Systematics of the Fissiculate Blastoidea

D. Bradford Macurda, Jr.

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SYSTEMATICS OF THE FISSICULATE BLASTOIDEA

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ABSTRACT

The fissiculate blastoids, comprising almost half of the known genera, range from Silurian to Permian in age. Their phylogeny was described in a previous monograph by Breimer and Macurda (1972). Each species is described to document the conclusions presented in the earlier monograph. The following new taxa are proposed: *Artuschisma*, n. gen., (type species(?)), *Phaenoschisma rossica* Arendt, Breimer, and Macurda, 1968, *Leptoschisma*? *pentagonum*, n. sp., *Phaenoschisma*? *parvum*, n. sp., and *Hadroblastus*? *hibernicus*, n. sp. *Heteroschisma gracilis* (Wachsmuth, 1883) is synonymized with *Heteroschisma subtruncatum* (Hall, 1858).

INTRODUCTION

The fissiculate blastoids, comprising 36 named and 2 unnamed genera, and 92 species, range in age from Silurian to Permian. The generic systematics, internal anatomy, ontogeny, phylogeny, and geographic and stratigraphic distribution were extensively detailed by Breimer and Macurda (1972). Insufficient space precluded the publication of the specific descriptions and any additional photographs at the time of original publication. This publication contains the detailed description of each fissiculate species or a reference to a recent description; this work is designed to provide documentation for the conclusions of Breimer and Macurda (1972). It is designed as a companion piece to Breimer and Macurda (1972); therefore the user should consult the earlier work for cited references prior to 1972, terminology, definitions, and acknowledgments. The plates presented herein are designed to complement those of Breimer and Macurda (1972); a few photographs are duplicated for continuity in the species descriptions. One new fissiculate genus and species has been discovered since 1972; it is being described elsewhere because of prior commitments (Macurda, 1979). This research was conducted under NSF grant GB-5802. Claude Pareyn and Harrell Strimple have made additional material of some species available; James Sprinkle was kind enough to review the manuscript.

SYSTEMATIC PALEONTOLOGY

Class BLASTOIDEA

Order FISSICULATA

Family **Phaenoschismatidae** Etheridge and Carpenter, 1886

Genus DECASCHISMA Fay, 1961b

Type species.– *Codaster pulchellus* Miller and Dyer, 1878. *Decaschisma* Breimer and Macurda, 1972, p. 14.

DECASCHISMA PULCHELLUM (Miller and Dyer,1878)
Pl. 1, figs. 1-15; Table 1

Decaschisma pulchellum Breimer and Macurda, 1972, Pl. I, figs. 1-3.

Description.– Theca conical, with vault relatively short in comparison to pelvis (Pl. 1, figs. 2,8,9). Pelvis narrow (pelvic angle 40-56°), tapering to a proximal point. Profile of sides straight, rarely very slightly concave in large specimens; basals may turn inward in smaller specimens, producing a more convex base (Pl. 1, figs. 8,13). Vault angular, convex, with straight sloping sides whose extent becomes greater during growth in proportion to the flattened top. In small specimens upper tips of radial and aboral part of deltoid crest extend only very slightly above the oral opening; becoming more pronounced with growth. Outline of theca pentagonal in plan view (Pl. 1, figs. 1,6,12); interambulacral areas may become slightly indented in large specimens. Length greater than width (Table 1). Most preserved specimens less than 10 mm in length but ranging up to 27 mm.

Basalia three, in normal position; form approximately one-half pelvis (Pl. 1, fig. 7). Outline in lateral view conical, rarely convex. Outline in basal view pentagonal, becoming triangular with flat or slightly concave areas along interbasal sutures toward base of theca near stem attachment area. Theca tapers proximally to a small ovoid-triangular platform. Small BA axis present. Columnals circular, with upper most plate extending slightly farther adorally along interbasal sutures. Diameter of stem attachment areas varies from 0.3-1.0 mm; known columnals from 0.8-1.0 mm.

Azygous basal quadrate in plan view with straight lateral edges and slightly sinusoidal distal edges. Length greater than width. BR sector very slightly convex parallel to BR axis (occasionally more pronounced), becoming very slightly concave in older specimens (thecal length > 15.0 mm); BR sector convex normal to BR axis, flattening out in larger specimens; adjacent sectors merge smoothly. Zygous basals pentagonal, with straight lateral edges, a very slightly sinusoidal lateral distal edge, and a slightly concave distal medial edge. Central and lateral BR sectors very slightly convex (occasionally more pronounced) parallel to growth axis in small specimens; with additional growth BR sectors become slightly concave in proximal portion of C zygous basal, flatten out in E zygous basal in large specimens (> 15.0 mm). Central sector convex normal to BR axis whereas lateral sectors flat, so central part of plate more pronounced. BB axis measurable on azygous and zygous basals, BB sector being straight parallel to BB axis but very slightly concave normal to it in proximal part, thereby producing slightly concave area along interbasal suture in lower part of cone formed by basals. Basals ornamented by extremely fine growth lines parallel to BR and BB fronts (Pl. 1, fig. 13). See Table 1 for measurements.

Radials five, forming upper half of pelvis and extending to top of vault. (One mutant with sixth radial in anal interarea known.) Radial pentagonal in plan view, with convex (or two straight) lower edge(s); lateral sides slowly expand in width to just below aboral tip of ambulacrum, then contract slightly to deltoid so lateral edges slightly convex. Upper edges part of an aborally directed V as RD sectors contained within ambulacral sinus; no external growth front. Sinus extends about one-quarter of the length of the plate in small specimens, over one-third in large. In lateral view radial has triangular profile, with relatively straight upper edges, that bordering the ambulacral sinus increasing proportionally during growth but never equaling the edge facing the basals; lower edge slightly concave. RD sector contained within an ambulacral sinus, straight both parallel and normal to RD axis; RDF concave. RD sector at very sharp angle to RR sector. RR sector straight parallel to RR axis; normal to axis, sector straight in upper and lower portions but bends over in plane of aboral tips of ambulacrum, being convex in this area. Smoothly merges with RB sector which is essentially straight parallel and normal to the RB axis. Adjacent RB sectors become convex in the area where they merge. RR and RB sectors ornamented by extremely fine growth lines parallel to growth fronts; the two sectors may be delineated from one another by a very shallow groove between them. RWB: 0.8-5.0 mm; RWA: 1.5-7.2 mm; RWD: 1.0-3.6 mm. See also Table 1.

Deltoids four, together with superdeltoid forming border to oral opening (Pl. 1, fig. 12). In plan view overall shape of deltoid is rhombic but appears arrow-like because of long sharp aboral crest. In lateral view edge around peristome pronounced as the deltoid crest originates 0.2-0.4 mm below this. Crest rises upward from here to a point at which the aboral tip is equal to or slightly above the level of the peristome (smaller specimens) to as much as 1.0 mm above peristome in largest specimen. (Thus the upper tips of the radials also extend this far above peristome.) Profile of crest is usually straight but may be slightly concave or convex; length: 0.6-2.1 mm. Deltoid lip very small (length: 0.2-0.3 mm). Adoral edge very slightly concave; width expands very slightly along very short straight DDF, then contracts slightly along very short straight DAF to the minimum exposed width (0.2-0.7 mm). Apparently growth along DD and DA axis as maximum adoral width of plate increases from 0.3 mm to 1.0 mm. Deltoid lip ornamented with a small V-shaped rim bordering ambulacral tracts; also borders peristome. Aboral face of this rim concave, drops down 0.2-0.4 mm to aboral part of deltoid, the center of which is a sharp deltoid crest which extends laterally out to edge of upper surface of theca. Aboral sides slope steeply down into ambulacral sinus and are completely covered by hydrospire slits (Pl. 1, figs. 10,14).

Anal deltoids three, a super-, sub-, and hypodeltoid (Pl. 1, figs. 5,11). Superdeltoid small, corresponds in outline to adoral part of regular deltoid; length: 0.2-0.5 mm; maximum width increases from 0.4 mm to 1.2 mm. Super-subdeltoid suture at base of aboral dropoff of superdeltoid corresponding in position to beginning

TABLE 1. Growth relationships of principal variables of *Decaschisma pulchellum* (Miller and Dyer, 1878)

Variables	n	r	a_o	a_1	Observed Range y	x
L/W	13	0.96	-3.22	2.06	4.2–27.1	2.8–13.7
V/P	13	0.96	-0.65	0.35	0.3– 6.8	3.9–20.3
L/ABBR	13	0.99	2.33	2.02	4.2–27.1	1.7–12.4
L/RD	13	0.99	1.91	3.53	4.2–27.1	0.7– 7.2
L/RB	13	0.99	-1.73	2.68	4.2–27.1	2.0–10.3
L/Del.L.	13	0.83	-10.12	10.45	4.2–27.1	1.0– 2.8
L/Amb.L.	13	0.98	0.70	2.94	4.2–27.1	1.0– 8.7
L/No.Hyd.Sl.	11	0.80	1.57	0.88	4.2– 9.8	3.0– 9.0
RD/Amb.L.	13	0.99	-0.33	0.83	0.7– 7.2	1.0– 8.7
Del.L./Amb.L.	13	0.88	1.26	0.21	1.0– 2.8	1.0– 8.7
ABL/ABW	12	0.91	-0.55	1.85	1.8– 7.0	1.1– 3.5
ABBR/ABBRF	12	0.79	-0.32	2.37	1.7– 6.3	0.6– 2.0
ABBB/ABBBF	12	0.73	0.13	0.12	0.2– 0.8	1.5– 6.2
ABBB/ABBR	12	0.72	0.13	0.12	0.2– 0.8	1.7– 6.3
ZBL/ZBW	12	0.92	-0.68	1.59	1.8– 7.0	1.4– 4.0
ZBBR/ZBBRF	12	0.73	0.40	2.02	1.7– 6.5	0.5– 2.0
ABBR/RB	13	0.97	-1.81	1.28	1.7–12.4	2.0–10.3
ABBR/RD	13	0.96	-0.07	1.69	1.7–12.4	0.7– 7.2
ABBR/Del.L.	13	0.75	-5.08	4.60	1.7–12.4	1.0– 2.8
RD/RDF	16	0.93	-0.72	1.86	0.7– 7.2	0.5– 3.6
RR/RRF	16	0.98	0.24	0.31	1.0– 5.5	2.5–16.5
RB/RBF	16	0.97	0.64	3.17	2.0–10.3	0.4– 3.1
RD/RR	16	0.98	-0.71	1.44	0.7– 7.2	1.0– 5.5
RD/RB	16	0.98	-0.91	0.73	0.7– 7.2	2.0–10.3
RR/RB	16	0.98	-0.10	0.50	1.0– 5.5	2.0–10.3
RD/Del.L.	16	0.88	-3.35	2.94	0.7– 7.2	1.0– 3.0
RB/Del.L.	16	0.91	-3.38	4.03	2.0–10.3	1.0– 3.0
Del.L./Gr.Ab.W.	14	0.88	1.04	0.61	1.2– 2.8	0.8– 3.0
Del.L./Anal Del.L.	14	0.89	1.14	0.30	1.2– 2.8	2.4– 6.4
Amb.L./Amb.W.	9	0.50	-3.99	9.16	1.5– 8.7	0.6– 1.0
Amb.L./No. S.P.	9	0.98	0.63	0.26	1.5– 8.7	5.0–29.0

n = number of specimens; r = correlation coefficient (y, x); a_o = y intercept; a_1 = regression coefficient of crest in regular deltoid. Subdeltoid a large horseshoe-shaped plate which expands in width aborally, and is convex against the superdeltoid; laterally the prongs border the lancets and extend out to the radiodeltoid suture. Two troughs, originating along the super-subdeltoid suture, pass outward along the upper surface of the subdeltoid limbs to the anal hydrospire fields which are developed across the subdeltoid-radial suture. Space between limbs of subdeltoid continually expands aborally, being nearly the full width of the hypodeltoid. Limbs of subdeltoid slope into ambulacral sinuses; length of subdeltoid (adoral edge of limb) increases during growth from 1.0 to 3.8 mm. Hypodeltoid rarely preserved, triangular in lateral view of theca (Pl. 1, fig. 11). Hypodeltoid pentagonal in plan view, with straight aboral edges reaching to edge of ambulacral sinus where they are in contact with the limbs of subdeltoid. Width of hypodeltoid at a maximum here, increasing during growth from 0.8 to 4.8 mm, as evidenced by facets. Plate contracts in width adorally, with straight sub-hypodeltoid suture which rises topographically to level of anal opening. Adoral edge is concave because of anal opening, rises up steeply to highest topographic point of hypodeltoid at aboral edge of anal opening. From this point, hypodeltoid slopes down into ambulacral sinuses on sides and on the side of the theca aborally. Hypodeltoid thus forms interambulacral pyramid corresponding to those of regular deltoids but not projecting quite as high. The aboral surface of hypodeltoid is ornamented by growth lines parallel to the hypodeltoid suture (Pl. 1, fig. 11). Thus origin of plate is at apex, and it has grown outward and downward along the hyporadial and sub-hypodeltoid sutures. Anal opening ovoid, with length greater than width, size apparently increasing during growth, but indeterminate because hypodeltoids so rarely preserved. Anal opening opens upward; level slightly below that of peristome. Radial limbs shorter in anal interarea, with large external growth sector against hypodeltoid in addition to that in ambulacral sinus.

Ambulacra five, sited in an ambulacral sinus and thus below level of surrounding plates throughout length (Pl. 1, fig. 10). Outline linear, being very slightly convex in small specimens (Pl. 1, fig. 3); slightly convex in lateral view. Lancet begins very close to oral center (0.3 mm) in small specimens, increasing to 0.8 mm in large. Adoral 0.4-0.5 mm of lancet completely exposed; then side and outer plates come in and lancet completely concealed, side plates meeting in a zigzag pattern in center of ambulacrum (Pl. 1, figs. 4,10,12,15). Upper surface slopes downward laterally from a median crest. Triangular outer side plate embays lateral edge of side plates; length in plan view 0.225 mm; width: 0.150 mm. Brachiolar facet developed on side and outer side plate on outer sloping surface of ambulacrum (Pl. 1, fig. 15), ovoid in shape, length: 0.30 mm; width: 0.225 mm. Adjacent facets very closely spaced, rims apparently in contact with one another. Minor lobes and grooves apparently present along main and adoral edge of side food grooves; absent along aboral edge?

Ten hydrospire groups, partly exposed, occupying full width of radiodeltoid suture and extending length of ambulacral sinus. Slits narrow, approximately 0.025-0.04 mm wide. Upper slits completely exposed; entry to lower slits by gap between ambulacrum and neighboring plates. Number varies from about 3 to 9. Ontogenetic relations somewhat vague as some of largest specimens have only 7. Number reduced in anal interarea, here 2-4.

Oral opening ovoid, width: 0.3-1.0 mm.

Distribution.– Silurian, Waldron Shale, Indiana and Tennessee, U.S.A.

Remarks.– The above description is based upon the specimens in the growth series (Appendix 1) plus additional specimens figured in Plate 1. The internal anatomy and ontogeny of this species were discussed and illustrated by Breimer and Macurda (1972) and are further summarized in Table 1.

Genus POLYDELTOIDEUS Reimann and Fay, 1961

Type species.– Polydeltoideus enodatus Reimann and Fay, 1961. *Polydeltoideus* Breimer and Macurda, 1972, p. 15.

POLYDELTOIDEUS ENODATUS
Reimann and Fay, 1961
Pl. 2, figs. 1-4,6,7,9-14; Table 2
Polydeltoideus enodatus Breimer and Macurda, 1972, Pl. I, figs. 8,12.

Description.– Theca conical, with vault short in comparison to pelvis (Pl. 2, figs. 2,3). Pelvis very narrow, with conical profile which is sometimes slightly concave because of the long extension of the basals. Pelvic angle 26-36°. Vault angular, convex, relatively low, with very slightly convex sides and flattened top. Upper part of radials and aboral part of deltoid crest project above oral opening. Outline of theca pentagonal in small specimens, becoming slightly pentalobate in larger specimens with indentation occurring in interambulacral areas (Pl. 2, figs. 6,7). Length greater than width; vault less than pelvis (Table 2).

Basalia three, in normal position, forming slightly over one-half of pelvis. Outline in lateral view conical, with concave curvature about one-third of length above stem attachment area. Outline in plan view decagonal at distal tip, becoming round medially, then rounded triangular proximally. Basals taper proximally to a small ovoid-triangular tip. Stem attachment area formed by growth of BA axis (Pl. 2, fig. 10); stem cicatrix a small, ovoid-triangular indentation at proximal tip of basals. Diameter of stem attachment area varies ontogenetically from 0.7-1.5 mm.

Azygous basal quadrate, elongate, narrow in plan view, with straight lateral and distal edges; concave near proximal end in lateral view. BR sector slightly concave proximally, straight distally parallel to BR axis; convex perpendicular to BR axis proximally, becoming nearly flat distally. BB sector slightly convex parallel to, concave perpendicular to BB axis. BA sector relatively large, straight parallel to and convex perpendicular to BA axis. BB and BA sectors merge smoothly while BR sectors slightly set off from BB sectors. All sectors ornamented by fine growth lines which parallel growth fronts. ABBA: 0.8-2.0 mm; ABBAF: 0.7-1.3 mm. Zygous basals pentagonal in plan view, with lateral edges being concave proximally, straight distally; lateral distal edges straight; medial distal edge concave. Profile laterally as for azygous basal. Medial and lateral BR sectors slightly concave proximally, becoming straight distally parallel to BR axis. Medial sector convex perpendicular to BR axis throughout while lateral sectors become flatter distally; adjacent BR sectors merge smoothly with one another and RB sectors. BB and BA sectors and ornament as for azygous basal.

Radials five, forming upper part of pelvis and extending to top of vault. Radial hexagonal in plan view, with strongly convex or straight lower edges, slightly convex lateral edges (recurvature occurring between ambulacral tip and upper apex), and two slightly concave distal edges which slant into ambulacral sinus. Radial sinus relatively short, parabolic, with straight sides. Radial triangular in lateral view, with short slightly convex adoral facing edge, long straight aboral facing edge, and concave lower edge. RB sector straight to very slightly convex parallel to RB axis and very slightly concave perpendicular to it. Adjacent RB sectors merge smoothly over convex surface and with an RR sector over a flat surface. RR sector very slightly convex parallel to RR axis and slightly convex normal to it. RD sector at a sharp angle to RR sector, being confined to an ambulacral sinus. RD sector straight parallel to RD axis and very slightly convex to concave perpendicular to it. RB sector ornamented by fine growth lines parallel to RBF; those in RR sector coarser (Pl. 2, fig. 4). RHt: 0.7-2.7 mm; RWB: 1.8-4.7 mm; RWA: 2.6-5.7 mm; RWD: 2.1-4.8 mm. See also Table 2.

Deltoids four, together with superdeltoid forming border to oral opening (Pl. 2, figs. 12,13). Deltoid rhombic in plan view and pyramidal in lateral view because of upward slope of deltoid crest; profile of crest is straight to very slightly convex. Deltoid lip small, confined to region near peristome. Adoral edge of deltoid bordering oral opening straight. Width of plate widens aborally along a short DDF, then constricts along a concave DAF to minimum width of exposed deltoid. Deltoid lip ornamented by an arcuate, adoral facing ridge whose adoral face bears minor grooves and furrows (Pl. 2, fig. 12). Aboral to ridge, deltoid lip slopes downward aborally into two adjacent ambulacral sinuses. Origin of deltoid crest at narrowest exposed part of deltoid between adjacent DAF; crest rises upward aborally to meet adoral tips of radials. Sides of deltoid crest slope down into ambulacral sinuses and are ornamented by hydrospire slits except near aboral apex. Deltoid body rhombic in plan view, with straight DAF and slightly concave DRF. Deltoid crest highest at its aboral tip (0.1-0.7 mm above peristome). Del.Gr.Ad.W.: 0.3-0.8 mm; Min.W.: 0.2-0.5 mm; L.Crest: 1.2-3.3 mm; DR: 0.8-3.1 mm.

Anal deltoids five, a superdeltoid, subdeltoid, two paradeltoids, and a hypodeltoid. Superdeltoid small, corresponding to deltoid lip of regular deltoids. Subdeltoid relatively large, horseshoe-shaped plate with a thin adoral connection joining two lateral limbs which correspond to the lower lateral parts of the deltoid body (Pl. 2, fig. 12). Limbs extend to radiodeltoid suture. Paradeltoids are two pentagonal plates which sit atop limbs of subdeltoid and form aboral border to anal opening (Pl. 2, fig. 13). Longest edge sits atop subdeltoid limb and is straight. Aboral face of plate is very slightly sinusoidal, faces hypodeltoid, and slants inward. Suture between paradeltoids short, straight; two edges bordering anal opening each slightly concave. Highest point of paradeltoid is at junction between these latter two sutures; two sides slope downward into ambulacral sinus and aborally toward hypodeltoid. Hypo-

TABLE 2. Growth relationships of principal variables of *Polydeltoideus enodatus* Fay and Reimann, 1961

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	11	0.99	0.40	2.11	9.8–21.5	4.8–10.0
V/P	11	0.74	0.26	0.07	0.8– 1.8	8.6–20.0
L/ABBR	11	0.96	-0.50	2.26	9.8–21.5	4.5– 9.3
L/RD	11	0.94	1.88	6.05	9.8–21.5	1.5– 3.3
L/RB	11	0.99	2.82	2.41	9.8–21.5	3.0– 8.0
L/Del.L.	11	0.90	-0.06	5.88	9.8–21.5	1.8– 3.5
L/Amb.L.	11	0.96	4.44	3.32	9.8–21.5	1.8– 5.2
L/No.Hyd.Sl.	12	0.80	-4.53	3.14	9.8–23.0	5.0– 9.0
RD/Amb.L.	14	0.98	0.32	0.59	1.5– 4.5	1.8– 7.2
Del.L./Amb.L.	14	0.96	1.12	0.44	1.8– 4.1	1.8– 7.2
ABL/ABW	11	0.96	0.95	3.53	6.7–12.4	1.7– 3.0
ABBR/ABBRF	11	0.80	1.42	2.77	4.5– 9.3	0.9– 2.5
ABBB/ABBBF	13	0.98	0.61	1.06	0.4– 1.0	5.4–10.9
ABBB/ABBR	11	0.65	0.27	0.06	0.4– 1.0	4.5– 9.3
ZBL/ZBW	11	0.95	1.39	2.03	5.8–11.4	2.4– 4.6
ZBBR/ZBBRF	11	0.83	0.19	3.44	4.8– 9.2	1.4– 2.5
ABBR/RB	11	0.93	1.95	0.97	4.5– 9.3	3.0– 8.0
ABBR/RD	11	0.86	1.70	2.36	4.5– 9.3	1.5– 3.3
ABBR/Del.L.	11	0.79	1.18	2.20	4.5– 9.3	1.8– 3.5
RD/RDF	18	0.95	-0.95	2.01	1.5– 4.5	1.2– 2.5
RR/RRF	18	0.97	-0.26	2.32	1.5– 4.3	3.6–12.0
RB/RBF	18	0.88	-0.01	3.13	3.0– 9.3	1.1– 3.2
RD/RR	18	0.98	-0.18	1.08	1.5– 4.5	1.5– 4.3
RD/RB	18	0.95	-0.05	0.44	1.5– 4.5	3.0– 9.3
RR/RB	18	0.96	0.15	0.40	1.5– 4.3	3.0– 9.3
RD/Del.L.	15	0.95	-0.97	1.25	1.5– 4.5	2.0– 4.1
RB/Del.L.	15	0.91	-1.22	2.49	3.0– 9.3	2.0– 4.1
Del.L./Gr.Ab.W.	16	0.94	0.98	0.95	2.0– 4.1	1.0– 3.5
Del.L./Anal Del.L.	16	0.99	0.28	0.79	2.0– 4.1	2.1– 4.8
Amb.L./Amb.W.	9	0.88	-3.36	6.52	1.8– 5.2	0.8– 1.2
Amb.L./No. S.P.	9	0.95	-0.34	0.31	1.8– 5.2	6.0–17.0

deltoid a broad hexagonal plate, with two slightly sinusoidal sutures bordering paradeltoids, a short straight suture where it rests atop the upper outer edge of the subdeltoid limb, and it has two convex edges against adjacent radial limbs, a short portion of which occurs within the ambulacral sinus but the larger part of which occurs on the thecal wall (Pl. 2, figs. 1,9). Highest point of hypodeltoid (its origin) slightly below that of paradeltoids. Its upper surface is pyramidal. Two surfaces slope downward adorally toward paradeltoids; third surface forms part of outer wall of theca (Pl. 2, figs. 1,9,13). Hypodeltoid and paradeltoids thus form interambulacral pyramid corresponding to that of regular deltoids. Anal opening ovoid, length greater than width, bordered adorally by subdeltoid, aborally by two paradeltoids. Super.Gr.Ad.W.: 0.3-0.8 mm; Anus L.: 0.9-2.0 mm; Anus W.: 0.5-1.0 mm; Hypo.L.: 0.4-2.0 mm; Hypo.W.: 0.9-3.1 mm; O.c.-anus: 0.4-1.2 mm.

Ambulacra five, sited in an ambulacral sinus and thus below level of surrounding plates (Pl. 2, figs. 11, 14). Ambulacra lanceolate-petaloid in plan view, slightly convex in lateral view, and flat in cross section except for sloping lateral edges. Lancet begins 0.3-0.5 mm from oral center. Lancet exposed only at its adoral tip (small hexagonal area), linear in plan view, slightly convex in lateral view, and strongly convex in cross section. Side plates meet in a zigzag pattern along center of ambulacrum (Pl. 2, fig. 14). Side plates pentagonal, with slightly convex admedial edge, straight adoral edge, two straight aboral edges (inner one bordering next side plate), and an outer edge. Triangular side plate, on sloping lateral edge of ambulacrum embays side plate and forms adoral half of brachiolar facet. Latter sited on sloping side of ambulacrum. Minor lobes and grooves border main groove (4 per side plate) and adoral side of side groove (Pl. 2, fig. 14).

Ten hydrospire groups, completely exposed except for innermost 1-2 slits, occupying full width and length of ambulacral sinus except in outermost part of large specimens. Number of hydrospires per regular group 5-10; length hydro. fld.: 1.2-6.5 mm; width hydro. fld.: 0.4-2.0 mm. Number of hydrospires in anal interarea reduced by 2-6 per group (usually 3-4); length of field slightly shorter, formed by subdeltoid and radials.

Oral opening pentagonal, width: 0.5-0.7 mm.

Distribution.— Silurian, Henryhouse Formation, Oklahoma, U.S.A.

Remarks.— The above description is based upon the specimens in the growth series (Appendix 1). The internal anatomy and ontogeny of this species were discussed by Breimer and Macurda (1972) and are further summarized in Table 2.

POLYDELTOIDEUS? PLASOVAE Prokop, 1962

?*Polydeltoideus plasovae* Breimer and Macurda, 1972, p. 14.

Description.— Theca conical, with long conical pelvis which bends out slightly at radials; convex vault, indented at peristome as deltoid crest rises above peristome. Theca pentagonal in cross section, sloping inward very slightly toward interradial suture; greatest width at aboral tip of ambulacra. L.: 14.3 mm; W.: 8.0 mm; V.: 2.5 mm; P.: 11.8 mm; pelvic angle: 46°.

Basals three, in normal position, form slightly more than one-half of conical pelvis. Basals taper proximally to narrow point; BA growth axis probably present. Azygous basal quadrate in plan view, straight lateral view. ABL: 8.6 mm; ABW: 3.6 mm; ABBB: 0.7 mm; ABBBF: 8.2 mm; ABBR: 8.4 mm; ABBRF: 2.0 mm. Zygous basals pentagonal, with straight lateral and distal lateral edges; distal medial edge slightly concave. BR sectors straight parallel to BR axis, medial sector convex normal to BR axis; lateral sectors flatter normal to axis; lateral sectors merge with medial sector over angular boundary; BB sector prominent, lateral BR sectors bend down into this. BA axis may be present. ZBL: 8.5 mm; ZBW: 5.1 mm; ZBOPt: 8.7 mm; ZBBR: 8.5 mm; ZBBRF: 2.0 mm. No growth lines preserved on basals.

Radials five, forming upper part of pelvis and complete lateral profile of vault, extending above peristome. Radials pentagonal in plan view, with convex base, slightly convex lateral sides which expand in width to aboral tip of ambulacrum, then contract adorally; V-shaped ambulacral sinus embays adoral one-third of plate; RD sector confined to sinus. Radial triangular in lateral view, with slightly convex adoral edge; edge facing basals slightly longer, straight; lower edge slightly concave. Growth of RD sector entirely within ambulacral sinus; sides slope steeply inward, RD sector straight parallel and normal to RD axis; hydrospire slits occupy full width of radiodeltoid suture. RR sector large, straight parallel to and convex normal to RR axis. RB sector straight parallel to RB axis, relatively flat normal to it; junctions with neighboring

RR and RB sector form slight angles. No growth lines preserved in RR or RB sectors. RHT: 1.5 mm; RWB: 3.0 mm; RWA: 4.1 mm; RWD: 3.0 mm; RD: 2.8 mm; RDF: 2.2 mm; RR: 2.7 mm; RRF: 5.7 mm; RB: 4.5 mm; RBF: 1.7 mm.

Deltoids four, together with epi- or superdeltoid forms border to peristome. Deltoids small, confined to upper surface of theca, no growth sector external to ambulacral sinus. Lip on adoral edge of deltoid; trough aboral to this which diverges aborally leading down into hydrospire area. Crest of deltoid rises aboral to this, extending 1.0 mm above peristome. Hydrospire slits occupy sides of crest, which slope steeply down into ambulacral sinus. Del.L.: 2.2 mm; Gr.Ad.W.: 0.5 mm; Max.Ab.W.: 1.7 mm; L.Crest: 1.7 mm; DR: 0.7 mm.

Configuration and number of anal deltoids unclear. Epi- or superdeltoid borders peristome, drops down aborally to level of anus and limbs continue aborally to radial; suggestion of suture at base of dropoff adoral to anus but not clear. Hypodeltoid, if present, now missing. Length anal deltoids: 2.3 mm; Gr.Ad.W.: 1.0(a) mm; O.c.-Ad.E.An.: 1.3 mm.

Ambulacra five, narrowly lanceolate in plan view, sloping downward from peristome; convex in cross section with depressed center. Lancet concealed. Side plates preserved A ambulacrum, 3 per mm. Amb. L.: 4.0 mm; Amb.W.: 1.0 mm.

Ten exposed hydrospire fields, in ambulacral sinus, occupy full width of radiodeltoid suture in non-anal areas, reduced in number in anal interarea. Approximately seven hydrospire slits on each side of ambulacrum, width of field: 1.5 mm; in anal interarea, approximately 3, width of field: 0.7(va) mm. (Anal hydrospires visible on D side; C weathered).

Occurrence.— Upper Silurian (Upper Budnanian), Přídolí Beds, "lobolite hillside," Reporyje near Prague, Czechoslovakia (Prokop, 1962, p. 302).

Remarks.— This blastoid was described by Prokop in 1962 and is significant because it is the only Silurian blastoid known outside North America. Prokop assigned it to the genus *Polydeltoideus*, but the anal area was covered by matrix. Further preparation of the specimen revealed the anal hydrospires but did not resolve the number of anal deltoids. For this reason, the generic position of this blastoid is uncertain.

The specimen is in the personal collection of Mrs. B. Plasová, Prague, who made it available for study. R. Prokop arranged for the study of the specimen and guided Breimer and Macurda to the locality where Mrs. Plasová found it. No further material was obtained during our visit. No photographs were obtained because my lighting system (220v) was incompatible with that (110v) in the old part of the city of Prague.

Genus LEPTOSCHISMA Breimer and Macurda, 1972

Type species.— *Codaster lorae* Dunbar, 1920. *Leptoschisma* Breimer and Macurda, 1972, p. 15.

LEPTOSCHISMA LORAE (Dunbar, 1920)
Pl. 2, figs. 5,8; Pl. 3, figs. 1-6, 8; Table 3
Leptoschisma lorae Breimer and Macurda, 1972,
Pl. I, figs. 4-7

Description.— Theca conical, with relatively short vault. Pelvis conical, with straight sides except for slight recurvature near base of theca (Pl. 2, fig. 5). Pelvic angle 32-44°. Vault angular to convex, with upper tip of radials and aboral tip of deltoid crest equal to or projecting above oral opening. Outline of theca pentagonal in plan view; occasionally slight indentation of interambulacral areas (Pl. 2, fig. 8). Length greater than width (Table 3); thecae relatively small.

Basalia three, in normal position; form lower half of pelvis. Outline in lateral view conical, with slight recurvature near tip of basals. Outline in basal view pentangular, becoming rounded-triangular near proximal tip. Stem attachment area formed by growth along short BA axis. Stem cicatrix a shallow depression at proximal tip of basalia; 0.3-0.7 mm diameter. Azygous basal elongate, narrow, quadrate in plan view, with straight lateral and distal edges. Azygous basal slightly concave in lateral view due to slight recurvature near proximal tip. BR sector slightly concave proximally, straight distally parallel to BR axis, slightly convex perpendicular to it; adjacent sectors merge over convex surface. Small BB sector present, straight parallel to and slightly concave perpendicular to BB axis. Small BA sector present, straight parallel to and convex perpendicular to BA axis. All sectors ornamented with fine growth lines which parallel the growth fronts. ABBA: 0.2-0.4 mm; ABBAF: 0.3-0.5 mm. Zygous basals pentagonal in plan view, with straight lateral and distal lateral edges and a concave distal medial edge. Lateral profile as for azygous basal. Medial and lateral BR sectors slightly concave proximally, straight distally parallel to BR axis; medial sector convex proximally, slightly convex distally perpendicular to BR axis while lateral sectors are flat. BR and RB sectors merge

TABLE 3. Growth relationships of principal variables of *Leptoschisma lorae* (Dunbar, 1920)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	5	0.99	-0.03	1.85	5.2–12.5	3.0– 7.0
V/P	5	0.83	-1.07	0.35	0.7– 3.0	4.5– 9.5
L/ABBR	5	0.99	-0.10	2.69	5.2–12.5	1.9– 4.7
L/RD	5	0.97	3.27	3.09	5.2–12.5	0.8– 3.2
L/RB	5	0.96	0.89	2.40	5.2–12.5	1.8– 4.5
L/Del.L.	5	0.44	-0.34	7.00	5.2–12.5	1.1– 1.5
L/Amb.L.	5	0.99	2.39	2.59	5.2–12.5	1.2– 4.0
L/No.Hyd.Sl.	6	0.89	1.14	1.47	5.2–12.5	3.0– 8.0
RD/Amb.L.	10	0.97	-0.18	0.85	0.8– 3.8	1.2– 4.9
Del.L./Amb.L.	10	0.72	0.96	0.14	1.1– 1.8	1.2– 4.9
ABL/ABW	5	0.94	0.12	2.29	2.5– 5.5	1.2– 2.5
ABBR/ABBRF	5	0.95	0.82	2.18	1.9– 4.7	0.7– 1.9
ABBB/ABBBF	5	0.57	0.18	0.05	0.2– 0.4	2.0– 4.8
ABBB/ABBR	5	0.53	0.20	0.04	0.2– 0.4	1.9– 4.7
ZBL/ZBW	5	0.99	0.01	1.66	2.3– 5.2	1.5– 3.2
ZBBR/ZBBRF	5	0.94	-1.10	4.37	1.9– 4.7	0.8– 1.4
ABBR/RB	5	0.97	0.36	0.90	1.9– 4.7	1.8– 4.5
ABBR/RD	5	0.97	1.26	1.14	1.9– 4.7	0.8– 3.2
ABBR/Del.L.	5	0.42	0.05	2.50	1.9– 4.7	1.1– 1.5
RD/RDF	10	0.71	-0.03	2.62	0.8– 3.8	0.4– 1.2
RR/RRF	10	0.87	0.14	0.29	0.9– 2.6	2.5– 8.0
RB/RBF	10	0.87	0.72	3.20	1.8– 5.1	0.5– 1.4
RD/RR	10	0.94	-0.52	1.62	0.8– 3.8	0.9– 2.6
RD/RB	10	0.89	-0.84	0.82	0.8– 3.8	1.8– 5.1
RR/RB	10	0.86	0.00	0.46	0.9– 2.6	1.8– 5.1
RD/Del.L.	10	0.61	-1.50	2.80	0.8– 3.8	1.1– 1.8
RB/Del.L.	10	0.60	-0.21	2.97	1.8– 5.1	1.1– 1.8
Del.L./Gr.Ab.W.	10	0.83	0.79	0.55	1.1– 1.8	0.6– 1.6
Del.L./Anal Del.L.	10	0.77	0.59	0.41	1.1– 1.8	1.3– 2.5
Amb.L./Amb.W.	5	0.84	-1.05	4.49	1.2– 4.0	0.6– 1.1
Amb.L./No.S.P.	5	0.97	-0.37	0.20	1.2– 4.0	8.0–20.0

smoothly. Ornament and BB and BA sectors as for azygous basal.

Radials five, forming upper half of pelvis and extending to top of vault. Radial hexagonal in plan view, with a convex or two straight lower edge(s); lateral edges slightly convex, expanding to maximum width at aboral tip of ambulacra, then contracting adorally; two adoral edges slope steeply downward (and aborally) into ambulacral sinus. Radial sinus short, parabolic indentation of upper part of radial. Radial triangular in lateral view, with very slightly convex adoral facing edge, straight aboral facing edge, and slightly concave lower edge. RB sector straight parallel to RB axis, very slightly convex perpendicular to it; adjacent sectors merge over convex surface; merge smoothly with RR sector on flat surface. RR sector straight to very slightly convex parallel to RR axis, slightly convex perpendicular to it. RD sector sharply set off from RR sector, being confined to an ambulacral sinus, slightly concave parallel to and perpendicular to RD axis. RB and RR sectors ornamented by fine growth lines; RD sector covered by hydrospire slits (Pl. 3, fig. 2). RHt: 0.4-1.8 mm; RWB: 1.0-2.7 mm; RWA: 1.5-4.2 mm; RWD: 1.2-2.1 mm. See also Table 3.

Deltoids four, together with superdeltoid forming border to peristome (Pl. 3, figs. 1,6). In plan view overall shape of deltoid is rhombic. In lateral view deltoid is concave because of pronounced deltoid lip and upward sloping deltoid crest which originates below deltoid lip. (In smallest specimen aboral tip of deltoid crest 0.1 mm below oral opening; in others even to 0.4 mm above.) Adoral edge of deltoid straight; width expands along short DDF, then contracts along concave DAF to narrowest exposed width of deltoid. Deltoid lip ornamented by horseshoe-shaped rim which forms border to peristome and adjacent ambulacral tracts (Pl. 3, fig. 1). Adoral face of rim bears minor grooves and furrows; aboral surface slopes down to origin of crest which is just aboral to greatest constriction. Deltoid body rhombic in plan view, with slightly convex aboral edge sloping nearly straight down into ambulacral sinus from aboral apex of deltoid. Deltoid crest straight to slightly concave in lateral profile, rising steeply upward from its origin. Deltoid body covered by hydrospire slits which parallel the ambulacrum and cross the radiodeltoid suture at an angle. Del.Gr. Ad.W.: 0.3-0.4 mm; Del.Min.W.: 0.1-0.4 mm; L. Crest: 0.4-1.2 mm; DR: 0.4-1.2 mm.

Anal deltoids three, a super-, sub-, and hypodeltoid. Outline and ornament of superdeltoid as for regular deltoid. Subdeltoid horseshoe-shaped, forming adoral border to anal opening, limbs extending aborally to meet radials, corresponding in position to lower lateral parts of regular deltoid body. Sides of limbs slope down into adjacent ambulacral sinuses. Hypodeltoid not preserved, but facets on limbs of subdeltoid and limbs of radials in anal interarea indicate its presence and suggest it was a pyramidal-shaped plate similar to that in *Decaschisma* whose outer side formed part of thecal wall and whose top formed an interambulacral pyramid corresponding to that of regular deltoid body. Adoral part of anal opening ovoid; width: 0.3-0.5 mm in two specimens. Anal opening bordered adorally and laterally by subdeltoid, aborally by hypodeltoid. Super.Gr.Ad.W.: 0.3-0.5 mm; Hypo.W.: 0.4-2.0 mm; O.c.-anus: 0.4-0.9 mm.

Ambulacra five, sited in an ambulacral sinus. Outline petaloid in plan view in small specimens (Pl. 3, fig. 3), becoming linear in large ones (Pl. 3, figs. 4,8). Ambulacrum slightly convex in lateral view, convex in cross section with median depression along ambulacral groove. Lancet begins close to oral center (0.2-0.4 mm); only its adoral tip is exposed (small hexagonal-shaped area – Pl. 3, figs. 5,6). Lancet relatively narrow, straight sided in plan view, slightly convex in lateral view, strongly convex in cross section. Lancet rests upon lateral parts of two deltoids and upturned edges of radial at center of radial sinus (Pl. 3, fig. 2). Side plates hexagonal, with two straight admedial edges which meet parts of two opposing side plates in a zigzag along middle of ambulacrum. Adoral edge straight, embayed laterally by triangular outer side plate (Pl. 3, fig. 8); aboral margin straight, slightly embayed by outer side plate; ablateral edge of side plate straight, short. Brachiolar facet on outer sloping edge of ambulacrum. Minor grooves and lobes border main and adoral edge of side grooves (Pl. 3, figs. 3,4,8).

The hydrospire fields, innermost (except for tips) concealed by ambulacra, occupying full width and length of ambulacral sinus (Pl. 3, figs. 2,4,5). No.Reg. Hydro.: 3-8; L.Hydro.Fld.: 0.6-3.9 mm; W.Hydro.Fld.: 0.3-1.0 mm; No.Anal Hydro.: 1?-6; length of field nearly equal to that of regular hydrospire field. Number of anal hydrospires equal in number to that of regular hydrospire field or up to three less.

Oral opening pentagonal, width 0.3-0.6 mm.

Distribution.– Devonian, Birdsong Formation, Tennessee, U.S.A.

Remarks.– The above description is based upon the specimens in the growth series. The internal anatomy and ontogeny of this species were discussed and illustrated by Breimer and Macurda, 1972, and are further summarized in Table 3.

LEPTOSCHISMA? PENTAGONUM n. sp.
Pl. 7, figs. 1,5,11

Genus et species indeterminate Breimer, Macurda, and Prokop, 1968, p. 133-135, Pl. I, figs. 2,5,6,10,16; Breimer and Macurda, 1972, Pl. II, figs. 1,6.

Description.– Theca elongate, narrow, conical, with long pelvis and short vault. Pelvis conical, flaring outward very slightly in upper portion. Vault hemispherical, flattened at oral opening. Outline pentagonal in plan view; greatest width at ambulacral tips. L.: 8.5 mm; W.: 3.9 mm; V.: 1.0 mm; P.: 7.5 mm; pelvic angle: 30°.

Basals very long, narrow, form over one-half of length of pelvis. Profile in lateral view conical, tapering proximally to narrow stem attachment area (diameter: 0.4 mm), formed by growth along BA axis (L.: 0.4 mm) on BAF (W.: 0.3 mm). Stem attachment area circular, slightly concave. In basal view cross section of basalia rounded triangular proximally, becoming pentagonal distally. Azygous basal pentagonal, very long, thin, narrow, with straight sides. BA sector very small, straight parallel to BA axis, convex normal to it; BB sector straight parallel and perpendicular to BB axis; initiation of BA sector causes slight break in profile. BB sector small, dies out distally. BR sector large, straight parallel to and gently convex normal to BR axis; two adjacent BR sectors merge smoothly. ABL: 4.8 mm; ABW: 1.5 mm; ABBR: 4.0 mm; ABBRF: 1.0 mm; ABBB: 0.3 mm; ABBBF: 4.3 mm. Zygous basal hexagonal, narrow, with slightly concave upper median edge; others straight (Pl. 7, fig. 11). BA and BB sectors as for azygous basal; BR sectors straight parallel to BR axes and convex normal to them, flattening out distally. Lateral and median sectors merge smoothly on a convex boundary. ZBL: 4.6 mm; ZBW: 2.0 mm; ZBBR: 4.2 mm; ZBBRF: 1.0 mm. Basals ornamented with fine growth lines parallel to BAF, BBR, and BRF.

Radials five, forming upper part of pelvis and extending to summit of theca, being even with the oral opening. Radial body long, lower edge convex, lateral edges very slightly convex as width expands to plane of ambulacral tip, then contracts slightly. Broadly parabolic radial sinus indents top; RD sector confined to sinus. In lateral profile radial triangular with long straight edge facing basals; short, slightly convex edge bordering ambulacrum; lower edge slightly concave. RD sector small, in ambulacral sinus, slopes steeply inward from sinus edge, straight parallel and normal to RD axis; hydrospire slits extend full width of RD sector. RDF slightly concave; plane of suture vertical, being parallel to polar axis. RD sector at sharp angle to RR sector; latter straight parallel to RR axis and slightly convex normal to it. RR sector merges smoothly with RB sector. RB sector straight parallel and normal to RB axis; two adjacent sectors meet on convex surface. RR and RB sectors ornamented with fine growth lines parallel to fronts; no secondary calcite at origin of radial. RHt: 0.8 mm; RWB: 1.2 mm; RWA: 2.0 mm; RWD: 1.5 mm; RD: 1.0 mm; RDF: 1.2 mm; RR: 1.2 mm; RRF: 3.9 mm; RB: 3.0 mm; RBF: 0.7 mm. RD axis represents 19 percent of total growth of radial, RR 23 percent, and RB 58 percent.

Deltoids four, with superdeltoid(?) form border to oral opening. Deltoids small, confined to upper surface of theca, do not form part of lateral wall. Adoral edge slightly concave; short straight DDF and DAF. V-shaped ridge on upper adoral surface borders ambulacral tracts; aborally surface of plate drops 0.2 mm to a saddle. Deltoid crest rises upward from this point extending above oral opening, slightly convex in lateral view. Aboral part of deltoid slopes steeply downward from crest into ambulacral sinuses and bears hydrospire slits. DRF convex, curves downward and inward. Del.L.: 1.2 mm; Gr.Ad.W.: 0.3 mm; Min.W.: 0.2 mm; Gr.Ab.W.: 0.8 mm; DR: 0.7 mm; L. crest: 0.7 mm; O.c.--crest: 0.5 mm.

Anal deltoids weathered, apparently either a superdeltoid and two cryptodeltoids or a superdeltoid and subdeltoid (Pl. 7, fig. 5). Superdeltoid as for deltoid lip of regular deltoid, width: 0.3 mm; aboral edge drops downward. Short ridge extends to anal opening. Limbs of cryptodeltoids? or subdeltoid? diverge aborally and bear hydrospire slits. Anal opening ovoid, width: 0.3 mm; opens upward, upper edge below level of oral opening. Oral center to anus: 0.6 mm. Anal interarea too weathered to provide any information on presence or absence of hypodeltoid.

Ambulacra five, sub-petaloid in plan view (Pl. 7, fig. 1), convex in lateral view. Adoralmost 0.3 mm of lancet completely exposed, then covered by side plates. Triangular outer side plate on outer edge of ambulacrum where brachiolar facet is sited. Upper surface of ambulacrum slightly below surface of surrounding plates. Ambulacrum fills much of ambulacral sinus; gaps at edge and hangs over space with hydrospire slits. Amb.L.: 1.9 mm; Amb.W.: 0.8 mm; nine side plates per side. O.c.--amb.: 0.2 mm.

Ten hydrospire groups, with outer three or four of approximately seven slits in regular groups exposed; others open into space beneath ambulacral overhang. Number of hydrospires reduced in anal interarea: approximately 3. Hydrospires sited across width of radiodeltoid suture and extend almost full length of RD and DR sectors. Length functional slit: 1.1 mm.

Oral opening rounded pentagonal, width: 0.4 mm. Width of ambulacral tract on deltoids: 0.2 mm.

Distribution.– Devonian, Slivenec Limestone, Konvarka, Bohemia, Czechoslovakia.

Remarks.– This phaenoschismatid is known only from a single individual; the number of anal deltoids is uncertain. It does not belong to *Polydeltoideus* because there is an external RD growth front in the anal interarea of *Polydeltoideus*; the same is true of *Decaschisma*. Its thecal shape and hydrospires exclude it from *Caryoblastus, Cryptoschisma, Pentremitidea, Pleuroschisma, Heteroschisma, Phaenoschisma, Dolichoblastus, Kazachstanoblastus, Artuschisma,* and the new genus to which "*Phaenoschisma*" *saharae* belongs. The only phaenoschismatid genus to which it may belong is *Leptoschisma*. Thecal shape, basal growth sectors, ambulacral sinuses, configuration of the deltoids, ambulacral shape, concealment of the lancet, reduction in the number of anal hydrospires, and partial coverage of hydrospire slits by the ambulacra are closely similar. If there are three anal deltoids, it would belong to *Leptoschisma*; otherwise it represents a new genus. The species name *pentagonum* is derived from its cross-sectional profile. It differs from *Leptoschisma lorae* in the more elongate pelvis and more hemispherical vault. The above description follows that given by Breimer, Macurda, and Prokop (1968).

Genus CARYOBLASTUS
Breimer, Macurda, and Prokop, 1968

Type species.– *Caryoblastus bohemicus* Breimer, Macurda, and Prokop, 1968.

CARYOBLASTUS BOHEMICUS
Breimer, Macurda, and Prokop, 1968
Pl. 3, figs. 7,9-12; Table 4

Caryoblastus bohemicus Breimer and Macurda, 1972, p. 15, Pl. I, figs. 10,11.

Description.– Theca small, bud-shaped, with concave conical pelvis (curvature in basals); vault hemispherical with top depressed as deltoids extend above peristome (Pl. 3, figs. 10,11). In plan view thecal outline pentagonal, ambulacral tips rounded, interambulacral areas slightly concave (Pl. 3, figs. 7,9); greatest width at ambulacral tip. Length greater than width in specimens in growth series. Vault less than pelvis in smaller specimens, becoming almost or equal to pelvis in largest specimens. Pelvic angle about 35° in smallest specimen, approaching 90° in some larger specimens; mean: 69°. See also Table 4.

Basalia three, in normal position, conical in lateral view with concave profile; taper proximally to elongate, cylindrical cross section to form stem attachment area; proximal diameter: 0.5-0.8 mm. In basal view outline is pentagonal. BB growth axis present. Rudiments of growth axis toward stem attachment area as well? Azygous basal pentagonal with very short straight base; lateral edges slightly concave; upper edges fronting radials straight. BR sector concave parallel to BR growth axis, slightly concave perpendicular to it; two adjacent BR sectors merge smoothly. Growth lines ornament plate parallel to BRF and BBF. Each of two zygous basals hexagonal in plan view with very short, straight lower edge; lateral edges slightly concave; upper three edges almost straight. Three BR sectors concave parallel to BR axes; median sector moderately concave normal to BR axis, others straight. Three sectors merge smoothly with each other and radials. Ornament as for azygous basal. See Table 4.

Radials five, form upper one-half of pelvis and full height of vault, extending above oral opening. In lateral view radial is triangular with convex upper edge bordering ambulacrum, edge facing basals straight; slightly concave lower edge. In plan view edge of radial against basal almost straight in C and E radials, or two straight edges in A, B, and D radials. Lateral edges convex with greatest width at ambulacral tip, contract adorally. Ambulacral sinus extends more than one-half length of radial; outline parabolic. RD sector not developed outside sinus; sides of sinus almost vertical. RD sector is straight parallel and perpendicular to RD axis; sector unornamented. RDF concave; plane of suture almost vertical, dropping down and curving inward from highest point on theca. RR sector is very slightly concave to straight parallel to RR axis, convex

TABLE 4. Growth relationships of principal variables of *Caryoblastus bohemicus* Breimer, Macurda and Prokop, 1968

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	11	0.97	0.80	0.95	3.0– 7.0	2.5– 6.5
V/P	11	0.65	-0.44	0.80	0.8– 3.5	2.1– 3.8
L/ABBR	11	0.91	-0.23	2.74	3.0– 7.0	1.3– 2.6
L/RD	11	0.99	1.89	1.66	3.0– 7.0	0.7– 3.2
L/RB	11	0.93	0.55	2.62	3.0– 7.0	1.0– 2.4
L/Del.L.	11	0.95	-1.59	4.92	3.0– 7.0	1.0– 1.7
L/Amb.L.	11	0.97	1.98	1.39	3.0– 7.0	0.7– 3.5
L/No.Hyd.Sl.	11	0.00	5.10	-0.01	3.0– 7.0	3.0– 4.0
RD/Amb.L.	11	0.97	0.09	0.82	0.7– 3.2	0.7– 3.5
Del.L./Amb.L.	11	0.92	0.79	0.25	1.0– 1.7	0.7– 3.5
ABL/ABW	11	0.91	0.73	0.95	1.4– 2.9	0.7– 2.2
ABBR/ABBRF	11	0.87	1.03	0.94	1.3– 2.6	1.0– 1.7
ABBB/ABBBF	10	0.79	0.02	0.18	0.2– 0.5	1.3– 2.5
ABBB/ABBR	10	0.82	0.01	0.17	0.2– 0.5	1.3– 2.6
ZBL/ZBW	11	0.91	0.84	0.57	1.5– 2.6	1.0– 2.9
ZBBR/ZBBRF	11	0.94	1.00	1.19	1.3– 2.5	0.3– 1.3
ABBR/RB	11	0.94	0.43	0.87	1.3– 2.6	1.0– 2.4
ABBR/RD	11	0.87	1.00	0.49	1.3– 2.6	0.7– 3.2
ABBR/Del.L.	11	0.86	-0.06	1.47	1.3– 2.6	1.0– 1.7
RD/RDF	11	0.85	-0.67	2.15	0.7– 3.2	0.8– 1.7
RR/RRF	11	0.96	0.25	0.39	0.8– 2.0	1.5– 5.0
RB/RBF	11	0.84	0.67	1.26	1.0– 2.4	0.4– 1.3
RD/RR	11	0.96	-0.61	1.70	0.7– 3.2	0.8– 2.0
RD/RB	11	0.90	-0.69	1.51	0.7– 3.2	1.0– 2.4
RR/RB	11	0.94	-0.03	0.88	0.8– 2.0	1.0– 2.4
RD/Del.L.	11	0.93	-1.94	2.85	0.7– 3.2	1.0– 1.7
RB/Del.L.	11	0.92	-0.56	1.69	1.0– 2.4	1.0– 1.7
Del.L./Gr.Ab.W.	11	0.78	0.78	0.68	1.0– 1.7	0.4– 1.1
Del.L./Anal Del.L.	11	0.86	0.64	0.44	1.0– 1.7	1.0– 2.6

normal to it. RR sector at sharp angle to RD sector but merges smoothly with RB sector; latter is straight parallel to RB axis and slightly convex normal to it. Convexity more pronounced where two adjacent RB sectors meet. Growth lines parallel RRF and RBF, fanning out slightly in upper part of RR sector, indicating acceleration of growth in RD, decrease in RB and a slight decrease in RR. No secondary overgrowth of calcite at origin of radials. RHt: 0.5-1.6 mm; RWB: 0.7-2.2 mm; RWA: 1.2-3.2 mm; RWD: 1.0-2.0 mm. See also Table 4.

Regular deltoids four, short, together with superdeltoid forming border of oral opening. Deltoids confined to upper surface of theca, not forming part of lateral wall. Adoral part of deltoid small, with slightly concave adoral edge; V-shaped ridge on deltoid lip. DDF and DAF short, straight. Adoral edge and DDF ornamented with minor grooves. Width of exposed deltoid constricts slightly behind lip, then expands aborally to radiodeltoid suture; width then decreases along DRF. Trough behind adoral rim; diverges aborally and leads downward to adjacent hydrospire groups. Crest rises sharply from center of plate behind trough to maximum height of theca, thus extending above peristome; profile of crest straight in lateral view. Sides of deltoid slope steeply downward from crest into adjacent ambulacral sinuses; sides of crest smooth, unornamented. Del.Gr.Ad.W.: 0.2-0.4 mm; Del.Min.W.: 0.2 mm; DR: 0.3-1.0 mm; L.crest: 0.4-1.2 mm; oral center to base of crest: 0.3-0.5 mm. Height of aboral apices of deltoid above peristome: 0.2-1.0 mm. See also Table 4.

Anal deltoids four: a superdeltoid, two cryptodeltoids, and a hypodeltoid. Configuration of superdeltoid as for adoral part of regular deltoid; length: 0.2-0.4 mm; width: 0.3-0.5 mm. Aboral edge of superdeltoid drops down to super-cryptodeltoid suture. Cryptodeltoids exposed externally, meet adorally to form adoral edge of anus. Adoral suture between two cryptodeltoids short, straight, being parallel to length of anal opening. Suture may be in median position or on left or right side of median axis of anal opening in different specimens. Limbs of two cryptodeltoids diverge aborally; width of limb narrower around anal opening, then expands aborally, convex against radial in ambulacral sinus. Suture slopes steeply downward and inward, being in plane of polar axis. Trough on adoral part of each cryptodeltoid leads into anal hydrospire field. Length of cryptodeltoid: 0.5-1.2 mm. Hypodeltoid missing but presence indicated by prominent facet. Greatest width (0.5-1.5 mm) is aboral where hypodeltoid abuts against radial. Adorally hypodeltoid rests on upper aboral surface of cryptodeltoid prongs. Aboral edges of hypodeltoid straight, meet at 180°. Lateral edges straight as well, border ambulacral sinus. Hypodeltoid visible in lateral view, forming upper lateral wall of theca; probably extended well above anal opening. Outline of anal opening ovoid, length greater than width, opens directly upward; elevation of upper edge slightly below oral opening. Anal opening bordered adorally and laterally by cryptodeltoids, aborally by hypodeltoid. Length: > 0.4-0.5 mm; width: 0.3-0.4 mm. Oral center to adoral edge of anus: 0.4-0.5 mm; oral center to crypto-hypodeltoid suture at anus: 0.8-1.5 mm. Length anal deltoids: 1.0-2.6 mm.

Ambulacra five, slope downward from oral opening, confined to upper part of theca. Set in deep ambulacral sinus, outline in plane view linear, convex in lateral view. Adoral 0.3 mm of lancet completely exposed, bears minor grooves and lobes; aboral to this lancet covered by side plates. Lancet rhombic in cross section. Side plates rarely preserved (Pl. 3, fig. 12). Adoral side plates not in contact with adjacent thecal plate. Outer side plate triangular; in contact with radial in some of aboral parts of ambulacrum to form pores? Details brachiolar facet unknown. Oral center to ambulacrum: 0.2-0.4 mm; ambulacral length: 0.7-3.5 mm; width of lancet: 0.3-0.5 mm; 4 side plates per mm where preserved.

Ten hydrospire groups, number per group most always reduced by one in anal interarea. Hydrospire slits exit into space between lancet and adjacent plates at level of lancet or below. (In smaller specimens, some parts of outermost slit exposed?) Each slit functional across radiodeltoid suture but not open to origins of radials and deltoids; length of longest functional slit: 0.3-1.5 mm. Three, occasionally four hydrospires per group for regular hydrospires, two, occasionally three per group in anal interarea. Number per group for the two groups in anal interarea may be equal or unequal. Unknown if variance in number per regular group is intraspecific variation or represents addition of hydrospire slit during growth. External entrance to hydrospire fields a combination of gaps and pores?

Oral opening rounded pentagonal, width: 0.2-0.5 mm.

Distribution.— Devonian, Slivenec Limestone, Czechoslovakia.

Remarks.— The description is based upon the specimens in the growth series.

CARYOBLASTUS SP.?

Pl. 4, figs. 1,5,11

Caryoblastus sp. Breimer and Macurda, 1972, p. 15, Pl. I, figs. 15,16.

Description.– Theca bud-shaped, with conical, very slightly concave pelvis (in upper part), vault hemispherical with top depressed as deltoid crest rises upward from origin (Pl. 4, fig. 5). Theca pentalobate in plan view (Pl. 4, fig. 1), with concave interambulacral areas, ambulacral tips rounded, greatest width at aboral end of ambulacra. L.: > 10.0 mm, (probably about 12 mm), W.: 10.2 mm, V.: 3.2 mm; P.: > 6.8 mm. Pelvic angle probably about 70°.

Basalia three, in normal position, weathered, only distal parts preserved. Outline decagonal in plan view. Distal edges of azygous basal straight, BR sectors slightly convex normal to BR axis and merging over slightly convex surface. No ornament preserved. ABW: 4.0 mm; ABBRF: 3.2 mm. Lateral distal edges of zygous basals straight, medial distal edge concave. Lateral BR sector apparently flat normal to BR axis. ZBW: 6.2(a) mm; ZBBRF: 2.5 mm.

Radials five, radial limbs extending above peristome. Radials hexagonal in plan view, with two straight or strongly convex lower edge(s), two slightly convex lateral edges, widest at aboral tip of ambulacra; adoral edges curve inward toward one another in an ambulacral sinus. Latter forms deep parabolic reentrant in plate, extending about one-half length of the plate. Radial triangular in lateral view, with convex adoral edge, slightly concave aboral edge, and slightly concave lower edge. RB sector slightly concave parallel to RB axis, moderately convex normal to it; adjacent sectors merge smoothly over strongly convex surface; also merge smoothly with RR sectors. Latter slightly convex parallel to RR axis, convex normal to it; moderately strong growth lines preserved here. RD sector at pronounced angle to RR sector, confined to ambulacral sinus, straight parallel to RD axis, slightly concave normal to it; RDF concave. Inner two-thirds of sector ornamented by hydrospire slits which extend well out toward origin; outer third smooth (Pl. 1, fig. 11). RHt: 2.3 mm; RWB: 3.8 mm; RWA: 5.1 mm; RD: 4.2 mm; RDF: 2.5 mm; RR: 3.0 mm; RRF: 7.8 mm; RB: 4.8 mm; RBF: 2.3 mm.

Deltoids four, together with adoral anal deltoid forming border of oral opening. Outline rhombic in plan view; short straight adoral edge and very short straight DDF. Width contracts slightly, then expands along concave DAF: DRF convex. Deltoid concave in lateral profile because of upward sloping crest. Adoral part of deltoid small, flat surface sloping aborally to origin of crest; flat surface splits, continues aborally, as 0.2 mm wide border between crest and lancet. Crest slopes moderately upward from its origin, 0.5 mm from adoral end of deltoid. Crest profile straight, highest at aboral tip; stereomic lineations perpendicular to inclined crest. Sides of crest drop almost straight down to hydrospire fields which are on the inner aboral two-thirds of DR sector. Outer third and adoral part smooth. Del.L.: 3.1 mm; Gr.Ad.W.: 0.7 mm; Min.W.: 0.5 mm; Gr.Ab.W.: 1.7 mm; L.crest: 2.2 mm; DR: 1.8 mm.

Anal deltoids apparently a superdeltoid, two cryptodeltoids; unknown if hypodeltoid present. Superdeltoid quadrate, with straight adoral edge; lateral edges formed by two short, straight, aborally diverging DDF and short concave DAF; aboral surface has two short ridges which abut against cryptodeltoids laterally and slightly embayed median aboral edge for anus. Aboral to adoral edge, surface of superdeltoid slightly concave, sloping down into anus. Super.L.: 0.6 mm; Super.Gr.Ad.W.: 0.8 mm.

Super-cryptodeltoid sutures apparently at base of drop of superdeltoid, straight, suture 0.4 mm wide. Upper edge of cryptodeltoid sharp, forms concave border to anus and extends to radial; smooth side slopes downward to anal hydrospires which begin near convex cryptoradial suture. Cryptodeltoids do not appear to be in contact adorally. Anal opening ovoid, elongate, bordered adorally by superdeltoid, laterally by cryptodeltoids; aboral boundary unclear as cryptodeltoid apparently in fault contact with D radial.

Radial prongs in anal interarea broken; extended above anal opening; margins weathered so impossible to determine if interradial growth lines are reflected near sinus or not. Anal opening directed upward; level below that of peristome. Length and width approximately 0.8 and 0.5 mm.

Ambulacral fields not preserved but they were sited in an ambulacral sinus. Lancet was 5.2 mm long, extending full length of sinus, almost reaching peristome, exposed in part to interior of theca, supported by troughs on radial and deltoids.

Ten hydrospire fields, formed mostly on radial and only 0.3 mm of their length (longest 3.2 mm) is formed on the deltoids. Additionally, groups only occupy inner part of ambulacral sinus; outer part of radiodeltoid suture in vertical plane; upon reaching hydrospire slits, bends and turns inward. Adoral end of hydrospire slits elevated. Degree of exposure of hydrospires unknown; if completely concealed, ambulacrum would have been unusually tall, suggesting outer slits were exposed. Seven or eight hydrospires per regular group (width of field: 1.6 mm), seven per group in anal interarea (width of field: 1.5 mm); cryptodeltoids appear to participate in formation of anal hydrospires.

Peristome pentagonal, width about 0.6 mm.

Distribution.– Devonian (Lower), La Vid Formation, Colle, Leon, Spain.

Remarks.– This blastoid is known from a single specimen. It closely resembles *Caryoblastus bohemicus* in the bud-shaped theca, configurations of the radials and deltoids, the shape of the deltoid crest, the arrangement and laterally restricted nature of the hydrospires, and insofar as known, the anal deltoids. No other blastoid species has this combination of characteristics. Generically, its closest affinity is to *Caryoblastus*, but information on the ambulacral fields and hypodeltoid are lacking. It is not co-specific with *C. bohemicus* because the slope of the deltoid crest is more moderate, the ambulacral sinus more open, the adoral ends of the hydrospire slits are elevated, not flush, and the ambulacra are apparently flat in lateral profile.

Genus CRYPTOSCHISMA Etheridge and Carpenter, 1886

Type species.– *Pentremites schultzii* De Verneuil and d'Archiac, 1845.

CRYPTOSCHISMA SCHULTZII (De Verneuil and d'Archiac, 1845)

Pl. 4, figs. 2-4, 6-10, 12-14, 16, 18; Table 5

Cryptoschisma schultzii Breimer and Macurda, 1972, Pl. I, figs. 9,13,17.

Description.– Theca small, broadly conical with stout cylindrical base (Pl. 4, figs. 3,6,7). Vault very short in lateral profile, forming very broad, gently convex upper surface of theca. Pelvic profile broadly conical through radials and upper part of basals, cylindrical proximally. Basals form slightly over one-half of pelvic profile. Theca pentagonal in cross section, with slight inward curvature toward interradial suture (Pl. 4, fig. 2). Greatest width occurs just below summit, at aboral tips of ambulacra. In lateral view, plane of surface of stem attachment not always parallel to that of upper surface of theca, imparting a bent appearance to lower part of theca (Pl. 4, fig. 8); inclination toward different rays in different thecae and no apparent preferred orientation. For dimensions see Table 5.

Basalia three, in normal position. Upper portion pentagonal in plan view, becoming circular proximally. Upper part of basals forms sloping part of conical profile; origin of basals now covered by massive secondary secretions (so-called infrabasals of Fay, 1961b) which convert lower half of profile to cylinder (Pl. 4, figs. 3,10). Diameter of secondary deposits increases throughout growth as does height; diameter also increases gradually upward away from stem attachment. Upper edge marked by slight collar. Proximal surface to which column attached may be flush or slightly scalloped, with central portion of basals projecting farther than along interbasal suture (Pl. 4, figs. 10,18). If scalloped, lower surface slopes inward and slightly upward toward center. Uppermost columnal unusual; instead of usual disc-shaped element, long (3.8 mm), gently tapering cylinder attached to basals (Pl. 4, fig. 8). Diam.columnal facet: 1.5-2.9 mm; height second.deposit: 1.7-4.8 mm.

Azygous basal pentagonal in plan view, with elongate sides, straight base, and two short, straight upper edges intersecting at broad angle. Because of inclination of lower part of basals, lateral edges not always parallel to polar axis of theca. In lateral view, profile of azygous basal is concave due to intersection of secondary deposit with sloping upper part of basal. Secondary deposit convex in cross section; straight or slightly concave in lateral view. Upper part of azygous basal straight parallel to each BR axis, very slightly convex normal to it; adjacent sectors meet on a very gently convex surface. Growth lines parallel radial-basal suture. Zygous basal relatively large, hexagonal in plan view, lateral and lower edges as for azygous basal; upper median edge slightly concave, other upper edges straight; width of plate expands distally. Lateral profile, possible non-parallelism of lateral edges, profiles of secondary deposit, and configuration of three BR sectors as for BR sectors of azygous basal. Growth lines parallel radial-basal sutures (Pl. 4, fig. 10). ABBBF: 3.7-6.3 mm; ZBOPt: 4.5-7.2 mm; see also Table 5.

Radials five, forming upper part of pelvis and extending along interradial suture to upper profile of theca (Pl. 4, fig. 3). Radial pentagonal or hexagonal in plan view with one convex or two straight lower edges, two slightly convex lateral edges which gradually diverge orally to plane of aboral tip of ambulacrum, then parallel one another or converge slightly adorally. Upper edge a very broad, shallow V with straight or very slightly concave edges along ambulacra. RD sectors at marked angle to RR sectors and almost completely concealed by ambulacrum in ambulacral sinus. Radial

TABLE 5. Growth relationships of principal variables of *Cryptoschisma schultzii* (De Verneiul & d'Archiac, 1845)

Variables	n	r	a_0	a_1	Observed y	Range x
L/W	17	0.90	0.82	1.24	6.9–12.0	5.2– 8.9
V/P	17	0.56	0.01	0.13	0.5– 1.9	5.9–10.4
L/ABBR	17	0.94	-0.67	1.90	6.9–12.0	4.0– 6.8
L/RD	17	0.89	3.48	2.79	6.9–12.0	1.2– 2.9
L/RB	17	0.93	2.58	1.99	6.9–12.0	2.3– 4.7
L/Del.L.	17	0.80	0.70	2.99	6.9–12.0	2.3– 3.7
L/Amb.L.	17	0.91	2.58	2.19	6.9–12.0	2.1– 4.2
L/No.Hyd.Sl.	8	0.40	7.13	0.45	8.0–10.8	4.0– 7.0
RD/Amb.L.	17	0.96	-0.19	0.74	1.2– 2.9	2.1– 4.2
Del.L./Amb.L.	17	0.93	1.02	0.60	2.3– 3.7	2.1– 4.2
ABL/ABW	17	0.66	1.10	1.83	4.5– 7.3	1.9– 2.9
ABBR/ABBRF	17	0.51	1.31	2.43	4.0– 6.8	1.3– 1.9
ZBL/ZBW	17	0.84	1.40	0.97	3.9– 6.6	2.8– 4.7
ZBBR/ZBBRF	17	0.79	1.35	2.51	4.1– 6.9	1.2– 2.0
ABBR/RB	17	0.81	2.32	0.87	4.0– 6.8	2.3– 4.7
ABBR/RD	17	0.80	2.65	1.25	4.0– 6.8	1.2– 2.9
ABBR/Del.L.	17	0.68	1.60	1.26	4.0– 6.8	2.3– 3.7
RD/RDF	17	0.80	-0.11	1.33	1.2– 2.9	1.1– 2.2
RR/RRF	17	0.90	0.51	0.47	1.5– 2.9	2.6– 4.9
RB/RBF	17	0.79	0.00	2.19	2.3– 4.7	1.1– 2.0
RD/RR	17	0.95	-0.71	1.25	1.2– 2.9	1.5– 2.9
RD/RB	17	0.89	0.01	0.61	1.2– 2.9	2.3– 4.7
RR/RB	17	0.90	0.66	0.47	1.5– 2.9	2.3– 4.7
RD/Del.L.	17	0.91	-1.02	1.08	1.2– 2.9	2.3– 3.7
RB/Del.L.	17	0.82	-0.78	1.44	2.3– 4.7	2.3– 3.7
Del.L./Gr.Ab.W.	17	0.08	2.64	0.39	2.3– 2.7	0.3– 0.6
Amb.L./Amb.W.	17	0.97	-0.06	1.19	2.1– 4.2	1.8– 3.6
Amb.L./No.S.P.	17	0.75	0.34	0.18	1.6– 3.3	6.0–16.0

triangular in lateral view, with upper apex displaced well adorally. Adoral edge short, straight or very slightly convex; aboral edge long, straight or slightly convex; lower edge slightly concave. RB sector triangular, elongate, straight or slightly convex parallel to RB axis, slightly convex normal to axis; adjacent sectors meet over a convex surface. RB sector merges smoothly with RR sector on slightly convex surface. RR sector is very slightly convex parallel to RR axis and convex normal to it. Growth lines in RB and RR sectors (Pl. 4, fig. 14); none in RD sectors which are small and part of ambulacral sinus; only aboral edge exposed at pronounced angle to RR sectors and forming part of upper, gently convex part of theca (Pl. 4, fig. 16). With lancet and side plates removed, RD sector is straight parallel to RR axis and slightly concave normal to it. Inner part of sector is occupied by hydrospire slits; smooth inward sloping border aboral to this (Pl. 4, figs. 4,16). Small raised element abuts against aboral end of lancet; concealed by side plates. RWB: 2.2-3.3 mm; RWA: 2.9-4.7 mm; RWD: 2.6-4.2 mm; see also Table 5.

Deltoids four, extending almost to edge of theca in plan view. With side plates and lancet removed, deltoid has rhombic shape; however, only adoral portion and part of crest exposed externally (Pl. 4, fig. 9). Deltoid lip small, with essentially straight edge against peristome; this and short, straight aborally diverging DD suture bear minor grooves of ambulacral system. Short, straight DA sutures converge aborally; aboral portion forms slight elevation above origin of crest. Crest essentially straight in lateral view, extends to radials; sides slope downward to hydrospire slits which embay sides; smooth flanks widen aborally to radiodeltoid suture, then converge. Smooth flanks continuous with smooth aboral part of RD sector. Side plates converge on median portion of crest and may completely conceal it, thereby forming an ovoid, spiracle-like opening adoral to side plate convergence. Exposed aboral tip of crest forms a small pyramid-like feature (Pl. 4, fig. 9). Del.Gr.Ad.W.: 0.4-0.8 mm; see also Table 5.

Four anal deltoids, a superdeltoid, two cryptodeltoids, and a hypodeltoid. Configuration of superdeltoid as for adoral part of regular deltoid; concave aboral face at position corresponding to greatest constriction of regular deltoid. Hypodeltoid is a small rhombic-shaped plate, corresponding to aboral tip of deltoid crest. Upper surface sharp, slopes down on either side into ambulacral sinus; hyporadial suture a sharp V, edges straight (Pl. 4, fig. 12). At place where hyporadial suture ends, radial suture bends slightly. Suture with cryptodeltoid straight. Space between hypodeltoid and lancet filled by a quadrate cryptodeltoid which forms part of ambulacral sinus; wider adorally than aborally, slightly longer than wide. With side plates removed, borders of anal opening are: adorally, the superdeltoid; laterally, the lancet; aborally, the two cryptodeltoids except at the aboralmost tip where it is apparently the hypodeltoid. With side plates in place, anal opening has a teardrop-shaped outline (Pl. 4, fig. 9), the cryptodeltoids are concealed, and only the aboral part of the hypodeltoid is visible. Anal opening opens directly upward at same level as peristome. Super.L.: 0.3-0.7 mm; Super.W.: 0.5-0.9 mm; Anal W.: 0.4-0.8 mm; O.c.-anus: 0.5-0.8 mm.

Ambulacra five, very strongly petaloid, being short and broad, and occupying most of surface area when theca viewed orally (Pl. 4, fig. 9). Ambulacrum convex in lateral view, almost flat in cross section with slight inward slope toward main ambulacral tract. Lancet very broadly exposed, lanceolate in plan view, lateral and cross-sectional view as for ambulacrum; sides straight, which side plates abut against; part of lower surface exposed to interior of theca through notch between RD sectors (Pl. 4, figs. 4,12,16). Length and width increase throughout growth. Lancet flares farther laterally into anal interarea than in other interareas. Lancet begins near peristome but side plates not encountered until aboral edge of spiracle-like opening; side plates extend farther aborally. Side plates elongate, slightly concave adorally and convex aborally, lying above radial and/or deltoid and only slightly convex admedial edge in contact with lancet along an almost perpendicular suture. Outer edge notched by small triangular outer side plate, adoral edge of which is more convex. Side ambulacral tract very long; widest near radiodeltoid suture as are side plates. Side ambulacral tract extends laterally from main ambulacral tract in a broad shallow arc (adorally concave) but turns aborally near lateral edges of ambulacrum where brachioles attached. Adoral side tracts intersect main tract at closer to right angles than aboral ones, thereby imparting fan-shaped appearance (Pl. 4, fig. 13). Side tract follows suture between side plates on ablateral half of suture but then swings onto the more adoral side plate of pair, diverges adorally from suture and may be on median portion of plate by the time it reaches the lancet. Side groove bordered by minor grooves both ad- and aborally. Main groove also bordered by minor grooves and furrows. Brachiolar facet apparently small, ovoid, with width (0.25(a) mm) slightly greater than height (0.20(a) mm), sited on lateral edge of ambulacrum on side and outer side plate; latter forms adoral part of facet. Brachioles questionably preserved on one specimen (Pl. 4, fig. 13). Aboral edge of ambulacrum even with or very slightly below edge of theca where RD sector turns over into RR sector. O.c.-amb.: 0.4-0.8 mm; Lanc.W.: 0.8-1.7 mm.

Eight hydrospire fields, about equally developed on radials and deltoids as hydrospire slits which parallel center line of ambulacrum; completely concealed by side plates; lancet projects over median parts of innermost slits. Greatest length near median portion of ambulacrum. Number: 4-7; width field: 0.5-1.3 mm, adoral entrance by a spiracle-like opening; L.: 0.4-0.8 mm; W.: 0.3-0.6 mm (see above); aboral circulation by gap below side plates?

Peristome pentagonal, superdeltoid projecting inward slightly more than other four deltoids; W.: 0.3-0.7 mm.

Distribution.– Devonian, La Vid Formation, Leon; Ferrones Formation, Asturias, Spain.

Remarks.– The description is based upon the 17 specimens in the growth series.

Genus PENTREMITIDEA d'Orbigny, 1850

Type species.– *Pentremites pailleti* De Verneuil, 1850. *Pentremitidea* Breimer and Macurda, 1972, p. 16.

PENTREMITIDEA ARCHIACI (Etheridge and Carpenter, 1882)

Pl. 5, figs. 3, 6-9, 11-14, 16, 17; Table 6

Pentremitidea archiaci Breimer and Macurda, 1972, Pl. I, figs. 14, 18-21.

Description.– Theca tall, narrow, with elongate conical pelvis and short convex vault (Pl. 5, figs. 12-14); aboral tip of deltoids and tip of radial limbs project above peristome so central portion of vault profile lower than sides. Basals form slightly more than one-half of pelvis. Pelvic profile is straight to very slightly convex in upper portion along radials, being very slightly to slightly concave in upper or median portions of basals and straightening out proximally, becoming cylindrical. In plan view thecal outline pentagonal in small specimens, becoming pentalobate with prominent indentation along interradial suture in larger specimens due to change in growth direction of RR axis; greatest width at aboral tip of ambulacra (Pl. 5, figs. 6-9). See Table 6.

Basalia three, in normal position, pentagonal in plan view in upper portion, becoming triangular in proximal portion. Lateral profile as above. Stem attachment area formed by BA growth sector (Pl. 5, figs. 3,11); growth outward and down; basals project farther proximally in center rather than along interbasal suture. Surface of attachment area thus scalloped; slopes inward and upward. Upper stem plate thus has a scalloped upper surface; and this plate is taller than succeeding plates which are about 0.5 mm high (Pl. 5, fig. 17). Upper stem plate widest, width tapering through next one or two plates, then constant through at least next 6 or 7. Diameter attachment area: 1.9-2.9 mm.

Azygous basal long, narrow, pentagonal in plan view, with convex lower edge, two straight lateral edges and two short straight upper edges which meet at about 90°. Origin of basal evident near proximal end; basal divided into three sectors. BA sector small, proximal, slightly convex to convex parallel to BA axis, strongly convex normal to it. BB sector elongate, excentric, slightly convex parallel to BB axis, straight to slightly concave normal to it. BB sector does not extend to radials. BR sector large, elongate, narrow, strongly set off from BB sector, rising sharply above it. BR sector straight to very slightly concave parallel to BR axis, becoming slightly more concave distally; sector very slightly to slightly convex normal to axis. Adjacent sectors merge over angular boundary in proximal part of plate; this becomes reduced distally to a gently convex surface. Zygous basal hexagonal in plan view; lower and lateral edges as for azygous basal except lateral edges diverge slightly distally. Upper medial edge concave, upper lateral edges straight. Origin, BA, and BB sectors as for azygous basal. Medial and lateral BR sectors as for azygous sectors parallel to BR axes; medial sector slightly convex to convex and lateral sectors flat normal to axes. Boundary between medial and lateral sectors angular in lower portion of plate, becoming less pronounced distally. Growth lines coarser in BA and BB sectors; only a faint suggestion rarely observed in BR sectors as weathering and intrastratal solution have usually destroyed fine detail. ABBA: 0.8-2.0 mm; ABBAF: 1.3-2.5 mm. See also Table 6.

Radials five, forming upper part of pelvis and extending to uppermost part of theca along interradial suture. Radials four-sided in plan view, with convex (or two straight angular sides) on lower edge; lateral edges diverge very slowly up to aboral tip of ambulacrum, then converge slightly adorally. Short, U-shaped radial sinus in upper part of plate contains ambulacrum and RD sector; both are in an ambulacral sinus. In lateral view radial is triangular, with apex displaced well adorally. Upper edges slightly convex, lower edge slightly concave. RB sector slightly convex parallel to RB axis, flat to slightly convex normal to axis; adjacent sectors meet over low angular slightly convex boundary. RB sectors ornamented with fine growth lines and merge smoothly with RR sector. RR sectors initially straight or slightly convex parallel to RR axis; in later growth stages, bends inward, producing angularity in RR axis. Sector is slightly convex normal to axis, more so in upper portion. RR sector ornamented with coarser growth lines. RD sectors small, form part of steeply inward dipping ambulacral sinus; no external growth lines. RD sector is slightly concave parallel and normal to RD axis. Part of exposed RD sector bears hydrospire slits; RD sector forms elevated collar to ambulacrum (Pl. 5, fig. 16). RHt: 0.8-2.0 mm; RWB: 1.9-3.3 mm; RWA: 2.6-4.3 mm; RWD: 1.7-2.6 mm. See also Table 6.

Deltoids four, together with superdeltoid forming borders of oral opening. Deltoid small, hexagonal in plan view, concave in lateral view due to deltoid crest. Adoral edge straight; width expands aborally along a short DDF which bears ambulacral tract. Exposed width then contracts, first due to contact with lancet, then projection of side plates over hydrospire cleft, forming concave arc, which expands aborally; DRF convex, rising straight upward parallel to polar axis on almost vertical sides of ambulacral sinus; overturned at tip. Deltoid lip small, a triangular-shaped mound in center which has two straight faces sloping down to DDF and a concave aboral face dropping down to origin of crest. Origin of crest slightly below adoral edge of deltoid, rising moderately upward in slightly concave arc. Sides drop steeply downward into ambulacral sinus; larger part of DR sector occupied by hydrospire slits (Pl. 5, figs. 6,7,9,16). Del.Gr.Ad.W.: 0.4-0.7 mm; Min.W.: 0.2-0.5 mm. See also Table 6.

Anal deltoids four, a super-, two crypto-, and a hypodeltoid. Configuration of superdeltoid as for deltoid lip of regular deltoid, with concave aboral edge at same position as greatest constriction of regular deltoid. RD sector in anal interarea has external growth sector in addition to that in ambulacral sinus, forming beveled area with exterior growth lines along hyporadial suture (Pl. 5, fig. 16). Other anal deltoids very rarely preserved, having fallen out during decomposition, leaving a large triangular void (Pl. 5, fig. 9). Each triangular cryptodeltoid fills part of the aboral lateral portion of this void, its position corresponding to a continuation of the RD sector in the ambulacral sinus; straight border along lancet, aboral tip just reaches radial, cryptohypodeltoid suture angles in toward anus. Hypodeltoid a pentagonal plate, greatest width aboral, convex, reaching from lancet to lancet, filling aboral part of void, median portion grows against external radial growth front, lateral portions grow against radial in ambulacral sinus. Cryptodeltoids do not extend to superdeltoid. Anal opening ovoid, with adoral boundary the superdeltoid, lateral boundaries the side plates and lancet, aboral lateral boundaries the exposed cryptodeltoids, and aborally the hypodeltoid which lies in the same plane as the oral opening. Anus opens directly upward at about same level as oral opening. Overall size of anal deltoids rather constant throughout growth series. Super.L.: 0.3-0.5 mm; Super.W.: 0.4-0.8 mm; Hypo.W.: 1.0-1.8 mm.

Ambulacra five, lanceolate in plan view, slightly convex in lateral view, flat in cross section, sited in moderate ambulacral sinus (Pl. 5, figs. 6-9, 16). Lancet almost reaches peristome, adoralmost 0.5 mm exposed, rest completely concealed, rhombic in cross section, extending farther laterally in anal interarea. Side plates meet along midline of ambulacrum, medial edges angular; adoral and aboral edges very slightly concave adorally; slant aborally from center line; edges (more so aborally) embayed by small triangular outer side plate; both plates form margin of ambulacrum. Brachiolar facets on lateral inclined edge of ambulacrum developed on side and outer side plates; side groove (0.4 mm) follows side plate suture for only a short distance before side plate suture bends aborally as it approaches midline of ambulacrum. Main and adoral (aboral unclear) edge of side groove ornamented by minor lobes and grooves.

Eight hydrospire groups, lacking in anal interarea, sited in ambulacral sinus, occupying most of RD and DR sectors but not full width of radiodeltoid suture; partly exposed, with outer two or three slits in each group usually visible; entrance to rest via a hydrospire cleft as side plates project over the hydrospire field. Ontogenetic development of hydrospire slits apparently rather static as 6 per group in a specimen 11 mm long and 7 per group in a specimen 17 mm long. Projection of adoral side plates toward deltoid crest produces an open bifid spiracle-like opening at adoral end of ambulacra which is continuous internally with the hydrospire cleft.

Oral opening pentagonal, width: 0.3-0.7 mm; width of ambulacral tract on deltoid: 0.2 mm.

Distribution.— Devonian, Ferrones and Santa Lucia formations, Provinces of Esturias and Leon, Spain.

Remarks.— The above description is based upon the twenty specimens in the growth series. The internal

TABLE 6. Growth relationships of principal variables of *Pentremitidea archiaci* (Etheridge & Carpenter, 1882)

Variables	n	r	a_o	a_1	Observed Range y	x
L/W	20	0.95	1.44	1.84	10.5–18.6	4.6– 8.8
V/P	20	0.52	0.15	0.06	0.5– 1.3	9.7–17.4
L/ABBR	20	0.97	1.91	1.95	10.5–18.6	4.7– 8.5
L/RD	20	0.93	5.77	3.69	10.5–18.6	1.2– 3.3
L/RB	20	0.97	0.89	2.46	10.5–18.6	4.0– 6.9
L/Del.L.	20	0.67	0.86	7.51	10.5–18.6	1.4– 2.1
L/Amb.L.	20	0.95	4.56	3.33	10.5–18.6	1.8– 4.0
L/No.Hyd.Sl.	12	0.22	10.79	0.47	10.5–18.6	4.0– 7.0
RD/Amb.L.	20	0.96	-0.17	0.85	1.2– 3.3	1.8– 4.0
Del.L./Amb.L.	20	0.74	1.11	0.23	1.4– 2.1	1.8– 4.0
ABL/ABW	20	0.84	-0.66	3.22	6.0–11.0	2.0– 3.5
ABBR/ABBRF	20	0.72	-1.28	3.98	4.7– 8.5	1.5– 2.2
ABBB/ABBBF	20	0.39	0.91	0.04	0.9– 1.5	5.2–10.0
ABBB/ABBR	20	0.37	0.90	0.05	0.9– 1.5	4.7– 8.5
ZBL/ZBW	20	0.93	-0.87	2.22	5.5–10.5	2.7– 5.2
ZBBR/ZBBRF	20	0.73	0.58	3.39	4.5– 8.7	1.3– 2.2
ABBR/RB	20	0.95	-0.81	1.20	4.7– 8.5	4.0– 6.9
ABBR/RD	20	0.87	2.34	1.74	4.7– 8.5	1.2– 3.3
ABBR/Del.L.	20	0.70	-0.72	3.96	4.7– 8.5	1.4– 2.1
RD/RDF	20	0.30	1.49	0.85	1.2– 3.3	0.5– 1.3
RR/RRF	20	0.92	-0.12	0.36	1.5– 3.0	4.3– 8.2
RB/RBF	20	0.49	2.85	1.60	4.0– 6.9	1.1– 2.4
RD/RR	20	0.92	-0.30	1.19	1.2– 3.3	1.5– 3.0
RD/RB	20	0.87	-0.73	0.56	1.2– 3.3	4.0– 6.9
RR/RB	20	0.95	-0.36	0.47	1.5– 3.0	4.0– 6.9
RD/Del.L.	20	0.67	-1.07	1.89	1.2– 3.3	1.4– 2.1
RB/Del.L.	20	0.60	0.66	2.67	4.0– 6.9	1.4– 2.1
Del.L./Gr.Ab.W.	16	0.19	1.51	0.28	1.4– 2.1	0.6– 1.2
Del.L./Anal Del.L.	16	0.81	0.63	0.54	1.4– 2.1	1.5– 2.7
Amb.L./Amb.W.	18	0.56	-2.57	5.56	1.9– 4.0	0.8– 1.1
Amb.L./No.S.P.	18	0.86	0.74	0.23	1.9– 4.0	6.0–14.0

anatomy and ontogeny of this species were discussed and illustrated by Breimer and Macurda (1972) and are further summarized in Table 6.

PENTREMITIDEA LUSITANICA
Etheridge and Carpenter, 1882
Pl. 6, figs. 1-9; Table 7

Pentremitidea lusitanica Breimer and Macurda, 1972, Pl. II, figs. 2,3.

Description.– Theca of moderate size, conical in lateral view, with short, broadly convex, slightly angular vault and conical pelvis which has a straight or very slightly concave profile (Pl. 6, fig. 6). Pelvic angle 36-40°. Outline in plan view pentagonal, with slightly concave interambulacral areas; greatest width at ambulacral tips which are angular (Pl. 6, fig. 2). Length greater than width (e.g., L: 21.0 mm; W.: 11.8 mm).

Basalia three, in normal position, pentagonal in plan view, becoming rounded triangular proximally, tapering to a narrow base, conical in lateral view, forming approximately one-half of pelvis; profile may be very slightly concave. Proximal tip of basals usually weathered or chipped but no evidence of flaring. Basals extend farther proximally along centerline of basals than interbasal suture.

Stem attachment area formed by growth of BA sector (Pl. 6, fig. 5). Upper surface of uppermost columnal scalloped as in *Pentremitidea archiaci*; but the BA sector above does not flare outward as in *P. archiaci*; lower surface of proximalmost columnal flat. Stem plate 0.5 mm high, 2.2 mm wide (Pl. 6, fig. 5).

Azygous basal quadrate in plan view, relatively long and narrow with straight lateral and distal edges; very slightly concave in lateral view. BR sectors very slightly concave parallel to BR axis, slightly convex normal to BR axis, in distal part of plate merge through slightly concave area. Zygous basals large, pentagonal in plan view, with long straight lateral edges, straight distal lateral edges, and a deeply convex distal median edge. Median and lateral BR sectors very slightly concave parallel to BR axis; median sector strongly convex normal to median BR axis, lateral sectors very slightly concave, median and lateral sectors merging through slightly concave area. Adjacent basals merge over slightly convex area.

BA and BB growth sectors preserved in one specimen (Pl. 6, fig. 5). Here BA growth sector slightly convex parallel to and convex normal to BA axis. BA: 1.2 mm; BAF: 2.0 mm. BB sector straight parallel to, concave perpendicular to BB axis. Basalia incomplete except for specimen 2 in growth series; here with thecal length 21.0 mm, ABL: 11.9 mm; ABW: 4.8 mm; ABBB: 1.1 mm; ABBBF: 10.0 mm; ABBRF: 3.6 mm; ZBL: 10.5 mm; ZBW: 7.2 mm; ZBOPt: 12.3 mm; ZBBR: 10.5 mm; ZBBRF: 3.5 mm.

Radials quadrate in plan view, with two straight or a convex lower edge; lateral edges slightly convex, being widest in the plane of the aboral tip of the ambulacra; upper edges confined to ambulacral sinus, concave, converging at broad angle. Least width at tip of limbs which project slightly above peristome. Tight parabolic ambulacral sinus indents upper third of radial. Radial triangular in lateral view, with adoral facing edge straight to slightly convex, straight aboral facing edge, and concave lower edge. RB sector straight parallel to RB axis, almost flat normal to BR axis, adjacent sectors merging over strongly convex boundary, merging smoothly with adjacent RR sectors. RR sector slightly convex parallel to RR axis (flattening out toward suture), convex normal to RR axis. RB and RR sectors ornamented by fine growth lines parallel to suture, frequently removed by intrastratal solution or weathering. RD sector at pronounced angle to RR sector, confined to shallow ambulacral sinus, slightly concave parallel and normal to RD axis; hydrospire slits developed on inner half of sector but outer half smooth, curving upward (Pl. 6, figs. 1,3). R.Ht: 2.2-2.7 mm; RWB: 3.7-6.0 mm; RWA: 5.0-7.7 mm; RWD: 3.1-3.7 mm. See also Table 7.

Deltoids four, together with superdeltoid forming border of oral opening (Pl. 6, fig. 1). Deltoid hexagonal in plan view, concave in lateral view due to deltoid crest which rises above peristome (0.3-0.7 mm). Adoral edge and short DDF straight, latter bearing ambulacral tract, and diverging slightly aborally. Exposed width contracts due to lancet, then expands aborally along concave DAF. Aboral edges convex, DRF rising straight up in sinus parallel to polar axis, overturned at tip. Deltoid lip small, triangular mound in center, with two straight edges dropping down to ambulacral tract; concave aboral edge drops down to origin of crest which is moderately below deltoid lip. Deltoid crest slopes moderately upward in slightly concave arc, rising slightly above oral opening. Sides of crest curve downward into ambulacral sinus. Hydrospire slits only on inner part of DRF; outer part smooth. Del.Gr.Ad.W.: 0.8-0.9 mm; Min.W.: 0.4-0.5 mm; L.Crest: 1.6-1.8 mm; DR: 1.6-2.0

TABLE 7. Growth relationships of principal variables of *Pentremitidea lusitanica* Etheridge & Carpenter, 1882

Variables	n	r	a_0	a_1	Observed Range y	x
RD/RDF	6	-0.12	6.42	-0.65	4.2–7.9	0.9– 1.5
RR/RRF	6	0.80	-0.68	0.48	3.5–5.5	8.8–11.4
RB/RBF	6	0.94	-0.33	3.05	7.2–8.9	2.5– 3.0
RD/RR	6	0.95	-2.36	1.83	4.2–7.9	3.5– 5.5
RD/RB	6	0.86	-8.28	1.72	4.2–7.9	7.2– 8.9
RR/RB	6	0.81	-2.45	0.84	3.5–5.5	7.2– 8.9
RD/Del.L.	4	0.20	7.08	-0.83	4.2–5.4	2.5– 2.8
RB/Del.L.	4	0.25	10.95	-1.17	7.2–8.5	2.5– 2.8
Del.L./Gr.Ab.W.	4	0.82	1.80	0.67	2.5–2.8	1.2– 1.5
Amb.L./Amb.W.	4	-0.09	8.10	-1.00	5.0–7.2	1.8– 2.0
Amb.L./No.S.P.	4	0.99	-0.03	0.39	5.0–7.2	13.0–18.0

mm. See also Table 7.

Four anal deltoids, a super-, two crypto-, and a hypodeltoid. Configuration of superdeltoid as for deltoid lip of regular deltoid, with concave aboral face corresponding in position to greatest constriction of regular deltoid. Two triangular externally exposed cryptodeltoids, aboral to anus and not in contact with superdeltoid. Each cryptodeltoid has its longest edge along the lancet, extending to or almost to the radial; straight edge forms aboral lateral edge of anus, opposite edges converging slightly aborally; very slightly convex crypto-hypodeltoid suture. Each cryptodeltoid forms part of continuation of ambulacral sinus. Hypodeltoid large, lying in same plane as peristome, with very broad V-shaped suture against radials where it is widest (Pl. 6, figs. 4,7). Radials have large external RD sector in anal interarea against hypodeltoid, width greater than that in ambulacral sinus. Hypodeltoid reaches ambulacral sinus but apparently separated from lancet. Lateral edges converge toward anus; edge facing anus, short, straight. Hypodeltoid has slight triangular elevation on surface, with two narrow surfaces inclined toward ambulacral sinus and a broader, or slightly concave face inclined toward radials; apex very near adoral edge of plate. Outline of anal opening thus ovoid hexagonal, with adoral edge bounded by the superdeltoid, the lateral edges the lancets, the aboral lateral edges the cryptodeltoids and the aboral edge the hypodeltoid. Super.L.: 0.5-0.8 mm; Super.W.: 0.9-1.2 mm. Hypo.L. and W.: 1.6 and 2.0 mm in one specimen, 1.5 and 2.5 mm in another; anal opening 1.2 mm in first case. O.c.-anus: 0.9-1.0 mm.

Ambulacra five, lanceolate in plan view, slightly convex in lateral view, flat in cross section (Pl. 6, figs. 8,9). Lancet is concealed except for its adoralmost 0.8 mm; exposed area rhombic-shaped, bears ambulacral tract; almost reaches peristome; wider in anal interarea (Pl. 6, figs. 1,3). Large side plates with two angular median edges, meeting along centerline of ambulacrum. The slightly sinusoidal ad- and aboral edges are adorally inclined; indented laterally by triangular outer side plate (length: 0.2 mm; width: 0.3 mm), more so the adoral than the aboral edge of the side plates (Pl. 6, figs. 8,9). Both plates form lateral edges of ambulacrum, the outer side plates about three-fifths of total length. Brachiolar facet heart-shaped, length and width about 0.3 and 0.2 mm respectively, developed on side and outer side plates on sloping lateral edge of ambulacrum; rim between adjacent facets. Side groove 0.7 mm long, does not follow suture between side plates over the inner two-thirds of its length as the former diverges aborally. Main groove ornamented by five minor lobes and grooves between each side groove; latter ornamented by minor lobes and grooves on both its ad- and aboral edges; spacing between grooves greater than along main groove. Area lateral to arcuate side plate crest produced into a small knob. See Table 7.

Eight hydrospire groups, lacking in anal interarea, developed only on inner part of RD and DR sectors, completely concealed by ambulacra, entrance via a hydrospire cleft which extends full length of ambulacrum; hydrospire slits extend almost full length of sinus. Number of hydrospire slits apparently between 5-9. Side plates cause constriction toward deltoid crest adorally, creating an open bifid, spiracle-like opening at the adoral end of the ambulacrum, which passes aborally into the hydrospire cleft (Pl. 6, fig. 1).

Oral opening pentagonal, width: 0.7-1.0 mm. Width of ambulacral tract on deltoids: 0.3 mm.

Distribution.– Devonian, La Vid Formation, Leon, and Arnao Formation, Asturias, Spain.

Remarks.– The above description is based upon the six specimens in the growth series (Appendix 1) plus those additional ones in Plate 6. The internal anatomy and ontogeny of this species were discussed by Breimer and Macurda (1972) and are further summarized in Table 7. This species is the rarest of the three species of *Pentremitidea*, being known only from a few specimens. The preserved specimens are usually about the same size, and small specimens are unknown. This species does not represent a mature form of one of the other two species; it is clearly distinguishable by the more restricted area occupied by the hydrospire slits, the less prominent ambulacral sinus, and the growth characters of the principal plates which do not follow a projection of the growth axes of the other species. The theca is larger and more robust, and the growth lines are finer than in other species of *Pentremitidea.*

PENTREMITIDEA PAILLETI (De Verneuil, 1844)
Pl. 4, figs. 15,17,19-23; Pl. 5, figs. 1,2,4,5,10,15; Table 8

Pentremitidea pailleti Breimer and Macurda, 1972, Pl. I, figs. 22-24.

Description.– Theca tall, narrow, conical in lateral view (Pl. 4, figs. 19,20,22); vault short, broad, convex, aboral tip of deltoid crest and upper tip of radial limbs project above oral opening; pelvis long, slender with a straight to slightly outward flaring profile; pelvic angle 26-40°. Theca pentalobate in plan view, only slightly so in smaller specimens, becoming slightly more pronounced with growth; curvature gradual, not interrupted (Pl. 4, figs. 15,21,23; Pl. 5, fig. 4). Greatest width at aboral tip of ambulacra. See Table 6.

Basalia three, in normal position, pentagonal in plan view, becoming rounded at proximal tip; narrowly conical in lateral view, forming slightly more than one-half of pelvis; profile may be very slightly concave. Stem attachment area at lowest point on theca, a narrow cylindrical platform formed by growth of BA sectors (Pl. 4, fig. 17; Pl. 5, fig. 5). Uppermost columnal occasionally preserved, height about 0.1 mm; slightly taller along interbasal suture. Lumen pierces center of stem plate. BA growth sectors do not flare outward from origin of basals, but continue to taper proximally. Diameter of base of theca: 0.5-1.3 mm; size increases ontogenetically.

Azygous basal long, narrow, quadrate in plan view, with straight lateral and distal edges; very slightly concave in lateral profile. BR sectors very slightly concave parallel to BR axis, convex normal to it proximally, becoming flatter distally; merge smoothly over slightly convex surface (more pronounced proximally). BB sectors well developed, convex parallel to BB axis, slightly concave normal to it; BA sector slightly convex parallel to BA axis, curving inward; strongly convex normal to it. Each sector ornamented by growth lines parallel to growth fronts. Zygous basals long, pentagonal in plan view, with straight lateral and distal lateral edges; concave distal medial edge. Straight to slightly concave in lateral view. Median and lateral BR sectors straight to slightly concave parallel to BR axes; median sector convex normal to median BR axis, lateral sectors only slightly so to flat normal to lateral BR axes. Adjacent sectors merge smoothly. Ornament, BB, and BA sectors as for azygous basal. ABBA: 0.2-1.1 mm; ABBAF: 0.4-1.0 mm; see also Table 6.

Radials quadrate in plan view, with two short straight or a single convex lower edge, two lateral edges which gradually diverge to aboral tip of ambulacrum, then converge slightly adorally; two upper edges confined to ambulacral sinus and converge toward one another in shallow concave arc. Short parabolic sinus indents upper part of radial; limbs short. Radial triangular in lateral view with short convex adoral facing edge and straight to very slightly concave aboral facing edge; concave lower edge. RB sector straight to very slightly concave parallel to RB axis, slightly convex normal to it, adjacent sectors merge over convex boundary; merge smoothly with RR sectors. Latter slightly convex parallel to RR axis, convex normal to it, convexity more pronounced in upper part. Opposing RR axes arc gradually in toward one another, producing a gently uninterrupted gull wing-shaped profile (Pl. 5, figs. 1,2). RB and RR sectors ornamented by moderate growth lines. RD sector small, confined to ambulacral sinus, boundary with RR sector abrupt, angular; RD sector is slightly concave parallel and normal to RD axis; RDF slightly concave. Slightly more than one-half of inner part of RD sector bears hydrospire slits, which extend almost full length of sector; outer part smooth, curving steeply upward to rim of sinus (Pl. 5, figs. 1,10). RWB: 1.3-3.0 mm; RWA: 1.6-3.8 mm; RWD: 1.5-2.5 mm; see also Table 6.

Deltoids four, together with superdeltoid forming borders of oral opening, small, elongate hexagonal in plan view, with short straight adoral edge and DDF which are ornamented with minor lobes and grooves; width then contracts along DAF; exposed width constricted further by projection of side plates over hydrospire cleft, forming concave profile which expands aborally. DRF slopes upward, aborally convex. Deltoid lip is small, an elevated triangular mound with straight faces toward the two DDF and a concave aboral surface which slopes, then drops straight downward to origin of deltoid which is relatively well below tip of mound (Pl. 5, figs. 1,2). Deltoid crest rises moderately upward in a concave arc to its aboral tip; DRF drops downward in a convex arc; upper portion parallel to polar axis to slightly overturned. Sides of deltoid crest slope almost vertically downward in a concave arc into the ambulacral sinus; the inner part of the DR sector bears hydrospire slits extending almost to the origin of the crest; the outer part is smooth and unornamented analogous to outer part of RD sector (Pl. 5, fig. 10). Del.Gr.Ad.W.: 0.3-0.5 mm; Min.W.: 0.1-0.3 mm; L.Crest: 0.4-1.3 mm; DR: 0.4-1.2 mm; Ht. above peristome: 0.2-0.5 mm.

Anal deltoids four, a super-, two crypto-, and a hypodeltoid. Configuration of superdeltoid as for deltoid lip of regular deltoid, hexagonal in plan view, with concave aboral edge sloping into anus (aboral edge at position corresponding with minimum width of regular deltoid). Length: 0.2-0.5 mm; width: 0.3-0.7 mm. Hypodeltoid almost never preserved. Aboral to superdeltoid, edges of side plates form border to ovoid opening; when side plates of adjacent ambulacra begin to diverge aborally, there is a pentagonal gap in the outer part of the anal interarea. RD sectors are truncated by almost straight suture; external growth lines in RD sectors. Anal RD sectors also developed in ambulacral sinus; height of development small to fairly pronounced above ambulacrum.

Cryptodeltoids are triangular plates, exposed externally, edge bordering lancet longest; one edge forms aboral lateral border of anus, the other edge borders the hypodeltoid. Aboral tip reaches radial; each plate forms part of ambulacral sinus. Not connected to superdeltoid. Adoral edge of cryptodeltoid about point where ambulacra sharply diverge aborally.

One pentagonal hypodeltoid preserved in specimen 20 in growth series, filling rest of gap in aboral part of anal interarea. Hyporadial suture of varying convexity, from slight to pronounced, having median external growth sector and growth within ambulacral sinuses laterally; almost reaching to lancet. Lateral edges of hypodeltoid straight, converging adorally to anal opening bordering cryptodeltoids. Anal opening ovoid, bordered adorally by superdeltoid, laterally by ambulacrum (lancet and side plates), aboral laterally by cryptodeltoids and aborally by hypodeltoid. Length and width in largest specimen in growth series 1.2 and 0.7 mm respectively. Hypodeltoid lies in almost flat plane on upper surface of theca; has a small knob on it. Anal opening directed upward; almost same level as that of oral opening. Total length and aboral width of area occupied by anal deltoids increases during ontogeny.

Ambulacra five, lanceolate in plan view, slightly convex in lateral view, rather flat in cross section, sited in an ambulacral sinus; walls of sinus relatively low (Pl. 5, fig. 15). Lancet lanceolate, almost reaching oral opening, only adoralmost 0.5 mm exposed; exposed area rhombic-shaped (Pl. 5, fig. 1), bears ambulacral tract; rest of lancet concealed. Lancet wider in anal interarea than elsewhere. Shape of side plates unusual. Medial edge convex, meeting along main groove. Inner parts of adoral and aboral edges do not bear side groove; the edges are adorally inclined until near the middle of the plate where they intersect the grooves 0.3 mm from main groove and underlie them for 0.2 mm; then adoral suture bends aborally as large triangular outer side plate (length: 0.2 mm; width: 0.3 mm) embays aboral edge of preceding side plate; both plates form margin of ambulacrum, about three-fifths being composed of outer side plates. Brachiolar facet heart-shaped, length and width about 0.2 mm, on outer sloping edge of ambulacrum, equally developed on side and outer side plate, closely spaced, with rim between facets; side groove extends inward to main groove, sloping slightly downward, aboral grooves enter at slightly more acute angle; adoral groove about 0.5 mm long in large specimen; main groove bordered by three minor lobes and grooves; latter also present along adoral and aboral(?) edge of side groove. Side plate crest very convex with area between boundaries raised into a small knob.

Eight hydrospire groups, lacking in anal interarea. Hydrospire slits developed on inner parts of DR and RD sectors in moderately concave ambulacral sinus, extending almost full length of sectors but not present full width of radiodeltoid suture (Pl. 5, fig. 10). Hydrospire slits concealed, except occasionally the outermost slit of each group is exposed. Lanceolate ambulacra converge toward deltoid crest, forming an open but restricted spiracle-like opening at adoral end of adjacent ambulacra (Pl. 5, fig. 2). Side plates project over hydrospire slits; lateral access via a hydrospire cleft along length of ambulacrum. Number of hydrospire slits apparently relatively constant during growth: approximately five in a specimen of 9 mm length; seven in a specimen 15 mm in length.

Oral opening pentagonal, 0.3-0.5 mm in width; width of ambulacral tract on deltoids: 0.2-0.3 mm.

Distribution.— Devonian, Ferrones Formation, Asturias, Spain.

Remarks.— The above description is based upon the specimens in the growth series (Appendix 1), plus those additional ones figured in Plates 5 and 6. The internal anatomy and ontogeny of this species were discussed by Breimer and Macurda (1972) and are further summarized in Table 8.

The distinguishing characteristics of this species are the inward curvature of the BA growth axis and resulting narrow base, the thin stem plates, the lack of a flexure in the RR growth axis, and the complete (or almost complete) concealment of the hydrospire slits.

Genus PLEUROSCHISMA Reimann, 1945

Type species.— *Pentremites lycorias* Hall, 1862. *Pleuroschisma* Breimer and Macurda, 1972, p. 16.

PLEUROSCHISMA LYCORIAS (Hall, 1862)

Pl. 7, figs. 2-4,6-10,12-21; Pl. 8, figs. 1-5; Tables 9A,B

Pleuroschisma lycorias Breimer and Macurda, 1972, Pl. II, figs. 4,7,8,10.

Description.— Theca club-shaped; pelvic profile steeply conical, slightly concave, with narrow pointed proximal end. Pelvic angle 35-48°. Vault strongly inflated, almost quadrate outline, sides rising almost straight up from ambulacral tips; crests of deltoids elevated above oral opening (Pl. 7, figs. 3,4,8-10,14). Vault profile becomes more rounded in largest specimens. Greatest width at or slightly adoral to ambulacral tips; cross section pentagonal with slightly concave interambulacral areas, becoming flush in largest specimens (Pl. 7, figs. 6,7,12,13,15). L.: 7.2-17.0 mm; W.: 3.8(a)-10.2 mm. Larger incomplete specimens. See Table 9B.

Basalia three, in normal position, steeply conical in lateral profile with straight to very slightly convex sides; form approximately one-half of pelvis; cross-sectional profile rounded proximally, pentagonal distally (Pl. 7, fig. 15). Basalia taper proximally to a slender cylindrical platform, caused by growth along BA axis; diameter: 0.7-1.2 mm. Proximal surface of platform not completely level, indented along interbasal sutures and concave lower surface. Diameter of attached stem plate same as platform, filling indentations. Stem plates disc-shaped cylinders, approximately 6 per mm about 3 mm below attachment area, suggestion of thinner plates between thicker plates near theca; width of plates decreases down stem (Pl. 7, fig. 18).

Azygous basal quadrate in plan view with straight lateral and distal edges. Origin of plate very near proximal end. BR sector straight to slightly concave parallel to BR axis, convex normal to it; sectors merge on convex surface proximally; surface becomes flatter distally. BB sector straight parallel to BB axis, concave normal to it; BA sector convex parallel and normal to BA axis. Surface ornamented by fine growth lines parallel to all fronts. Zygous basals pentagonal in plan view, long straight sides, straight upper lateral edges, and concave distal edge against C and E radials. BR sectors are straight to slightly concave parallel to BR axis, median sector convex normal to it, lateral sectors slightly flatter; merge smoothly over convex or slightly angular boundary. Ornament as for azygous basal (Pl. 7, figs. 16,17). ZBBA: 0.3-0.5 mm. See Table 9B.

Radials five, forming upper half of pelvis and extending slightly above level of oral opening. In plan view radial is elongate, with almost straight sides; narrow at base, expanding adorally to greatest width which is slightly adoral to ambulacral tip, then contracting slightly to adoral tip of radials. Upper edges slope into ambulacral sinus. In lateral view radial has low triangular outline: base, formed by interradial suture, is almost level, with upward inflection at basal-radial sutures. Profile from aboral end of ambulacrum toward base slightly concave, about equal in length to that of edge from aboral end of ambulacrum toward oral opening but this

TABLE 8. Growth relationships of principal variables of *Pentremitidea pailleti* (De Verneuil, 1844)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	16	0.95	-1.37	2.40	6.7–17.7	3.2– 7.8
V/P	16	0.84	-0.89	0.17	0.2– 2.1	6.5–14.9
L/ABBR	16	0.99	-0.25	2.10	6.7–17.7	3.3– 8.8
L/RD	16	0.96	2.80	4.57	6.7–17.7	0.8– 3.2
L/RB	16	0.96	1.51	2.36	6.7–17.7	2.5– 7.0
L/Del.L.	16	0.85	-4.69	9.94	6.7–17.7	1.1– 2.0
L/Amb.L.	16	0.96	3.27	3.37	6.7–17.7	1.0– 4.2
RD/Amb.L.	12	0.99	0.11	0.73	0.8– 3.2	1.0– 4.2
Del.L./Amb.L.	12	0.91	0.97	0.27	1.1– 2.0	1.0– 4.2
ABL/ABW	16	0.96	-2.02	3.85	4.2–10.7	1.7– 3.2
ABBR/ABBRF	16	0.96	0.09	3.76	3.3– 8.8	1.0– 2.2
ABBB/ABBBF	16	0.87	-0.05	0.09	0.3– 0.8	3.7– 9.4
ABBB/ABBR	16	0.87	-0.05	0.10	0.3– 0.8	3.3– 8.8
ZBL/ZBW	16	0.96	-0.48	2.23	4.0– 9.5	2.0– 4.7
ZBBR/ZBBRF	16	0.90	1.19	3.40	3.5– 8.6	0.8– 2.2
ABBR/RB	16	0.93	1.08	-1.07	3.3– 8.8	2.5– 7.0
ABBR/RD	16	0.94	1.60	2.11	3.3– 8.8	0.8– 3.2
ABBR/Del.L.	16	0.85	-1.98	4.66	3.3– 8.8	1.1– 2.0
RD/RDF	16	0.26	1.05	1.41	0.8– 3.2	0.5– 0.8
RR/RRF	16	0.95	0.22	0.32	1.0– 2.8	2.8– 8.0
RB/RBF	16	0.89	-0.81	4.28	2.5– 7.0	0.8– 1.8
RD/RR	16	0.97	-0.40	1.29	0.8– 3.2	1.0– 2.8
RD/RB	16	0.89	-0.02	0.46	0.8– 3.2	2.5– 7.0
RR/RB	16	0.92	0.30	0.35	1.0– 2.8	2.5– 7.0
RD/Del.L.	16	0.90	-1.66	2.19	0.8– 3.2	1.1– 2.0
RB/Del.L.	16	0.77	-1.73	3.68	2.5– 7.0	1.1– 2.0
Del.L./Gr.Ab.W.	16	0.57	0.93	0.95	1.1– 2.0	0.6– 1.0
Del.L./Anal Del.L.	16	0.88	0.66	0.49	1.1– 2.0	1.2– 3.0
Amb.L./Amb.W.	14	0.89	-0.36	2.72	1.3– 4.2	0.6– 1.5
Amb.L./No.S.P.	14	0.88	-0.70	0.28	1.3– 4.2	7.0–15.0

TABLE 9A. Growth relationships of principal variables of *Pleuroschisma lycorias* (Hall, 1862) (New York)

Variables	n	r	a_0	a_1	Observed Range y	Observed Range x
RD/Amb.L.	6	0.99	0.94	0.82	5.5–12.6	5.0–14.2
Del.L./Amb.L.	6	0.95	1.63	0.17	2.5– 4.0	5.0–14.2
RD/RDF	9	0.79	-1.12	4.31	5.5–12.6	1.5– 3.1
RR/RRF	9	0.95	0.02	0.22	1.8– 3.9	9.1–18.2
RB/RBF	9	0.89	2.01	1.66	3.5– 5.5	0.7– 2.0
RD/RR	9	0.95	-1.83	3.68	5.5–12.6	1.8– 3.9
RD/RB	9	0.93	-7.00	3.36	5.5–12.6	3.5– 5.5
RR/RB	9	0.94	-1.28	0.89	1.8– 3.9	3.5– 5.5
RD/Del.L.	9	0.96	-6.80	4.70	5.5–12.6	2.5– 4.0
RB/Del.L.	9	0.91	0.59	1.23	3.5– 5.5	2.5– 4.0
Del.L./Gr.Ab.W.	9	0.94	1.49	1.04	2.5– 4.0	1.0– 2.3
Amb.L./Amb.W.	6	0.85	-28.52	35.60	5.0–14.2	1.0– 1.2
Amb.L./No.S.P.	6	0.99	0.26	0.32	5.0–14.2	15.0–42.0

latter edge becomes longer in large specimens due to accelerated growth; very slightly convex, sloping toward oral opening. RD growth sector entirely within ambulacral sinus, being slightly convex parallel to RD axis, straight normal to it, no growth lines preserved; area occupied by hydrospire slits. Radial sinus deepens adorally from aboral end of ambulacrum to deepest point at radiodeltoid suture; latter concave toward radial in sloping sides of ambulacral sinus. Small keel at end of ambulacrum (Pl. 7, fig. 4) which increases in size during growth. RD axis longest, accelerates during growth, evidenced by fanning of growth lines in RR sector (Pl. 7, fig. 2; Pl. 8, fig. 4). RR sector straight to slightly concave parallel to RR axis, slightly convex normal to it. RB sector very slightly concave normal to RB axis, almost straight normal to it; RB sectors merging smoothly over convex surface; merge smoothly with RR sectors. RR and RB sectors ornamented by fine growth lines. Number growth lines per 0.25 mm interval in RR sector 6-11; number apparently does not show any trend to increase or decrease with later stages of growth (as measured from near origin to interradial suture). Very occasionally a growth line in the RB sector will pass into the RR sector and then fade out; otherwise continuous. Stereom preserved in a few specimens in radials and basals, axes of meshwork being perpendicular to sutures. R.Ht: 0.5-2.4 mm; RWB: 1.4-3.5 mm; RWA: 2.2-6.0 mm; RWD: 1.6-4.4 mm. See also Tables 9A,B.

Deltoids four, together with superdeltoid form border to oral opening (Pl. 7, fig. 20); short, confined to upper edge of vault. Deltoid hexagonal in plan view, with short straight adoral edge; width expands slightly along very short, straight DDF, then contracts to expand again aborally along long concave DAF; DRF convex, rising upward and outward in ambulacral sinus. Deltoid convex in lateral view because of slightly convex crest which curves slightly upward and outward from origin of deltoid (Pl. 7, fig. 21; Pl. 8, fig. 5). In large specimens, aboral part of crest may curve downward and form part of upper outer profile of theca. Deltoid lip has a raised ridge which is convex toward oral opening. Deltoid crest originates 0.2 mm below deltoid lip. Small groove follows adoral lateral edges of crest and

TABLE 9B. Growth relationships of principal variables of *Pleuroschisma lycorias* (Hall, 1862) (Ontario)

Variables	n	r	a_o	a_1	Observed Range y	x
L/W	6	0.99	-3.07	2.53	8.5–17.0	4.5– 7.8
V/P	8	0.91	-2.70	1.11	2.7– 7.9	4.5– 9.4
L/ABBR	6	0.95	-1.11	3.60	8.5–17.0	2.7– 5.0
L/RD	6	0.98	3.40	1.87	7.2–17.0	2.5– 7.9
L/RB	6	0.97	-1.27	3.82	7.2–17.0	2.6– 5.1
L/Del.L.	6	0.91	-3.27	6.18	8.5–17.0	2.0– 3.5
L/Amb.L.	6	0.99	3.78	1.72	8.5–17.0	2.9– 7.9
L/No.Hyd.Sl.	7	0.81	2.35	1.70	7.2–17.0	2.0– 8.5
RD/Amb.L.	10	0.99	0.37	0.86	2.5–10.5	2.5–12.3
Del.L./Amb.L.	10	0.92	1.23	0.25	1.3– 4.3	2.5–12.3
ABL/ABW	6	0.96	0.50	1.80	3.3– 5.5	1.6– 3.0
ABBR/ABBRF	6	0.94	-0.33	2.78	2.4– 5.0	1.1– 2.0
ABBB/ABBBF	5	0.55	0.10	0.11	0.4– 0.8	3.0– 4.7
ABBB/ABBR	6	0.38	0.34	0.05	0.4– 0.8	2.4– 4.8
ZBL/ZBW	6	0.94	1.76	0.80	3.0– 5.3	1.9– 4.6
ZBBR/ZBBRF	6	0.90	-0.59	3.33	2.5– 5.0	1.0– 1.8
ABBR/RB	6	0.91	0.55	0.94	2.4– 5.0	2.3– 5.1
ABBR/RD	6	0.94	1.45	0.48	2.4– 5.0	2.6– 7.9
ABBR/Del.L.	6	0.74	0.41	1.34	2.7– 5.0	2.0– 3.5
RD/RDF	10	0.81	-1.60	3.90	2.5–10.5	1.0– 2.7
RR/RRF	10	0.99	0.37	0.19	1.2– 3.1	4.5–15.2
RB/RBF	10	0.98	0.77	2.18	2.4– 5.1	0.8– 2.0
RD/RR	10	0.97	-2.41	3.82	2.5–10.5	1.2– 3.1
RD/RB	10	0.91	-4.02	2.60	2.5–10.5	2.4– 5.1
RR/RB	10	0.96	-0.48	0.70	1.2– 3.1	2.4– 5.1
RD/Del.L.	10	0.92	-2.50	2.91	2.5–10.5	1.3– 4.3
RB/Del.L.	10	0.84	1.09	0.93	2.4– 5.1	1.3– 4.3
Del.L./Gr.Ab.W.	9	0.97	0.55	1.69	1.3– 4.3	0.6– 2.3
Del.L./Anal Del.L.	6	0.86	0.56	0.75	1.3– 4.3	1.8– 5.0
Amb.L./Amb.W.	10	0.69	-5.92	14.67	2.5–12.3	0.5– 1.0
Amb.L./No.S.P.	10	0.93	-1.03	0.40	2.5–12.3	8.0–32.0

ornaments aboral side of ridge above adoral end of crest. Deltoid crest very sharp, extending aborally and rising above oral opening. Highest point along deltoid crest changes during ontogeny due to mode of growth along radiodeltoid suture. Aboral sides of deltoid slope steeply downward into ambulacral sinus below crest, bear hydrospire slits over full width of DRF; no growth lines present. Del.Gr.Ad.W.: 0.2-0.5 mm; Del.Min.W.: 0.2-0.3 mm; L.Crest: 0.9-3.7 mm; DR: 1.0-3.5 mm. See also Tables 9A and 9B.

Anal deltoids four, a superdeltoid, two cryptodeltoids, and a hypodeltoid. Adoral edge of superdeltoid forms part of border of oral opening; adoralmost upper edge bears small groove which extends aborally on both edges of plate to hydrospire fields which begin on cryptodeltoids (Pl. 7, fig. 20). Adorally directed U-shaped ridge rises aboral to trough, elevated above rest of plate; crests of ridge pass into cryptodeltoid crests aborally. Anal opening begins behind U-shaped ridge; embays 0.4 mm into superdeltoid in one of larger specimens; elongate ovoid in outline. Each cryptodeltoid an elongate, narrow plate which extends from prong of superdeltoid to radial, forming lateral wall of ambulacral sinus; exposed externally. Upper crest convex, bending sharply downward to meet the radial; crest not as elevated as that of regular deltoid. Cryptodeltoid convex against superdeltoid and radial. Hypodeltoid forms part of lateral wall of theca, elongate U-shaped outline in plan view with greatest width near middle at junction of crypto-hypodeltoid-radial suture; below this point, hypodeltoid present only on outer wall of theca with convex outline; above this sides of plate developed and form part of ambulacral sinus where it abuts against cryptodeltoids. Growth lines on outer sloping sides indicate plate has grown downward from apex at aboral end of anal opening toward radial and inward toward cryptodeltoids (Pl. 8, figs. 1,2). Super.L.: 0.5-1.3 mm; Super.W.: 0.4-0.9 mm; Hypo.L.: 2.5-3.0 mm in 3 specimens; Hypo.W.: 0.5-2.0 mm.

Ambulacra five, very elongate, narrow, with linear sides (Pl. 7, fig. 19). In lateral profile, ambulacrum convex outward, more so in adoral portion. Ambulacra sited in deep, rhombic ambulacral sinus with radial edges much longer than deltoid. Length of ambulacrum increases throughout growth but very little increase in greatest width (from 0.7 to 1.0 mm in growth series). Lancet concealed by side plates except at adoralmost end of ambulacrum where 0.4 mm of length is exposed; this rhombic-shaped area bears ambulacral tract; lancet extends to edge of oral opening. Lancet underlies side plates throughout length of ambulacrum; upper surface slopes sharply downward from centerline of plate. Admedial half of ambulacrum flat. Ambulacrum slopes downward on ablateral sides where brachiolar plates attached. Admedial edges of side plates bear main groove (width 0.04 mm); three minor grooves are sited above main groove on each side plate. None along side grooves. No ambulacral cover plates preserved but presumably present; width of area occupied 0.20 mm at aboral end of ambulacrum, expanding to 0.25 mm in large specimens. Short side groove (L.: 0.2 mm in adoral portion of ambulacrum; W.: 0.1 mm); aborally inclined to main food groove; abmedially expands into teardrop-shaped brachiolar pit (L.: 0.13 mm; W.: 0.15 mm), deepest near point of tear where converges with side food groove. Brachiolar facet heart-shaped, surrounding ablateral half of brachiolar pit (Pl. 8, fig. 1). Facet inclined on side of ambulacrum; axis of facet rotated toward peristome. Brachiolar facet (L.: 0.24 mm; W.: 0.23 mm) developed on side plate and rounded triangular outer side plate (L. adoral end ambulacrum: 0.26 mm; W.: 0.14 mm) which embays adoral abmedial edge of side plate. Facet is elevated above other abmedial parts of ambulacrum. That half of facet developed on outer side plate is lower than half on side plate; thus lowest plate of presumed biserial brachiole would have been on the adoral side. Medial lateral edge of heart-shaped facet notched by small triangular depression. Arcuate side plate furrow originates on line parallel with admedial edge of brachiolar pit (Pl. 8, fig. 1). Arcuate side plate crest separates admedial portion of side plate furrow from area ornamented by minor lobes and grooves of main groove. Furrow curves downward in an aboral direction to lower edge of ambulacrum, broadening as it does so to 0.08 mm, following adoral suture of outer side plate and aboral ablateral edge of side plate for half its length. Since furrow descends and broadens and facets protrude outward, triangular area is produced between facets which mimics a pore. Longest edge of outer side plate is that along interior of facet; admedial portion of adoral edge perpendicular to main groove, curving aborally to form part of side plate furrow and then outer edge of adoral half of facet.

Brachioles (Pl. 8, fig. 2) biserial, ellipsoidal cross section, six plates per mm on each side of brachiole; plates just above side plates much larger than plates farther up brachiole; depth decreasing; lower plates also bear a ridge paralleling upper edge of plate not borne by higher plates.

Ten hydrospire fields, filling entire ambulacral sinus; wholly exposed except for slight coverage of innermost slit. In smallest specimens in growth series number of slits in regular field 2; those in anal interarea equal. In largest specimens, number in regular field has increased to 7 or 8 (number may differ in different fields); number in anal interarea equal or one less. Width of slit 0.05 mm; width of hydrospire wall approximately 0.01 mm; width of thecal wall (radial) 0.18 mm. When sloping sides of ambulacral sinus are viewed laterally, hydrospire slits are slightly convex toward exterior of theca (Pl. 7, fig. 21; Pl. 8, fig. 5). Convexity apparently produced by an increasing amount of calcite being secreted between adjacent slits along radiodeltoid suture during growth. Distance from center of slit to center of adjacent slit increases from approximately 0.20 mm at aboral end of ambulacrum to 0.23 mm at radiodeltoid suture in largest specimens.

Peristome pentagonal: W.: 0.5-0.8 mm.

Distribution.– Devonian, Centerfield Limestone and Kashong Shale Member, Moscow Shale, New York, U.S.A. and Hungry Hollow Formation, Ontario, Canada.

Remarks.– P. lycorias was originally described from the Devonian of New York. Most specimens are crushed so the data matrix derived from the measurement of these specimens is incomplete (Table 9A). The species also occurs in Ontario and the specimens from there are more complete in their preservation (Table 9B). The above description is based primarily upon specimens from Ontario (growth series II, Appendix I) with some ambulacral and brachiolar detail being derived from New York specimens. The internal anatomy and ontogeny of this species were discussed and illustrated by Breimer and Macurda (1972) and are further summarized in Table 9.

In the smallest specimen in growth series II, the azygous basal is missing due to mutation. One ZB is centered under the A ambulacrum and has a normal configuration. The other ZB is centered under the anal opening and is larger and has three peaks instead of two. The interbasal sutures are 180° opposite one another, being slightly offset to C side under center of B ambulacrum, the other being centered under C. The stem facet is a narrow ellipse, 1.0 mm long and 0.2 mm wide. The suture crosses this 0.4 mm from the end; a lumen pierces the center. The BB axis is well developed on these basals. The ornament of the deltoid is also slightly different. Instead of the deltoid crest originating below the adoral part of the deltoid, there is a small knob at the adoral end of the crest, apparently just aboral to the trough on the deltoid. This knob projects above the adoral edge of the deltoid. Aborally, the crest drops into a saddle and then rises again aborally. There is a suggestion of some type of suture in all four regular deltoids extending aborally from the point where the crest begins to rise from the saddle to the outer hydrospire slit.

Specimens in growth series I comprise specimens numbered 14-22 in Appendix I; those in growth series II are numbered 2-13. Specimen 5 was figured by Fay (1961b, Text-fig. 49) as having a hypodeltoid but this is erroneous as the plate is not preserved in this specimen. Measurements given within the text are taken from growth series I and II as data for some of these characters is very limited.

Three species of *Pleuroschisma* have been described from the United States: *P. lycorias* (Hall, 1862), the type species; *P. hibbardi* Reimann, 1945; and *P. ontario* Reimann, 1945. These are found in the Devonian Hamilton Group: *P. lycorias* from the Kashong Member of the Moscow Shale near West Alden, New York, and from the Tichenor Limestone near Springbrook, New York (no material seen from this latter locality); *P. hibbardi* from the Centerfield Limestone in the Ludlowville Formation near East Alexander, New York, and *P. ontario* from the Hungry Hollow Formation in the outcrop belt extending from Hungry Hollow, east of Arkona, to Thedford, Ontario. The New York species range through two formations, the Centerfield being the oldest horizon, the Kashong, the youngest; the three members are separated from one another by other rock units. The specimens from different areas in the United States and Canada have a similar temporal distribution. Hall's 1862 description of *P. lycorias* was only one paragraph in length, the species was not illustrated, and the ambulacra were covered by the brachioles. Fay (1962) was unable to locate Hall's original material nor have I. Reimann (1935) questionably identified a specimen as *Pentremitidea* cf. *lycorias* Hall but disavowed this identification in 1945 (p. 24). In 1945 he described the genus *Pleuroschisma* with the type species *Pentremites lycorias* Hall. The material attributed to Hall's species by Reimann appears to be in accord with Hall's description as far as it goes but the presence of the brachioles in Hall's material obscured the ambulacral structure (and presumably the hydrospire slits); thus a note of uncertainty still surrounds the identity of Hall's original material. Reimann described *P. hibbardi* and *P. ontario* in 1945. He distinguished *P. hibbardi* from *P. lycorias* by the very narrow interradial areas, by the narrower and smaller hypodeltoid plate as indicated by the radial ornamentation, by the longer, more compressed and crenulate process of the radial lip, and by the slightly crenulate and apparently less elevated deltoid crests. It is the most slender of the species (1945, p. 25). *P. ontario* was differentiated from the first two on the basis of its form, having a more slender base than *P. lycorias*, having a wider summit than the other two species named above, being depressed along the interradial suture, and having deltoids that are less elevated than *P. lycorias* (Reimann, 1945, p. 25). Fay (1962) reviewed the three species and differentiated between them on the basis of form (wide or narrow, vault/width ratio) and the relative height of the deltoids.

In any comparison based upon the parameters used by Reimann or Fay, the mode of preservation must be taken into account. The holotype (and only known specimen) of *P. hibbardi* (specimen no. 19, Appendix I) has been flattened, the basals are missing, and it is impossible to accurately specify a vault/width ratio for it. The same is true for *P. lycorias* s.s.; specimens are laterally compressed, though not as severely as for *P. hibbardi*. Complete basals are known from only one specimen. In contrast, specimens of *P. ontario* are usually complete and uncrushed. When allowance is made for preservation, there does not appear to be any major difference in the relative elevation of the deltoid in any of the forms. A comparison of the growth axes and fronts of the radials of all three species shows coincidence of the parameters (Breimer and Macurda, 1972, Text-fig. 60) and the order of the specimens from graph to graph varies by only one or two positions. What is known of the basals of *P. lycorias* s.s. does not suggest any major difference from *P. ontario*; they may be a few tenths of a mm longer at a comparable growth stage; a comparison between the radials and deltoids shows the same coincidence as for the radials alone as does the number of hydrospires and width of the hydrospire field, length of the ambulacrum compared to its width and number of side plates, length and width of the ambulacral sinus, and the configuration of the radial and basal sectors. The small ridge at the aboral end of the ambulacrum is longer and thinner in *P. hibbardi* than the other two species. This, plus the slightly longer basals of *P. lycorias* s.s. are the only apparent differences between the described species and do not appear to constitute a basis for specific differentiation. Therefore, the three described species from North America were synonymized by Breimer and Macurda (1972).

PLEUROSCHISMA VERNEUILI (Etheridge and Carpenter, 1882)
Pl. 8, figs. 6-14; Pl. 9, figs. 1-9;
Pl. 10, figs. 1,2,8,10,11,14,17; Table 10

Pleuroschisma verneuili Breimer and Macurda, 1972, Pl. II, figs. 5,9,11.

Description.– Theca biconical to club-shaped in lateral profile (Pl. 8, fig. 12; Pl. 9, figs. 1,4,5,7,8), with conical, straight sided to very slightly concave pelvic profile; pelvic angle 44-46° (measurable in two specimens). Vault one-fourth to one-third length of pelvis, sloping steeply upward with truncate top as deltoid crest and tip of radial limbs elevated above oral opening. Theca pentagonal-decagonal in plan view, with greatest width at aboral tip of ambulacra (Pl. 8, figs. 6-11,13,14). Length approximately twice the width (where measurable); largest theca over 36 mm in length. See Table 10.

Basalia three, in normal position, forming one-half of pelvis, conical in lateral profile, with slight bend at base due to BA growth axes (Pl. 10, fig. 14). Basals pentagonal in plan view distally, becoming rounded-triangular proximally. Stem attachment area formed by short BA growth axes, at tapering base of theca. Uppermost stem plate rounded triangular, thin (0.1 mm), with lumen piercing center; diameter where known 1.5 mm. Thickest part of plate along interbasal sutures where there is a very slight indentation.

