Asteroidea (Echinodermata)

By J. W. BRANSTRATOR

CONTRIBUTIONS TO THE ORDOVICIAN PALEONTOLOGY OF KENTUCKY AND NEARBY STATES

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Systematics and paleoecology of four species, with comments on two species of uncertain systematic position

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CONTENTS

	Page
Abstract	F1
Introduction	1
Acknowledgments	1
Terminology	2
Systematic paleontology	2
Promopalaeasteridae	2
Promopalaeaster	2
Promopalaeaster speciosus	2
Promopalaeaster finei	4
Schuchertiidae	4
Lanthanaster	4
Lanthanaster intermedius	4
Stenasteridae	5
Stenaster	5
Stenaster obtusus	5
Species inquirenda	6
References cited	6

ILLUSTRATIONS

PLATE 1. *Promopalaeaster*.
2. *Promopalaeaster, Stenaster*.
3. *Lanthanaster, Mesopalaeaster*, Species Inquirenda.

SYSTEM OF MEASUREMENT UNITS

The investigations underlying this series of reports were made over a period of years, and distances and stratigraphic measurements appear fairly uniformly in English units. Measurements of fossil specimens, on the other hand, follow the long-standing convention of appearing in metric units. Because of the dates of the investigations and the amount of resulting data, the English measurements have been retained. Conversions to metric units may be made by using the following conversion table:

To convert English unit:	To metric unit:	Multiply by:
Mile (mi)	Kilometer (km)	1.61
Foot (ft)	Meter (m)	.305

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ASTEROIDEA (ECHINODERMATA)

By J. W. BRANSTRATOR [1]

ABSTRACT

Specimens belonging to the stelleroid genera *Promopalaeaster, Lanthanaster,* and *Stenaster* have been obtained from Kentucky's Middle and Upper Ordovician rocks. *Promopalaeaster speciosus* (Meek) is a subjective senior synonym of *P. prenuntius* Schuchert. Lectotype and paralectotype specimens are designated from the syntypes of *Palaeaster finei* Ulrich and *Mesopalaeaster proavitus* Schuchert; both type suites are composed of immature specimens of *Promopalaeaster finei* (Ulrich) n. comb. By subjective synonomy, *Mesopalaeaster intermedius* (Schuchert) n. comb. replaces *Lanthanaster cruciformis* as the type species of *Lanthanaster* Branstrator. The generic affinities of *"Hudsonaster milleri"* Schuchert and *"Mesopalaeaster? dubius"* (Miller and Dyer) Schuchert cannot be determined from available materials.

INTRODUCTION

Verrill (1914, p. 17) noted that a particular difficulty in the determination of genera and species of starfishes is that many do not attain their adult or diagnostic characteristics until of considerable size. Thus, young individuals of a species may appear to belong to different species, or even different genera, unless they can be compared with individuals in a growth series. I have attempted to piece together growth series for the fossil starfish species known from North America. This report deals with the results as applied to specimens from Kentucky.

Most asteroid specimens from the later Ordovician strata in Kentucky belong to species, described previously, from Cincinnati and southwestern Ohio. Geographic and lithostratigraphic data accompanying the type and supplementary specimen material from Ohio are usually poor, however. Kentucky's earlier Ordovician rocks have no time-equivalent strata exposed in the classic collecting sites in adjacent states. Some specimens from these earlier rocks belong to species described from ostensibly time-equivalent and lithologically similar strata in southeastern Canada and the British Isles. Although commonly coarsely recrystallized or disarranged during preservation, new specimens of *Promopalaeaster finei, Lanthanaster intermedius,* and *Stenaster obtusus* from Kentucky are most valuable because of the fine lithostratigraphic control with which they were collected. These specimens shed light on the succession and paleoecology of species originally described from elsewhere.

Museum's from which specimens were borrowed have their names abbreviated as follows: U.S. National Museum of Natural History—USNM; Museum of Comparative Zoology, Harvard University—MCZ; University of Kentucky—UK; Yale University Peabody Museum—YPM; American Museum of Natural History—AMNH; Field Museum of Natural History—FM; University of Michigan, Museum of Paleontology—UM; and University of Cincinnati, Geology Museum—UC.

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TERMINOLOGY

Spencer and Wright (1966, p. 28–30) provided a useful glossary of morphological terms applied to asterozoans. Their terminology is used herein, with exceptions and additions as follows: **Brachium** is used interchangeably with **arm. Odontophore** refers only to one of the ossicles functionally involved in the operation of the mouth frame. This particular ossicle is seldom visible on the external skeletal surface of fossil specimens, and many authors incorrectly refer to any unpaired, exposed axillary inferomarginal as an odontophore. **Perradial** indicates a feature on or near a vertical plane that would longitudinally bisect each brachium. **Abradial** indicates a position relatively away from this plane.

Brachial length (R) is commonly used to denote size in stelleroids. It is the mean distance between the geometric center of the disc and each arm tip. Only an approximate value for this parameter is possible for most fossil specimens because they are commonly fragmental or distorted from their living proportions.

Systematic Paleontology

Family PROMOPALAEASTERIDAE Schuchert, 1914
Genus PROMOPALAEASTER Schuchert, 1914

Palaeaster [*part*], 1868–1914.
Mesopalaeaster Schuchert [*part*], 1914, p. 24–25; [*part*], 1915, p. 74–77.
Promopalaeaster Schuchert [*part*], 1914, p. 5–6, 33–34; [*part*], 1915, p. 102–106.
Spencer [*part*], 1916, p. 91–92.
Spencer and Wright [*part*], 1966, p. 53.
Anorthaster Schuchert, 1914, p. 5–6, 11–12; 1915, p. 125–126.
Spencer and Wright, 1966, p. 53.

