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Asteroids from the Nawodzice Sands (Middle Miocene; Holy Cross Mountains, Central Poland)

ABSTRACT: An assemblage of the extremely well preserved Middle Miocene (Badenian) starfishes from Nawodzice in the Holy Cross Mountains, Central Poland, is taxonomically recognized to be composed primarily of the two species, new to the science. The dominant is *Astropecten navodicensis* sp.n. that usually occurs in groups of several specimens, and is preserved with the arms either extended, or closed in a tulip-like form. Associated is *Ceramaster polonicus* sp.n., the holotype of which has its ossicle arrangement intact. Isolated ossicles are assigned tentatively to the higher taxa, *Astropecten* sp. and Goniasteridae gen.et sp. indet., respectively. All starfishes of the studied assemblage are thought to be buried in life position, presumably while still alive, under extremely shallow marine (shallow subtidal to intertidal) environmental conditions some 15 m.y. ago (Badenian stage corresponding to the Langhian/Serravallian boundary interval).
The species name *Astropecten granulatus* WIENBERG RASMUSSEN, 1972, used by WIENBERG RASMUSSEN (1972) for an Eocene species from England, and also by KACZMARSKA (1987) for the Middle Miocene isolated ossicles from the Korytnica Basin in Poland, appears to be a younger homonym of the common present-day species *Astropecten granulatus* MÜLLER & TROSCHEL, 1842; it is thus superseded herein by a new species name, *Astropecten anglicus* nom.n.

INTRODUCTION

The aim of the present paper is to describe a unique assemblage of the starfish specimens, discovered and collected thirty years ago by BAŁUK & RADWAŃSKI (1968) within the Middle Miocene (Badenian) sands exposed at Nawodzice on the southern slopes of the Holy Cross Mountains, Central Poland.

The studied starfish were found within a member of the highly fossiliferous sandy sequence that yields a very diversified assemblage of fossils, both invertebrates and vertebrates (Layer *2* of BAŁUK & RADWAŃSKI 1968, Figs 2-3; *see also* RADWAŃSKI 1970, 1973; RADWAŃSKA 1992, Fig. 3). Amongst these fossils the almost fully preserved starfishes, occurring usually in groups of several specimens, became apparently one of the most valuable, top-graded items. They were first determined by BAŁUK & RADWAŃSKI (1968, pp. 450 and 468) as *Astropecten* sp. and a member of the family Goniasteridae FORBES, and illustrated in several papers (BAŁUK & RADWAŃSKI 1968, Fig. 3/*10-10a*; RADWAŃSKI 1970, p. 383, Fig. 3/*j*; RADWAŃSKI 1977, pp. 748-749, Fig. 172/*9*), to announce their significance in studies of the ancient starfish. It has gone a time of over twenty years until the present Authoress had a favor to undertake such studies, realized as an M.Sc. project (NOSOWSKA 1990), under the supervision of Ass.-Prof. W. BAŁUK at the Faculty of Geology, University of Warsaw.