Azygous basal quadrate in plan view with long straight lateral edges which are reflected slightly outward at base and short, very slightly concave distal edges. Azygous basal straight in lateral profile except near base; slightly recurved due to BA axis. Origin very near proximal edge; BR sectors large, straight parallel to BR axis, slightly convex normal to axis; adjacent sectors meet over convex surface. BR sector curves into small BB sector which is straight parallel to BB axis and slightly concave normal to it. Short triangular BA sector at proximal end of basal, straight parallel to BA axis, convex normal to it; merging evenly with adjacent BB sectors. BA: 0.8 mm; BAF: 1.3 mm. All sectors ornamented by growth lines parallel to growth fronts. Zygous basals pentagonal in plan view, with

TABLE 10. Growth relationships of principal variables of *Pleuroschisma verneuili* (Etheridge and Carpenter, 1882)

Variables	n	r	a_o	a_1	Observed Range y	x
L/W	5	0.75	10.95	0.63	14.5–17.5	7.2–11.0
V/P	5	0.13	1.16	0.22	2.5– 5.3	12.0–13.5
L/ABBR	5	0.54	9.28	1.09	14.5–17.5	6.2– 7.7
L/RD	5	0.88	11.43	1.04	14.5–17.5	3.4– 6.3
L/RB	5	0.78	-3.57	3.31	14.5–17.5	5.7– 6.5
L/Del.L.	5	0.83	11.47	1.20	14.5–17.5	3.2– 5.5
L/Amb.L.	5	0.83	10.79	0.98	14.5–17.5	4.6– 7.4
L/No.Hyd.Sl.	5	0.87	11.83	0.32	14.5–17.5	10.0–19.0
RD/Amb.L.	23	0.96	1.07	0.66	3.4–11.5	4.6–15.1
Del.L./Amb.L.	23	0.93	-0.96	0.85	3.0–12.5	4.6–15.1
ABL/ABW	5	0.41	5.79	0.49	6.8– 8.3	2.6– 3.8
ABBR/ABBRF	5	0.22	5.89	0.32	6.2– 7.7	1.8– 2.8
ABBR/RB	5	-0.07	7.59	-0.16	6.2– 7.7	5.7– 6.5
ABBR/RD	5	0.13	6.28	0.07	6.2– 7.7	3.4– 6.3
ABBR/Del.L.	5	0.09	6.38	0.06	6.2– 7.7	3.2– 5.5
RD/RDF	23	0.89	2.26	1.08	3.4–11.5	2.2– 8.0
RR/RRF	13	0.95	0.32	0.25	2.3– 5.7	9.0–21.0
RB/RBF	13	0.93	-0.07	3.38	5.5–14.8	1.5– 4.0
RD/RR	21	0.88	1.55	1.18	3.4– 9.7	2.3– 7.5
RD/RB	13	0.76	2.32	0.47	3.4– 8.7	5.5–14.8
RR/RB	13	0.95	0.95	0.33	2.3– 5.7	5.5–14.8
RD/Del.L.	23	0.89	2.46	0.67	3.4–11.5	3.0–12.5
RB/Del.L.	13	0.94	0.51	1.42	5.5–14.8	3.0– 9.5
Del.L./Gr.Ab.W.	22	0.95	-0.81	2.48	3.0–12.5	1.6– 5.2
Del.L./Anal Del.L.	10	0.75	1.37	0.81	3.0– 5.7	3.1– 5.5
Amb.L./Amb.W.	23	0.83	-8.60	14.06	4.6–15.1	1.0– 1.6
Amb.L./No.S.P.	23	0.89	-1.20	0.41	4.6–15.1	13.0–18.0

straight lateral edges which are reflected slightly outward at base, very slightly sinusoidal upper lateral edges, and a concave upper median edge; lateral profile as for azygous basal. Median BR sector straight parallel to BR axis, slightly convex normal to it; lateral sectors straight and very slightly convex respectively. Adjacent sectors merge over angular boundary. BB, BA, and ornament as for azygous basal. Width zygous basal two-thirds of length. See Table 10.

Radials five, pentagonal in plan view, with convex or two straight lower edges; lateral edges straight, diverging in width upward; may contract slightly adoral to origin of plate. Upper edges straight, slope inward towards one another in a V, confined to prominent ambulacral sinus which forms prominent depression in upper half (approximate) of plate. Radial low, triangular in lateral view, with very slightly concave adoral lateral edge; very slightly concave aboral facing and lower edges. RB sector long, narrow, very slightly concave parallel to RB axis, straight to very slightly convex normal to it; adjacent sectors merge over convex boundary; merge smoothly with RR sectors which are straight to very slightly convex parallel to RR axis, slightly convex normal to it. RB and RR sectors ornamented by growth lines, those of latter usually more prominent (Pl. 10, figs. 2,17). RD sector at pronounced angle to RR sector, boundary sharp; sectors confined to ambulacral sinus (except anal interarea). RD sector straight parallel to RD axis, very slightly convex normal to it; entire width and length of sector occupied by hydrospire slits; no other ornament observed (Pl. 10, fig. 1). In anal interarea, RD sector also has an external sector convex parallel to axis and concave normal to it produced by growth along hyporadial suture (Pl. 9, fig. 2; Pl. 10, fig. 10). R.Ht.: 1.7-3.0 mm; RWB: 2.8-4.5 mm; RWD: 4.2-6.0 mm. See also Table 10.

Deltoids four, together with superdeltoid forming border to oral opening (Pl. 9, figs. 3, 6). Deltoid rhombic in plan view. Short straight edge borders oral opening; width expands along short DDF; both ornamented with minor lobes and grooves; width then contracts at beginning of ambulacra and expands again aborally along DAF; contracts along straight DRF. Deltoid concave angular in lateral view, with long sharp crest sloping moderately upward from origin; profile of crest straight in smaller specimens, becoming slightly convex in larger. Deltoid lip small, ornamented with small triangular pyramid; two faces slope down adorally to DDF; aboral face slopes down short distance to origin of deltoid crest. Aboral part of deltoid prominent, dominated by crest, sides of which slope steeply downward into ambulacral sinus. Full width and length of DR sector occupied by hydrospire slits (Pl. 10, fig. 1). Del.Gr.Ad.W.: 0.6-1.2 mm; Min.W.: 0.3-1.2 mm; L.Crest: 2.7-10.9 mm; DR: 1.8-7.4 mm. See also Table 10.

Anal deltoids four, a super-, two crypto- and a hypodeltoid. Superdeltoid as for deltoid lip of regular deltoid, except larger; aboral face notched by adoral edge of oral opening (Pl. 9, figs. 2,3,6). Two cryptodeltoids abut against small ridges on aboral face of superdeltoid. Each cryptodeltoid is a tablet-shaped plate, externally exposed, reaching to the radial, thin along the border of the anus, then widening aborally to form rim between ambulacral sinus and respectively, the anal opening, then the hypodeltoid. Cryptodeltoids not pronounced in small specimens but becoming so with growth, forming higher and higher wall to ambulacral sinus in anal interarea (Pl. 9, fig. 6; Pl. 10, figs. 8,10,11). Hypodeltoid forms part of upper lateral wall of theca. Shape is pentagonal, with concave adoral edge bordering anal opening; two crypto-hypodeltoid sutures diverge aborally; hyporadial sutures are the longest, forming a convex U (Pl. 9, figs. 2,3,6; Pl. 10, figs. 8,10, 11). Part of plate adoral to hyporadial suture usually lies in same plane as anal opening; surface slightly scalloped; growth lines adjacent crypto-hypodeltoid suture. Aboral to this plate bends sharply downward, ornamented with growth lines parallel to hyporadial suture; cross section of aboral part of plate usually slightly convex; may be slightly concave. Hypodeltoid separated from ambulacral sinus by rims of cryptodeltoids. May develop knob on adoral part of plate. Anal opening elongate ovoid, bordered adorally by superdeltoid, laterally by exposed cryptodeltoids, and aborally by hypodeltoid. Anal opening opens directly upward, level just slightly below oral opening. Size increases during ontogeny. Slight median constriction in one specimen. Super.L.: 0.5-0.8 mm; Super Gr.Ad.W.: 0.8-1.2 mm; Super Min.W.: 0.5-0.9 mm; Hypo.L.: 1.0-4.5(va) mm; Hypo W.: 1.0-3.0 mm; O.c.-anus: 0.8-1.5 mm; Anus L.: 1.3-2.5 mm; Anus W.: 0.5-1.0 mm.

Five ambulacra in base of prominent ambulacral sinus, linear in plan view, slightly convex in lateral view. Lancet almost reaches peristome; thin and narrow, rhombic in cross section, only adoral 0.4 mm exposed where it bears ambulacral tract (Pl. 9, fig. 3). Lancet exposed to interior of theca along part of underside of plate; supported by trough on radial and deltoids. Side plates quadrate, slightly convex along admedial edge; adoral edge straight, aborally inclined to axis of ambulacrum as is admedial half of aboral edge; outer part of aboral edge bends adorally, providing space for large triangular outer side plate; both plates form lateral margin of ambulacrum, more so the latter. Heart-shaped brachiolar facet equally developed on side and outer side plate, on outer sloping edge of ambulacrum, very closely spaced with no lateral separation of facets except for small aboral rim to each facet; axis of facet aborally rotated. Facet 0.3 mm long, 0.2 mm wide. Short (0.3 mm) side groove leads into main groove, aboral (but not adoral) edge ornamented by minor lobes and groove; latter also present along main groove (about four per side plate) (Pl. 9, fig. 9). Arcuate ridge on side plate separates ambulacral tract from lateral parts of side plates; extends in a convex inward arc from brachiolar pit to brachiolar pit; aboral edge longer. See Table 10.

Ten hydrospire fields, sited in a prominent, steep-walled ambulacral sinus which is formed by radials and regular or cryptodeltoids (Pl. 10, fig. 1). Hydrospire slits widely exposed, only the innermost being concealed (except for aboral tips) by the ambulacrum, extending full length and width of RD and DR sectors; no apparent ontogenic closure of ad- or aboral ends. When viewed laterally, each hydrospire slit is slightly convex outward. Number of slits reduced in anal interarea, formed by radials and cryptodeltoids, inner slits concealed by ambulacra (except for aboral tips) and slits become evident only in larger specimens where continued growth along the crypto-radial suture has produced a more prominent ambulacral sinus and provided additional space for hydrospire slits. Number of hydrospire slits per mm very constant in regular and anal interareas and between specimens but degree of reduction in anal interarea highly variable, ranging from slight to strong. In a series of 18 specimens in which both regular and anal hydrospires could be counted, No.Reg.Hydro.Sl.: 10-32; W.Reg.Hydro.Fld.: 2.5-8.8 mm. No.Anal Hydro.Sl.: 5-12. Difference ranged from 3 to 20 less in the anal groups, mean difference = 9.1; standard deviation = 4.2. The correlation coefficient between the numbers of hydrospires in both areas = 0.65.

Oral opening pentagonal, width: 0.7-1.0 mm. Width of ambulacral tract on deltoids: 0.3-0.4 mm.

Distribution.– Devonian, La Vid Formation, Colle, Villayandre Province of Leon; Arnao Limestone, Arnao, Fenolleda, Province of Asturias, Spain.

Remarks.– The above description is based upon the specimens in the growth series (Appendix I). The internal anatomy and ontogeny of this species were discussed and illustrated by Breimer and Macurda (1972) and are further summarized in Table 10. Etheridge and Carpenter (1882, 1883) described *Phaenoschisma verneuili* and *nobile* from Colle as two separate, distinct species. However, *P. nobile* is merely a large representative of *P. verneuili* and therefore was synonymized by Breimer and Macurda (1972). The theca of *P. verneuili* is usually incomplete; it is preserved uncrushed only in the small specimens. The basals are often broken or missing completely; no complete large specimen is known. The size range from one locality is also variable. Those from Colle range from about 14 mm in length to over 36 mm; the largest from Arnao is only about 15 mm, most being smaller than this. Here also the thecae are most always crushed but basals are intact. In a specimen of *P. verneuili* from Fenolleda, the two cryptodeltoids are in contact behind the anus for 0.4 mm and the hypodeltoid does not border the anus. This appears to also be true for specimen number 19 from Colle.

P. verneuili is easily distinguished from *P. lycorias* by the more restricted vault of the former and the greater upward slope of the deltoid crest.

Genus HETEROSCHISMA Wachsmuth, 1883

Type species.– *Pentremites subtruncatus* Hall, 1858. *Heteroschisma* Breimer and Macurda, 1972, p. 17.

HETEROSCHISMA ALATUM (Reimann, 1935)

Pl. 10, figs. 3-7,12,13,15,16,21; Table 11

Heteroschisma alatum Breimer and Macurda, 1972, Pl. III, figs. 7-9.

Description.– Theca conical, with relatively short vault (Pl. 10, figs. 5,7). Pelvis conical, with straight to very slightly convex sides except at proximal tip where slight recurvature present due to stem attachment area. Pelvic angle 40-52°. Vault low, broad, convex in small specimens, becoming angular in some larger specimens due to upward growth of aboral part of deltoid crest from its origin; aboral tip varies from -0.2 mm below to +0.5 mm above the oral opening. Outline of theca pentagonal-pentalobate in plan view, with greatest width at ambulacral tips (Pl. 10, figs. 3,4,6). Length greater than width (Table 11); thecae relatively small.

Basalia three, in normal position, form slightly less than one-half of pelvis. Outline in lateral view conical except for slight projection of stem attachment area. Outline in plan view pentagonal, becoming circular medially and rounded triangular at proximal tip. Small BA sector present, forming stem attachment area which is a very shallow circular to ovoid depression on proximal tip of basals (Pl. 10, fig. 12); diameter: 0.8-1.3 mm.

Azygous basal quadrate in plan view, with straight lateral edges (except at proximal tip) and straight to very sinusoidal distal edges; latter meet at a very broad angle. BR sector straight parallel to BR axis, very slightly convex normal to it; adjacent BR sectors merge over very slightly convex surface. BB sector small, narrow, straight parallel to and straight perpendicular to (except proximally) BB axis. BA sector very small, straight parallel to and convex normal to BA axis. BR and BB sectors ornamented by very fine growth lines paralleling growth fronts; ornament not evident in BA sector. Zygous basals broad, pentagonal in plan view, with straight lateral (except proximally) and distal lateral edges and a very slightly concave distal medial edge. BR sectors straight parallel to BR axes; medial sector slightly convex and lateral sectors very slightly convex normal to BR sectors. Sectors merge smoothly with one another and with adjacent BB and RB sectors. BB and BA sectors and ornament as for azygous basal. See Table 11.

Radials five, forming upper half of pelvis; upper tip may extend above oral opening. Radial pentagonal in plan view, with slightly convex lower edge; lateral edges slightly convex, expanding in width up to aboral tip of ambulacrum, then contracting adorally. Upper edges slope in toward one another in ambulacral sinus at a broad angle. Radial sinus short, V-shaped. Radial triangular in lateral view, with shorter upper adoral face being straight to slightly convex, the aboral upper face is also straight to very slightly convex while the lower face is slightly concave. RB sector straight parallel to and slightly convex normal to RB axis; adjacent RB sectors merge over convex surface. RR sector very slightly convex in inner part; it may be slightly reflected outward as growth proceeds, producing a slightly sinusoidal profile. RR sector slightly convex normal to RR axis; RR sector merges smoothly with RB sector over very slightly convex surface. RD sector sharply set off from RR sector, confined to a fairly shallow ambulacral sinus, being straight normal and perpendicular to RD axis. RB sector ornamented by fine growth lines while those of RR sector are coarser (Pl. 10, fig. 21); nearly full length and width of RD sector ornamented by hydrospire slits (Pl. 10, fig. 16). R.Ht.: 0.7-1.8 mm; RWB: 1.5-3.1 mm; RWA: 2.0-3.9 mm; RWD: 1.6-3.5 mm. See also Table 11.

Deltoids four, together with superdeltoid forming border to oral opening (Pl. 10, figs. 15,16). Deltoid rhombic in plan view, very slightly to slightly concave in lateral view because of upward growth of deltoid crest. Adoral edge of deltoid bordering oral opening straight; width expands aborally along straight DDF; width then contracts to minimum exposed width along concave DAF to expand again aborally; DRF straight. Deltoid lip small, ornamented with horseshoe-shaped rim which points adorally. Adoral face of rim bears minor lobes and grooves; aboral surface slopes down to origin of deltoid crest. Latter grew outward and upward (to varying degrees) from its origin. Sides of crest slope down into ambulacral sinuses and ornamented by hydrospire slits; top of crest fairly broad adorally. Del.Gr.Ad.W.: 0.4-0.8 mm; Min.W.: 0.3-0.5 mm; L.Crest: 0.6-1.9 mm; DR: 0.6-1.5 mm. See also Table 11.

Anal deltoids two, a super- and subdeltoid. Configuration and ornament of superdeltoid as for deltoid lip of regular deltoid. Subdeltoid a horseshoe-shaped plate which forms a border to adoral two-thirds of anal opening. Upper surface of subdeltoid flat, adoral edge abuts against nearly vertical aboral surface of superdeltoid. Limbs abut against C and D radials in ambulacral sinuses. Anal opening vertically directed, ovoid-triangular, with adoral and lateral margins formed by the subdeltoid, the aboral edge by the outer parts of the limbs of the C and D radials; growth fronts of the latter clearly reflect the growth as part of the aboral margin of the anal opening and thus its ontogenetic enlargement (Pl. 10, fig. 16). Super.L.: 0.3-0.8 mm; Super.W.: 0.4-0.8 mm; Sub.L.: 0.4-1.4 mm; Sub.W.: 1.0-2.2 mm; Anus L.: 0.4-1.3 mm; Anus W.: 0.7-1.5 mm; O.c.-anus: 0.7-1.3 mm. See also Table 11.

Ambulacra five, sited in a shallow to moderately shallow ambulacral sinus (Pl. 10, figs. 13,15,16). Ambulacra lanceolate in small specimens, becoming slightly more linear in larger specimens, moderately convex in lateral view and rather flat in cross section. Lancet only exposed at adoral end of ambulacrum. Side plates quadrate, with two straight admedial edges which abut against two opposing side plates; adoral and aboral edges straight, tapering to a point abmedially. Outer side plates quadrate, large, inner part wedged in between side plates; inner narrow part bears adoral half of brachiolar facet; width widens ablaterally so outer side plates in contact beyond brachiolar facets; outer edge of outer side plate forms a tooth-shaped projection along border of ambulacrum, imparting a serrate profile (Pl. 10, figs. 13,15,16). Side plates thus do not extend to margin of ambulacrum. Brachiolar facets heart-shaped, on sloping side of main part of ambulacrum, L.: 0.20 mm; W.: 0.18 mm. Main groove and adoral margin of side groove bordered by minor grooves and lobes. See also Table 11.

TABLE 11. Growth relationships of principal variables of *Heteroschisma alatum* (Reimann, 1935)

Variables	n	r	a_0	a_1	Observed y	Range x
L/W	14	0.97	-0.95	1.69	4.8–11.7	3.5– 7.5
V/P	14	0.63	0.75	0.15	1.0– 2.5	3.8–10.0
L/ABBR	14	0.98	0.95	2.55	4.8–11.7	1.5– 4.3
L/RD	14	0.94	0.77	3.48	4.8–11.7	1.2– 3.2
L/RB	14	0.98	1.37	2.05	4.8–11.7	1.7– 5.4
L/Del.L.	14	0.92	-0.63	4.45	4.8–11.7	1.3– 3.0
L/Amb.L.	14	0.95	0.65	2.74	4.8–11.7	1.8– 4.3
L/No.Hyd.Sl.	14	0.92	3.14	1.10	4.8–11.7	3.0– 9.0
RD/Amb.L.	14	0.98	0.06	0.76	1.2– 3.2	1.8– 4.3
Del.L./Amb.L.	14	0.96	0.42	0.57	1.3– 3.0	1.8– 4.3
ABL/ABW	14	0.97	-0.74	1.78	2.3– 5.5	1.7– 3.6
ABBR/ABBRF	14	0.95	-0.64	2.43	1.5– 4.3	1.0– 2.2
ABBB/ABBBF	14	0.81	0.18	0.15	0.4– 1.0	2.0– 5.0
ABBB/ABBR	14	0.79	0.23	0.16	0.4– 1.0	1.5– 4.3
ZBL/ZBW	14	0.96	0.01	1.13	2.2– 5.7	2.0– 5.0
ZBBR/ZBBRF	14	0.90	0.49	2.35	1.8– 5.0	0.7– 2.0
ABBR/RB	14	0.98	0.21	0.79	1.5– 4.3	1.7– 5.4
ABBR/RD	14	0.90	0.09	1.29	1.5– 4.3	1.2– 3.2
ABBR/Del.L.	14	0.90	-0.45	1.66	1.5– 4.3	1.3– 3.0
RD/RDF	14	0.90	0.68	1.75	1.2– 3.2	0.3– 1.4
RR/RRF	14	0.93	0.44	0.28	1.2– 2.5	2.5– 7.0
RB/RBF	14	0.94	-0.99	3.23	1.7– 5.4	0.7– 1.6
RD/RR	14	0.89	0.03	1.21	1.2– 3.2	1.2– 2.5
RD/RB	14	0.90	0.46	0.51	1.2– 3.2	1.7– 5.4
RR/RB	14	0.93	0.49	0.38	1.2– 2.5	1.7– 5.4
RD/Del.L.	14	0.94	-0.27	1.22	1.2– 3.2	1.3– 3.0
RB/Del.L.	14	0.90	-0.76	2.07	1.7– 5.4	1.3– 3.0
Del.L./Gr.Ab.W.	14	0.82	0.48	1.56	1.3– 3.0	0.6– 1.5
Del.L./Anal Del.L.	14	0.73	-0.09	1.17	1.3– 3.0	1.4– 2.5
Amb.L./Amb.W.	14	0.53	0.81	2.51	1.8– 4.3	0.6– 1.2
Amb.L./No.S.P.	14	0.98	-0.38	0.22	1.8– 4.3	9.0–20.0

Eight hydrospire groups; none present in anal interarea. Inner hydrospire slits partly concealed by projecting teeth of outer side plates. 3-9 hydrospires per group; L.Hydro.Fld.: 0.7-2.7 mm; W.Hydro.Fld.: 0.3-1.5 mm.

Oral opening pentagonal, width: 0.4-0.5 mm. Width ambulacral tract on deltoids: 0.2-0.3 mm.

Distribution.– Devonian, Potter Farm Formation, Michigan, U.S.A.

Remarks.– The above description is based upon the specimens in the growth series (Appendix 1). The internal anatomy and ontogeny of this species were discussed by Breimer and Macurda (1972) and are further summarized in Table 11.

The distinguishing characteristics of this species are the development of the outer side plates into a tooth-like projection, the change in growth direction within the RR sector which produces a sinusoidal profile, the stark appearance of the hydrospire fields, and the difference in the coarseness of the growth lines in the RB and RR sectors.

There is a small partial infilling of the ends of the hydrospire slits with growth.

HETEROSCHISMA ALTERNATUM (Lyon, 1857)
Pl. 11, figs. 1-24; Tables 12A, B, C

Heteroschisma alternatum Breimer and Macurda, 1972, Pl. III, figs. 1,2,5,6.

Description.– Theca obconical to obpyramidal, of small to intermediate size; slightly greater maximum in other collections (see below); with a short vault and longer pelvis (Pl. 11, figs. 5,10,11,12-17). Latter usually conical (pelvic angle 40-50°) with straight sides, but may vary to include profiles which are slightly concave in part of the basals or convex in part of the radial bodies and upper basals. Vault usually low, convex, domed; however, occasionally angular and truncate due to upward projection of aboral part of deltoids. Cross section usually pentagonal with straight sides; however, the RR growth axis may turn inward slightly in later growth stages, producing an indented or decagonal profile; also, occasionally slightly convex in interareas (Pl. 11, figs. 1-4,6-9,19). Greatest width at aboral tips of ambulacra. Oral view dominated by hydrospire fields; upper part of RR sectors may be readily visible where they bend inward slightly from the greatest width, or scarcely visible (see Tables 12A-C).

Basalia three, in normal position, conical in lateral view with flat base, forming lower one-third to two-fifths of pelvis. Outline of basals is rounded pentagonal in plan view, becoming rounded trigonal at very base (Pl. 11, fig. 18). Stem attachment area a small (0.6-1.5 mm) flat platform at lowest end of theca, very close to origin of plate. Platform produced largely by growth in BB sector, producing a very short, broad stubby cylinder at lower end of theca, with a rounded trigonal outline. (Very small BA sector present?) Details of stem plates (except that they were circular) or crenullar ring unknown. Small lumen at lower junction of three plates passes into interior.

Azygous basal quadrate, with two short upper edges which meet at a broad angle and two longer straight sides which merge proximally. Lateral profile straight to slightly convex, occasionally concave in lower portion due to stem attachment area. BB sectors set off from BR sectors by being flatter and merging evenly with BB sector on adjoining basal. Junction of flat BB sectors and more convex BR sectors produces prominent convex bump in proximal portion of basals at origin. BB sectors may bend outward proceeding upward from base. BR sector longer than wide, with sector usually being straight (occasionally slightly convex) parallel to BR axis and slightly convex to convex perpendicular to it, adjacent sectors merging on convex surface. Zygous basals pentagonal in plan view, with three straight upper edges (median larger) and two straight longer tapering sides which merge proximally. Lateral profile and BB sectors as for azygous basal. BR sectors flat or slightly convex parallel to BR axis, almost flat (lateral) to convex (median) normal to axis. Very rarely, growth lines are preserved parallel to the basi-radial suture. See Tables 12A-C.

Radials five, forming middle and upper parts of pelvis and extending close to or to upper profile of vault along interradial suture. Radial quadrate in plan view, with an almost straight lower edge (C and E) or two straight lower edges which meet at a broad angle; lateral edges very slightly convex, expanding upward in width to aboral tip of ambulacrum, then contracting slightly adorally. Upper edges extend slightly farther adorally, forming part of radial sinus. Radial sinus short, V-shaped. Radial has a low triangular profile in lateral view, with a very slightly concave lower edge, and two straight upper edges, the adorally directed portion being smaller; aboral part may be very slightly convex. RB sectors long, narrow, usually being straight (occasionally being very slightly convex) parallel to the RB axis and

TABLE 12A. Growth relationships of principal variables of *Heteroschisma alternatum* (Lyon, 1857) (Population 1)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	39	0.98	0.03	1.57	5.0–19.8	3.3–12.6
L/ABBR	39	0.97	-2.88	3.40	5.0–19.8	2.5– 7.0
L/RD	39	0.95	1.41	3.85	5.0–19.8	1.0– 4.1
L/RB	39	0.98	2.52	1.62	5.0–19.8	1.8–10.6
L/Del.L.	39	0.96	1.47	3.56	5.0–19.8	1.0– 5.2
L/Amb.L.	39	0.98	1.71	2.75	5.0–19.8	1.3– 6.5
L/No.Hyd.Sl.	39	0.82	1.23	1.40	5.0–19.8	3.0–12.0
RD/Amb.L.	39	0.97	0.24	0.67	1.0– 4.1	1.3– 6.5
Del.L./Amb.L.	39	0.97	0.19	0.74	1.0– 5.2	1.3– 6.5
RD/RDF	41	0.91	0.70	1.47	1.0– 4.1	0.4– 2.7
RR/RRF	41	0.97	0.27	0.30	1.0– 4.4	2.4–12.5
RB/RBF	41	0.88	-0.61	4.69	1.8–10.6	0.4– 2.7
RD/RR	41	0.95	0.13	1.10	1.0– 4.1	1.0– 4.4
RD/RB	41	0.92	0.51	0.39	1.0– 4.1	1.8–10.6
RR/RB	41	0.96	0.37	0.35	1.0– 4.4	2.4–12.5
RD/Del.L.	41	0.92	0.20	0.87	1.0– 4.1	1.0– 5.2
RB/Del.L.	41	0.96	-0.51	2.14	1.8–10.6	1.0– 5.2
Amb.L./Amb.W.	46	0.84	-0.14	3.61	1.3– 6.5	0.4– 1.7
Amb.L./No.S.P.	46	0.93	0.49	0.18	1.3– 6.5	6.0–33.0

slightly convex normal to it, meeting over a slightly convex surface. Junction of RR and RB sectors marked by a slight trough where growth lines bend from one sector to another (Pl. 11, fig. 24). RR sector straight (usual) to slightly convex to very slightly concave parallel to RR axis, and very slightly convex normal to it. RR and RB sectors usually marked by strong growth lines parallel to suture; these are often stronger in the younger parts of the plate. Small specimens fine or medium ornament. Ornament often stronger in RR sector (Pl. 11, figs. 21,24). RR axis may bend inward in later growth stages to produce indented interradial suture. RD sector forms aboral part of ambulacral sinus which is usually a broad open V in cross section but may have steeper walls. Each RD sector is relatively small, straight parallel and normal to RD axis, bears hydrospire slits for full width of radiodeltoid suture; slits are progressively fitted in aborally as ontogeny proceeds, producing a field which does not occupy full length of ambulacral sinus. No growth ornament in RD sector except for traces of infilled slits. Radiodeltoid suture straight. RD sectors of anal interarea form flat shoulder to ambulacrum and slope upward to anus and lack hydrospire slits (Pl. 11, fig. 23). R.Ht.: 0.5-2.5 mm; RWB: 1.2-3.2 mm; RWA: 1.7-6.3 mm; RWD: 1.5-5.4 mm. See also Tables 12A-C.

Deltoids four, together with superdeltoid forming borders of peristome (Pl. 11, figs. 20,22). Deltoid approximately hexagonal in plan view with short straight edge bordering oral opening and two short, aborally

TABLE 12B. Growth relationships of principal variables of *Heteroschisma alternatum* (Lyon, 1857) (Population 2)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	18	0.99	-0.18	1.56	4.5–16.8	3.2–10.8
V/P	18	0.74	0.52	0.16	0.9– 3.5	3.7–13.3
L/ABBR	18	0.96	0.14	2.94	4.5–16.8	1.5– 5.6
L/RD	18	0.97	1.68	3.68	4.5–16.8	1.0– 4.0
L/RB	18	0.99	1.57	1.68	4.5–16.8	2.0– 9.0
L/Del.L.	18	0.96	-0.01	3.67	4.5–16.8	1.3– 4.4
L/Amb.L.	18	0.98	0.47	2.83	4.5–16.8	1.4– 5.6
L/No.Hyd.Sl.	18	0.87	1.99	1.34	4.5–16.8	3.0–11.0
RD/Amb.L.	24	0.96	-0.16	0.73	1.0– 4.0	1.4– 5.6
Del.L./Amb.L.	24	0.98	0.31	0.72	1.3– 4.4	1.4– 5.6
ABL/ABW	18	0.98	-0.61	1.60	1.6– 5.8	1.5– 4.1
ABBR/ABBRF	18	0.93	-0.65	2.42	1.5– 5.6	1.0– 2.5
ZBL/ZBW	18	0.98	0.07	1.08	1.7– 5.5	1.8– 5.0
ZBBR/ZBBRF	18	0.74	0.83	2.18	1.6– 5.5	0.8– 2.0
ABBR/RB	18	0.94	0.80	0.52	1.5– 5.6	2.0– 9.0
ABBR/RD	18	0.93	0.77	1.16	1.5– 5.6	1.0– 4.0
ABBR/Del.L.	18	0.91	0.29	1.14	1.5– 5.6	1.3– 4.4
RD/RDF	31	0.89	0.30	1.80	1.0– 4.0	0.5– 2.0
RR/RRF	31	0.94	0.34	0.29	1.1– 3.8	2.5–11.2
RB/RBF	31	0.86	0.18	4.57	2.0– 9.0	0.6– 1.8
RD/RR	31	0.94	0.00	1.09	1.0– 4.0	1.1– 3.8
RD/RB	31	0.93	0.18	0.42	1.0– 4.0	2.0– 9.0
RR/RB	31	0.94	0.34	0.36	1.1– 3.8	2.0– 9.0
RD/Del.L.	24	0.94	-0.32	0.96	1.0– 4.0	1.3– 4.4
RB/Del.L.	24	0.96	-0.87	2.17	2.0– 9.0	1.3– 4.4
Del.L./Gr.Ab.W.	24	0.94	0.26	1.80	1.3– 4.4	0.6– 2.5
Del.L./Anal Del.L.	24	0.92	-0.65	1.64	1.3– 4.4	1.5– 3.1
Amb.L./Amb.W.	27	0.85	-0.07	3.32	1.4– 5.6	0.5– 1.6
Amb.L./No.S.P.	27	0.99	-0.37	0.26	1.4– 5.6	7.0–12.0

diverging DD sutures, all of which bear minor lobes and grooves (Pl. 11, fig. 22). Deltoid width constricts slightly to a point near the origin of the deltoid crest, then diverges to maximum width along a concave DAF.

TABLE 12C. Growth relationships of principal variables of *Heteroschisma alternatum* (Lyon, 1857) (Population 3)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	24	0.98	-0.76	1.64	6.2–17.8	3.8–10.7
L/ABBR	24	0.94	2.03	2.26	6.2–17.8	2.1– 7.6
L/RD	24	0.97	-0.10	4.25	6.2–17.8	1.5– 3.8
L/RB	24	0.97	1.48	1.79	6.2–17.8	2.8– 8.2
L/Del.L.	24	0.95	-0.29	3.29	6.2–17.8	1.7– 4.4
L/Amb.L.	24	0.96	1.12	2.76	6.2–17.8	1.9– 5.5
L/No.Hyd.Sl.	24	0.94	0.77	1.30	6.2–17.8	4.0–13.0
RD/Amb.L.	24	0.98	0.32	0.64	1.5– 3.8	1.9– 5.5
Del.L./Amb.L.	24	0.97	0.47	0.70	1.7– 4.4	1.9– 5.5
ABBR/RB	24	0.85	0.40	0.66	2.1– 7.6	2.8– 8.2
ABBR/RD	24	0.89	-0.33	1.62	2.1– 7.6	1.5– 3.8
ABBR/Del.L.	24	0.92	-0.62	1.53	2.1– 7.6	1.7– 4.4
RD/RDF	24	0.93	0.70	1.52	1.5– 3.8	0.5– 2.3
RR/RRF	24	0.92	0.43	0.28	1.3– 3.5	3.3–10.3
RB/RBF	24	0.88	0.28	4.03	2.8– 8.2	0.7– 2.1
RD/RR	24	0.96	0.12	1.08	1.5– 3.8	1.3– 3.5
RD/RB	24	0.95	0.47	0.40	1.5– 3.8	2.8– 8.2
RR/RB	24	0.92	0.43	0.35	1.3– 3.5	2.8– 8.2
RD/Del.L.	24	0.95	0.04	0.86	1.5– 3.8	1.7– 4.4
RB/Del.L.	24	0.91	-0.58	1.96	2.8– 8.2	1.7– 4.4
Amb.L./Amb.W.	23	0.73	-1.16	4.14	1.9– 5.5	0.8– 1.5
Amb.L./No.S.P.	23	0.93	0.07	0.18	1.9– 5.5	9.0–28.0

Width tapers aborally along two straight DRF which meet in a narrow V toward or very near outline of theca in cross section. In lateral view part of deltoid adjacent to oral opening is usually the highest portion and the deltoid crest slopes slightly downward from it in a straight profile; this may be slightly concave; in addition the aboral tip of the crest may be elevated slightly above the adoral portion. The crest may extend outward in a flat plane. Ornament of deltoid lip is a broad, massive, V-shaped elevation; deltoid crest begins aboral to it at greatest constriction of deltoid between adjacent ambulacra. Deltoid crest appears as a long narrow V between the adjacent hydrospire fields. Its length increases through aboral deltoid growth, its width through progressive infilling of adoral ends of hydrospire slits. Crest is usually angular in small specimens and originates below deltoid lip; with growth, this is converted to a smoother merger between crest and the deltoid lip; the crest also assumes a smooth, broad profile. The sides of the crest slope into the adjacent ambulacral sinuses and the sides are incised by hydrospire slits. The slope is usually gentle but may be steeper. Del.Gr.Ad.W.:

0.5-1.5 mm; Min.W.: 0.4-1.1 mm; L.Crest: 0.7-3.0 mm. See also Tables 12A-C.

Anal deltoids two, a super- and subdeltoid (Pl. 11, fig. 22). Superdeltoid a small hexagonal-shaped plate which corresponds to the deltoid lip of a regular deltoid. Subdeltoid an open U-shaped collar which forms adoral and most of lateral sides of anal opening. Aboral side of superdeltoid drops down to super- subdeltoid suture which is a straight line near maximum convergence of C and D ambulacra (Pl. 11, fig. 22). Subdeltoid is abutted laterally by lancets and aborally by part of limbs of radials. Limbs form smooth platforms which slope gradually downward from anal opening; rim on adoral edge of anal opening. Subdeltoid is a narrow (0.1-0.2 mm) plate; length and width increase throughout growth. Plate set in plane of anal opening which is in a flat space below level of oral opening. Anal opening angular ovoid, with adoral portion having a greater length and sharper curve; anal opening increases in size with growth. Anal opening bordered aborally by C and D radials; no hypodeltoid; apparently atrophied. Super.L.: 0.4-1.2 mm; Super.W.: 0.5-1.3 mm; Sub.L.: 0.4-1.4 mm; Sub.W.: 0.8-1.8 mm; Anus L.: 0.4-1.2 mm; Anus W.: 0.5-1.4 mm; O.c.-super-subdeltoid: 0.5-1.6 mm; O.c.-anus: 0.7-2.0 mm. See also Tables 12A-C.

Ambulacra five, in radial sinus (usually shallow), with shape either linear or lanceolate, tending to be somewhat petaloid in smaller specimens (Pl. 11, figs. 19,20,23). Ambulacrum relatively flat in lateral view in small specimens, becoming more convex with growth. When viewed parallel to length, in an inclined view of the theca, part of the ambulacrum may either be even with or above or below the aboral tip of the deltoid. Lancet underlies entire ambulacrum and conforms to its shape, extends to near aboral end of radial sinus, originates near oral opening, and is concealed except for a small rhomb-shaped portion at the adoralmost end. (0.5 mm in large specimen, half this in small, so apparently increases during growth.) Part of center of lancet exposed to interior of theca; adoralmost part underlain by two deltoids (or superdeltoid); bordered laterally and partially beneath by deltoids (or subdeltoid) and then radials; aboral half underlain entirely by radial. Side and outer side plates overlie and conceal lancet; latter prominently developed. Side plates are arrayed along centerline of ambulacrum; shape is quadrate. Straight edge along centerline, two aborally inclined ad- and aboral edges; aboral edge bends so that it is perpendicular to admedial edge and intersects adoral edge ablaterally in a point. Outer side plate pentagonal, has a V-shaped inner edge that fits into gap formed by bend in edge of side plate, straight ad- and aboral edges which project to edge of ambulacrum, and a straight, steep outer edge which drops down to level of thecal plate adjoining ambulacrum. Brachiolar facet is a small heart-shaped area (0.2 mm by 0.2 mm), aboral part of which is developed on ablateral point of side plate, adoral part of which is developed on part of aboral side of inner point of outer side plate. Brachiolar facet inclined to upper surface of ambulacrum. Side groove follows suture between side plates. At aboral tip of ambulacrum, aboralmost side plate extends to edge of ambulacrum. However, ablateral growth of outer side plate closes it off; continued growth forms a rounded ridge ablateral to the brachiolar facet; width of ridge increases throughout the ontogeny of the animal; upper surface of each plate occasionally developed into spikes. The width of the area occupied by the side plates (0.4-0.7 mm; most all are 0.5 or 0.6 mm) is apparently constant as is the number per mm throughout growth. Thus after their initial formation, side plates cease to grow and the position of a brachiolar facet is constant with respect to the side and main grooves. The outer portion of the outer side plate continues to grow producing a wider ambulacrum (ambulacral width 0.5-0.6 mm in smallest specimens, 1.5-1.6 mm in largest). In S5414 and number 19 in growth series I, traces of minor lobes and grooves can be seen along main and adoral part of side groove, but not aboral part of latter. Main groove underlain by side plates except at adoralmost end of ambulacrum. Brachioles unknown. See Tables 12A-C.

Eight exposed hydrospire groups, lacking in anal interarea. Each hydrospire group has a triangular appearance, the longest slit being adjacent to the ambulacrum, the shortest farthest away (Pl. 11, fig. 23). Hydrospire groups in part of ambulacral sinus, which is usually open but may have moderately steep sides. Each slit develops initially as small equal invagination on the radial and deltoid across their respective suture. With growth, the major portion of the slit is borne by the radial. Ends of slits progressively infilled during growth. Number of slits increases ontogenetically from three in small specimens to eleven in a large specimen. Innermost slits beneath overhanging edge of ambulacrum. No. Hydro.Sl.: 3-11; L.Hydro.Fld.: 0.6-2.0 mm; W.Hydro. Fld.: 0.4-2.1 mm.

Oral opening pentagonal, width 0.3-1.0 mm. Width of ambulacral tract on deltoids: 0.2-0.4 mm.

One mutation seen; development of extra ambulacrum and abbreviated radial in number 2 of growth series.

Distribution.– Devonian, Jeffersonville Limestone, Kentucky and Indiana; Columbus Limestone, Ohio; and Onondaga Limestone, New York, U.S.A.

Remarks.– The description of this species is based upon the specimens in growth series II. Data within the description are from growth series II. The internal anatomy and ontogeny were discussed and illustrated by Breimer and Macurda (1972) and are further summarized in Table 12A.

The earliest known species of *Heteroschisma* are those found in the Jeffersonville Limestone at or near Louisville, Kentucky. The most thorough study of these species was by Cline and Heuer (1950). They recognized three species from the Jeffersonville Limestone: *Heteroschisma alternatus* (Lyon, 1857), *H. americanus* (Shumard, 1858), and *H. pyramidatus* (Shumard, 1858); a variety of *H. pyramidatus* was raised to specific rank (*H. robustus* Cline and Heuer, 1950). (Cline and Heuer discussed these species as part of the genus *Codaster*; in the following discussion I am using the generic name *Heteroschisma* to which they are now assigned to avoid any confusion with the genus *Codaster sensu stricto*.) The latter species, *H. robustus*, was supposed to occur only in the Beechwood Limestone, which is separated from the underlying Jeffersonville by an unconformity and the Silver Creek Limestone of the North Vernon Formation. Cline and Heuer's revision was based almost entirely on museum collections as exposures available to Cline in 1948 had been collected out (see 1950, p. 155). The stratigraphic horizon of some specimens could be accurately placed with the Jeffersonville from their labels but the information for most was minimal, few having anything more than "Onondaga, Falls of the Ohio, Louisville, Kentucky." The large bulk of the specimens which they studied were originally classified as *Heteroschisma alternatus* or *H. pyramidatus*, and species assignments to the four species they recognized had to be made without benefit of a comparative population from a single locality or precise stratigraphic or locality information.

Cline and Heuer (1950, fig. 1) gave a size range (based upon width) and frequency distribution for the well-preserved specimens they studied. Almost all of these are in the Springer collection, U.S. National Museum and the following discussion pertains to these. They graphed 14 specimens of *H. americanus*, most all of which are small (width 4-6 mm), 26 specimens of *H. alternatus*, the large majority of which are also small specimens, and 13 specimens of *H. robustus*, none of which are smaller than 7 mm in width, most being between 8 and 10 mm. Their curve for *H. pyramidatus* includes specimens from Columbus, Ohio; with these removed, there are only nine reasonably well-preserved specimens from the Jeffersonville Limestone which were recognized as *H. pyramidatus* from the 120 (approximate) *Heteroschisma* in the U.S. National Museum collections from this horizon, only two of which are small. In their study of the collection, Cline and Heuer tended to recognize small specimens (width less than 6 mm) as *H. alternatus* or *H. americanus* and large specimens (width greater than 7 mm) as *H. pyramidatus* or *H. robustus* (and no juvenile specimens of the latter).

The holotype of *H. robustus* came from the old Clark County Cement Quarry, Clark County, Indiana (Rowley, 1902, p. 94). Cline and Heuer (1950, p. 170) quote a handwritten label with the specimen as giving the age as Hamilton and attempted to further pinpoint the locality and horizon. They concluded the specimen was probably from the Beechwood. Cline and Heuer (1950) raised Rowley's *Codaster attenuatus* var. *robustus* to species status; most of the material they assigned to this species and illustrated was originally cataloged as USNM S3202 and labeled "upper Helderberg" at the Falls of the Ohio, Louisville, Kentucky. Cline and Heuer felt that old collections from the Louisville area frequently included material from two different stratigraphic horizons: Onondagan and Hamilton. Since they believed Rowley's holotype to be Hamilton (Beechwood) in age, any specimens they identified as *Heteroschisma robustus* were taken to be of Hamilton age and therefore admixed with Onondagan collections. Such a procedure depended upon their concept of *H. robustus*. They regarded *H. robustus* and *H. pyramidatus* as gradational species but from different formations. In speciating the collections in the U.S. National Museum, they assigned 14 specimens to *H. robustus*, nine to *H. pyramidatus*, but labeled six as being intermediate between the two species.

The above discussion illustrates the problems of speciating specimens of *Heteroschisma* from the Louisville, Kentucky region. Due to a roadbuilding program in the Louisville area, a new exposure of the Jeffersonville Limestone afforded the opportunity to collect a sizable population of *Heteroschisma* (over 40 individuals) from a restricted horizon (three-foot interval in the *Paraspirifer acuminatus* zone (see Perkins, 1963) in the

Jeffersonville Limestone (UMMP locality 1968/D-8). This population has been used to provide a comparative control on the museum specimens of *Heteroschisma* of the Louisville region. Extensive comparison of the numerical data and presence and absence data from these two populations shows all of the characters used to differentiate the four species by Cline and Heuer (1950) are present and gradational in the single population (Table 12B). Therefore all four were synonymized by Breimer and Macurda (1972). Data from UMMP 1968/D-8, the museum specimens, and specimens from Columbus, Ohio are given in Tables 12B, 12A, and 12C respectively.

The distinguishing characteristics of this species are the downward slope of the deltoid crest and the development of coarse growth lines in the RR sector of the radial.

HETEROSCHISMA CANADENSE (Billings, 1869)
Pl. 12, figs. 1-7,13; Table 13

Heteroschisma canadense Breimer and Macurda, 1972, Pl. III, figs. 3,4.

Description.– Theca conical, with relatively short vault (Pl. 12, figs. 2,4,5). Pelvis conical, with straight to very slightly convex sides except at proximal tip where slight recurvature present due to stem attachment area. Pelvic angle 30-44°. Vault low, broad, usually convex but sometimes angular because of upward growth of aboral part of deltoid crest. Aboral tip of deltoid crest varies from -1.0 mm below peristome to 0.5 mm above. (Of twenty specimens, 18 have negative values of which 17 are from -0.2 to -0.4 mm.) Outline of theca pentagonal in plan view, with interambulacral areas sometimes projecting farther outward, making the interambulacral profile very slightly convex (Pl. 12, figs. 1,3). Most thecae relatively small, length greater than width (Table 13).

Basalia three, in normal position, forming lower one-half of pelvis. Outline in lateral view conical except for slight recurvature at stem attachment area. Outline in plan view circular-pentagonal distally, becoming circular medially and rounded-triangular proximally. Small BA sector present, forming stem attachment area (Pl. 12, fig. 13). ABBA: 0.1-0.7 mm; ABBAF: 0.3-1.0 mm. Stem cicatrix a shallow ovoid depression on lowermost surface of basals; diameter 0.3-1.2 mm. Lumen pierces junction of basals on proximal surface.

Azygous basal quadrate in plan view with straight to very slightly convex lateral edges (except at proximal tip), and straight distal edges which meet at a very broad angle. BR sector straight parallel to BR axis and slightly convex normal to it; adjacent sectors meet over flatter surface. BB sector small, not extending as far as basal-radial suture, straight parallel to and straight distally, concave proximally normal to BB axis. BA sector slightly convex parallel to, strongly convex normal to BA axis. BR and BB sectors ornamented by very fine growth lines which parallel growth fronts; BA sector smooth. Zygous basals pentagonal, with straight lateral edges (except distally), straight distal lateral edges, and a straight to very slightly concave distal medial edge. BR sectors straight parallel to BR axis, medial sector convex and lateral sectors flat normal to BR axis. Sectors merge smoothly with one another and adjacent RB sectors. BB and BA sectors and ornament as for azygous basal. See Table 13.

Radials five, forming upper half of pelvis. Radial pentagonal in plan view, with very slightly convex (or two straight) lower edge(s); lateral edges slightly convex, expanding in width to aboral tip of ambulacrum, then contracting adorally; adoral edges slope into broad ambulacral sinus at nearly 180° to one another. Radial sinus short, V-shaped. Radial triangular in lateral view with adoral facing upper edge being shortest, straight to slightly convex; aboral facing upper edge straight; aboral edge slightly concave. RB sector straight parallel to RB axis, very slightly convex normal to it. Adjacent RB sectors merge over convex surface; merge smoothly with RR sectors over flat surface. RR sector straight to very slightly convex parallel to RR axis, slightly convex normal to it. RD sector sharply set off from RR sector, being confined to an ambulacral sinus. RD sector very slightly convex parallel to, straight normal to RD axis. RB and RR sectors ornamented by fine growth lines which parallel growth fronts (Pl. 12, fig. 7); RD sectors fully ornamented by hydrospire slits. R.Ht.: 0.3-1.5 mm; RWB: 0.8-3.1 mm; RWA: 1.0-4.5 mm; RWD: 0.9-4.0 mm. See also Table 13.

Deltoids four, together with superdeltoid forming border to oral opening (Pl. 12, fig. 6). Deltoids rhombic in plan view, slightly concave in lateral view due to origin of deltoid crest below deltoid lip. Adoral edge of deltoid bordering oral opening straight; width expands aborally along straight DDF, then contracts along concave DAF to minimum exposed width of deltoid which is at origin of deltoid crest; width expands again aborally; DRF straight. Deltoid lip small, ornamented by horseshoe-shaped rim which points adorally. Highest

TABLE 13. Growth relationships of principal variables of *Heteroschisma canadense* (Billings, 1869)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	19	0.98	-0.42	1.77	3.0–14.5	2.0– 7.7
V/P	19	0.86	-0.17	0.23	0.5– 3.2	2.5–11.3
L/ABBR	19	0.99	-0.24	2.90	3.0–14.5	1.0– 5.0
L/RD	19	0.98	0.92	4.55	3.0–14.5	0.5– 3.1
L/RB	19	0.99	0.68	2.21	3.0–14.5	1.1– 6.2
L/Del.L.	19	0.95	0.40	3.98	3.0–14.5	0.8– 3.2
L/Amb.L.	19	0.97	1.64	2.83	3.0–14.5	0.6– 4.3
L/No.Hyd.Sl.	20	0.94	1.34	1.24	3.0–14.5	2.0–10.0
RD/Amb.L.	19	0.96	0.19	0.61	0.5– 3.1	0.6– 4.3
Del.L./Amb.L.	19	0.99	0.35	0.69	0.8– 3.2	0.6– 4.3
ABL/ABW	19	0.96	-0.22	1.85	1.5– 5.8	1.0– 3.0
ABBR/ABBRF	19	0.91	-0.32	2.64	1.0– 5.0	0.5– 1.8
ABBB/ABBBF	19	0.79	0.01	0.15	0.2– 1.0	1.4– 5.5
ABBB/ABBR	19	0.76	0.05	0.16	0.2– 1.0	1.0– 5.0
ZBL/ZBW	19	0.96	-0.15	1.31	1.5– 5.9	1.2– 4.0
ZBBR/ZBBRF	19	0.95	-0.01	3.03	1.1– 5.3	0.3– 1.6
ABBR/RB	19	0.99	0.34	0.75	1.0– 5.0	1.1– 6.2
ABBR/RD	19	0.97	0.44	1.53	1.0– 5.0	0.5– 3.1
ABBR/Del.L.	19	0.92	0.33	1.31	1.0– 5.0	0.8– 3.2
RD/RDF	20	0.93	0.37	1.47	0.5– 3.1	0.2– 1.7
RR/RRF	20	0.98	0.21	0.31	0.4– 2.6	1.3– 8.1
RB/RBF	20	0.97	-0.35	3.80	1.1– 6.2	0.4– 1.7
RD/RR	20	0.97	-0.13	1.11	0.5– 3.1	0.4– 2.6
RD/RB	20	0.98	0.03	0.46	0.5– 3.1	1.1– 6.2
RR/RB	20	0.99	0.17	0.40	0.4– 2.6	1.1– 6.2
RD/Del.L.	20	0.96	-0.10	0.87	0.5– 3.1	0.8– 3.2
RB/Del.L.	20	0.95	-0.17	1.84	1.1– 6.2	0.8– 3.2
Del.L./Gr.Ab.W.	20	0.96	0.11	1.78	0.8– 3.2	0.3– 1.9
Del.L./Anal Del.L.	20	0.96	-0.14	1.08	0.8– 3.2	0.8– 3.5
Amb.L./Amb.W.	20	0.80	-1.39	5.96	0.6– 4.3	0.4– 0.8
Amb.L./No.S.P.	20	0.98	-0.40	0.23	0.6– 4.3	4.0–21.0

point of rim at adoral center. Adoral face of rim bears minor grooves and lobes. Aboral surface slopes into shallow concave depression; deltoid crest originates aboral to depression. Deltoid crest usually slopes downward from its origin but may slope slightly upward. Sides of deltoid crest slope down into broad ambulacral sinuses; sides fully ornamented by hydrospire slits. Deltoid crest wider adorally than aborally. Del.Gr.Ad.W.: 0.3-0.9 mm; Min.W.: 0.2-0.7 mm; L.Crest: 0.5-2.2 mm; DR: 0.2-1.6 mm. See also Table 13.

Anal deltoids two, a super- and subdeltoid. Configuration and ornament of superdeltoid as for deltoid lip of regular deltoid. Subdeltoid a horseshoe-shaped plate which forms border to adoral half of anal opening. Upper surface of subdeltoid flat, adoral edge abuts against sloping aboral edge of superdeltoid. Limbs abut against C and D radials in ambulacral sinus. Anal opening vertically directed, ovoid-quadrate, with adoral half being bordered by subdeltoid and aboral half bordered by modified outer limbs of C and D radials. Super.L.: 0.3-1.0 mm; Super.W.: 0.3-1.0 mm; Sub.L.: 0.2-1.5 mm; Sub.W.: 0.4-2.2 mm; Anus L.: 0.2-1.2 mm; Anus W.: 0.4-1.5 mm; O.c.-anus: 0.4-1.5 mm.

Ambulacra five, sited in a shallow ambulacral sinus. Ambulacra slightly petaloid in small specimens in plan view, becoming linear in larger specimens, convex in lateral view, and rather flat in cross section. Lancet exposed only at adoral end of ambulacrum (see Breimer and Macurda, 1972, p. 84). Side plate pentagonal, with two straight inner edges which abut against opposing side plates. Adoral edge straight as is aboral edge. Side plate embayed on adoral lateral margin by large triangular side plate which produces fifth straight edge. Large triangular outer side plates in contact beyond edge of brachiolar facet; side plate does not extend to margin of ambulacrum. Rim on upper outer surface of side plate forms an external border to the brachiolar facet (Pl. 12, fig. 6). Adoral half of brachiolar facet sited on the corner edge of the outer side plate and the aboral half on the outer edge of the side plate. Brachiolar facet heart-shaped. L.: 0.18 mm; W.: 0.15 mm.

Eight hydrospire groups, none present in the anal interarea. Almost complete length and width of hydrospire field exposed. 2-10 hydrospires per group; L. hydro.Fld.: 0.3-2.0 mm; W.Hydro.Fld.: 0.2-1.6 mm.

Oral opening pentagonal, width: 0.2-0.7 mm. Width ambulacral tract on deltoids: 0.2-0.3 mm.

Distribution.— Devonian, Hungry Hollow Formation, Ontario, Canada. This species has recently been found in the Ludlowville Formation in New York by G. McIntosh and C. Brett. (*Stictopora* bed of the Wanakah Shale Member, NW corner of the Olivieri quarry of the Penn-Dixie cement Company, just north of the intersection of Bay View and Big Tree Roads, Bay View, New York.) This is a geographic extension at a younger time horizon. Thirteen specimens, most very well preserved and varying in size from 4.0 to 14.7 mm in length, have been deposited in Buffalo Museum of Science (BBNS E23956).

Remarks.— The above description is based upon the specimens in the growth series (Appendix 1). The internal anatomy and ontogeny of this species were discussed and illustrated by Breimer and Macurda (1972) and are further discussed in Table 13. The distinguishing characters of this species are the fine growth lines in both the RB and RR sectors, the less pronounced upward growth of the deltoid crest, resulting in a broader, less pronounced ambulacral sinus and a more gradual transition between deltoid lip and crest, and the occurrence of the aboral tip of the deltoid crest below the oral opening.

Stereomic microstructure is preserved in some specimens.

HETEROSCHISMA SUBTRUNCATUS (Hall, 1858)
Pl. 10, figs. 9,18-20; Pl. 12, figs. 8,9; Tables 14A,B

Pentremites subtruncatus Hall, 1858.
Heteroschisma gracile Wachsmuth, 1883, p. 354.
Heteroschisma gracile Breimer and Macurda, 1972, Pl. III, figs. 10,11.
Heteroschisma subtruncatum Breimer and Macurda, 1972, Pl. III, figs. 15,20.

Description.— Theca obpyramidal, of small to intermediate size with a short vault and long pelvis. Pelvic profile conical, with slightly concave area near proximal end of basals; vault angular, truncate, with outer edges sloping up sharply, and median portion angling down into peristome; center flat to slightly convex between deltoid crests (Pl. 10, fig. 19; Pl. 12, fig. 9). Vault profile developed throughout observed size range, becoming more pronounced with growth. Greatest width is at aboral tip of ambulacra; cross section this plane pentagonal (Pl. 10, figs. 9,18; Pl. 12, fig. 8). Interambulacral areas may be very slightly convex. Upper part of RR sectors always bend inward above maximum width and are always readily visible in oral view; radial limbs combine with elevated deltoid crest to form four elevated triangular pyramids above the peristome; lacking in anal interarea. Pelvic angle 40-50°.

Basalia three, in normal position, lateral profile conical, with slight concave bend near stem attachment area, forming lower half of pelvis (slightly more in smallest specimens, slightly less in largest). In plan view outline of basals is rounded-pentagonal distally; cross section is rounded distally, becoming rounded-triangular proximally. Stem attachment area a very short, stout, rounded-triangular platform which merges with the main part of the basals, extending farther distally along interbasal suture than along centerline of plate; apparently formed by growth on BB and BA(?) axes. Origin of basals very near proximal end. BB sectors merge smoothly with BR sectors; BB sectors slightly convex parallel to BB axis; they bend normal to axis in plane passing through origin of basals and then fade out distally along interbasal suture. Stem facet on lowest surface of basals, rounded; crenellae at outer edge (?). Lumen pierces center of facet where three basals meet. Diam.base: 0.7-1.4(va) mm.

Azygous basal quadrate in plan view, with two straight to very slightly concave upper edges which meet at a broad angle, and two long straight parallel sides which converge at base of theca. Straight in lateral view except for slight bend near proximal end. BR sector straight, may be very slightly concave, more so in proximal section, parallel to BR axis; very slightly convex normal to BR axis; adjacent sectors merge smoothly with each other over gently convex surface and with RB sectors. Zygous basals pentagonal in plan view with two straight or very slightly concave upper lateral edges, a larger slightly concave upper median edge, and two longer straight lateral sides which converge proximally and may bend slightly near proximal end. BR sectors as for azygous basal parallel to BR axes; median BR sector slightly convex whereas lateral sectors are nearly flat normal to BR axes; adjacent sectors merge smoothly. Fine, closely spaced growth lines ornament the basals parallel to the basi-radial sutures. See Tables 14A, B.

Radials five, quadrate in plan view, with a single slightly convex lower edge (or two straight to very slightly convex edges meeting at a broad angle); lateral sides long, very slightly convex and bending gradually inward above aboral tip of ambulacrum; tips of radial limbs always project above peristome. Prominent V in upper edge of plate for radial sinus. In lateral view radial is triangular, with a slightly convex lower edge, a straight upper adoral facing edge, and a straight to very gently concave longer, lower lateral edge. RB sectors are long, narrow, straight to very gently convex parallel to RB axis, almost flat normal to it, and merge smoothly over a convex boundary; also merge smoothly with RR sector. Latter are triangular, long, straight to very slightly convex parallel to RR axis and slightly convex normal to it. RB and RR sectors are ornamented with fine growth lines which parallel sutures. RD sector small, at a pronounced angle to RR sector, forming part of steeply inward dipping ambulacral sinus. RD sector is straight parallel and normal to RD axis; radiodeltoid suture is gently concave aborally. Hydrospire slits occupy full width of suture; progressively infilled aborally. RD sector in anal interarea is a small, narrow, flat or slightly inward sloping border to ambulacrum; may not be well developed near aboral end of ambulacrum; lacking hydrospire slits (Pl. 10, fig. 20). R.Ht.: 0.7-2.0 mm; RWB: 1.5-3.7 mm; RWA: 2.2-5.4 mm; RWD: 1.9-3.8 mm. See also Table 14A, B.

Deltoids four, together with superdeltoid forming border to peristome (Pl. 10, fig. 20). Overall shape hexagonal. Short straight edge borders oral opening; width then expands aborally along short, straight DDF. These and adoralmost edge bear minor lobes and grooves. Width contracts slightly, then expands aborally along concave DAF which slants downward. Width then contracts along two slightly convex DR sutures which rise topographically to apex of pyramid above oral opening. In lateral view deltoid is concave, with deltoid lip being slightly elevated above oral opening; then crest begins below level of adoral edge and curves upward into straight profile of main part of crest. Deltoid lip triangular-shaped elevation; sinks slightly aborally to merge through broad swell with beginning of crest which is sharp throughout its length (Pl. 10, fig. 20). Sides of crest slope downward into ambulacral sinuses and bear hydrospire slits for full width of DR suture. Tip of crest is higher in larger specimens than small. Del.Gr.Ad.W.: 0.4-0.9 mm; Del.Min.W.: 0.3-0.7 mm; L.Crest: 0.8-2.1 mm; DR: 0.6-1.7 mm; Ht.Crest above oral opening: -0.1 mm to +1.0 mm (only one negative value). See Table 14A, B.

Anal deltoids two, a super- and subdeltoid. Superdeltoid a hexagonal plate, outline as for deltoid lip of regular deltoid, except slightly larger in size (Pl. 10, fig. 20). Aboral side of superdeltoid drops down aboral to constriction between C and D ambulacra to nearly straight super- subdeltoid suture. Subdeltoid a thin open U-shaped collar plate, expanding in width aborally

TABLE 14A. Growth relationships of principal variables of *Heteroschisma subtruncatum* (Hall, 1858)

Variables	n	r	a_o	a_1	Observed Range y	x
L/W	14	0.99	-0.60	1.73	6.2–16.7	4.2– 9.8
V/P	14	0.95	0.45	0.16	1.2– 2.9	5.0–13.8
L/ABBR	14	0.98	1.40	2.34	6.2–16.7	2.5– 6.7
L/RD	14	0.98	1.34	3.57	6.2–16.7	1.5– 4.4
L/RB	14	0.98	1.03	2.18	6.2–16.7	2.5– 7.2
L/Del.L.	14	0.94	-0.60	5.14	6.2–16.7	1.5– 3.2
L/Amb.L.	14	0.98	0.45	2.98	6.2–16.7	2.0– 5.5
L/No.Hyd.Sl.	14	0.96	2.09	1.38	6.2–16.7	3.0–10.0
RD/Amb.L.	14	0.98	-0.19	0.82	1.5– 4.4	2.0– 5.5
Del.L./Amb.L.	14	0.92	0.46	0.51	1.5– 3.2	2.0– 5.5
ABL/ABW	13	0.97	-0.40	1.86	3.0– 8.1	2.0– 4.6
ABBR/ABBRF	13	0.96	-0.81	2.88	2.5– 6.7	1.2– 2.5
ABBB/ABBBF	13	0.88	0.19	0.13	0.5– 1.2	2.9– 7.3
ABBB/ABBR	13	0.86	0.25	0.13	0.5– 1.2	2.5– 6.7
ZBL/ZBW	13	0.98	-0.06	1.26	3.0– 7.5	2.5– 6.3
ZBBR/ZBBRF	13	0.91	0.10	2.95	2.5– 7.0	0.8– 2.4
ABBR/RB	14	0.97	-0.04	0.91	2.5– 6.7	2.5– 7.2
ABBR/RD	14	0.96	0.13	1.47	2.5– 6.7	1.5– 4.4
ABBR/Del.L.	14	0.91	-0.61	2.10	2.5– 6.7	1.5– 3.2
RD/RDF	14	0.96	0.34	1.88	1.5– 4.4	0.5– 2.0
RR/RRF	14	0.99	0.15	0.29	1.3– 3.2	3.6–10.1
RB/RBF	14	0.96	0.24	3.02	2.5– 7.2	0.8– 2.2
RD/RR	14	0.97	-0.20	1.41	1.5– 4.4	1.3– 3.2
RD/RB	14	0.93	0.13	0.57	1.5– 4.4	2.5– 7.2
RR/RB	14	0.98	0.20	0.41	1.3– 3.2	2.5– 7.2
RD/Del.L.	14	0.89	-0.30	1.34	1.5– 4.4	1.5– 2.9
RB/Del.L.	14	0.96	-0.73	2.35	2.5– 7.2	1.5– 2.9
Del.L./Gr.Ab.W.	14	0.93	0.57	1.24	1.5– 3.2	0.8– 2.1
Del.L./Anal Del.L.	14	0.84	-0.23	1.16	1.5– 3.2	1.7– 2.9
Amb.L./Amb.W.	14	0.72	-2.31	7.99	2.0– 5.5	0.5– 0.9
Amb.L./No.S.P.	14	0.95	-0.73	0.24	2.0– 5.5	10.0–24.0

TABLE 14B. Growth relationships of principal variables of *Heteroschisma subtruncatum* (Hall, 1858)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	3	0.99	-2.98	1.99	10.0–15.3	6.7– 9.2
V/P	3	0.99	-0.43	0.23	1.5– 2.5	8.5–12.8
L/ABBR	3	0.99	1.94	2.27	10.0–15.3	3.7– 5.9
L/RD	3	0.98	-1.89	4.98	10.0–15.3	2.3– 3.4
L/RB	3	0.99	-0.55	2.27	10.0–15.3	4.7– 7.0
L/Del.L.	3	0.96	-8.50	7.17	10.0–15.3	2.6– 3.3
L/Amb.L.	3	0.96	-0.01	3.39	10.0–15.3	2.8– 4.4
L/No.Hyd.Sl.	3	0.96	0.75	1.62	10.0–15.3	6.0– 9.0
RD/Amb.L.	5	0.99	0.38	0.67	2.3– 3.4	2.8– 4.4
Del.L./Amb.L.	5	0.82	1.34	0.43	2.6– 3.3	2.8– 4.4
ABL/ABW	3	0.89	-4.51	3.01	4.5– 6.7	2.9– 3.6
ABBR/ABBRF	3	0.53	-2.82	3.83	3.7– 5.9	1.7– 2.0
ABBB/ABBBF	3	-0.43	1.07	-0.04	0.8– 1.0	4.2– 6.4
ABBB/ABBR	3	-0.46	1.06	-0.04	0.8– 1.0	3.7– 5.9
ZBL/ZBW	3	1.00	-0.83	1.33	4.5– 6.5	4.0– 5.5
ZBBR/ZBBRF	3	0.91	-6.57	7.29	3.8– 6.0	1.4– 1.7
ABBR/RB	3	0.99	-1.05	0.99	3.7– 5.9	4.7– 7.0
ABBR/RD	3	0.95	-1.45	2.11	3.7– 5.9	2.3– 3.4
ABBR/Del.L.	3	0.99	-4.80	3.23	3.7– 5.9	2.6– 3.3
RD/RDF	5	0.82	0.80	1.23	2.3– 3.4	1.4– 2.0
RR/RRF	5	0.83	0.52	0.27	2.2– 3.0	6.2– 8.4
RB/RBF	5	0.94	-1.68	4.65	4.7– 7.0	1.3– 1.8
RD/RR	5	0.94	-0.25	1.24	2.3– 3.4	2.2– 3.0
RD/RB	5	0.93	0.54	0.42	2.3– 3.4	4.7– 7.0
RR/RB	5	0.98	0.65	0.34	2.2– 3.0	4.7– 7.0
RD/Del.L.	5	0.85	-0.37	1.10	2.3– 3.4	2.6– 3.3
RB/Del.L.	5	0.84	-1.61	2.43	4.7– 7.0	2.6– 3.3
Del.L./Gr.Ab.W.	5	0.64	1.32	1.00	2.6– 3.3	1.3– 1.8
Del.L./Anal Del.L.	5	0.88	-0.63	1.64	2.6– 3.3	2.0– 2.4
Amb.L./Amb.W.	5	0.01	-18.72	32.00	2.8– 4.4	0.7– 0.7
Amb.L./No.S.P.	5	0.92	1.35	0.11	2.8– 4.4	15.0–26.0

where it abuts against inner limbs of C and D radials. Laterally it is in contact with ambulacra. Length and width of subdeltoid increase throughout growth. Anal opening set in horizontal plane below level of oral opening; shape is ovoid angular, with adoral part being longer and having a sharper curve. Adoral two-thirds of anal opening bordered by subdeltoid, aborally by RD sector of radials and part of RR sector, more so than in *H. alternatus*. Size of anal opening increases throughout growth. Aboral rim of anus may be slightly higher than other portions. No hypodeltoid. Super.L.: 0.5-1.0 mm; Super.W.: 0.5-1.0 mm; Sub.L.: 0.5-1.2 mm; Sub.W.: 1.0-2.8 mm; Anus L.: 0.7-1.2 mm; Anus W.: 0.7-1.5 mm. O.c.-anus: 0.8-1.8 mm. See Table 14A, B.

Ambulacra five, long and narrow, lanceolate in small specimens, linear in larger specimens, lacking external growth zone on outer side plates. Ambulacra slightly convex in lateral view in small specimens, becoming more convex in larger specimens through growth. Ambulacrum is set in a prominent, deep ambulacral sinus but sides rise above lowest parts of sinus; merge with radial near aboral end. Lancet concealed except for small rhomb-shaped area at adoralmost end; shape conforms to that of ambulacrum; overlain by side and outer side plates which are of about equal size. Side plate pentagonal; relatively straight suture along midline of ambulacrum, two straight aborally inclined ad- and aboral edges; both bend to converge to a point. Pentagonal outer side plate fits in gap caused by convergence and forms lateral edge of ambulacrum. Brachiolar facets small, heart-shaped (0.2 mm by 0.2 mm) near outer upper edge of ambulacrum. Side food groove follows suture between side plates. Main food groove and adoral part of side groove bordered by minor lobes and grooves. See Table 14 A, B.

Eight hydrospire groups, each a triangular area on sloping wall of ambulacral sinus, with number of slits increasing ontogenetically. Longest slit near ambulacrum; oldest slits are longer on radial than deltoid. No hydrospires in anal interarea. No.Hydro.Sl: 3-10; L.Hydro.Fld.: 0.6-1.8 mm; W.Hydro.Fld.: 0.4-1.8 mm.

Oral opening pentagonal, width 0.3-0.7 mm. Width of ambulacral tract on deltoid: 0.2-0.3 mm.

Distribution.– Devonian, Cedar Valley Limestone, Iowa, and Thunder Bay Limestone and Petoskey Formation, Michigan, U.S.A.

Remarks.– The size of the brachiolar facet was determined on the lectotype (USNM S5418); the rest of this description was based upon growth series I. One specimen slightly larger than the largest in the growth series (L.: 17.2 mm (10 hydrospires); W.: 9.7 mm) and one smaller than the smallest in the growth series (L.: 4.7 mm; W.: 3.6 mm) were found in the specimens cataloged under USNM S3209 after the data matrix for this species had already been processed. The internal anatomy and ontogeny of this species were discussed by Breimer and Macurda (1972) and are further summarized in Table 14A.

Wachsmuth did not designate a holotype for *Heteroschisma gracilis*, but simply referred to the "type specimens in the collections of Prof. Barris, and Charles Wachsmuth." (1883, p. 357). There are two lots of specimens in the U.S. National Museum which Springer cataloged as the "cotypes" of this species; these include over 30 specimens. One specimen is clearly recognizable as the specimen of Wachsmuth's figure 2 (a polished surface; recataloged as S5417). The specimen which Wachsmuth used for figure 1 cannot be recognized with certainty from amongst the above specimens. Since no type was designated, one specimen was chosen from the lot in which the specimen in figure 2 was found and is herein designated the lectotype (S5418); this collection would appear to be part of that used by Wachsmuth. The specimen in his figure 2 (S5417) was not chosen because much of the top was ground away. Although Wachsmuth (1883) only gave the stratigraphic position and locality of this species as being near the top of the Hamilton group, the above specimens are clearly recognizable as being from the Thunder Bay Formation on Partridge Pt., 4 mi. SE of Alpena, Michigan because of the gritty, greenish-gray siltstone matrix which still adheres to the specimens.

Heteroschisma subtruncatum (Hall, 1858) is a senior synonym of *H. gracilis* Wachsmuth, 1858, agreeing in all observable characters. Breimer and Macurda (1972, p. 209) noted the close similarity of these forms; while maintaining them as separate species; restudy of the material showed their co-identity. *H. subtruncatum* therefore becomes the type species of *Heteroschisma*. A data matrix is summarized in Table 14B; see also Appendix I.

The distinguishing characteristics of this species is the strong upward slope of the deltoid crest, the narrow outline of the ambulacrum, and the very fine growth lines of the sectors of the radials and basals.

HETEROSCHISMA sp.

Heteroschisma sp. Breimer and Macurda, 1972, Pl. III, figs. 12,13.

Remarks.– The specimens of *Heteroschisma* that occur in the Devonian North Vernon Formation (Beechwood Member) in Indiana (UMMP 58661, 58662) and Kentucky (UMMP 1968/D-9) and the Lingle Formation of southern Illinois (UMMP 56502) cannot be definitely assigned to one of the four described species of *Heteroschisma*. The downward slant of the deltoid crest excludes *H. subtruncatum*, the lack of serrated ambulacra excludes *H. alatum*, and the lack of coarse growth lines excludes *H. alternatum*, leaving by default *H. canadense*. The specimens of *Heteroschisma* sp. are preserved in crinoidal grainstones and the surface detail is largely obliterated. They have fine growth lines and the thecae are relatively long and narrow. The deltoid crests slope downward from their origin. The specimens are small (less than 10 mm in length). There is insufficient information to definitely assign them to *H. canadense*.

Genus PHAENOSCHISMA Etheridge and Carpenter, 1882

Type species.– *Pentatrematites acutum* Sowerby, 1834.

Phaenoschisma Breimer and Macurda, 1972, p. 17.

PHAENOSCHISMA ACUTUM (Sowerby, 1834)

Pl. 12, figs. 10-12,14,16,17; Table 15

Phaenoschisma acutum Breimer and Macurda, 1972, Pl. IV, figs. 3,5,10,14.

Description.– Theca conical, with vault moderately well developed in comparison to pelvis (Pl. 12, fig. 12). Pelvis conical in lateral view, with very slightly concave lateral profile; pelvic angle 42-50°. Vault convex, angular in lateral profile due to aboral extension of deltoid crest and upward extent of tips of radials; neither equals level of oral opening. Outline of theca pentagonal in oral view, with tendency toward very slight convexity in interambulacral areas (Pl. 12, fig. 11). Thecae small to intermediate in size (Table 15).

Basalia three, in normal position, form approximately one-half of pelvis. Outline in lateral view conical, straight to very slightly concave, tapering almost to a point proximally. Outline in plan view pentagonal distally, becoming rounded proximally. Diameter stem attachment area 1.0 mm in specimen 1.

Azygous basal quadrate in plan view, with straight lateral and distal edges. BR sector very slightly concave parallel to BR axis, convex normal to it proximally, becoming flatter medially and distally; adjacent sectors merging over convex surface proximally, flat surface distally. Zygous basals pentagonal in plan view, with very slightly concave lateral edges, straight distal lateral edges, and a concave distal medial edge. BR sectors straight parallel to BR axis; medial sector slightly convex, lateral sectors very slightly convex normal to BR axis. BR and RB sectors merge smoothly. Basals measurable only in specimens 1-3. ABL: 4.0(a)-4.9 mm; ABW: 1.8-2.2(a) mm; ABBBF: 3.0(a)-3.9 mm; ABBR: 3.5(a)-4.4 mm; ABBRF: 1.5-1.7 mm; ZBL: 3.5(a)-4.3 mm; ZBW: 2.5-3.3 mm; ZBBR: 3.6(a)-4.6 mm; ZBBRF: 1.3-1.7 mm.

Radials five, hexagonal in plan view, forming upper half of pelvis and lower two-thirds of vault. Lower edge strongly convex (or 2 straight edges); lateral edges slightly convex, diverging in width up to level of aboral tip of ambulacrum, then converging slightly. Adoral edges slightly concave, slope toward one another at steep angle in ambulacral sinus. Radial sinus parabolic, with very slightly convex sides. Radial triangular in lateral view, with slightly convex upper adoral facing edge, very slightly concave aboral facing edge, and slightly concave lower edge. RB sector very slightly concave parallel to and very slightly convex normal to RB axis; adjacent sectors merge over a convex surface; merge smoothly with RR sectors. RR sector very slightly convex parallel to RR axis, slightly convex normal to it. RD sector at sharp angle to RR sector, confined to a moderately well developed ambulacral sinus, straight parallel to and slightly concave perpendicular to RD axis (Pl. 12, fig. 14). R.Ht.: 1.0-1.5 mm; RWB: 1.9-3.0 mm; RWA: 3.4-5.8 mm; RWD: 3.0-3.6 mm. See also Table 15.

Deltoids four, together with epideltoid forming border to oral opening. Deltoid pentagonal in plan view. Adoral edge bordering peristome very slightly concave; width expands along straight DDF, then contracts along concave DAF, with minimum exposed width being aboral to origin of deltoid crest, then expanding aborally; DRF slightly convex. Deltoid slightly concave in lateral view because of origin of deltoid crest below level of deltoid lip. Deltoid lip small, ornamented by arcuate ridge which points toward oral opening (Pl. 12, fig. 14). Slightly concave aboral face of ridge slopes down to origin of deltoid crest below deltoid lip. Deltoid crest sharp, projecting slightly downward from its origin, with very slightly convex profile (Pl. 12, fig. 17). Sides drop steeply down into ambula-

TABLE 15. Growth relationships of principal variables of *Phaenoschisma acutum* (Sowerby, 1834)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	4	0.82	-4.85	2.45	10.0–14.2	6.2– 7.4
V/P	4	0.84	-0.56	0.61	3.2– 5.0	6.8– 9.2
L/RD	4	0.64	9.22	0.76	10.0–14.2	2.0– 5.4
L/RB	4	0.85	3.49	2.13	10.0–14.2	3.5– 5.0
RD/Amb.L.	4	0.54	-4.66	1.74	2.0– 4.2	4.2– 4.9
RR/RRF	5	0.97	0.21	0.31	2.0– 3.2	5.6– 9.5
RB/RBF	5	0.65	0.66	2.26	3.3– 5.0	1.2– 1.7
RD/RR	5	0.77	-0.96	1.97	2.0– 5.4	2.0– 3.2
RD/RB	5	0.83	-2.41	1.57	2.0– 5.4	3.3– 5.0
RR/RB	5	0.98	-0.45	0.72	2.0– 3.2	3.3– 5.0
Amb.L./Amb.W.	4	0.58	3.24	0.66	4.2– 4.9	1.6– 2.2
Amb.L./No.S.P.	4	0.97	2.99	0.16	4.2– 4.9	8.0–12.0

cral sinuses; sides ornamented with hydrospire slits on inner two-thirds of ambulacral sinus. Deltoids measurable in only three specimens (1,3,5). Del.L.: 2.0-3.0 mm; Gr.Ad.W.: 0.8-1.0 mm; Min.W.: 0.5 mm; Gr.Ab.W.: 0.8-1.2 mm; L.Crest: 1.8-2.5 mm; DR: 1.7-2.0 mm.

Two anal deltoids, an epi- and hypodeltoid. Outline of deltoid lip of epideltoid as for regular deltoid except broader; rim present on upper surface with trough behind it which diverges aborally in both directions, leading into ambulacral sinuses of anal interarea. Raised area with median groove between two grooves in center of aboral vertical face where epideltoid forms adoral border to anal opening apparently served to guide anus. Limbs of epideltoid extend outward laterally to form adoral part of walls of ambulacral sinuses in anal interarea. Hypodeltoid a prominent pyramidal plate with three sides which sits atop aboral part of limbs of epideltoid and abuts against tip of radial limbs. Two surfaces slope down into adjacent ambulacral sinuses; third surface is a concave margin to anal opening. Anal opening ovoid, level below that of peristome, opening directly upward. Anal interarea measurable in specimen 3. Anal Del.L.: 2.8 mm; Epi.L.: 2.3 mm; Epi.Gr.Ad.W.: 1.0 mm; Epi.Min.W.: 0.8 mm; Anus L.: 1.7 mm; Anus W.: 1.0 mm; O.c.-anus: 0.9 mm.

Ambulacra five, sited in moderate ambulacral sinus. Ambulacra petaloid in plan view, convex in lateral view, broadly convex in cross section with median depression for ambulacral tract. Lancet lanceolate in plan view, broadly exposed almost to aboral tip of ambulacrum with side plates resting against its side (Pl. 12, figs. 10, 16,17). Side plates hexagonal in plan view with convex admedial edge; two straight adoral edges (major bend caused by insertion of outer side plate), two straight aboral edges; minor bend caused by insertion of next aboral outer side plate, and narrower convex outer edge. Triangular outer side plates embay ablateral margins of side plates; longest edge of outer side plate aboral (bisecting brachiolar facet), shorter slightly convex adoral edge and convex outer edge; outer side plates form more than fifty percent of ablateral margins of ambulacrum. Brachiolar facet on outer sloping side of ambulacrum, equally divided between side and outer side plate. Main grooves and ad- and aboral margins of side grooves bordered by minor lobes and grooves. See Table 16.

Ten hydrospire fields, occupying most of width of ambulacral sinuses. Hydrospire slits largely concealed by petaloid ambulacra (compare Pl. 12, figs. 10,14,16, 17). Entrance to concealed hydrospires by way of cleft which extends full length of ambulacrum. No.Reg. Hydro.Sl.: 4-6; W.Hydro.Fld.: 0.8-1.2 mm. Number of anal hydrospires reduced by one or two per group.

Oral opening circular, diameter 1.0 mm in specimen 3.

Distribution.– Lower Carboniferous, Upper Clitheroe Limestone and Chatburne Limestone, Clitheroe, England; Feltrim Hill Reef, County Dublin, Ireland; and D1 (D2?) Dartry Group(?), bedded crinoidal limestone above a large mudbank reef. Roadside quarry on south side of road, below crest of ridge, 1 mile west of Knockmere, latter 2.5 miles WSW of Derrogonelly, HO 72502, County Fermangh, Northern Ireland (UMMP 62562).

Remarks.– The above description is based upon the five specimens in the growth series (Appendix I) plus one from Ireland (see below). The internal anatomy and ontogeny of the species were discussed and illustrated by Breimer and Macurda (1972) and are further summarized in Table 15. An earlier discussion of the exterior was given by Macurda (1964) as well as a table (p. 723) by which the species of *Phaenoschisma* can be differentiated from one another.

The outer part of the epideltoid is weathered or not preserved in any of the English specimens and no hypodeltoids are preserved. A hypodeltoid was found in an Irish specimen which forms the basis for the discussion of this plate given above. An attempt to further prepare the specimen (Trinity College Dublin 7968) with an airabrasive resulted in the plate parting from the specimen along a fracture and being lost. Its ornament and position left no doubt as to its identity.

PHAENOSCHISMA CHOUTEAUI Macurda, 1964

Phaenoschisma chouteaui Breimer and Macurda, 1972, Pl. III, figs. 16,21,23.

Remarks.– This species was described and illustrated by Macurda (1964); it was based upon a single individual. A second specimen was used for the description of the internal anatomy by Breimer and Macurda (1972) but did not add to previous knowledge of external characteristics.

PHAENOSCHISMA CONICUM (Fay, 1962)
Pl. 12, figs. 15,18-23; Table 16

Phaenoschisma conicum Breimer and Macurda, 1972, Pl. III, figs. 18,24,25.

Description.– Theca conical, with a vault moderately well developed in comparison to pelvis (Pl. 12, figs. 18, 19). Pelvis slightly convex in upper part of profile, slightly reflected near stem attachment area, producing slightly sinusoidal profile; pelvic angle 48-52°. Vault convex in lateral view, with profile dominated by ambulacra; minor break in profile at aboral tip of deltoids. Outline of theca pentagonal-decagonal in plan view, with greatest protusion in center of interambulacral areas. Thecae small, length greater than width. L.: 6.5 mm: W.: 4.0 mm; L.: 6.7 mm; W.: 5.2 mm; lengths up to 10.5 mm known. V.: 1.7 mm; P.: 4.8 mm; V.: 1.2 mm; P.: 5.5 mm.

Basalia three, in normal position; form approximately one-half of pelvis. Outline in lateral view conical, with slight recurvature proximally, tapering almost to a point. Outline in plan view pentagonal distally, becoming rounded-pentagonal medially and circular distally. Small BA growth axis forms stem attachment area which is a small ovoid area with a very shallow depression at the proximal tip of the basals; diameter: 0.4-0.5 mm.

Azygous basal pentagonal, with very short straight edge bordering stem attachment area; lateral edges slightly concave proximally, straight medially and distally; distal edges straight. BR sector slightly concave proximally, straight medially and distally parallel to BR axis, slightly convex normal to it; BR sectors merge over convex surface and slightly elevated above BB sector. Latter slightly convex parallel to and slightly concave normal to BB axis. BA sector small, straight parallel to and convex normal to BA axis. BA and BB sectors merge smoothly. BR sectors ornamented by relatively strong growth lines which parallel growth fronts; those in BB and BA sectors less pronounced. Zygous basals hexagonal in plan view, with short, straight edge parallel to stem attachment area; lateral edges slightly concave proximally, straight medially and distally; distal lateral edges straight; medial distal edge concave. Medial and lateral BR sectors concave proximally, straight medially and distally parallel to BR axes; medial sector slightly convex and lateral sectors flat normal to BR axes; adjacent sectors merge over convex surfaces (Pl. 12, fig. 18). BR and RB sectors merge smoothly. Ornament, BB, and BA sectors of zygous basals as for azygous basal. Complete basals usually not preserved; representative measurements from specimen 1 in growth series. ABL: 4.0 mm; ABW: 1.7 mm; ABBB: 0.3 mm; ABBBF: 3.0 mm; ABBR: 3.3 mm;

TABLE 16. Growth relationships of principal variables of *Phaenoschisma conicum* (Fay, 1962)

Variables	n	r	a_0	a_1	Observed Range y	x
RD/Amb.L.	4	0.94	0.14	0.71	1.5– 2.7	1.8– 3.3
Del.L./Amb.L.	4	0.93	0.21	0.74	1.5– 2.8	1.8– 3.3
RD/RDF	4	0.80	0.22	2.24	1.5– 2.7	0.5– 1.0
RR/RRF	8	0.95	0.52	0.35	1.3– 2.2	2.7– 4.8
RB/RBF	8	0.89	0.37	1.43	1.7– 3.4	1.0– 2.1
RD/RR	8	0.88	-0.74	1.56	1.5– 2.8	1.3– 2.2
RD/RB	8	0.77	0.11	0.74	1.5– 2.8	1.7– 3.4
RR/RB	8	0.96	0.42	0.53	1.3– 2.2	1.7– 3.4
RD/Del.L.	4	0.75	0.46	0.71	1.5– 2.7	1.5– 2.8
RB/Del.L.	4	0.84	1.00	0.65	1.7– 2.7	1.5– 2.8
Del.L./Gr.Ab.W.	4	0.94	0.23	2.33	1.5– 2.8	0.5– 1.0
Amb.L./Amb.W.	4	0.79	-0.43	2.54	1.8– 3.3	1.0– 1.5
Amb.L./No.S.P.	4	0.92	-0.83	0.47	1.8– 3.3	6.0– 9.0

ABBRF: 1.4 mm; ZBL: 3.2 mm; ZBW: 2.3 mm; ZBBR: 3.2 mm; ZBBRF: 1.2 mm.

Radials five, forming upper part of pelvis and lower half of vault. Radial hexagonal in plan view, with strongly convex lower edge; lateral edges moderately convex; greatest width at aboral tip of ambulacrum; upper edges slope downward into ambulacral sinus. Radial sinus parabolic. Radial triangular in lateral view, with very slightly convex upper adoral edge, straight upper aboral edge, and concave lower edge. RB sector straight parallel to and very slightly convex normal to RB axis. Adjacent RB sectors merge over convex surface; merge smoothly with RR sector. RR sector straight parallel to and convex normal to RR axis. RD sector sharply set off from RR sector, being confined to a shallow ambulacral sinus; straight parallel to and very slightly concave normal to RD axis. RB and RR sectors ornamented by strong growth lines which parallel growth fronts; RD sector fully ornamented by hydrospire slits (Pl. 12, figs. 18-20). R.Ht.: 0.5-1.1 mm; RWB: 1.8-3.0 mm; RWA: 2.2-3.7 mm; RWD: 1.8-2.9 mm. See also Table 16.

Deltoids four, together with epideltoid forming border to oral opening. Deltoid hexagonal in plan view. Adoral edge bordering oral opening straight; width expands along short, straight DDF, then contracts aborally to minimum exposed width at origin of deltoid crest, then expands again aborally on concave DAF. DRF straight. Deltoid slightly concave in lateral view because of origin of deltoid crest below deltoid lip. Latter ornamented by prominent horseshoe-shaped ridge that points aborally. Deltoid lip slopes downward aborally to origin of deltoid crest. Latter sharp, usually sloping downward from origin of apex of radials; sides of deltoid crest slope downward into adjacent ambulacral sinuses (Pl. 12, figs. 21,22). Sides ornamented by hydrospire slits. Del.Gr.Ad.W.: 0.4-0.7 mm; Min.W.: 0.2-0.6 mm; L.Crest: 0.9-1.5 mm; DR: 1.0-1.5 mm.

Anal deltoids two, an epi- and hypodeltoid. Outline and ornament of deltoid lip of epideltoid as for regular deltoid. Two limbs extend aborally to radials, forming walls of ambulacral sinus in anal interarea (Pl. 12, fig. 20). Small notch at apex of radials in anal interarea indicates position of hypodeltoid (Pl. 12, figs. 15,20) which is a very small plate and was only found preserved in a thin-sectioned specimen (Breimer and Macurda, 1972, p. 89); not forming part of wall of theca. Outline in Plate 12, figures 15, 20, indicates hypodeltoid was pentagonal in outline, pyramidal in relief, with two sides sloping down into ambulacral sinuses and adoral face being concave and elevated above anal opening. Anal opening ovoid, level below that of oral opening, directed straight upward, with adoral and lateral borders formed by epideltoid; only the aboralmost part is bordered by hypodeltoid. Length of epideltoid almost the same as that of regular deltoid while maximum adoral width is 0.1-0.2 mm greater than that of regular deltoid. Anus W.: 0.5-0.6 mm; O.c.-anus: 0.5-0.6 mm.

Ambulacra five, sited in a shallow ambulacral sinus; broad, petaloid in plan view, convex adorally, flat aborally in lateral view, and broadly convex in cross section with median depression along main ambulacral tract. Lancet lanceolate, widely exposed almost to aboral tip of ambulacrum; side plates rest upon sloping sides (Pl. 12, figs. 15,19). Side plates hexagonal in plan view, with convex admedial edge against lancet; two straight adoral edges, abmedial one due to slight bend induced by presence of outer side plate; aboral edges straight, outer half bends adorally due to presence of large rounded-triangular outer side plate; outer edge of side plate convex, borders ambulacral sinus. Outer side plate indents adoral and aboral outer margins of side plate; aboral edge longest, straight; adoral edge slightly convex against side plate; outer edge convex. Brachiolar facet large, heart-shaped, on outer sloping side of ambulacrum (Pl. 12, figs. 21-23); L.: 0.3 mm; W.: 0.25 mm; sited on side and outer plates. Brachiolar pit leads into side groove. Arcuate side plate furrow borders aboral margin of brachiolar facet and appears to extend to edge of ambulacrum. See Table 16.

Ten hydrospire fields, occupying full width of radio-deltoid suture, inner slits largely covered by ambulacra; entrance to these via a hydrospire cleft. Number of hydrospires per group reduced by one or two in anal interarea. No.Hydro.Sl.: 5-7; W.Hydro.Fld.: 0.6-1.5 mm.

Oral opening pentagonal; width 0.5 mm.

Distribution.– Mississippian, Caballero and Lake Valley (Nunn Mb.) formations, New Mexico, U.S.A.

Remarks.– The above description is based upon the eight specimens in the growth series (Appendix I). The internal anatomy and ontogeny of this species were discussed and illustrated by Breimer and Macurda (1972) and are further summarized in Table 16. A description of another specimen from the Caballero Formation in New Mexico was given by Macurda (1964; Pl. 117, figs. 1-3).

One of the five paratypes designated by Fay in 1962 (Oklahoma University 4347) belongs to the phaenoschismatid UA. One of the other paratypes, specimen 2 in the growth series, has two additional plates developed in the anal interarea (illustrated by Fay, 1962, Pl. II, figs. 2-4). The first of these is a small hexagonal plate, apparently a radial, which embays the base of the interradial suture and the C and D radials. A small pentagonal plate, apparently a zygous basal, occurs immediately below this and embays the upper left edge of the C zygous basal. Growth lines parallel the margins of the two plates.

The specimens illustrated herein do not show the proximal tip of the basals because this is usually broken off.

PHAENOSCHISMA GRACILLIMUM
(Rowley and Hare, 1891)
Table 17

Phaenoschisma gracillimum Breimer and Macurda, 1972, Pl. III, figs. 14,19.

Description.– Theca conical in lateral view, with long pelvis and low convex vault with angular profile. Pelvis conical in lateral view, with straight to very slightly convex lateral profile; slight recurvature proximally. Pelvic angle: 19 to 29°. Vault low, convex with angular profile due to upward extension of deltoid crest. Outline of theca pentagonal in oral view; interambulacral areas can be very slightly convex. Thecae small to intermediate in size (Table 17).

Basalia three, in normal position, form lower half of pelvis. Outline in lateral view conical, with slight recurvature proximally, tapering almost to a point proximally. Outline in plan view decagonal due to pointed distal apices of basals, becoming rounded medially and rounded-triangular proximally. Stem attachment area formed by growth of BA axis up to 1.0 mm; cicatrix a shallow circular depression of proximalmost tip of basals. Diameter of base 0.5-1.0 mm; two preserved stem plates 0.5 and 0.6 mm in diameter.

Azygous basal very elongate, narrow; lateral edges straight except proximally where slight recurvature; distal edges straight. BR sector slightly concave proximally, straight medially and distally parallel to BR axis; strongly convex proximally and slightly convex medially and distally normal to BR axis. BB sector slightly convex

TABLE 17. Growth relationships of principal variables of *Phaenoschisma gracillimum* (Rowley and Hare, 1891)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	6	0.85	2.84	1.88	7.9–13.7	3.0– 5.5
V/P	6	-0.88	8.63	-0.74	0.5– 9.4	0.9–12.2
L/ABBR	6	0.97	-5.76	2.61	7.9–13.7	5.2– 7.5
L/RD	6	0.63	3.80	6.92	7.9–13.7	0.8– 1.3
L/RB	6	0.99	4.02	1.78	7.9–13.7	3.0– 5.2
L/Del.L.	6	0.74	3.55	6.08	7.9–13.7	1.0– 1.5
L/Amb.L.	6	0.89	4.07	4.44	7.9–13.7	1.0– 2.0
L/No.Hyd.Sl.	6	0.69	1.12	1.44	7.9–13.7	6.0– 8.0
RD/Amb.L.	6	0.87	0.42	0.40	0.8– 1.3	1.0– 2.0
Del.L./Amb.L.	6	0.94	0.33	0.57	1.0– 1.5	1.0– 2.0
ABL/ABW	6	0.68	3.69	1.73	6.0– 8.4	1.6– 2.5
ABBR/ABBRF	6	0.59	2.30	2.00	5.2– 7.5	1.7– 2.3
ZBL/ZBW	6	0.73	3.00	0.99	5.0– 7.1	2.2– 3.5
ZBBR/ZBBRF	6	0.60	3.86	1.25	5.4– 7.5	1.5– 2.5
ABBR/RB	6	0.93	3.97	0.63	5.2– 7.5	2.3– 5.2
ABBR/RD	6	0.56	4.02	2.31	5.2– 7.5	0.8– 1.3
ABBR/Del.L.	6	0.61	4.11	1.88	5.2– 7.5	1.0– 1.5
RD/RDF	6	0.74	0.36	0.53	0.8– 1.3	0.8– 1.5
RR/RRF	6	0.88	0.71	0.16	0.9– 1.6	2.0– 5.5
RB/RBF	6	0.26	-1.97	3.25	2.3– 5.2	1.7– 1.9
RD/RR	6	0.89	0.18	0.64	0.8– 1.3	0.9– 1.6
RD/RB	6	0.70	0.58	0.12	0.8– 1.3	2.3– 5.2
RR/RB	6	0.90	0.53	0.21	0.9– 1.6	2.3– 5.2
RD/Del.L.	6	0.89	0.22	0.67	0.8– 1.3	1.0– 1.5
RB/Del.L.	6	0.83	-0.70	3.77	2.3– 5.2	1.0– 1.5
Amb.L./No.S.P.	4	0.98	-0.48	0.36	1.0– 2.0	4.0– 7.0

parallel to BB axis, concave normal to it. BA axis well developed, sector slightly convex parallel to BA axis, convex normal to it. Fine growth lines parallel growth fronts. Zygous basals hexagonal, with long, slightly concave lateral edges (becoming straight distally), straight distal lateral edges; distal medial edges also straight, meeting centrally at a sharp angle. Medial and lateral BR sectors straight parallel to BR axis; medial sector very convex proximally, becoming slightly convex medially and distally normal to BR axis while lateral sectors are very slightly convex throughout. BB and BA sectors as for azygous basal. See Table 17.

Radials five, forming upper half of pelvis and upper tips extending as high as level of oral opening. Radial elongate, hexagonal in plan view, with two straight lower edges, lateral edges slightly convex, diverging adorally to level of adoral tip of ambulacrum, then converging slightly adorally. Upper edges slope steeply into ambulacral sinus. Radial sinus short, parabolic. Radials triangular in lateral view, with short slightly convex adoral facing edge, long straight to slightly convex aboral facing edge and slightly concave lower edge. RB sector straight to very slightly convex parallel to RB axis, moderately convex normal to it; adjacent sectors merge over convex surface. RB sectors merge smoothly with RR sectors over slightly convex surface. RR sector straight to very slightly convex normal to RR axis, moderately convex normal to it proximally, becoming straight proximally. RD sector sharply set off from RR sector, being confined to an ambulacral sinus, being straight parallel to RD axis and slightly concave normal to it. RB and RR sectors ornamented by fine growth lines which parallel the plate boundary. R.Ht.: 0.3-0.9 mm; RWB: 1.6-2.5 mm; RWA: 1.6-3.0 mm; RWD: 1.3-2.0 mm. See also Table 17.

Deltoids four, together with epideltoid forming border to oral opening. Deltoid hexagonal in plan view. Width of deltoid expands aborally from oral opening along straight DDF, then contracts aborally along concave DAF to a point aboral to origin of deltoid crest, then widens aborally to convex radiodeltoid suture; contracts aborally along this. Deltoid concave in cross section. Deltoid lip small, ornamented with arcuate ridge which points toward oral opening. Concave aboral face of deltoid lip drops down (up to 0.5 mm) to origin of deltoid crest which slopes upward from its origin (may be slightly concave); aboral tip of crest reaching up to or above level of oral opening. Sides drop steeply down into ambulacral sinuses, ornamented by hydrospire slits. Del.Gr.Ad.W.: 0.5 mm; Min.W.: 1.0-1.5 mm; L.Crest: 0.6-1.2 mm; DR: 0.6-1.0 mm.

Anal deltoids two, an epi- and hypodeltoid(?). Outline of deltoid lip of epideltoid as for regular deltoid; prongs extend to radial. Anal opening apparently ovoid; hypodeltoid not preserved; probably a very small triangular plate. Epi.L.: 1.1-1.6 mm; Epi.Gr.Ad.W.: 0.5-0.7 mm; Anus L.: 0.8-1.5 mm (approximate); Anus W.: 0.4-0.7(a) mm.

Ambulacra five, sited in a modest ambulacral sinus. Ambulacra short, petaloid in plan view, moderately convex in lateral view, and broadly convex in cross section with median depression for ambulacral tract. Lancet lanceolate in plan view, broadly exposed almost to aboral tip of ambulacrum with side plates resting against its side. Side plates pentagonal, with a convex admedial edge, straight adoral edge, and two straight aboral edges, tapering to straight shorter ablateral edge. Triangular outer side plate embays side plates along margin of ambulacrum.

Ten hydrospire fields, occupying most of full width of radiodeltoid suture, more than half concealed by ambulacra. Entrance to hydrospire fields via spiracle-like opening and hydrospire cleft. No.Reg.Hydro.Sl.: 6-8; reduced by one or two in anal interarea.

Width of oral opening: 0.5-0.7 mm.

Distribution.— Mississippian, Burlington Limestone, Missouri, U.S.A.

Remarks.— The above description is based upon a specimen from the *Cryptoblastus melo* zone of the Burlington Limestone at Hannibal, Missouri (UMMP 62563) plus those in the growth series. The internal anatomy and ontogeny of this species were discussed and illustrated by Breimer and Macurda (1972) and are further summarized in Table 17. An earlier discussion and illustration of specimens was given by Macurda (1964).

PHAENOSCHISMA LAEVICULUM (Rowley, 1900)
Pl. 13, figs. 4,7,8,11; Table 18

Phaenoschisma laeviculum Breimer and Macurda, 1972, Pl. III, figs. 26,27; Pl. IV, figs. 19,21.

Description.— Theca conical, with moderately well developed vault. Pelvis conical in lateral view, with very slightly convex lateral profile; pelvic angle 38-45°. Vault convex, angular in lateral profile due to outward projection of deltoid crest from its origin. Outline of theca pentagonal, with tendency for interambulacral areas to be slightly convex. Thecae small-intermediate in size.

Basalia three, in normal position, form slightly over one-half of pelvis. Outline in lateral view conical, with very slightly concave profile, tapering almost to a point proximally. Outline in plan view pentagonal, becoming rounded medially and proximally. Diameter of base 0.6-1.1 mm; diameter of stem plate 1.0 mm where diameter of base 1.1 mm.

Azygous basal quadrate in plan view, with straight lateral and distal edges. BR sector very slightly concave parallel to BR axis, very slightly convex normal to it;

TABLE 18. Growth relationships of principal variables of *Phaenoschisma laeviculum* (Rowley, 1900)

Variables	n	r	a_o	a_1	Observed y	Range x
L/W	7	0.99	-0.63	1.73	6.5–14.5	4.0– 8.5
V/P	7	0.95	-2.18	0.82	1.7– 5.4	4.8– 9.1
L/ABBR	7	0.96	-2.28	3.05	6.5–14.5	1.2– 3.7
L/RD	7	0.98	2.55	3.10	6.5–14.5	1.2– 3.7
L/RB	7	0.91	0.01	2.86	6.5–14.5	2.5– 4.8
L/Del.L.	7	0.95	-0.64	4.26	6.5–14.5	1.7– 3.4
L/Amb.L.	7	0.99	0.69	2.96	6.5–14.5	2.0– 4.7
L/No.Hyd.Sl.	6	0.27	4.80	0.68	6.5–12.5	6.0– 8.0
RD/Amb.L.	7	0.99	-0.51	0.92	1.2– 3.7	2.0– 4.7
Del.L./Amb.L.	7	0.93	0.55	0.62	1.7– 3.4	2.0– 4.7
ABL/ABW	7	0.99	0.53	1.53	3.3– 6.0	1.7– 3.5
ABBR/ABBRF	7	0.95	1.31	1.36	2.9– 5.2	1.5– 3.0
ZBL/ZBW	7	0.97	0.32	1.07	2.8– 5.0	2.4– 4.5
ZBBR/ZBBRF	7	0.93	0.80	1.90	2.9– 4.0	1.3– 2.5
ABBR/RB	7	0.87	1.03	0.86	2.9– 5.2	0.7– 1.3
ABBR/RD	7	0.93	1.81	0.93	2.9– 5.2	1.2– 3.7
ABBR/Del.L.	7	0.98	0.60	1.38	2.9– 5.2	1.7– 3.4
RD/RDF	7	0.86	-0.16	1.75	1.2– 3.7	1.0– 2.1
RR/RRF	7	0.96	0.57	0.27	1.3– 2.7	3.2– 7.8
RB/RBF	7	0.83	0.65	1.82	2.4– 4.8	1.0– 2.2
RD/RR	7	0.98	-1.23	1.85	1.2– 3.7	1.3– 2.7
RD/RB	7	0.82	-0.46	0.82	1.2– 3.7	2.4– 4.8
RR/RB	7	0.81	0.47	0.43	1.3– 2.7	2.4– 4.8
RD/Del.L.	7	0.94	-0.92	1.33	1.2– 3.7	1.7– 3.4
RB/Del.L.	7	0.86	0.45	1.22	2.4– 4.8	1.7– 3.4
Amb.L./No.S.P.	6	0.88	0.22	0.30	2.0– 3.9	7.0–12.0

adjacent sectors meet over slightly concave surface. Zygous basal pentagonal in plan view, with very slightly concave lateral edges, straight distal lateral edges, and a concave medial distal edge. BR sectors very slightly concave parallel to BR axis, medial sector slightly convex, lateral sectors very slightly convex normal to BR axes; BR sectors merge smoothly with one another and RB sectors. BB sector straight parallel to BB axis, very slightly concave normal to it. If BA sector present, very weakly developed. BR and BB sectors ornamented by fine growth lines which parallel the growth fronts. See Table 18.

Radials five, pentagonal in plan view, forming slightly less than upper half of pelvis and lower half of vault. Lower edge convex; lateral edges slightly convex, diverging in width up to level of aboral tip of ambulacrum, then converging slightly. Adoral edges very slightly concave, dipping into ambulacral sinus at a broad angle toward one another. Radial sinus short, broad, parabolic, with straight or very slightly convex sides. Radial triangular in lateral view, with upper edges straight to very slightly convex and lower edge straight to very slightly concave. RB sector very slightly convex parallel and normal to BR axis, adjacent sectors merging over slightly convex surface; also merging smoothly with RR sector. Latter very slightly convex parallel to and slightly convex normal to RR axis. RD sector sharply set off from RR sector, being confined to an ambulacral sinus. RD sector straight parallel to and slightly concave normal to RD axis. RB and RR sectors ornamented by fine growth lines which parallel growth fronts; RD sector ornamented by hydrospire slits over inner two-thirds to three-quarters of sector. R.Ht.: 0.7-1.3 mm; RWB: 1.7-3.7 mm; RWA: 2.2-4.7 mm; RWD: 2.3-4.4 mm. See also Table 18.

Deltoids four, together with epideltoid forming border to peristome (Pl. 13, figs. 4,7). Deltoid hexagonal in plan view, with slightly convex edge bordering oral opening; width expands aborally on straight DDF, then contracts because of petaloid ambulacra; minimum exposed width at or just aboral to origin of deltoid crest; width expands again aborally; DRF slightly convex. Deltoid concave in lateral view because of origin of deltoid crest below deltoid crest. Deltoid lip ornamented by horseshoe-shaped rim which is adorally directed. Aboral face of deltoid lip slopes down to origin of deltoid crest. Deltoid crest sharp, projects aborally, may slope slightly up or down from its origin; sides slope steeply down into ambulacral sinuses. Inner two-thirds to three-quarters of DR sector ornamented by hydrospire slits. Del.L.: 1.7-3.4 mm; Del.Gr.Ad.W.: 0.4-0.9 mm; L.Crest: 1.0-2.5 mm; DR: 1.0-2.1 mm.

Anal deltoids two, an epi- and hypodeltoid. Outline of deltoid lip of epideltoid as for regular deltoid except broader; aboral surface of deltoid lip slopes down into ambulacral sinus laterally (two lateral grooves) with a median groove between that apparently served to guide the anus. Limbs of epideltoid extend outward laterally to form adoral part of walls of ambulacral sinuses in anal interarea. Small hypodeltoid at aboral margin of anal opening, rarely preserved; position indicated by V-shaped notch (see Breimer and Macurda, 1972, Pl. IV, fig. 26). Anal opening ovoid, opening directly upward, level below that of peristome, bordered adorally and laterally by epideltoid, aborally by hypodeltoid. Epi.L.: 1.6-3.0 mm; Epi.Gr.Ad.W.: 0.5-0.7 mm; Anus L.: 1.2-2.0 mm; Anus W.: 0.5-1.0 mm.

Ambulacra five, sited in a moderate ambulacral sinus, petaloid in plan view, convex in lateral view (more so adorally than aborally), broadly convex in cross section with median depression for ambulacral tract (Pl. 13, fig. 11). Lancet lanceolate in plan view, broadly exposed almost to aboral tip of ambulacrum, with side plates abutting against its side. Lancet supported by radial and deltoid (Pl. 13, fig. 4). Side plates hexagonal in plan view, with convex admedial edge against lancet, two straight adoral and one straight and one slightly concave aboral edges (bend in these edges caused by outer side plate abmedially), and a narrower convex outer edge. Triangular outer side plate embays outer edges of side plate; longest edge aboral, bisecting brachiolar facet; adoral edge against side plate slightly convex, and a convex outer edge bordering hydrospire fields. Amb.L.: 2.0-3.9 mm; No.S.P.: 7-12. Amb.W.: 1.0 mm when Amb.L.: 2.0 mm; 2.0 mm when 3.2 mm.

Ten hydrospire fields, occupying most of width of ambulacral sinus. Hydrospire slits largely concealed by petaloid ambulacra. Entrance to hydrospires by way of cleft which extends full length of ambulacrum. No.Reg. Hydro.Sl.: 6-8. Number anal hydrospire slits reduced by one or two per group.

Oral opening pentagonal; width: 0.5-0.7 mm.

Distribution.— Mississippian, Fern Glen Limestone, Missouri; Burlington Limestone, Missouri and Illinois; St. Joe Limestone, Oklahoma and Arkansas.

Remarks.— The above description is primarily based upon the specimen illustrated in Plate 13, figures 4,7,11, plus three other specimens from the same locality which are in the Sprinkle collection, Harvard University. The internal anatomy and ontogeny of the species were discussed and illustrated by Breimer and Macurda (1972) and are further summarized in Table 17. An earlier discussion of the external characters of this species is given by Macurda, 1964.

The number of hydrospires per regular hydrospire group is higher in some other specimens not included in the growth series; the highest number known is 12 (Macurda, 1964). In some internal chert molds, hydrospire slits are developed across the full width of the radiodeltoid suture in larger specimens; in some others they are not. There is a tendency in some individuals to stop adding hydrospire slits when the number reaches 7-8 per group. The most extreme example is a large specimen from the St. Joe Limestone of Oklahoma (Pl. 13, fig. 8; see also Breimer and Macurda, 1972, Pl. IV, figs. 19,21). There are only 3-4 hydrospire slits developed on the inner part of a DRF of 5.0 mm.

PHAENOSCHISMA? PARVUM n. sp.
Pl. 13, figs. 9,10,14-17,19,20,23,24; Table 19

Phaenoschismatid UA Breimer and Macurda, p. 217-219, Pl. IV, figs. 17, 20; Pl. V, figs. 1, 2

Description.– Theca biconical, with conical pelvis; upper part of pelvis slightly convex, lower part tapering into protuberant stem attachment area and thus recurved; vault angular, with radial limbs reaching to highest part of thecal part; radial limbs and deltoid crest form five three-sided pyramids which surround oral opening; upper profile thus highly serrate (Pl. 13, figs. 9,10,14, 16). Outline pentagonal in plan view, with greatest width at ambulacral tips (Pl. 13, figs. 15, 17, 19, 23). Thecae small (less than 10 mm), with length greater than width (approximately 1.2 times) and vault about one-half the length of the pelvis. Pelvic angle 54° and 74° where known.

Basals three, in normal position, slightly concave in lateral view, form slightly over one-half of length of pelvis. Basals pentagonal in plan view. Stem attachment a narrow cylinder (0.5 mm) at tapering proximal extremity of basals. Mode of formation (i.e.: BA axis or secondary calcite) not clear; rarely preserved. Stem plate thin, about 0.1 mm. AB quadrate in plan view, with slightly concave lateral edges and straight distal edges. BR sector concave parallel to BR axis (becoming flatter distally), convex normal to it. Zygous basal pentagonal, with concave lateral edges, straight lateral medial edges, and concave distal medial edge. BR sectors slightly concave parallel to BR axis; medial sector convex, lateral sectors very slightly convex normal to their BR axes. Where visible, ornament of basals fine growth lines parallel to basal-radial fronts. A few also visible in BB sectors. Specimen No. 3: ABL: 2.7 mm; ABW: 1.5 mm; ABBBF: 2.1 mm; ABBR: 2.4 mm; ABBRF: 1.2 mm; ZBL: 2.3 mm; ZBW: 2.2 mm; ZBOPt: 2.6 mm; ZBBR: 2.3 mm; ZBBRF: 1.0 mm.

Radials five, forming upper part of pelvis and entire profile of vault, projecting well above oral opening. Radial pentagonal in plan view, with convex lower edge, convex lateral edges, and two very slightly concave adoral edges which plunge very steeply into the ambulacral sinus. Radial embayed by a narrow, elongate radial sinus. Radial triangular in lateral view, with straight ad- and aboral facing edges and a concave lower edge. RB sector straight parallel and normal to RB axis; adjacent sectors meet over convex surface; RB sector merges smoothly with RR sector. Latter straight parallel to and convex normal to RR axis. RD sector at sharp angle to RR sector, confined to narrow, steep-walled ambulacral sinus, straight parallel to and slightly concave normal to RD axis. RB and RR sectors ornamented by fine growth lines which parallel sutures; inner part of RD sector bears hydrospire slits but full width of RDF not used for hydrospire formation. RWB: 1.7-2.4 mm; RWA: 2.2-3.5 mm; RWD: 1.5-2.8 mm. See also Table 19.

Deltoids four, together with epideltoid forming border to oral opening. Deltoid strongly concave in lateral profile due to very strong upward slant of deltoid crest. Deltoid pentagonal in plan view, with straight adoral edge bordering oral opening; width expands slightly along straight DDF, then contracts along slightly concave DAF, widening again aborally. DRF convex, rising steeply upward in ambulacral sinus to upper tip of interambulacral pyramids. Deltoid lip small; deltoid crest originates immediately behind it and slopes upward at a very steep angle. Sides of deltoid crest form the nearly vertical wall of the ambulacral sinus. Inner part of DD sector bears hydrospire slits. Del.Gr.Ad.W.: 0.5-0.8 mm; Del.Min.W.: 0.5-0.6 mm; Del.Crest: 1.0-1.3 mm; DR: 0.8-1.5 mm; Del.Ht. above oral opening: 0.5-1.3 mm.

Anal deltoids two, an epi- and hypodeltoid. Configuration of epideltoid as for lip and lower part of body of regular deltoid. Aboral edge of epideltoid embayed by ovoid anal opening. Part of hypodeltoid occasionally preserved. Facet clearly visible (Pl. 13, fig. 23) as are growth lines on radial limbs in anal interarea which reflect presence of hypodeltoid (Pl. 13, fig. 24). External surface of hypodeltoid forms part of external wall of theca. Upper edge probably formed a counterpart to the pyramids in the other four interambulacral areas. Epi.L.: 1.2-1.9 mm; Epi.Gr.Ad.W.: 0.6-0.8 mm; Hypo. W.: 0.8-1.4 mm. See also Table 19.

Ambulacra five, short, lanceolate in plan view, confined to deep ambulacral sinus; very slightly convex in lateral view (more so adorally). Lancet narrow (Pl. 13, fig. 20), apparently narrowly exposed in adoral

TABLE 19. Growth relationships of principal variables of *Phaenoschisma? parvum* n.sp.

Variables	n	r	a_0	a_1	Observed Range y	x
RD/Amb.L.	10	0.90	-0.07	0.90	1.3– 3.0	1.5– 3.5
Del.L./Amb.L.	10	0.89	0.66	0.48	1.5– 2.4	1.5– 3.5
RD/RDF	9	0.61	-0.24	1.95	1.3– 3.0	1.0– 1.5
RR/RRF	9	0.95	0.34	0.33	1.2– 2.1	2.7– 5.2
RB/RBF	10	0.91	-0.40	2.50	1.6– 2.8	0.8– 1.3
RD/RR	10	0.88	-0.49	1.60	1.3– 3.0	1.2– 2.1
RD/RB	10	0.84	-0.10	1.03	1.3– 3.0	1.6– 2.8
RR/RB	10	0.89	0.35	0.60	1.2– 2.1	1.6– 2.8
RD/Del.L.	10	0.91	-0.91	1.66	1.3– 3.0	1.5– 2.4
RB/Del.L.	10	0.78	0.08	1.17	1.6– 2.8	1.5– 2.4
Del.L./Gr.Ab.W.	10	0.57	0.79	0.96	1.5– 2.4	0.8– 1.5
Del.L./Anal Del.L.	8	0.57	0.81	0.47	1.5– 2.2	1.6– 2.6

half of ambulacrum. Side plates pentagonal; outer side plates triangular; both forming part of outer edge of ambulacrum. O.c.-amb.: 0.5-0.7 mm; Amb.L.: 1.5-3.5 mm; 3-4 side plates per mm.

Ten hydrospire fields, confined to ambulacral sinus, running length of ambulacral sinus but not developed across full width of radiodeltoid suture. Slits functional over full length; number reduced by one or more in anal interarea. No.Reg.Hydro.Sl.: 4-6; W.Hydro.Fld.: 0.5-1.0 mm.

Oral opening pentagonal.

Distribution.– Mississippian, Lake Valley Limestone, New Mexico, U.S.A.

Remarks.– The above description is based upon the specimens in the growth series (see Appendix 1), primarily numbers 1, 3, and 5. Specimen 5 is designated the holotype; specimens 1 and 3 are paratypes. (Most specimens are partially weathered or silicified.) The specific name *parvum* is derived from the Latin word for small. The ontogeny and significance of this species was discussed by Breimer and Macurda (1972) as phaenoschismatid UA. The species is questionably assigned to *Phaenoschisma* but it does not belong there. As indicated by Breimer and Macurda (1972), there is a species, phaenoschismatid (UB) (Table 20), being described from the Mississippian of Montana by James Sprinkle and R. C. Gutschick which they intend to make the type species of a new genus. *P.*? *parvum* and *Phaenoschisma*? *saharae* belong to their new genus. *P.*? *parvum* differs from *P.*? *saharae* in the elongate proximal taper of the basals, the steep upward slope of the deltoid crest, and the confinement of the ambulacrum to a narrow ambulacral sinus.

Other Mississippian phaenoschismatids are known but are too incomplete to allow taxonomic assignment (Pl. 13, figs. 18, 21, 22, 25, 26; see also Breimer and Macurda, 1972).

PHAENOSCHISMA? SAHARAE
Breimer and Macurda, 1972
Pl. 14, figs. 1-14; Table 21

Phaenoschisma? *saharae* Breimer and Macurda, 1972, Pl. V, figs. 4, 5, 10.

Description.– Theca of moderate size, conical in lateral view, with short, broadly convex, slightly angular vault and conical pelvis with a straight or very slightly convex profile (Pl. 14, figs. 5, 6, 10, 12). Outline in plan view pentagonal, with slightly concave interambulacral areas; greatest width at ambulacral tips which are

TABLE 20. Growth relationships of principal variables of *Phaenoschismatid UB*

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	16	0.96	-0.72	1.48	5.8–12.5	4.5– 8.9
V/P	16	0.89	-0.80	0.64	1.7– 4.5	3.8– 8.0
L/ABBR	16	0.97	-0.78	3.14	5.8–12.5	2.0– 4.1
L/RD	16	0.93	2.31	2.24	5.8–12.5	1.6– 4.3
L/RB	16	0.97	0.29	2.45	5.8–12.5	2.4– 5.3
L/Del.L.	16	0.91	-2.15	4.72	5.8–12.5	1.7– 3.0
L/Amb.L.	16	0.97	1.86	1.97	5.8–12.5	2.2– 5.6
L/No.Hyd.Sl.	16	0.50	4.00	0.88	5.8–12.5	4.0– 8.0
RD/Amb.L.	16	0.96	0.05	0.81	1.6– 4.3	2.2– 5.6
Del.L./Amb.L.	16	0.92	1.04	0.36	1.7– 3.0	2.2– 5.6
ABBR/RB	16	0.92	0.55	0.72	2.0– 4.1	2.4– 5.3
ABBR/RD	16	0.92	1.07	0.68	2.0– 4.1	1.6– 4.3
ABBR/Del.L.	16	0.92	-0.35	1.47	2.0– 4.1	1.7– 3.0
RD/RDF	16	0.66	0.19	2.49	1.6– 4.3	0.8– 1.5
RR/RRF	16	0.93	0.83	0.20	1.5– 2.5	4.0– 8.8
RB/RBF	16	0.61	0.91	2.02	2.4– 5.3	0.8– 1.7
RD/RR	16	0.88	-2.07	2.46	1.6– 4.3	1.5– 2.5
RD/RB	16	0.90	-0.40	0.95	1.6– 4.3	2.4– 5.3
RR/RB	16	0.92	0.79	0.35	1.5– 2.5	2.4– 5.3
RD/Del.L.	16	0.87	-1.48	1.88	1.6– 4.3	1.7– 3.0
RB/Del.L.	16	0.89	-0.74	1.81	2.4– 5.3	1.7– 3.0
Del.L./Gr.Ab.W.	16	0.93	0.62	1.64	1.7– 3.0	0.7– 1.5
Amb.L./Amb.W.	16	0.89	-1.10	3.89	2.2– 5.6	0.8– 1.5
Amb.L./No.S.P.	16	0.99	0.13	0.32	2.2– 5.6	6.0–17.0

angular (Pl. 14, figs. 1, 2). Theca sometimes slightly asymmetrical in base (Pl. 14, fig. 6). Pelvic angle: 34-48°. See also Table 21.

Basalia three, in normal position, pentagonal in plan view, becoming rounded proximally, conical in lateral view, forming approximately one-half of the pelvis, slight recurvature proximally. Stem attachment area broad (2.5 mm), formed by secondary calcite secretion; proximal surface almost flat with crenellae almost at edge.

Azygous basal quadrate in plan view, with very slightly concave distal and straight lateral edges; straight in lateral view. BR sector very slightly convex parallel to BR axis, slightly convex normal to it. Adjacent BR sectors merge smoothly over slightly convex surface, merge smoothly with slightly convex BB sectors; proximal

TABLE 21. Growth relationships of principal variables of *Phaenoschisma? sahare* Breimer and Macurda, 1972

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	8	0.93	-0.27	1.74	15.2–27.3	8.7–15.2
V/P	8	0.30	3.02	0.06	2.8– 5.2	11.7–23.1
L/ABBR	8	0.94	4.82	1.96	15.2–27.3	5.8–11.7
L/RD	8	0.78	9.60	2.11	15.2–27.3	3.3– 7.1
L/RB	8	0.92	-0.09	2.20	15.2–27.3	7.0–12.0
L/Del.L.	8	0.73	4.31	5.37	15.2–27.3	2.3– 3.8
L/Amb.L.	8	0.81	9.33	1.75	15.2–27.3	4.3– 8.9
L/No.Hyd.Sl.	7	0.32	15.00	0.97	15.2–27.3	5.0– 9.0
RD/Amb.L.	11	0.94	0.53	0.73	3.3– 7.1	4.3– 8.9
Del.L./Amb.L.	11	0.52	1.42	0.24	2.3– 4.0	4.3– 8.9
ABL/ABW	8	0.87	-0.48	1.90	6.5–12.5	3.8– 6.4
ABBR/ABBRF	8	0.88	-1.23	2.93	5.8–11.7	2.6– 4.2
ZBL/ZBW	8	0.60	0.05	1.14	5.5–11.9	5.5– 8.5
ZBBR/ZBBRF	8	0.89	-3.09	3.97	6.0–11.5	2.3– 3.6
ABBR/RB	8	0.89	-1.59	1.03	5.8–11.7	7.0–12.0
ABBR/RD	8	0.62	3.92	0.79	5.8–11.7	3.3– 6.9
ABBR/Del.L.	8	0.55	2.19	1.93	5.8–11.7	2.3– 3.8
RD/RDF	11	0.67	-1.73	3.98	3.3– 6.9	1.7– 2.1
RR/RRF	10	0.62	2.55	0.11	3.2– 4.9	9.4–19.1
RB/RBF	10	0.26	7.23	0.89	7.0–12.0	2.0– 3.4
RD/RR	11	0.77	-2.51	1.94	3.3– 7.1	3.2– 4.9
RD/RB	10	0.52	0.98	0.46	3.3– 6.9	7.0–12.0
RR/RB	10	0.71	1.74	0.24	3.2– 4.9	7.0–12.0
RD/Del.L.	11	0.69	0.39	1.60	3.3– 7.1	2.3– 4.0
RB/Del.L.	10	0.60	4.60	1.58	7.0–12.0	2.3– 4.0
Del.L./Gr.Ab.W.	11	0.85	1.25	0.95	2.3– 4.0	1.5– 2.8
Del.L./Anal Del.L.	8	0.46	1.59	0.39	2.9– 4.0	3.8– 5.0
Amb.L./Amb.W.	11	0.57	-0.56	5.05	4.3– 8.9	1.2– 1.8
Amb.L./No.S.P.	7	0.96	0.21	0.27	5.0– 8.6	18.0–32.0

portions of both covered by secondary calcite. Zygous basals pentagonal in plan view, with straight lateral edges and slightly concave distal edges. BR sectors slightly convex parallel and normal to BR axis, merging smoothly over convex surface. Adjacent basals merge over very convex area. Surface of basals ornamented with moderately strong growth lines except where obscured distally by secondary calcite. See Table 21.

Radials quadrate in plan view, projecting slightly above oral opening, with two straight or a convex lower edge(s); lateral edges slightly convex, widening up to plane of ambulacral tip, then contracting adorally; upper edges slightly concave, confined to ambulacral sinus, inclined inward toward one another. Parabolic sinus indents upper one-third of radial with small lip with keel at aboral end. Plate is triangular in lateral view, with slightly convex adoral facing edge, and slightly concave lower edge. RB sector straight parallel to, straight or very slightly convex normal to RB axis, adjacent sectors merging over convex surface, merging smoothly with adjacent RR sectors. Each RR sector is straight parallel to, slightly convex normal to RR axis. RB and RR sectors ornamented by moderately strong growth lines. RD sector at pronounced angle to RR sector, confined to moderate ambulacral sinus, straight parallel to, slightly concave normal to RD axis. Hydrospire slits developed in adoral part of sector, apparently infilled in aboral part; slits do not occupy outermost part of RDF. RR and RB sectors ornamented by growth lines parallel to growth fronts. Stereomic microstructure visible in some weathered radials. R.Ht.: 2.2-3.0 mm; RWB: 3.5-5.5 mm; RWA: 5.2-8.3 mm; RWD: 3.2-4.7 mm. See also Table 21.

Deltoids four, together with epideltoid forming border to oral opening; deltoid body confined to ambulacral sinus (Pl. 14, fig. 7). Deltoid hexagonal in plan view, slightly concave in lateral view due to deltoid crest which rises above oral opening. Adoral edge slightly convex; DDF short, straight, diverging aborally. Exposed width contracts due to ambulacra, then expands aborally along concave DAF which becomes straight. Aboral edges convex, DRF curving upward and outward to top of low interambulacral pyramid. Deltoid lip small, ornamented by arcuate rim which points adorally; adoral face bears minor grooves and lobes. Area behind rim on deltoid lip flat, merging into deltoid crest. Crest originates at narrowest exposed point of deltoid, curves slightly upward from its origin to interambulacral pyramid; sides curve downward into ambulacral sinus; only aboral part of DR sector ornamented with hydrospire slits, adoral part apparently being secondarily infilled. Del.Gr.Ad.W.: 1.0-1.5 mm; Min. W.: 0.8-1.0 mm; Del.Cr.: 1.2-2.4 mm; DR: 1.2-2.7 mm. See also Table 21.

Anal deltoids two, an epi- and hypodeltoid (Pl. 14, figs. 7-9, 11). Configuration of epideltoid as for adoral and lateral parts of regular deltoid, except position corresponding to crest now occupied by anal opening and hypodeltoid. Epideltoid prongs extend to radial, forming part of ambulacral sinus. Anal opening ovoid, opens directly upward, level slightly below that of peristome. Hypodeltoid of moderate size, pentagonal in outline, projecting upward to form counterpart of regular interambulacral pyramid. Aboral surface almost vertical, slopes steeply downward on outer surface of theca to external part of very slightly convex hyporadial suture. Surface is ornamented with growth lines as is external portion of anal RD sectors. Lateral surfaces of hypodeltoid slope downward into adjacent ambulacral sinuses, smooth; lower edge against radial in aboral part and epideltoid in adoral part; V-shaped. Epi-hypodeltoid suture straight; slopes upward to level of anal opening. Adoral face of hypodeltoid concave, dropping steeply down into anal opening. Epi.Del.L.: 3.3-4.3 mm; Epi.Gr.Ad.W.: 1.2-1.5 mm; Hypo.L.: 1.2-1.5 mm; Hypo.W.: 1.3-2.8 mm; O.c.-anus: 1.7-2.2 mm.

Ambulacra five, positioned in ambulacral sinus which they moderately fill; almost reaching oral opening. In plan view ambulacrum sublanceolate in smaller specimen, becoming almost linear in larger; slightly convex in lateral view (Pl. 14, fig. 4). Strongly convex in cross section except for indentation of ambulacral tract. Lancet exposed along midline of ambulacrum (0.4 mm), almost to aboral tip; lancet rhombic in cross section; underlain by radial and deltoids (Pl. 20, fig. 3). Side plates quadrate, with straight ad- and aboral edges which incline aborally from ambulacral midline; outer aboral edge of side plate embayed by large triangular side plate which forms part of lateral edge of ambulacrum. Side plates sit atop lancet. Brachiolar facet on outer sloping edge of convex ambulacrum, heart-shaped, equally developed on side and outer side plates. Four minor grooves and lobes per side plate along main ambulacral tract; a few present along adoral edge of side groove as well (Pl. 14, figs. 13, 14). Three side plates per mm. O.c.-amb.: 0.8-1.5 mm. See also Table 21.

Ten hydrospire groups, developed in middle portion of ambulacral sinus; ad- and aboral parts of sinus are smooth, apparently a result of secondary infilling of slits by calcite. Hydrospire slits extend from ambulacrum out to near end of radiodeltoid suture but not occupying its full width. Functional area of each hydrospire group thus has a somewhat ovoid outline. Hydrospire slits completely exposed except for those near or beneath ambulacral overhang. Number of hydrospire slits in anal interarea reduced. No.Reg.Hydro.Sl.: 5-9; W.Fld.: 1.0-1.4 mm; No. Anal Hydro.Sl.: 3-6; W.Fld.: 0.5-1.2 mm.

Oral opening pentagonal. Width: 0.7-1.2 mm.

Distribution.– Carboniferous: (1) Couverture stratifiee du Djebel Ioucha (massifs recifaux du Grand Erg occidental rive gauche de la Zousfana), Horizon: Ioucha 10 (=Dalle à *Syringothyris*), Formation d'Akacha-Mazzer, Zone P^2 (Viséen superieur) (no. 437a and b), (2) Col du Teniet el Aouidja au Nord du Chabet el Oubeur (rive gauche de la Zousfana), Horizon: "Mouizeb el Atchane" (Sommet de la formation d'El Guelmouna), Zone E^1: Namurien inferieur (no. 518). Occidental Sahara. (Pareyn, personal communication). Both of these localities are just southeast of Bechar in northwest Algeria, Département de la Saoura, near the border. The first is at 31°5'N, 1°32'W, the second and stratigraphically higher is at 31°1'N, 2°4'W. For further detail, see the geologic maps which accompany Pareyn, 1961.

Remarks.– The above description is based upon the eleven specimens in the growth series (Appendix 1). The ontogeny of the species was discussed by Breimer and Macurda (1972). Eight of the specimens became available since the original designation (Breimer and Macurda, 1972); some are illustrated in Plate 14.

Genus PENTREMOBLASTUS Fay and Koenig, 1963

Type species.– *Pentremoblastus conicus* Fay and Koenig, 1963.

Pentremoblastus Fay and Koenig, 1963, p. 267; Fay and Wanner, 1967, p. S438.

Phaenoschisma ? Breimer and Macurda, 1972, p. 216.

Phaenoblastus ? Breimer and Macurda, 1972, p. 216.

Diagnosis.– Theca biconical in lateral view, pentagonal in plan view; vault moderate; angle of ambulacral sinus about 80°; interambulacral pyramids low to moderate; deltoid crest slopes slightly upward from its origin; ambulacra lanceolate, most of full width of lancet exposed; 10 hydrospire groups, number of hydrospire slits in anal interarea slightly reduced; hydrospire slits partially exposed; 3(4?) anal deltoids: Super-, sub-, and hypodeltoid; latter not forming part of vertical wall of theca; hypodeltoid moderately developed; anal hydrospires formed by subdeltoid. *Miss.*, Illinois, U.S.A.

Remarks.– *Pentremoblastus* was originally described by Fay and Koenig (1963) as being a spiraculate blastoid but Breimer and Macurda (1972, p. 216) suggested it was a phaenoschismatid fissiculate, most closely allied to *Phaenoschisma* or *Phaenoblastus*. It clearly does not belong to *Phaenoschisma* because of the presence of more than two anal deltoids. I cannot be absolutely positive that a suture doesn't divide the subdeltoid internally but this plate appears to be solid and even if there was a suture (and thus two cryptodeltoids), the structure would be different than that of *Phaenoblastus* in which the cryptodeltoids abut against the superdeltoid but are not in contact adorally. The superdeltoid of *Phaenoblastus* extends deeply internally while that of *Pentremoblastus* is small and does not project far internally. While the three genera are very similar, *Pentremoblastus* appears to be generically distinct whether there are three or four anal deltoids.

The second species assigned to *Pentremoblastus* by Fay and Koenig (1963) is *P. subovalis* Fay and Koenig, 1963. The description is brief. The structure of the anal deltoids needs further study; there are apparently functional hydrospire pores. It is apparently one of the earliest pentremitid blastoids. It does not belong to *Pentremoblastus*; its generic assignment is uncertain until study of other early pretremitids is completed (see Breimer and Macurda, 1972, Pl. IV, figs. 13, 16).

PENTREMOBLASTUS CONICUS
Fay and Koenig, 1963
Pl. 13, figs. 1-3, 5, 6; Table 22

Pentremoblastus conicus Fay and Koenig, 1963, p. 267, 268, Pl. I, figs. 1a, 1b.

?*Pentremoblastus conicus* Breimer and Macurda, 1972, Pl. IV, figs. 4, 9.

Description.– Theca conical, with vault about one-half the length of the pelvis; thecae small. Pelvis conical in lateral view, with slight proximal recurvature; pelvic angle 42-50° (Pl. 13, fig. 1). Vault convex, truncate, with angular break in profile caused by aboral tip of deltoid crest and upper tips of radial prongs. Outline of theca pentagonal in oral view; interambulacral areas may be very slightly convex or very slightly concave (Pl. 13, fig. 6). See Table 22.

Basalia three, in normal position, form one-half of pelvis. Outline in lateral view conical, tapering almost to a point proximally. Outline in plan view pentagonal

TABLE 22. Growth relationships of principal variables of *Pentremoblastus conicus* Fay and Koenig, 1963

Variables	n	r	a_0	a_1	Observed Range y	Observed Range x
L/W	4	0.51	4.77	0.45	5.8– 6.5	3.0– 3.8
V/P	4	-0.57	5.73	-0.86	1.7– 2.5	4.0– 4.6
L/ABBR	5	0.95	-2.36	3.11	5.8– 9.0	2.7– 3.6
L/RD	5	0.87	3.01	2.06	5.8– 9.0	1.3– 2.6
L/RB	5	0.61	0.08	3.67	5.8– 9.0	1.5– 2.0
L/Del.L.	5	0.83	0.45	4.50	5.8– 9.0	1.1– 1.7
L/Amb.L.	4	0.82	4.71	0.72	5.8– 6.5	1.8– 2.6
L/No.Hyd.Sl.	5	0.57	3.38	0.79	5.8– 9.0	3.0– 5.0
RD/Amb.L.	4	0.99	-0.48	0.97	1.3– 2.0	1.8– 2.6
Del.L./Amb.L.	4	0.97	0.28	0.48	1.1– 1.5	1.8– 2.6
ABL/ABW	4	-0.44	6.73	-2.09	2.9– 3.9	1.6– 1.8
ABBR/ABBRF	5	0.58	0.80	2.00	2.7– 3.6	1.0– 1.2
ZBL/ZBW	5	0.63	1.52	0.65	2.7– 3.6	2.0– 2.8
ZBBR/ZBBRF	5	0.82	-0.76	3.56	2.8– 3.7	1.0– 1.2
ABBR/RB	5	0.57	1.06	1.03	2.7– 3.6	1.5– 2.0
ABBR/RD	5	0.68	2.05	0.49	2.7– 3.6	1.3– 2.6
ABBR/Del.L.	5	0.65	1.43	1.08	2.7– 3.6	1.1– 1.7
RD/RDF	5	0.87	0.60	1.29	1.3– 2.6	0.5– 1.5
RR/RRF	5	0.92	0.32	0.26	1.0– 1.5	2.8– 4.5
RB/RBF	5	0.72	1.14	0.82	1.5– 2.0	0.7– 1.1
RD/RR	5	0.97	-1.39	2.66	1.3– 2.6	1.0– 1.5
RD/RB	5	0.68	-1.33	1.73	1.3– 2.6	1.5– 2.0
RR/RB	5	0.66	0.09	0.62	1.0– 1.5	1.5– 2.0
RD/Del.L.	5	0.96	-1.31	2.23	1.3– 2.6	1.1– 1.7
RB/Del.L.	5	0.82	0.78	0.75	1.5– 2.0	1.1– 1.7
Del.L./Gr.Ab.W.	5	0.69	-0.05	1.75	1.1– 1.7	0.8– 1.0
Amb.L./Amb.W.	4	0.53	-0.28	2.50	1.8– 2.6	0.9– 1.1
Amb.L./No.S.P.	4	0.96	-0.07	0.25	1.8– 2.6	8.0–11.0

distally, becoming distinctly triangular proximally. Stem attachment area apparently formed by secondary deposition of calcite at proximalmost tip of basals. Its form that of a very short rounded-triangular cylinder, upper margin equal to level of origin of radial; equal or slightly greater extent along intrabasal suture and apparently truncating growth lines proximally in BB sector; diameter of attachment area: 0.3-0.4 mm; stem plate has same diameter when preserved.

