

CONTRIBUTIONS FROM THE MUSEUM OF PALEONTOLOGY

THE UNIVERSITY OF MICHIGAN

Vol. 23, No. 2, p. 37-51, (6 pls. 2 text-figs.)

NOVEMBER 28, 1969

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A NEW BRITTLE-STAR FROM THE MIDDLE DEVONIAN  
ARKONA SHALE OF ONTARIO

BY

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## CONTRIBUTIONS FROM THE MUSEUM OF PALEONTOLOGY

*Director:* ROBERT V. KESLING

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### VOLUME 23

1. The rodents from the Hagerman local fauna, Upper Pliocene of Idaho, by Richard J. Zakrzewski. Pages 1-36, with 13 text-figures.

# A NEW BRITTLE-STAR FROM THE MIDDLE DEVONIAN ARKONA SHALE OF ONTARIO

ROBERT V. KESLING

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ABSTRACT—Discovery of a community of brittle-stars in the Middle Devonian Arkona Shale permits the description of a new species with exceptional thoroughness. Details of preservation and association indicate the paleoecology of the unit.

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## INTRODUCTION

NOW AND THEN a new kind of fragile invertebrate is discovered at a famous Middle Devonian collecting site, but the find of a whole community of well-preserved brittle-stars must be regarded as an extremely rare event and must stand as a lasting tribute to the perspicacity and perseverance of the collector.

Last year Dr. G. Denis Thorn, chemist of London, Ontario, on one of his numerous visits to the exposures of Arkona Shale in Hungry Hollow noted a thin lens of crinoidal "hash" on which were exceptional numbers of platy-zerid gastropods. Closer inspection of the surface revealed that tiny brittle-stars were even more abundant than the dark conspicuous gastropods.

Inasmuch as the Hungry Hollow locality has been known since before the turn of the century and in recent times is visited annually by about 5000 fossil collectors (conservatively estimated), I was astonished and, I must confess, somewhat dubious when Dr. Thorn wrote that he had numerous fine brittle-stars. After another visit to the outcrop, he brought the specimens to the Museum of Paleontology. Fourteen of the better slabs were catalogued, and some of the specimens on them are illustrated herewith. Other specimens are retained by Dr. Thorn. Last October I visited the locality with Mrs. Edward P. Wright and my wife, searching for additional brittle-stars. We found none. We prefer to attribute our failure to Dr. Thorn's thoroughness.

The matrix was scarcely consolidated, and drying developed serious cracks. To prevent further damage to the specimens, each slab was soaked repeatedly in dilute glyptol, impregnating all except the uppermost surface on which the brittle-stars were situated. This controlled the crumbling and dismemberment of the small slabs.

The specimens were cleaned with small needles and brushes. A trial application of air abrasive proved too drastic, damaging the delicate spines associated with the adambulacrals. The upper surface, including the brittle-stars, was somewhat obscured by mud, although the matrix itself contained remarkably little clay. Picking and brushing under the binocular microscope uncovered the wonderfully preserved specimens illustrated in the plates.

In classifying the brittle-stars, it was soon obvious that many of the characters used in taxonomy are insecurely substantiated and that several differ according to the manner of preservation. In particular, the classification within the family Protasteridae needs extensive revision and clarification. Nevertheless, the species is new and I take pleasure in naming it for Dr. G. Denis Thorn. He whimsically suggested that *thorni* might be interpreted as a reference to the adambulacrals and disk spines; therefore, I specially stress that the name is patronymic, in honor of the man who found the types and generously donated them to our Museum.

Several colleagues helped prepare this paper. Mrs. Gladys Newton typed the final manuscript, Mr. Karoly Kutasi made the excellent photographs, Prof. D. B. Macurda offered helpful suggestions, and Prof. C. A. Arnold and Prof. E. C. Stumm did editorial work. All deserve my grateful thanks.

## LOCALITY

Middle Devonian Arkona Shale, about fifteen feet below top of the formation, a thin lens (about 3.2 cm greatest thickness) exposed about three feet below the top of a little hummock and about 15 feet above the river, on the north bank of the Ausable River, about 400 yards downstream (west) of the old bridge (shown on the Parkhill 40P/4 West Half Sheet, Canada, Army Survey Establishment, 3d ed., 1956), about 1¾ miles east-northeast of Ar-

kona, in Williams Township, Middlesex County, Ontario.

#### ABBREVIATIONS

For convenience in discussion of morphology, the following common abbreviations are used:

- Adm(m)—adambulacral(s) or side shield(s).  
 Adm<sub>1</sub>—first adambulacral, adjacent to mouth-angle plate.  
 Adm<sub>2</sub>—second adambulacral.  
 Amb(b)—ambulacral(s).  
 Amb<sub>1</sub>—first ambulacral, adjacent to mouth-angle plate and first adambulacral.  
 Amb<sub>2</sub>—second ambulacral.  
 M—madrepore.  
 MAP(s)—mouth-angle plate(s).

- Subclass OPHIUROIDEA Gray 1840  
 Order OEGOPHIURIDA Matsumoto 1915  
 Suborder LYSOPHIURINA Gregory 1896  
 Family PROTASTERIDAE S. A. Miller 1889

The specimens investigated here qualify as ophiuroids by their disk sharply distinct from the arms, their complex ossicles of the axial skeleton nearly filling the arm cavity, and their adambulacrals developed as side plates. They possess podial cupules shared by Amb and Adm plates, weakly calcified madrepore, separate Amb ossicles (not fused into solid vertebrae), and a single pair of radial elements per ray involved in the mouth frame; they lack dorsal and ventral arm plates, oral and radial shields, genital plates, and bursae; this combination of characters is limited to the order Oegophiurida. It can also be readily and clearly seen that the Amb ossicles alternate, which further restricts these brittle-stars to the suborder Lysophiurina. The Admm are developed as side shields, the oral edges of Ambb are narrow, and the disk has no marginal frame; hence the specimens belong to the family Protasteridae.

Generic placement is not as clear. Primarily because species have been incompletely preserved and/or inadequately or poorly described, they have been grouped into genera of exceptional geologic duration. For example, Spencer & Wright (1966, p. 87) give the range of *Protaster* as Middle Ordovician to Lower Carboniferous. It would seem unlikely that such active and ecologically responsive animals would have been so conservative. Until species are better known, lumping of genera seems unwarranted.

#### Genus EUGASTERELLA Schuchert

*Eugaster* Hall, 1866, p. 9; 1867 (1868), p. 290; 1870, p. 332.  
 not *Eugaster* Seville 1839.

*Eugasterella* Schuchert, 1914, p. 19; 1915, p. 237–238.  
*Protaster* Forbes 1849, Spencer & Wright, 1966, p. 87 (in part).

In the *Treatise*, Spencer & Wright made *Eugasterella* Schuchert a junior synonym of *Protaster* Forbes; their description of *Protaster* was very brief: "Depressions for attachment of dorsal arm muscles weak; laterals with articulating nose near oral edge." Whether the species of *Protaster*, which apparently originated in Ordovician time in England, and the species of *Eugasterella*, which have their first record in the Devonian of North America, belong in one genus cannot be demonstrated at this time. Until Paleozoic brittle-stars have been investigated in greater depth, it seems prudent to keep *Eugasterella* and *Protaster* as separate genera.

