol. 43, No. 196, p. 286, fig. 21, pl. 22, figs. 4-6, 8; pl. 26, figs. 16, 17, 19.
1961. *Involutina exserta* (Cushman), Mound, Indiana Dept. Conserv., Geol. Sur., Bull. No. 23, p. 20, pl. 1, figs. 3-5.

Description—Test free, consisting of small proloculus and tubular second chamber planispirally coiled with several volutions, the last becoming uncoiled in the same plane but at right angles to the preceding whorls; wall fine grained in present specimens, well cemented; aperture circular, at end of uncoiled portion of second chamber.

Measurements—Diameter of figured specimen U. C. 37851 is 0.33 mm., thickness 0.09 mm., length of uncoiled portion 0.10 mm.

Occurrence—Uncommon, three specimens; locality 9.

Discussion—*Ammodiscus exsertus* is most closely related to *A. longexsertus* (Gutschick and Treckman, 1959), from the Rockford limestone of northern Indiana but has a definitely shorter uncoiled portion. The tests show no evidence of being broken off near the aperture and no specimens of *A. longexsertus* were found in the present study.

Ammodiscus brevitubus Dunn (1942), from the Osgood limestone of Illinois, supposedly has fewer volutions and the second chamber is less compressed laterally, giving the test a more robust nature. It shows little evidence of being less compressed laterally and furthermore the number of volutions can vary within *A. exsertus*. It has been shown by Conkin (1961, pp. 287, 288) that the number of volutions varies from two to six and the amount of inflation also varies (he measured 22 specimens ranging in thickness from 0.033 mm. to 0.118 mm).

Genus **PSAMMONYX** Döderlein, 1892

1892. *Psammonyx* Döderlein, in "Demonstrationen", Deutsch. Zool. Gesell., Verhandl., vol. 2, p. 145.

1913. *Arpsammonyxum* Rhumbler, Die Foraminiferen der Plankton-Expedition, Pt. 2 Systematik, vol. 3, Lief. c, p. 386 (*nom. van.*).

Type species—Psammonyx vulcanicus Döderlein, (1892, *ibid.*, p. 146).

Döderlein (1892, p. 145) originally described the genus from Recent material found near Japan:

> The tests are compressed to thin walled plates coiled in the most varied manner in a single plane, sometimes only incidentally, others more hook-shaped, or even enrolled snail-like with as much as two complete turns. In some cases the narrow proloculus end is swollen to a type of primary chamber having a ball-like form. The often widened oral end bears the slit-like aperture; only seldom is the oral end tube-like in appearance. The largest complete example which the author possesses is coiled in a hook-like manner, 33 mm. long by 7 mm. wide, however fragments are present having a length of 26 mm. and width of 50 mm. These indicate specimens having a minimum length of 50-60 mm. The thickness of these is only 1 to 2 mm.

This genus is similar to *Ammodiscus* but the tubular chamber is compressed and the test is evolutely coiled instead of involute. The type species, *Psammonyx vulcanicus*, is one of the largest Foraminifera known while its Paleozoic ancestors, as discussed below, are no larger than their contemporary genera.

Psammonyx campbelli Browne and Schott Pl. 36, fig. 8; Pl. 40, fig. 8

1963. *Psammonyx campbelli* Browne and Schott, Bull. Amer. Paleont., vol. 46, No. 209, p. 204, pl. 49, fig. 6.

Description—Test free, compressed but expanding adorally, spherical proloculus and rapidly enlarging second chamber with evolute planispiral coiling for about 1¾ revolutions; wall finely arenaceous, well cemented; aperture terminal, slitlike.

Measurements—U. C. 37852 has larger diameter of 0.12 mm. near the proloculus and 0.20 mm. at the apertural end. Diameters in the direction of compression are 0.08 mm. near the proloculus and 0.14 mm. at the aperture. Measurements of the proloculus were not made because it was broken during study of the specimen.