Azygous basal quadrate in plan view, with straight lateral and distal edges. BR sector very slightly concave proximally, flat distally parallel to BR axis; sector slightly convex normal to BR axis; adjacent sectors merge smoothly. BB sector flat parallel to BB axis, very slightly concave normal to it. BR and BB sectors ornamented by fine growth lines which parallel the growth fronts. Zygous basals pentagonal, with slightly concave lateral edges, straight distal lateral edges, and a concave medial edge. Lateral and medial BR sectors straight to very slightly concave parallel to BR axis; medial sector strongly convex, lateral sectors flat normal to BR axis. BB sector and ornament of sectors as for azygous basal. See Table 22.

Radials five, pentagonal in plan view, forming upper half of pelvis and much of vault, reaching almost to level of oral opening. Lower edge strongly convex (or two straight edges), lateral edges very slightly convex, expanding in width to level of aboral tip of ambulacrum, then contracting slightly adorally. Upper edges slope steeply inward toward one another in ambulacral sinus. Radial triangular in lateral view, with straight to very slightly convex adoral facing edge, straight aboral facing edge, and slightly concave lower edge. RB sector straight parallel to RB sector, very slightly convex normal to RB axis; adjacent sectors merge over convex surface. RR sector straight parallel to and convex normal to RR axis. RD sector at sharp angle to RR sector, straight parallel to and normal to RD axis. RB and RR sectors ornamented by fine growth lines which parallel growth fronts; RD sector ornamented by hydrospire slits which occupy most of full width of radiodeltoid suture (Pl. 13, figs. 2, 3). R.Ht.: 0.5-0.8 mm; RWB: 1.2-2.0 mm; RWA: 1.6-2.2 mm; RWD: 1.3-2.0 mm. See also Table 22.

Deltoids four, together with epideltoid forming border to oral opening (Pl. 13, fig. 6). Deltoid bi-lobed in oral view, constriction caused by impingement of ambulacra on deltoid crest. Straight adoral edge; width expands aborally on short DDF, then constricts along arcuate DAF; side plates impinge upon middle of deltoid crest, project above it; aboral part of deltoid body rhombic, relatively small. Deltoid lip ornamented by V-shaped, adorally pointing ridge; deltoid crest originates from aboral surface of deltoid lip, 0.2-0.3 mm below its upper surface; deltoid crest sharp, slopes gradually upward from its origin. Sides of deltoid crest slope steeply downward into ambulacral sinus; sides ornamented by hydrospire slits (Pl. 13, figs. 2, 3). Del.Gr.Ad.W.: 0.4-0.5 mm; Min.W.: 0.3-0.4 mm; Gr.Ab.W.: 0.8-1.0 mm; L.Crest: 0.7-1.2 mm; DR: 0.6-1.1 mm.

Anal deltoids apparently either three or four. Superdeltoid a small pentagonal-shaped plate, corresponding in outline to deltoid lip of regular deltoid; aboral edge embayed by anal opening. Suture with subdeltoid or two cryptodeltoids runs horizontally at about level of origin of deltoid crest in regular deltoid (Pl. 13, fig. 2). Subdeltoid (or two cryptodeltoids) extend(s) aborally, with part bordering anal opening internally (unknown if suture separates plates here) and limbs extending out to radial, corresponding to lower parts of deltoid body. Suture with radial convex toward radial, dropping steeply downward into ambulacral sinus. Hypodeltoid a rectangular plate, with slightly concave adoral edge, straight lateral sides which rest atop limbs of subdeltoid (or cryptodeltoids), and straight aboral edge which abuts against adoral edges of radial limbs immediately adjacent to interradial suture (Pl. 13, fig. 2). Upper surface of plate is convex in cross section; upper surface slopes downward from anal opening to radial limbs; adoral surface drops straight down into anal opening. Latter ovoid, bordered adorally by superdeltoid (internally by cryptodeltoids or subdeltoid), laterally by limbs of subdeltoid (or cryptodeltoids), and aborally by hypodeltoid. Anal opening opens directly upward at a level slightly below that of oral opening. Epi.Gr. Ad.W.: 0.4-0.7 mm; O.c.-anus: 0.3-0.4 mm; Anus W.: 0.6 mm.

Ambulacra five, largely filling an ambulacral sinus, lanceolate in plan view, slightly convex in lateral view, and rather flat in cross section (Pl. 13, figs. 3, 5, 6). Lancet narrowly lanceolate, widely exposed over almost full length of ambulacrum, with side plates abutting against its nearly vertical sides (Pl. 13, fig. 6). Lancet supported internally by two deltoids and a radial (Pl. 13, fig. 2). Upper surface of lancet bears main ambulacral tract and admedial part of side tract. Brachiolar facets on outer sloping edge of ambulacrum (Pl. 13, fig. 5), small, ovoid, supported equally by side and outer side plate. Side plate pentagonal, tapering abmedially, with convex edge against lancet, straight aboral edge, narrow abmedial edge, and two straight adoral edges, caused by embayment of relatively large triangular outer side plate. Main groove and adoral edge of side groove bordered by minor lobes and grooves. O.c.-amb.:

0.3-0.5 mm. See Table 22.

Ten hydrospire fields, occupying most of full width of ambulacral sinuses. Hydrospire slits almost completely concealed except for outermost and aboral tips of others (Pl. 13, figs. 2, 3, 6). No.Reg.Hydro.Sl.: 3-5; W.Hydro. Fld.: 0.4-0.7 mm; No.Anal Hydro.Sl.: 2-5(a); W. Anal Hydro.Fld.: 0.2-0.7 mm. Number anal hydrospires usually reduced one or two per group. Impingement of side plates on deltoid crest produces spiracle-like opening at adoral end of hydrospire fields (Pl. 13, fig. 6). Length opening: 0.3-0.5 mm; W.: 0.3-0.4 mm.

Oral opening pentagonal, width: 0.5 mm.

Distribution.— Mississippian, McCraney Formation, Illinois, U.S.A.

Remarks.— The above description is based upon the specimens in the growth series (Appendix 1). The ontogeny was discussed and illustrated by Breimer and Macurda (1972) and is further summarized in Table 22.

Genus PHAENOBLASTUS Fay, 1961b

Type species.— *Pentremites caryophyllatus* De Koninck and Le Hon, 1854.

PHAENOBLASTUS CARYOPHYLLATUS
(De Koninck and Le Hon, 1854)

Phaenoblastus caryophyllatus Breimer and Macurda, 1972, Pl. IV, figs. 8, 12.

Distribution.— Lower Carboniferous, Tournai, Belgium.

Remarks.— The ontogeny and external morphology of this species was discussed and illustrated by Macurda (1967a) and the ontogeny was reviewed by Breimer and Macurda (1972); the internal anatomy was detailed in the latter publication. R.Ht.: 0.3-2.5 mm; RWB: 1.4-2.5 mm; RWA: 2.0-5.4 mm; RWD: 1.8-5.4 mm; Del.Gr.Ad. W.: 0.5-1.0 mm; Del.Min.W.: 0.1 mm; Del.Gr.Ab.W.: 0.6-3.4 mm; L.Crest: 1.0-3.5 mm; DR: 0.7-3.4 mm. The ontogeny is further summarized in Table 23.

PHAENOBLASTUS PECKI (Macurda, 1964)
Pl. 15, figs. 1, 4

Phaenoblastus pecki Breimer and Macurda, 1972, Pl. IV, figs. 11, 15, 18.

Description.— Theca biconical in lateral view, with conical pelvis with slightly outward flaring edges; vault upward sloping, straight sides and convex top, break in profile at upper apex of radials. Vault and pelvis subequal. Theca rounded decagonal in plan view, with interradial sutures being expanded slightly outward; greatest width at aboral tip of ambulacra. L: 7.5-11.0 mm; W: 6.0-8.0 mm; V: 3.4-4.5 mm; P: 4.1-6.5 mm; Pelvic angle: 60-70°.

Basalia three, in normal position, conical in lateral view with slightly convex flare; small stem attachment area at proximal apex forms a cylindrical cap to the profile. Basals pentagonal in plan view. Stem attachment area a small cylinder covering origin of basals, apparently formed by secondary calcite secretion (Pl. 15, fig. 4). Ht: 0.3 mm; W: 0.8-0.9 mm. Azygous basal quadrate in plan view, with straight lateral and distal edges (Pl. 15, fig. 4). Small but pronounced BB sector, convex parallel to and straight normal to BB axis. BR sector very slightly convex parallel to and slightly convex normal to BR axis; adjacent BR sectors meet over very slightly convex surface. BR sector ornamented by strong growth lines, BB sector by massive ridge. Zygous basal pentagonal in plan view, with straight lateral and distal lateral edges and concave medial distal edge. Medial BR sector slightly convex parallel and normal to BR axis; lateral BR sectors flat parallel to and very slightly convex normal to BR axis. Adjacent BR sectors merge smoothly. Ornament of BR and BB sectors as for azygous basal. ABL: 3.6-5.4 mm; ABW: 2.7-3.7 mm; ABBBF: 2.6-4.5 mm; ABBR: 3.0-4.9 mm; ABBRF: 1.9-2.4 mm; ZBL: 3.0-4.8 mm; ZBW: 3.4-6.0 mm; ZBOPt: 3.6-5.4 mm; ZBBR: 3.1-4.8 mm; ZBBRF: 1.6-2.0 mm.

Radials five, forming upper half of pelvis and lower three-fourths of vault. Radial pentagonal in plan view with convex lower edge, convex lateral edges (widest medially), and two concave adoral edges which slant aborally into ambulacral sinus. Radial deeply embayed by parabolic radial sinus. Radial triangular in lateral view, with slightly convex adoral facing edge, straight aboral facing edge, and concave lower edge. RB sector straight parallel to and very slightly convex normal to RB axis, adjacent sectors meet over convex surface; merge smoothly with RR sector. RR sector very slightly convex parallel to and convex normal to RR axis. RD sector at pronounced angle to RR axis, confined to radial sinus, very slightly convex parallel to and slightly concave normal to RD axis. RB and RR sectors ornamented by strong growth lines. Length and width of RD sector covered by hydrospire slits except for narrow smooth band next to edge of radial sinus. RWB: 2.5-3.5 mm; RWA: 3.4-4.5 mm; RDW: 2.8-3.4 mm; RD: 2.5-3.5 mm; RDF: 1.0-1.5 mm; RR: 1.9-2.7 mm; RRF: 3.7-5.7 mm;

TABLE 23. Growth relationships of principal variables of *Phaenoblastus caryophyllatus* (De Koninck and Le Hon, 1854)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	15	0.89	1.37	1.34	5.2–14.9	3.5–10.0
V/P	14	0.60	-2.33	1.39	1.5– 8.9	3.7– 6.5
L/ABBR	14	0.94	-4.97	4.35	5.2–14.9	2.4– 4.4
L/RD	14	0.97	3.12	2.09	5.2–14.9	1.1– 5.1
L/RB	14	0.89	-2.03	4.86	5.2–14.9	1.6– 3.5
L/Del.L.	14	0.94	0.62	2.97	5.2–14.9	1.6– 4.3
L/Amb.L.	15	0.97	3.19	1.47	5.2–14.9	1.6– 8.0
L/NO.Hyd.Sl.	15	0.84	-3.08	2.04	5.2–14.9	4.5– 8.0
RD/Amb.L.	15	0.99	0.01	0.71	1.1– 5.5	1.6– 8.0
Del.L./Amb.L.	15	0.95	1.10	0.44	1.6– 4.3	1.6– 8.0
ABL/ABW	14	0.87	0.81	1.30	2.6– 4.4	1.6– 3.0
ABBR/ABBRF	14	0.76	1.45	1.51	2.4– 4.4	1.0– 2.0
ZBL/ZBW	14	0.83	-0.85	0.98	2.5– 4.6	2.0– 3.8
ZBBR/ZBBRF	14	0.87	1.30	2.00	2.5– 4.6	0.6– 1.5
ABBR/RB	14	0.90	0.82	1.06	2.4– 4.4	1.6– 3.5
ABBR/RD	14	0.88	2.12	0.41	2.4– 4.4	1.1– 5.1
ABBR/Del.L.	14	0.86	1.62	0.58	2.4– 4.4	1.6– 4.3
RD/RDF	15	0.86	-0.88	2.17	1.1– 5.5	1.1– 2.9
RR/RRF	15	0.95	0.37	0.28	1.0– 2.8	2.5– 8.5
RB/RBF	15	0.87	0.63	1.79	1.6– 3.5	0.6– 1.5
RD/RR	15	0.96	-1.44	2.52	1.1– 5.5	1.0– 2.8
RD/RB	15	0.92	-2.61	2.39	1.1– 5.5	1.6– 3.5
RR/RB	15	0.97	-0.51	0.97	1.0– 2.8	1.6– 3.5
RD/Del.L.	15	0.94	-1.26	1.46	1.1– 5.5	1.6– 4.3
RB/Del.L.	15	0.87	0.88	0.51	1.6– 3.5	1.6– 4.3
Del.L./Gr.Ab.W.	15	0.90	0.95	1.01	1.6– 4.3	0.6– 3.4
Amb.L./No.S.P.	15	0.99	-0.80	0.42	1.6– 8.0	5.0–20.0

RB: 2.2-2.9 mm; RBF: 1.5-1.9 mm.

Deltoids four, together with superdeltoid forming border to oral opening, confined to upper surface of theca, not forming part of lateral wall of theca (Pl. 15, fig. 1). Deltoid arrowhead shaped in plan view due to constriction by ambulacra, sinusoidal in lateral view due to origin of crest 0.4-0.7 mm below deltoid lip and slight convexity of crest. Adoral edge of deltoid bordering oral opening straight; width expands slightly along short straight DDF; width constricts along concave DAF; lateral edges of ambulacra impinge on deltoid crest, forming a spiracle-like opening; only aboral part of flanks of deltoid crest exposed externally forming a rhombic-shaped area. Deltoid lip ornamented by a horseshoe-shaped rim to oral opening and adoral part of ambulacral tract. Deltoid crest originates below deltoid crest and slopes downward in a slightly convex arc to upper apex of radial limbs. Sides of deltoid crest slope steeply downward into ambulacral sinus, ornamented by hydrospire slits. Del.L.: 2.4-2.9 mm; Del. Gr.Ad.W.: 0.5-0.7 mm; L.Crest: 1.5-1.6 mm; DR: 1.6-1.7 mm.

Anal deltoids four: a superdeltoid, two cryptodeltoids, and a hypodeltoid. Configuration of superdeltoid as for deltoid lip; aboral edge embayed by anal opening. Two spurs on lower aboral surface of superdeltoid pass aborally (0.3 mm) into two tablet-shaped cryptodeltoids which form lateral margins to anal opening; outer sides slope down into ambulacral sinus, forming part of its surface, and bearing hydrospire slits. Super-cryptodeltoid suture slopes down and in toward polar axis. Aborally tops of cryptodeltoids converge but do not quite touch. Upper surface beveled for a small hypodeltoid which is not preserved. With ambulacra in place, only the outer tips of the cryptodeltoids are exposed. Anal opening elongate, ovoid, bordered adorally by superdeltoid, laterally by cryptodeltoids internally and ambulacra externally, and hypodeltoid aborally. Anal Del.L.: 2.3-? mm; Epi.Gr.Ad.W.: 0.8-1.0 mm.

Ambulacra five, petaloid in plan view, slightly convex in lateral view (more so though at adoral end), confined to shallow ambulacral sinus. Lancet lanceolate in plan view, broadly exposed throughout ambulacral length, upper surface bearing ambulacral tract, very slightly concave in cross section; sides slope steeply downward; side plates abut against. Side plates pentagonal in plan view with convex inner edge; ad- and aboral edges straight; outer adoral edge embayed by small triangular outer side plate. Outer edge of side plate straight, forms one-third of outer edge ambulacrum while straight edge of outer side plate forms two-thirds of lateral border. Brachiolar facet elliptical, on outer sloping edge of ambulacrum. Amb.L.: 3.6-4.5 mm; Amb.W.: 1.6-1.9 mm; No.S.P.: 12-13, O.c.-lanc.: 0.5-0.7 mm.

Ten hydrospire fields, filling length and width of ambulacral sinus. In anal interarea developed across cryptoradial sutures. Seven to eight in regular groups, may be equal in number in anal interarea or reduced by up to fifty percent in number. Only the outer two or three hydrospire slits are directly exposed; the others, except for their aboral tips, are concealed by the ambulacra. Adoral entrance by way of an open spiracle-like opening (Pl. 15, fig. 1).

Oral opening pentagonal, approximately 0.7 mm wide.

Distribution.– Mississippian, Chouteau Limestone, Missouri, U.S.A.

Remarks.– The above description is primarily based upon the specimen illustrated in Plate 15, figures 1, 4. Measurements are derived from this specimen (the smallest), the holotype (Univ. Missouri 3574), and B.M. (N.H.) 30089, the largest. The ontogeny was discussed by Breimer and Macurda (1972).

This species was originally assigned to *Phaenoschisma* (Macurda, 1964). The discovery of another specimen (Pl. 15, figs. 1, 4) has made it clear there are four anal deltoids so it was therefore reassigned to *Phaenoblastus* by Breimer and Macurda (1972).

Genus KAZACHSTANOBLASTUS
Arendt, Breimer, and Macurda, 1968

Type species.– *Kazachstanoblastus carinatus* Arendt, Breimer, and Macurda, 1968.

Kazachstanoblastus Breimer and Macurda, 1972, p. 21.

KAZACHSTANOBLASTUS CARINATUS Arendt, Breimer and Macurda, 1968
Pl. 15, figs. 2,3,5-10; Table 24

Kazachstanoblastus carinatus Breimer and Macurda, 1972, Pl. V, figs. 14, 16, 17.

Description.– Theca broad, rounded, biconical, width greater than length. Pelvis broad, bowl-shaped with sloping sides (Pl. 15, fig. 5). Proximal portion convex with slight recurvature near stem attachment area; upper sides of pelvis straight. Vault angular with straight sides; top of vault slopes down to oral opening (Pl. 15, fig. 2). Cross section pentagonal with slightly convex interambulacral areas (Pl. 15, fig. 10). Greatest width in plane of aboral tip of ambulacra which is above equator; vault less than pelvis. Pelvic angle broad (94-120°). See Table 24.

Basalia form lower two-fifths of pelvis, low, broad, convex in lateral view with lowest point at origins of plates; slightly recurved to stem attachment area from origins along a short BA axis (Pl. 15, fig. 7). Pentagonal outline to basals in basal view. Stem attachment area slightly recessed above origins of basals but not above

TABLE 24. Growth relationships of principal variables of *Kazachstanoblastus carinatus* Arendt, Breimer, and Macurda, 1968

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	4	0.93	3.33	0.59	10.2–14.0	12.2–16.5
V/P	4	0.09	3.57	0.20	3.5– 6.6	6.4– 7.9
L/ABBR	4	0.93	-4.90	2.89	10.2–14.0	5.4– 6.5
L/RD	4	0.86	3.13	1.57	10.2–14.0	4.8– 6.9
L/RB	4	1.00	-0.10	2.28	10.2–14.0	4.5– 6.2
L/Del.L.	4	0.97	-0.27	2.42	10.2–14.0	4.3– 6.0
L/Amb.L.	4	0.95	3.36	1.16	10.2–14.0	6.0– 9.3
RD/Amb.L.	5	0.95	-0.54	0.84	4.8– 9.2	6.0–11.0
Del.L./Amb.L.	5	0.94	0.82	0.58	4.3– 7.5	6.0–11.0
ABL/ABW	4	0.94	1.46	0.76	6.1– 7.4	6.0– 7.8
ABBR/ABBRF	4	0.99	3.28	0.60	5.4– 6.5	3.5– 5.5
ABBB/ABBBF	4	0.16	0.92	0.03	1.0– 1.2	4.9– 6.0
ABBB/ABBR	4	0.00	1.10	0.00	1.0– 1.2	5.4– 6.5
ZBL/ZBW	4	0.93	1.97	0.44	5.2– 6.6	7.8–11.0
ZBBR/ZBBRF	4	0.58	2.38	1.02	5.1– 6.7	3.0– 4.0
ABBR/RB	4	0.99	1.25	0.71	4.5– 5.7	4.5– 6.2
ABBR/RD	4	0.87	2.22	0.50	4.5– 5.7	4.8– 6.9
ABBR/Del.L.	4	0.97	1.18	0.76	4.5– 5.7	4.3– 6.0
RD/RDF	7	0.93	1.08	1.37	4.8– 9.2	3.0– 6.0
RR/RRF	7	0.88	2.03	0.32	4.1– 7.5	8.5–18.8
RB/RBF	7	0.82	1.35	1.28	4.5–10.0	3.5– 6.2
RD/RR	7	0.90	-0.17	1.23	4.8– 9.2	4.1– 7.5
RD/RB	7	0.78	2.26	0.72	4.8– 9.2	4.5–10.0
RR/RB	7	0.94	1.69	0.63	4.1– 7.5	4.5–10.0
RD/Del.L.	5	0.93	-1.06	1.34	4.8– 9.2	4.3– 7.5
RB/Del.L.	5	0.93	1.81	0.69	4.5– 6.7	4.3– 7.5
Del.L./Gr.Ab.W.	5	0.96	1.64	0.91	4.3– 7.5	3.0– 6.5
Del.L./Anal Del.L.	4	0.98	0.22	0.93	4.3– 7.5	4.7– 8.0
Amb.L./Amb.W.	5	0.88	-2.04	6.50	6.0–11.0	1.3– 2.0
Amb.L./No.S.P.	5	0.86	0.48	0.57	6.0–11.0	9.0–17.0

interbasal sutures. Stem attachment area circular depression in low mound apparently made of secondary calcite; two circular rings ornament area outside stem attachment area which has a diameter of 1.0 mm (Pl. 15, fig. 9). Proximal stem plate occasionally preserved; circular, 1.0-1.2 mm in diameter.

Azygous basal quadrate in plan view with straight edges; length and width about equal. Each BR sector is very convex parallel to the growth axis in the proximal portion of the plate, flattening out distally; sector flat normal to axis. Two BR sectors meet at sharp angle with a median ridge separating them; plate thus has angular outline. BB sector set off by ridge from BR sector; BB sector is convex normal to the axis in the proximal portion of the sector, flattening out distally. BB sectors on adjacent plates form irregular elongate triangular area which broadens proximally from radial-basal suture; all BB sectors taken together have pattern of triradiate spicule in basal view (Pl. 15, fig. 9). Small perpendicular ridges cross interbasal suture. Short BA axis in form of ridge extends slightly upward from origin of azygous basal to stem attachment area. See Table 24.

Zygous basals pentagonal in plan view, with straight lateral edges; very slightly sinusoidal distal lateral edges; and a very slightly concave medial distal edge; width greater than length. Origin of plate same relative position as azygous basal; lowest point on theca. BR sectors parallel to BR axis as for azygous basal, being quite convex proximally and flattening out distally. Central BR sector is very slightly convex normal to BR axis; lateral BR sector bordering azygous basal slightly concave normal to axis whereas other lateral sector is flatter, thus causing an asymmetry in the plates. Central BR sector separated by ridges from lateral BR sectors. Plate thus an angular cross section. BB and BA sectors developed as on azygous basal. BR sectors of all basals ornamented with very fine growth lines parallel to BRF; in addition BR sectors of some specimens ornamented with low elongate discontinuous ridges perpendicular to basal-radial sutures. See Table 24.

Radials five, forming three-fifths of pelvis; that portion forming vault extends above oral opening almost to summit of theca. Radial pentagonal or hexagonal in plan view (Pl. 15, figs. 6, 8), relatively broad, with deep ambulacral sinus extending half the length of the plate. Lower edge of C and E radials slightly convex; A, B, and D radials have two distinct edges, being either straight or slightly sinusoidal. Radial expands adorally to greatest width at aboral tip of ambulacrum, then contracts to minimum width at radiodeltoid suture so interradial suture convex; radiodeltoid sutures slightly concave, slant toward aboral end of ambulacrum so junction of interradial and radiodeltoid sutures is highest point on radial. In lateral view radial has outline of regular triangle with upper two edges about equal. Edge toward basals straight; edge above ambulacrum slightly convex; base along interradial suture slightly concave. RD sector in deep ambulacral sinus, straight both parallel and normal to growth axis with slightly concave suture. RR sector straight parallel to growth axis, convex normal to it. In C and E radials RB sector is flat to very slightly convex both parallel and normal to the growth axis; two adjacent sectors meet at slight angle. In D radial, RB sector is straight to very slightly convex parallel to growth axis but is very slightly concave normal to it, curving upward slightly into median line of plate which is elevated. In A and B radials, RB sectors asymmetric due to continuation of slightly concave BR sectors of zygous basals which border azygous basal. Thus, RB sector of C side of B radial and E side of A smaller than other RB sector on plate; these former sectors are straight to very slightly convex parallel to growth axis but slightly concave normal to it; other two sectors of A and B radials larger, also straight to very slightly convex parallel to growth axis but very slightly convex normal to growth axis. Sectors meet at angle. Ridges separate RR from RB sectors in all radials and separate adjacent RB sectors in A, B, and D radials. Ornament of RR and RB sectors as for basals — very fine growth lines parallel to growth fronts; may have development of discontinuous ridges. (Pl. 15, figs. 6-8.) RD sector ornamented only by fine growth lines. R.Ht.: 2.2-3.0 mm; RWB: 5.7-9.0 mm; RWA: 7.0-12.0 mm; RWD: 5.4-8.9 mm. See also Table 24.

Deltoids four, together with epideltoid forming border to oral opening (Pl. 15, fig. 10). Deltoid quadrate in plan view. DDF short, bears main groove. Deltoid expands in width from oral opening along DDF, constricts slightly at adoral end of ambulacrum, then widens rapidly along DAF which is very slightly concave. Aboral border of plate is broad, DRF being slightly convex and adjacent fronts meeting at very broad angle. Deltoid lip small triangular flat area behind main grooves; small flat border at base of crest extends aborally as border to ambulacra on either side; width of flat area decreases aborally. Deltoid crest rises from area near oral opening and becomes further elevated above oral opening aborally; in lateral view crest is convex and aboral tip becomes slightly lower. Sides of crest slope steeply and unbroken into ambulacral sinus, thus together with RD sector, forming continuous ambulacral sinus. Occasionally, small nodes along adoral base of crest. Sides of crest ornamented with very fine convex growth lines parallel to radiodeltoid suture. Del.Gr.Ad. W.: 1.2-2.0 mm; Min.W.: 1.2-1.6 mm; Gr.Ab.W.: 3.0-6.5 mm; L.Crest: 3.2-6.0 mm; DR: 3.1-5.8 mm; Ht. above oral opening: 1.2-3.0 mm. See also Table 24.

Anal deltoids two, a smaller epideltoid and a large hypodeltoid. Epideltoid as for adoral one-third of regular deltoid except for anal opening which embays aboral edge. Epi-hypodeltoid suture straight, extends aborally from anal opening to ambulacrum. Hypodeltoid as for aboral two-thirds of regular deltoid except for anal opening embaying adoral edge. Hypodeltoid crest rises from aboral edge of anal opening, not rising as high above oral opening as that of regular deltoid. Ornament of hypodeltoid fine growth lines parallel to radiodeltoid suture. Anal opening ovoid to circular, with length equal to or greater than width. Level of anal opening above oral opening on upper surface of theca. Epi.Gr. Ad.W.: 1.7 mm; Anus L.: 1.0-1.5 mm; Anus W.: 0.7-1.0 mm; Hypo L.: 2.0-5.0 mm; Hypo.W.: 3.6-6.8 mm; O.c.-anus: 1.5-2.0 mm.

Ambulacra five, depressed in deep rhombic ambulacral sinus (Pl. 15, fig. 10). Adoral end of ambulacrum close to oral opening; ambulacrum elongate in plan view with slightly convex sides; greatest width near middle. Slightly convex in lateral view; relatively flat in cross section. Lancet exposed along median one-half of ambulacrum for most of its length; ambulacral tract wide. Main groove 0.06 mm wide, forms zigzag along center of lancet. Side grooves long, extend almost to edge of ambulacrum, width 0.025 mm. Seven minor lobes and grooves border main groove (Pl. 15, fig. 3); also border side groove, those along adoral edge more prominent. Side ambulacral tract relatively wide V. Brachiolar facets on lateral edge of ambulacrum, heart-shaped, L.: 0.23 mm; W.: 0.2 mm. Axis of brachiolar facet aborally rotated. Suggestion of small arcuate side plate furrow just aboral to brachiolar facet; may be due to buildup of calcite for facet. Both side and outer side plates present, 1.5 to 2 per mm. Outer side plate relatively large, rounded triangular, supports adoral half of brachiolar facet. Space between brachiolar facets greater than normal. Area between side grooves relatively flat; admedial edge normal hook-shaped outline. Aborally, area between side grooves slopes down to edge of ambulacrum. O.c.-Amb.: 1.2-1.9 mm. See also Table 24.

Regular hydrospire structures absent.

Oral opening rounded? pentagonal.

Distribution.– Lower Carboniferous, Kazachstan, U.S.S.R.

Remarks.– The above description is based upon the specimens in the growth series (Appendix 1). The internal anatomy and ontogeny of this species were described and illustrated by Breimer and Macurda (1972); ontogeny is further summarized in Table 24. The above description is an expansion of that given by Arendt, Breimer, and Macurda (1968).

Genus ARTUSCHISMA n. gen.

Type species.– ? *Phaenoschisma rossica* Arendt, Breimer, and Macurda, 1968.

Diagnosis.– Theca biconical in lateral profile, pentagonal in plan view; angle of ambulacral sinus narrow, sinus very shallow; interambulacral pyramids very low; deltoid crest slopes slightly upward, short, restricted; ambulacra linear, half of length of lancet exposed; 10 hydrospire groups, number per group limited, reduced in number in anal interarea; hydrospire slits concealed, entrance via a hydrospire cleft extending full length of ambulacrum; 3(?) anal deltoids, a superdeltoid and two cryptodeltoids (or a single epideltoid); hypodeltoid unknown if present. *Lower Carboniferous*, Namurian, Kazachstan, U.S.S.R.

Remarks.– The type species was questionably assigned to *Phaenoschisma* when it was described by Arendt, Breimer, and Macurda (1968). They commented that if the form really had an epi- and hypodeltoid, it would be an almost typical *Phaenoschisma*. Breimer and Macurda (1972, p. 223) excluded it from the genus *Phaenoschisma* but did not propose a definite generic assignment. It is not a *Phaenoschisma* because this genus has lanceolate ambulacra and the lancet is widely exposed, whereas "*P.*" *rossica* has linear ambulacra and the lancet is exposed over only half its length. It is excluded from *Pentremoblastus* and *Phaenoblastus* for the same reasons. The very narrow, shallow ambulacral sinus excludes it from the Silurian genera *Decaschisma* and *Polydeltoideus*, the Devonian genera *Caryoblastus, Cryptoschisma, Heteroschisma, Leptoschisma, Pentremitidea* and *Pleuroschisma*, and the other Mississippian/Lower Carboniferous genera *Dolichoblastus, Kazachstanoblastus*, and the undescribed genus to which "*Phaenoschisma*" *saharae* belongs. Even though the number of anal deltoids is uncertain, the other structures are clearly different from other phaenoschismatid genera so the genus *Artuschisma* is herein proposed; the name is derived from the Latin artus which refers to the narrowness of the ambulacra and ambulacral sinuses.

ARTUSCHISMA ROSSICA (Arendt, Breimer, and Macurda, 1968)
Pl. 13, figs. 12, 13

?*Phaenoschisma rossica* Arendt, Breimer, and Macurda, 1968, p. 172, 173, Pl. I, figs. 7, 9; Breimer and Macurda, 1972, Pl. V, figs. 12, 15.

Description.— Theca small, broadly conical with convex vault. Pelvis conical with break in profile at radial-basal sutures, basals having conical but slightly concave profile whereas body of radials are almost straight in profile. Cross section is rounded pentagonal with convex interambulacral areas (Pl. 13, fig. 13). Greatest width in plane of aboral tips of ambulacrum. L.: 7.2 mm; W.: 5.5 mm; V.: 1.8 mm; P.: 5.4 mm; pelvic angle: 58°.

Basalia three, in normal position, form lower two-thirds of pelvis; lateral profile conical, concave, tapering proximally to a small cylindrical stem attachment area. Stem attachment area indented along interbasal sutures, filled by proximal stem plate; both attachment area and stem plate 0.6 mm in diameter; plate 0.1 mm thick. Basals pentagonal in plan view, becoming rounded triangular in proximal extremities. Azygous basal quadrate in plan view with straight sides; longer than wide. BR sector is slightly concave parallel to growth axis, straight normal to it; two sectors meet at angle so plate has angular profile. ABL: 4.1 mm; ABW: 2.5 mm; ABBBF: 3.4 mm; ABBR: 3.7 mm; ABBRF: 1.8 mm. Zygous basals pentagonal in plan view; all edges straight except for distal center which is very slightly concave. Median and lateral BR sectors slightly concave parallel to growth axes and straight normal to them; sectors meet at angle producing angular cross section to plate. ZBL: 3.9 mm; ZBW: 3.5 mm; ZBOPt: 4.2 mm; ZBBR: 3.8 mm; ZBBRF: 1.5 mm. Concavity of BR sectors in basals produces small elevations on theca at junctions of basal-radial and interradial sutures. A few growth lines preserved in proximal portion of C zygous basal indicates presence of BA growth axis in basals; no other surface ornament preserved.

Radials five, short, broad, with deep radial sinus extending three-fifths length of plate. Radial quadrate in plan view; lower edge very slightly convex or two straight sutures; lower part of lateral edge straight; expands slightly to maximum width at aboral tip of ambulacrum; converge toward deltoids, with minimum width at radiodeltoid suture; DR sutures aborally directed. Radial sinus a deep narrow V. Profile of radial triangular in lateral view with edge above ambulacrum slightly convex, longer than edge facing basals which is very slightly concave; lower edge along interradial suture concave. RD sector shallow, in narrow ambulacral sinus; no external growth front. RD sector is slightly convex parallel to growth axis, straight normal to it. RR sector straight parallel to growth axis, markedly convex normal to it due to bend in midsection of theca; upper and lower portions fairly straight normal to axis. RB sector very slightly concave parallel to growth axis and flat normal to it; two sectors merge so lower part of radial almost flat across width of plate. No surface ornament preserved. R.Ht.: 0.8 mm; RWB: 2.7 mm; RWA: 3.2 mm; RWD: 1.2 mm; RD: 2.5 mm; RDF: 0.7 mm; RR: 1.8 mm; RRF: 3.8 mm; RB: 2.0 mm; RBF: 1.4 mm.

Deltoids four, together with superdeltoid forming border to peristome (Pl. 13, figs. 12, 13). Deltoids short, confined to upper surface of theca. Quadrate in plan view; adoral edge very slightly concave; plate expands aborally along a very short DDF which bears main groove. Lateral edges slightly concave, expand in width aborally. DR suture slightly convex, directed toward peristome. Deltoid lip ornamented by an adorally directed V-shaped rim; deltoid body in form of deltoid crest which slopes downward to hydrospire field, origin slightly below level of deltoid lip. Del.L.: 1.0 mm; W.Ad.E.: 0.4 mm; Gr.Ad.W.: 0.5 mm; Gr.Ab.W.: 0.8 mm; L.crest: 0.5 mm; DR: 0.5 mm.

Preserved anal deltoids apparently three, a superdeltoid and two cryptodeltoids. Superdeltoid quadrate, with very slightly concave adoral edge; expands in width along straight, short DD sutures; DAF very slightly concave, parallel; aboral edge slightly concave against anal opening. Apparently two cryptodeltoids, thin (0.1 mm) tablet-shaped plates (L.: 0.7 mm) extending from aboral side of superdeltoid to radials, forming lateral border to anal opening. Unknown if hypodeltoid once present. Present anal opening rounded triangular, greatest width near aboral edge. O.c.-anus: 1.0 mm; to aboral edge of "anus": 2.0 mm; Super.Gr.Ad.W.: 0.6 mm. Length of opening in anal interarea: 1.0 mm; width: 1.2 mm.

Ambulacra five, linear, slightly convex in lateral profile, side plates preserved only on D ambulacrum. Lancet exposed for one-half of its length; V-shaped upper profile; impressions of side plates visible (Pl. 13, figs. 12, 13). Uppermost surface of lancet very slightly below level of surrounding plates. Oral center to ambulacrum: 0.5 mm; Amb.L.: 2.9 mm; approximately 9 side plates per side.

Ten hydrospire groups, two per group except in anal interarea where one; two slits visible in V-shaped depression along either side of lancet when side plates removed. Slits long, parallel lancet. When side plates present, entrance to hydrospire groups apparently a hydrospire cleft extending full length of ambulacrum.

Oral opening rounded pentagonal; width: 0.6 mm.

Distribution.— Lower Carboniferous, Kazachstan, U.S.S.R.

Remarks.— The above description is based upon the holotype which is the only known specimen (PIN 1788/8). This description is an expanded version of one given earlier by Arendt, Breimer, and Macurda (1968).

Genus DOLICHOBLASTUS
Breimer and Macurda, 1972

Type species.— *Codaster shimanskii* Arendt, Breimer, and Macurda, 1968.

Dolichoblastus Breimer and Macurda, 1972, p. 21.

DOLICHOBLASTUS SHIMANSKII
(Arendt, Breimer, and Macurda, 1968)
Pl. 16, figs. 1, 2, 5

Dolichoblastus shimanskii Breimer and Macurda, 1972, Pl. VI, figs. 1, 4.

Description.— Theca conical, elongate with convex vault. Pelvic profile conical, with slight flaring at junction of radials and basals; profile expanded in upper part of pelvis due to radial wings formed along upper part of interradial suture; wings hemispherical. In cross section theca is pentagonal with points along radial wings. Ambulacral areas convex, recurved into radial wings; interambulacral areas thus slightly concave. Greatest width in plane of aboral ends of ambulacra. Parts of theca damaged. L.: > 21.5 mm; W.: 13.0 mm.

Basalia three, forming slightly more than one-half of pelvis; conical in lateral view; proximal extremities broken. Outline strongly pentagonal in basal view. Azygous basal rhombic in plan view. Two BR sectors of azygous basal essentially flat parallel to growth axis, very slightly convex normal to it. Two growth sectors meet at pronounced angle along median line of plate, making cross section angular in profile. ABL: > 11.1 mm; ABW: 6.3 mm; ABBBF: > 9.6 mm; ABBR: > 10.1 mm; ABBRF: 3.5 mm. Zygous basals pentagonal in plan view; edges straight except for distal central edge which is slightly concave. Three BR sectors of lateral and central portions of plate flat both parallel and normal to growth axes; meet at pronounced angle so plate has sharply angular profile in cross section. ZBL: > 11.0 mm; ZBW: 8.0 mm; ZBOPt: > 11.5 mm; ZBBR: > 11.0 mm; ZBBRF: 2.5 mm. Basals are ornamented with fine growth lines parallel to basal-radial sutures with regularly spaced small beady granular ornament sited on top of welt between growth lines. In upper part of BR sectors and lower part of RB sectors, ornament of adjacent welts aligned, producing small ridges perpendicular to radial-basal sutures. Rate of growth in BB sectors very slow; little development. Boundaries between BR sectors marked by ridges with beaded ornament.

Radials five, pentagonal in plan view, with convex (C and E radials) or two straight (A, B, and D radials) lower edges. Width of plate increases adorally, flaring outward in radial wing, then contracting to minimum width at aboral apex of deltoids; interradial suture thus convex; radiodeltoid sutures straight; short radial sinus. Lateral view of radial along median line of plate triangular, with lower edge slightly concave, ambulacral edge slightly convex; third edge from aboral end of ambulacrum to radial-basal suture very slightly convex. Profile along median line modified laterally by radial wing which is a convex hump in the upper part of the plate. RB sector very slightly convex parallel to growth axis in all radials; in C and E radials flat normal to growth axis and two adjacent sectors in same plane; in A, B, and D radials, RB sector is slightly convex normal to growth axis and adjacent RB sectors meet at a slight angle. Boundary line between RB and RR sectors a small, beaded ridge. RR sectors are concave parallel to growth axis where passing into radial wing; sector convex normal to axis. Radial wing sited along upper two-thirds of interradial suture, ellipsoidal in plan view, greatest dimension parallel to suture, hump-shaped in lateral view, produced by gradual increase in thickness of calcite secreted along RR front. Length of hump: 6.0 mm; height: 1.7 mm. RB and RR sectors ornamented by fine growth lines parallel to sutures with regularly spaced small beady granular ornament as in the basals.

Growth lines on radial wing. RD sector flat both parallel and normal to RD growth axis, forming part of a shallow ambulacral sinus. In lower part of RD sector, growth lines bend into it from RR sector; growth lines in form of low ridges visible between hydrospire slits in RD sector; no granulose ornament. RD sectors at aboral end of ambulacrum (aboral to second hydrospire slit) slightly set off from more adoral portions of sectors as a triangular area in a slightly different plane. R.Ht.: 1.2 mm; RWB: 5.2 mm; R width wing: 8.3 mm; RWD: 4.7 mm; RD: 3.1 mm; RDF: 1.7 mm; RR: 4.0 mm; RRF: 10.5 mm; RB: 8.8 mm; RBF: 2.7 mm. Deltoids four, short, confined to upper surface of vault, together with epideltoid forming border to peristome (Pl. 16, fig. 1). Deltoid hexagonal in plan view with concave adoral edge bordering oral opening (width: 0.5 mm). Plate widens aborally along DDF to adoral end of ambulacrum. Edges bordering ambulacra constrict slightly and then broaden aborally; slightly concave in outline. DRF meet at fairly broad angle. Edge bordering oral opening and DDF ornamented with minor lobes and grooves (width of ornament on adjacent deltoids: 0.4 mm); ornament of remainder of plate unknown due to chipping. Aboral part of plate bears two sets of exposed hydrospire slits but unknown if external growth front or deltoid crest between. Del.L.: 4.3 mm(a); Gr.Ad.W.: 2.0 mm; Gr.Ab.W.: 4.0 mm; DR: 2.2 mm(a).

Anal deltoids two; an epi- and hypodeltoid. Configuration of epideltoid as for regular deltoid except aboral portion where anal opening present (Pl. 16, fig. 1). Hypodeltoid not preserved but facets clearly indicate its presence; surrounded by epideltoid and radials; hemispherical shape. Anal Del.L.: 4.3 mm(a); width adoral edge epideltoid: 0.8 mm; Epi.Gr.Ad.W.: 2.5 mm; Hypo.W.: 1.5 mm. Anal opening, L.: 1.5 mm(a); W.: 1.0 mm. Oral center to adoral edge anus: 2.2 mm; to anus-epi-hypodeltoid suture: 3.2 mm; to epi-hypodeltoid-radial suture: 3.5 mm.

Ambulacra five, sublanceolate in plan view with slightly convex sides; convex in lateral view (Pl. 16, figs. 2, 3). Lancet exposed (0.3 mm) along adoral half of ambulacrum; concealed aboral half. Upper surface of lancet forms a sharp V; indentations of side plates visible on it. Side and outer side plates present. Ambulacrum convex in cross section with brachiolar facets on outer sloping edge. Latter are heart-shaped, L.: 0.3 mm; W.: 0.2 mm, equally developed on side and large triangular outer side plates. Both plates appear to form lateral edges of ambulacrum, more so the outer side plate. Oral center to ambulacrum: 1.6 mm; Amb.L.: 3.8 mm; Amb.W.: 1.0 mm. Approximately 10 side plates each side of ambulacrum.

Eight hydrospire fields, exposed except for aboral half of innermost slit; lacking in anal interarea. Three hydrospire slits per group, elongate, parallel to ambulacrum; occupy aboral part of deltoid and RD sector of radial. Length of field: 3.0 mm; width: 1.3 mm.

Oral opening ovoid, width: 1.0 mm.

Distribution.– Lower Carboniferous, Kazachstan, U.S.S.R.

Remarks.– This species was described from a single specimen by Arendt, Breimer, and Macurda (1968). The above description is an expansion of the original, giving additional data.

FAMILY OROPHOCRINIDAE Jaekel, 1918

Genus BRACHYSCHISMA Reimann, 1945

Type species.– *Codaster corrugatus* Reimann, 1935.

Brachyschisma Breimer and Macurda, 1972, p. 22.

BRACHYSCHISMA CORRUGATUM (Reimann, 1935)
Pl. 16, figs. 3,4,6-13; Table 25

Brachyschisma corrugatum Breimer and Macurda, 1972, Pl. VI, figs. 2,5,6,15.

Description.– Theca conical to parachute-shaped (Pl. 16, fig. 4); pelvic profile varied from: almost conical with relatively broad basalia which are slightly convex in lateral view with straight sided radials inclined slightly outward from basalia to: narrower, conical basalia with radials strongly inclined outward; here radial intersects basals at marked angle, causing abrupt break in profile. Pelvic angle 70-75°; however, angle of intersection of radials and basals varies from 15° to 30°. Vault convex, parabolic. Greatest width at ambulacral tips; cross section decagonal with sharply indented interambulacral areas (Pl. 16, figs. 3,6,7). See Table 25.

Basalia three, in normal position, steeply conical in lateral profile with straight to slightly convex sides; form approximately one-half of pelvis. Outline pentagonal in basal view, becoming rounded pentagonal medially and circular proximally. Basals taper toward a point at base; outline modified by somewhat warty secondary deposit of calcite (Pl. 16, fig. 11) which is thicker and extends farther distally along interbasal sutures; truncates BB growth lines except for growth line nearest suture which may extend across. Secondary deposit circular in cross section, tapering proximally.

TABLE 25. Growth relationships of principal variables of *Brachyschisma corrugatum* (Reimann, 1935)

Variables	n	r	a_0	a_1	Observed y	Range x
L/W	7	0.96	2.32	0.88	8.3–14.5	7.0–14.5
V/P	6	-0.25	7.35	-0.24	4.2– 6.8	6.7– 9.2
L/ABBR	7	0.94	2.76	2.10	8.3–14.5	2.7– 5.7
L/RD	7	0.83	4.31	1.72	8.3–14.5	3.0– 6.4
L/RB	7	0.96	0.11	2.50	8.3–14.5	3.4– 6.0
L/Del.L.	7	0.64	6.24	1.40	8.3–14.5	2.8– 5.8
L/Amb.L.	7	0.82	4.50	1.17	8.3–14.5	4.2– 9.3
L/No.Hyd.Sl.	7	0.73	2.10	1.70	8.3–14.5	5.0– 8.0
RD/Amb.L.	14	0.89	0.87	0.58	3.0– 6.4	4.2– 9.5
Del.L./Amb.L.	14	0.75	1.55	0.43	2.8– 5.8	4.2– 9.5
ABL/ABW	7	0.47	2.27	0.70	3.0– 6.3	2.3– 4.9
ABBR/ABBRF	7	0.81	0.44	1.64	2.7– 5.7	1.7– 3.1
ZBL/ZBW	7	0.87	0.49	0.96	3.3– 6.0	3.2– 5.7
ZBBR/ZBBRF	7	0.53	2.98	0.82	3.3– 6.0	1.5– 3.2
ABBR/RB	7	0.97	-0.93	1.12	2.7– 5.7	3.4– 6.0
ABBR/RD	7	0.86	0.88	0.79	2.7– 5.7	3.0– 6.4
ABBR/Del.L.	7	0.62	1.94	0.61	2.7– 5.7	2.8– 5.8
RD/RDF	14	0.60	2.53	1.58	3.0– 6.4	1.0– 2.2
RR/RRF	14	0.76	1.18	0.47	2.8– 5.0	4.4– 8.3
RB/RBF	14	0.27	4.38	0.60	3.4– 6.7	1.2– 2.6
RD/RR	14	0.95	-0.74	1.37	3.0– 6.4	2.8– 5.0
RD/RB	14	0.83	0.49	0.86	3.0– 6.4	3.4– 6.7
RR/RB	14	0.87	0.92	0.63	2.8– 5.0	3.4– 6.7
RD/Del.L.	14	0.72	1.32	0.83	3.0– 6.4	2.8– 5.8
RB/Del.L.	14	0.54	2.72	0.60	3.4– 6.0	2.8– 5.8
Del.L./Gr.Ab.W.	10	0.54	2.15	1.03	4.0– 5.8	2.4– 3.2
Del.L./Anal Del.L.	10	0.25	3.19	0.36	4.0– 5.8	4.5– 5.7
Amb.L./Amb.W.	14	0.60	2.07	2.49	4.2– 9.5	1.4– 2.6
Amb.L./No.S.P.	14	0.84	2.84	0.23	4.2– 9.5	13.0–29.0

Stem attached at very bottom of theca to a circular area whose diameter scarcely exceeds that of the stem (e.g., base 2.4 mm; stem plate 2.0 mm in diameter).

Azygous basal quadrate in plan view. Lateral and distal edges straight. BR sector straight parallel to and moderately convex normal to BR axis; adjacent sectors merge smoothly over nearly flat surface. Zygous basals pentagonal with medial distal suture slightly concave; those lateral to it shorter and straight; two lateral edges straight. Median and lateral BR sectors straight to very slightly convex parallel to BR axis; median sector slightly convex normal to it while lateral sectors are very slightly convex normal to it. Basals ornamented with coarse, rugose growth lines parallel to interradial sutures; less pronounced along BB growth front. See Table 25.

Radials five, essentially quadrate in plan view with sides along interradial sutures very slightly convex, narrowest at radial basal suture, expanding outward until widest point is opposite ambulacral tip; width of radials at intersection of interradial suture and aboral tip of deltoid equal or slightly less than width of ambulacral tip (maximum difference 0.5 mm). Lower edge of radial along radial basal suture slightly convex or broadly pointed, dependent on whether intersection is with the center of a large basal or interbasal suture. Upper edge of radial along radiodeltoid suture very broad V in general outline. Radial triangular in side view with lower edge along interradial suture slightly concave; proximal facing upper edge convex with lower edge that may turn in strongly to meet the radial-basal suture; oral facing edge under ambulacrum slightly convex. RB axis slightly convex parallel and normal to RB axis; adjacent sectors merge over convex surface; merge smoothly with RR sector. RR sector slightly convex parallel and normal to RR axis. RD sector at sharp angle to RR sector, forming a shoulder to ambulacrum. RD sector slightly convex parallel to RD axis, slightly concave normal to it. RB and RR sectors ornamented by strongly rugose growth lines, approximately 2/mm. No growth lines visible in RD sector. R.Ht.: 1.9-4.6 mm; RWB: 2.1-4.5 mm; RWA: 3.6-6.7 mm; RWD: 3.5-6.8 mm. See also Table 25.

Regular deltoids four, together with superdeltoid forming border to peristome. Deltoid hexagonal in plan view, with width relatively great in relation to length (Pl. 16, fig. 12). Short straight edge borders oral opening. Width expands aborally along straight DDF, then contracts slightly aborally along concave DAF, then expands again aborally; DRF slightly convex. Adoral lateral edges of deltoid bear ambulacral tract which is fairly wide (0.6-0.7 mm). Deltoid lip ornamented by a triangular elevated mound. Aboral to this, plate rather flat except for aboral edges which are embayed by hydrospire fields, producing two inwardly concave depressions and a broad keel at the aboral edge (Pl. 16, fig. 12). Ambulacra become more elevated above deltoid aborally; lateral edges of deltoid bordering ambulacra faceted where outer side plates rest against it. Apparent infilling of hydrospire field ontogenetically. Del.Gr.Ad.W.: 1.2-2.4 mm; Min.W.: 1.0-2.2 mm; Gr.Ab.W.: 1.6-3.2 mm; DR: 1.7-3.5 mm. See Table 25.

Anal deltoids three, a super-, sub-, and hypodeltoid. Superdeltoid occupies anal interarea from oral opening to point of narrowest constriction between ambulacra (Pl. 16, fig. 10). Ornament as for deltoid of regular deltoid. Greatest width usually slightly greater than that of regular deltoid. Suture with subdeltoid depressed as both plates slope down to it; in plan view suture is convex toward oral opening.

Subdeltoid a horseshoe-shaped plate, with limb on D side shorter than that of C and not reaching to radial. D limb of subdeltoid extends to approximately aboral edge of anal opening where it abuts against hypodeltoid; narrower than C limb which extends aboral to anal opening and abuts against radial. Length of C limb from super-subdeltoid suture to subdeltoid-radial suture 2.1-2.4 mm.

Hypodeltoid roughly pentagonal. Plate inclined at sharp angle to plane of anal opening and may form part of lateral wall of theca. Adoral edge forms aboral edge of anal opening; sub-hypodeltoid sutures originating on aboral lateral edge of anal opening; lateral C side bordered by subdeltoid (Pl. 16, fig. 10); aboral edge abuts against radials, D hyporadial suture may be longer. D side bordered adorally by subdeltoid, laterally by D lancet; each suture may be about equal in length and form a sharp angle between them or the subdeltoid may taper to a point, almost reaching the radial, in which case D edge of hypodeltoid almost straight. That portion of hypodeltoid which abuts against radial forming vertical wall of theca; ornamented by growth lines parallel to suture. Radials in anal interarea also have reflected growth lines in adoral portion of RD sector because of hypodeltoid. Lateral portion of hypodeltoid merges with inward sloping RD sector; in cross sections hypodeltoid has flat aboral surface with sides inclined at an angle to it. Anal opening elliptical, bordered principally by subdeltoid, aborally by hypodeltoid. Adoral edge of anal opening 2.1-2.5 mm from oral center; intersection of sub-hypodeltoid suture on C side of anal opening 3.3-3.7 mm from oral center; intersection of sub-hypodeltoid suture with radial on C side 4.3-4.8 mm from oral center. Super.L.: 1.2-2.0 mm; Super.Gr.Ad.W.: 1.8-2.3 mm; Sub.L.: 2.1-3.5 mm; Anus L.: 1.2-1.5 mm; Anus W.: 0.8-1.3 mm; Hypo.L.: 1.2-2.8 mm; Hypo.W.: 1.6-3.1 mm.

Ambulacra five, lanceolate, with sharply angular corners laterally and aborally. Ambulacrum convex in lateral view, strongly elevated above surrounding plates. Lancets five, completely concealed by side and outer side plates except for small rhombic area at adoralmost end. Shape of lancet that of ambulacrum except not quite as wide; strongly elevated above surrounding plates; apparently a keel on lower edge near radiodeltoid suture which extends into theca. Very convex in cross section. Side plates small, pentagonal (Pl. 16, figs. 8, 12), adlateral edges forming main groove; laterally plates extend to crest of ambulacrum on either side of main groove. Outer side plates extend from crest of ambulacrum downward to hydrospire field, thus forming lateral sloping sides of ambulacrum; sutures aborally directed. Brachiolar facet (Pl. 16, fig. 13) small, heart-shaped, located just ablateral to crest of ambulacrum; facet depressed below surrounding plates, borne by side and outer side plates; length 0.20 mm; width 0.25 mm. Side grooves thus short (0.4 mm); main groove and adoral edge of side grooves bordered by minor lobes and grooves. Side grooves slope downward into main grooves. See Table 25.

Regular hydrospire fields eight, lying athwart radiodeltoid suture at right angle, from edge of lancet outward toward aboral apex of deltoid but not reaching this point (Pl. 16, fig. 12). In plan view the hydrospire fields on either side of an ambulacrum resemble a pair of human ears at right angles to the head, with the top of the ear adorally directed (Pl. 16, fig. 9). Thus the longest hydrospire is not along the border of the ambulacrum but two or three ablateral to this. Except for occasional coverage of part of innermost, hydrospire slits completely exposed to exterior. Hydrospire fields in slightly concave area of RD sector but this does not constitute an ambulacral sinus as in *Phaenoschisma* but is more analogous with the configuration of the hydrospires of *Hadroblastus*. Hydrospire field does not extend to aboral tip of radial or very far adorally beyond radiodeltoid suture. Unless hydrospires originated very late in the development of *Brachyschisma*, the entrances to earlier formed portions must have been infilled during growth; calcite on aboral part of deltoid has the appearance of a frozen wave, and is interpreted to represent a front of secondary calcite which is secreted over the hydrospire field as further growth occurs along the radiodeltoid suture. There is no such elevated feature on the radial but infilling has occurred here as well as evidenced by traces of the infilled slits along the E side of the D radial of BNHS E 12133. Length of hydrospire field varies from 1.9-3.2 mm; width 0.8-1.5 mm. Number of hydrospires 5-8 per group. Number of hydrospires per individual group per specimen may vary by one. Slits themselves narrow, internal width 0.025 mm. Internal lateral wall of hydrospire fold 0.0105 mm thick; wall of bulbous base approximately 0.0195 mm; 0.154 mm across (internal diameter).

Anal hydrospires present only on C side of anal interarea, developed across subdeltoid-radial suture. Number reduced (2-4), apparently 4 less than number in regular field. Width of field (0.2-0.6 mm) closely related to number of hydrospires; hydrospires again border lancet and extend ablaterally from it. On D side of anal interarea, D lancet extends abnormally far into interarea (Pl. 16, fig. 10), reaching as far as the hypodeltoid and occupying almost the entire area that would be the normal position of the field which is absent.

Oral opening pentagonal, with shortest axis being from superdeltoid to A ambulacrum, longest axis (1.2-1.9 mm) from BC-DE deltoid. Cover plates and brachioles unknown.

Calcite of plates shows pronounced meshwork with long thin, straight rods perpendicular to plate boundary, 0.018 mm apart, joined by cross bars 0.020 mm apart, producing a rectangular fenestrate appearance with the open mesh occupying a large percentage of the total area. Fenestrate pattern apparently most clearly developed just below plate surface.

Distribution.– Devonian, Onondaga and Tichenor limestones, New York, U.S.A.

Remarks.– The above description is based upon the specimens in the growth series (Appendix I). The internal anatomy and ontogeny of this species were discussed and illustrated by Breimer and Macurda (1972) and are further discussed in Table 25.

Reimann (1935) described two species of *Codaster* (*C. corrugatus* and *C. curtus*) which were synonymized by Breimer and Macurda (1972). In 1945 Reimann made *C. corrugatus* the type species of a new genus, *Brachyschisma*, and described two additional species, *B. subcrassum* and *B. subumbrosum*. He noted that a large series of specimens might prove the last two named species to be variable expressions of the first. An ontogenetic analysis (Breimer and Macurda, 1972) revealed no discontinuities in the three species in question so the latter two were synonymized with *B. corrugatus*.

Fay (1962, Pl. II, figs. 2,4,5,6) showed the subdeltoid in contact with radial on the D side of the anus. The specimen in the first two figures is too poorly preserved on the D side of the anus to determine any configuration as the plates bordering the anus on the D side have been weathered away. The prong of the subdeltoid of the specimen figured in the last two figures abuts against the hypodeltoid, not the radial. This would imply that Fay's other figure (1961, text-fig. 4 – configuration same as above) of the anal deltoids should be reinvestigated if the material in question is ever located. Fay (1961) also described two hydrospire slits on the D side of the anus in the specimen which he illustrated in text-figure 4, noting that they appeared to be in an incipient stage of development and did not appear to penetrate the plates at depth. He further illustrated this specimen in Plate 6, figure 9, but inked in the "hydrospires" on the figure so it is impossible to determine what features are actually present. One of his inked lines appears to follow what would be the boundary between the abnormally large CD side of the D lancet and radial as in Plate 16, figure 10. None of the specimens described above appear to have hydrospires on the D side of the anal interarea. Thin sections originally prepared by Reimann (1945, Pl. 5, fig. 8) and Breimer and Macurda (1972) demonstrate their absence, thus resulting in an asymmetry in the hydrospires of this blastoid. Fay (1962) also lists only nine hydrospire fields.

BRACHYSCHISMA? OOSTHEIZENI
Breimer and Macurda, 1972

Brachyschisma? *oostheizeni* Breimer and Macurda, 1972, p. 22,23, Pl. VI, figs. 3,10.

Description.– Theca broadly conical, with wide, broad convex vault, and conical pelvis; profile of latter slightly concave near tip of radials. Pelvis approximately two-three times length of vault. Greatest width at aboral tips of ambulacra; cross section here angular decagonal with indented interambulacral areas. Thecae of intermediate size, length and width about subequal, largest specimen approaches 20 mm. Pelvic angle large.

Basalia form conical base of theca, tapering to a proximal stem attachment area. Detail of latter unknown, diameter approximately 1.5 mm. Azygous basal unknown. Zygous basals pentagonal, with slightly concave upper edges and straight lateral edges; in normal position. BR sectors straight parallel to BR axis and slightly convex normal to it; adjacent sectors merge smoothly over more convex surfaces. BB sectors evident; both BB and BR sectors ornamented with growth lines. Length and width of zygous basal about equal (e.g., ZBL: 6.0 mm; ZBW: 5.7 mm; ZBBR: 5.5 mm; ZBBRF: 2.5 mm).

Radials five, forming upper half of pelvis and part of vault profile. In lateral view radial is triangular, with straight base along interradial suture, slightly convex oral facing edge and slightly concave basal facing edge. Height of radial large relative to width (e.g., radial height above interradial suture 3 mm while RWB: 5.3 mm, RWA: 5.3 mm, and RWD: 4.8 mm). In plan view radial is hexagonal, with straight lateral edges, slightly convex lower edges, and straight upper edges; moderate radial sinus. Aboral tip of radial a rounded point. RB sector of moderate size, longer than wide, slightly concave parallel to RB axis (mostly near origin of radial), slightly convex normal to RB axis, merges evenly with adjacent RB sector and RR sector over slightly convex surfaces. Also merge smoothly with basals. RR sector larger, varies from slightly concave near origin, then straight parallel to RR axis to slightly convex throughout; slightly convex normal to RR axis. RB and RR sectors ornamented by fairly pronounced growth lines. RD sector at pronounced angle to RR sector, former being part of upper convex surface, latter part of vertical side of theca. RD sector relatively long and narrow; relatively straight to slightly convex parallel to RR axis and slightly concave normal to it. RD sector forms slightly sloping shoulder to ambulacrum which is strongly elevated above it. Aborally, RD sector becomes less distinct and merges into round tip of radial. Growth parameters of one radial: RD: 3.6 mm; RDF: 1.8 mm; RR: 2.8 mm; RRF: 5.9 mm; RB: 4.7 mm; RBF: 2.7 mm.

Deltoids four, bordering peristome, deltoid lip small, deltoid body relatively much larger, both rhombic-shaped; deltoid lip has straight edges along DDF, contracting along DAF, then aboral part expands aborally along straight DAF. Deltoid is slightly convex in lateral view; deltoid apparently relatively flat, deltoid body has very pronounced hump in center (up to 0.8 mm above edges) which extends to edge of thecal outline;

deltoid slopes downward laterally to lowest edge of ambulacra and into slightly concave RD sector. Parameters of a deltoid: L.: 3.7 mm; Gr.Ad.W.: 1.2 mm; Min.W.: 0.5 mm; Gr.Ab.W.: 1.5 mm; length of deltoid lip one-third that of deltoid body.

Number of anal deltoids unknown. Hypodeltoid present, with slightly convex aboral suture, lies in same plane as anal sector of RD sector of D radial, merging evenly with it. Anal opening opens on upper surface of theca; outline indeterminate.

Ambulacra five, lanceolate in plan view, rounded tip (tip of radial projecting slightly beyond), convex in lateral view, strongly elevated above surrounding plates at RD suture (up to 0.8 mm), decreasing ad- and aborally therefrom. Form high points of vault profile. Lancet concealed. Pentagonal side plates form two rows of plates centered along ambulacral groove. Form half of ambulacral width, slope inward toward main groove. Outer side plates form outward sloping and vertical edges of ambulacrum, completely separating side plates from radial or deltoid. Parameters of an ambulacrum: Amb.L.: 5.5 mm; Amb.W.: 1.5 mm; 3 side plates per mm. O.c. to ambulacrum: 0.8 mm.

Eight hydrospire groups preserved, outline triangular, with slits in slight concavity in RD sector and on aboralmost part of deltoid; occupying full width of RDF. Lacking on D side of anus. C side not observed. Five to eight hydrospires observed in different specimens; most of length is developed on radial, very short on deltoids. Parameters: L.: 3.5 mm; W.: 1.5 mm for 5-6 hydrospires.

Oral opening pentagonal, width of one: 0.8 mm; width of main groove on deltoid: 0.3 mm. Peristomal plates preserved in one specimen?

Distribution.– Devonian, Bokkeveld Beds, Union of South Africa.

Remarks.– The above description is an enlargement of that given by Breimer and Macurda (1972). It is based on six fragmentary specimens preserved as external casts in a greenish shale. They are too fragile to permit casting. The only other Devonian blastoid which resembles them in form is *Brachyschisma* but the lack of knowledge on the number of anal deltoids prevents a definite generic assignment of this form.

Genus KATOBLASTUS Macurda, 1967a

Type species.– *Pentremites püzos* Munster, 1843.
Katoblastus Breimer and Macurda, 1972, p. 24.

KATOBLASTUS KONINCKI Macurda, 1967a
Table 26

Katoblastus konincki Breimer and Macurda, 1972, Pl. VI, figs. 7,8,12.

Distribution.– Lower Carboniferous, Tournai, Belgium.

Remarks.– The ontogeny and external morphology of this species was discussed and illustrated by Macurda (1967a) and the ontogeny was reviewed in Breimer and Macurda (1972). RWB: 1.5-2.2 mm; RWA: 2.0-3.2 mm; RWD: 1.8-2.4 mm; Del.Gr.Ad.W.: 0.5-0.8 mm; Del.Gr.Ab.W.: 0.5-0.9 mm; DR: 0.8-1.2 mm. The ontogeny is further summarized in Table 26.

KATOBLASTUS PÜZOS (Munster, 1843)
Table 27

Katoblastus püzos Breimer and Macurda, 1972, Pl. VI, figs. 9,11,14.

Distribution.– Lower Carboniferous, Tournai, Belgium.

Remarks.– The ontogeny and external morphology of this species was discussed and illustrated by Macurda (1967a) and the ontogeny was reviewed in Breimer and Macurda (1972); a description of the internal anatomy was also given in the latter. RWB: 1.1-2.5 mm; RWA: 1.8-3.8 mm; RWD: 1.5-3.0 mm; Del.Gr.Ad.W.: 0.4-0.6 mm; Del.Gr.Ab.W.: 0.4-1.5 mm. The ontogeny is further summarized in Table 27. The characteristics which differentiate between the two species assigned to this genus were given by Macurda (1967a, p. 473).

Genus OROPHOCRINUS von Seebach, 1865

Type species.– *Pentremites stelliformis* Owen and Shumard, 1850.
Orophocrinus Breimer and Macurda, 1972, p. 24.

Remarks.– The diagnostic characters which distinguish between the species assigned to this genus was given by Macurda (1965, p. 1056-1057).

OROPHOCRINUS CATACTUS Macurda, 1965
Table 28

Orophocrinus catactus Breimer and Macurda, 1972, Pl. VIII, figs. 2,5.

Distribution.– Mississippian, St. Joe Limestone, Arkansas and Oklahoma; Burlington Limestone, Missouri; and Lake Valley Limestone, New Mexico, U.S.A.

TABLE 26. Growth relationships of principal variables of *Katoblastus konincki* Macurda, 1967

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	7	0.85	2.38	0.68	4.5– 6.3	3.5– 6.0
V/P	7	0.16	1.95	0.09	1.9– 2.8	2.6– 4.0
L/ABBR	7	0.89	0.73	2.05	4.5– 6.3	1.8– 2.7
L/RD	7	0.84	1.70	1.73	4.5– 6.3	1.8– 2.8
L/RB	7	0.91	2.02	2.00	4.5– 6.3	1.4– 2.3
L/Del.L.	7	0.79	1.54	2.49	4.5– 6.3	1.5– 2.0
L/Amb.L.	7	0.58	2.62	1.26	4.5– 6.3	2.0– 2.8
RD/Amb.L.	7	0.80	0.26	0.84	1.8– 2.8	2.0– 2.8
Del.L./Amb.L.	7	0.47	0.89	0.32	1.5– 2.0	2.0– 2.8
ABL/ABW	7	0.95	-0.37	1.60	2.0– 3.0	1.5– 2.1
ABBR/ABBRF	7	0.80	1.10	1.15	1.8– 2.7	0.8– 1.4
ZBL/ZBW	7	0.89	0.46	0.74	1.9– 2.8	2.0– 3.3
ZBBR/ZBBRF	7	0.73	1.20	1.15	1.9– 2.8	0.8– 1.4
ABBR/RB	7	0.81	0.99	0.78	1.8– 2.7	1.4– 2.3
ABBR/RD	7	0.75	0.88	0.67	1.8– 2.7	1.8– 2.8
ABBR/Del.L.	7	0.48	1.31	0.66	1.8– 2.7	1.5– 2.0
RD/RDF	7	0.74	1.34	2.58	1.8– 2.8	0.2– 0.5
RR/RRF	7	0.94	-0.36	0.65	1.1– 1.9	2.2– 3.5
RB/RBF	7	0.89	-0.09	1.81	1.4– 2.3	0.8– 1.2
RD/RR	7	0.87	0.67	1.05	1.8– 2.8	1.1– 1.9
RD/RB	7	0.89	0.55	0.96	1.8– 2.8	1.4– 2.3
RR/RB	7	0.84	0.19	0.75	1.1– 1.9	1.4– 2.3
RD/Del.L.	7	0.77	0.33	1.19	1.8– 2.8	1.5– 2.0
RB/Del.L.	7	0.85	-0.20	1.22	1.4– 2.3	1.5– 2.0
Del.L./Gr.Ab.W.	7	0.37	1.23	0.59	1.5– 2.0	0.5– 0.9
Del.L./Anal Del.L.	6	0.59	0.92	0.38	1.5– 2.0	1.4– 2.4
Amb.L./No.S.P.	7	0.60	0.78	0.17	2.0– 2.8	8.0–11.0

Remarks.– The ontogeny and external morphology of this species was discussed and illustrated by Macurda (1967a) and the ontogeny was reviewed in Breimer and Macurda (1972). R.Ht.: 1.8-9.8 mm; RWB: 2.5-8.0 mm; RWA: 3.5-11.5 mm; RWD: 3.0-9.5 mm; Del. Gr.Ad.W.: 1.2-3.5 mm; Del.Min.W.: 0.5-2.1 mm; Del. Gr.Ab.W.: 1.1-4.3 mm; DR: 1.2-3.8 mm; L.Hyd.Cl.: 2.2-9.7 mm. The ontogeny is further summarized in Table 28.

TABLE 27. Growth relationships of principal variables of *Katoblastus puzos* (Munster, 1843)

Variables	n	r	a_0	a_1	Observed Range y	Observed Range x
L/W	6	0.70	0.26	1.20	3.8–10.0	3.5– 7.3
V/P	6	0.29	2.08	0.43	1.8– 6.4	2.0– 5.0
L/ABBR	6	0.95	-6.08	7.09	3.8–10.0	1.5– 2.3
L/RD	6	0.95	0.70	1.70	3.8–10.0	2.0– 5.2
L/RB	6	0.94	-2.29	4.43	3.8–10.0	1.3– 2.5
L/Del.L.	6	0.96	-0.33	3.07	3.8–10.0	1.5– 3.2
L/Amb.L.	6	0.97	1.28	1.32	3.8–10.0	2.3– 6.5
RD/Amb.L.	8	0.94	0.36	0.79	2.0– 5.5	2.3– 6.5
Del.L./Amb.L.	8	0.91	0.72	0.37	1.5– 3.2	2.3– 6.5
ABL/ABW	6	0.77	0.85	0.75	1.8– 2.9	1.3– 2.5
ABBR/ABBRF	6	0.95	0.45	1.00	1.5– 2.3	1.0– 1.8
ZBL/ZBW	6	0.81	0.61	0.65	1.5– 2.6	1.5– 2.8
ZBBR/ZBBRF	6	0.77	0.98	0.92	1.3– 2.5	0.5– 1.6
ABBR/RB	6	0.95	0.69	0.60	1.5– 5.2	1.3– 2.5
ABBR/RD	6	0.81	1.22	0.19	1.5– 5.2	2.0– 5.2
ABBR/Del.L.	6	0.85	1.08	0.36	1.5– 5.2	1.5– 3.2
RD/RDF	8	0.97	1.08	5.02	2.0– 5.5	0.2– 0.9
RR/RRF	8	0.96	0.32	0.30	1.0– 2.3	2.6– 6.2
RB/RBF	8	0.89	0.91	1.13	1.3– 2.5	0.4– 1.5
RD/RR	8	0.92	-1.00	2.80	2.0– 5.5	1.0– 2.3
RD/RB	8	0.80	-0.99	2.37	2.0– 5.5	1.3– 2.5
RR/RB	8	0.88	-0.02	0.86	1.0– 2.3	1.3– 2.5
RD/Del.L.	8	0.92	-0.62	1.91	2.0– 5.5	1.5– 3.2
RB/Del.L.	8	0.90	0.57	0.63	1.3– 2.5	1.5– 3.2
Del.L./Gr.Ab.W.	8	0.97	1.02	1.37	1.5– 3.2	0.4– 1.5
Del.L./Anal Del.L.	4	0.94	1.07	0.54	2.0– 3.0	1.7– 3.5
Amb.L./Amb.W.	5	0.69	0.32	4.93	2.3– 5.5	0.6– 1.1
Amb.L./No.S.P.	6	0.84	-1.42	0.33	2.3– 6.5	13.0–24.0

OROPHOCRINUS CELTICUS Macurda, 1965

Orophocrinus celticus Breimer and Macurda, 1972, Pl. IX, figs. 1,2.

Distribution.— Lower Carboniferous, Ireland.

Remarks.— The ontogeny and external morphology of this species was discussed and illustrated by Macurda (1965) and the ontogeny was reviewed in Breimer and Macurda (1972).

TABLE 28. Growth relationships of principal variables of *Orophocrinus catactus* Macurda, 1965

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	7	0.97	-0.87	0.92	5.7–32.2	6.8–36.4
V/P	7	0.90	0.59	0.57	1.8–12.9	3.7–20.9
L/ABBR	6	0.99	-1.79	2.97	5.7–32.2	2.5–11.5
L/RD	7	0.97	-0.19	2.29	5.7–32.2	2.1–13.5
L/RB	7	0.97	-2.97	2.65	5.7–32.2	2.7–13.6
L/Del.L.	7	0.95	-4.86	4.38	5.7–32.2	2.5– 8.6
L/Amb.L.	7	0.95	0.51	1.68	5.7–32.2	2.9–19.0
RD/Amb.L.	8	0.98	0.31	0.75	2.1–13.5	2.9–19.0
Del.L./Amb.L.	8	0.88	1.76	0.34	2.5– 8.6	2.9–19.0
ABL/ABW	6	0.97	-0.62	1.28	2.9–12.6	2.7– 9.6
ABBR/ABBRF	6	0.94	-0.50	1.77	2.5–11.5	2.0– 6.0
ZBL/ZBW	6	0.97	-1.68	1.09	2.5–12.1	3.6–11.8
ZBBR/ZBBRF	6	0.99	-0.80	2.21	2.5–11.3	1.5– 5.5
ABBR/RB	6	0.99	-0.21	0.84	2.5–11.5	2.7–13.6
ABBR/RD	6	0.95	0.51	0.78	2.5–11.5	2.1–12.2
ABBR/Del.L.	6	0.98	-0.84	1.37	2.5–11.5	2.5– 8.6
RD/RDF	8	0.92	0.79	4.68	2.1–13.5	0.7– 2.8
RR/RRF	8	0.93	1.65	0.44	2.2– 9.0	2.9–17.4
RB/RBF	8	0.79	0.88	2.39	2.7–14.0	1.7– 5.5
RD/RR	8	0.99	-1.96	1.66	2.1–13.5	2.2– 9.0
RD/RB	8	0.91	0.35	0.94	2.1–13.5	2.7–14.0
RR/RB	8	0.90	1.48	0.56	2.2– 9.0	2.7–14.0
RD/Del.L.	8	0.92	-1.33	1.83	2.1–13.5	2.5– 8.6
RB/Del.L.	8	0.90	-0.63	1.74	2.7–14.0	2.5– 8.6
Del.L./Gr.Ab.W.	8	0.94	0.69	1.64	2.5– 8.6	1.1– 4.3
Del.L./Anal Del.L.	6	0.97	-0.42	0.94	3.5– 8.6	4.0– 9.5
Amb.L./Amb.W.	8	0.93	-3.36	5.36	2.9–19.0	1.0– 3.5
Amb.L./No.S.P.	9	0.99	-3.87	0.60	2.9–19.0	13.0–38.0

TABLE 29. Growth relationships of principal variables of *Orophocrinus conicus* Wachsmuth & Springer, 1888

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	22	0.97	2.28	1.00	6.0–23.5	4.4–20.8
V/P	22	0.94	-1.70	0.61	1.2– 8.2	4.6–15.3
L/ABBR	22	0.97	-1.94	2.73	6.0–23.5	2.7– 8.0
L/RD	22	0.97	4.11	2.12	6.0–23.5	1.6– 9.6
L/RB	22	0.98	0.23	2.62	6.0–23.5	2.0– 9.1
L/Del.L.	22	0.96	-0.05	3.65	6.0–23.5	1.7– 6.0
L/Amb.L.	22	0.97	4.08	1.61	6.0–23.5	2.0–12.5
RD/Amb.L.	22	0.99	0.02	0.75	1.6– 9.6	2.0–12.5
Del.L./Amb.L.	22	0.96	1.23	0.42	1.7– 6.0	2.0–12.5
ABL/ABW	22	0.97	0.21	1.35	3.1– 8.9	2.2– 6.3
ABBR/ABBRF	22	0.95	-0.10	2.07	2.7– 8.0	1.4– 3.7
ZBL/ZBW	22	0.98	0.57	0.91	3.0– 8.0	2.8– 8.5
ZBBR/ZBBRF	22	0.89	1.10	2.00	3.0– 8.0	1.0– 3.6
ABBR/RB	22	0.94	1.10	0.89	2.7– 8.0	2.0– 9.1
ABBR/RD	22	0.92	2.44	0.71	2.7– 8.0	1.6– 9.6
ABBR/Del.L.	22	0.94	0.90	1.28	2.7– 8.0	1.7– 6.0
RD/RDF	22	0.94	-0.75	4.77	1.6– 9.6	0.5– 2.0
RR/RRF	22	0.97	-0.03	0.48	1.5– 6.5	2.9–12.9
RB/RBF	22	0.95	0.02	2.23	2.0– 9.1	0.9– 3.5
RD/RR	22	0.99	-0.72	1.56	1.6– 9.6	1.5– 6.5
RD/RB	22	0.95	-1.49	1.16	1.6– 9.6	2.0– 9.1
RR/RB	22	0.97	-0.51	0.75	1.5– 6.5	2.0– 9.1
RD/Del.L.	22	0.94	-1.70	1.64	1.6– 9.6	1.7– 6.0
RB/Del.L.	22	0.95	0.02	1.35	2.0– 9.1	1.7– 6.0
Del.L./Gr.Ab.W.	21	0.98	0.72	1.82	1.7– 6.0	0.7– 3.0
Del.L./Anal Del.L.	21	0.98	-0.18	0.88	1.7– 6.0	2.2– 6.7
Amb.L./Amb.W.	22	0.96	-3.28	5.22	2.0–12.5	0.8– 2.6
Amb.L./No.S.P.	22	0.99	-1.52	0.30	2.0–12.5	11.0–44.0

TABLE 30. Growth relationships of principal variables of *Orophocrinus gracilis* (Meek & Worthen, 1870)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	4	0.86	-4.31	1.52	14.5–18.2	12.6–15.0
V/P	4	0.35	13.78	-0.59	8.0–12.5	5.7– 8.0
L/RD	4	0.86	6.22	1.22	14.5–18.2	7.0–10.2
L/RB	4	-0.66	35.15	-3.77	14.5–18.2	4.5– 5.3
L/Del.L.	4	-0.81	28.25	-2.87	14.5–18.2	3.5– 4.8
RD/Amb.L.	6	0.92	2.69	0.54	7.0–10.2	8.2–13.1
Del.L./Amb.L.	6	-0.07	4.49	-0.02	3.5– 5.0	8.2–13.1
ZBBR/ZBBRF	4	-0.08	5.07	-0.50	3.6– 4.8	1.9– 2.1
RD/RDF	6	-0.30	4.69	-0.08	3.5– 4.5	8.5–12.4
RR/RRF	4	-0.51	4.51	-0.06	3.5– 4.0	8.5–12.4
RB/RBF	6	0.44	4.26	0.35	4.5– 5.7	1.0– 2.5
RD/RR	4	-0.79	26.64	-4.76	7.0–10.2	3.5– 4.0
RD/RB	6	-0.42	13.08	-0.93	7.0–10.2	4.5– 5.7
RR/RB	6	0.94	0.34	0.71	3.5– 4.5	4.5– 5.7
RD/Del.L.	4	-0.57	14.24	-1.42	7.0–10.2	3.5– 4.8
RB/Del.L.	4	0.09	4.71	0.06	4.5– 5.3	3.5– 4.8
Del.L./Gr. Ab. W.	6	0.86	2.81	0.78	3.5– 5.0	1.5– 3.0
Del.L./Anal Del. L.	5	0.03	4.15	0.05	4.0– 5.0	4.9– 5.6
Amb.L./Amb. W.	5	0.68	0.12	4.26	8.2–13.1	2.2– 3.0
Amb.L./No.S.P.	6	0.72	6.06	0.16	8.2–13.1	16.0–39.0

OROPHOCRINUS CONICUS Wachsmuth and Springer, 1888
Table 29

Orophocrinus conicus Breimer and Macurda, 1972, Pl. VII, figs. 1,2,4; Pl. IX, fig. 7.

Distribution.– Mississippian, Hampton Formation, Iowa, U.S.A.

Remarks.– The ontogeny and external morphology of this species was discussed and illustrated by Macurda (1965) and the ontogeny was reviewed in Breimer and Macurda (1972); a description of the internal anatomy was also given in the latter. R.Ht.: 1.0-4.5 mm; RWB: 1.9-6.0 mm; RWA: 2.4-9.0 mm; RWD: 2.0-6.5 mm; Del.Gr.Ad.W.: 0.5-2.4 mm; Del.Min.W.: 0.4-1.5 mm; Del.Gr.Ab.W.: 0.7-3.0 mm; DR: 0.5-2.5 mm; Anus L.: 0.5-2.3 mm; Anus W.: 0.3-1.5 mm; Hypo.L.: 0.5-2.4 mm; Hypo.W.: 1.0-3.7 mm; L.Hyd.Cl.: 0.6-5.4 mm. The ontogeny is further summarized in Table 29.

OROPHOCRINUS GRACILIS (Meek and Worthen, 1870)
Table 30

Orophocrinus gracilis Breimer and Macurda, 1972, Pl. VII, figs. 5-7.

TABLE 31. Growth relationships of principal variables of *Orophocrinus orbignyanus* (De Koninck, 1844)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	5	1.00	6.55	0.87	13.9–29.2	9.0–26.0
V/P	5	0.70	0.39	0.42	3.5– 8.7	10.4–20.5
L/ABBR	4	1.00	3.63	2.12	13.9–29.2	5.6–12.2
L/RD	5	0.99	7.91	1.82	13.9–29.2	3.5–11.8
L/RB	5	0.94	0.23	2.24	13.9–29.2	6.4–12.4
L/Del.L.	4	0.96	-2.17	5.18	13.9–29.2	3.0– 5.7
L/Amb.L.	5	0.95	6.80	1.61	13.9–29.2	4.3–13.0
RD/Amb.L.	6	0.99	-0.46	0.93	2.4–11.8	2.7–12.4
Del.L./Amb.L.	6	1.00	1.59	0.34	2.5– 5.7	2.7–12.4
ZBL/ZBW	5	0.92	2.89	0.58	4.8– 8.5	4.0– 9.8
ZBBR/ZBBRF	5	0.94	1.33	1.98	4.7– 9.0	1.9– 3.5
RD/RDF	8	0.79	-0.49	6.49	2.4–11.8	0.5– 1.5
RR/RRF	8	0.98	-0.93	0.50	2.2– 8.2	5.0–17.5
RB/RBF	8	0.90	3.44	1.97	4.5–12.4	1.1– 4.6
RD/RR	8	0.99	-1.08	1.58	2.4–11.8	2.2– 8.2
RD/RB	8	0.90	-3.60	1.13	2.4–11.8	4.5–12.4
RR/RB	8	0.94	-1.73	0.73	2.2– 8.2	4.5–12.4
RD/Del.L.	6	0.98	-4.93	2.77	2.4–11.8	2.5– 5.7
RB/Del.L.	5	-0.52	9.00	-0.44	6.4–11.1	3.0– 4.9
Del.L./Gr.Ab.W.	6	0.97	1.22	1.56	2.5– 5.7	0.9– 2.7
Del.L./Anal Del.L.	5	0.98	0.55	0.67	2.5– 5.7	3.0– 8.0
Amb.L./Amb.W.	6	0.92	-11.81	9.41	2.7–13.0	1.5– 2.5
Amb.L./No.S.P.	6	0.95	-1.14	0.43	2.7–13.0	10.0–31.0

Distribution.— Mississippian, Northview Formation, Missouri; and Burlington Limestone, Iowa and Missouri, U.S.A.

Remarks.— The ontogeny and external morphology of this species was discussed and illustrated by Macurda (1965) and the ontogeny was reviewed in Breimer and Macurda (1972). RWB: 3.5-6.0 mm; RWA: 5.5-7.6 mm; RWD: 4.2-5.0 mm; Del.Gr.Ad.W.: 1.8-3.0 mm; Del.Min.W.: 0.8-1.6 mm; Del.Gr.Ab.W.: 1.5-3.0 mm; DR: 2.3-2.9 mm; L.Hyd.Cl.: 4.6-8.3 mm. The ontogeny is further summarized in Table 30.

OROPHOCRINUS ORBIGNYANUS
(De Koninck, 1844)
Table 31

Orophocrinus orbignyanus Breimer and Macurda, 1972, Pl. VII, figs. 3,8.

Distribution.– Lower Carboniferous, Tournai, Belgium; and Tournaisian, England(?).

Remarks.– The ontogeny and external morphology of this species was discussed and illustrated by Macurda (1965) and the ontogeny was reviewed in Breimer and Macurda (1972). R.Ht.: 1.5-4.1 mm; RWB: 2.5-5.1 mm; RWA: 4.0-7.6 mm; RWD: 3.2-5.4 mm; Del.Gr.Ad.W.: 0.9-1.8 mm; Del.Min.W.: 0.2-1.0 mm; Del.Gr.Ab.W.: 0.9-2.7 mm; DR: 1.2-3.0 mm; Epi.Gr.Ad.W.: 1.1-2.5 mm; Epi.Min.W.: 0.6-1.5 mm; Epi.Gr.Ab.W.: 1.1-3.5 mm; L.Hyd.Cl.: 1.6-10.1 mm. The ontogeny is further summarized in Table 31.

OROPHOCRINUS PENTANGULARIS (Sowerby, 1834) Table 32

Orophocrinus pentangularis Breimer and Macurda, 1972, Pl. IX, figs. 3,6.

Distribution.– Lower Carboniferous, Tournaisian, Ireland and Worston Shale Group, Lancashire, England.

Remarks.– The ontogeny and external morphology of this species was discussed and illustrated by Macurda (1965) and the ontogeny was reviewed in Breimer and Macurda (1972). R.Ht.: 1.5-5.0 mm; RWB: 2.4-7.6 mm; RWA: 3.0-11.0 mm; RWD: 2.4-7.2 mm; Del.Min.W.: 0.4-1.5 mm; Del.Gr.Ab.W.: 1.0-4.4 mm; DR: 1.0-3.5 mm; L.Hyd.Cl.: 1.7-11.7 mm. The ontogeny is further summarized in Table 32. A few additional specimens have been collected from the Salt Hill reef knoll at Clitheroe, England since the original summary of the distribution of this species by Macurda (1965).

OROPHOCRINUS PRAELONGUS Bailey, 1886

Orophocrinus praelongus Breimer and Macurda, 1972, Pl. VIII, figs. 1,3; Pl. IX, figs. 4,5.

Distribution.– Lower Carboniferous, Ireland. Additional specimens have been discovered at Feltrim Knoll, Dublin since the original listing by Macurda, 1965.

Remarks.– The ontogeny and external morphology of this species was discussed and illustrated by Macurda (1965) and the ontogeny was reviewed in Breimer and Macurda (1972); a description of the internal anatomy was also given in the latter.

OROPHOCRINUS SALTENSIS Macurda, 1965 Table 33

Orophocrinus saltensis Breimer and Macurda, 1972, Pl. IX, figs. 8,9; Pl. X, fig. 4.

Distribution.– Mississippian, Escabrosa Formation and Redwall Limestone, Arizona, U.S.A.

Remarks.– The ontogeny and external morphology of this species was discussed and illustrated by Macurda (1965) and the ontogeny was reviewed in Breimer and Macurda (1972). R.Ht.: 1.5-7.5 mm; RWB: 1.9-5.4 mm; RWA: 2.8-8.3 mm; RWD: 2.5-7.4 mm; Del.Gr.Ad.W.: 1.0-3.0 mm; Del.Min.W.: 0.5-2.0 mm; Del.Gr.Ab.W.: 0.8-3.5 mm; DR: 0.6-3.7 mm; Epi.Gr.Ad.W.: 1.5-3.5 mm; Epi.Min.W.: 1.3-2.7 mm; Anus L.: 0.7-2.0 mm; Anus W.: 0.5-1.0 mm; Hypo.L.: 0.6-3.5 mm; Hypo.W.: 1.5-3.5 mm; L.Hyd.Cl.: 1.1-4.0 mm. The ontogeny is further summarized in Table 33.

OROPHOCRINUS STELLIFORMIS (Owen and Shumard, 1865) Table 34

Orophocrinus stelliformis Breimer and Macurda, 1972, Pl. VII, figs. 9-11.

Distribution.– Mississippian, Burlington Limestone, Iowa, Illinois, and Missouri, U.S.A.

Remarks.– The ontogeny and external morphology of this species was discussed and illustrated by Macurda (1966) and the ontogeny was reviewed in Breimer and Macurda (1972); a description of the internal anatomy was also given in the latter. R.Ht.: 1.0-11.5 mm; RWB: 1.5-9.5 mm; RWA: 2.3-15.1 mm; RWD: 2.0-12.5 mm; Del.Gr.Ad.W.: 0.9-4.4 mm; Del.Min.W.: 0.4-2.5 mm; Del.Gr.Ab.W.: 0.6-4.9 mm; DR: 0.6-4.7 mm; Epi.Gr. Ad.W.: 1.2-6.0 mm; Anus L.: 0.7-2.8 mm; Anus.W.: 0.6-2.0 mm; Hypo.L.: 0.6-5.4 mm; Hypo.W.: 1.1-5.0 mm; L.Hyd.Cl.: 0.8-6.4 mm. The ontogeny is further summarized in Table 34.

OROPHOCRINUS VERUS (Cumberland, 1826) Table 35

Orophocrinus verus Breimer and Macurda, 1972, Pl. VIII, figs. 4,6; Pl. X, fig. 7.

Distribution.– Lower Carboniferous, Visean, Ireland and Worston Shale Group, Lancashire, England.

Remarks.– The ontogeny and external morphology of this species was discussed and illustrated by Macurda (1966) and the ontogeny was reviewed in Breimer and Macurda (1972); a description of the internal morphology

TABLE 32. Growth relationships of principal variables of *Orophocrinus pentangularis* (Sowerby, 1834)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	6	0.96	1.00	1.45	9.1–35.0	6.4–24.8
V/P	7	0.64	0.70	0.34	2.5–12.9	6.6–27.0
L/ABBR	5	0.99	-2.65	3.15	9.1–34.2	3.7–11.7
L/RD	6	1.00	2.47	2.82	9.1–35.0	2.4–12.0
L/RB	6	0.98	0.62	2.23	9.1–35.0	3.9–16.0
L/Del.L.	6	0.99	-1.34	5.78	9.1–35.0	1.9– 6.4
L/Amb.L.	6	0.99	3.97	2.01	9.1–35.0	3.2–15.0
RD/Amb.L.	7	0.98	0.75	0.69	2.4–13.0	3.2–18.0
Del.L./Amb.L.	7	0.98	1.17	0.32	1.9– 6.4	3.2–18.0
ABL/ABW	5	0.92	1.08	1.39	4.0–12.7	2.2– 7.7
ABBR/ABBRF	5	0.70	3.17	1.43	3.7–11.7	1.3– 5.0
ZBL/ZBW	5	0.97	0.61	1.03	3.9–12.4	2.8–10.5
ZBBR/ZBBRF	5	0.87	2.14	1.77	3.5–12.5	1.0– 5.3
ABBR/RB	5	0.99	0.76	0.74	3.7–11.7	3.9–15.1
ABBR/RD	5	0.99	1.50	0.92	3.7–11.7	2.4–10.8
ABBR/Del.L.	5	0.99	0.75	1.73	3.7–11.7	1.9– 6.4
RD/RDF	6	0.92	-0.85	7.97	2.4–12.0	0.5– 1.6
RR/RRF	6	0.99	0.45	0.34	2.0– 7.5	5.0–21.0
RB/RBF	6	0.94	-0.20	3.48	3.9–16.0	1.1– 4.4
RD/RR	6	0.99	-1.26	1.68	2.4–12.0	2.0– 7.5
RD/RB	6	0.98	-0.65	0.79	2.4–12.0	3.9–16.0
RR/RB	6	0.99	0.41	0.47	2.0– 7.5	3.9–16.0
RD/Del.L.	6	0.98	-1.20	2.02	2.4–12.0	1.9– 6.4
RB/Del.L.	6	0.96	-0.24	2.45	3.9–16.0	1.9– 6.4
Del.L./Gr.Ab.W.	7	0.94	1.30	1.36	1.9– 6.4	1.0– 4.4
Del.L./Anal Del.L.	4	0.79	1.61	0.56	4.2– 6.4	5.8– 9.2
Amb.L./Amb.W.	7	0.97	-3.66	5.98	3.2–18.0	1.0– 3.4
Amb.L./No.S.P.	7	0.50	7.12	0.18	3.2–18.0	3.8–45.0

was also given in the latter. R.Ht.: 2.4-7.3 mm; RWB: 4.0-7.5 mm; RWA: 6.0-14.5 mm; RWD: 4.4-7.5 mm; Del.Min.W.: 0.7-1.6 mm; Del.Gr.Ab.W.: 1.7-3.6 mm; DR: 1.5-4.0 mm; L.Hyd.Cl.: 4.6-15.0 mm. The ontogeny is further summarized in Table 35.

TABLE 33. Growth relationships of principal variables of *Orophocrinus saltensis* Macurda, 1965

Variables	n	r	a_o	a_1	Observed Range y	x
L/W	12	0.95	3.45	0.66	7.0–20.6	7.0–23.2
V/P	12	0.71	-2.72	0.98	1.6–10.3	5.4–12.3
L/ABBR	9	0.96	-0.69	2.71	7.0–18.4	2.8– 7.5
L/RD	12	0.95	4.33	1.43	7.0–20.6	2.3–11.4
L/RB	12	0.96	0.28	2.33	7.0–20.6	3.0– 8.3
L/Del.L.	12	0.98	1.60	2.77	7.0–20.6	2.0– 6.5
L/Amb.L.	12	0.97	4.73	1.02	7.0–20.6	3.0–15.0
RD/Amb.L.	12	0.99	0.42	0.70	2.3–11.4	3.0–15.0
Del.L./Amb.L.	12	0.99	1.13	0.37	2.0– 6.5	3.0–15.0
ABL/ABW	9	0.98	0.23	1.26	3.0– 8.4	2.5– 6.2
ABBR/ABBRF	9	0.93	1.17	1.41	2.8– 7.5	1.5– 4.5
ZBL/ZBW	12	0.95	0.50	0.88	3.0– 8.9	2.9– 9.0
ZBBR/ZBBRF	12	0.89	0.69	1.94	3.0– 8.5	1.5– 3.5
ABBR/RB	9	0.99	0.39	0.85	2.8– 7.5	3.0– 8.3
ABBR/RD	9	0.94	2.07	0.48	2.8– 7.5	2.5–11.4
ABBR/Del.L.	9	0.97	1.22	0.93	2.8– 7.5	2.0– 6.5
RD/RDF	12	0.95	0.42	3.81	2.3–11.4	0.5– 2.8
RR/RRF	12	0.95	-0.95	0.83	1.9– 7.4	3.8–10.4
RB/RBF	12	0.93	1.37	1.86	3.0– 8.3	1.0– 3.9
RD/RR	12	0.98	-0.48	1.42	2.3–11.4	1.9– 7.4
RD/RB	12	0.96	-2.33	1.55	2.3–11.4	3.0– 8.3
RR/RB	12	0.98	-1.37	1.10	1.9– 7.4	3.0– 8.3
RD/Del.L.	12	0.98	-1.53	1.86	2.3–11.4	2.0– 6.5
RB/Del.L.	12	0.98	0.76	1.15	3.0– 8.3	2.0– 6.5
Del.L./Gr.Ab.W.	12	0.97	0.61	1.67	2.0– 6.5	0.8– 3.5
Del.L./Anal Del.L.	10	0.99	-0.49	0.98	2.0– 6.5	2.5– 7.2
Amb.L./Amb.W.	12	0.97	-5.15	7.46	3.0–15.0	1.0– 2.5
Amb.L./No. S.P.	12	0.95	-1.08	0.34	3.0–15.0	11.0–45.0

TABLE 34. Growth relationships of principal variables of *Orophocrinus stelliformis* (Owen & Shumard, 1850)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	39	0.96	3.52	0.62	5.4–32.2	5.6–42.0
V/P	39	0.72	-2.02	0.92	1.1–15.2	4.0–17.0
L/ABBR	39	0.98	-0.37	2.75	5.4–32.2	2.2–12.2
L/RD	39	0.95	4.99	1.28	5.4–32.2	1.8–17.0
L/RB	39	0.96	0.23	2.01	5.4–32.2	2.2–13.0
L/Del.L.	39	0.95	1.62	2.55	5.4–32.2	1.9–10.8
L/Amb.L.	39	0.93	5.80	0.91	5.4–32.2	2.4–25.5
RD/Amb.L.	39	0.99	0.54	0.72	1.8–17.0	2.4–25.5
Del.L./Amb.L.	39	0.98	1.69	0.35	1.9–10.8	2.4–25.5
ABL/ABW	39	0.97	0.14	1.19	2.5–14.0	2.0– 9.6
ABBR/ABBRF	39	0.94	0.43	1.47	2.2–12.2	1.3– 6.8
ZBL/ZBW	39	0.98	0.45	0.83	2.4–12.4	2.3–13.4
ZBBR/ZBBRF	39	0.92	0.26	2.03	2.2–12.2	1.2– 5.1
ABBR/RB	39	0.93	0.52	0.69	2.2–12.2	2.2–13.0
ABBR/RD	39	0.93	2.15	0.44	2.2–12.2	1.8–17.0
ABBR/Del.L.	39	0.93	0.95	0.89	2.2–12.2	1.9–10.8
RD/RDF	39	0.93	1.85	4.32	1.8–17.0	0.3– 4.5
RR/RRF	39	0.98	-0.64	0.72	1.6–11.6	2.7–17.1
RB/RBF	39	0.94	0.68	2.53	2.2–13.0	1.0– 5.5
RD/RR	39	0.99	-1.40	1.58	1.8–17.0	1.6–11.6
RD/RB	39	0.97	-3.21	1.51	1.8–17.0	2.2–13.0
RR/RB	39	0.99	-1.20	0.96	1.6–11.6	2.2–13.0
RD/Del.L.	39	0.97	-2.34	1.94	1.8–17.0	1.9–10.8
RB/Del.L.	39	0.96	0.86	1.24	2.2–13.0	1.9–10.8
Del.L./Gr.Ab.W.	39	0.99	0.43	2.03	1.9–10.8	0.6– 4.9
Del.L./Anal Del.L.	39	0.99	-0.30	0.93	1.9–10.8	2.4–12.2
Amb.L./Amb.W.	39	0.96	-6.56	6.86	2.4–25.5	0.9– 4.5
Amb.L./No.S.P.	39	0.99	-1.12	0.36	2.4–25.5	10.0–70.0

TABLE 35. Growth relationships of principal variables of *Orophocrinus verus* (Cumberland, 1826)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	8	0.98	3.20	0.89	15.4–31.2	14.2–32.4
V/P	8	0.36	3.96	0.54	5.9–16.7	5.7–14.5
L/ABBR	8	0.95	-2.45	3.59	15.4–31.2	5.0– 9.4
L/RD	8	0.97	8.35	1.19	15.4–31.2	6.3–19.8
L/RB	8	0.81	0.81	2.58	15.4–31.2	5.5–11.0
L/Del.L.	8	0.74	2.92	3.62	15.4–31.2	3.9– 6.9
RD/Amb. L.	8	0.99	-0.17	0.86	6.3–19.8	7.4–22.9
Del.L./Amb.L.	8	0.91	2.52	0.20	3.9– 6.9	7.4–22.9
ABL/ABW	8	0.87	-1.64	1.58	5.6–10.4	4.8– 7.5
ABBR/ABBRF	8	0.90	-1.82	2.28	5.0– 9.4	3.0– 4.7
ZBL/ZBW	8	0.89	-0.69	0.96	5.0– 9.4	5.7– 9.5
ZBBR/ZBBRF	8	0.88	2.38	1.46	5.0– 9.5	2.0– 4.9
ABBR/RB	8	0.89	0.71	0.74	5.0– 9.4	5.5–11.0
ABBR/RD	8	0.94	3.30	0.30	5.0– 9.4	6.3–19.8
ABBR/Del.L.	8	0.77	1.55	0.99	5.0– 9.4	3.9– 6.9
RD/RDF	8	0.60	3.16	5.06	6.3–19.8	0.9– 2.3
RR/RRF	8	0.94	1.34	0.33	4.0– 8.5	9.5–20.5
RB/RBF	8	0.82	2.58	1.67	5.5–11.0	2.2– 4.5
RD/RR	8	0.97	-6.85	3.06	6.3–19.8	4.0– 8.5
RD/RB	8	0.73	-4.15	1.89	6.3–19.8	5.5–11.0
RR/RB	8	0.79	0.66	0.65	4.0– 8.5	5.5–11.0
RD/Del.L.	8	0.85	-6.29	3.38	6.3–19.8	3.9– 6.9
RB/Del.L.	8	0.45	4.38	0.69	5.5–11.0	3.9– 6.9
Del.L./Gr.Ab.W.	8	0.96	1.15	1.53	3.9– 6.9	1.7– 3.6
Del.L./Anal Del.L.	8	0.97	0.76	0.67	3.9– 6.9	4.8– 9.0
Amb.L./Amb.W.	5	0.96	-20.76	12.85	7.5–26.0	2.0– 3.5
Amb.L./No.S.P.	5	0.97	-3.60	0.59	7.5–26.0	19.0–48.0

Genus ACENTROTREMITES Etheridge and Carpenter, 1883

Type species.– *Mitra elliptica* Cumberland, 1826. *Acentrotremites* Breimer and Macurda, 1972, p. 25.

ACENTROTREMITES ELLIPTICUS (Cumberland, 1826)

Pl. 17, figs. 1-7; Pl. 18, figs. 3,4

Acentrotremites ellipticus Breimer and Macurda, 1972, Pl. X, figs. 3,5.

Description.– Theca large, with almost flat lower surface (the pelvis), and a broad hemispherical vault, with flattening at the top. Ambulacra extend almost to base of theca. Basals invaginated into basal concavity (Pl. 17, fig. 1). Greatest width near base of theca. Outline in plan view pentagonal, with slightly indented interambulacral areas and raised rims at aboral end of ambulacrum (Pl. 17, fig. 7). Basal view stellate due to raised RB sectors (Pl. 17, fig. 1). L.: 28.3 mm; W.: 29.3 mm (measurements are for BMNH E872).

Basalia confined to basal concavity, detailed structure not established. Phillips (1936) thought she saw only one in her thin sections, the result of the fusion of the usual three into a single pentagonal unit. She mentioned earlier authors' opinions of having seen three or five. Diameter of concavity 7.0 mm. Remnant of stem plate seen in one basal concavity.

Radials quadrate in lateral view, with lower visible edge straight, lateral sides convex, and upper edges converging at broad angle. Radial indented by deep narrow radial sinus with very slightly concave sides. Radial triangular in lateral view with short, slightly convex aboral facing edge, long slightly convex adoral facing edge, and concave lower edge. RB sector straight parallel to RB axis, slightly convex normal to it. Adjacent sectors merge smoothly over convex surface; merge smoothly with adjacent RR sectors through a slight concavity. RR sector straight parallel to RR axis, convex normal to it. RR sector merges smoothly with RD sector over slight convexity; RD sector slightly convex parallel and normal to RD axis. Aboral lip surrounding ambulacrum has rim of secondary deposit of calcite. Other parts ornamented by growth lines parallel to RDF. RWB: 6.5 mm; RWM: 15.2 mm; RWD: 12.8 mm; RD: 22.5 mm; RDF: 3.1 mm; RR: 8.8 mm; RRF: 26.2 mm; RB: 12.0 mm; RBF: 1.5 mm.

Deltoids four, together with epi- or superdeltoid forming border of oral opening. Deltoid confined to upper, flattened surface of vault externally, slightly convex in lateral view, concave in cross section due to rim along edges. Deltoid elongate hexagonal in plan view with short straight DDF, concave DAF which contracts to narrowest width at adoral end of hydrospire cleft, then widening aborally. Radiodeltoid suture gull-wing shaped, with point of flexure at edge of hydrospire cleft (Pl. 18, fig. 3). Concave toward oral opening. Radial overlaps deltoid. Del.L.: 11.2 mm; Gr.Ad.W.: 2.0 mm; Min.W.: 1.3 mm; Gr.Ab.W.: 5.8 mm.

Anal deltoids two or four, with overall outline as for regular deltoids. There is a large epi- or superdeltoid adoral to the anal opening (which begins at a position corresponding to minimum width) and two prongs lateral to the anal opening. There is a large hypodeltoid, corresponding to the aboral part of a regular deltoid. Hypodeltoid extends full aboral width of anal interarea from ambulacrum to ambulacrum. Adoral edge of hypodeltoid begins near aboral part of anal opening, then slants outward toward ambulacrum (Pl. 17, figs. 3,6). Not clear if material adoral to the hypodeltoid and forming border between anal opening and ambulacrum is one of two laterally exposed cryptodeltoids or the prong of an epideltoid. Anal opening ovoid, opening directly upward. Anal Del.L.: 11.2 mm; "Epi.L.": 3.7 mm; Anus L.: 3.2 mm; Anus W.: 1.4 mm; Hypo.L.: 8.0 mm; Hypo.W.: 5.5 mm; O.c.-anus: 1.6 mm.

Ambulacra five, sublanceolate in plan view, convex laterally, long, extending almost to base of theca (Pl. 17, fig. 7). Ambulacrum relatively flat in cross section. Edges of ambulacrum about flush with surrounding plates. Lancet covered by side plates, rhombic in cross section (Pl. 18, fig. 4). Brachiolar facets form two linear rows which are 1.3 mm apart; greater width due to lateral outgrowth of side plates. Approximately four minor lobes and grooves per side plate along main ambulacral groove (Pl. 17, fig. 5). O.c. Amb.: 1.5 mm; Amb. L.: 29.3 mm; Amb.W.: 5.5 mm; 3.5 side plates per mm or 103 per ambulacral side.

Entrance to hydrospire groups a barred cleft between ambulacrum and radial and deltoid (Pl. 17, fig. 2; Pl. 18, fig. 3). Adoral end widest, looking like a teardrop-shaped opening, bordered adorally by deltoid, laterally by ambulacrum on one side, and deltoid and radial on other (Pl. 17, fig. 2). This portion is 2.2 mm long, 0.7 mm wide. Remainder of cleft has been subdivided into "pores" by pronged outgrowths of the radial which extend to the ambulacrum (Pl. 17, figs. 4,5; Pl. 18, figs. 3,4). Barred portion of hydrospire cleft is in adoral part of RD sector, 11.8 mm long, with 17 pores in this length. Aboral to this, the cleft is completely closed off by radial growth (12.5 mm here). There are ten barred hydrospire clefts. Phillips (1936) cited four hydrospires in each group, with the development of a fifth in one.

Distribution.– The two specimens in the B.M.(N.H.) are cited as coming from the Lower Carboniferous of Somerset; Phillips' specimen came from the "Brynhyfryd Quarry, Kidwelly, Carmarthenshire, in beds of the *Dibunophyllum* zone of the Carboniferous Limestone," Wales (1936, p. 360).

Remarks.– *Acentrotremites ellipticus* has been considered to be a spiraculate blastoid because of the presence of the teardrop-shaped openings at the aboral edges of the deltoids (the "spiracles") and the "pores" which are aboral to it. The position of its "spiracles" was highly anomalous with other spiraculates, however, as was the mode of formation of the pores. By comparing this species to *Pentablastus supracarbonicus* it is possible to understand *Acentrotremites ellipticus.* The most essential difference from *Pentablastus* is the formation of outgrowths from the radial which produce a barred hydrospire cleft. *Acentrotremites* is thus a modified fissiculate, and does not belong to the spiraculates.

There has always been some confusion over the structure of the anal deltoids in *Acentrotremites ellipticus*. Beaver (1967) considered it to be an anideltoid; i.e., a solid plate pierced by the anal opening. The use of an airabrasive clearly demonstrated the presence of a hypodeltoid distinct from the other part of the anal deltoids. Cleavage reflections here were not clear enough to establish whether there are one (epideltoid) or three (super- and two cryptodeltoid) adoral plates.

Acentrotremites is a very rare blastoid. The above description was based upon two specimens in the B.M. (N.H.) (E872 and E8256). Cumberland's holotype was apparently lost during the 19th century. Phillips (1936) studied another specimen from Carmarthenshire. The top was damaged; she progressively thin sectioned the specimen from the bottom and the whereabouts of her slides could not be established. Her so-called subradial plate is almost assuredly an internal continuation of the deltoid beneath the interradial suture as determined by Joysey and Breimer (1963) in *Pentablastus.*

Genus MASTOBLASTUS Arendt,
Breimer and Macurda, 1968

Type species.– *Mastoblastus ornatus* Arendt, Breimer, and Macurda, 1968.

Mastoblastus Breimer and Macurda, 1972, p. 25.

MASTOBLASTUS ORNATUS Arendt,
Breimer and Macurda, 1968
Pl. 18, figs. 1,2,5-7; Pl. 19, figs. 1-3; Table 36

Description.– Theca broad, biconical, with conical pelvis and convex vault; vault may be equal to, but usually less than pelvis (Pl. 18, figs. 2,5). Sides of pelvis vary from very slightly convex to very slightly concave; profile widens out slightly at junction of radials and basals. Pelvic angle 84-108°. Vault convex, hemispherical. Greatest width at aboral tips of ambulacrum, usually above equator. Outline in plan view strongly pentangular, with very slightly concave interambulacral areas; profile these latter areas angular, not rounded (Pl. 19, fig. 2). See Table 36.

Basalia three, in normal position, forming lower one-half of pelvis in lateral view. Profile near stem attachment area varies from broadly conical, with small flat proximal end to more rounded, bowl-shaped with slight indentation at proximal junction of plates. Stem attachment area at proximal junction of plates, has shape of low shield volcano with slight circular depression at top for stem plate; diameter: 1.0-2.0 mm (Pl. 19, fig. 3). Buildup due to secondary calcite. Lowest point of basals usually at apparent origin and usually slightly recurved into proximal junction; secondary calcite builds stem attachment area outward. Usually a slight concavity across lower part of interbasal suture. Outline of basals strongly pentagonal in plan view. Azygous basal quadrate in plan view with straight sutures; may be slightly asymmetric (Pl. 18, fig. 1). BR sector is convex parallel to growth axis, particularly in the proximal portion; sector is also convex normal to growth axis. Adjacent sectors merge smoothly. Each zygous basal pentagonal in plan view, with straight lateral edges, very slightly convex to very slightly concave distal lateral edges, and very slightly to slightly concave distal medial edge. BR sectors, both lateral and medial, as for azygous basal; merge smoothly. Basals ornamented with faint growth lines parallel to BRF; none visible parallel to BBF. See Table 36.

Radials five, forming upper half of pelvis and lower half of vault. Quadrate in plan view (Pl. 19, fig. 1), with very slightly convex lower edge (C and E radials) or two straight edges (A, B, and D radials). Greatest width at ambulacral tip (except in smallest specimen) so width increases from base to plane of ambulacral tip, then decreases slightly to aboral tip of deltoids; interradial suture very slightly convex. Radiodeltoid sutures approach one another at 180°; suture slightly convex. Radial sinus narrow, V-shaped, extends half of length of radial. In lateral view, radial has triangular profile with lower edge (along interradial suture) slightly concave. Upper two edges about equal; edge bordering ambulacrum slightly convex; edge facing toward basals straight to very slightly convex. RD sector is very slightly convex parallel to growth axis, essentially flat normal to axis; slopes down very gradually from ambulacrum.

TABLE 36. Growth relationships of principal variables of *Mastoblastus ornatus* Arendt, Breimer, and Macurda, 1968

Variables	n	r	a_o	a_1	Observed y	Range x
L/W	10	0.96	0.24	0.86	5.8–25.4	8.0–29.5
V/P	10	0.82	0.74	0.71	2.3–11.7	2.5–14.6
L/ABBR	10	0.90	0.80	2.13	5.8–25.4	2.9–11.0
L/RD	10	0.98	1.71	2.20	5.8–25.4	2.4–10.7
L/RB	10	0.93	1.33	2.22	5.8–25.4	2.7–11.0
L/Del.L.	10	0.96	-0.14	2.09	5.8–25.4	4.0–13.0
L/Amb.L.	10	0.98	2.43	1.25	5.8–25.4	4.0–18.3
RD/Amb.L.	14	0.99	0.33	0.57	2.4–10.8	4.0–18.3
Del.L./Amb. L.	14	0.97	1.65	0.56	4.0–13.0	4.0–18.3
ABL/ABW	10	0.96	0.13	1.00	3.1–13.0	4.0–13.8
ABBR/ABBRF	10	0.95	0.79	1.41	2.9–11.0	2.1– 7.5
ZBL/ZBW	10	0.97	0.15	0.69	3.1–12.0	4.7–16.9
ZBBR/ZBBRF	10	0.91	2.21	1.27	3.2–12.2	1.9– 7.5
ABBR/RB	10	0.92	1.23	0.92	2.9–11.0	2.7–11.0
ABBR/RD	10	0.89	1.89	0.84	2.9–11.0	2.4–10.7
ABBR/Del.L.	10	0.82	1.56	0.76	2.9–11.0	4.0–13.0
RD/RDF	22	0.98	-0.36	1.83	2.4–14.4	1.5– 8.0
RR/RRF	22	0.90	1.98	0.52	2.5–11.3	3.2–18.5
RB/RBF	22	0.90	0.51	1.49	2.7–14.0	2.0– 8.3
RD/RR	22	0.93	-0.98	1.26	2.4–14.4	2.5–11.3
RD/RB	22	0.85	0.53	0.93	2.4–14.4	2.7–14.0
RR/RB	22	0.94	1.02	0.76	2.5–11.3	2.7–14.0
RD/Del.L.	10	0.96	-0.63	0.93	2.4–10.7	4.0–13.0
RB/Del.L.	10	0.87	0.64	0.80	2.7–11.0	4.0–13.0
Del.L./Gr.Ab.W.	9	0.97	1.05	0.98	4.0–13.0	2.7–11.6
Del.L./Anal Del.L.	7	0.98	2.05	0.75	7.5–11.7	7.3–12.7
Amb.L./Amb. W.	12	0.73	2.71	4.45	4.0–18.3	1.2– 3.5
Amb.L./No. S.P.	12	0.90	-0.08	0.63	4.0–18.3	8.0–27.0

Linear ridge separates RD and RR sectors which are at an angle to one another, latter forming part of lateral wall of theca (Pl. 19, fig. 1). Ornament of RD sector consists of strong, slightly convex, very slightly sinusoidal (bending near ambulacrum) growth lines parallel to RDF with the occasional development of ridges perpendicular to the RDF giving appearance of hydrospire slits but these do not penetrate into plate. RR sector is very slightly convex parallel to growth axis, convex perpendicular to it. Ornament consists of fine growth lines parallel to RRF with occasional development of ridges perpendicular to RRF; ridges continuous to discontinuous. RB sector very slightly concave (rare) to very slightly convex parallel to growth axis and convex perpendicular to growth axis. Ornament consists of very fine growth lines; no development of ornament perpendicular to RBF. No development of ridge separating RB and RR sectors as RD and RR sectors; adjacent RR and RB sectors merge smoothly. R.Ht.: 1.2-6.7 mm; RWB: 3.5-17.0 mm; RWA: 4.3-19.0 mm; RWD: 4.7-16.4 mm. See also Table 36.

Deltoid essentially triangular in plan view with greatest width at aboral extremities. Adoral edge of deltoid straight, width of plate expands along short DDF, constricts slightly at adoral end of ambulacrum producing very slightly concave DA suture which becomes straight aborally as width of plate increases. On aboral side two slightly concave DRF approach one another at 180°. Radiodeltoid suture very broad gull-wing outline, being concave toward the deltoid. Deltoid quite convex in lateral profile; slightly convex across width of plate. Adoral edge and DDF bears main groove with minor lobes and grooves; small rim on plate borders this ornament; aboral to this deltoid lip slightly depressed and ornamented with a few irregular low nodes. Deltoid body quite large in comparison, with low median ridge in center of plate originating at constriction of plate; low, broad, shallow depression on either side; surface ornamented with growth lines parallel to gull-winged radiodeltoid suture. Del.Gr.Ad.W.: 1.0-2.4 mm; Min.W.: 0.9-1.7 mm; Gr.Ab.W.: 2.7-11.6 mm; DR: 2.8-10.8 mm. See also Table 36.

Anal deltoids two, a small epideltoid and a large hypodeltoid. Epideltoid (outline and ornament) as for deltoid lip of regular deltoid; anal opening located in position corresponding to slight constriction in regular deltoid; epi-hypodeltoid suture runs at right angle from anal opening to ambulacrum. Hypodeltoid large, ornament and outline as for deltoid body of regular deltoid. Anal opening circular to elliptical, on upper surface of theca near oral opening. Hypo.L.: 5.6-9.8 mm; Hypo.W.: 6.9-12.0 mm. See also Table 36.

Ambulacra five, elevated above surrounding plates, narrowly lanceolate, with greatest width usually at radiodeltoid suture where there is a flaring of the sides of the ambulacrum which meet at an angle at the radiodeltoid suture. Lancet widely exposed to aboral tip of ambulacrum; greatest exposed width 0.3-0.8 mm (Pl. 18, fig. 6). Impressions of side plates visible upon lancet; side and outer side plates along sides of ambulacrum; outer side plate triangular with convex ad- and aboral edges; embays edge of side plate, supports adoral half of brachiolar facet. Brachiolar facets on inclined edge of ambulacrum; heart-shaped, length: 0.4-0.45 mm; width: 0.45-0.48 mm (Pl. 18, fig. 7). Adoral half of facet lower than aboral half. Axis of facet aborally rotated to side groove. Very little space between adjacent facets. Main groove bordered by five minor grooves and furrows; adoral edge of side groove has three, aboral edge one or two(?). Those along main groove borne by lancet as well as most of those bordering side groove. See also Table 36.

Entrance to rudimentary hydrospire by means of a few interradial pores or a short slit (Breimer and Macurda, 1972, p. 106).

Oral opening pentagonal, 1.0-1.7 mm wide.

Distribution.– Lower Carboniferous, Kazachstan, U.S.S.R.

Remarks.– The above description is based upon the specimens in the growth series (Appendix I). It is an expansion of the description given by Arendt, Breimer, and Macurda (1968). The internal anatomy and ontogeny were discussed and illustrated by Breimer and Macurda (1972).

Genus PENTABLASTUS Sieverts-Doreck, 1951

Type species.– *Pentablastus supracarbonicus* Sieverts-Doreck, 1951.

Pentablastus Breimer and Macurda, 1972, p. 25, 26.

PENTABLASTUS SUPRACARBONICUS Sieverts-Doreck, 1951

Pl. 19, figs. 4-7; Table 37

Pentablastus supracarbonicus Breimer and Macurda, 1972, Pl. IX, figs. 10-12.

Description.– Theca elliptical to pear-shaped, with ambulacra nearly reaching the base of theca (Pl. 19, fig. 6). Vault parabolic, of varying degree of curvature, top flattened; lower end of vault may be slightly recurved. Pelvis low, broad, with slightly convex sides and flat base; basals are invaginated in prominent basal concavity (Pl. 19, fig. 5). Greatest width sub-equatorial but above ambulacral tips. Outline in plan view pentagonal with pronounced rims along ambulacra; interambulacral areas

TABLE 37. Growth relationships of principal variables of *Pentablastus supracarbonicus* Sieverts-Doreck 1951

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	10	0.88	6.19	0.81	13.2–29.0	11.2–28.1
V/P	5	0.40	11.18	1.74	10.8–24.8	2.3– 6.1
L/ABBR	5	0.88	1.92	7.03	13.2–29.0	1.8– 3.8
L/RD	10	0.97	4.66	1.00	13.2–29.0	8.5–24.0
L/RB	10	0.96	1.85	2.45	13.2–29.0	4.2–11.1
L/Del.L.	10	0.90	-5.15	4.33	13.2–29.0	4.5– 8.0
L/Amb.L.	10	0.99	2.57	1.02	13.2–29.0	11.2–25.4
RD/Amb.L.	10	0.99	-1.39	0.99	8.5–24.0	11.2–25.4
Del. L./Amb. L.	10	0.93	2.49	0.20	4.5– 8.0	11.2–25.4
ABL/ABW	5	0.91	-0.76	1.17	1.9– 4.0	2.3– 4.0
ABBR/ABBRF	5	0.89	-2.59	2.55	1.8– 3.8	1.7– 2.5
ZBL/ZBW	5	0.99	-0.69	0.92	1.9– 3.7	2.7– 4.8
ZBBR/ZBBRF	5	0.95	-0.80	2.07	1.7– 3.5	1.1– 2.0
ABBR/RB	5	0.90	0.34	0.30	1.8– 3.8	4.2–10.3
ABBR/RD	5	0.90	0.80	0.11	1.8– 3.8	8.5–24.0
ABBR/Del.L.	5	0.99	-0.74	0.56	1.8– 3.8	4.5– 8.0
RD/RDF	9	0.69	-2.01	9.07	10.7–24.0	1.5– 2.9
RR/RRF_1	9	0.96	2.34	0.24	4.2– 7.7	8.0–23.0
RR/RRF_2	9	0.87	-0.37	0.91	4.2– 7.7	5.3– 9.1
RB/RBF	9	-0.14	10.70	-0.70	5.8–11.1	1.8– 2.5
RD/RR	9	0.98	-4.84	3.74	10.7–24.0	4.2– 7.7
RD/RB	9	0.94	-3.33	2.49	10.7–24.0	5.8–11.1
RR/RB	9	0.93	0.57	0.65	4.2– 7.7	5.8–11.1
RD/Del.L.	9	0.93	-6.07	3.83	10.7–24.0	4.5– 8.0
RB/Del.L.	9	0.92	-0.45	1.44	5.8–11.1	4.5– 8.0
Del.L./Gr.Ab.W.	9	0.95	1.94	1.41	4.5– 8.0	2.0– 4.2
Del.L./Anal Del.L.	5	0.99	0.77	0.77	4.5– 7.5	4.8– 8.9
Amb.L./Amb.W.	9	0.91	-3.33	8.41	11.2–25.4	1.8– 3.7
Amb.L./No.S.P.	10	0.94	-6.47	0.41	11.2–25.4	48.0–89.0

vary from very slightly concave to very slightly convex between rims. See Table 37.

Basals three, invaginated in basal concavity 3.5 mm deep in larger specimens (Pl. 19, fig. 5). Basals reach almost lower edge of concavity; straight edges. Azygous basal quadrate. Zygous basals pentagonal; lateral edges straight, distal edges very slightly concave. BR sectors concave parallel and normal to growth axes in all basals. Stem plates large, filling most of concavity (e.g., 3.1 mm of 4.7 mm width); crenellar ring of smaller diameter: 1.8 mm on 3.1 mm plate, with approximately 44 facets in the ring. Rate of growth of basals slow, diameter of basal concavity being almost constant in all specimens. Depth of concavity may increase during growth. See Table 37.

Radials five, forming entire lateral profile of theca. In lateral view plate has quadrate outline with flat base at edge of basal concavity; lateral sides slightly convex, greatest width subequatorial, decreasing ad- and aborally. Upper edges short, converge toward oral opening, interrupted by deep V-shaped radial sinus which extends almost to base of theca. Length of pelvis remains almost the same throughout growth series while vault increases because rate of growth highest on RD axis. A discontinuity divides the radial into two parts: the infraradial which corresponds to the normal radial body and the supraradial which corresponds to the radial limbs (see Joysey and Breimer, 1963, p. 475 for detailed analysis). In lateral view radial has triangular profile, with long convex edge bordering ambulacrum, slightly concave lower edge along interradial suture, and slightly convex proximal facing edge. RD sector convex parallel to growth axis. Buildup of calcite at origin of radial to form lip to aboral end of ambulacrum; swollen rim in lower part of RD sector (see Joysey and Breimer, 1963, p. 475) merging into plate adorally (Pl. 19, fig. 6); upper part of RD sector slightly convex, with edge turning over sharply and dropping into ambulacrum. Proportion of sector occupied by rim greatest in small specimens, decreasing in larger as rate of growth of secondary calcite deposition on free surface slower than growth of RD axis. Lowest point of rim near aboral end of ambulacrum where discontinuity between two parts of radial cross. RR sector divided by discontinuity; flat parallel to RR axis except near origin where surface turns up sharply because of lip to ambulacrum; convex normal to axis. No ornament preserved. RB sector straight or very slightly convex parallel to axis, very slightly convex normal to it except near origin where convexity increases sharply because of radial lip. Surface usually smooth; may have bulbous buildup (Pl. 19, fig. 6). R.Ht.: 3.4-9.0 mm; RWB: 2.5-4.1 mm; RWA: 6.0-12.0 mm; RWD: 5.5-8.8 mm. See also Table 37.

Deltoids four, together with epideltoid forming border to oral opening (Pl. 19, fig. 7), confined to upper, flattened surface of vault externally, but extending well under radials internally (see Joysey and Breimer, 1963, p. 475). Deltoid slightly convex in lateral view, elongate hexagonal in plan view, with slightly convex short edge bordering oral opening. Width expands slightly aborally along DDF, then constricts slightly at adoral end of ambulacrum, to slowly widen again aborally; bordered by ambulacrum, then hydrospire cleft. Aboral edges along radiodeltoid suture are slightly concave, the whole suture having a sharp V-shaped gull-winged profile. DDF bears main groove and minor lobes and grooves; width on adjacent plates: 0.4 mm. Deltoid lip forms V, elevated above main groove, and ornamented with irregular nodose ornament. Deltoid body much larger, ornamented with a central, radially oriented groove which has two well rounded ridges as a border which drop down to ambulacra or hydrospire clefts. Del.Gr.Ad.W.: 0.8-1.6 mm; Min.W.: 0.6-1.3 mm; Gr.Ab. W.: 2.0-4.2 mm; DR: 3.2-5.7 mm. See also Table 37.

Anal deltoids two, an epi- and hypodeltoid. Exposed epideltoid small, as for deltoid lip of regular deltoid. Internally, the prongs of the epideltoid extend under the hypodeltoid (see Joysey and Breimer, 1963, p. 475); these may be exposed between the aboral lateral edges of the hypodeltoid and the ambulacra but are more commonly concealed. Hypodeltoid as for deltoid body of regular deltoid except for rim to anal opening which interrupts adoral part of central trough. Anal opening ovoid, bordered externally by the epideltoid adorally, ambulacra laterally, and the hypodeltoid aborally. Epi.Gr.Ad.W.: 1.0-2.3 mm; Hypo.L.: 2.3-5.7 mm; Hypo.W.: 2.8-7.0 mm; Anus L.: 0.9-2.0 mm; Anus W.: 0.9-1.7 mm; O.c.-anus: 1.0-1.8 mm.

Ambulacra five, long, convex, sublanceolate, greatest width at radiodeltoid suture; lancet concealed (Pl. 19, fig. 4). Edges of side plates always slightly below surrounding plates: in aboral part below ambulacral rim; adorally where this widens out below smooth RD sector or deltoid. Brachiolar facets form two linear rows, normally 1.0 mm wide (range: 0.9-1.2 mm) along center of ambulacrum (Pl. 19, fig. 4). Side plates grow out beyond brachiolar facet, increasing width of ambulacrum during growth and forming an elevated border. Outer side plate a small elongate rounded triangular plate which is surrounded by side plates in broader parts of ambulacrum; L.: 0.25-0.33 mm; W.: (greatest abmedially): 0.10-0.15 mm. Brachiolar facets small, depressed, ovoid, closely spaced; L.: 0.25-0.30 mm; W.: 0.18-0.20 mm. Brachiolar facet equally developed on side and outer side plate. Main groove bordered by two-three minor lobes and grooves. May be present along adoral edge of side groove but lacking on aboral edge. (L.: 0.20 mm). O.c.-amb.: 0.7-1.3 mm. See Table 37.

Ten hydrospire groups, concealed, with five hydrospires per group in smaller specimens and six per group in longer specimens (Joysey and Breimer, 1963, p. 481); not reduced in number in anal interarea. Entrance via a narrow hydrospire cleft extending one-third of length of ambulacrum on upper sloping side of theca, bordered by ambulacrum on one side and deltoid and radial on the other; greater external length along radial. Length increases from 2.0 mm in small specimens to 8.0 mm in largest; distance of adoral end from oral opening increases from 2.8 to 6.4 mm. See Joysey and Breimer, 1963 for detailed analysis of internal development of hydrospires.

Oral opening pentagonal, width: 1.0 mm.

Distribution.— Carboniferous, Upper Namurian, Rabanal Limestone, Spain.

Remarks.— The above description is based upon the specimens in the growth series (Appendix I). The internal anatomy was discussed and illustrated by Joysey and Breimer (1963) and reviewed in Breimer and Macurda (1972); the ontogeny was detailed in the latter and is further summarized in Table 37.

Genus ANTHOBLASTUS Wanner 1924b

Type species.— *Anthoblastus brouweri* Wanner, 1924b.

Anthoblastus Breimer and Macurda, 1972, p. 26.

ANTHOBLASTUS BROUWERI Wanner 1924b

Pl. 19, figs. 8,9; Pl. 20, figs. 1,4,8

Description.— Theca ovoid, flaring in lateral view, with short, broadly conical pelvis with slightly concave or convex sides which flare outward near the ambulacra; latter may bend slightly downward; vault convex, hemispherical; profile broken near oral opening by deltoid prongs (Pl. 20, fig. 1). Outline in plan view petaloid, with extensions of ambulacra on short prongs with rounded tips; interambulacral areas indented; profile within convex (Pl. 20, fig. 4). Width greater than length; vault (peristome-aboral tips of ambulacra, not including deltoid prongs) twice pelvis. Pelvic angle 123-130°. L.: 9.7-13.7 mm; W.: 13.7-18.2 mm; V.: 6.2-9.0 mm; P.: 3.5-4.7 mm.

Basals three, in normal position, forming proximal half of broad pelvis, with pentagonal outline in plan view; broadly conical in lateral view, tapering proximally to a short, stubby truncated conical area, diameter 1.7 mm. Basals gently convex in lateral cross section, slightly concave to convex in longitudinal profile. Azygous basal rhombic, with straight lateral edges and very slightly convex distal edges. BR sector slightly concave parallel to BR axis, slightly convex normal to it; adjacent sectors merge smoothly. Zygous basals pentagonal in plan view, with straight lateral edges and slightly convex distal and medial edges. BR sectors slightly concave parallel to BR axes, very slightly convex normal to axes. Surface of plates now smooth due to weathering. E zygous basal of larger specimen mutated with left side forming a fourth rhombic basal; suture with E basal stops short of stem attachment area. ABL: 4.3, 5.9 mm; ABW: 4.5, 6.0 mm; ABBBF: 3.1, 4.2 mm; ABBR: 3.6, 5.0 mm; ABBRF: 2.9, 4.0 mm; ZBL: 3.8, 5.0 mm; ZBW: 5.8, 8.2 mm; ZBBR: 4.0, 5.1 mm; ZBBRF: 2.5, 3.1 mm.

Radials five, short, broad, with wide, long ambulacral sinus. Radial basal sutures very slightly convex on C and E radials; very slightly concave on two sutures of A, B, and D radials. Lateral edges convex in lower portions, expanding adorally, becoming straight; greatest width at radiodeltoid suture. Radial sinus a broad V in plan view, V-shaped in cross section and mostly floored by radial plate material. Raised rim along edge of radial sinus due to growth on a free surface. In lateral view radial has triangular outline; slightly concave lower edge; strongly convex (even reflected) long edge along radial rim; slightly concave on proximal facing limb. Surface of radial smooth due to weathering; the origin of radial is concealed by the rim around the ambulacrum. This appears to be an outbuilding of the radial by growth on a free surface as in *Anthoblastus stelliformis*, but not to the same intensity or same direction (being straight outward, perpendicular to the polar axis in *A. stelliformis*, in a curved plane beneath the ambulacrum in *A. brouweri*). RB sectors proximal to rim convex laterally, slightly concave longitudinally; RR sectors slightly convex in both directions. Only that portion of RD sector near radiodeltoid suture apparently not overgrown; bends downward into RR sector. Rim strongly developed with very convex profile; height at aboral end of ambulacrum, 1.3-2.3 mm. Suggestion of a higher knob near radiodeltoid suture; rim terminates before suture, producing a concave area between the radial rim and deltoid prong. Some trabeculae of stereom visible in RB and BR sectors; perpendicular to sutures. Scattered traces visible in other, more weathered parts of radial as well. R.Ht.: 3.5, 4.9 mm; RWB: 4.2, 6.2 mm; RWA: 6.2, 8.2 mm; RWD: 6.5, 8.4 mm; R.width top prong: 4.9, 4.8 mm; RD: 6.7, 9.3 mm; RDF: 1.3, 2.5 mm; RR: 4.5, 6.2 mm; RRF: 6.0, 10.0 mm; RB: 3.7, 5.8 mm; RBF: 2.5, 3.7 mm; L.Prong: 1.3, 2.3 mm.

Deltoids four, together with epideltoid forming border to oral opening (Pl. 19, fig. 8). Adoral half rhomb-shaped; medial tapering caused by presence of ambulacrum. Aboral half also rhomb-shaped. Adoralmost edge slightly concave, width 0.5, 0.8 mm. DDF edges straight, radiating away from oral opening; greatest adoral width 2.5, 3.5 mm. Lateral edges long concave arc, caused by ambulacra; contracting fairly rapidly to minimum width of 1.5, 2.7 mm, expanding aborally to maximum width of 2.5, 4.3 mm. Aboral edges straight to slightly convex, meet in broad V. DDF bear ambulacral tract. Adoral half of deltoid slopes up sharply from trough and adoral edge; bears small mound on adoral surface; surface rises very sharply at beginning of constriction to form radially elongate, steep sided knob with rounded top in aboral half of plate; height: 2.5(a); 4.5 mm; solid interior (Pl. 20, fig. 1). At greatest constriction, sides of deltoid descend perpendicularly to ambulacrum; aborally, sides flare outward toward a radiodeltoid suture; aboral lower edge flattens out and flares into radiodeltoid suture. Stereomic lineations perpendicular to radiodeltoid suture along suture; also visible along aboral face of knob parallel to long axis (i.e., parallel to polar axis) so deltoid knob apparently produced by growth on free surface. Del.L.: 5.5, 7.0 mm.

Anal deltoids two, an epi- and hypodeltoid. Configuration of epideltoid as for regular deltoid to a point just adoral to greatest constriction where short, straight epi-hypodeltoid suture, almost at right angles to anal opening (Pl. 19, fig. 8). Aboral part of epideltoid embayed by anal opening. Unknown if a small mound present on adoral part. Configuration of hypodeltoid as for rest of regular deltoid with knob and steep sides, except for anal opening which embays adoral edge; small rim surrounds anal opening. Width of adoral edge of epideltoid 0.7, 0.8 mm; greatest adoral width: 2.3, 3.6 mm, thus apparently some increase in size with growth as distance from oral center to anus (1.7, 2.5 mm) increases. Hypodeltoid length 3.5, 4.5(va) mm; width: 2.8, 5.2(a) mm. Anal opening elliptical, L.: 1.1, 1.3 mm; W.: 0.7, 0.8 mm.

