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NATURE AND OCCURRENCE OF *GENNAEOCRINUS GOLDRINGAE* EHLERS

BY

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VOLUME XIX

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ABSTRACT

Specimens of *Gennaeocrinus goldringae* Ehlers have been found in the Middle Devonian Bell Shale of Michigan. The preservation of the holotype strongly suggests that it also came from the Bell Shale—not from strata exposed "on the bank of the Thunder Bay River near the Four Mile Dam about 4 miles upstream from Alpena, Michigan," as originally reported. One previously undescribed crinoid retains the well-preserved tegmen, having pits marking the former positions of radial tegminal plates. Associated with the specimens in the Bell Shale are numerous isolated plates of two general types: some are thin, polygonal, and provided with a long central spine, like the *RR, PBrBr,* and $IBrBr_1$ in the dorsal cups of *G. goldringae,* whereas others are spines with tapering, faceted bases that are counterparts of the tegminal pits. At one locality where no other crinoids are known to occur, spine-bearing and spinelike plates are numerous, supporting the assumption that they belong to *Gennaeocrinus goldringae.* Of the spinelike plates, the smaller are simple, long, tapered spikes, the intermediate branch beyond mid-length, and the larger are palmate, with several tips, resembling antlers in miniature. Inclination of the base on these spines and the orientation of the pits in the tegmen indicate that the spines sloped upward and outward from the tegmen. Other species of *Gennaeocrinus* possess radial tegminal plates developed as spines which protrude beyond the arms and divide the arms of the left and right half-rays, but none has spines as bizarre as those reported here. In *G. goldringae,* spinosity is associated with a thin, fragile calyx.

CONTENTS

INTRODUCTION

When studying crinoids of the Middle Devonian Bell Shale of Michigan, I had occasion to re-examine a crinoid of the genus *Gennaeocrinus* which was discovered in 1954 by Professor (now Professor Emeritus) George Marion Ehlers and deposited in our Museum of Paleontology. In comparing it with the holotype of *Gennaeocrinus goldringae* Ehlers, stated to have been found "on the bank of the Thunder Bay River about 4 miles upstream from Alpena, Michigan," I noted that the preservation of the latter does not conform with that known for other fossils in the area from which it was reported. Professor Ehlers reported that H. H. Hindshaw, who found the specimen, was known to have made some errors in recording locality and stratigraphic occurrence of his fossils. In my opinion the Bell Shale specimen and the holotype of *Gennaeocrinus goldringae* are conspecific and preserved in the same manner.

In hope of obtaining additional specimens to confirm the occurrence, Mr. Karoly Kutasi and I searched at exposures of Devonian strata in Alpena and Presque Isle Counties, Michigan, in August, 1964. At one locality, numerous isolated plates and spines were collected from the weathered exposure. About fifty pounds of shale from the plate-bearing layer were brought to the laboratory, disaggregated, and washed free of clay. The residue yielded part of a dorsal cup and additional plates.

Careful comparison of the isolated plates and those retained on the calyces of *Gennaeocrinus goldringae* indicates that they are conspecific. Yet the lack of a calyx with articulated tegminal spines compels me to classify the isolated spines as *? Gennaeocrinus goldringae*. The isolated plates provided with spines are distinctive, of two general types: those with thin, polygonal bases and those with very narrow, tapering, faceted bases. The former are obviously from the dorsal cup, like the *RR, PBrBr,* and $IBrBr_1$ present in the calyces; the latter appear to be from the tegmen. One previously undescribed calyx retains the well-preserved tegmen in which pits mark the former positions of a central tegminal plate and three of the five radial tegminal plates. Each pit is polygonal, surrounded by several smaller plates, and has sloping sides. Since the spinelike isolated plates have tapered bases that are counterparts of the tegminal pits, there can be little doubt that they originally formed an armature atop the calyx of *Gennaeocrinus goldringae*.

Professor Chester A. Arnold and Professor Lewis B. Kellum critically read this paper. Mr. Karoly Kutasi assisted in photography. Mrs. Helen Mysyk typed the final draft.

All specimens described and illustrated are deposited and catalogued in the Museum of Paleontology of The University of Michigan.

LOCALITIES

Crinoids described and illustrated in this paper were collected from the upper parts of the Middle Devonian Bell Shale at the following localities:

Locality:

1. Exposure of Bell Shale in drainage ditch in abandoned Rockport quarry of the Kelley's Island Lime and Transport Company, west of old quarry buildings, NW¼ sec. 6, T. 32 N., R. 9 E., in the northeast corner of Alpena County, Michigan. UMMP 30505, obtained by Prof. George M. Ehlers in 1954, is thought to have come from the lowest bed exposed in the ditch, which contains numerous well-preserved brown valves of *Atrypa* and lies about 12 feet below the contact with the Rockport Quarry Limestone and about 1 foot below the bed containing numerous *Gennaeocrinus variabilis* Kesling and Smith.
2. Exposure of Bell Shale in cut along abandoned road, formerly a private railway of the Kelley's Island Lime and Transport Company connecting Rockport and Lake-of-the-Woods quarries, about 1½ miles north of the Rockport quarry and 1 mile south of the former village of Bell, SW¼ SW¼ sec. 24, T. 33 N., R. 8 E., Presque Isle County, Michigan. Part of a calyx and numerous spines associated with valves of *Atrypa,* other brachiopods, and a few corals; no other crinoids known from this exposure. Specimens collected by Robert V. Kesling and Karoly Kutasi in 1964.

SYSTEMATIC DESCRIPTIONS

Subclass CAMERATA Wachsmuth and Springer
Order MONOBATHRIDA Moore and Laudon
Suborder Tanaocrinina Moore
Superfamily Periechocriniticae Ubaghs
Family Periechocrinitidae Austin and Austin
Genus *Gennaeocrinus* Wachsmuth and Springer

Type species.—By original designation of Wachsmuth and Springer (1881, p. 161), *Actinocrinus kentuckiensis* Shumard (1866, p. 345).

Gennaeocrinus goldringae Ehlers
(Figs. 1–2; Pl. I, Figs. 1–5; Pl. II, Figs. 1–6)

Gennaeocrinus goldringae Ehlers, 1925, pp. 101–4, Pl. I, Figs. 3–6.

The following description is based primarily upon hypotype UMMP 30505:

Dorsal cup.—Cup-shaped, thin-walled, its basal part spinose, its upper part flared so that arms are directed outward (laterally). Interray areas nearly flat, slightly convex. Posterior (CD) interray apparently exceptionally wide for the genus.

BB three, equal, together forming a regular hexagon, bearing a circular ridge concentric to the columnar cicatrix (Fig. 1; Pl. II, Fig. 2).

