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GENNAEOCRINUS VARIABILIS, A NEW SPECIES OF CRINOID FROM THE MIDDLE DEVONIAN BELL SHALE OF MICHIGAN

BY

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CONTENTS

INTRODUCTION

ONLY RARELY are Paleozoic crinoids of one species found abundant, well preserved, restricted to a thin stratigraphic unit, and within a small exposure. In many species, the specimens are too few, too poorly preserved, and too widely disseminated stratigraphically and geographically to permit a reliable and comprehensive description. For many years, a low ledge of the Middle Devonian Bell shale in the abandoned Kelley's Island Lime and Transport Company quarry has yielded numerous specimens of *Gennaeocrinus*. Gradually, these crinoids have been amassed in the Museum of Paleontology of The University of Michigan and in other museums. Now the variations within an ontogenetic series can be assessed.

All specimens in the collection belong to one species. They vary greatly in shape and ornamentation in all stages of development. If only the extremes were known, they would undoubtedly be assigned to several species. In the collection at the Museum of Paleontology, however, intermediate stages of size, elongation of the cup, height of the tegmen, and ornamental ridges, nodes, and cockscomb structures are represented. We can distinguish only one species.

The manuscript of this paper was criticized by Dr. C. A. Arnold. All specimens described and illustrated are deposited and catalogued in the Museum of Paleontology of The University of Michigan.

LOCALITY

All known specimens of the new species are from the following locality:

Upper part of the Middle Devonian Bell shale, 10 feet below the contact with the Rockport Quarry limestone in the abandoned "Rockport" quarry of the Kelley's Island Lime and Transport Co. (formerly Great Lakes Stone and Lime Co.), NW ¼ sec. 6, T. 32 N., R. 9 E., about ⅓ mi. NW of the fishing village of Rockport, northeastern corner of Alpena Co., Mich. Locality 38 of Michigan Geological Survey. The specimens are from a narrow stratum a few inches thick exposed as a small, low ledge along the east side of a drainage ditch west of the quarry buildings. The stratum is light bluish-gray shale, which weathers readily to release the fossils contained in it. Most specimens collected by Irving G. Reimann and George M. Ehlers.

SYSTEMATIC DESCRIPTION

Class Crinoidea

Subclass CAMERATA Wachsmuth and Springer, 1885

Order MONOBATHRIDA Moore and Laudon, 1943

Family Periechocrinitidae Austin and Austin, 1843

Genus *Gennaeocrinus* Wachsmuth and Springer, 1881

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

Gennaeocrinus variabilis, sp. nov.

(Figs. 1–2; Pl. I, Figs. 1–9; Pl. II, Figs. 1–13; Pl. III, Figs. 1–10; Pl. IV, Figs. 1–10; Pl. V, Figs. 1–12; Pl. VI, Figs. 1–8; Pl. VII, Figs. 1–9; Pl. VIII, Figs. 1–10; Pl. IX, Figs. 1–14)

Shape of calyx.—Calices of both small and large specimens ranging from low and broad (Pl. VI, Fig. 4; Pl. II, Fig. 1) to high and narrow (Pl. II, Fig. 10; Pl. V, Fig. 1). Cup at the base of *RR* ranging from wide, (Pl. VII, Fig. 8) to rather narrow (Pl. VII, Fig. 4); sides of cup correspondingly steep or sloping.

Cup ratio adopted as average height measured from base of *RR* to apices of posterior $PBrBr_2$ divided by the average interarm width measured between apices of $PBrBr_2$ on all arms. Cup ratio varying from .62 to .97, averaging .786; ratio of smallest ten specimens averaging .782, of largest ten averaging .753. Hence, larger specimens with slightly lower cups on the average; but ratios variable for calices at all sizes (Table I), and the same ratio found in small (Pl. II, Fig. 7), medium (Pl. VII, Fig. 8), and large (Pl. V, Fig. 3) specimens.

Relative height of tegmen varying with no relation to cup ratio. Tegmen ratio adopted as height measured from center of arm openings divided by

width of calyx measured at center of arm openings from posterior interradius. Tegmen ratio varying from .22 to .60, averaging .390; ratio of smallest ten specimens averaging .345, of largest ten averaging .450. Hence larger specimens with definitely higher tegmens on the average; but tegmen ratios variable for calices at all sizes (Table I), and very high ratios in both the smallest (Pl. II, Fig. 10) and largest (Pl. VI, Fig. 1) specimens. Comparable low ratios found in several small (Pl. V, Fig. 5; Pl. IX, Fig. 12) and medium (Pl. IV, Fig. 3; Pl. III, Fig. 1) specimens.

In graphs of average height (from base of *RR* to apices of $PBrBr_2$) plotted *vs.* average interarm width (between apices of $PBrBr_2$) and *vs.* posterior interarm width (Fig. 1), variable ratios apparent for calices of all sizes. The former expressing graphically the cup ratio discussed above.

Radial ridges (on *RR* and *PBrBr*) much more strongly raised in smaller specimens (Pl. VIII, Fig. 9) than in larger (Pl. VIII, Fig. 4); cup of small calyx resembling frustrum of subpentagonal pyramid, and that of large calyx resembling frustrum of cone. Posterior interradius wider (Fig. 2) and more strongly convex than other interradii (Pl. V, Figs. 4, 12; Pl. IX, Figs. 9, 14).

Plates of calyx.—Monocyclic. Cup containing three *BB*, five *RR*, ten *PBrBr*, twenty *SBrBr*, twenty $TBrBr_1$, five *ISBrBr*, about twenty *IBrBr*, and about 14 to 16 plates in the *X* series. Arms normally free above $TBrBr_1$. Boundary of tegmen and cup marked by reversal of slope, but interbrachial series extending from cup onto tegmen in many specimens without change in pattern. Periproct eccentric.

BB nearly equal, together forming a greatly expanded disk, somewhat lobate (Pl. I, Fig. 7), about half the diameter of the total calyx (Pl. IV, Fig. 9) and more than three times the diameter of the adjoining columnal of the stem (Pl. IX, Fig. 13), in large specimens more than four times the diameter of the columnal (Pl. VI, Fig. 3). *BB* only about half as high as *RR*. One suture posterior, the other two *BB* sutures about 120° from it. Each *B* wide and hexagonal in lateral view, subtriangular in basal view.

RR hexagonal, the same size and shape as *X*, with it forming a ring of six equal plates above the *BB* (Fig. 2*b*). Each *R* broader than high. *RR* the largest plates in the calyx.

PBrBr 2 × 5. $PBrBr_1$ smaller than *RR*, each broader than high, regularly hexagonal (right posterior radius, Fig. 2*b*) and rarely pentagonal (left posterior radius, Fig. 2*b*). Each PBr_1 invariably directly above corresponding *R*, bounded laterally by IBr_1 or, in the posterior radii, by X_1 and X_2.

$PBrBr_2$ only slightly smaller than $PBrBr_1$, axillary. Each PBr_2 atop a PBr_1 and below a pair of $SBrBr_1$, laterally adjacent to IBr_2 (or X_2). PBr_2

TABLE I

CERTAIN CHARACTERISTICS OF SPECIMENS OF *Gennaeocrinus variabilis*

Catalog Number	Plate	Figure	Width in mm†	Cup Ratio‡	Tegmen Ratio§	Ornamentation Type‖	Remarks
37854...	II	10–13	2.7	.78	.56	1	Strong, high *RR* ridges.
37853...	V	9–12	2.8	.72	.35	1	*RR* ridges acute; few *IR* ridges reduced.
37842...	...	...	3.0	.97	*	2	Some plates nearly flat with large nodes.
40530...	I	5–9	3.1	.87	.41	1	Ridges broad and rounded.
37386...	...	...	3.3	.67	*	1	Strong *RR* ridges.
37382...	...	...	3.3	.79	.29	1	*RR* ridges very heavy; few *IR* ridges reduced.
37851...	...	...	3.3	.73	.25	1	Nodes biserial, absent between arm bases. Calyx plates moderately thick.
37852...	V	5–8	3.3	.73	.32	1	Few *IR* ridges reduced.
40537...	VI	4–8	3.3	.73	.42	1	*RR* ridges heavy; few *IR* ridges reduced.
40522...	...	...	3.5	.83	.22	1	Strong *RR* ridges; some *IR* ridges broken.
37380...	...	...	3.6	.83	.25	1	All ridges low and continuous.
40529...	...	...	3.6	.78	.38	2	Biserial plates between arm bases. Calyx plates very thick.
37378...	...	...	3.7	.76	.33	1	Biserial plates between arm bases. Calyx plates slightly thickened.
40528...	VIII	6–10	3.7	.76	.46	1	All ridges very strong.
40526...	II	5–9	3.7	.81	.36	1	*RR* ridges heavy.
40525...	III	6–10	3.7	.84	.38	1	*RR* ridges heavy; few *IR* ridges reduced.
40534...	...	...	3.7	.84	.25	1	*RR* ridges heavy. Plates moderately thick.
37841...	...	...	3.8	.77	.44	2	Most ridges broken.
40531...	IX	1–5	3.9	.69	.40	1	*RR* ridges heavy. Plates moderately thick.
37855...	...	...	4.1	.76	.30	1	All ridges broken. Plates very thick.
40533...	IX	10–14	4.1	.76	.30	1	*RR* ridges strong; few *IR* ridges reduced.
37397...	...	...	4.1	.88	.50	1	Heavy nodes on tegmen.
40524...	IV	6–10	4.2	.84	.38	1	*RR* ridges heavy; few *IR* ridges reduced.
40532...	IX	6–9	4.2	.84	.44	1	Few *IR* ridges reduced.
37379...	...	...	4.3	.75	.40	1	Plates slightly thickened.
37393...	...	...	4.3	.79	.30	2	*IR* ridges partially broken. Large calyx nodes.
37398...	...	...	4.3	.84	.40	2	Ridges broken. Plates thick.
37846...	...	...	4.3	.91	.36	2	Most ridges broken.
37392...	...	...	4.5	.82	.30	2	Not all ridges broken. Plates very thick.
37400...	...	...	4.5	.82	.45	2	Plates moderately thick. Vertical ridge on anal *IR*.