Ambulacra five, lanceolate-petaloid, convex lengthwise, concave in cross section, extending well down on theca, depressed below surrounding plates. L.: 7.9, 10.3 mm; W.: 3.2, 3.4 mm. Lancet widely exposed throughout length, side plates being confined to ablateral margins (Pl. 19, fig. 9); oral center-lancet: 2.1, 3.2 mm. Lancet a massive plate, triangular in cross section with concave upper surface and two straight lower surfaces; along latter edges stereomic lineations appear to be at right angles to suture with radial, fanning out at apex; axis of tabeculae may be somewhat adorally inclined (lower end extending farther aborally). Height of lancet greater than 1.3 mm. Center apparently pierced by lancet canal. Long, slightly aborally convex side grooves descend sides of ambulacrum to main groove, length of side groove increases during growth apparently by addition of calcite along edge of lancet (Pl. 20, fig. 8). Triangular outer side plate embays ablateral edge of side plates, extending slightly more than one-half way to lancet on surface. Brachiolar facet small, heart-shaped, L.: 0.18 mm; W.: 0.15 mm; entrance to side groove—width: 0.03 mm. Facet equally developed on side and outer side plate on ablateral, sloping edge of ambulacrum. Further ambulacral details obscured by weathering.

Configuration of hydrospire clefts unclear due to weathering. Suggestion of presence from ornament of deltoid just ablateral to ambulacrum but no gap visible between ambulacrum and surrounding plates. Number of hydrospires unknown.

Oral opening rounded pentagonal, width 0.9 mm.

Distribution.— Permian, Somohole, Timor, Indonesia.

Remarks.— The above description is based upon the only two known specimens, the holotype, and a second specimen which turned up in the collection at the Technische Hogeschool, Delft.

Anthoblastus brouweri is specifically distinct from *A. stelliformis* in the following characters: the lack of a bulbous overgrowth on the basals; the convex ambulacra which curve toward the base of the theca instead of being elongated on elongate radial prongs; the greater width of the ambulacra and presence of numerous side plates bordering the deltoid; greater concavity of the lancet; and the convex edge of the deltoid prong.

ANTHOBLASTUS STELLIFORMIS Wanner, 1924b
Pl. 20, figs. 2,3,5-7,9-12; Table 38

Anthoblastus stelliformis Breimer and Macurda, 1972, Pl. XI, figs. 5,6,8,9.

TABLE 38. Growth relationships of principal variables of *Anthoblastus stelliformis* Wanner, 1924

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	4	0.88	2.46	0.50	8.8–12.5	12.6–19.5
V/P	4	0.28	2.62	0.45	3.9– 6.5	4.3– 6.0
L/ABBR	4	0.97	-2.47	3.11	8.8–12.5	3.7– 4.8
L/RD_1	4	0.55	-0.92	2.22	8.8–12.5	4.5– 5.4
L/RB_1	4	0.80	-10.11	5.51	8.8–12.5	3.5– 4.0
L/Del.L.	4	0.80	-15.62	5.51	8.8–12.5	4.5– 5.0
L/Amb.L.	4	0.79	3.57	0.79	8.8–12.5	6.4–10.4
RD_2/Amb.L.	4	0.96	-0.96	1.00	5.8– 9.7	6.4–10.4
Del.L./Amb.L.	4	0.84	3.67	0.12	4.5– 5.0	6.4–10.4
ABL/ABW	5	0.76	1.73	0.53	4.0– 5.4	4.7– 6.6
ABBR/ABBRF	5	0.49	2.04	0.63	3.7– 4.8	2.8– 3.6
ZBL/ZBW	5	0.53	2.99	0.19	3.7– 4.7	4.4– 7.2
ZBBR/ZBBRF	5	-0.07	4.30	-0.11	3.6– 4.8	1.7– 2.4
ABBR/RB_1	4	0.91	-3.08	1.94	3.7– 4.8	3.5– 4.0
ABBR/RD_1	4	0.74	-0.59	0.93	3.7– 4.8	4.5– 5.4
ABBR/Del.L.	4	0.91	-5.02	1.94	3.7– 4.8	4.5– 5.0
RD_1/RDF	8	0.35	2.83	1.02	4.5– 8.4	2.0– 3.1
RR_1/RRF	8	0.86	0.02	1.01	3.6– 7.0	3.3– 6.5
RB_1/RBF	8	-0.54	4.38	-0.28	3.1– 4.7	2.1– 6.0
RD_1/RR_1	8	0.92	1.05	0.98	4.5– 8.4	3.6– 7.0
RD_1/RB_1	8	-0.49	8.69	-0.92	4.5– 8.4	2.4– 4.7
RR_1/RB_1	8	-0.47	7.46	-0.84	3.6– 7.0	2.4– 4.7
RD_1/Del.L.	4	0.90	-2.21	1.54	4.5– 5.4	4.5– 5.0
RB_1/Del.L.	4	1.00	-1.00	1.00	3.5– 4.0	4.5– 5.0
Del.L./Gr.Ab.W.	5	0.89	3.65	0.33	4.5– 5.0	2.7– 4.0
Del.L./Anal Del.L.	5	0.76	1.40	0.63	4.5– 5.0	5.0– 5.6
Amb.L./Amb.W.	6	-0.08	13.04	-1.03	6.4–22.8	1.3– 2.5
Amb.L./No.S.P.	5	0.96	-0.16	0.40	5.2– 9.8	13.0–25.0

Description.– In lateral view pelvis of theca has profile of a broadly flaring flower, caused by long extension of radial prongs which support ambulacra (Pl. 20, figs. 3,5). Base is broad and flat in profile, caused by bulbous basals. Profile of pelvis from base upward concave, flaring broadly upward, then outward (and at times slightly downward) along prongs of radial. Profile of vault very broadly conical, interrupted at top of vault by deltoid prongs which project strongly above anal opening. Cross section strongly stellate due to radial prongs which support ambulacra (Pl. 20, figs. 2,6,7). Thus interambulacral areas strongly concave (curvature parabolic). Greatest width at ambulacral tips; vault and pelvis approximately equal; width greater than length; pelvic angle 110-128°. See Table 38.

Basalia three, in normal position, large, massive, bulbous, forming broad boxy low base to theca (Pl. 20, figs. 6,7,10). In plan view outline of basal circlet pentagonal. Part of proximal surface of each basal projects downward and outward, thereby imparting trilobate bulbous appearance to base. In one specimen a narrow (1.2 mm), deep (2.0 mm) cylindrical concavity is present at proximal junction of plates, but of variable development as hardly developed in a second specimen. Crenellar facets unknown. Basal concavity apparently for stem attachment; upper stem plate would be rounded triangular. Sutures between basals and radials may or may not be slightly indented.

Azygous basal in AB interarea; rhombic outline in plan view. Basal-radial sutures straight; interbasal sutures slightly convex against zygous basals in proximal position. Thus BBF descends from radial-basal suture and then curves upward and inward to basal concavity. Surface of basal has distinctly rounded pyramidal form in basal view, one surface sloping downward and inward toward basal concavity; other surfaces have rounded convex outline and slope away to distal portions of interbasal sutures and radial-basal sutures. Zygous basals two, pentagonal in basal view, short, broad with proximal portion of edge against azygous basal slightly concave; otherwise interbasal sutures straight; upper lateral edge very slightly concave, with upper medial edge slightly concave against radial. Relief of zygous basals as for azygous basal; slopes of sides identical also. No surface ornament preserved so mode of growth of basal "pyramid" unknown. See Table 38.

Radials five, flaring out sharply from basals, and elongated into deeply convex trough-shaped radial prong which supports ambulacrum. In plan view a radial is short, broad, with body and limbs about equal. Width at base and top about equal; widest near base of radial prong. Lower edges very slightly or slightly convex against basals; lateral edges convex against neighboring radial; radiodeltoid suture slopes downward or proximally toward polar axis so in plan view radiodeltoid suture rises upward to edge of radial trough, then descends into trough. In lateral view radial has a triangular outline; the long height of the triangle being elongate at right angles to the polar axis. Thus base essentially flat along interradial suture, turning outward at radial-basal and radiodeltoid sutures. Lower or proximal edge of profile rises outward from basals, straight or slightly convex profile, then turns sharply outward in base of radial prong which is straight or slightly concave; overall profile concave. Profile of upper surface straight to convex. Point of break in lower profile marks point where radial prong flares outward to merge with rest of plate (Pl. 20, fig. 9). When viewed orally, upper part of radial is concave because of ambulacral prong; concavity deepens toward radiodeltoid suture. Trabeculae of calcite on upper inner edge of prong have long axis oriented at an inclined angle to upper edge of trough. Thus it has grown upward and outward at the same time. Trabeculae over rest of surface of plate have honeycomb appearance and there is no obvious orientation of the axes, except right along radial-basal sutures where trabeculae are perpendicular to sutures on both radials and basals. Breaks in profile at base of radial prong indicates that growth, in addition to normal additive growth along suture, has proceeded on a free surface as well to form the prong, and the origin of the plate is now concealed beneath the prong by overlayers of calcite (Pl. 20, fig. 9). Thus measurements of growth axes from base of prong inexact reflection of true growth. Viscera does not extend into prongs; radial is solid internally from sutures outward, with only a very slight concavity present on inner surface of radial facing viscera. Thickness of plate along central edge of interradial suture 0.7-0.8 mm, becoming thinner toward junctions with radiodeltoid and radial-basal sutures. Thicker in center of surface largest isolated radials: 3.1 mm. Surface of radial can either be smooth or have strong warty ridges which trend from under surface of radial prong into main portion of plate at right angles to interradial and radiodeltoid sutures, becoming less regular toward the sutures. No growth lines preserved. R.Ht.: 5.6-22.0 mm; RWB: 4.0-9.5 mm; RWA: 5.2-10.2 mm; RWD: 4.6-8.5 mm. Length prong: 3.0-19.2 mm. See also Table 38.

Deltoids four, together with epideltoid forming border to oral opening. In plan view outline hexagonal, with two long, straight DDF sutures which diverge from the oral opening to the beginning of the ambulacrum. Edges forming lateral sides constrict slightly aboral to beginning of ambulacrum; outline slightly concave as pass across hydrospire cleft and pass up lateral side of ambulacral trough. At crest of trough, two edges turn sharply inward to meet at a broad angle, on steep lateral wall of theca, forming aboral part of deltoid; each suture straight. Adoralmost edge against oral opening short (0.6-0.7 mm); some minor lobes and grooves preserved. Adoral lateral edges rise upwards from interdeltoid suture in a concave profile to form a broad trough along adoral base of deltoid which continues into trough of lancet; width: 0.9-1.6 mm. Main groove forms a small concave trough along the suture itself; width: 0.4 mm. Thus main groove occupies only admedial portion of deltoid trough. In lateral view, deltoid rises very steeply from oral opening into a three-sided, very prominent pyramidal knob, elevated as much as 4.0 mm above peristome. Aboral surface faces that portion of radiodeltoid suture which is outside ambulacral trough. Aboral surface concave in cross section, steepening toward tip of deltoid knob, becoming vertical near top. Junction with other two sides of pyramid a sharp edge. Latter two surfaces face interdeltoid sutures, drop almost straight down to edges of broad trough on adoral lateral edges of deltoid. Adoral junction between two sides rounded; small sharp keel apparently developed at very base. Axes of trabeculae of calcite on aboral side of deltoid knob oriented toward top of knob. Trabeculae of calcite on adoral two surfaces of knob also oriented toward top of knob, generally parallel to polar axis. Trabeculae along radiodeltoid suture within ambulacral trough oriented perpendicular to suture on both radial and deltoid. No surface ornament apparent on deltoids. Del.Gr.Ad.W.: 0.5-0.7 mm; Gr.Ab.W.: 3.2-4.5 mm. See also Table 38.

Anal deltoids two, an epi- and hypodeltoid. Configuration of adoral and lateral edges of epideltoid as for regular deltoid; greatest width at adoral end of lancets. Prongs of epideltoid reach to adoral end of hydrospire cleft; adoral end of hydrospire cleft embayed in epideltoid prong; abmedial edge is bordered by radial; adlateral edge by lancet. Thus epideltoid in contact with radial over a short distance (0.1-0.2 mm) and hypodeltoid not in contact with ambulacrum. Epi-hypodeltoid suture originates slightly abmedial to center of anal opening; then slopes downward and diverges outward to position just ablateral to hydrospire cleft; slightly sinusoidal. Adoral surface of epideltoid rises from troughs to form a low mound directly adoral to anus; surfaces bordering lateral side slope steeply downward into deltoid troughs. Aboral surface embayed by anal opening. Hypodeltoid large, length and width approximately equal; hexagonal in plan view. Aboral surfaces part of steeply dipping lateral wall of theca; edges meet at broad angle; each straight. Suture plunges downward and outward from crest of ambulacral trough to near hydrospire cleft, still bordering radial; rises from near hydrospire cleft to anal opening along slightly sinusoidal suture bordering epideltoid. Main body of hypodeltoid rises into deltoid knob as for regular deltoids; slopes of surfaces as for regular deltoids except for adoral edge which is embayed by aboral portion of anal opening and is apparently recurved in lateral profile. Stereomic lineations in lowermost portion of aboral edge on lateral wall of theca parallel to polar axis; becoming perpendicular to hypodeltoid radial suture along suture. Anal opening ovoid, bordered by epi- and hypodeltoid. Length slightly greater than width, opening directly upward at level slightly above that of oral opening. Epi.Gr.Ad.W.: 0.4-0.7 mm; Epi.Gr.Ab.W.: 2.3-4.1 mm; Hypo.L.: 3.0-3.9 mm; Hypo.W.: 3.0-4.1 mm; Anus L.: 0.6-1.0 mm; Anus W.: 0.5-0.8 mm; O.c.-anus: 1.3-1.7 mm. See also Table 38.

Ambulacra five, lanceolate in plan view (Pl. 20, fig. 12), originating well away from oral opening (2.7-3.0 mm); supported throughout almost entire length by radial prong which also rises above its lateral edges. Greatest width just aboral to radiodeltoid suture; 2.5 side plates per mm. Lancet widely exposed, extremely concave in cross section, U-shaped (Pl. 20, fig. 11), thickest near base and tapering in arms of "u," side plates confined to ablateral extremities. Adoral end lancet broadly pointed against deltoid; maximum depth near radiodeltoid suture: 1.2-2.0 mm. Trabeculae of lateral edges of lancet oriented perpendicular to suture with side plates. Central axis of lancet bears main groove, latter bordered by minor lobes and grooves, five per side in the distance between adjacent side grooves; width of area occupied by minor lobes and grooves approximately 0.3 mm wide. Long, arcuate side grooves descend steeply sloping concave ambulacral sides to meet main grooves at approximately 45° angle. 2.5 side grooves per mm; each side of side grooves bordered by minor lobes and grooves; width of groove and area ornamented with lobes: 0.2 mm. Maximum lengths of side grooves: 1.6-2.0 mm. Side grooves begin aboral to hydrospire clefts where lancet broadens out in concave arc. Area between side grooves broad, flat, slightly higher adorally than aborally.

Brachioles attached to side and outer side plates at very ablateral edges of ambulacrum. Small, aborally curving troughs on edge of wall of ambulacral trough above side plates marks position of brachioles as they rose above side plates. Brachiolar facet small, heart-shaped, developed on side and outer side plate, mostly on former. Side plates small, trapezoidal in plan view; ablateral narrowing caused by blunt wedge-shaped outer side plate which tapers ablaterally from edge of ambulacrum, reaching to lancet; side groove follows aboral border of outer side plate. Food particle descending brachiole upon reaching ambulacrum continued to descend along long arcuate side groove, then was conveyed adorally up a slightly inclined concave slope which steepened markedly at the adoral end of the lancet where it was conveyed up a steep, concave groove developed along the interdeltoid suture to the peristome. See Table 38.

Hydrospire clefts ten, developed across radiodeltoid or epideltoid-radial suture; bordered by lancet, epideltoid, and radial (see previous discussion); short (1.0-1.2 mm), elongate teardrop-shaped. For discussion of hydrospires see Breimer and Macurda, 1972, p. 119-120.

Oral opening pentagonal, width: 0.7-0.8 mm.

Distribution.– Permian, Timor, Indonesia.

Remarks.– The above description is based largely upon specimens 1-4 in the growth series, and supplemented by other specimens in the series (Appendix I). The internal anatomy and ontogeny were described and illustrated by Breimer and Macurda (1972).

The orientation of the stereomic lineations within the calcite of the plates, the apparent absence of growth lines, and development of basal protuberances, radial prongs, and deltoid knobs appear to indicate that in addition to the normal growth along plate boundaries, *Anthoblastus stelliformis* also secreted a great deal of calcite on the surface of the plates, resulting in the development of features as those found in the basals, radials, and deltoids. Thus the ambulacra would increase in length by the addition of calcite on the free surface of the radial, increasing the length as the radial prong lengthened. The lancet also increased in width; at their origin, side plates would be near the admedial center of the ambulacral trough. With growth, they were moved abmedially and elevated by growth along the suture between the lancet and side plates, most all the calcite being added to the lancet, very little if any to the side plates. The secretion of calcite on the free surface of the plates in the amount found in this genus is a rare phenomenon in blastoids, being exploited by only a few other genera such as *Dentiblastus* Macurda and *Thaumatoblastus* Wanner.

Family NYMPHAEOBLASTIDAE Wanner, 1940

Genus PACHYBLASTUS Breimer and Macurda, 1972

Type species.– *Pachyblastus dicki* Breimer and Macurda, 1972.

PACHYBLASTUS DICKI Breimer and Macurda, 1972

Pachyblastus dicki Breimer and Macurda, 1972, p. 27, 28; Pl. XII, figs. 1,2; Pl. XIII, fig. 1.

Description.– Theca oblate spheroidal, with short, broad pelvis forming one-quarter to one-third length of theca, and tall, strongly paraboloid vault. Pelvic profile conical, slightly concave; pelvic angle about 80°. Ambulacra extend well below equator of theca, forming outline of paraboloid vault, curving inward proximally. Cross section is rounded pentagonal, with very slightly indented or inflated interambulacral areas. Greatest width subequatorial. Theca large, being over 40 mm in length, with corresponding widths between 15 and 20 mm.

Basalia form one-half of broad, conical, slightly concave pelvis. Stem diameter about 2 mm. Azygous basal unknown. Zygous basal pentagonal, with concave median upper edge, slightly concave upper lateral edges, and straight lateral edges. Zygous basal straight in lateral view. Median BR sector straight parallel to BR axis, strongly convex normal to it; lateral BR sectors straight parallel to BR axis and flat normal to it; merge smoothly with median sector. BB sectors present, form slight lip at edge of plate. Both BR and BB sectors ornamented by fine growth lines. Dimensions of zygous basal from a large theca: ZBL: 8.0 mm; ZBW: 11.5(va) mm; ZBOPt: 9.7 mm; ZBBR: 8.3 mm; ZBBRF: 5.2 mm; ZBBB: 8.0 mm.

Radials five, forming upper half of pelvis and lower three-fourths of vault. Radials quadrate in plan view, with slightly convex lower and lateral edges; radial sinus very deep narrow V. Radial a low triangle in lateral view, with a slightly concave face on the lower edge and short proximal facing edge, and a long, convex, adorally facing edge. RB sector small, slightly concave parallel to RB axis and flat normal to it; adjacent RB sectors merge over highly convex surface; merge smoothly with RR sectors. RR sector large, straight parallel to RR axis and convex normal to it. RB and RR sectors ornamented by fine growth lines. RD sector long, narrow, convex parallel to RR axis and slightly convex normal to it. RD sector rounds into RR sector; ambulacrum slightly elevated above RD sector. Entire width of RD sector occupied by hydrospire slits which extend from aboral tip of ambulacrum onto deltoid. No one specimen completely exposes all parts of a radial but when RD is about 24 mm, RR is 6.2 mm, RRF: 29.2 mm and RB is 7.2 mm; RBF: 3.0 mm. When RD is about 24.5 mm, RDF is about 3.5 mm.

Deltoids are rhombic-shaped plates, being narrow near the oral opening, expanding aborally and forming upper two-sevenths of parabolic vault. Length approaches 11 mm on a large specimen; maximum aboral width: 4 mm. Deltoid is convex in lateral view and slightly convex in cross section. Adoral part of plate small, aboral part large, ornamented with a low rounded crest from which hydrospire slits extend across radiodeltoid suture, giving appearance of many inverted chevrons. Ambulacrum slightly elevated above deltoid.

Number of anal deltoids unknown. Hypodeltoid present, with pentagonal shape and corresponding to aboral part of deltoid in curvature and position on theca. (L.: 4.5 mm; W.: 3.0 mm). Ornament of hypodeltoid unknown; plate apparently separated from ambulacra by exposed hydrospires on prongs of epi- or other anterior deltoid.

Ambulacra five, linear in plan view, width tapering gradually aborally. Convex in lateral view, extending from near oral opening to sub-equatorial position, recurving slightly proximally. Length of ambulacra over 30 mm; maximum width of ambulacrum (which is close to oral opening) almost 3 mm. Slightly elevated above surrounding plates throughout length. In cross section ambulacrum convex, has broad, shallow, V-shaped interior with short downward-sloping lateral edges where brachioles are attached. Suggestion that lancet is exposed (up to 1 mm) given by dislocated side plates. Details of side and outer side plates unknown. Side grooves long, 4 per mm; minor lobes and grooves only on adoral side of groove; admedial ones long. Brachiolar facets small, heart-shaped, with small ridge dividing center where two brachiolar plates attached; facet faces laterally outward on edge of ambulacrum. Brachioles preserved, more than 25 mm long.

Ten hydrospire groups, completely exposed, occupying full width of RD sector and most of aboral part of deltoid, each field being slightly convex lengthwise and triangular in outline, up to nine hydrospires per regular group, reduced to 3 in anal interarea when there are seven in a regular group (here width of fields 1.0 and 2.8 mm respectively).

Details of oral opening unknown.

Distribution.— Devonian, Bokkeveld Beds, Union of South Africa; Belen Formation, Bolivia.

Remarks.— This form is represented by about a dozen external molds from South Africa in varying states of completeness and preservation which were used for the above description. They were collected from the Bokkeveld beds on the road from Hex River Pass to Montague Koo, 8.7 miles south of turnoff from N 9, east of de Doorns, Cape Province, South Africa.

Subsequent to the discovery and description of the South African material, specimens which appear to be specifically co-identical have been found in Bolivia. These are described elsewhere (Macurda, 1979). Based upon this material, the generic definition of *Pachyblastus* (Breimer and Macurda, 1972) is herein amended to include four anal deltoids (super-deltoid, two cryptodeltoids, and a hypodeltoid), narrow exposure of the lancet in the adoral one-quarter of the ambulacrum, and the number of hydrospires may be slightly reduced in the anal interarea.

The ontogeny of the South African specimens was discussed by Breimer and Macurda (1972).

Genus XENOBLASTUS Breimer and Macurda, 1972

Type species.— Pentremites decussatus Shumard, 1858

XENOBLASTUS DECUSSATUS (Shumard, 1858)

Pl. 21, figs. 1,2,4,7,8

Xenoblastus decussatus Breimer and Macurda, 1972, Pl. XIII, figs. 2-6, 8.

Description.— Theca ellipsoidal in lateral view, with conspicuous ambulacra almost reaching base of theca, recurved; pelvis small, almost flat (Pl. 21, fig. 1). Cross section rounded pentagonal, with slight depression along center of interareas. Greatest width slightly below equator. Width two-thirds of length where known (L.: 18.3(a) mm; W.: 11.5(a) mm).

Basalia three, in normal position, forming one-half of flat pelvis; lying in a horizontal plane (Pl. 21, fig. 4). Pentagonal in plan view. Lumen pierces center of proximal junction. Large circular stem facet developed on proximal portion of basals, diameter 1.8 mm, with approximately 40 crenellar lobes in the ring which are at outer edge of the facet.

Azygous basal rhombic, straight lateral edges, slightly sinusoidal distal edges; BR sector very slightly convex normal and parallel to BR axis, with adjacent sectors merging over flat surface, inner part ornamented by stem facet, outer by low, bumpy indistinct ornament. ABL: 2.0 mm; ABW: 2.5 mm; ABBBF: 1.5 mm; ABBR: 1.7 mm; ABBRF: 1.5 mm. Zygous basals pentagonal with straight lateral and distal lateral edges; median distal edge slightly concave. Median and lateral BR sectors as for azygous basal parallel and normal to BR axes, except median sector which is flatter normal to its axis. Stereomic lineations perpendicular to BRF in median sector. ZBL: 1.8 mm; ZBW: 2.6 mm; ZBOPt: 2.1 mm; ZBBR: 1.9 mm; ZBBBF: 1.0 mm.

Radials five, forming outer half of flat pelvis and slightly more than the lower two-thirds of the ellipsoidal vault. Radial quadrate in plan view, with a convex or two angular lower edges, lateral sides convex in lower portion, becoming subparallel adorally, being widest at or near the aboral end of the deltoids. Upper edges straight, slant upward toward ambulacrum. Long linear ambulacrum indents the radial almost to its base. Radial convex in lateral view with short, straight horizontal basal edge or sloping upward toward center of theca; upper edge bordering ambulacrum convex; lower edge concave along interradial suture; radial convex in cross section. Lip covers origin of radial at aboral end of ambulacrum, extends adorally as a ridge which flattens out to become the RD sector (Pl. 21, fig. 2). RB sector very small, straight parallel to RB axis, sloping upward and inward, convex normal to axis; two sectors meet on very convex surface; merge smoothly into RR sector. Latter slightly concave parallel to RR axis at aboral end of ambulacrum because of radial lip but elsewhere flat; convex normal to axis. Sector ornamented by growth lines subparallel to RRF; fan out adorally, indicating acceleration of growth along RD. Cross striae perpendicular to growth lines, imparting reticulate pattern to RR sector. Stereomic lineations parallel to RRF in lower part of sector. RD sector forms angle of about 135° with RR sector. Former is convex parallel to RD axis; slightly convex in aboral extremity normal to RD axis; adorally it becomes flat with slight concavity where it turns up to meet edge of RR sector; RD sector slopes in slightly toward ambulacrum. RD sector bears exposed hydrospire slits toward RDF, a maximum of six or seven; aborally, they have been sealed off and this part of RD sector is almost smooth. As one approaches the radiodeltoid suture, the width of the area between the outermost hydrospire slit and the edge of the RD sector increases in large specimens, and growth lines are developed in the outermost part of the sector parallel to RDF. Length of radials was greater than 25 mm; width approached 15 mm. Complete dimensions of a small radial: R.Ht.: 1.5 mm; RWB: 3.0 mm; RMW: 5.3 mm; RWD: 6.3(a) mm; RD: 12.5 mm; RDF: 2.1(va) mm; RR: 2.1 mm; RRF: 12.7(a) mm; RB: 1.7 mm; RBF: 1.5 mm.

Deltoids four, together with epideltoid(?) forming border of oral opening. Deltoid rhombic in plan view, convex in lateral view, forming upper one-fourth of theca. Ambulacra almost reach oral opening so deltoid lip small, width expanding along short, straight DDF, then contracting to expand again aborally along concave DAF, becoming straight aborally. Aboral edges apparently straight, forming a V of about 90°. Deltoid slightly convex in cross section. Deltoid lip ornamented by a few bumpy nodes; subdued nodose crest ornaments deltoid body (Pl. 21, fig. 8); hydrospire slits converge on crest, occupying full width of DR sectors in only known specimen with deltoids. Ridges between slits nodose. Del.L.: 6.5 mm; Gr.Ad.W.: 1.4 mm; Min. W.: 1.0 mm; Gr.Ab.W.: 3.0(va) mm; DR: 5.5 mm.

Number of anal deltoids unknown with certainty. Single specimen with anal deltoids has a plate which appears to be an epideltoid corresponding to the deltoid lip of a regular deltoid with two prongs extending aborally to separate the anal opening from the ambulacra (Pl. 21, fig. 7). Plate ends at a point that would correspond with the usual position of an epi-hypodeltoid suture. Break in profile of anal opening suggests another plate necessary to fill the aboral void; it would be a hypodeltoid corresponding to the aboral part of a regular deltoid body. Epi.(?) L.: 2.4 mm (if prong is aboral termination); Gr.Ad.W.: 1.7 mm. Anal opening apparently ovoid, W.: 1.0 mm; opening upward at about level of oral opening on upper surface of theca. O.c.-anus: 1.5 mm.

Ambulacra elongate, reaching to base of theca, elongate, linear in plan view, widening toward radiodeltoid suture, convex, conspicuous, in lateral view elevated above surrounding plates; convex in cross section with depressed main groove; almost reaching oral opening. Lancet not exposed along main groove on that part of ambulacrum on radial. Side plates meet along main groove, quadrate, medial edge slightly convex. Ablaterally, aboral half of side plate embayed by large triangular outer side plate. At aboral end of ambulacrum, side plates and outer side plates in contact with radial;

with further development, side plates continue to grow laterally and completely surround side plate. This continued growth forms a rim to the ambulacrum. Brachiolar facet on upper sloping side of ambulacrum, ovoid heart-shaped, 0.5 mm long, 0.3 mm wide, adjacent facets in contact, admedial edge embayed by lateral termination of side groove (Pl. 21, fig. 2). Adoral half of facet on outer side plate, aboral half on side plate. Main groove has about 6 minor lobes and grooves per side plate; side groove has four bordering adoral margin but none on aboral. Convex sinuous side plate crests connect lateral terminations of side grooves, separating area ornamented by minor lobes and grooves from rest of plate; high point in cross-sectional profile. Complete Amb.L.: 16.9 mm; W.: 2.4 mm; 34 side plates per side.

Ten hydrospire groups, with four (width of field: 1.2 mm) to seven slits per group in regular groups; present in anal interarea but number unknown. Hydrospire slits occupy full width of RDF in medium sized specimens but not in the largest specimens (see previous discussion under radials). Secondary infilling occurs on the radial, hydrospires being functional for about one-third of the RD sector in a medium sized specimen. Apparently there is also well-developed infilling on the deltoid as well.

Configuration of oral opening not clear.

Distribution.– Mississippian, New Providence Formation, Kentucky, U.S.A.

Remarks.– This blastoid was described by Shumard in 1858 from isolated radials. Only the recent discovery of a complete specimen has permitted a more complete diagnosis of this species (Pl. 21, fig. 1). The original specimens were calcitic; the complete specimen is ferruginized, preventing further cleaning. The *Pentremites decussatus* identified by Weller (1909) from the Fern Glen Limestone of Missouri is a spiraculate and not the same form; it is undescribed. *Xenoblastus decussatus* is known only from the New Providence Shale in Kentucky. Plate dimensions are from the complete specimen except where otherwise noted. The ontogeny of this species was discussed by Breimer and Macurda (1972).

Genus NYMPHAEOBLASTUS von Peetz, 1907

Type species.– *Nymphaeoblastus miljukovi* von Peetz, 1907.

Nymphaeoblastus Breimer and Macurda, 1972, p. 28,29.

NYMPHAEOBLASTUS BANCROFTI McKellar, 1964

Pl. 21, figs. 3,5,6,9,10; Pl. 22, fig. 1

Nymphaeoblastus bancrofti Breimer and Macurda, 1972, Pl. XV, figs. 2,8.

Description.– Theca ellipsoidal in lateral profile with ambulacra reaching to base of theca; basals invaginated in basal concavity. Theca rounded decagonal in plan view with greatest width at junction of radials and deltoids (supraequatorial). Length of theca approaches 35 mm, width 30 mm in largest thecae.

Basals unknown, invaginated in basal concavity.

Radials five, forming lower two-thirds of vault in lateral profile; RB sector invaginated into basal concavity. Radial quadrate in plan view, with straight lower edge where radial turns up into basal concavity; lateral edges straight to very slightly convex, diverging adorally; adoral edges slightly convex, approach one another nearly head on. Radial triangular in lateral view, with short straight aboral edge, long convex adoral edge, and concave lower edge. RB sector small, slightly convex parallel to RB axis as it curves up into basal concavity, slightly concave normal to RB axis; adjacent sectors merge through concave arc. RB sector ornamented by ridges which are perpendicular to interradial suture and nodose overgrowth of the origin of the plate. RB merges with RR sector over strongly concave boundary. RR sector straight parallel to RR axis, convex normal to it. RR sector ornamented by ridges perpendicular to RRF in lower part, giving way to growth lines in upper part of radial limb. Inner growth lines can be obliterated by nodose ornament. RD sector merges smoothly with RR sector over very slightly convex boundary, sector convex parallel to and very slightly convex normal to RD axis. Full width of RD sector ornamented by hydrospire slits adjacent to RDF; ridges between slits show numerous growth lines (Pl. 21, fig. 9). Earlier formed portions of RD sector are covered by nodose ornament which seals hydrospire slits (Pl. 21, figs. 5,10). In three measurable radials, RWA: 4.0-6.6 mm; RWD: 7.5-15.4 mm; RD: 8.4-19.5 mm; RDF: 3.3-5.0 mm; RR: 2.2-5.4 mm; RRF: 9.4-18.5 mm (a).

Deltoids four, together with epideltoid forming border to oral opening (Pl. 21, fig. 3). Deltoid quadrate in plan view, convex in lateral view, extending down one-third of thecal length; also convex in cross section. Deltoid width expands along straight DDF, then contracts slightly at adoral end of ambulacrum, then width expands aborally along straight edge bordering ambulacra; radiodeltoid suture V-shaped; each part very slightly concave adorally. Deltoid lip small, with adoral edges bearing main ambulacral tract. Triangular elevation rises up just behind adoral edge, merges smoothly into deltoid body. Adoral half of deltoid body ornamented with nodose ornament, becoming more linear aborally, representing infilled hydrospire slits. Latter occupy full width of deltoid body aborally but only functional immediately adjacent to radiodeltoid suture. When Del.L. 16.5 mm in large specimens, Del.Gr.Ab.W.: 9.2 mm and DR: 13.5 mm.

Two anal deltoids, an epi- and hypodeltoid. Epideltoid small, corresponding to deltoid lip of regular deltoid; epi-hypodeltoid suture on either side of anal opening. Configuration and ornament of hypodeltoid as for regular deltoid body. Anal opening ovoid, with flat aboral border probably representing the base of an anal chimney (Pl. 21, fig. 3). In large specimen when Del.L. 17.8 mm; Anal Del.L.: 15.3(a) mm; Anus L.: 1.9 mm; Anus W.: 0.7 mm; Hypo.L.: 13.2 mm; Hypo.W.: 11.0 mm.

Ambulacra five, linear in plan view, convex in lateral view, reaching to base of theca. Lancet concealed? Main ambulacral tract narrow, deep V, with four minor grooves and lobes per side plate (Pl. 22, fig. 1). Side grooves short, bordered ad- and aborally by four minor grooves and lobes. Area between side grooves a sharp pyramidal peak. Brachiolar facets elliptical, on outward sloping surface which borders main ambulacral tract (Pl. 21, fig. 6; Pl. 22, fig. 1). Side or outer side plates (or both) expand laterally to form massive side border to ambulacrum; dying out aborally (Pl. 21, figs. 5,6,10); rim also fades out adorally near oral opening (Pl. 21, fig. 3). Ambulacral lengths exceed 26 mm; widths exceed 4.5 mm in large specimens but the width of the area between the outer edges of the brachiolar facets is constant at 1.5 mm. 2.5 side plates per mm of ambulacral length.

Ten hydrospire fields, functional across full width of radiodeltoid suture but infilled on most of deltoid body and much of RD sector, producing an elliptical-shaped area (Pl. 21, fig. 9). Hydrospire slits in anal interarea developed only on hypodeltoid. Up to 12 hydrospire slits per group; number in anal interarea probably almost equal in number.

Distribution.— Mississippian, Tellebang Formation, Queensland, Australia.

Remarks.— The specimens occur as molds in a siltstone; rubber casts show excellent preservation, including traces of stereomic pores. The above description is based upon duplicate casts of McKellar's original specimens (which are at the University of Queensland); the rubber casts are now catalogued as UMMP 62239-62346.

NYMPHAEOBLASTUS MILJUKOVI von Peetz, 1907
Pl. 22, figs. 2,4,5,9

Nymphaeoblastus miljukovi Breimer and Macurda, 1972, Pl. XIV, figs. 1-5.
Nymphaeoblastus kazachstanensis Breimer and Macurda, 1972, Pl. XIV, fig. 6.

Description.— Theca large, ellipsoidal in lateral view, with length greater than width. Greatest width equatorial, cross section rounded pentagonal (Pl. 22, fig. 2) with interambulacral areas forming points of pentagon. Ambulacra apparently extend to base of theca; basals contained in a basal concavity? L.: > 31.0 mm; W.: 27.6 mm; V.: 30.5 mm.

Basals unknown. Von Peetz (1907, Pl. 1, fig. 5) figured a basal concavity but the basals were not known to him.

Radials five, forming lower two-thirds of theca. In plan view radials pentagonal, with lower edge formed by edge of basal concavity(?); lateral sides gradually diverge upward, with greatest width at radiodeltoid suture; upper edges straight against deltoid; deep radial sinus for ambulacrum. In lateral view radial is triangular; slightly concave base along interradial suture, slightly convex along ambulacral edge; what visible of lateral edge (RB sector) flat. In plan view, RR sector is convex both parallel and perpendicular to the growth axis. RD sector similarly convex except near the radiodeltoid suture where it becomes concave perpendicular to the growth axis. Surface of radial ornamented with bumpy, very coarsely granulose ornament except for the hydrospire field. Infilling of earlier formed portions of hydrospire slits by granulose ornament visible. RWA: 11.5 mm; RWD: 17.2 mm; RD: 19.8 mm; RDF: 5.8 mm; RR: 7.0 mm; RRF: > 20.3 mm.

Deltoids four, together with epideltoid forming border to oral opening. Deltoid forms approximately one-third of the length of the theca; rhombic in plan view with slight constriction at beginning of ambulacrum; otherwise lateral edges essentially straight as are aboral edges. Deltoid very convex in profile, both along length and width of plate, aboral half of plate becoming more convex across width and thus producing pentagonal outline to thecal cross section. Plate slopes down to bordering ambulacra. Adoralmost portion of plate elevated above oral opening; apparently a rounded mound but ornament here unclear. Most of plate is ornamented with coarse, heavy, granulose ornament (Pl. 22, fig. 2). Del.L.: 16.2 mm; Gr.Ad.W.: 2.7 mm; Gr.Ab.W.: 9.5(a) mm; DR: 15.0(a) mm.

Number of anal deltoids unclear; no anal sutures visible due to preservation (rubber mold). Configuration as for regular deltoids except for ovoid anal opening located 2.2 mm from oral center. Anal Del.L.: 18.2(a) mm; Epi.(?)Gr.Ad.W.: 2.7 mm; Anus L.: 3.2 mm; Anus W.: 1.8 mm; Hypo.L.: 14.0(a) mm; Hypo.W.: 9.7(va) mm; O.c.-ad.e.anus: 2.2 mm.

Ambulacra five, elongate, linear, narrow, apparently reaching to base of theca. Two side grooves per mm; lateral edges of side plates increase in width during growth, producing a rim along the edge of the ambulacrum in that part of ambulacrum near radiodeltoid suture; greatest width at radiodeltoid suture. Brachiolar facets depressed below rim or bordering plates throughout length of ambulacrum; at adoralmost end of ambulacrum, the deltoids; then the rim on the side plates; aborally the radial forms the border. Width of area occupied by brachioles on ambulacra 2.0 mm throughout length. Entire ambulacrum depressed below surrounding radials and deltoids except near radiodeltoid suture where border hydrospire fields. Indeterminate if lancet exposed; configuration of outer side plate unknown. Width of ambulacral tract on deltoid 0.8 mm. Amb.L.: 30.0 mm; Amb.W.: 5.7(a) mm. No.S.P.: 60(a).

Ten completely exposed hydrospire fields, sited on upper rounded sides of theca, occupying full width of radiodeltoid suture, with length of slits about equal on both radials and deltoids(?). Not reduced in number in anal interarea. Hydrospire slits do not extend to origins of radial and deltoid but are infilled during growth. Length field in anal and non-anal interarea 3.2 and 3.3 mm respectively; width: 4.5 and 4.4 mm respectively; number of hydrospires: 11 in each. Adoral and aboral edges of field convex outward; shortest slit at apex radiodeltoid suture. Innermost slit borders ambulacrum.

Configuration oral opening indeterminate.

Remarks.— The above description and measurements are from a rubber cast of a silicified chert mold identified by Yakovlev as *N. miljukovi* von Peetz, now in the Central Geological Museum. Leningrad (CGM 6163—Breimer and Macurda, 1972, Pl. XIV, fig. 4). The cast has contracted very slightly so measurements given above are slightly less than the true values. Yakovlev described two other species. The first, *N. anossofi* is based on a plaster cast which was apparently made from a mold at the University of Leningrad; only the upper half of the specimen is preserved (CGM 4/1887—Breimer and Macurda, 1972, Pl. XIV, fig. 1; Pl. 22, fig. 2 herein). There is nothing to distinguish it from *N. miljukovi* and it was synonymized by Breimer and Macurda (1972). There is a suggestion of an epi-hypodeltoid suture; the deltoids surrounding the oral opening are elevated above it. Its measurements are: W.: 24.0 mm; RWD: 15.0(a) mm; Del.L.: 16.5 mm; Del.Gr.Ab.W.: 7.5(a) mm; DR: 12.5 mm; Anal Del.L.: 15.0 mm; Anus W.: 2.0 mm; Hypo.L.: 10.2(va) mm; Hypo.W.: 9.0 mm; O.c.-ad.e. anus: 3.2 mm; Amb.W.: 5.5 mm; 2 SP/mm; No.Reg. Hydro.Sl.: 10(a); L.Reg.Hydro.Fld.: 3.7 mm; W.Reg. Hydro.Fld.: 4.8 mm.

The second species, *N. kazachstanensis* Yakovlev 1941, is based upon a very large silicified specimen (CGM 6163) which is somewhat weathered on the surface (Breimer and Macurda, 1972, Pl. XIV, fig. 6). In oral view, this specimen is rounded pentagonal as in the *N. miljukovi* described above but the most pronounced points are the ambulacra. The deltoids are slightly longer, forming two-fifths of the length of the theca which had a concave base. The ornament of the deltoids is coarse, heavy, granulose as in the *N. miljukovi* described above but more linear near the radiodeltoid suture and the deltoid is less convex in cross section. The ambulacra are elevated above the surrounding plates in their adoral and medial portions (aboral indeterminate). Characters now available do not appear to justify specific differentiation from *N. miljukovi*. Its measurements are: L.: 65.0(va) mm; W.: 40.0(a) mm; RWA: 10.5(a) mm; RWD: 32.8(a) mm; RD: 41.8(a) mm; RDF: 15.0(a) mm; RR: 12.0(a) mm; RRF: 43.2(a) mm; Del.L.: 33.8 mm; Del.Gr.Ab.W.: 24.9 mm; DR: 30.6 mm; Anal Del.L.: 38.4(va) mm; Hypo.L.: 34.0(va) mm; Hypo.W.: 30.6(va) mm; Amb.L.: 79.5(va) mm; Amb.W.: 8.5 mm; 2 SP/mm; No.Reg.Hydro.Sl.: 20(a); L.Reg.Hydro.Fld.: 8.3 mm; W.Reg.Hydro.Fld.: 12.5 mm.

Yakovlev (1926) also described and figured some portions of some thecae as *Nymphaeoblastus* sp. (CGM 7/1887—Yakovlev, 1926, figs. 3,3a; fig. 8; CGM 5/1887—fig. 4; CGM 6/1887—figs. 8a,b). They are preserved as molds in a fossiliferous siltstone. Ornament and the configuration of the ambulacra and hydrospires appear to indicate they are identifiable as *N. miljukovi*. The lancet is only exposed along the narrow main groove in the adoral half of the ambulacrum; the upper surface of the lancet forms a strong V. There are four minor grooves along the main groove on each side plate and about five along the adoral edge of each side groove; those along the aboral edge of the side groove are poorly developed if at all. The brachiolar facet is well developed with a median ridge between the two halves of the facet; the axis of the facet is at an angle to that of the side groove being more nearly perpendicular to the main groove. A ridge separates adjacent facets. In the aboral part of the ambulacrum, there is a notch at the position corresponding with the probable position of the adoral edge of the outer side plate suture (indeterminate from mold). This is not a functional pore; it is lost when growth along the lateral edges of the ambulacrum grow outward to form a rim.

Two other specimens which appear to be assignable to *N. miljukovi* are in the collections of the Paleontological Institute, Academy of Sciences, Moscow (PIN 2760/1—Breimer and Macurda, 1972, Pl. XIV, figs. 2,3; PIN 2760/2). The dimensions are (PIN 2760(1): L.: 21.2 mm; W.: 19.2 mm; V.: 21.2 mm; RWA: 8.5 mm; RWD: 11.0 mm; RD: 13.0 mm; RDF: 5.2 mm; RR: 4.5 mm; RRF: 12.5(a) mm; RB: > 5.7 mm; Del.L.: 12.7 mm; Del.Gr.Ad.W.: 2.0 mm; Del.Gr.Ab.W.: 8.3 mm; DR: 10.5 mm; Anal Del.L.: 13.0 mm; Epi.(?)Gr. Ad.W.: 2.6 mm; Anus L.: 1.5 mm; Anus W.: 1.3 mm; Hypo.L.: 10.0(a) mm; Hypo.W.: 9.0 mm; O.c.ad.e.anus: 2.5 mm; O.c.-amb. 2.0(a) mm; Amb.L.: 21.6 mm; Amb.W.: 2.5 mm; No.SP: 2.5/mm. No.Reg.Hydro. Sl.: 13(a): W.Reg.Hydro.Fld.: 5.2(a) mm; No.Anal Hydro.Sl.: > 12; W.Anal Hydro Fld: 4.5 mm; Oral opening W.: 1.2 mm. PIN 2760/2 is a large theca: L.: > 70.0 mm; W.: > 46.0 mm; RWD: 35.0(va) mm; RD: 41.4 mm; RDF: 17.3 mm; RR: 13.0 mm; RRF: 39.0 mm; RB: 10.2(a) mm; RBF: 8.3(a) mm. The only locality data on these two specimens is that they are from the Carboniferous of Central Asia.

Locality.— Von Peetz's original specimen of *N. miljukovi* came from the Lower Carboniferous of north Kazachstan, U.S.S.R. The specimen of *N. miljukovi* described above (CGM 6163) came from the Lower Carboniferous (C_1) in the vicinity of Lake Chunkurul, (51°22′N; 68°16′E), Timojeevskian Village, north Kazachstan. The holotype of "*N. anossofi*" (CGM 4/1887—Pl. 22, fig. 2) came from the Lower Carboniferous Tournaisian C_1 of Akmolin Province near survey mark Kon-Kuduk, north Kazachstan. The holotype of "*N. kazachstanensis*" (CGM 6163) is from the Lower Carboniferous Visean C_1, town of Kyz-Dzhar, north Kazachstan. The "*Nymphaeoblastus* sp." (Yakovlev, 1926; CGM 5/1887, 6/1887, 7/1887) are from the portage between the rivers Archaly and Ir Sou in Central Asia.

Specimens of *Nymphaeoblastus* from the Lower Carboniferous Do zone, Jumonji Stage, Arisu Series, Nasiosawas, Joumonji, Simoarisu-mura, Kitakami Massif, Kesen-gun, Iwate Prefecture, Northeast Honshu, Japan also appear to be assignable to *N. miljukovi* (Pl. 22, figs. 4,5,9).

Genus SPHAEROSCHISMA Wanner, 1924b

Type species.— *Sphaeroschisma somoholense* Wanner, 1924b.

Sphaeroschisma Breimer and Macurda, 1972, p. 29.

SPHAEROSCHISMA SOMOHOLENSE Wanner, 1924b

Pl. 22, figs. 3,6,7,8

Sphaeroschisma somoholense Breimer and Macurda, 1972, Pl. XV, figs. 4,5,7.

Description.— Theca spheroidal in lateral view, with ambulacra almost reaching to base of theca. Pelvis very short and broad, protuberant, with concave profile; vault: 8.8 mm(a); pelvis: 0.8 mm; pelvic angle: 152°. Vault large, convex throughout, slightly flattened orally; recurved toward base. Cross section circular, greatest width at about middle; interambulacral areas convex. Length: 9.6 mm (fide Wanner, 1924, p. 197); width: 10.2 mm (10.6 mm according to Wanner, 1924b, p. 197; theca was cut in two by Wanner to show hydrospires).

Basals three, small, forming half of flattened conical pelvis, pentagonal in plan view, slightly concave in lateral view; those portions of plates on radial line from base of theca to ambulacra slightly more raised than areas between (center and lateral edges of zygous basals; edges azygous basal). Proximal tips of basals weathered. Azygous basal rhombic in plan view. BR sector slightly concave parallel to BR axis; left BR sector convex, right concave normal to BR axis. L. and W.: 2.5 mm; ABBBF: 1.8 mm; ABBR: 2.0 mm; ABBRF: 1.6 mm. Zygous basals pentagonal, each having straight lateral and lateral distal edges and a slightly concave distal edge. BR sectors slightly concave parallel to BR axis; median sector convex, lateral sector flat or concave normal to BR axis; merge smoothly. ZBL: 2.0 mm; ZBW: 3.4 mm; ZBOPt: 2.5 mm; ZBBR: 2.2 mm; ZBBRF: 1.4 mm. Surface of basals weathered so ornament unknown. Trabeculae of stereom well displayed along basal-radial sutures; perpendicular to suture in BR and RB sectors of basals and radials respectively.

Radials five, elongate, with long narrow radial sinus which almost reaches to base of plate. Quadrate in plan view, with a slightly convex (C and E radials) or two straight radiobasal sutures (A, B, and D radials); lateral edges convex outward; radial narrowest at base (2.5 mm), expanding rapidly to greatest width (about center of theca); width: 6.0 mm; then contracting slightly adorally up to radiodeltoid suture (5.2 mm). In lateral view radial has strongly concave lower edge and strongly convex upper edge. RB sector very slightly concave both in direction of growth axis and normal to it; adjacent sectors merge on angular boundary, merge smoothly with RR sectors; latter sector convex in both directions as is RD sector. Aboral portion of RD sector tends to be slightly inclined toward ambulacrum; flattens out adorally and smoothly merges with RR sector. Edge of adoral part of RD turns downward slightly to ambulacrum so ablateral lower edge of ambulacrum below level of bordering plates while crest is above. RB and RR sectors weathered and ornament if any unknown. Linear ornament of deltoid continues into RD sector; aboral half weathered. RD: 7.7 mm (va); RDF: 1.7 mm; RR: 2.2 mm; RRF: 7.5 mm (va); RB: 1.6 mm; RBF: 1.6 mm. (RD, RRF, and ambulacral length are indicated as va (very approximate) since the specimen has been cut; apparently 1.2 mm has been eliminated by cutting and polishing. This has been added, as a correction.)

Deltoids four, together with epideltoid forming border to oral opening (Pl. 22, fig. 3). Wedge-shaped in plan view with straight adoral edge; expanding but very slightly along very short DDF before lancets are met (maximum adoral width: 0.8 mm); edges approximately parallel until beginning of hydrospire slits 1.5 mm from oral center, then diverge in long concave arc bordering ambulacra (Pl. 22, fig. 6). Each half radiodeltoid suture slightly convex outward, producing gull-winged profile; meet at very broad angle (Pl. 22, fig. 7). When suture crosses outer hydrospire slit near ambulacrum, offset 0.3-0.4 mm adorally. In lateral view deltoid is convex, long, forms one-quarter of thecal wall. Length: 4.5 mm; Del.Gr.Ab.W.: 3.3 mm; DR: 3.5 mm. Ornament of that portion adoral to hydrospire slits weathered; two short grooves present which are parallel to adoralmost edge and at right angles to neighboring lancet; function unknown. Variable number of hydrospire slits (see later) which originate in adoral portion of plate, that closest to ambulacrum extending farthest adorally; all extend across radiodeltoid suture and converge with ambulacrum, usually but not always becoming concealed by it, with entrance a gap between side plate and radial; outermost may continue to be exposed. The central aboral portion of deltoid between adjacent hydrospire groups ornamented by low, broad V-shaped chevron of ridges (point adorally); not continuous internally to form hydrospires. Ornament continues into RD sector (Pl. 22, fig. 8).

Anal interarea somewhat weathered; number of plates not clear. Length of anal deltoids: 4.0 mm. Epideltoid borders oral opening; adoral configuration as for regular deltoid; greatest adoral width: 1.0 mm. Very narrow prongs continue aborally (ambulacra may border lateral edges of anal opening externally), then each prong flares out into a flat region which extends to radiodeltoid suture and forms aboral lateral margin of anal opening (Pl. 22, fig. 3). Two flattened areas do not meet aborally; gap between with leveled edges suggests presence of small pentagonal hypodeltoid, with a length and width of about 0.8 mm; wider adorally, bordered by epideltoid prongs laterally, radials aborally. There is a suggestion of a suture between the epideltoid and prong on the D side (C too weathered), 1.2 mm from adoral edge of epideltoid. If present, prong and flaring aboral portion of plate would be a cryptodeltoid; if suture absent, there would be two anal deltoids, an epi- and hypodeltoid.

Anal opening apparently large, ovoid; L.: 2.0 mm(va); W.: 1.3 mm(va). Oral center to anal opening: 1.1 mm.

Ambulacra five, linear, elongate, almost reaching to base of theca, thus very convex in lateral view. Amb.L.: 10.6 mm(va); Amb.W.: 1.7 mm; four side plates per mm over length of 9.5 mm(va). Lancet almost reaches oral opening, exposed throughout ambulacral length (0.7 mm(a). Lancet hexagonal in cross section with slightly concave upper surface, straight upper lateral edges, slightly concave lower lateral sides, and straight base. Ambulacrum convex in cross section; higher points elevated above surrounding plates. Large triangular outer side plate extends slightly more than half way to lancet; brachiolar facet equally developed on side and outer side plate. Brachiolar facet on ablateral, sloping edge of ambulacrum. Both side and outer side plates form lateral edge of ambulacrum, more so the latter. Further ambulacral details obscured by weathering.

Ten hydrospire groups, with one, two, or three hydrospires per group. Proceeding clockwise from the anal opening: in the DE interarea there are two hydrospires on the D side (two slits exposed) and three on the E side (three slits exposed); EA deltoid: three E side (two slits exposed); two A side (two slits exposed); AB deltoid: three A side (two slits exposed); two B side (two slits exposed); BC deltoid: two B side (two slits exposed); one C side (one slit exposed); one each side of anal interarea (largely concealed by side plates). The innermost exposed slits apparently originated at the same time as they are all at approximately the same distance from the oral center (1.3-1.6 mm). As the deltoid grew larger, a second slit was apparently added in some but not all groups (where slit exposed) at about the same time (distance adoral end from o.c.–1.5-1.9 mm) and ultimately a third slit was added at a less regular stage in three groups (2.0-2.5 mm). Thus number of hydrospires per group variable as is exposed of hydrospire slits, some being conjunct with one another; also variable in length of exposure, most always just concealed near aboral end of ambulacra; inner slit of D ambulacrum extends almost to aboral end; second slit on E side begins 1.0 mm adoral to this.

Distribution.– Permian, Somohole, Timor, Indonesia.

Remarks.– The above description is based upon the holotype which is in the collections of the Technische Hogeschool Delft; it is the only known specimen. The ontogeny of this species was discussed by Breimer and Macurda (1972).

Family ASTROCRINIDAE Austin and Austin, 1843
Genus ASTROCRINUS Morris, 1843

Type species.– *Astrocrinus tetragonus* (Austin and Austin, 1843).

Astrocrinus Breimer and Macurda, 1972, p. 29,30.

ASTROCRINUS TETRAGONUS
(Austin and Austin, 1843)

Astrocrinus tetragonus Breimer and Macurda, 1972, p. 29, Pl. XI, figs. 4,7; Pl. XV, figs. 1,3,6; Macurda, 1977, p. 228, 230-233, Pl. 31, figs. 1-7; Pl. 32, figs. 1-4,7,9.

Distribution.– Lower Carboniferous, Middle Limestone, Yorkshire, England; Visean, Counties Kilkenny and Kenny, Ireland; Lower Limestone Group, Scotland.

Remarks.– The internal anatomy and ontogeny were discussed and illustrated by Breimer and Macurda (1972). The external morphology was described and illustrated by Macurda (1977).

Family NEOSCHISMATIDAE Wanner, 1940
Genus HADROBLASTUS Fay, 1962

Type species.– *Hadroblastus convexus* Fay, 1962. *Hadroblastus* Breimer and Macurda, 1972, p. 30.

Remarks.– The following characters can be used to distinguish the species of *Hadroblastus* from one another:

H. blairi: Theca biconical; outline pentagonal-decagonal; slightly protuberant interradial areas; strong growth lines; ridges radiating to apices of basals; ambulacra narrow and lanceolate.

H. convexus: Theca biconical; outline rounded pentagonal; slightly protuberant interradial areas; fine growth lines; slight indentation of interbasal sutures; ambulacra broad, lanceolate.

H. kentuckyensis: Theca biconical; outline pentagonal; growth lines low, broad; ambulacra narrow, sublanceolate.

H. whitei: Theca biconical; outline rounded-pentagonal to pentagonal; very slight concavity in interambulacral areas; fine growth lines; ambulacra lanceolate.

H. (?) *benniei*: Theca biconical; outline pentagonal; strong growth lines; ambulacra sublanceolate; strong rim separates RD and RR sectors.

H. (?) *hibernicus*: Theca biconical; outline pentagonal; slightly concave interradial areas; strong growth lines; ridges separating all basal and radial sectors.

HADROBLASTUS BLAIRI (Miller and Gurley, 1895)

Hadroblastus blairi Breimer and Macurda, 1972, p. 30, Pl. XVII, figs. 1-6.

Description.– Theca biconical in lateral view, with broad conical pelvis and convex vault. Outline pentagonal-decagonal in plan view, with slightly protuberant interradial areas. Greatest width at aboral tips of ambulacra (equatorial). L.: 10.4 mm; W.: 11.7 mm; V.: 5.2 mm; P.: 5.2 mm; Pelvic angle 83°.

Basals three, in normal position, forming lower half of conical pelvis. Basals pentagonal in plan view. Stem attachment area a small protuberance at proximal tip of basals, probably produced by secondary calcite secretion. Azygous basal rhombic in plan view, with straight lateral and distal edges. BR sector straight parallel and normal to BR axis, with adjacent sectors merging over convex surface. Strong growth lines parallel BRF. Zygous basal pentagonal in plan view, with straight lateral and distal lateral edges, concave distal medial edge. BR sectors flat parallel and normal to BR axes, merging over convex boundaries which are visible as radiating ridges which extend to triple junction of interradial and two radial-basal sutures. Ornament as for azygous basal. ABL: 5.6 mm; ABW: 4.0 mm; ABBBF: 4.3 mm; ABBR: 4.5 mm; ABBRF: 3.0 mm; ZBL: 4.5 mm; ZBW: 5.5 mm; ZBOPt: 5.5 mm; ZBBR: 4.7 mm; ZBBRF: 2.3 mm.

Radials five, forming upper half of pelvis and lower part of vault. Radial pentagonal in plan view, with concave lower edge; lateral edges convex, expanding in width up to contact with deltoid; adoral edges converging adorally toward ambulacrum. Radial triangular in plan view, with slightly convex adoral facing edge, straight aboral facing edge, and concave lower boundary. RB sector straight parallel and normal to RB axis, curve smoothly into RR sector which is very slightly convex parallel to and convex normal to RR axis. RB and RR sectors ornamented by strong growth lines. RD sector sharply set off from RR sector, forming part of sloping surface of vault, straight parallel and normal to RD axis. Full length and width of RD sector ornamented by hydrospire slits. RWB: 4.8 mm; RWD: 6.7 mm; RD: 4.3 mm; RDF: 4.0 mm; RR: 3.6 mm; RRF: 3.7 mm; RB: 3.9 mm; RBF: 2.5 mm.

Deltoids four, together with epideltoid? forming border to oral opening. Deltoid rhombic in plan view, convex in lateral view due to curvature of deltoid crest. Deltoid body extensively developed compared to deltoid lip, bisected medially by a broad, arcuate deltoid crest; flanks of crest bear hydrospire slits across full width of DR sector. Del.L.: 6.5 mm; Del.Gr.Ad.W.: 2.0(a) mm; Del.L.Crest: 4.9 mm; DR: 3.0(a) mm.

Configuration of anal deltoids unclear.

Ambulacra five, extending half way down the theca, narrow and lanceolate in plan view, convex in lateral view. Lancet exposed. Amb.L.: 6.9 mm; Amb.W.: 1.0 mm; O.c.-lanc.: 0.9 mm; No.S.P.: 17.

Eight hydrospire groups visible in non-anal interareas, developed across full length and width of RD and DR sectors. Approximately 9 hydrospires per group; W.Reg. Hydro.Fld.: 2.8 mm. Anal hydrospires (> 6) visible on D side of C ambulacrum so presumably ten hydrospire groups.

Distribution.— Mississippian, Chouteau Limestone, Missouri, U.S.A.

Remarks.— The above description is based upon the holotype, Univ. Cincinnati 3845; it was collected near Sedalia, Missouri. The tip of the basals, the oral opening, the ambulacrum, and the anal interarea are weathered so detail in these areas is obscured. The only other specimen of *Hadroblastus* known from the Chouteau Limestone is the holotype of *Codaster jessiae* Miller and Gurley, 1896, from the Chouteau Limestone at Sedalia, Missouri. It was synonymized with *H. blairi* by Breimer and Macurda (1972; see Pl. XVI, figs. 4-6). The specimen is weathered, no growth lines are visible, and the plates are smooth. The top is deeply weathered and only the aboral tips of the deltoids are preserved. A hypodeltoid is preserved in the anal interarea. The D side of the anal interarea is very weathered; one questionable hydrospire slit is apparently still visible on the C side. The weathered base is more rounded than the holotype of *H. blairi* and there are shallow depressions along the proximal part of the interbasal sutures.

HADROBLASTUS CONVEXUS Fay, 1962
Pl. 23, figs. 1-22; Tables 39A,B

Hadroblastus convexus Breimer and Macurda, 1972, p. 30, Pl. XVII, figs. 8, 10-13.

Description.— Theca small, biconical in lateral view, pelvis with slightly convex sides, rounded proximally; vault convex, high points of profile being ambulacra and deltoid crests (Pl. 23, figs. 6-9). Theca rounded pentagonal in oral view, with slight outward flaring of interradial areas (Pl. 23, figs. 1-5). Vault less than pelvis. Pelvic angle broad. See Table 39A.

Basalia three, in normal position, forming lower half of convex base of theca. Basals pentagonal in plan view (Pl. 23, fig. 10). Stem attachment area formed by deposition of secondary calcite at proximal apex of each basal to form a shallow raised rim which slopes in toward the lumen at the proximal junction of the three basals. Stem attachment area thus looks like a very shallow crater on the proximal junction of the three basals; crenellar facets occur near outer edge of crater. Occasional stem plate preserved (Pl. 23, fig. 11). Small ridge extends from secondary deposit to approximate origin of each basal.

Azygous basal quadrate, with convex lateral edges (becoming straight distally), and straight distal edges. BR sector strongly convex parallel to BR axis, becoming flatter distally; convex normal to BR axis; ornamented by fine growth lines. BB sector merges smoothly with BR sector, ornamented by very fine growth lines. Area

TABLE 39A. Growth relationships of principal variables of *Hadroblastus convexus* Fay, 1962

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	10	0.89	1.32	0.76	4.0–10.0	4.8–12.8
V/P	10	0.43	1.52	0.39	1.2– 5.5	2.8– 6.5
L/ABBR	10	0.95	0.24	2.10	4.0–10.0	2.0– 5.0
L/RD	10	0.90	1.44	2.08	4.0–10.0	1.5– 4.3
L/RB	10	0.95	0.68	2.51	4.0–10.0	1.5– 3.8
L/Del.L.	10	0.91	1.10	1.46	4.0–10.0	2.5– 6.5
L/Amb.L.	10	0.90	1.60	1.43	4.0–10.0	2.0– 6.0
L/No. Hyd. Sl.	10	0.85	1.58	0.78	4.0–10.0	4.0–12.0
RD/Amb.L.	10	0.97	0.04	0.69	1.5– 5.0	2.0– 6.7
Del.L./Amb.L.	10	0.98	0.36	0.97	2.5– 7.0	2.0– 6.7
ABL/ABW	10	0.96	0.05	1.06	2.2– 5.6	2.2– 5.5
ABBR/ABBRF	10	0.99	-0.17	1.49	2.0– 5.0	1.5– 3.5
ZBL/ZBW	10	0.98	0.53	0.63	2.1– 4.7	2.8– 7.0
ZBBR/ZBBRF	10	0.87	0.78	1.36	2.2– 4.6	1.5– 3.0
ABBR/RB	10	0.90	0.54	1.08	2.0– 5.0	1.5– 3.8
ABBR/RD	10	0.95	0.58	0.99	2.0– 5.0	1.5– 4.3
ABBR/Del.L.	10	0.95	0.41	0.69	2.0– 5.0	2.5– 6.5
RD/RDF	11	0.95	0.36	1.09	1.5– 5.0	1.2– 3.7
RR/RRF	11	0.94	-0.14	0.88	1.5– 3.9	1.9– 4.5
RB/RBF	11	0.93	0.24	1.27	1.5– 4.0	1.2– 3.0
RD/RR	11	0.97	-0.29	1.24	1.5– 5.0	1.5– 3.9
RD/RB	11	0.90	-0.11	1.14	1.5– 5.0	1.5– 4.0
RR/RB	11	0.94	0.12	0.93	1.5– 3.9	1.5– 4.0
RD/Del.L.	11	0.95	-0.12	0.70	1.5– 5.0	2.5– 7.0
RB/Del.L.	11	0.94	0.33	0.54	1.5– 4.0	2.5– 7.0
Del.L./Gr.Ab.W.	11	0.88	0.70	2.18	2.5– 7.0	0.9– 2.9
Del.L./Anal Del.L.	9	0.96	0.08	1.02	2.5– 6.5	2.5– 5.8
Amb.L./Amb.W.	10	0.83	0.07	3.12	2.0– 6.7	0.8– 2.1
Amb.L./No. S.P.	10	0.89	0.01	0.37	2.0– 6.7	6.0–17.0

along interbasal sutures slightly concave relevant to rest of basals (Pl. 23, fig. 10). Zygous basal pentagonal in plan view, with convex lateral edges (becoming straight distally), straight distal lateral edges, and concave distal

TABLE 39B. Growth relationships of principal variables of *Hadroblastus convexus* Fay, 1962

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	4	0.92	0.23	0.92	6.3–10.8	6.3–10.5
V/P	4	0.23	1.51	0.33	2.0– 5.4	3.8– 6.0
L/ABBR	4	0.53	0.10	2.14	6.3–10.8	3.1– 4.3
L/RD	4	0.99	2.11	2.09	6.3–10.8	2.1– 4.2
L/RB	4	0.86	0.65	2.34	6.3–10.8	2.3– 3.8
L/Del.L.	4	0.99	1.30	1.71	6.3–10.8	2.9– 5.5
L/Amb.L.	4	0.98	3.86	1.04	6.3–10.8	2.1– 6.6
L/No.Hyd.Sl.	4	0.97	2.22	0.91	6.3–10.8	4.0– 9.0
RD/Amb.L.	5	0.95	0.99	0.48	2.1– 4.2	2.1– 6.6
Del.L./Amb.L.	5	0.99	1.46	0.61	2.9– 5.5	2.1– 6.6
ABL/ABW	4	0.89	2.84	0.36	3.7– 4.8	2.1– 5.0
ABBR/ABBRF	4	0.87	1.96	0.74	3.1– 4.3	1.6– 3.0
ZBL/ZBW	4	0.80	0.96	0.59	3.2– 4.4	3.9– 5.5
ZBBR/ZBBRF	4	0.88	-0.13	2.31	3.0– 4.1	1.3– 1.8
ABBR/RB	4	0.89	1.76	0.61	3.1– 4.3	2.3– 3.8
ABBR/RD	4	0.46	2.99	0.24	3.1– 4.3	2.1– 4.2
ABBR/Del.L.	4	0.56	2.72	0.24	3.1– 4.3	2.9– 5.5
RD/RDF	5	0.67	0.83	1.05	2.1– 4.2	1.5– 2.5
RR/RRF	5	0.87	0.73	0.44	2.0– 3.2	2.9– 5.6
RB/RBF	5	0.72	-0.20	1.76	2.3– 3.8	1.6– 2.3
RD/RR	5	0.88	-0.90	1.50	2.1– 4.2	2.0– 3.2
RD/RB	5	0.70	0.29	0.85	2.1– 4.2	2.3– 3.8
RR/RB	5	0.95	0.46	0.68	2.0– 3.2	2.3– 3.8
RD/Del.L.	5	0.96	-0.13	0.78	2.1– 4.2	2.9– 5.5
RB/Del.L.	5	0.85	0.81	0.57	2.3– 3.8	2.9– 5.5
Del.L./Gr.Ab.W.	5	0.96	0.19	2.56	2.9– 5.5	1.0– 2.0
Del.L./Anal Del.L.	4	0.99	0.33	0.91	2.9– 5.5	2.8– 5.7
Amb.L./Amb.W.	4	0.82	-0.51	3.57	2.9– 6.6	1.0– 1.7
Amb.L./No.S.P.	5	0.99	-0.77	0.49	2.1– 6.6	6.0–15.0

medial edge. Medial BR sector strongly convex proximally parallel to medial BR axis, becoming flatter distally; convex normal to BR axis. Lateral BR sectors convex parallel to BR axis, becoming flatter distally;

slightly convex normal to BR axis. Ornament as for azygous basal. See Table 39A.

Radials five, forming upper half of pelvis and lower part of vault. Radial pentagonal in plan view, with convex lower edge, convex lateral edges which expand in width adorally, and two straight adoral edges which converge adorally. Radial triangular in lateral view, with straight adoral and aboral facing edges and a slightly concave lower edge. RB sector straight parallel to, very slightly convex normal to RB axis, merge smoothly with each other and RR sectors. Latter very slightly convex parallel to, convex normal to RR axis. RB and RR sectors ornamented by fine growth lines (Pl. 23, fig. 21). RD sector at pronounced angle to RR sector, straight parallel and normal to RD axis. Full length and width of RD sector ornamented by hydrospire slits. RWB: 2.0-5.1 mm; RWA: 2.6-6.8 mm; RWD: 3.0-7.0 mm. See also Table 30A.

Deltoids four, together with epideltoid forming border to oral opening (Pl. 23, fig. 20). Deltoid hexagonal in plan view, convex in lateral view. Adoral edge bordering oral opening straight, with minor grooves and lobes ornamenting it and DDF. Width expands slightly along short, straight DDF, then contracts aborally along concave DAF to expand again aboral to origin of deltoid crest. DRF meet at a narrow angle; sutures straight (Pl. 23, fig. 22). Surface of deltoid lip aboral to ambulacral tract relatively flat; deltoid crest arises from its flat surface and arcs down to edge of vault. Deltoid crest sharp, narrow, becoming slightly broader in adoral part of deltoid body as growth proceeds. Sides of deltoid crest slope gently down toward base of ambulacra; full length and width of DR sectors occupied by hydrospire slits. Del.Gr.Ad.W.: 1.0-1.9 mm; Del. Min.W.: 0.8-1.5 mm; Del.Gr.Ab.W.: 0.9-2.9 mm; Del. L.Crest: 1.0-5.8 mm; DR: 1.5-5.0 mm. See also Table 39A.

Anal deltoids two, an epi- and hypodeltoid (Pl. 23, figs. 12-14,17,20). Configuration of epideltoid as for regular deltoid except portion equivalent to central portion of deltoid body removed. Ovoid anal opening borders aboral edge of epideltoid lip; limbs of epideltoid extend to radials and form hydrospires. Rim on epideltoid borders adoral part of anal opening (Pl. 23, fig. 17). Hypodeltoid a pentagonal-shaped plate, with its aboral surface forming part of thecal wall (Pl. 23, fig. 13); this is reflected in growth lines in the RD sectors in the anal interarea. Upper apex of hypodeltoid forms a high collar to aboral part of anal opening; lateral sides of hypodeltoid slope steeply downward to the hydrospire slits; sutures with epideltoid prongs straight as are two sutures with radials in anal interarea. Anal opening ovoid, longer than wide, opening directly upward; low rim on adoral margin on epideltoid; high collar on aboral margin formed by hypodeltoid. Epi.Gr.Ad.W.: 1.5-2.0 mm; O.c.-anus: 1.0-2.0 mm; Anus L.: 1.3-2.0 mm; Anus W.: 0.7-1.3 mm; Hypo.L.: 2.0-2.8 mm; Hypo.W.: 1.5-2.6 mm (data drawn from 4 specimens but covering almost full range of thecal sizes in growth series).

Ambulacra five, broad, lanceolate in plan view, convex in lateral view (Pl. 23, figs. 15,16,18,19,22). Lancet exposed (0.4-0.8 mm) nearly to tip of ambulacrum, upper surface bears main ambulacral tract with five minor lobes and grooves per side plate. Side plates quadrate, with convex inner edge, two straight ad- and aboral edges; ablateral adoral edge of side plate embayed by large triangular side plate; suture runs through middle of brachiolar facet. Minor grooves present only along adoral edge of side groove. Brachiolar facets ovoid, on outer sloping surface of ambulacrum, length and width 0.3 mm. O.c.-amb.: 0.5-1.2 mm. See Table 39A.

Ten hydrospire fields, occupying full width of DR and DR sectors in non-anal interareas; completely exposed (Pl. 23, fig. 22). In anal interarea restricted to lateral parts by anal opening and hypodeltoid (Pl. 23, fig. 15). Number of hydrospire slits reduced by 3 to 8 in anal interarea. No.Reg.Hydro.Sl.: 4-13; W.Reg. Hydro.Fld.: 1.0-2.8 mm; No.Anal Hydro.Sl.: 1-6; W. Anal Hydro.Fld.: 0.0-1.5 mm.

Oral opening pentagonal.

Distribution.— Mississippian, Lake Valley Limestone, New Mexico, U.S.A.

Remarks.— The above description is based upon the specimens in Growth Series I (see Appendix I). A comparative population from scattered localities in the Sacramento Mountains of New Mexico is given in Table 39B. The internal anatomy and ontogeny was discussed and illustrated by Breimer and Macurda (1972).

HADROBLASTUS KENTUCKYENSIS
(Shumard, 1858)
Pl. 25, figs. 6(?),7(?),8,9,11,14(?)

Hadroblastus kentuckyensis Breimer and Macurda, 1972, p. 31, Pl. XVIII, figs. 3,5,6.

Description.– Theca of holotype squashed flat, with one zygous basal, two radials, three deltoids, and ambulacra preserved; parts of other plates (radials or basals) present beneath deltoids but identity unclear (see Breimer and Macurda, 1972, Pl. XVIII, figs. 3,5). Based upon profile of plates, theca was bipyramidal, with convex vault and shorter conical pelvis with convex base and straighter upper sides which diverge further; theca pentagonal in oral view. Reconstructed length would have been about 35 mm, width about 45 mm.

Zygous basal convex in lateral view with small stem attachment area with flat base proximally; proximal half of plate slopes outward and upward with straight profile; plate then arcs upward and slopes upward on steeper but still straight profile. In plan view zygous basal is pentagonal, short and broad. Lateral edges straight; lateral distal edges straight, sub-parallel, converging gradually aborally, at 90° angle to broad medial distal suture which is gently concave. Small circular stem attachment area (diameter: 2.0 mm) at proximal tip of basal, slightly elevated (0.3 mm) above plate, sides slope down steeply; suggestion of crennellar lobes and facets at edge of very slightly concave lower surface to which stem attached. Lumen pierces proximal junction of basals. Medial BR sector is convex parallel and normal to BR axis; slightly more so in center of plate, producing very slightly concave areas adjacent to faint medial broad ridge; lateral sectors are also convex parallel to BR axis but very slightly concave normal to it; sectors merge with medial over slightly convex surface, producing a faint broad ridge radiating away from origin of plate. Broad low growth lines parallel BRF and BBF, more closely spaced along latter. ZBL: 6.9 mm; ZBW: 9.2 mm (a); O-Pt: 8.1 mm; ZBBR: 7.5 mm (a); ZBBRF: 5.3 mm (a).

The preserved zygous basal appears originally to have been in juxtaposition with the radial on the left side of Plate XVIII, figure 5 (Breimer and Macurda, 1972); this is thus either the C or E radial and the radial on the right of it either D or B. Since the radial-basal suture on the right radial is shorter on the left side of the plate, it is interpreted as the B radial which would have abutted against the azygous basal which would cause the observed asymmetry. The sutures on the D radial would be symmetric. Left radial thus C, right radial B.

Radial hexagonal in plan view, with lower edge a very broad V with straight edges; lateral sides straight, gradually diverging in width adorally up to aboral apex of deltoid; upper edges straight, approach each other in an adoral direction at a very broad angle. Deep, narrow V-shaped sinus extends well down into radial (Pl. XVIII, fig. 5, Breimer and Macurda, 1972). Radial triangular in lateral view with short, very slightly concave edge facing basals; longer, slightly convex edge bordering ambulacrum; and straight lower edge along interradial suture. RB sectors smallest, very slightly concave parallel and normal to RB axis, smoothly merge with one another over slightly concave surface; bend over convex surface into RR sector. Ornamented with low broad growth lines. RR sector straight parallel to RR axis, very slightly convex normal to it, ornamented with low broad growth lines which diverge slightly adorally, indicating acceleration along RD axis during growth. RD sector at about 90° angle to RR sector in adoral portions (angle flattens out toward origin); RD and RR sectors merge over sharp edge. RD sector slightly convex parallel to RR axis, slightly concave normal to RD axis; concavity decreases aborally, flattening out by origin; concavity also more pronounced toward boundary with RR sector. Entire width of RD sector occupied by exposed hydrospire field (Pl. 25, fig. 9); these have been closed off ontogenetically in the aboral 11.5 mm of the RD sector; filled-in trace visible almost to origin. RHt: 3.0 mm; RWB: 9.2 mm; RWA: 12.2 mm; RWD: 17.0 mm; RD: 19.1 mm (a); RDF: 8.4 mm; RR: 7.2 mm; RRF: 22.0 mm (va); RB: 6.9 mm; RBF: 4.3 mm.

Deltoid elongate (L: 14.2 mm), rhombic in plan view, strongly convex in lateral view (height about 10 mm). In cross section, two concave sides rise upward to meet sharp, elevated, narrow, deltoid crest (Pl. 25, fig. 8). Adoral edge straight, broad (1.6 mm); width increases aborally along short, straight DDF, then more slowly along short, straight subparallel edge with lancets; (Gr.Ad.W.: 2.4 mm); plate slightly embayed at beginning of deltoid crest, then increases in width aborally along straight suture with ambulacrum; (Gr.Ab.W.: 8.0 mm); aboral half of plate elongate, strong V-shaped suture with radials. Broad V-shaped rim parallels DDF (Pl. 25, fig. 8) and extends to beginning of side plates, forming border to main ambulacral tract and its minor grooves and lobes on deltoid (total width: 0.6 mm). Small, shallow V-shaped trough behind this rim; deltoid crest originates a short distance aboral to this and arches down to aboral apex of deltoid, becoming more elevated above surrounding parts of the deltoid aborally. Upper edge of crest knife-like; drops downward in concave arc (more pronounced closer to crest and aborally) into hydrospire field. Aborally, entire width of DRF filled by hydrospire field; these are functional only within about 3 mm suture, having been progressively infilled during growth, visible as parallel ridges which converge on base of crest. Deltoid flattens out toward ambulacrum. Length crest: 13.5 mm (a); DR: 9.5 mm (a). Anal deltoids not preserved.

Ambulacra narrow, sublanceolate in plan view, convex in lateral view, convex in cross section, and entire side plate strongly elevated above surrounding plate. Near widest point of ambulacrum (2.6 mm), 0.8 mm of lancet exposed; some exposure continues almost to aboral tip. Outline of lancet in plan and lateral view as for ambulacrum; outline hexagonal in cross section, with concave upper surface under ambulacral tract; upper sloping sides straight; lateral sides parallel, straight; bottom slightly concave, exposed to interior of theca. Side plate wider than long; inner edge slightly convex against lancet; adoral and aboral sides against neighboring side plates straight; embayed ablaterally by large elongate ellipsoidal outer side plate; in widest part of ambulacrum, side plates completely surround outer side plates and form vertical elevated wall of ambulacrum rising above surrounding deltoid. Brachiolar facet on ablateral upper inclined surface of ambulacrum, adoral half developed on outer side plate, aboral half on side plate. Facet ellipsoid, about 0.5 mm long and wide, upper edge embayed where brachiolar groove descends to theca; adjacent facets in contact. Side grooves relatively long, bordered adorally and aborally by six minor lobes and grooves (Pl. 25, fig. 11); developed on side plate and lancet; main food groove bordered by 5 minor lobes and grooves per adjacent side plate. Arcuate, medially convex ridge connects aboral ends of side grooves, separates area ornamented by minor lobes and grooves from remainder of side plate, forms highest part of ambulacrum in cross section. Side plates two per mm; ambulacral length about 24 mm. Adoral end of ambulacrum about 1.7 mm from center of oral opening.

Ten hydrospire fields, developed across full width of radiodeltoid suture in non-anal interareas, with approximately 21 hydrospire slits per field, width: 7.8 mm; longest length of functional slit 9.0 mm (6.0 mm on radial); slits progressively infilled adorally and aborally while growing medially along suture. If left radial in Plate XVIII, figure 5 (Breimer and Macurda, 1972) is C radial, infilled hydrospires visible on left aboral part of RD sector indicating anal hydrospires.

Oral opening approximately pentagonal, relatively large.

Distribution.— Mississippian, New Providence Formation, Kentucky and Indiana(?).

Remarks.— The above description and measurements are derived from the holotype, USNM S 3210, which comes from Buttonmold Knob, 7 miles south of Louisville, Kentucky. Another large isolated radial (USNM 160589) is known from a nearby knob. Three other small incomplete specimens which are probably assignable to this species are known. (USNM 160590, Pl. 25, figs. 6,7), New Providence Shale, top of knob 0.25 mile northwest of Lebanon Junction, Kentucky; Indiana University 8266 (Pl. 25, fig. 14), Borden Group, Monroe Reservoir SE¼ SE¼ NE¼ sec. 4, T7N, R1E, Monroe County, Indiana; USNM 160585 (Pl. 26, fig. 2), Rockford Shaly beds, center lot 62, Clark Grant, 1.5 miles north of New Albany city limits in verges of Mt. Tabor and Klerner roads, 1.0 miles west of US route 31W, Floyd County, Indiana.

HADROBLASTUS WHITEI (Hall, 1861)
Pl. 24, figs. 1-16; Pl. 25, figs. 1-5, 10,13; Tables 40A,B

Hadroblastus whitei Breimer and Macurda, 1972, Pl. XVI, figs. 9,14,15; Pl. XVII, figs. 1-15.

Description.— Thecae biconical in lateral view with vault and pelvis being subequal but length to width varying to produce both tall and squat thecae (Pl. 24, figs. 2,4,5,7); profile of pelvis varies from moderately to broadly conical to convex. Vault convex, sometimes angular. Outline in plan view rounded pentagonal to pentagonal with very slight concavity in interradial areas (Pl. 24, figs. 1,8,9). See Tables 40A,B.

Basals three, in normal position, forming lower half of pelvic profile, varying from rounded conical to bowl-shaped in lateral profile. May be highly emphasized in more conical thecae or appear rather inconspicuous in flatter forms. In small specimens they merge evenly with the radials but in large specimens they may be distinctly set off by differences in curvature. Stem attachment area can be a single depression at proximal junctions of basals (which are usually slightly recurved to provide a slight recess) to one in which there is a small rim of secondary calcite (Pl. 24, fig. 12). Occasionally small cylindrical stem plate preserved (Pl. 24, fig. 10). Basals pentagonal in plan view.

Azygous basal rhombic in plan view, with very slightly convex lateral edges and straight distal edges.

BR sector convex parallel and normal to BR axis; adjacent sectors merge smoothly. In more conical basals, degree of curvature more pronounced proximally than distally. Zygous basals pentagonal, with straight to very slightly convex lateral edges, straight distal lateral edges, and concave distal medial edge. Medial BR sector strongly convex parallel and normal to BR axis. Lateral BR sectors moderately to strongly convex parallel to BR axis, flat to slightly convex perpendicular to BR axis; adjacent sectors merge smoothly. Curvature of central BR sector more heavily emphasized. Fine growth lines parallel BRF in all basals when preserved; rarely, transverse ridges (Pl. 25, fig. 13). Interbasal sutures may be slightly indented, particularly in large specimens. See Tables 40A,B.

Radials five, forming upper half of pelvis and lower part of vault. Radial pentagonal in plan view, with convex lower edge, very slightly convex to convex lateral edge, and two straight adoral edges which converge adorally (Pl. 24, fig. 3). Radial triangular in lateral view, with very slightly to slightly convex adoral facing edge, straight to very slightly concave aboral facing edge, and very slightly to slightly concave lower edge. BR sector straight to very slightly concave parallel to RB axis, very slightly convex to slightly convex normal to RB axis, adjacent sectors merge smoothly with one another or across a more convex surface in more conical thecae; merge smoothly with RR sectors. RR sector straight to slightly convex parallel to RR axis, very slightly convex to convex normal to it. RD sector at pronounced angle to RR sector, forming shoulder to ambulacrum which is elevated above it. RD sector straight to very slightly convex parallel to, straight to very slightly concave normal to RD axis. Full length and width of RD sector occupied by hydrospire slits (Pl. 24, figs. 6,15, 16; Pl. 25, figs. 1,2). Ornament of RB and RR sectors consists of fine growth lines parallel to growth fronts; occasionally, transverse ornament developed (Pl. 25, figs. 1,13). RWB: 1.9-5.0; 6.6-13.5 mm; RWA: 2.5-5.7; 8.7-16.7 mm; RWD: 2.5-6.1; 10.0-25.4 mm (Growth Series I and II). See also Tables 40A,B.

Deltoids four, together with epideltoid forming border to oral opening. Deltoid quadrate in plan view, with straight edge bordering oral opening; width expands aborally along short DDF, then contracts slightly along concave DAF to increase in width again aborally. DRF straight, meet at a sharp angle. Deltoid convex in lateral view, with downward curving deltoid crest. Adoral edge and DDF bordered by minor grooves and lobes; narrow rim forms a broad V-shaped border aboral to this. Rest of surface of deltoid lip flat, smooth. Deltoid crest arises near greatest constriction of DAF and then curves downward aborally. Sides of deltoid crest ornamented by hydrospire slits (Pl. 24, figs. 11,14-16; Pl. 25, figs. 5,10). Del.Gr.Ad.W.: 0.7-1.7 mm; Del.Min.W.: 0.5-1.5 mm; L.Del.Crest: 1.2-4.9 mm; DR: 1.3-3.8 mm. (Growth Series I). See Table 40A.

Anal deltoids two, an epi- and hypodeltoid. Configuration of epideltoid as for regular deltoid except central region of deltoid body of regular deltoid removed; replaced by anal opening and hypodeltoid. Limbs of epideltoid extend to radials forming hydrospires. Ovoid anal opening embays aboral part of epideltoid lip; opens directly upward. Hypodeltoid a relatively large plate, pentagonal in plan view, with two convex aboral edges; lateral sutures straight; adoral edge concave, embayed by anal opening (Pl. 24, fig. 15; Pl. 25, fig. 4). Hydrospires invaginated across outer part of hypodeltoid in larger specimens (Pl. 24, fig. 13). Epi.Gr.Ad.W.: 1.0-2.4 mm; O.c.-anus: 1.3-2.3 mm; Anus L: 1.4-2.3 mm; Anus W: 0.6-1.5 mm; Hypo.L.: 2.1-3.9 mm; Hypo.W.: 2.1-3.0 mm. (These measurements derived from only 5 specimens in Growth Series I.)

Ambulacra five, lanceolate in plan view, convex in lateral view. Lancet exposed (0.3-0.8 mm) almost to aboral tip of ambulacrum (Pl. 24, fig. 14); upper surface bears 5 minor grooves and lobes per side plate; impressions of side plates on lateral surfaces of lancet. Side plate quadrate, with convex inner edge, two straight ad- and aboral edges; adoral edge embayed abmedially by large triangular outer side plate; both form part of lateral edge of ambulacrum (outer side plate more so). Side groove bordered by 4 minor grooves and lobes (Pl. 24, figs. 15,16). Brachiolar facet on outer sloping edge of ambulacrum.

Ten hydrospire fields, developed across full length and width of RD and DR sectors, reduced in number on epiradial suture in anal interarea but developing across outer part of hyporadial suture in some larger specimens. No.Reg.Hydro.Sl.: 4-11; W.Reg.Hydro. Fld.: 0.9-3.8 mm; No.Anal Hydro.Sl.: 1-9; W.Anal Hydro.Fld.: 0.2-4.5 mm. (Growth Series I). In Growth Series II, No.Reg.Hydro.Sl.: 7-28; W.Reg.Hydro.Fld.: 3.2-10.3 mm.

Oral opening pentagonal.

Distribution.— Mississippian, Burlington Limestone, Missouri and Iowa; St. Joe Limestone, Oklahoma and Arkansas, U.S.A.

TABLE 40A. Growth relationships of principal variables of *Hadroblastus whitei* (Hall, 1861)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	15	0.93	-0.14	1.00	4.0–17.8	4.8–17.6
V/P	10	0.69	2.56	0.27	2.0– 5.8	1.4–12.0
L/ABBR	15	0.97	-0.08	2.90	4.0–17.8	1.6– 6.5
L/RD	18	0.89	1.50	1.96	4.0–17.8	1.5– 8.5
L/RB	18	0.96	-1.23	3.39	4.0–17.8	1.5– 5.9
L/Del.L.	15	0.89	0.91	1.83	4.0–17.8	2.2– 9.0
L/Amb.L.	18	0.84	2.50	1.18	4.0–17.8	2.5–13.7
L/No.Hyd.Sl.	15	0.67	0.79	1.19	4.0–17.8	4.0–12.0
RD/Amb.L.	22	0.98	0.42	0.62	1.5– 8.5	2.5–12.1
Del.L./Amb.L.	22	0.87	1.18	0.56	2.2– 9.0	2.5–13.7
ABL/ABW	17	0.92	-0.31	1.13	1.9– 8.2	1.9– 6.9
ABBR/ABBRF	17	0.93	-0.14	1.40	1.6– 6.5	1.4– 4.9
ZBL/ZBW	17	0.95	0.35	0.68	1.7– 7.0	2.1– 9.2
ZBBR/ZBBRF	17	0.92	0.32	1.51	1.5– 7.0	0.9– 4.6
ABBR/RB	17	0.94	-0.18	1.06	1.6– 6.5	1.5– 5.9
ABBR/RD	17	0.89	0.68	0.62	1.6– 6.5	1.5– 8.5
ABBR/Del.L.	17	0.92	0.36	0.63	1.6– 6.5	2.2– 9.0
RD/RDF	22	0.89	1.29	1.39	1.5– 8.5	0.8– 5.0
RR/RRF	22	0.95	0.54	0.45	1.4– 4.8	2.4–10.3
RB/RBF	22	0.81	0.61	1.33	1.5– 5.9	1.2– 3.7
RD/RR	22	0.92	-0.43	1.55	1.5– 8.5	1.4– 4.8
RD/RB	22	0.84	-0.06	1.28	1.5– 8.5	1.5– 5.9
RR/RB	22	0.93	0.17	0.85	1.4– 4.8	1.5– 5.9
RD/Del.L.	22	0.93	-0.04	0.92	1.5– 8.5	2.2– 9.0
RB/Del.L.	22	0.84	0.77	0.55	1.5– 5.9	2.2– 9.0
Del.L./Gr.Ab.W.	18	0.91	0.59	1.65	2.2– 6.2	1.1– 3.3
Del.L./Anal Del.L.	9	0.95	0.48	0.84	2.2– 6.2	1.8– 6.6
Amb.L./Amb.W.	20	0.85	-3.29	6.26	2.5–13.7	0.9– 2.2
Amb.L./No.S.P.	20	0.91	-1.65	0.48	2.5–13.7	8.0–27.0

Remarks.– The above description is based upon the specimens in Growth Series I and II (see Appendix 1). The internal anatomy and ontogeny were discussed and illustrated by Breimer and Macurda (1972).

TABLE 40B. Growth relationships of principal variables of *Hadroblastus whitei* (Hall, 1861)

Variables	n	r	a_0	a_1	Observed Range y	x
ABL/ABW	5	0.99	1.37	0.86	7.5–11.9	7.1–12.0
ABBR/ABBRF	5	0.97	2.07	0.96	6.5–10.9	4.8– 9.0
ZBL/ZBW	5	0.85	1.15	0.54	6.9–11.3	11.0–16.4
ZBBR/ZBBRF	5	0.90	2.91	1.05	6.9–11.6	4.3– 7.9
ABBR/RB	5	0.99	2.20	0.73	6.5–10.9	6.3–12.0
ABBR/RD	5	0.83	0.58	0.57	6.5–10.9	10.7–17.0
RD/RDF	8	0.83	4.77	1.26	7.7–18.6	3.7–10.2
RR/RRF	10	0.93	1.60	0.47	5.7–11.4	9.7–22.4
RB/RBF	10	0.64	1.47	1.09	5.1–12.0	4.0– 7.6
RD/RR	10	0.87	0.68	1.47	7.7–18.6	5.7–11.4
RD/RB	10	0.85	2.85	1.35	7.7–18.6	5.1–12.0
RR/RB	10	0.93	1.79	0.88	5.7–11.4	5.1–12.0

The variability in the thecal form of the specimens from the Burlington Limestone which are assigned to *H. whitei* raises the possibility that two species are present (compare Breimer and Macurda, 1972, Pl. XVII, figs. 7,8 and 13). I cannot find any consistent differences other than in the basals so have assigned the conical thecae to *H. whitei* as well (but with some uncertainty). The smallest specimens from the St. Joe Limestone are almost all larger than the largest Burlington Limestone specimens.

Hall's holotype (specimen 2 in the growth series) looks like the specimen in Plate 24, figure 3 (the flatter thecal form). The holotype of *Codaster grandis* Rowley and Hare, 1891 is clearly similar to Hall's specimen so it was synonymized with *H. whitei* by Breimer and Macurda (1972).

HADROBLASTUS(?) BENNIEI
(Etheridge and Carpenter, 1886)
Pl. 25, figs. 12,15; Pl. 26, figs. 1,4

(?)*Phaenoschisma benniei* Breimer and Macurda, 1972, p. 18, Pl. V, figs. 8,11,13.
Hadroblastus(?) *benniei* Macurda, 1977, p. 234, Pl. 32, figs. 5,6,8.

Distribution.— Carboniferous, Visean, Lower Limestone Group, Scotland.

Remarks.— A description was given by Macurda (1977). Additional illustrations of the ambulacra are given herein (Pl. 25, figs. 12,15; Pl. 26, figs. 1,4).

HADROBLASTUS(?) HIBERNICUS n. sp.

Hadroblastus sp.(?) Breimer and Macurda, 1972, p. 31, Pl. XVIII, figs. 2,4.

Description.— Theca biconical in lateral view, with conical pelvis; lower part of vault convex. Pelvic profile slightly recurved in medial part. Cross section pentagonal with slightly concave interambulacral areas; greatest width at aboral tips of ambulacra. Vault and pelvis probably subequal. L: >7.6 mm; W: 8.2 mm; V: >1.9 mm; P: 5.7 mm; Pelvic angle: 102°.

Basalia three, convex in lateral view, forming lower half of pelvis; pentagonal in plan view. Stem attachment area a small circular depression at proximal tips of basals; diameter: 0.8 mm. Azygous basal quadrate, with lateral edges being slightly convex proximally, straight distally; distal edges straight. BR sector convex parallel to BR axis proximally, becoming straighter distally, BR sector slightly convex normal to BR axis.

Adjacent sectors merge over a convex boundary with median ridge serving as a boundary. BB sector very slightly convex, parallel and normal to BB axis, separated from BR sector by a thin ridge. BB and BR sectors ornamented by growth lines; transverse ridges also present in BR sectors. BA axis apparently present, with growth from origin of radial to form stem attachment area. Zygous basal pentagonal, with straight lateral and distal lateral edges, convex medial distal edge. Medial BR sector as for azygous basal sector; lateral sector convex parallel to BR axis proximally, becoming straighter distally; flat normal to BR axis. Ornament of BR and BB sectors, including ridges separating growth sectors, as for azygous basal. ABL: 4.5 mm; ABW: 3.6 mm; ABBB: 1.0 mm; ABBBF: 3.6 mm; ABBR: 3.8 mm; ABBRF: 2.5 mm; ZBL: 3.9 mm; ZBW: 5.1 mm; ZBOPt: 4.4 mm; ZBBR: 4.0 mm; ZBBRF: 1.5 mm.

Radials five, forming upper part of pelvis and lower part of vault. Radial intersects basal at a slight angle, producing a slight recurvature in the pelvic profile. Radial pentagonal in plan view, with convex lower edge, two slightly convex lateral edges, and two straight adoral edges which converge adorally. Radial triangular in lateral view, with very slightly convex adoral facing edge, straight aboral facing edge, and slightly concave lower edge. RB sector very slightly convex parallel to RB axis, slightly convex normal to RB axis, with ridge separating RB sectors from one another and RR sectors. RB sector ornamented by growth lines parallel to RBF and transverse ridges which cut across growth lines, producing a reticulate pattern. RR sector straight parallel to, slightly convex normal to RR axis. Ornament of RR sector as for RB sector. RD sector at pronounced angle to RR sector, forming a shoulder to the ambulacrum which is elevated above it. RD sector very slightly convex parallel and normal to RD axis. Full length and width of sector occupied by hydrospire slits. RHt: 1.8 mm; RWB: 3.5 mm; RWA: 4.5 mm; RWD: 4.2 mm; RD: 3.2 mm; RDF: 1.8 mm; RR: 2.8 mm; RRF: 4.0 mm; RB: 3.5 mm; RBF: 2.2 mm.

Except for the aboral half of the A ambulacrum and outer part of the AB deltoid body, the vault is missing. Aboral part of deltoid body forming a deltoid crest; sides slope gradually downward, covered with hydrospire slits. Ambulacra elevated above radial and deltoid, lancet exposed almost to aboral tip of ambulacrum, 3 side plates per mm. Hydrospire fields occupy full width of radiodeltoid suture. No.Reg.Hydro.Sl.: 4; W.Reg.Hydro.Fld.: 1.4 mm.

Distribution.— Lower Carboniferous, Visean, Feltrim Hill Knoll, County Dublin, Ireland.

Remarks.— The above description is based upon the only known specimen which is incomplete; it is an unregistered specimen in the collections of Trinity College, Dublin. All preserved characters are compatible with an assignment to *Hadroblastus* but the absence of any information on the anal interarea precludes definite generic assignment. The combination of the thecal form and ornament distinguish it from any known blastoid and the species name *hibernicus* is therefore proposed for it.

Dark bands which apparently represent color bands are preserved in the specimen.

Genus NEOSCHISMA Wanner 1924a

Type species.— *Neoschisma verrucosum* Wanner, 1924a.

Neoschisma Breimer and Macurda, 1972, p. 31.

NEOSCHISMA AUSTRALE Breimer and Macurda, 1972
Pl. 27, figs. 1-12; Pl. 28, figs. 1-16; Pl. 30, fig. 3; Table 41

Neoschisma australe Breimer and Macurda, 1972, Pl. XIX, figs. 1-4, 6-8.

Description.— One partial theca, plus numerous isolated plates, form the basis for the description of this species. Theca broadly conical in lateral view with flat vault; ambulacra restricted (Pl. 27, fig. 1). Outline in plan view decagonal, with slightly depressed ambulacral areas; interambulacral areas wider than ambulacral areas. Greatest width just below top of theca, at upper junction of radials with aboral tips of deltoids. Length probably greater than width and exceeded 35 mm in largest specimens.

Basalia three, in normal position, pentagonal in plan view, becoming rounded proximally; conical in lateral profile, slightly concave near base due to proximal extension of broad stem attachment area (Pl. 27, figs. 11,12). Latter deposited by secondary calcite secretion, forming broad proximal cylinder whose diameter increases ontogenetically, from 2.0 to 5.0 mm. Crenellar facets at edge of attachment area.

Azygous basal quadrate in plan view, with straight lateral and distal edges. Straight in lateral profile except for curvature caused by stem attachment area. BR sector straight parallel to BR axis, very slightly convex normal to it; adjacent sectors merge smoothly over very slightly convex surface. Zygous basals pentagonal in plan view (Pl. 27, figs. 11,12), with straight distal lateral edges,

TABLE 41. Growth relationships of principal variables of *Neoschisma australe* Breimer and Macurda, 1972

Variables	n	r	a_0	a_1	Observed Range y	x
ZBL/ZBW	7	0.97	0.41	0.80	6.1–13.8	7.3–16.0
ZBBR/ZBBRF	7	0.97	1.75	1.70	6.0–13.8	2.8–16.8
RD/RDF	18	0.96	0.62	0.54	2.2– 8.8	3.0–15.0
RR/RRF	18	0.87	1.61	0.31	3.2– 9.7	5.3–25.0
RB/RBF	20	0.79	3.25	1.34	5.0–14.5	2.8– 8.7
RD/RR	20	0.92	-0.54	0.90	2.2– 8.8	3.2– 9.7
RD/RB	20	0.92	-1.18	0.63	2.2– 8.8	5.0–14.5
RR/RB	20	0.96	-0.43	0.67	3.2– 9.7	5.0–14.5
Del.L./Gr.Ab.W.	17	0.90	0.38	1.75	5.5–18.0	3.5–10.0

concave distal medial edge, and straight lateral edges except near base. Lateral profile as for azygous basal. BR sectors straight parallel to BR axis and very slightly convex normal to it; adjacent sectors merge smoothly over very slightly convex surfaces. Surface of basals ornamented with broad, almost smooth growth lines which parallel BR fronts; BB sectors not evident.

Radials quadrate to V-shaped in plan view, depending on stage of development of radial limbs (Pl. 28, figs. 2-5, 8-14). Limbs extend slightly or well above ambulacra. Radials form upper part of broadly conical pelvis and extend upward to near highest point of theca at aboral tip of deltoid. Lower edge of radial has two straight or a single convex edge(s). Radial width widens adorally along straight lateral edges; upper edges slope inward toward ambulacrum with extremely broad V-shaped profile which becomes steeper with growth. Small notch at center for ambulacrum; sinus very short. Radial straight to very slightly concave (medially) in lateral profile. RB sector straight to very slightly convex parallel to RB axis, very slightly convex normal to it; merging smoothly with adjacent RR and RB sectors. RR sector slightly convex parallel to RR axis, slightly concave normal to RR axis due to outward flaring of radial limbs. RD sectors at pronounced angle to RR sectors, forming upward or inward sloping face (Pl. 28, figs. 1,7). RD sector straight parallel to RD axis, usually straight normal to it. Surfaces of RR and RB sectors ornamented with growth lines as in basals; full width of RD sectors occupied by hydrospire slits; strong secondary infilling so remnants of infilled slits visible (Pl. 27, fig. 8). Ambulacrum does not extend to origin of radial, forming a small radial sinus. Aboral end apparently displaced adorally (relatively) during growth; area between ambulacrum and origin filled with nodose ornament. Where inner part of hypodeltoid abuts against radial, hydrospire slits missing and broad convex humped area formed (Pl. 28, figs. 9,10,12). Later hydrospires usually added on hypodeltoid and radial anal interareas often have well developed anal hydrospire slits (Pl. 28, figs. 2,4,13). See Table 41.

Deltoids four, together with epideltoid forming borders of oral opening. Deltoid rhombic in plan view (Pl. 27, figs. 3,5,6,7), with short facet at adoral tip where plate borders oral opening. Adoral edges straight, relatively long, bordering adjacent deltoid and ambulacrum (Pl. 28, fig. 6). Aboral edges straight, converging to a point, bearing short hydrospire slits along full length (Pl. 27, fig. 10). Deltoid usually flat in lateral profile but may be slightly concave with aboral part curving upward (rarely convex to S-shaped). Plate is convex in cross section, particularly the aboral portion. DDF bears minor grooves and furrows as part of broad (0.6 mm) shallow ambulacral tract (Pl. 28, fig. 6). Ambulacral tract bordered by broad, smooth ridges. Adoral end and sides of lancet cause a small indentation along DAF; ornament paralleling DAF more bumpy and irregular. Origin of plate located near adoral end and former outlines of plate visible from rhombic-shaped growth ornament on upper surface of plate; some irregular bumpy ornament may also be present. Aboral growth ridges are broad and smooth; at same time that calcite was added to lateral edges, there was also a downward component to produce the convex cross section and gradual elevation of the origin relative to the surrounding plates (Pl. 27, fig. 6). Aboral tip of deltoid may be produced into a short blade or hook and sharp, irregular keel may occupy upper aboral surface. See Table 41.

Anal deltoids two, an epi- and hypodeltoid (Pl. 27, figs. 2,4,9; Pl. 30, fig. 3). Epideltoid corresponds to adoral part of regular deltoid. Surface ornamented with slightly nodose ornament which is highest around anal opening. Epi-hypodeltoid suture straight; epiradial suture straight and at a right angle to length of ambulacrum. Hypodeltoid corresponds to aboral part of regular deltoid. Adoral part of hypodeltoid forms a very high collar to anal opening, buildup apparently produced by secondary deposition. Elevated area slopes downward to outer part of hypodeltoid which looks like aboralmost part of regular deltoid, including formation of hydrospire slits (Pl. 27, fig. 9). Anal opening ovoid, longer than wide, surrounded by high collar with aboral groove which is directed outward and upward. On interior surface of hypodeltoid, a low, thin ridge originates near aboral edge of anal opening, then curves downward into D sector of plate, somewhat dividing plate internally.

Ambulacra five, lanceolate, removed from oral opening, of moderate length, not reaching to radial origin. Lancet lanceolate, adoral part relatively long, exposed, bordering deltoids and bearing ambulacral tract. Aboral part of ambulacrum which borders radials relatively short, lancet concealed, and space occupied by relatively tall side plates which fill excavated space in radial sinus between end of lancet (indicated by that part opening into thecal interarea) and end of excavated area. Side plates thin, wide, with brachioles probably attached at edge of ambulacrum in parabolic arc but details of facets not preserved.

Ten hydrospire groups, developed across full width of RDF in regular interareas and across epi- and part of hypodeltoid suture in anal interarea (rarely absent). Hydrospire slits short, closely spaced except for occasional irregularities in outer part of hydrospire field (Pl. 28, figs. 15,16). When deltoid aborally produced, hydrospire slits are not developed to aboral tip of plate.

The number of hydrospire slits encountered on the measured radials varied from 11 to over 23; the width of the hydrospire fields varied from 2.8 to 11.5 mm. The number in the anal interarea may be nearly equal or reduced (rarely absent). Representative figures for the number of regular hydrospires vs. number of anal hydrospires (subdivided into those developed across the epiradial suture and those across the hyporadial suture are: 17(4,7); 11(3,6); 14(2,0); 16(0,0); 11(3,7); 8(2,2); 11(3,0). The number of hydrospire slits measured on the isolated regular deltoids ranged from 7 to 22, the width of the hydrospire fields from 3.5 to 11.2.

Oral opening pentagonal.

Distribution.— Permian, Callytharrra Fm., Western Australia.

Remarks.— The above descriptions are based upon the isolated plates listed in Appendix 1. Measurements derived from these isolated plates are summarized in Table 41; the ontogeny was discussed by Breimer and Macurda (1972).

Occasional irregularities in plate development are encountered such as apparent presence of part of an extra radial or deltoid. Steromic lineations are well preserved.

NEOSCHISMA TIMORENSE Wanner, 1940
Pl. 26, figs. 3,6,8,10,11; Pl. 27, fig. 13

Neoschisma timorense Breimer and Macurda, 1972, p. 31, Pl. XX, figs. 4,8.

Description.— Theca broadly obverse conical with oral surface serving as base of cone and proximal end truncate. Profile of pelvis slightly convex, more so in proximal portion. Lateral profile formed by basals, radials, and adoral tip of deltoid knob which is elevated above oral opening. Base of theca indented by basal concavity where column attached. Profile of vault from tips of deltoids to oral opening concave toward oral opening. Cross section strongly pentagonal with slightly concave ambulacral areas in region of vault, becoming circular in pelvis. Greatest width in interambulacral areas at tip of deltoid knob, in ambulacral areas at origin of radials. L.: 15.7 mm; W.: 13.3 mm; V.: 2.6 mm; P.: 13.1 mm.

Basalia three, forming lower half of broadly conical pelvis. Lower surface is truncate where column attached; basal concavity present. Width of concavity at base:

3.9 mm, depth: 3.0 mm; width at top of concavity: 2.0 mm. Crenellar facets along lowermost proximal edge of concavity, approximately 50-60 facets in the ring. Small shelf 0.2 mm wide borders concavity, apparently marking position of proximal stem plate against theca. Thus proximal stem plate had a diameter of 4.3 mm, unusually large in blastoids.

Azygous basal in AB interarea, with broad pentagonal form in plan view due to lower edge of basal concavity. Point of junction of three basals at top of concavity. Upper edges bordering radial straight, meet at broad angle; lateral edges straight, tapering slowly toward base of theca; converge in basal concavity. Thus when azygous basal viewed from base of theca, rhombic outline. Lateral profile of azygous basal is convex with slight indentation just below midline. Basal concavity has probably been formed by massive secondary deposit of calcite on proximal surface of basal and break in profile represents distal edge of secondary deposit; however, no ornament preserved. However, fenestrate trabeculae of calcite in plate are oriented approximately perpendicular to edge of basal concavity in all basals. Thus diameter of attached stem plate would have increased throughout growth. Part of BR sectors are slightly convex both parallel and normal to BR axis, merge smoothly with each other; exterior of probable secondary deposit is slightly convex in length and width and merges with rest of azygous basal through slightly concave area. ABL: 8.2 mm; ABW: 7.7 mm; ABBBF: 6.5 mm; ABBR axis: 7.5 mm; ABBRF: 4.7 mm.

Zygous basals broadly hexagonal in outline because of truncate lower edge on border of basal concavity. Uppermost edge of basal slightly concave against C or E radials, upper lateral edges straight. Lateral sides straight, tapering slowly toward proximal edge of theca. Lowermost edge truncated by basal concavity but converge within concavity; thus, in basal view, zygous basals pentagonal. Lateral profile as for azygous basal; upper part of BR sectors slightly convex both parallel and normal to BR axes, merging smoothly over more convex surface; probably secondary deposit as for azygous basal. ZBL: 8.1 mm; ZBW: 8.6 mm; ZBOPt: 8.5 mm; ZBBR axis: 7.5 mm; ZBBRF: 3.6 mm.

Radials five, forming upper half of pelvis and limbs extending to level of oral opening; radial pentagonal, short and broad in plan view, with convex or two straight lower edges; width expands upward to tip of deltoids along straight to slightly convex suture. RD sector confined to broad concave ambulacral sinus; upper straight edges slope in toward one another in a very broad V. Origin of radial at aboral end of sinus; no ornament preserved; origin slightly depressed. Radial flat in lateral view, RB sector very slightly convex parallel and normal to RB axis, adjacent sectors merge over slightly convex surface, with RR sectors over flat surface. RR sectors slightly convex parallel and normal to RR axis. RR sectors bend over into broad, V-shaped, concave ambulacral sinus to which RD sectors are confined (Pl. 26, fig. 11). Latter are slightly concave parallel and normal to RD axis, smooth except where ornamented by hydrospire slits at radiodeltoid suture. RWB: 6.5 mm; RWA: 8.5 mm; RWD: 9.1 mm; RD: 3.2 mm; RDF: 4.7 mm; RR: 4.0 mm; RRF: 7.8 mm; RB: 5.0 mm; RBF: 3.5 mm.

Deltoids four, together with epideltoid forming border to oral opening. In plan view deltoid is rhombic. Adoral half of rhomb slightly smaller, convex in cross section. Adoralmost edge and lateral edges ornamented by minor lobes and grooves (Pl. 27, fig. 13). Most of adoral half ornamented by small warty knobs, densest near edges of plate, becoming low, streaked out ridges which pass into aboral portion of plate, rising toward deltoid knob. Aboral tip of deltoid is highest point, being elevated above oral opening; thus, in lateral view upper surface of deltoid is slightly concave as plate descends to oral opening. Lowest edge of plate in lateral profile is where radiodeltoid suture intersects interdeltoid suture; lower edges rise toward oral opening and aboral tip. Upper surface of aboral half of plate constricts from adoral half, tapering to a smooth, rounded, short, finger-like projection beyond edge of theca (Pl. 26, fig. 11) and radiodeltoid sutures which meet interradial suture just below the projection. Lateral walls of aboral half of deltoid drop away at right angles to form vertical sided adoral one-third of ambulacral sinus. Ornament of this area smooth except for short hydrospire slits. Small recess formed where sector bends to meet ambulacrum. Del.L.: oral center–radiodeltoid–interradial suture: 7.6 mm; to tip of prong: 7.9 mm; width of plate bordering oral opening: 0.8 mm; maximum width (at adoral end of ambulacrum): 4.8 mm; DDF: 3.2 mm; height from lowest edge to radiodeltoid suture: 1.5 mm; height of prong above this: 2.0 mm.

Adoral edge of epideltoid forms part of border to oral opening; width: 0.9 mm. Ornament and configuration as for adoral half of regular deltoid; maximum width: 5.0 mm. Plate begins to constrict beyond adoral edge of ambulacrum, meets hypodeltoid 1.7 mm beyond this.

Aboral edge of epideltoid almost straight except where embayed by anal opening (Pl. 26, figs. 8,10); aboral edge elevated above oral opening. Hypodeltoid now missing but presence indicated by large deep concave facet. In plan view outline of hypodeltoid would have been hemispherical; flaring outward slightly from epi-hypodeltoid suture. Length of hypodeltoid greater than 3.7 mm; width: 4.0 mm. Anal opening, L.: 1.2 mm; W.: 1.1 mm. Oral center to adoral edge of anal opening: 4.0 mm; to epi-hypodeltoid suture at edge of anal opening: 5.0 mm, to epi-hypodeltoid-radial suture: 5.5 mm.

Ambulacra five, short, wide (L.: 2.0 mm; W.: 2.3 mm), confined to a small area at junction of radiodeltoid and interdeltoid sutures, not extending to aboral end of ambulacral sinus (Pl. 26, figs. 3,6). Outline in plan view elongate hemispherical; in lateral profile extremely convex in aboral portion, curled through over 90°; flattens in adoral one-third with adoralmost portion recurved. Main groove ascends slightly from oral opening along interdeltoid suture which is ornamented by ambulacral furrows (width 0.4 mm), then descends in broad convex arc to adoral end of ambulacrum. Main groove of ambulacrum bordered by minor lobes and furrows. Side grooves (12 per side) are long in adoral half, become progressively shorter in aboral half, enter main groove of ambulacrum in fan-shaped pattern, from almost parallel at aboral end, to almost at right angles in mid portion, to an aborally oriented direction at adoral end; brachiolar facets at ablateral edges of ambulacrum. Lancet plate broad, lanceolate, exposed almost to aboral tip of ambulacrum with side and outer side plates arrayed in a parabolic arc on lateral and aboral edges. Side plates long, slightly arcuate, abutting against lancet; usually about 0.19 mm apart but thinner admedially than abmedially. Outer side plate elongate, ellipsoidal, pointed ends, positioned between two side plates at point where edge of ambulacrum begins to turn downward (L.: 0.06 mm; W.: 0.13 mm), ablateral edge 0.19 mm from ablateral edge of ambulacrum. Brachiolar facets on lateral edges of ambulacrum; weathered but ellipsoidal outline, length about 0.25 mm; width: about 0.19 mm; developed on side plate and outer side plate.

Ten hydrospire fields; non-anal interarea hydrospire slits short, longest near ambulacrum (1.3 mm with longest portion on radial), becoming shorter ablaterally, tapering to those in incipient state of development. 6 to 7 per field, crossing radiodeltoid suture, width of field 2.5 mm, thus not extending full width of radiodeltoid suture (4.7 mm); spacing within field slightly irregular. Apparently 2 per group in anal interarea, cross epideltoid-radial suture; none across hypodeltoid-radial suture.

Oral opening pentagonal, width: 1.1 mm.

Distribution.– Permian, Sonnebait Series, Timor, Indonesia.

Remarks.– The above description is based upon the only known specimen, the holotype (Univ. Amsterdam Ge.0.9993).

Although the ambulacrum does not extend to the aboral end of the ambulacral sinus, the mechanics of growth would appear to demand the growth of the radial outward from this point. Thus, the ambulacrum failed to grow at rate equal to that of the radial and is now confined to a smaller area. Calcite trabeculae are not clearly distinguishable from cleavage in the RD sector. If there was normal growth in this area, however, ends of hydrospire slits would appear to have been infilled. The decreasing length of the hydrospire slits ablateral to the ambulacrum appears to indicate a normal growth pattern. The trabeculae of the deltoid are visible in the knob; the long axes point toward the tip. Thus there was apparently growth on a free surface. Those in the median portion of the base of lateral wall of aboral part of the deltoid are parallel to radiodeltoid suture 0.5 mm from it.

The description of the side and outer side plates is based upon the C ambulacrum using xylene as a wetting agent.

NEOSCHISMA VERRUCOSUM Wanner, 1924a
Pl. 26, figs. 5,7,9

Neoschisma verrucosum Breimer and Macurda, 1972, p. 31, Pl. XIX, fig. 5, Pl. XX, fig. 7

Description.– Theca fragmentary, comprised of small portion of distal parts of zygous basals, C and D radials, parts of two deltoids, two lancets, and the epi- and hypodeltoid. Lateral profile of upper part of pelvis convex outward. Top of vault flat with small prong on hypodeltoid; lateral sides slope steeply downward, merging with pelvis. Cross section rounded pentagonal at junction of vault and pelvis with points of pentagon in interambulacra areas; cross-sectional outline becomes rounded proximally. Greatest width at aboral ends of ambulacral sinuses. Length greater than 16.6 mm; W.: 19.6 mm (va); V.: 5.5 mm. Pelvic angle unknown.

Basals fragmentary; azygous basal unknown; distal portion of C zygous basal under CD interarea preserved and very small distal fragment of adjoining E zygous basal. Zygous basal rounded in cross section; surface smooth (plates weathered); ZBW: 10.0 mm (a); ZBBRF: 4.2 mm. Thickness of plate along BBF: 1.0 mm.

Two radials preserved, C and D; surface now smooth. In plan view radials short, broad. Radial-basal sutures either slightly convex (C radial) or two straight edges (D radial); interradial sutures straight, expanding adorally with greatest width at radiodeltoid suture (RWB: 6.2 mm (a); RWA: 11.4 mm; RWD: 12.4 mm). In lateral view radial has rounded triangular profile with straight base, edge along ambulacral sinus straight, and edge forming upper part of vault convex outwards. Origin of radial presumably at aboral end of ambulacral sinus which is not completely filled by ambulacrum. RB sector convex both parallel and normal to RB axis, merging smoothly over convex surface with adjacent RB and RR sectors. RR sectors slightly convex parallel, convex normal to RR axis; no surface ornament preserved. RR sector bends across angular boundary into RD sector which is confined to a broad ambulacral sinus, straight parallel and normal to RD axis, full width of sector ornamented by hydrospire slits. RD: 4.8 mm; RDF: 5.2 mm; RR: 5.9 mm; RRF: 12.3 mm (a); RB: 8.7 mm; RBF: 3.0 mm.

Parts of two regular deltoids (BC and DE) preserved. Deltoid rhombic in plan view, ad- and aboral halves approximately equal. Each DDF bears a shallow main groove which is bordered by closely spaced minor lobes and grooves; width of ornamented area on two adjacent plates 0.6 mm; concave in cross section. Narrow smooth area borders area ornamented with minor lobes and grooves. Rest of adoral half of plate elevated above this and strongly ornamented with irregular lumpy, nodose ornament. Lateral parts of aboral half of deltoid slope sharply down into ambulacral sinus which is gently concave in cross section, and covered by closely spaced hydrospire slits (Pl. 26, fig. 5). Lowest exposed point of deltoid at lateral edges of rhomb, 2.3 mm below adoral surface. Although medial aboral portion of deltoid not preserved, adoral terminations of hydrospire slits visible, indicating this portion of plate was probably similar to the adoral half, tapering as in *Neoschisma timorense*; beginning of such a taper visible on DE deltoid. Unknown if aboral portion of deltoid developed into knob. Deltoid length: 10.3 mm (va); maximum width at adoral end of ambulacrum: 8.0 mm (va); DDF: 5.7 mm (a).

Anal deltoids two, an epi- and hypodeltoid. Epideltoid hexagonal in plan view, with narrow adoral edge (width: 1.2 mm (a)), diverges along straight DDR which extend to adoral end of ambulacrum; each aboral lateral edge borders adoral edge of lancet and part of lateral edge on ablateral portion and radial on adlateral portion. Lateral portions of aboral edge converge adorally toward anal opening, slightly concave against hypodeltoid, with medial aboral edge deeply embayed by anal opening. Adoral portion of epideltoid ornamented as regular deltoid; nodose ornament extends onto prongs of epideltoid until they bend downward to form part of the ambulacral sinus (Pl. 26, fig. 9); aboral portion of prongs bear closely spaced hydrospire slits. Anal Del.L.: 10.2 mm (a); Epi.L. (oral center–center–epi-hypodeltoid suture): 6.7 mm (a); maximum width: 7.8 mm (a).

Hypodeltoid large, bordered by epideltoid (suture slightly convex against epideltoid) and radials (suture strongly convex against radials) (Pl. 26, fig. 7). Aboral edge drops very steeply down from edge of anal opening (profile straight) to form part of lateral wall of theca. Surface curves around laterally to epi-hypodeltoid suture; thus all sides slope downward from edge of plate bordering anal opening. Adoral edge itself is medially embayed by anal opening; edge bordering anal opening rises from suture to highpoint of plate near aboral end of ambulacrum. Hypo.L.: 4.8 mm; Hypo.W.: 4.8 mm.

Anal opening large, very elongate, form of a narrow ellipse; L.: 4.3 mm; W.: 1.4 mm. Oral center to anus: 4.0 mm (a); o.c. to epihypodeltoid suture at anus: 6.2 mm (a); o.c. to junction epideltoid, hypodeltoid, and radial sutures: 7.6 mm (a).

Ambulacra rhombiform, greatest width near median (Pl. 26, fig. 5), just adoral to radiodeltoid suture, removed from oral opening; slightly convex in lateral view. Upper surface of ambulacrum weathered; no side plates preserved in aboral half; apparently overlie lancet on most of adoral part except for exposed rhombic area 0.8 mm long at adoral end of ambulacrum. No brachiolar facets in adoral half of ambulacrum. Lancet has a V-shaped upper profile, underlies side plates. Oral center to ambulacrum: 3.3 mm; Amb.L.: 6.3 mm; W.: 1.9 mm; side plates 3 per mm. Width of ambulacral tract: 0.7 mm.

Ten exposed hydrospire fields, occupying width of ambulacral sinus and RDF, crossing radiodeltoid suture. Adoral edge of field convex toward oral opening; aboral edge straight along outer edge RD sector. Number of hydrospire slits in regular field 16 (17?); maximum functional length 2.7 mm on either side of radiodeltoid suture; width of field: 5.3 mm. Number of hydrospires reduced to 5 in anal interarea; maximum length:

2.0 mm, minimum: 1.0 mm; width of field: 1.5 mm; developed across radio-epideltoid suture. Width of slit 0.05 mm. New slits apparently added during growth in all fields as shortest slits are found near ablateral edges of fields. Deltoid ornament would appear to indicate some infilling of adoral ends of hydrospire slits during growth; aboral ends prominent secondary infilling. Functional length about equal on radial and deltoids.

Configuration oral opening indeterminate.

Distribution.— Permian, Kapan, Timor, Indonesia.

Remarks.— The type species of *Neoschisma* is *N. verrucosum*, which is known from only the one partial specimen described above (Technische Hogeschool Delft 12254). This is specifically distinct from *N. timorense*, which is also known from one specimen; the latter, however, is much better preserved. The generic characters of these specimens are identical; the points of specific difference appear to be in the more closely spaced hydrospire slits and longer hydrospire fields of *N. verrucosum*, as well as the more gently sloping lateral sides of the deltoids of the latter, the irregular nodose ornament of the deltoids, and larger ambulacra. *Neoschisma australe* is easily distinguished from the other two species by the broader flat upper surface of the deltoid and the development of a prominent stem attachment area, whereas there is a basal invagination in *N. timorense*.

Genus NOTOBLASTUS Brown, 1942

Notoblastus Breimer and Macurda, 1972, p. 33,34.

Remarks.— The following characters can be used to differentiate between the species of *Notoblastus*.

N. brevispinus: Theca biconical, squat; pentagonal outline; RB sectors concave; short spine on origin of radial; strong growth lines on RB and RR sectors; surface of deltoids relatively smooth?; ambulacra medium size, lanceolate.

N. cornutus: Theca very broad, biconical; taller than *N. brevispinus*; pentagonal outline; RB sectors concave; short blunt spine on origin of radial; strong growth lines on radials; DD and DR sectors equal; strong ridge separating DR and DD sectors; ambulacra large, lanceolate.

N. oyensi: Theca bowl shaped; convex base; pentagonal outline; RB sectors convex; short spine on origin of radial; granulose ornament on basals and radials; DD sector smaller than DR; only a small ridge between DR and DD sectors; ambulacra small, lanceolate.

N. stellaris: Theca cup shaped; pentagonal outline; convex basals and RB sectors; blade shaped prong with serrate tip at origin of radials; granulose ornament and growth lines on radials; DR and DD sectors subequal; strong ridge separates the two sectors; ambulacra broadly lanceolate.

NOTOBLASTUS BREVISPINUS Brown, 1942
Pl. 29, figs. 1,2

Notoblastus brevispinus Breimer and Macurda, 1972, p. 33, Pl. XXII, fig. 1.

Description.— Theca biconical, relatively squat(?), pelvis and vault convex. Theca pentagonal in plan view with greatest width at ambulacral tips. Theca squashed; length probably about 14 mm, width 28 mm.

Basals three, in normal position, forming lower half of convex pelvic profile. Stem cicatrix a shallow depression (diameter 1.8 mm) at slightly recurved proximal junction of the three basals. Basals decagonal in plan view (Pl. 29, fig. 1). Azygous basal rhombic in plan view with straight lateral and distal edges. BR sector convex parallel to and very slightly convex normal to BR axis. Adjacent sectors merge over very convex boundary. Zygous basals pentagonal in plan view, with straight lateral and distal lateral edges and a concave medial distal edge. Medial BR sector convex parallel to, concave normal to BR axis. Lateral sectors convex parallel to, very slightly convex normal to BR axis. Lateral sectors merge with medial sector across very convex boundaries which reach to apices of basals; merge there with two strongly convex boundaries which radiate to aboral end of two adjacent ambulacra, producing five concave areas on pelvis, centered under ambulacra. Growth lines parallel basal radial fronts. ABL: 11.5 mm; ABW: 9.8 mm; ABBBF: 7.0 mm; ABBR: 7.8 mm; ABBRF: 8.5 mm; ZBL: 9.3 mm; ZBW: 12.0 mm; ZBOPt: 12.1 mm; ZBBR: 9.0 mm; ZBBRF: 8.2 mm.

Radials five, forming upper half of pelvis and lower part of vault. Radial pentagonal in plan view, with convex lower edge, slightly convex lateral edges, and straight adoral edges which converge adorally. RB sector slightly concave parallel to, very slightly concave normal to BR axis; adjacent BR sectors merge across concave boundary, producing a concave area below ambulacrum (Pl. 29, fig. 2). RR sector slightly convex parallel to, convex normal to RR axis. RB and RR sectors ornamented by growth lines. RD sector now flattened, probably slightly convex parallel to and straight normal to RD axis. Hydrospire slits developed across full width of radiodeltoid suture. Apparently a prong developed at origin of radial; only base now visible (Pl. 29, fig. 2). RWB: 12.3(a) mm; RWA: 15.4(a) mm; RWD: 14.4(a) mm; RD: 8.0 mm; RDF: 5.5 mm; RR: 9.1 mm; RRF: 6.6(va) mm; RB: 9.9 mm; RBF: 6.7 mm.

Deltoids four, together with epideltoid forming border of oral opening. Deltoid flattened and surface ornament partially removed by weathering. Deltoid hexagonal in plan view. DD sector large; width expands aborally along straight DDF, then contracts along concave DAF, expanding again aborally; DRF straight. Deltoid body rhombic in shape. Del.L.: 10.3 mm; Del.Gr.Ad.W.: 6.0 mm; Del.Min.W.: 4.8 mm; Del.Gr.Ab.W.: 7.8 mm; DR: 7.8(va) mm; DD: 2.0(va) mm.

Anal deltoids two, an epi- and hypodeltoid. Configuration of epideltoid as for regular deltoid except central and aboral part of deltoid body which are occupied by anal opening and hypodeltoid. Anal opening ovoid, opening upward. Hypodeltoid pentagonal; adoral edge deeply embayed by anal opening. Anal Del.L.: 10.3 mm; O.c.-ad.e.anus: 6.0 mm; Epi.Gr.Ad.W.: 6.7 mm; Anus L.: 2.7 mm; Anus W.: 1.5 mm; Hypo.L.: 1.6 mm; Hypo.W.: 6.0 mm.

Ambulacra five, lanceolate, moderately removed from oral opening. Brachiolar facets along lateral margins of ambulacrum. O.c.-amb.: 6.1 mm; Amb.L.: 9.2 mm; Amb.W.: 3.5 mm; approximately 18 side plates.

Nine or ten hydrospire groups. Those in non-anal interareas developed across full width of radiodeltoid suture; 15 per group. 3 or 4 sutures are developed across the epiradial suture on the C side of the anal interarea; absent on D side unless there may be 1.

Distribution.— Permian, Branxton, New South Wales, Australia.

Remarks.— The above description is based upon the holotype (Australian Museum F.39762) and only known specimen. The holotype has been flattened but the original calcite is preserved.

NOTOBLASTUS CORNUTUS (McKellar, 1969)
Pl. 29, figs. 4,8-10; Table 42

Notoblastus cornutus Breimer and Macurda, 1972, p. 34, Pl. XXII, figs. 4,5.

Description.— Theca (based upon reassembly of disarticulated plates) very broadly biconical, with slightly convex vault, and straight sided or gradually tapering radials. Pelvic profile probably sigmoid, curving upward in upper part of radials and out in basals. Basals unknown. Thecal outline pentagonal in plan view, with projection at aboral tip of ambulacrum due to short spine at origin of radial. When length approached 15 mm, width probably near 20 mm.

Basalia unknown.

Radials five, forming upper part of pelvis and lower part of vault. Radial pentagonal, with slightly concave lower edge, straight to slightly convex lateral edges, and straight adoral edges which converge adorally. Radial triangular in lateral view, with slightly convex adoral facing edge, slightly concave aboral facing edge, and slightly concave lower edge. Short stubby spine at origin of radial, which projects slightly outward and up (Pl. 29, figs. 4,8). RB sector slightly concave proximally, becoming straight distally parallel to RB axis, straight normal to RB axis, adjacent RB sectors merging through a concave arc; RB sector merging with RR sector over a convex boundary. RR sector straight (except for spine) to very slightly convex parallel to RR axis, straight parallel to RR axis. RB and RR sectors ornamented by moderately strong growth lines. RD sector forms sloping shoulder to ambulacrum which is strongly elevated above it. RD sector separated from RR sector by a strong angle; narrow ridge forms boundary between the two. RD sector very slightly convex parallel to, straight normal to RD axis. RD sector ornamented by functional hydrospire slits across full width RDF near suture; infilled aborally. RWB: 7.0-9.7 mm; RWD: 9.0-10.6 mm. See Table 42.

Deltoids four, together with epideltoid forming border to oral opening. Deltoid rhombic in plan view, with very well developed DD sector. In lateral view, deltoid flat in DD sector, becoming convex in deltoid body. Width of deltoid expands aborally along relatively long DDF, two DAF short, parallel; width then converges along straight DRF. Adoral edge of DDF bears main ambulacral tract; growth lines record adoral growth (Pl. 29, fig. 9). Most of DD sectors flat; curve upward aborally into a sharp, V-shaped ridge which separates ad- and aboral halves of plate. Deltoid crest bisects V-shaped ridge, curves downward aborally. Aboralmost part of DRF bears functional hydrospire slits; slits on sloping sides of deltoid crest have been infilled. Del.L.: 9.2-10.5 mm; Del.Ad.W.: 1.0-1.2 mm; Del.Gr.Ad.W.: 5.5-6.8 mm; Del.Gr.Ab.W.: 5.1-6.0 mm; L.Del.Crest: 4.7-5.3 mm; DR: 3.3-4.0 mm; DRF: 3.5-

TABLE 42. Growth relationships of principal variables of *Notoblastus cornutus* (McKellar, 1969)

Variables	n	r	a_o	a_1	Observed Range y	x
RD/RDF	5	0.66	2.86	0.50	4.3– 5.0	3.4– 4.2
RR/RRF	5	-0.43	7.22	-0.19	5.0– 6.3	8.0–10.9
RB/RBF	5	0.31	2.89	1.15	6.9–10.3	4.0– 5.0
RD/RR	5	0.78	2.18	0.47	4.3– 5.0	5.0– 6.3
RD/RB	5	0.24	4.35	0.05	4.3– 5.0	6.9–10.3
RR/RB	5	-0.23	6.19	-0.08	5.0– 6.3	6.9–10.3
Amb.L./Amb.W.	4	-0.10	6.68	-0.14	5.4– 7.0	2.6– 3.7
Amb.L./No.S.P.	4	0.67	1.84	0.32	5.4– 7.0	12.0–15.0

4.2 mm; DD: 3.7-4.0 mm; DDF: 3.9-5.3 mm; DAF: 2.6-3.2 mm; DDF: 6.0-7.3 mm.

Anal deltoids two, an epi- and hypodeltoid. Outline of epideltoid as for adoral part of regular deltoid; aboral edge of epideltoid embayed by anal opening; surface of plate elevated into a collar-shaped rim for the anal opening. Hydrospire slits formed across epiradial sutures. Hypodeltoid a smaller plate, pentagonal in shape in plan view, with convex edges against the radials, straight epi-hypodeltoid sutures, and a concave adoral edge due to the anal opening. Anal opening ovoid, elongate (L.: 2.5 mm; W.: 1.5 mm in one specimen).

Ambulacra five, lanceolate, elongate in plan view, convex in lateral view. Ambulacra separated from oral opening by relatively long DDF. Long arcuate ridges between side grooves; main groove bordered by 4 minor grooves and lobes; present along adoral edge of side groove as well. Brachiolar facets on outer sloping edge of ambulacrum. Lancet apparently broadly exposed with side plates confined to lateral edges of ambulacrum. See Table 42.

Ten hydrospire groups, developed across full width of radiodeltoid sutures and epiradial sutures in anal interarea; functional only immediately adjacent to suture; infilled ad- and aborally. Number of anal hydrospire slits strongly reduced in number compared to regular group (14 to 3), No.Reg.Hydro.Sl.: 9-14; W.Reg.Hydro. Fld.: 2.6-3.7 mm.

Oral opening pentagonal.

Distribution.– Permian, Berserker Beds, Rockhampton, Queensland, Australia.

Remarks.– The specimens are preserved as molds; the specimens described herein are duplicate rubber casts of McKellar's original material which is at the Queensland Geological Survey (F11119, F11122, F11131, F11385, F11388, F11389). The duplicate casts are catalogued as UMMP 62348-62353.

NOTOBLASTUS OYENSI (Wanner, 1940)
Pl. 28, figs. 17,18; Pl. 29, fig. 3

Notoblastus oyensi Breimer and Macurda, 1972, p. 34, Pl. XXII, figs. 4,5.

Description.– Theca bowl-shaped with wide pelvis, sides of which are relatively straight, base broadly convex. Vault now somewhat squashed but apparently very gently convex. Outline of theca pentagonal, points along ambulacral axes. Probably an extension of the radials beyond edge of theca but now weathered. Greatest width at junction of vault and pelvis. Length slightly greater than 7 mm; width: 10.7 mm (va); vault quite short in relation to pelvis.

Basals three, broadly convex in lateral view, form lower one-third of pelvis; pentagonal in plan view (Pl. 28, fig. 17), extending well out toward edge of outline of theca. Stem attachment area at proximal junction of basals, a small raised area, diameter 0.8 mm; crenellar facets at edge. Azygous basal rhombic with straight edges, BR sector convex both parallel and perpendicular to BR axis; adjacent BR sectors merge smoothly. ABL: 4.9 mm; ABW: 5.0 mm (a); ABBBF: 4.0 mm; ABBR: 4.4 mm; ABBRF: 3.0 mm. Zygous basal pentagonal in plan view, edges straight except for distal medial edge which is slightly concave. BR sectors as for azygous basal, merge smoothly. ZBL: 4.3 mm; ZBW: 6.4 mm; ZBOPt: 5.0 mm; ZBBR: 4.3 mm; ZBBRF: 2.0 mm; ornament of basals granulose.

