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NEOPALAEASTER ENIGMATICUS, NEW STARFISH
FROM UPPER MISSISSIPPIAN PAINT CREEK
FORMATION IN ILLINOIS

BY
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THE UNIVERSITY OF MICHIGAN
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3. *Neopalaeaster enigmaticus*, New Starfish from Upper Mississippian Paint Creek Formation in Illinois, by Robert V. Kesling, Pages 73-85, with 2 plates and 3 figures.

NEOPALAEASTER ENIGMATICUS, NEW STARFISH FROM
UPPER MISSISSIPPIAN PAINT CREEK FORMATION
IN ILLINOIS

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ABSTRACT

A well-preserved starfish from the Paint Creek Formation is a new species. Its assignment to the genus *Neopalaeaster* necessitates revision of the genus. Large, shield-like plates forming sides of arms are shown to be inframarginals (*Im*'s), not fused inframarginal and supramarginal (*Im* + *Sm*) plates as reported for *Neopalaeaster crawfordsvillensis* (Miller), the type species. Unusual paired plates under and distal to each primary radial (*R*₁) seem to have no counterparts in other starfish; their phylogenetic background, therefore, is enigmatic. The new starfish reveals, for the first time, the oral surface of *Neopalaeaster*. First inframarginals (*Ax*) are axillary, large, nearly confined to oral surface and scarcely reaching the border; second inframarginals (*Im*₂'s) dominate the axils; first adambulacrals (*Ad*₁'s) are modified as oral armature; and ambulacrals (*Am*'s) are definitely opposite, equal in number to adambulacrals (*Ad*'s).

CONTENTS

Introduction 73
Locality 74
Systematic description 74
Literature cited 83
Plates (after) 83

INTRODUCTION

EVEN THOUGH numerous Paleozoic starfish have been discovered in the last century, well-preserved specimens exhibiting both oral and aboral surfaces of disks and arms are still so exceptional that they command attention. Special scientific value is attached to the fossil starfish which proves to be a new species of a previously monospecific genus, for therewith our understanding of the taxon is greatly increased. This is the case of the specimen described here. It distinctly shows most of the

generic characteristics and it is the second species ever discovered of *Neopalaeaster*. Previously, the genus has been known only from two specimens of the type species, neither of which had the oral side exposed. The new starfish assumes an important role in revealing the morphology of *Neopalaeaster* and the monogeneric family Neopalaeasteridae.

In 1965 Professor Donald B. Macurda of our Museum collected a generous sample of the Paint Creek Formation from an exposure on the south bank of Prairie du Long Creek in St. Clair County, Illinois, primarily for the purpose of extracting blastoids. In washing the material by successive immersion in kerosene and water, Mr. Richard L. Wilson, Museum Assistant, noticed the starfish among residues. Additional search of the washings yielded an arm fragment which fitted onto the specimen and another arm fragment which, although similar in structure, did not fit onto the stump of any arm. The larger specimen, in the two parts, consists of the complete disk and the proximal sections of all arms. Careful cleaning with fine needles, dolomite powder abrasion, and brief ultrasonic vibration produced the starfish as illustrated in the plates.

I am very grateful to Professor Macurda for collecting the sample, to Mr. Wilson for finding the specimen, to Mr. Karoly Kutasi for photographic assistance, to Mrs. Helen Mysyk for typing the manuscript, and to Professors Lewis B. Kellum and Chester A. Arnold for critical reading. The starfish is deposited and catalogued in the Museum of Paleontology of The University of Michigan.

LOCALITY

South bank of Prairie du Long Creek, SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 3, T. 2S., R. 9W., St. Clair County, Illinois, Millstadt Quadrangle, near section line between secs. 3 and 10. Mississippian Chester Series, Paint Creek Formation, 0 to 6 inches above basal limestone bed. Sample collected by D. B. Macurda in 1965, accessioned as M-11.

SYSTEMATIC DESCRIPTION

Subclass ASTEROIDEA Burmeister 1837

Order PHANEROZONIDA Sladen 1889

Suborder PUSTULOSA Spencer 1951

Family Neopalaeasteridae Schuchert 1915

Revised description.—Disk capped by numerous small, irregular ossicles surrounded by coronet of conspicuous R_1 and Sm_1 plates. No interbranchial arcs. Sm plates more or less confined to disk. Im plates large, those alongside arms particularly large, shieldlike, reaching from oral surface to near

top of arm. R 's indistinguishable from accessory ossicles beyond R_1 . Orally, Im_1 expressed as large Ax , scarcely reaching border; Im_2 's of each interradius set close together, practically forming axil. Ad_1 's modified into oral armature. Ambulacral groove narrow. Am 's opposite, equal in number to Ad 's. M aboral.