* Calyx and/or tegmen crushed or incomplete.

† Average interarm width in mm between apices of $PBrBr_2$ on all arms.

‡ Average height in mm from base of *RR* to apices of posterior $PBrBr_2$ divided by average interarm width in mm between apices of $PBrBr_2$ on all arms.

§ Height of tegmen in mm from center of arm openings divided by width of calyx in mm at center of arm openings measured from posterior interradius.

‖ Types of ornamentation arbitrarily set as follows:

Type 1: *RR* ridges generally broad, rounded, and continuous. Most *IR* ridges continuous. Calyx plates not conspicuously thickened. Tegmen plates usually with single, central node.

Type 2: *RR* ridges broken or depressed at sutures forming nodes or elevated area in center of plate. *IR* ridges usually reduced or broken at sutures; remainder of each ridge causing plate to thicken conspicuously toward its center, often forming node. Tegmen plates with central node or several nodes that may concrese.

Type 3: Ridges reduced to nodes or thin and steep-sided. Calyx nodes large. Plate surfaces evenly convex and not thickened toward center by ridges. Tegmen plates with large nodes or cockscombs.

TABLE I (*Continued*)

Catalog Number	Plate	Figure	Width in mm†	Cup Ratio‡	Tegmen Ratio§	Ornamentation Type‖	Remarks
37843...	...	...	4.5	.82	.50	2	All ridges broken. Plates thick.
37850...	...	...	4.5	.89	.45	2	All ridges broken. Plates thick.
37857...	...	...	4.5	.92	*	2	Few *IR* ridges unbroken.
37847...	...	...	4.6	.74	.30	2	Some ridges unbroken. Biserial plates between arm bases. Several nodes on tegmen plates
37849...	...	...	4.7	.72	.25	2	Plates very thick. Vertical anal ridge.
37840...	...	...	4.7	.77	.45	1	*RR* slightly depressed at sutures.
37383...	...	...	4.7	.83	.45	2	*RR* ridges partially broken.
37856...	...	...	4.8	.82	.45	2	Biserial plates between arm bases.
37399...	...	...	4.9	.69	.50	2	Most ridges reduced to nodes.
37401...	...	...	4.9	.82	.54	2	Most ridges broken. Several nodes on each tegmen plate.
37395...	...	...	5.0	.82	.41	2	All ridges broken.
37845...	...	...	5.1	.69	.25	2	Biserial plates between arm bases. *RR* ridges broken; few *IR* ridges unbroken.
40527...	VII	1–5	5.1	.77	.32	2	All ridges broken; plates very thick; plates between arm bases nearly biserial.
40538...	VII	6–9	5.2	.81	.41	2	Some ridges broken.
37391...	...	...	5.2	.88	.31	2	All ridges broken. Plates extremely thick.
40523...	IV	1–5	5.3	.62	.32	2	Nearly all ridges broken. Plates very thick; plates between arm bases nearly biserial.
37848...	...	...	5.3	.74	.33	2	Some ridges unbroken.
40539...	III	1–5	5.3	.91	.32	2	Some ridges unbroken. Plates moderately thick. Several nodes on each tegmen plate.
40541...	...	...	5.6	.72	.54	2	Few unbroken ridges. Very thick plates.
40542...	VIII	1–5	5.6	.80	.36	2	Ridges partially broken. Very thick plates.
37390...	...	...	5.7	.79	.33	3	Some *IR* ridges unbroken. Ridges high and thin. Large flared nodes on tegmen.
37396...	...	...	5.8	.78	.56	3	Large calyx nodes. Low acute ridges.
37376...	...	...	6.0	.73	.35	3	High, thin, broken ridges.
40520...	II	1–4	6.1	.69	.41	2	Plates very thick. Most ridges broken. Biserial plates between arm bases.
40540...	...	...	6.2	.73	.46	2	Most ridges broken. Biserial plates between arm bases.
37388...	...	...	6.2	.81	.46	2	Several ridges unbroken.
37389...	...	...	6.3	.76	.50	2	Plates very thick. Most ridges broken.
37394...	...	...	6.6	.74	.28	3	Large central nodes on calyx plates. Some ridges reduced to nodes, others complete.
40521...	I	1–4	6.6	.76	.38	3	Very heavy calyx nodes. Few ridges. Large cockscombs on tegmen.
40535...	V	1–4	6.7	.81	.47	3	Ridges low and thin or reduced to nodes.
37377...	...	...	6.8	.78	.50	3	Low, thin ridges and large calyx nodes.
37381...	...	...	7.2	.70	.44	3	Few low, thin, unbroken ridges.
40536...	VI	1–3	7.3	.75	.60	3	Ridges, nearly reduced. Large calyx nodes. Large and small nodes on tegmen plates.
37844...	...	...	*	*	*	1	Nodes on tegmen.
37384...	...	...	*	*	*	2	Plates moderately thick.
37385...	...	...	*	*	*	2	Ridges broken.
37387...	...	...	*	*	*	2	Ridges broken.
37839...	...	...	*	*	*	2	Ridges broken. Biserial plates without nodes between arm bases.

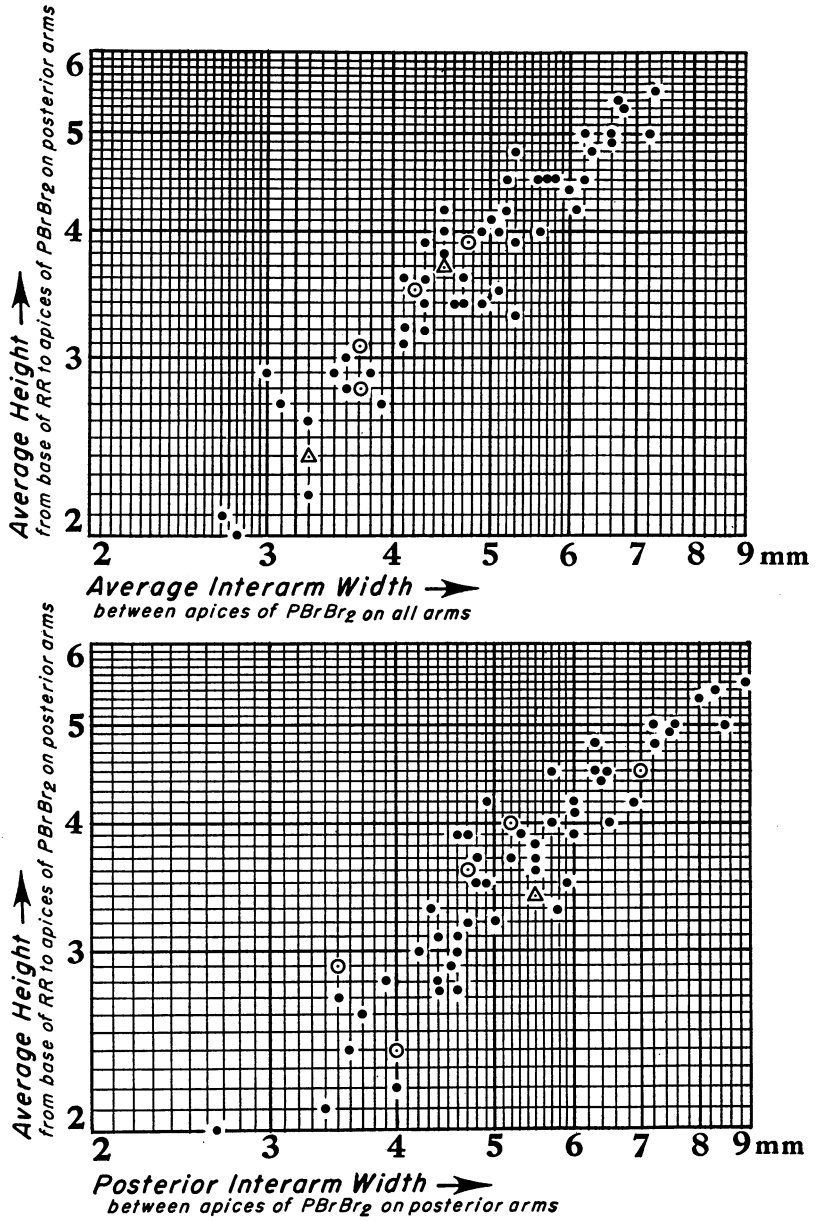

FIG. 1. Graphs of measurements of 63 specimens of *Gennaeocrinus variabilis*, sp. nov. Average height plotted *vs.* average interarm width (above) and against posterior interarm width (below). Average height measured from base of *RR* to apices of $PBrBr_2$ on posterior arms, average interarm width measured between apices of $PBrBr_2$ on all arms, and posterior interarm width between apices of $PBrBr_2$ on posterior arms. From inspection of all specimens, these parameters were adjudged to be the least affected by distortion due to crushing. A binocular microscope with a calibrated eyepiece was used to measure the specimens. Large dots represent one specimen; dots within circles, two specimens; and dots within triangles, three.

therefore normally pentagonal, but rarely hexagonal where adjacent to IBr_1 and IBr_2 (left posterior radius, Fig. 2*b*).

SBrBr 2 × 10. $SBrBr_1$ almost as large as $PBrBr_2$ on which they rest; each plate broader than high, normally hexagonal, bounded by PBr_2, IBr_2, IBr_3, SBr_2, *ISBr*, and the other SBr_1 of the pair, rarely pentagonal where adjacent laterally to IBr_2 only. $SBrBr_1$ next to anal series bounded by X_2 and X_3 (Fig. 2*b*). In right anterior radius of one specimen (Pl. IV, Fig. 10) $SBrBr_2$ not in contact and *ISBr* extending down to PBr_2.