Diagnosis.—Asteroids with all external ossicle surfaces having numerous, prominent spine-base pustules, each pustule carrying or having carried, a single articulating spine; paxillae never present. All primary columns of ossicles prominent throughout life. Intermarginal and adradial ossicles arranged in longitudinal columns as well as transverse rows. More prominent transverse rows of intermarginals alternate with less prominent ones. Podial pores abradial to ambulacral ossicle bodies at junctions of ambulacral and adambulacral ossicle columns. Proximal podial cupules quadriserial; distal podial cupules biserial.

Type species.—*Palaeaster speciosus* Meek (1872); by original designation of Schuchert (1914) as "*Palaeaster granulosus* Meek" [=*Palaeaster speciosus* Meek].

Promopalaeaster speciosus (Meek, 1872)
Plate 1, figures 1–3

Palaeaster granulosus? Hall. Meek, 1872, p. 227; 1873, p. 60–61, pl. 4, figs. 3a–c.
Palaeaster speciosus? Meek, 1872, p. 227; 1873, p. 60–61, pl. 4, figs. 3a–c.
Promopalaeaster prenuntius Schuchert, 1915, p. 107–108, pl. 13, fig. 3; pl. 15, fig. 5.
Promopalaeaster speciosus (Meek). Schuchert, 1914, p. 34; 1915, p. 109-112, pl. 14, figs. 3–4; pl. 15, figs. 1–4.
Spencer and Wright, 1966, p. 53.

Diagnosis.—*Promopalaeaster* with intermarginal, but not adradial accessory ossicles arranged in alternately prominent transverse rows. Intermarginals and adradials tumid and nearly as massive as adjacent ossicles of primary columns; not substantially excavated on ossicle margins.

Materials and occurrence.—The holotype MCZ 22, Dyer Colln.) is from Cincinnati, Ohio. No additional stratigraphic or locality data accompany the specimen or are included in Meek's description. Schuchert (1915, p. 110–111) states unequivocally that the specimen was collected "in the Maysvillian at Cincinnati, Ohio." Although no specific reason exists to doubt this information, its authenticity cannot be documented, and it must be regarded as an inference on Schuchert's part.

Promopalaeaster prenuntius Schuchert (1915, 107–108) is a subjective synonym of *P. speciosus*. It was described from its holotype (UK 403), which was found in a coarse calcarenite in the Lexington Limestone (Middle Ordovician part) near Frankfort, Ky. A brachial fragment of another individual (YPM 3405) came from the same area and is similarly preserved. Natural molds of eight poorly preserved individuals in a calcarenitic slab (AMNH 1100) labeled "Hudson River Group [Upper Ordovician], near Rome, New York" considerably extend the geographic range of *P. speciosus*.

Description.—Known specimens of *P. speciosus* range in size from $R=20$ mm (Rome, N.Y. specimen) to $R=44$ mm (the holotype). Both Kentucky specimens have brachial lengths near 35 mm.

Dorsal and ventral aspects are available from the *P. speciosus* holotype (pl. 1, figs. 1*A–C*). The specimen is composed of two, nearly complete, adjacent brachia, which meet at their bases in an acute angle. Each arm tapers slowly to a broadly acuminate tip.

One open ambulacral groove is clear of matrix and shows details of ambulacral ossicle structure and arrangement.

Each ambulacral ossicle possesses a prominent ventral carina. Perradial nodes (pl. 1, fig. 1*C*) on the ventral carina are also prominent, and form deep ambulacral channels for the lengths of the brachia. The ventral carinae on the distal half of each brachium are straight and define two columns of podial cupules in the ambulacral groove. On the proximal portion of each brachium the ventral ambulacral carinae lie alternately diagonally on the ambulacral ossicles and form four longitudinal columns of cupules. Dentition, or hinge structure, marks abutting surfaces between opposite ambulacral ossicles of adjacent columns. Contact with the adjacent adambulacral ossicle is by means of a prominent abradial flange on the ventral carina of each ambulacral ossicle. Most of the ossicle body of each ambulacral ossicle overlies the proximal portion of the next more distal ossicle.

The intermarginal ossicles of *P. speciosus* are arranged in longitudinal columns as well as diagonally transverse rows. Close examination reveals that these rows are composed of ossicles in two size groups. A row of small ossicles intercalates between each row of larger ossicles (pl. 1, fig. 1*A*), and one of these paired series occurs for each inferomarginal and corresponding superomarginal on the lateral surface of an arm. This biserial intermarginal condition is common to all promopalaeasterids, but the intermarginals of *P. speciosus* are relatively more massive and carried many more spines than those of other promopalaeasterid species.

Like the intermarginals, the adradial ossicles of this species are relatively massive and carried many more spines than similar ossicles of other promopalaeasterids. Abradial adradials of *P. speciosus* are at least as prominent as adjacent superomarginals (pl. 1, figs. 1*A–B*). The adradials are excavated only slightly at their margins for the accommodation of dermal papulae. Furthermore, the paired subseries arrangement common to the adradials of other promopalaeasterids and the intermarginals of all promopalaeasterids does not occur in this species.

Discussion.—The Kentucky specimens of *P. speciosus*, from the Lexington Limestone, are probably older than the holotype and New York specimens, as much of the Lexington Limestone is Middle Ordovician and the New York specimens are Late Ordovician in age. Schuchert (1915, p. 107) assumed the holotype of his *P. prenuntius* to be distinct from *P. speciosus* because of its "smaller size, less pustulose ornamentation of the plates, and lower position in the geological column." These are not tenable criteria for species differentiation among asteroids.

Overall size, arm length, disc width, number of ossicles in a particular brachial column, number of intercalating ossicles in a brachial column, and number of intercalating columns—all increase with maturity in asteroids. The "pustulose ornamentation" referred to by Schuchert in distinguishing *P. prenuntius* from *P. speciosus* is simply an indication of overall spinosity of an individual. Spinosity varies intraspecifically in asteroids and, in fact, increases with size in some genera (Rasmussen, 1965). Hence, the morphological characteristics used by Schuchert to distinguish *P. prenuntius* from *P. speciosus* may be useful in describing individuals, but they should be avoided in species characterization, unless the maturity of the examined specimens can be determined by comparison with other individuals in a growth series. Without substantiating morphological evidence, the stratigraphic occurrence criterion Schuchert used to distinguish his new species is meaningless.