Remarks.—The distinguishing feature of the family is the large, shield-like plates forming sides of the arms. This was pointed out by Schuchert 1915, p. 134), although he interpreted them as fused $Im + Sm$ plates.

Genus *Neopalaeaster* Schuchert 1915

Type Species.—*Palaeaster crawfordsvillensis* Miller, 1880, pp. 256–57, Pl. 15, Fig. 3, by designation of Schuchert, 1915, p. 135.

Original description (Schuchert, 1915, pp. 134–35).—

“Disk of medium size, without interbrachial arcs. Rays five, short and tapering rapidly. Abactinally [aborally] the disk has a small central [C] plate surrounded by numerous smaller plates. Bounding the smaller accessory disk plates is a ring of very large, thick, tumid, variously shaped, radial [R_1] and interradian [Sm_1] plates. Of the latter, there may be one plate inside of the basal supramarginals [Sm_2 's] of adjoining columns, or this plate may be divided, when the pieces appear as inwardly crowded supramarginals. Laterally and distally upon the interradians [Sm_1 's] are situated the large basal radial pieces [R_1 's]. The rays are bounded laterally by columns of large, thick, subquadrate, tubercular supramarginals [actually Im 's] terminated distally by single ocular plates. These plates appear to be common to both the actinal [oral] and abactinal [aboral] areas and must therefore be the united infra- and supramarginal columns. Between the supramarginals distally appear single small isolated plates which proximally become larger and continuous, forming an inconspicuous column of radial [R] ossicles. On each side of this column are inserted a number of apparently irregularly arranged small accessory plates [dI] which are like those of the disk. . . .

“Madreporite [M] small, rounded, not very convex, very finely radially striated and resting directly upon two basal supramarginal plates [Sm_2 's] of adjoining rays. . . . Supra- and inframarginal plates large and conspicuous, apparently firmly united and indistinguishable laterally as separate columns. Abactinally [aborally] the supra-marginal [actually Im 's] are wider and overlie more or less the ambulacrals [Am 's]. Adambulacrals [Ad 's] smaller than the inframarginals [Im 's] but otherwise resemble the latter. Ambulacral grooves narrow. Ambulacral [Am] plates alternating, about as numerous as the adambulacrals [Ad 's], T-shaped, with the podial openings between adjoining plates.”

Revised description.—Disk relatively low; rays tapering to termination in single plate. No interbrachial arcs. Disk flat-topped as preserved, originally probably gently domed, its central area composed of numerous small plates loosely associated and embedded in integument; no C , cR , or cI plates distinguishable from similar intercalated plates, all in shape of

small, rounded, irregular ossicles. Surrounding coronet of ten narrow plates, presumed to have overlapped to a degree and formed a regular decagon, providing some rigidity to top of disk. Sides of disk sloping, radially descending to nearly flat-topped rays.

Coronet containing ten prominent but narrow plates: five R_1 's set normal to radii and five Sm_1 's set normal to interradii. Other Sm plates of disk few but distinct, forming the sides. Border of disk formed entirely by prominent Im plates. Im_1 axillary, confined to oral surface, scarcely reaching border, overlapping edges of Im_2 's. The latter strongly bent, from overlap by Im_1 curving outward and sharply upward onto sides of disk; paired Im_2 's in each interradius set close together. M aboral, low on side of disk; bounded laterally by pair of Sm_2 's.

Arms nearly flat-topped, gently arched, subtrapezoidal in cross section with oral surface wider than aboral. Beyond R_1 of the coronet, R plates degenerate, indistinguishable from numerous dl plates, all in form of small, rounded, irregular ossicles embedded in integument across top of arm and covering upper edges of Am 's. At most, only few Sm plates extending onto arm, filling triangular area between basal row of Im 's, top edge of arm, and disk. Im plates long and large, imbricating distally, strongly convex, curving from edge on oral face, around side of arm, and onto aboral side of arm (there bounding the slightly arched band of irregular ossicles), very similar to side shields of ophiuroids. Im columns converging at end of arm, leading to single terminal plate, perhaps an ocular.

On flat oral surface, Ad plates small, much shorter than bordering edges of Im 's, internally adjoining Am plates. Ad_1 's large and modified as oral armature. Other Ad 's subquadrate to subrhomboidal, very gradually decreasing in size distally, their arrangement opposite, the two columns of each arm set rather close together and restricting ambulacral groove to narrow channel. Am 's equal in number to Ad 's; each plate T-shaped, its median extension directed downward and outward to contact with middle of dorsal edge of corresponding Ad .