Radials five, forming straight sides of pelvis. Essentially quadrate in plan view with a slightly convex or two straight lower edges; lateral sides almost parallel, diverge slightly adorally, maximum width short distance below radiodeltoid suture, then contracting adorally. Upper edges of plate converge at broad angle. In lateral view radial has triangular profile; adoral facing edge convex, aboral facing edge slightly sinusoidal, and slightly concave lower edge. Origin of radial near upper center. Apparently there was some type of radial prong or wing as the origin is now covered by secondary calcite; the base of this projection is relatively small so it probably did not extend too far beyond the theca. RB sector essentially straight parallel to RB axis except where it turns over to meet the basals; sector convex normal to axis; adjacent sectors merge smoothly with one another and the RR sectors. RR sector straight parallel to RR axis, slightly convex normal to it, more so in the adoral region, where it curves over to meet the RD sector which is on the gently sloping upper surface of the vault. RD sector small but broad, slightly convex parallel to the RD axis and very slightly concave normal to it. Hydrospire field occupies width of RD sector, relatively short, open part not extending more than 0.3 mm from suture. Apparently infilled during growth. Ornament of rest of radial granular; that of prong unknown. RHT: 1.5 mm (va); RWB: 4.8 mm; RMW: 5.3 mm; RWD: 4.3 mm; RD: 3.8 mm; RDF: 1.8 mm; RR: 3.5 mm; RRF: 4.2 mm; RB: 5.0 mm (a); RBF: 2.0 mm.

Deltoids four, together with epideltoid forming border to oral opening, confined to upper surface of theca. Convex in lateral view because of ornament of plate, hexagonal in plan view (ignoring adoral edge). Adoral edge straight; 0.4 mm wide. Deltoid expands to maximum width (2.3 mm) at adoral end of ambulacrum along straight DDF (width: 1.9 mm); width contracts slightly along a short, slightly concave DAF (width: 0.7 mm), then straight aboral edges abut against radials, meeting at a sharp V. Adoral part of deltoid (adoral to ambulacrum) smaller than aboral part (lengths: 1.0 mm and 2.4 mm respectively). DDF ornamented with minor lobes and grooves, forming sharp V on adjacent plates, width: 0.3 mm. Most of adoral part of plate ornamented with irregular nodose ornaments and a central median ridge which ascends to the high point of the deltoid, a sharp pyramid dividing the ad- and aboral parts of the plate (Pl. 28, fig. 18). Two ridges radiate laterally, and slightly aborally, toward adoral ends of ambulacra, thus completing separation of ad- and aboral parts of plate. Deltoid crest extends aborally down the center of the aboral part of the plate. Hydrospire slits fill the rest of the aboral part of the plate, crossing the radiodeltoid suture; maximum open extension: 0.3 mm.

Anal deltoids apparently two, an epi- and hypodeltoid. Epideltoid large (Pl. 29, fig. 3), outline as for adoral part of regular deltoid; prongs extend to radials; epideltoid interrupted aborally by anal opening and hypodeltoid. Ornament as for regular deltoid except pyramid more V-shaped and more elevated; forms a broad crescent to anal opening; rim of anal opening at lower elevation. Width adoral edge epideltoid: 0.8 mm (a); maximum width: 3.0 mm. Hypodeltoid now missing but presence indicated by break in profile of anal opening as edge of epideltoid turns sharply outward on either side (Pl. 29, fig. 3). Hypodeltoid apparently pentagonal-shaped with very slightly convex aboral edges and very slightly convex adoral lateral edges. Maximum width: 1.5 mm. Surrounded by epideltoid and radials. Adoral half of anal opening ovoid; maximum width: 1.0 mm. Anal opening opens upward and slightly outward. Oral center to anal opening: 2.3 mm; to anus-epi-hypodeltoid suture: 2.6 mm; to epi-hypo-radial junction: 3.0 mm.

Ambulacra five, small, lanceolate, lying almost entirely upon radials. Only adoralmost portions preserved. Configuration and length indicated by trough in deltoid. Structure of lancet not clear due to weathering; appears to have underlain ambulacra, exposed along main groove, upper edges which abut against side plates slightly concave; lower edge, broad, convex against radial? No brachiolar facets preserved. Amb.L.: 2.5 mm; Amb.W.: 1.0 mm; No.S.P.: 2 per mm. Oral center to ambulacrum: 2.4 mm; to hydrospire slits: 2.3 mm.

Nine functional hydrospire groups, completely exposed. Eight in non-anal interareas, developed across almost full width of radiodeltoid suture, 7 hydrospires per group; maximum length: 0.6 mm, become shorter toward apex of deltoid; width of field: 1.3 mm. In anal interarea, 3 very short slits across epi-radial suture on D side of anus; lacking on C side. Ornament on limb of radial on C side suggests secondary infilling or recent atrophy. Maximum length: 0.3 mm, central slit being longest; width of field: 0.4 mm.

Oral opening pentagonal; width: 1.0 mm (a).

Distribution.– Permian, Sonnebait Series, Basleo, Timor, Indonesia.

Remarks.– The above description is based upon the single known specimen, University Amsterdam Ge.O. 9925. A large isolated deltoid described as *Pteroblastus* spec. nov. (Wanner 1940) may belong to *N. oyensi* (Breimer and Macurda, 1972, p. 256, Pl. XX, fig. 2). The plate is flat lying, the aboral tip is broken but there is a short adoral edge, a straight DDF, and DAF bears an ambulacral tract, 0.5 mm wide. The DD sector is moderately developed, ornamented with warty granulose ornament and rising upward to an elevation from which a well-developed crest extends aborally and two ridges extend aboral laterally to the ambulacra. The aboral part slopes down, then flattens out, ornamented by hydrospire slits which are infilled, so they were probably functional only along the DRF. Del.L.: 7.2 mm; Ad.W.: 1.7 mm; Gr.Ad.W.: 6.5 mm; DDF: 3.8 mm; DAF: 2.2 mm; No.Hydro Sl.: 14; width of these: 3.2 mm. The plate was collected near Basleo, Timor, Indonesia. It is in the University of Amsterdam collections (Ge.O.9927).

The ontogeny of *N. oyensi* was discussed by Breimer and Macurda (1972). This species is distinguished from others which are assigned to *Notoblastus* by the bowl-shaped theca, the subdued crest between the ad- and aboral portions of the deltoid, granulose ornament on the thecal plates, and a less sharp boundary between the RD and RR sectors.

NOTOBLASTUS STELLARIS
Breimer and Macurda, 1972
Pl.29, figs. 5-7,11,12;Pl. 30, figs. 1,2,4-10,15-17;Table 43

Notoblastus stellaris Breimer and Macurda, 1972, p. 34, Pl. XX, fig. 1; Pl. XXI, figs. 1,2,7,8.

Description.– Theca cup-shaped in lateral view (Pl. 30, fig. 4), with broadly convex vault; radials have upward flaring blade-shaped prong with serrate tip. Outline in plan view pentagonal; profile interrupted by radial prongs. Greatest width just below top, at junction of vault and pelvis. Length less than width, latter approaching 20 mm in larger specimens.

Basalia three, in normal position, pentagonal in plan view, convex in lateral view, forming lower convex portion of cup-shaped pelvis. Stem attachment area a circular area at proximal tip of basals with crenellar facets at edge of attachment area; low raised rim borders area, 39 crenellae in ring when diameter 1.6 mm.

Azygous basal quadrate in plan view, with straight lateral and distal edges; convex in lateral profile. BR sector convex parallel to BR axis, slightly convex normal to it, adjacent sectors merging smoothly over relatively flat area. Zygous basals pentagonal in plan view, with a slightly concave distal medial edge and straight distal lateral and lateral edges. Lateral profile as for azygous basal. BR sectors convex parallel to BR axis, medial convex normal to it while lateral sectors are flatter, adjacent sectors merging smoothly on slightly convex to slightly concave surfaces. Surface of basals has broad low growth lines ornamented with granulose ornament parallel to BR fronts; BB sectors slightly evident.

Radials hexagonal in plan view, with two straight or a convex lower edge(s), with relatively straight sides (width usually increases slightly orally), and two straight adoral edges which converge upward (Pl. 29, figs. 5-7, 11). Adoral center embayed by a short radial sinus (Pl. 29, fig. 12). Radial convex in lateral view with blade-shaped radial prong extending outward and upward; wider in lower part than upper. Radial prongs are relatively large (up to 8.7 mm long), cover origin of radial, are relatively thin, and have a serrated tip. RB sector slightly convex parallel and normal to RB axis, merging smoothly with each other and adjacent RR sector over slightly convex surfaces. RR sector very slightly convex parallel to RR axis, slightly convex normal to it. RD sector at an angle to RR sector, forms sloping shoulder to ambulacrum, straight parallel and normal to RD axis. RB and RR sectors ornamented with smooth growth lines; inner portion of plate has granulose ornament. Small beaded ridge separates RD and RR sectors. RD sector ornamented with parallel ridges indicating infilled hydrospire slits (Pl. 30, figs. 10,16); latter occupy full width of RDF. Radial sinus bordered by broad low ridge. For measurements of isolated radials see Table 43.

Deltoids four, together with epideltoid(?) forming border to oral opening. Deltoid hexagonal in plan view (Pl. 30, figs. 5-8), with DAF being shortest edge; convex in lateral view, with aboral portion curving downward. Plate slightly convex in cross section. Short edge bordering oral opening slightly concave. DDF long, straight,

TABLE 43. Growth relationships of principal variables of *Notoblastus stellaris* Breimer and Macurda, 1972

Variables	n	r	a_0	a_1	Observed Range y	x
RD/RDF	13	0.56	2.20	0.58	2.6– 5.5	2.2– 4.4
RR/RRF	13	0.68	1.63	0.46	3.3– 6.3	5.1– 9.2
RB/RBF	13	0.72	3.80	0.93	5.9– 9.8	2.5– 5.7
RD/RR	13	0.67	1.50	-0.51	2.6– 5.5	3.3– 6.3
RD/RB	13	0.18	3.30	0.09	2.6– 5.5	5.9– 9.8
RR/RB	13	0.69	1.23	0.48	3.3– 6.3	5.9– 9.8
Del.L./Gr.Ab.W.	6	0.99	0.92	1.14	5.1–12.0	3.7– 9.5

well developed, bearing ambulacral tract with minor lobes and grooves; bordered by ridge with fluted ornament. DAF short, slightly concave, caused by indentation of lancet. Ornament bordering DAF leads into ridge which divides ad- and oral parts of plate. Aboral edges straight, bearing short hydrospire slits along full width of DRF. A pronounced V-shaped ridge, adorally pointed, divides the adoral (DD and DA sectors) from the aboral (DR) sectors. Ridge produced by secondary upbuilding of calcite and may be strongly serrate. Aboral part of plate ornamented with irregular granulose ornament or granulose ornament which parallels DDF (Pl. 30, fig. 1). Aboral part of plate divided medially by crest which may have teeth or knobs along top; development not as pronounced as dividing ridge. Each DR sector ornamented with ridges indicating infilled hydrospire slits (may be smooth adorally). For measurements of isolated deltoids see Table 43.

Anal deltoids unknown from isolated plates; may be fragments preserved in crushed oral area of holotype. Growth lines on radials in anal interarea suggest large hypodeltoid (Pl. 30, fig. 9).

Ambulacra five, broadly lanceolate, removed from oral opening (Pl. 30, figs. 2,15), almost straight in lateral view, convex in cross section. Strongly elevated above surrounding plates. Lancet broadly lanceolate, exposed to aboral tip of ambulacrum, with side plates arrayed along sides. Upper surface bears main and arcuate inner portion of side ambulacral tracts. Brachiolar facet small, heart-shaped, lateral downward sloping on edge of ambulacrum (Pl. 30, fig. 17). Facet equally developed on side and outer side plates. Outer side plate wedge-shaped, becomes wider below facet; both side and outer side plate form a series of bulbous knobs at their lower abmedial extremities below the facet. Main groove bordered by minor lobes and grooves as are both sides of side furrows. Ambulacral lengths of up to 5.3 mm; ambulacral widths about three-fifths of length, 2.5 side plates per mm.

Ten hydrospire fields, those in anal interarea reduced in number. Functional length of slit very short; occupying full width of RDF, closely spaced. Number of hydrospires known on radials measured in Table 43 ranges from 5-14; width of hydrospire field from 2.0 to 4.0 mm. Number of anal hydrospire slits known from 4 isolated radials when number of regular hydrospire slits 5,7,9 and 10 number of anal hydrospire slits 3,2,3 and 1 respectively.

Oral opening ovoid-pentagonal.

Distribution.— Permian, Callytharra Formation, Western Australia, Australia.

Remarks.— The above description is based upon the holotype and isolated plates listed in Appendix 1. The ontogeny was discussed by Breimer and Macurda (1972) and is further summarized in Table 43. This species of *Notoblastus* is distinguished from the others assigned to the genus by its cup-shaped theca, granulose ornament on the growth lines, the extremely prominent ridge which divides the ad- and aboral portions of the deltoid, and the blade-shaped prong on the radial.

NOTOBLASTUS sp.
Pl. 30, figs. 11-14,18-21

Notoblastus sp. Breimer and Macurda, 1972, p. 253, 254, Pl. XXI, figs. 3-5,9.

Remarks.– A series of isolated radials with long prongs from the Permian Callytharra Formation of Western Australia were tentatively assigned to *Notoblastus* and discussed by Breimer and Macurda (1972, p. 253, 254). Further examples are illustrated in Plate 30, figures 11-14, 18-21.

Genus AUSTROBLASTUS McKellar, 1969

Type species.– *Austroblastus whitehousei* McKellar, 1969.

Austroblastus Breimer and Macurda, 1972, p. 36.

AUSTROBLASTUS WHITEHOUSEI McKellar, 1969
Pl. 31, figs. 3,5,6

Austroblastus whitehousei Breimer and Macurda, 1972, p. 36, Pl. XXIII, figs. 1,6,8; Pl. XXIV, fig. 1.

Description.– Theca beaker shaped; vault convex; upper sides of pelvis apparently straight; outline pentagonal in plan view. Thecae of large size, probably approaching 40-50 mm in length and 50-60 mm in width.

Basals known in only one specimen, displaced, but apparently forming a broad conical base to theca in lower part of pelvis. Stem cicatrix at proximal junction of basals; broad (diameter, approximately 3.0 mm). Only proximalmost part of azygous basal preserved. Zygous basal pentagonal in plan view, with straight lateral and distal lateral edges, and slightly concave distal lateral edge. Medial BR sector straight parallel to, concave normal to BR axis. Medial BR sector merges with lateral BR sector over convex boundary. Lateral BR sector straight parallel and normal to BR axis. When an RB is 11.3 mm, ZBBR is 10.1 mm.

Radials five, forming upper straight sides of pelvis and lower part of vault. Radial quadrate in plan view, with straight or slightly concave lower edge; lateral edges very slightly convex; upper edges converge toward one another almost straight on. Upper part of radial embayed by radial sinus which has a prominent rim around it. Radial nearly flat in lateral view, with very slightly convex adoral facing edge, almost straight aboral facing edge and nearly straight lower edge. RB sector nearly straight parallel and normal to RB axis; adjacent RB sectors merge through a concave depression. Sector ornamented by growth lines. Ridge separates RB and RR sectors. RR sector straight parallel to, very slightly convex normal to RR axis. Sector ornamented by growth lines; some very strong ridges parallel RRF (Pl. 31, fig. 6). RR and RD sectors separated by a sharp ridge; RD sector at moderate angle to RR sector. RD sector straight parallel and normal to RD axis. Surface ornamented by hydrospire slits; these are only functional immediately adjacent to the radiodeltoid suture. In three completely measurable radials, RWB: 13.0-14.4 mm; RWD: 11.6-19.9 mm; RD: 6.8-11.3 mm; RDF: 4.8-8.3 mm; RR: 6.8-10.5 mm; RRF: 17.5-25.2 mm; RB: 11.3-18.5 mm; RBF: 5.8-7.8 mm. Larger radials with an RD of 16.5 mm and RWD of 33.0 mm known.

Deltoids four, together with epideltoid forming border to oral opening. Deltoids rhombic in plan view, with straight adoral and aboral edges (Pl. 31, figs. 3,6). Greatest width along DAF. Deltoid slightly convex in lateral view. DR sector larger than RD sector. DDF bears ambulacral tract; rest of DD sector slopes gently upward to boundary between DD and DR sectors; ornamented with granulose ornament. Sharp ridge divides DD from DR sector (Pl. 31, figs. 3,6). Deltoid crest extends aborally from separating ridge. Sides of DR sector slope down from deltoid crest, ornamented by hydrospire slits; infilled except immediately adjacent to radiodeltoid suture (Pl. 31, fig. 5). In a complete deltoid (from specimen with RD of 16.5 mm), Del.L.: 26.8 mm; Ad.W.: 2.5 mm; Gr.Ad.W.: 13.2 mm; Gr.Ab. W.: 16.6 mm; L.Del.Crest: 20.5 mm; DR: 16.4 mm; DRF: 14.5 mm; DD: 4.8 mm; DDF: 9.0 mm; DAF: 8.5(a) mm; DDF: 16.0(a) mm.

Anal deltoids two, an epi- and hypodeltoid. Configuration of epideltoid as for regular deltoid in the DD sectors and lower lateral parts of the DR sectors. Anal opening behind dividing line between DR and DD sectors; large rim to anal opening proper. Hypodeltoid as for aboral part of deltoid body, with deltoid crest and hydrospire slits across hyporadial suture. Anal opening embays adoral end. Hypodeltoid pentagonal; epihypodeltoid and hyporadial sutures straight. Massive rim to aboral margin of ovoid anal opening. Dimensions (from same specimen as for regular deltoid): Anal Del.L.: 27.0 mm; Epi.L.: 8.7 mm; Epi.Gr.Ad.W.: 11.6 mm; Anus L.: 6.5 mm; Anus W.: 2.3 mm; Hypo.L.: 12.0 mm; Hypo.W.: 12.2 mm.

Ambulacra five, lanceolate in plan view, convex in lateral view, removed from oral opening. Lancet lanceolate, broadly exposed. Details of side plates and outer side plates unknown but from facets on lancet, 2 per mm. Measurements for same specimen as deltoids: Amb.L.: 18.8(va) mm; Amb.W.: 2.2(va) mm.

Ten hydrospire groups, developed across full width of radiodeltoid suture in non-anal interareas; functional only adjacent to radiodeltoid suture. Developed across hyporadial suture; unknown if developed across epiradial suture. In same specimen as above, No.Reg.Hydro. Sl. (across hyporadial suture) 33; W.Reg.Hydro.Fld.: 12.4 mm; No. Anal Hydro.Sl.: 25(a); W.Hydro.Fld.: 9.2 mm.

Distribution.— Permian, Berserker Beds, Rockhampton, Queensland, Australia.

Remarks.— The original specimens are preserved as molds; and deposited in the Geological Survey of Queensland (F11121, F11230, F11128, F11128c, F11132, F11134, F11135, F11137, F13533). The above description is based upon duplicate casts of the molds which are catalogued as UMMP 62354-62362.

Genus THAUMATOBLASTUS Wanner, 1924b

Type species.— *Thaumatoblastus longiramus* Wanner, 1924b.

Thaumatoblastus Breimer and Macurda, 1972, p. 36.

THAUMATOBLASTUS LONGIRAMUS Wanner 1924b

Pl. 31, figs. 7-10; Pl. 32, figs. 1-10

Thaumatoblastus longiramus Breimer and Macurda, 1972, p. 36, Pl. XXIV, fig. 2; Pl. XXV, figs. 1-8; Pl. XXVIII, fig. 5.

Description.— Species known only from isolated radials. Reassembly of five of radials along interradial sutures suggests convex parabolic pelvis. Radials extend laterally into extremely elongate radial prongs (Pl. 32, figs. 1,4,6,7), the upper surface of which apparently sloped very gradually down to the oral opening, producing a very broad, very slightly concave vault. Profile of deltoids unknown. Overall width of theca large due to prongs, with some broken isolated prongs over 54 mm in length; internal volume of viscera can be quite small in comparison to length of prongs. Outline of internal cavity rounded pentagonal. Outline of theca strongly stellate in plan view, with interambulacral areas having parabolic outline, turning inward at base of ambulacral prong. Asymmetry of some radials suggests that the angles between adjacent ambulacra were not always equal (broader in anal interarea?).

Basals unknown; apparent pelvic outline suggests they were convex in both length and width.

Radial body may be quite small in comparison to length of radial prong. In plan view radial hexagonal (Pl. 31, figs. 7,8), with lower edge convex or two straight edges; interradial sutures usually parallel, although may widen out in medial or lower portions. Radiodeltoid sutures concave, converge in an adoral direction. In lateral view radial is concave along interradial suture, outer surface convex in lower portion facing basals, then recurves into radial prong. Upper surface of prong flat, slightly recurved at adoral end. RB sector slightly convex parallel to its growth axis, more convex normal to it. RR sector merges with RB sector, is straight to slightly convex parallel to its growth axis and convex normal to it. RD sector quite small in small specimens (probably due in part to overgrowth by radial prong); sector at angle to RR sector, giving angular profile in lateral view of body of larger radials. Sector is straight parallel to growth axis, slightly concave normal to it. Radiodeltoid suture is concave.

Radials elongated into very long solid prong, which in cross section is elliptical to U-shaped; profile may change from former to latter in aboral direction in one prong. Small concave upper surface, underlies narrow ambulacrum. Proximal end of prong flares into radial body; concavity for ambulacrum continues across body to deltoids. Abpolar to radial body prong quite constant in size at one growth stage; total length in relation to any radial unknown in specimens from Permian of Timor. Extremity of prong can be seen to taper to a point in isolated broken fragments. Surface of radial ornamented with granulose ornament with occasional irregular lineations; also occasional faint growth lines in body of radials in RB and RR sectors. In one specimen broad bands preserved on interior parallel to plate margins; apparently growth lines. Prong grew by secretion of calcite on free surface, covering origin of radial and earlier formed parts of RD, RR, and RB sectors. Calcite stereom occasionally visible, where long axes of stereom in prong lie parallel to surface but on angle to axis of prong and frequently cross it at right angles. Occasional development of swellings on prongs near ambulacrum (caused by parasites?) (Pl. 32, figs. 1,3). Wide range in size of body of radials, from approximately 10 mm in length and width to dimensions over 25-30 mm; height and width of prong vary from 4.0 and 3.5 mm respectively to 11.0 mm and 6.7 mm. Thus entire plate increases in size during growth. When radial is viewed internally, all sectors converge at apex marking origin of plate. Plate has grown outward laterally along RD, RR, and RB fronts from this point. The internal keel (Pl. 31, fig. 8) separating the two RD sectors records the gradual topologic elevation of the ambulacrum with respect to the origin of the plate. Externally additional calcite was secreted on all surfaces of the prong, increasing its height and width, and presumably its length. The groove supporting the ambulacrum grew upward and expanded in width as it did so (amount for any one specimen indicated approximately by width of keel internally). External width of preserved ambulacrum varies from 1.5-4.5 mm.

Deltoids unknown; aboral edges convex against radials; probably quadrate in outline and forming relatively flat upper central surface of vault; aboral parts would have to be slightly convex to fill space between radials on upper lateral surface of vault. Number of anal deltoids unknown.

Hydrospire groups apparently ten, completely exposed, with very short slit at adoral end of concave RD sector, occupying width of RDF (Pl. 31, figs. 7-9; Pl. 32, fig. 2). Ornament suggests aboral ends of slits infilled during growth. Traces of hydrospires visible on interior of radials. Massive blunt keel underlies groove in radial between RD sectors, widens adorally, separates hydrospire groups internally. Hydrospires apparently reduced in number in anal interarea if C and D radials correctly identified.

Ambulacra extremely long, linear, narrow, supported by a shallow groove on upper surface of radial and radial prong. Ambulacra were apparently elevated above oral opening and main groove, gradually descended toward oral opening, flattened out on vault itself as indicated by alignment of radials along interradial suture and slight flattening out of groove as it passes from prong to radial body. Lancet occupies center of upper concavity on radial and prong. Convex lower edge; lateral sides straight, converging upward; upper edge V-shaped, bearing main groove and most of minor grooves and furrows which border groove. Lancet exposed to at least within 7 mm of aboral tip of ambulacrum; width of exposure: 0.6-0.7 mm. Side plates abut against lancet and fill rest of width of groove; 1.5 per mm. Main groove 0.1 mm wide, bordered by five minor lobes and grooves per side plate; are on upper surface of lancet and lower admedial edge of side plates (Pl. 32, figs. 5,8). Side grooves (width 0.025 mm(a)) slope steeply down from brachiolar facet into main groove; length on sloping surface about 0.6 mm; abmedial portion almost at right angle to main groove but curving adorally and entering main groove at lesser angle; 6 minor lobes and grooves on adoral and aboral edges of side groove. Area occupied by grooves and minor lobes and grooves forms a relatively deep (0.2 mm) narrow depression. Brachiolar facets are perpendicular on sides of ambulacrum, facing directly outwards, ovoid, height: 0.275 mm; width: 0.25 mm; with small keyhole-shaped opening (width: 0.03 mm) providing entrance to side groove from upper part of facet; upper part of entrance constricts to 0.013 mm; total height of opening 0.1 mm (Pl. 32, figs. 9, 10). Area abmedial to facet a U-shaped valley which slopes down slightly to edge of ambulacrum; lateral end usually above lowest edge of ambulacrum. Area between abmedial ends of side food grooves is a prominent elevated knob, which becomes a crest between brachiolar facets and drops to edge of ambulacrum. Variably developed U-shaped depression on base of ambulacrum at aboral edge of crest on lateral lower edge of ambulacrum, vertically oriented (Pl. 32, fig. 9); may be smaller, similar depression at adoral base of crest on lower edge of ambulacrum; these two embay the outer edge of the more nearly horizontal valley ablateral to the brachiolar facet. Side plates quadrate. Triangular outer side plate forms adoral part of brachiolar facet and extends admedially to lancet with adoral suture extending from U-shaped depression at aboral base of crest on side plates along aboral edge of knob and adoral edge of facet, then passing to lancet, its course running adoral to ornament of minor lobes and grooves which are on adoral edge of side groove; aboral suture follows food groove, and crosses adoral part of facet.

Distribution.— Permian, Timor, Indonesia; Noonkahbah (Pl. 31, fig. 10) and Coyrie formations, Western Australia, and the Bernidale Limestone, Tasmania, Australia.

Remarks.— The above description is based upon the specimens described by Wanner in 1924 and other specimens in the collections of Leiden University, Municipal University of Amsterdam, and Free University of Amsterdam. The ontogeny was discussed by Breimer and Macurda (1972).

Wanner described a second species of *Thaumatoblastus, T. longispinus.* This radial is weathered, but has remnants of the same granulose ornamentation found in *T. longiramus* and its other preserved characters are as for *T. longiramus*, so it was synonymized by Breimer and Macurda (1972).

Genus DIPTEROBLASTUS Wanner, 1940

Type species.– *Dipteroblastus permicus* Wanner, 1940.

Dipteroblastus Breimer and Macurda, 1972, p. 36.

DIPTEROBLASTUS PERMICUS Wanner, 1940

Pl. 33, figs. 1-7

Dipteroblastus permicus Breimer and Macurda, 1972, p. 36, Pl. XXI, fig. 6; Pl. XXII, figs. 2,3,6; Pl. XXIII, fig. 4.

Description.– Theca irregular in form, a compromise between pentameral and bilateral symmetry. In oral view theca has shape of an elongate ellipsoid. B and D ambulacra are greatly extended in relation to other three, forming major axis of ellipse. Axes of these ambulacra do not meet at quite 180° so ellipse is warped toward anal side. Maximum width greater than 18.0 mm, extending from ends of B and D ambulacra. Minimum width across AE deltoid and C ambulacrum, below plane of ambulacra, 12.0 mm. When long axis of theca is viewed laterally, pelvis has a very broadly conical outline while vault is almost flat, being very slightly concave; resulting profile broadly cup-shaped with lower edges somewhat rounded. When short axis is viewed laterally, theca has an angular ovoid outline, with rounded conical pelvis and rounded angular conical vault. L.: 11.5 mm.

Basals three, in normal positions but asymmetric because of secondary bilateral symmetry. Form lower one-third of theca, outline pentagonal in basal view, rounded conical in lateral view (being slightly convex), and convex outwards in cross section. Well-developed stem facet present at proximal end of basals, equally developed on all three, diameter 2.1 mm (Pl. 33, fig. 6). Approximately 40 crennellar facets in ring, slightly concave within; lumen present at proximal junction of three basal plates.

Azygous basal rhombic in outline, broad, straight edges. Convex in cross section. BR sector is slightly convex parallel and normal to BR axis; adjacent sectors merge smoothly. Most growth has occurred along BR axis; small amount along BB. Surface ornamented by broad, rounded growth lines. ABL: 6.5 mm; ABW: 5.9 mm; ABBBF, left side (when viewed basally): 5.0 mm, right: 4.5 mm; ABBR, left: 5.9 mm, right: 5.2 mm; ABBRF, left: 3.9 mm, right: 3.6 mm.

Zygous basals large, asymmetric, pentagonal in outline, rounded in cross section; ornament and growth, and BR sectors as for azygous basal. Lower lateral edges straight; upper lateral edges very slightly convex; uppermost edge slightly concave against C and R radials. Zygous basal centered under C radial broader because it is along the maximum axis of distortion; also more symmetric than other zygous basal. "C" basal: ZBL: 5.7 mm; ZBW: 8.9 mm; lower edge to uppermost edge, left: 6.7 mm, right: 6.2 mm; ZBBR, left: 6.0 mm, right: 5.7 mm; ZBBRF, left: 4.0 mm, right: 3.3 mm. "E" basal distorted, with right side being larger. ZBL: 5.6 mm; ZBW: 7.0 mm; lower edge to uppermost edge, left: 6.0 mm, right: 6.5 mm; ZBBR axis, left: 5.2 mm, right: 5.8 mm; ZBBRF, left: 1.8 mm; right: 4.1 mm.

Radials five, irregular in shape due to secondary bilateral symmetry; convex in outline in both horizontal and vertical cross section. B and D radials underlie long ambulacra, have more conventional shape with straight radial-basal sutures; interradial sutures convex outward (when viewed in plan view), and straight radiodeltoid sutures; height of radial greater than 4.5 mm because underlie ambulacra so in lateral view strong vertical development, profile triangular. "B" radial, RWB: 6.2 mm; RWA: 8.0 mm; RWD: 6.0 mm. Surface of RR and RB sectors ornamented with rounded growth lines; RD sectors near radiodeltoid suture bear closely spaced hydrospire slits, filling all of width of suture (Pl. 33, fig. 5); remainder of exposed surface bears pebbly ridges, probably resulting from infilling of distal portions of hydrospire slits as on other radials. Extremities of B and D radials weathered and not preserved. "B" radial, RD: > 5.6 mm; RDF: 2.3 mm; RR: > 5.4 mm; RRF: 6.6 mm; RB: > 6.9 mm; RBF: 3.5 mm.

E and A radials strongly asymmetric with straight suture between them, convex lower edges, convex lateral edges, and straight but asymmetric upper edges, with those parts of radiodeltoid suture bordering EA deltoid much shorter than other edges; radiodeltoid sutures intersect at slightly more than 90°. Strongly convex in vertical cross section, less so in lateral cross section, form lateral wall of part of elongate asymmetric theca. Ornament of RR and RB sectors as for B and D deltoids: RD sector bears closely spaced hydrospire slits filling all of width of suture. Ornament just outside slits consisting of ridges representing bars between hydrospire slits show slits are infilled distally during growth (Pl. 33, fig. 3); ornament of RD sector becomes pebbly aboral to this. Maximum elevation of "A" radial 2.2 mm above radial-basal suture; RWB: 5.1 mm; RMW: 6.0 mm; RWD: 4.5 mm. Origin of plate not exactly determinable; RDF, left (when in plan view):

3.1 mm, right: 1.5 mm; RRF, left: 6.8 mm, right: 7.5 mm; RBF, left: 3.7 mm, right: 1.8. E radial essentially a mirror image of this except narrower in RB sectors.

C radial large, asymmetric, forms other lateral wall of theca. Strongly convex in vertical section, less so in horizontal. Radial-basal and interradial sutures convex outward in plan view; radiodeltoid sutures relatively straight except where embayed by strongly asymmetric hypodeltoid on left side. Ornament of all sectors as for other radials except growth lines border hypodeltoid-radial suture. Maximum elevation of C radial above radial-basal suture: 1.5 mm; RWB: 6.5 mm; RMW: 9.0 mm (thus it is the widest of all radials); RWD: 6.8 mm. Following sector measurements for right side when in plan view: RD: 3.0 mm; RDF: 3.2 mm; RR: 4.3 mm; RRF: 6.5 mm; RB: 6.2 mm; RBF: 3.5 mm. Length of axes approximate.

Deltoids four, forming border of anal opening together with epideltoid; sizes variable. In plan view deltoids rhombic; some distorted; admedial lateral edges slightly embayed by lancets. Adoral edge of each deltoid bears minor lobes and grooves; also on lateral edges of plate along interdeltoid suture which bears main groove. Thus adoral and adoral lateral edges plunge in toward oral opening. Aboral to minor lobes and grooves there is a short sharp ridge which rises along central axis of plate to form highest point on plate, a pyramid-shaped prominence (Pl. 33, figs. 2,3,5). Upper adoral edge of pyramid smooth, becoming slightly warty toward base where slope merges into ridge forming aboral border to area ornamented by minor lobes and grooves. Adoral edges also extend slightly aboral to beginning of ambulacrum. Deltoid crest originates from center of pyramid, tapering in width aborally. Aboral lateral edges of pyramid slope down into hydrospire fields. Closely spaced hydrospire slits fill aboral portions of deltoid not occupied by crest. Fenestrations of lattices of calcite within plate visible on deltoids and parts of RD sectors. EA deltoid the most symmetric, also the smallest. Del.L.: 3.0 mm; width of adoral edge: 0.8 mm; greatest aboral width along centerline of ambulacrum: 1.7 mm; length of crest: 1.8 mm; DR axis: 1.2 mm; number of hydrospire slits per side: 5; length of longest slit: 1.2 mm; width of hydrospire field: 1.2 mm (not synonymous with RDF) as field measured at right angle to slits. AB and DE deltoids border EA; skewed to left and right respectively. Measurements of AB: L.: 4.2 mm; width adoral edge: 0.7 mm; maximum width: 3.1 mm; length of crest: 3.0 mm; DR axis, left (when adoral edge north): 2.1 mm, right: 1.7 mm; number of hydrospire slits, left: 11, right: 12-13; width of field, left: 2.1 mm, right: 3.0 mm. Maximum length of slit (on both radial and deltoid), left: 1.5 mm, right: 1.0 mm. Hydrospire slit with maximum length not bordering ambulacrum but displaced abmedially from it. New hydrospires added during growth so field tapers to essentially zero at aboral tip of deltoid. Distal parts of hydrospire slits infilled along both radial and deltoid. Hydrospire slits are longer on the deltoid than the radials. DE deltoid essentially mirror image of AB. BC deltoid skewed, essentially same as DE. Del.L.: 4.2 mm; width of adoral edge: 0.8 mm (approximate); maximum width: 3.0 mm; length crest: 3.0 mm; DR axis, left (when adoral edge north): 1.6(a) mm, right: 1.8(a) mm; number of hydrospire slits, left: 12, right: 11; length of longest slit, left: 1.3 mm, right: 1.4 mm; width of field, left: 2.7 mm, right: 2.4 mm.

Adoral edge of epideltoid forms part of border of oral opening, width: 1.5 mm. Adoral surface of epideltoid slopes up steeply from oral opening to form a crescent-shaped adorally directed ridge (Pl. 33, fig. 7) adoral to anal opening, 0.7 mm high, 2.6 mm wide. Aboral edge of ridge drops almost vertically to a small flat area adoral to anal opening and beginning of hydrospire fields. Left aboral side more extensively developed than right, being wider and longer. Hydrospire slits present on epideltoid-radial sutures. Those on D side cross suture; those on C side have been infilled across the suture and are functional only on the epideltoid. Length both anal deltoids: 4.5 mm; greatest width of epideltoid: 4.7 mm. Number hydrospire slits, left side: 7, right: 4; length of longest slit, left: 1.1 mm, right: 0.6 mm; width of field, left: 1.5 mm, right: 1.0 mm.

Anal opening bordered by epi- and hypodeltoid, ellipsoidal with nearly pointed adoral end, L.: 1.5 mm, W.: 1.0 mm. Hypodeltoid irregular, shaped like a broad, shallow piece of pie, with aboral edge convex against C radial with only 0.1 mm of its aboral width of 2.8 mm in contact with the D radial; thus skewed in its orientation (Pl. 33, fig. 7). Maximum length perpendicular to hyporadial suture: 1.4 mm. Adoral edge bordering epideltoid on D side straight, 1.8 mm long. Other adoral edge borders anal opening and short suture with epideltoid on C side (1.6 mm for both). Thus C side, as for epideltoid, restricted in its development. Oral center to anal opening: 1.9 mm; to epi-hypodeltoid suture at anal opening, D side: 2.9 mm, C side: 2.7

mm; to epi-hypodeltoid radial suture, D side: 4.5 mm, C side: 3.0 mm.

Ambulacra five, A, C, and E much shorter than B and E. Side plates now missing in three shorter ambulacra but lancet preserved in each. In C, main groove extends from oral opening to adoral portion of short lanceolate-shaped lancet (L.: 1.2 mm; W.: 0.4 mm); latter extends to radial and abuts against but does not lie on top of it. Thus C ambulacrum confined to deltoid. Depressions on either side indicate where side plates were positioned. Adoral part of lancet exposed. Lancets of E and A ambulacra shorter, but trough along interdeltoid suture would appear to indicate a configuration and size for these ambulacral fields similar to that of C, perhaps extending very slightly (0.2 mm) onto radial. Normal main groove leads to both lancets. Probable length, A ambulacrum: 1.5 mm; B: 1.7 mm. Lancets are 0.6 mm in length and 0.4 mm wide, rhombic-shaped, aboral part slightly longer, adoral part exposed, with side plates having been arrayed in an arc on aboral part to produce a rhombiform-shaped ambulacrum.

B and D ambulacra are long, lengths greater than 3.8 and 4.6 mm respectively (aboral ends weathered), linear (width, 1.8 mm), with one side plate per mm; elevated above oral opening (Pl. 33, fig. 4). Adoral end of ambulacrum farther from oral center (oral center to adoral edge of A ambulacrum: 1.2 mm; C: 1.6 mm; E: 1.2 mm; B: 2.2 mm; D: 2.6 mm). Lancet exposed along main groove of B and D ambulacra and forms lower part of minor lobes and grooves above main groove (latter has a width of 0.1 mm); width of exposed lancet: 0.4 mm. Center of B lancet pierced by internal canal. Arcuate side groove (length: 0.6 mm) curves downward adorally to deep main groove; approximately five minor grooves border adoral edge of side groove and five along main groove per side plate as well. Minor lobes and grooves present along aboral edge of side groove as well (Pl. 33, fig. 1). Brachiolar facet a heart-shaped depression on abmedial side of ambulacrum (L.: 0.25 mm, W.: 0.28 mm); large raised ridge between each facet. Configuration of outer side plate somewhat unclear but apparently a relatively large ellipsoidal elongate plate with pointed lateral ends which forms part of adoral half of facet and extends admedially to form part of aboral portion of a side groove as well as extending to near ablateral edge of ambulacrum.

Ten exposed hydrospire fields, number per field dependent on space available (see previous discussion). Width of a slit 0.08-0.09 mm.

Oral opening elongate, arcuate, concave toward anal opening, bordered by minor lobes and grooves.

Stereomic microstructure well preserved in upper part of theca.

Distribution.— Permian, Sonnebait Series, Basleo, Timor, Indonesia.

Remarks.— The above description is based upon the only known specimen, the holotype (University Amsterdam Ge.O.9939). The ontogeny of the species was discussed by Breimer and Macurda (1972). *D. permicus* was originally interpreted by Wanner to have only two ambulacra. Breimer and Macurda (1965) suggested that there were five. A restudy of the holotype using xylene as a wetting agent has definitely shown the presence of five ambulacra with main food grooves and lancets. The "damaged C ambulacrum" referred to by Breimer and Macurda (1965, p. 212) is now known to be only matrix in the adoral portion of the main groove on the deltoid.

Two interpretations are possible for *Dipteroblastus*; first that it is a truly asymmetric blastoid with secondary bilateral symmetry. It apparently did not lie on the ocean floor as there is no flattened area to rest on as in *Eleutherocrinus* Shumard and Yandell and it apparently had a functional stem. Alternatively it might represent a mutant but of what is unknown (*Pterotoblastus oyensi*?).

Genus TIMOROBLASTUS Wanner 1924a

Type species.— *Timoroblastus coronatus* Wanner, 1924a.

Timoroblastus Breimer and Macurda, 1972, p. 37.

TIMOROBLASTUS CORONATUS Wanner, 1924a

Pl. 34, figs. 1-10; Pl. 35, figs. 1-6;
Pl. 36, figs. 1-4, 7-11; Tables 44A-D

Timoroblastus coronatus Breimer and Macurda, 1972, p. 37, Pl. XXIII, figs. 2,3,5,7; Pl. XXVI, figs. 1,4,5, 8-11; Pl. XXVII, figs. 1, 3-5, 9.

Description.— Theca box-like in lateral profile with broad, flat to concave base with convex to concave sides rising steeply upward from base to flattened vault (Pl. 34, figs. 1,2,5,8,9; Pl. 35, figs. 1,3,6; Pl. 36, fig. 3). Deltoids conspicuous; ambulacra restricted, confined to upper surface. Theca pentagonal to strongly stellate in plan view, angles of pentagon; in interambulacral areas; profile between angles becoming pronouncedly concave as thecal outline becomes more stellate (Pl. 34, figs. 4,6,10; Pl. 35, fig. 5; Pl. 36, fig. 4). Length

TABLE 44A. Growth relationships of principal variables of *Timoroblastus coronatus* Wanner, 1924

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	26	0.39	5.85	0.27	6.2–15.5	10.5–21.4
L/ABBR	26	0.39	6.50	0.53	6.2–15.5	3.5–10.0
L/RD	26	0.16	8.51	0.53	6.2–15.5	1.7– 4.1
L/RB	26	0.60	4.22	0.56	6.2–15.5	6.3–16.2
L/Del.L.	26	0.21	7.87	0.30	6.2–15.5	4.0–10.5
L/Amb.L.	26	0.49	6.22	1.47	6.2–15.5	1.2– 4.4
RD/Amb.L.	26	0.76	0.94	0.72	1.7– 4.1	1.2– 4.4
Del.L./Amb.L.	26	0.76	2.83	1.63	4.0–10.5	1.2– 4.4
ABL/ABW	26	0.05	8.28	0.09	5.0–16.8	4.0–10.1
ABBR/ABBRF	26	0.84	2.89	0.58	3.5–10.0	3.8–14.3
ZBL/ZBW	26	0.94	0.12	0.60	3.5– 8.4	6.2–13.4
ZBBR/ZBBRF	26	0.73	3.99	0.46	4.0– 9.5	2.5–13.2
ABBR/RB	26	0.77	1.07	0.52	3.5–10.0	6.3–16.2
ABBR/RD	26	0.76	1.54	1.80	3.5–10.0	1.7– 4.1
ABBR/Del.L.	26	0.83	0.49	0.86	3.5–10.0	4.0–10.5
RD/RDF	26	0.89	0.90	0.50	1.7– 4.1	2.0– 7.0
RR/RRF	26	0.78	1.05	0.30	2.5– 7.1	7.5–18.7
RB/RBF	26	0.55	6.89	0.60	6.3–16.2	2.5–12.1
RD/RR	26	0.90	0.34	0.52	1.7– 4.1	2.5– 7.1
RD/RB	26	0.56	1.10	0.16	1.7– 4.1	6.3–16.2
RR/RB	26	0.68	1.10	0.34	2.5– 7.1	6.3–16.2
RD/Del.L.	26	0.89	0.07	0.39	1.7– 4.1	4.0–10.5
RB/Del.L.	26	0.66	3.38	1.00	6.3–16.2	4.0–10.5
Del.L./Gr.Ab.W.	26	0.88	1.07	2.09	4.0–10.5	1.6– 4.0
Del.L./Anal Del.L.	26	0.94	0.41	0.89	4.0–10.5	5.0–11.0
Amb.L./Amb.W.	26	0.54	0.03	1.40	1.2– 4.4	1.2– 2.2
Amb.L./No. S.P.	22	0.88	0.47	0.28	1.2– 3.4	4.0–11.0

(maximum height from lowest part of basals to tip of deltoids) and width subequal, the latter usually being slightly greater; maximum length about 25 mm. Maximum width of theca along interambulacral radius is usually at base of radials; however, it may also be in the median position along the interradial suture or at the aboral tip of the deltoids. Maximum width in midline of radial usually just below origin of plate but may be at base of radial. See Table 44A.

Basalia three, in normal position, forming wide, broad base of theca. When theca viewed basally, basalia form the almost entire view; pentagonal to strongly stellate in plan view (Pl. 34, fig. 3; Pl. 35, figs. 2,4; Pl. 36, fig. 2). The basalia may lie in the same plane, thus forming a flat base to the theca, or curve downward and outward forming a broad, concave, arcuate base with the stem facet well recessed in lateral view. Degree of concavity varies from flat to pronounced, usually slight, and varies in expression from population to population. Rarely basalia may also be slightly convex, with stem facet as lowest point of theca. Stem facet at proximal junction of basalia, a slightly raised circular area with 30-40 crenellae at periphery of facet. Rarely, facet may also be a slight depression at proximal junction of basalia without raised edges. Interior of facet slightly depressed, lumen pierces junction of three basals. Diameter of facet increases ontogenetically, ranging from 1.0 to 2.0 mm. Occasionally, uppermost stem plate preserved, being rounded-triangular to circular in outline, crenellae at very edge, 0.1 mm in height, and lumen pierces center.

Azygous basal quadrate in plan view, shape usually rhombic but may become quite elongate along BRF. Lateral edges usually straight but may be slightly convex; distal edges straight to slightly convex or sinusoidal. Shape of BR sectors variable in different specimens, because of different rates of growth along BR axis with respect to other parts of theca. Sectors range from slightly convex parallel and normal to BR axis to slightly convex parallel but concave normal to slightly concave both parallel and normal to the BR axis. First configuration is the most common; stem facet may be lowest point on theca or recessed but azygous basal still grows in slightly convex arc so plate has slightly convex profile. Adjacent BR sectors usually merge smoothly over slightly convex surface (occasionally concave). Some secretion of calcite along proximal part of BBF to allow increase in diameter of stem facet; also slight overgrowth of origin of basal. Ornament of azygous basal may be fine growth lines parallel to BRF or granulose growth lines or small ridges perpendicular to BRF which meet at a median ridge between the BR sectors. Calcite secreted along BBF smooth, slightly raised along suture.

Zygous basals pentagonal, with each half of a plate corresponding to the azygous basal in its configuration, adjacent halves meeting over slightly convex to concave profile. Outline in plan view of distal medial edge thus varies from slightly concave to strongly bifurcate. In forms with slightly concave edge BR sector adjacent to azygous basal may be reduced in size, producing asymmetry in plate (configuration produced by fitting three plates into a pentagonal area). Ornament of zygous basals as for azygous basal. ABL and ZBOPt may be variable between plates, one or the other being greater; also variable within a zygous basal. Width of basal usually greater than RWB except in stellate forms. See Table 44A.

Radials five, forming lateral sides of box-like theca, extending from lowest part of lateral thecal profile (unless basalia convex) to level of ambulacra. Radials quadrate in plan view, with lower edges varying from slightly convex to strongly concave (in stellate forms); lateral edges range from slightly convex to slightly concave (concavity may become pronounced a short distance below apex of deltoid); upper edges straight, converging at broad angle to meet at a very short radial sinus. Greatest width of radial variable, usually at base or median portion; rarely at deltoid apex. Thus, lateral edges of radials usually constrict toward deltoids. In lateral view radial is rather flat, its profile being that of the lateral edge. Cross section of radial highly unusual as lateral edges are almost always higher topographically than the median part of the plate. Origin of radial slightly below aboral end of ambulacrum. RB sector large, being straight (rare) to slightly convex parallel to RB axis, straight (rare) to concave normal to it, with adjacent sectors merging smoothly over straight (rare) to concave boundary. Boundary between RB and BR sectors very convex or angular. RB sector merges smoothly with RR sector over straight boundary (rarely slightly convex or concave). RR sector large, straight parallel to RR axis (may become strongly convex in part farthest from origin) and slightly convex normal to the axis (rarely straight). RD sector small, at an angle to RR sector, sloping upward, the two sectors may merge smoothly or have an angular boundary. RD sector is straight to slightly concave parallel to the RD axis, straight normal to it. RD sectors incline inward toward one another, producing a broad sinus with the ambulacrum at the center. Ornament of RB and RR sectors are growth lines parallel to RBF and RRF; growth lines may be faint, prominent, or granulose; may have beaded line at junction of sectors or slight trough. There may be perpendicular ridges across the RR suture. Ornament of RD sector less prominent, often smooth but there

TABLE 44B. Growth relationships of principal variables of *Timoroblastus coronatus* Wanner, 1924

					Observed	Range
Variables	n	r	a_0	a_1	y	x
L/W	21	0.39	8.79	0.22	8.7–15.2	2.5–16.8
L/ABBR	21	0.83	4.45	1.36	8.7–15.2	3.2– 7.0
L/RD	21	0.70	2.63	3.45	8.7–15.2	1.8– 3.2
L/RB	21	0.76	4.47	0.91	8.7–15.2	4.5– 9.9
L/Del.L.	21	0.78	3.02	1.25	8.7–15.2	5.0– 8.6
L/Amb.L.	21	0.72	6.15	2.17	8.7–15.2	1.7– 4.0
RD/Amb.L.	21	0.74	1.47	0.45	1.8– 3.2	1.7– 4.0
Del.L./Amb.L.	21	0.60	4.01	1.13	5.0– 8.6	1.7– 4.0
ABL/ABW	21	0.77	-2.04	1.77	4.0–10.0	4.0– 6.6
ABBR/RB	21	0.84	0.41	0.62	3.2– 7.0	4.5– 9.9
ABBR/RD	21	0.58	0.71	1.74	3.2– 7.0	1.8– 3.2
ABBR/Del.L.	21	0.74	0.33	0.72	3.2– 7.0	5.0– 8.6
RD/RDF	21	0.56	1.71	0.26	1.8– 3.2	2.2– 5.3
RR/RRF	21	0.66	2.07	0.23	2.8– 4.7	5.6–11.3
RB/RBF	21	0.64	4.45	0.70	4.5– 9.9	2.0– 6.5
RD/RR	21	0.60	0.86	0.44	1.8– 3.2	2.8– 4.7
RD/RB	21	0.46	1.72	0.11	1.8– 3.2	4.5– 9.9
RR/RB	21	0.79	1.90	0.26	2.8– 4.7	4.5– 9.9
RD/Del.L.	21	0.71	1.02	0.23	1.8– 3.2	5.0– 8.6
RB/Del.L.	21	0.73	1.17	0.97	4.5– 9.9	5.0– 8.6
Del.L./Gr.Ab.W.	21	0.72	2.84	1.28	5.0– 8.6	2.0– 4.1
Amb.L./Amb.W.	17	0.82	-0.04	1.35	1.7– 3.2	1.3– 2.5
Amb.L./No. S.P.	16	0.81	0.23	0.31	1.7– 4.0	4.0–10.0

may be strong, closely spaced ridges which extend across onto deltoid, occupying full width of RDF. There is apparently also a small RA sector in some specimens for the aboral end of the radial sinus and ambulacrum is slightly removed from the apparent origin of the plate in these forms (Pl. 36, fig. 11). Interradial suture may bend sharply in upper part if rate of growth of deltoid more pronounced than usual in relation to RR. RWB: 5.4-14.1 mm; RMW: 6.5-13.8 mm; RWD: 4.8-12.0 mm. See also Table 44A.

Deltoids four, together with epideltoid forming border of oral opening. Deltoids hexagonal in plan view, with short adoral edge bordering oral opening; width expands along moderately long DDF (both bear minor lobes and grooves); width then constricts slightly (externally) due to indentation by lancet and side plates; DAF short to moderate in length, concave. Minimum width near aboral end of ambulacrum where adoral end of hydro-

TABLE 44C. Growth relationships of principal variables of *Timoroblastus coronatus* Wanner, 1924

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	6	0.61	-1.56	0.42	9.3–15.3	28.8–39.2
L/RD	6	-0.02	12.22	-0.04	9.3–14.5	2.5– 4.8
L/RB	5	0.48	6.50	0.37	9.3–14.5	12.1–19.8
L/Del.L.	4	0.69	5.26	0.69	10.8–14.5	9.2–13.5
L/Amb.L.	5	0.80	6.96	1.57	10.8–14.5	2.7– 5.0
RD/Amb.L.	5	0.76	0.82	0.67	2.5– 4.1	2.7– 5.0
Del.L./Amb.L.	4	0.97	3.69	1.90	9.2–13.5	2.7– 5.0
ABL/ABW	4	0.52	13.93	0.56	18.0–24.2	11.3–18.0
ABBR/ABBRF	4	0.64	9.55	0.48	14.0–17.7	10.4–16.8
ZBL/ZBW	7	0.96	-2.01	0.67	7.8–13.0	14.5–21.6
ZBBR/ZBBRF	6	0.84	3.42	0.80	12.7–19.7	11.8–21.0
RD/RDF	5	0.77	2.35	1.03	2.5– 4.8	5.0– 6.7
RR/RRF	5	0.59	3.58	0.15	5.1– 7.2	14.0–22.6
RB/RBF	5	0.93	-4.30	1.32	12.1–19.8	12.5–18.0
RD/RR	6	0.64	-1.11	0.76	2.5– 4.8	5.1– 7.2
RD/RB	5	0.41	1.81	0.13	2.5– 4.8	12.1–19.8
RR/RB	5	0.77	2.68	0.23	5.1– 7.2	12.1–19.8
RD/Del.L.	4	0.69	0.56	0.27	2.5– 4.1	9.2–13.5
RB/Del.L.	4	0.97	-2.53	1.64	12.1–19.8	9.2–13.5
Del.L./Gr.Ab.W.	4	0.99	0.66	2.49	9.2–13.5	3.4– 5.1
Amb.L./Amb.W.	5	0.95	-3.39	3.24	2.7– 5.0	2.0– 2.6
Amb.L./No. S.P.	4	0.95	0.54	0.35	2.7– 5.0	6.0–12.0

spire slit begins. Maximum width at junction of DAF-DRF; width contracts along the two DRF which are straight (rarely convex) to slightly sinusoidal. Angle at aboral apex of deltoid narrow, becoming more so with growth. Deltoid prominent in lateral view, forming entire upper surface of theca, with a median ridge which projects well above the oral opening. Adoral part of deltoid (DD sectors) moderately large, the surface usually being smooth and rising upward on all sides in a concave arc from the ambulacral tract into the median ridge. Rarely sector bears growth lines parallel to DDF. Ridge becomes pronounced in the adoral center. Deltoid ridge extends to aboral edge of plate, upper edge usually sharp; highest point variable, with profile being convex, hackneyed, straight, sloping downwards or upwards aborally. Height became more pronounced as animal grew. Aboral part of plate becomes more prominent with growth, dominated by median ridge; sides slope steeply downward to RDF. Upper parts of ridge may be fluted; sides usually smooth. Aboral part of deltoid adjacent to radiodeltoid suture may be smooth or bear strong ridges perpendicular to the suture; die out at base of ridge. At the minimum width of the deltoid, there is a pair or aborally concave grooves which ornament and indent the side of the ridge; these descend to the adoral end of the hydrospire slit. Del.Gr.Ad.W.: 1.7-4.7 mm; Del.Min.W.: 1.3-3.4 mm; L.Del.Crest: 2.9-8.0 mm. See also Table 44A.

Anal deltoids two, an epi- and hypodeltoid. Length of anal deltoids usually slightly greater than that of regular deltoid; combined outline as for regular deltoid. Outline of epideltoid as for adoral part of regular deltoid; epi-hypodeltoid suture at point of narrowest constriction on regular deltoid; suture slants aborally from anal opening. Adoral part of epideltoid rises upward to form rim to anal opening which embays its aboral edge. Hypodeltoid as for aboral part of regular deltoid, except hyporadial suture has convex bulge near ambulacrum. Anal opening embays adoral edge; trough leads upward for extension of anus (Pl. 36, fig. 8). Hypodeltoid larger than epideltoid; aboral to anal opening, hypodeltoid forms ridge as in regular deltoids. Hyporadial sutures rarely bordered by ambulacra at greatest width. Plane of contact of epi-hypodeltoid suture slopes outward; aboral lower surfaces of hypodeltoid and regular deltoids V-shaped, resting in notch formed by adjacent radials (Pl. 34, fig. 6). Anal opening ovoid to ovoid-angular (Pl. 36, fig. 10), opening upward, may be bordered by scalloped grooves on both epi- and hypodeltoid (former rarer, may also be a beveled area). Very rarely, long ramp-like projection formed on hypodeltoid (Pl. 36, figs. 8,9). Epi.L.: 1.0-3.0 mm; Epi.Gr.Ad.W.: 2.0-4.9 mm; Anus L.: 0.9-3.2 mm; Anus W.: 0.6-1.8 mm; HDL: 2.0-7.0 mm; HDW: 2.3-4.7 mm; O.c.-anus: 1.3-3.2 mm. See also Table 44A.

Ambulacra five, small, petaloid (Pl. 36, fig. 9), slightly elevated above surrounding plates, moderately removed from oral opening, aboral end near outer edge of thecal outline. Lancet is rhombic-shaped plate. Side plates rest upon inclined aboral part of lancet so plate only exposed in adoral part of ambulacrum; exposed adoral part also rhombic in shape. Size of lancet appears to increase ontogenetically. Side plates and outer side plates arrayed in a hemispherical arc to parabola on aboral part of lancet. In aboral part of ambulacrum, each side plate is wedge-shaped and extends onto the lancet; the outer side plate is a smaller wedge between the outer parts of the side plates (Pl. 36, fig. 9). Brachiolar facet a small heart-shaped area on vertical edge of ambulacrum (L.: 0.3 mm; W.: 0.2 mm). Aboralmost side groove almost enters main groove of ambulacral field parallel to ambulacral axis; angle of meeting diverges adorally, length of side groove increasing. Side grooves concave adorally, bordered by minor grooves and lobes both ad- and aborally; former stronger. Spacing wider than along main groove. As more side plates and brachioles are added aborally the adoral brachioles atrophy, so that an ambulacrum with up to 11 side plates per side would only have six functional brachioles per side. Size of adoral side and outer side plates increases when brachiole atrophied, principally in width but difficult to distinguish from one another. Shape more quadrate. O.c.-amb.: 1.7-3.6 mm. See also Table 44A.

Ten hydrospire groups, one slit per group, a short opening across the radiodeltoid suture which is mostly concealed by the adoral lateral edges of the ambulacrum, only the adoral end being evident.

Oral opening pentagonal, width: 0.5-1.5 mm. Ambulacral tract prominent on deltoids; width: 0.3-0.5 mm.

Stereom occasionally seen in radials and basals.

Occasional abnormalities in development of basals, radials, or deltoids, producing an asymmetry in the theca (Pl. 34, fig. 7; Pl. 36, fig. 1).

Distribution.– *Timoroblastus coronatus* is found at several Permian localities in the Basleo region of Timor (Basleo, Kioemoko, Moil Fatoe, Moil Tonini, Tuniun Eno, Noa (near Tuniun Eno) and from Kampung Sebot, near Kapang, Timor, Indonesia.

Remarks.– The above description is based upon the specimens measured in the four growth series (see Appendix 1). Measurements within the description are from Growth Series I. The internal anatomy and ontogeny were discussed and illustrated by Breimer and Macurda (1972).

A collection of *Timoroblastus* from one locality usually shows a large amount of variation in thecal form, ranging from flat to concave bases and pentagonal to stellate outlines. This is not solely an ontogenetic phenomenon, for one finds thecal shapes representing both ends of the scale throughout the available size range. The growth lines preserved in the plates seem to indicate that the ultimate shape was carried throughout development; stellate patterns are enhanced ontogenetically but downward growth of the basals had an early beginning. This amount of variation led Wanner to name a large number of varieties of *Timoroblastus coronatus*. The forms appear to be gradational and represent one species. However, the amount of variation per population does not appear to be constant. The population

TABLE 44D. Growth relationships of principal variables of *Timoroblastus coronatus* Wanner, 1924

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	20	0.86	1.71	0.83	9.5–25.5	9.8–26.2
L/ABBR	20	0.89	1.19	2.09	9.5–25.5	4.3–10.2
L/RD	20	0.77	4.41	3.41	9.5–25.5	1.8– 5.0
L/RB	20	0.90	-0.98	1.71	9.5–25.5	5.9–13.8
L/Del.L.	20	0.74	4.87	1.31	9.5–25.5	4.3–13.4
L/Amb.L.	20	0.86	5.29	3.17	9.5–25.5	1.7– 6.0
RD/Amb.L.	20	0.85	0.98	0.72	1.8– 5.0	1.7– 6.0
Del.L./Amb.L.	20	0.75	3.12	1.59	4.3–13.4	1.7– 6.0
ABL/ABW	20	0.57	1.14	1.34	9.0–18.2	4.5– 9.1
ABBR/RB	20	0.92	-0.24	0.74	4.3–10.2	5.9–13.8
ABBR/RD	20	0.80	1.98	1.50	4.3–10.2	1.8– 5.0
ABBR/Del.L.	20	0.82	1.83	0.62	4.3–10.2	4.3–13.4
RD/RDF	20	0.92	0.95	0.53	1.8– 5.0	2.0– 9.0
RR/RRF	20	0.83	1.09	0.33	2.8– 7.3	6.8–20.3
RB/RBF	20	0.78	5.63	0.64	5.9–13.8	2.3–14.1
RD/RR	20	0.86	0.23	0.61	1.8– 5.0	2.8– 7.3
RD/RB	20	0.76	0.14	0.33	1.8– 5.0	5.9–13.8
RR/RB	20	0.90	-0.24	0.54	2.8– 7.3	5.9–13.8
RD/Del.L.	20	0.93	0.23	0.37	1.8– 5.0	4.3–13.4
RB/Del.L.	20	0.77	3.76	0.72	5.9–13.8	4.3–13.4
Del.L./Gr.Ab.W.	20	0.92	0.24	2.36	4.3–13.4	1.8– 5.0
Amb.L./Amb.W.	18	0.81	-2.21	2.86	1.7– 5.2	1.3– 2.5
Amb.L./No. S.P.	10	0.92	0.51	0.27	1.7– 3.2	5.0–10.0

measured in the greatest detail (Table 44A; from Tuniun Eno) has a fair number of representatives with a stellate outline and concave base. There is a fair range in the size of specimens. The second population (from Kampung Sebot; Table 44B) has much less of a tendency to develop stellate, concave-based forms, the growth of the deltoid appears to be more pronounced, and the size range is more restricted, most individuals being of approximately the same size. What conditioned or promoted the difference in or amount of variation of form is not apparent, unless it may be related to the ecological mode of the animals. Data on a general collection from all localities is given in Table 44D.

Two of the varieties named by Wanner represent the highest development of a broad base. *T. c. ungulatus* (Pl. 36, figs. 2-4) has spatulate tips on the lower extremities of the basals and radials. Growth lines are not preserved but these appear to be mature growth modifications as the form is not reflected in earlier parts of the plates. The prolonged extremities of the basals and radials are solid calcite and do not provide space for an expansion of the thecal cavity.

The other very broad form, *T. c. ingens* Wanner, was collected at Tuniun Eno and represented by one specimen. Recently, nine other examples of this form have been found; they are the largest specimens of *Timoroblastus* (Pl. 35, fig. 5; Table 44C). Growth lines indicate a constancy in form throughout ontogeny. They are strongly stellate with a gently concave base. They appear to represent another phenotypic variant of *T. coronatus*, not a separate species.

Van Eykeren (1942) described the genus *Microblastus pocilliformis* from a single very small specimen. It is an immature specimen; comparison of the radial shape, the ambulacral sinus, the shape of the deltoid, the angularity of outline suggests it is an immature *Timoroblastus*. Therefore, Breimer and Macurda (1972) synonymized *Microblastus* as a junior synonym of *Timoroblastus*. The basals of "*M. pocilliformis*" are broadly conical, unusual in *Timoroblastus* but known to occur. The only point of difference lies in the apparent lack of a hydrospire slit in the anal interarea but in *Codaster* there is a suggestion that the formation of anal hydrospires occurs slightly later in the ontogeny of the animal than the formation of regular hydrospires. The size range in which this occurred was about 3 mm (length) and it is suggested that since "*M. pocilliformis*" is about this size and immature, the apparent absence of anal hydrospires may be because of the stage of development. It was thought to have ten hydrospire groups but further cleaning in the anal interarea appears to indicate that the anal hydrospires were a dirt-filled crevice on the side of the ambulacrum which does not penetrate the plate. Because the specimen (University Amsterdam B6637) was the basis for a genus and much smaller than the usual *Timoroblastus coronatus*, a description follows. The specimen was illustrated by Breimer and Macurda (1972, Pl. XXIV, figs. 2,3,5,7).

Theca small, cup-shaped in lateral view, with lower part of pelvis broadly conical with a slightly concave profile; bending upward at the radial-basal suture to form the upper straight sides of the pelvis. Vault very short, flat. Theca pentagonal in oral view, with points of pentagon along interradial sutures. Ambulacra do not quite extend to edge of theca. Greatest width equatorial. L.: 3.0 mm; W.: 3.0 mm; V.: 0.3 mm; P.: 2.7 mm.

Basals short, broadly conical in lateral view, forming lower one-third of pelvis. Taper proximally to round stem attachment area whose diameter is 0.4 mm. Basals pentagonal in plan view, with two edges which include the azygous basal being indented. Azygous basal quadrate in plan view, with straight edges. BR sector very slightly concave parallel to BR axis, straight normal to it; sectors meet at a broad angle. Edges of plate drop down very slightly to sutures. Surface ornamented with a few coarse nodes. ABL: 1.6 mm; ABW: 1.5 mm; ABBBF: 1.2 mm; ABBR: 1.5 mm; ABBRF: 1.0 mm. Zygous basals pentagonal, with straight lateral edges; three distal edges very slightly concave. BR sectors slightly concave parallel to BR axis, straight normal to it; sectors meet at slight angle. Ornament and edges of plates as for azygous basal. ZBL: 1.5 mm; ZBW: 1.6 mm; ZBOPt: 1.5 mm; ZBBR: 1.2 mm; ABBRF: 1.0 mm.

Radials five, form upper two-thirds of pelvis. C and E radials quadrate in plan view, with convex lower edge (A, B, and D two straight lower edges); width expands very slightly to radial deltoid suture; upper edge flat. Plate flat in lateral profile. RB sector largest, very slightly convex parallel to RB axis and flat normal to it; lower edge of plate turns in toward radial-basal suture. RB sectors essentially flat in relation to one another and RR sectors; RR sector flat parallel and normal to RR axis. Ornament of RR and RB sectors a few coarse nodes as on basals. RD sector very small, almost at right angle to RR sector as top of plate bends abruptly over. Sector very slightly concave parallel to RD axis, slightly convex normal to it. RHT: 0.3 mm; RWB: 1.3 mm; RWD: 1.5 mm; RD: 0.5 mm; RDF: 0.4 mm; RR: 1.0 mm; RRF: 1.8 mm; RB: 1.7 mm; RBF: 0.5 mm.

Deltoids four, small, confined to upper flat surface of theca together with epideltoid forming border of oral opening. Pentagonal in plan view with straight adoral edge; width increases aborally along straight DDF to greatest width at adoral end of ambulacrum; width decreases along straight DAF; aboral edge crosses hydrospire slit and then borders radial along straight suture, meet at broad V at edge of theca. Adoral edge and DDF ornamented with minor lobes and grooves; adoral part of plate (that portion adoral to hydrospire slits) flat aboral to minor lobes and grooves. Aborally upper surface of plate constricted by two grooves which pass into hydrospire slits; upper surface forms a very short crest which passes into a pyramid-shaped aboral part of the plate; edges of this slope down to radiodeltoid suture. Del.L.: 1.4 mm; width adoral edge: 0.3 mm; Gr.Ad.W.: 0.7 mm; width lateral edges ambulacrum: 0.5 mm; DDF: 0.4 mm; DAF: 0.3 mm; length aboral part of deltoid: 0.4 mm.

Anal deltoids two, an epi- and hypodeltoid; L.: 1.8 mm. Epideltoid as for adoral part of regular deltoid, aboral edge embayed by anal opening. Width adoral edge: 0.3 mm; greatest width: 1.0 mm. Hypodeltoid missing but facet well delineated; broad (0.9 mm), hemispherical plate on upper surface of theca. Anal opening (width: 0.5 mm) apparently ovoid, opening upwards and outwards on lateral edge of upper surface. Oral center to anal opening: 0.8 mm; to epideltoid anus-radial suture: 1.0 mm; to ambulacrum: 0.7 mm.

Ambulacra five, very small (L.: 0.4 mm; W.: 0.3 mm), removed from oral opening in a shallow depression so brachiolar facets which are on aboral edges face outward. Two brachiolar facets per ambulacrum; heart-shaped, approximately 0.25 mm long and wide. Lancet exposed?

Eight hydrospire groups, lacking in anal interarea. One hydrospire per group, 1.0 mm from oral center, a very short slit along the adoral part of aboral edge of the ambulacrum, passing across the radiodeltoid suture onto the deltoid. Length: 0.1 mm(a).

Oral opening pentagonal, width: 0.4 mm.

TIMOROBLASTUS WEIENSIS Wanner, 1940
Pl. 36, figs. 5,6

Timoroblastus weiensis Breimer and Macurda, 1972, p. 37, Pl. XXIV, figs. 3-5.

Description.– Theca small, somewhat pyramidal, with very broad, very slightly convex base, sides of pelvis extend straight upwards, then slope inwards to merge with broad conical deltoids which form apex of pyramid. Theca stellate in plan view, with pointed interambulacral areas and broadly concave ambulacral areas. L.: 5.8 mm; W.: 8.3 mm; V (including deltoids which extend above oral opening): 1.5 mm; P.: 4.4 mm.

Basalia three, in normal position, all lying in same plane and forming lower, almost flat surface of theca. Pentagonal in plan view. Azygous basal rhombic in plan view, lateral edges straight, distal edges slightly concave. BR sector very gently convex parallel to BR axis and straight normal to it; edges turn upward to meet radials. Distal apex becomes convex in cross section. Ornament on low median ridge where BR sectors meet suggests broad growth lines. ABL: 4.7 mm; ABW: 4.8 mm; ABBRF: 2.8 mm; ABBR: 3.1 mm; ABBRF: 3.5 mm. Zygous basal pentagonal, with straight lateral edges, slightly concave distal lateral edges, and concave median lateral edge. Broad ridges extend to distal pointed extremities. BR sector of each zygous basal bordering azygous basal smaller than counterpart bordering adjacent zygous basal. Configuration of BR sectors as for those of azygous basals except for lateral BR sectors which are very slightly concave normal to BR axes. ZBL: 3.2 mm; ZBW: 4.9 mm; ZBOPt: 5.0 mm; ZBBR: 3.4 mm; ZBBRF for sector bordering azygous basal: 2.5 mm; ZBBRF for sector bordering zygous basal: 3.2 mm. Small round stem attachment area at proximal junction of three basals; diameter: 0.5 mm. Crenellar lobes visible near outer edge.

Radials five, forming vertical side of theca; radial depressed along mid-line parallel to polar axis, forming broad trough. In plan view radial very broad base with gentle, gull-winged shaped suture. Lateral edges straight up to an imaginary horizontal plane through origin of radials, then slope upward along serrated edge to meet deltoid. Top almost straight with extremely short radial sinus. RB sector very gently concave parallel to, and concave normal to RB axis; adjacent RB sectors merge smoothly with each other and RR sectors. RR sector concave parallel to and convex normal to RR axis. RD sector small, straight parallel and normal to RD axis; slopes upward toward oral opening. RA sector a small deposit filling former ambulacral space. Radial ornament very fine grained–growth lines parallel to RRF and RBF. RWB: 5.2 mm; RWM: 5.8 mm; RWD: 3.2 mm; RD: 1.5 mm; RDF: 1.5 mm; RR: 2.5 mm; RRF: 4.6 mm; RB: 3.5 mm; RBF: 2.7 mm; RA: 1.0 mm.

Deltoids four, together with epideltoid forming border to oral opening. Deltoid rhombic in plan view with short straight adoral edge, straight DDF, very short DAF, long aboral body, narrowing to V of less than 90°. Minor lobes and grooves ornament adoral edge and DDF, bordered aboral to this by small rim. Deltoid rises upward from this into elongate ovoid elevation, now weathered; apparently higher adorally, tapering downward to aboral apex of deltoid (Pl. 36, fig. 6). Sides of elevated area slope down to ambulacra and DR sectors. Surface of latter sector becomes flat, passes evenly into RD sector; near radiodeltoid suture both ornamented with grooves leading to hydrospire slits (Pl. 36, fig. 5). Del.L.: 2.9 mm; width adoral edge: 0.3 mm; greatest adoral width at adoral end ambulacra: 1.5 mm; DDF:

1.0 mm; DAF: 0.4 mm; length aboral part deltoid: 1.3 mm; height above oral opening: 1.0 mm.

Configuration of anal deltoids two (?). Epideltoid as for adoral part of regular deltoid; elevation on upper surface forms U-shaped rim to anal opening; highest point on theca? Hypodeltoid if present now missing. Anal opening ovoid. Width adoral edge epideltoid: 0.5 mm; greatest width: 2.0 mm. Anal opening width: 0.8 mm. Oral center to anal opening: 1.4 mm; to epi-hypodeltoid(?) suture on anal opening: 2.0 mm.

Ambulacra five, very small, broadly petaloid in plan view, on upper sloping side of theca, contained in depression formed by sides of deltoid and RA: L.: 1.0 mm; W.: 0.8 mm. Ambulacrum convex in cross section. Two side grooves per ambulacral side. Lancet a rhombic-shaped plate exposed in adoral half of ambulacrum; side plates arrayed on aboral edges. Side plate wedge-shaped, with triangular outer side plate inserted between aboral edges of two plates; both form aboral lateral margin of ambulacrum. Heart-shaped brachiolar facet developed on inclined edge of ambulacrum, formed on side and outer side plate; L.: 0.3 mm; W.: 0.3 mm. O.c.-amb.: 1.5 mm.

Ten hydrospire groups; slits short, opening across radiodeltoid suture. In regular interareas, one slit opens out beneath ambulacrum; two additional ones developed lateral to this (Pl. 36, fig. 5). One hydrospire per group in anal interarea, opening beneath ambulacra.

Oral opening pentagonal, width: 0.5 mm; main groove 0.3 mm wide on deltoid; groove ascends from ambulacrum onto deltoid, then curves downward to oral opening.

Family CODASTERIDAE Etheridge and Carpenter, 1886

Genus CODASTER M'Coy, 1849

Type species.— *Codaster acutus* M'Coy, 1849.
Codaster Breimer and Macurda, 1972, p. 37, 38.

CODASTER ACUTUS M'Coy, 1849

Pl. 37, figs. 1-6; Pl. 38, figs. 1,2,8,17; Tables 45 A-C

Codaster acutus Breimer and Macurda, 1972, p. 37, Pl. XXVI, figs. 2,3,6,7; Pl. XXVII, figs. 2, 6-8; Pl. XXVIII, figs. 1,2,4,8,9.

Description.—Theca cup-shaped in lateral view, with very low, almost flat vault confined to upper surface of theca. Lower half of pelvis convex, conical curving down to proximal stem attachment; upper walls of pelvis straight to slightly inflated. Outline in plan view pentagonal, with slightly convex interambulacral areas. Greatest width almost always below level of vault in median portion of radial. Length almost always slightly greater than width; vault much shorter than pelvis. See Table 45A.

Basalia three, in normal position, large, forming approximately lower one-half of pelvis, convex in lateral view, tapering proximally to a small conical stem attachment area at proximal junction of basals. Stem attachment area slightly concave internally (Pl. 38, fig. 1), with a small rim around it; low ridges radiate distally into center of three basals. Diameter of stem attachment area increases from 0.5 to 1.4 mm; proximal stem plate known. Outline of basals pentagonal in basal view; only small portion of radials visible (Pl. 38, fig. 2). Proximal portion of basals triangular cross section, becoming more pronounced in larger specimens. Azygous basal quadrate in plan view, with slightly convex lateral edges (more pronounced proximally) and sinusoidal distal edges, becoming more pronounced in larger specimens. BR sector convex parallel and normal to BR front. BR sectors merge with one another and those of adjacent zygous basals on relatively flat surface. Zygous basals pentagonal, with slightly convex lateral edges, slightly concave to sinusoidal lateral distal edges, and concave medial distal edge. BR sectors convex parallel to BR axes; medial sector convex normal to medial BR axis while lateral sectors are flat to very slightly convex, merging smoothly with medial sector on flat or very slightly concave surface. Ornament of basals usually not preserved; but when present, in the form of low, broad growth lines parallel to BRF; narrower parallel to BBF. BRF bordering azygous basal shorter than that of BRF bordering adjacent zygous basal, producing asymmetry in plate and lower correlation coefficient. See Table 45A.

Radials five, forming upper half of pelvis, bending over sharply adorally to form part of vault. Radials quadrate in plan view with short, broad body and very short radial sinus. Lower edge of C and E radials convex against zygous basals, lateral edges straight, with width at base and deltoids usually almost equal; upper edges short, straight, converge at broad angle. Outline of A and B radials asymmetric in plan view; lower edges pointed, those of A and B broader on edge facing azygous basal than zygous basal; D radial pointed but usually symmetric; all three broader at base than adoral-

TABLE 45A. Growth relationships of principal variables of *Codaster acutus* M'Coy, 1849

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	20	0.95	1.27	1.03	6.2–15.2	4.8–14.5
V/P	20	0.66	-0.13	0.08	0.2– 1.2	6.0–14.0
L/ABBR	20	0.97	0.73	1.84	6.2–15.2	3.2– 8.2
L/RD	20	0.93	1.95	4.16	6.2–15.2	1.1– 3.5
L/RB	20	0.97	0.80	1.74	6.2–15.2	3.3– 8.4
L/Del.L.	20	0.95	0.46	2.86	6.2–15.2	2.0– 5.0
L/Amb.L.	20	0.96	3.04	2.70	6.2–15.2	1.2– 4.8
L/No.Hyd.Sl.	20	0.88	2.06	1.39	6.2–15.2	3.0– 9.0
RD/Amb.L.	20	0.94	0.43	0.59	1.1– 3.5	1.2– 4.8
Del.L./Amb.L.	20	0.96	1.03	0.90	2.0– 5.0	1.2– 4.8
ABL/ABW	20	0.93	0.01	1.06	3.6– 9.0	3.1– 8.2
ABBR/ABBRF	20	0.86	0.51	1.32	3.2– 8.2	1.8– 5.2
ZBL/ZBW	20	0.96	0.31	0.80	3.3– 7.8	3.4– 9.7
ZBBR/ZBBRF	20	0.89	1.90	1.28	3.2– 7.5	1.5– 4.5
ABBR/RB	20	0.94	0.35	0.89	3.2– 8.2	3.3– 8.4
ABBR/RD	20	0.91	0.91	2.15	3.2– 8.2	1.1– 3.5
ABBR/Del.L.	20	0.94	0.08	1.50	3.2– 8.2	2.0– 5.0
RD/RDF	20	0.90	0.12	1.16	1.1– 3.5	0.8– 2.5
RR/RRF	20	0.89	-0.01	0.51	1.5– 4.4	3.0– 7.7
RB/RBF	20	0.93	-0.08	1.09	3.3– 8.4	1.3– 3.9
RD/RR	20	0.93	0.20	0.70	1.1– 3.5	1.5– 4.4
RD/RB	20	0.92	0.01	0.37	1.1– 3.5	3.3– 8.4
RR/RB	20	0.93	-0.10	0.50	1.5– 4.4	3.3– 8.4
RD/Del.L.	20	0.92	-0.10	0.62	1.1– 3.5	2.0– 5.0
RB/Del.L.	20	0.94	0.07	1.57	3.3– 8.4	2.0– 5.0
Del.L./Gr.Ab.W.	20	0.94	0.58	1.49	2.0– 5.0	1.0– 3.0
Del.L./Anal Del.L.	20	0.94	-0.38	1.31	2.0– 5.0	1.8– 4.1
Amb.L./Amb.W.	20	0.84	-1.24	3.47	1.2– 4.8	0.8– 1.6
Amb.L./No. S.P.	19	0.94	0.61	0.28	1.2– 4.8	3.0–14.0

ly; asymmetry causes some irregularities in outline of theca. In lateral view radial has slightly convex upper edge, slightly concave lower edge; height of radial not great. RB sector largest, very slightly convex parallel to, and flat to slightly convex normal to RB axis; adjacent sectors merging with one another on convex surface in median portion of radial; merge smoothly with RR sector on flat boundary and curve into BR sector. RR sector relatively large, flat to slightly convex parallel to RR axis (variation may occur in one specimen) and slightly convex normal to it, curving slightly inward toward vault adorally. Ornament of RR and RB sectors low broad growth lines parallel to fronts. RD sector small, almost at a right angle to RR sector, on upper, almost flat upper surface of theca, straight parallel and normal to RD axis; slopes inward very slightly toward ambulacrum. Hydrospire slits occupy full width of RD sector in smallest to largest specimens; aboral 0.5-1.0 mm of RD sector smooth, with apparent infilling of aboral portions of hydrospire slits during growth. RWB: 2.2-6.5 mm; RWD: 2.3-6.4 mm. See also Table 45A.

Deltoids four, together with epideltoid forming border to oral opening (Pl. 37, figs. 1,2,4,5). Deltoids confined to upper surface of vault, do not quite extend to outline of edge of theca in oral view. Deltoid slightly convex in lateral view, being highest in median or adoral portion. Outline of deltoid hexagonal in plan view. Adoral edge straight against oral opening; width expands aborally along straight, relatively long DDF which bears main groove; these three edges ornamented with minor lobes and grooves; width of this area on two adjacent deltoids 0.2-0.5 mm. Width of deltoid contracts slightly (to 0.1-0.6 mm) on slightly concave DAF, at adoral end of ambulacrum, then expands again aborally to maximum width at junction of DAF and DRF; width contracts to zero along straight DRF; adjacent DRF meet at angle of 70-80°. Adoral portion of deltoid relatively large, rises above main groove, forming low rim; interior relatively flat and featureless although it may bear a faint expression of the deltoid crest. Aboral to deltoid constriction, this relatively smooth part of deltoid tapers aborally into a deltoid crest which narrows aborally, has a fairly sharp upper edge and slopes gently down into the hydrospire fields. That portion of deltoid bordering DRF bears hydrospire slits for full width of suture; adoral ends apparently infilled during growth as width of adoral part of crest increases. Del.Gr.Ad.W.: 1.0-2.2 mm; Del.Min.W.: 0.5-1.6 mm; L. Crest: 1.0-3.0 mm; DR: 0.7-2.3 mm. See also Table 45A.

One anal deltoid, an epideltoid, adoral outline of which as for regular deltoids, embayed aborally by anal opening (Pl. 37, fig. 3; Pl. 38, fig. 17). No development of crest; aboral parts in form of two broad prongs which extend to radial; slope slightly downward toward ambulacrum in cross section, most always bear one or more hydrospire slits adjacent to ambulacrum (exceptions only in very small thecae). Anal opening rounded triangular, pointed adorally, convex aborally; sometimes becoming more rhombic. Surrounded adorally by epideltoid and limbs of radials aborally. No trace of hypodeltoid or facets for it observed. Broad growth lines parallel aboral edges of anal opening where preserved on C and D radials. RR sector extends up to anal opening in anal interarea, tends to extend closer to oral opening, bending over further, and RD sector is more convex normal to RD axis. Anal opening opens directly upward. Epi.W.: 1.0-2.5 mm; Anus L.: 0.5-1.5 mm; Anus W.: 0.8-1.5 mm; O.c.-anus: 1.2-2.5 mm.

Ambulacra five, adoral end relatively far from center of oral opening, lanceolate in plan view, convex in cross section, being elevated above surrounding plates, and slightly convex in lateral view (Pl. 37, figs. 5,6; Pl. 38, fig. 17). Aboral tip does not quite reach to origin of radial. Lancet exposed almost to aboral tip of ambulacrum, maximum exposed width: 0.2-0.3 mm. Outline in plan view as for ambulacrum; upper central surface relatively flat; upper sides slope steeply down to adjacent plates; impressions of side and outer side plates visible on lancet. Lancet bordered laterally by small triangular side plates which are convex against lancet, taper to a point laterally; adoral edge at about 45° to axis of lancet, aboral edge at 90°. Large outer side plates form outer margin of ambulacrum, completely surrounding outer parts of side plates. At aboral tip of ambulacrum, side plate extends to side of ambulacrum but lateral growth of outer side plate quickly surrounds it. Outer side plates triangular in plan view, extend almost to or to lancet between side plates, outer edges form vertical wall above surrounding thecal plates and they lie directly upon the lancet; thus, along lower part of lancet outer side plates are in continuous contact with it. Brachiolar facet ellipsoidal, developed on upper outer sloping side of ambulacrum; facet depressed; adoral half developed on outer side plate, aboral half on side plate and next aboral outer plate. Main groove and adoral half of side groove ornamented with numerous minor lobes and grooves; grooves do not quite extend to main groove, configuration being similar to that in *Mesoblastus crenulatus* (Roemer) (see Macurda, 1967).

Ten hydrospire groups, reduced in number in anal interarea. Hydrospire fields in non-anal interareas occupy full width of radiodeltoid suture, new slits being added

TABLE 45B. Growth relationships of principal variables of *Codaster acutus* M'Coy, 1849

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	24	0.96	1.51	1.00	4.6–18.5	3.5–16.0
L/ABBR	24	0.97	0.06	2.04	4.6–18.5	2.5– 9.2
L/RD	24	0.89	2.46	3.80	4.6–18.5	1.0– 4.5
L/RB	24	0.98	1.30	1.63	4.6–18.5	2.4–10.0
L/Del.L.	24	0.95	0.67	2.78	4.6–18.8	1.5– 6.1
L/Amb.L.	24	0.95	3.43	2.57	4.6–18.5	0.8– 5.9
L/No.Hyd.Sl.	25	0.93	1.04	1.77	4.6–18.5	2.0–10.0
RD/Amb.L.	24	0.95	0.49	0.60	1.0– 4.5	0.8– 5.9
Del.L./Amb.L.	24	0.98	1.05	0.91	1.5– 6.1	0.8– 5.8
RD/RDF	24	0.95	0.12	1.17	1.0– 4.5	0.6– 3.1
RR/RRF	24	0.92	0.37	0.43	1.2– 4.5	2.4– 9.6
RB/RBF	24	0.90	0.62	2.55	2.4–10.0	1.4– 4.5
RD/RR	24	0.95	-0.16	0.86	1.0– 4.5	1.2– 4.5
RD/RB	24	0.91	0.15	0.36	1.0– 4.5	2.4–10.0
RR/RB	24	0.92	0.46	0.40	1.2– 4.5	2.4–10.0
RD/Del.L.	24	0.94	-0.12	0.64	1.0– 4.5	1.5– 6.1
RB/Del.L.	24	0.95	-0.26	1.67	2.4–10.0	1.5– 6.1
Amb.L./No. S.P.	22	0.94	0.09	0.38	1.0– 5.9	4.0–15.0

during growth; slits are longer on radial than deltoid; length of slits increases during growth but more slowly than growth of radial and deltoid due to some infilling at ends of slits. Innermost slit partially concealed by ambulacrum. Those in anal interarea usually one or two in number (Pl. 38, fig. 17), number on either side may be different; in growth series only one individual failed to develop a slit on at least one side. Slits shorter, inner one (if more than one) often concealed by ambulacrum. Internally, walls of hydrospires 0.025 mm thick. No.Reg.Hydro.Sl.: 3-9; L.Reg.Hydro.Fld.: 0.5-2.8 mm; W.Reg.Hydro Fld.: 0.4-2.2 mm.

Oral opening pentagonal, W.: 0.3-1.0 mm.

Occasional mutant known (Pl. 38, fig. 8).

Distribution.– Lower Carboniferous, Middle Limestone, Yorkshire, England; Visean, County Kilkenny, Ireland.

Remarks.– *Codaster* is the type genus of the family Codasteridae Etheridge and Carpenter which was defined by Fay (1961, 1964, 1967) as having eight hydrospire groups. However, the type species of the genus, *C. acutus*, possesses ten as was noted by Bather (1899, p. 6,7), Wanner (1940, p. 233, apparently referring to the type species), and Joysey (personal communication). These anal hydrospires are visible in a figure, published by Fay (1961, Pl. 12, fig. 4). Therefore the family Codasteridae was revised by Breimer and Macurda (1972).

Joysey (1953) established the synonymy of *C. acutus* M'Coy and *C. trilobatus* M'Coy. Joysey also discussed the stratigraphic distribution of *Codaster* in central England. He studied several populations, including one from the D_2 Limestone near Grassington. The population on which the above description is based came from this locality; all but one were part of a collection of 300 individuals found by Breimer, Joysey, and Macurda. The size range of this population is the same as that given by Joysey (1953). The internal anatomy and ontogeny of *Codaster* was discussed and illustrated by Breimer and Macurda (1972). Populations from other localities reach slightly greater size and have more hydrospire slits in the anal interarea. Many of the specimens in this comparative population (Growth Series II; Table 45B) are the same as those studied by Joysey (see Appendix I). A comparative population from Ireland (Growth Series III) is given in Table 45C.

Very small blastoids are quite uncommon. Among the specimens of *Codaster* from Lisdowney, Ireland, there is one which has a length of 1.6 mm and width of 0.9 mm (collected by G. Sevastopulo from washings). It is instructive on the early ontogenetic form of blastoids. The basals are the largest plates (ABBR: 1.1 mm) and well developed; the radials are quite small, C and E radials being noticeably smaller than the other radials (dimensions of C and E radials: RD: 0.1 mm; RDF: 0.1 mm; RR: 0.2 mm; RRF: 0.4 mm; RB: 0.5 mm; RBF: 0.2 mm); a relatively large oral opening (diameter: 0.25 mm); it is surrounded by four very small deltoids (length: 0.2 mm; aboral width: 0.2 mm) and the epideltoid; the anal opening is also relatively large (diameter: 0.25 mm) and opens outward on the upper side of the theca; there is only 0.08 mm of radial calcite between it and the basals. The ambulacra are very small, only the lancets are apparently preserved (L.: 0.2 mm; W.: 0.1 mm); they are small pentagonal plates sitting atop the radials and bordered adorally by the deltoids. There are no hydrospires developed; a larger theca with a length of 3.5 mm has one developed in each group, including the anal interarea. The small specimen described above has the normal complement of plates found in a blastoid and appears to represent a very early stage in the ontogenetic development of *Codaster*. A detailed interpretation of its significance was given by Breimer and Macurda (1972, p. 351-353; Text-fig. 103).

Codaster acutus is the only species assignable to the genus. Other species such as *Codaster gratiosus* S. A. Miller, 1880, (Pl. 38, figs. 9,10) were considered nomina dubia by Breimer and Macurda (1972).

Genus ANGIOBLASTUS Wanner, 1931

Type species.— *Angioblastus variabilis* Wanner, 1931.
Angioblastus Breimer and Macurda, 1972, p. 38.
Agmoblastus Strimple and Mapes, 1977, p. 358.

Remarks.— Breimer and Macurda (1972) synonymized three other genera with *Angioblastus: Agmoblastus* Fay, 1961, *Paracodaster* Yakovlev, 1940, and *Sagittoblastus* Yakovlev, 1937. Strimple and Mapes (1977) strongly disagreed with the synonymization of *Angioblastus* and *Agmoblastus*. Breimer and Macurda characterized *Angioblastus variabilis* (Permian) as being an evolutionary derivative of early species of *Angioblastus* (assigned to *Agmoblastus* by Strimple and Mapes, 1977). The important question is how much variability does one allow in their definition of a genus, particularly thecal shape. Breimer and Macurda (1972) believe there is a continuum; Strimple and Mapes (1977) do not. A complete description of each species of *Angioblastus* either follows or is given in Breimer and Macurda (1972). Extensive illustrations (Plates 37-42) of the species of *Angioblastus* are given to allow a reader to evaluate thecal variability in populations and with time. See also Tables 46-48.

Trying to characterize geometrical shapes such as that of the theca leads to arbitrary subdivision. Strimple and Mapes (1977) correctly point out that Breimer and Macurda failed to include the terms "globose" or "conical" in the familial definition of the Codasteridae (1972, p. 37) while using them for defining end points in morphologic variation in generic definitions. The definition of the Codasteridae is herein amended to include this. We did establish the presence of a hypodeltoid in the type species of *Angioblastus, A. variabilis* (p. 269). Strimple and Mapes (1977, p. 360) call attention to an "undefined character state" for *Angioblastus*, character 2. Our Table 1, character 2 should have read 0-2, not 1-3; data in Table II are consistent with this coding. Separate coding for the Pennsylvanian and Permian Systems would have been more accurate but it only involved *Angioblastus*. Strimple and Mapes (1977, p. 359) question the inclusion of our specimen number 13 in the growth series of *A. variabilis*. Each of our populations was a randomized sample of the available material and number 13 simply reflects the variation in thecal shape that led Wanner to propose the species name *variabilis*. Our concept of neoteny was not based upon this single specimen as should be clear from our discussion of codasterid phylogeny (1972, p. 349-356). We believe the evidence is clear that the following species

TABLE 45C. Growth relationships of principal variables of *Codaster acutus* M'Coy, 1849

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	9	0.98	0.77	1.14	1.6–18.2	0.9–14.5
L/ABBR	9	0.99	-0.31	1.92	1.6–18.2	1.1– 9.3
L/RD	9	0.95	1.90	5.37	1.6–18.2	0.1– 3.2
L/RB	9	0.98	0.93	1.78	1.6–18.2	0.5– 9.0
L/Del.L.	9	0.98	0.74	3.57	1.6–18.2	0.2– 5.0
L/Amb.L.	9	0.97	2.71	4.85	1.6–18.2	0.2– 3.5
L/No.Hyd.Sl.	9	0.97	1.76	2.28	0.2– 3.5	0.0– 8.0
RD/Amb.L.	9	0.96	0.24	0.85	0.1– 3.2	0.2– 3.5
Del.L./Amb.L.	9	0.95	0.63	1.31	0.2– 5.0	0.2– 3.5
RD/RDF	9	0.99	0.01	1.42	0.1– 3.2	0.1– 2.2
RR/RRF	9	0.97	0.06	0.38	0.2– 3.7	0.4– 8.9
RB/RBF	9	0.98	-0.20	2.42	0.5– 9.0	0.2– 3.5
RD/RR	9	0.99	-0.11	0.84	0.1– 3.2	0.2– 3.7
RD/RB	9	0.92	0.02	0.30	0.1– 3.2	0.5– 9.0
RR/RB	9	0.96	0.10	0.36	0.2– 3.7	0.5– 9.0
RD/Del.L.	9	0.98	-0.13	0.63	0.1– 3.2	0.2– 5.0
RB/Del.L.	9	0.97	0.07	1.94	0.5– 9.0	0.2– 5.0
Del.L./Gr.Ab.W.	9	0.98	0.07	1.92	0.2– 5.0	0.2– 2.5
Amb.L./Amb.W.	9	0.95	-0.25	2.14	0.2– 3.5	0.1– 1.6
Amb.L./No. S.P.	7	0.92	0.15	0.30	0.2– 3.5	1.0–13.0

form an easily recognizable, coherent, natural grouping for which the name *Angioblastus* is appropriate.

Strimple and Mapes (1977, p. 358) took issue with the suggestion by Breimer and Macurda (1972) that the scarcity of post-Morrowan Pennsylvanian fissiculate blastoids is an artifact of the geological record, not an evolutionary crisis as they would hold. They note the large number of intensively collected Pennsylvanian crinoid localities. Most of these are in North America. Breimer and Macurda (1972) suggested the continuity of most Mississippian fissiculate families into the Permian. The spiraculate genus *Orbitremites* is known from the Lower Carboniferous and Permian; no Pennsylvanian representatives have yet been recovered. If Permian outcrops on the small island of Timor were not available to us, we would know of only half the present number of Permian blastoid genera. The appropriate Pennsylvanian localities either are not preserved or still await discovery (probably in Asia), but there is continuity through the Pennsylvanian.

The following characters distinguish the species of *Angioblastus* from one another:

A. boliviensis: Theca cup-shaped, cylindrical sides, convex lower base, a medial ridge which divides the radial, a vault which almost reaches the edge of the pentagonal profile in plan view, and a deltoid crest which is more well developed than the ridge separating the ad- and aboral parts of the deltoid. Hydrospire slits functional only over short distance.

A. caddense: Theca cup-shaped with tapering convex base, fine growth lines ornamenting basals and radials, a vault which reaches the edge of the decalobate profile in plan view, and a strong, well developed deltoid crest which is equal in height to the ridge dividing the ad- and aboral parts of the deltoid. Hydrospire slits functional over relatively long length.

A. dotti: Theca cup-shaped with slightly inflated base, convex lower base, radials and basals ornamented with relatively broad growth lines, a vault which almost reached the edge of the ovoid-pentagonal profile in plan view, and a strongly developed deltoid crest which is as well developed as the ridge separating the ad- and aboral parts of the deltoid. Hydrospire slits functional only over a short distance.

A. ellesmerensis: Theca cup-shaped with tapering sides; fine granulose growth lines with cross ridges ornamenting basals and radials, a vault which reaches the edge of the pentagonal profile in plan view, and a strong well-developed ridge which separates the ad- and aboral parts of the deltoid; deltoid crest originates at a lower elevation. Functional length of hydrospire slits short.

A. miloradovitchi: Theca sub-globose, bowl-shaped pelvis with recurvature toward top, smooth broad growth lines ornamenting basals and radials, vault not reaching to edge of rounded pentagonal profile in plan view, ad- and aboral parts of deltoid separated by pyramidal mound. Hydrospires functional over relatively long length.

A. variabilis: Theca angular oblate spheroid in lateral view, recurvature of pelvis toward top, ornament of radials and basals nodose growth lines (to massive ridges in RB sectors), vault restricted, not reaching to edge of pentagonal profile, and massive deltoid ornament, no sharp ridge between ad- and aboral portions. Hydrospire slits functional only over a short distance.

A. wanneri: Theca sub-globlose with bowl-shaped pelvis with recurvature toward top, broad faint growth lines ornamenting basals and radials, vault restricted, not reaching edge of rounded-pentagonal to pentagonal profile in plan view, and the deltoid crest and ridge separating ab- and adoral parts of deltoid arrowhead-shaped profile. Hydrospire slits functional only over a short length.

ANGIOBLASTUS BOLIVIENSIS
Breimer and Macurda, 1972
Pl. 40, figs. 1-3

Angioblastus boliviensis Breimer and Macurda, 1972, p. 38-40, Pl. XXIX, figs. 19-21.
Agmoblastus boliviensis Strimple and Mapes, 1977, p. 357.

Description.– A complete description was given by Breimer and Macurda (1972) except for metric measurements which follow: L.: 9.1 mm; W.: 7.7 mm; V.: 1.7 mm; P.: 7.4 mm; Pelvic angle: 38°; ABL: 4.3 mm; ABW: 5.0 mm; ABBBF: 3.2 mm; ABBR: 3.7 mm; ABBRF: 3.0 mm; ZBL: 4.8 mm; ZBW: 6.0 mm; ZBOPt: 5.0 mm; ZBBR: 4.5 mm; ZBBRF: 2.6 mm; RHt: 1.0 mm; RWB: 3.6 mm; RWD: 3.5 mm; RD: 1.7 mm; RDF: 1.2 mm; RR: 2.2 mm; RRF: 4.6 mm; RB: 4.3 mm; RBF: 2.1 mm; Del.L.: 3.0 mm; Gr.Ad.W.: 2.0 mm; Del.W.adoral edge ambulacrum: 1.5 mm; DDF: 1.2 mm; DAF: 1.0 mm; Length aboral part deltoid: 1.8 mm; Anal Del.L.: 3.2 mm; Epi.Gr.Ad.W.: 2.2 mm; Anus W.: 1.0 mm; HDW: 1.4 mm; O.c.-adoral edge anal opening: 2.2 mm; O.c.-adoral end ambulacrum: 1.7 mm; Amb.L.: 2.0 mm; Amb.W.: 1.2 mm; No. S.P.: 6; O.c.-hydrospire slits: 2.2 mm; L. Hydro.Fld.: 0.3 mm; W. Hydro.Fld.: 0.7 mm; No. Hydro.: 3; W.oral opening: 0.8 mm.

Distribution.– Lower Permian, Zudanez syncline, Bolivia.

Remarks.– The description (Breimer and Macurda, 1972) and the above data are derived from the holotype, USNM 160591.

ANGIOBLASTUS DOTTI
(Moore and Strimple, 1942)
Pl. 40, figs. 4-17,21,24; Table 46

Angioblastus dotti Breimer and Macurda, 1972, p. 38, Pl. XXIX, figs. 1-5.
Agmoblastus dotti Strimple and Mapes, 1977, p. 357.

Description.– Theca subglobular, with short, low, broadly convex vault and tall, broad, cup-shaped pelvis which turns inward adorally. Base of pelvis flattened. Thecae usually disarticulated; flattened when complete, and plates may be faulted internally and with respect to one another (Pl. 40, figs. 4-8,10). Outline of theca in plan view rounded pentagonal with slightly concave interambulacral areas. Greatest width equatorial in

TABLE 46. Growth relationships of principal variables of *Angioblastus dotti* (Moore and Strimple, 1942)

Variables	n	r	a_0	a_1	Observed y	Range x
L/ABBR	4	0.73	-1.58	3.04	8.4–14.0	3.4– 4.7
L/RD	5	0.76	-2.28	7.21	8.4–14.0	1.5– 2.1
L/RB	5	0.72	3.14	1.38	8.4–14.0	4.2– 7.2
L/Del.L.	5	0.91	0.69	2.62	8.4–14.0	3.0– 4.7
L/Amb.L.	5	0.77	4.26	4.18	8.4–14.0	1.2– 2.1
L/No.Hyd.Sl.	5	0.54	6.95	0.82	8.4–14.0	3.0– 7.0
RD/Amb.L.	5	0.95	0.96	0.55	1.5– 2.1	1.2– 2.1
Del.L./Amb.L.	5	0.55	2.23	1.03	3.0– 4.7	1.2– 2.1
ABL/ABW	7	0.88	-1.07	1.09	4.9– 7.9	5.5– 8.3
ABBR/ABBRF	7	0.89	-0.21	1.33	4.3– 6.9	3.3– 5.5
ZBL/ZBW	12	0.90	1.01	0.62	5.2– 7.7	6.1–10.2
ZBBR/ZBBRF	12	0.77	1.91	1.03	4.5– 7.0	2.7– 4.8
ABBR/RB	4	0.84	0.75	0.64	3.4– 4.7	4.2– 6.0
ABBR/RD	4	0.49	1.37	1.51	3.4– 4.7	1.5– 2.0
ABBR/Del.L.	4	0.94	1.56	0.64	3.4– 4.7	3.0– 4.7
RD/RDF	13	0.11	2.00	0.06	1.7– 2.5	1.2– 2.9
RR/RRF	13	0.29	2.29	0.13	2.6– 3.7	5.0– 7.0
RB/RBF	13	0.18	5.54	0.36	5.4– 7.5	2.3– 3.7
RD/RR	13	0.38	1.10	0.33	1.7– 2.5	2.6– 3.7
RD/RB	13	0.25	1.50	0.09	1.7– 2.5	5.4– 7.5
RR/RB	13	0.44	1.86	0.19	2.6– 3.7	5.4– 7.5
RD/Del.L.	5	0.58	1.12	0.18	1.5– 2.1	3.0– 4.7
RB/Del.L.	5	0.62	1.93	0.93	4.2– 7.2	3.0– 4.7
Del.L./Gr.Ab.W.	4	0.73	-1.06	3.29	3.0– 4.7	1.2– 1.7
Amb.L./Amb.W.	5	0.51	0.50	1.00	1.2– 2.1	0.8– 1.4
Amb.L./No. S.P.	5	0.73	-0.24	0.37	1.2– 2.1	4.0– 6.0

median portion of radials. Length of three thecae on which this description is based between 11 and 14 mm; width of 11 mm theca is 8.5 mm. Pelvic angle not measurable but broad. Vault small, about 1.5 to 2 mm in height.

Basals three, in normal position, broad, bowl-shaped profile in lateral view with slight indentation at point of stem attachment. Outline of basals pentagonal in basal view, extending almost to edge of outline of theca. Stem attachment area at proximal junction of three basals, diameter 0.7 mm; center slightly depressed with low rim bordering it. Azygous basal rhombic in plan view (Pl. 40, fig. 11), with straight lateral edges and slightly convex distal edges. BR sector strongly convex through 90° parallel to BR axis (greatest in lower part of plate, curving slightly inward near origin) and convex normal to BR axis, with sectors merging on flatter surface. Zygous basals pentagonal in plan view (Pl. 40, figs. 9,12), with straight lateral edges, slightly sinusoidal distal lateral edges, and slightly concave distal medial edge. Configuration of medial BR sector as for those of azygous basal; lateral BR sectors less convex parallel and normal to their respective BR axes; sectors merge smoothly. Ornament of basals broad, irregular, smooth growth lines parallel to plate sutures. BR sector of each zygous basal broader where two zygous basals meet than along junction with azygous basal, producing asymmetry in plate. See Table 46.

Radials five, forming slightly convex sides of theca. C and E radials quadrate in plan view, with convex lower edge, slightly convex lateral edges; upper edges straight, approaching one another at broad angle. Radial body large in comparison to small radial limbs (Pl. 40, figs. 13-17). Radial body convex in lateral view, with slightly concave lower edge. RB sector large, convex parallel to and very slightly convex normal to RB axis. Sectors merge smoothly over convex surface; also merge smoothly with RR sectors. RR sectors very slightly convex parallel and normal to RR axis. RD sector very small, almost at 90° to RR sector, slopes upward very slightly toward oral opening, straight parallel and normal to RD axis. Short RA axis present, forming convex hump extending from origin of radial to aboral end of ambulacrum where it forms an aboral collar. Radial ornamented with low broad growth lines in RB and RR sectors, may become slightly granulose in uppermost part of RR sector as in RA sector; width of RDF occupied by hydrospire slits but slits short, not extending more than 0.5 mm from suture. Width of C and E radials about equal at base of plate and at deltoids; A, B, and D are wider at basals. In A and B radials, BRF facing azygous basal much wider than that facing zygous basal, producing asymmetry in plate. Lower edges of D radial symmetric. Radials of preserved specimens of approximately same size but from preserved growth lines, growth on RB has apparently accelerated during development. RWB: 3.9-5.4 mm; RWD: 4.6-6.7 mm. See also Table 46.

Deltoids four, together with epideltoid form margin to oral opening; small, confined to upper surface of theca. Upper surface deltoid convex in lateral view; outline hexagonal in plan view. Short (0.5-0.7 mm) straight edge borders oral opening; width of plate expands aborally along straight DDF to Gr.Ad.W. (1.8-2.5 mm), contracts slightly along straight DAF (minimum width: 1.6-2.0 mm), then expands very slightly aborally to junction with radial; radiodeltoid suture forms a sharp V. Adoral edge and DDF bears minor lobes and grooves; less closely spaced (6 per mm) than in most blastoids. Adoral part of deltoid immediately adjacent to main grooves flat; plate rises aborally into prominent cross-shaped protuberance (Pl. 40, fig. 24); end of extension in adoral quadrant enlarged into knob; lateral extensions of cross curve aborally to adoral end of ambulacra; aboral extension a sharp, convex deltoid crest which drops down steeply at radiodeltoid suture; sides of crest smooth, slope steeply down to hydrospire field which extends full width of suture; slits short. In lateral view highest point of deltoid is apex of cross, or just aboral to it. Deltoid thus strongly elevated above oral opening. Crest: 1.5-3.1 mm in length; DR: 1.2-2.3 mm. See Table 46.

Anal deltoids two, an epi- and hypodeltoid; length of anal deltoids: 3.0-4.1 mm (a). Configuration of epideltoid as for adoral part of regular deltoid (Gr.Ad.W.: 1.7-2.2 mm); what would be aboral extension of cross now embayed by anal opening; lateral extensions more strongly curved to form high (1.0-1.3 mm) adoral collar to anal opening (Pl. 40, fig. 21). Presence of hypodeltoid indicated by facets on limbs of C and D radials. Hypodeltoid small, on outer upper edge of theca, pentagonal in outline with slightly convex aboral edges; lateral edges slightly concave, converging slightly adorally. Hypodeltoid rests upon beveled edge of radial limbs; width about 1 mm; does not extend to ambulacrum. Hypodeltoid apparently not in contact with epideltoid as can also be seen in *Angioblastus variabilis*; anal opening opens directly upward, bordered adorally by epideltoid, laterally by radials, and aborally by hypodeltoid. See Table 46.

Ambulacra five, small; removed from oral opening; 5-6 side plates per side. Ambulacrum petaloid in plan view, convex in cross section; ambulacrum slightly elevated above radial; lateral deltoid ridges curve down to ambulacrum. Lancet exposed for about one-half of ambulacral length. Side plates quadrate, taper laterally due to large indentation by triangular outer side plate which forms larger percentage of lateral border of ambulacrum than side plate. Elliptical brachiolar facet developed on side and outer side plate on sloping edge of ambulacrum.

Eight hydrospire fields, apparently absent in anal interarea. Those on regular deltoids occupy full width of radiodeltoid suture; ad- and aboral extension small. 4-7 slits counted in different specimens (up to 9 in an isolated deltoid); length and width of largest hydrospire field 0.7 (a) and 1.8 mm respectively.

Oral opening not well preserved; width of main groove on deltoid: 0.2-0.3 mm.

Distribution.— Pennsylvanian, Hogshooter Formation (Missourian), Oklahoma, U.S.A.

Remarks.— The above description is based upon the complete specimens and isolated plates listed in Appendix I. The data in Table 46 is derived from both the complete thecae and isolated plates so there is not a one to one correspondence, e.g. for basal and radial measures. Moore and Strimple (1942) suggested that there were no side plates on the posterior ambulacra; these can be seen in the second specimen referenced by them (USNM 160569). Fay (1961, p. 279) could not definitely ascertain the presence of a hypodeltoid on the specimen he studied (Okla. Univ. 14130). Fay designated this specimen as a lectotype as he believed the holotype (USNM 111249) to be missing but it was found after a search of the collections by Macurda.

The anal interarea of the specimens studied is not sufficiently well preserved to exclude the possibility of a hydrospire slit immediately adjacent to or just beneath the bordering ambulacra as in *Codaster*. There is a suggestion of a slit on the D radial of USNM 160569 but it is not conclusive.

The meshwork of the calcite is well preserved in the holotype, being visible in weathered areas on the A radial and azygous basal. Within the interior of the plate, the meshwork is quite open; the meshwork resembles a jumble of polyaxial sponge spicules fused together. The size of the pores and diameter of the "spicular rods" are both much reduced near the external surface of the plate.

Strimple and Mapes (1977) described and illustrated a new species they assigned to *Agmoblastus* (*A. caddense*) from the Pennsylvanian (Lower Virgilian) Finis Shale of Texas. This is slightly younger than specimens from the Hogshooter Formation in Oklahoma. The single specimen (SUI 39465) is well preserved. The growth lines are finer than in most specimens of *A. dotti*, the functional length of the hydrospire slits is slightly greater, and the radials taper more in their lower parts, producing a more tapered appearance to the pelvis than the bulbous appearance in *A. dotti.*

The ontogeny of *A. dotti* was discussed by Breimer and Macurda (1972).

ANGIOBLASTUS CADDENSE
(Strimple and Mapes, 1977)

Agmoblastus caddense Strimple and Mapes, 1977, p. 360, 361, Text-fig. 1A-D.

Description.— L.: 6.5 mm; W.: 5.4 mm; V.: 0.5 mm; P.: 6.0 mm. Stem cicatrix: 0.5 mm.

BR sector of azygous basal convex proximally, becoming flatter distally parallel to BR axis, convex normal to BR axis; adjacent sectors merge over very slightly convex surface. BB sector restricted to very edge of basal. Convexity of medial BR sector of zygous basal as for azygous basal; a lateral sector slightly convex parallel and normal to BR axis. ABL: 3.4 mm; ABW: 3.8(va) mm; ABBBF: 2.4 mm; ABBR: 2.8 mm; ABBRF: 2.2 mm; ZBL: 3.1 mm; ZBW: 4.0 mm; ZBOPt: 3.3 mm; ZBBR: 3.0 mm; ZBBRF: 1.8 mm.

RB sector slightly convex parallel to, very slightly convex normal to RB axis; adjacent sectors merge over convex boundary. RR sector straight, very slightly convex normal to RR axis. RD sector at sharp angle to RR sector, straight parallel and normal to RD axis. Small RA axis borders aboral end of ambulacrum. RWB: 2.2 mm; RWD: 3.5 mm; RD: 1.5 mm; RDF: 1.5 mm; RR: 2.2 mm; RRF: 3.5 mm; RB: 3.3 mm; RBF: 1.5 mm; RA: 0.5 mm.

Del.L.: 3.5 mm; Del.Gr.Ad.W.: 1.3 mm; Del.Gr.Ab.W.: 1.5 mm; Del.L.Crest: 2.2 mm; DR: 1.4 mm; Anal Del.L.: 2.7 mm; Epi.Gr.Ad.W.: 1.2 mm; Anus L.: 1.0 mm; Anus W.: 0.8 mm; Hypo.W.: 1.4(a) mm; O.c.-amb.: 0.6 mm; Amb.L.: 1.6 mm; Amb.W.: 0.8 mm; No.Reg.Hydro.Sl.: 6; W.Reg.Hydro.Fld.: 1.5 mm; W.Oral Opening: 0.5 mm.

Distribution.— Pennsylvanian, Graham Formation, Finis Shale Member, Caddo, Texas, U.S.A.

Remarks.— The above description is based upon the single known specimen, State University Iowa 39465. The above description and measurements are presented to complement the description and illustrations given by Strimple and Mapes (1977) so that comparable data is available for all species of *Angioblastus*. The only substantial differences is in the measurement of ambulacral length. My measurements reflect the length of the preserved lancet; the measurement given by Strimple and Mapes (1977) probably includes part of the RA axis.

ANGIOBLASTUS ELLESMERENSIS
Breimer and Macurda, 1972
Pl. 40, figs. 18-20,22,23,25,26

Angioblastus ellesmerensis Breimer and Macurda, 1972, p. 40-42, Pl. XXIX, figs. 6-10.
Agmoblastus ellesmerensis Strimple and Mapes, 1977, p. 357.

Description.– A complete description was given by Breimer and Macurda (1972, p. 40-42) except for metric measurements. These are given for two specimens, the holotype which is smaller (GSC 67261, Pl. 40, figs. 18-20,23,25), and an unregistered GSC specimen (Pl. 40, figs. 22,26) from a second locality. A third, less complete specimen had intermediate values. L.: 9.0, > 14.2 mm; W.: 6.7, 13.8 mm; V.: 1.2, > 1.0 mm; P.: 7.8, 13.2 mm; Pelvic angle: 60°; ABL: 4.1, 7.5 mm; ABW: 3.6, 7.2 mm; ABBBF: 3.2, 6.2 mm; ABBR: 3.7, 6.5 mm; ABBRF: 2.3, 4.0 mm; ZBL: 3.7, 7.5 mm; ZBW: 4.5, 10.1 mm; ZBOPt: 4.2, 8.0 mm; ZBBR: 3.7, 7.1 mm; ZBBRF: 1.8, 4.8 mm; RHt: 1.0, 1.1 mm; RWB: 3.0, 6.7 mm; RWD: 4.0, 7.0(a) mm; RD: 2.5, 4.0 mm; RDF: 1.2, 2.5 mm; RR: 2.5, 4.3 mm; RRF: 4.3, 7.5(va) mm; RB: 4.5, 8.0 mm; RBF: 1.9, 4.0 mm; Del.L.: 3.2, 5.3 mm; Gr.Ad.W.: 2.5, 2.7 mm; Del.W.Ad.E.Amb.: 2.5, 2.7 mm; DDF: 1.7, 1.8 mm; DAF: 1.2, 1.8 mm; Anal Del.L.: 3.3, 5.5 mm; Epi.Gr.Ad.W.: 2.5(a), 2.9 mm; Anus L.: < 1.5, 2.8 mm; Anus W.: 1.0, 1.8 mm; O.c.-ad.e.anus: 2.1, 3.2 mm; O.c.-anus epi.suture: 2.8, 4.5 mm; O.c.-amb.: 2.0, 2.5 mm; Amb.L.: 2.0, 4.0 mm; Amb.W.: 1.0, 1.5 mm; No. S.P.: 6,--; O.c.-hydro.sl.: 2.6, 4.2 mm; L.Reg.Hydro.Fld.: 0.3, 0.4 mm; W.Reg. Hydro.Fld.: 1.0, 2.0 mm; No. Reg.Hydro.Sl.: 6, 8; No. Anal Hydro.Sl.: --; 1C, 3D; Oral opening: 0.8, 1.2 mm.

Distribution.– Pennsylvanian, Atokan, Ellesmere Island, Canada.

Remarks.– The ontogeny of this species was discussed by Breimer and Macurda (1972).

ANGIOBLASTUS MILORADOVITCHI
(Yakovlev, 1940)
Pl. 41, figs. 1-5,15

Angioblastus miloradovitchi Breimer and Macurda, 1972, p. 38, Pl. XXX, figs. 10,11.

Description.– Theca subglobose in lateral view with bowl-shaped pelvis with recurved top and short convex vault confined to top of theca (Pl. 41, fig. 15). In plan view outline of theca is pentagonal with slightly rounded edges along ambulacral axes (Pl. 41, fig. 1). Greatest width equatorial, slightly below origin of radials. L.: 14.5 mm; W.: 16.0 mm; V.: 1.0 mm; P.: 13.5 mm; pelvic angle: 46°.

Basals three, forming lower one-third of broad, bowl-shaped pelvis. Basals pentagonal in plan view (Pl. 41, fig. 4); each basal convex both parallel and perpendicular to BR growth axes; convexity of zygous basals more pronounced in median part of plate. Small, shallow depression for stem at proximal junction of basals; crenellar facets present at outer edge of depression. Diameter of depression and crenellar ring: 1.5 mm. Surface of basals ornamented with almost smooth, broad growth lines; accentuated by darker areas in calcite; growth lines parallel both BRF and BBF but latter much narrower. Main rods of stereom of calcite perpendicular to BRF and RBF in basals and radials. Radial-basal sutures of azygous basal and upper lateral sutures of zygous basals very slightly sinusoidal; distal medial suture of zygous basals slightly concave. Azygous basal rhombic in plan view. ABL: 8.7 mm; ABW: 9.0 mm; ABBBF: 6.5 mm; ABBR: 7.6 mm; ABBRF: 6.0 mm. Zygous basals pentagonal in plan view: ZBL: 8.0 mm; ZBW: 10.7 mm; ZBOPt: 8.5 mm; ZBBR: 7.3 mm; ZBBRF: 5.5 mm.

Radials five, forming upper two-thirds of pelvis and part of vault. In plan view, radial is quite broad, C and E radials expanding from base to median position, then contracting orally so RR suture is convex in plan view as is RB. A, B, and D radials broadest at base; contract adorally. RD suture straight. Radial sinus very small; bordered by RA growth axis. Thus origin of radial displaced from aboral tip of ambulacrum. In lateral view bottom of radial is concave while top is convex, curving toward base and toward ambulacrum from center of plate. RA sector is straight parallel to the RA axis and convex perpendicular to it. RA passes into RD sector which lies lower than it through a concave arc; RD otherwise flat, inclined to ambulacrum. RR sector essentially straight parallel to growth axis, convex perpendicular to it. RB sector convex both parallel and perpendicular to growth axis. Low, broad growth lines ornament RB and RR sectors. RD sector contains hydrospire field which occupies full width of suture. Earlier formed portions infilled by calcite. RA sector forms border to aboral one-third of ambulacrum; growth lines parallel to border so parabolic (Pl. 41, fig. 1). RWB: 7.0 mm; greatest width of radial: 8.0 mm; RWD: 6.5 mm; RD: 3.1 mm; RDF: 2.5 mm; RR: 4.2 mm; RRF: 8.4 mm; RB: 8.0 mm; RBF: 4.2 mm; RA: 2.0 mm.

Deltoids four, restricted to relatively small slightly convex area at top of theca, together with epideltoid forming border to oral opening (Pl. 41, fig. 2). Deltoid hexagonal in plan view. Short edge borders oral opening (0.5 mm); plate broadens aborally along interdeltoid sutures; these sutures bear main grooves which are bordered by minor lobes and grooves (width of area 0.4 mm on both adjoining plates). Greatest width of deltoid (2.5 mm) at adoral end of ambulacrum, 2.2 mm from oral center. Width of deltoid contracts slightly aborally along convex DA sutures to greatest width of ambulacra, then diverges for short distance along aboral sides of ambulacra before bending at almost right angles to form the straight radiodeltoid sutures which meet at almost 90°. Adoral part of deltoid rises up aborally to a sharp pyramid-shaped mound which separates adoral and aboral parts of plate (Pl. 41, fig. 3). Adoral part ornamented with furrows and ridges which fan out radially from the pyramid. Pyramid probably results from deposition of calcite on free surface of plate. Aboral part of deltoid slopes steeply down into hydrospire field from pyramid along sloping sides of moderately broad crest present in center of aboral part; top of crest slopes down toward side of theca. Hydrospire slits on aboral edges of deltoid; slits apparently progressively infilled during growth. Greater length of slits on radial than deltoid. Del.L.: 5.6 mm; DD: 2.5 mm; DDF: 2.0 mm; DAF: 1.4 mm; L.crest: 3.5 mm; DR: 2.5 mm.

Shape of epideltoid as for adoral part of regular deltoid except anal opening embays aboral edge. Hypodeltoid now lost but facets indicate former presence; convex aboral edges; hemispherical shape (Pl. 41, fig. 5). Anal opening apparently ovoid, opening on upper sloping surface of theca; directed upward and outward. Anal Del.L.: 5.4 mm; width of edge bordering oral opening: 0.5 mm; Epi.Gr.Ad.W.: 2.6 mm; oral center to anal opening: 3.2 mm; width anal opening: 1.5 mm; HDW: 2.1 mm.

Ambulacra five, relatively small, on upper surface of theca, not reaching lateral edge. Ambulacra broadly lanceolate in plan view; almost flat lengthwise and widthwise. Adoralmost side groove is longest, slightly concave toward oral opening. Brachioles at edge of ambulacrum and thus formed a parabolic arc. Lancet widely exposed; rhomboid in plan view; side plates and outer side plates about 0.6 mm wide along aboral edges. Large triangular outer side plate reaches almost to lancet; outer side plates continue to grow ablaterally after formation and eventually isolate side plates from edge of ambulacrum. Brachiolar facet small, length and width: 0.2 mm; in normal position on side and outer side plates. Amb.L.: 3.5 mm; Amb.W.: 2.3 mm; No. S.P.: 8(a).

Eight completely exposed hydrospire fields, developed more on radial than deltoid, on upper surface of theca, parallel to aboral edge of ambulacrum. Longest slit near ambulacrum; apparently new slits added during growth; older portions of slits infilled during growth. Width of slit: 0.3 mm. Six hydrospires per group, length of field: 1.2 mm; width: 1.5 mm. There are two small dark areas between the ambulacrum and prongs of the epideltoid in the CD interarea. These might represent anal hydrospires but it is impossible to ascertain without use of an air-abrasive machine, not available where this specimen was studied.

Oral opening pentagonal; width: 0.5 mm.

Distribution.– Permian, River Kozhim, Artinskian Stage, P_1, (found at exposure number 5 by A. A. Chernov in suite 88, shaly); Pechora Region, U.S.S.R.

Remarks.– The above description is based upon the holotype, Central Geological Museum, Leningrad collection 6324. The ontogeny was discussed by Breimer and Macurda (1972). This species formed the type species of Yakovlev's genus *Paracodaster* which was distinguished by having the hydrospire slits only developed on the deltoids. Examination of the only specimen of *miloradovitchi* clearly shows the radiodeltoid suture crossing the hydrospire field and as noted, the length of the slits is greater on the radial than the deltoid. Therefore, *Paracodaster* was considered a junior synonym of *Angioblastus* by Breimer and Macurda (1972).

ANGIOBLASTUS VARIABILIS Wanner, 1931
Pl. 38, figs. 3-7,11-16,18; Pl. 39, figs. 1-17; Table 47

Angioblastus variabilis Breimer and Macurda, 1972, p. 38, Pl. XXVIII, figs. 3,6; Pl. XXIX, fig. 14; Pl. XXX, figs. 1-4, 6-9, 12.

Description.– Thecae small, commonly having outline of angular oblate spheroid in lateral view with greatest width near equator but varying to thecae which have greatest width near top, pelvis thus parabolic (Pl. 38, figs. 4,6,12,15,18; Pl. 39, figs. 2,4). Ambulacra small, restricted to top of theca; thus pelvic profile is recurved, quite markedly in larger specimens. Vault small, convex, restricted to summit of theca. Outline of theca sharply pentagonal in plan view, with ambulacra on a line with the points of the pentagon. Ambulacra and deltoids do not reach to edge of thecal outline and thus have an encircled appearance, though lying above the plane of the radials (Pl. 38, figs. 3,5,11,16; Pl. 39, figs. 1,3). Length less than width; vault much less than pelvis. Pelvic angle not measurable as normal; angle between aboral tips of ambulacra and stem attachment area 26-58°; angle of base of theca much greater. See Table 47.

Basals three, in normal position (except for one specimen where azygous basal centered in DE interarea), have lateral profile which varies from bowl-shaped to nearly flat, with proximal ends being either the lowest point on the theca or slightly recurved. Convex in lateral view, degree of convexity varying; form from one-fourth to one-third of length of pelvis. Stem attachment area at proximal end (Pl. 39, fig. 15), usually being a broad (0.9-1.2 mm) depression with a low rim, being slightly recessed below the lowest surface of the basals but varying to also being the lowest point on the theca, here narrower (0.5 mm). Proximal stem plate circular. When theca viewed basally (Pl. 38, figs. 7,13,14; Pl. 39, fig. 8), basals fill most of field of view, reaching almost to the edge of the thecal outline. Outline of basals pentagonal in basal view. Azygous basal quadrate in plan view, length most always less than width. Lateral sutures straight, distal edges slightly sinusoidal. Azygous basal convex parallel to the BR growth axis and slightly convex normal to it. Degree of convexity parallel to axis variable, from slight to pronounced; normally degree of convexity constant throughout but may increase distally. Degree of convexity normal to BR axis also variable, normally slight but may be pronounced. In flatter azygous basals, BR sectors merge smoothly, with development of very slight concavity in distal portion of plate; as convexity of plate increases, concavity lost and area becomes convex. Zygous basals pentagonal, with straight lateral edges; distal lateral edges straight except near BBF where proximally curved; medial distal edge essentially straight. Slightly asymmetric because of shorter BRF on side bordering azygous basal than along the mutual BBF. Convexity of central BR sector as for azygous basal, both parallel and normal to BR axis, with concomitant variability. Lateral BR sectors less convex, both parallel and normal, thus emphasizing convexity in central BR sector. In flatter plates, development of very slight concavity in distal portion where sectors merge. Ornament of basals variable; usually smooth due to weathering; amount of ornament usually much less pronounced than neighboring RB sectors. Ornament can be smooth growth lines parallel to BR fronts; rarely become slightly granulose. Also variable development of low broad ridges from presumed origin of basals to origins of adjacent radials, one in center of each BR sector, (two in azygous basal, three in zygous basals; lateral ridges often subdued in latter). See Table 47.

Radials five (Pl. 39, figs. 6,7,9,11), with convex lower base on C and E radials or two straight edges on A, B, and D. C and E radials expand in width adorally, greatest width usually below center of plate, then contract to radiodeltoid suture; width here usually slightly less than at base. Other radials widest at or near base, with straighter sides, converging adorally. RD sutures straight; radial sinus almost non-existent because of presence of RA growth sector. In lateral view radial is very convex, pentagonal. Origin is in upper center of plate; radial convex outward and downward from origin; profile of RA sector straight to slightly convex. Interradial suture concave, with two straight lateral lower edges forming remainder of profile. Four sectors present in plate, RB being the most pronounced. Sector is convex parallel to the growth axis and normal to it; lower edges of sector may be reflected near radial-basal suture to form seeming overhang to basals in wider specimens. Ornament of sector variable, ranging from granulose growth lines with a low ridge separating the RB sectors to massive lobed ridges radiating from the origin to the radial-basal sutures. RR sector straight parallel to growth axis, convex normal to it, continuous with RD sector; while rounding into RB, set apart by ornament. RR sector usually ornamented by growth lines (rarely granulose ornament) with occasional low ridges across suture but ornament much reduced from RB sector. RD sector small, usually straight normal and parallel to axis; occasional granulose ornament. One RA sector, growing from origin towards ambulacrum, convex parallel and normal to axis; forms border to aboral edges of ambulacrum. Ornament may be sharp medial ridge; may also be granulose. RWB: 1.9-5.7 mm; RWD: 1.8-4.8 mm. See also Table 47.

Deltoids four, together with epideltoid forming border of oral opening (Pl. 39, figs. 10,13,14,16,17). Deltoids small, confined to upper surface of theca, with relatively flat upper surface; slightly convex in lateral view. Outline hexagonal. Short straight edge bordering oral opening; width expands aborally along long straight

TABLE 47. Growth relationships of principal variables of *Angioblastus variabilis* Wanner, 1931

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	18	0.78	2.46	0.43	3.9– 7.5	4.5–12.0
V/P	18	0.15	0.40	0.03	0.3– 0.8	3.5– 7.0
L/ABBR	18	0.85	1.86	1.20	3.9– 7.5	1.9– 4.8
L/RD	18	0.82	3.00	1.31	3.9– 7.5	0.8– 3.5
L/RB	18	0.92	0.98	1.46	3.9– 7.5	2.0– 4.3
L/Del.L.	18	0.88	1.75	1.41	3.9– 7.5	1.7– 4.2
L/Amb.L.	18	0.91	3.31	1.68	3.9– 7.5	0.5– 2.5
RD/Amb.L.	18	0.92	0.54	1.06	0.8– 3.5	0.5– 2.5
Del.L./Amb.L.	18	0.93	1.27	1.07	1.7– 4.2	0.5– 2.5
ABL/ABW	18	0.98	0.51	0.75	2.2– 5.2	2.4– 6.5
ABBR/ABBRF	18	0.95	0.45	1.02	1.9– 4.8	1.5– 4.6
ZBL/ZBW	18	0.96	0.39	0.65	2.2– 5.0	2.6– 7.4
ZBBR/ZBBRF	18	0.90	0.75	1.08	1.9– 4.7	1.2– 3.3
ABBR/RB	18	0.91	-0.14	1.03	1.9– 4.0	2.0– 4.2
ABBR/RD	18	0.89	1.12	1.00	1.9– 4.8	0.8– 3.5
ABBR/Del.L.	18	0.94	0.18	1.08	1.9– 4.0	1.7– 4.2
RD/RDF	18	0.87	0.35	2.27	0.8– 3.5	0.3– 1.2
RR/RRF	18	0.87	-0.23	0.83	1.3– 3.5	1.8– 3.8
RB/RBF	18	0.86	1.13	1.10	2.0– 4.3	1.1– 3.1
RD/RR	18	0.96	-0.48	1.11	0.8– 3.5	1.3– 3.5
RD/RB	18	0.93	-0.96	0.93	0.8– 3.5	2.0– 4.3
RR/RB	18	0.92	-0.30	0.80	1.3– 3.5	2.0– 4.3
RD/Del.L.	18	0.91	-0.54	0.93	0.8– 3.5	1.7– 4.2
RB/Del.L.	18	0.94	0.56	0.96	2.0– 4.3	1.7– 4.2
Del.L./Anal Del.L.	18	0.98	0.06	0.84	1.7– 4.2	2.0– 4.8
Amb.L./Amb.W.	18	0.98	-0.21	1.35	0.5– 2.5	0.5– 2.0
Amb.L./No. S.P.	18	0.94	-0.20	0.41	0.5– 2.5	2.0– 6.0

DDF which bears main groove and is ornamented with minor lobes and grooves. Greatest width usually at adoral end of ambulacrum. Width usually decreases along straight DAF; suture then crosses hydrospire slit(s), then converges aborally in a short pointed V. Adoral portion of deltoid (that adoral to hydrospires) relatively large; usually flat except toward edges where curves down to main grooves and ambulacra. May have low irregular ornament. Aboral part of plate constricted by two vertical troughs which slope adorally into hydrospires on either side of deltoid. Part aboral to this produced as a knob which may overhang radial (Pl. 39, fig. 11). May be small knob just adoral to constriction as well. Del.Gr.Ad.W.: 0.8-2.0 mm; Del.W. Ad.E.Amb.: 0.8-2.2 mm; DDF: 0.5-1.5 mm; DAF: 0.5-1.6 mm; Del.Aboral L.: 0.3-1.5 mm. See also Table 47.

Anal deltoids two, an epi- and hypodeltoid. Epideltoid as for adoral part of regular deltoid; aboral edge embayed by anal opening. Hypodeltoid a small hemispherical-shaped plate on upper lateral edge of theca with convex hyporadial sutures; greatest width in center (Pl. 39, figs. 5,7,12). Contact with epideltoid variable; may have short straight epi-hypodeltoid suture on C side of anal opening but epideltoid separated externally from hypodeltoid by radial on D side or may be separated on both sides. Adoral edge of hypodeltoid concave, bears lip for extension of anus. Hypodeltoid frequently lost, apparently during early diagenesis but facet evident. Anal opening ovoid with angular sides, opens through upper sloping side of theca. Epi.Gr.Ad.W.: 1.0-2.2 mm; Anal opening W.: 0.5-1.0 mm; HWD: 0.8-1.7 mm; O.c.-ad.e.anus: 1.0-2.8 mm. See also Table 47.

Ambulacra five, small, rhomboid, well removed from oral opening, set below deltoids but above hydrospire fields and about flush with radial. Lancet exposed, rhombic. Brachiolar facets arrayed along aboral sides of ambulacrum. Large elongate triangular outer side plate embays side plates, extending almost to or to lancet. Side grooves alternately enter main food groove, with the adoralmost groove being the longest; the left (facing adorally) side groove is the first to enter. In largest specimens additional calcite added to edge of ambulacrum along outer side plates beyond brachiolar facets forming shelf on aboral edges of ambulacrum; side plates no longer reach to edge of ambulacrum. Brachiolar facets on sloping sides of ambulacrum; facet elliptical, developed on side plate and outer side plate; L.: 0.23 mm; W.: 0.18 mm. Main and both edges of side grooves bordered by minor lobes and grooves. O.c.-amb.: 0.7-1.8 mm. See also Table 47.

Eight hydrospire groups, lacking anal interarea, with normally one slit per group, though two specimens in the growth series have two (in one, second lacking on C and D ambulacra; in the other, one slit lacking on the side of A but in an incipient state of development). Hydrospire slit a short (0.3-0.6 mm) groove across radiodeltoid suture, bordering adoral edge of aboral side of ambulacrum and adjacent radial and crossing radiodeltoid onto radial; trough in side of deltoid reflects position. Occasionally a second shorter slit is developed across the radiodeltoid suture just aboral to the first. Orientation of hydrospires almost normal to oral opening rather than radial as usual because of outline of ambulacra.

Oral opening pentagonal, width: 0.3-0.6 mm, bordered by minor lobes and grooves. Trabeculae of stereom commonly well preserved in plates as in RB and BR sectors where long axes at right angles to growth fronts.

Distribution.– Permian, Sonnebait Series, Timor, Indonesia.

Remarks.– The above description is based upon the specimens in the growth series, principally numbers 1,8,9-14, and 16 (see Appendix I). The internal anatomy and ontogeny were described and illustrated by Breimer and Macurda (1972).

Wanner (1940) described a specimen from Nifu Muti, Timor, as a new species of *Angioblastus; A. depressus* (Univ. Amsterdam Ge.O. 9923). It is flat and wide and in basal view there is a massive development of the radials visible (Pl. 39, figs. 3,4,8). This form is an almost duplicate of the characters of specimen 7 in the growth series, which is part of a population assignable to *A. variabilis*. Therefore, *A. depressus* was regarded as a synonym of *A. variabilis* (Breimer and Macurda, 1972).