The holotype, UK 403, presents a ventral aspect that reveals details of ambulacral ossicle structure. Quadriserial podial cupules occupy less of the arm lengths in this less mature specimen than they do in the larger *P. speciosus* holotype. An overturned arm tip (pl. 1, fig. 2) reveals that the specimen possesses the adradial ossicle condition unique to this species of *Promopalaeaster*.

The Lexington Limestone specimens show the fenestrate nature of the ossicles. The coarse calcarenitic matrix imposed some distortion to the ossicle surfaces, but has allowed differential weathering of replaced stereom and stromal canal filling. Spines (pl. 1, fig. 3) and ossicles of these early asteroids had internal microstructures similar to those of modern echinoderms.

Paleoecology.—Where matrix is available with specimens of *P. speciosus* (all but the holotype), it is calcarenite, rather than the fossiliferous calcilutite found with the other species of the genus. The internal ampullae, the primary organs of respiration in modern asteroids, were connected remotely to the external podia in the promopalaeasterids. This imposed a respiratory inefficiency on this system in these early forms (Branstrator, 1975). Furthermore, the alternate organs of respiration in asteroids, dermal papulae, were not well developed in this species. *P. speciosus* probably inhabited relatively high energy, oxygen-rich areas.

Promopalaeaster finei (Ulrich, 1879) n. comb.

Plate 1, figures 4–9; plate 2, figures 1–6

Palaeaster finei Ulrich, 1879, p. 19, pl. 7, figs. 15a–b.
Mesopalaeaster finei (Ulrich). Schuchert, 1914, p. 25; 1915, p. 81–82, pl. 7, fig. 5; pl. 9, fig. 5.
Mesopalaeaster proavitus Schuchert, 1915, p. 83–84.

Diagnosis.—*Promopalaeaster* with intermarginal and adradial accessory ossicles arranged in alternately prominent transverse rows. Intermarginal and adradial ossicles less massive than adjacent ossicles in primary columns; substantially excavated on ossicle margins.

Materials and occurrence.—The syntype material of *Palaeaster finei* Ulrich, 1879 (USNM 60604) is from the Upper Ordovician "Eden Shale" (=Kope Formation) in eastern Cincinnati, Ohio. The lectotype is herein designated as the specimen figured on plate 2, figure 1 of this report; it has been circled on its slab by this author to distinguish it from other syntypes, which become paralectotypes. Ulrich's original suite may have included YPM 14779, but because this is uncertain I am excluding these latter specimens from paralectotype designation.

William H. White, Jr., of Milford, Ohio, found a number of small specimens (UC 40371–40383) in the Kope Formation at the junction of Beechmont and Elstun Avenues in eastern Cincinnati. USNM 236052 is from USGS locality 6419–CO (Logana Member of the Lexington Limestone). The syntypes of *Mesopalaeaster proavitus* Schuchert (1915) (FM 54069, Walker Colln.) are from the "Eden Shale" (=Kope Formation) at Covington, Ky. The largest specimen (pl. 1, fig. 4) in the suite is herein designated as the lectotype of Schuchert's *M. proavitus;* the remainder of the syntype specimens become paralectotypes (pl. 1, fig. 5). *M. proavitus* material has not been figured previously. UM 6230 came from Cincinnati, but its stratigraphic occurrence is unknown. UC 40758, Winnes Colln. (pl. 1, fig. 9), is from an undetermined stratum near Augusta, Ky. Two coarsely silicified specimens, USNM 236051 and 236050 (pl. 2, fig. 5), are known from USGS locality 6134–CO (Clays Ferry Formation). AMNH 1196 and USNM 92613 are from undetermined strata in Cincinnati, Ohio, and Covington, Ky., respectively. Finally, USNM 236049 is from USGS locality 6803–CO (Grier Limestone Member of the Lexington Limestone).

Description.—The specimens listed after the type material above are in order of increasing size. They range from $R=2$ mm (UC 40378), through the juvenile *P. finei* lectotype with $R=9$ mm, to USNM 236049 with a brachial length greater than 40 mm. The generic and specific diagnoses serve to distinguish *P. finei* from other Kentucky asteroids.

The numerous specimens of various sizes make available some important information on skeletal ontogeny in this promopalaeasterid. The nonadaxial relationship between the axial and extraxial skelton is apparent from the smallest of juvenile growth stages; there are always more adambulacral ossicles than inferomarginal ossicles in adjacent columns (pl. 1, figs. 5, 7; pl. 2, figs. 1, 2*B*, 3*B*, 4, 6*A*)—this characteristic is useful in distinguishing all growth stages of this genus from those of *Mesopalaeaster,* which always has 1–to–1 ratio of ossicles in adjacent adambulacral and inferomarginal columns. Adoral carinae are absent in small individuals (pl. 2, fig. 6*A*), but develop in specimens over 20 mm (pl. 2, fig. 2*B*). Unpaired axillaries become isolated from the ambitus by radial length 6 mm (pl. 2, fig. 6*A*), and become progressively more isolated throughout growth (pl. 2, fig. 2*B*, lower axil). The youngest specimens (less than 3 mm) do not have adradial or intermarginal accessory ossicles, but both kinds of ossicles are present by $R=5$ mm and increase in number throughout growth (pl. 2, figs. 6*B–D*, 2*A*, 3*A;* pl. 1, figs. 4, 6, 8, 9). Mature specimens of *Mesopalaeaster* developed no more than two or three columns of intermarginal ossicles (pl. 3, fig. 4); juvenile *Promopalaeaster* are difficult to distinguish from this latter genus when only dorsal aspects are available.