$SBrBr_2$ nearly the same size as $SBrBr_1$, axillary, followed by a pair of $TBrBr_1$. Each SBr_2 normally pentagonal, laterally bordered by *ISBr* and IBr_3 orX_3; in the left posterior ray of the holotype (Fig. 2*b*), the left SBr_2 also in contact with IBr_2.

TBrBr at least 2 × 20. $TBrBr_1$ normally the last of the radial series definitely a part of the cup, with arms becoming free in succeeding plates. Each TBr_1 a broad disk, subpentagonal in lateral view, adjoining the paired TBr_1 through about two-thirds of its height, extending around the outer part of the food groove as a thick crescent (Pl. I, Fig. 3; Pl. III, Fig. 3; Pl. IV, Fig. 3).

In some series TBr_2 axillary, giving rise to *QBrBr*; in others 5 or 6 *TBrBr* observed with none axillary. Insofar as observed, all axillary $TBrBr_2$ on the inner side of the half-ray.

Arms four to six per ray, 20 to 30 per crinoid. Each half-ray with two or three arms, not in a regular branching pattern. Plates biserial above TBr_5 or TBr_6, or, where TBr_2 on inner side of half-ray is axillary, biserial above QBr_5 or QBr_6. Arms with relatively flat backs. Pinnules long and slender.

Interbrachials in small specimens distinctly below strong radial ridges, in large specimens only slightly lower if at all. $IBrBr_1$ large, only slightly smaller than *RR*, normally hexagonal, with lower apex between *RR*, upper apex between $IBrBr_2$, and sides adjacent to $PBrBr_1$. In left posterior ray of holotype (Fig. 2*b*) IBr_1 septagonal, also in contact with PBr_2. Successive rows of *IBrBr* with smaller plates, most specimens with two $IBrBr_2$ and two $IBrBr_3$, a few with an extra plate in one or more rows. Most plates hexagonal or septagonal, arranged opposite or offset. *IBrBr* series merging with tegmen above third or fourth row.

Anal series wider than other interbrachial series, in its center almost twice as wide (Fig. 2*b*). *X* the same size and shape as the *RR* with which it is laterally aligned. Successive rows of *XX* smaller. Three XX_1, hexagonal; five XX_2, variously pentagonal, hexagonal, or septagonal; four or five XX_3, more irregular than preceding row; and two or three XX_4, various shapes. Series merging with tegmen above fourth row.

One large, vertically elongate *ISBr* in each radius (Fig. 2*b*) extending up between $SBrBr_2$ and $TBrBr_1$ to tegmen in most specimens (Pl. IV, Fig. 1;

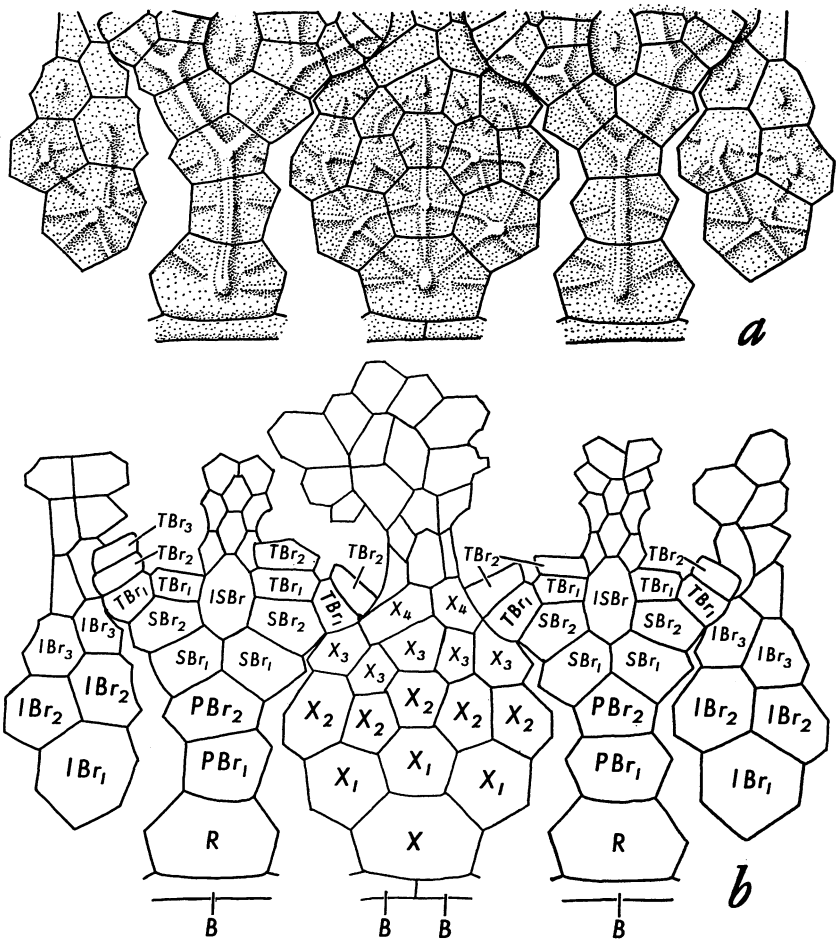

FIG. 2. Plate diagrams of the holotype of *Gennaeocrinus variabilis,* sp. nov., showing ornamentation (*a*) and plate designations (*b*). In each diagram, the specimen is figured in plan view centered on the posterior interradius, extending from the left posterior to the right posterior interradius; the plates are shown in contact at the greatest circumference of the calyx, which is approximately at the arm bases (at the level of $TBrBr_1$). Plates in each radius and in each interradius are grouped together. A camera lucida was used to draw each plate to the same scale. For each plate the specimen was placed at a fixed distance from the camera lucida and rotated until the line of sight was normal to the particular plate. In assembling the plate drawings into the diagrams, the outlines were slightly adjusted to group the associated plates together.

Pl. V, Fig. 1); in a few rays replaced by two plates of nearly equal size (Pl. III, Fig. 5; Pl. VII, Fig. 1) or even three (Pl. VIII, Fig. 1). Some series with one narrow *ITBr*, others without any plate between $TBrBr_2$.

Tegminal plates varying in number, shape, and arrangement. In some specimens, biserial plates extending regularly from cup onto tegmen in interradii (Pl. III, Fig. 2; Pl. IV, Fig. 2; especially Pl. VII, Fig. 2; and Pl. VIII, Fig. 2). In others, plates in interradii with no biserial arrangement. Radial plates normally much smaller and less regular than interradial.

Periproct eccentric, displaced toward the posterior side, consisting of very small plates around the anus and a ring of larger plates bearing strong ornamentation to form a wreath, the whole having the shape of a rosette. In small specimens (Pl. I, Fig. 5; Pl. II, Fig. 11; Pl. V, Fig. 10) the ornamentation on the outer ring of plates not strongly differentiated from that on other plates of the tegmen; in large specimens (Pl. I, Fig. 2; Pl. V, Fig. 2) plates increasing in size from anus outward, with the plates of the outer ring bearing cockscomb structures flared outward like petals of a flower.

Uppermost columnal of stem leaving a distinct impression on center of *BB* disk, in small specimens about one-third the diameter of the disk (Pl. I, Fig. 7; Pl. II, Fig. 12), in medium specimens about one-fourth (Pl. IV, Fig. 9; Pl. VIII, Fig. 4; Pl. IX, Figs. 4, 13), and in large specimens about one-fifth (Pl. VI, Fig. 3), but with exceptions. Outer margin of impression radially grooved. Central opening of columnals quinquelobate, about one-fourth the diameter of the columnal.

Ornamentation.—In general, strongly developed vertical ridges through the middle of each plate in the radial series as far as arm bases, and smaller and narrower ridges radiating from the center of each cup plate to the centers of adjoining plates. Ornamentation of cup and tegmen variable at each size of calyx, but generally increasing in thickness with increase in size of calyx. Ornamentation of calyx classified in three ornamentation types (Table I).

Type 1, characteristic of small calices: radial ridges broad, high, rounded, and continuous. Most interradial ridges distinct, sharp, and continuous. Tegminal plates with small central spines, very small specimens with a single, central spine on each plate. Typical specimens shown in Pl. V, Figs. 9–12; Pl. VIII, Figs. 6–10.

Type 2, characteristic of medium calices: radial ridges interrupted or depressed at sutures, forming node or elevated bar in middle of each plate. Interradial ridges interrupted at sutures, many further dissected into segments, centers of plates conspicuously thickened at junctions of ridges. Tegminal plates with central nodes, fused nodes, and/or cockscomb struc-

tures, with the central plates bearing the more complex ornamentation. Typical specimens shown in Pl. III, Figs. 1–5; Pl. IV, Figs. 1–5; Pl. VIII, Figs. 1–5.

Type 3, characteristic of large calices: radial ridges reduced to nodes or very thin and steep-sided. Interradial ridges very discontinuous, in some specimens expressed only as central large nodes or cockscomb structures. Remainder of plate surfaces evenly convex, not thicker in positions of ridges. Tegminal plates thick in center, with groove along sutures, bearing large nodes, irregular vermiform nodes, or large cockscomb structures. Typical specimens shown in Pl. I, Figs. 1–4; Pl. V, Figs. 1–4; Pl. VI, Figs. 1–3.

Cockscomb structures on tegmen apparently result of fusion of several small nodes or spines. Interradial plates of tegmen in some specimens biserial and unornamented (Pl. VII, Fig. 2; Pl. VIII, Fig. 2).

Remarks.—The variable nature of this species is well documented in the plate illustrations. Calices of the same size vary in shape (Fig. 1). The number of plates varies in the *IBrBr* series and in the arms.