RR large, each about two-thirds the dimensions of the combined *BB*. *R* of A ray hexagonal, adjoining *B, 2 RR, 2* $IBrBr_1$, and PBr_1; *RR* of B

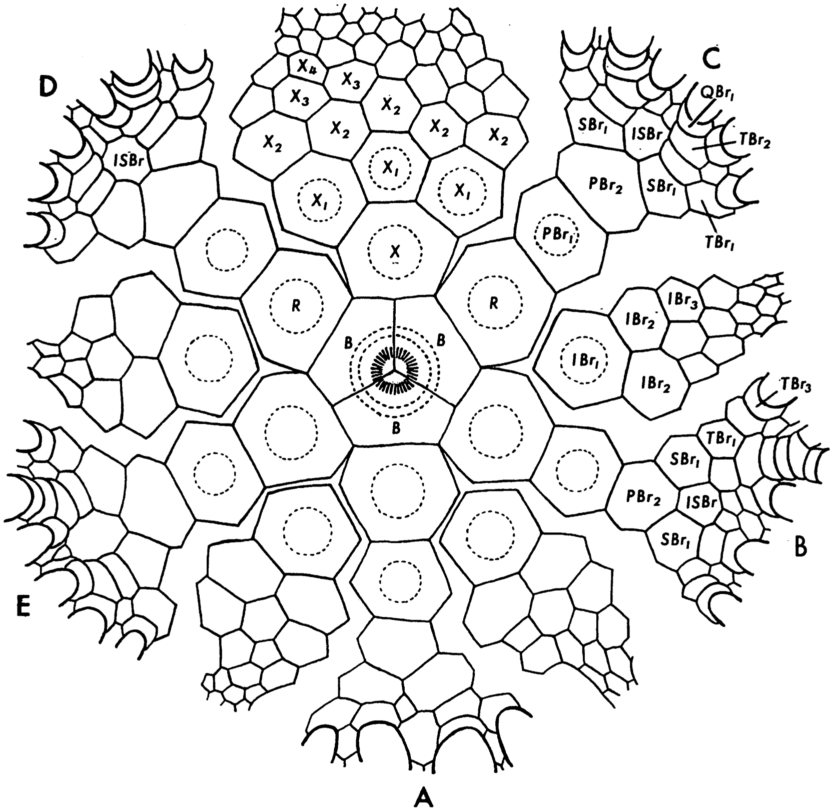

FIG. 1. *Gennaeocrinus goldringae* Ehlers. Plate diagram based upon UMMP 30505. Most of C and D rays and part of CD (posterior) interray restored to fit available space on crushed parts of specimen. Dashed lines on *BB* indicate ridge; those on *RR, X*, XX_1, $PBrBr_1$, and $IBrBr_1$ indicate bases of spines.

and E rays septagonal, each basally adjoining 2 *BB;* and *RR* of C and D rays hexagonal, each adjoining *B, R, X*, IBr_1, X_1, and PBr_1 (Fig. 1). Each *R* bearing a nearly central spine, apparently large and curved downward in large specimens (Pl. I, Figs. 3, 5).

$PBrBr_1$ hexagonal, varying in size, each distinctly smaller than the adjacent *R*. Each PBr_1 bearing a central spine; in large specimens, flaring base of the long spine nearly attaining borders of the plate (Pl. I, Figs. 2–5).

$PBrBr_2$ variable in size and shape, each bordered dorsally by PBr_1, on each side by 1 or 2 *IBrBr*, ventrolaterally by the 2 $SBrBr_1$, and, in most rays, ventrally by $ISBr_1$. In UMMP 30505, PBr_2 of A ray hexagonal, bordered by PBr_1, 2 $IBrBr_2$, IBr_3, and 2 $SBrBr_1$ (Pl. I, Fig. 5); that of

B ray septagonal, bordered ventrally by $ISBr_1$; and that of E ray octagonal, bordered laterally by 2 $IBrBr_2$ and 2 $IBrBr_3$ (Fig. 1; Pl. I, Fig. 4).

Branching beyond $SBrBr_1$ irregular. In UMMP 30505 (Fig. 1), A ray with apparently 4 arms, 2 in each half-ray; left SBr_1 octagonal, bordered by PBr_2, the right SBr_1, 2 *ISBrBr*, SBr_2 (axillary), and 3 *IBrBr* of AB interray; right SBr_1 axillary, bordered by PBr_1, left SBr_1, $ISBr_1$, 2 $TBrBr_1$, and 2 *IBrBr* of AE interray (Pl. I, Fig. 5). B ray with at least 6 arms, 2 in the right half-ray and 4 in the left; both $SBrBr_1$ axillary, hexagonal, separated by prominent septagonal $ISBr_1$; left SBr_1 giving rise to 2 $TBrBr_1$ in contact, the outer succeeded by 2 additional *TBrBr,* the inner rather small and succeeded by a large axillary TBr_2, which supports QBr_1 on the right and 3 *QBrBr* on the left, the QBr_3 axillary; right SBr_1 succeeded by 2 $TBrBr_1$ in contact, other *TBrBr* of each quarter-ray separated by *ITBrBr* (Pl. II, Fig. 1). E ray with at least 6 arms, 3 on each side; $SBrBr_1$ axillary, separated by a large suboval $ISBr_1$ (bounded by PBr_2, 2 $SBrBr_1$, 4 *TBrBr,* 2 *QBrBr,* and 3 $ISBrBr_2$, hence 12-sided); left SBr_1 pentagonal, bordered laterally by 1 *IBr;* right SBr_1 hexagonal, bordered laterally by 2 *IBrBr;* each *SBr* succeeded by uniserial *TBrBr* in the outer quarter-ray and by 2 *TBrBr* in the inner, of which TBr_2 is axillary and supports two series of *QBrBr;* outer and inner quarter-rays separated by *ITBrBr* above $TBrBr_1$ (Pl. I, Fig. 4). C ray incomplete and distorted, but apparently with 6 arms.

Posterior interray apparently much wider than other interrays. *X* septagonal, atop 2 *BB* and supporting 3 XX_1, in the circlet of *RR* and about the same size as one *R*. Three XX_1, each hexagonal, the outer bordered by *R* and PBr_1 of the adjacent ray. Five XX_2, apparently all hexagonal, slightly more than half the dimensions of *X*. Succeeding *XX* smaller and irregular.

Surface of plates marked by faint, irregular, tiny dents, discernible only with low-angle lighting. Large central spines on *RR*, $PBrBr_1$, $IBrBr_1$, *X*, and XX_1. Branching of arms emphasized by rounded Y-shaped ridge on PBr_2 of each ray, extending onto $SBrBr_1$; beyond *SBrBr,* arm ridges faint and indistinct (Pl. I, Figs. 4–5).