*Eugasterella* differs from *Taeniaster* Billings 1858, *Drepanaster* Whidborne 1898, and *Mastigophiura* Lehmann 1957 in lacking deep pits for musculature on the aboral side of the Ambb. It differs from *Bohemura* Jaekel 1903 in having the articulating noses of Admm near the oral edge, rather than set higher and nearer the center of the plates; in addition, its arms taper gradually rather than terminate in a whiplike section. *Eugasterella* can be separated from *Aulactis* Spencer 1930 by the absence of an aboral groove in the Ambb. It appears to differ from *Protaster* in the relative sizes of MAPs, Ambb, and Admm, although the original figures of *E. logani*, the type species (Hall, 1867, pl. 9, fig. 8), show more similarity to the type of *Protaster*, *P. sedgwickii*, than do specimens of *E. thorni* n. sp.

#### EUGASTERELLA THORNI n. sp.

Text-figs. 1–2; pls. 1–6

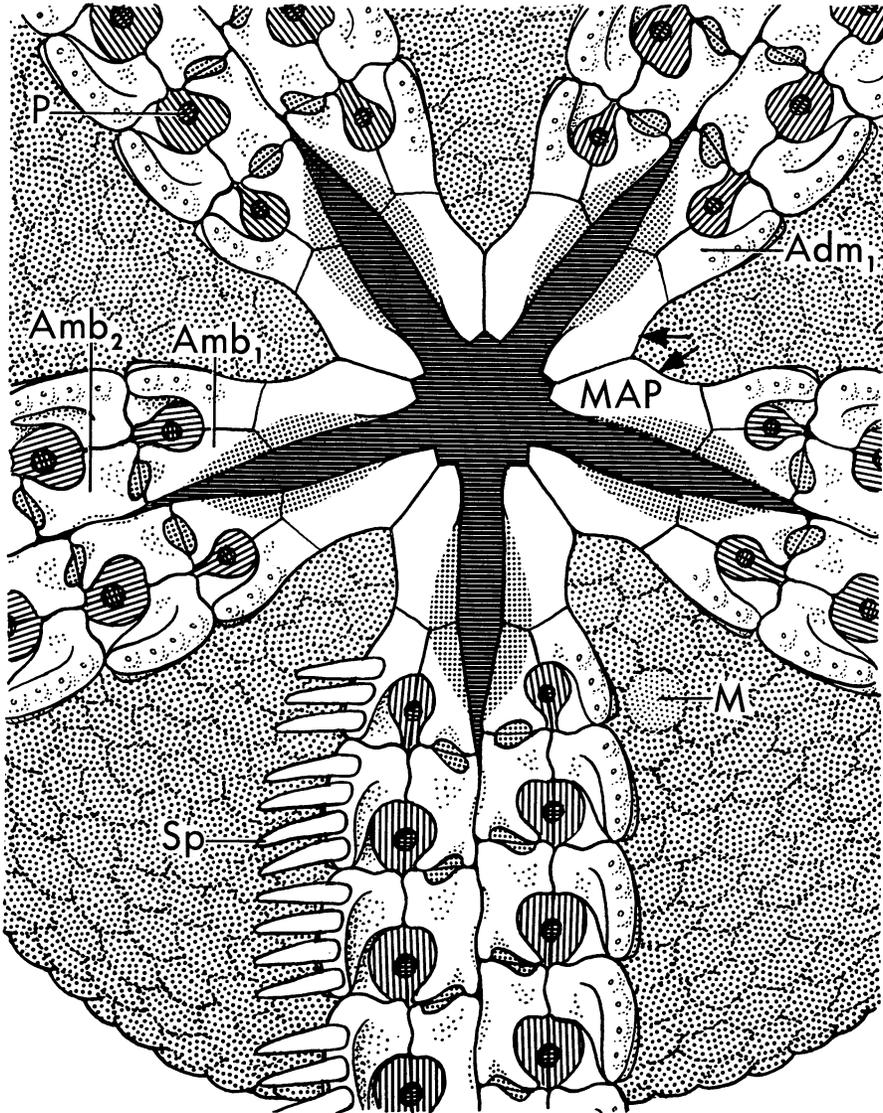
*Disk*.—Subcircular to subpentagonal, not actually set off from bases of arms on aboral surface (pl. 1; pl. 2, figs. 2–4). Interradial radius of large specimens measuring slightly over 4½ mm. Radial radius (from center of disk to tip of arm) nearly five times the interradian radius (table 1); hence, free part of arm nearly twice as long as the diameter of the disk.

Disk composed of small plates, poorly delineated because of overlying integument (pl. 5, fig. 2). Plates along interradian margin distally convex, probably imbricating; those near center apparently more nearly mosaic. No centrale, radial shields, oral shields, or genital plates associated with disk. Disk pliable in life, the axils compressed or distended in many specimens (pl. 1; pl. 2, figs. 3, 4).

Integument on aboral side of disk (and extending out onto the middle of the arms, covering the Ambb aborally), on rounded edges of

TABLE 1—SELECTED MEASUREMENTS OF SOME SPECIMENS OF *Eugasterella thorni* n. sp. (in mm).

	57475a	57480	57484	57473b	57479	57477	57483	57473a	57478a
Radial radius (along arm)	—	16.9	18.9	18.5 22.0	—	—	—	—	—
Interradial radius	3.9	3.6	4.1	4.6	—	2.5	2.8	3.5	3.4
Arm width near edge of disk	1.60	1.87	2.00	1.50	1.90	1.62	1.50	1.63	1.44
Diam. podial cups	0.35	0.34	—	—	0.33	0.37	0.35	—	0.31
Spacing of podial cups	0.66	0.58	—	—	0.60	0.50	0.50	—	0.56



TEXT-FIG. 1—Sketch of part of oral side of disk, with significant plates labeled. Pits for interambulacral muscle attachment between  $Amb_1$  and  $Amb_2$  larger in some specimens than indicated here (for example, see pl. 6, fig. 1), but in others more nearly conforming to the sketch. Arrows indicate apophyses of the mouth-angle plates, probably the sites of attachment of interradian thrusting muscles. P = pore for tube from radial water vessel to ampulla of tube-foot; Sp = ventral spines of Adm.