ANGIOBLASTUS WANNERI Yakovlev, 1926
Pl. 41, figs. 6-14, 16-22; Pl. 42, figs. 1-9; Table 48

Angioblastus wanneri Breimer and Macurda, 1972, p. 38, Pl. XXIX, figs. 7, 11-13, 15-18.

Description.– Theca small, with length usually slightly greater than width, with irregular sub-sphaeroidal outline in lateral view, with greatest width equatorial or sub-equatorial, with long pelvis and very short vault (Pl. 41, figs. 6,8,9,12,17,20,21). Pelvis cup-shaped in outline, with upper edges bent, converging inward; base of theca very broad, not as convex as sides, slightly indented at stem attachment area; vault gently convex, with ambulacra restricted to very top of theca; deltoid ornament projects above oral opening. Outline of theca in plan view is circular-pentagonal to pentagonal (Pl. 41, figs. 10,11,14,19,22); vault restricted, deltoids and ambulacra not reaching edge of thecal outline; vault pentagonal in outline. Greatest width in middle or lower part of radials; ambulacra not as wide. Pelvic angle as normally measured 38-53° but sides of theca extend well beyond, angle of base of theca being much greater. See Table 48.

TABLE 48. Growth relationships of principal variables of *Angioblastus wanneri* (Yakovlev, 1940)

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	18	0.96	0.51	0.99	4.0–13.5	3.7–12.3
V/P	18	0.82	0.03	0.15	0.4– 1.7	3.6–12.0
L/ABBR	18	0.96	0.53	2.06	4.0–13.5	1.7– 5.6
L/RD	18	0.96	0.75	4.78	4.0–13.5	0.9– 2.5
L/RB	18	0.98	0.75	1.61	4.0–13.5	2.1– 7.6
L/Del.L.	18	0.96	-0.48	3.23	4.0–13.5	1.4– 4.1
L/Amb.L.	18	0.93	3.72	3.01	4.0–13.5	0.4– 3.0
L/No.Hyd.Sl.	17	0.58	4.85	1.72	4.0–11.0	1.0– 3.0
RD/Amb.L.	18	0.95	0.64	0.62	0.9– 2.5	0.4– 3.0
Del.L./Amb.L.	18	0.93	1.35	0.90	1.7– 5.6	0.4– 3.0
ABL/ABW	18	0.97	0.16	0.91	2.0– 6.2	2.1– 6.1
ABBR/ABBRF	18	0.96	0.09	1.25	1.7– 5.6	1.4– 4.1
ZBL/ZBW	18	0.99	0.24	0.68	2.0– 6.4	2.5– 9.3
ZBBR/ZBBRF	18	0.94	0.32	1.52	1.7– 6.3	1.0– 3.5
ABBR/RB	18	0.98	0.25	0.75	1.7– 5.6	2.1– 7.6
ABBR/RD	18	0.90	0.46	2.09	1.7– 5.6	0.9– 2.5
ABBR/Del.L.	18	0.96	-0.34	1.51	1.7– 5.6	1.4– 4.1
RD/RDF	18	0.89	0.27	1.30	0.9– 2.5	0.4– 1.8
RR/RRF	18	0.92	0.06	0.41	1.1– 3.7	2.0– 7.9
RB/RBF	18	0.94	0.31	2.15	2.1– 7.6	0.8– 3.1
RD/RR	18	0.93	0.24	0.67	0.9– 2.5	1.1– 3.7
RD/RB	18	0.91	0.16	0.30	0.9– 2.5	2.1– 7.6
RR/RB	18	0.91	0.02	0.42	1.1– 3.7	2.1– 7.6
RD/Del.L.	18	0.93	-0.13	0.63	0.9– 2.5	1.4– 4.1
RB/Del.L.	18	0.96	-0.64	1.96	2.1– 7.6	1.4– 4.1
Del.L./Anal Del.L.	17	0.84	0.61	0.63	1.4– 3.6	1.7– 4.4
Amb.L./Amb.W.	18	0.95	-0.14	1.37	0.4– 3.0	0.4– 2.2
Amb.L./No. S.P.	18	0.92	-0.61	0.46	0.4– 3.0	2.0– 7.0

Basals three, in normal position; very broad and shallow in lateral view, extending almost full width of theca but not very far vertically; outline bowl-shaped with slight recurvature at stem attachment area. Outline in plan view is pentagonal (Pl. 41, figs. 7,13,16); only very small portion of radials visible at edge of theca. Stem attachment area at proximal junction of three basals, a small (0.3-1.0 mm) rounded to rounded-triangular facet which is slightly concave internally with crenellar facets at edge; space above may have been site of formation of new stem plates; small lumen pierces proximal junction passing into interior of theca. May be a very small rim around stem attachment area with short ridge radiating into center of each plate. Stem plates cylindrical (Pl. 42, fig. 8). Azygous basal rhombic in plan view, with lateral sides being straight except where converge proximally; distal edges straight or very slightly sinusoidal. BR sector very strongly convex through over 90° parallel to BR axis; BR sector slightly convex normal to BR axis; adjacent sectors meet on very slightly convex to (distally) very slightly concave boundary. Zygous basals pentagonal in plan view with essentially straight lateral edges; distal lateral edges vary from very slightly concave to straight, slightly sinusoidal, or very slightly convex; distal medial edge slightly concave. BR sectors of zygous basals as for azygous basal parallel to BR axes; medial sector convex normal to BR axis while lateral sectors only very slightly convex; meet on straight to slightly concave boundary; lateral BR sector bordering azygous basal slightly narrower than BR sector bordering adjacent zygous basal, thereby producing slight asymmetry in plate. When preserved, ornament of basals low broad growth lines parallel to BRF; much narrower along BBF. See Table 48.

Radials five, forming lateral walls of theca. C and E radials quadrate in plan view, with convex lower edge; width expands slightly adorally to greatest width which is in lower or median portion of plate, then contracts to minimum width at radiodeltoid suture; plate thus narrower adorally, reflecting greatest width of theca in lower half. Lateral sides thus slightly convex; upper edges quite short, approach each other at broad angle. Very short radial sinus. A, B, and D radials broadest at very base, sides converge adorally; A and B may be slightly asymmetric because of difference of ABBRF and ZBBRF; D radial usually symmetric. Radial low in lateral view, with convex upper edge and slightly concave lower edge. RB sector large, slightly convex normal and parallel to RB axis, adjacent sectors merging smoothly with one another and RR sectors on slightly convex surfaces. RR sectors straight to very slightly convex normal to RR axis, slightly convex normal to RR axis. RD sector small, curves down into RR sector, straight parallel to RD axis but slightly convex normal to it with adoral part of RDF embayed by short hydrospire slit(s). Small RA axis present, forms low collar (pointed aborally) to part of aboral edge of ambulacrum (Pl. 42, fig. 6). RA sector ornament most prominent radial ornament; rest of plate almost smooth except for broad low faint growth lines parallel to RRF and RBF. Rods of stereom preserved in one specimen in RB and BR sectors; perpendicular to radial-basal suture. RWB: 1.5-6.0 mm; RMW: 1.8-7.3 mm; RWD: 1.4-5.7 mm. See also Table 48.

Deltoids four, together with epideltoid forming border of oral opening (Pl. 41, fig. 18; Pl. 42, figs. 1-7,9). Deltoids quite small, confined to upper surface of theca; overall shape rhombic. Short straight edge borders oral opening; width expands aborally along relatively long DDF to maximum width at adoral end of ambulacrum, then contracts along straight DAF which bends into straight DRF. Adoral edge and DDF ornamented with prominent minor lobes and grooves; width on two adjacent deltoids 0.2 mm except in one large specimen where 0.3 mm. Low collar-shaped rim borders adoral edge, ornamented area along DDF, and side grooves on DAF (Pl. 42, fig. 4). Surface of deltoid slopes steeply upward from this rim, forming protuberance which is arrowhead-shaped in plan view. Adoral surface is convex, usually smooth except for occasional slightly nodose or linear ornament; shaft of arrowhead aborally directed ridge which widens slightly aborally and slopes downward; its aboral edge overhangs deltoid and slopes back down into radiodeltoid suture. Sides drop steeply down to RDF; reentrant on either side of "shaft" a steeply inclined trough which drops down to hydrospire field; width widens downward. Upper edge of shaft slopes upward adorally and may merge smoothly with adoral collar or originate slightly below it. Adoral part of deltoid larger than aboral. Hydrospire slit(s) very short oval on adoral part of RDF parallel to ambulacrum, opening across radial and deltoid. Aboral parts of radiodeltoid suture form convex U which is pointed aborally. Del.Gr.Ad.W.: 0.8-2.2 mm; Del.W.Ad.E.Amb.: 0.8-1.5 mm; DDF: 0.8-1.3 mm; DAF: 0.3-1.3 mm; Del.Aboral L.: 0.2-0.5 mm. See also Table 48.

Anal deltoids two, an epi- and hypodeltoid. Epideltoid as for adoral part of regular deltoid except "shaft" missing, being embayed by adoral part of anal opening. Prominence of regular deltoid extends about 0.5 mm above oral opening in small specimens, increasing to 1.0 mm in large; that of epideltoid may extend farther. Hypodeltoid a small pentagonal plate on outer upper edge of theca (Pl. 42, fig. 6); lower edges slope into vertical side of theca; longest edge against radial where convex, greatest width slightly aboral to epi-hypodeltoid suture which is quite short, straight; adoral edge against anal opening concave. Hypodeltoid usually missing and presence indicated by facet which slopes downward and out from anal opening (Pl. 42, figs. 4,9). Anal opening angular ovoid, opening directly upward, collar of epideltoid forming a high adoral rim (Pl. 42, fig. 6). Epi.Gr.Ad.W.: 1.0-2.1 mm; Anal opening W.: 0.4-1.2 mm; HDW: 0.6-1.8 mm; O.c.-ad.e.anus: 0.7-1.8 mm. See also Table 48.

Ambulacra five, small, restricted to upper surface of theca, adoral end relatively far from center of oral opening, rhombic in plan view (aboral portion slightly larger), gently convex parallel and perpendicular to axis of ambulacrum (Pl. 41, fig. 18; Pl. 42, figs. 1-7,9). Lancet broadly exposed, rhombic in plan view, side plates forming ring on aboral half. Brachiolar facets on outer aboral sloping edge of ambulacrum, facet ellipsoidal heart-shaped, length and width: 0.2 mm, adjacent facets very closely spaced, aboral half on elongate triangular side plate which tapers to a point laterally and may extend to edge of ambulacrum, adoral half on triangular outer side plate which widens in width laterally. Ambulacral width widens during ontogeny, principally by growth of lancet but partially by growth of side plates lateral to brachiolar facet, forming a low shelf lateral to them, scalloped where brachiole passes to exterior. Adoralmost side groove long, curves adorally into main groove; length of side grooves decreases aborally; bordered on ad- and aboral sides by minor lobes and grooves as is main groove. Width of ornamented area along side groove decreases laterally on side grooves, producing a narrow V-shaped ridge between side grooves which broadens laterally. First side groove to enter main groove adorally may either be on left or right side of ambulacrum; whichever it is, it is consistent in all ambulacra of that specimen. O.c.-amb.: 0.7-2.1 mm. See Table 48.

Eight hydrospire fields, completely exposed, lacking in anal interarea. Hydrospire slits open to exterior as short ellipsoidal openings across radiodeltoid suture (usually 0.1-0.3 mm; maximum: 0.8 mm), occurring just beyond edge of ambulacrum. One slit per group in small specimens, may increase to three in large specimens (Pl. 41, fig. 18). O.c.-ad.e.hyd.sl.: 1.0-2.5 mm.

Distribution.— Permian, Krasnofimsk, U.S.S.R.

Remarks.— The above description is based upon the specimens in the growth series (Appendix I). The internal anatomy and ontogeny were discussed and illustrated by Breimer and Macurda (1972).

Genus TYMPANOBLASTUS
Breimer and Macurda, 1972

Type species.— *Codonaster pousirewski* Stuckenberg, 1875.

Tympanoblastus Breimer and Macurda, 1972, p. 42.

TYMPANOBLASTUS ELONGATUS (Yakovlev, 1937)
Pl. 43, figs. 7,8,10,11

Description.— Theca cylindrical with slightly convex sides and low, flat, bowl-shaped base. Vault small, convex in outline. Cross section pentagonal with slightly concave interambulacral areas; points of pentagon on ambulacral axes. Greatest width approximately equatorial. L.: 19.5(a) mm; W.: 15.0 mm; V.: 2.7(a) mm; P.: 16.8(a) mm.

Basals three, form lower two-fifths of pelvis, flat, bowl-shaped profile in lateral view with slight concavity near stem attachment area. Pentagonal in plan view. Small stem attachment area at proximal junction of plates; diameter 1.0 mm. No crenellar facets preserved. Basals sharply convex lengthwise, particularly in proximal portions; width less pronouncedly convex. Radial-basal sutures (except for center of zygous basals) very slightly sinusoidal. Ornament of basals consists of very coarsely granulose broad growth lines parallel to plate margins, including BBF. Azygous basal rhombic in plan view; ABL: 10.0 mm; ABW: 11.0 mm; ABBBF: 8.4 mm; ABBR: 9.5 mm; ABBRF: 6.1 mm. Zygous basals pentagonal in plan view, with straight lateral edges and slightly concave distal medial edge. ZBL: 9.8 mm; ZBW: 10.3 mm; ZBOPt: 10.2 mm; ZBBR: 9.0 mm; ZBBRF: 4.2 mm.

Radials five, forming upper three-fifths of cylindrical pelvis. In plan view long, moderately broad, with very short radial sinus. Width variable, greater at base of plate than adorally in radials with V-shaped bases; in C and E radials width expands slightly upward. Thus sides of radials semi-parallel, contracting or expanding adorally. In lateral profile radials pentagonal, base of radial is flat; upper surface very slightly convex. Aboral end straight, as are adoral ends along radiodeltoid suture and ambulacrum, meeting in a V. Small RA growth sector (?) at aboral end of ambulacrum; growth directed more upward than adorally. RA curves downward into RD sector which is flat both parallel and perpendicular to the growth axis; sector inclined to ambulacrum. The RR sector is also flat parallel and perpendicular to the RR axis. The RB sector is convex both parallel and perpendicular to the axis. Ornament of RR and RB sectors is very coarsely granulose, broad growth lines parallel to radial-basal and interradial sutures. RHt: 1.7 mm; RWB: 5.7 mm: greatest radial width (variable depending on radial): 8.0(a) mm; RWD: 6.7 mm; RD: 3.7 mm; RDF: 2.0 mm; RR: 4.5 mm; RRF: 10.0 mm; RB: 10.3 mm; RBF: 3.7 mm; RA: 1.2 mm.

Deltoids four, together with epideltoid forming border of oral opening (Pl. 43, figs. 8,10), confined to upper, slightly convex surface of theca. Plate hexagonal in plan view; widens aborally from oral opening (where approximately 1.0 mm wide) along interdeltoid suture to greatest width (3.0 mm) at adoral end of ambulacrum 2.5 mm from oral center. These edges ornamented with minor lobes and grooves of main groove. Deltoid contracts slightly aborally at greatest width of ambulacrum (convex against latter), then forms borders to aboral part of ambulacrum, turning to form radiodeltoid suture which is straight; two sutures meet at slightly less than 90°. Small pyramid present between adoral and aboral parts of plate; probably marks the origin. Adoral surface of plate largely flat, elevated above main grooves, curving upward aborally into pyramid. Surface weathered but suggestion of concentric ornament, convex toward oral opening. Sharp elevated crest forms median portion of aboral part of deltoid; aboral sides of pyramid drop almost straight into hydrospire field which is a concave area. Furrows in crest lead to hydrospire slits. Del.L.: 6.0 mm; DD: 2.5 mm; DDF: 1.6 mm; DAF: 2.0 mm; length crest: 3.0 mm; DR: 2.5 mm.

Anal deltoids two, an epi- and hypodeltoid. Epideltoid weathered and chipped; that present as for adoral part of regular deltoid. Hypodeltoid (Pl. 43, fig. 7) weathered, apparently isolated from ambulacrum by epideltoid and radials. Hypodeltoid convex lower edges, relatively long, with adoral lip; anal opening ovoid. Anal Del.L.: 6.7 mm; width of epideltoid at oral opening; 1.0 mm(a) mm; Epi.Gr.Ad.W.: 3.0 mm; O.c.-anus: 3.1 mm; anal opening probably about 3 mm long; width: 2.3 mm(a); HDL: > 1.7 mm; HDW: 2.5 mm.

Ambulacra five, rhombic in plan view, relatively flat, slope slightly downward (Pl. 43, fig. 11). Brachioles arrayed in sharply parabolic arc at edge of ambulacrum which does not quite reach edge of theca; aboral end ambulacrum pointed. Adoralmost side groove longest; side plates and outer side plates apparently confined to edge of ambulacrum with lancet broadly exposed. Outer side plates do not reach lancet. Surface weathered and other details not discernible. Amb.L.: 4.5 mm; Amb.W.: 2.8 mm; approximately 8 side plates per ambulacral side.

Eight exposed hydrospire fields. Each field concave; on upper surface of theca. Hydrospire slits small, restricted to area along short radiodeltoid suture. Slits parallel ambulacrum. 2(3) slits per group; length of field: 1.4 mm; width: 1.0 mm.

Oral opening pentagonal, weathered, width: 1.5 mm.

Distribution.— Permian, Ural Mountains, U.S.S.R.

Remarks.— The above description is based upon the single known specimen (Central Geological Museum, Leningrad, 8/6109. The ontogeny was discussed by Breimer and Macurda (1972).

TYMPANOBLASTUS POUSIREWSKII
(Stuckenberg, 1875)
Pl. 42, figs. 10-12; Pl. 43, figs. 1-5

Tympanoblastus pousirewskii Breimer and Macurda, 1972, p. 42, Pl. XXX, figs. 5, 14; Pl. XXXI, figs. 3, 6.

Description.— Thecae of small to medium size, with conical to cup-shaped pelvis with high sides, slightly reflected at top; vault very gently convex (Pl. 42, fig. 12). Greatest width at ambulacral tips where cross section is strongly pentagonal; may become rounded distally (Pl. 42, fig. 11). At plane of ambulacral tips, interambulacral areas are concave but due to rounder pelvis, overall interambulacral profile appears slightly convex. L.: 10.5, 16.5 mm; W.: 9.1, 15.8 mm; V.: 1.5, 4.0 mm; P.: 9.0, 12.5 mm; pelvic angle: > 60°.

Basals three, forming slightly less than one-half of pelvis, conical or hemispherical in lateral view, octagonal in plan view (Pl. 42, fig. 10). Plates are convex in cross section both lengthwise and widthwise. Small indentation at proximal junction where stem apparently attached; diameter: 1.0 mm in larger specimen; no crenellar facets preserved. Azygous basal rhombic in plan view; surface ornament broad growth lines. ABL: 4.1, 8.5 mm; ABW: 3.6, 9.0 mm; ABBBF: 3.5, 6.0 mm; ABBR: 3.8, 7.0 mm; ABBRF: 2.6, 7.1 mm. Zygous basal pentagonal in plan view; surface ornament broad growth lines. ZBL: 4.3, 7.8 mm; ZBW: 4.1, 10.0 mm; ZBOPt: 4.5, 8.5 mm; ZBBR: 3.9, 7.2 mm; ZBBRF: 2.0, 4.5 mm.

Radials five, forming upper lateral walls of theca but not part of vault. In plan view edge(s) against radial-basal suture is convex (C and E radials) or straight (A, B, and D radials); lateral edges of C and E straight, expand slightly adorally; radiodeltoid suture straight with short radial sinus. In lateral view radial triangular, with straight interradial suture; edge bordering ambulacrum straight; aboral facing edge slightly sinusoidal because of slight elevation on radial at aboral tip of ambulacrum; apparently original growth. RB sector is gently convex both parallel and perpendicular to RB growth axis. RR sector straight parallel to (except at origin) and slightly convex perpendicular to RR axis. RD sector flat beyond buildup at origin of radial; strongly inclined to ambulacrum. Ornament in RB and RR sectors broad growth lines, granulose in buildup at radial tip. A few growth lines are preserved in the RD sector. RWB: 1.8, 6.5 mm; RWD: 4.3, 7.0 mm; RD: 2.5, 4.3 mm; RDF: 1.5, 2.5 mm; RR: 3.1, 4.8 mm; RRF: 4.9, 7.5 mm; RB: 6.6, 9.2 mm; RBF: 1.7, 3.7 mm.

Deltoids four, together with epideltoid forming border of oral opening. Each plate consists of two parts, the larger adoral portion which together with the ambulacra forms the vault (Pl. 43, fig. 4); and the aboral portion which bends sharply downward to form part of the lateral wall of the theca and bears that part of hydrospire field developed on deltoid (Pl. 43, fig. 1). Surface of adoral part flat; truncate rhombic in plan view with small edge bordering oral opening bearing minor lobes and grooves as well as those edges along straight interdeltoid sutures; width of plate increases aborally along this suture to adoral edge of ambulacrum; then contracts slightly along straight edge bordering ambulacrum to edge of vault where there is a small knob in center of plate which appears to be the origin. Ornament of adoral part of deltoid is coarsely knobby, ridged granulose ornament with a suggestion of a concentric pattern, convex toward oral opening. This plus the configuration of the plate with the sharp bend in the aboral portion suggests that the knob at the edge of the vault marks the origin and the plate has grown outward from this point. Thus, most growth has occurred in adoral portion of plate. Aboral portion forming part of lateral wall of theca drops almost straight down, rhombic in plan view with edge of vault and border along adoral portion of aboral half of ambulacrum forming two edges and straight radiodeltoid sutures the other two; latter meet at slightly less than 90°. Pronounced crest in center of aboral part (Pl. 43, fig. 1); hydrospire field occupies remainder and borders ambulacrum. New hydrospires added during growth; longer near ambulacrum. Del.L.: 4.0, 6.9 mm; Gr.Ad.W.: 2.3, 3.0 mm; width edge vault: 1.5, 2.5 mm; DD: 2.0, 3.8 mm; DDF: 1.5, 1.8 mm; DA: 1.2, 2.2 mm; DAF: 2.6, 3.1 mm; L.Crest: 1.7, 3.0 mm; DR: 1.3, 2.0 mm.

Epideltoid (Pl. 43, fig. 3) as for adoral part of regular deltoid except for anal opening which notches knob; aboral edge may rise upward above rest of plate. Prongs of epideltoid bend sharply downward to form part of lateral wall of theca and extend to radial; thus small broad, pentagonal hypodeltoid bordered by radials and epideltoid (Pl. 43, fig. 2). Aboral edges of hypodeltoid convex; straight along epi-hypodeltoid suture; edge bordering anal opening concave. Hypodeltoid forms part of lateral wall of theca. Surface low to high convexity. Anal opening ovoid, mostly on side of theca; axis of anal opening directed diagonally upward. Anal Del.L.: 4.5, 6.2 mm; Epi.Gr.Ad.W.: 2.6, 3.5 mm; O.c.-ad.e.anus: 3.0, 4.6 mm; Anus L.: 1.8, 2.1 mm; Anus W.: 1.0, 1.5 mm; HDL: 1.5, 1.3 mm; HDW: 1.0, 2.2 mm.

Ambulacra five, extending to edge of theca, broadly lanceolate, slightly convex lengthwise, almost flat in cross section (Pl. 43, fig. 5). Longest side groove at adoral edge; brachioles at edge of ambulacrum and arrayed in arc along edge of vault. In adoral side grooves which are slightly concave toward oral opening, distance between grooves decreases abmedially. Angle between side grooves and main groove becomes broader aborally. Minor lobes and grooves along both edges of side grooves as well as along main groove. Lancet broadly exposed with side plates confined to outer 0.5 mm of ambulacrum; lancet rhombic in plan view. Large elongate triangular outer side plate embays outer edge of side plate, almost extending to lancet. Brachiolar facets small, not well preserved; apparently developed on both side and outer side plates. Facet: L.: 0.2 mm (a); W.: 0.5 mm (a). Amb.L.: 3.0, 6.0 mm; W.: 2.4, 4.5 mm; No.S.P.: 9, 14.

Eight completely exposed hydrospire fields, developed on upper lateral wall of theca. Six; eight hydrospires per group, shortest at apex of radiodeltoid suture; longest not quite at ambulacrum. Length of slits on radial and deltoid about equal; do not extend to origin of radial so apparently older parts infilled on radial during growth. L.Hyd.Fld.: 0.5, 2.0 mm; W.Hydro. Fld.: 1.0, 2.2 mm. Width of slit: 0.125 mm.

Oral opening pentagonal; width: –; 1.2 mm.

Distribution.– Lower Permian, Timor, Pechora region, at the Rivers Sula, Beloi, and Gusinets, P, and at the River Inding, U.S.S.R.

Remarks.– *Codaster barkhatovae* Yakovlev, 1941 was synonymized with *Codonaster pousirewskii* Stuckenberg, 1875 by Breimer and Macurda (1972). The latter was made the type species of the genus *Tympanoblastus*. The above description is primarily based upon the holotype of *Codaster barkhatovae* (Central Geological Museum, Leningrad, collection 7191) which is better preserved than the holotype of *Codonaster pousirewskii* (Mining Institute, Leningrad, 106/43). The shape of the theca of the only two known specimens differs in the base, *pousirewskii* having a conical base with *barkhatovae* having a bowl-shaped base. The basals of the former are less markedly convex. The A, B, and D radials of *barkhatovae* are very broad at the base and midline and less so at the deltoids; the same radials in *pousirewskii* expand adorally and are narrowest at the base. Otherwise, the specimens are apparently the same. *Pousirewskii* (the first set of measurements given above) is smaller than *barkhatovae* and the difference could be ontogenetic variation within a species of different sizes. The two were synonymized for this reason (Breimer and Macurda, 1972) but more specimens could show this to be incorrect.

Tympanoblastus pousirewskii is easily differentiated from *T. elongatus* by the extension of the vault to the edge of the thecal outline in plan view, the flat concentrically ornamented adoral part of the deltoid, and the smaller width of the deltoid crest.

Genus PTEROTOBLASTUS Wanner, 1924a

Type species.— *Pteroblastus gracilis* Wanner, 1924a. *Pterotoblastus* Breimer and Macurda, 1972, p. 42, 43.

Remarks.— The following characteristics differentiate the species of *Pterotoblastus* from one another.

P. brevialatus: Theca cup shaped in lateral view, rounded pentagonal in plan view; no prolongation of ambulacra onto radial prongs, only a slight vertical buildup beneath the ambulacrum; A, B, and D radials widest aborally.

P. decemcostis: Theca cup shaped in lateral view, decagonal in plan view, with bulges along interradial sutures; no prolongation of ambulacra onto radial prongs.

P. ferrugineus: Theca bowl shaped in lateral view with straight sides, relatively flat base; pentagonal in plan view with extension of ambulacra onto radial prongs, producing stellate outline.

P. gracilis: Theca hydra-shaped in lateral shape due to radial prongs, conical, tapering pelvis; outline extremely stellate in plan view with extension of ambulacra onto radial prongs. A, B, and D radials widest adorally.

PTEROTOBLASTUS BREVIALATUS Wanner, 1931
Pl. 46, figs. 1-13; Table 49

Pterotoblastus brevialatus Breimer and Macurda, 1972, p. 43, Pl. XXXI, figs. 2,5,7,9,13-15.

Description.— Theca small; pelvis usually cup shaped in lateral view but varying from parabolic to bowl-shaped (Pl. 46, figs. 2,6). Pelvis long, ambulacra being restricted to upper part of theca where form very slightly convex vault. Side of pelvis convex in lateral profile, convexity greater near base. Greatest width of theca varies from equatorial to junction of vault and pelvis; may be very slightly recurved toward vault. Outline of theca rounded pentagonal in plan view, with convex interambulacral areas; elevated angular ambulacra give appearance of pentagonal star on top of theca (Pl. 46, figs. 1,4,5,9,12). Length of theca usually slightly less than width but variable. Vault small; angle of base and ambulacral tips 40-70°. See Table 49.

Basals three, with azygous basal normally in AB interarea but in CD interarea and DE interarea respectively of two specimens in growth series. In former azygous is restricted in size and does not extend to base of theca; stem facet on suture between two zygous basals. Basals convex in lateral view, parabolic to bowl-shaped, with proximal ends flattened for stem attachment area which is at very base of theca. Stem attachment area circular, slightly depressed interior, diameter: 0.3-0.7 mm. Stem plates disc-shaped, height: 0.2 mm; diameter: 0.5-1.0 mm in different specimens. Outline of basals pentagonal in basal view (Pl. 46, figs. 3,10). Azygous basal quadrate in plan view with straight edges, convex both parallel and normal to BR growth axis. Sectors curve into one another. Zygous basals pentagonal, straight lateral and distal lateral edges; medial distal edge very slightly concave. BR sectors as for azygous basal except convexity of central BR sector normal to BR axis greater than lateral sectors. Ornament of basals varied; some specimens with growth lines parallel to BR and BB fronts; others have granulose plate surfaces. Slight indentation of radial-basal sutures. See Table 49.

Radials five, forming upper two-thirds of pelvis but not forming part of vault. C and E radials quadrate in lateral view, with slightly convex lower edge; width expands to maximum near middle of plate, then contracting slightly toward radiodeltoid suture; lateral edges thus

TABLE 49. Growth relationships of principal variables of *Pteroblastus brevialatus* Wanner, 1931

Variables	n	r	a_0	a_1	Observed Range y	Observed Range x
L/W	15	0.90	-0.27	1.05	2.8– 6.6	2.8– 6.0
V/P	15	0.07	0.40	0.02	0.1– 1.0	2.2– 5.9
L/ABBR	15	0.91	0.69	2.06	2.8– 6.6	1.1– 2.9
L/RD	15	0.78	1.45	2.42	2.8– 6.6	0.5– 2.0
L/RB	15	0.94	0.23	1.83	2.8– 6.6	1.5– 3.5
L/Del.L.	15	0.91	0.00	2.83	2.8– 6.6	1.0– 2.2
L/Amb.L.	15	0.82	1.56	2.20	2.8– 6.6	0.5– 2.1
RD/Amb.L.	15	0.95	0.16	0.82	0.5– 2.0	0.5– 2.1
Del.L./Amb.L.	15	0.85	0.60	0.74	1.0– 2.2	0.5– 2.1
ABL/ABW	15	0.90	0.18	0.91	1.4– 3.2	1.3– 2.9
ABBR/ABBRF	15	0.89	0.03	1.26	1.1– 2.9	0.9– 2.0
ZBL/ZBW	15	0.94	-0.38	0.97	1.2– 3.5	1.9– 3.8
ZBBR/ZBBRF	15	0.82	0.03	1.58	1.1– 3.1	0.8– 1.7
ABBR/RB	15	0.83	0.19	0.71	1.1– 2.9	1.5– 3.5
ABBR/RD	15	0.65	0.74	0.89	1.1– 2.9	0.5– 2.0
ABBR/Del.L.	15	0.81	0.08	1.12	1.1– 2.9	1.0– 2.2
RD/RDF	15	0.71	0.62	1.16	0.5– 2.0	0.3– 1.0
RR/RRF	15	0.85	0.42	0.42	0.8– 1.9	1.2– 3.9
RB/RBF	15	0.84	0.48	1.84	1.5– 3.5	0.7– 1.5
RD/RR	15	0.85	0.02	0.91	0.5– 2.0	0.8– 1.9
RD/RB	15	0.84	0.03	0.53	0.5– 2.0	1.3– 3.5
RR/RB	15	0.88	0.16	0.52	0.8– 1.9	1.5– 3.5
RD/Del.L.	15	0.83	-0.07	0.84	0.5– 2.0	1.0– 2.2
RB/Del.L.	15	0.88	0.12	1.40	1.5– 3.5	1.0– 2.2
Del.L./Gr.Ab.W.	15	0.91	0.28	1.31	1.0– 2.2	0.5– 1.4
Del.L./Anal Del.L.	15	0.93	-0.20	1.01	1.0– 2.2	1.2– 2.3
Amb.L./Amb.W.	15	0.70	0.18	1.65	0.5– 2.1	0.4– 1.0
Amb.L./No. S.P.	15	0.78	0.30	0.30	0.5– 2.1	2.0– 6.0

slightly convex. Upper edges converge adorally but profile interrupted by small buildup at origin of plate which elevates and supports ambulacrum. Buildup of radial under ambulacrum primarily vertical (minimum of 0.0 in smallest specimen, most about 0.5 mm; maximum of 0.9 mm), may extend length of ambulacrum slightly.

Outline of buildup horseshoe-shaped in oral view, a slight overhang in side view. A, B, and D radials have greatest width at base; contract adorally. In lateral view radial has profile of elongate right triangle, with short vertical edge bordering ambulacra, very slightly concave lower edge along interradial suture, and long convex edge along upper surface. RB sector largest, slightly convex (degree variable) parallel to RB axis and slightly convex perpendicular to it; two sectors meet along fairly pronounced curve. RR sector very slightly convex parallel to RR axis and convex perpendicular to it; curves into RB sectors. RD sector small, aboral part overgrown by buildup of radial, adoral part inclined to ambulacrum and RR sector, straight parallel to axis, much of width dominated by hydrospire slit in small specimens, giving concave profile but becoming slightly convex in larger specimens. Ornament of radial: growth lines parallel to radial growth fronts with granulose ornament of varying intensity on the growth lines. Trabeculae of stereom perpendicular to BRF, RBF, and RRF. RWB: 1.0-2.5 mm; RMW: 1.3-3.1 mm; RWD: 1.1-2.5 mm. See also Table 49.

Deltoids four, together with epideltoid forming border to oral opening. Outline in plan view (disregarding adoral edge) hexagonal. Adoral edge straight, short (0.2-0.4 mm); width of plate expands along relatively long straight DDF to adoral end of ambulacrum; maximum width usually here. Width usually contracts slightly along two straight to very slightly concave DAF to point of maximum width of ambulacrum. That portion of plate adoral to this point forms large adoral part of plate on upper slightly convex surface of theca (Pl. 46, figs. 9,12). Aboral to this point, plate contracts along two short straight DRF which cross hydrospire slits, meet at almost right angles (Pl. 46, figs. 7,13). This aboral part of the plate is at a sharp angle to the adoral part, being on the upper sloping lateral surface of the theca. It has a short, almost vertical median crest; this is deeply embayed on either side by the ellipsoid hydrospire slits which appear as the entrances to a pair of tunnels in specimens with only one hydrospire slit per group. Adoral edge and DDF of deltoid bear main groove and prominent minor lobes and grooves; width of ornament on adjacent deltoids 0.2-0.4 mm in center of front, broadening adorally. Most of adoral part of plates a triangular area which rises above ornament and often slopes gradually downward aborally, usually smooth; may be buildup in center giving low dome-shaped profile. Del.Gr.Ad.W.: 0.5-1.6 mm; DDF: 0.4-1.0 mm; DAF: 0.3-0.7 mm; Del.L.Adoral Pt.: 0.5-1.5 mm; Del.L.Aboral Pt.: 0.2-0.7 mm. See also Table 49.

One anal deltoid present, an epideltoid which is large; configuration as for regular deltoid except aboral part which is embayed by anal opening (Pl. 46, fig. 8). Elevation of center of triangular area in adoral part of epideltoid greater than corresponding area in regular deltoid; may be concave trough on upper aboral edge of epideltoid to guide anus when extended. Hypodeltoid apparently absent; no obvious facet. Anal opening ovoid to circular, opening outward and upward on upper lateral side of theca. Small flat platform borders anal opening on aboralmost edge of epideltoid (support area for anal cover plates?). Epi.Gr.Ad.W.: 0.8-1.7 mm; Anus L.: 0.4-1.0 mm; Anus W.: 0.4-0.8 mm; O.c.-anus: 0.7-1.5 mm. See also Table 49.

Ambulacra five, small, lanceolate in plan view (Pl. 46, fig. 9), removed from oral opening, supported by slight buildup of radial. Lancet exposed, rhombic-hexagonal, present only at adoralmost end of ambulacrum, side plates and outer side plates resting on radial; aborally side plates meet along main groove without being in contact with lancet. Ambulacrum quite convex in cross section; outer side plates on sloping side. Outline of latter triangular, L: 0.18 mm in one specimen; W: 0.15 mm; greatest width at edge of ambulacrum. Brachiolar facet on steeply sloping side of ambulacrum; ellipsoidal, L: 0.20 mm in one specimen; W: 0.18 mm. Small trough (width: 0.02 mm (a)) leads from uppermost edge of facet into side groove. Small ridge separates two halves of facet which is equally developed on side and outer side plate; adoral half of facet slightly lower than aboral half. Facet very slightly concave lengthwise. Adoral side groove is the longest; length decreases aborally. First to enter is that on the left side of ambulacrum when facing orally; adoral part of groove crosses onto deltoid before entering main groove. Main and adoral edge (absent aboral) of side groove bear minor lobes and grooves. Number of side plates small; number on left side apparently one more than on right. O.c.amb.: 0.6-1.3 mm. See also Table 49.

Eight exposed hydrospire groups, with one hydrospire slit per group except in largest specimens; sited across radiodeltoid suture on upper sloping side of theca, short elongate ovoid opening (0.1-0.4 mm). In largest specimens, two per group, and in one specimen, incipient development of third in one interarea. (Also, in this same specimen dividing septum between two slits not fully developed in one interarea and two slits open through common opening).

Oral opening pentagonal, width: 0.3-0.5 mm. Small pentagonal ring present just beyond edge of oral opening on deltoid (present as a groove in the deltoid); lies adoral to minor lobes and grooves (Breimer and Macurda, 1972, Pl. XXXIII, fig. 8).

One tetramerous mutant known (Pl. 46, fig. 11).

Distribution.– Permian, Sonnebait Series, Timor, Indonesia.

Remarks.– The above description is based upon the specimens in the growth series. The internal anatomy and ontogeny were discussed and illustrated by Breimer and Macurda (1972).

PTEROTOBLASTUS DECEMCOSTIS Wanner, 1931

Pterotoblastus decemcostis Breimer and Macurda, 1972, p. 43.

Distribution.– Permian, Basleo, Timor, Indonesia.

Remarks.– This species was described and illustrated from a single specimen by Wanner (1931). Breimer and Macurda were unable to locate the holotype in collections in Indonesia, Netherlands, or West Germany. The illustrations given by Wanner closely resemble a *P. gracilis* in which the radial prongs have been worn off. Since Wanner illustrates granulose ornament on the surface of the radial knobs, these are apparently the original surface of radial. The theca is small (L: 6.7(a) mm; W: 6.4(a) mm). The ambulacra are short with two side plates per side, and a single hydrospire slit is developed across four of the radiodeltoid sutures, are present as small invaginations on two others, and are absent on the remaining two. The decagonal outline in plan view is different from that of any other species of *Pterotoblastus.*

PTEROTOBLASTUS FERRUGINEUS Wanner, 1940
Pl. 44, fig. 5; Pl. 45, fig. 4

Pterotoblastus ferrugineus Breimer and Macurda, 1972, p. 43, Pl. XXXI, figs. 4,8.

Description.– Theca bowl-shaped, with straight sides and broad, relatively flat base, bending sharply at junction of basals and radials; pelvis long; radials extended into prongs or wings; now broken. Vault essentially flat, confined to upper surface of theca. Outline of theca pentagonal; in plan view with radial extensions restored, modified to stellate. Greatest width in plane of ambulacral prongs. L: 7.8 mm(va); W: 9.5 mm (not including radial extensions).

Theca consists of some plates preserved around a steinkern. The basals are missing but their outline is well preserved and the sutures are quite visible. The following remarks and measurements on the basals apply to the configuration as deduced from the steinkern. Basals three, in normal position. In lateral view outline broad, slightly convex; pentagonal in basal view. Proximal junction slightly recessed. Azygous basal rhombic with straight edges. BR sector convex parallel to BR axis, very gently convex normal to axis; adjacent sectors merge smoothly(?). ABL: 4.1 mm; ABW: 5.0 mm; ABBBF: 3.2 mm; ABBR: 3.5 mm; ABBRF: 3.2 mm. Zygous basals pentagonal; distal median edge slightly concave; others straight. BR sectors gently convex parallel to BR axes; median sector gently convex normal to axis while lateral sectors are gently concave. ZBL: 4.1 mm; ZBW: 5.5 mm; ZBOPt: 4.5 mm; ZBBR: 3.7 mm; ZBBRF: 3.0 mm.

Radials five, forming sides of theca, quadrate in plan view with slightly convex or two straight sutures on lower edge; lateral sides almost straight; widen slowly adorally, greatest width is very near deltoid. A, B, and D radials widest at base. Upper edges converge at broad angle. Upper center of radial elongated into extension which is elliptical in cross section (height: 2.1 mm; width: 1.5 mm) and apparently extended above vault but only base preserved. RB sector large, very gently convex parallel to axis and gently convex normal to it; adjacent sectors merge smoothly with one another and in the RR sectors. RR sector straight normal to RR axis; very gently convex normal to it; RR sector at sharp angle to RD sector which forms part of top of theca. RD sector small, straight parallel to RD axis, very gently convex normal to it, bears hydrospire slits across width of radiodeltoid suture. Ornamentation of radial not preserved. Only C radial missing from specimen; others in part or complete. RWB: 3.8 mm; RMW: 4.5(a) mm; RWD: 4.4 mm; RD: 2.5 mm(a); RDF: 1.5 mm; RR: 3.0 mm(a); RRF: 5.0 mm(a); RB: 5.2 mm(a); RBF: 2.3 mm.

Deltoids four, together with epideltoid forming border of oral opening (Pl. 45, fig. 4); restricted to upper flat surface of theca; extending to edge. Deltoid hexagonal in plan view (ignoring adoral edge). Adoral edge straight, 0.5 mm wide. Width expands along straight DDF to maximum width at adoral end of ambulacrum, then contracts slightly along a short DAF; aboral edges converge along straight suture at approximately 90°. Plate divisible into a large adoral part (that part bordered laterally by DDF and DAF) and a smaller aboral part. DDF and adoral edge ornamented by minor lobes and grooves; width ambulacral tract on adjacent deltoids: 0.3 mm. Most of adoral part of plate flat, ornamented with low nodose ornament; aborally, surface slopes up to a V-shaped mound which separates two parts of plate. Aboral part slopes down to radial, center bears thin crest which zigzags between grooves on either side which lead into the hydrospire slits. Del.L.: 3.8 mm; Del.Gr. Ad.W.: 3.2 mm; Del.Min.W.: 2.6 mm; DDF: 2.0 mm; DAF: 0.8 mm; Del.L. Adoral Pt.: 2.0 mm; Del.L. Aboral Pt.: 1.3 mm.

Anal deltoids two, an epi- and hypodeltoid. Epideltoid large (Pl. 44, fig. 5), as for adoral part of regular deltoid except for anal opening which embays aboral edge; elevated area forms U-shaped rim above anal opening. Presence of hypodeltoid indicated by sutures against epideltoid and raised line on steinkern. Plate small, surrounded by epideltoid and radial, shape of plate a broad U with slightly convex aboral edges, straight epihypodeltoid sutures, and a concave adoral edge. Anal opening ovoid, opens upward and slightly outward near outer edge of vault. Epi.L.: 2.0 mm; Epi.Gr.Ad.W.: 3.1 mm; HDW: 1.5 mm; Anus L.: 1.0 mm; Anus W.: 0.7 mm.

Ambulacra five (Pl. 45, fig. 4), extend onto radial prongs; only adoral part preserved. Lancet exposed, a small rhombic plate which extends to interior of theca, in contact only with adoral side plates, others resting on the radial. Main groove and adoral and aboral(?) edges of side grooves ornamented with minor lobes and grooves; left side groove first to enter ambulacrum. Brachiolar facets on vertical sides of ambulacrum, brachioles would thus be directed outward. Amb.L.: 2.0 mm; Amb.W.: 1.2 mm; No. S.P.: > 2; O.c.-amb.: 2.5 mm.

Eight completely exposed hydrospire fields, developed across width of radiodeltoid suture; 3 slits per group, short (0.5 mm); width of field: 1.0 mm. On outer sloping upper edge of theca. None in anal interarea. O.c.-hyd.sl.: 2.9 mm.

Oral opening pentagonal, width: 0.7 mm.

Distribution.— Permian, Tai Wei, Timor, Indonesia.

Remarks.— The above description is based upon the only known specimen, the holotype (Univ. Amsterdam Ge.O.9924).

Pterotoblastus sp. no. 2 of Wanner, 1940, is a large deltoid of the *Pterotoblastus* type. It is incomplete, slightly convex lengthwise. There is a moderately developed DD sector, ornamented with warty angular ornaments, bearing parts of the ambulacral tract along the adoral edge and straight DDF. There is a beveled edge along DDF, 0.8 mm wide. Growth lines can be seen on the interior of the plate, parallel to the DDF and DAF; the latter are also straight, parallel. The median part of the DD sector is slightly higher, passes aborally to the highest point on the plate from which ridges radiate to the ambulacra and a slightly developed sinusoidal crest trends aborally. The aboral part of the plate is rather flat, with broad troughs between sharp ridges which diverge aborally to the beginnings of the hydrospire slits. These slits are unusual in that they are quite wide openings for hydrospire slits and the slits do not oppose one another on the deltoid crest but are offset. Wide, offset slits of this type can be seen in *P. ferrugineus*. Del.L.: > 18.7 mm; Ad.W.: 2.5 mm; Gr.Ad.W.: 14.0 mm; DDF: 9.8 mm; DAF: 4.8 mm; No. Hydro.Sl.: 6; their width: 7.2 mm, width of individual opening: 0.8 mm; partly infilled from crest. The theca of this *Pterotoblastus* would have been larger than any other known species. (Univ. Amsterdam Ge.O.9926, Nepa near Basleo, Timor.) Breimer and Macurda (1972, Pl. XXXI, fig. 10) illustrated the deltoid and suggested it might represent the deltoid of a *Pterotoblastus* sp. similar to *P. ferrugineus*.

PTEROTOBLASTUS GRACILIS Wanner, 1924a
Pl. 43, figs. 6,9,12,13; Pl. 44, figs. 1-4, 6-12;
Pl. 45, figs. 1-3; Table 50

Pterotoblastus gracilis Breimer and Macurda, 1972, p. 42, Pl. XXXI, figs. 11,12; Pl. XXXII, figs. 3,4,6,9, 10.

Description.— Thecae small, hydra-shaped, with lower half of pelvis conical with straight to slightly convex sides (varying to cup-shaped), flaring outward sharply in upper half due to presence of radial wings which reach outward and upward, extending above oral opening; wings have convex lower surface and concave upper surface; ambulacra extend partly onto radial wings (Pl. 43, figs. 6,9; Pl. 44, fig. 6). Upper lateral profile of theca of varying concavity, sloping downward and flattening out near oral opening. Outline in plan view extremely star shaped, pentagonal (Pl. 44, figs. 1-4). Interambulacral areas between tips of radial wings parabolic; profile of theca excluding wings straight to slightly concave in interambulacral areas. Greatest width in

TABLE 50. Growth relationships of principal variables of *Pteroblastus gracilis* Wanner, 1924

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	18	0.97	0.54	0.75	3.2–10.7	3.7–13.5
L/ABBR	18	0.99	0.77	2.03	3.2–10.7	1.3– 5.1
L/Del.L.	18	0.97	-0.45	3.80	3.2–10.7	1.0– 2.9
L/Amb.L.	18	0.96	2.60	1.98	3.2–10.7	0.5– 4.4
Del.L./Amb.L.	18	0.93	0.86	0.49	1.0– 2.9	0.5– 4.4
ABL/ABW	18	0.94	-0.16	1.34	1.6– 5.3	1.3– 3.8
ABBR/ABBRF	18	0.94	-0.45	2.27	1.3– 5.1	0.8– 2.3
ZBL/ZBW	18	0.96	-0.46	1.06	1.2– 5.3	1.7– 4.8
ZBBR/ZBBRF	18	0.90	0.15	2.16	1.2– 5.2	0.5– 2.0
ABBR/Del.L.	18	0.96	-0.50	1.82	1.3– 5.1	1.0– 2.9
Del.L./Gr.Ab.W.	18	0.98	0.26	1.47	1.0– 2.9	0.5– 1.8
Amb.L./Amb.W.	18	0.93	-0.72	3.20	0.5– 4.4	0.3– 1.5
Amb.L./No. S.P.	18	0.90	-0.80	0.85	0.5– 4.4	1.0– 5.0

interambulacral areas near vault, just below deltoids. Length less than width (including radial wings), angle of top of radial limbs with center of base of theca 58-82°. See Table 50.

Basals three, in normal position, forming slightly less than one-half of pelvis, with lateral profile conical to cup shaped with flat base. Outline of distal edges of basal circlet rounded pentagonal in plan view (Pl. 43, fig. 13); within basals profile is circular. Basals taper to stem attachment area which is a flat to slightly invaginated circle on proximal surface of basals (Pl. 43, fig. 12). Polar axis of blastoid and stem slightly inclined to one another, with theca bent toward posterior half (usually right posterior); basals thus somewhat asymmetric. Stem plates large, circular in outline, cylindrical, 0.2-0.3 mm in height; width increases during growth from 0.8-2.0 mm; diameter of stem attachment area increases correspondingly. Azygous basal pentagonal in plan view with straight proximal edge along border of attachment area (converges within attachment area), two straight lateral and two straight distal edges. BR sector is usually slightly convex parallel to growth axis, although may be straight; rarely slightly concave if asymmetry of basal pronounced; BR sector convex perpendicular to growth axis; adjacent sectors merge smoothly. Length of plate equal to but usually greater than width. Zygous basal has straight lateral and lateral distal edges; medial and lateral sectors as for those of azygous basal; merge smoothly. Ornament of basals usually granulose, regular to anastomosing. Growth lines occasionally visible parallel to BRF (and BBF) when ornament subdued. See Table 50.

Radials five, basically quadrate in outline in plan view. Slightly convex or two straight lower edges; width expands adorally along lateral edges to a point just below deltoids, then becoming slightly narrower; edges straight (but diverging) in lower part, convex in upper part of lateral wall. Upper edges short, converge adorally at broad angle. No radial sinus. Lateral profile of radial dominated by radial wing which has the appearance of a human thumb viewed laterally. Radial wing is the dominant feature of the radial. Grows continuously during ontogeny, increasing in length, width, and height. In cross section it is ellipsoidal. In lateral view, it has the appearance of a thumb, varying from short and thick to longer and narrower; degree of convexity varies as evidenced by height above oral opening. Tips vary from angular to rounded; outermost edge usually sharp. In plan view, radial wing has narrow, triangular profile. Wings may show obvious variation in length in one specimen. Base of wing merges into body of radial, obscuring origin in smallest specimen and progressively increases in size thereafter. Growth axes per se not measurable. RB sector outside wing straight to very slightly convex parallel to growth axis, straight to slightly convex normal to axis, convexity increasing toward junction of sectors. RR sector straight parallel to growth axis, straight normal to axis in lower part of sector, becoming increasingly convex in upper portion. RR sector merges with RB sector, bends over sharply into upper surface of theca. RD sector very small, in part due to overgrowth by prong; upper surface of wing and RD sectors form a concave triangular area, broadening out near the radiodeltoid sutures in the RD sectors, which slopes down toward the oral opening, the deltoids rising sharply above the radiodeltoid suture adoral to the RD sectors. RD sector slopes gently down from lowest edge of ambulacrum (profile straight), bears short hydrospire slits on suture. Ornament of RB and RR sectors varies from granulose growth lines through granulose to irregular anastomosing ridges; RD sector granulose. Radial wing ornamented by irregular anastomosing ridges which usually parallel the long axis of the wing (Pl. 44, fig. 10). RWB: 1.0-3.3 mm; RMW: 1.4-4.5 mm; RWD: 1.2-3.3 mm; RDF: 0.3-1.0 mm; RRF: 1.5-5.2 mm; RBF: 0.6-1.9 mm; L.Prong: 1.4-6.0 mm; W.Prong: 0.7-2.0 mm; Ht.Prong: 0.9-4.6 mm.

Deltoids four, together with epideltoid forming border to oral opening, restricted to upper central flat surface of theca. Outline in plan view (disregarding adoral edge) hexagonal (Pl. 44, figs. 7-9, 11, 12). Adoral edge short (0.2-0.5 mm), straight. Width of deltoid expands aborally along straight DDF to greatest width at adoral end of ambulacrum, then converges slowly aborally along a short, straight to very slightly concave DAF. Aboral edges converge at slightly greater than 90°. DDF bears main groove, together with adoral edge of deltoid ornamented with minor lobes and grooves which form a narrow (0.2-0.3 mm, on adjacent plates), relatively deep ambulacral tract (Pl. 44, fig. 8). Adoral part of plate elevated above this, relatively large, sloping up very gently or fairly steeply to low or high rounded pyramidal medial point which may be at border with aboral part of plate (Pl. 45, fig. 2); irregular ornament may radiate linearly in an adoral direction from this point. Strength of development of ornament in adoral part of plate variable; in a small specimen adoral surface may slope slightly downward from rim along main groove; high point may be in adoral center. Aboral part of plate small, slopes gently to steeply down to radiodeltoid suture, with short broad median crest separating groove(s) which become more pronounced with age which lead into the hydrospire slit(s) (Pl. 44, figs. 7, 11). Del.Gr. Ad.W.: 0.7-2.4 mm; Del.Gr.Ab.W.: 0.5-1.8 mm; DDF: 0.4-1.8 mm; DAF: 0.3-1.0 mm; Del.L.Adoral Pt.: 0.5-2.0 mm; Del.L.Aboral Pt.: 0.2-0.8 mm. See Table 50.

One anal deltoid, an epideltoid (Pl. 45, fig. 3). Configuration as for regular deltoid except aboral central edge embayed by anal opening. High point of epideltoid usually more pronounced than regular deltoid, aboral edge of which slopes down to anal opening and epiradial suture. Concave groove on medial aboral edge to guide anus when extended. May be small flat platform around adoral edge of anal opening. Anal opening ovoid to circular, length may be greater or less than width; increases in size slightly during growth. Anal opening near edge of upper surface of theca, directed largely upward. No evidence of hypodeltoid facet; aboral margins of anal opening formed by adjacent radials (Pl. 45, fig. 3). Anal.Del.L.: 1.2-3.0 mm; Epi.Gr.Ad.W.: 0.8-3.0 mm; O.c.-anus: 0.7-2.1 mm; Anus L.: 0.3-1.0 mm; Anus W.: 0.3-1.0 mm.

Ambulacra five, lanceolate in plan view, scalloped at brachiolar facets (Pl. 45, figs. 1-3). Ambulacrum removed from oral opening, slightly concave lengthwise, convex in cross section with brachiolar facets on lateral sides. Lancet a small rhombic-shaped plate, exposed, present only at adoralmost end of ambulacrum (Pl. 44, fig. 12) with only adoralmost side and outer side plates in contact with it. Side plates and outer side plates rest directly on radial and grow outward along top of inner part of upper surface of radial wing during growth. Outer side plate a triangular plate at edge of ambulacrum which embays side plates; does not extend to center of ambulacrum. Brachiolar facet small, elliptical, L: 0.18-0.20 mm; W: 0.125-0.20 (a) mm, equally developed on aboral part of outer side plate and adoral part of side plate. Facet at very edge of ambulacrum, almost vertical, and lower edge just above radial. Lower part of brachiole thus extended almost straight out. Side grooves alternately enter main groove with right hand side entering first. Ad- and aboral edges of side groove and main groove are bordered by minor lobes and grooves. Area between side grooves on side plates relatively narrow, ornamented by a high ridge, is almost parallel to the main groove medially but parallels the side food groove laterally. Number of brachioles relatively small. Rate of addition of brachioles not proportional to increase in ambulacral length. Side plates grow in size as distance from adoralmost facet to deltoid increases from about 0.1 mm to 0.7 mm during growth while distance between center of adjacent facets increases from 0.2 to 0.5 mm. Size of facet appears to remain relatively stable throughout growth. O.c.-amb.: 0.5-2.2 mm. See Table 50.

Eight exposed hydrospire groups, developed across width of radiodeltoid suture, absent in anal interarea. Number of slits varies from one in smallest specimens through the irregular gradual addition of a second in medium-sized specimens in the growth series to three per group in the largest. Four known in one broken specimen with a length of 11.2 mm. Slits are very short (length: 0.2-0.5 mm), elongate ovoid openings across radiodeltoid suture. Slit nearest ambulacrum usually longest, new slits added in center of interambulacral area. Slits on upper sloping side of theca; adjacent slits separated by pronounced ridge. Slits are offset, not opposing, along deltoid crest.

Oral opening pentagonal; roof of cover plates known in one specimen (Pl. 44, fig. 9) which cover part of main groove of deltoid as a biserial row.

Trabeculae of stereom may be well preserved. Along radial-basal and interradial sutures, the long axes are perpendicular to the sutures; in the prongs, the long axes parallel the axis of the prong. Part of the ornament of the deltoid may result from a vertical buildup on a free surface.

Occasional irregularities in development found as a swollen basal or failure to develop an ambulacrum.

Distribution.— Permian, Sonnebait Series, Basleo, Timor, Indonesia; Komuk, Thailand.

Remarks.— The above description is based upon the specimens in the growth series (see Appendix I). The internal anatomy and ontogeny was discussed and illustrated by Breimer and Macurda (1972).

Genus NANNOBLASTUS Wanner, 1924b

Type species.— *Nannoblastus pyramidatus* Wanner, 1924b.

Nannoblastus Breimer and Macurda, 1972, p. 43.

NANNOBLASTUS CUSPIDATUS Wanner, 1924b

Nannoblastus cuspidatus Breimer and Macurda, 1972, p. 43, Pl. XXXII, figs. 7, 8.

Description.— Theca only partially complete; upper part of pelvis conical, vault almost flat with deltoid process projecting upward; stellate in plan view, points along ambulacral radii; greatest width slightly below plane of ambulacra. L: > 4.5 mm; W: 5.8 mm.

Basalia missing.

Radials five, forming upper part of pelvis and extending to level of ambulacra; quadrate in plan view, with narrow convex base; width expands upwards to deltoid along straight suture; upper straight edges converge at very broad angle; very short V-shaped radial sinus notches upper edge of plate. Radial triangular in lateral view, with short, straight, adoral edge, longer straight proximal facing edge, and straight lower edge. RB sector straight parallel and normal to RB axis; adjacent sectors merge over broad angular boundary with several ridges radiating from origin of radial; merge smoothly with RR sector which is straight, both parallel and normal (except for slight curvature near top) to RR axis. RR sector ornamented by ridges which cross interradial suture. RR sector rounds into RD sector which is straight parallel to and convex normal to RD axis; surface rather smooth. RHt: 1.5 mm; RWB: 1.0 mm; RWD: 2.1 mm; RD: 1.9 mm; RDF: 0.7 mm; RR: 2.0 mm; RRF: 3.7 mm; RB: 3.7 mm; RBF: 0.7 mm.

Deltoids four, together with epideltoid forming border of oral opening. Confined to upper flat surface. Deltoid hexagonal in plan view, with short, straight adoral edge, relatively long DDF; width expands aborally to ambulacrum; short DAF against lancet; width contracts along straight DRF; meet at slightly more than 90°. DDF bears 0.2 mm wide rim, part of ambulacral tract; aboral to this, deltoid rises into a high, pointed knob or process on aboral part of deltoid which projects beyond edge of theca. Surface of process ornamented with irregular broad ridges which run down sides; aboral sides slope on a reverse incline to the radiodeltoid suture. Del.L.: 2.0 mm; Ad.W.: 0.5 mm; Gr.Ad.W.: 1.4 mm; Gr.Ab.W.: 1.4 mm; Ab.process: 1.0 mm; DDF: 0.8 mm; DAF: 0.5 mm.

Anal deltoids two, an epi- and hypodeltoid. Epideltoid as for adoral part of regular deltoid; process embayed on aboral side, forming an adoral collar to anal opening. Hypodeltoid now missing, presence indicated by break in profile of anal opening. Hypodeltoid broad, pentagonal, with convex aboral edges, forming part of upper part of theca. Anal opening apparently ovoid, opening upward and outward near edge of theca. Anal Del.L.: 2.6 mm; Epi.L.: 1.5 mm; Epi.Gr.Ad.W.: 1.7 mm; Anus W: 1.0 mm; Hypo.W: 1.5 mm.

Ambulacra five, side plates missing, but rhombic-shaped lancet present, exposed in its adoral part, confined to area near radiodeltoid suture, side plates apparently arrayed in an arc on aboral side, covering aboral part of lancet. Adoral part of lancet higher, inclined upward; aboral part flat. Ambulacra removed from oral opening (1.3 mm); also large part of radial exposed aboral to ambulacrum. Food particles thus ascended to deltoid, then proceeded along flat surface to ultimately curve downward into oral opening. Length of lancet: 0.5 mm; width: 0.4 mm.

Nature of hydrospires unknown.

Oral opening pentagonal, width: 0.6 mm.

Distribution.– Permian, Somohole, Timor, Indonesia.

Remarks.– The above description is based upon the only known specimen, the holotype (Technische Hogeschool Delft 12270). Its ontogeny was discussed by Breimer and Macurda (1972).

This form is differentiated from *N. pyramidatus* by the transverse ridges of the RR sector and the form of the deltoid process which in *N. pyramidatus* is triangular in cross section, has smooth adoral faces which are almost vertical, whereas that of *N. cuspidatus* has rough ornament, the process rises more in the aboral part of the plate, and has a rhombic cross section.

NANNOBLASTUS PYRAMIDATUS Wanner, 1924b
Pl. 46, figs. 14-24; Pl. 47, fig. 7; Table 51

Nannoblastus pyramidatus Bremier and Macurda, 1972, p. 43, Pl. XXXIII, figs. 1, 2, 5-7.

Description.– Thecae small, angular, strongly biconical (Pl. 46, fig. 21). Pelvic profile cup shaped with convex sides, except near base where stem attachment area interrupts profile; latter may form either short or elongate protuberance, tapering slightly proximally, circular in cross section. Pelvic profile varies from broad to narrow, dependent on length of basal protuberance and length to width of theca. Pelvis 1.6-4.25 times length of vault, average 2.3; greatest in smallest specimens where prong of deltoids has not grown out; least in specimens with elongate basal protuberance. Vault has hemispherical to broadly conical profile with truncate top where interrupted by gap between deltoid prongs; edges of deltoids convex or straight, providing difference in vault profile. Lower edges of vault profile slightly indented from edge of pelvis because of radial lip (Pl. 46, fig. 18). Vault varies from low and broad to high and narrow. Cross section of theca strongly pentagonal with slightly concave interambulacra (Pl. 46, figs. 14, 22). Greatest width at or slightly below plane of ambulacra. Width most always less than length (base of stem attachment area to tip of deltoid prong); width 0.80-0.95 of length except in larger specimens with basal protuberance; here 0.70; very occasionally width greater than length (1.07). Width of largest known incomplete specimens approaches 8.0 mm. Pelvic angle 70-80° in specimens in growth series except for longest with basal protuberances; here 56-60°. In basal view pelvis has strongly ribbed appearance, with ridges radiating from near origin of basals at proximal end to near origin of radials beyond aboral end of ambulacra (Pl. 46, figs. 15-17). Three ridges radiate away from center of each zygous basal, two from azygous basal, producing single ridge on C and E radials, and a pair of slightly asymmetric converging ridges on A, B, and D radials. Strength of development of ridges varies from weak to strong, but always imparting angular profile to plates in cross section. See Table 51.

Basals three, in plan view, with edges against C and E radials shorter. In lateral view narrowly to broadly conical edges convex except when merging with basal protuberance where concave. Proximal end of basals forms stem attachment area; latter low or prominent tapering cylindrical protuberance (Pl. 46, figs. 17, 21; Pl. 47, fig. 7); stem attached to proximal end in small concave depression with raised lip on proximal end of protuberance. Proximal end of protuberance diameter of 0.8-1.0 mm (0.4-0.7 in smaller specimens); diameter of area to which stem attached 0.4-0.6 mm; occasional short proximal cylindrical stem plate preserved; width 0.5-0.6 mm.

Azygous basal in AB interarea, length greater than width, quadrate in basal view with straight upper edges, straight lateral sides, lateral sutures converging on proximal surface. Lower surface of basal convex in cross section, upper portion strongly angular. Two ridges diverge in proximal portion and record gradual divergence of originally contiguous points on the theca; less regular single ridge continues to proximal edge of plate. If origin of plate is at point at which they meet, there has been some growth in a proximal direction to form the basal protuberance. Normal ornament nodose but occasional specimen with growth lines parallel to interbasal suture in proximal portion of suture would appear

TABLE 51. Growth relationships of principal variables of *Nannoblastus pyramidatus* Wanner, 1924

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	14	0.72	-0.67	1.33	4.2– 8.7	3.5– 6.2
V/P	14	0.77	-0.76	0.63	0.8– 3.3	3.4– 5.8
L/ABBR	14	0.87	2.11	2.17	4.2– 8.7	1.5– 3.0
L/RD	14	0.51	2.26	2.55	4.2– 8.7	1.1– 2.2
L/RB	14	0.44	2.34	1.55	4.2– 8.7	2.0– 3.2
L/Del.L.	14	0.70	-0.21	3.19	4.2– 8.7	1.5– 2.5
L/Amb.L.	14	0.89	1.89	8.49	4.2– 8.7	0.3– 0.8
RD/Amb.L.	14	0.38	1.27	0.73	1.1– 2.2	0.3– 0.8
Del.L./Amb.L.	14	0.56	1.47	1.18	1.5– 2.5	0.3– 0.8
ABL/ABW	15	0.55	0.26	1.20	1.5– 3.2	1.2– 2.0
ABBR/ABBRF	15	-0.07	2.24	-0.20	1.5– 3.0	0.8– 1.5
ZBL/ZBW	15	0.63	-0.39	1.20	1.5– 3.0	1.6– 2.5
ZBBR/ZBBRF	15	0.34	1.04	1.10	1.5– 3.1	0.7– 1.3
ABBR/RB	14	0.11	1.62	0.15	1.5– 3.0	2.0– 3.2
ABBR/RD	14	0.15	1.54	0.29	1.5– 3.0	1.1– 2.2
ABBR/Del.L.	14	0.46	0.25	0.84	1.5– 3.0	1.5– 2.5
RD/RDF	15	0.47	0.92	0.64	1.1– 2.2	0.6– 1.5
RR/RRF	15	0.62	0.77	0.44	1.3– 2.0	1.7– 3.0
RB/RBF	15	0.39	1.45	1.27	2.0– 3.2	0.7– 1.1
RD/RR	15	0.68	0.30	0.76	1.1– 2.2	1.3– 2.0
RD/RB	15	0.62	0.39	0.47	1.1– 2.2	2.0– 3.2
RR/RB	15	0.82	0.28	0.55	1.3– 2.0	2.0– 3.2
RD/Del.L.	15	0.68	0.25	0.66	1.1– 2.2	1.5– 2.5
RB/Del.L.	15	0.75	0.65	0.97	2.0– 3.2	1.5– 2.5
Del.L./Anal Del.L.	13	0.78	0.22	0.83	1.7– 2.5	2.0– 2.5
Amb.L./Amb.W.	14	0.93	-0.03	1.17	0.3– 0.8	0.3– 0.7
Amb.L./No. S.P.	14	0.56	-0.03	0.27	0.3– 0.8	1.0– 2.0

to indicate proximal extension along a BA axis. Development of growth along this axis quite variable, resulting in differences in development of basal protuberance. Distal portion of plate between two diverging ridges very slightly concave. Surfaces lateral to ridges slope downwards toward interbasal sutures; merge with surface of proximal portion of plate. Ornament either nodose or growth lines parallel to radial-basal sutures. Zygous basals two, centered under C and E radials, pentagonal in basal view, with slightly concave distal medial edge, very slightly concave lateral distal edges, and straight lateral edges. Ratio of length/width variable because of growth in proximal direction; usually length slightly less than width unless elongate basal protuberance. Three ridges originate in manner analogous to two on azygous basal; also less regular proximal continuation. Distal areas between ridges slightly concave; other comments for ornament for azygous basal also applicable. See Table 51.

Radials five, hexagonal, short, and broad in plan view with no indentation for ambulacrum. Height above basal suture large (0.8 mm in smallest specimen in growth series, increasing to a maximum of 2.1 mm). In plan view, C and E radials convex against basal; two proximal edges of A, B, and D radials very slightly convex. Width of radial expands orally (C and E narrowest: 1.2-1.8 mm; A, B, and D wider), expanding to maximum width at or slightly below junction with radiodeltoid suture. Lateral edges thus slightly to pronouncedly convex. Radiodeltoid sutures on lateral wall of theca external to ambulacral trough very slightly to slightly concave. Sixth edge of radial profile in plan view formed by edge of radial lip; concave. Within ambulacral trough, radiodeltoid sutures converge to a point at adoral end of ambulacrum which is borne only on radials. In lateral view radial has strongly angular triangular profile; lower edge slightly to more pronouncedly concave, dependent on width of theca; adoral-facing edge essentially straight except for indented area at radial lip; upper edge slightly convex to concave, reflexed if greatest width is below radial lip. Origin of radial near edge of radial lip; except for latter, radial slopes down toward sutures in all directions from this point. Radial-basal sectors of each radial bear one or two proximally diverging ridges (Pl. 46, fig. 21; Pl. 47, fig. 7); thus these sectors angular in cross section with straight or very slightly concave sides; median area between two diverging ridges slightly concave. RR sector slopes down toward interradial suture; essentially straight to very slightly concave in cross section. Ridge extends from approximate origin of each radial across interradial suture to same position on adjacent radial; development variable, very occasionally absent; usually barely discernible; may be extremely pronounced (Pl. 46, fig. 20). Rarely, other low ridges may parallel this in RR sectors perpendicular to interradial suture (Pl. 46, fig. 21). Radiodeltoid sectors small, medial portion interrupted by radial lip which in oral view is reminiscent of palm of a short stubby hand, with a convex top and slightly concave interior which supports the ambulacrum at its adoral end. On the lateral wall of the theca the lip appears as a convex shelf, rising above the origin of the plate, then sloping downward toward the ambulacrum. Ornament of radial variable. RR and RB sectors may be ornamented with fine growth lines parallel to sutures while radiating ridges are almost smooth or ridges may have nodes; very occasionally nodes along growth lines. Ablateral portions of radiodeltoid sector may be lightly ornamented but growth lines less regularly developed; ornament quickly becomes more massive and irregular toward radial lip; medial portions, particularly those bordering radial origin have heavy, massive, nodose ornament and this type of ornament covers origin of plate and may spread into medial portions of RR and RB sectors; more pronounced in larger specimens when developed (Pl. 46, figs. 19, 20). Stereomic lineations oriented perpendicular or almost so to sutures in RR and RB sectors of radials; have grown by addition of calcite along edges but apparently radial tip has grown upward and slightly inward from origin by secretion on a free surface, producing an RA growth sector; total length of latter growth not clear because of other nodose secretions but apparently 0.5-1.1 mm. Trabeculae in concavity of upper surface of radial lip are parallel to axis of ambulacrum and are directed outward. RWB: 1.2-1.8 mm; RWA: 1.7-2.9 mm; RW Amb.Trunc.: 0.8-1.5 mm. See also Table 51.

Deltoids four, together with epideltoid forming border to oral opening (Pl. 46, figs. 18, 22, 24). Vault best depicted as being a flat pentagonal surface from which five triangular pyramid-shaped prongs rise above ambulacra and oral opening, comprising body of deltoids and hypodeltoid. In plan view outline of deltoid is hexagonal with short concave adoral edge bordering oral opening (width invariant in growth series: 0.5 mm), adoral lateral edges long, diverging aborally at slightly less than 90° to adoral end of ambulacra (0.9-1.7 mm); lateral edges sub-parallel, converging slightly aborally, slightly concave, bordering adoral edges of ambulacra (in contact with radial beneath this), crossing hydrospire slit, and rising slightly in elevation in ambulacral trough to lateral edge of theca, in contact with radial throughout length. Aboral edge comprised of two segments which border edges to two adjacent radials and meet at approximately 180°; outline of aboral edge broad, shallow, adorally directed concavity; suture descends slightly on lateral wall of theca. Relatively little growth along edges of deltoids; length (oral center-aboral tip): 1.5-2.5 mm; greatest width at adoral end of ambulacrum: 1.3-2.8 mm; DDF: 0.9-1.7 mm. Thickness of deltoid along lateral edge varies; internal to oral opening, under surface of deltoid flares out as broad inverted triangle; edge of plate thickens to 0.5 mm beneath adoral end of prong and then thins to 0.3 mm by adoral end of ambulacrum. Upper adoral edge bordering oral opening ornamented by approximately three short minor grooves (Pl. 46, fig. 24); adoral lateral edges bear shallow main groove into which short shallow minor grooves enter at right angles, directly opposite one another. Minor grooves relatively widely spaced, at approximately 0.2 mm intervals. Total width of area that would have been covered by cover plates on neighboring deltoids 0.3-0.4 mm, apparently becoming slightly narrower aborally. Adoral and adoral lateral portions of deltoid have a broad, almost flat shelf (being very slightly concave), which together with neighboring deltoid form a very broad (0.5-0.9 mm wide near adoral end), shallow concavity which extends from oral opening to radial and merges with upper surface of radial lip, forming an ambulacral trough, the main groove being confined to the medial portion and the ambulacrum to the aboral end on the radial (Pl. 46, figs. 18, 22, 24). Most of deltoid is in the form of a sharp, triangular pyramid which rises from the surface of the deltoid (Pl. 46, fig. 19). Two surfaces face ambulacral trough; edges drop straight down, flare out at base to merge with trough. Surface smooth; straight to slightly convex outwards. Adoral edge between these faces oral opening, somewhat rounded; edge slopes very steeply downward toward oral opening (in some instances slightly recurved), flares outward in long concave arc at base to merge with adoral portion of plate. Aboral edge of pyramid slopes downward and outward, forming part of lateral wall of theca; edge is slightly to fairly markedly concave in cross section; edges with other lateral sides of pyramid fairly sharp; lateral profile of these edges straight to convex. Surface of aboral side variably ornamented with elongate nodose ornament. Upper apex of deltoid prong a rounded point. Interior of prong solid calcite. Stereomic lineations on outer surface of pyramid parallel polar axis; at base perpendicular to radiodeltoid suture. Lineations on inner facing sides of pyramid also parallel to polar axis. Prong of deltoid thus represents growth in a vertical direction from surface of plate; height of prong above lower edge of plate increases from 0.8 mm in smallest specimen to a maximum of 2.7 mm. See Table 51.

Anal deltoids two, an epi- and hypodeltoid. Adoral and adoral lateral edges of epideltoid have configuration and ornament as regular deltoid. Lateral edges border adoral half of ambulacrum; contracting slightly aborally. After passing beyond ambulacrum and bordering the radial, suture turns adorally toward anal opening, bordering hypodeltoid. Area of contact between epi- and hypodeltoid plates slants outward. When hypodeltoid is removed, that part of epideltoid prong in contact with hypodeltoid in contact with the radials internally. Epideltoid rises from ambulacral trough to form a rim around the anal opening; latter deeply embays aboral edges of epideltoid.

Hypodeltoid hexagonal in plan view, with concave adoral edges embayed by anal opening; two adoral lateral edges bordering epideltoid straight, diverge very rapidly aborally to a point just ablateral to edge of ambulacrum; lateral edges as for normal radiodeltoid suture aboral to ambulacrum as is aboral edge on wall of theca (Pl. 46, fig. 23). Hypodeltoid rises to form prong as regular deltoid except forward edge attenuated because of anus; adoral edge of hypodeltoid prong is concave and arched over anus, thus guiding anus upward and toward position above oral opening when extended. Apparently slightly shorter than regular prongs but growth data not available as plate has usually weathered off, leaving a prominent facet. Maximum width at edge of theca: 1.5-2.2 mm. One mutant hypodeltoid observed; radial extends farther adorally on D side and D side of normal hypodeltoid split into two smaller plates. Anal opening ovoid, width: 0.5-0.8 mm; length probably about equal. Anal opening opens upward on theca at same level as oral opening. Hypo.W.: 1.5-2.2 mm; O.c.-anus: 0.8-1.3 mm. See also Table 51.

Ambulacra five, very small, confined to aboral end of ambulacral trough (Pl. 46, fig. 24). Rhombic in plan view, with brachiolar facets arrayed as the crests of a small fan. Ambulacra appear to have changed very little in size during growth of theca; length and width 0.3 mm in smallest specimen; maximum in growth series 0.8 mm and 0.7 mm respectively. Number of brachiolar facets apparently four per ambulacrum for most of specimens in growth series; five visible in some larger specimens. Adoral brachiolar facets have longest side grooves; enter main groove at broader angle while more medial ones enter at acute angle since all at edge of fan-shaped ambulacrum. Lancet apparently broadly exposed with side plates confined to aboral edges of ambulacral fan. Small rounded triangular outer side plate forms part of adoral half of each facet; configuration of side plate not clear. Brachiolar facet faces outward; occasionally small depressions preserved in upper surface of radial lip which suggest area which may have supported brachiole.

Hydrospire slits six, one each side of ambulacrum, missing on C and D ambulacra; a short (0.3-0.5 mm) elongate ellipsoidal opening across the radiodeltoid suture just lateral to the ambulacrum.

Oral opening circular (occasionally rounded pentagonal); width: 0.6-0.8 mm.

Remarks.— The above description is based upon the specimens in the growth series (Appendix I). The internal anatomy and ontogeny were discussed and illustrated by Breimer and Macurda (1972).

The basic configuration of the plates in this species is the same throughout all specimens but the apparent variability in the appearance of specimens is due largely to variation in the deposits of calcite laid down upon the surface of the plates (length of deltoid prongs, degree of expression of radial and basal ridges, buildup of radial lip, etc.).

Family CERATOBLASTIDAE
Breimer and Macurda, 1972
Genus CERATOBLASTUS Wanner, 1940

Type species.— *Ceratoblastus nanus* Wanner, 1940. *Ceratoblastus* Breimer and Macurda, 1972, p. 43, 44.

CERATOBLASTUS NANUS Wanner, 1940
Pl. 47, figs. 1-4

Ceratoblastus nanus Breimer and Macurda, 1972, p. 43, Pl. XXXII, figs. 5, 11.

Description.— Theca extremely long and narrow, having the shape of a long, slender horn in lateral view, curved near base (direction of curvature non-constant in different specimens), with a very small restricted summit which occupies only the area of the mouth of the horn (Pl. 47, figs. 2, 3). Curvature apparently primary as present in six known specimens. Pelvis thus extremely elongate cone (pelvic angle 9-17°) with very gently curved sides (unless viewed parallel to plane bisecting curvature); vault low, dome shaped, 0.3-0.6 mm. Greatest width at ambulacral tips; cross section here strongly pentagonal with very slightly concave interambulacral areas. Cross section becomes rounded proximally (Pl. 47, fig. 1). Length much greater than width. See Table 52.

Basals three, in normal position, form lower half of pelvis; very elongate and narrow, circular pentagonal in plan view; conical in lateral view. Taper proximally to a very narrow base (0.5-1.2 mm); growth lines of BB axis visible near base but preservation insufficient to determine if BA axis or secondary deposits present or presence of crenellar ring. However, flatness of proximal surface suggests stem was present. Azygous basal quadrate, elongate, narrow, with long, straight, slowly diverging sides. Distal edges straight, meet at almost 180°. BR sector nearly straight parallel to BR axis, convex normal to it, merging smoothly with adjacent sector. Surface of plate ornamented with very fine, closely spaced, slightly wiggly growth lines (approximately 8 per 0.25 mm interval). Zygous basals pentagonal, also very narrow and elongate, with long straight sides and straight distal edges which meet at almost 180°. BR sectors nearly straight parallel to BR axis, flat or convex normal to BR axis, continuing flatness of pentagonal profile proximally. Ornament as for azygous basal. Almost all growth has been along BR axes. Growth of both radials and basals normal; trabeculae and fenestrations of stereom can be seen oriented perpendicular to radial-basal sutures in specimen no. 1 in growth series. ABL: 4.0-6.6 mm; ABW: 1.1-1.8 mm; ABBBF: 4.0-6.5 mm; ABBR: 4.0-6.6 mm; ABBRF: 0.7-1.1 mm; ZBL: 4.3-6.5 mm; ZBW: 1.4-2.4 mm; ZBOPt: 4.4-6.5 mm; ZBBR: 4.3-6.4 mm; ZBBRF: 0.4-0.7 mm.

Radials five, very long and narrow, with straight base (C and E radials) or two straight edges which meet at almost 180° (A, B, and D radials), long, straight sides which expand only slightly distally to edge of vault, then extend partially across vault to meet deltoid, contracting slightly as they do so. In lateral view radial has long, low triangular profile, with narrow side being the vault. RB sector nearly straight parallel to RB axis, flat normal to it, sectors merging over convex boundary, merging evenly with RR sector which is straight parallel and normal to RR axis; RD sector at pronounced angle to RR sector, apparently straight both parallel and normal to axis. Area occupied by RD sector very small; RR and RB quite large by comparison; RB and RR sectors ornamented by very fine growth lines which parallel sutures. See Table 52.

Deltoids four, together with epideltoid forming border to oral opening (Pl. 47, fig. 4). Deltoids short, broad, pentagonal in plan view; do not reach to edge of vault. Adoral edge concave, forms border to oral opening; width: 0.3-0.4 mm. Plate expands in width aborally

TABLE 52. Growth relationships of principal variables of *Ceratoblastus nanus* Wanner, 1940

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	4	0.84	-0.17	3.99	6.0–14.8	1.7– 3.5
RD/RDF	4	0.98	-0.03	1.90	0.5– 1.1	0.3– 0.6
RR/RRF	4	0.82	0.20	0.10	0.5– 1.0	3.5– 7.7
RB/RBF	4	0.93	-1.98	9.89	3.3– 7.2	0.5– 0.9
RD/RR	4	0.87	0.20	0.89	0.5– 1.1	0.5– 1.0
RD/RB	4	0.67	0.42	0.09	0.5– 1.1	3.3– 7.2
RR/RB	4	0.80	0.22	0.11	0.5– 1.0	3.3– 7.2
RD/Del.L.	4	0.73	-1.10	3.67	0.5– 1.1	0.5– 0.6
RB/Del.L.	4	0.99	-14.80	36.67	3.3– 7.2	0.5– 0.6
Del.L./Gr.Ab.W.	4	0.98	0.39	0.21	0.5– 0.6	0.5– 1.0

along straight DDF until meets radial(?), then tapers to a point aborally along very slightly convex sutures. Ornament comprised of an ovoid or horseshoe-shaped elevation (opening aborally), elevation highest adorally with a depressed interior; near aboral margin of plate. Opening apparently passing into interior on BC and DE deltoids. Small elongate, ellipsoidal-shaped depression present aboral to this, beginning on deltoid and continuing along interradial suture. Except for anal opening, rest of vault occupied by grooves and facets. Del.Gr. Ad.W.: 0.3-0.4 mm. See Table 52.

Adoral edge of epideltoid forms part of border of oral opening. Outline as for regular deltoid except for aborally tapering edges which are interrupted by a concavity for the anal opening. Suggestion of a horseshoe-shaped ridge adoral to anal opening. Anus ovoid, length and width almost equal. There do not appear to have been any other anal deltoids; anal opening of conventional form; grooves touch lateral edges of anal opening. Epi.Max.W.: 0.5-1.0 mm; O.c.-anus: 0.5-0.7 mm; Anus L.: 0.3-0.6 mm; Anus W.: 0.4-0.5 mm.

Ambulacra five, of unusual form. Each has the shape of a coniferous tree, with the side grooves being limbs inclined away from trunk; adoralmost side groove is the longest. All brachioles were attached along the very outer edge of vault and thus formed a pentagonal ring, interrupted only along the interradial sutures and at the anal opening (Pl. 47, fig. 4). In the largest specimen there are four brachiolar facets on each side of the ambulacrum. When viewed in plan view, with the anal opening north the outermost brachioles have the longest side groove. The outermost right hand brachiole has a side groove which leads almost to or to the oral opening. As one proceeds aborally along the main groove from this point, the outermost left side groove enters (and since it is coming from the edge of the vault, it is the second longest), then the next from the right, left, etc., until each side groove has entered. Because side grooves are subparallel and as deep as the main groove (which is shallow) and as wide (0.03 mm), pattern is that of an inverted conifer with straight limbs. Outermost side grooves of left side of C ambulacrum and right side of D ambulacrum have outer wall of groove interrupted by anal opening so grooves closely skirt lateral edges of anal opening. In plan view ambulacra are rhombic; lengths of main grooves 0.9-1.5 mm; maximum width of areas occupied by brachiolar facets 0.6-1.3 mm. There is a small ovoid knob present in the area between side grooves, beginning about one-third to one-half of distance from main groove to facet; adoral face steeper. Spacing between side grooves becomes closer aborally (spacing at right angles to grooves 0.28, 0.23, 0.15 mm respectively in largest specimen); size of knobs also decreases. Adoral and lateral edges of knobs between side plates and ovoid elevations in center of deltoid and epideltoid appear to be ornamented with small minor lobes and furrows. Thus a very large percentage of the vault would have been covered by ambulacral cover plates. Maximum width of area covered between deltoid prominences 0.4 mm. Pattern of cover plates in plan view would have been a tapering cone with stubby fingers where plates extend to ends of side grooves. Number of side grooves increases from smaller to larger specimens but growth pattern unclear because configuration of plates in ambulacrum (lancet, side, and outer side plates) unclear from external examination.

No regular hydrospires present; openings on BC and DE deltoids provide entrance to some type of internal sac.

Oral opening round, width: 0.3-0.5 mm.

Thickness of thecal wall 0.5 mm along interradial suture; thicker in median part of plate.

Distribution.– Permian, Sonnebait Series, Basleo, Timor, Indonesia.

Remarks.– The description of this species is based largely upon the holotype, supplement by others in the growth series (see Appendix I). Wanner ground two of the six known specimens to determine the nature of the hydrospires but found no trace of them. It is possible because of the very small size of the internal thecal(?) cavity that hydrospires were no longer necessary and had atrophied.

The internal anatomy and ontogeny were discussed by Breimer and Macurda (1972).

INCERTAE SEDIS
Genus INDOBLASTUS Wanner, 1924a

Type species.– Indoblastus granulatus Wanner, 1924a.

Indoblastus Breimer and Macurda, 1972, p. 44.

INDOBLASTUS GRANULATUS Wanner, 1924a
Pl. 47, figs. 5,6,8-12; Pl. 48, figs. 1-5;
Pl. 49, figs. 2-18; Table 53

Indoblastus granulatus Breimer and Macurda, 1972, p. 44, Pl. XXXII, fig. 2; Pl. XXXIII, fig. 4.

Description.– Theca rounded trapezoidal in size view with very broad, slightly convex vault; sides also slightly convex, gradual decrease in width aborally; base rounded convex with indentation at point of stem (Pl. 47, figs. 5, 12; Pl. 48, fig. 5; Pl. 49, fig. 7). Pentagonal to nearly round in oral view with convex interambulacral areas; greatest width at or slightly aboral to ambulacral tips (Pl. 47, figs. 6, 11; Pl. 48, figs. 1, 4). Vault very short, pelvis long. See Table 53.

Basalia three, simple, forming base and lower one-fourth to one-third of sides of theca. Pentagonal in plan view (Pl. 47, fig. 9; Pl. 48, fig. 3; Pl. 49, fig. 2). Azygous basal in AB interarea, rhombic shape in plan view, BR sector convex through 90° parallel to growth axis; slightly convex normal to BR axis. Lateral edges of azygous basal straight; distal edges slightly sinusoidal. Zygous basals pentagonal in plan view, with straight lateral edges, very slightly sinusoidal distal lateral sutures, and a concave distal medial suture. BR sectors convex through 90° parallel to growth axis; central BR sector more convex normal to axis than are lateral sectors which are flat or only very slightly convex. Surfaces are ornamented with low, broad growth lines parallel to BR fronts; rarely may have small granules on growth lines. BB very slow rate of growth; BR growth lines turn into this sector where very fine growth lines present (Pl. 48, figs. 2, 3); rarely preserved. Origin of basals proximal to lowest point on theca; slight recurvature from lowest point through origin of each plate into proximal junction where stem attachment located (Pl. 49, fig. 6). Proximal interbasal sutures thus in very shallow, broad concavity. Stem attachment area at proximal junction of basals, being a small circular depression with a low raised lip due to secondary calcite; short ridge extends from lip to apparent origin of basals. Diameter: 0.9-1.8 mm. Crenellae apparently at edge of stem plates. See Table 53.

Radials five, pentagonal in plan view, with a convex or two slightly sinusoidal lower edge(s); interradial sutures very slightly convex, C and E radials increasing slightly in width to point near aboral tip of ambulacrum, then decreasing slightly in width to radiodeltoid suture. A, B, and D radials broader at base so width decreases adorally. Radial body long, forming three-fourths of side of theca; limbs short, bent over on upper convex side, forming one-third of very slightly convex vault. In lateral view radial has triangular profile with short straight edge bordering ambulacrum; long, slightly convex edge along interradial suture. RD sector small, straight parallel to growth axis and slightly convex normal to the axis; RD sector rounds into RR sector. RR sector very slightly convex parallel to RR growth axis and slightly convex normal to axis. RB sector is slightly convex parallel to RB axis and very slightly convex normal to it; RB and RR sectors merge smoothly. Ornament of radial consists of broad growth lines parallel to RDF, RRF, RBF (7-8/mm on RR axis); rarely irregular low granulose ornament on growth lines, become more pronounced in RD sector. RWB:

TABLE 53. Growth relationships of principal variables of *Indoblastus granulatus* Wanner, 1924

Variables	n	r	a_0	a_1	Observed Range y	x
L/W	8	0.93	2.20	0.92	11.6–29.6	10.5–28.2
V/P	7	0.71	-1.16	0.27	1.0– 7.5	10.4–25.6
L/ABBR	7	0.99	-1.05	2.37	11.6–29.6	5.2–12.4
L/RD	8	0.90	6.71	2.44	11.6–29.6	2.0– 8.9
L/RB	8	0.99	-0.43	1.68	11.6–29.6	6.9–18.0
L/Del.L.	8	0.98	0.98	2.62	11.6–29.6	4.0–11.0
L/Amb.L.	7	0.98	6.95	2.11	11.6–28.0	2.3–10.4
RD/Amb.L.	9	0.93	0.67	0.86	2.0– 9.5	2.3–10.4
Del.L./Amb.L.	9	0.94	2.28	0.85	4.0–11.5	2.3–10.4
ABL/ABW	6	0.95	-0.06	0.93	5.9–13.5	6.8–15.3
ABBR/ABBRF	6	0.94	-0.20	1.38	5.2–12.4	4.1– 9.6
ZBL/ZBW	6	0.97	-0.75	0.81	5.3–13.0	7.6–18.3
ZBBR/ZBBRF	6	0.96	0.00	1.74	4.9–12.5	2.6– 7.5
ABBR/RB	7	0.98	0.53	0.69	5.2–12.4	6.9–18.0
ABBR/RD	7	0.95	2.98	1.13	5.2–12.4	2.0– 8.9
ABBR/Del.L.	7	0.99	0.78	1.15	5.2–12.4	4.0–10.0
RD/RDF	16	0.95	-0.07	1.70	2.0–10.4	1.5– 6.5
RR/RRF	16	0.95	-0.04	0.49	3.0–10.3	7.3–21.9
RB/RBF	16	0.79	2.48	2.08	6.9–24.0	3.0– 8.5
RD/RR	16	0.94	-1.20	1.10	2.0–10.4	3.0–10.3
RD/RB	16	0.87	-0.54	0.51	2.0–10.4	6.9–24.0
RR/RB	16	0.92	0.61	0.46	3.0–10.3	6.9–24.0
RD/Del.L.	10	0.97	-1.36	0.97	2.0– 9.5	4.0–11.5
RB/Del.L.	10	0.97	1.26	1.50	6.9–18.0	4.0–11.5
Del.L./Gr.Ab.W.	7	0.97	-0.23	1.22	4.6–11.0	4.1–10.5
Del.L./Anal Del.L.	8	0.94	-0.42	1.03	4.0–11.5	4.5–10.7
Amb.L./Amb.W.	9	0.97	-0.70	3.37	2.3–10.4	1.0– 3.5
Amb.L./No. S.P.	9	0.88	0.15	0.66	2.3–10.4	5.0–16.0

5.0-13.0 mm; RWA: 5.5-17.3 mm; RWD: 4.6-14.8 mm. See also Table 53.

Deltoids four, together with epideltoid form border of oral opening; rhombic in plan view (Pl. 47, figs. 8, 10), slightly convex both lengthwise and in width; on upper surface of theca. Radiodeltoid suture a simple V, slightly greater than 90°. Adoral tip of ambulacra just adoral to lateral points of rhomb of deltoid. Adoral edge of deltoid straight; DDF long, bear narrow V-shaped main groove with low minor lobes and grooves which reach almost to the main groove. Deltoid expands in width aborally, greatest at adoral tip of ambulacrum. Deltoids ornamented with granulose ornamentation, revealing mode of growth. More prominent rows of granules parallel the adoral edge. In center and aboral portion of plate growth lines can be seen paralleling radiodeltoid suture. Rarely, development of granules on DRF growth lines. Growth along DD axis with consequent reformation of food groove adoral to this; aboral to this growth along DR axis. Del.Max.Ad.W.: 2.2-8.7 mm; DD: 1.1-2.2 mm; DDF: 2.1-7.1 mm; DR: 2.0-7.1 mm. See also Table 53.

Anal deltoids two, epi- and hypodeltoid (Pl. 49, figs. 3, 5), surround elongate ellipsoidal anal opening which represents the highest elevation on the theca. The anal deltoids slope gradually up to this point and are elevated above the level of the other deltoids around the anal opening. Epideltoid as for regular deltoid adoral to ambulacra; prongs of epideltoid reach radiodeltoid suture. Epihypodeltoid suture slants aborally from point of origin on lateral aboral margin of anal opening. Hypodeltoid rhombic in overall shape (Pl. 49, fig. 3), mostly forming part of upper sloping side of theca but adoral edges turn over onto upper surface. Granulose ornamentation on epideltoid; it grew along DD and epihypodeltoid suture with both contributing to aboral ontogenetic migration of anal opening. Hypodeltoid ornamented with low, broad growth lines (rarely there is granulose ornament on the lines) parallel to hyporadial suture; most growth along this suture. Unknown if hypodeltoid grew along epihypodeltoid suture as well. Epi.Gr.Ad.W.: 2.9-8.0 mm; O.c.-ad.e.anus: 2.2-4.3 mm; Anus L.: 1.0-2.6 mm; Anus W.: 0.6-1.5 mm; Hypo.L.: 1.5-6.0 mm; Hypo. W.: 2.2-7.7 mm. See also Table 53.

Ambulacra five, adoral end relatively far away from oral opening. Shape elongate elliptical-spatulate, with greatest width toward aboral end (Pl. 49, figs. 4, 8). Abmedial edges of side and outer side plates merge with theca; ambulacra elevated above surrounding plates. Relatively short in smaller specimens and on upper surface but in larger specimens located on outer half of top of theca and uppermost part of side of theca; convex through 90° in lateral view. Side plates large (1 per mm; in most blastoids 2.5-3/mm), wide, abmedial edge embayed by large triangular outer side plate. Lancet covered by side plates except at adoral end; rhombic shaped area 1.0 by 0.8 mm exposed. Lancet underlies approximately half of ambulacrum (4.0-7.0 mm) so aboral plates rest directly on radial. Main groove bordered by many minor lobes and grooves; long, very slightly sinusoidal side grooves also bordered by these. Brachioles attached to a small heart-shaped facet (length: 0.30 mm; width: 0.35 mm) at very edge of ambulacrum; equally developed on side plate and outer side plate. See Table 53.

Very short, straight, narrow hydrospire slits (length: 0.7 mm); one present on each side of ambulacra except in anal interarea; sited at adoral end of ambulacrum across radiodeltoid sutures, lie mostly on deltoid. Aboral end of slit borders ambulacrum, adoral end diverges away into deltoid as ambulacra contracts in width adorally. Slight ridge on deltoid of one specimen between DR and DD sectors may represent ontogenetic migration of spiracle slits.

Oral opening small, pentagonal.

Distribution.— Permian, Timor, Indonesia.

Remarks.— The above description is based upon the specimens in the growth series (Appendix I). The internal anatomy and ontogeny were discussed and illustrated by Breimer and Macurda (1972). *Indoblastus nuciformis* Wanner, 1940 was synonymized with *I. granulatus* in this publication because it is an immature individual of *I. granulatus*.

INDOBLASTUS WEBERI (Wanner), 1924a
Pl. 49, fig. 1

Indoblastus weberi Breimer and Macurda, p. 44, Pl. XXXIII, fig. 3.

Description.— Theca of holotype squashed, outline in lateral view originally broad, rounded, squat, being widest near base and decreasing adorally. Cross section round. Length and width of holotype originally about 20 mm. Vault very short, being restricted to top of theca.

Basals not well preserved; that in AB interarea large, broad, convex. Surface ornament not preserved.

Radials broad, convex, with very short radial sinus in plan view. Greatest width is near aboral extremity. Radial broadly convex in lateral view. RD sector very small, confined to upper surface of theca, essentially straight parallel to RD axis and very slightly convex perpendicular to it. RR sector slightly convex parallel to RR axis and convex perpendicular to it. RB sector large, convex parallel and perpendicular to RB axis. No surface ornament preserved. Adjacent radial sectors merge smoothly. RWB about 12 mm; RWD: 6.4 mm; RD: 2.5 mm; RDF: 2.2 mm; RR: 4.3 mm; RRF: 15 mm (va); RB: 15 mm (va).

Deltoid relatively small, confined to upper flat surface, outline rhombic, very slightly convex lengthwise and in cross section. Adoral edge straight; width expands along straight DDF, expansion continuing along concave DAF; contraction occurs along straight DRF, meeting at about 135°. Origin of plate near adoral edge at a low knob; moderately developed; DD sectors sloping slightly upward from ambulacral tract. Low broad crest in center of DR sector; plate slopes gently downward from this. A small trough parallel to main groove borders the DD sector and leads from origin to adoral end of hydrospire slit. Del.L.: 4.3 mm; Gr.Ad.W.: 3.0 mm; Gr.Ab.W.: 4.0 mm; DR: 2.8 mm; DD: 1.1 mm; DDF: 1.5 mm; DAF: 2.1 mm.

Anal deltoids two, an epi- and hypodeltoid. Large epideltoid, as for adoral part of regular deltoid; prongs abut against radials, isolating hypodeltoid from ambulacra. Hypodeltoid relatively large, horseshoe shaped, on outer upper sloping surface of theca, convex aboral edge; straight lateral edges, tapering adorally; concave adoral edge. Plate convex in both length and width. Anal opening ovoid, opening directly upward at a level slightly above that of oral opening. Anal Del.L.: 6.2 mm; Epi.Gr.W.: 4.2 mm; HDL: 2.5 mm; HWD: 3.7 mm; Anus: L: 2.2 mm; W: 1.5 mm.

Ambulacra five, short, linear (aboral tip rounded), confined to upper surface of theca, slope slightly downward from center of oral opening. Adoral end approximately 2 mm from oral opening. Ambulacrum concave in cross section, slightly depressed relative to radial and deltoids. Side plates cover lancet in aboral half; adoral half not well enough preserved to be determined, but possibly exposed as a rhombiform area at the adoral end. Side plates quadrate, wider than long, two angular edges along main groove, ad- and aboral edges parallel, only slightly rotated aborally; small, triangular outer side notches lateral margins of side plates, more so adoral edge; length: 0.2 mm; width: 0.25 mm. Both side and outer plates form lateral margins of ambulacrum. Brachiolar facet not preserved. Amb.L.: 3.5 mm; Amb.W.: 1.2 mm; 3 side plates/mm.

Eight hydrospire groups, one slit per group, lacking in anal interarea. Each slit a short (1.3 mm) opening across radiodeltoid suture, apparently just under lateral edge of ambulacrum.

Oral opening relatively large, about 2 mm across.

Distribution.— Permian, Tuani, Niki Niki, Hata Dame, Ramelau Mountains, Timor, Indonesia.

Remarks.— The above description is based upon the holotype, Geologische Palaontologische Institute, Friedrich Wilhelm University, Bonn, no. 127B.

Indoblastus weberi is distinguished from *I. granulatus* by the squat ovate form of the theca, the radials being widest at the base and much more restricted at ambulacra. *I. weberi* was the type species of the genus *Sundablastus*, but these two genera have the same number of hydrospire groups and the other generic characters are the same. Wanner (1940) figured a second specimen of *I. weberi* but its whereabouts is now unknown.

LITERATURE CITED

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APPENDIX 1

Localities for specimens used in growth series.

Family Phaenoschismatidae

Decaschisma pulchellum (Miller and Dyer, 1878)

Specimens 1, 4-6, 8-10. Field Museum, Chicago. Formerly Walker Museum, University of Chicago No. 2810. Washburn collection. Silurian, Niagaran, Waldron, Indiana. Above specimens now cataloged as 2810A-G respectively.

Specimen 2. University Oklahoma 3233. Waldron Shale, Waldron, Indiana.

Specimen 3. Field Museum, Chicago. Formerly Walker Museum, University of Chicago 18875. Gurley collection. Niagaran, Waldron, Indiana.

Specimens 7, 11. Field Museum, Chicago. Formerly Walker Museum, University of Chicago 18913. Gurley collection. Niagaran, Hartsville, Indiana. Above specimens now cataloged as 18913A and B respectively.

Specimens 12, 13. Field Museum, Chicago. Formerly Walker Museum, University of Chicago 18912. Gurley collection. Niagaran, Shelby County, Indiana. Above specimens now cataloged as 18912A and B respectively.

Specimens 14, 15. Field Museum, Chicago. Formerly Walker Museum, University of Chicago 2554. Washburn collection. Niagaran, Waldron, Indiana. Now cataloged as 2554A and B respectively.

Specimen 16. Field Museum, Chicago. P 19660. Niagaran Group, Waldron, Indiana.

Polydeltoideus enodatus Reimann and Fay, 1961

Specimens 1, 2. UMMP 47560, 47478. Silurian, Henryhouse Formation, Lawrence uplift near Ada, Oklahoma.

Specimens 3, 11. USNM 160699, 160700. Henryhouse Formation, CNW¼ SW¼ sec. 33, T3N, R6E, Pontotoc County, Oklahoma.

Specimens 4, 5, 7, 8. USNM 160701-160704. Henryhouse Formation, south of Ada, Oklahoma.

Specimens 6, 12. USNM 139569, 160705. Henryhouse Formation (upper). SW¼ NW¼ NW¼ sec. 33, T3N, R6E, Pontotoc County, Oklahoma.

Specimens 9, 18. USNM 139567, 139568. Henryhouse Formation (upper coral beds). N½ SW¼ sec. 4, T2N, R6E, Pontotoc County, Oklahoma.

Specimens 10 (Holotype), 13, 15, 16. UMMP 37805, 37807, 37806 and 43930. Henryhouse Formation. SE¼ SE¼ SE¼ NE¼ sec. 5, T2N, R6E, east side of road, Pontotoc County, Oklahoma.

Specimen 14. USNM 139566. Henryhouse Formation. East side of road in bluff for one-half mile. NW¼ SW¼ sec. 4, T2N, R6E, Pontotoc County, Oklahoma.

Specimen 17. USNM 160706. Henryhouse Formation. NW¼ SW¼ sec. 4, T2N, R6E, Pontotoc County, Oklahoma.

Leptoschisma lorae (Dunbar, 1920)

Specimens 1-4, 6-8. USNM 160707-160713. Devonian, Birdsong Formation. Tributary to Lick Creek, on west bank, 1.2 miles north of Tennessee highway 69, northeast of Jeanette, Sugar Tree TVA quadrangle, Tennessee.

Specimen 5. USNM 160714. Birdsong Formation. Cedar glade on hillside in timber on small tributary to Lick Creek on west bank, 1.2 miles north of Tennessee highway 69, northeast of Jeanette, Sugar Tree TVA quadrangle, Tennessee.

Specimen 9. Peabody Museum 9730, Yale University. Birdsong Formation. 1.5 miles south of Allen's Mill, Tennessee.

Specimen 10. USNM 27759. Birdsong Formation, near Chaseville, Wolf Creek, Benton County, Tennessee.

Caryoblastus bohemicus Breimer, Macurda, and Prokop, 1968

Specimens 1-10, 12, 13. Plas and Prokop collections. Geological Survey and Natural History Museum, Prague, Czechoslovakia. Lower Devonian, Slivenec Limestone, Konvarka, Bohemia, Czechoslovakia.

Cryptoschisma schultzii (De Verneuil and d'Archiac, 1845)

Specimens 1-17. UMMP 60599-60615. Devonian, La Vid Formation, Colle, Leon, Spain.

Pentremitidea pailleti (De Verneuil, 1844)

Specimens 1-16. A. Breimer collection, Institute Earth

Sciences, Free Reformed University, Amsterdam. Devonian, Calcaire de Ferrones, Ferrones, Spain.

Pentremitidea archiaci (Etheridge and Carpenter, 1882)

Specimens 1-20. UMMP 60616-60635. Devonian, La Vid Formation, Colle, Leon, Spain.

Pentremitidea lusitanica Etheridge and Carpenter, 1882

All specimens A. Breimer collection, Institute Earth Sciences, Free Reformed University, Amsterdam.

Specimens 1, 2. Devonian, La Vid Formation, Portilla de Luna, Leon, Spain.

Specimens 3-5. Top of La Vid Formation, Colle, Leon, Spain.

Specimen 6. Fenolleda, Oviedo, Spain.

Pleuroschisma lycorias (Hall, 1862)

Specimens 2-5, 13. USNM 160715-160717, UMMP 35033, USNM 160719. Devonian Hungry Hollow Formation, Hungry Hollow of Ausable River valley, 2.0-2.5 miles northeast of Arkona, Ontario, Canada.

Specimens 6, 9. UMMP 56499, USNM 114491 (latter the holotype of *Pleuroschisma ontario* Reimann, 1945). Hungry Hollow Formation, Tileyard, 1.0 mile north of Thedford, Ontario, Canada.

Specimen 7. USNM 160718. Hungry Hollow Formation, Harrison's Field, Thedford, Ontario, Canada.

Specimen 8. UMMP 62253. Moscow Shale, Kashong Member, Tributary of Cayuga Creek, road from West Alden to Cowlesville, Erie County, New York.

Specimens 10, 11. BSNS E15936, E15937. Hungry Hollow Formation near Thedford, Ontario, Canada.

Specimen 12. I. G. Reimann collection. Hungry Hollow Formation, Thedford, Ontario.

Specimens 14, 16-18. I. G. Reimann collection (16), BSNS E15987, E16305, E11800. Moscow Shale, Kashong Member, Salt shaft, Wadsworth, New York.

Specimen 15. BSNS E15700. Moscow Shale, Kashong Member, West Alden, New York.

Specimen 19. Kopf collection, University of Cincinnati. (Holotype of *Pleuroschisma hibbardi* Reimann, 1945). Centerfield Limestone, East Alexander, New York.

Specimens 20-22. University of Cincinnati 37405a, 37405b, 37133. Moscow Shale, Livingston County, New York.

Pleuroschisma verneuili (Etheridge and Carpenter, 1882)

Specimen 1. University California Los Angeles 31680. Devonian, La Vid Formation, Colle, Leon(?), Spain.

Specimens 2, 3. BMNH E832, E8030. Cotypes. Calcaire d'Arnao (=La Vid Formation), Colle, Leon, Spain.

Specimens 4, 7. A. Breimer Collection. Institute Earth Sciences, Free Reformed University, Amsterdam. La Vid Formation, Colle, Leon, Spain.

Specimens 5, 6. A. Breimer collection. Institute Earth Sciences, Free Reformed University, Amsterdam. La Vid Formation, Villayandre, Leon, Spain.

Specimens 8-19. Museo del Instituto geologico y Minera de Espana en Madrid. La Vid Formation, Colle, Leon, Spain.

Specimens 20, 21. BMNH 663b, 663a. (Cotypes of *Phaenoschisma nobile* Etheridge and Carpenter, 1883). Calcaire d'Arnao (=La Vid Formation), Colle, Leon, Spain.

Specimens 22, 23. A. Breimer collection. Institute Earth Sciences, Free Reformed University, Amsterdam. Arnao Limestone, Arnao, Asturias, Spain.

Heteroschisma alatum (Reimann, 1935)

All specimens from Devonian, Potter Farm Formation. Shale pit just west of Evergreen Cemetery. NW¼ SW¼ sec. 21, T31N, R8E, Alpena County, Michigan.

Specimens 1, 3-8, 10, 12, 13. USNM 160720-160729.

Specimens 2, 9, 11, 14. UMMP 33733, 62257, 62255, 62256.

Heteroschisma alternatum (Lyon, 1857)

Growth series I

Specimens 1-65. Collections of USNM (S3201, 3203, 3204, 3207, 3214, 4534, 4536-4538, 4541, 4542, 4545, 4546, 4550, 4554, 4555, 4558-4561, 4563-4568, 4570-4581, 4584-4586, 4590, 4591, 4598, 4600, 4601, 4603, 4604, 5403-5416) and AMNH (23790, 23791, 23796) from various localities in the Jeffersonville Limestone, in and near Louisville, Kentucky. See Cline and Heuer, 1950. Catalog numbers do not correspond to numerical order in growth sequence.

Growth series II

Specimens 1-31. UMMP 62258-62288. Devonian, Jeffersonville Limestone, *Paraspirifer acuminatus* zone. Roadcuts on northeast and southwest sides of dual lane Kentucky Route 871, just southwest of its intersection with U.S. Route 42, 8 miles northeast of Louisville, Kentucky.

Growth series III

Specimens 1, 3-6, 8, 10, 11. OSU 14519. Devonian, Columbus Limestone, Columbus, Ohio.

Specimens 2, 16, 22, 24. AMNH 25920, 4173/1, and 4173 (latter two). Western Upper Helderberg, 8-12 feet below black slate, Columbus, Ohio.

Specimens 7, 23. AMNH 4173. Western Upper Helderberg, Columbus, Ohio.

Specimens 9, 14, 15, 17, 20, 21. USNM 114326, 160570, 160571, 114325, 160572, 114324. Onondaga, Columbus, Ohio.

Specimens 12, 19. OSU 19852, 19853. Columbus Limestone, Columbus, Ohio.

Specimens 13, 18. AMNH 23885. Columbus, Ohio.

Heteroschisma canadense (Billings, 1869)

Specimens 1-3, 7. UMMP 62298-62301. Devonian. Hungry Hollow Formation, Hungry Hollow of Ausable River, 2-2.5 miles northeast of Arkona, Ontario.

Specimens 4-6, 8-20. USNM 160731-160746. Hungry Hollow Formation, Hungry Hollow of Ausable River, 2-2.5 miles northeast of Arkona, Ontario.

Heteroschisma subtruncatum (Hall, 1858)

Growth series I

Specimens 1-7, 13, 14. UMMP 62289-62297. Devonian. Thunder Bay Limestone. North side of Partridge

Point, SE¼ sec. 30, T8N, R11E, four miles south of Alpena, Michigan.

Specimens 8-12. USNM 160747-160751. Thunder Bay Limestone. North side of Partridge Point, SE¼ sec. 30, T8N, R11E, four miles south of Alpena, Michigan.

Growth series II

Specimens 1, 4. State University Iowa 11507a, b. Devonian. Cedar Valley Limestone, *Bellula* zone. Dewey Portland Cement quarry, Linwood, Iowa.

Specimens 2, 3, 5. USNM 160753-160755. Cedar Valley Limestone, Brandon substage, *Euryocrinus* zonule, Iowa.

Phaenoschisma acutum (Sowerby, 1834)

Specimen 1. BMNH 8130. Holotype. Lower Carboniferous, Carboniferous Limestone, Bolland, Lancashire, England.

Specimen 2. Manchester Museum L8706A. Bellman Park (apparently Bellman Park knoll in the Salt Hill-Warsaw knoll series), Clitheroe, Lancashire, England.

Specimens 3-5. UMMP 60597, 62302, 62303. Lower Carboniferous. Upper Clitheroe Limestone, C2 subzone. Disused eastern end of Bellman Park quarry, coor. 763429, Salt Hill knoll, Clitheroe, England.

Phaenoschisma conicum (Fay, 1962)

Specimens 1, 2, 4-6, 8. University Oklahoma 4344, 4345, 4346, 4347A, 4347B; USNM S5694. Mississippian, Lake Valley Limestone, Nunn Member, Lake Valley, New Mexico.

Specimen 3. UMMP 58664. Lake Valley Limestone, Nunn Member. Dump beside small prospect, on south side of high part of Apache Hill, SW¼ SW¼ SE¼ NW¼ sec. 21, T18S, R7W, Lake Valley quadrangle, Sierra County, New Mexico.

Specimen 7. USNM 160756. Lake Valley Limestone, Nunn Member. NNE and NW slope of Apache Hill, SE¼ NE¼ NW¼, NE¼ SE¼ NW¼, and SW¼ NE¼ NW¼ sec. 21, T18S, R7W, Lake Valley quadrangle, Sierra County, New Mexico.

Phaenoschisma gracillimum (Rowley and Hare, 1891)

Specimens 1-6. University Illinois RX-131, RX-131B, RX-131A, RX-131D, RX-131E, RX-131F. Mississippian, Burlington Limestone, Louisiana, Missouri.

Phaenoschisma laeviculum (Rowley, 1900)

Specimens 1-7. University Illinois RX-94G, H, X, F, A, S, T. Mississippian, Burlington Limestone, Louisiana, Missouri.

Phaenoschismatid UB

Specimens 1-16. UMMP 60679-60694. Mississippian, Lodgepole Formation. One-foot bed of limestone approximately five feet below massive ledges, first major gully west of ridge, south side of Bandbox Mountain. NE¼ NW¼ sec. 20, T14N, R10E, Cascade County, Little Belt Mountains, Montana.

Phaenoschisma? *parvum*

Specimen 1. UMMP 62304. Mississippian, Lake Valley Limestone, Nunn Member. Dump beside small prospect, on south side of high part of Apache Hill, SW¼ SW¼ SE¼ NW¼ sec. 21, T18S, R7W, Lake Valley quadrangle, Sierra County, New Mexico.

Specimens 2-5, 9, 10. USNM 160581, 160579, 160758, 160580, S5485, S5486. Lake Valley Limestone, Nunn Member, Apache Hill, Lake Valley, New Mexico.

Specimens 6-8. USNM 160759(7)-160760(8); number 6 peeled. Lake Valley Limestone, Nunn Member. NNE and NW slope of Apache Hill, SE¼ NE¼ NW¼, NE¼ SE¼ NW¼, and SW¼ NE¼ NW¼ sec. 21, T18S, R7W, Lake Valley quadrangle, Sierra County, New Mexico.

Phaenoschisma? *saharae* Breimer and Macurda, 1972

Specimens 1, 10. Pareyn collection, Université de Caen 437. Carboniferous, Visean, Akacha-Mazzer Formation, Ioucha 10 (=Dalle à *Syringothyris*). Couverture stratifice du Djebel Koucha (massifs récifaux du Grand Erg Occidental, rive gauche de la Zousfana), Algeria.

Specimens 2-9, 11. Pareyn collection, Université de Caen 3420A-H, 518. Carboniferous, Visean. Djenien Formation, Mouizeb el Atchane Member. Col du Tenient el Aouidja, au Nord du Chabet el Oubeur, Rive gauche de l'Oued Zousfana, Algeria.

Phaenoblastus caryophyllatus (de Koninck and le Hon, 1854)

Specimens 1-15. See Macurda, 1967a, p. 483.

Pentremoblastus conicus Fay and Koenig, 1963

Specimens 1-5. University Missouri 15180, 15187, 15184, 15185, 15183. Mississippian. McCraney Formation, Seahorn Hollow, SW¼ NE¼ SW¼ sec. 31, T3S, R7W, Adams County, Illinois.

Kazachstanoblastus carinatus Arendt, Breimer, and Macurda, 1968

Specimens 1-7. Paleontological Institute, Academy Sciences, Moscow. PIN 1788/301, 1787/3, 1787/2, 1788/300, 1787/7, 1787/5, 1787/323. Carboniferous, Namurian, Dombar Hills, Zhaksa-Kargol River basin, 1 km SW of Tshan-Tshar, Aktiubinsk districk, North Kazachstan, U.S.S.R.

Family Orophocrinidae

Brachyschisma corrugatum (Reimann, 1935)

Specimen 1. Unregistered specimen. Oklahoma Geological Survey.

Specimens 2, 4, 6, 8, 12-14. I. G. Reimann collection.

Specimens 3, 10. BSNS 16045, E9070 (Cotypes of *Brachyschisma subcrassum* Reimann, 1945).

Specimens 5, 9. BSNS E15981, E12133 (Cotypes of *Brachyschisma subumbrosum* Reimann, 1945).

Specimen 7. BSNS E12581.

Specimen 11. USNM S4063. (Holotype of *Codaster curtus* Reimann, 1935). Devonian, Tichenor Limestone, 18 Mile Creek, Erie County, New York.

Specimens 1-10, 12-14. Devonian, Onondaga Limestone, Vogelsanger quarry, Williamsville, New York.

Katoblastus konincki Macurda, 1967

Specimens 1-7. See Macurda, 1967a, p. 483.

Katoblastus pūzos (Münster, 1843)

Specimens 1-8. See Macurda, 1967a, p. 483.

Orophocrinus catactus Rowley, 1908

Specimens 1-9. See Macurda, 1965, p. 1091-1092.

Orophocrinus conicus Wachsmuth and Springer, 1888
Specimens 1-22. See Macurda, 1965, p. 1092.
Orophocrinus gracilis (Meek and Worthen, 1870)
Specimens 1-6. See Macurda, 1965, p. 1092.
Orophocrinus orbignyanus (De Koninck, 1844)
Specimens 1-8. See Macurda, 1965, p. 1092.
Orophocrinus pentangularis (Sowerby, 1834)
Specimens 1-7. See Macurda, 1965, p. 1092.
Orophocrinus saltensis Macurda, 1965
Specimens 1-12. See Macurda, 1965, p. 1093.
Orophocrinus stelliformis (Owen and Shumard, 1850)
Specimens 1-39. See Macurda, 1966, p. 120-121.
Orophocrinus verus (Cumberland, 1826)
Specimens 1-8. See Macurda, 1965, p. 1093.
Mastoblastus ornatus Arendt, Breimer, and Macurda, 1968
Specimens 1-22. Paleontological Institute, Academy Sciences, Moscow. PIN 1788/321, 1788/312, 1788/311, 1788/313, 1787/8, 1787/18, 1787/15, 1787/16, 1787/13, 1787/12, 1787/11, 1788/315, 1788/305, 1788/306, 1788/308, 1787/17, 1788/314, 1787/19, 1788/303, 1788/302, 1788/310, 1788/307. Carboniferous, Namurian, Dombar Hills, Zhaksa-Kargol River basin, 1 km SW of Tshan-Tshar, Aktiubinsk district, North Kazachstan, U.S.S.R.
Pentablastus supracarbonicus Sieverts-Doreck, 1951
Specimens 1-10. Rijksmuseum, University Leiden 102451, 102473, 102452, 102463, 102458, 102454, 102457, 102453, 102456, 102474. Carboniferous, Upper Namurian, Rabanal Limestone, Rabanal de los Caballeros, Palencia, Spain.
Anthoblastus stelliformis Wanner, 1924
Specimens 1, 2. University Amsterdam, unregistered specimens. Permian. Near Basleo, Timor, Indonesia.
Specimens 3, 4. University Amsterdam Ge.0.9929, 0.9928. Permian, Noko, Timor, Indonesia.
Specimens 5, 6. Breimer collection, Institute Earth Sciences, Free Reformed University, Amsterdam. Permian, Sum Peh, Timor, Indonesia.
Specimen 7. Manchester University L8549. Permian, Timor, Indonesia.
Specimens 8, 9. Technische Hogeschool, Delft 12266 (holotype), 12265. Permian, Basleo, Timor, Indonesia.
Specimen 10. Rijksmuseum, University Leiden. Unregistered specimen. Permian (loc. 29), Timor, Indonesia.
Family Neoschismatidae
Hadroblastus convexus Fay, 1962
Growth series I
Specimens 1, 3-8. USNM 160761, 160763-160767, 248244. Mississippian, Lake Valley Limestone, Nunn Member. Apache Hill, Lake Valley, New Mexico.
Specimen 2. USNM 160762. Lake Valley Limestone, Nunn Member. Lake Valley, Sierra County, New Mexico.
Specimen 9. USNM 248245. Lake Valley Limestone, Nunn Member. A few miles south of Nunn Ranch, Hillsboro quadrangle, New Mexico.
Specimens 10, 11. Oklahoma University 4342 (paratype), 4341 (holotype). Lake Valley Limestone, Nunn Member. Apache Hill, Lake Valley, New Mexico.
Growth series II
Specimen 12. USNM 248246. Mississippian, Caballero Formation. Marble Canyon, Sacramento Mountains, New Mexico.
Specimen 13. USNM 248247. Caballero Formation. Pig Canyon, Sacramento Mountains, New Mexico.
Specimen 14. USNM 248248. Caballero Formation. North wall of Alamo Canyon, NE of type section, Sacramento Mountains, New Mexico.
Specimen 15. USNM 248249. Lake Valley Formation, Arcente Member. Upper Alamo Canyon, Sacramento Mountains, New Mexico.
Specimen 16. USNM 248250. Lake Valley Formation, Nunn Member? Right flank of bioherm 22, Sacramento Mountains, New Mexico.
Hadroblastus whitei (Hall, 1861)
Population I. Mississippian
Specimen 1. USNM unregistered. Upper Burlington Limestone, Burlington, Iowa.
Specimen 2. USNM S3238. Holotype. Burlington Limestone, Burlington, Iowa.
Specimens 5, 6. University Illinois RX-67B, D. Base upper part Burlington Limestone, Pratt's Quarry, Louisiana, Missouri.
Specimen 7. University Illinois RX-67E. Burlington Limestone (Lower?). Top blue styolite bed, Louisiana, Missouri.
Specimens 8, 10. University Illinois RX-67F, C. Burlington Limestone (Upper). Louisiana, Missouri.
Specimen 9. University Illinois RX-67A. Upper Burlington Limestone, Curryville, Missouri.
Specimen 11. University Illinois RX-67. Holotype of *Codaster grandis* Rowley and Hare, 1891. Upper Burlington Chert, Louisiana, Missouri.
Specimens 15, 17, 18. 15, 18 – A. Breimer collection, Institute Earth Sciences, Free Reformed University, Amsterdam. 17 – UMMP 59712. Burlington Limestone. Roadcuts on north and south sides of I-70, 16-24 feet above base, 2.0-2.1 miles east of intersection of I-70 and County Route K, at milepost 92, NW¼ sec. 13, T48N, R19W, Cooper County, Missouri.
Specimen 16. UMMP 62306. Burlington Limestone. Roadcuts on north and south sides of I-70, 0-24′ above base, 2.0-2.1 miles east of intersection of I-70 and County Route K, at milepost 92, NW¼ sec. 13, T48N, R19W, Cooper County, Missouri.
Specimen 19. MCZ 747. Roadcut on south side of I-70. Milepost 92, NW¼ sec. 13, T48N, R19W, Cooper County, Missouri.
Specimen 21. USNM 160588. Burlington Limestone, Sweeney quarry, Clifton City, Missouri.
Specimens 23-29. MCZ 746; unregistered – Sprinkle collection, Harvard University; UMMP 59713; Sprinkle collection; UMMP 62307; Sprinkle collection; MCZ 745. Burlington Limestone. Roadcut (8′ of section) on north side of I-44, 0.3 miles east of Dry Branch

Bridge, SW¼ SE¼ SE¼ sec. 26, T29N, R25W, Greene County, Missouri.

Population II. St. Joe Limestone

Specimens 1, 2. USNM 248251, 248252. Mississippian. St. Joe Formation. Type section, St. Joe, Arkansas.

Specimens 3-7. USNM 160586, 160587, 248253-248255. St. Joe Formation, 1.5 miles upstream from Grand River damsite. Pensacola Dam, Mayes County, Oklahoma.

Specimens 8-10. UMMP 62305, 58658, 58659. St. Joe Formation, roadcut, NW¼ NE¼ sec. 9, T23N, R24E, Delaware County, Oklahoma.

Neoschisma australe Breimer and Macurda, 1972

Permian, Callytharra Formation. Outcrops on south bank of Wooramel River, 0.5 miles west of Callytharra Springs, 60 miles NW of Bryo Station, 25°52′S, 115°30′E, Western Australia.

Azygous basals. UMMP 58634, 59730.

Zygous basals. Specimens 1-7, UMMP 58627-58633.

Radials.

Specimens 1, 2. Bureau Mineral Resources, Canberra, GW 134.

Specimens 3-5. University Western Australia 27021A-C.

Specimen 6. Geological Survey Western Australia F5636.

Specimens 7-20. UMMP 58594-58605, 58682, 58593.

Deltoids.

Specimens 1-18. UMMP 58606-58623.

Epideltoid. UMMP 58626.

Hypodeltoids. Bureau Mineral Resources, Canberra GL87; UMMP 58625; Geological Survey Western Australia F5714G.

Notoblastus cornutus (McKellar, 1969)

Specimens 1-5. Geological Survey Queensland F11389, F11119, F11385, F11122, F11131. Lower Permian, Berserker Beds, Nerimbera Quarry, near Rockhampton, Queensland, Australia.

Notoblastus stellaris (Breimer and Macurda, 1972)

All specimens are from Permian Callytharra Formation. Outcrops on south bank Wooramel River, 0.5 miles west of Callytharra Springs and 60 miles northwest of Bryo Station, 25°52′S, 115°30′E, Western Australia.

Basals. UMMP 58651, 58683 (holotype), 58653, 58654.

Radials. Specimens 1-9, 12, 13. UMMP 58636-58644, 58683 (holotype), and 58655.

Specimens 10, 11. University Western Australia F5714I,J.

Deltoids. Specimens 1-7. UMMP 58645-58650, 58683 (holotype).

Timoroblastus coronatus Wanner, 1924a

Growth Series I

Specimens 1-26. UMMP 59745-59770. Permian. Sonnebait Series; Basleo Zone? Tuniun Enu, between Noil Toeninoe and Noil Boenoe, 1.3 km southeast of Basleo, Timor, Indonesia.

Growth series II

Specimens 1-21. UMMP 60738-60758. Kampong Sebot, Timor Indonesia.

Growth series III

Specimens 1-9. UMMP 60729-60737. Permian. Sonnebait Series, Basleo Zone? Noa near Tuniun Enu, between Noil Toeninoe and Noil Boenoe, 1.3 km southeast of Basleo, Timor, Indonesia.

Growth series IV

Specimens 1-20. UMMP 60761-60780. Permian, Timor, Indonesia.

Family Codasteridae

Codaster acutus M'Coy, 1849

Growth series I

Specimens 1, 3-20. UMMP 60642-60660. Lower Carboniferous, Upper Visean, D2 Subzone, Middle Limestone. One-fourth mile south of Bare House, bearing 150° in the crinoidal limestone capping the knolls, coordinates SE 007668, 1.8 miles north of Grassington, England.

Specimen 2. K. A. Joysey collection. University Cambridge. Locality as above.

Growth series II

A population of 25 specimens from older collections, most of which are localized as being from the Carboniferous Limestone, Settle, Yorkshire, England.

Specimens 1-17. BMNH E30521-E30524, E30501-E30504, E30525, E30505, E30646, E30647, E30650, E30648, E30645, E30644, E30643.

Specimens 18-25. Geological Survey Museum (London), GSM 69568, 69562, 69553, 69565, 69567, 69563, 69566, 69564.

Growth series III

Lower Carboniferous, Visean. Quarry, 100 yards west of Sean Delaney's Farm, Bally Phillip, 0.8 miles south of Lisdowney, which is 2.5 miles east of Ballyragget, County Kilkenny, Ireland.

Specimens 1-3. Trinity College Dublin 8067, 8017, 8018.

Specimens 4-9. UMMP 60636-60641.

Angioblastus dotti (Moore and Strimple, 1942)

Pennsylvanian, Hogshooter Limestone. West of railroad bridge, along creek north of Ramona School near CN½ sec. 28, T24N, R13E, Washington County, Oklahoma.

Complete specimens. USSM 160568, 111249, 160569; State University Iowa 31813; University Oklahoma 4310.

Azygous basals 1-5. UMMP 60695-60699.

Zygous basals 1-11. UMMP 60700-60710.

C radials 1-8. UMMP 60711-60718.

E radials 1-2. UMMP 60719, 60720.

Angioblastus variabilis Wanner, 1931

Permian, Sonnebait Series, Noko, Basleo, Timor, Indonesia.

Specimens 1-12, 15, 17, 18. USNM 160641-160655.

Specimens 13, 14, 16. University Amsterdam, unregistered specimens.

Angioblastus wanneri (Yakovlev, 1926b)

Specimens 1-18. UMMP 60661-60678. Permian, Krasnoufimsk, Perm, Urals, U.S.S.R.

Pterotoblastus brevialatus Wanner, 1931

Permian, Sonnebait Series. Noko, Basleo, Timor, Indonesia.

Specimens 1, 14, 15. University Amsterdam, unregistered specimens.

Specimens 2-13. USNM 160656-160667.

Pterotoblastus gracilis Wanner, 1924a

Permian, Sonnebait Series. Noko, Basleo, Timor, Indonesia.

Specimens 1, 2, 4-18. USNM 160624-160640.

Specimen 3. University Amsterdam, unregistered specimen.

Nannoblastus pyramidatus Wanner, 1924b

Specimens 1-15. UMMP 62312-62315, 62328-62338. Permian, Sonnebait Series, Noko, Basleo, Timor, Indonesia.

Family Ceratoblastidae

Ceratoblastus nanus Wanner, 1940

Specimens 1, 4. University Amsterdam, unregistered specimens.

Specimens 2, 3. University Amsterdam Ge.O.9934 (holotype); Ge.O.9935. Permian, Noko, Basleo, Timor, Indonesia.

Incertae Sedis

Indoblastus granulatus Wanner, 1924a

Specimen 1. Holotype of *Indoblastus nuciformis* Wanner, 1940. University Amsterdam Ge.O.9930. Permian, Maun Molo, Timor, Indonesia.

Specimen 2. University Amsterdam, unregistered specimen. Permian, Noko, Timor, Indonesia.

Specimen 3. University Amsterdam, unregistered specimen. Permian, Tuniun Enu, near Basleo, Timor, Indonesia.

Specimens 4, 5. University Amsterdam, unregistered specimens. 1935 expedition. Permian, Timor, Indonesia.

Specimens 6, 7. University Amsterdam, unregistered specimens. Permian, Nipol Soenpek, east of Noil Boenoe, Timor, Indonesia.

Specimen 8. A. Bremier collection, Institute Earth Sciences, Free Reformed University, Amsterdam. Permian, Basleo, Timor, Indonesia.

Specimen 9. University Amsterdam, unregistered specimen. Permian, near Basleo, Timor, Indonesia.

Specimens 10, 11. University Amsterdam L.8462. Permian, Timor, Indonesia.

Specimens 12, 14. Technische Hogeschool Delft 12279, 12282. Permian, Basleo, Timor, Indonesia.

Specimen 13. Technische Hogeschool Delft 12280. Permian. Niki Niki, Noil Fatoe, east of Noil Fatoe River, near Basleo, Timor, Indonesia.

Specimen 15. University Leiden ST 32873. Permian, Fatoe Inoe, Timor, Indonesia.

Specimen 16. University Leiden ST 32874. Permian, Soem Peh, Timor, Indonesia.

PLATES

EXPLANATION OF PLATE 1

FIGS.

1, 7, 15 – *Decaschisma pulchellum* (Miller and Dyer, 1878). Oral, basal, and BC deltoid views. (Anus at 6 o'clock in oral view). No. 5 in growth series. Silurian, Waldron Shale, Indiana, U.S.A. Figs. 1, 7, x 3; fig. 15, x 17.5.

2, 6 – *D. pulchellum*. Lateral (A) and oral views (anus at 6 o'clock). No. 7 in growth series. Silurian, Waldron Shale, Indiana, U.S.A. x 3.

3 – *D. pulchellum*. Inclined view of E ambulacrum. No. 2 in growth series. Silurian, Waldron Shale, Indiana, U.S.A. x 7.

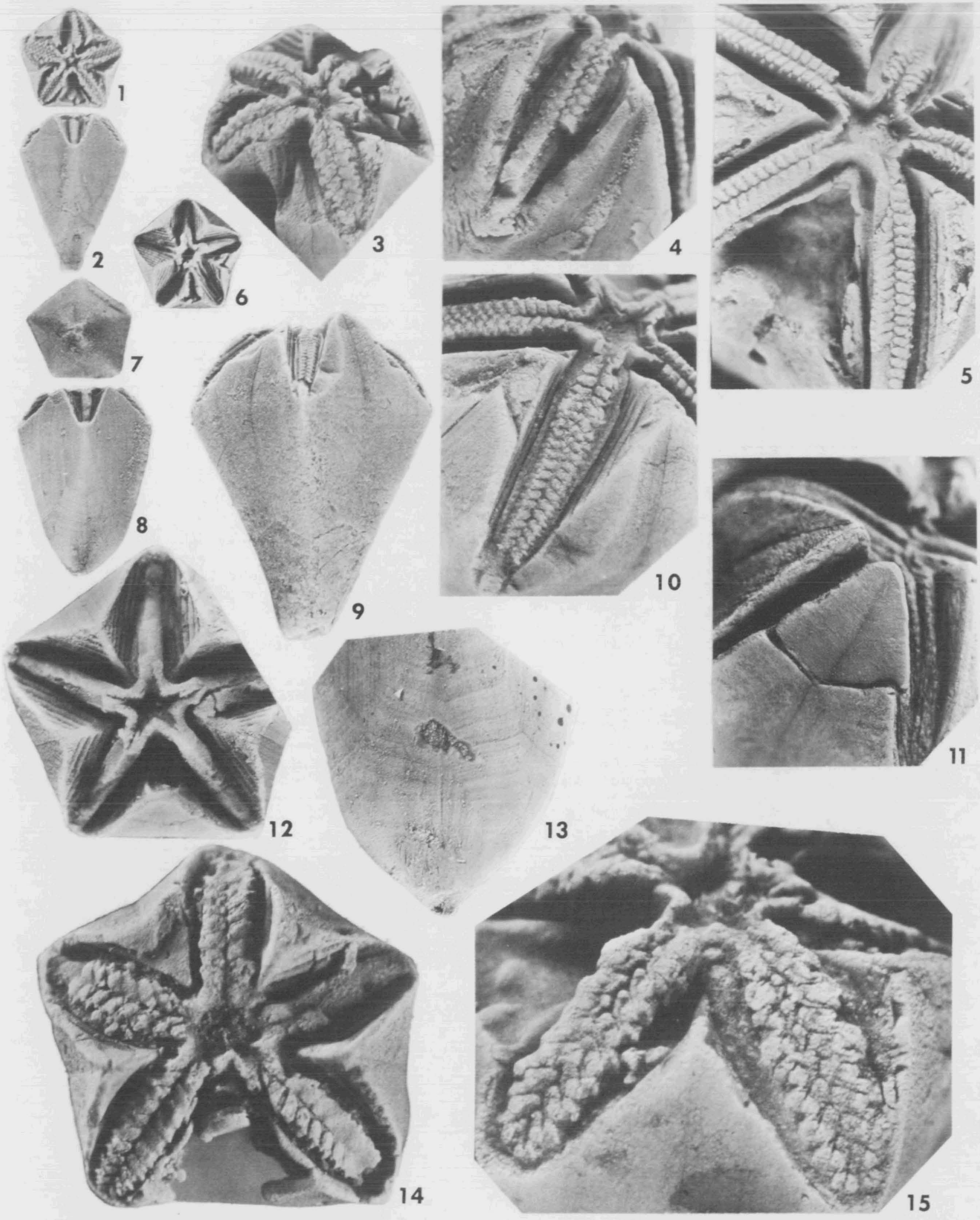
4 – *D. pulchellum*. Inclined view of A ambulacrum. No. 12 in growth series. (See also Breimer and Macurda, 1972, Pl. I, fig. 2). Silurian, Waldron Shale, Indiana, U.S.A. x 7.

5, 9, 10 – *D. pulchellum*. View of anal interarea, lateral (A) view, and view of A ambulacrum respectively. No. 14 in growth series. (See also Breimer and Macurda, 1972, Pl. I, fig. 1; Pl. XXXIV, fig. 3). Silurian, Waldron Shale, Indiana, U.S.A. Figs. 5, 10, x 7; fig. 9, x 3.

8, 12, 13 – *D. pulchellum*. Lateral (A) view, oral view (anus at 6 o'clock), and view of basals in D ambulacral area. No. 10 in growth series. Silurian, Waldron Shale, Indiana, U.S.A. Fig. 8, x 3; figs. 12, 13, x 7.

11 – *D. pulchellum*. View of hypodeltoid. USNM 160698. Silurian, Waldron Shale, Tennessee, U.S.A. x 7.