Paleoecology.—This species appears to have been adapted to a less oxygenated habitat than *P. speciosus.* Quadriserial podia occupied more of the brachial lengths in *P. finei.* Individuals of all sizes possessed numerous large papulae protruding through pores in the dorsal and lateral wall; these were necessary to supplement podial respiration. All specimens of *P. finei* are in, or appear to have come from, a calcilutite or mixed calcilutite-calcarenite matrix suggestive of quieter waters than the calcarenite matrix of *P. speciosus.*

Family SCHUCHERTIIDAE Schuchert, 1915
Genus LANTHANASTER Branstrator, 1972
Lanthanaster Intermedius (Schuchert, 1915) n. comb.

Plate 3, figures 1–3

Mesopalaeaster intermedius Schuchert, 1915, p. 79–81, pl. 9, fig. 4.
Lanthanaster cruciformis Branstrator, 1972, p. 66–69, pl. 1.

Diagnosis.—Stelleroid possessing only ambulacral, adambulacral, and inferomarginal primary ossicles in the brachia. Dorsal skeleton of small cruciform ossicles, each surmounted by a single articulating spine. Ambulacral ossicles dorsoventrally flattened except for a high ventral carina. Ampullar pores at

junctions of ambulacral and adambulacral columns. Few short, broad spines on low spine-base pustules on inferomarginals and large, deltoid ventral interbrachials. Madreporite on ventral surface.

Materials and occurrence.—The holotype (FM 9575, Faber Colln.) is from rocks of Maysvillian Age at Cincinnati, Ohio. The holotype of the synonymous species *Lanthanaster cruciformis* Branstrator (1972), UC 6433, is also from Maysvillian-Age rocks in Cincinnati. Another Cincinnati specimen (USNM 92608) came from the Kope Formation. Silicified fragments of at least five small individuals (USNM 236053) have been etched from the upper part of the Clays Ferry Formation at USGS locality 6143-CO.

Description.—The holotype (pl. 3, fig. 1) is fragmental and shows portions of the ventral surfaces of two brachia. Its brachial length is nearly 14 mm. The more mature University of Cincinnati specimen possesses all five brachia, shows both dorsal and ventral surfaces, and is more than twice the size of the holotype. The other known specimens are smaller and less well preserved than either of these.

The University of Cincinnati specimen best shows the cruciform dorsal ossicles and dorsal (pl. 3, fig. 2*B*) and ventral (pl. 3, fig. 2*A*) spines. No spines are preserved with the holotype, nor are any cruciform dorsal ossicles apparent. The Kentucky specimens (pl. 3, figs. 3*A–C*) are too coarsely recrystallized to preserve well either of these characteristics.

The madreporites of the Kentucky specimens (pl. 3, fig. 3*B*) are more tumid than that of the University of Cincinnati specimen (pl. 3, fig. 2*A*), but this may be an ontogenetic difference. Other than this difference, the newly recognized Ohio and Kentucky specimens confirm my earlier description of this species (Branstrator, 1972, p. 66–68). Schuchert's supposition (1915, p. 81) that the hidden dorsal surface of his specimen, was similar to that of *Mesopalaeaster* was an error.

Discussion.—Schuchert (1915, p. 80) believed his species to be an intermediate form between the species he included in *Hudsonaster* and *Mesopalaeaster*. The single, large, marginal, ventral interbrachial ossicle (characteristic of *Hudsonaster*), the wide ambulacral groove (a feature he believed common to *Promopalaeaster* species), and the ambulacral ossicles of a form "known in *Mesopalaeaster*" make a paradoxical combination best reconciled (to Schuchert's thinking) by the supposition that his new species was an evolutionarily intermediate form. The axillary intermarginals, while single as in *Hudsonaster*, are not otherwise similar to those of that genus. *Lanthanaster* axillary intermarginals are deltoid, possess few, scattered spine-base pustules, and are widest orad of their midlength; *Hudsonaster* axillaries are sagittate, have many, crowded spine-base pustules, and are widest distal to their midlength. Had Schuchert known of the distinctive dorsal ossicles and of the ventral madreporite in the species that his specimen represented, he would not have placed it in *Mesopalaeaster*.

I did not recognize Schuchert's error in placing his specimen among the *Mesopalaeaster* prior to my description of *Lanthanaster cruciformis*. I have subsequently examined Schuchert's holotype and found that it must be included in the same species as the specimen I described. Schuchert's trivial name has priority, but the species does not belong in *Mesopalaeaster* or any genus erected prior to *Lanthanaster*.

Paleoecology.—Until the ecological significance of the ventral madreporite is known, it will be difficult to determine the paleoecology of *Lanthanaster*. The Kentucky specimens are from a unit reported to be representative of outer infralittoral (Cressman and Karklins, 1970, p. 21). The cruciform ossicles provided a fenestrated dorsal surface, probably as an aid to papular respiration—a necessity in an infralittoral habitat.

Family STENASTERIDAE Schuchert, 1914
Genus STENASTER Billings, 1858
Stenaster obtusus (Forbes, 1848)

Plate 2, figures 7, 8

Uraster obtusus Forbes, 1848, p. 463; 1849, p. 2, pl. 1, fig. 3.
Stenaster salteri Billings, 1858, p. 78, pl. 10, fig. 1a. Schuchert, 1915, p. 165–166, p. 32, fig. 1.
Stenaster obtusus (Forbes). Stürtz, 1886, p. 152; Spencer, 1914, p. 23, pl. 1, figs. 6–7; Schuchert, 1915, p. 167; Spencer, 1927, p. 356–359, pl. 23, figs. 1–9; pl. 24, fig. 10; Fedotov, 1936, p. 10–17, pl. 1, figs. 3–6; Spencer and Wright, 1966, p. 82, text figs. 70, 2a–d.