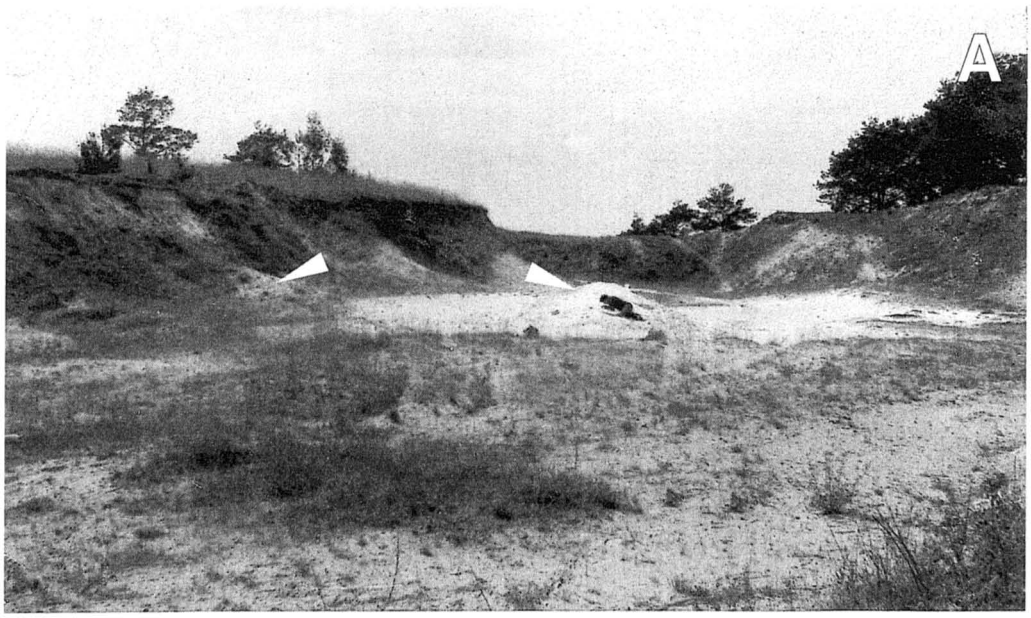
Through these two decades that have elapsed since the starfish discovery at Nawodzice the taxonomic recognition of other invertebrate groups from the Nawodzice Sands has also progressed, and finalized in a series of monographic descriptions. The monographs of the decapod crustaceans (by R. FÖRSTER; *cf. also* P. MÜLLER 1996), chitons (by B. STUDENCKA & W. STUDENCKI), bivalves (by B. STUDENCKA), and echinoids (by S. MĄCZYŃSKA) have recently been listed and referenced concisely by RADWAŃSKA (1992), who studied therefrom an assemblage of fish otoliths (*see* RADWAŃSKA 1992, pp. 149-150 and 315-316).

In the meantime, when the Nawodzice starfish themselves were still under investigation by the present Authoress, a fame of their occurrence and unique preservation penetrated into the European literature (*see* JAGT 1991, p. 39).

The age of the Middle Miocene sandy sequence at Nawodzice is the same as that of the Korytnica Basin in the western part of the Holy Cross Mountains (*see* BAŁUK & RADWAŃSKI 1968, 1977), that is Badenian in the Paratethys stratigraphic scheme, corresponding to the Langhian/Serravallian boundary interval (about 15m.y. ago) of the standard geochronologic scale.

TYPE LOCALITY CHARACTERISTICS

A general characteristics, regional setting and age of the Nawodzice Sands, exposed in a sand-pit at the village of Nawodzice, have comprehensively been presented by the former authors (BAŁUK &



A farewell to the Nawodzice locality

A — Overall view of the sand-pit in 1966, when the studied starfish where collected by W. BAŁUK & A. RADWAŃSKI; arrowed is the starfish-bearing member of the sandy sequence (*compare* W. BAŁUK & A. RADWAŃSKI 1968, Figs 1–2)

Photo taken by A. RADWAŃSKI

B — Recent situation of the forested sand-pit, as seen in 1989, when the Authoress collected some supplementary material

Photo taken by E. NOSOWSKA

RADWAŃSKI 1968; RADWAŃSKI 1970, 1973; RADWAŃSKA 1992), whose papers were, in majority, published in former issues of the present journal. Thereby, there is no reason to repeat their content, but it is worthy to recall that the environmental conditions were assessed by these authors as extremely shallow marine, close to the shallow subtidal or even intertidal zone (*see* RADWAŃSKI 1970, pp. 378-384, Figs 2-3; 1973, pp. 392-393, 396-399 and Fig. 6).

The preservation of the Nawodzice starfish, with their ossicle arrangement almost intact, has originally been interpreted by BAŁUK & RADWAŃSKI (1968, pp. 455 and 468) as a result of their burial in life position, presumably just during their life (*cf.* BLAKE & ZINSMEISTER 1988). This opinion is now regarded to be fully justified.