Remarks.—Present knowledge of *Neopalaeaster* has been based only upon the type species, *N. crawfordsvillensis* (Miller), itself based upon two specimens, both with aboral plates of the disk somewhat disarranged, both small, and neither showing the oral surface.

One question concerning the new starfish described herein has prime importance: does it belong to the same genus as *Neopalaeaster crawfordsvillensis*? It is perhaps a question that has no conclusive answer until better specimens of the latter are found. Nevertheless, some striking similarities are definitely established: (1) interbranchial arcs absent; (2) numerous

small plates comprising center of disk; (3) disk surmounted by ring of large radial and interradial plates; (4) *M* set between large plates on side of disk; (5) arms composed of large lateral plates, oral *Ad*'s, internal *Am*'s, and aboral covering of small, irregular ossicles; (6) *Ad*'s smaller than lateral plates of arms; and (7) *Am*'s as numerous as *Ad*'s, T-shaped.

Schuchert's information on arm plates was gained from broken ends of arms and a few spots where the aboral ossicles are missing in the two known specimens of *Neopalaeaster crawfordsvillensis*. His report that *Am* plates alternate may be the result of poor preservation in the few places observed. As for his supposed fusion of *Sm* and *Im* plates, the sides of the disk in the holotype, as interpreted by Schuchert in his reconstructed drawing (1915, Pl. 23, Fig. 4), have the two large plates in interradial position set distinctly proximal to other plates forming the margin. This suggests that the large plates are paired *Sm*'s and that the actual bordering *Im* plates are missing or unrecognizable in each axil. Furthermore, Schuchert's drawing does not portray the small *C* of the disk or the *R* plates of the arms as conspicuously differentiated from accessory plates.

Perhaps the two specimens of *Neopalaeaster crawfordsvillensis* died when very young. The larger measures only 25 mm from center of disk to end of arm. In addition to their small size, certain features of the starfish suggest immaturity: many plates appear to be modified little if any by contact with adjacent plates; marginal plates of arms are few; and accessory plates of central areas of arms are also few. Ontogenetic series of other Paleozoic starfish show that wherever accessory plates were developed, they appeared first in proximal regions and spread distally on the arms, becoming more numerous all the while.

The new species of *Neopalaeaster* differs in having proportionally longer arms, more numerous irregular ossicles on disk and arms, and a pair of curious plates on each arm just beyond *R*₁. In addition, the *Im* plates alongside the arms are relatively thin and curved to fit around *Am* and *Ad* plates, not thick and bulky as they appear to be in *N. crawfordsvillensis*.

Although the two species are distinct, major ostensible differences are probably due to preservation and ontogenetic stage, and not true differences at all. That is my analysis at this time. Later, should differences of generic magnitude be established, there will be time and opportunity to create a new genus for the new starfish from the Paint Creek Formation.

In Table I, *Neopalaeaster* is compared with three somewhat similar genera. The limitation of *Sm* plates to the disk and bases of arms readily separates the genus from other phanerozonidans.

TABLE I
COMPARISON OF FOUR GENERA OF PALEOZOIC STARFISH

Character	<i>Neopalaeaster</i>	<i>Palaeaster</i>	<i>Mesopalaeaster</i>	<i>Promopalaeaster</i>
Central plates	Numerous irregular ossicles	Large <i>C</i> and 5 <i>R</i> ₁ 's set in mosaic of accessory plates	Two circlets of plates between <i>C</i> and <i>R</i> ₁	Small ossicles, indistinguishable except for <i>Sm</i> columns
<i>R</i> ₁	Large, very distinct, part of coronet	Distinct, not part of coronet	Large, very distinct	Small, may not be distinct from accessory plates
<i>Sm</i> ₁	Large, very distinct	Large, distinct	Absent (Schuchert, 1915, p. 74)*	Small to medium, distinct
<i>Sm</i> ₂	Distinct, forming sides of disk, continuous with <i>Sm</i> columns of arms			
<i>M</i>	Aboral, set in interradius between two <i>Sm</i> ₂ plates.			
<i>Im</i> ₁ (<i>Ax</i>)	Large, oral, scarcely reaching margin	Very large, oral, definitely marginal	Large, oral restricted from margin by <i>Im</i> ₂ 's	Small, one to several pairs of succeeding <i>Im</i> 's crowded into interbrachial area
<i>Im</i> ₂	Pair forming margin at axil	Pair in each interradius not touching	Pair forming margin at axil	Restricted from margin by <i>Im</i> ₃ 's
<i>Ad</i> ₁	Pair of plates in adjoining columns forming oral armature			
<i>Am</i>	Directly opposite, equal in number to <i>Ad</i> 's		Slightly alternating or opposite, equal in number to <i>Ad</i> 's	
Ambulacral groove	Narrow			Wide
<i>Arms</i>	<i>R</i>	Not distinct, amid accessory ossicles	Not distinct, amid accessory plates in mosaic	Distinct column, few <i>dl</i> accessory plates
	<i>Sm</i>	Few if any, none in distal part	Medium to large	Medium, distinct
	<i>Im</i>	Very large, shieldlike, forming sides of arms	Medium to large, overlain by <i>Sm</i> column	Medium, distinct, alternating with <i>Sm</i> 's above
				Small, may not be distinct from <i>dl</i> accessory plates
				Small to medium, alternating with <i>Im</i> below
				Small to medium, alternating with <i>Sm</i> 's above