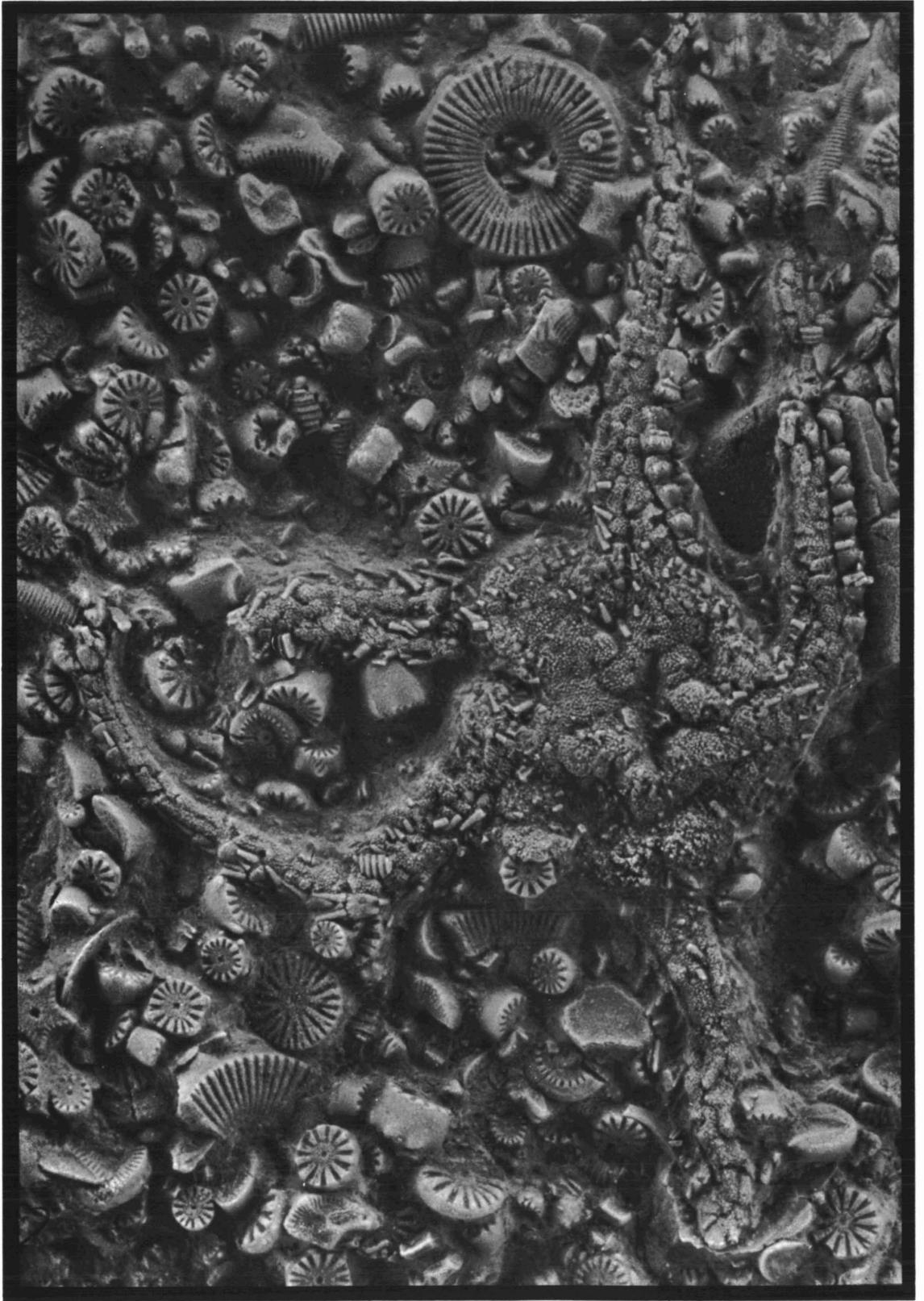
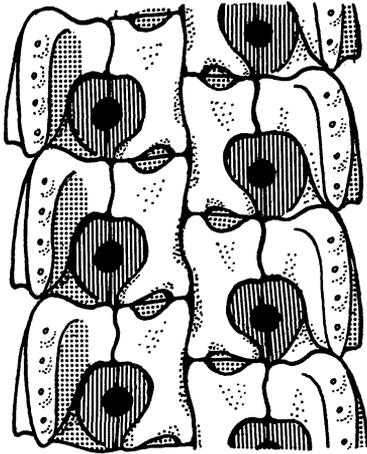


PLATE 1

interradii, and on oral interarm (axil) areas of disk. Surface studded with numerous small papillae (pl. 1; pl. 5, fig. 2), about 140 per mm<sup>2</sup>. Scattered subdermal ossicles, convex, their ovate outlines fairly well defined, each 0.3 mm in longest diameter. Pustules forming bases for attachment of spines, circular, elevated, their central concavity extended in radial grooves to produce a crenulate or radiate outline (pl. 5, fig. 2). Spines of disk tapering, 0.5 to 0.6 mm long, base about 0.2 mm in diameter, longitudinally striate with about 15 faint, irregular, granulose ridges.

M not clearly discernible; probably represented by a circular to ovate convexity on the



TEXT-FIG. 2.—Sketch of oral surface of median segment of arm.

oral surface, slightly offset from the junction of  $Adm_1$  and  $Adm_2$ , with a granulose rather than papillose surface (text-fig. 1).

*Arms.*—Long and tapering, in large specimens about 1.8 mm wide at junction with disk and less than 0.5 mm near the attenuated tip. Each arm consisting of a pair of MAPs, two rows of about 40 Ambb each, and two rows of an equal number of Admm.

MAPs slightly longer than any Amb or Adm plate (text-fig. 1), complexly curved. No

tori or denticles preserved. Each MAP adjoining the other MAP of the interradius along a straight suture about half the length of the plate (pl. 3, fig. 5; pl. 4, fig. 5; pl. 5, fig. 1). Oral surface of MAP proximally convex, sloping aborally from the junction at mid-interradius toward the axis of the ambulacrum, distally becoming gently convex and nearly flat, with less aboral slope; distal interradiial margin developed as a thin apophysis. Each MAP slightly sinuous along midheight (horizontally), its proximal half gently convex toward the axis of the ambulacrum and its distal half flaring toward the axis to become very slightly concave (text-fig. 1). Each interradiial pair of MAPs sharing a lunate proximal depression, presumably the junction with a torus (pl. 3, fig. 5). Each MAP distally bluntly acuminate, with two facets, one fitting against  $Adm_1$  and the other against  $Amb_1$  (text-fig. 1). MAPs probably laced together with interradiial thrusting muscles between the distal edges of each interradiial pair and with radial thrusting muscles between the oral edges of each radial pair; no distinct muscle scars.

Ambb basically quadrate, but orally strongly modified at ends by facets for attachment of interambulacral muscles and orolaterally by the podial cups. Ambb becoming more elongate distally; proximal Ambb nearly as wide as long, those near tip of arm only about half as long. Actual length of Ambb varying little; in large specimens, proximal plates about 0.6 mm long and distal plates about 0.5 mm long.

Oral surface of each Amb bearing adaxial ridge usually characterized as "boot-shaped"; in each "boot" the "instep" and the "top" outlining concavities for attachment of interambulacral muscles, the "front" outlining the adaxial half of the podial cup (text-fig. 2). Except near the mouth, Ambb of left side offset by half a length from those of right side of arm, their junction along the ambulacral groove sinuous; interambulacral muscle facet elongate, slanting distally away from the ambulacral axis (abaxially).  $Amb_1$  and  $Amb_2$  unlike succeeding plates in details.  $Amb_1$  shorter than other ambulacra; no conspicuous muscle pit adjacent to MAP;

#### EXPLANATION OF PLATE 1

Figure  $\times 8$

*Eugasterella thorni* n. sp. Aboral view of specimen on upper surface of thin unit composed chiefly of crinoidal columnals, presumably in approximately the living position; specimen shown natural size in plate 2, figure 1 (at left side); paratype UMMP 57473a.