Tegmen.—Large, extending beyond dorsal cup by reason of the laterally directed arm bases. Tegmen gently arched, the radial areas elevated and the interradial depressed; anal pyramid not preserved, but evidently offset from center and probably near edge of tegmen (Pl. I, Figs. 1–2).

Central pit in tegmen, polygonal with sloping sides, like interior of frustrum of a hollow, several-sided pyramid, obviously the former site of a plate differing somewhat from surrounding plates. Similar pits in radial positions in tegmen, nearer to arms than to center of tegmen; small plates around each pit, sloping slightly upward to its rim.

Illustrated specimens.—Holotype, UMMP 9434, small crushed calyx. Hypotype, UMMP 30505, larger and more nearly complete than holotype; Locality 1. Hypotype, UMMP 49194, base of dorsal cup; Locality 2.

? *Gennaeocrinus goldringae* Ehlers

(Pl. I, Figs. 6–22; Pl. II, Figs. 7–19; Pl. III, Figs. 1–78; Pl. IV, Figs. 1–56; Pl. V, Figs. 1–72)

Spine-bearing plates, presumably from dorsal cup.—At Locality 2, where no other crinoid has been found, thin polygonal plates, each bearing a central spine, are common. In a few, the central spine has a bifid termination (Pl. III, Figs. 45, 49; Pl. IV, Fig. 28; Pl. V, Fig. 14). Proportions and measurements of selected spines are summarized in Table I.

In the dorsal cups of *Gennaeocrinus goldringae,* all ends of the spines are broken off, but the bases show that well-developed central spines were present on *RR*, $PBrBr_1$, $IBrBr_1$, *X*, and XX_1 (Pl. I, Figs. 2–4; Pl. II, Figs. 1–6). Small central papillae are present on most of the other *IBrBr* and *XX* (Pl. I, Figs. 2, 5; Pl. II, Fig. 6). Some of the spine-bearing plates found free are larger than any in place in the dorsal cups, indicating that the heads described here had not attained maximum size.

In general, these plates are divisible into two types: those with short, strongly inclined or curved spines and those with long, slightly inclined or nearly straight spines. These appear to be morphologic types, inasmuch as both kinds of spines occur in small and large plates. Strongly curved spines have a length/width ratio less than 1.10, and the slightly curved spines have a greater ratio (Table I). The first type is exemplified by UMMP 49397 (Pl. III, Fig. 53), UMMP 49382 (Pl. III, Fig. 35), UMMP 49352 (Pl. IV, Fig. 2), UMMP 49359 (Pl. IV, Fig. 15), and UMMP 49343 (Pl. V, Fig. 16). The second type is exemplified by UMMP 49376 (Pl. III, Fig. 11), UMMP 49371 (Pl. III, Fig. 13), UMMP 49403 (Pl. III, Fig. 37), and UMMP 49395 (Pl. III, Fig. 65). Probably, those of the first type, with short, strongly curved spines, are *RR* and *X*, whereas those of the second, with long, slightly inclined spines, are $PBrBr_1$, $IBrBr_1$, and XX_1.

Well-preserved plates with central spines have a granular surface with irregular longitudinal striations on the spine (Pl. III, Figs. 61–62, 67–68; Pl. IV, Figs. 3–4, 27–28; Pl. V, Figs. 14–17). Except for the spine, these plates are very thin, and many show effects of abrasion around the edge.

Plates developed as spines, presumably tegminal.—At Locality 2, associated with the plates described above, are plates developed as spines with tapered, multifaceted bases. These bases are counterparts of the pits observed on the tegmen of a nearly complete calyx, UMMP 30505 (Pl. I, Fig. 1). The resemblance in conformation is so strong that I have no doubt

TABLE I

PROPORTIONS AND MEASUREMENTS OF SPINE-BEARING PLATES, PRESUMABLY FROM DORSAL CUP

L/W	D/W	W	No.	Pl., Figs.	L/W	D/W	W	No.	Pl., Figs.
0.68	.34	7.1	49347	V, 35–36	1.05	.40	4.3	49401	III, 29–30
0.69	.26	5.8	49392	I, 14–15	(1.07)	.28	4.6	49390	I, 18–19
(0.72)	.35	6.5	49352	IV, 1–2	1.09	.40	4.3	49381	III, 23–24
0.72	.36	3.9	49400	III, 25–26	1.12	.39	5.9	49344	V, 22–23
0.74	.28	5.4	49364	IV, 23–24	*1.14	.61	5.7	49345	V, 14–15
0.80	.26	5.0	49397	III, 53–54	1.17	.43	6.0	49349	V, 20–21
0.85	.32	4.1	49427	III, 33–34	1.22	.34	4.1	49385	III, 47–48
(0.87)	.27	5.2	49391	I, 12–13	1.23	.42	4.8	49386	I, 8–9
0.88	.31	4.8	49384	III, 51–52	1.24	.35	6.3	49346	V, 12–13
0.89	.52	5.4	49388	I, 16–17	1.25	.28	3.6	49402	III, 19–20
0.91	.40	5.5	49359	IV, 15–16	1.26	.56	5.4	49367	IV, 21–22
0.91	.42	5.5	49360	IV, 25–26	1.27	.30	3.0	49409	III, 15–16
0.93	.30	4.6	49382	III, 35–36	1.30	.35	4.6	49380	III, 3–4
0.96	.36	4.7	49343	V, 16–17	1.30	.44	5.0	49365	IV, 17–18
1.03	.27	3.7	49426	III, 21–22	1.32	.24	3.7	49370	III, 17–18
*1.03	.59	3.4	49408	III, 49–50	1.37	.35	5.1	49378	III, 63–64
1.39	.38	3.9	49375	III, 1–2	1.62	.40	4.2	49371	III, 13–14
1.41	.55	5.1	49366	IV, 13–14	(1.66)	.55	4.4	49372	III, 31–32
1.43	.51	3.5	49396	III, 55–56	1.69	.43	3.5	49374	III, 9–10
1.44	.35	4.6	49387	I, 10–11	1.69	.43	4.2	49376	III, 11–12
1.45	.39	3.8	49399	III, 59–60	1.70	.54	4.6	49361	IV, 27–28
1.45	.40	4.7	49368	III, 7–8	(1.72)	.42	3.6	49393	III, 27–28
1.46	.44	4.1	49383	III,61–62	1.74	.32	3.1	49403	III, 37–38
1.46	.56	5.0	49357	IV, 5–6	(1.74)	.47	4.9	49362	IV, 9–10
1.47	.59	5.1	49356	IV, 3–4	(1.76)	.44	5.0	49358	IV, 19–20
(1.52)	.45	5.6	49355	IV, 7–8	1.77	.42	3.1	49398	III, 43–44
1.53	.33	3.6	49406	III, 41–42	(1.82)	.61	4.4	49369	III, 69–70
(1.54)	.39	5.4	49379	III, 5–6	1.83	.58	4.0	49373	III, 67–68
1.56	.46	5.0	49353	IV, 11–12	2.12	.54	2.6	49405	V, 39–40
1.57	.40	3.0	49407	III, 39–40	2.17	.67	3.0	49377	III, 45–46
1.58	.47	3.6	49404	III, 57–58	2.22	.56	3.6	49395	III, 65–66
(1.60)	.56	4.5	49363	V, 18–19					

* Bifid tip on spine.