Diagnosis.—Only ambulacral and adambulacral primary ossicles in the brachial skeleton. Dorsal skeleton of minute granules originally invested in an integument, but commonly not apparent in fossils. A deep groove between opposite pairs of dorsoventrally thick ambulacral ossicles accommodated the radial vessels.

Materials and occurrence.—The holotype is a mold in a mudstone of Caradocian Age from Waterford, Ireland. Spencer (1927, pl. 23, fig. 8) illustrated a cast of the specimen. He also included in the species specimens from the Cardocian of Bala, Wales, the Ashgillian of Scotland, and North Ameri-

can specimens referred to *Stenaster salteri* Billings by Schuchert (1915, p. 165–166). Most North American specimens come from Ontario, where *S. obtusus* is common in the Hull Limestone (Middle Ordovician) at the Kirkfield quarries. In addition, Marshall Kay found a well-preserved specimen in the Long Point Limestone (Middle Ordovician), Newfoundland. Fedotov (1936) reported it from two Middle Ordovician localities in Kazakhstan (U.S.S.R.).

Three coarsely silicified brachial fragments of *Stenaster cf. S. obtusus* (USNM 263054) have been etched from the Curdsville Limestone Member of the Lexington Limestone at USGS locality 5101–CO. Schuchert (1915, p. 166) reported that Ulrich obtained four isolated brachial fragments from the same rock unit near Curdsville, Ky.

Description.—Beekite has replaced the calcitic stereom in the USNM 263054 specimens, but the diagnostic characteristics of the primary ossicles are apparent (pl. 2, fig. 8). Only ambulacral and adambulacral ossicles are present, and the deep groove that accommodated the radial vessels is apparent.

The typical asteroid dorsal skeleton of massive primary and intercalated ossicles is absent in *Stenaster*. The dorsal integument was ossified by small elongate granules (Ruedemann, 1916, p. 54) that are commonly not apparent in fossils. A specimen (UC 36426) from Kirkfield, Ontario, retains some of these granules (pl. 2, fig. 7), but they are not apparent on the Kentucky specimens owing to poor preservation.

The Curdsville Limestone Member of the Lexington from which the Kentucky specimens were extracted is reported to have been a calcarenite deposited in littoral and infralittoral zones (Cressman and Karklins, 1970, p. 18). The Welsh specimen is also preserved in a calcarenite. The peculiar disarrangement of individuals in the rich faunas associated with the Kirkfield, Ontario, and the Scottish specimens suggest that they were swept some distance and then buried as the results of storms.

Species inquirenda

Plate 3, figures 5–8

Several asteroid specimens of indeterminable affinities are known from Kentucky rocks and deserve mention because they have been designated holotypes of species or have been mentioned in the literature.

The holotype of "*Hudsonaster milleri*" Schuchert (1915), UK 1344, shows its ventral surface and is preserved in a recrystallized calcarenite of the lower part of the Lexington Limestone in Fayette County, Ky. Parts of four brachia remain, although preservation is poor and taxonomically significant details have been obscured. The large axial inferomarginals (pl. 3, fig. 5), which did not function as odontophores, suggest that Schuchert's generic placement of the specimen was incorrect because axillary inferomarginals are odontophores in *Hudsonaster*.

Schuchert (1915, p. 60) conditionally placed a coarsely silicified specimen (YPM 13178) found at Curdsville, Ky., in *Hudsonaster narrawayi* (Hudson), 1912 [=*Protopalaeaster narrawayi* Hudson] because it posseses a smaller disc, a stouter appearance, and smaller axillary ossicles than other specimens of that species known to him. The specimen (pl. 3, figs. 6*A–B*) has a few adradial and intermarginal ossicles on its dorsal surface, however, which suggests that it is a developmental form of *Promopalaeaster*. The suite of young *P. finei* donated to University of Cincinnati by William H. White, Jr., shows such a hudsonasterid-like stage in the very early postlarval development of that species.

Schuchert (1915, p. 62) reported a specimen (USNM 60617, Ulrich Colln.) of "*Hudsonaster incomptus*" from the "Maysville formation" south of Covington, Ky. The specimen is disarranged and abraded, however, and generic determination is impossible.

A specimen (MCZ 25) from the "river quarries" (Point Pleasant Tongue of the Clays Ferry Formation) at Ludlow, Ky., was designated the holotype of "*Palaeaster ?dubius*" Miller and Dyer (1878). More of this specimen (pl. 3, fig. 7) has been rendered from its matrix since its original description, but still no diagnostic characters can be seen. It appears to be an asteroid and therefore distinct from a poorly preserved oegophiurid (YPM 11771) from the same quarries. The oegophiurid specimen (pl. 3, fig. 8) has unusually long mouth-angle ossicles, distinct tori, and long narrow ambulacral ossicles.

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PLATES 1–3

Contact photographs of the plates in this report are available, at cost, from U.S. Geological Survey Library, Federal Center, Denver, Colorado 80225

PLATE 1

FIGURE 1. *Promopalaeaster speciosus* (Meek). Unknown horizon, Cincinnati, Ohio; MCZ 22, holotype. *A*, Arm, dorsolateral aspect, arrow 1 points ossicle of smaller intermarginal subseries; arrow 2 points ossicle of larger intermarginal subseries, × 8 (p. F2). *B*, Theca, dorsal aspect × 2 (p. F2). *C*, Theca, ventral aspect, arrow points to perradial node × 2 (p. F2).

2. *Promopalaeaster speciosus* (Meek). Lexington Limestone, near Frankfort, Ky.; UK 403 (holotype of *P. prenuntius* Schuchert). Ventral aspect with one brachial tip (arrow) overturned, × 1.5 (p. F2).