* Schuchert (1915, Pl. 10, Fig. 2) shows large and distinct *Sm*₁ plates in *Mesopalaeaster* (?) *clarki* (Clarke and Swartz).

Neopalaeaster enigmaticus, sp. nov.

(Figs. 1-3; Pls. I-II)

Description.—Disk relatively low, flat-topped as preserved (Pl. I, Fig. 4) but probably originally gently domed (Fig. 3). Central aboral area composed of numerous small plates or ossicles loosely associated and presumably embedded in integument stretched across framework of corona. No *C*, *cR*, or *cI* plates distinguishable from similar intercalated small, rounded, irregular ossicles. Periproct probably incorporated in central area, not observed.

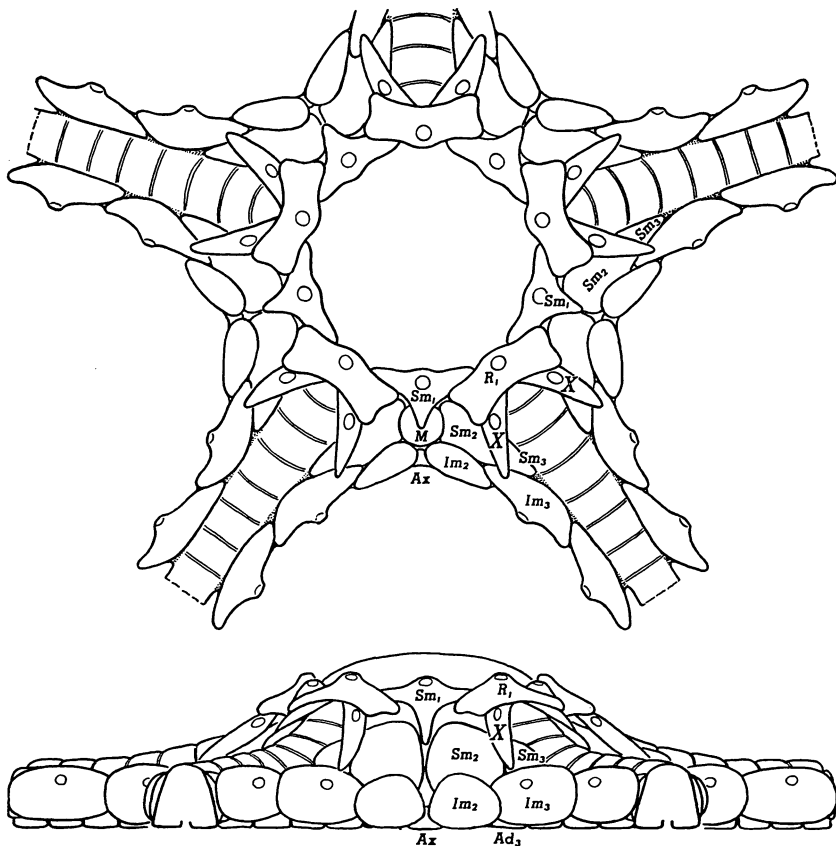


FIG. 1. *Neopalaeaster enigmaticus*, sp. nov. Reconstructed aboral and lateral views of disk and proximal parts of arms. Plate symbols: *Ad*, adamabulacral; *Ax*, axillary, first inframarginal; *Im*, inframarginal; *M*, madreporite plate; *R*, radial; *Sm*, supramarginal; *X*, supernumerary plate, adradial (?).