() tip broken from spine, length estimated; W—width of base (mean) in mm; L—length, measured perpendicular to base; D—diameter, measured 2 mm above level of articulating surface.

that the tegminal pits were sockets from which such spines protruded.

The spines are of two major types: some are nearly straight and distally tapered, whereas most are somewhat curved and branched. All of the thin spines are straight and tapered (Pl. V, Figs. 55–56, 58–60), but only a few of the thick spines are straight (Pl. V, Figs. 24, 45–46, 69–70). Some of the intermediate spines are essentially straight, but have small tips of branches originating from their sides (Pl. IV, Fig. 46; Pl. V, Figs. 26, 44, 61).

Large branched spines tend to be palmate, with flat branches developed mostly in one plane (Pl. II, Figs. 11–12, 19; Pl. III, Fig. 73; Pl. IV, Figs. 35–36, 40). Of the somewhat smaller branched spines, some are subequally trifurcate (Pl. II, Figs. 10, 13–15, 17; Pl. IV, Figs. 30, 41–43), some are trifurcate with the lateral branches quite small (Pl. IV, Figs. 29, 32, 37–38, 46–48, 50–51), some have the termination splayed into branches (Pl. III, Fig. 71; Pl. IV, Figs. 48, 53; Pl. V, Figs. 25, 32), and a few are irregular, branching in several planes (Pl. IV, Figs. 33–34, 39, 45, 56). The largest spine is palmate, antler-shaped (Pl. II, Figs. 7–8).

Invariably, the smaller spines have one cycle of facets around the base (Pl. II, Fig. 16), but large spines contain additional facets (Pl. I, Fig. 21; Pl. II, Fig. 7). This may be interpreted as the encroachment of adult spines over the surrounding small tegminal plates.

Ornamentation of large well-preserved spines differs on opposite sides. The slightly concave side has a network of irregular raised elements, somewhat linear and slightly anastomosing, tending to be elongate longitudinally (Pl. II, Fig. 8; Pl. IV, Figs. 48–49; Pl. V, Figs. 26, 34, 56). To judge from the inclination of the base, this side was uppermost on the crinoid head. The slightly convex side, however, is sculptured by irregular patches of large, shallow dents (Pl. II, Figs. 7, 19; Pl. III, Fig. 73; Pl. IV, Figs. 43, 47; Pl. V, Figs. 33, 69).

Sizes and shapes of these isolated spines prompt the interpretation that all tegminal spines began nearly straight, unbranched, and tapered. The central tegminal spine either failed to branch or had only a few tines directly distally. A typical example of a supposed mature central tegminal spine is UMMP 49270 (Pl. V, Fig. 70); possibly, some of the robust spines with distally directed tines are also mature central tegminal spines, such as UMMP 49216 (Pl. II, Fig. 10) and UMMP 49221 (Pl. IV, Fig. 34).

Branching of the radial tegminal spines is presumed to have started laterally or nearly terminally from young nearly straight spines. The proximal part of the spine assumed a robust, nearly cylindrical form (Pl. I, Fig. 20) and the distal part grew out in the tined, palmate shape exemplified by UMMP 49195 (Pl. II, Fig. 12) and UMMP 49196 (Pl. II, Fig. 19) and attained full development in UMMP 49428 (Pl. II, Fig. 8).

The radial tegminal spines extended upward and outward from the slightly arched tegmen, each spine dividing the arms of the ray in which it occurred. In mature crinoids, the outer tips of each radial tegminal spine reached to or nearly to the adjacent spine.

Columnals.—Sections of pelmatozoan columns occur in considerable numbers at Locality 2. Like the isolated plates at this place, the sections belong, with little doubt, to *Gennaeocrinus goldringae.*

The columnals are of several types, cyclically arranged. The smallest columnals are disposed in groups of three or four. Larger columnals of two sizes typically alternate between groups of the smallest (Pl. III, Fig. 76; Pl. V, Fig. 6), with some exceptions. Many sections have cirri, which protrude from the column at one general level, originating from a group of the smallest columnals adjacent to one of the largest (Pl. III, Fig. 76; Pl. V, Figs. 1–4, 6–11).

Remarks.—Perhaps the best known crinoid bearing specialized radial tegminal plates is *Pterotocrinus* from the Chester Series of midcontinental United States. These plates occur as large flat oval alate processes, variously tapered spines, and stout bifurcated spines; all were joined to the tegmen in vertically elongate sockets in radial positions. Because of their distinctive shapes, the isolated plates have been considered sufficient for specific identification of the crinoid which bore them. In complete specimens, which are rare, each radial tegminal plate of *Pterotocrinus* projects beyond the rest of the tegmen, dividing the arms of the radius in which it occurs.

Other species of *Gennaeocrinus* have radial tegminal plates. In *G. mourantae* the five are clustered near the summit of the tegmen and their tips can be seen in a complete head extending out between the arms. In *G. sculptus* spines are present in about the same positions as those in *G. goldringae,* but they are short and blunt. In *G.* sp. from the Dock Street Clay, the spines project through the arms, much like those in *G. mourantae.* In no other species of *Gennaeocrinus,* however, are the spines branched into such bizarre shapes as those described herein, which I believe grew from the tegmen of *G. goldringae.*

From the series of spines described and illustrated here, one concludes that the radial tegminal spines in young crinoids (such as the holotype) were straight and unbranched (Fig. 2*a*), those in intermediate crinoids (such as UMMP 30505) possessed a few lateral branches (Fig. 2*b*), and those in adult and gerontic individuals were large, palmate, and antler-shaped (Fig. 2*c*). The central tegminal spine probably increased in diameter but did not branch, at least not laterally.

Presumably, the radial tegminal plates, with their tines projecting outward beyond the arms, constituted an effective armature for the crinoid head. Whatever inference may be drawn from the association, it should be pointed out that *Gennaeocrinus goldringae* Ehlers has the thinnest calyx plates and the greatest spinosity of any species of the genus yet discovered.