Nevertheless, it is also to note that the sand-pit at Nawodzice, being at work in the sixties when the starfish specimens were collected (*see* Text-fig. 1*A*), has been abandoned since that time and, as now, it makes up an almost fully forested area (*see* Text-fig. 1*B*). In field seasons of 1988-89 the Authoress was able to collect there only a scarce supplementary material of minor importance. The present report may thus be treated as a kind of farewell to the Nawodzice sand-pit, in which any further access to the Middle Miocene (Badenian) starfish has definitely been exhausted (!).

All the studied specimens, both collected by the former authors and by the present author herself, are deposited in the collection of the Department of Paleontology, Faculty of Geology, University of Warsaw.

SOME METHODOLOGIC REMARKS

The structure of the starfish skeleton and terminology of its ossicles have been adequately presented by KACZMARSKA (1987), when describing a rich material of isolated ossicles from the coeval deposits of the Korytnica Basin. In this study the ossicle terminology is thus the same as that used by KACZMARSKA (1987) who adopted it from the recognized papers, referenced also herein (HYMAN 1955; SPENCER & WRIGHT 1966; BLAKE 1973; A.H. MÜLLER 1963, 1978). For the readers' convenience it is shown in an abbreviated form (Text-fig. 2*A-B*).

All plural abbreviations of names of the ossicles used in this paper are given by the doubling the last letter of a singular abbreviation.

In the description of taxa with broad interbrachial angles, marginal ossicles directly adjoining the interradius are named the *median marginals* (abbreviated as *median MM*), while the others are named *arm*

marginals. The marginals are numbered starting from the interradius towards the tip of the arm, as follows: SupM (InfM) No. 1, 2, *etc*.