Coronet of ten prominent but narrow plates, from their size and location presumed to have overlapped to form regular decagon: five R_1 's normal to radii and five Sm_1 's normal to interradii. Each R_1 shaped like broad chevron, its corners somewhat lobate; central articulation pit for well-developed spine (Figs. 1-3; Pl. I, Fig. 2; Pl. II, Fig. 1). Disarticulated robust spines attached to disk, probably from R_1 , Sm_1 , and/or X plates; each spine tapering from rim of articulation, long, stout. R_1 nearly in one plane, set upon shoulder of disk, its lateral extensions probably overlapping ends of adjacent Sm_1 's. Each Sm_1 triradiate, bearing central articulation pit for well-developed spine (Pl. I; Fig. 2; Pl. II, Figs. 1, 4); originally, therefore, caltrop-shaped (Fig. 3).

Sm_2 's largest plates of starfish, a flat pair forming each sloping of disk (Fig. 1; Pl. I, Fig. 4), not firmly abutting against Sm_1 above and possibly not in contact with it. M subcircular, set low on side of disk, fitting into indentations of a pair of Sm_2 's; surface with rather irregular vermiculate pattern of ridges and furrows (Pl. I, Fig. 1). Sm_3 's small, subtri-

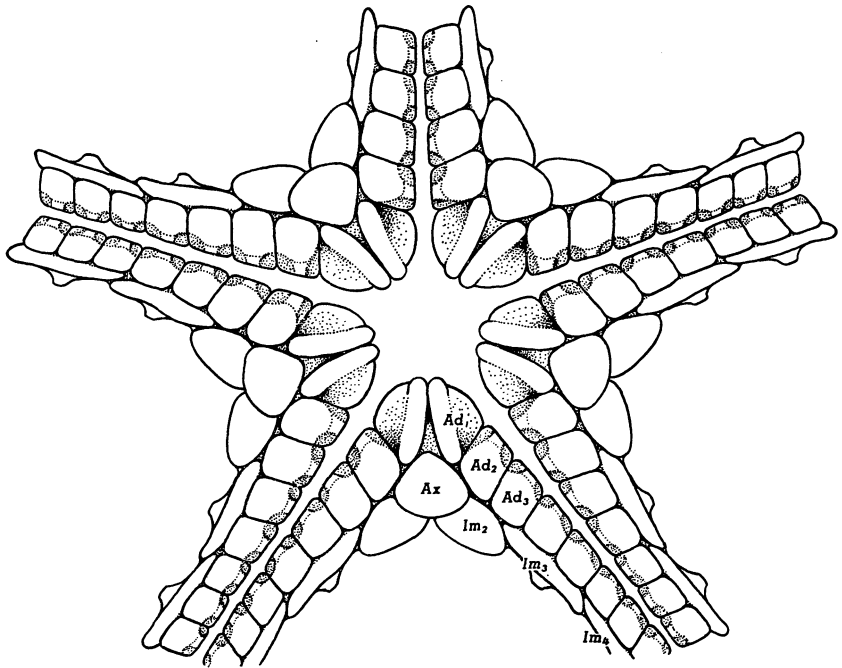


FIG. 2. *Neopalaeaster enigmaticus*, sp. nov. Reconstructed oral view of disk and proximal parts of arms. Plate symbols same as in Figure 1.

angular, each set in angle at junction of arm and disk, continuous with plane of adjacent Sm_2 (Pl. II, Fig. 4).

Im plates especially large and well developed, forming border of disk and arms (Figs. 1-3; Pl. I, Figs. 2-3; Pl. II, Figs. 1-3). Each Ax (first Im) axillary, subcardiform, set on oral surface (Fig. 2; Pl. I, Fig. 3; Pl. II, Fig. 2), nearly tangent to border and overlapping edges of Im_2 's. Im_2 plates large, curving from oral surface (Fig. 2; Pl. I, Fig. 3) onto sides of disk (Fig. 1; Pl. I, Fig. 4), set close together, overlapping Im_3 's. Successive Im plates large, suboval, curved around side of arm, imbricating distally, each bearing prominent elevated articulation pit for spine near its upper middle (Figs. 1, 3; Pl. I, Fig. 4; Pl. II, Fig. 1). Columns of Im 's practically concealing Ad plates in lateral view (Pl. II, Fig. 4).

Pair of long, tapering extraneous plates (X 's) astride each arm at its base, possibly adradial in origin; bases attached close together to shoulder of disk under edge of R_1 (Fig. 1; Pl. I, Fig. 2; Pl. II, Fig. 1), distal tips apparently free, directed distally and downward, and serving as spines (Fig. 3). Prominent, slightly raised articulation pit for spine near middle of each plate.