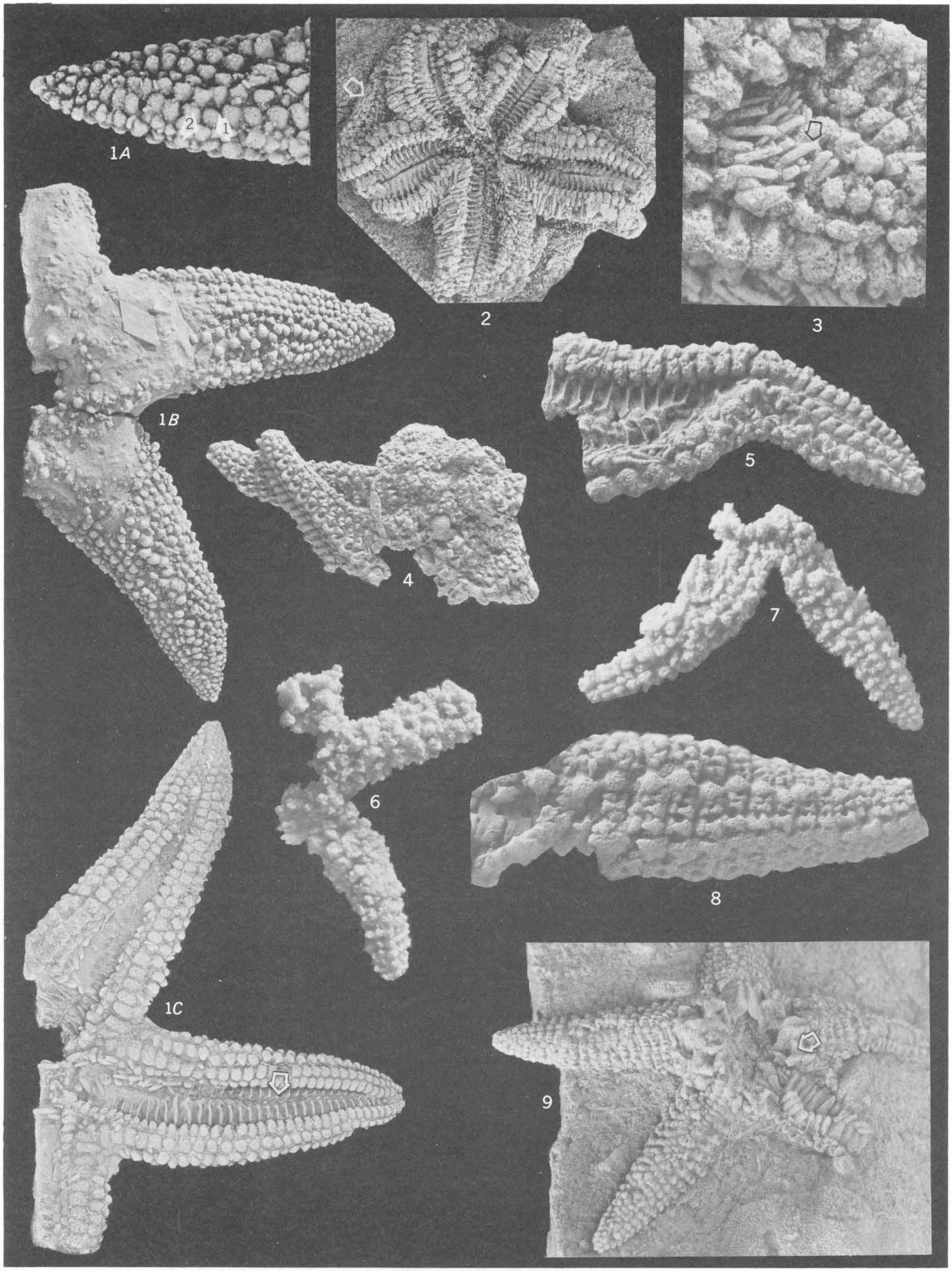
3. *Promopalaeaster speciosus* (Meek). Lexington Limestone, near Frankfort, Ky.; YPM 3405. Arm, ventrolateral aspect showing relic structure of spine stereom (arrow), × 9 (p. F2).

4,5. *Promopalaeaster finei* (Ulrich) n. comb. Kope Formation, Covington, Ky.; FM 54069. 4, Lectotype of *Mesopalaeaster proavitus* Schuchert, × 3 (p. F4). 5, Paralectotype in ventral aspect, × 6 (p. F4).

6,7. *Promopalaeaster finei* (Ulrich) n. comb. Logana Member of Lexington Limestone, USGS locality 6419–CO; USNM 236052. 6, Dorsal aspect of larger fragment, × 4 (p. F4). 7, Ventral aspect of smaller fragment, × 4 (p. F4).

8. *Promopalaeaster finei* (Ulrich) n. comb. Unknown horizon, Cincinnati, Ohio; UM 6230. Brachium, dorsolateral aspect showing relative prominence of dorsal primary and secondary ossicles. Note biserial arrangement of adradials and intermarginals, × 5 (p. F4).

9. *Promopalaeaster finei* (Ulrich) n. comb. Unknown horizon, near Augusta, Ky.; UC 40758. Theca, dorsal aspect with exposed buccal frame showing internal odontophores (arrow on one), × 2 (p. F4).



PROMOPALAEASTER

PLATE 2

FIGURE 1. *Promopalaeaster finei* (Ulrich) n. comb. Kope Formation, Cincinnati, Ohio; USNM 60604, lectotype. Ventral aspect of disarticulated juvenile, × 6 (p. F4).

2. *Promopalaeaster finei* (Ulrich) n. comb. Unknown horizon, Cincinnati, Ohio; AMNH 1196, (largest specimen in suite). *A*, Dorsal aspect, × 2.4 (p. F4). *B*, Ventral aspect, arrow points to adoral carina, × 2.5 (p. F4).

3. *Promopalaeaster finei* (Ulrich) n. comb. Clays Ferry Formation, USGS locality 6143–CO; USNM 236050. *A*, Theca, dorsal aspect. (Most ossicles removed by preparational acidization; interossicle fillings remain.) × 2 (p. F4). *B*, Oral area, × 4 (p. F4).