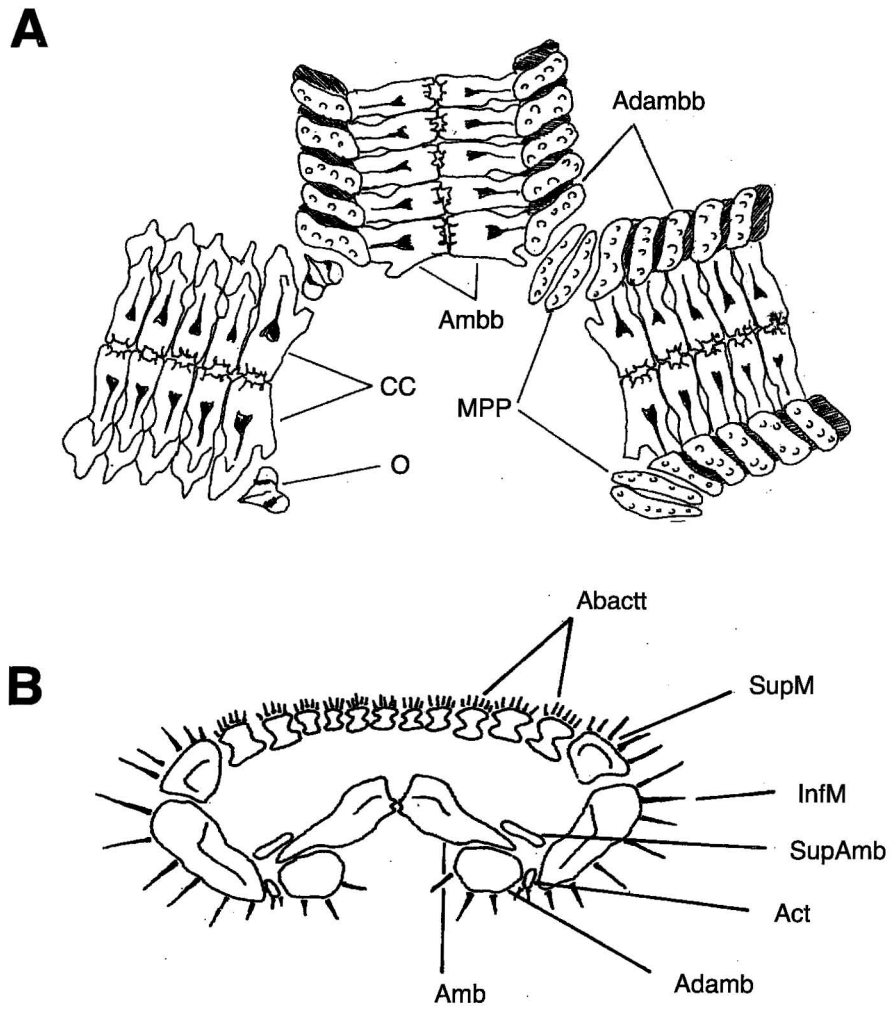


Fig. 2

A — Position of ossicles in the oral region of an asteroid (oral view; at left, adambulacrals and mouth-angle plates partly removed): **Ambb** – ambulacrals, **Adambb** – adambulacrals, **MPP** – mouth-angle plates, **CC** – circumorals, **O** – odontophore

B — Section through an idealized asteroid arm, to show the position of particular ossicles: **SupM** – superomarginal, **InfM** – inferomarginal, **Amb** – ambulacral, **Adamb** – adambulacral, **SupAmb** – superambulacral, **Act** – actinal, **Abactt** – abactinals (commonly, these are the paxillae)

Adopted from: KACZMARSKA (1987, Figs 2-3)

SYSTEMATIC ACCOUNT

Order **Paxillosida** PERRIER, 1884
Suborder **Diplozonina** SPENCER & WRIGHT, 1966
Family **Astropectinidae** GRAY, 1840
Subfamily **Astropectininae** GRAY, 1840

Genus *Astropecten* GRAY, 1840

Astropecten navodicensis sp.n.
(Pls 1-5 and Pl. 6, Figs 1-12)

HOLOTYPE: The specimen shown in an overall view (Pl. 5, Fig. 1) and in close-ups of its isolated ossicles (Pl. 5, Figs 4, 6-8, 11-14, 16 and Pl. 6, Figs 9-12).

TYPE LOCALITY: Nawodzice, member *2* of the sand sequence.

TYPE HORIZON: Middle Miocene (Badenian = Langhian/Serravallian boundary interval).

DERIVATION OF THE NAME: Adjective, neo-Latinized – coming from the locality Nawodzice.

DIAGNOSIS: Outer face of marginal ossicles densely covered by tubercles; superomarginal tubercles very small, of equal size; inferomarginal tubercles differentiated into smaller ones, ball- or horseshoe-shaped, and bigger ones, always horseshoe-shaped, spaced in variable number along the abradial margin (at least two at one arm ossicle) and the distal margin; tubercles make a basis for large, strongly flattened scales (the largest are of the length equal to the width of the ossicle they grow on); adambulacrals with relatively long, sharp spines.

MATERIAL: (**1**) One specimen with partly preserved disc and fragments of three arms aborally curved. Mouth-angle plates, as well as numerous MM, Ambb, and Adambb are situated in their nearly natural position. The SupAmbb, paxillae, scales, spines, and one terminal and one circumoral ossicle are well exposed. This specimen is chosen as the **holotype** of the species.

(**2**) Two nearly complete specimens with aborally bent arms (Pl. 1, Fig. 2 and Pl. 2, Fig. 3). On the oral side of both specimens, preserved are in position the mouth-angle plates, InfMM, and Adambb. Moreover, exposed are spines, scales, Ambb, few distal SupMM, two terminals, and one SupAmb.

(**3**) Five nearly flat specimens (Pl. 1, Fig. 1; Pl. 2, Figs 1-2; Pl. 3, Fig. 1; Pl. 4, Fig. 1), of which three have straight arms, whereas the other two have their arms very twisted. The original arrangement of MM, Ambb, Adambb, and of mouth-angle plates is well preserved; exposed are also spines, scales, paxillae, and one circumoral (Pl. 2, Fig. 2b).

(**4**) Five partly preserved specimens with arms aborally bent. Apart from odontophores, Actt, madreporite, circumorals and SupAmbb, all other ossicles are visible, although some of them strongly damaged.