The most pronounced variation is in the number of arms. A specimen may have two or three arms in each half-ray. There is invariably only one arm in the outer part of each half-ray in the *TBrBr* series, but the inner part (nearest the median line of the ray) may have either a uniserial *TBrBr* series forming one arm, or the TBr_2 may be axillary giving rise to two arms of the *QBrBr* series. The two halves of one ray may or may not have the same number of arms. We found no indication of branching in the *QBrBr* series. In the specimens studied, no ray has a constant number of arms.

The unusually large range in ornamentation indicates that the species followed a general trend toward coalescence and simplification of elements, but exceptions were found. It would appear imperative, in studying a species of *Gennaeocrinus,* to include specimens of as many growth stages as possible.

Comparison with other species.—The distinguishing characters of all described species are tabulated in Table II. Much of the desired information about several species is not available in literature, and we hope to complete a more thorough study of *Gennaeocrinus* based on our own observations.

Our new species is readily differentiated from the other species that have two *SBrBr.* It has a variable number of arms and smooth margins on the *PBrBr, SBrBr,* and *TBrBr,* whereas *G. arkonensis* is reported to have 20 arms and crenulate margins on the bachial plates. *G. variabilis,* sp. nov., has one or two arms on the inner half-ray, but *G. decorus* has only one in known specimens. Our crinoid differs from *G. kentuckiensis* in that it has

one or two arms on the inner half-ray, the tegmen lacks a central spine, and the ornamentation is coarse. The absence of five long spines around the periproct (at the summit of the tegmen) distinguishes *G. variabilis* from *G. mourantae*. Further, the anal series in *G. variabilis* is ornamented with ridges comparable to those in other interbrachial series, whereas the anal series in *G. mourantae* is ornamented with much stronger ridges than the other interbrachial series. The smooth basals and one or two arms on the inner half-ray separate *G. variabilis* from *G. similis*, which has tuberculated margins on the basals and invariably only one arm on the inner half-ray. On *G. similis* the radial ridge bifurcates at the center of the *RR* to form an inverted V.

Types.—Holotype, UMMP 40535. Paratypes, UMMP 37376–37401, 40520–40542, and 37839–37857.

LITERATURE CITED

BASSLER, R. S., and MOODY, M. W. 1943. Bibliographic and Faunal Index of Pelmatozoan Echinoderms. Geol. Soc. Amer., Spec. Papers, No. 45, vi + 734 pp.

EHLERS, G. M. 1925. Two New Crinoids from the Devonian of Michigan. Contrib. Mus. Paleontol. Univ. Mich., Vol. 2, No. 6, pp. 99–104, 1 pl.

GOLDRING, WINIFRED. 1923. The Devonian Crinoids of the State of New York. N. Y. State Mem. 16, 670 pp., 60 pls., 63 figs.

——— 1934. Some Hamilton Crinoids of New York and Canada. Buffalo Soc. Nat. Sci. Bull., Vol. 15, No. 3, pp. 182–200, 2 pls.

——— 1935*a*. Crinoids of the Tully Formation, *in:* COOPER, G. A., and WILLIAMS, J. S., Tully Formation of New York. Bull. Geol. Soc. Amer., Vol. 46, No. 5, pp. 831–37, Pl. 58.

——— 1935*b*. New and Previously Known Middle Devonian Crinoids of New York. Ann. Carnegie Mus., Vol. 24, Art. 11, pp. 349–74, Pls. 25–27.

——— 1938. Additional Notes on Previously Described Devonian Crinoids. N. Y. State Mus. Bull., Vol. 315, pp. 77–83, 2 pls.

MOORE, R. C., and LAUDON, L. R. 1943. Evolution and Classification of Paleozoic Crinoids. Geol. Soc. Amer. Spec. Papers, No. 46, x + 153 pp., 14 pls., 18 figs.

ROWLEY, R. R. 1903. *In:* GREENE, G. K., Contributions to Indiana Paleontology, Vol. 1, Pt. 11, pp. 98–109, Pls. 31–33.

——— 1904. *In:* GREENE, G. K., *Ibid.*, Vol. 2, Pt. 18, pp. 176–84, Pls. 52–54.

SHIMER, H. W., and SHROCK, R. R. 1949. Index Fossils of North America. ix + 837 pp., 303 pls. New York: John Wiley & Sons, Inc.

SHUMARD, B. F. 1866. A Catalogue of the Paleozoic Fossils of North America, Pt. 1, Paleozoic Echinodermata. Trans. Acad. Sci. St. Louis, Vol. 2, pp. 334–407.

WACHSMUTH, CHARLES, and SPRINGER, FRANK. 1881. Revision of the Paleocrinoidea. Proc. Acad. Nat. Sci. Phila., Pt. 1, pp. 177–536, 10 pls.

——— 1897. The North American Crinoidea Camerata. Mem. Mus. Comp. Zool. Harvard College, Vol. 21, Vol. 2 (Pt. 2), xiii + 476 pp., 18–21; 83 pls. in accompanying vol.

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TABLE II

COMPARISON OF SPECIES OF GENNAEOCRINUS*

Species	Secundibrachs	Arm Branching Pattern Above Secundibrachs		Arms Per Ray	Total Number of Arms	Interbrachial series	Anal Series	Distinctive Ornamentation
		Inner Half-Ray	Outer Half-Ray					
arkonensis Whiteaves	2 × 10	One arm, biserial above TBr_3	One arm, biserial above TBr_3	4	20	?	1–3–5	Dorsal cup finely pitted, forming reticulate pattern; crenulate margin on *PBrBr, SBrBr, TBrBr.*
carinatus Wood	1 × 10	Axillary *TBr* with two arms	One arm, biserial above TBr_3	6	30	1–2–3 or 1–3–4	1–3–4 or 1–3–5	Strong spine surrounded by smaller spines on ambulacral area adjacent to free arms.
carinatus var. *crassicostatus* Goldring	1 × 10	Axillary *TBr* with two arms	One arm, biserial above TBr_3	6	30	1–2–3 or 1–3–4	1–3–4 or 1–3–5	Tegmen spines longer and stouter.
comptus Rowley	1 × 10	One? *TBr* with two arms	One arm	6	30	1–3–3	1–3–5 –?	Short, stout central spine; smooth ventral plates.
comptus var. *spiniferus* Rowley	1 × 10	One? *TBr* with two arms	One arm	6	30	1–3–3	1–3–5 –?	Short, stout central spine directed slightly backward; five stout amb. spines directed slightly outward; smooth ventral plates.
decorus Goldring	2 × 10	One arm, biserial above TBr_5 or TBr_6	Two *TBrBr,* 2d axillary with two arms	6	30	1–2–3	unknown	No spines or nodes on plates of dorsal cup and arms.
eucharis Hall	1 × 10	One axil. *TBr* with 3–4 *QBrBr* on each face; last *QBr* on outside axillary with two arms; last *QBr* on inside with one arm	One arm, biserial above TBr_3	8	40	1–2–3 –2 (or 3)–?2	1–3–5	Small node or tubercle on outer side of each brachial above place of attachment of each arm pinnule.
facetus Rowley	1 × 10	One axillary *TBr* with two arms	One arm	6	30	1–3–2	1–3–5 –5–(5)	Long, slender spine on each amb. ridge, just above arm openings, directed slightly backward; strong, central tubercular prominence, sharp and angular, extending horizontally from center of *RR.*
goldringae Ehlers	1 × 10	Two *TBrBr* with two arms	Two *TBrBr* with two arms; TBr_2 indicates arm bifurcation on two rays	4?†	20?	1–2–3 –2	1–3–3 –2 (or 3)–2	Prominent spines at or near center of *RR, PBrBr, IBrBr, X* and X_1 series.
kentuckiensis (Shumard)	1 × 10 or 2 × 10‡	Axillary *TBr* on face nearest median line with two *QBrBr* on each face; QBr_2 away from median line axillary with quinquebrach series on each face	TBrBr with one arm	8	40	1–3–4 (or 5) or 1–2–4	1–3–5 –5 (or more)	Long central spine on tegmen.

mourantae Goldring	2 × 10	Two *TBrBr*, 2d axillary with two arms, biserial above QBr_2–QBr_3	One arm, biserial above TBr_4	6 (8 on posterior radii)	34	1–2–2 –2–2	1–3–5 –?5	Five stout, vertical spines on summit of tegmen; strong, star-shaped nodes on center anal series plates.
nyssa Hall	1 × 10	Axillary *TBr* with two arms; arm away from median line bifurcates near calyx	One arm, biserial above TBr_2–TBr_3	8	40	1–2–3 –(3–3)	1–3–5 –5 (or more)	Prominent nodes on radial series up to *SBrBr*; spinose nodes on PBr_1
peculiaris Goldring	Variable, 1 × 10 or 2 × 10 on same specimen	Usually one axillary *TBr* with two arms	One arm	5–6	30?	1–2 (or 3)–4	unknown	Strong, continuous radial ridge without nodes at center of plates; concave, three sided pyramid on center of each radial, extending beyond basals.
percarinatus Goldring	Apparently 1 × 10	Number and character of arms unknown	Number and character of arms unknown			1–2–3 (to 5)	1–3–5 –6	Ridges and carinae sharply defined; 2d and often 3d well-defined carinae parallels main one; scattered or broken lines of tubercles in angles between coarse and fine carinae.
sculptus Rowley	1 × 10	§	§	6	30	1–2–3 –4	1–3–4	Five short amb. spines and probably low central spine; strong central node on *RR*, projecting outward.
similis Goldring	2 × 10	One arm, biserial above TBr_4	One arm, biserial above TBr_4	‖	‖	1–2–2	1–3–5 –?7	Surface reticulated or granulose; tuberculated margins on projecting basals.
simulans Rowley	2 × 10	¶	¶	6	30	1–2–3 –3–3	unknown	Right and left radial ridges fork at center or radial and form inverted V.
variabilis, sp. nov.	2 × 10	Two *TBrBr*, 2d axillary with two arms, biserial above 5th–6th QBr; or one arm, biserial above 5th–6th *TBr*	One arm, biserial above 5th–6th *TBr*	4–6	20–30	1–2–2 –2(occ. extra plate)	1–3–5–4(or 5) –2(or 3)	Flaring extensions on large plates around anus forming rosette; tegmen plates with central protuberance ranging from node to elevated cockscomb structure; node to elevated cockscomb structure on dorsal plates.