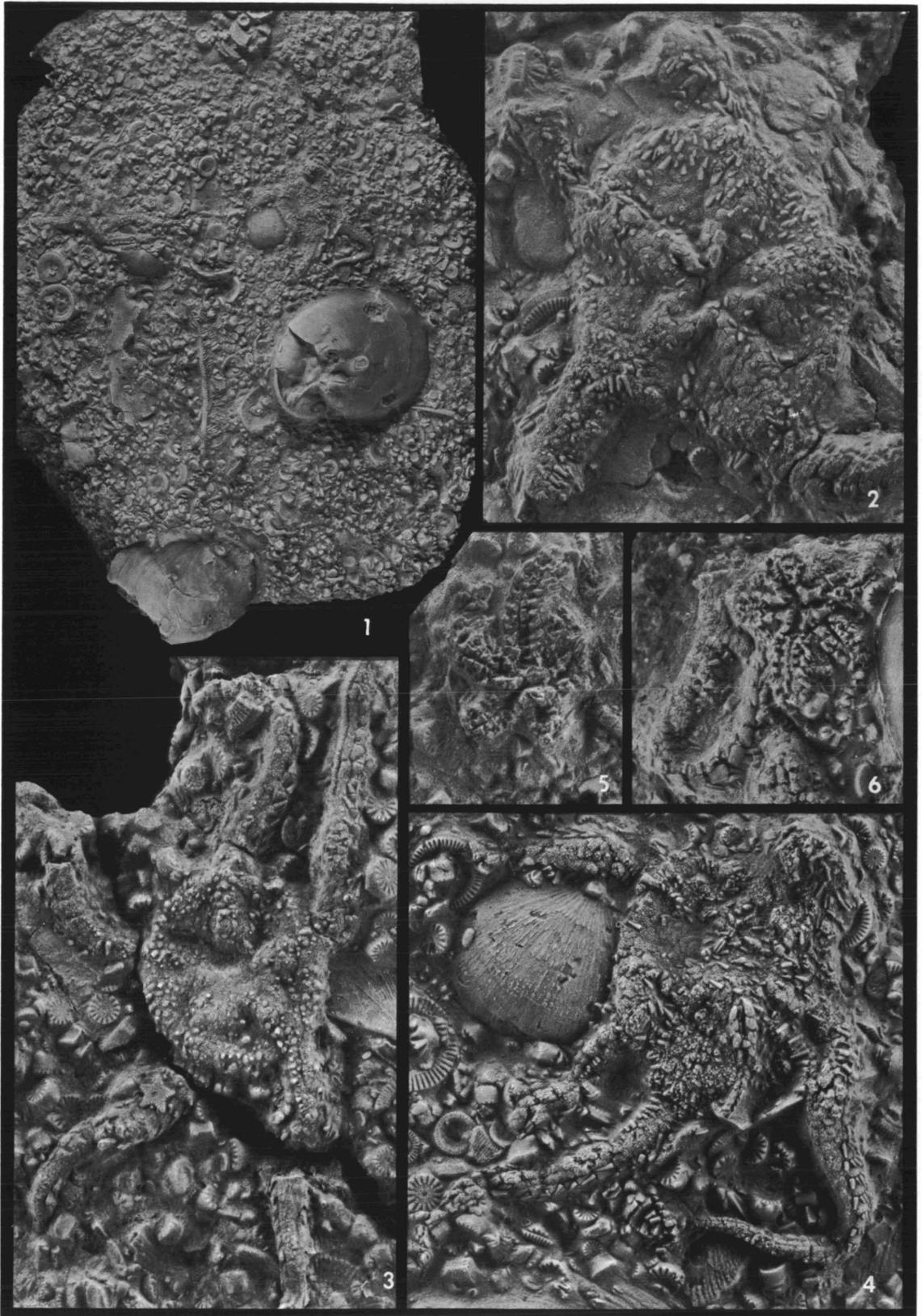


PLATE 2

podial cup notably smaller than adjacent one and set closer to ambulacral axis. Interambulacral muscle facet between  $Amb_1$  and  $Amb_2$  deeper and larger than those between other  $Amb$ , nearly as deep as a podial cup, slanting proximally away from the ambulacral axis instead of distally.

Aboral sides of  $Amb$  (seen only where integument absent) with simple junctures in series, lacking depressions for strong interambulacral muscle attachment. Aboral face of each  $Amb$  rectangular, having long lateral sutures with opposite  $Amb$  and with the associated  $Adm$ , somewhat narrower than oral face.

Podial cups (also called podial basins, ampullar cups, or cupules) deep, subcardiform, with a distal extension. Each cup shared nearly equally by the distal two-thirds of an  $Amb$  and adjacent  $Adm$  (pl. 6, fig. 1). Pore for passage of the tube from the radial water vessel to the ampulla of the tube-foot shared equally by  $Amb$  and  $Adm$ , about one-fourth to one-third the diameter of the cup (text-fig. 1). Radial water vessel set well within  $Amb$ , orally protected by the "boot-shaped" ridges.

$Adm$  developed as lateral plates or side shields, curved around sides of arm (pl. 6, figs. 1-4). Each  $Adm$  subquadrate in lateral view, but with slightly convex sides, convex ends, and rounded corners (pl. 6, figs. 2, 3); crescentic in vertical section, with convex outer surface and concave inner surface; wedge-shaped in horizontal section, increasing in thickness distally, the distal end bearing a shallow groove parallel to its edge (pl. 6, figs. 3, 4). Pustules for attachment of four or five ventral spines along oral edge of each  $Adm$ , and larger and more elevated pustules for attachment of four lateral spines along the outer distal edge, just outside the shallow groove.  $Adm$  with very little overlap except in laterally flexed arm (pl. 6, fig. 4).  $Adm$  near tips of arms much narrower than those in middle part; spacing of

$Adm$  and  $Amb$  equal throughout each side of arm.

Adambulacral "nose" developed as a short, stout, subcylindrical adaxial projection near the proximo-oral inner corner of  $Adm$  (pl. 6, figs. 1, 4); "nose" surface slightly convex, rather blunt, fitting against the proximo-oral edge of  $Amb$ . "Nose" forming part of proximal wall around podial cup (text-figs. 1, 2; pl. 3, fig. 5).

Ventral spines of  $Adm$  with bases somewhat flattened laterally, in large specimens about 0.12 mm in greatest diameter and 0.80 mm long, the distal ends tapered and circular in cross section; four or five spines per  $Adm$ . Lateral spines subconical throughout, in large specimens about 0.15 mm in greatest diameter and 0.75 mm long; each lateral spine reaching the distal end of the next  $Adm$  (pl. 6, figs. 1, 3, 4), except near tip of arm, there somewhat shorter (pl. 6, fig. 2); four spines per  $Adm$ . All  $Adm$  spines longitudinally striate with faint, irregular, granulose ridges.

$Adm$  of opposite sides widely separated in proximal part of arm, but only narrowly in distal section, there nearly concealing ambulacral groove.

*Remarks.*—The species with which *Eugasterella thorni* can be compared is *E. logani* (Hall), the type species of the genus. The two differ in several respects. Statements by Hall in the original description (1868, p. 290), which was repeated in the revised edition (1870, p. 333), can be contrasted with the characters in *E. thorni*.

#### First:

The diameter, measured from the sinus [inter-ray] to its extension on the opposite ray, is about half as great as the length of the ray measured from the centre of the disk.

In effect, this says that *E. logani* has a radial radius four times its interradial radius. In *E. thorni* the ratio is nearly five; thus, its disk is

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#### EXPLANATION OF PLATE 2

Figures  $\times 4$ , except as noted

*Eugasterella thorni* n. sp. 1, upper surface of part of small slab showing two brittle-stars and two platycerid gastropods upon crinoidal debris; paratype UMMP 57473a at left, enlarged in plate 1; paratype UMMP 57473b at right, enlarged in figure 4 on this plate;  $\times 1$ . 2, aboral view of disk and bases of arms, showing associated spines; enlarged section shown in plate 5, figure 2; paratype UMMP 57476. 3, aboral view of specimen with three arms broken off and attached with cement; disk is exceptionally circular; paratype UMMP 57486. 4, aboral view of disk and parts of arms; the two lower arms nearly complete; specimen shown natural size in figure 1 (at right); paratype UMMP 57473b. 5, 6, oral views of two smaller than average specimens, paratypes UMMP 57483 and 57477; enlargement of part of the latter in plate 4, figure 5.

proportionally smaller. Furthermore, the axils of *E. logani* are concave (as shown in Hall's figure on his pl. 9, fig. 7) and appropriately described as a "sinus"; those of *E. thorni* are slightly convex.