Occurrence—Rare, one specimen; locality 9.

Discussion—This is a rare form which also occurs in the Osgood formation in the same area. It is much smaller than the type species, discussed above, from the Recent. A Devonian form from Oklahoma, *P. maxwelli* Ireland (1939), is larger and only slightly coiled. Possibly this represents the next stage in the phylogeny of the genus from *P. campbelli* to *P. vulcanicus*.

Subfamily **TOLYPAMMININAE** Cushman, 1928

Genus **LITUOTUBA** Rhumbler, 1895

1895. *Lituotuba* Rhumbler, Gesell. Wess. Göttingen, mathphysik Kl., Nachr., No. 1, p. 83.
1899. *Ammonema* Eimer and Fickert, Zeitschr. Wiss. Zool., vol. 65, No. 4, p. 685.
1913. *Arlituotubum* Rhumbler, Die Foraminiferen der Plankton-Expedition, Pt. 2 Systematik, vol. 3, Lief. c., p. 386 (*nom. van.*).
1943. *Thalmannina* Majzon, Evköyve, Magyar Kiralyi Föld. Intezet, vol. 37, No. 1, pp. 64, 154 (*fetae*).

Type species—*Lituotuba filum* (Schmid), 1867 (subsequent designation by Schellwien, 1898, Paleontographica, vol. 44, p. 265).

Cushman (1910, p. 114) redescribed the genus from Recent material from the North Pacific.

> Test of two distinct parts, an early close coiled portion and a long tubular uncoiled later portion; wall arenaceous, with an excess of cement, either indistinctly or irregularly divided.

This genus is related to *Ammodiscus* Reuss (1862), described above, but the initial coiling is not in a single plane. The uncoiled portion is similar except that it is longer than in most *Ammodiscus* species. *Glomospira* Rzehak (1888), which has been recognized in the Brassfield limestone of southern Indiana (Mound, 1961, p. 22), is also closely related by its similar manner of irregular coiling of the initial chamber. It does not possess a rectilinear second chamber.

Lituotuba? elongata Dunn Pl. 36, fig. 14; Pl. 40, fig. 14

1942. *Lituotuba elongata* Dunn, Jour. Paleont., vol. 16, No. 3, p. 340, pl. 44, fig. 36.

Description—Test free, consisting of proloculus about which a tubular second chamber is irregularly coiled; chamber then straightens in last portion forming a rectilinear tube normal to coiled portion; uncoiled portion almost as long as diameter of coiled part; wall thick to thin, medium grained, moderately cemented; aperture at end of uncoiled portion.

Measurements—Figured specimen U. C. 37830 has diameter of coiled portion 0.24 mm. and length of uncoiled portion 0.22 mm.

Occurrence—Rare, one specimen; locality 10.

Discussion—This specimen is poorly preserved and does not show much detail. It has questionably been referred to *Lituotuba* because of its definite affinities for *L. elongata.* Without being able to follow the pattern of coiling in the early part of the test, the possibility remains that this may be an *Ammodiscus longexsertus* (Gutschick and Treckman, 1959). It is considered to be more likely a *Lituotuba* because the tubular second chamber appears irregularly coiled, not in the definite planar fashion found in *Ammodiscus longexsertus.*