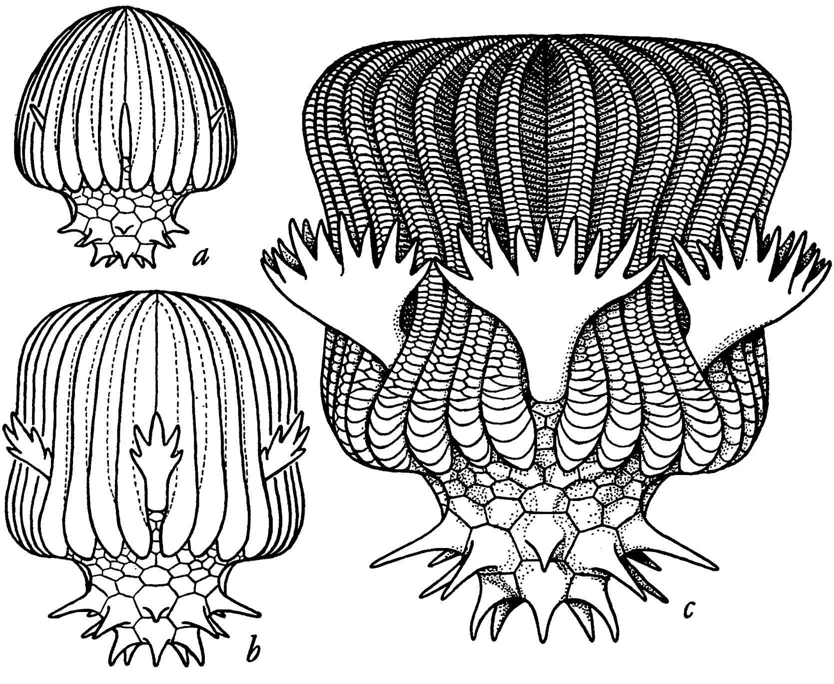

FIG. 2. *Gennaeocrinus goldringae* Ehlers. *a–c.* Reconstructions of ontogenetic sequence of calyces as viewed anteriorly, showing the supposed relationship of arms and radial tegminal plates.

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PLATES

EXPLANATION OF PLATE I

(All figures × 3)

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FIGS. 1–5. Tegminal, anterior (A ray), basal, and two inclined lateral (E and A rays) views of calyx, Hypotype UMMP 30505. Locality 1.

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FIGS. 6–7. Lateral and basal views of bifurcated spine, presumably tegminal, UMMP 49208. Locality 2.

FIGS. 8–9. Lateral and top views of spine-bearing plate, presumably from dorsal cup, UMMP 49386. Locality 2.

FIGS. 10–11, 14–19. Top and lateral views of spine-bearing plates, presumably from dorsal cup, UMMP 49387, 49392, 49388, and 49390. Locality 2.

FIGS. 12–13, 22. Top and two lateral views of spine-bearing plate, presumably from dorsal cup, UMMP 49391. Locality 2.

FIGS. 20–21. Lateral and basal views of bifurcated spine, presumably tegminal, UMMP 49199. Locality 2.