#### Second:

There are about eight pairs of plates inclosed within the limits of the disk.

In *Eugasterella thorni* each ray has about four pairs of plates situated within the limits of the disk.

#### Third:

This specimen measures, from the centre of the disk to the extremities of the rays, about one inch and a half [38 mm]; the widest part of the ray, which is near the margin of the disk, is about an eighth of an inch in diameter [3.2 mm].

As can be seen in table 1, the largest specimen of *E. thorni* is not much more than half this size.

#### Fourth:

The adambulacral plates as seen from below are extremely narrow and very convex on their outer surfaces, forming the margins of the ray.

The side shields of *E. thorni* are more robust and thicker, with less convex abaxial borders.

#### Lastly:

The rays toward their extremities have an ambulacral field covered by the curving of the marginal plates over the groove, and which, closely uniting by their margins, give a teretiform termination of nearly one-third the entire length . . .

The arms of *E. thorni* do not taper as rapidly as those of *E. logani*.

In the specimens studied of *Eugasterella thorni*, the larger are about 4.5 mm in inter-radial radius and the smallest is about three-fifths that size. Obviously, the collection does not include a complete ontogenetic series.

Despite the excellent preservation and the exceptional number of specimens, no tori or denticles are present and most arms are incomplete. The lack of complete specimens in this and other species makes comparative studies difficult and classification of brittle-stars uncertain.

*Types*.—Holotype UMMP 57475a (pl. 3, fig. 5; pl. 6, fig. 1). Paratypes UMMP 57473a (pl. 1; pl. 2, fig. 1), 57473b (pl. 2, figs. 1, 4), 57474 (pl. 3, fig. 2; pl. 6, fig. 3), 57475b (pl. 3, fig. 5), 57476 (pl. 2, fig. 2; pl. 5, fig. 2), 57477 (pl. 2, fig. 6; pl. 4, fig. 5), 57478a (pl. 3, fig. 4; pl. 5, fig. 1), 57478b (pl. 3, fig. 4), 57479 (pl. 6, fig. 4), 57480 (pl. 4, fig. 1), 57481 (pl. 3, fig. 1; pl. 4, fig. 4), 57482 (pl. 3, fig. 3), 57483 (pl. 2, fig. 5), 57484 (pl. 4, fig. 2; pl. 6, fig. 2), 57485 (pl. 4, fig. 3), and 57486 (pl. 2, fig. 3).

#### PALEOECOLOGY

Interpretation of the deposit must account for an unusual combination of factors:

- (1) brittle-stars in abundance, perhaps as many as three hundred per square meter;
- (2) platycerid gastropods also in abundance, probably about a hundred per square meter;
- (3) excellent preservation of delicate structures in the brittle-stars;
- (4) matrix consisting of a "hash" of completely disarticulated crinoid elements, with occasional brachiopods, tentaculites, and other small fossils;
- (5) matrix containing so little lime and so poorly consolidated that it still readily disintegrates and must be preserved by impregnation;
- (6) relatively small amount of clay;
- (7) fossils without discernible lineation; and
- (8) unit lens-shaped, thin, originally covering perhaps less than a hundred square meters.

Obviously, this bed exhibits strong contrasts in energy. The lens shape of the deposit and the concentration of crinoidal remains indicate high-energy action. Yet the excellent

#### EXPLANATION OF PLATE 3

Figures  $\times 8$ , except as noted

*Eugasterella thorni* n. sp. 1, small slab with three platycerid gastropods and part of a brittle-star (at left); paratype UMMP 57481;  $\times 1$ ; part of specimen enlarged in plate 4, figure 4. 2, specimen with arms swept back over disk; some of side shields enlarged in plate 6, figure 3; paratype UMMP 57474;  $\times 4$ . 3, oral view of incomplete specimen; paratype UMMP 57482. 4, oral views of two specimens, showing mouth-angle plates; paratypes UMMP 57478a (at left) and 57478b (at right); enlargement of the former in plate 5, figure 1. 5, oral view of large specimen, holotype UMMP 57475a (left center); enlargement of part of mouth frame and one arm in plate 6, figure 1; view of smaller specimen with arms turned back over disk; paratype UMMP 57475b (lower right); both specimens close beside large platycerid gastropod.