(**5**) Thirteen fragments of arms with partly preserved scales and spines of InfMM and Adambb (Pl. 3, Fig. 2), as well as a fragment of the ambulacral groove (Pl. 4, Fig. 2) that contains 8 Ambb, 8 Adambb with spines, and 1 SupAmb.

(**6**) Ossicles connected confusedly (4 InfMM, 4 SupMM, 8 Ambb, 9 Adambb, one mouth-angle plate, 1 paxilla); their size and morphology suggest that they come from both distal and proximal parts of the arm (Pl. 4, Fig. 3).

(**7**) Loose ossicles: 51 terminals, 14 circumorals, 13 mouth-angle plates, 28 Adambb, 90 Ambb, 734 SupMM, and 840 InfMM.

DESCRIPTION: The new species represents a small-sized *Astropecten*, featured by five long (R/r ≅ 5), sharply ended arms turning into a small disc. The margin of the body consists of the differently developed SupMM and InfMM connected with each other by small, concave intermarginal faces; SupMM are smaller than corresponding InfMM. Neighboring MM are connected by relatively prominent articulation ridge, and they are positioned diagonally towards the axis of the arm. Between the ossicles there are relatively big fasciolar grooves. InfMM as well as interbrachial SupMM have their width distinctly larger than the length. Outer face of SupMM is covered by very delicate, tiny tubercles of equal size, which probably bore small spines or scales during the life-time of the animal. However, the InfMM outer face is covered by smaller, rounded or horseshoe-shaped and bigger, always horseshoe-shaped, tubercles which are spaced in variable number along the abradial and the distal margin; they create a base for long, strongly flattened scales, the longest ones of which are situated near the abradial margin, and their length approximately equals the width of the ossicle they are positioned on. The remaining part of outer face is covered by considerably smaller spines. Tips of the arms are ended with terminals. Aboral surface is covered with typical paxillae. Relatively broad and open ambulacral grooves are formed by an equal number of Adambb and Ambb, over which there are SupAmbb. Proximal part of the ambulacral body overlaps the distal margin of the adjacent ambulacral ossicle. Outer face of Adambb is covered with tubercles, which carry the sharply ended spines (the length of the biggest one equals approximately the width of the ossicle it grows on). The Adambb within the arms touch InfMM; on average, there are 10 Adambb corresponding to 6 InfMM. In the center of disc of the oral surface, exposed are five pairs of interradially spaced, protruding mouth-angle plates. Interradial surfaces are very small and triangular.

Superomarginal ossicles (Pl. 5, Figs 7-8) are massive and high; length, width, and height of 3 ossicles are respectively (mm): 1.9, 2.1, 2.5; 1.2, 1.2, 1.5; 0.9, 1.0, 1.2; outer face is convex and covered by tiny tubercles; side faces, of similar shape are triangular; big fasciolar surface is thickly covered by tiny fasciolar spinelet bases recognizable on the better preserved ossicles; articulation surface, quarter-circular in shape, is limited adradially by a roll; articulation ridge continuous or disjunct on the interbrachial ossicles; inner face smooth, flat or slightly convex; intermarginal face concave. Interbrachial ossicles are higher and wedge-shaped; outer face tubercles are visible only on the better preserved

specimens; height of the articulation ridge decreases in the oral direction. Ossicles from the distal parts of arms are less symmetric.

Inferomarginal ossicles (Pl. 5, Figs 4-6) are massive, wide and low; length, width, and height of 3 ossicles are respectively (mm): 1.6, 4.2, 2.0; 1.4, 2.5, 1.6; 1.0, 1.8, 1.1; outer face is slightly convex, covered with tubercles (besides abradial, vertical part); the tubercles are differentiated into smaller ones, rounded or horseshoe-shaped, and bigger ones, always horseshoe-shaped; two big horseshoe-shaped scale-bases, and, on certain ossicles, a smaller proximal one, touch the abradial margin; similar big tubercles create in different numbers (2-3) a row positioned adradially, as well as along the distal margin; proximal side face is concave, distal one-convex; large fasciolar surface (higher in the abradial part) with thickly positioned tiny fasciolar spinelet bases (visible on the better preserved ossicles); articulation surface is adradially limited by a low roll; articulation ridge is prominent, roll-shaped or composed of several articulation processes; intermarginal face is narrow and concave; inner face is wide with one or two superambulacral bosses. On some ossicles the width of the intermarginal and inner faces is approximately identical. InfMM from the distal parts of arms are less symmetric, and interbrachial ossicles are wedge-shaped; all of them have the number of big, horseshoe-shaped scale-bases smaller than the other arm InfMM.