PLATE I

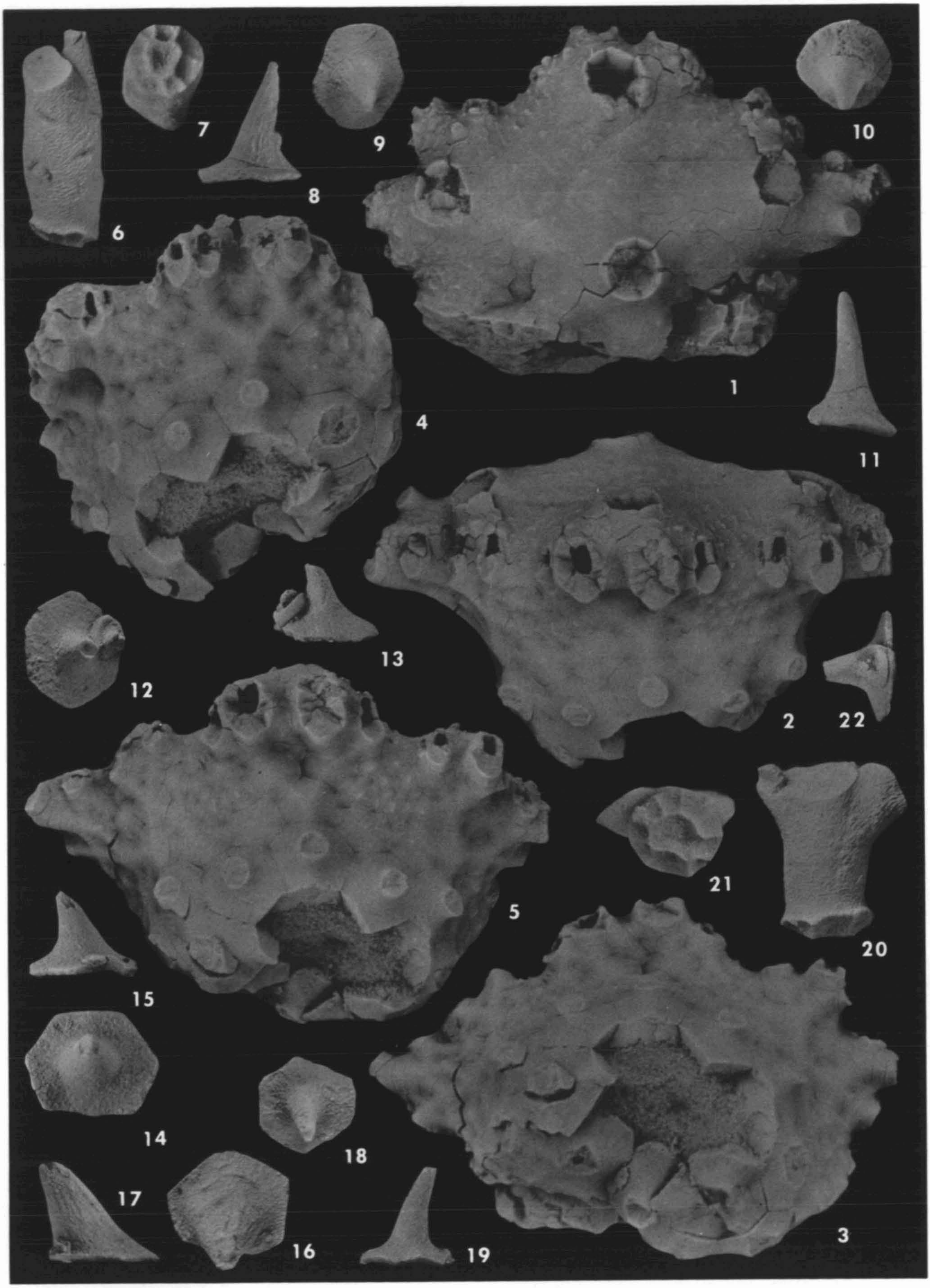
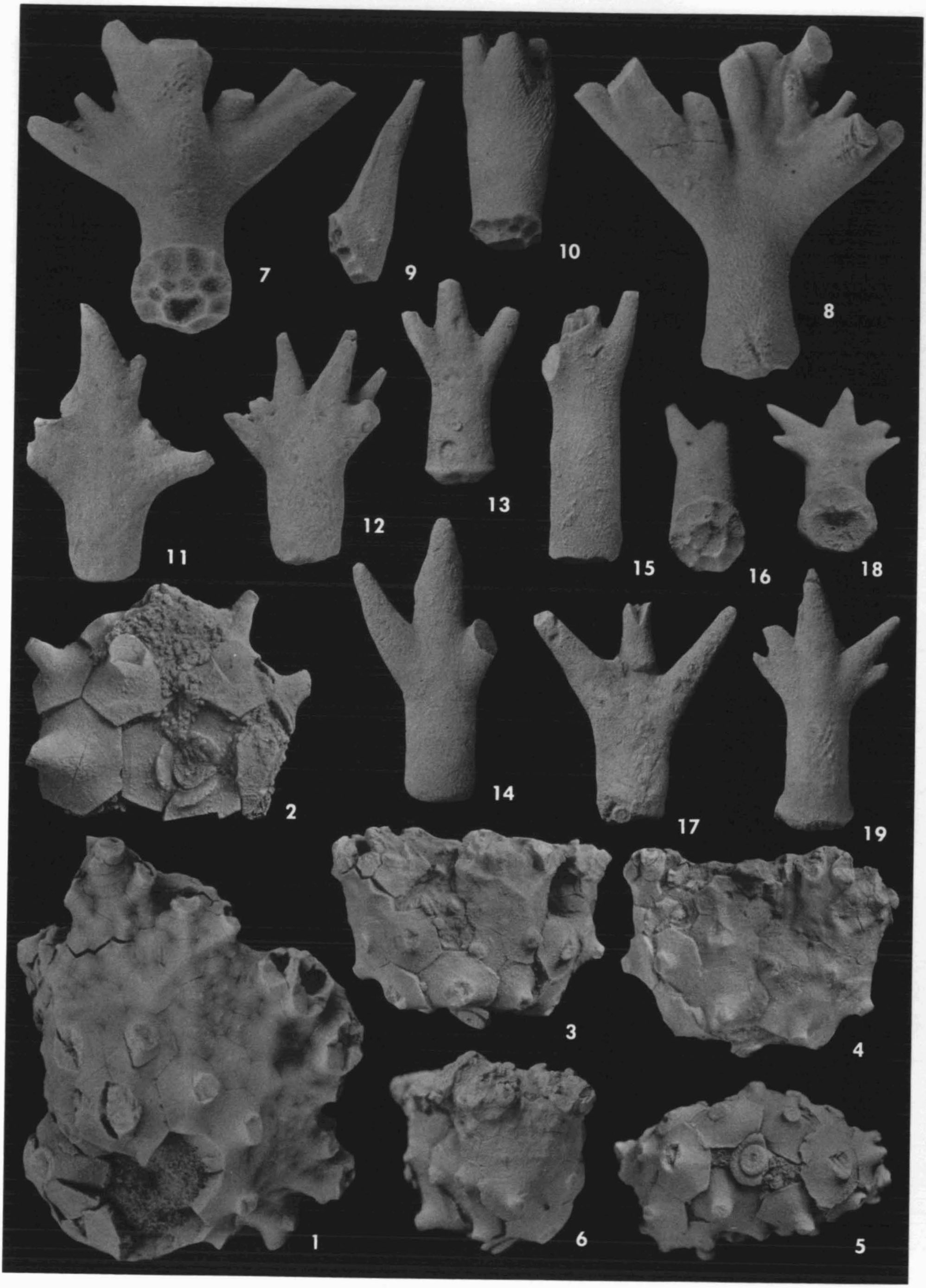


PLATE II



EXPLANATION OF PLATE II

(All figures × 3)

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FIG. 1. Inclined view of B ray, UMMP 30505. Other views in Plate I, Figures 1–5. Locality 1.

FIG. 2. Dorsal view of incomplete calyx, showing *BB,* UMMP 49194. Locality 2.

FIGS. 3–6. Posterior, anterior, dorsal, and side views, Holotype, UMMP 9434. Locality uncertain.

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FIGS. 7–8. Largest spine found, presumably tegminal, UMMP 49428. Facets form more than one row around base. Locality 2.

FIG. 9. Large inclined spine, presumably tegminal, UMMP 49204. Locality 2.

FIG. 10. Nearly circular spine with three tines, presumably tegminal, UMMP 49216. Locality 2.

FIGS. 11–12. Broken spines with branches, presumably tegminal, UMMP 49197 and 49195. Locality 2.

FIGS. 13–14, 17. Triply branched spines, presumably tegminal, UMMP 49205, 49207, and 49202. Locality 2.

FIGS. 15–16. Lateral and end views of spine, presumably tegminal, UMMP 49209. Locality 2.

FIGS. 18–19. Inclined and lateral views of multiply branched spine, presumably tegminal, UMMP 49196. Locality 2.

EXPLANATION OF PLATE III

(All figures × 3; all specimens from Locality 2)

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FIGS. 1–44, 47–70. Lateral and top views of spine-bearing plates, presumably from dorsal cup, UMMP 49375, 49380, 49379, 49368, 49374, 49376, 49371, 49409, 49370, 49402, 49426, 49381, 49400, 49393, 49401, 49372, 49427, 49382, 49403, 49407, 49406, 49398, 49385, 49408, 49384, 49397, 49396, 49404, 49399, 49383, 49378, 49395, 49373, and 49369.

FIGS. 45–46. Lateral and basal views of spine-bearing plate, presumably from dorsal cup, UMMP 49377.

FIGS. 71–74, 77–78. Lateral and basal views of bifurcated spines, presumably tegminal, UMMP 49210, 49198, and 49201.

FIGS. 75–76. Top and lateral views of section of column with cirri, UMMP 49200.