* All species have three *BB*, five *RR*, and two *PBrBr*.
† "The seeming axillary nature of the two tertibrachs may indicate the presence of more than four arms to the ray" (Ehlers, 1925, p. 104).
‡ "The single secundibrach is probably the fusion of two secundibrachs" (Kirk *in* Goldring, 1923, p. 211).
§ "Like *G. comptus* and *G. facetus*, it has thirty arm bases . . ." (Rowley *in* Greene, 1903, p. 104).
‖ "No statement can be made as to the total number of arms, but it would appear there are fewer than thirty" (Goldring, 1935, p. 78).
¶ "The second distichial [SBR_2] is an axillary plate, the second palmer [TBr_2] of one division being also a bifurcating plate making 30 arms in all" (Rowley *in* Greene, 1903, p. 183).

EXPLANATION OF PLATE I

(All figures x 3)

PAGE

Gennaeocrinus variabilis, sp. nov. 174

FIGS. 1–4. Anterior, tegminal, posterior, and basal stereograms of paratype, UMMP 40521. Cup plates are greatly thickened by nodes at junctions of ornamental ridges, ridges are thin and discontinuous (Fig. 4). Tegmen is ornamented by large cockscomb structures (Fig. 2). In Figs. 2 and 4, posterior is at the lower left. Ornamentation is type 3.

FIGS. 5–9. Tegminal, anterior, basal, posterior, and inclined right posterior stereograms of paratype, UMMP 40530. Radial ridges are broad and strongly developed (Fig. 9), and interbrachial ridges are complete (Fig. 8). Tegmen ornamented by spines, nodes, and small cockscomb structures; rosette around periproct not as strongly developed as in larger specimens (Fig. 5). Disk of *BB* trilobate (Fig. 7).

PLATE I

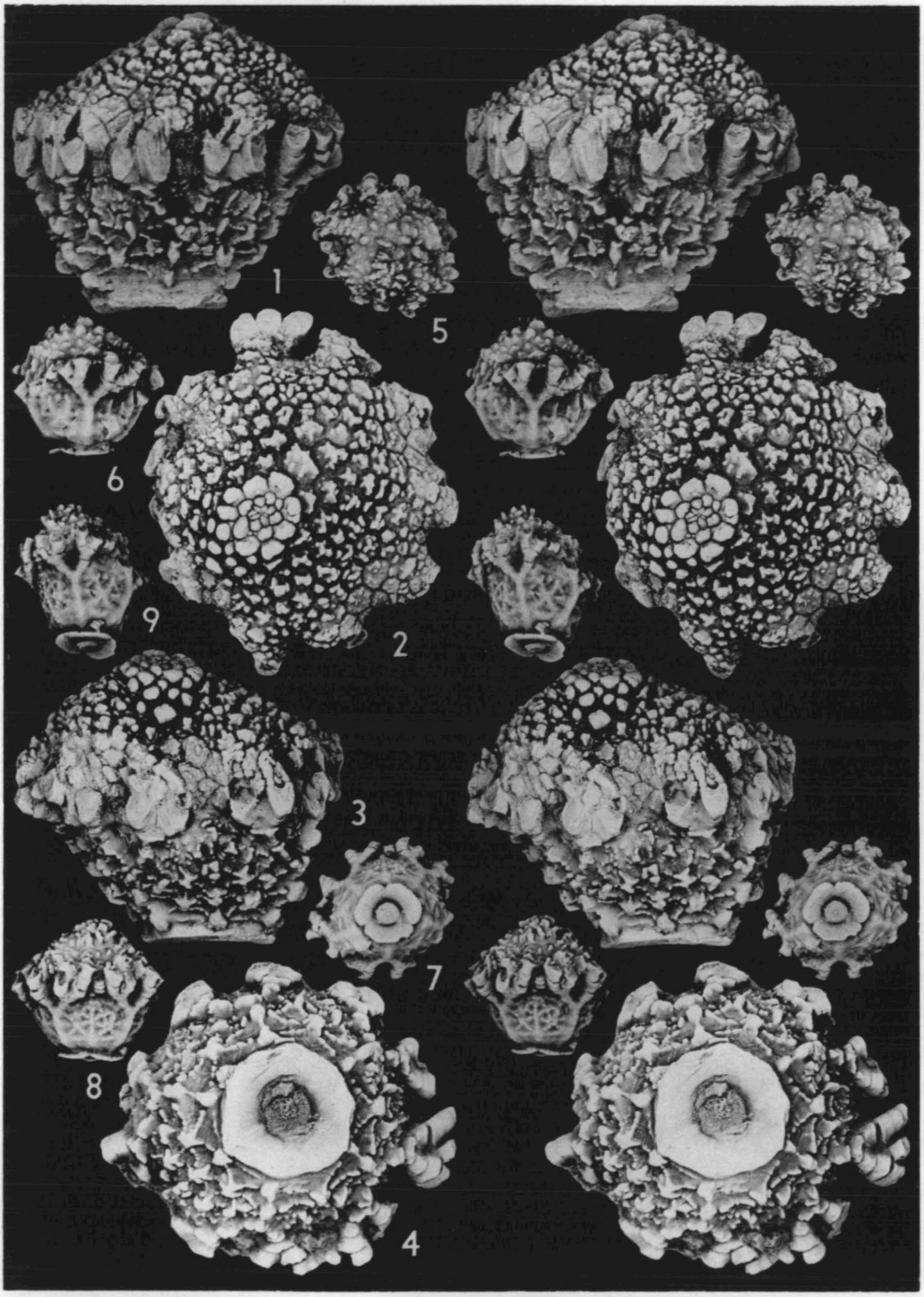
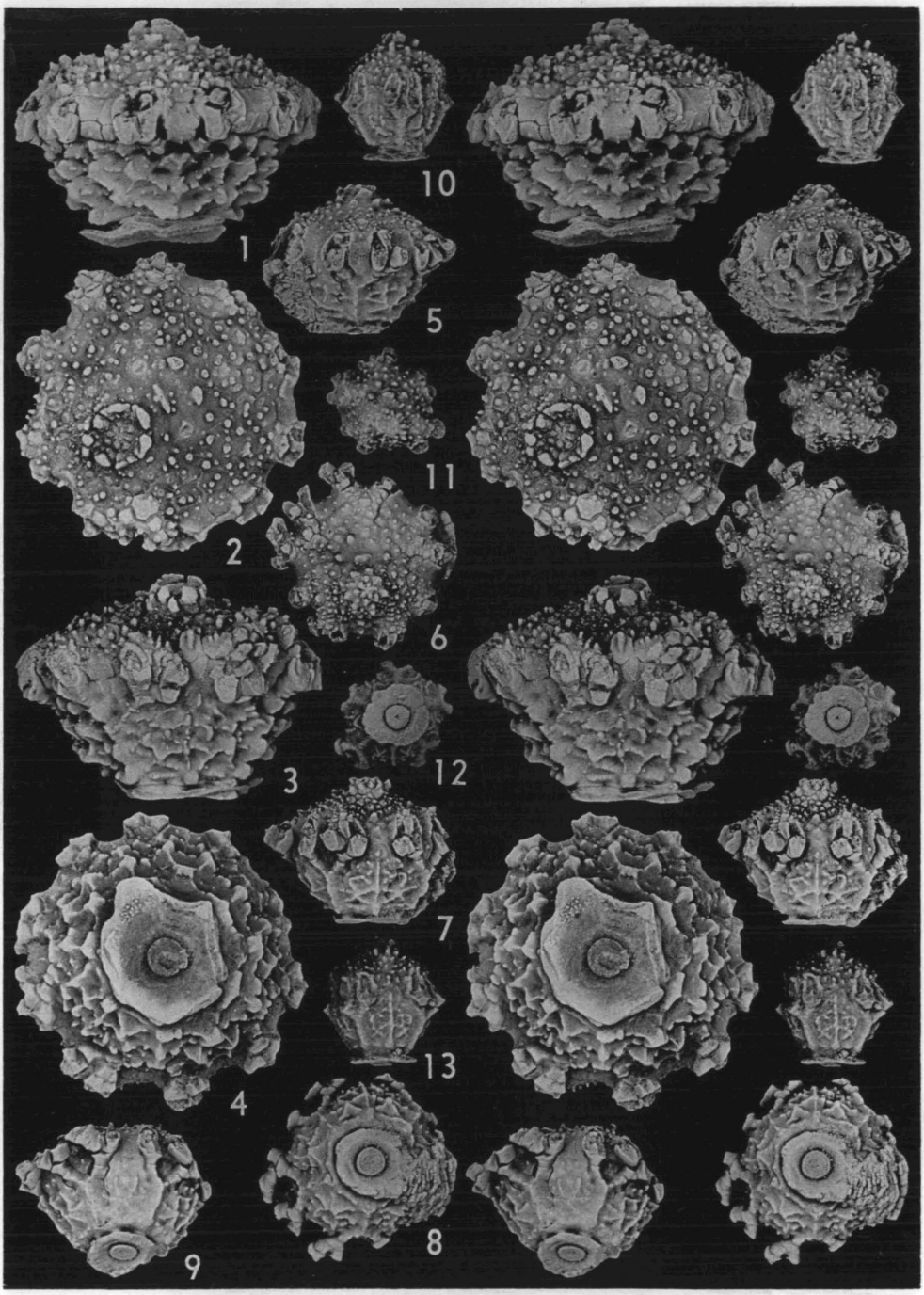


PLATE II



EXPLANATION OF PLATE II

(All figures x 3)

FIGS. 1–4. Anterior, tegminal, posterior, and basal stereograms of paratype, UMMP 40520. Ornamental ridges of cup with nodes at their junctions, making plates very thick in their centers (Fig. 4). Ridges interrupted at sutures (Figs. 1, 3). Tegmen crushed down over edge of cup anteriorly (Fig. 1). Interbrachial plates extending onto tegmen in biserial arrangement (Fig. 2). In Figs. 2 and 4, posterior at the lower left. *BB* very wide in relation to adjacent columnal of stem (Fig. 4).