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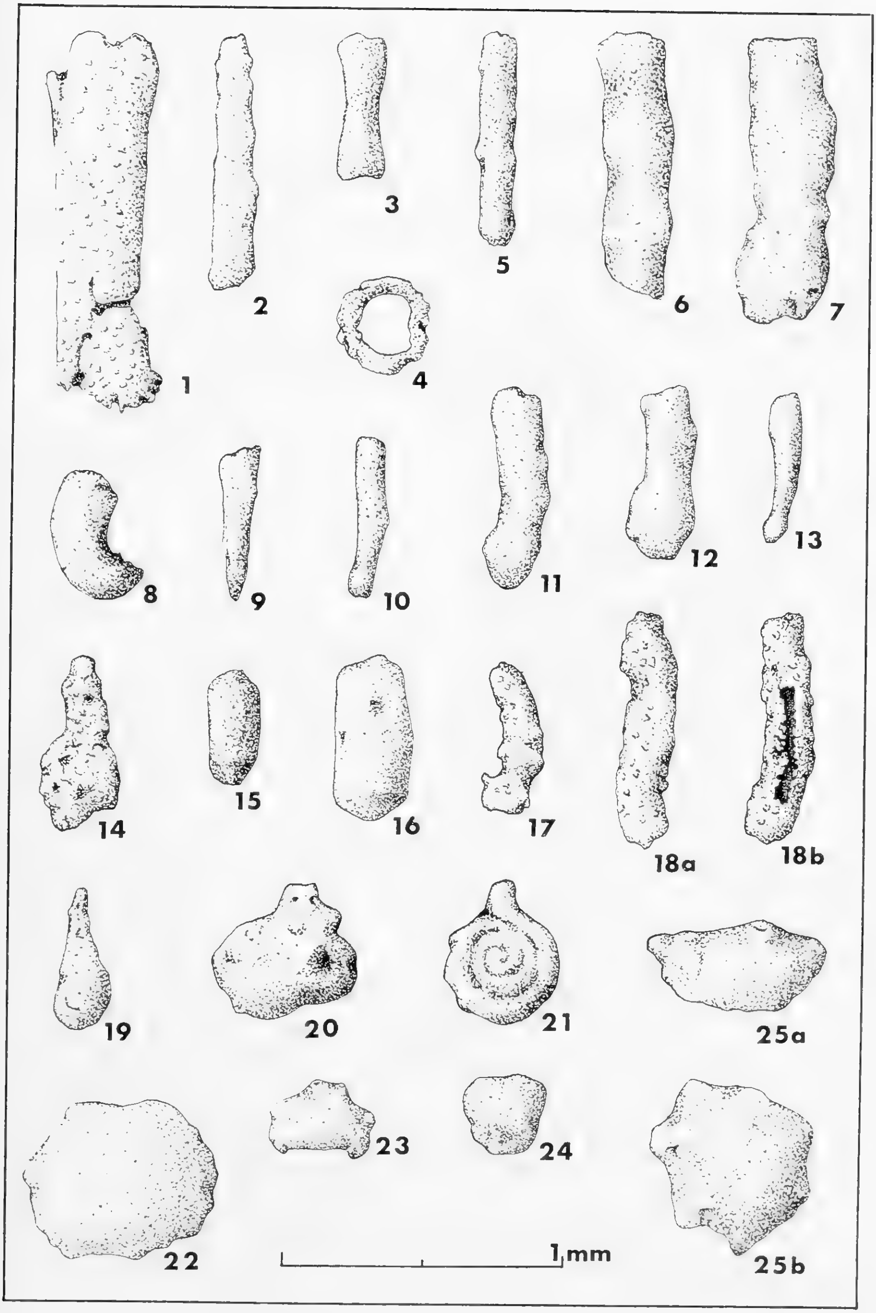
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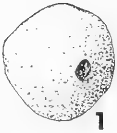
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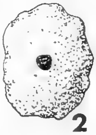
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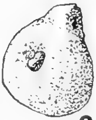
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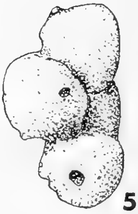
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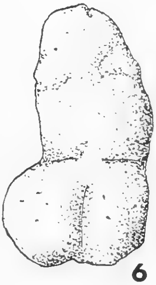
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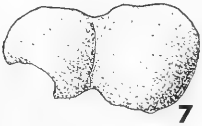
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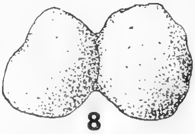
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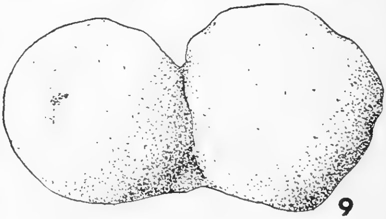
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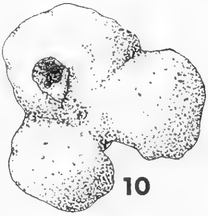
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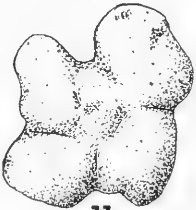
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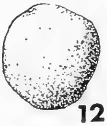
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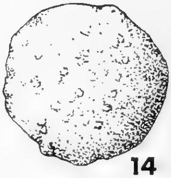
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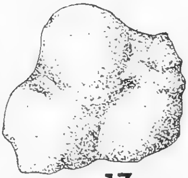
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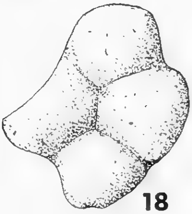
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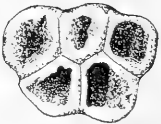
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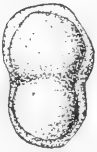
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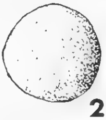
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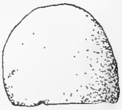
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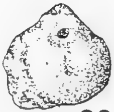
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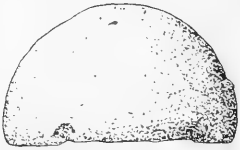
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1-5. **Sorostomasphaera waldronensis** McClellan, sp. nov. 479