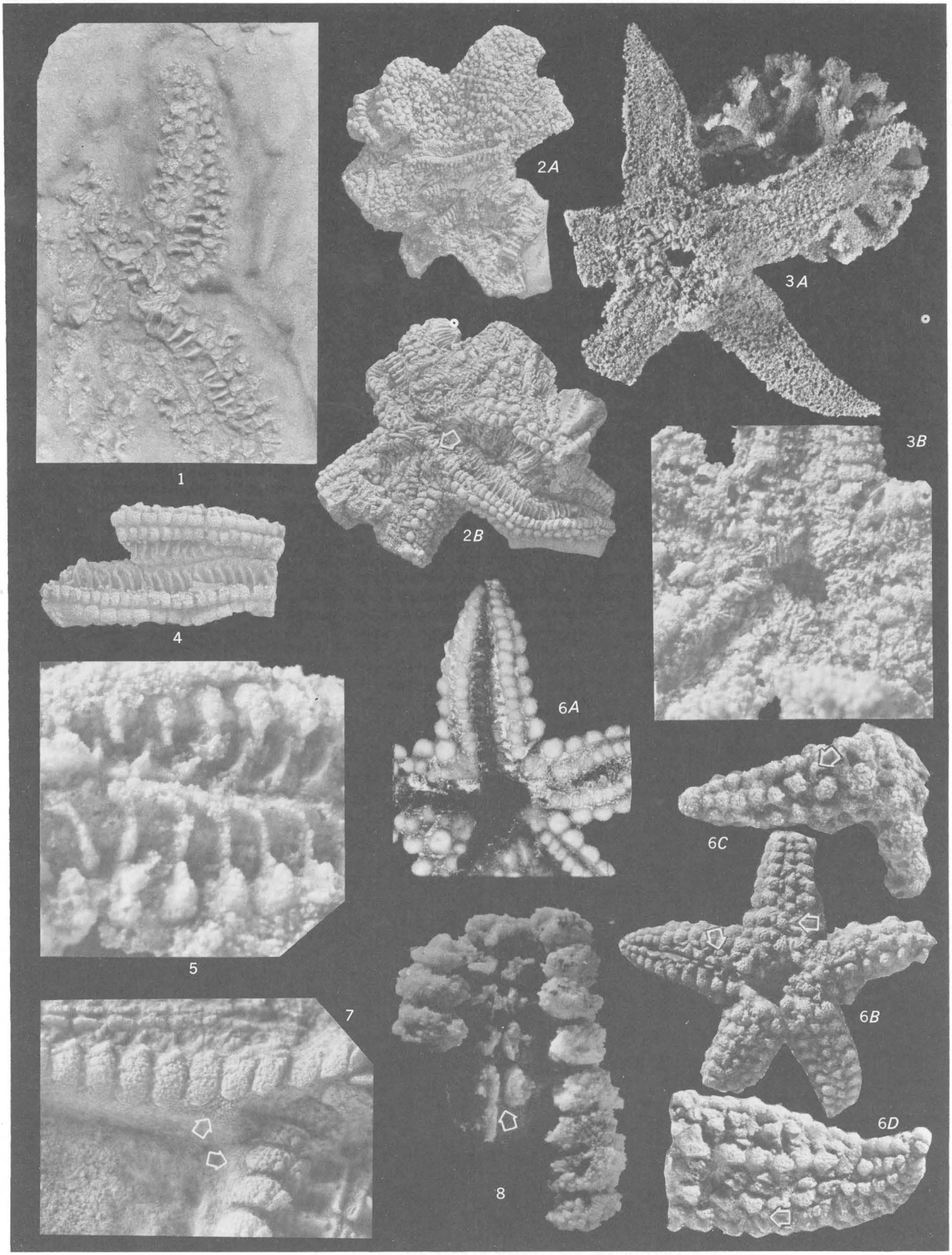
4. *Promopalaeaster finei* (Ulrich) n. comb. Unknown horizon, Covington, Ky.; USNM 92613. Brachial fragment, ventral aspect. Note tendency toward quadriserial podial cupules on proximal (left) end, × 2 (p. F4).

5. *Promopalaeaster finei* (Ulrich) n. comb. Clays Ferry Formation, USGS locality 6143–CO; USNM 236051. Brachium, ventral aspect, × 11 (p. F4).

6. *Promopalaeaster finei* (Ulrich) n. comb. Kope Formation, Cincinnati, Ohio. *A*, A brachium and disc, ventral aspect (photographed in xylol). UC 40371, × 7 (p. F4). *B*, Theca, dorsal aspect. (Arrows point developing adradials.) UC 40371, × 5 (p. F4). *C*, Brachium, dorsal aspect. (Arrow points early adradial.) UC 40381, × 10 (p. F4). *D*, Brachium, dorsal view (Arrow points intermarginals.) UC 40382, × 6 (p. F4).

7. *Stenaster obtusus* (Forbes). Hull Limestone, Kirkfield, Ontario; UC 36426. Interbrachial area, ventrolateral aspect. (Arrows point granular ossicles of lateral integument.) Note deep furrow between opposing ambulacral ossicles, × 6 (p. F5).

8. *Stenaster cf. S. obtusus* (Forbes). Curdsville Limestone Member of Lexington Limestone, USGS locality 5101–CO; USNM 263054. Brachial fragment, ventral aspect. (Arrow points deep radial furrow.) × 6 (p. F6).



PROMOPALAEASTER, STENASTER

PLATE 3

FIGURE 1. *Lanthanaster intermedius* (Schuchert) n. comb. Maysvillian Age (horizon unknown), Cincinnati, Ohio; FM 9575, holotype. Ventral aspect, × 3 (p. F4).