PLATE III

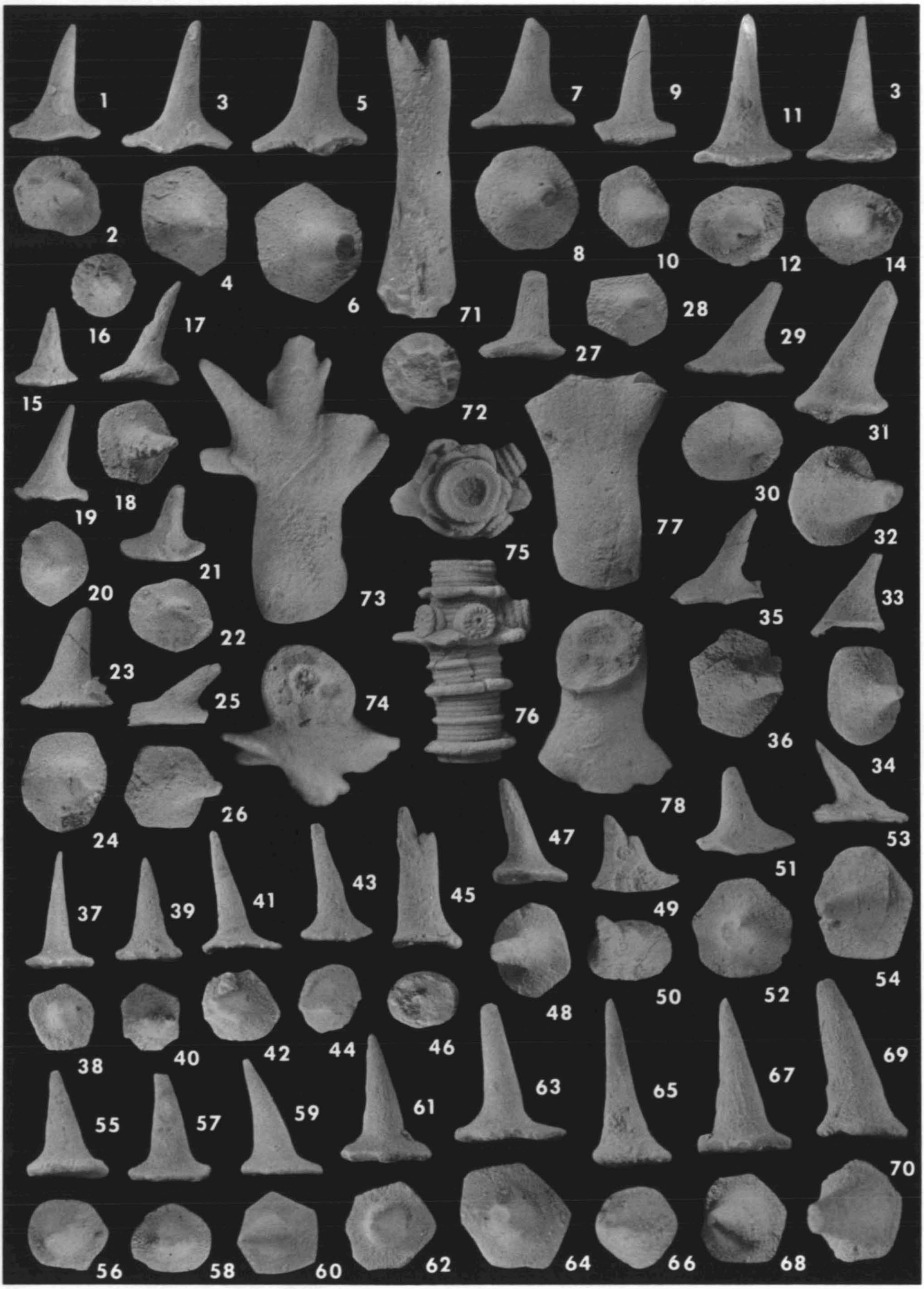
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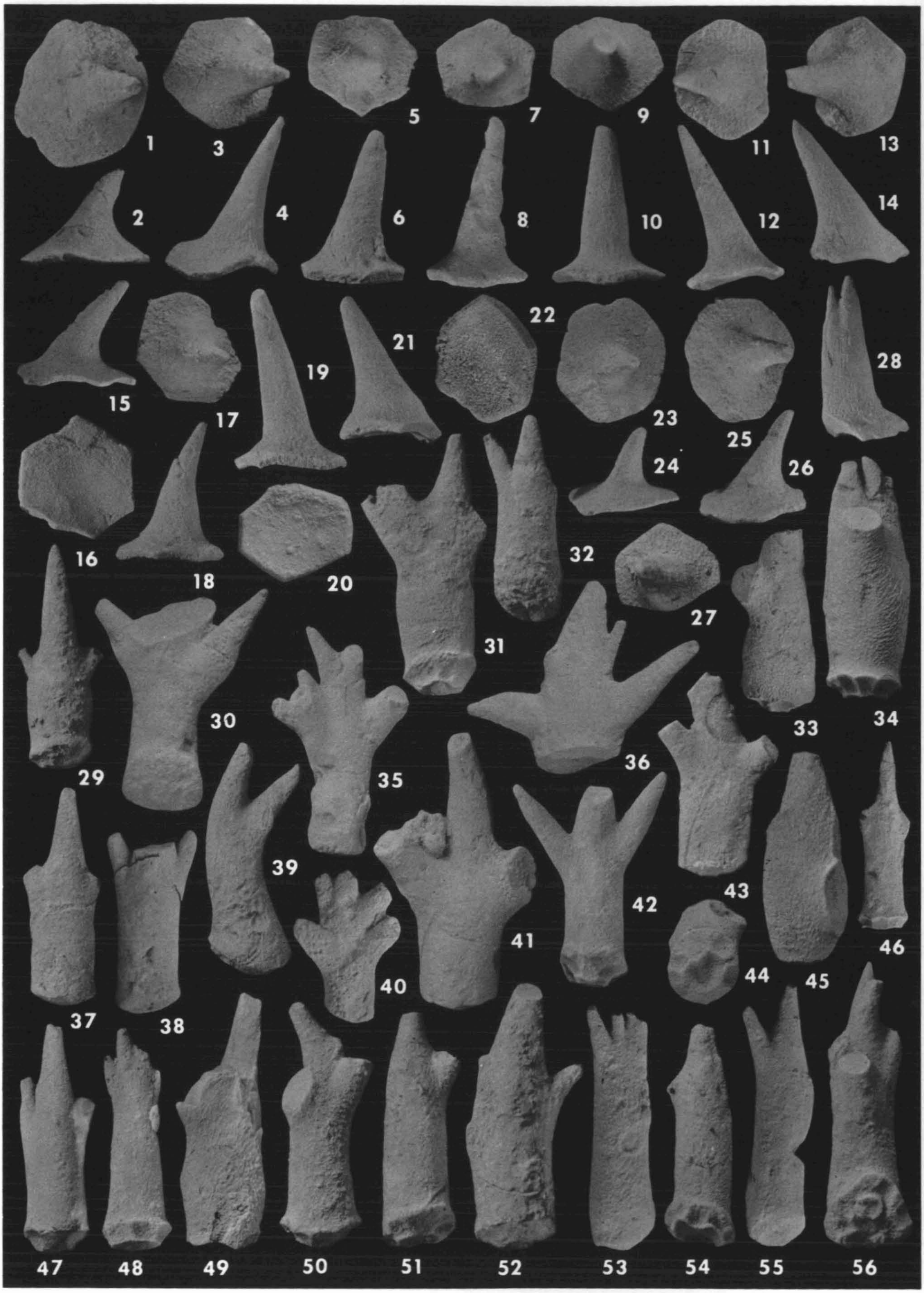
PLATE IV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EXPLANATION OF PLATE IV

(All figures × 3; all specimens from Locality 2)

FIGS. 1–14. Top and lateral views of spine-bearing plates, presumably from dorsal cup, UMMP 49352, 49356, 49357, 49355, 49362, 49353, and 49366.