1. U.C. 37813 paratype, single chamber. 2. U.C. 37816 paratype, single chamber. 3. U.C. 37815 paratype, single chamber with fragment of another. 4. U.C. 37814 paratype, five-chambered form with two complete. 5. U.C. 37812 holotype, four-chambered form.

6. **Sorosphaera confusa** Brady 471

U.C. 37798, four-chambered form.

7-9. **Sorosphaera bicella** Dunn 471

7. U.C. 37799, chambers closely joined. 8. U.C. 37801, chambers loosely joined. 9. U.C. 37800, large form.

10. **Sorosphaera tricella** Moreman 472

U.C. 37802.

11. **Sorosphaera osgoodensis** Stewart and Priddy 473

U.C. 37803, four-chambered form.

12-14. **Psammosphaera cava** Moreman 467

12. U.C. 37795. 13. U.C. 37797. 14. U.C. 37796. Show size variation.

15-19. **Metamorphina tholus** (Moreman) 489

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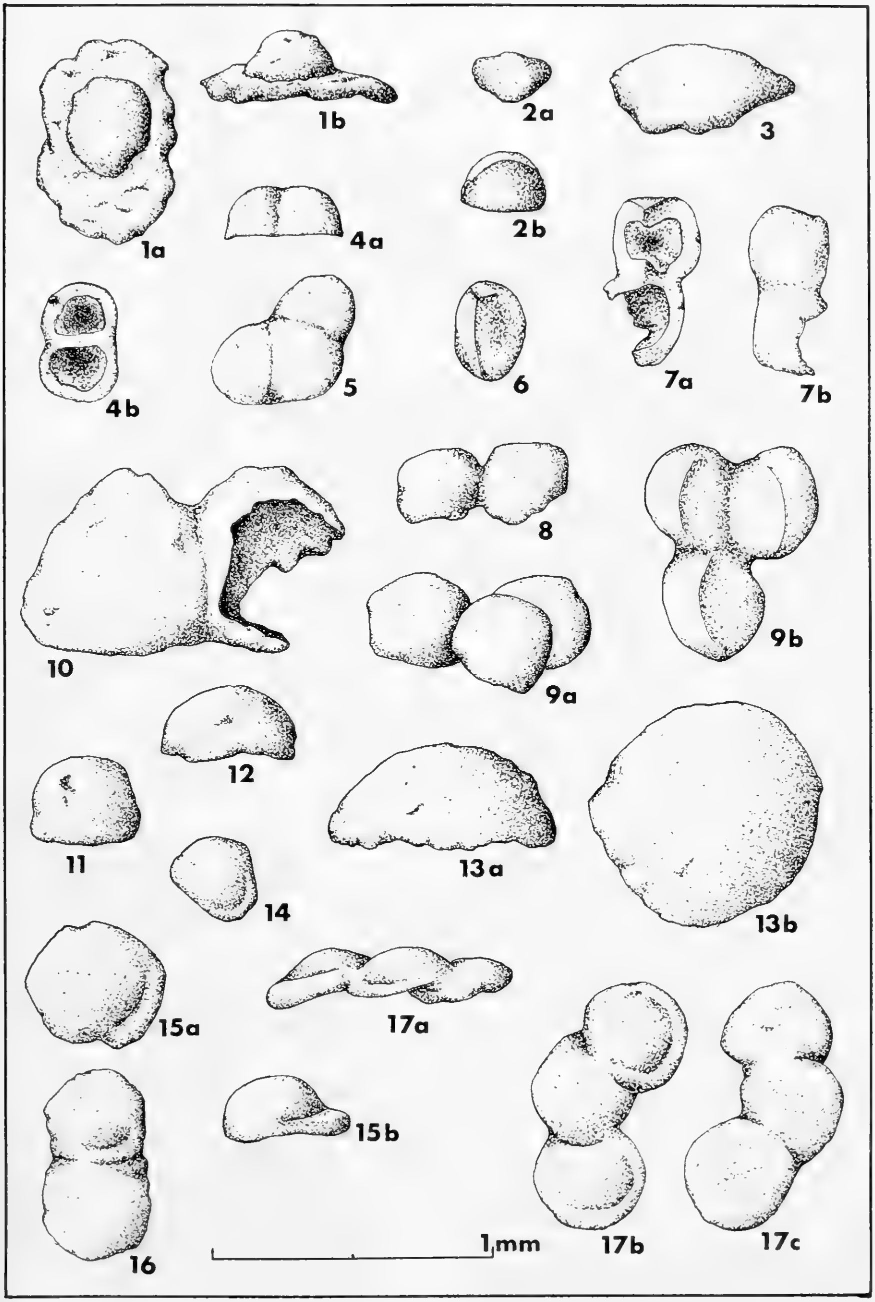
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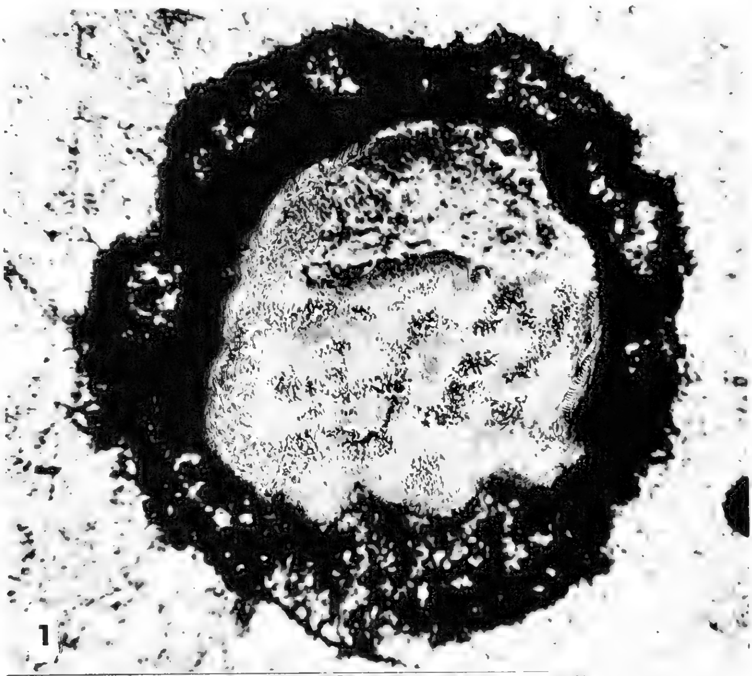