2. *Lanthanaster intermedius* (Schuchert) n. comb. Maysvillian Age (horizon unknown), Cincinnati, Ohio; UC 6433 (holotype of *Lanthanaster cruciformis* Branstrator). *A*, Theca, ventral aspect. (Arrow points madreporite.) × 1.5 (p. F4). *B*, Theca, dorsal aspect, × 1.5 (p. F4).

3. *Lanthanaster intermedius* (Schuchert) n. comb. Clays Ferry Formation, USGS locality 6143–CO; USNM 236053. *A*, Brachium, dorsal aspect, × 8 (p. F4). *B*, Theca, ventral aspect. (Arrowpoints madreporite) × 2.5 (p. F4). *C*, Theca, dorsal aspect, × 2.5 (p. F4).

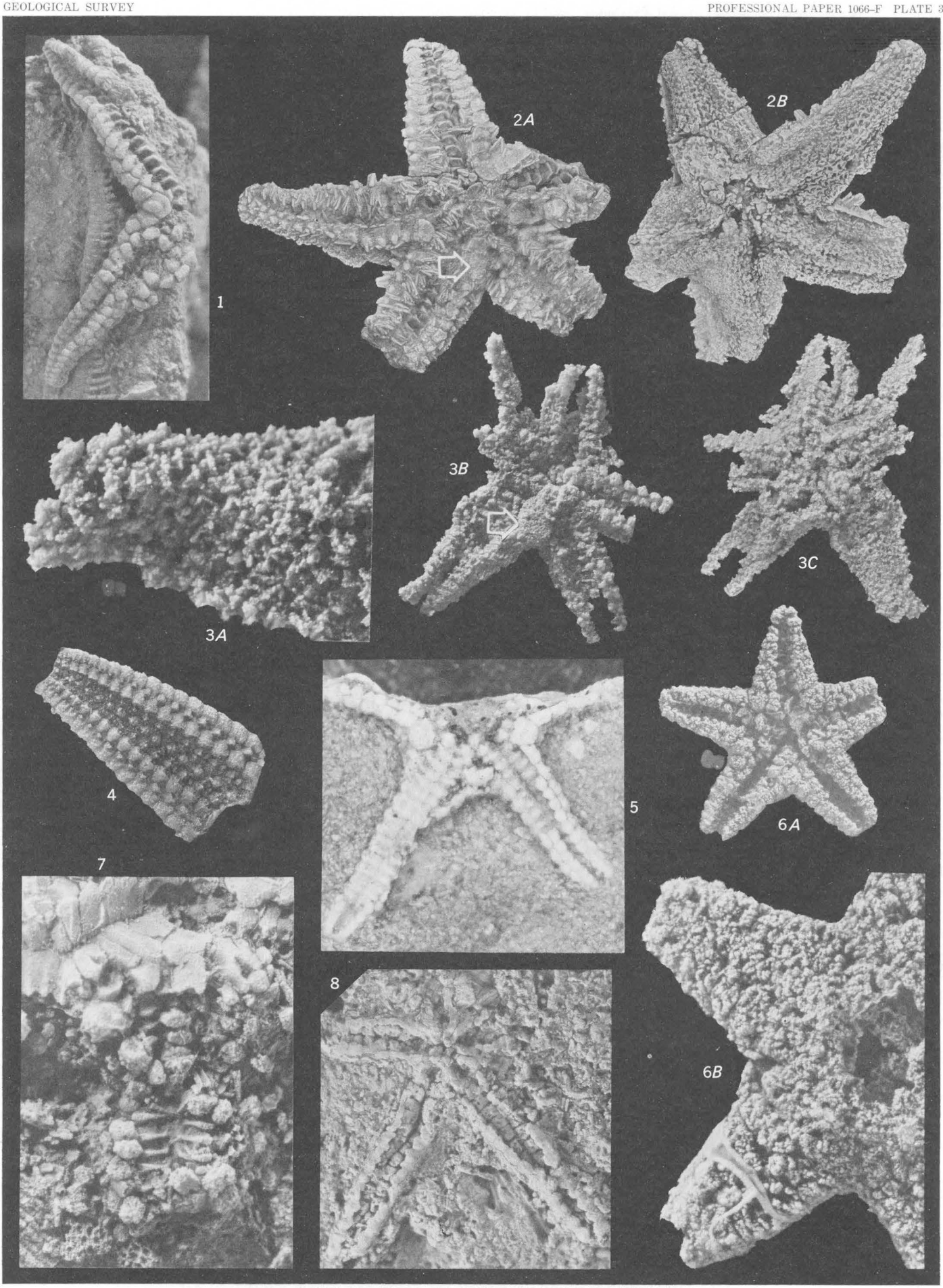
4. *Mesopalaeaster shafferi* (Hall). Maysvillian Age (horizon unknown), Cincinnati, Ohio; USNM 60621. Brachium, dorsal aspect, × 2.5 (p. F4).

5. *"Hudsonaster milleri"* Schuchert. Lexington Limestone, Fayette County, Ky.; UK 1344. Theca, ventral aspect (photographed in xylol), × 4 (p. F6).

6. *"Hudsonaster narrawayi"* (Hudson) *fide* Schuchert. Unknown horizon, near Curdsville, Ky.; YPM 13178. *A*, Theca, ventral aspect, × 3.5 (p. F6). *B*, Brachia and disc, dorsal aspect (note adradial columns), × 7 (p. F6).

7. *"Palaeaster ?dubius"* Miller and Dyer. Point Pleasant Tongue of Clays Ferry Formation, Ludlow, Ky.; MCZ 25. Fragmented and eroded theca, ventral aspect, × 10 (p. F6).

8. Oegophiurid. Point Pleasant Tongue of Clays Ferry Formation, Ludlow, Ky.; YPM 11771. Theca, ventral aspect, × 6 (p. F6).



LANTHANASTER, *MESOPALAEASTER*, SPECIES INQUIRENDA