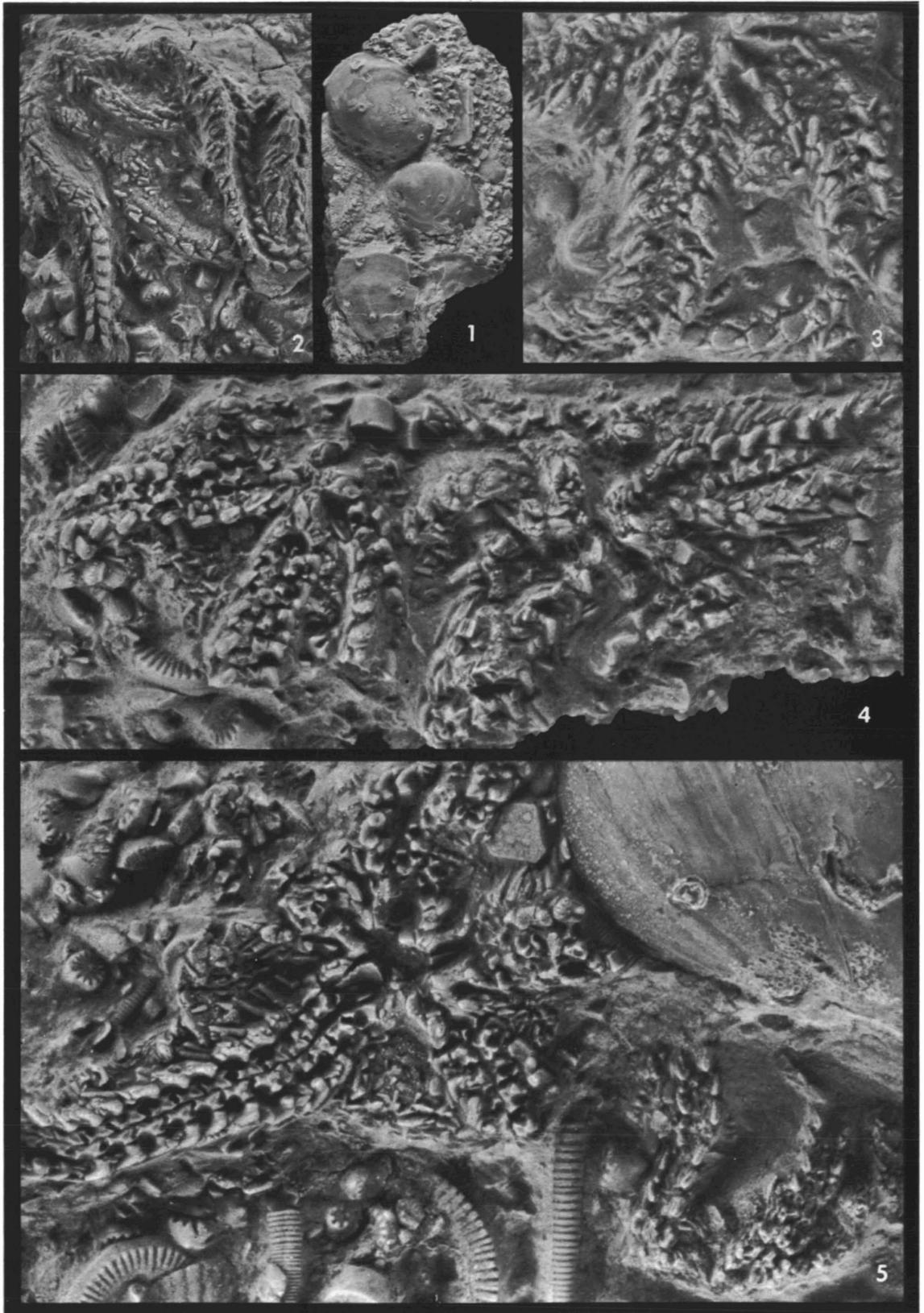


PLATE 3

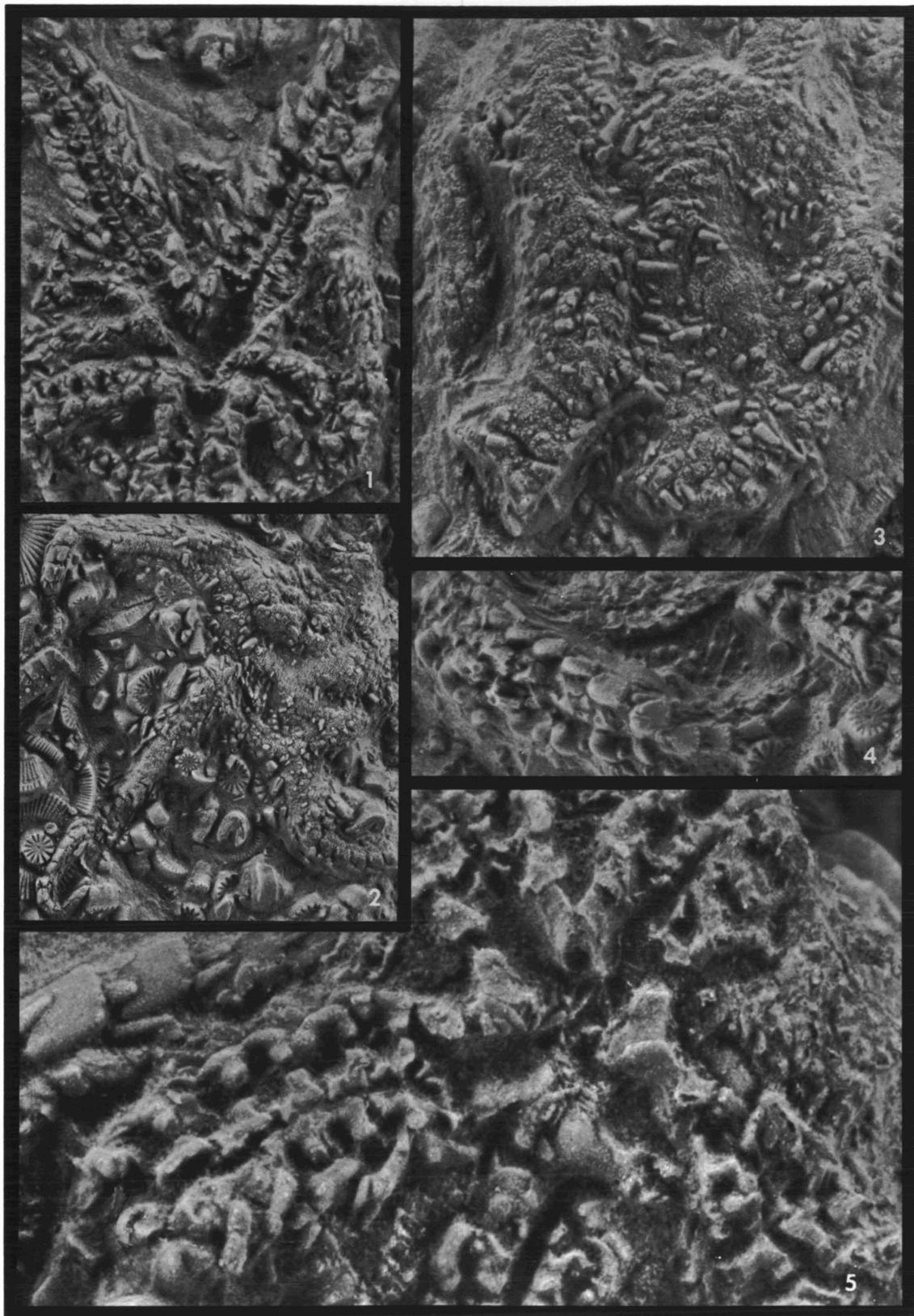


PLATE 4

preservation of fragile brittle-stars, many with spines still associated with disk and arms, points to a very low energy situation. It seems likely that both levels of energy entered into the history of the bed.

The key to paleoecology of this unit, it seems to me, lies in the brittle-stars. From their occurrence on the surface of the bed, it is clear that they were among the last living things to leave a record. From their numbers, one can infer that these brittle-stars were not swept in by a current, nor were they chance visitors to this area. This was their homeland, where they found food and thrived in comparative peace.

Previously, to my knowledge, only one specimen of brittle-star had been found relatively intact in the Arkona Shale. Hence, if these animals were widespread over the bottom during this interval of geologic time, their remains were soon destroyed under normal conditions. The conclusion seems inescapable that they congregated upon this particular area of the sea bottom because the deposit supplied their food. The assembly of this dense population must have required a considerable period of quiescence.

It seems likely that these brittle-stars, like many of their living descendants, were scavengers. Their associates, the platyцерid gastropods, at this place and time abandoned their usual role of excrement eaters atop the tegmens of crinoids, crawled about on the bottom, and found suitable nourishment. The logical diet of both brittle-stars and platyцерids was decaying organic debris, chiefly from the integument of the crinoids. Undoubtedly there were other scavengers, such as worms, which left no record. A few filter-feeders joined the community, such as brachiopods and bryozoa, and the bottom-dwelling ostracods *Ctenoloculina*, *Dizygopleura*, and *Ponderodictya* crawled about in the uppermost zone. Whatever organisms took part in the feast, they left the crinoids disarticulated and thoroughly disarranged before the adhering

tissues were completely decayed and destroyed by bacteria.

The distribution of columnals and other crinoid plates and ossicles shows that they were shifted thither and yon, both laterally and vertically, by the scavengers. Perhaps the destruction of the crinoids proceeded in stages, with larger animals (such as trilobites) taking the initial role in raking and delving through the deposit. When the readily accessible tissues had been eaten up, they may have moved on, leaving the field for smaller creatures to complete the cleaning operation.

The crinoid remains must have been deposited quickly, before decomposition became advanced. Thousands of individuals were involved. Such concentrations occur in thin layers at several levels in the Arkona Shale and in other Middle Devonian formations. In the upper Bell Shale in northeastern Michigan, specimens of *Gemmaocrinus variabilis* occur in "nests," in which many calyces are attached or closely associated with a tangled mat of stems; it is not exceptional to discover more than fifteen calyces in such a "nest." It would seem that from time to time a storm of exceptional intensity tore great numbers of crinoids loose or uprooted them by its accompanying swell. Borne along by currents, the stems became entangled wherever eddies occurred, and the whole mat finally came to rest on the floor. As the currents abruptly decreased, the remains were left exposed, with little or no covering of mud.

In the transportation of the crinoidal material here considered, some of the crowns may have become detached; certainly, the ratio of preserved calyx plates and arm ossicles to columnals is very low. Reduction of calyces to isolated plates is not unusual; near the base of the Bell Shale is a unit of crinoidal "hash" over a foot thick, which has yet to yield one calyx.