FIGS. 5–9. Anterior, tegminal, posterior, basal, and inclined left posterior stereograms of paratype, UMMP 40526. Radial ridges are strongly developed, other ridges of the cup nearly complete; ornamentation of type 1. Most tegminal plates with single spines, a few with cockscomb structures (Fig. 6).

FIGS. 10–13. Anterior, tegminal, posterior, basal, and posterior stereograms of paratype, UMMP 37854, the smallest specimen studied. *BB* nearly complete (Fig. 12). Periproct rosette of ornamented plates not sharply differentiated from other tegminal plates (Fig. 11).

EXPLANATION OF PLATE III

(All figures x 3)

FIGS. 1–5. Posterior, tegminal, anterior, basal, and inclined right posterior stereograms of paratype, UMMP 40539. Tegmen ornamented with small nodes, some of which are fused to form incipient cockscomb structures (Fig. 2). Some ridges on cup uninterrupted; plates moderately thickened at centers; ornamentation type 2 (Fig. 5).

FIGS. 6–10. Posterior, tegminal, anterior, basal, and inclined right posterior stereograms of paratype, UMMP 40525. Radial ridges strongly developed, other ridges for the most part continuous; ornamentation type 1.

PLATE III

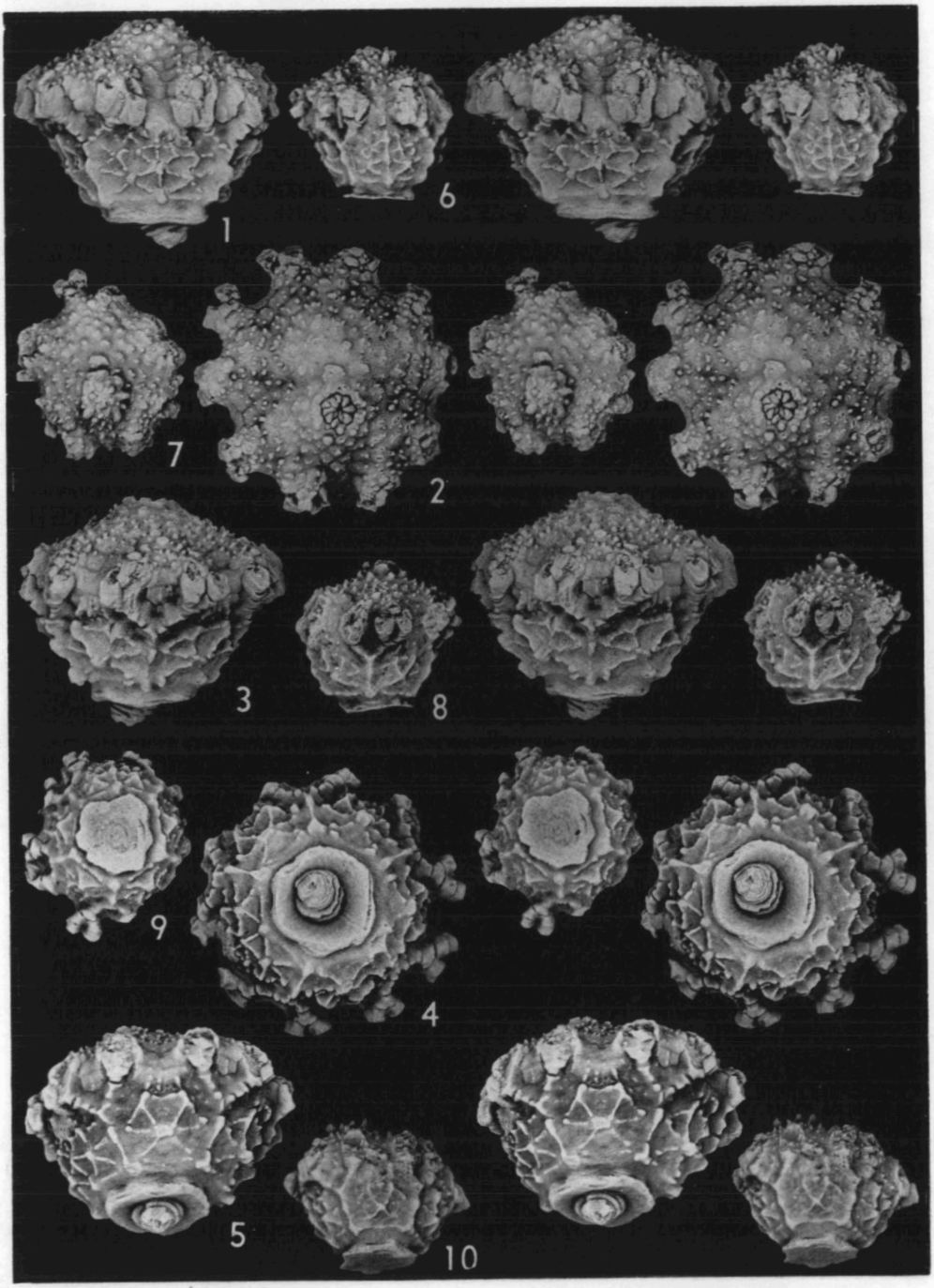
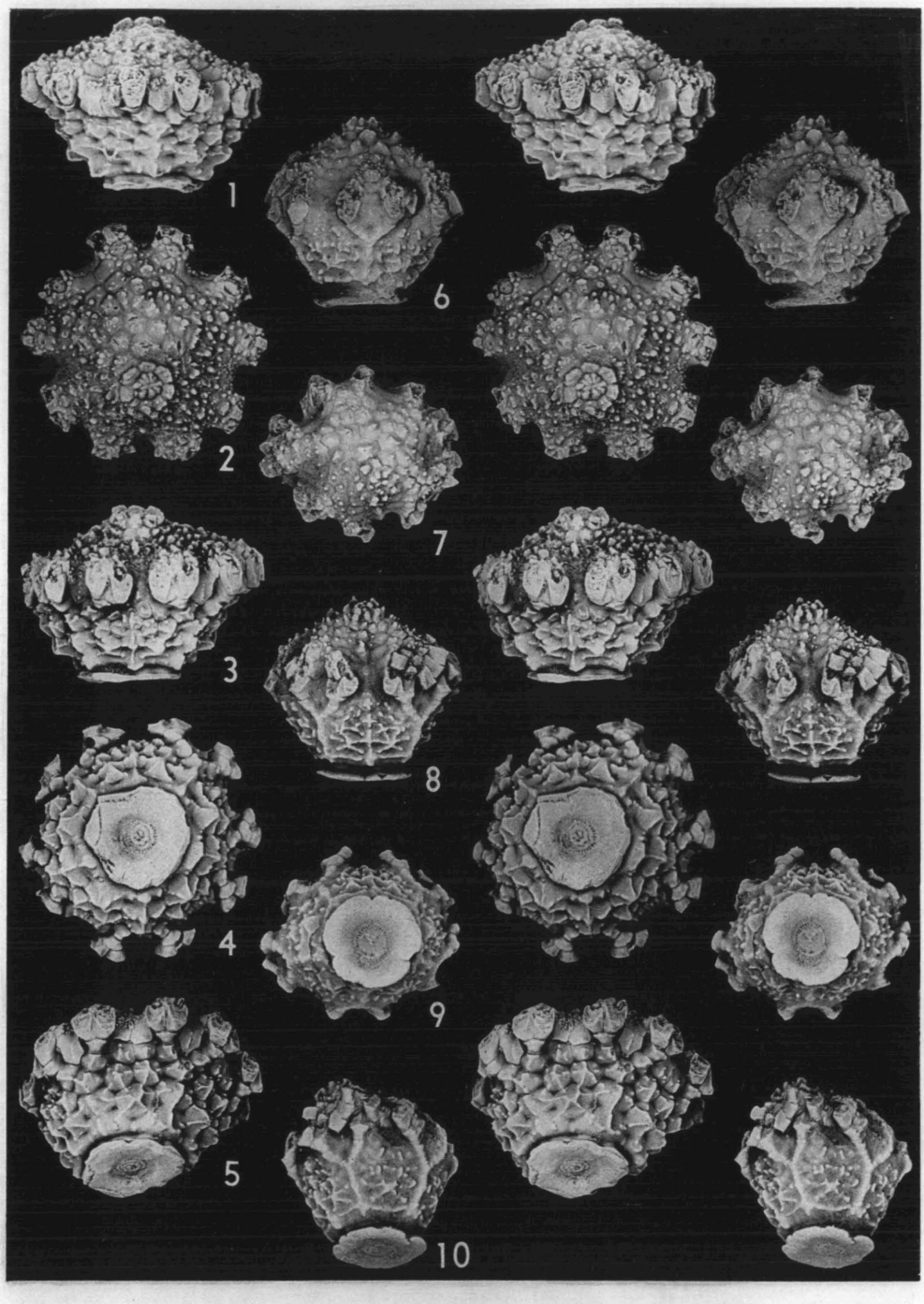


PLATE IV



EXPLANATION OF PLATE IV

(All figures x 3)

FIGS. 1–5. Anterior, tegminal, posterior, basal, and inclined right posterior stereograms of paratype, UMMP 40523. Calyx low and broad, with wide interarm areas (Fig. 1). The two *SBrBr* and *ISBr* in right anterior and right posterior radii readily distinguished (Fig. 5). Nearly all ridges interrupted; ornamentation type 2. Unornamented interbrachial plates extending onto tegmen in biserial arrangement (Fig. 2).