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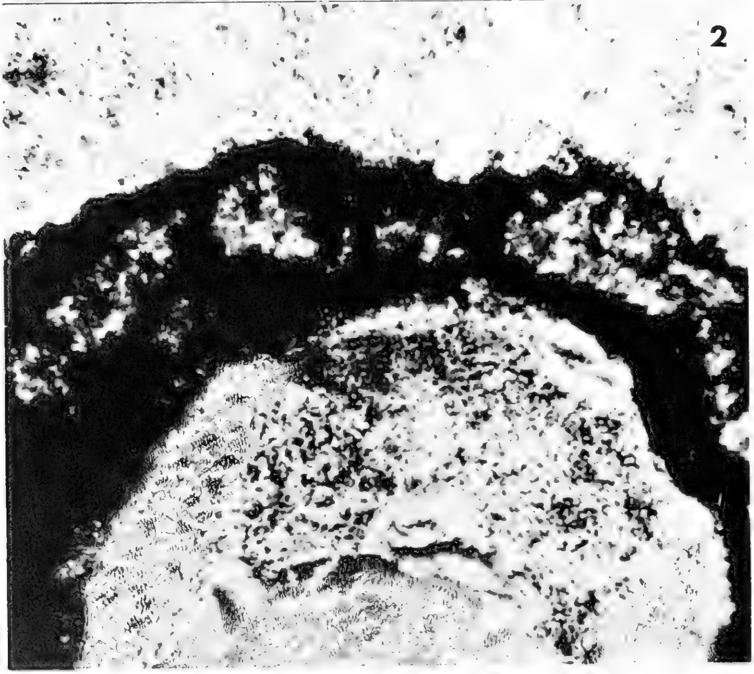