One cannot identify all the crinoids which were deposited here. Most of them were prob-

#### EXPLANATION OF PLATE 4

Figures  $\times 8$ , except as noted

*Eugasterella thorni* n. sp. 1, oral view of disk and basal parts of arms; paratype UMMP 57480. 2, aboral view of specimen, one arm nearly or quite complete; enlargement of some side shields in plate 6, figure 2; paratype UMMP 57484;  $\times 4$ . 3, aboral view of disk, somewhat contorted, showing associated spines; paratype UMMP 57485. 4, inclined oral view of part of arm with side shields drawn away from lower left side to show articulating noses; specimen shown natural size in plate 3, figure 1; paratype UMMP 57481. 5, oral view of parts of disk and arms, showing mouth frame; side shields drawn away from arm at left to expose articulations; specimen at lower magnification in plate 2, figure 6; paratype UMMP 57477;  $\times 20$ .

ably known species. Stumm & Wright (1958) recorded 13 species from the Arkona. Some of these were described from specimens which lacked columns, and others had more than one kind of columnal. The sharply pentastellate columnals with narrow crenulate margins (pl. 1) seem to belong to *Poteriocrinites ? arkonensis* Goldring. Certain of the circular columnals appear to belong to *Arthroacantha carpenteri* (Hinde) and others to *Corocrinus ? calypso* (Hall) (= *Gennaeocrinus arkonensis* Whiteaves). The obtusely quadrangular columnals of *Ancyrocrinus bulbosus* Hall, the pentastellate columnals with rounded tips of *Botryocrinus arkonensis* Goldring, and the distinctive columnals (heteromorphic, each nodal with decastellate facet and thick decalobate epifacet) of *Botryocrinus reimanni* Goldring were not found. None of the specimens have the pentalobate axial canal associated with *Gennaeocrinus mourantae* Goldring. At this time, I cannot identify some of the columnals, due in some degree to the general indifference with which these fossils have been treated in crinoid descriptions.

This, therefore, appears to be the history of the bed. A great storm dislodged crinoids from their garden, exposing them to current action. In the process of being carried along, their stems became entangled and some crowns may have become disengaged. More and more stems matted together. Finally the subsiding current could no longer roll the mass along and it was left on the sea floor. Almost immediately this source of food was set upon by one kind of scavenger after another, digging through the mat and dragging out segments of column to be eaten upon. Gradually the crinoids were reduced to isolated columnals, plates, and ossicles, and these were constantly being moved about and sorted through for remaining shreds of integument.

For a long time, perhaps months, the sea was quiet. As far as the scent could be detected,

brittle-stars and platycerid snails were attracted to this area. Some of the platycerids may have arrived as passengers on *Arthroacantha carpenteri*, their favorite host species. A thriving community of these diverse scavengers developed upon the localized crinoidal debris. They were joined by the bottom-dwelling ostracods, which, like their living counterparts, clambered about on the floor and crept into available crevices. The few brachiopods occurring in the deposit may have originally lived in the area and made their way up through the debris to feed at the surface; or they may have been survivors from the storm which swept them in along with the crinoids. Only one specimen of the large alate *Mucrospirifer* was noted. It seems highly unlikely that decomposition and destruction of crinoidal tissues was slow enough to permit a new generation of any of the inhabitants.

This utopian environment came to an abrupt end. It began with a sudden quickening of the current. About half of the brittle-stars reacted almost immediately, thrusting their arms among the columnals and holding fast (as the specimen in pl. 1). The rest of the brittle-stars were overturned; of these, some still clung to columnals or other heavy bottom objects with one or more of their arms to keep from being swept away, but others were probably not so successful. Some found temporary refuge on the lee side of the gastropods, which were so heavy, streamlined, and well-anchored that the current affected them scarcely at all. About one out of four brittle-stars is preserved beside a gastropod (two examples are seen in pl. 3, fig. 5).

Upon this community descended an influx of mud, snuffing out all life and burying it so deeply that other scavengers could not disturb the dead. During fossilization, differential pressures on the brittle-stars broke some of the spines free and spread some of the ambulacra apart, but otherwise they are preserved just as they were when they perished.

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#### EXPLANATION OF PLATE 5

Both figures  $\times 20$

*Eugasterella thorni* n. sp. 1, oral view of part of disk and arms, showing mouth-angle plates in mouth frame; some arm plates displaced slightly from natural position; another view of this specimen in plate 3, figure 4; paratype UMMP 57478a. 2, aboral view of part of disk, showing papillae, spines, and spine bases; view at lower magnification in plate 2, figure 2; paratype UMMP 57476.

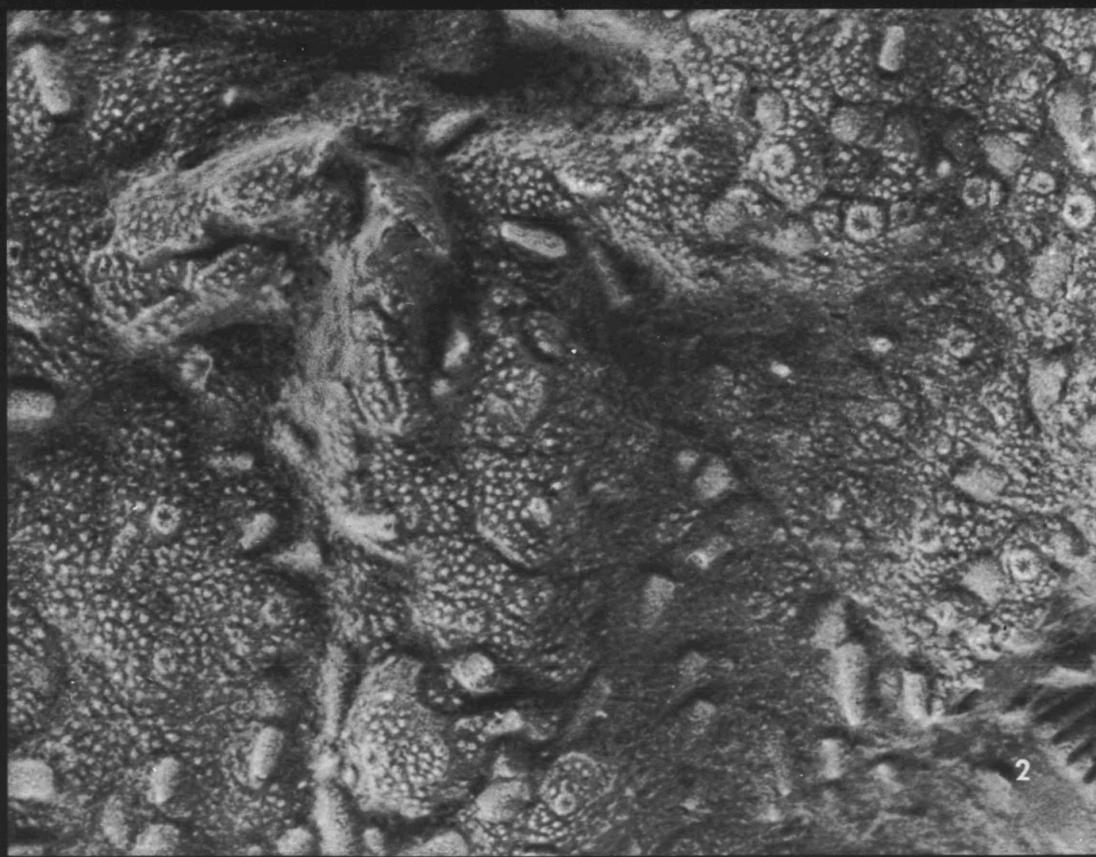
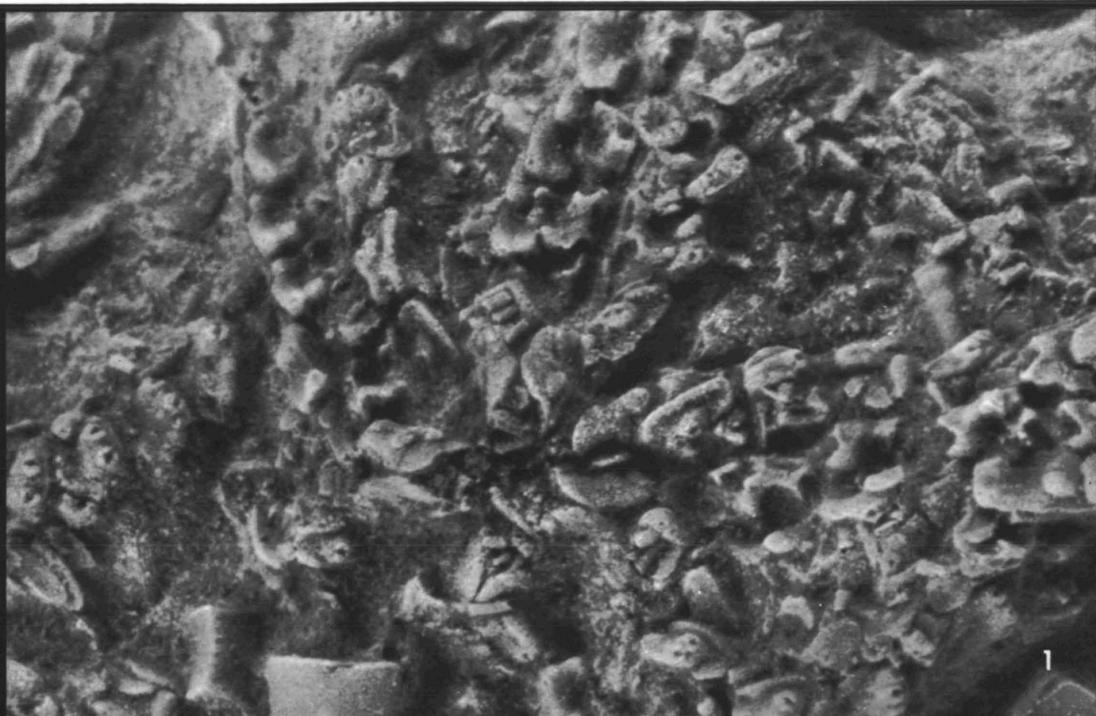