14 – *D. pulchellum*. Oral view (anus at 6 o'clock). C.R.C. Paul collection, Cambridge University. Silurian, Waldron Shale, Indiana, U.S.A. x 12.5.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EXPLANATION OF PLATE 2

FIGS.

1 – *Polydeltoideus enodatus* Reimann and Fay, 1961. View of hypodeltoid. No. 18 in growth series. Silurian, Henryhouse Formation, Oklahoma, U.S.A. x 7.

2, 7, 10, 12 – *P. enodatus*. Lateral (C) view, oral view (anus at 6 o'clock), view of basals, and view of peristome and CD interarea. No. 10 in growth series. (See also Breimer and Macurda, 1972, Pl. I, figs. 8, 12). Silurian, Henryhouse Formation, Oklahoma, U.S.A. Figs. 2, 7, x 2; figs. 10, 12, x 7.

3, 6, 11 – *P. enodatus*. Lateral (C) and oral views, and inclined view of DE interarea (anus at 6 o' clock in figure 11). No. 1 in growth series. Silurian, Henryhouse Formation, Oklahoma, U.S.A. Figs. 3, 6, x 3; fig. 11, x 17.5.

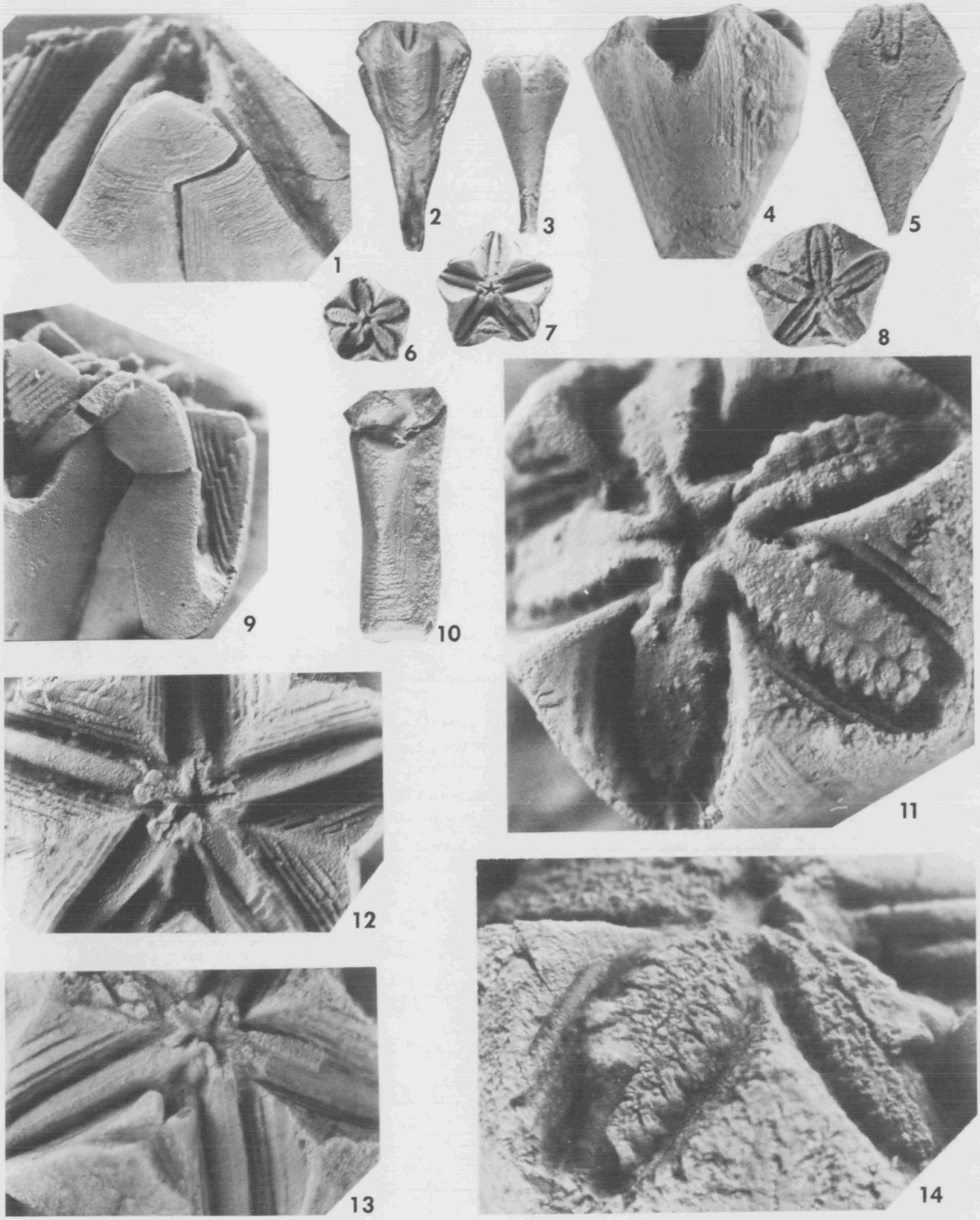
4 – *P. enodatus*. Lateral (E) view of radial. No. 5 in growth series. Silurian, Henryhouse Formation, Okalhoma, U.S.A. x 7.

5, 8 – *Leptoschisma lorae* (Dunbar, 1920). Lateral (C) and oral views (anus at 6 o'clock). No. 8 in growth series. See also Pl. 3, figs. 4, 8 herein. Devonian, Birdsong Formation, Tennessee, U.S.A. x 3.

9 – *P. enodatus*. View of anal interarea. UMMP 51601. Silurian, Henryhouse Formation, Lawrence uplift near Ada, Oklahoma, U.S.A. x 7.

13 – *P. enodatus*. View of anal interarea. No. 9 in growth series. Silurian, Henryhouse Formation, Oklahoma, U.S.A. x 7.

14 – *P. enodatus*. View of E ambulacrum. No. 14 in growth series. Silurian, Henryhouse Formation, Oklahoma, U.S.A. x 17.5.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EXPLANATION OF PLATE 3

FIGS.

1, 3 – *Leptoschisma lorae* (Dunbar, 1920). Oral (anus at 6 o'clock) and C ambulacral views. No. 1 in growth series. Devonian, Birdsong Formation, Tennessee, U.S.A. x 17.5.

2, 5 – *L. lorae*. A and B ambulacral views. No. 3 in growth series. (See also Breimer and Macurda, 1972, Pl. I, figs. 5, 6). Devonian, Birdsong Formation, Tennessee, U.S.A. x 7.

4, 8 – *L. lorae*. D ambulacral views. No. 8 in growth series. See also Pl. 2, figs. 5, 8 herein. Devonian, Birdsong Formation, Tennessee, U.S.A. x 7 and x 45.

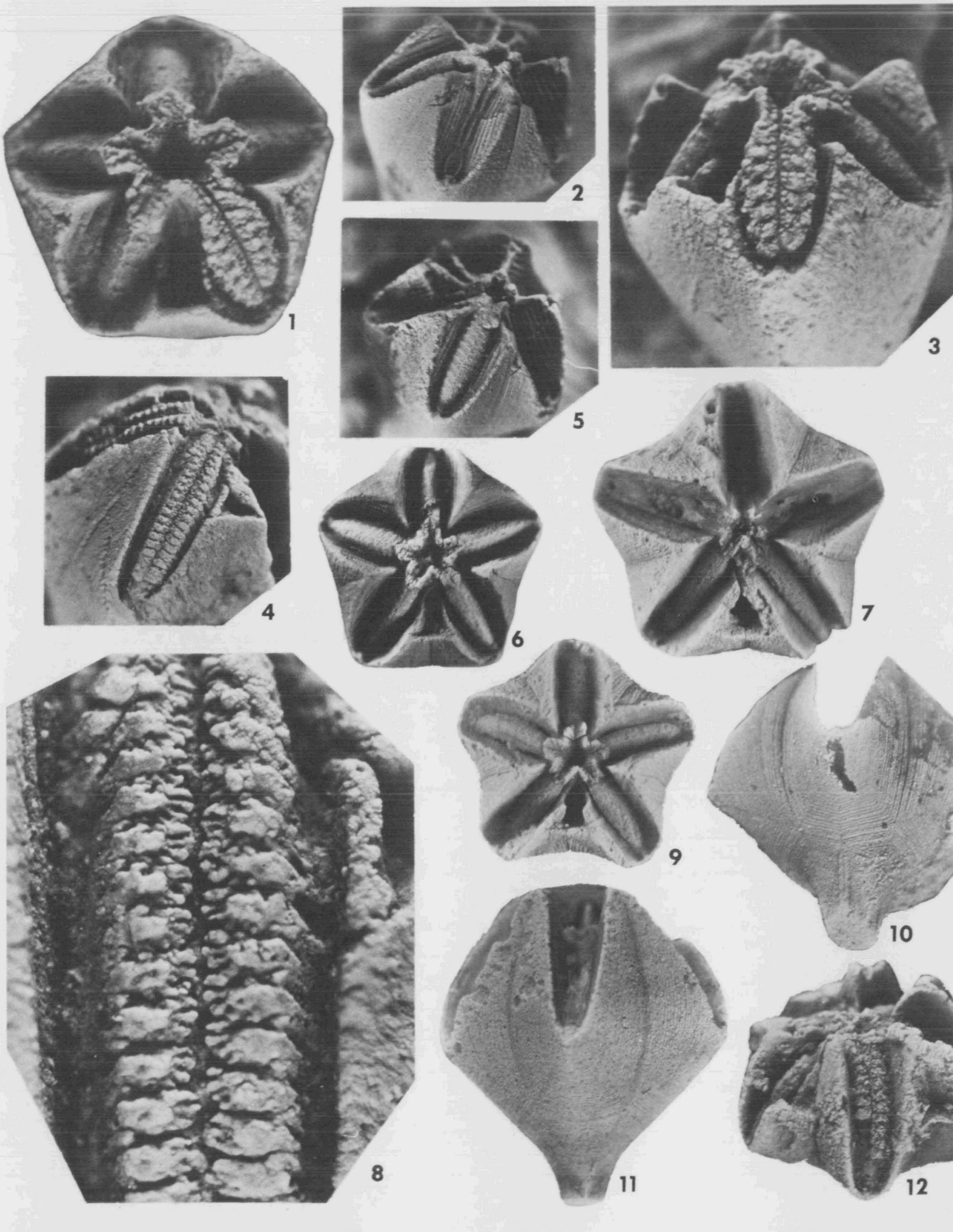
6 – *L. lorae*. Oral view. No. 5 in growth series. (See also Breimer and Macurda, 1972, Pl. I, figs. 4, 7). Devonian, Birdsong Formation, Tennessee, U.S.A. x 7.

7, 11 – *Caryoblastus bohemicus* Breimer, Macurda, and Prokop, 1968. Oral (anus at 6 o'clock) and lateral (E) ambulacral views. No. 12 in growth series. (See also Breimer, Macurda, and Prokop, 1968, Pl. 1, figs. 4, 13). Devonian, Slivenec Limestone, Konvarka, Bohemia, Czechoslovakia. x 7.7.

9 – *C. bohemicus*. Oral view (anus at 6 o'clock). No. 9 in growth series. (See also Breimer, Macurda, and Prokop, 1968, Pl. 1, fig. 3). Devonian, Slivenec Limestone, Konvarka, Bohemia, Czechoslovakia. x 7.7.

10 – *C. bohemicus*. Lateral view, unregistered specimen. (See also Breimer, Macurda, and Prokop, 1968, Pl. 1, fig. 8). Devonian, Slivenec Limestone, Konvarka, Bohemia, Czechoslovakia. x 7.7.

12 – *C. bohemicus*. Inclined view of D ambulacrum. No. 13 in growth series. (See also Breimer, Macurda, and Prokop, 1968, Pl. 1, fig. 1). Devonian, Slivenec Limestone, Konvarka, Bohemia, Czechoslovakia. x 7.7.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EXPLANATION OF PLATE 4

FIGS.

1, 5, 11 – *Caryoblastus* sp. Oral (anus at 6 o'clock), lateral, and D ambulacral views. Collection Institute Earth Sciences, Free Reformed University, Amsterdam. (See also Breimer and Macurda, 1972, Pl. I, figs. 15, 16). Devonian, La Vid Formation, Colle, Leon, Spain. Figs. 1, 5, x 3; fig. 11, x 7.

2 – *Cryptoschisma schultzii* (De Verneuil and d'Archiac, 1845). Oral view. (Anus at 6 o' clock.) No. 8 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 3.

3 – *C. schultzii*. Lateral (E) view. No. 16 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 3.

4 – *C. schultzii*. View of A ambulacrum. No. 12 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 11.

6 – *C. schultzii*. Basal view. (Anus at 6 o'clock.) No. 13 in growth series. (See also Breimer and Macurda, 1972, Pl. I, figs. 9, 13, 17). Devonian, La Vid Formation, Colle, Leon, Spain. x 3.

7, 12, 18 – *C. schultzii*. Lateral (B) view, view of anal interarea, and view of proximal surface of basals. No. 5 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. Fig. 7, x 3; figs. 12, 18, x 7.

8 – *C. schultzii*. Lateral (C) view. UMMP 62249. Devonian, La Vid Formation, Colle, Leon, Spain. x 3.

9 – *C. schultzii*. Oral view. (Anus at 6 o'clock.) No. 4 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 7.

10, 13, 14 – *C. schultzii*. Views of basals, oral area, and radials. UMMP 62250. Devonian, La Vid Formation, Colle, Leon, Spain. x 7.

15 – *Pentremitidea pailleti* (De Verneuil, 1844). Oral view. (Anus at 6 o'clock.) No. 3 in growth series. Devonian, Calcaire de Ferrones, Ferrones, Asturias, Spain. x 3.

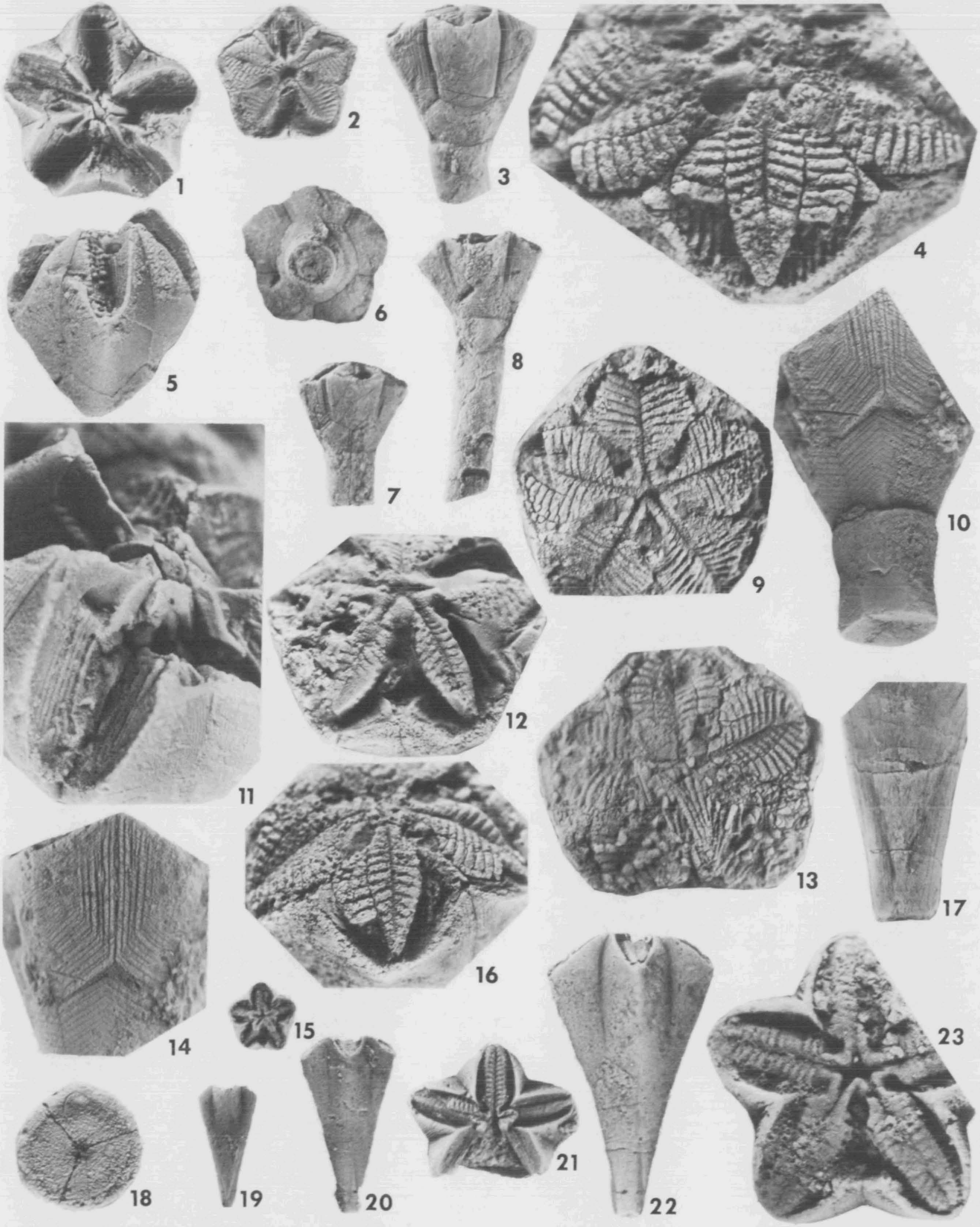
16 – *C. schultzii*. View of E ambulacrum. No. 11 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 7.

17, 21, 22 – *P. pailleti*. View of proximal end of basals, oral (anus at 6 o'clock), and lateral (A) views. See also Pl. 5, figs. 2, 10, 15 herein. Breimer collection (specimen A). Institute Earth Sciences, Free Reformed University, Amsterdam. Devonian, Calcaire de Ferrones, Ferrones, Asturias, Spain. Fig. 17, x 7; figs. 21, 22, x 3.

19 – *P. pailleti*. Lateral (E) view. No. 1 in growth series. Devonian, Calcaire de Ferrones, Ferrones, Asturias, Spain. x 3.

20 – *P. pailleti*. Lateral (A) view. No. 6 in growth series. Devonian, Calcaire de Ferrones, Ferrones, Asturias, Spain. x 3.

23 – *P. pailleti*. Detail of oral area. (Anus at 6 o'clock.) No. 12 in growth series. (See also Breimer and Macurda, 1972, Pl. I, fig. 22). Devonian, Calcaire de Ferrones, Ferrones, Asturias, Spain. x 7.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EXPLANATION OF PLATE 5

FIGS.

1 – *Pentremitidea pailleti* (De Verneuil, 1844). Oral view. (Anus at 6 o'clock.) Breimer collection (specimen B). Institute Earth Sciences, Free Reformed University, Amsterdam. Devonian, Calcaire de Ferrones, Ferrones, Asturias, Spain. x 7.

2, 10, 15 – *P. pailleti*. Oral and inclined oral views (anus at 6 o'clock), and view of A ambulacrum. See also Pl. 4, figs. 17, 21, 22 herein. Breimer collection (specimen A), Institute Earth Sciences, Free Reformed University, Amsterdam. Devonian, Calcaire de Ferrones, Ferrones, Asturias, Spain. Figs. 2, 10, x 7; fig. 15, x 17.5.

3 – *Pentremitidea archiaci* (Etheridge and Carpenter, 1882). View of proximal tip of basals and proximalmost columnal. No. 6 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 12.

4 – *P. pailleti*. Oral view. (Anus at 6 o'clock.) Breimer collection (specimen C). Institute Earth Sciences, Free Reformed University, Amsterdam. Devonian, Calcaire de Ferrones, Ferrones, Asturias, Spain. x 7.

5 – *P. pailleti*. Lateral view of proximal tip of basals. No. 13 in growth series. Devonian, Calcaire de Ferrones, Ferrones, Asturias, Spain. x 7.

6 – *P. archiaci*. Oral view. (Anus at 6 o'clock.) No. 13 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 3.

7 – *P. archiaci*. Oral view. (Anus at 6 o'clock.) (See also Breimer and Macurda, 1972, Pl. I, fig. 21). BMNH E8033. Devonian, Calcaire de Ferrones, Ferrones, Asturias, Spain. x 3.

8 – *P. archiaci*. Oral view. (Anus at 6 o'clock.) UMMP 61251. Devonian, La Vid Formation, Abelgas y Cacabelos, Leon, Spain. x 3.

9, 13 – *P. archiaci*. Oral (anus at 6 o'clock) and lateral (B) views. UMMP 61252. Devonian, La Vid Formation, Abelgas y Cacabelos, Leon, Spain. x 3.

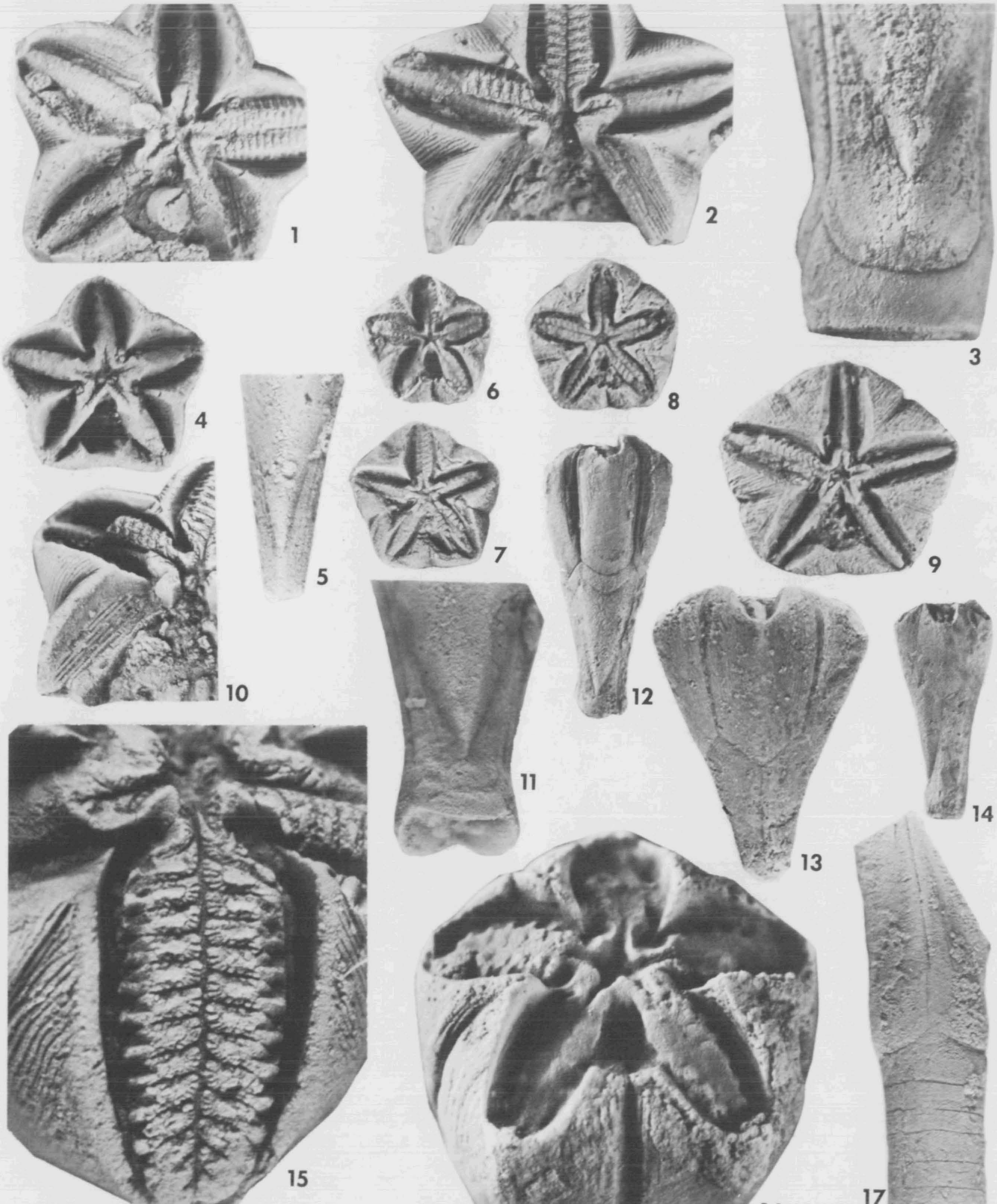
11 – *P. archiaci*. View of BA growth front at proximal tip of basals. No. 5 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 7.

12 – *P. archiaci*. Lateral (C) view. No. 16 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 3.

14 – *P. archiaci*. Lateral (B) view. No. 3 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 3.

16 – *P. archiaci*. Inclined view of anal interarea. No. 6 in growth series. Devonian, Calcaire de Ferrones, Ferrones, Asturias, Spain. x 11.

17 – *P. archiaci*. Proximal tip of basals and proximal columnals. No. 11 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 7.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EXPLANATION OF PLATE 6

FIGS.

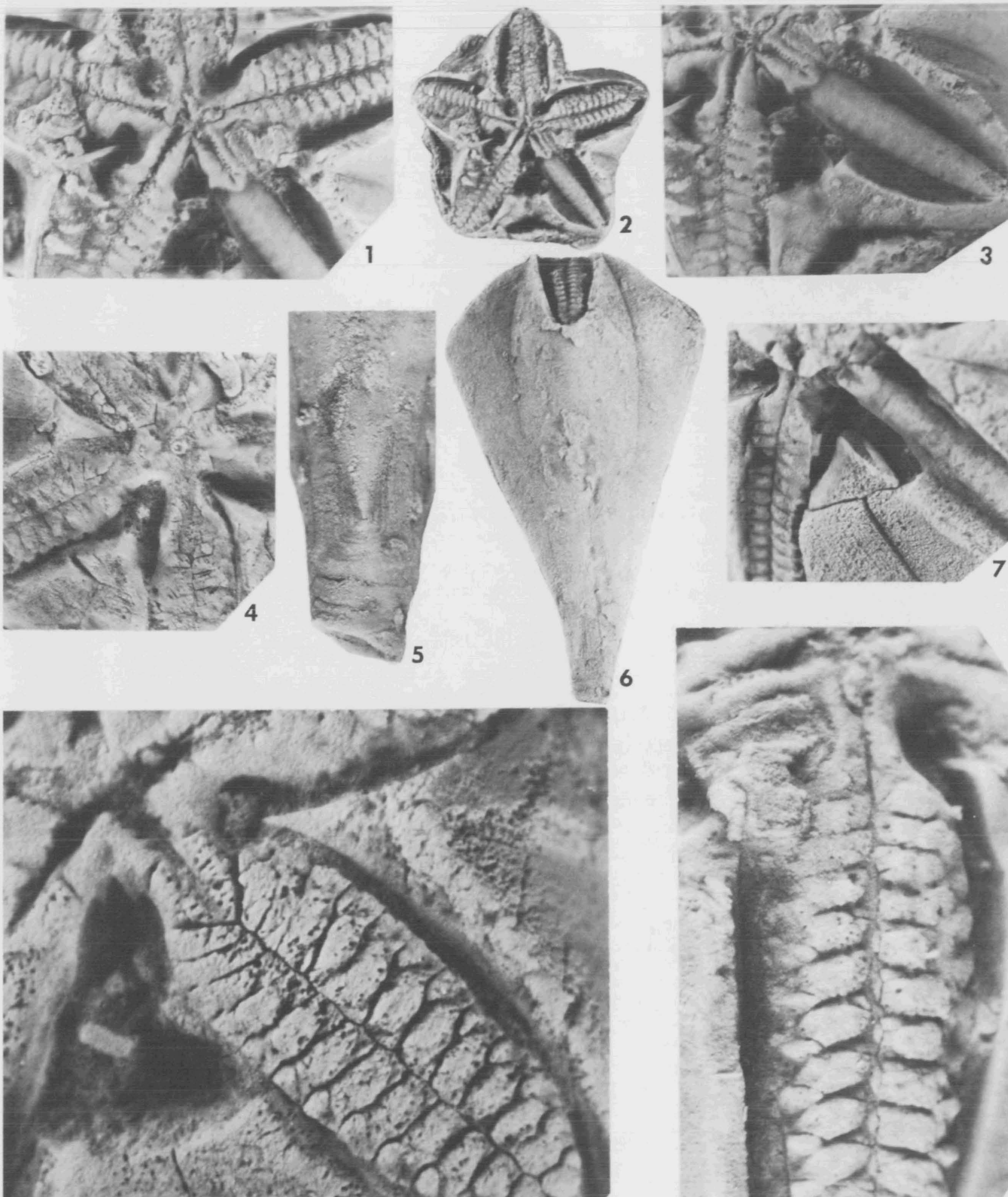
1, 3, 9 – *Pentremitidea lusitanica* Etheridge and Carpenter, 1882. View of oral area, oral view (anus at 6 o'clock), view of anal interarea, and view of B ambulacrum respectively. A. Breimer collection (specimen B). Institute of Earth Sciences, Free Reformed University, Amsterdam. Devonian, La Vid Formation, Colle, Leon, Spain. Figs. 1, 3, x 7; fig. 2, x 3; fig. 9, x 17.5.

4 – *P. lusitanica*. Oral view. (Anus at 6 o'clock.) No. 1 in growth series. Devonian, La Vid Formation, Portilla de Luna, Leon, Spain. x 7.

5, 6 – *P. lusitanica*. View of proximal part of basals and proximal columnals and lateral (A) view. BMNH E789. (See also Breimer and Macurda, 1972, Pl. II, figs. 2, 3). Devonian, Calcaire de Ferrones, Asturias, Spain. x 7 and x 3 respectively.

7 – *P. lusitanica*. View of anal interarea with hypodeltoid. A. Breimer collection (specimen A). Institute of Earth Sciences, Free Reformed University, Amsterdam. Devonian, La Vid Formation, Colle, Leon, Spain. x 7.

8 – *P. lusitanica*. View of anal interarea and C ambulacrum. No. 3 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 17.5.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EXPLANATION OF PLATE 7

FIGS.

1, 5, 11 – *Leptoschisma*? *pentagonum* n. sp. View of AB interambulacrum, anal interarea, and proximal tip of basals. (See also Breimer, Macurda, and Prokop, 1968, Pl. 1, figs. 2, 5, 6, 20, 16 and Breimer and Macurda, 1972, Pl. II, figs. 1, 6). Prokop collection, Geological Survey, Prague. Devonian, Slivinec Limestone, Konvarka, Bohemia, Czechoslovakia. x 11.4.

2, 4, 13 – *Pleuroschisma lycorias* (Hall, 1862). View of radials in DE interambulacral area, lateral (C) and oral view (anus at 6 o'clock). No. 7 in growth series. See also Pl. 8, fig. 4 herein. Devonian, Hungry Hollow Formation, Ontario, Canada. Fig. 2, x 7; fig. 4, x 4; fig. 13, x 3.

3, 6, 17 – *P. lycorias*. Lateral (A) and oral (anus at 6 o'clock) views, and view of basals. No. 2 in growth series. Devonian, Hungry Hollow Formation, Ontario, Canada. Fig. 3, x 4; fig. 6, x 3; fig. 17, x 7.

7, 14 – *P. lycorias*. Oral and lateral (B) views. No. 15 in growth series. Devonian, Moscow Shale, New York, U.S.A. x 3.

8, 12, 15 – *P. lycorias*. Lateral (B), oral, and basal views (anus at 6 o'clock in last two). No. 20 in growth series. Devonian, Moscow Shale, New York, U.S.A. x 3.

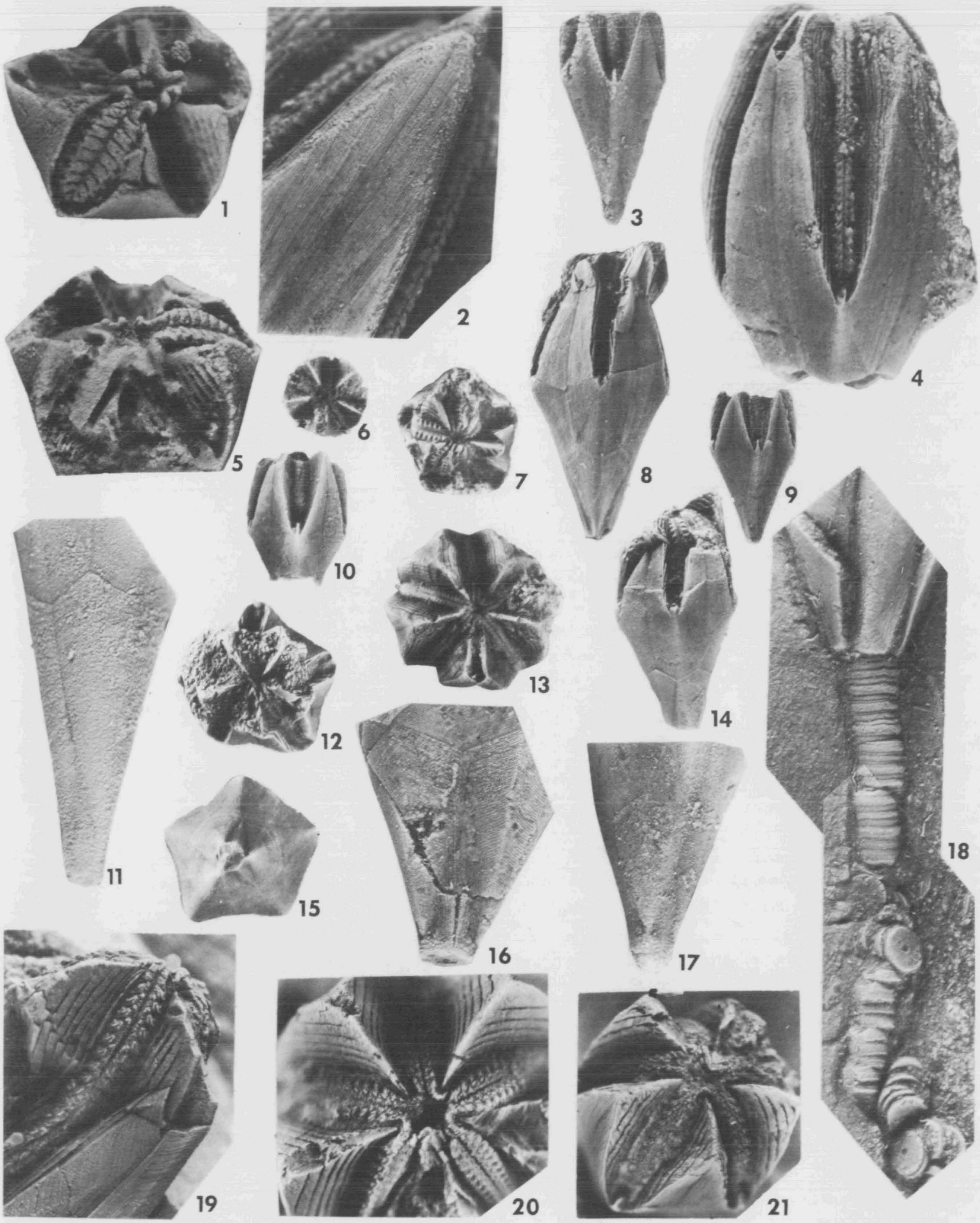
9, 21 – *P. lycorias*. Lateral (A) view and view of B ambulacrum. No. 3 in growth series. Devonian, Hungry Hollow Formation, Ontario, Canada. Fig. 9, x 3; fig. 21, x 7.

10 – *P. lycorias*. Lateral (B) view. No. 5 in growth series. Devonian, Hungry Hollow Formation, Ontario, Canada. x 3.

16, 20 – *P. lycorias*. Views of proximal part of basals and oral area (anus at 6 o'clock in latter). No. 6 in growth series. (See also Breimer and Macurda, 1972, Pl. II, figs. 8, 10; Pl. XXXIV, fig. 4; also Pl. 8, fig. 5 herein). Devonian, Hungry Hollow Formation, Ontario, Canada. x 7.

18 – *P. lycorias*. View of proximal part of basals and proximal columnals. No. 18 in growth series. (See also Breimer and Macurda, 1972, Pl. II, fig. 4). Devonian, Moscow Shale, New York, U.S.A. x 7.

19 – *P. lycorias*. View of D ambulacrum. No. 19 in growth series. (See also Breimer and Macurda, 1972, Pl. II, fig. 7). Devonian, Centerfield Limestone, New York, U.S.A. x 7.



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EXPLANATION OF PLATE 8

FIGS.

1 – *Pleuroschisma lycorias* (Hall, 1862). View of D ambulacrum. No. 22 in growth series. Devonian, Moscow Shale, New York, U.S.A. x 10.5.

2, 3 – *P. lycorias*. Views of hypodeltoid and C ambulacrum. No. 16 in growth series. Devonian, Moscow Shale, Kashong Member, New York, U.S.A. x 7.

4 – *P. lycorias*. View of growth lines in RR sectors, DE interambulacral area. No. 7 in growth series. See also Pl. 7, figs. 2, 4, 13 herein. Devonian, Hungry Hollow Formation, Ontario, Canada. x 7.

5 – *P. lycorias*. View of B ambulacrum and AB deltoid. No. 6 in growth series. (See also Breimer and Macurda, 1972, Pl. II, figs. 8, 10; Pl. XXXIV, fig. 4; also Pl. 7, figs. 16, 20 herein). Devonian, Hungry Hollow Formation, Ontario, Canada. x 7.

6 – *Pleuroschisma verneuili* (Etheridge and Carpenter, 1882). Oral view. (Anus at 6 o'clock.) No. 22 in growth series. Devonian, Arnao Limestone, Fenolleda, Asturias, Spain. x 3.

7 – *P. verneuili*. Oral view (Anus at 6 o'clock.) No. 3 in growth series. See also Pl. 9, figs. 3, 8; Pl. 10, fig. 10 herein. Devonian, La Vid Formation, Colle, Leon, Spain. x 3.

8 – *P. verneuili*. Oral view. (Anus at 6 o'clock.) No. 7 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 3.

9 – *P. verneuili*. Oral view. (Anus at 6 0'clock.) No. 12 in growth series. See also Pl. 9, fig. 1 herein. Devonian, La Vid Formation, Colle, Leon, Spain. x 3.

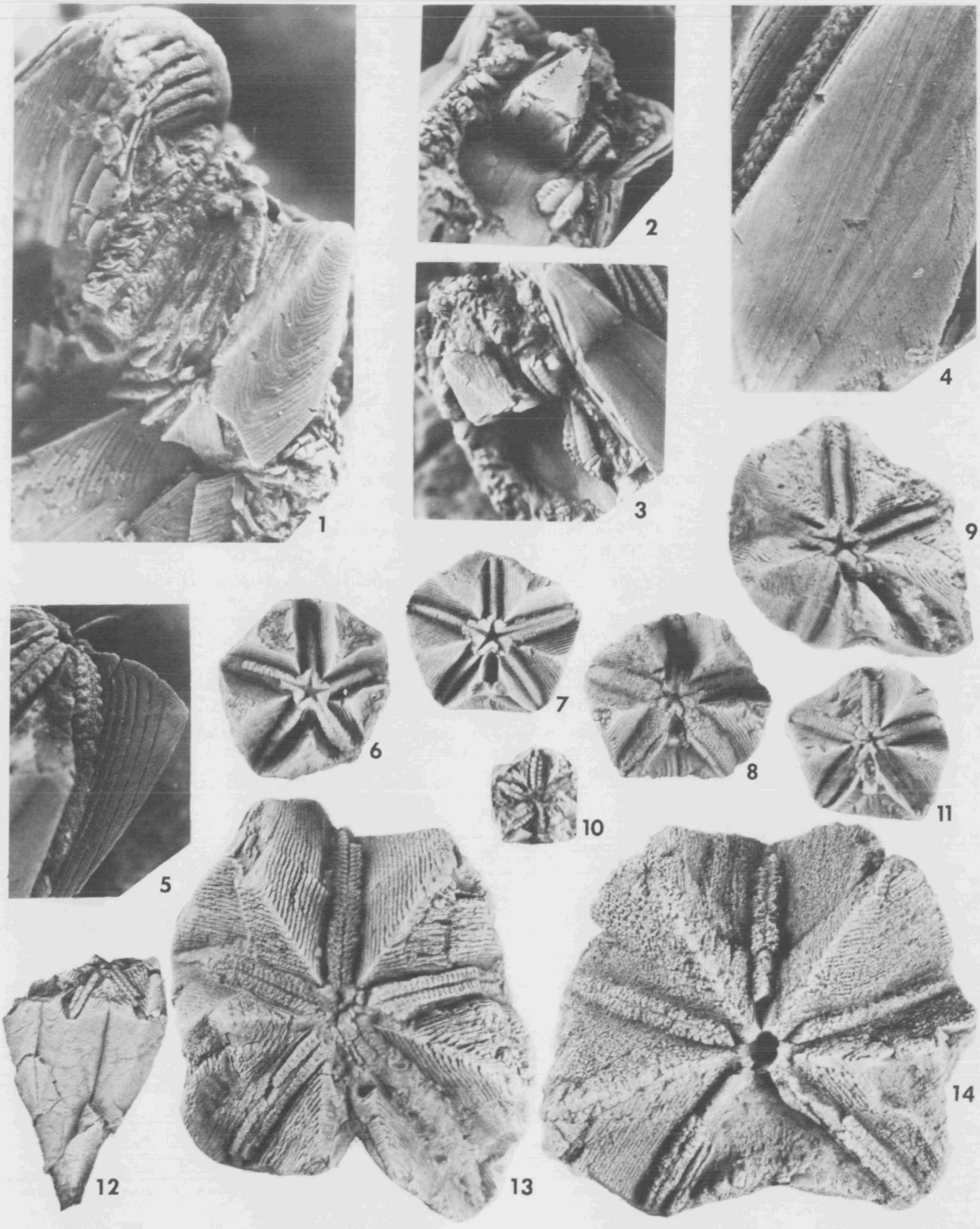
10 – *P. verneuili*. Oral view. UMMP 62254. Devonian, Arnao Limestone, type section. Exposure on seacoast on west edge of harbor,Arnao, Asturias, Spain. x 3.

11 – *P. verneuili*. Oral view. (Anus at 6 o'clock.) No. 8 in growth series. See also Pl. 9, fig. 4 herein. Devonian, La Vid Formation, Colle, Leon, Spain. x 3.

12 – *P. verneuili*. Lateral view. Devonian, Aranao Limestone, type section. Exposure on seacoast on west edge of harbor, Arnao, Asturias, Spain. x 3.

13 – *P. verneuili*. Oral view. (Anus at 6 o'clock.) No. 21 in growth series. See also Pl. 9, fig. 7 herein. Devonian, La Vid Formation, Colle, Leon, Spain. x 3.

14 – *P. verneuili*. Oral view (Anus at 6 o'clock.) No. 20 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 3.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EXPLANATION OF PLATE 9

FIGS.

1 – *Pleuroschisma verneuili* (Etheridge and Carpenter, 1882). Lateral (DE) view. No. 12 in growth series. See also Pl. 8, fig. 9 herein. Devonian, La Vid Formation, Colle, Leon, Spain. x 3.

2 – *P. verneuili*. View of anal interarea with hypodeltoid. No. 6 in growth series. Devonian, La Vid Formation, Villayandre, Leon, Spain. x 7.

3, 8 – *P. verneuili*. View of anal interarea and lateral (D) view. No. 3 in growth series. See also Pl. 8, fig. 7, and Pl. 10, fig. 10 herein. Devonian, La Vid Formation, Colle, Leon, Spain. x 7 and x 3.

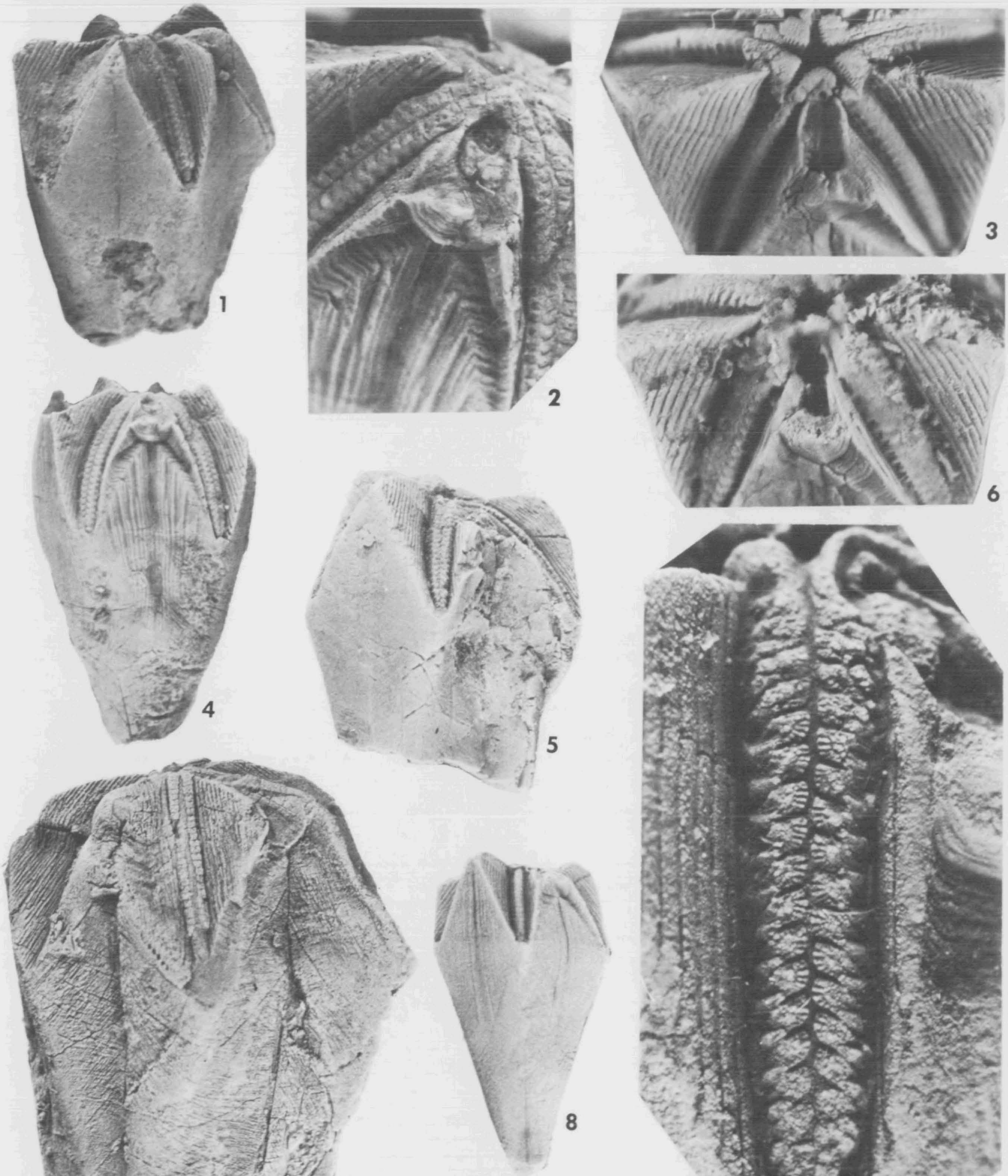
4 – *P. verneuili*. Lateral (CD) view. No. 8 in growth series. See also Pl. 8, fig. 11 herein. Devonian, La Vid Formation, Colle, Leon, Spain. x 3.

5 – *P. verneuili*. Lateral (D) view. No. 17 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 3.

6 – *P. verneuili*. View of anal interarea. No. 9 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 7.

7 – *P. verneuili*. Lateral (D) view. No. 21 in growth series. See also Pl. 8, fig. 13 herein. Devonian, La Vid Formation, Colle, Leon, Spain. x 3.

9 – *P. verneuili*. View of D ambulacrum. No. 1 in growth series. (See also Breimer and Macurda, 1972, Pl. II, figs. 5, 9, and Pl. 10, figs. 2, 8, 11, 14, 17 herein.) Devonian, La Vid Formation, Colle, Leon, Spain. x 17.5.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EXPLANATION OF PLATE 10

FIGS.

1 – *Pleuroschisma verneuili* (Etheridge and Carpenter, 1882). View of E ambulacrum. No. 14 in growth series. Devonian, La Vid Formation, Colle, Leon, Spain. x 7.

2, 8, 11, 14, 17 – *P. verneuili*. Views of EA interambulacral area (figs. 2, 17), anal interarea (two perspectives – figs. 8, 11), and proximal tip of azygous basal. No. 1 in growth series. (See also Breimer and Macurda, 1972, Pl. II, figs. 5, 9, and Pl. 9, fig. 9 herein). Devonian, La Vid Formation, Colle, Leon, Spain. x 7.

3, 7, 15 – *Heteroschisma alatum* (Reimann, 1935). Oral, lateral (E), and enlarged oral views. (Anus at 6 o'clock in oral views.) No. 9 in growth series. Devonian, Potter Farm Formation, Michigan, U.S.A. Figs. 3, 7, x 3; fig. 15, x 7.

4, 5 – *H. alatum*. Oral (anus at 6 o'clock) and lateral (B) views. No. 5 in growth series. Devonian, Potter Farm Formation, Michigan, U.S.A. x 3.

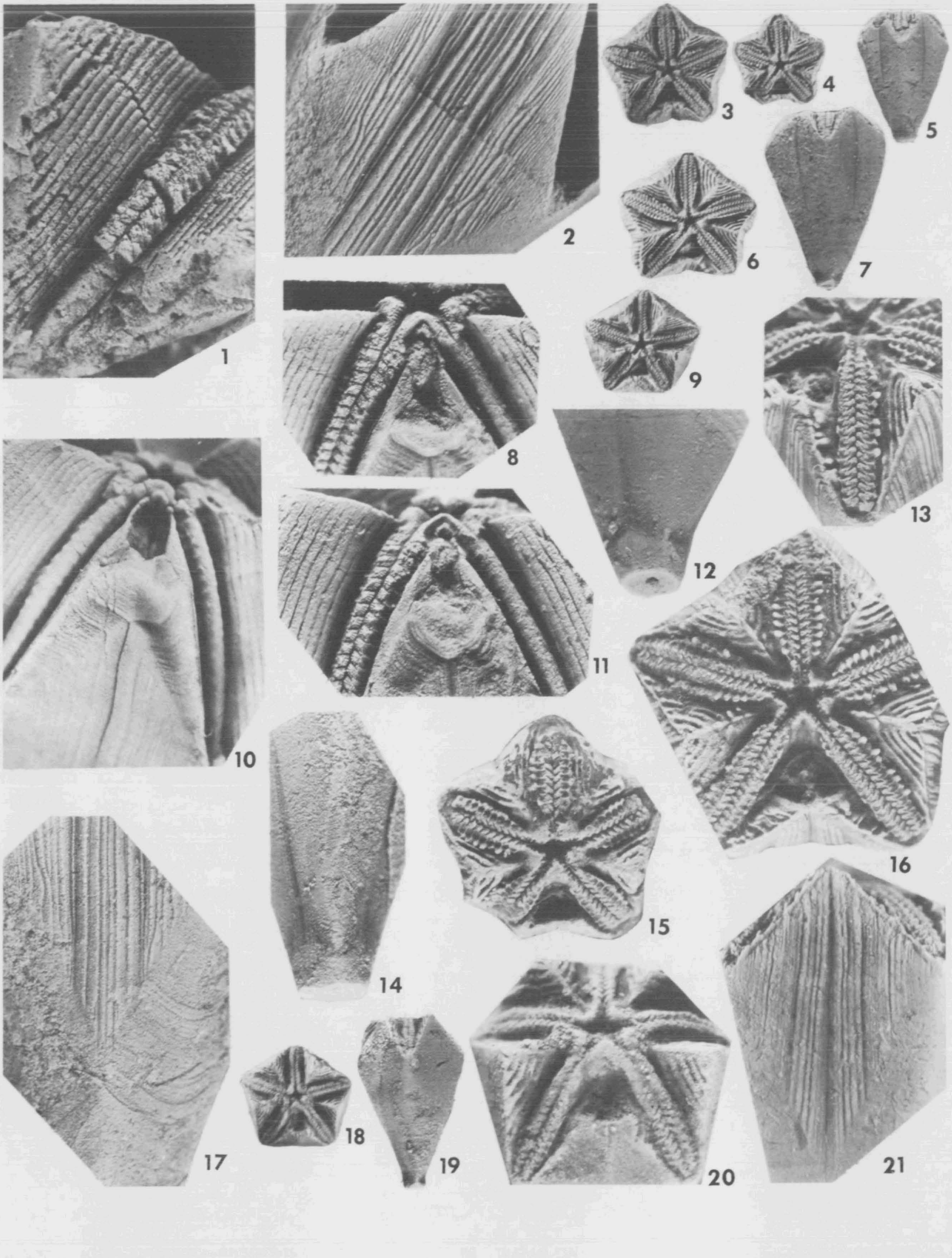
6 – *H. alatum*. Oral view. (Anus at 6 o'clock.) No. 10 in growth series. Devonian, Potter Farm Formation, Michigan, U.S.A. x 3.

9 – *Heteroschisma subtruncatum* (Hall, 1858). Oral view. (Anus at 6 o'clock.) USNM 160730. Devonian, Petoskey Formation. Scenic road, 1.6 miles north of Norwood, Michigan, U.S.A. x 3.

10 – *P. verneuili*. View of anal interarea. No. 3 in growth series. See also Pl. 8, fig. 7, and Pl. 9, figs. 3, 8 herein. Devonian, La Vid Formation, Colle, Leon, Spain. x 7.

12, 13, 16, 21 – *H. alatum*. View of basals, D ambulacrum, oral view (anus at 6 o'clock), and DE interambulacral area. No. 14 in growth series. (See also Breimer and Macurda, 1972, Pl. III, figs. 7, 9). Devonian, Potter Farm Formation, Michigan, U.S.A. x 7.

18-20 – *H. subtruncatum*. Oral (anus at 6 o'clock) and lateral (E) views and view of anal interarea. No. 6 in growth series I. Devonian, Thunderbay Limestone, Michigan, U.S.A. Figs. 18, 19, x 3; fig. 20, x 7.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EXPLANATION OF PLATE 11

FIGS.

1, 10, 19 – *Heteroschisma alternatum* (Lyon, 1857). Oral and lateral (A) views and enlarged oral view (anus at 6 o'clock in oral views). USNM S4567. Figured plesiotype of *Codaster americanus* Shumard, 1858 (Cline and Heuer, 1950). Devonian, Jeffersonville Limestone, Louisville, Kentucky, U.S.A.. Figs. 1, 10, x 3; fig. 19, x 7.

2 – *H. alternatum*. Oral view. (Anus at 6 o'clock.) USNM 4585. Figured plesiotype of *Codaster robustus* Rowley, 1902 (Cline and Heuer, 1950). Devonian, Jeffersonville Limestone, Louisville, Kentucky, U.S.A. x 3.

3 – *H. alternatum*. Oral view. (Anus at 6 o'clock.) USNM 3207. Figured plesiotype of *Codaster alternatus* Lyon, 1857 (Cline and Heuer, 1950). Devonian, Jeffersonville Limestone, Louisville, Kentucky, U.S.A. x 3.

4 – *H. alternatum*. Oral view. (Anus at 6 o'clock.) USNM S4536. Devonian, Jeffersonville Limestone, Louisville, Kentucky, U.S.A. x 3.

5 – *H. alternatum*. Lateral (E) view. Ohio State University 19853. Figured plesiotype of *Codaster pyramidatus* Shumard, 1858 (Cline and Heuer, 1950). Devonian, Columbus Limestone, Columbus, Ohio, U.S.A. x 3.

6 – *H. alternatum*. Oral view. (Anus at 6 o'clock.) USNM 4603. Figured plesiotype of *Codaster pyramidatus* (Cline and Heuer, 1950). Devonian, Jeffersonville Limestone, Louisville, Kentucky, U.S.A. x 3.

7, 17 – *H. alternatum*. Oral and lateral (A) views. (Anus at 6 o'clock.) AMNH 4173. Devonian, Columbus Limestone, Columbus, Ohio, U.S.A. x 3.

8 – *H. alternatum*. Oral view. (Anus at 6 o'clock.) USNM S4591. Devonian, Jeffersonville Limestone, Louisville, Kentucky, U.S.A. x 3.

9, 13, 20, 23 – *H. alternatum*. Oral (anus at 6 o'clock) lateral (B), enlarged oral, and C ambulacral views. USNM S4580. Devonian, Jeffersonville Limestone, Louisville, Kentucky, U.S.A. Figs. 9, 13, x 3; figs. 20, 23, x 7.

11 – *H. alternatum*. Lateral (C) view. USNM 4602. Figured plesiotype of *Codaster robustus* (Cline and Heuer, 1950). Devonian, Jeffersonville Limestone, Louisville, Kentucky, U.S.A. x 3.

12 – *H. alternatum*. Lateral (B) view. USNM 4603. Figured plesiotype of *Codaster pyramidatus* (Cline and Heuer, 1950). Devonian, Jeffersonville Limestone, Louisville, Kentucky, U.S.A. x 3.

14, 18 – *H. alternatum*. Lateral (B) and basal (anus at 6 o'clock) views. USNM S4584. Figured plesiotype of *Codaster pyramidatus* (Cline and Heuer, 1950). Devonian, Jeffersonville Limestone, Louisville, Kentucky, U.S.A. x 3.

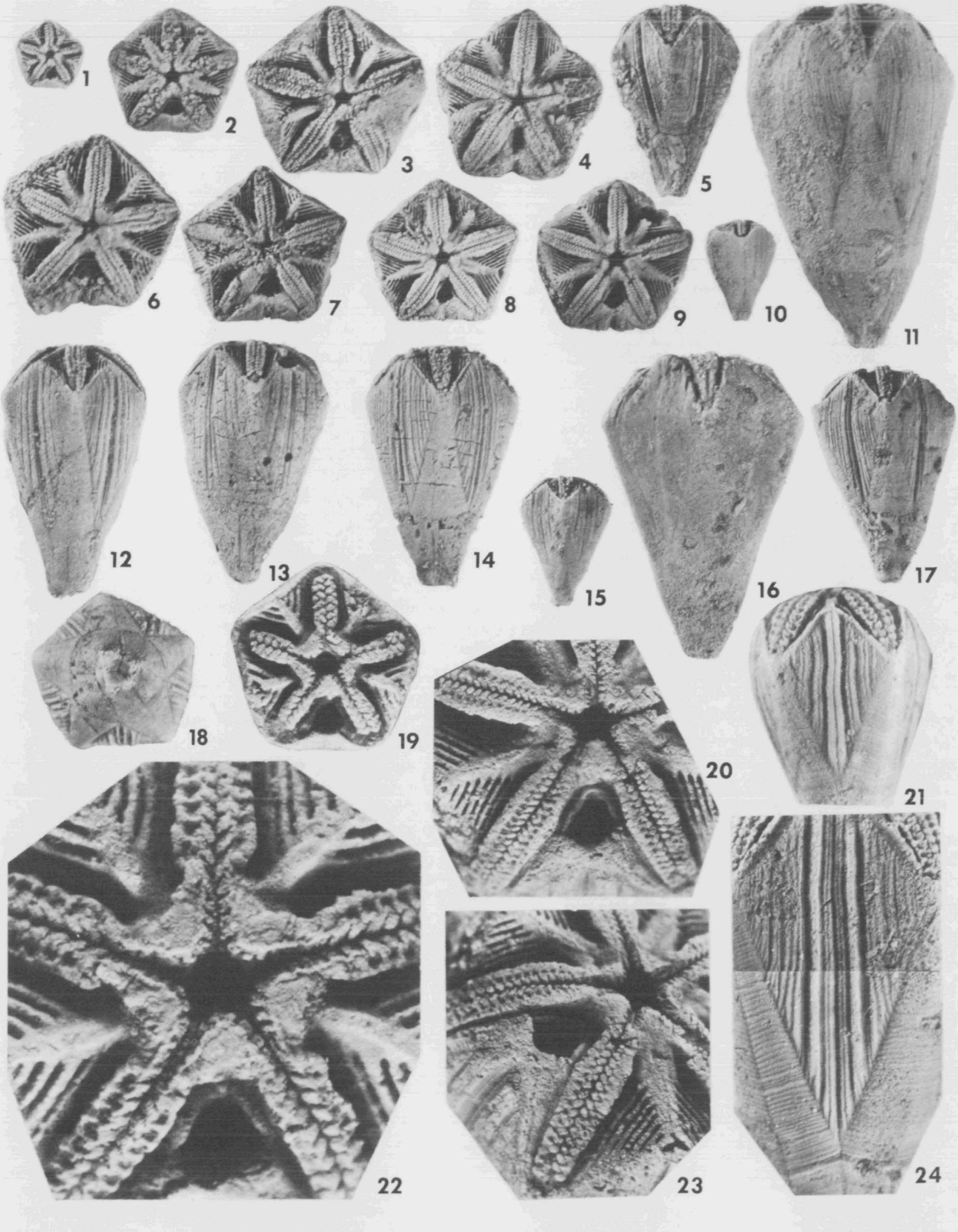
15 – *H. alternatum*. Lateral (A) view. No. 7 in growth series. Devonian, Columbus Limestone, Columbus, Ohio, U.S.A. x 3.

16 – *H. alternatum*. Lateral (D) view. USNM S3201. Lectotype of *Codaster alternatus* (Cline and Heuer, 1950). Devonian, Jeffersonville Limestone, Louisville, Kentucky, U.S.A. x 3.

21 – *H. alternatum*. Lateral (DE) view. USNM S4534. Figured plesiotype of *Codaster pyramidatus* (Cline and Heuer, 1950). Devonian, Jeffersonville Limestone, Louisville, Kentucky, U.S.A. x 7.

22 – *H. alternatum*. Oral view. (Anus at 6 o'clock.) USNM 4565. Neotype of *Codaster americanus* (Cline and Heuer, 1950). Devonian, Jeffersonville Limestone, Louisville, Kentucky, U.S.A. x 7.

24 – *H. alternatum*. Detail CD interambulacral area. USNM 5414. Devonian, Jeffersonville Limestone, Louisville, Kentucky, U.S.A. x 7.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EXPLANATION OF PLATE 12

FIGS.

1, 2, 13 – *Heteroschisma canadense* (Billings, 1869). Oral (anus at 6 o'clock) and lateral (B) views and view of tip of basals. No. 10 in growth series. Devonian, Hungry Hollow Formation, Ontario, Canada. Figs. 1, 2, x 3; fig. 13, x 7.

3, 5 – *H. canadense*. Oral (anus at 6 o'clock) and lateral (D) views. USNM 160752. Devonian, upper Widder Beds, Bell's quarry, Thedford, Ontario, Canada. x 3.

4 – *H. canadense*. Lateral (A) view. No. 5 in growth series. Devonian, Hungry Hollow Formation, Ontario, Canada. x 3.

6 – *H. canadense*. Oral view. (Anus at 7 o'clock.) No. 20 in growth series. Devonian, Hungry Hollow Formation, Ontario, Canada. x 7.

7 – *H. canadense*. Lateral (AB) view. No. 17 in growth series. Devonian, Hungry Hollow Formation, Ontario, Canada. x 7.

8, 9 – *Heteroschisma subtruncatum* (Hall, 1858). Oral (anus at 6 o'clock) and lateral (C) views. No. 5 in growth series II. Devonian, Cedar Valley Limestone, Iowa, U.S.A. x 3.

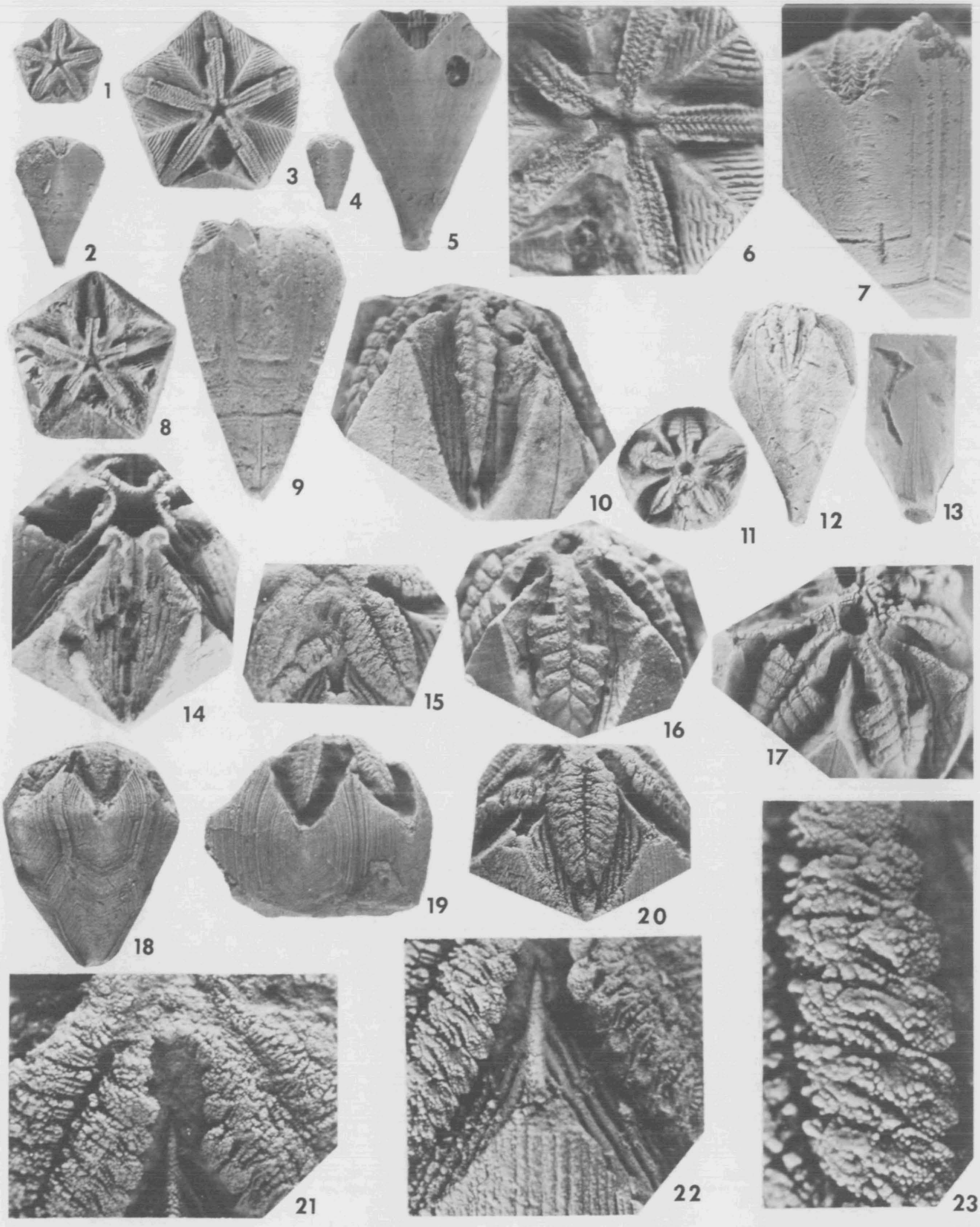
10-12, 16, 17 – *Phaenoschisma acutum*. View of D ambulacrum, oral (anus at 6 o'clock) and lateral (C) views, and views of E ambulacrum and EA interarea respectively. No. 1 in growth series. Carboniferous Limestone, Bolland, Lancashire, England. Figs. 10, 16, 17, x 7; figs. 11, 12, x 3.

14 – *P. acutum*. View of B ambulacrum. No. 3 in growth series. (See also Breimer and Macurda, 1972, Pl. IV, figs. 3, 5.) Lower Carboniferous, Clitheroe Limestone, Clitheroe, England. x 7.

15, 20-23 – *Phaenoschisma conicum* (Fay, 1962). View of anal interarea, C ambulacrum, BC interambulacrum (2 views) and B side of C ambulacrum. (See also Breimer and Macurda, 1972, Pl. III, fig. 24.) No. 3 in growth series. Mississippian, Lake Valley Limestone, Nunn Member, Lake Valley, New Mexico, U.S.A. Figs. 15, 20, x 7; figs. 21, 22, x 17.5; fig. 23, x 40.

18 – *P. conicum*. Lateral (C) view. No. 4 in growth series. Mississippian, Lake Valley Limestone, Nunn Member, Lake Valley, New Mexico, U.S.A. x 4.

19 – *P. conicum*. Lateral (D) view. No. 8 in growth series. Mississippian, Lake Valley Limestone, Nunn Member, Lake Valley, New Mexico, U.S.A. x 4.



EXPLANATION OF PLATE 13

FIGS.

1 – *Pentremoblastus conicus* Fay and Koenig, 1964. Lateral (A) view. No. 3 in growth series. Mississippian, McCraney Formation, Illinois, U.S.A. x 4.

2, 3, 5, 6 – *Pentremoblastus conicus.* Lateral (D and CD) views, view of C ambulacrum and view of oral area (anus at 6 o'clock). No. 1 in growth series. (See also Breimer and Macurda, 1972, Pl. IV, figs. 4, 9.) Mississippian, McCraney Formation, Illinois, U.S.A. Figs. 2, 3, 6, x 7; fig. 5, x 17.5.

4, 7, 11 – *Phaenoschisma laeviculum* (Rowley, 1900). Inclined view of AB interambulacral area, oral view (anus at 6 o'clock) and B ambulacral view. J. Sprinkle collection, Museum Comparative Zoology 1001, Harvard University. Mississippian, Burlington Limestone. Roadcut north side of I-44, 0.3 mile east of Dry Branch Bridge, SW¼ SE¼ SE¼ sec. 26, T29N, R25W, Greene County, Missouri, U.S.A. x 7.

8 – *P. laeviculum.* View of E ambulacrum. UMMP 58665. (See also Breimer and Macurda, Pl. IV, figs. 19, 21.) Mississippian, St. Joe Formation. Roadcut, NW¼ NE¼ sec. 9, T23N, R24E, Delaware County, Oklahoma, U.S.A. x 7.

9 – *Phaenoschisma*? *parvum* n. sp. Lateral (B) view. No. 7 in growth series. Mississippian, Lake Valley Limestone, Nunn Member, New Mexico, U.S.A. x 4.

10, 15 – *Phaenoschisma*? *parvum* n. sp. Lateral (A) and oral views (anus at 6 o'clock). No. 6 in growth series. Mississippian, Lake Valley Limestone, Nunn Member, New Mexico, U.S.A. x 4.

12, 13 – *Artuschisma rossica* (Arendt, Breimer, and Macurda), 1968. View of A ambulacrum and oral view (anus at 6 o'clock). (See also Arendt, Breimer, and Macurda, 1968, Pl. I, figs. 7, 9; Breimer and Macurda, 1972, Pl. V, figs. 12, 15). Paleontological Institute, Academy Sciences, Moscow. PIN 1788/8. Carboniferous, Namurian, Dombar Hills, Zhaksa-Kargol River basin, 1 km southwest of Tshan-Tshar, Aktiubinsk district, North Kazachstan, U.S.S.R. x 7.

14, 19 – *Phaenoschisma*? *parvum* n. sp. Lateral (C) and oral (anus at 6 o'clock) views. No. 4 in growth series. Mississippian, Lake Valley Limestone, Nunn Member, New Mexico, U.S.A. x 4.

16 – *Phaenoschisma*? *parvum* n. sp. Lateral (B) view. No. 8 in growth series. Mississippian, Lake Valley Limestone, Nunn Member, New Mexico, U.S.A. x 4.

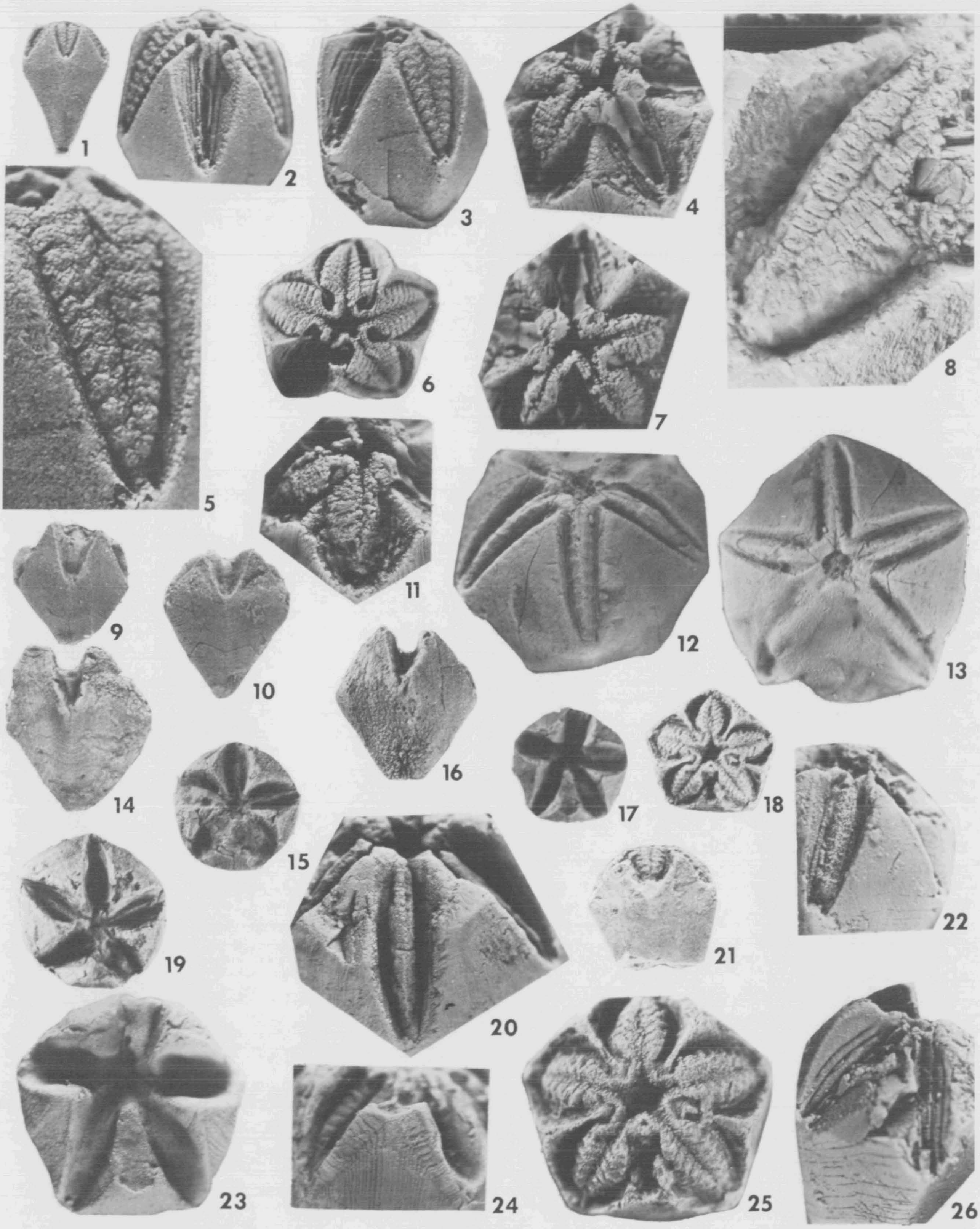
17, 23 – *Phaenoschisma*? *parvum* n. sp. Oral view (anus at 6 o'clock) and inclined view of anal interarea. No. 1 in growth series. Mississippian, Lake Valley Limestone, Nunn Member, New Mexico, U.S.A. x 4 and x 7.

18, 21, 25 – Phaenoschismatid (unidentified). Oral, lateral (D) and enlarged oral views (anus at 6 o'clock in oral views). UMMP 58663. (See also Breimer and Macurda, 1972, Pl. III, figs. 17, 22). Mississippian, Caballero Formation, Sacramento Mountains, New Mexico, U.S.A. Figs. 18, 21, x 4; fig. 25, x 7.

20 – *Phaenoschisma*? *parvum* n. sp. View of B ambulacrum. No. 2 in growth series. (See also Breimer and Macurda, 1972, Pl. V, figs. 1, 2.) Mississippian, Lake Valley Limestone, Nunn Member, New Mexico, U.S.A. x 7.

22, 26 – Phaenoschismatid (unidentified). Views of B ambulacrum and EA interambulacral areas. (See also Breimer and Macurda, 1972, Pl. V, figs. 3, 6.) Mississippian, Osage or Keokuk, Missouri. x 7.

24 – *Phaenoschisma*? *parvum* n. sp. View of anal interarea. No. 5 in growth series. (See also Breimer and Macurda, 1972, Pl. IV, fig. 20.) Mississippian, Lake Valley Limestone, Nunn Member, New Mexico, U.S.A. x 7.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EXPLANATION OF PLATE 14

FIGS.

1, 5, 7, 8 – *Phaenoschisma*? *saharae* Breimer and Macurda, 1972. Oral, lateral (A), enlarged oral, and anal interarea views (anus at 6 o'clock in oral views). No. 5 in growth series. Carboniferous, Visean, Djenien Formation, Algeria. Figs. 1, 5, x 3; figs. 7, 8, x 7.

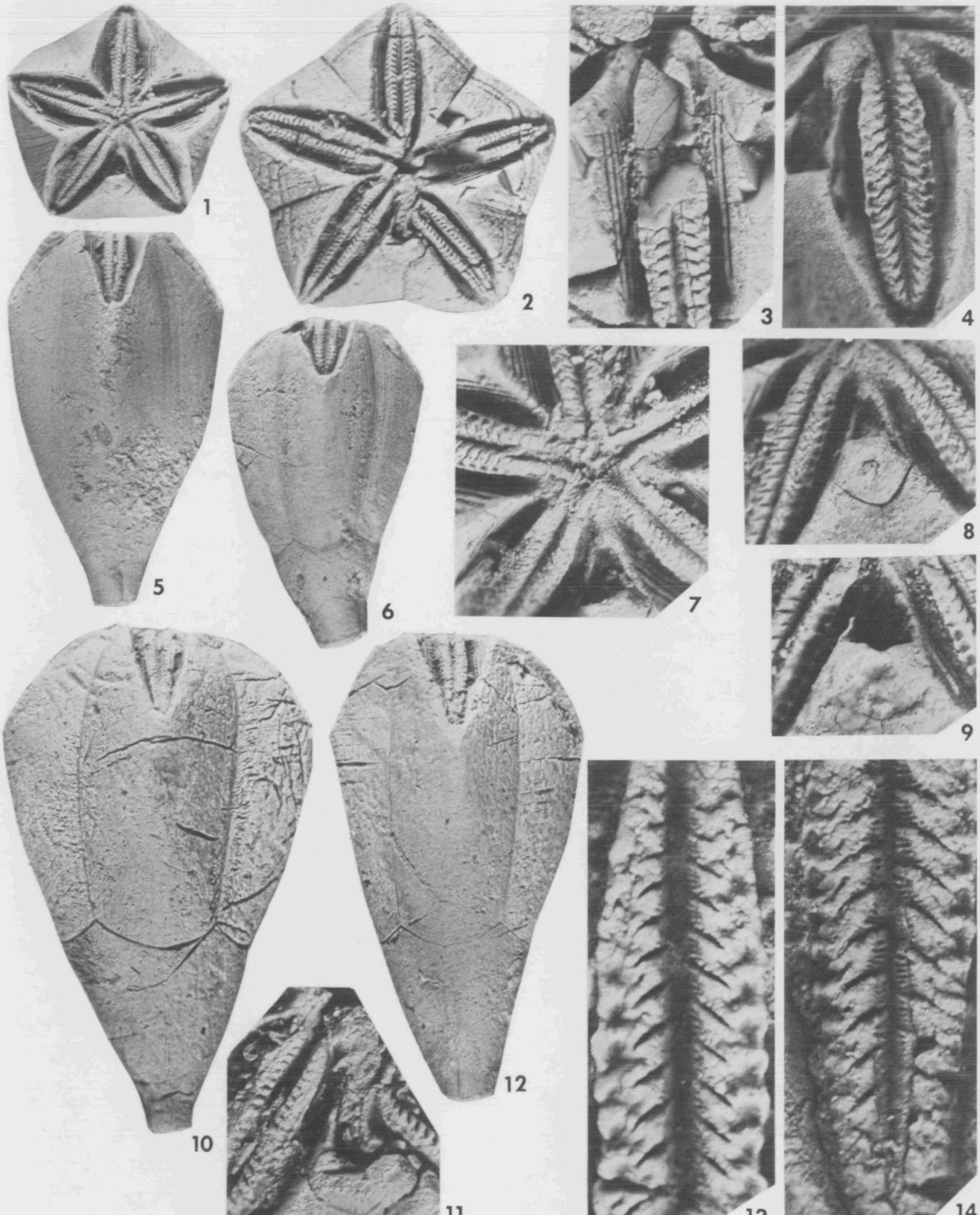
2, 3, 10, 11 – *P.*? *saharae*. Oral view, view of B ambulacrum, lateral (D) view, and view of anal interarea. No. 8 in growth series. Visean, Djenien Formation, Algeria. Figs. 2, 10, x 3; figs. 3, 11, x 7.

4, 6, 14 – *P.*? *saharae*. View of C ambulacrum, lateral (C) view, and view of D ambulacrum. No. 3 in growth series. Visean, Djenien Formation, Algeria. Fig. 4, x 7; fig. 6, x 3; fig. 14, x 17.5.

9 – *P.*? *saharae*. View of anal interarea. No. 6 in growth series. Visean, Djenien Formation, Algeria. x 7.

12 – *P.*? *saharae*. Lateral (B) view. No. 7 in growth series. Visean, Djenien Formation, Algeria. x 3.

13 – *P.*? *saharae*. View of C ambulacrum. No. 9 in growth series. Visean, Djenien Formation, Algeria. x 17.5.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EXPLANATION OF PLATE 15

FIGS.

1 – *Phaenoblastus pecki* (Macurda, 1964). Oral view. (Anus at 6 o'clock). Oklahoma University, 8665. (See also Breimer and Macurda, 1972, Pl. IV, figs. 11, 15, 18.) Mississippian, Chouteau Limestone, quarry west of Sedalia, Missouri, U.S.A. x 7.

2, 3, 10 – *Kazachstanoblastus carinatus* Arendt, Breimer, and Macurda, 1968. Lateral (E), D ambulacral, and oral (anus at 6 o'clock) views. No. 4 in growth series. (See also Arendt, Breimer, and Macurda, 1968, Pl. I, fig. 8.) Carboniferous, Namurian, Kazachstan, U.S.S.R. Fig. 2, x 3; fig. 3, x 7; fig. 10, x 3.6.

4 – *P. pecki*. View of azygous basal. University Missouri 3574. Mississippian, Chouteau Limestone, Providence, Missouri, U.S.A. x 7.

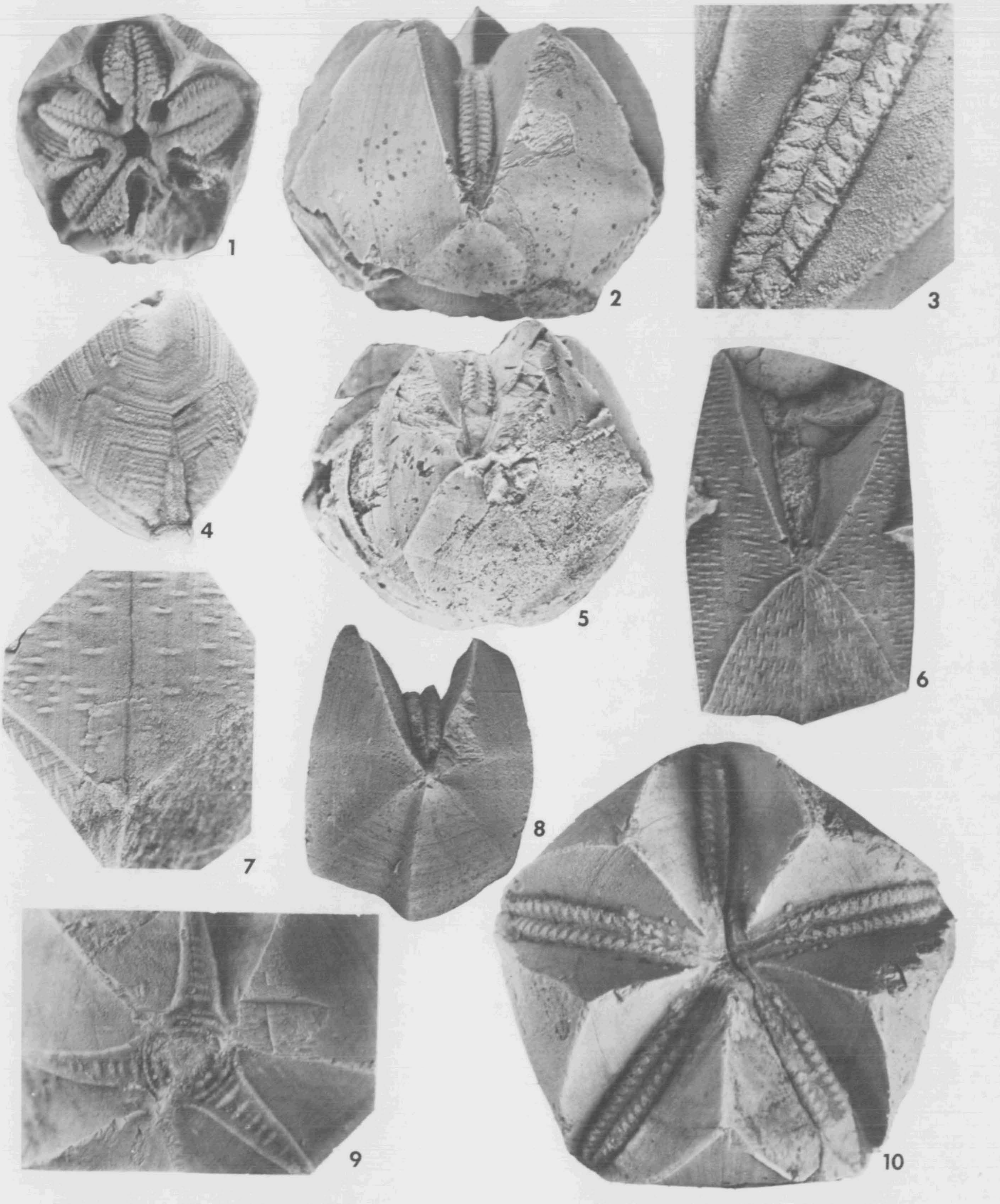
5 – *K. carinatus*. Lateral (D) view. No. 1 in growth series. Namurian, Kazachstan, U.S.S.R. x 3.

6 – *K. carinatus*. View of isolated radial. No. 6 in growth series. Namurian, Kazachstan, U.S.S.R. x 3.

7 – *K. carinatus*. View of RR sectors. No. 2 in growth series. Namurian, Kazachstan, U.S.S.R. x 7.

8 – *K. carinatus*. View of isolated radial. No. 5 in growth series. Namurian, Kazachstan, U.S.S.R. x 7.

9 – *K. carinatus*. View of basals. Azygous basal NW. No. 3 in growth series. (See also Arendt, Breimer, and Macurda, 1968, Pl. I, fig. 5; Breimer and Macurda, 1972, Pl. V, figs. 14, 16, 17.) Namurian, Kazachstan, U.S.S.R. x 7.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EXPLANATION OF PLATE 16

FIGS.

1, 2, 5 – *Dolichoblastus shimanski* Arendt, Breimer, and Macurda, 1968. Views of anal interarea, B ambulacrum, and D ambulacrum. Paleontological Institute, Academy Sciences, Moscow. PIN 1787/1. (See also Arendt, Breimer, and Macurda, 1968, Pl. I, figs. 6, 10; Breimer and Macurda, 1972, Pl. VI, figs. 1, 4.) Carboniferous, Namurian, Dombar Hills, Zhaksa-Kargol River basin, 1 km SW of Tshan-Tshar, Aktiubinsk district, North Kazachstan, U.S.S.R. x 7.

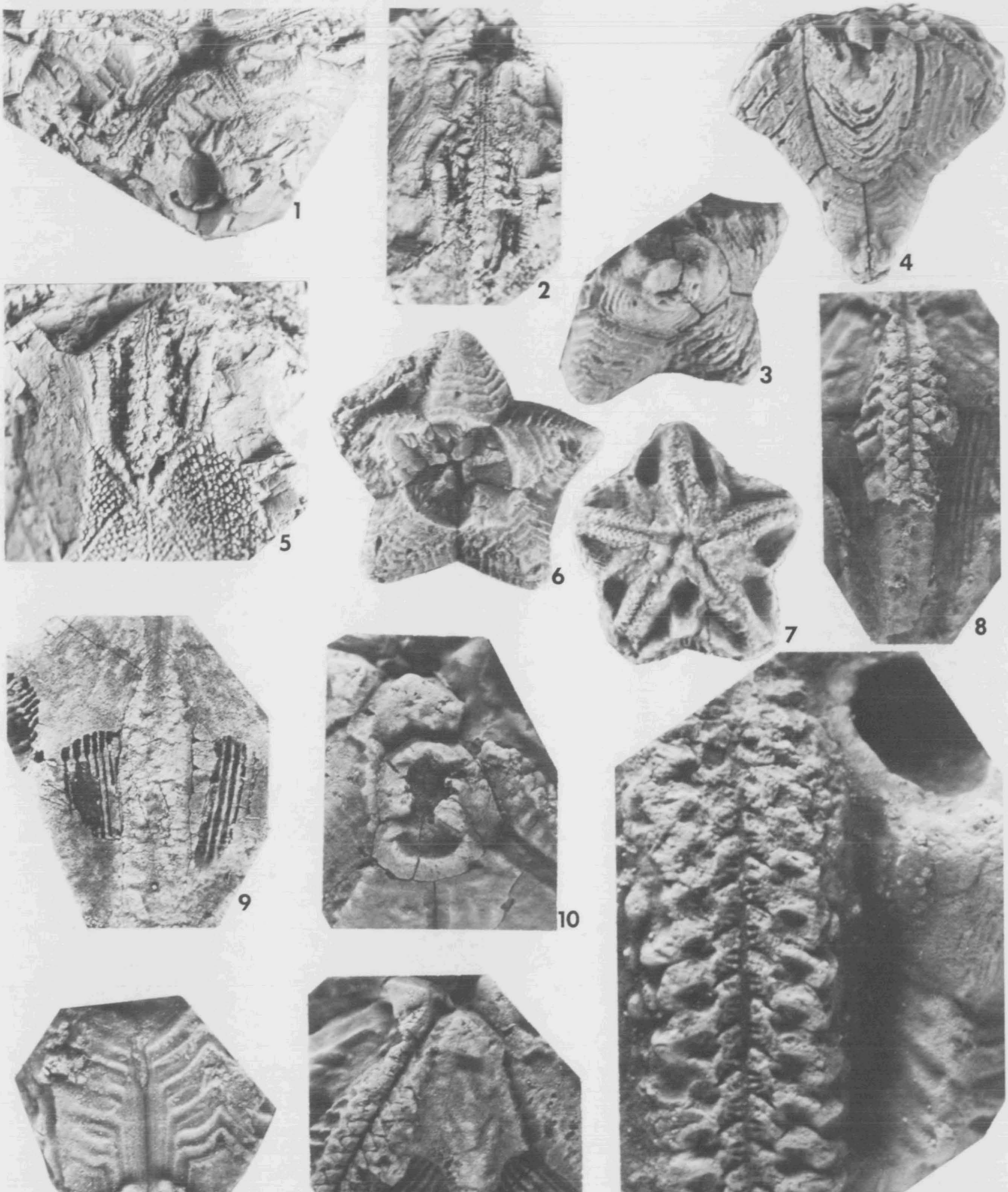
2, 3, 8, 10, 12 – *Brachyschisma corrugatum* (Reimann, 1935). Basal (anus at 6 o'clock) and lateral (D) views, and views of E ambulacrum, anal interarea, and DE deltoid respectively. No. 5 in growth series. Devonian, Onondaga Limestone, New York, U.S.A. Figs. 3, 4, x 3; figs. 8, 10, 12, x 7.

6, 9 – *B. corrugatum*. Basal view and view of A ambulacrum. No. 9 in growth series. Devonian, Onondaga Limestone, New York, U.S.A. x 3 and x 7.

7 – *B. corrugatum*. Oral view. (Anus at 6 o'clock.) No. 3 in growth series. (See also Breimer and Macurda, 1972, Pl. VI, figs. 2, 5, 6.) Devonian, Onondaga Limestone, New York, U.S.A. x 3.

11 – *B. corrugatum*. View of basals. No. 7 in growth series. Devonian, Onondaga Limestone, New York, U.S.A. x 7.

13 – *B. corrugatum*. View of D ambulacrum. No. 12 in growth series. Devonian, Onondaga Limestone, New York, U.S.A. x 17.5.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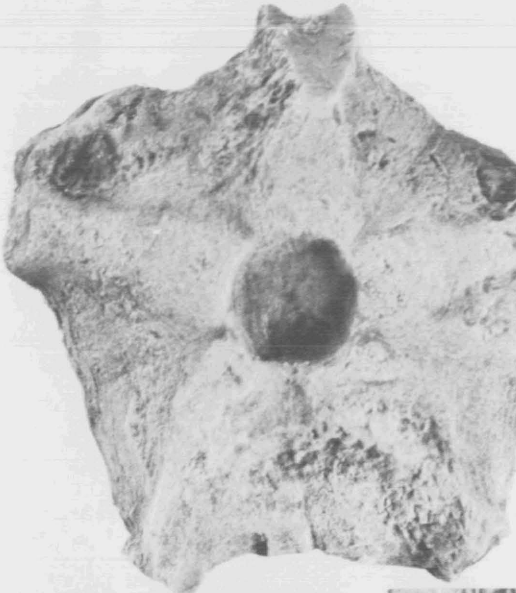
EXPLANATION OF PLATE 17

FIGS.

1 – *Acentrotremites ellipticus* (Cumberland, 1826). (See also Breimer and Macurda, 1972, Pl. X, figs. 3, 5.) Basal view. BMNH E8256. Lower Carboniferous, Visean, Wrington, Somerset, England. x 3.

2-7 – *A. ellipticus*. Views of C ambulacrum, anal interarea, E ambulacrum, C ambulacrum, hypodeltoid, and oral area respectively. BMNH E872. See also Pl. 18, figs. 3, 4 herein. Lower Carboniferous, Visean, Somerset, England. Figs. 2-6, x 7; fig. 7, x 3.



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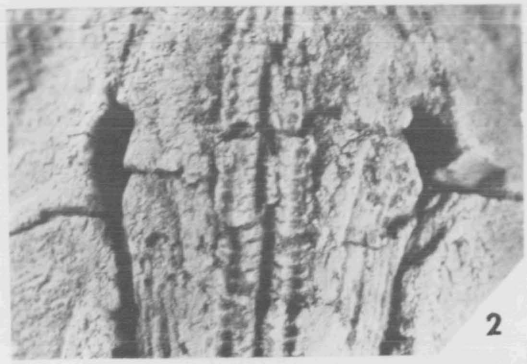

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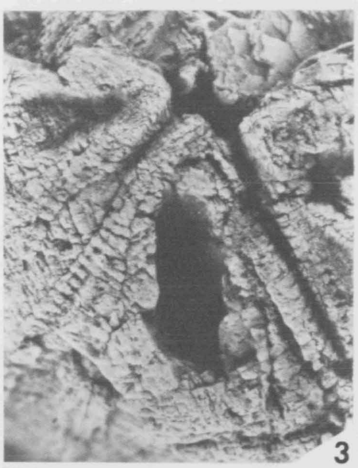

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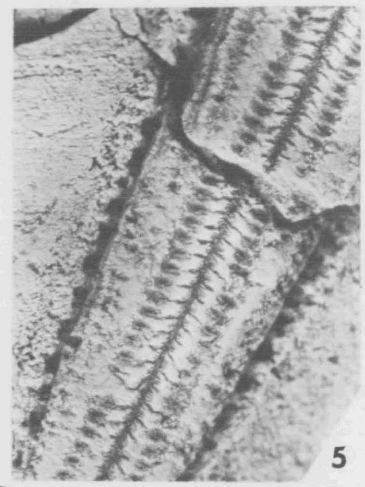

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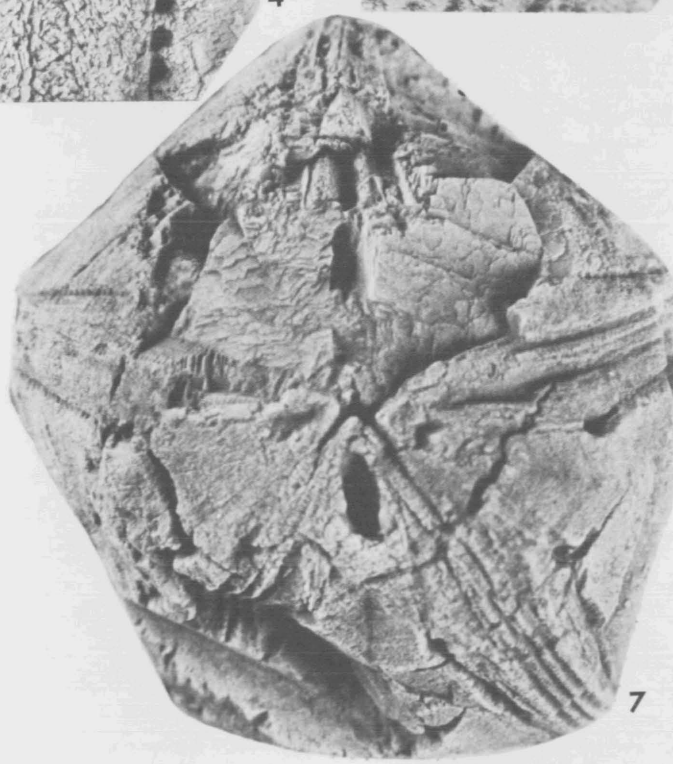

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EXPLANATION OF PLATE 18

FIGS.

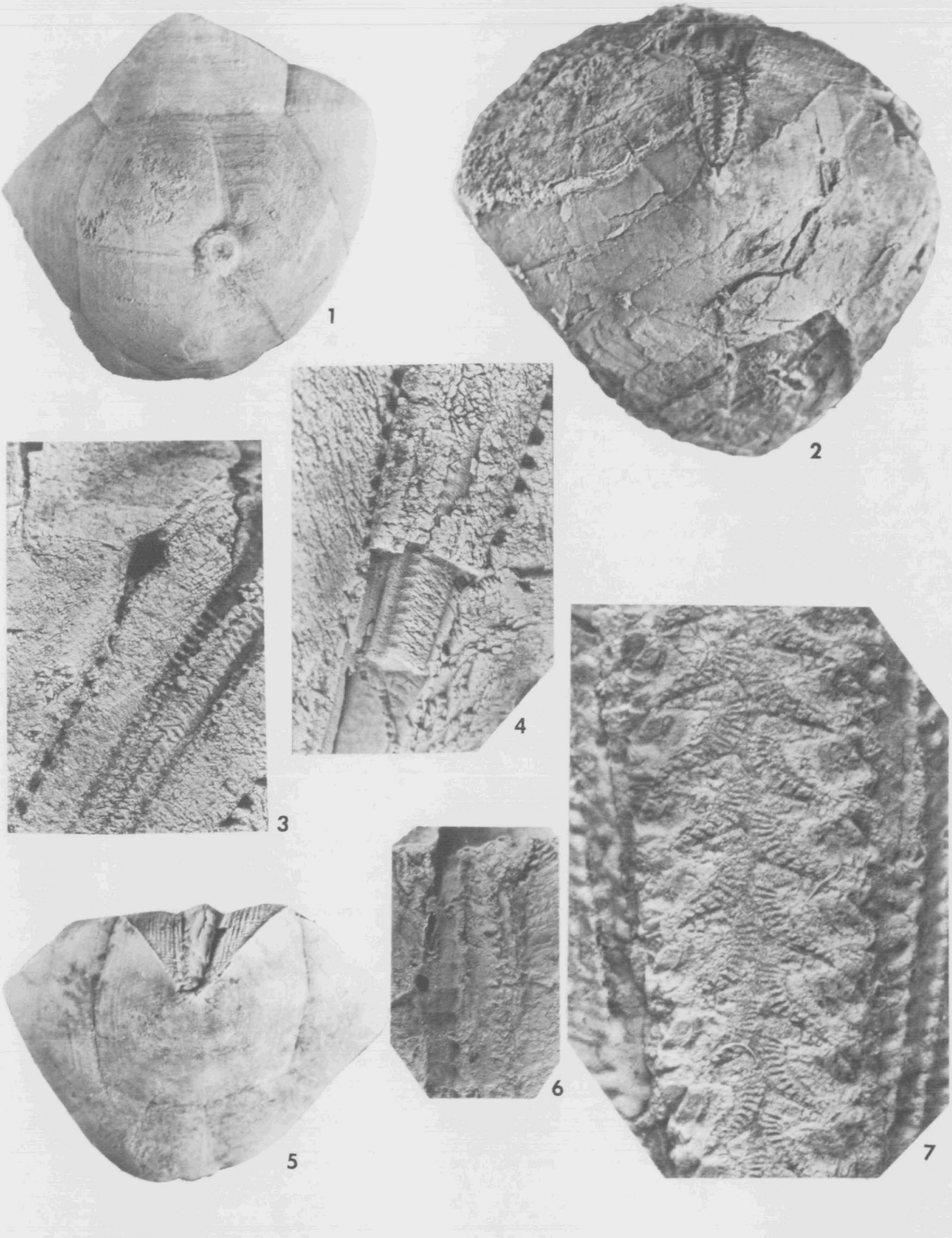
1, 5 – *Mastoblastus ornatus* Arendt, Breimer, and Macurda, 1968. Basal (anus at 6 o'clock) and lateral (A) views. No. 8 in growth series. See also Pl. 19, fig. 3 herein. Carboniferous, Namurian, Kazachstan, U.S.S.R. x 3.

2 – *M. ornatus*. Lateral (A) view. No. 5 in growth series. Namurian, Kazachstan, U.S.S.R. x 3.

3, 4 – *Acentrotremites ellipticus* (Cumberland, 1826). Views of B and E ambulacra. BMNH E872. See also Pl. 17, figs. 2-7 herein. Lower Carboniferous, Visean, Somerset, England. x 7.

6 – *M. ornatus*. View of A ambulacrum. No. 2 in growth series. (See also Breimer and Macurda, 1972, Pl. X, figs. 1, 2, 6.) Namurian, Kazachstan, U.S.S.R. x 7.

7 – *M. ornatus*. View of B ambulacrum. No. 15 in growth series. Namurian, Kazachstan, U.S.S.R. x 17.5.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EXPLANATION OF PLATE 19

FIGS.

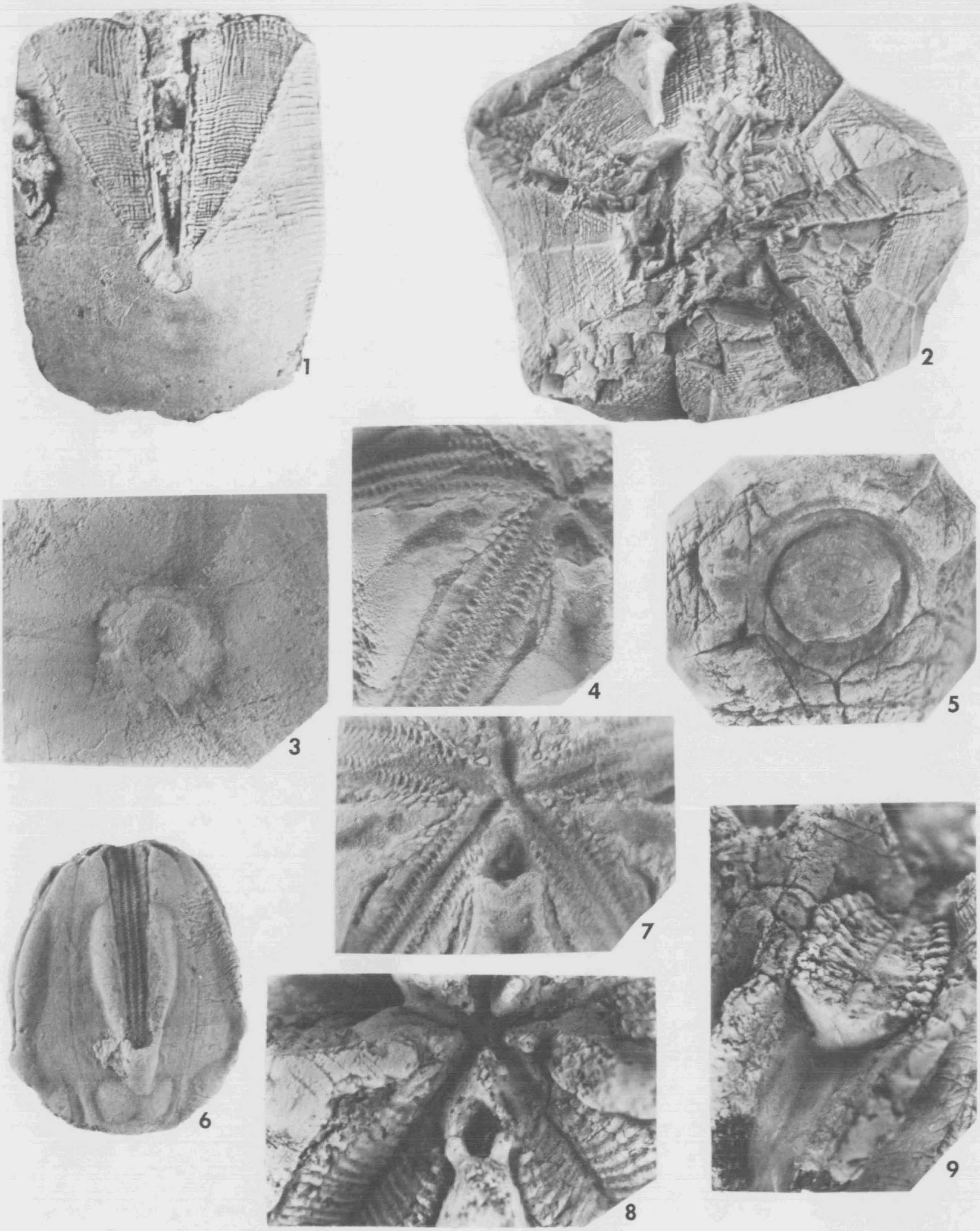
1 – *Mastoblastus ornatus* Arendt, Breimer, and Macurda, 1968. View of isolated radial. No. 13 in growth series. Carboniferous, Namurian, Kazachstan, U.S.S.R. x 3.

2 – *M. ornatus*. Oral view. No. 10 in growth series. Namurian, Kazachstan, U.S.S.R. x 3.

3 – *M. ornatus*. Detail of stem attachment area. No. 8 in growth series. See also Pl. 18, figs. 1, 5 herein. Namurian, Kazachstan, U.S.S.R. x 7.

4-7 – *Pentablastus supracarbonicus* Sieverts-Doreck, 1951. Views of D ambulacrum, base, lateral (A) side, and oral area respectively. No. 1 in growth series. (See also Breimer and Macurda, 1972, Pl. IX, figs. 10-12). Carboniferous, Namurian, Rabanal Limestone, Palencia, Spain. Figs. 4, 5, 7, x 7; fig. 6, x 3.

8, 9 – *Anthoblastus brouweri* Wanner, 1924b. Views of anal interarea and B ambulacrum. Technische Hogeschool, Delft 12264. Holotype. (See also Breimer and Macurda, 1972, Pl. XI, figs. 1-3, and Pl. 20, fig. 8 herein.) Permian, Somohole, Timor, Indonesia. x 7.



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EXPLANATION OF PLATE 20

FIGS.

1, 4 – *Anthoblastus brouweri* Wanner, 1924b. Lateral (E) and oral (anus at 6 o'clock) views. Technische Hogeschool, Delft, unregistered specimen. Permian, Somohole, Timor, Indonesia. x 3.

2, 7 – *Anthoblastus stelliformis* Wanner, 1924b. Oral and basal views. (Anus at 6 o'clock.) No. 1 in growth series. Permian, Timor, Indonesia. x 2 and x 3.

3, 9, 10 – *A. stelliformis*. Lateral (A) view and views of base of the radial prong and the basals. No. 8 in growth series. Permian, Basleo, Timor, Indonesia. Fig. 3, x 3; figs. 9, 10, x 7.

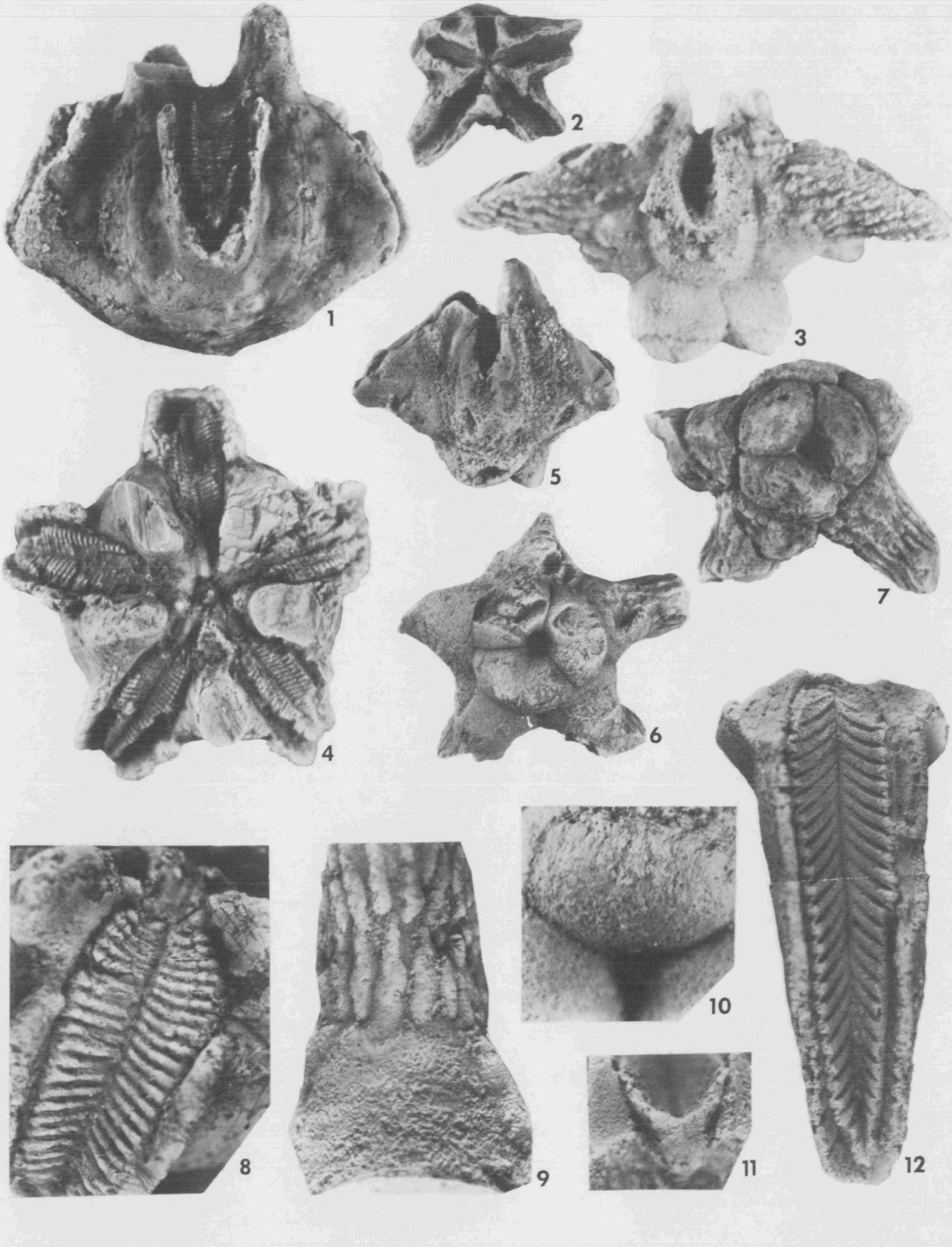
5 – *A. stelliformis*. Lateral (C) view. No. 2 in growth series. Permian, Timor, Indonesia. x 3.

6 – *A. stelliformis*. Basal view. (Anus at 6 o'clock.) No. 9 in growth series. Permian, Timor, Indonesia. x 3.

8 – *A. brouweri*. View of C ambulacrum. Technische Hogeschool, Delft 12264. Holotype. (See also Breimer and Macurda, 1972, Pl. XI, figs. 1-3, and Pl. 19, figs. 8, 9 herein.) Permian, Somohole, Timor, Indonesia. x 7.

11 – *A. stelliformis*. Tip of adoral end of ambulacrum. No. 4 in growth series. Permian, Timor, Indonesia. x 7.

12 – *A. stelliformis*. View of isolated radial and ambulacrum. No. 3 in growth series. Permian, Timor, Indonesia. x 7.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EXPLANATION OF PLATE 21

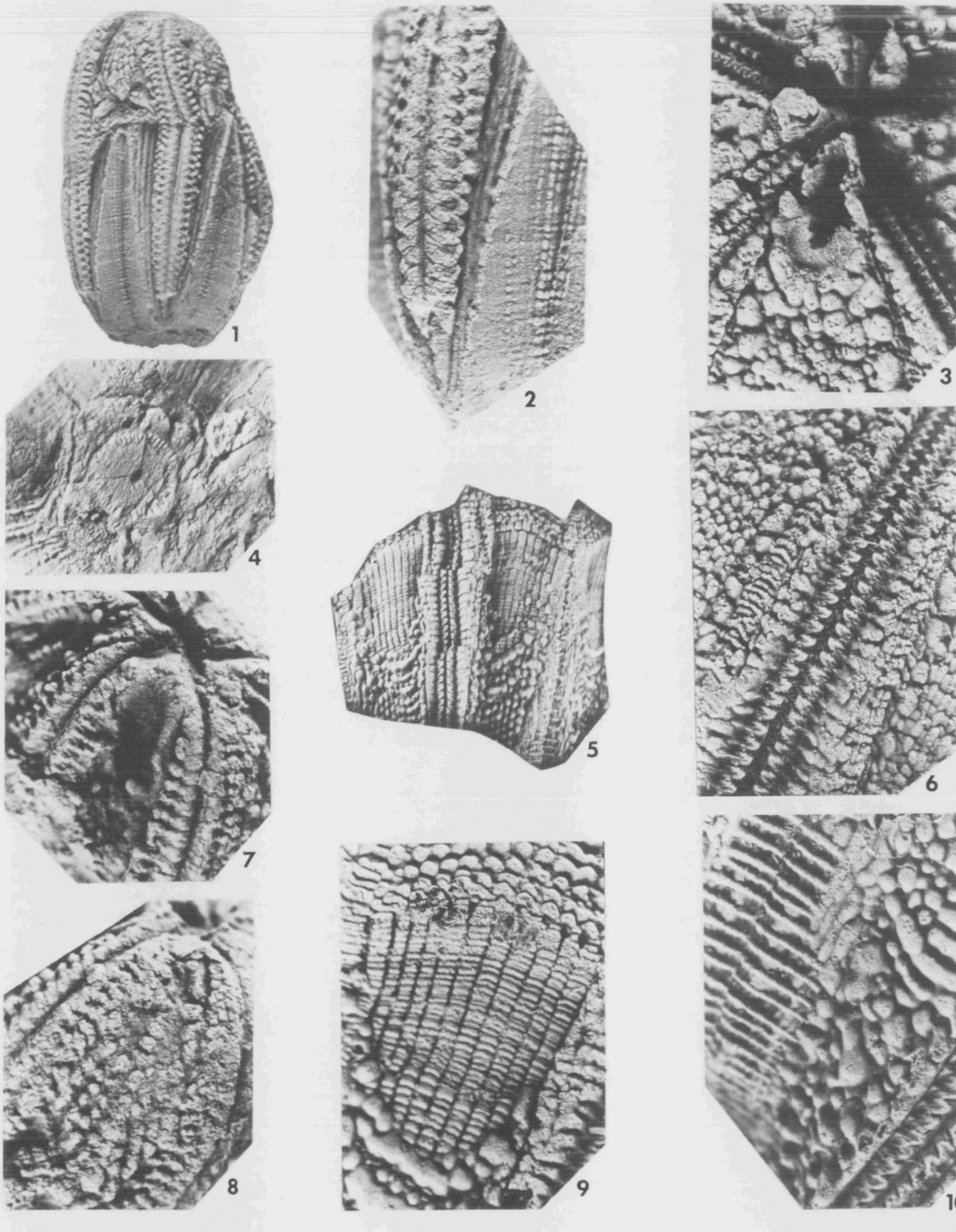
FIGS.

1, 2, 4, 7, 8 – *Xenoblastus decussatus* (Shumard, 1858). Lateral (A) view, and views of B ambulacrum, base of theca (anus at 6 o'clock), anal interarea, and BC deltoid respectively. USNM 160583. See also Breimer and Macurda, 1972, Pl. XIII, figs. 2, 3, 5). Mississippian, New Providence Formation, Coral Ridge Member. Overlook across Brooks, Bullitt County, Kentucky. Fig. 1, x 3; figs. 2, 4, 7, 8, x 7.

3, 6 – *Nymphaeoblastus bancrofti* McKellar, 1964. View of anal deltoids and ambulacrum. University Queensland F39410. (See also Breimer and Macurda, 1972, Pl. XV, fig. 2.) Lower Carboniferous, Visean, Tellebang Formation. Northern part of Portion 72, Parish of Cannindah, County of Yarrol, Queensland, Australia. x 7.

5 – *N. bancrofti*. View of upper part of radial. University Queensland F39411B. Tellebang Formation. Northern part of Portion 72, Parish of Cannindah, County of Yarrol, Queensland, Australia. x 3.

9, 10 – *N. bancrofti*. View of hydrospire field on radial and ornament in median part of RR sector. University Queensland F39411A. (See also Breimer and Macurda, 1972, Pl. XV, fig. 8, and Pl. 22, fig. 1 herein.) Tellebang Formation. Northern part of Portion 72, Parish of Cannindah, County of Yarrol, Queensland, Australia. x 7.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EXPLANATION OF PLATE 22

FIGS.

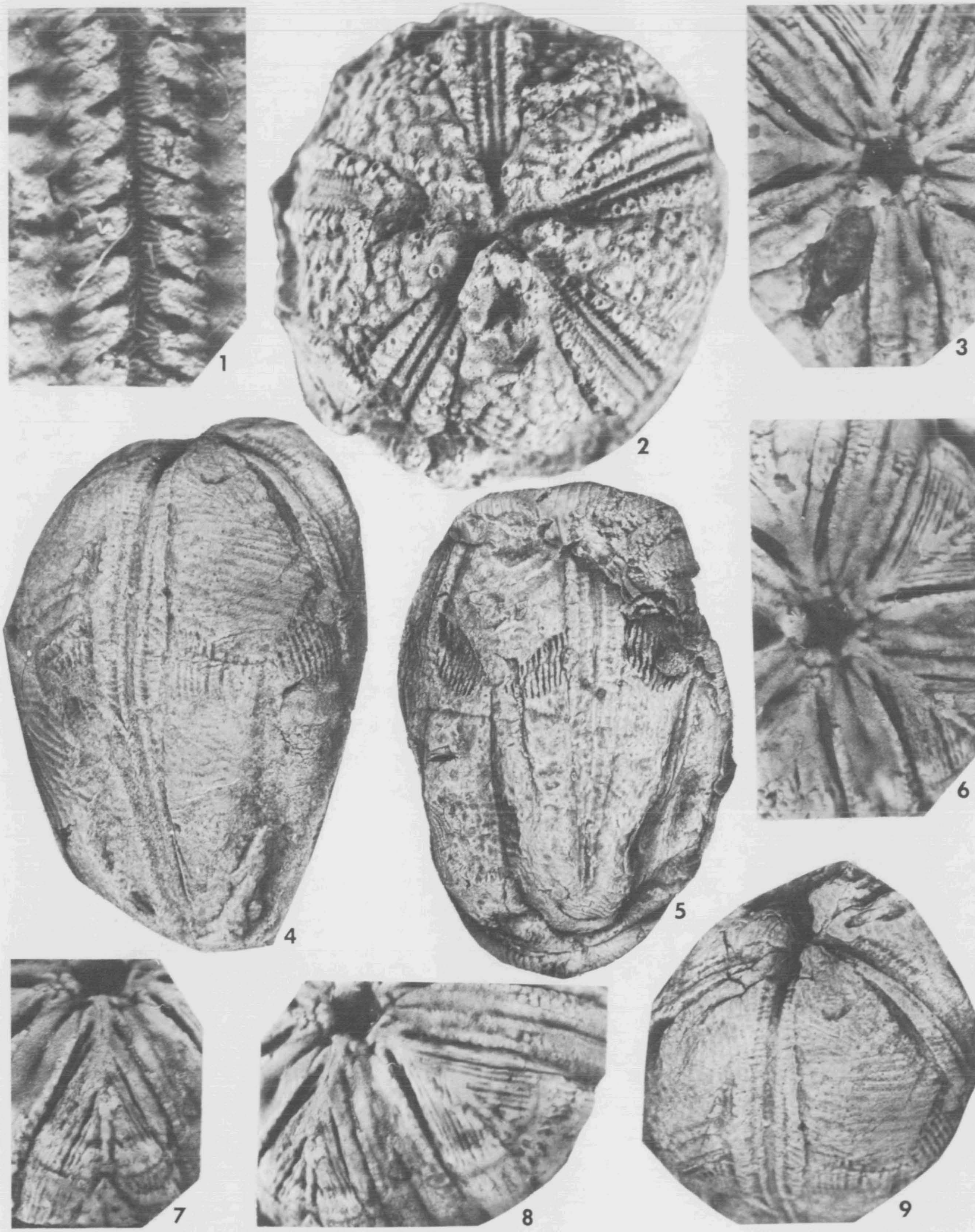
1 – *Nymphaeoblastus bancrofti* McKellar, 1964. View of ambulacrum. University Queensland F39411A. (See also Breimer and Macurda, 1972, Pl. XV, fig. 8, and Pl. 21, figs. 9, 10 herein.) Lower Carboniferous, Visean, Tellebang Formation. Northern part of Portion 72, Parish of Cannindah, County of Yarrol, Queensland, Australia. x 17.5.

2 – *Nymphaeoblastus miljukovi* Von Peetz, 1907. Oral view of plaster cast. (Anus at 6 o'clock.) Leningrad Central Geological Museum 4/1887. (See also Breimer and Macurda, 1972, Pl. XIV, fig. 1.) Carboniferous, Tournaisian, Province d'Akmolinsk, North Kazachstan, U.S.S.R. x 3.

3, 6, 7, 8 – *Sphaeroschisma somoholense* Wanner, 1924b. Views of oral area (anus at 7 o'clock and 9 o'clock respectively), AB deltoid, and EA deltoid. Holotype. Technische Hogeschool, Delft. (See also Breimer and Macurda, 1972, Pl. XV, figs. 4, 5, 7.) Permian, Somohole, Timor, Indonesia. x 7.

4, 9 – *N. miljukovi*. Lateral (E to left) and inclined oral (anus at 2 o'clock) view of cast. University Hokaido 16001. Lower Carboniferous, Do zone, Jumonji Stage, Arisu Series, Nasiosawas, Jumonji, Simoarisu-mura, Kitakami Massif, Kesen-gun, Iwate Prefecture, northeast Honshu, Japan. x 3.

5 – *N. miljukovi*. Lateral view of cast. University Hokaido 16001. Lower Carboniferous Do zone, Jumonji, Simoarisu-mura, Kitakami Massif, Kesen-gun, Iwate Prefecture, northeast Honshu, Japan. x 3.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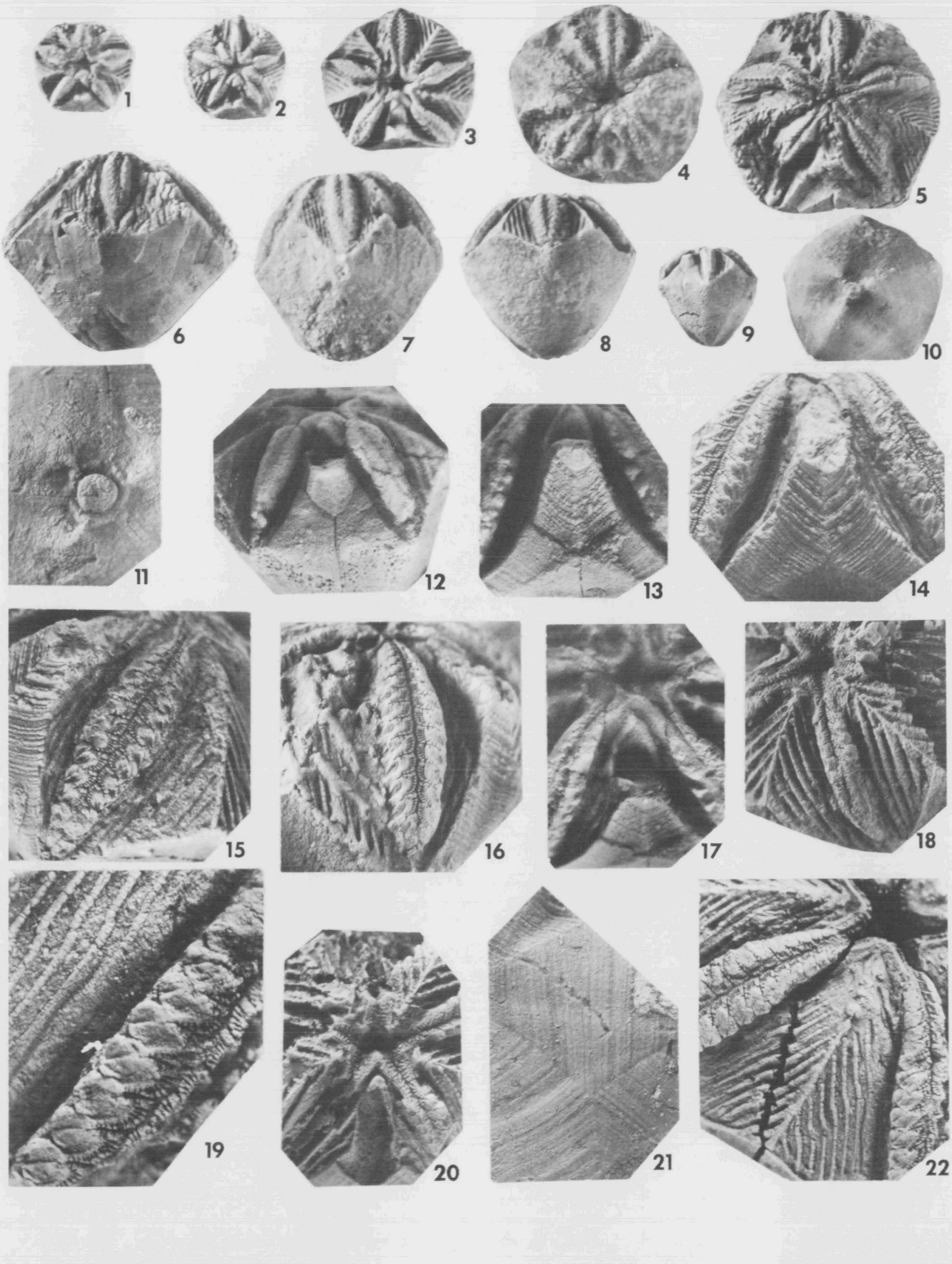
EXPLANATION OF PLATE 23

FIGS.

1, 9, 12 –	*Hadroblastus convexus* Fay, 1962. Oral (anus at 6 o'clock) and lateral (C) views and view of anal interarea. No. 12 in growth series. Mississippian, Caballero Formation, New Mexico, U.S.A. Figs. 1, 9, x 3; fig. 12, x 7.
2 –	*H. convexus*. Oral view. (Anus at 6 o'clock.) No. 14 in growth series. Mississippian, Caballero Formation, New Mexico, U.S.A. x 3.
3, 8, 10, 13, 17 –	*H. convexus*. Oral, lateral (A) and basal views (anus at 6 o'clock in oral and basal views), and views of anal interarea (two perspectives). No. 4 in growth series. Mississippian, Lake Valley Limestone, Nunn Member, New Mexico, U.S.A. Figs. 3, 8, 10, x 3; figs. 13, 17, x 7.
4, 7 –	*H. convexus*? Oral (anus at 6 o'clock) and lateral (A) views. No. 16 in growth series. Mississippian, Lake Valley Limestone, Nunn or Tierra Blanca members, New Mexico, U.S.A. x 3.
5, 6 –	*H. convexus*. Oral (anus at 6 o'clock) and lateral (A) views. No. 11 in growth series. Mississippian, Lake Valley Limestone, Nunn Member, New Mexico, U.S.A. x 3.
11, 19, 22 –	*H. convexus*. View of basals, E ambulacrum, and EA deltoid. No. 8 in growth series. (See also Breimer and Macurda, 1972, Pl. XVI, figs. 8, 12.) Mississippian, Lake Valley Limestone, Nunn Member, New Mexico, U.S.A. Figs. 11, 22, x 3; fig. 19, x 17.5.
14-16, 21 –	*H. convexus*. Views of hypodeltoid, C ambulacrum, D ambulacrum, and lower part of anal interarea. No. 5 in growth series. (See also Breimer and Macurda, 1972, Pl. XVI, fig. 13.) Mississippian, Lake Valley Limestone, Nunn Member, New Mexico, U.S.A. x 7.
18, 20 –	*H. convexus*. Views of B ambulacrum and oral area (anus at 6 o'clock). No. 1 in growth series. Mississippian, Lake Valley Limestone, Nunn Member, New Mexico, U.S.A. x 7.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EXPLANATION OF PLATE 24

FIGS.

1, 2 – *Hadroblastus whitei* (Hall, 1861). Oral (anus at 6 o'clock) and lateral (A) views. No. 6 in growth series. Mississippian, Burlington Limestone, Missouri, U.S.A. x 3.

3 – *H. whitei.* Lateral view of crushed theca. USNM 160565. Mississippian, Burlington Limestone, Burlington, Iowa. x 3.

4 – *H. whitei.* Lateral (B) view. UMMP 62308. Mississippian, Burlington Limestone, Unit 5, 85′ above datum. Galloway quarry, E-W certerline SE¼ sec. 8, NW¼ SW¼ sec. 9, T28N, R21W, Galloway, Greene County, Missouri. x 3.

5 – *H. whitei.* Lateral (B) view. No. 4 in population II. Mississippian, St. Joe Limestone, Oklahoma, U.S.A. x 3.

6 – *H. whitei.* Isolated radial. USNM 160566. Mississippian, Burlington Limestone (lower part), Burlington, Iowa. x 3.

7, 8 – *H. whitei.* Lateral (E) and oral (anus at 6 o'clock) views of internal chert mold. No. 11 in growth series. Mississippian, Burlington Limestone, Missouri, U.S.A. x 3.

9, 11 – *H. whitei.* Oral view (anus at 6 o'clock) and view of EA deltoid. No. 25 in growth series. (See also Breimer and Macurda, 1972, Pl. XVII, fig. 13, and Pl. 25, fig. 10 herein.) Mississippian, Burlington Limestone, Missouri, U.S.A. x 3 and x 7.

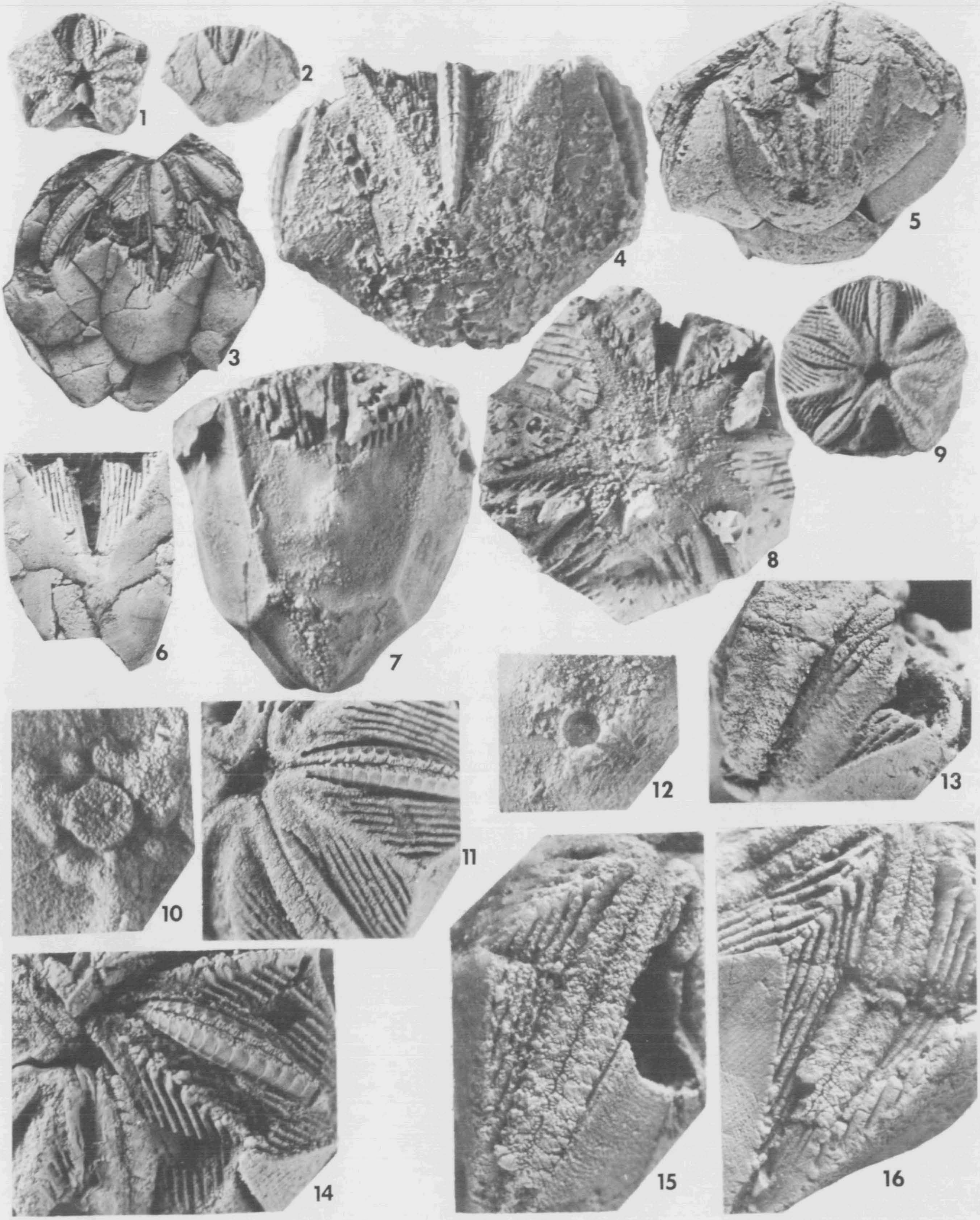
10 – *H. whitei.* View of proximal tip of basals and proximal columnal. No. 5 in growth series. (See also Breimer and Macurda, 1972, Pl. XVII, figs. 3, 4.) Mississippian, Burlington Limestone, Missouri, U.S.A. x 7.

12 – *H. whitei.* View of proximal tip of basals. No. 17 in growth series. (See also Breimer and Macurda, 1972, Pl. XVII, figs. 7, 12, 15 and Pl. XXXIV, fig. 6; see also Pl. 25, fig. 3 herein.) Mississippian, Burlington Limestone, Missouri, U.S.A. x 7.

13 – *H. whitei.* View of hydrospires on D side of anal interarea. No. 10 in growth series. (See also Breimer and Macurda, 1972, Pl. XVII, fig. 5.) Mississippian, Burlington Limestone, Missouri, U.S.A. x 7.

14 – *H. whitei.* View of EA deltoid. No. 28 in growth series. Mississippian, Burlington Limestone, Missouri, U.S.A. x 7.

15, 16 – *H. whitei.* Views of D and B ambulacra. No. 19 in growth series. (See also Breimer and Macurda, 1972, Pl. XVII, fig. 9.) Mississippian, Burlington Limestone, Missouri, U.S.A. x 7.



EXPLANATION OF PLATE 25

FIGS.

1 – *Hadroblastus whitei* (Hall, 1861). View of RR and RD sectors of radial; ambulacrum in northeast. USNM 248256. (See also Macurda, 1965, Pl. 2, fig. 2.) Mississippian. Residual chert above St. Joe Formation, just west of Shawnee Cave near Bruno, CNW¼ sec. 9, T17N, R16W, Yellville quadrangle, Arkansas. x 7.

2 – *H. whitei*. Lateral view of radial and part of deltoid. No. 27 in growth series. Mississippian, Burlington Limestone, Missouri, U.S.A. x 7.

3 – *H. whitei*. Detail A ambulacrum. No. 17 in growth series. (See also Breimer and Macurda, 1972, Pl. XVII, figs. 7, 12, 15 and Pl. XXXIV, fig. 6; see also Pl. 24, fig. 12 herein.) Mississippian, Burlington Limestone, Missouri, U.S.A. x 7.

4 – *H. whitei*. View of anal interarea. University Illinois RX-67G. Mississippian, Burlington Limestone, Missouri?, U.S.A. x 7.