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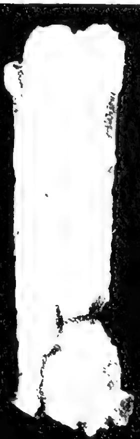
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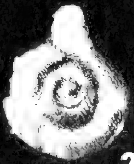
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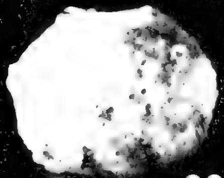
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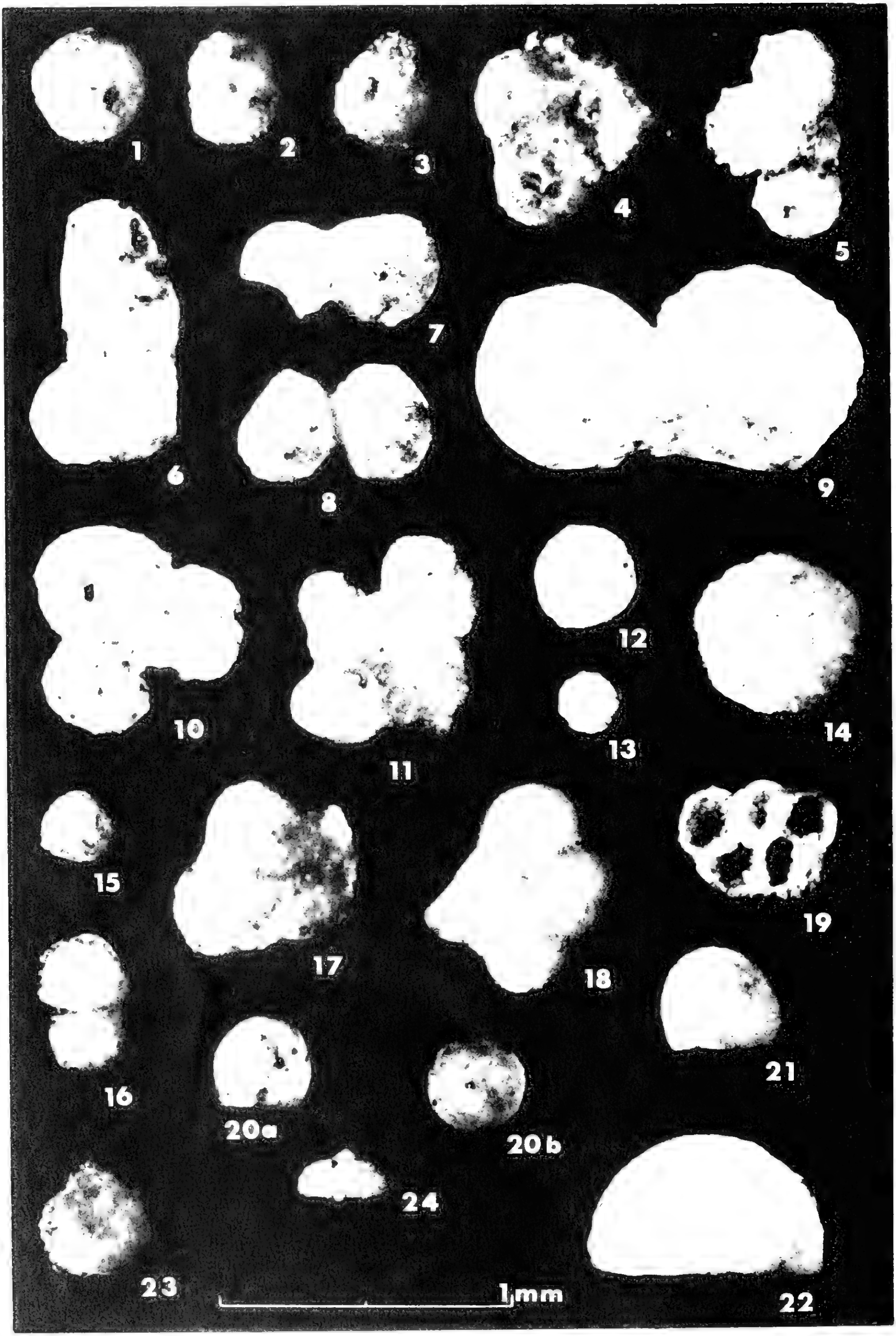
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1. U.C. 37813 paratype, single chamber. 2. U.C. 37816 paratype, single chamber. 3. U.C. 37815 paratype, single chamber with fragment of another. 4. U.C. 37814 paratype, five-chambered form with only two complete. 5. U.C. 37812 holotype, four-chambered form.

6. **Sorosphaera confusa** Brady 471
U.C. 37798, four-chambered form.

7-9. **Sorosphaera bicella** Dunn 471
7. U.C. 37799, chambers closely joined. 8. U.C. 37801, chambers loosely joined. 9. U.C. 37800, large form.

10. **Sorosphaera tricella** Moreman 472
U.C. 37802.

11. **Sorosphaera osgoodensis** Stewart and Priddy 473
U.C. 37803, four-chambered form.

12-14. **Psammosphaera cava** Moreman 467
12. U.C. 37795. 13. U.C. 37797. 14. U.C. 37796. Show size variation.

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15. U.C. 37829, single chamber. 16. Two-chambered form with prominent flange. 17. U.C. 37831, three-chambered form partially broken. 18. U.C. 37832, four-chambered form. 19. U.C. 37833, bottom view of partially broken five-chambered form.

20-22. **Hemisphaerammina bradyi** Loeblich and Tappan 485
20. U.C. 37824, highly convex form, a) side view b) top view. 21. U.C. 37823, slightly distorted. 22. U.C. 37822, large typical specimen.