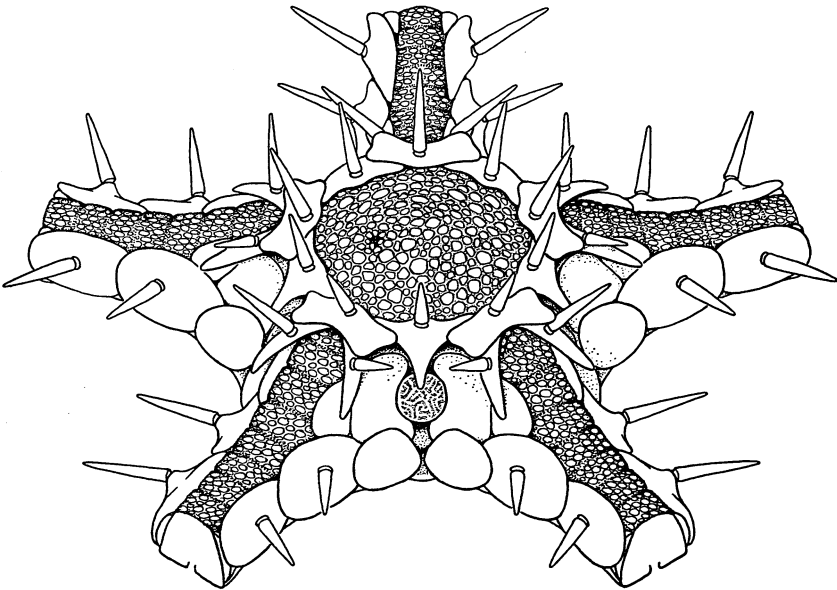


FIG. 3. *Neopalaeaster enigmaticus*, sp. nov. Reconstructed oblique view of disk and proximal parts of arms. M in nearest interradial area. Position of periproct inferred.

Arms nearly flat-topped, gently arched, covered by small, rounded, irregular ossicles (Fig. 3; Pl. II, Fig. 4), undoubtedly embedded in integument stretched between tops of opposing *Im* columns; no *R* or *Sm* plates discernible as such beyond *R*₁ and *Sm*₃. As seen where integument and ossicles absent, *Am* plates equal in number to *Ad*'s (Pl. I, Fig. 4), each T-shaped with its adoral extension directed downward and outward to contact with middle of dorsal edge of corresponding *Ad*.

Oral surface flat. Ambulacral grooves narrow, bordered by columns of *Ad*'s (Fig. 2; Pl. I, Fig. 3; Pl. II, Figs. 2, 3). *Ad*₁'s large, modified as oral armature (Fig. 2; Pl. I, Fig. 3). Other *Ad* plates subrhomboidal, their sutures slanting distally away from ambulacral groove, much shorter than edges of bordering *Im*'s (Fig. 2; Pl. I, Fig. 3; Pl. II, Fig. 2). *Ad* (and presumably *Am*) plates decreasing very gradually in size toward end of arm. Each axil occupied by large *Ax* and parts of adjacent overlapped *Im*₂'s, as mentioned (Pl. II, Fig. 2).

Remarks.—The unusual paired extraneous plates seem to serve a double function. Proximally they are plates of the disk-arm contact, perhaps giving a degree of rigidity to the arm base; distally they act as protective spines, in addition to the spines borne at their centers. These plates seem to have no counterparts in other starfish, although they are clearly represented in *Neopalaeaster enigmaticus*, suggesting the trivial name.

The large, curved, oval *Im* plates, on each arm set like shields along the sides of a Viking long ship, provided strong lateral protection by their mass and spines and also supplied the frame for the integument across the top of the arm. This form and function constitute an example of convergence with the side shields of the ophiuroids. To judge from the imbrication of these *Im* plates, reduced lateral flexibility was the price for such armor. Flat, spineless *Ad* columns suggest that this starfish was not a typical filter-feeder, despite the generally weak construction of the disk and arms.

Types.—Holotype, UMMP 54262, disk and parts of arms. Paratype, UMMP 54263, distal part of an arm, found in association with holotype and perhaps part of it even though the two do not fit together.

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- MILLER, S. A. 1880. Description of Two New Species from the Niagara Group, and Five from the Keobuk Group. Journ. Cincinnati Soc. Nat. Hist., Vol. 2, pp. 254-59, Pl. 15.
- SCHUCHERT, CHARLES. 1915. Revision of Paleozoic Stellerioidea with Special Reference to North American Asteroidea. U. S. Nat. Mus., Bull. 88, 311 pp., 38 pls., 41 figs. in text.