Terminal ossicles (Pl. 5, Figs 9-10) are relatively big; length and width of 3 ossicles is respectively (mm): 2.1, 2.2; 1.5, 1.5; 1.0, 1.1; their outline is rectangular or trapezoid; outer face is covered by tiny tubercles; aboral surface is flat or divided by a longitudinal concavity, relatively wide but shallow; distal niche is circular, reaching 1/3 of the ossicle length and turning into the proximal niche, which gradually widens; in the proximal part there appears a relatively deep, wide and oval opening of the proximal niche; in the distal part – a deep, oval but slightly narrower opening of the distal niche; lateral edges are relatively long, bent inwards: from the oral side there can be seen crescent, flat, or slightly concave structures for attachment to the arm.

Ambulacral ossicles (Pl. 5, Figs 13-14) are asymmetric, short and wide; length, width, and height of 3 ossicles are respectively (mm): 1.5, 5.0, 1.9; 1.1, 3.5, 1.4; 0.6, 2.0, 0.7; ambulacral body outline is rectangular; dentation is well developed, consisting of horizontal lateral slats and vertical medial slats; lower insertion for transverse muscles is small, triangular; the upper one is big and deep; oral groove is deep and narrow; winglike structures are asymmetric: proximal one is small, *U*-shaped, opened orally, distal one is big, semielliptical, flattened; apophyse is weak; depressions for longitudinal muscles are large, oval; aboral ridge is high, sharp. Ossicles coming from the disc differ from arm Ambb by the outline of aboral surface, they are much shorter and have less prominent articulation processes on the sides of the ambulacral body.

Adambulacral ossicles (Pl. 5, Figs 11-12) are small; length, width, and height of 3 ossicles are respectively (mm): 0.8, 1.5, 2.0; 0.5, 1.3, 1.5; 0.4, 1.0, 1.3; they are rectangular in outline; adradial prominence is quite distinct. On the proximal side there are: articulation surface pa1 cuneate, pa2 not so distinct (small and circular), pa3 very prominent and oval, pa4 shaped in the form of a high ridge; depression for the muscle (also on proximal side) pm1 relatively large, prominent, triangular, pm2 (smaller) and pm3 (much bigger) consists of loculuses, also triangular. On the distal side there are: articulation surface da1 weak, da2 well visible, triangular; also on distal side there is a large depression for muscle dm1; oral surface of the ossicle is covered by tubercles. Adambulacral ossicles coming from the disc have their shape differing from that of arm ossicles, and they are shorter and wider; they have very prominent adradial prominence, weak articulation surfaces and depressions for muscle attachment. Ossicles from the distal parts of arms are relatively high and narrow.

Superambulacral ossicles (Pl. 6, Fig. 9) are very small; width and length of 3 ossicles are respectively (mm): 0.9, 0.4; 0.8, 0.3; 0.3, 0.1; they look like an aborally curved scale; both ends from the oral side are obliquely truncated; the abradial end is widened and more flat.

Mouth-angle plates (Pl. 5, Fig 16) are relatively small; length, and height of 3 plates are respectively (mm): 3.1, 2.7; 2.2, 1.9; 1.7, 1.3; main body is rectangular; inner-face (abradial) is slightly concave: of the two dentition surfaces along the oral margin, the proximal one consists of irregular tubercle-like slats, while the distal one consists of horizontal slats; outer face (adradial) is convex: a small ridge runs obliquely in the proximal direction, on its both sides there are deep insertions for muscles; oral margin is covered by tubercles, which are also on the outer face (usually, three in number) in the proximal part of the main body; first ambulacral articulation bar is low, directed adorally and obliquely.