FIGS. 6–10. Anterior, tegminal, posterior, basal, and inclined right posterior stereograms of paratype, UMMP 40524. *BB* with flaring trilobate rim (Fig. 9). Most ornamental ridges complete; ornamentation type 1. Rosette around periproct not well developed (Fig. 7).

EXPLANATION OF PLATE V

(All figures x 3)

FIGS. 1–4. Anterior, tegminal, posterior, and basal stereograms of holotype, UMMP 40535, one of the large specimens. The pattern of ornamentation on the cup is distinct, although the ridges are narrow and in part reduced to knobs and nodes. Sutures are exceptionally distinct. Both nodes and cockscomb structures are present on the elevated tegmen (Fig. 2).

FIGS. 5–8. Anterior, tegminal, posterior, and basal stereograms of paratype, UMMP 37852, one of the small specimens. The ornamentation is distinct and the radial ridges strong. The disk of *BB* is trilobate (Fig. 8).

FIGS. 9–12. Anterior, tegminal, posterior, and basal stereograms of paratype, UMMP 37853, the smallest of the types. Note the strong radial ridges and well-developed ornamentation.

PLATE V

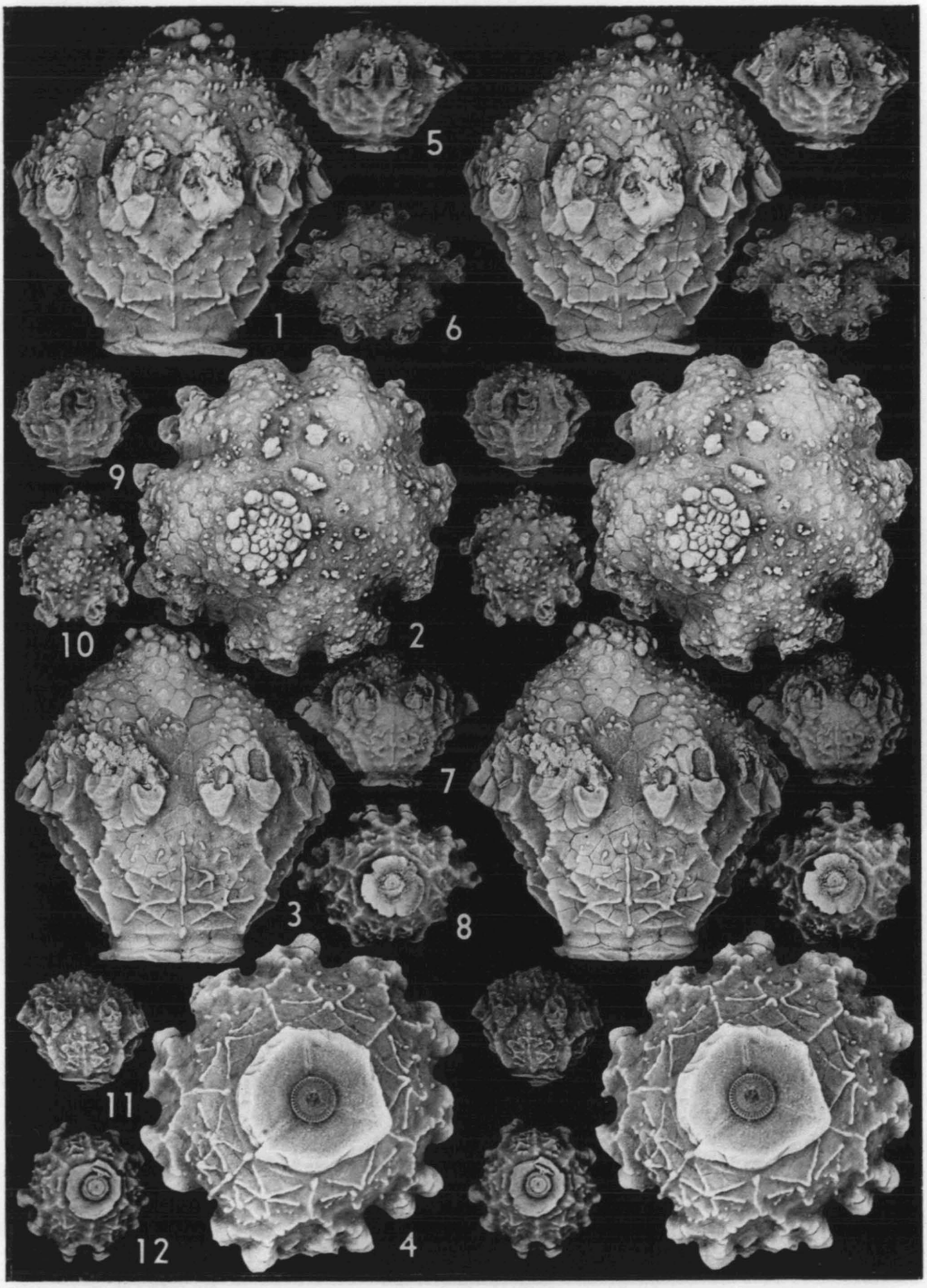
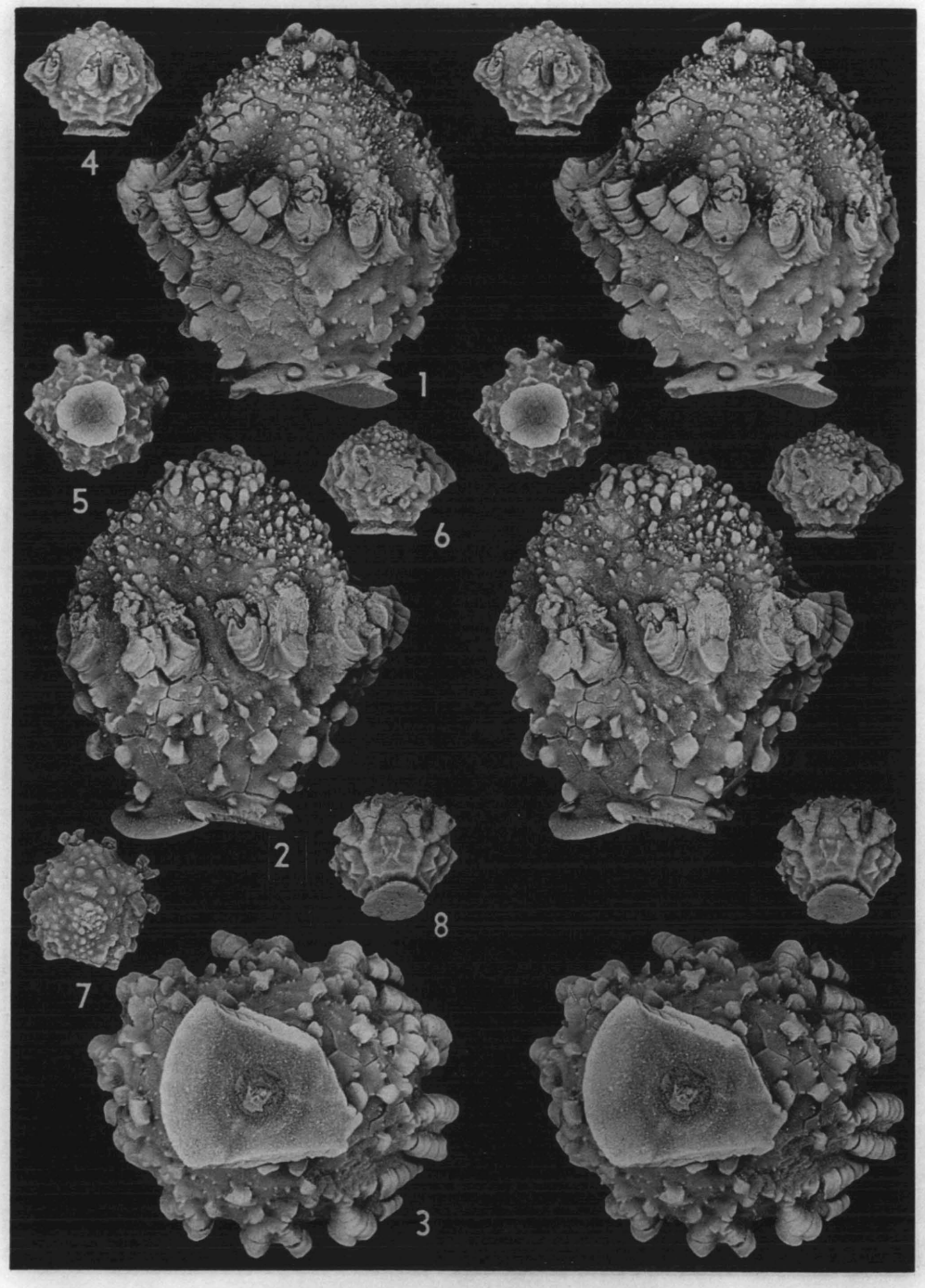


PLATE VI



EXPLANATION OF PLATE VI

(All figures x 3)

FIGS. 1–3. Anterior, posterior, and basal stereograms of paratype, UMMP 40536, the largest specimen found and presumably gerontic. Ornamental ridges on plates of the cup are reduced to small nodes and large cockscomb structures (Fig. 1). The flaring *BB* are complete on the left side of the specimen (Figs. 2–3). Anteriorly the tegmen is ornamented with small nodes (Fig. 1) and posteriorly with large nodes and cockscomb structures (Fig. 2). The right half of the right anterior ray has two single arms with a *TBrBr* series; the left half of the anterior ray has a single arm on the outside and an axillary TBr_2 on the inside, which would give rise to two arms (Fig. 1).