FIGS. 15–16, 19–22. Lateral and basal views of spine-bearing plates, presumably from dorsal cup, UMMP 49359, 49358, and 49367.

FIGS. 17–18, 23–28. Top and lateral views of spine-bearing plates, presumably from dorsal cup, UMMP 49365, 49364, 49360, and 49361.

FIGS. 29–43, 45–56. Lateral views of bifurcated spines, presumably tegminal, UMMP 49234, 49213, 49222, 49237, 49229, 49221, 49215, 49212, 49232, 49225, 49206, 49230, 49214, 49203, 49217, 49224, 49226, 49218, 49231, 49223, 49235, 49236, 49219, 49227, 49239, 49228, and 49220.

FIG. 44. Basal view of bifurcated spine, presumably tegminal. UMMP 49211.

EXPLANATION OF PLATE V

(All figures × 3; all specimens from Locality 2)

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FIGS. 1–2, 10–11. End and lateral views of columnal sections, UMMP 49333 and 49334.

FIGS. 3–9. Lateral views of columnal sections, UMMP 49341, 49337, 49335, 49338, 49339, 49336, and 49342.

FIGS. 12–23, 39–40. Lateral and top views of spine-bearing plates, presumably from dorsal cup, UMMP 49346, 49345, 49343, 49363, 49349, 49344, and 49405.

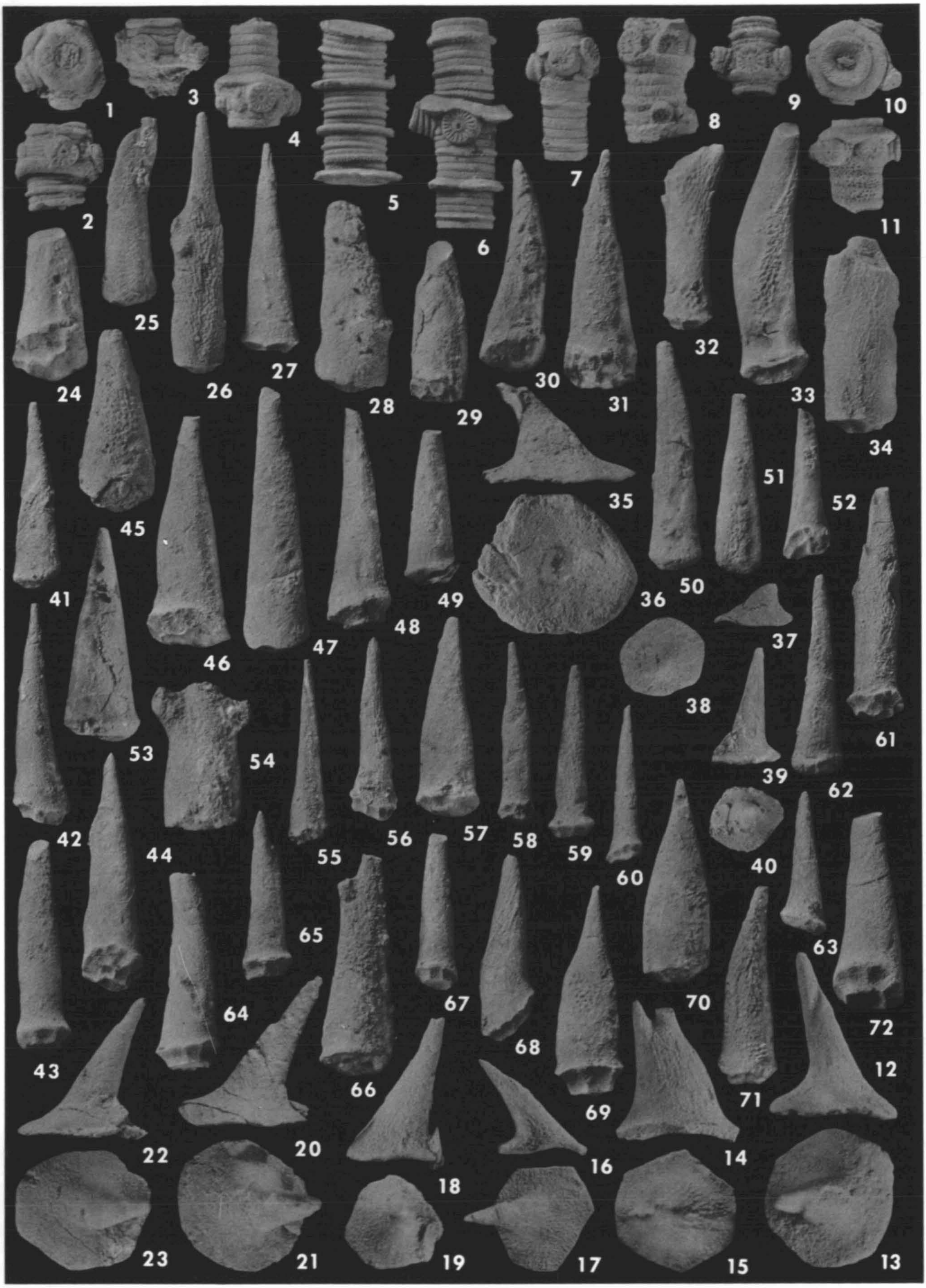
FIGS. 24–34. Lateral views of spines, presumably tegminal, UMMP 49246, 49271, 49243, 49256, 49238, 49247, 49249, 49255, 49263, 49259, and 49331.

FIGS. 35–36. Lateral and basal views of spine-bearing plate, presumably from dorsal cup, UMMP 49347.

FIGS. 37–38. Lateral and top views of spine-bearing plate, presumably from posterior interradius, UMMP 49394.

FIGS. 41–72. Lateral views of spines, presumably tegminal, UMMP 49258, 49252, 49274, 49266, 49272, 47269, 49260, 49257, 49286, 49262, 49290, 49284, 49244, 49250, 49291, 49282, 49267, 49281, 49287, 49275, 49276, 49321, 49278, 49264, 49280, 49253, 49283, 49279, 49273, 49270, 49254, and 49268.

PLATE V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