PLATES

EXPLANATION OF PLATE I

- | | PAGE |
|---|------|
| <i>Neopalaeaster enigmaticus</i> , sp. nov. | 79 |
| <p>FIG. 1. Madrepor (<i>M</i>) plate of holotype, UMMP 54262; about x 20. Specimen coated with ammonium chloride.</p> | |
| <p>FIGS. 2-4. Aboral, oral, and lateral views of holotype, x 5. Specimen submersed in xylol. <i>Am</i> plates visible in Figures 2, 4, where <i>Im</i> plates are missing from side of arm.</p> | |

PLATE I

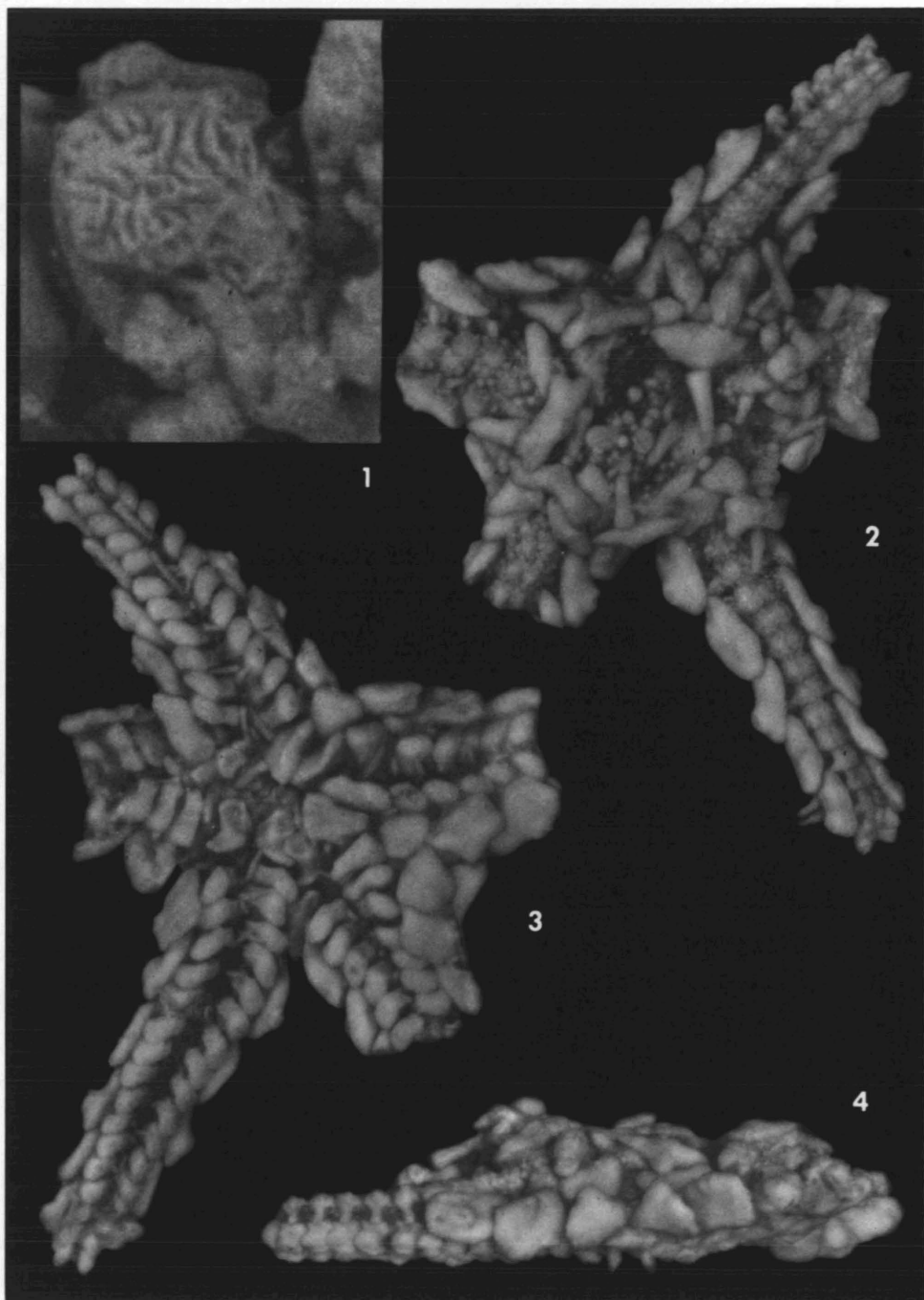
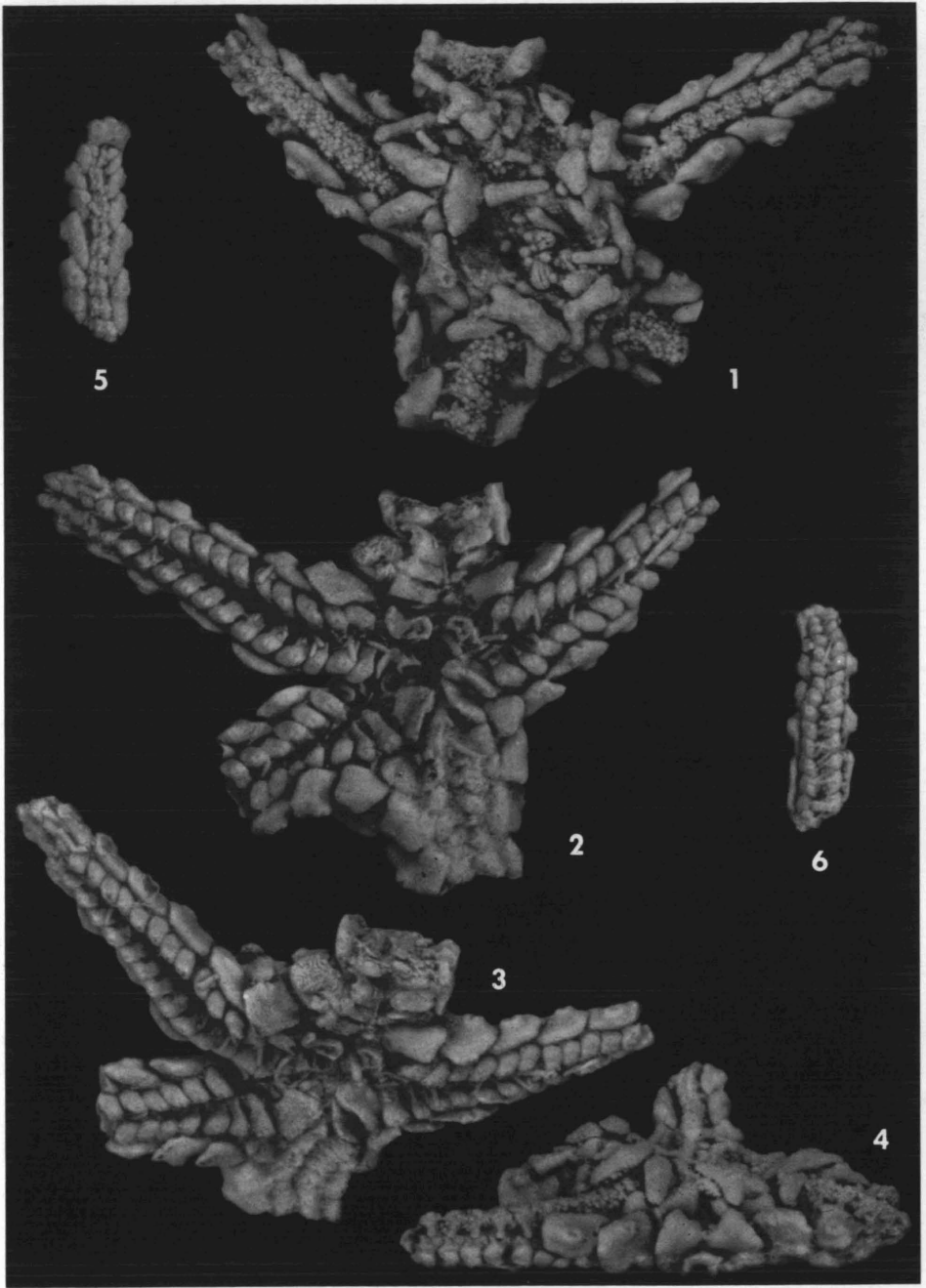


PLATE II



EXPLANATION OF PLATE II

(All figures x 4)

	PAGE
<i>Neopalaeaster enigmaticus</i> , sp. nov.	79
FIGS. 1-4. Aboral, oral, inclined oral, and lateral views of holotype, UMMP 54262. Specimen coated with ammonium chloride. <i>M</i> plate shown in Figure 3; <i>Am</i> plates visible in Figure 4.	
FIGS. 5-6. Aboral and oral views of paratype, UMMP 54263, nearly terminal section of arm.	