FIGS. 4–8. Anterior, basal, posterior, tegminal, and inclined left anterior stereograms of paratype, UMMP 40537. The *BB* are nearly complete (Fig. 5). Radial ridges are strongly developed (Fig. 8).

EXPLANATION OF PLATE VII

(All figures x 3)

FIGS. 1–5. Anterior, tegminal, inclined left posterior, posterior, and basal stereograms of paratype, UMMP 40527. Wide, biserial, unornamented plates extend far onto the tegmen in regular series in the interambulacra (Fig. 2). The eccentric anal rosette is bordered by flaring plates (Fig. 2). Centers of cup plates are thickened conspicuously by nodes developed at junctions of the discontinuous ridges (Fig. 5).

FIGS. 6–9. Tegminal, anterior, posterior, and basal stereograms of paratype, UMMP 40538. In Figs. 6 and 9, posterior is at the lower left. Ornamentation on the cup is well defined, with the ridges more continuous than those in UMMP 40527 (compare Figs. 1 and 7, 4 and 8).

PLATE VII

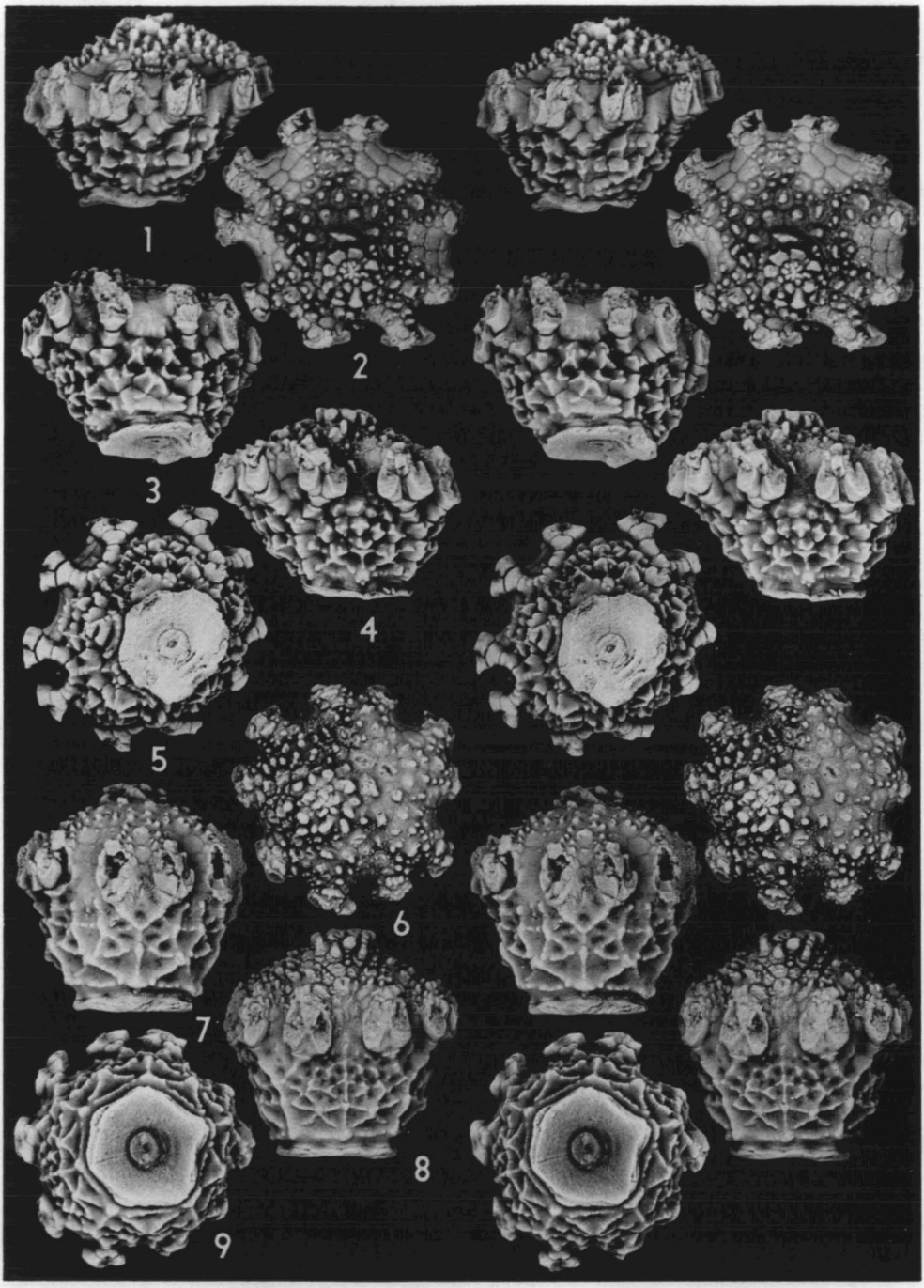
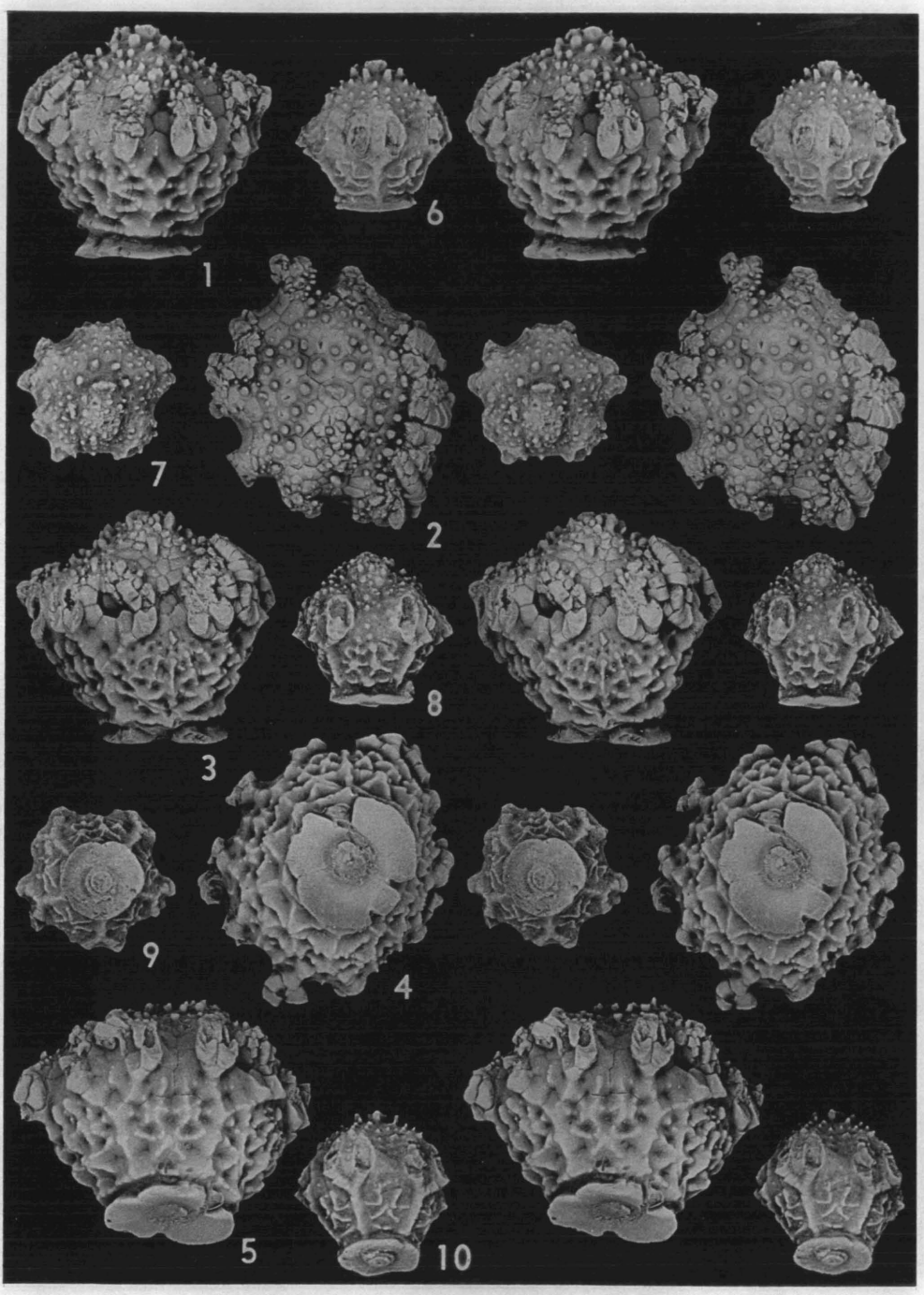


PLATE VIII



EXPLANATION OF PLATE VIII

(All figures x 3)

FIGS. 1–5. Anterior, tegminal, posterior, basal, and inclined left posterior stereograms of paratype, UMMP 40542. Arm plates above the TBr_5–TBr_6 level are biserial (Fig. 2). Most of the tegmen plates have a single central node (Fig. 2). Unornamented biserial plates extend onto the tegmen (Figs. 1–2).

FIGS. 6–10. Anterior, tegminal, posterior, basal, and inclined left anterior stereograms of paratype, UMMP 40528. Radial ridges are strong in contrast to the interradial ridges. High, pointed nodes are present near the center of the tegmen (Fig. 10). The *BB* are complete (Fig. 9).

EXPLANATION OF PLATE IX

(All figures x 3)

PAGE

Gennaeocrinus variabilis, sp. nov. 174

FIGS. 1–5. Anterior, tegminal, posterior, basal, and inclined right posterior stereograms of paratype, UMMP 40531.

FIGS. 6–9. Anterior, tegminal, posterior, and inclined right anterior stereograms of paratype, UMMP 40532.

FIGS. 10–14. Anterior, tegminal, posterior, basal, and inclined right anterior stereograms of paratype, UMMP 40533.

PLATE IX