PLATE 5

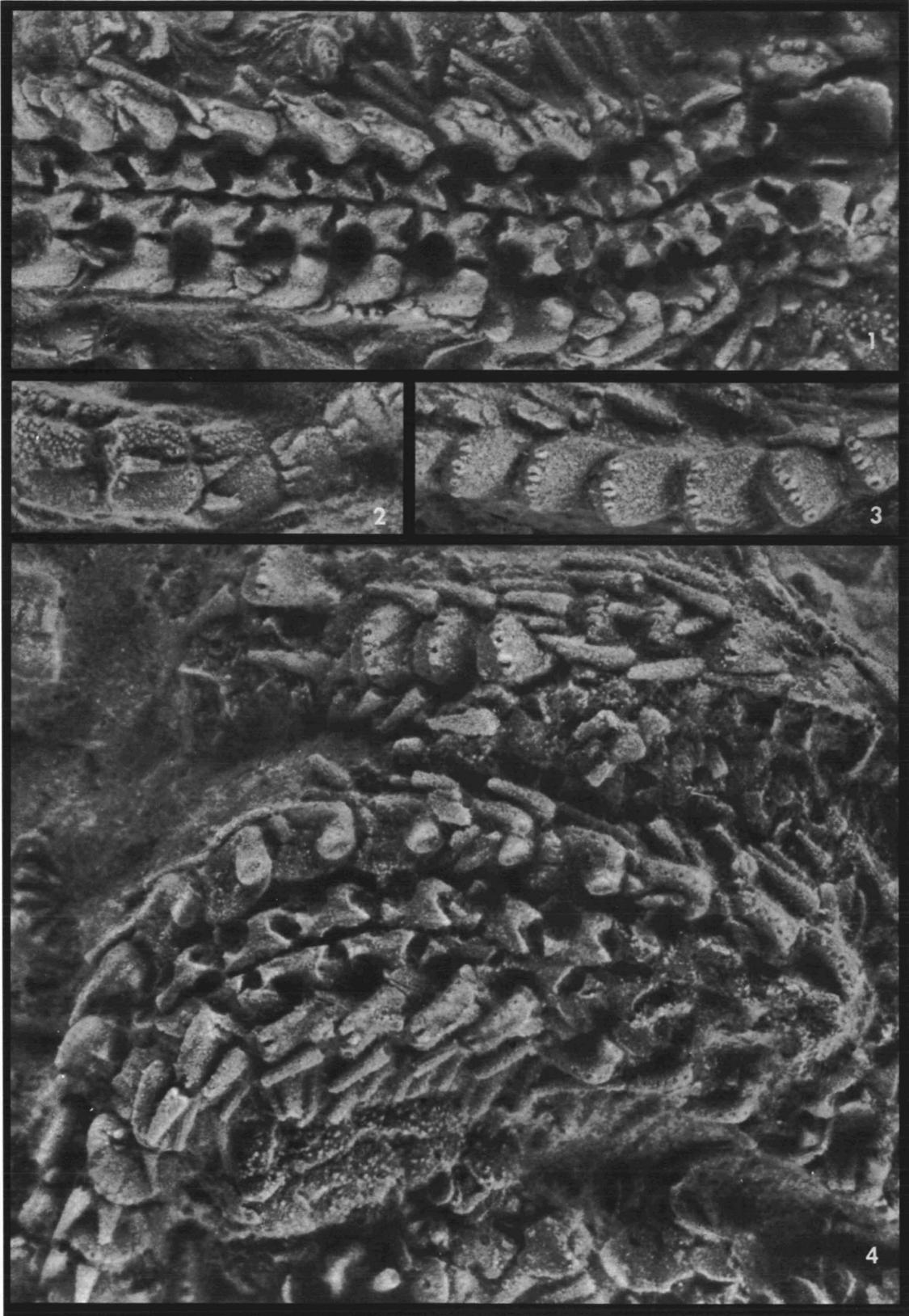


PLATE 6

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MANUSCRIPT RECEIVED MARCH 13, 1969.

## EXPLANATION OF PLATE 6

All figures  $\times 20$

*Eugasterella thorni* n. sp. 1, oral view of proximal part of arm; the junction of  $Amb_1$  and  $Amb_2$  on the lower side marked by an exceptionally large pit for interambulacral muscle attachment; some lateral and ventral spines of side shields shown; view of most of specimen in plate 3, figure 5; holotype UMMP 57475a. 2, inclined lateral view of arm, showing side shields and some adhering aboral integument with papillae; specimen also shown in plate 4, figure 2; paratype UMMP 57484. 3, lateral view of side shields, showing attachment bases for lateral spines; other view of specimen in plate 3, figure 2; paratype UMMP 57474. 4, oral view of parts of two arms, the upper one twisted; in lower arm, the upper row of side shields turned to expose the articulating noses; side shields showing attachment bases of both lateral and ventral spines; paratype UMMP 57479.