23. **Stomasphaera brassfieldensis** Mound 480
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24. **Colonammina verruca** Moreman 487
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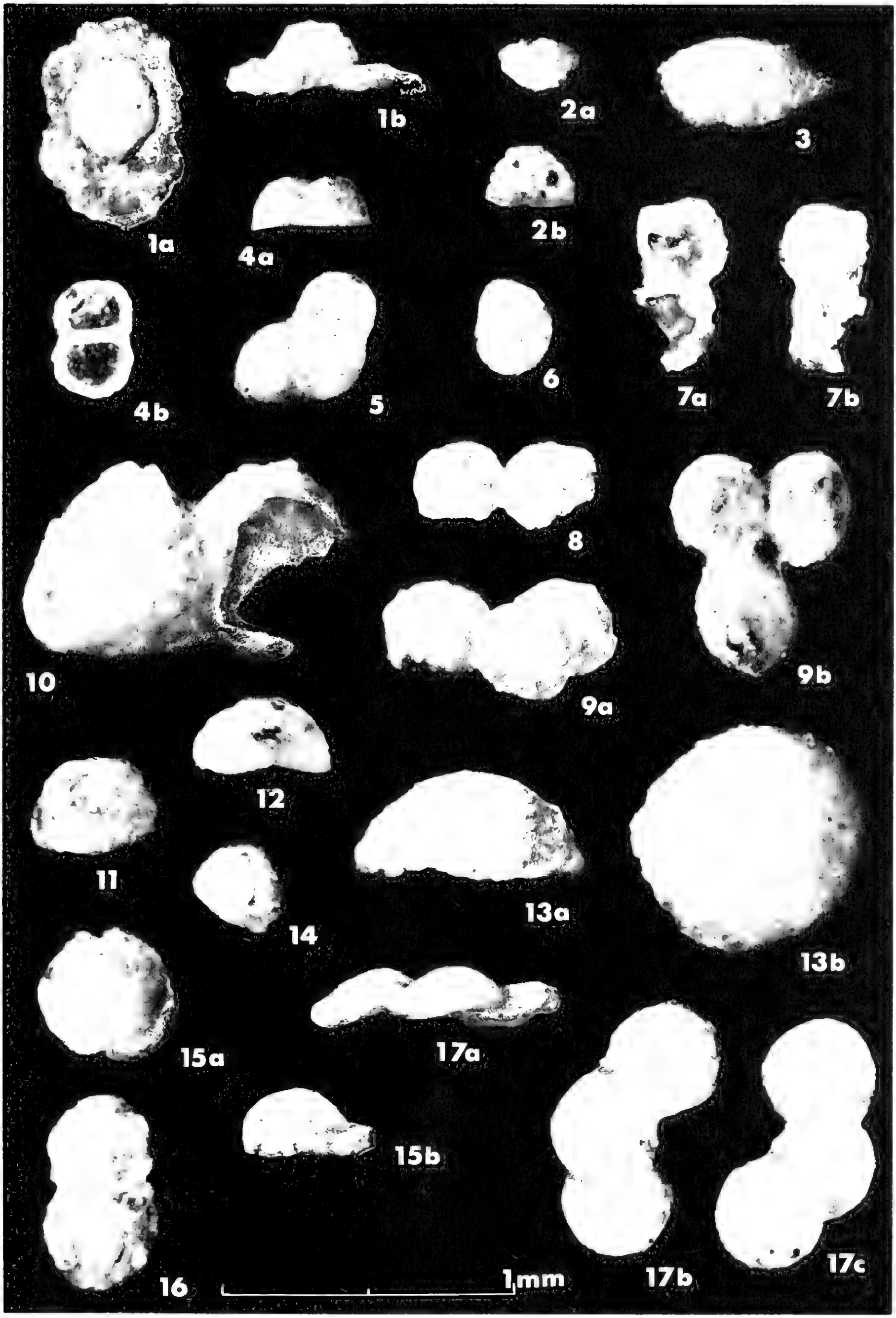
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