5 – *H. whitei*. View of oral area centered on DE deltoid. Sprinkle collection, unregistered, Harvard University. Mississippian, Burlington Limestone. Roadcut on north side of I-70, milepost 92, 2.0-2.1 miles east of junction with County K, NW¼ sec. 13, T48N, R19W, Cooper County, Missouri, U.S.A. x 7.

6, 7 – *Hadroblastus kentuckyensis*(?) (Shumard, 1858). Lateral (AB) and oral views. USNM 160590. See also Breimer and Macurda, 1972, Pl. XVIII, fig. 7.) Mississippian, New Providence Formation (top). Top of knob, ¼ mile NW of Lebanon Junction, Kentucky, U.S.A. x 3.

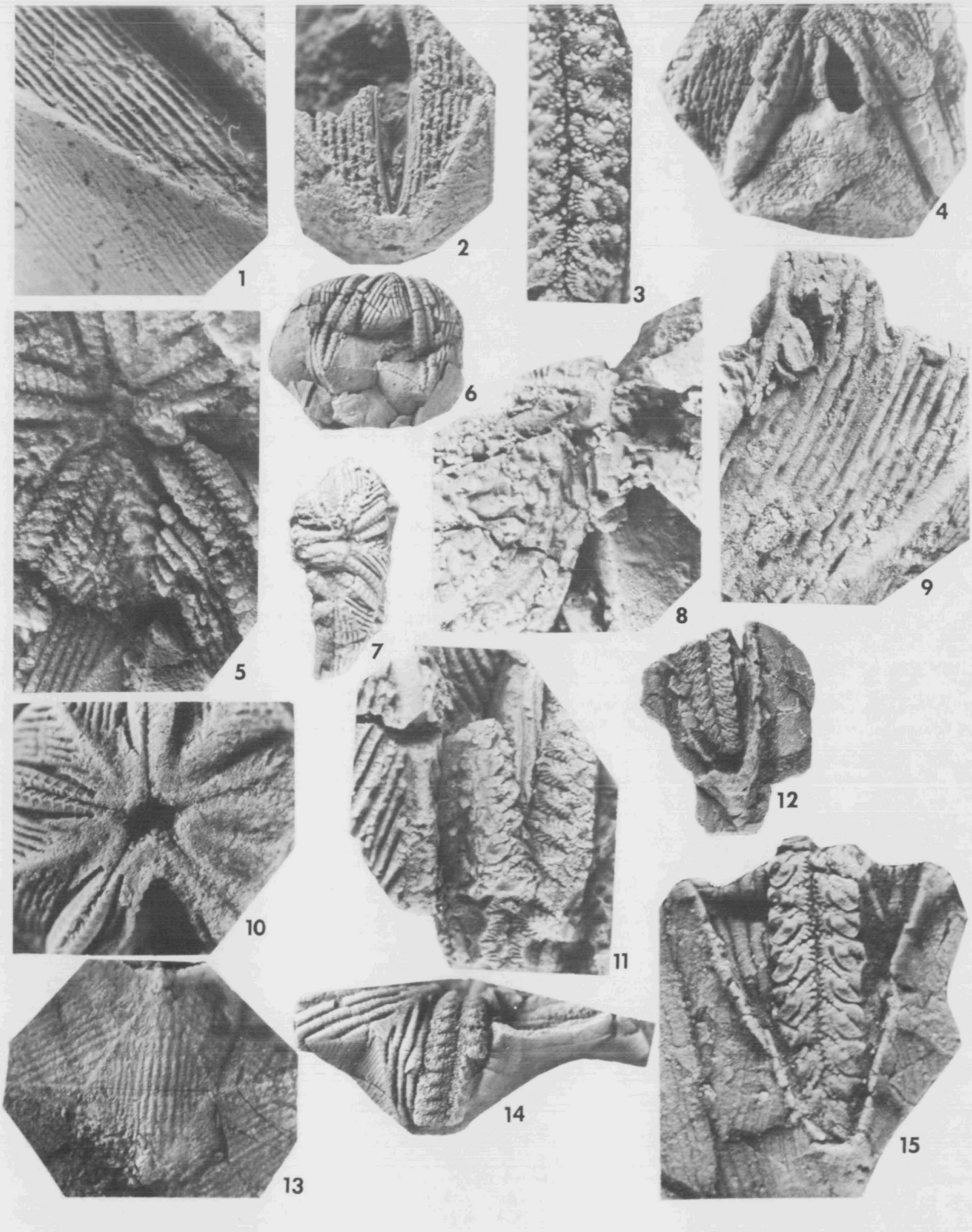
8, 9, 11 – *H. kentuckyensis*. Views of adoral tip of deltoid, hydrospire field on radial, and ambulacrum. USNM S3210. Holotype. (See also Breimer and Macurda, 1972, Pl. XVIII, figs. 3, 5.) Mississippian, New Providence Formation, Button Mold Knob, 7 miles south of Louisville, Kentucky, U.S.A. x 7.

10 - *H. whitei*. Oral view. (Anus at 6 o'clock.) No. 25 in growth series. (See Breimer and Macurda, 1972, Pl. XVII, fig. 13, and Pl. 24, figs. 9, 11 herein.) Mississippian, Burlington Limestone, Missouri, U.S.A. x 7.

12, 15 – *Hadroblastus* (?) *benniei* (Etheridge and Carpenter, 1886). Views of radials with ambulacra. Royal Scottish Museum 1958.1.2461. Lower Carboniferous, Lower Limestone Group, Carlops, Peebleshire, Scotland. x 7 and x 17.5.

13 – *H. whitei*. View of radials (above) and basals (below). No. 26 in growth series. Mississippian, Burlington Limestone, Missouri, U.S.A. x 7.

14 – *H. kentuckyensis*? View of D ambulacrum. Indiana University 8266. (See also Breimer and Macurda, 1972, Pl. XVIII, fig. 8.) Mississippian, Borden Group. Monroe Reservoir, SE¼ SE¼ NE¼ sec. 4, T7N, R1E, Monroe County, Indiana, U.S.A. x 7.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EXPLANATION OF PLATE 26

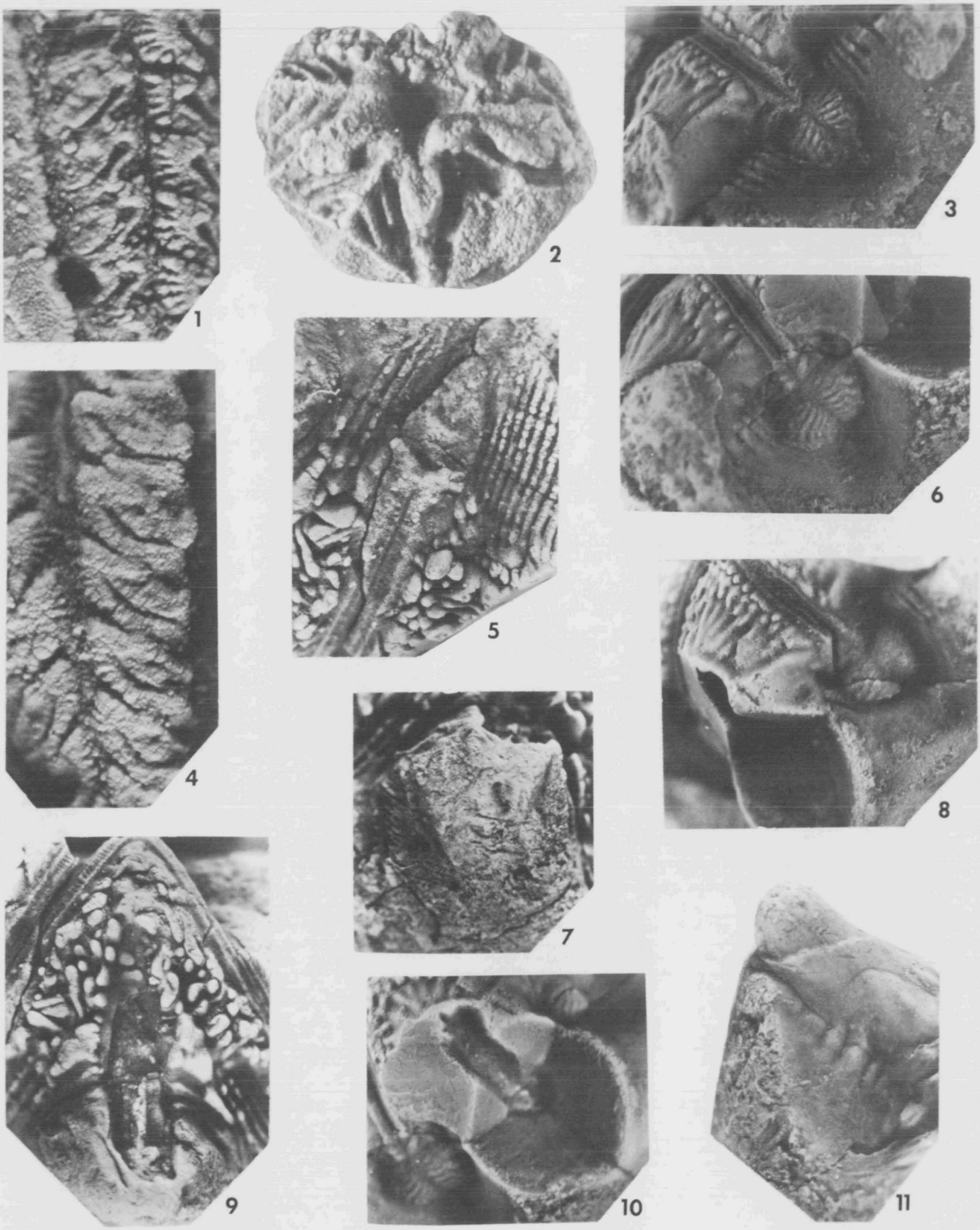
FIGS.

1, 4 – *Hadroblastus* ? *benniei* (Etheridge and Carpenter, 1886). Views of ambulacra. Royal Scottish Museum 1958.1.2461. Lower Carboniferous, Lower Limestone Group, Carlops, Peebleshire, Scotland. x 45.

2 – *Hadroblastus* sp. Oral view, anus at 5 o'clock. USNM 160585. (See also Breimer and Macurda, 1972, Pl. XVI, fig. 7.) Mississippian, Shaly beds in Rockford Formation (= Jacobs Chapel), center lot 62, 1½ miles north of New Albany City limits in verges of Mt. Table and Kleener Roads, 1 mile W of US 31W, Clark Grant, Floyd County, Indiana, U.S.A. x 17.5.

3, 6, 8, 10, 11 – *Neoschisma timorense* Wanner, 1940. Views of B ambulacrum, D ambulacrum, C ambulacrum, anal deltoids, and E side of EA deltoid. University Amsterdam Ge.O. 9993. Holotype. (See also Breimer and Macurda, 1972, Pl. XX, figs. 4, 8 and Pl. 27, fig. 13 herein.) Permian, Sonnebait Series, Basleo, Timor, Indonesia. x 7.

5, 7, 9 – *Neoschisma verrucosum* Wanner, 1924a. Views of D ambulacrum, hypodeltoid, and epideltoid. Technische Hogeschool, Delft 12254. Holotype. (See also Breimer and Macurda, 1972, Pl. XX, fig. 7.) Permian, 1 km south of Kapan, Timor, Indonesia. x 7.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EXPLANATION OF PLATE 27

FIGS.

1 – *Neoschisma australe* Breimer and Macurda, 1972. View of reassembled plates to model configuration of complete specimen. (See also Breimer and Macurda, 1972, Pl. XIX, fig. 1.) Viewed laterally from D ambulacrum. x 3.

2 – *N. australe.* View of hypodeltoid and part of adjacent radial. UMMP 58625. Permian, Callytharra Formation, Western Australia. x 3.

3 – *N. australe.* View of deltoid. No. 11 in deltoid growth series. Callytharra Formation, Western Australia. x 3.

4 – *N. australe.* View of epideltoid. UMMP 58626. Callytharra Formation, Western Australia. x 3.

5 – *N. australe.* View of deltoid. No. 8 in deltoid growth series. Callytharra Formation, Western Australia. x 3.

6 – *N. australe.* View of deltoid. No. 17 in deltoid growth series. Permian, Callytharra Formation, Western Australia. x 3.

7 – *N. australe.* View of deltoid. No. 9 in deltoid growth series. Permian, Callytharra Formation, Western Australia. x 3.

8 – *N. australe.* View of RD sector of radial. UMMP 58624A. Permian, Callytharra Formation, Western Australia. x 3.

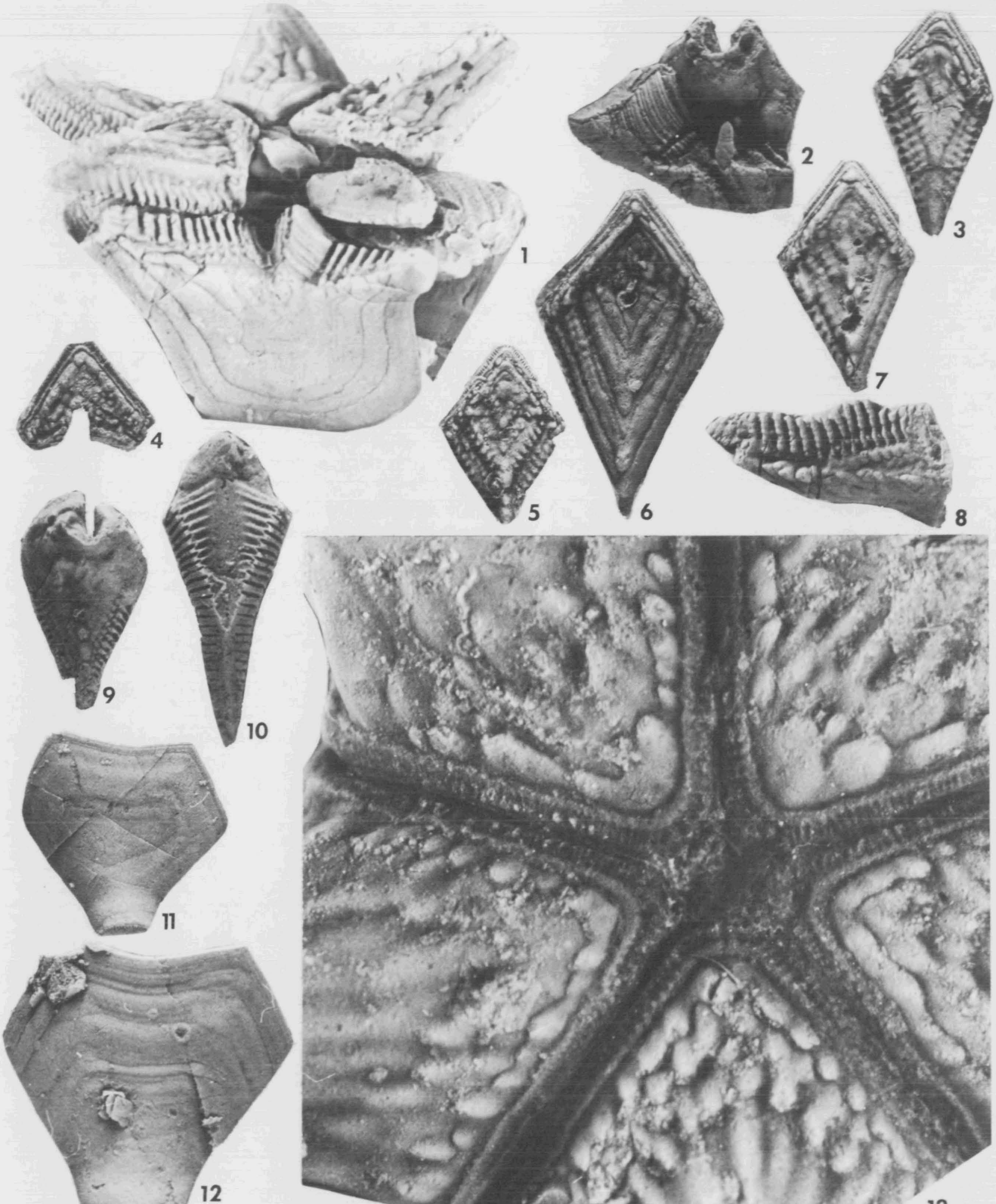
9 – *N. australe.* Oral view of hypodeltoid. Bureau Mineral Resources, Canberra G.W.87. See also Pl. 30, fig. 3 herein. Permian, Callytharra Formation, Western Australia. x 3.

10 – *N. australe.* View of interior of deltoid. No. 15 in deltoid growth series. Permian, Callytharra Formation, Western Australia. x 3.

11 – *N. australe.* View of zygous basal. No. 5 in zygous basal growth series. Permian, Callytharra Formation, Western Australia. x 3.

12 – *N. australe.* View of zygous basal. No. 7 in zygous basal growth series. Permian, Callytharra Formation, Western Australia. x 3.

13 – *Neoschisma timorense* Wanner, 1940. Enlarged view of oral area. (Anus at 6 o'clock.) University Amsterdam Ge.O.9993. Holotype. (See also Breimer and Macurda, 1972, Pl. XX, figs. 4, 8 and Pl. 26, figs. 3, 6, 8, 10, 11 herein.) Permian, Sonnebait Series, Basleo, Timor, Indonesia. x 17.5.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EXPLANATION OF PLATE 28

FIGS.

1-3, 15 – *Neoschisma australe* Breimer and Macurda, 1972. Oral, lateral, internal, lateral and internal oral views of isolated D radial. No. 4 in radial growth series. Permian, Callytharra Formation, Western Australia. Figs. 1-3, x 3; fig. 15, x 4.5.

4 – *N. australe*. Lateral view of isolated C radial. No. 10 in radial growth series. Permian, Callytharra Formation, Western Australia. x 3.

5 – *N. australe*. Lateral view of isolated E radial. No. 7 in radial growth series. Permian, Callytharra Formation, Western Australia. x 3.

6, 16 – *N. australe*. Oral view of adoral part of deltoid and lateral view of hydrospire slits on aboral side of deltoid. Geological Survey Western Australia F-5714A. Permian, Callytharra Formation, Western Australia. x 7.

7-9 – *N. australe*. Oral, internal, and lateral views of isolated C radial. No. 4 in radial growth series. Permian, Callytharra Formation, Western Australia. x 3.

10 – *N. australe*. Lateral view isolated D radial. No. 11 in radial growth series. Permian, Callytharra Formation, Western Australia. x 3.

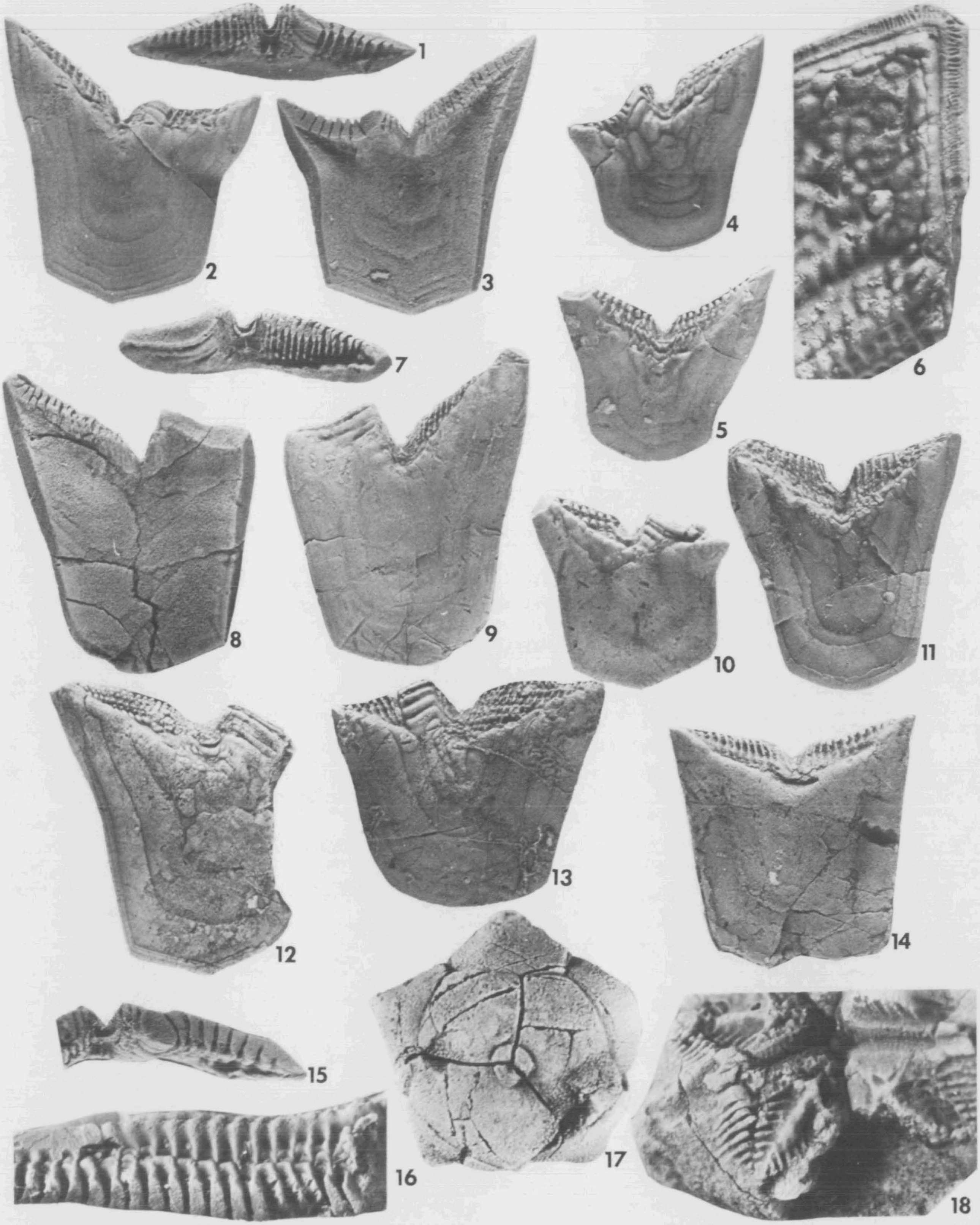
11 – *N. australe*. Lateral view isolated E radial. No. 14 in radial growth series. Permian, Callytharra Formation, Western Australia. x 3.

12 – *N. australe*. Lateral view isolated D radial. No. 8 in radial growth series. Permian, Callytharra Formation, Western Australia. x 3.

13 – *N. australe*. Lateral view isolated C radial. No. 2 in radial growth series. Permian, Callytharra Formation, Western Australia. x 3.

14 – *N. australe*. Lateral view isolated A radial. No. 15 in growth series. Permian, Callytharra Formation, Western Australia. x 3.

17, 18 – *Notoblastus oyensi* (Wanner, 1940). Basal (anus at 6 o'clock) view and oral view with EA deltoid at 7 o'clock. University Amsterdam Ge.O.9925. Holotype. (See also Breimer and Macurda, 1972, Pl. XX, figs. 3, 5, 6 and Pl. 29, fig. 3 herein.) Permian, Sonnebait Series, Basleo, Timor, Indonesia. x 4 and x 7.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EXPLANATION OF PLATE 29

FIGS.

1, 2 – *Notoblastus brevispinus* Brown, 1942. Basal (anus at 6 o'clock) and lateral (C) views. Australian Museum F.39762. Holotype. (See also Breimer and Macurda, 1972, Pl. XXII, fig. 1.) Permian, Upper Marine Series, Branxton Formation, Fenestella Shale, 4.5 miles south of Cessnock, New South Wales, Australia. x 3.

3 – *Notoblastus oyensi* (Wanner, 1940). View of oral area and anal interarea (latter at 4 o'clock). University Amsterdam Ge.O.9925. Holotype. (See also Breimer and Macurda, 1972, Pl. XV, figs. 3, 5, 6 and Pl. 28, figs. 17, 18 herein.) Permian, Sonnebait Series, Basleo, Timor, Indonesia. x 7.

4, 8 – *Notoblastus cornutus* (McKellar, 1969). Lateral view of aboral tip of ambulacrum and radial spine of A ambulacrum and oral view of aboral tip of E ambulacrum and radial spine. Geological Survey Queensland F11119. Rubber cast of mold. (See also Breimer and Macurda, 1972, Pl. XXII, fig. 5.) Lower Permian, Berserker Beds, Nerimbera Quarry, near Rockhampton, Queensland, Australia. x 7.

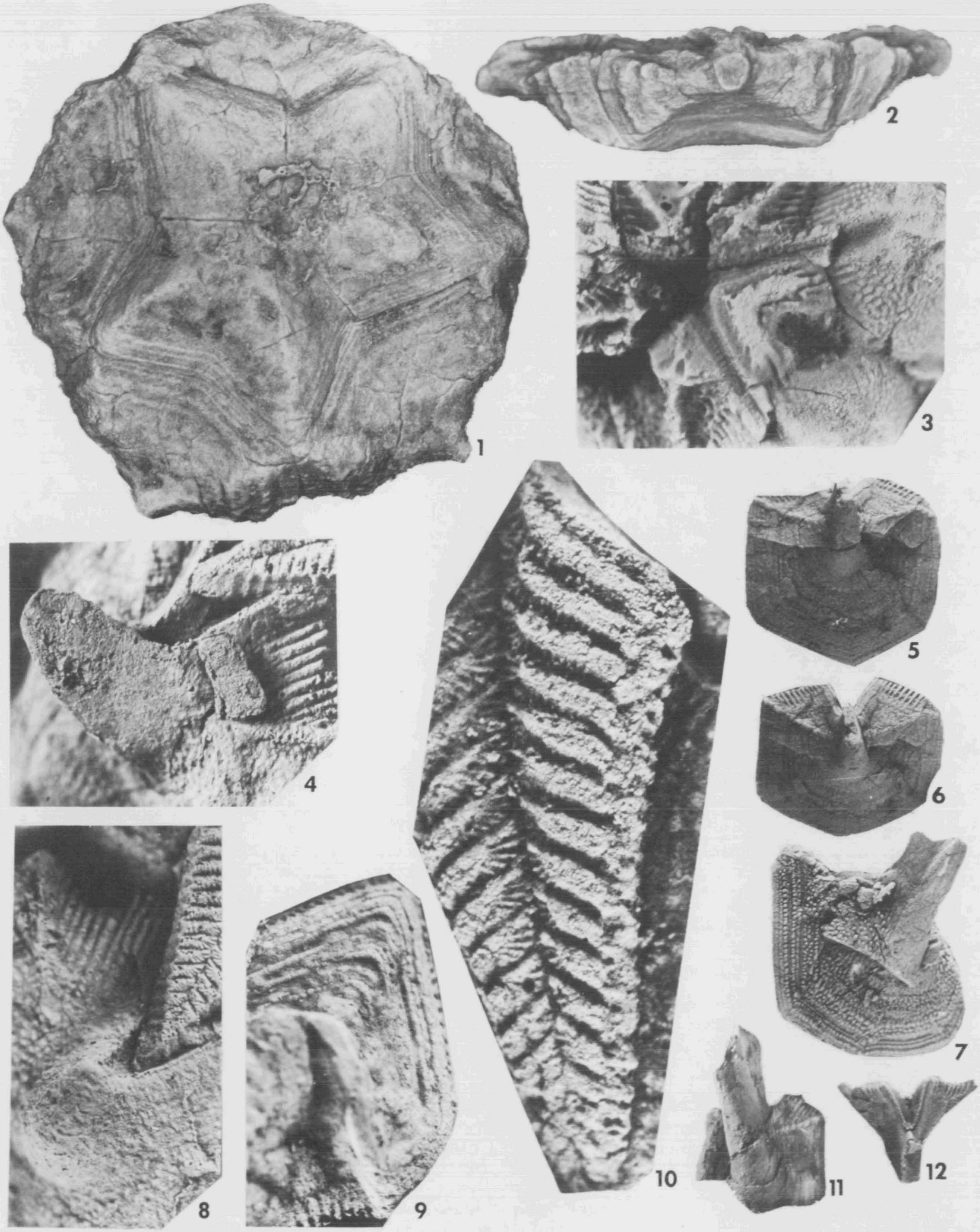
5, 6 – *Notoblastus stellaris* Breimer and Macurda, 1972. Lateral and inclined oral views of isolated radial. No. 1 in radial growth series. Permian, Callytharra Formation, Western Australia. x 3.

7 – *N. stellaris*. Lateral view of isolated radial. UMMP 60782A. Locality as for growth series. x 3.

9, 10 – *N. cornutus*. Oral view of adoral part of deltoid and view of ambulacrum. Geological Survey Queensland F11389. Lower Permian, Berserker Beds, Nerimbera Quarry, near Rockhampton, Queensland, Australia. x 7 and x 17.5.

11 – *N. stellaris*. Lateral view of isolated radial. Geological Survey Western Australia F5714K. Locality as for growth series. x 3.

12 – *N. stellaris*. Oral view of isolated radial UMMP 60782B. Locality as for growth series. x 3.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EXPLANATION OF PLATE 30

FIGS.

1, 2, 4, 15, 17 – *Notoblastus stellaris* Breimer and Macurda, 1972. Oral view of E (5 o'clock) and A ambulacra of broken half of holotype, oral view centered on B ambulacrum of crushed reassembled holotype, lateral view centered on BC interarea of other half of broken holotype, and oral and lateral view of B ambulacrum respectively. No. 12 in radial growth series. (See also Breimer and Macurda, 1972, Pl. XX, fig. 1 and Pl. XXI, figs. 1, 7, 8.) Permian, Callytharra Formation, Western Australia. Figs. 1, 2, 4, x 3; fig. 15, x 7; fig. 17, x 45.

3 – *Neoschisma australe* Breimer and Macurda, 1972. Internal view of hypodeltoid. Bureau Mineral Resources, Canberra G.W.87. See also Pl. 27, fig. 9 herein. Permian, Callytharra Formation, Western Australia. x 3.

5 – *N. stellaris*. Oral view of isolated deltoid. No. 5 in deltoid growth series. Permian, Callytharra Formation, Western Australia. x 3.

6 – *N. stellaris*. Oral view of isolated deltoid. No. 4 in deltoid growth series. Permian, Callytharra Formation, Western Australia. x 3.

7 – *N. stellaris*. Oral view of isolated deltoid. No. 6 in deltoid growth series. Permian, Callytharra Formation, Western Australia. x 3.

8 – *N. stellaris*. Oral view of isolated deltoid. No. 3 in deltoid growth series. Permian, Callytharra Formation, Western Australia. x 3.

9 – *N. stellaris*. Oral-lateral view of isolated radial. Geological Survey Western Australia F5714M. Locality as for growth series. x 7.

10 – *N. stellaris*. Oral view of isolated radial. No. 11 in radial growth series. Permian, Callytharra Formation, Western Australia. x 7.

11, 12 – *Notoblastus* sp. Lateral and oral views of isolated radial. UMMP 60724. Lower Permian. Callytharra Formation, outcrop on west side of north-south wash, 1/8 mile south of Wooramel River, 1/4 mile SSE of Wooramel River and Bilung Creek, 25°43′S, 115° 52.5′E, Western Australia (UMMP locality 1968/Pe 3). x 3.

13 – *Notoblastus* sp. Oral view of isolated radial. UMMP 60723. UMMP locality 1968/Pe 3. x 3.

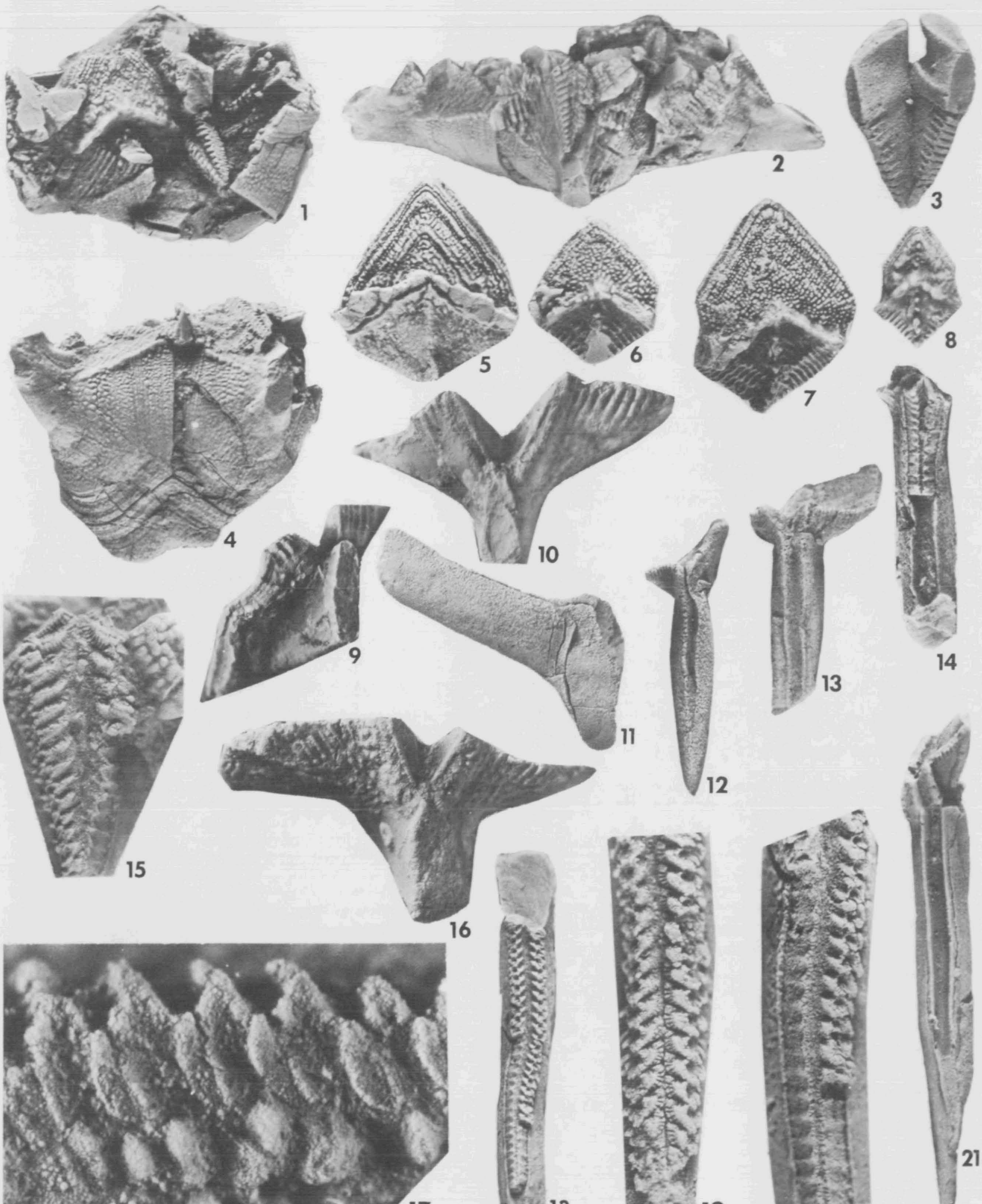
14 – *Notoblastus* sp. Oral view of isolated radial prong. UMMP 60726. UMMP locality 1968/Pe 3. x 3.

16 – *N. stellaris*. Oral view of isolated radial. No. 10 in radial growth series. Permian, Callytharra Formation, Western Australia. x 7.

18, 20 – *Notoblastus* sp. Oral views of isolated radial prong and ambulacrum thereon. UMMP 59729. (See also Breimer and Macurda, 1972, Pl. XXI, fig. 9, and Pl. 31, fig. 1 herein.) UMMP locality 1968/Pe 3. x 3 and x 7.

19 – *Notoblastus* sp. Oral view of ambulacrum. UMMP 59726. (See also Breimer and Macurda, 1972, Pl. XXI, fig. 3 and Pl. 31, fig. 2 herein.) UMMP locality 1968/Pe 3. x 7.

21 – *Notoblastus* sp. Oral view of radial and radial prong. UMMP 59728. (See also Breimer and Macurda, 1972, Pl. XXI, fig. 5.) UMMP locality 1968/Pe 3. x 3.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EXPLANATION OF PLATE 31

FIGS.

1 – *Notoblastus* sp. Lateral view of ambulacrum; oral direction to left. UMMP 59729. (See also Breimer and Macurda, 1972, Pl. XXI, fig. 9 and Pl. 30, figs. 18, 20 herein.) UMMP locality 1968/Pe 3. x 7.

2, 4 – *Notoblastus* sp. Lateral view of opposing sides of ambulacrum; oral direction to left in fig. 2, to right in fig. 4. UMMP 59726. (See also Breimer and Macurda, 1972, Pl. XXI, fig. 3, and Pl. 30, fig. 19 herein.) UMMP locality 1968/Pe 3. x 7.

3 – *Australoblastus whitehousei* McKellar, 1969. Inclined oral view of rubber cast of mold of crushed specimen. Geological Survey Queensland F11128. Lower Permian, Berserker Beds, Nerimbera Quarry, near Rockhampton, Queensland, Australia. x 3.

5 – *A. whitehousei*. View of aboral part of a deltoid. Geological Survey Queensland F11126. (See also Breimer and Macurda, 1972, Pl. XXIV, fig. 1.) L. Permian, Berserker Beds, Nerimbera Quarry, near Rockhampton, Queensland, Australia. x 7.

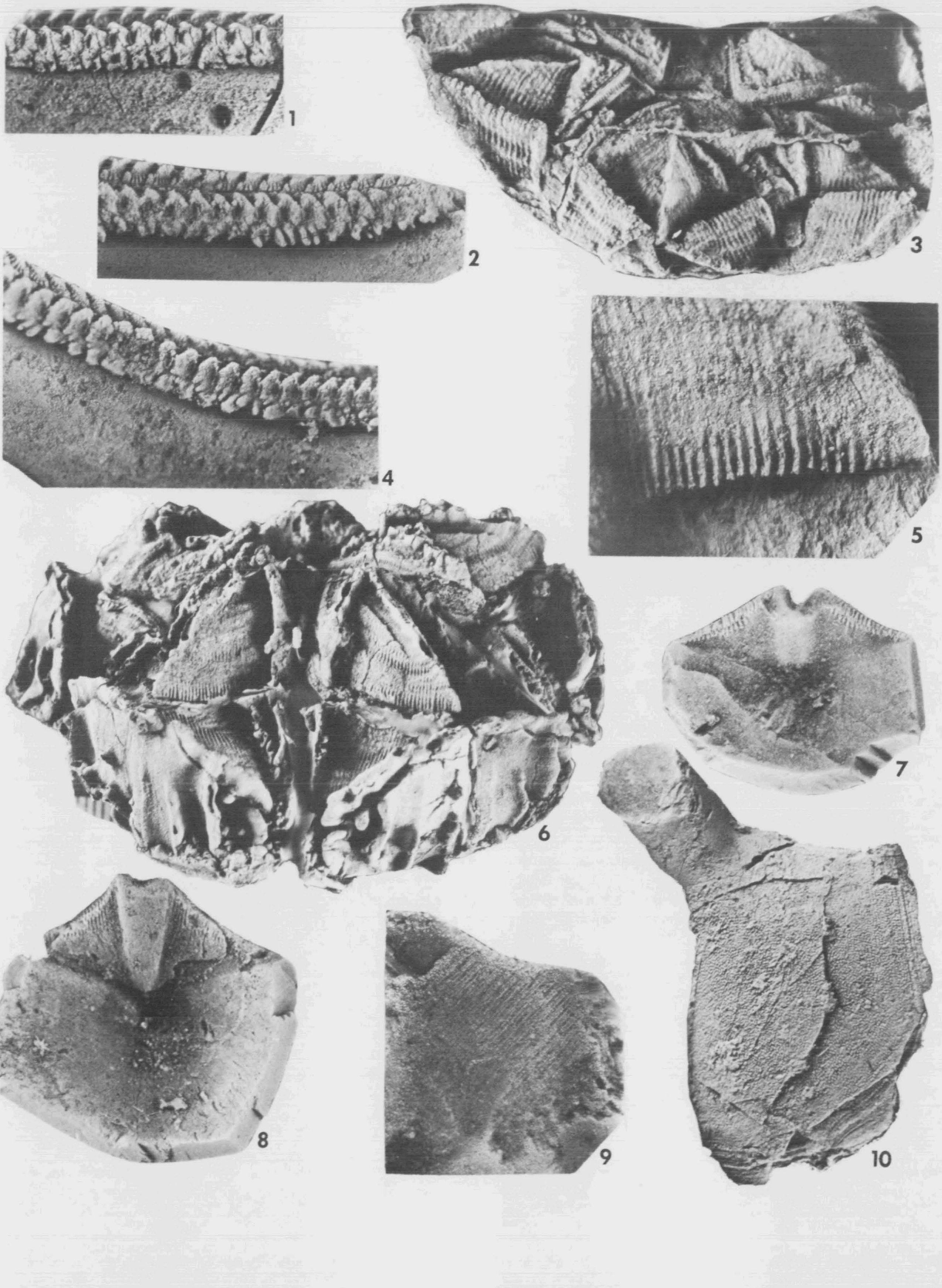
6 – *A. whitehousei*. Inclined oral view of restored specimen. Rubber cast of mold. Geological Survey Queensland F11239. (See also Breimer and Macurda, 1972, Pl. XXIII, figs. 1, 6.) L. Permian, Berserker Beds, Nerimbera Quarry, near Rockhampton, Queensland, Australia. x 1.5.

7 – *Thaumatoblastus longiramus* Wanner, 1924b. View of interior of radial. A. Breimer collection, Institute Earth Sciences, Free Reformed University, Amsterdam. Permian, near Basleo, Timor, Indonesia. x 3.

8 – *T. longiramus*. View of interior of radial. Leiden University, unregistered specimen. Permian, Timor, Indonesia. x 3.

9 – *T. longiramus*. View of interior of radial showing places of attachment for hydrospires. A. Breimer collection, Institute Earth Sciences, Free Reformed University, Amsterdam. Permian, near Basleo, Timor, Indonesia. x 3.

10 – *T. longiramus*. View of body of radial. Australia Bureau Mineral Resources KNF73. Permian, Noonkabah Formation, 2.2 miles bearing 288° from Bruten's old yard Cherrabun Station, Fitzroy Basin, Western Australia. x 3.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EXPLANATION OF PLATE 32

FIGS.

1 – *Thaumatoblastus longiramus* Wanner, 1924b. Oral view of radial and ambulacrum on radial prong. Technische Hogeschool, Delft 12259. Permian, Basleo, Timor, Indonesia. x 3.

2 – *T. longiramus*. View of interior of upper part of radial. Leiden University, unregistered specimen. Permian, Timor, Indonesia. x 7.

3 – *T. longiramus*. View of swollen area on radial prong. Leiden University, unregistered specimen. Permian, Soem Peh, Niki Niki, Basleo, Timor, Indonesia. x 7.

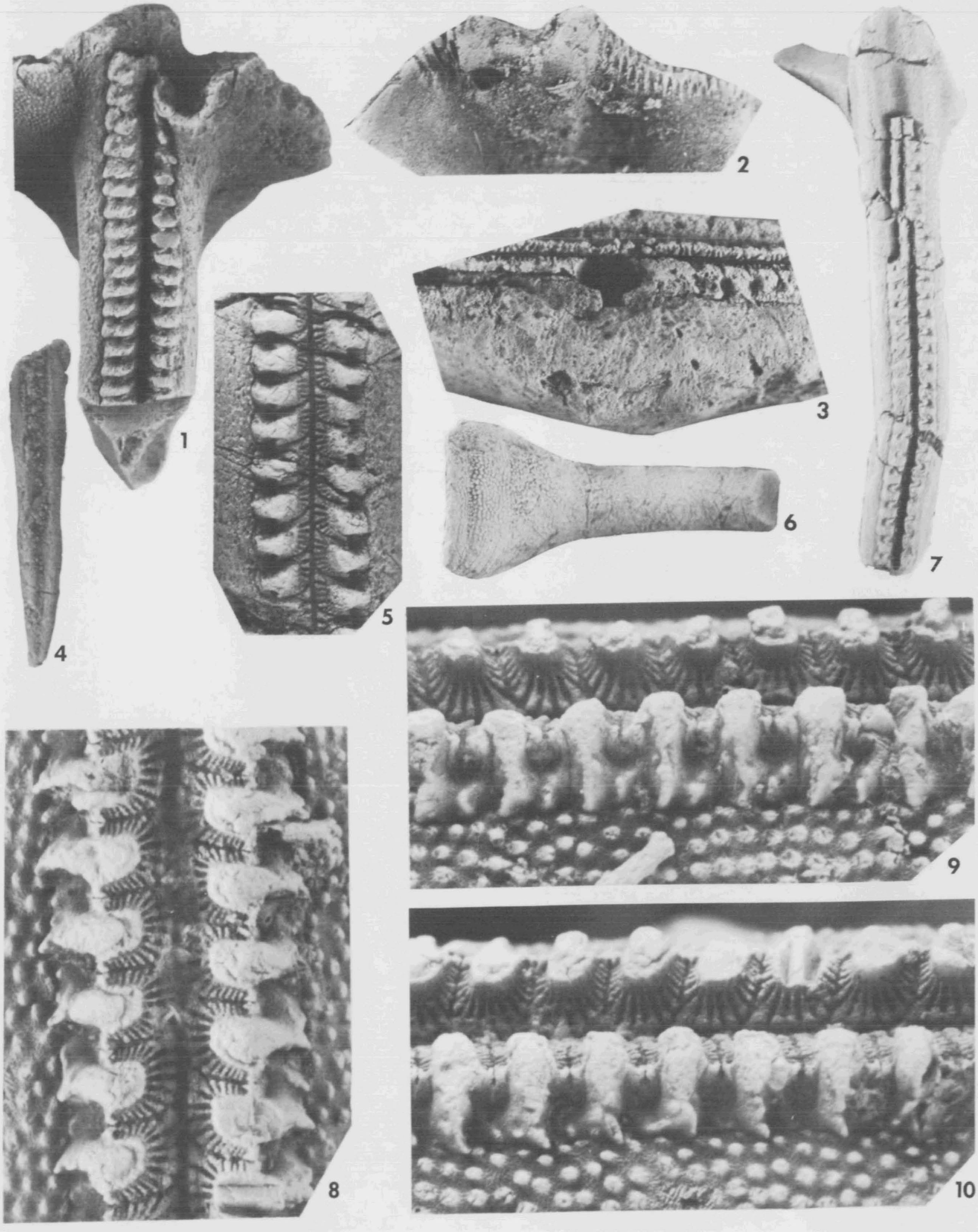
4 – *T. longiramus*. View of tip of radial prong. Leiden University, unregistered specimen. Permian, Soem Peh, Niki Niki, Basleo, Timor, Indonesia. x 3.

5 – *T. longiramus*. Oral view of ambulacrum. Leiden University, unregistered specimen. Permian, Soem Peh, Niki Niki, Basleo, Timor, Indonesia. x 7.

6 – *T. longiramus*. Aboral view of radial. Leiden University, unregistered specimen. Permian, Timor, Indonesia. x 3.

7 – *T. longiramus*. Oral view of broken radial and radial prong. Permian, Timor, Indonesia. x 3.

8-10 – *T. longiramus*. Oral and lateral views of ambulacrum from opposing sides. Leiden University, unregistered specimen. Permian, Toeboelopo, Timor, Indonesia. x 17.5.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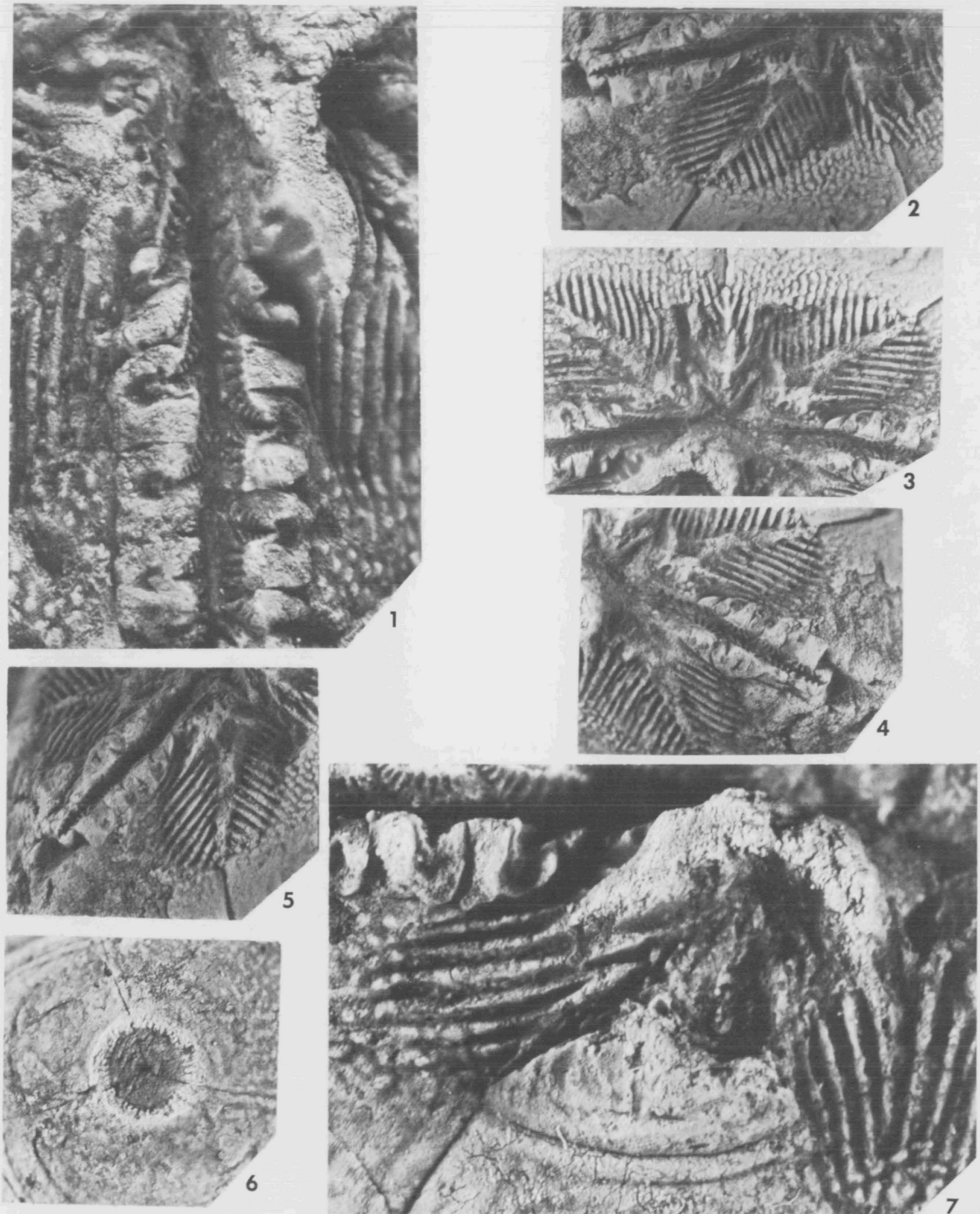
EXPLANATION OF PLATE 33

FIGS.

1-7 – *Dipteroblastus permicus* Wanner, 1940. Views of D ambulacrum (1), AB deltoid (left) and EA deltoid (right) (2), oral area (anus at 6 o'clock) (3), B ambulacrum (4), AB deltoid and B ambulacrum (5), column cicatrix (6), and anal interarea (7). University Amsterdam Ge.O.9939. Holotype. (See also Breimer and Macurda, 1972, Pl. XXI, fig. 6; XXII, figs. 2, 3, 6; XXIII, fig. 4.) Permian, Sonnebait Series, Tuniun Enu, Basleo, Timor, Indonesia. Figs. 1, 7, x 17.5; figs. 2-5, x 7; fig. 6, x 8.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EXPLANATION OF PLATE 34

FIGS.

1 – *Timoroblastus coronatus* Wanner, 1924a. Lateral (DE) view. No. 5 in growth series IV. Permian, Timor, Indonesia. x 3.

2, 4 – *T. coronatus*. Lateral and oral (anus at 6 o'clock) views. No. 7 in growth series IV. See also Pl. 36, fig. 11 herein. Permian, Timor, Indonesia. x 3.

3 – *T. coronatus*. Basal view (anus at 6 o'clock). No. 21 in growth series I. (See Breimer and Macurda, 1972, Pl. XXVI, fig. 4.) Permian, Timor, Indonesia. x 3.

5 – *T. coronatus*. Lateral (AB) view. No. 2 in growth series I. Permian, Timor, Indonesia. x 3.

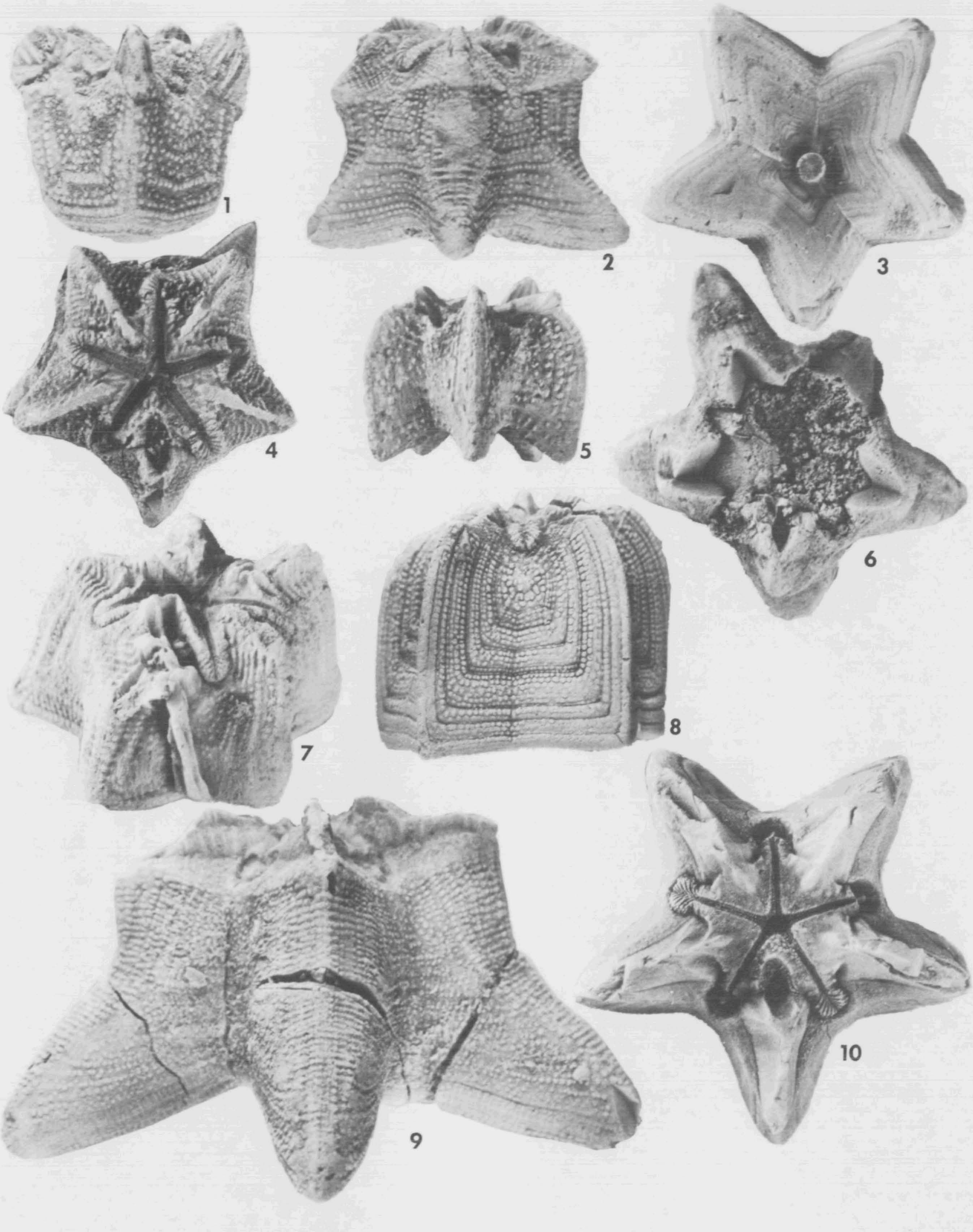
6 – *T. coronatus*. Oral view (anus at 6 o'clock) with deltoids missing. UMMP 59776. Locality as for growth series I. Permian, Timor, Indonesia. x 3.

7 – *T. coronatus*. Inclined CD view, with abnormal growth development. No. 7 in growth series I. Permian, Timor, Indonesia. x 3.

8 – *T. coronatus*. Lateral (B) view. No. 12 in growth series I. (See also Breimer and Macurda, 1972, Pl. XXVII, fig. 3.) Permian, Timor, Indonesia. x 3.

9 – *T. coronatus*. Lateral (AB) view. No. 18 in growth series IV. Permian, Timor, Indonesia. x 3.

10 – *T. coronatus*. Oral view (anus at 6 o'clock). No. 22 in growth series I. See also Pl. 35, figs. 3, 4 herein. Permian, Timor, Indonesia. x 3.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EXPLANATION OF PLATE 35

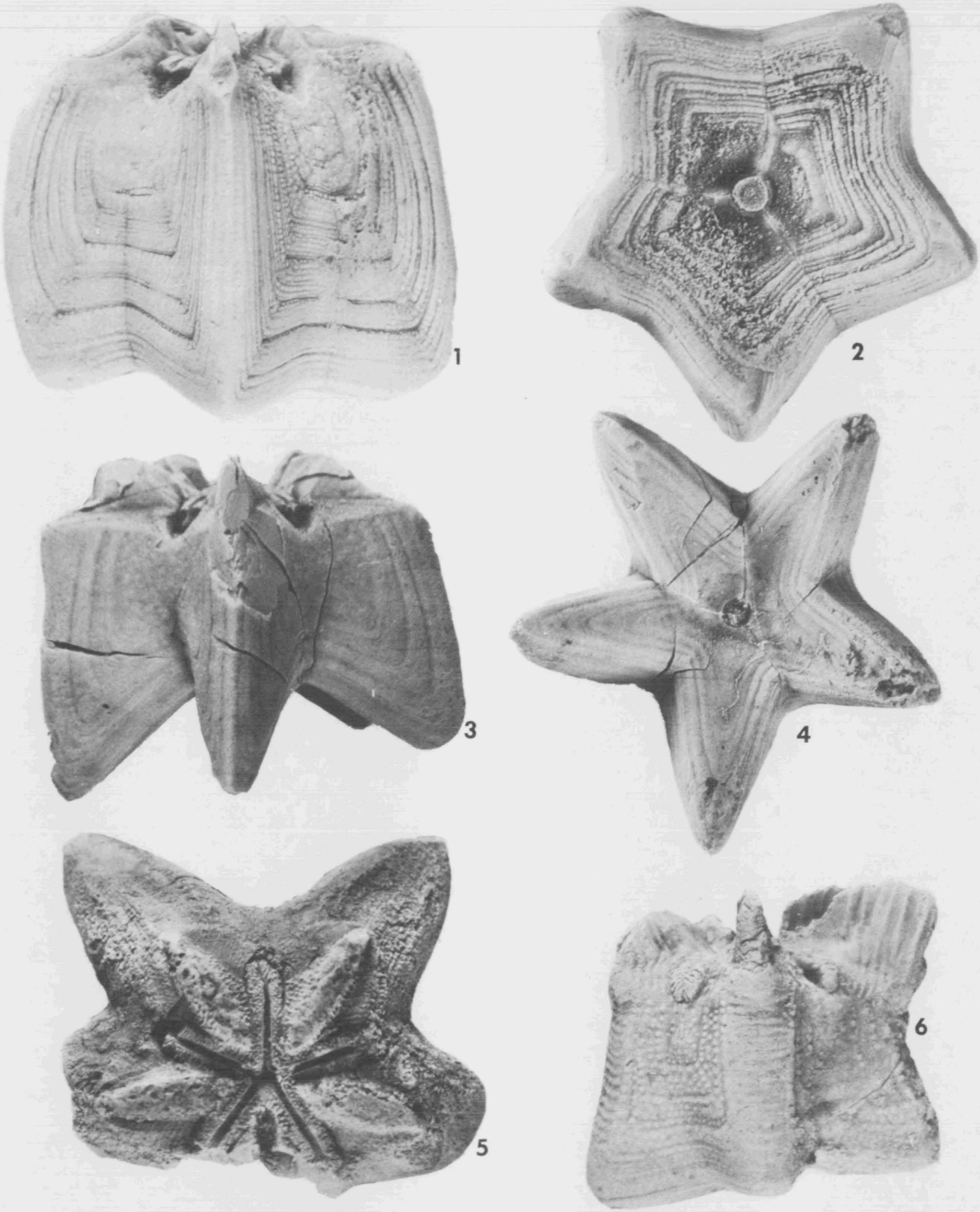
FIGS.

1, 2 – *Timoroblastus coronatus* Wanner, 1924a. Lateral (AB) and basal (anus at 6 o'clock) views. No. 24 in growth series I. Permian, Timor, Indonesia. x 3.

3, 4 – *T. coronatus*. Lateral (AB) and basal (anus at 6 o'clock) views. No. 22 in growth series I. See also Pl. 34, fig. 10 herein. Permian, Timor, Indonesia. x 3.

5 – *T. coronatus*. Oral view (anus at 6 o'clock). No. 1 in growth series III. (See also Breimer and Macurda, 1972, Pl. XXVII, fig. 1.) Permian, Timor, Indonesia. x 2.

6 – *T. coronatus*. Lateral (DE) view. No. 21 in growth series II. Permian, Timor, Indonesia. x 3.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EXPLANATION OF PLATE 36

FIGS.

1 – *Timoroblastus coronatus* Wanner, 1924a. Inclined basal-lateral (B) view of irregular growth development. UMMP 62309. Locality as for growth series II. Permian, Timor, Indonesia. x 3.

2-4 – *T. coronatus*. Basal, lateral (CD), and oral (anus at 6 o'clock) views of holotype of *T. coronatus* var. *ungulatus* Wanner, 1940. University Amsterdam collections. Permian, Basleo, Timor, Indonesia. x 2, x 3.7 and x 3.

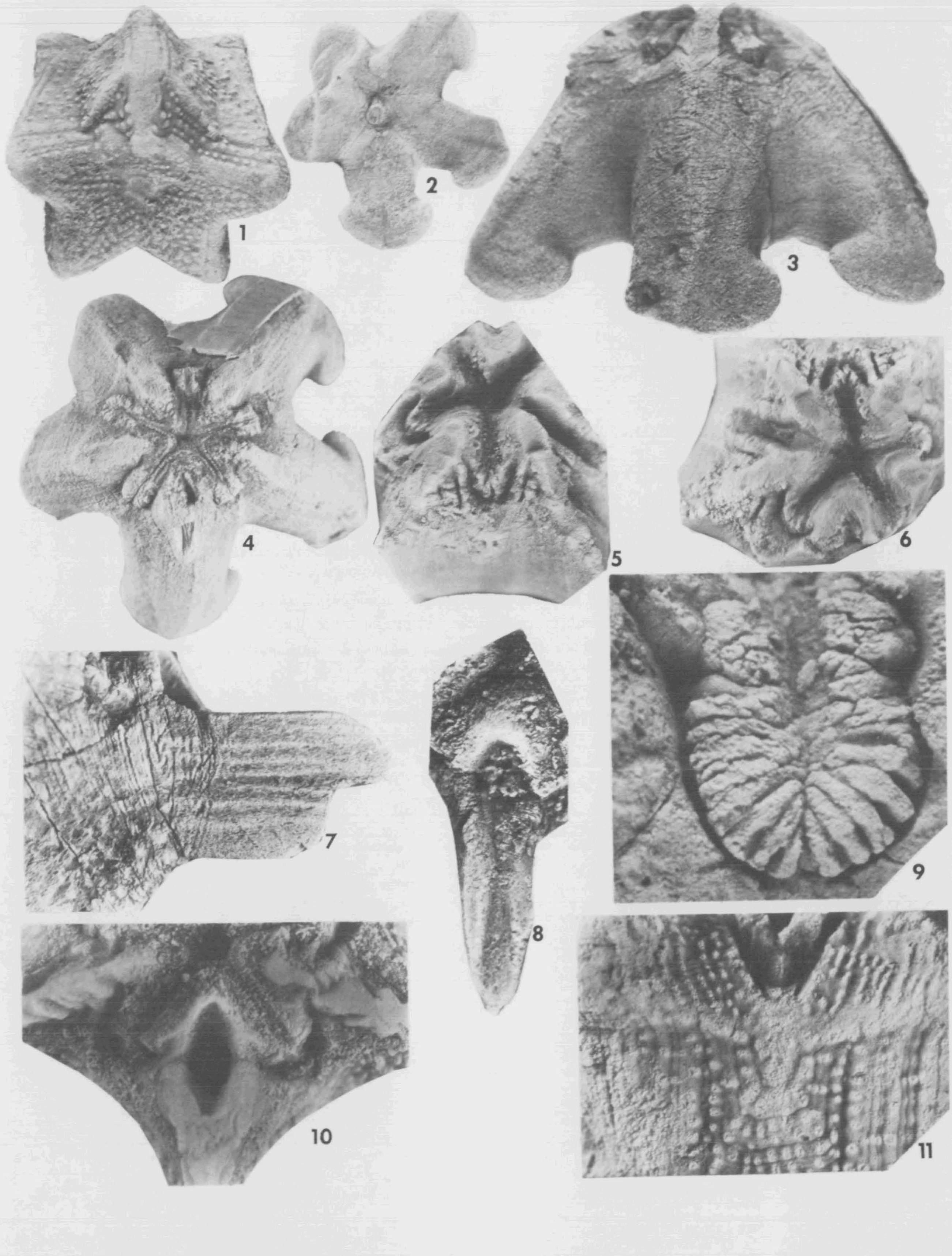
7, 8 – *T. coronatus*. Lateral and oral view of prong on hypodeltoid. Manchester University L8464. Permian, Timor, Indonesia. x 7.

9 – *T. coronatus*. View of C ambulacrum. No. 8 in growth series II. Permian, Timor, Indonesia. x 17.5.

10 – *T. coronatus*. Oral view of anal interarea. University Leiden 32864. Permian, Timor, Indonesia. x 7.

11 – *T. coronatus*. View of D radial. No. 7 in growth series IV. Permian, Timor, Indonesia. x 7.

5, 6 – *Timoroblastus weiensis* Wanner, 1940. Inclined lateral (A) and oral (anus at 6 o'clock) views. University Amsterdam Ge.O.9931. Holotype. (See also Breimer and Macurda, 1972, Pl. XXIV, figs. 3-5.) Permian, Tai Wei, east of Basleo, Timor, Indonesia. x 7.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EXPLANATION OF PLATE 37

FIGS.

1 – *Codaster acutus* M'Coy, 1849. Oral view (anus at 6 o'clock). No. 7 in growth series I. (See also Breimer and Macurda, 1972, Pl. XXVII, figs. 6, 8.) Lower Carboniferous, England. x 7.

2 – *C. acutus*. Ambulacral detail. K. A. Joysey collection, specimen 24, Cambridge University. Locality as for growth series I. x 7.

3, 5 – *C. acutus*. View of D ambulacrum and anal interarea and of oral area (anus at 5 o'clock). No. 10 in growth series I. Lower Carboniferous, England. x 17.5 and x 7.

4, 6 – *C. acutus*. Views of AB deltoid and D ambulacrum. No. 18 in growth series. (See also Breimer and Macurda, 1972, Pl. XXVI, fig. 6.) Lower Carboniferous, England. x 7 and x 17.5.

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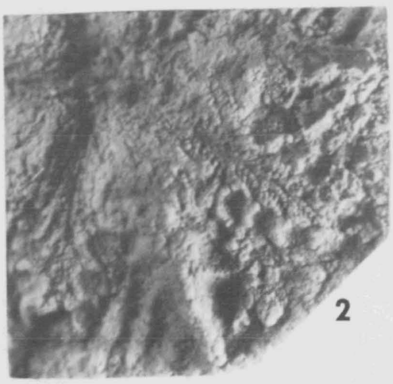

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EXPLANATION OF PLATE 38

FIGS.

1 – *Codaster acutus* M'Coy, 1849. View of stem attachment area. No. 17 in growth series I. Lower Carboniferous, England. x 7.

2, 17 – *C. acutus*. Basal (anus at 6 o'clock) view and view of D ambulacrum. No. 8 in growth series III. (See also Breimer and Macurda, 1972, Pl. XXVIII, figs. 1, 2.) Lower Carboniferous, Ireland. x 3 and x 17.5.

3, 4 – *Angioblastus variabilis* Wanner, 1931. Oral (anus at 6 o'clock) and lateral (B) views. No. 2 in growth series. (See also Breimer and Macurda, 1972, Pl. XXX, figs. 1,2.) Permian, Sonnebait Series, Timor, Indonesia. x 4.

5 – *A. variabilis*. Oral view. No. 4 in growth series. See also Pl. 39, fig. 12 herein. Permian, Sonnebait Series, Timor, Indonesia. x 4.

6, 7 – *A. variabilis*. Lateral (A) and basal (anus at 6 o'clock) views. No. 7 in growth series. (See also Breimer and Macurda, 1972, Pl. XXX, figs. 3, 4 and Pl. 39, figs. 11, 13 herein.) Permian, Sonnebait Series, Timor, Indonesia. x 4.

8 – *C. acutus*. Oral view of tetramerous mutant. K. A. Joysey collection, University of Cambridge. Locality as for growth series I. x 3.

9, 10 – *"Codaster" gratiosus* Miller, 1880. Oral and lateral (A) views of internal chert mold. University Cincinnati 3814. Holotype. (See also Breimer and Macurda, 1972, Pl. V, figs. 7, 9.) Mississippian, Keokuk Limestone, New Bloomfield, Missouri. x 3.

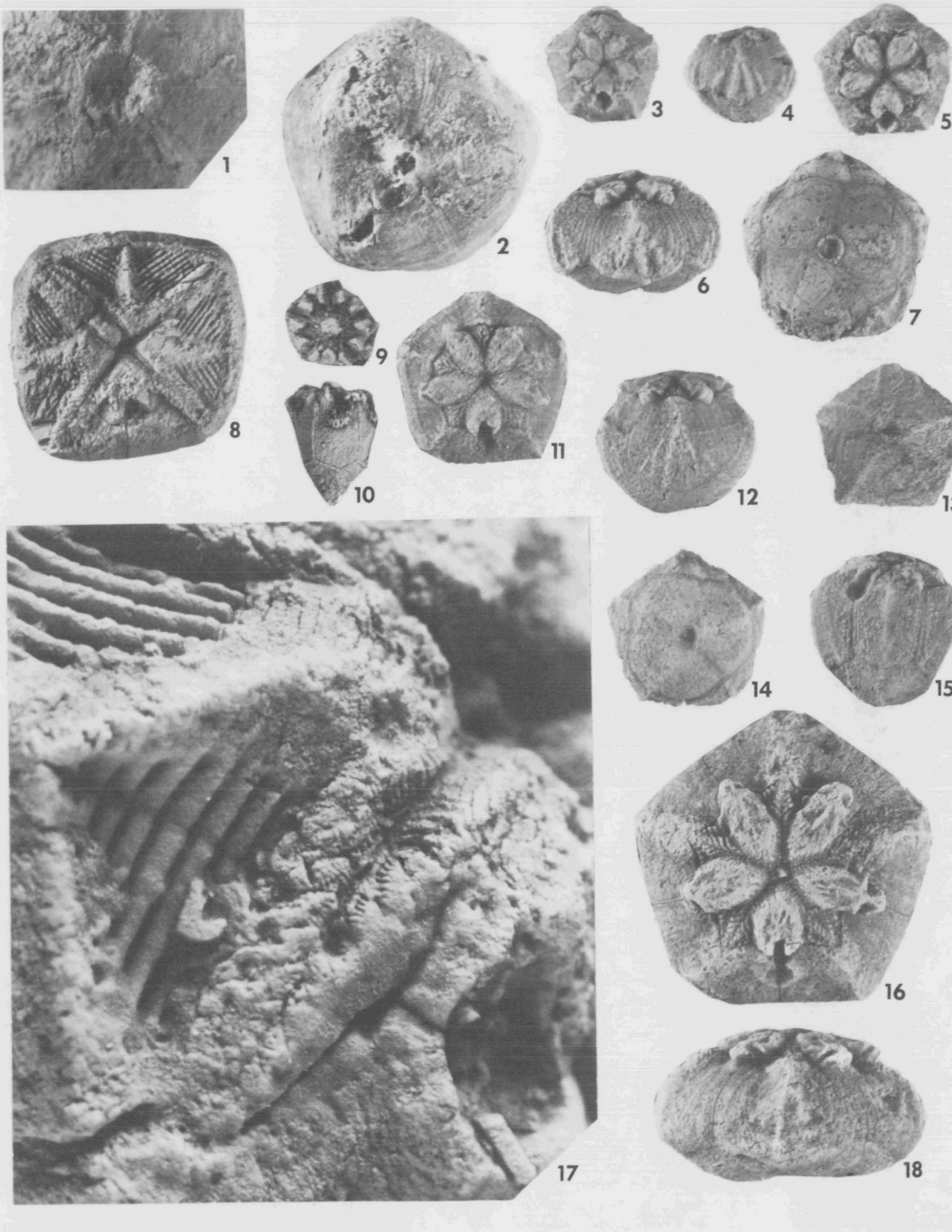
11, 12 – *A. variabilis*. Oral (anus at 6 o'clock) and lateral (A) views. No. 10 in growth series. (See also Breimer and Macurda, 1972, Pl. XXX, figs. 6, 12 and Pl. 39, fig. 10 herein.) Permian, Sonnebait Series, Timor, Indonesia. x 4.

13 – *A. variabilis*. Basal view (anus at 6 o'clock). No. 11 in growth series. See also Pl. 39, fig. 9 herein. Permian, Sonnebait Series, Timor, Indonesia. x 4.

14 – *A. variabilis*. Basal view (anus at 6 o'clock). No. 12 in growth series. See also Pl. 39, figs. 6, 17 herein. Permian, Sonnebait Series, Timor, Indonesia. x 4.

15 – *A. variabilis*. Lateral (C) view. No. 13 in growth series. (See also Breimer and Macurda, 1972, Pl. XXX, fig. 8.) No. 13 in growth series. Permian, Sonnebait Series, Timor, Indonesia. x 4.

16, 18 – *A. variabilis*. Oral and lateral (B) views. No. 14 in growth series. (See also Breimer and Macurda, 1972, Pl. XXX, figs. 7, 9 and Pl. 39, figs. 14, 15 herein.) Permian, Sonnebait Series, Timor, Indonesia. x 4.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EXPLANATION OF PLATE 39

FIGS.

1 – *Angioblastus variabilis* Wanner, 1931. Oral view. No. 16 in growth series. Permian, Sonnebait Series, Timor, Indonesia. x 4.

2 – *A. variabilis*. Lateral (E) view. No. 17 in growth series. Permian, Sonnebait Series, Timor, Indonesia. x 4.

3, 4, 8 – *A. variabilis*. Oral, lateral (A), and basal views (anus at 6 o'clock in oral and basal views). Holotype of *Angioblastus depressus* Wanner, 1940. University Amsterdam Ge.O.9933. Permian, Nifu Muti, Timor, Indonesia. x 4.

5, 7, 16 – *A. variabilis*. Views of anal interarea, C radial, and BC deltoid. No. 9 in growth series. Permian, Sonnebait Series, Timor, Indonesia. x 7.

6, 17 – *A. variabilis*. Views of B radial and oral (anus at 6 o'clock) area. No. 12 in growth series. See also Pl. 38, fig. 14 herein. Permian, Sonnebait Series, Timor, Indonesia. x 7.

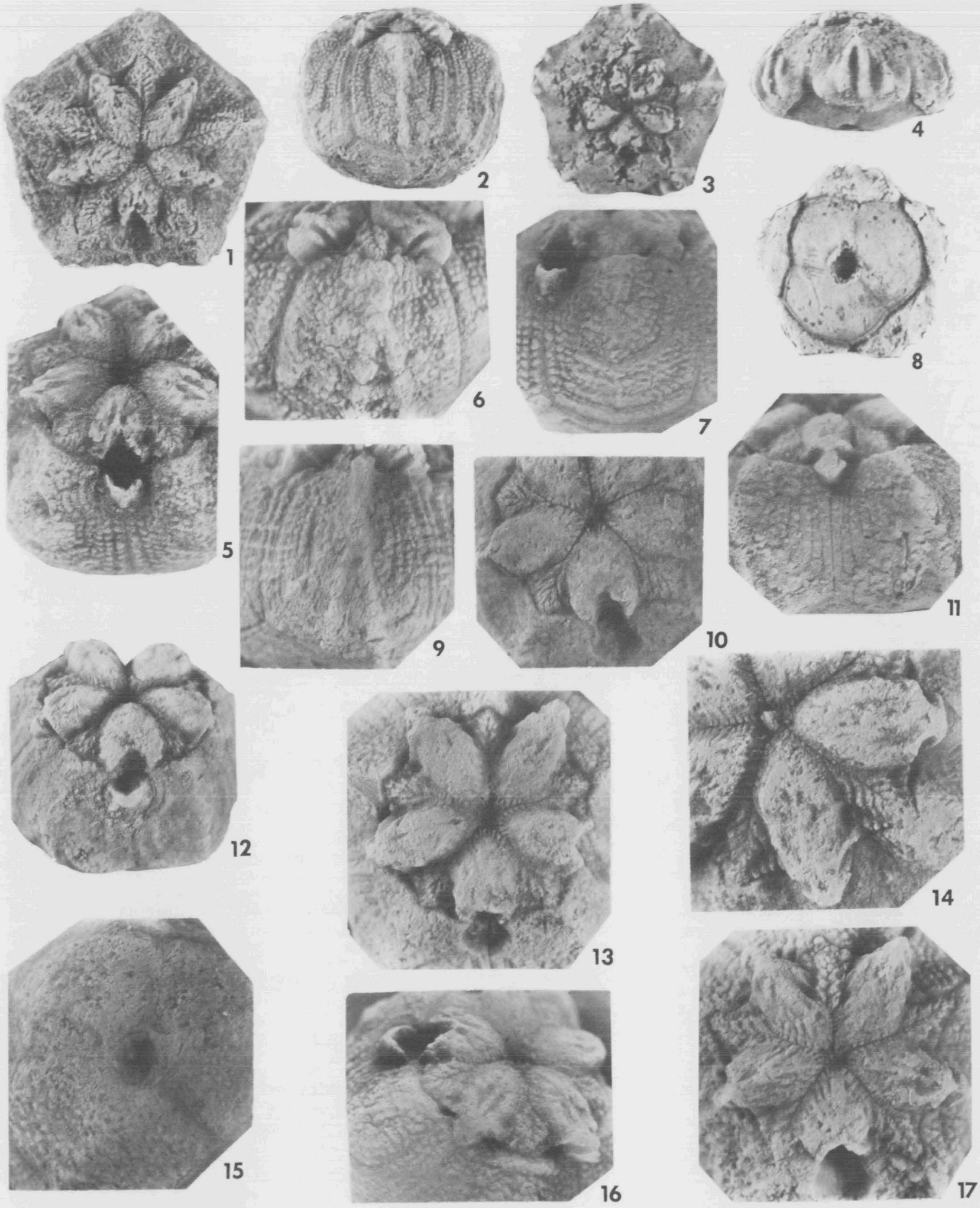
9 – *A. variabilis*. View of E radial. No. 11 in growth series. See also Pl. 38, fig. 13 herein. Permian, Sonnebait Series, Timor, Indonesia. x 7.

10 – *A. variabilis*. View of oral area (anus at 5 o'clock). No. 10 in growth series. (See also Breimer and Macurda, 1972, Pl. XXX, figs. 6, 12 and Pl. 38, figs. 11, 12 herein.) Permian, Sonnebait Series, Timor, Indonesia. x 7.

11, 13 – *A. variabilis*. Views of AB interarea and oral (anus at 6 o'clock) area. No. 7 in growth series. (See also Breimer and Macurda, 1972, Pl. XXX, figs. 3, 4 and Pl. 38, figs. 6, 7 herein.) Permian, Sonnebait Series, Timor, Indonesia. x 7.

12 – *A. variabilis*. View of anal interarea. No. 4 in growth series. See also Pl. 38, fig. 5 herein. Permian, Sonnebait Series, Timor, Indonesia. x 7.

14, 15 – *A. variabilis*. View of EA deltoid and base of theca (anus at 6 o'clock). (See also Breimer and Macurda, 1972, Pl. XXX, figs. 7, 9 and Pl. 38, figs. 16, 18 herein.) Permian, Sonnebait Series, Timor, Indonesia. x 7.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EXPLANATION OF PLATE 40

FIGS.

1-3 – *Angioblastus boliviensis* Breimer and Macurda, 1972. Oral, lateral (C), and basal views (anus at 6 o'clock in oral and basal views). USNM 160591. (See also Breimer and Macurda, 1972, Pl. XXIX, figs. 19-21.) Lower Permian, Zudanez syncline about 1 mile south of village of Zudanez, Bolivia. x 4.

4, 8, 24 – *Angioblastus dotti* (Moore and Strimple, 1942). Lateral (C), oral (anus at 7 o'clock), and view of BC deltoid. USNM 111249. (See also Breimer and Macurda, 1972, Pl. XXIX, figs. 1, 2.) Locality as for growth series. Pennsylvanian, Hogshooter Formation, Oklahoma, U.S.A. Figs. 4, 8, x 3; fig. 24, x 7.

5, 6, 10 – *A. dotti.* Lateral (B), oral and basal views (anus at 9 o'clock in last two). USNM 160568. (See also Breimer and Macurda, 1972, Pl. XXIX, figs. 3, 4.) Locality as for growth series. Pennsylvanian, Hogshooter Formation, Oklahoma, U.S.A. x 3.

7, 21 – *A. dotti.* Lateral (D) view and view of anal interarea and D ambulacrum. USNM 160569. (See also Breimer and Macurda, 1972, Pl. XXIX, fig. 5.) Locality as for growth series. Pennsylvanian, Hogshooter Formation, Oklahoma, U.S.A. x 3 and x 7.

9 – *A. dotti.* Aboral view of isolated zygous basal. No. 7 in zygous basal growth series. Pennsylvanian, Hogshooter Formation, Oklahoma, U.S.A. x 3.

11 – *A. dotti.* Aboral view of isolated azygous basal. No. 3 in azygous basal growth series. Pennsylvanian, Hogshooter Formation, Oklahoma, U.S.A. x 3.

12 – *A. dotti.* Aboral view of isolated zygous basal. No. 4 in zygous basal growth series. Pennsylvanian, Hogshooter Formation, Oklahoma, U.S.A. x 3.

13 – *A. dotti.* Lateral view of isolated (C) radial. No. 8 in C radial growth series. Pennsylvanian, Hogshooter Formation, Oklahoma, U.S.A. x 3.

14 – *A. dotti.* Lateral view of isolated (E) radial. No. 1 in E radial growth series. Pennsylvanian, Hogshooter Formation, Oklahoma, U.S.A. x 3.

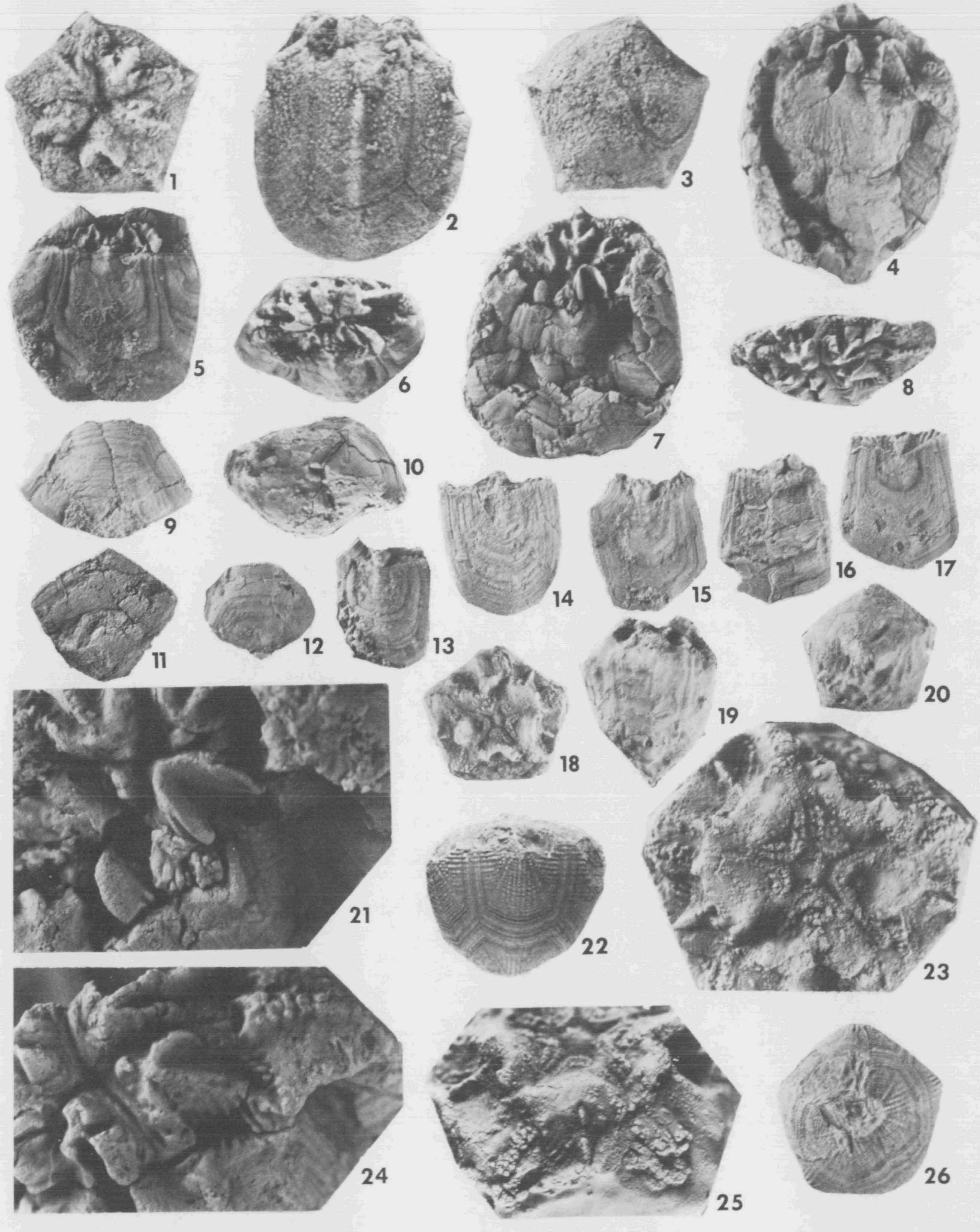
15 – *A. dotti.* Lateral view of isolated (C) radial. No. 1 in C radial growth series. Pennsylvanian, Hogshooter Formation, Oklahoma, U.S.A. x 3.

16 – *A. dotti.* Lateral view of isolated (D) radial. UMMP 62310. Locality as for growth series. Pennsylvanian, Hogshooter Formation, Oklahoma, U.S.A. x 3.

17 – *A. dotti.* Lateral view of isolated (A) radial. UMMP 62311. Locality as for growth series. Pennsylvanian, Hogshooter Formation, Oklahoma, U.S.A. x 3.

18-20, 23, 25 – *Angioblastus ellesmerensis* Breimer and Macurda, 1972. Oral, lateral (C), and aboral views (anus at 6 o'clock in oral and aboral views), and enlarged oral view and view of DE deltoid. Geological Survey Canada 67261. Holotype. (See also Breimer and Macurda, 1972, Pl. XXIX, figs. 6, 9, 10.) Pennsylvanian, Atokan, east side of Van Hauen Pass, Ellesmere Island, Canadian Arctic Archipelago. Figs. 18-20, x 3; figs. 23, 25, x 7.

22, 26 – *A. ellesmerensis.* Lateral (E) and basal views. Geological Survey Canada, unregistered specimen. (See also Breimer and Macurda, 1972, Pl. XXIX, fig. 8.) Pennsylvanian, Atokan, bioherm, north side of Hare Fiord, Ellesmere Island, 81°07.5′N, 80°17′W, Canada. x 3.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EXPLANATION OF PLATE 41

FIGS.

1-5, 15 – *Angioblastus miloradovitchi* (Yakovlev, 1940). Oral view, views of oral area and B ambulacrum, aboral view, view of anal interarea, and lateral (D) view. Anus at 6 o'clock in figs. 1, 2, 4. Central Geological Museum (Leningrad) collection 6324. (See also Breimer and Macurda, 1972, Pl. XXX, figs. 10, 11.) Lower Permian, Pechora region, U.S.S.R. Figs. 1, 4, 15, x 3; figs. 2, 3, 5, x 7.

6, 7 – *Angioblastus wanneri* (Yakovlev, 1926b). Lateral (A) and basal (anus at 6 o'clock) views. No. 1 in growth series. Permian, Krasnoufimsk, U.S.S.R. x 3.

8, 10 – *A. wanneri.* Lateral (D) and oral (anus at 6 o'clock) views. No. 3 in growth series. (See also Breimer and Macurda, 1972, Pl. XXIX, fig. 7.) Permian, Krasnoufimsk, U.S.S.R. x3.

9 – *A. wanneri.* Lateral (D) view. No. 6 in growth series. Permian, Krasnoufimsk, U.S.S.R. x 3.

11 – *A. wanneri.* Oral view (anus at 6 o'clock). No. 8 in growth series. (See also Breimer and Macurda, 1972, Pl. XXIX, fig. 18, and Pl. 42, fig. 2 herein.) Permian, Krasnoufimsk, U.S.S.R. x 3.

12 – *A. wanneri.* Lateral (E) view. No. 9 in growth series. (See also Breimer and Macurda, 1972, Pl. XXIX, fig. 11.) Permian, Krasnoufimsk, U.S.S.R. x 3.

13 – *A. wanneri.* Basal view (anus at 6 o'clock). No. 10 in growth series. (See also Breimer and Macurda, 1972, Pl. XXIX, fig. 15.) Permian, Krasnoufimsk, U.S.S.R. x 3.

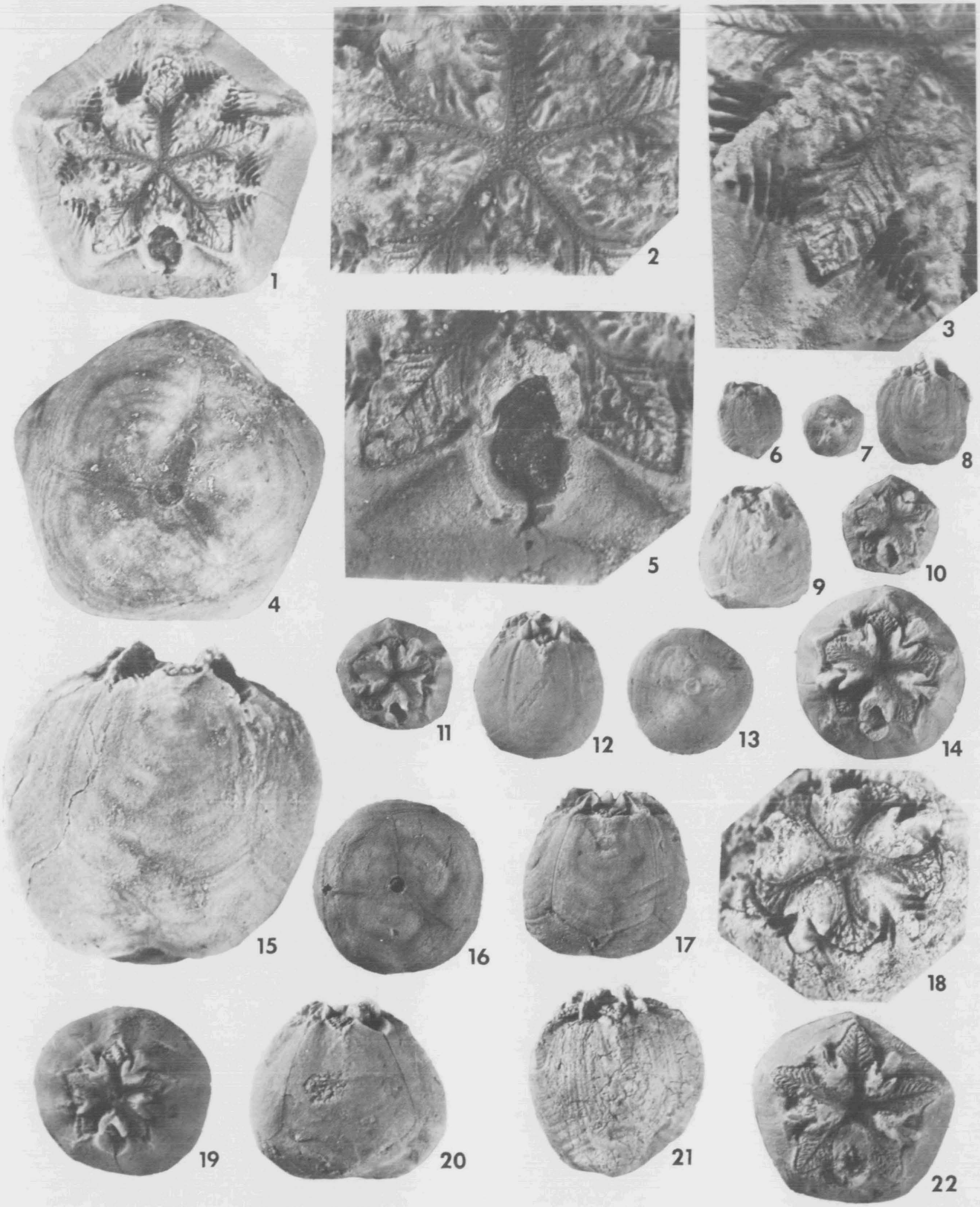
14, 16, 17 – *A. wanneri.* Oral, basal (anus at 6 o'clock in both figures), and lateral (B) views. No. 13 in growth series. (See also Breimer and Macurda, 1972, Pl. XXIX, figs. 12, 13, 16, and Pl. 42, figs. 6, 7 herein.) Permian, Krasnoufimsk, U.S.S.R. x 3.

18 – *A. wanneri.* Oral view (anus at 9 o'clock). Central Geological Museum (Leningrad). Plesiotype, 1937. Permian, Krasnoufimsk, U.S.S.R. x 7.

19, 20 – *A. wanneri.* Oral (anus at 6 o'clock) and lateral (D) views. No. 14 in growth series. Permian, Krasnoufimsk, U.S.S.R. x 3.

21 – *A. wanneri.* Lateral (E) view. No. 16 in growth series. See also Pl. 42, figs. 3, 9 herein. Permian, Krasnoufimsk, U.S.S.R. x 3.

22 – *A. wanneri.* Oral view (anus at 6 o'clock). No. 17 in growth series. (See also Breimer and Macurda, 1972, Pl. XXIX, fig. 17, and Pl. 42, fig. 1 herein.) Permian, Krasnoufimsk, U.S.S.R. x 3.



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EXPLANATION OF PLATE 42

FIGS.

1 – *Angioblastus wanneri* (Yakovlev, 1926b). Inclined view of BC deltoid. No. 17 in growth series. (See also Breimer and Macurda, 1972, Pl. XXIX, fig. 17, and Pl. 41, fig. 22 herein.) Permian, Krasnoufimsk, U.S.S.R. x 7.

2 – *A. wanneri*. Oral view (anus at 6 o'clock). No. 8 in growth series. (See also Breimer and Macurda, 1972, Pl. XXIX, fig. 18, and Pl. 41, fig. 11 herein.) Permian, Krasnoufimsk, U.S.S.R. x 7.

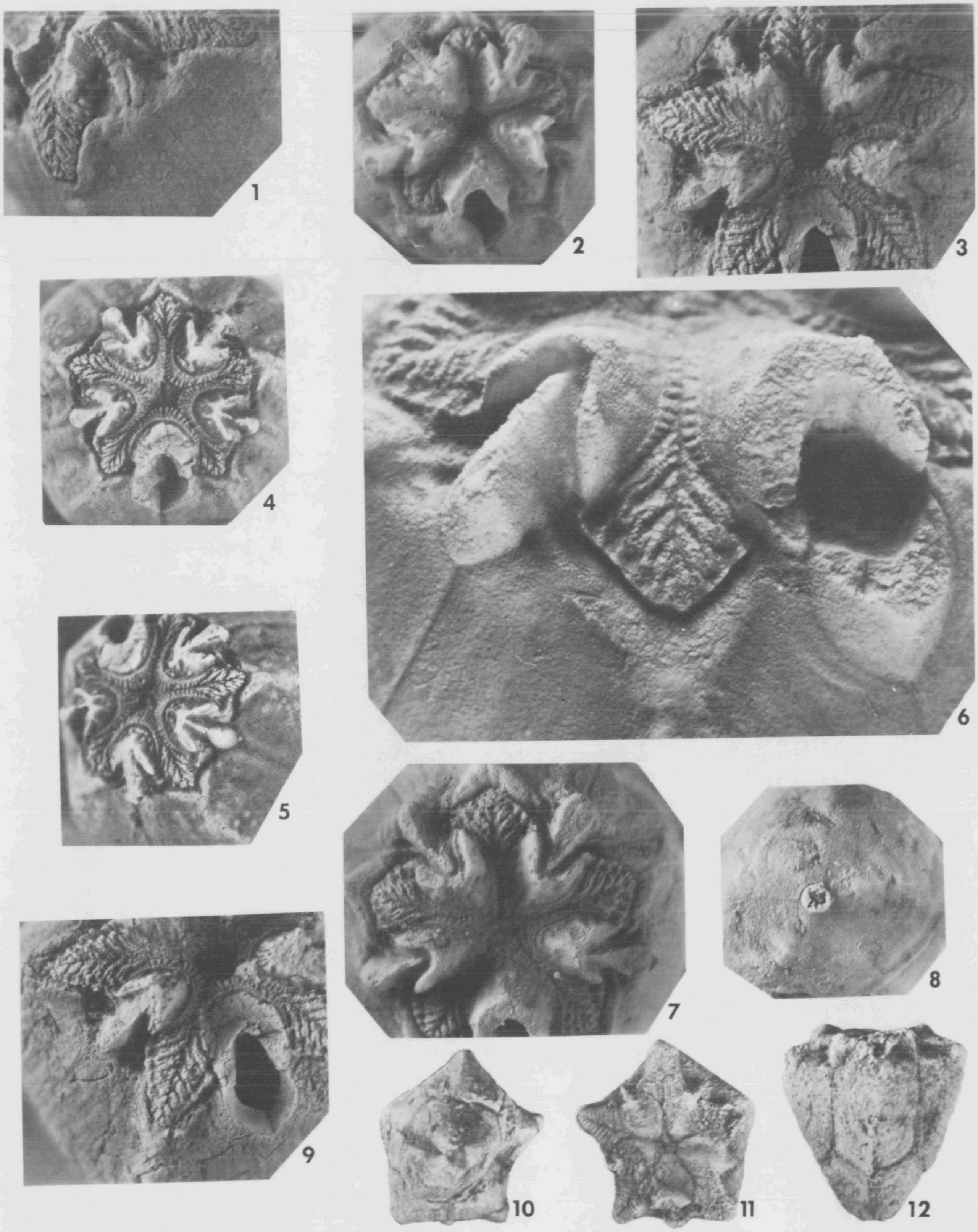
3, 9 – *A. wanneri*. Oral view (anus at 6 o'clock), and view of D ambulacrum. No. 16 in growth series. See also Pl. 41, fig. 21 herein. Permian, Krasnoufimsk, U.S.S.R. x 7.

4, 5 – *A. wanneri*. Oral (anus at 6 o'clock) view and view of A ambulacrum. Central Geological Museum (Leningrad). Plesiotype, 1937. Permian, Krasnoufimsk, U.S.S.R. x 7.

6, 7 – *A. wanneri*. Views of D ambulacrum and oral (anus at 6 o'clock) area. No. 13 in growth series. (See also Breimer and Macurda, 1972, Pl. XXIX, figs. 12, 13, 16, and Pl. 41, figs. 14, 16, 17 herein.) Permian, Krasnoufimsk, U.S.S.R. x 17.5 and x 7.

8 – *A. wanneri*. Basal view (anus at 6 o'clock). No. 4 in growth series. Permian, Krasnoufimsk, U.S.S.R. x 7.

10-12 – *Tympanoblastus pousirewskii* (Stuckenberg, 1875). Basal, oral (anus at 6 o'clock in both views) and lateral (A) views. Mining Institute, Leningrad, 106/43. (See also Breimer and Macurda, 1972, Pl. XXX, fig. 5, and Pl. XXXI, fig. 6.) Lower Permian, Timan tundra, Pechora region, U.S.S.R. x 3.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EXPLANATION OF PLATE 43

FIGS.

1-5 – *Tympanoblastus pousirewskii* (Stuckenberg, 1875). Views of aboral part of AB deltoid, anal opening, epideltoid, adoral part of AB deltoid, and B ambulacrum. Central Geological Museum (Leningrad) collection 7191. (Holotype of *Codaster barkhatovae* Yakovlev, 1941. See also Breimer and Macurda, 1972, Pl. XXX, fig. 14; and Pl. XXXI, fig. 3.) Lower Permian, Timan, U.S.S.R. x 7.

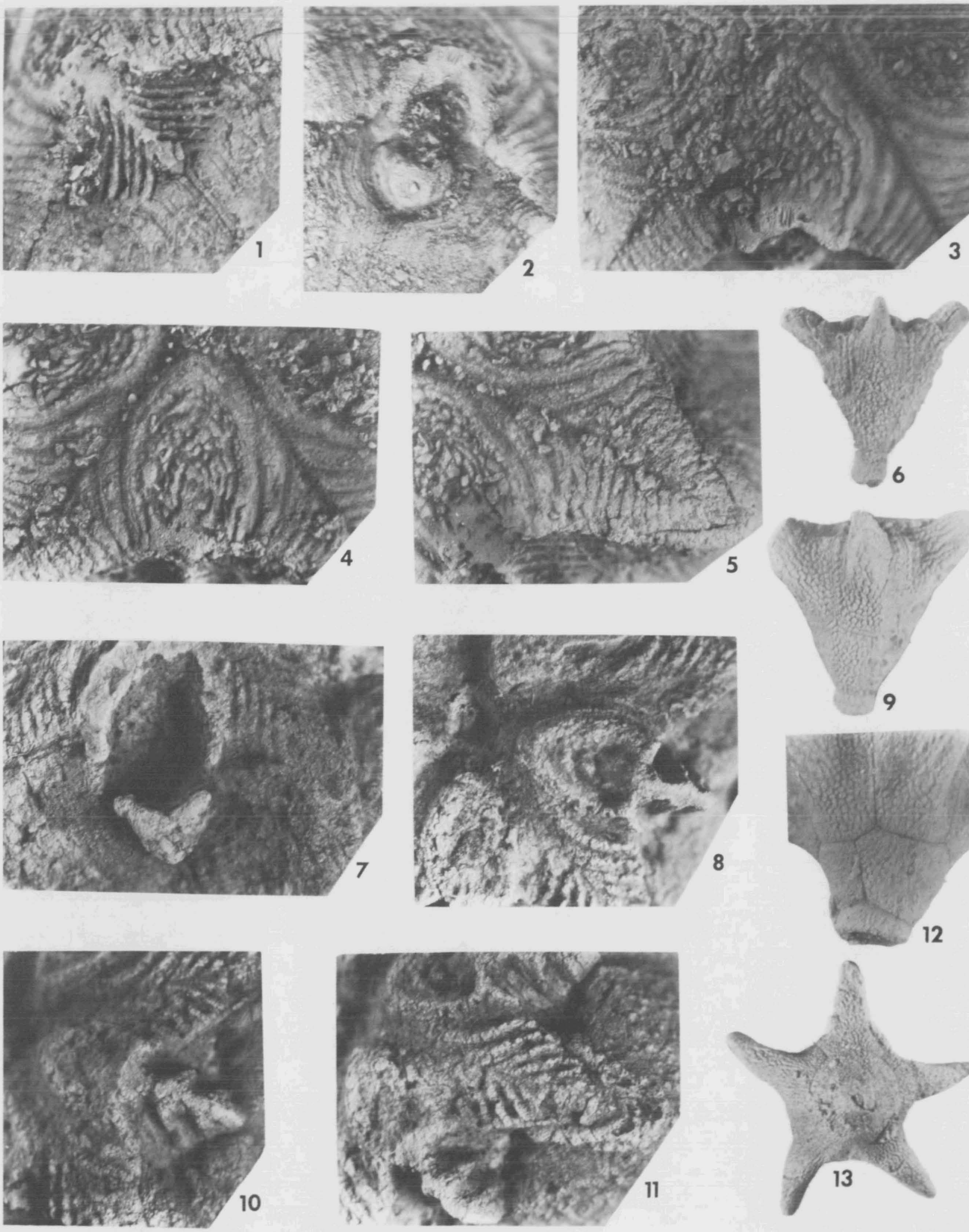
6 – *Pterotoblastus gracilis* Wanner, 1924a. Lateral (B) view. No. 1 in growth series. Permian, Sonnebait Series, Timor, Indonesia. x 8.3.

7, 8, 10, 11 – *Tympanoblastus elongatus* (Yakovlev, 1937). Views of anal opening, adoral and aboral parts of DE deltoid, and E ambulacrum. Central Geological Museum (Leningrad) 8/6109. (See also Breimer and Macurda, 1972, Pl. XXX, fig. 13; Pl. XXXI, fig. 1.) Lower Permian, Ural Mountains, U.S.S.R. x 7.

9 – *P. gracilis*. Lateral (A) view. No. 3 in growth series. See also Pl. 44, fig. 1 herein. Permian, Sonnebait Series, Timor, Indonesia. x 8.3.

12 – *P. gracilis*. Lateral view of lower part of theca and proximal columnal. No. 5 in growth series. (See also Breimer and Macurda, 1972, Pl. XXXII, fig. 3.) Permian, Sonnebait Series, Timor, Indonesia. x 7.

13 – *P. gracilis*. Basal view (anus at 6 o'clock). No. 13 in growth series. Permian, Sonnebait Series, Timor, Indonesia. x 4.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EXPLANATION OF PLATE 44

FIGS.

1 – *Pterotoblastus gracilis* Wanner, 1924a. Oral view (anus at 6 o'clock). No. 3 in growth series. See also Pl. 43, fig. 9 herein. Permian, Sonnebait Series, Timor, Indonesia. x 8.3.

2 – *P. gracilis*. Oral view (anus at 6 o'clock). No. 15 in growth series. (See also Breimer and Macurda, 1972, Pl. XXXII, fig. 9.) Permian, Sonnebait Series, Timor, Indonesia. x 4.

3, 6 – *P. gracilis*. Oral (anus at 6 o'clock), and lateral (D) views. No. 18 in growth series. Permian, Sonnebait Series, Timor, Indonesia. x 4.

4 – *P. gracilis*. Oral view (anus at 6 o'clock). No. 6 in growth series. Permian, Sonnebait Series, Timor, Indonesia. x 7.

5 – *Pterotoblastus ferrugineus* Wanner, 1940. View of anal interarea. University Amsterdam Ge.O. 9924. Holotype. (See also Breimer and Macurda, 1972, Pl. XXXI, figs. 4, 8, and Pl. 45, fig. 4 herein.) Permian, Tai Wei, east of Basleo, Timor, Indonesia. x 7.

7 – *P. gracilis*. Inclined view of AB deltoid. University Amsterdam, unregistered specimen (E). See also Pl. 45, figs. 1-3 herein. Permian, Timor, Indonesia. x 7.

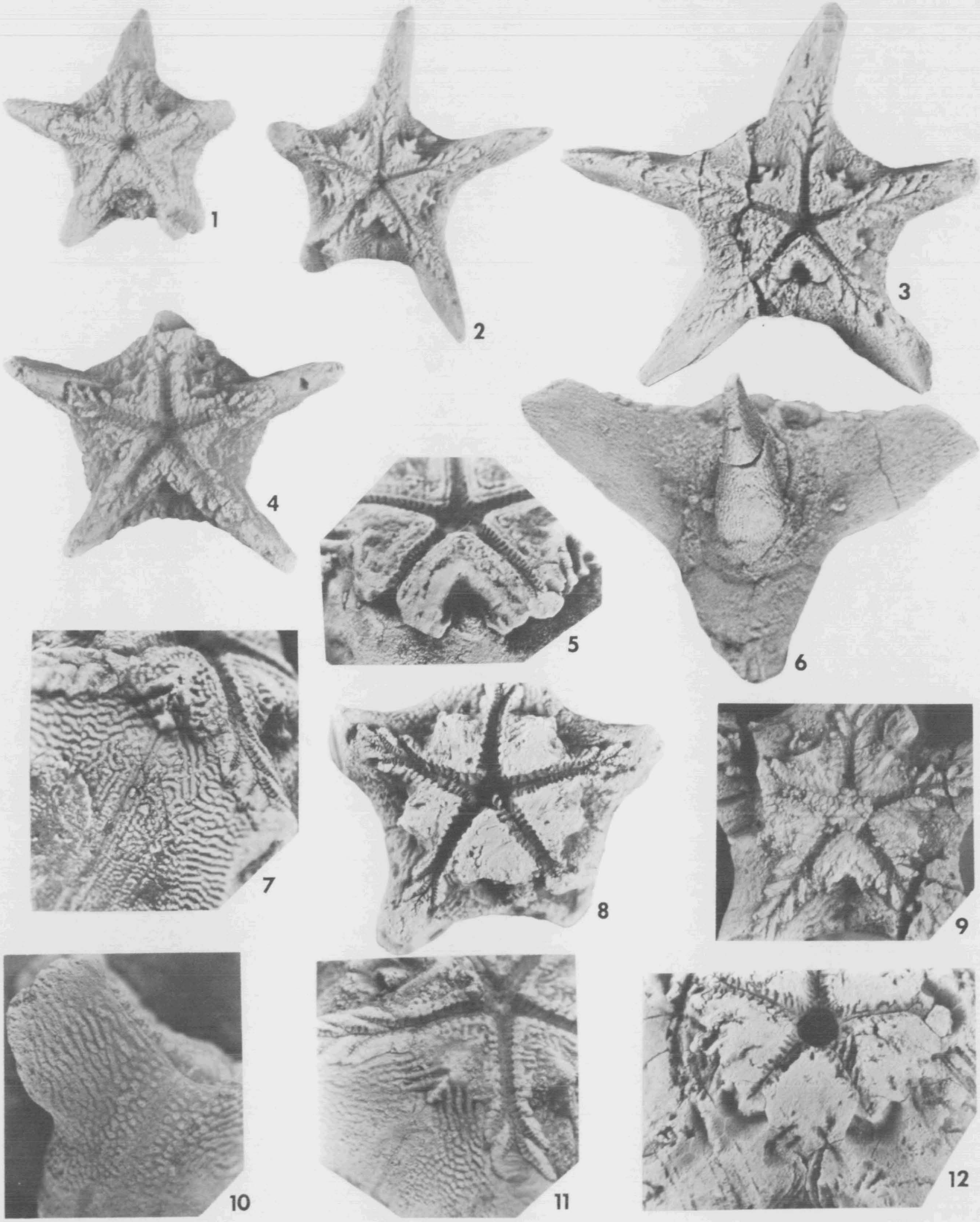
8 – *P. gracilis*. Oral view (anus at 6 o'clock). University Amsterdam, unregistered specimen (A). Permian, near Basleo, Timor, Indonesia. x 7.

9 – *P. gracilis*. Oral view (anus at 6 o'clock). University Amsterdam, unregistered specimen (F). Permian, Noko, Timor, Indonesia. x 7.

10 – *P. gracilis*. View of radial (A) prong. No. 10 in growth series. Permian, Sonnebait Series, Timor, Indonesia. x 7.

11 – *P. gracilis*. View of BC deltoid. University Amsterdam, unregistered specimen (C). Permian, near Basleo, Timor, Indonesia. x 7.

12 – *P. gracilis*. Oral view with ambulacra weathered away. University Amsterdam, unregistered specimen (B). Permian, Nipol Soempek, Timor, Indonesia. x 7.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EXPLANATION OF PLATE 45

FIGS.

1-3 – *Pterotoblastus gracilis* Wanner, 1924a. Views of C ambulacrum, A ambulacrum, and anal interarea. University Amsterdam, unregistered specimen (E). See also Pl. 44, fig. 7 herein. Permian, Timor, Indonesia. x 7.

4 – *Pterotoblastus ferrugineus* Wanner, 1940. Oral view (anus at 6 o'clock). University Amsterdam Ge.O. 9924. (See also Breimer and Macurda, 1972, Pl. XXXI, figs. 4, 8, and Pl. 44, fig. 5 herein.) Permian, Tai Wei, east of Basleo, Timor, Indonesia. x 7.

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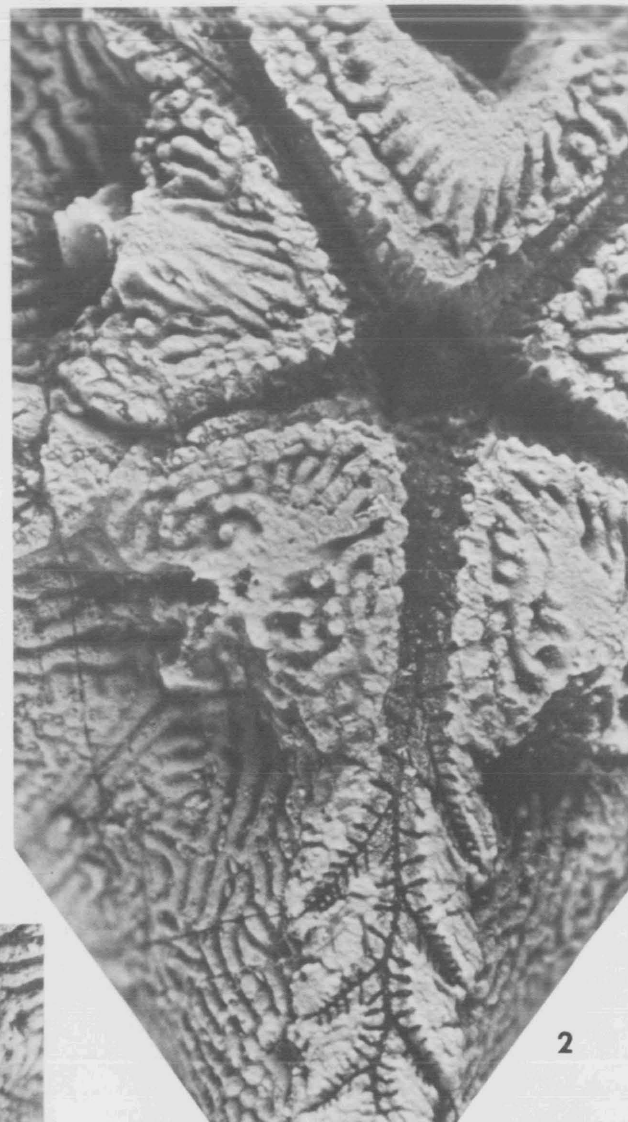

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EXPLANATION OF PLATE 46

FIGS.

1-3 – *Pterotoblastus brevialatus* Wanner, 1931. Oral, lateral (A), and basal views (anus at 6 o'clock in oral and basal views.) No. 2 in growth series. Permian, Sonnebait Series, Timor, Indonesia. x 5.

4, 7 – *P. brevialatus*. Oral (anus at 6 o'clock) and inclined lateral (EA) views. No. 4 in growth series. Permian, Sonnebait Series, Timor, Indonesia. x 5 and x 7.

5, 8, 10 – *P. brevialatus*. Oral, inclined lateral (CD) and basal views (anus at 6 o'clock in oral and basal views). No. 9 in growth series. Permian, Sonnebait Series, Timor, Indonesia. Figs. 5, 8, x 7; fig. 10, x 5.

6 – *P. brevialatus*. Lateral (E) view. No. 12 in growth series. (See also Breimer and Macurda, 1972, Pl. XXXI, figs. 7, 9.) Permian, Sonnebait Series, Timor, Indonesia. x 7.

9 – *P. brevialatus*. Oral view (anus at 6 o'clock). No. 8 in growth series. (See also Breimer and Macurda, 1972, Pl. XXXI, fig. 5.) Permian, Sonnebait Series, Timor, Indonesia. x 7.

11 – *P. brevialatus*. Oral view of tetramerous mutant (anus at 6 o'clock). USNM 160668. Locality as for growth series. x 5.

12, 13 – *P. brevialatus*. Oral (anus at 6 o'clock) and A ambulacral views. No. 15 in growth series. Permian, Sonnebait Series, Timor, Indonesia. x 5 and x 7.

14 – *Nannoblastus pyramidatus* Wanner, 1924b. Oral view (anus at 6 o'clock). No. 3 in growth series. Permian, Sonnebait Series, Timor, Indonesia. x 4.

15, 23 – *N. pyramidatus*. Basal view (anus at 6 o'clock) and view of anal interarea. No. 2 in growth series. Permian, Sonnebait Series, Timor, Indonesia. x 4 and x 7.

16, 19 – *N. pyramidatus*. Basal view (anus at 6 o'clock) and lateral view. No. 8 in growth series. Permian, Sonnebait Series, Timor, Indonesia. x 4 and x 7.

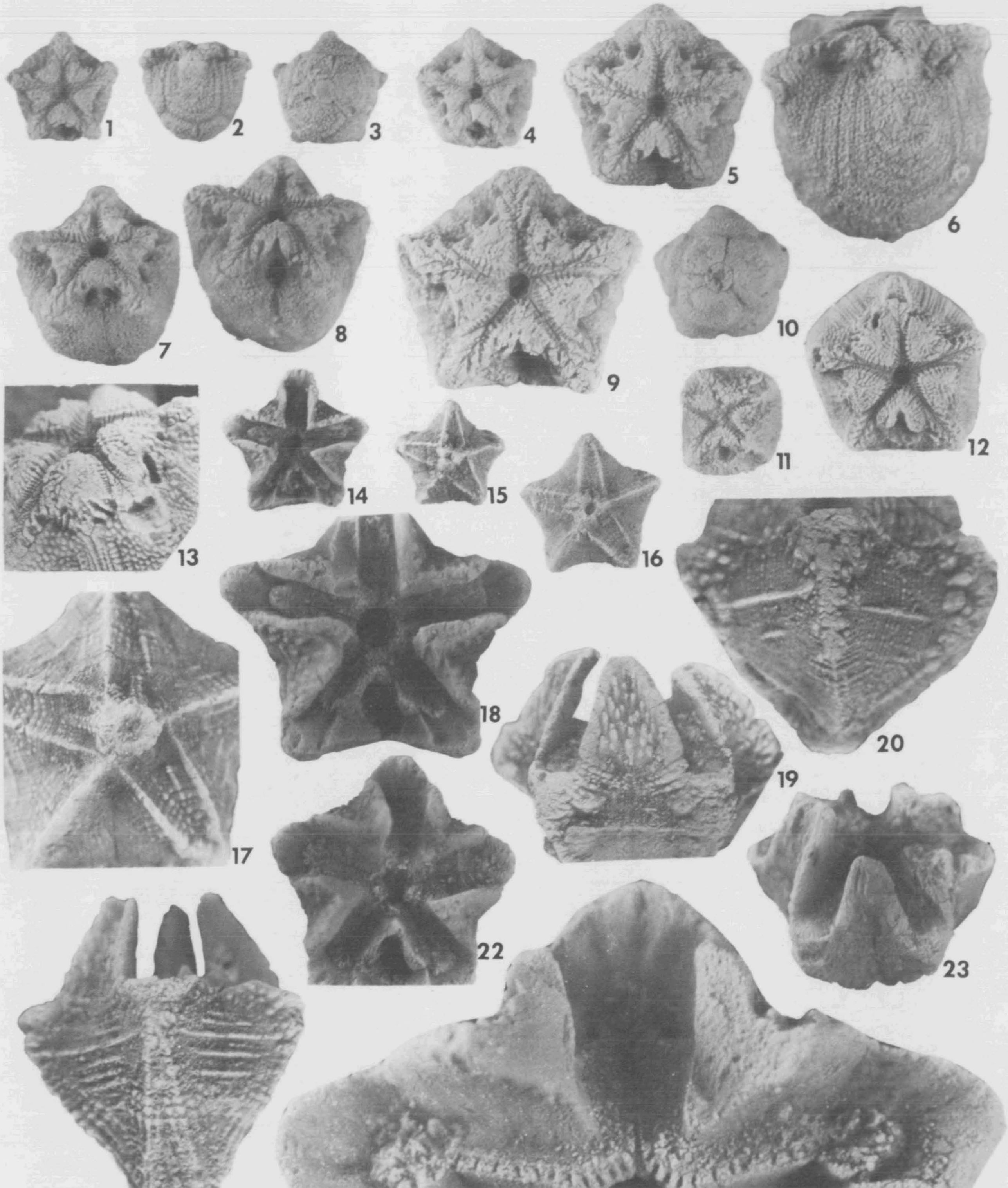
17, 24 – *N. pyramidatus*. Basal view (anus at 6 o'clock) and oral view. University Amsterdam, unregistered specimen (C). Locality as for growth series. x 7 and x 17.5.

18 – *N. pyramidatus*. Oral view (anus at 6 o'clock). University Amsterdam, unregistered specimen (E). Locality as for growth series. x 7.

20 – *N. pyramidatus*. Lateral (A) view. No. 10 in growth series. (See also Breimer and Macurda, 1972, Pl. XXXIII, figs. 2, 6.) Permian, Sonnebait Series, Timor, Indonesia. x 7.

21 – *N. pyramidatus*. Lateral (B) view. No. 14 in growth series. (See also Breimer and Macurda, 1972, Pl. XXXIII, fig. 7.) Permian, Sonnebait Series, Timor, Indonesia. x 7.

22 – *N. pyramidatus*. Oral view (anus at 6 o'clock). University Amsterdam, unregistered specimen (D). Locality as for growth series. x 7.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EXPLANATION OF PLATE 47

FIGS.

1, 3 – *Ceratoblastus nanus* Wanner, 1940. Oral (anus at 6 o'clock) and lateral (C) views. No. 3 in growth series. Permian, Timor, Indonesia. x 12 and x 5.

2 – *C. nanus*. Lateral (E) view. No. 1 in growth series. Permian, Timor, Indonesia. x 3.

4 – *C. nanus*. Inclined oral view of anal interarea. No. 2 in growth series. Holotype. (See also Breimer and Macurda, 1972, Pl. XXXII, figs. 5, 11.) Permian, Timor, Indonesia. x 17.5.

5, 6, 9 – *Indoblastus granulatus* Wanner, 1924a. Lateral (C), oral, and aboral views (anus at 6 o'clock in last two). No. 1 in growth series. (Holotype of *Indoblastus nuciformis* Wanner, 1940.) Permian, Timor, Indonesia. x 3.

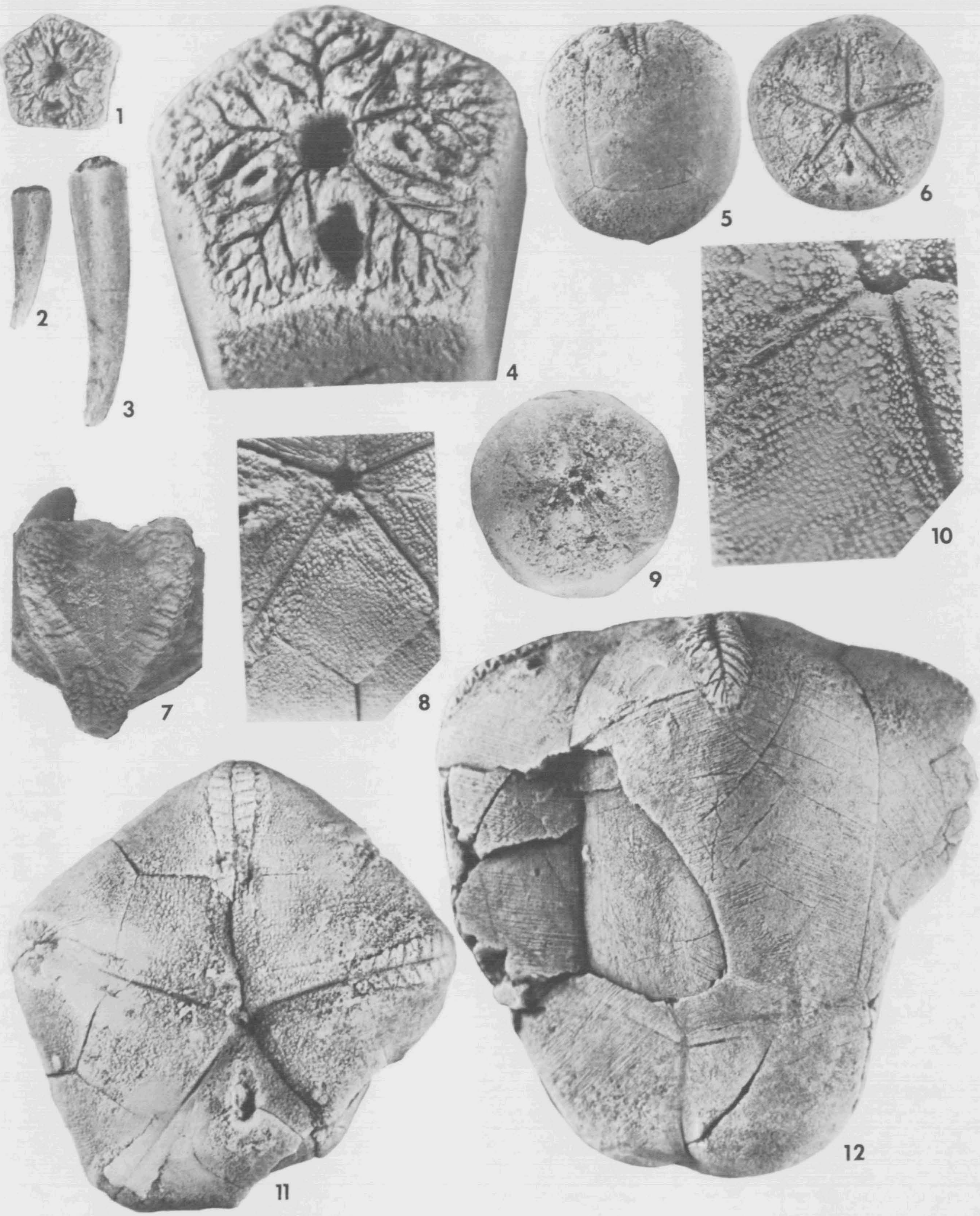
7 – *Nannoblastus pyramidatus* Wanner, 1924b. Inclined view of lower part of theca. No. 5 in growth series. Permian, Sonnebait Series, Timor, Indonesia. x 7.

8 – *I. granulatus*. View of BC deltoid. BMNH E30688. (See also Breimer and Macurda, 1972, Pl. XXXII, fig. 2, XXXIII, fig. 4, and Pl. 49, figs. 4, 5 herein.) Permian, Neoepantokak, Timor, Indonesia. x 5.5.

10 – *I. granulatus*. View of AB deltoid. No. 16 in growth series. See also Pl. 48, figs. 2-5, and Pl. 49, fig. 3 herein. Permian, Timor, Indonesia. x 7.

11 – *I. granulatus*. Oral view (anus at 6 o'clock). No. 2 in growth series. Permian, Timor, Indonesia. x 3.

12 – *I. granulatus*. Lateral (B) view. No. 8 in growth series. See also Pl. 49, fig. 2 herein. Permian, Timor, Indonesia. x 3.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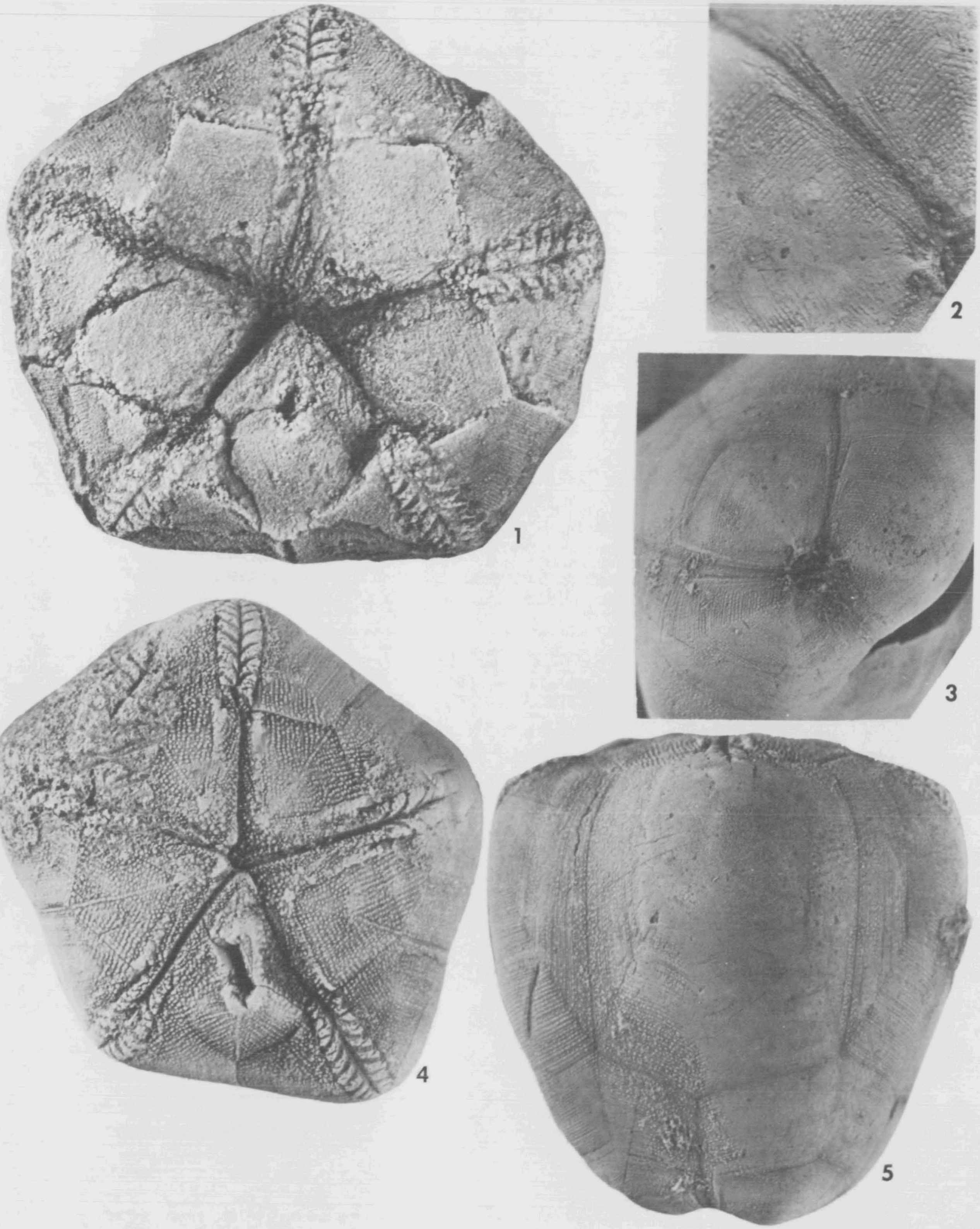
EXPLANATION OF PLATE 48

FIGS.

1 – *Indoblastus granulatus* Wanner, 1924a. ·Oral view (anus at 6 o'clock). No. 10 in growth series. See also Pl. 49, fig. 7 herein. Permian, Timor, Indonesia. x 3.

2-5 – *I. granulatus*. Lateral view of basals, aboral view of basals, oral (anus at 6 o'clock in figs. 3, 4), and lateral (B) views. No. 16 in growth series. See also Pl. 47, fig. 10, and Pl. 49, fig. 3 herein. Permian, Timor, Indonesia. Fig. 2, x 7; figs. 3-5, x 3.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EXPLANATION OF PLATE 49

FIGS.

1 – *Indoblastus weberi* Wanner, 1924a. Oral view (anus at 7 o'clock). Collections Geologische Paläontologische Institute, Friedrich-Wilhelm University, Bonn. (See also Breimer and Macurda, 1972, Pl. XXXIII, fig. 3.) Permian, Tuani, Niki Niki, Hatu Dame, Ramelau Mountains, Timor, Indonesia. x 3.

2 – *Indoblastus granulatus* Wanner, 1924a. Basal view (anus at 7 o'clock). No. 8 in growth series. See also Pl. 47, fig. 12 herein. Permian, Timor, Indonesia. x 3.

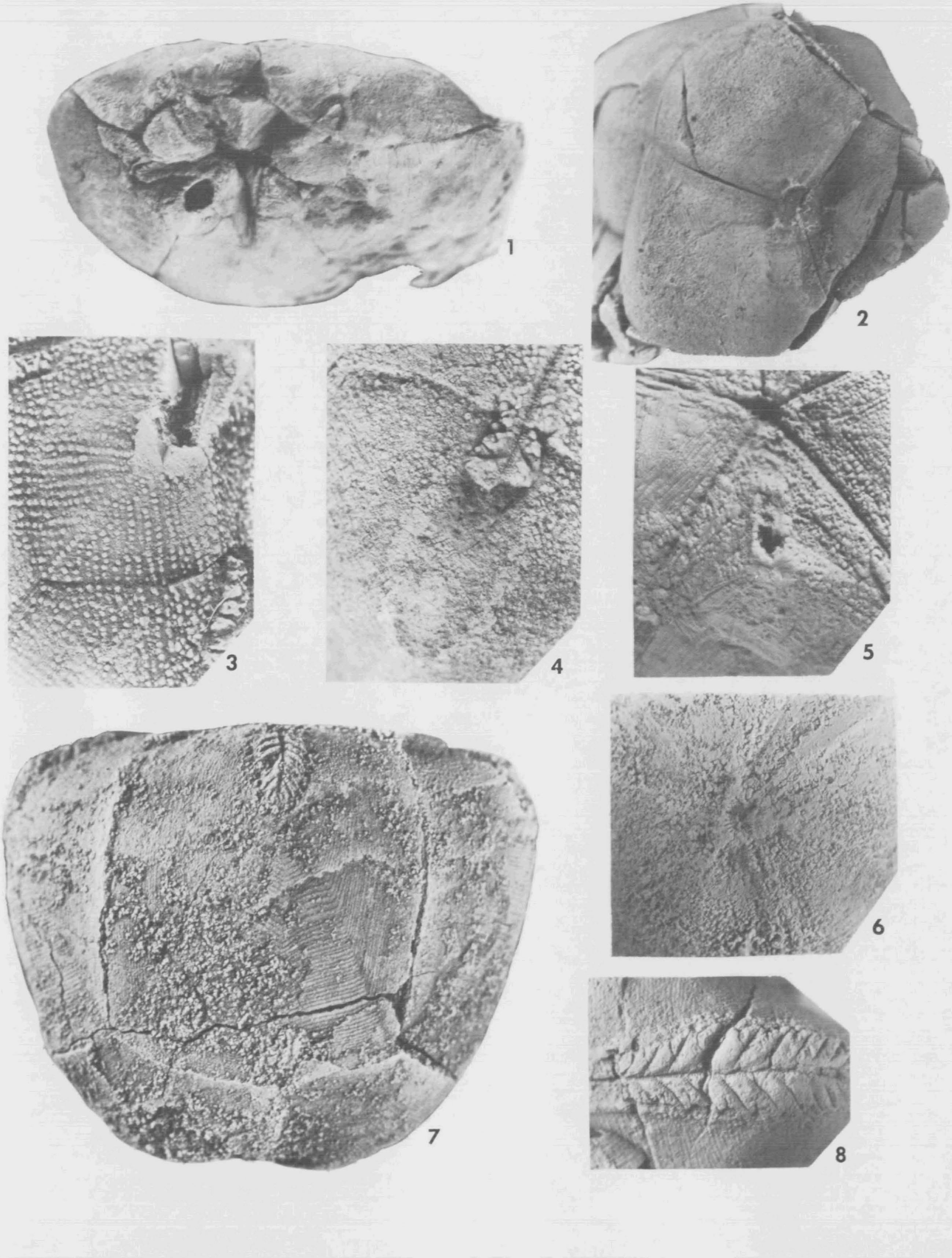
3 – *I. granulatus*. View of hypodeltoid. No. 16 in growth series. See also Pl. 47, fig. 10, and Pl. 48, figs. 2-5 herein. Permian, Timor, Indonesia. x 7.

4, 5 – *I. granulatus*. Views of A ambulacrum and anal interarea. BMNH 30688. (See also Breimer and Macura, 1972, Pl. XXXII, fig. 2; Pl. XXXIII, fig. 4, and Pl. 47, fig. 8 herein.) Permian, Neoepantokak, Timor, Indonesia. x 5.8 and x 7.

6 – *I. granulatus*. View of tip of basals. No. 9 in growth series. Permian, Timor, Indonesia. x 7.

7 – *I. granulatus*. Lateral (A) view. No. 10 in growth series. See also Pl. 48, fig. 1 herein. Permian, Timor, Indonesia. x 3.

8 – *I. granulatus*. View of B ambulacrum. BMNH 30689. Permian, Timor, Indonesia. x 7.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Papers on Paleontology No. 22

Macurda: Systematics of the Fissiculate Blastoidea

1983