Circumoral ossicles (Pl. 5, Fig. 15) are relatively long and wide; length and width of 3 ossicles are respectively (mm): 1.5, 2.8; 1.3, 2.5; 1.0, 1.9; their main body is large; dentation is well developed and consists of horizontal lateral slats and vertical medial slats; lower insertion for transverse muscles is small, triangular; the upper one is oval; on distal side of the main body there is an oval, very low articulation process with depression for the longitudinal muscle; distal circumoral extension is wide and not long; adoral circumoral extension is much smaller.

Paxillae (Pl. 6, Figs 10-12) are generally small; height of 3 ossicles is respectively (mm): 0.7, 0.5, 0.3; the basal part is oval, or with radial extensions, convex; column is relatively high, circular or flattened; tabula is very weak and convex.

Spines (Pl. 6, Figs 6-8) are predominantly sharp, circular or oval in cross-section; length of 3 spines is respectively (mm): 2.0, 1.5, 0.5; the length of the biggest spines equals approximately the width of the ossicle they are settled on. Some of the spines show traces or regeneration.

Scales (Pl. 6, Figs 1-5) of the InfMM ossicles are long; length of 3 scales is respectively (mm): 3.0, 1.5, 1.0; they are strongly flattened, ended sharply or ovally; their basal part bears a loculus.

REMARKS: The three kinds of ossicles (odontophore, madreporite, and actinals) are not recognizable in the collected specimens, because their aboral surface is either covered by cemented sand, or hidden in tulipe-like bent arms. As far as the actinal ossicles are concerned, probably they were very small and few, like in other species of *Astropecten*, with a little chance to be preserved.

Many of the collected specimens have their life arrangement of MM, Ambb, Adambb, and mouth-angle plates well preserved. However, some of the specimens have whole series of SupMM displaced in relation to InfMM, both in the distal and adradial direction.

The studied specimens were originally classified (BAŁUK & RADWAŃSKI 1968) as of the genus *Astropecten* GRAY. In the classification of modern species of the genus *Astropecten*, a special attention is paid to the shape, size, number and arrangement of spines, scales and granules connected with the outer surface of MM, Adambb, Actt and Abactt. A usage of these criteria for the fossil species represented commonly by isolated ossicles deprived of spines, scales, *etc.* is usually impossible. Therefore, in the fossil material considered are mainly the shape of ossicles and of their elements, and especially, in the case of MM or Adambb, an ornamentation of their outer face.

The SupMM and InfMM ossicles of *Astropecten navodicensis* sp.n. resemble, in their shape and development of the side-face elements, the respective ossicles of the Eocene species *Astropecten* illustrated by WIENBERG RASMUSSEN (1972, pp. 38-39, Pl. 3, Figs 5-6) under the name of *A. granulatus* WIENBERG RASMUSSEN. However, none of the SupMM ossicles of *A. navodicensis* sp.n. have horseshoe-shaped and big ball-shaped and crater-shaped scale bases or spine bases, which occur on SupMM of *A. granulatus* WIENBERG RASMUSSEN. Since InfMM arm ossicles of *A. navodicensis* sp.n. have very dis-

tinct arrangement of horseshoe-shaped scale bases, they are easily distinguishable from those of *A. granulatus* WIENBERG RASMUSSEN.

The Ambb, Adambb, terminals, mouth-angle plates, circumorals, and paxillae of *Astropecten navodicensis* sp.n. are slightly different from those coming from the Korytnica Basin and assessed to *A. granulatus* WIENBERG RASMUSSEN by KACZMARSKA (1987, pp. 135-137, Pl. 2, Figs 1-2, 5-6; Pl. 3, Figs 2-3, 5-6).

Astropecten sp.
(Pl. 6, Figs 13-18)

MATERIAL: Isolated 192 SupMM and 34 InfMM ossicles.

DESCRIPTION and REMARKS:

Superomarginal ossicles (Pl. 6, Figs 13-17) are represented by four types.

To the first type belong 4 interbrachial, wedge-shaped and high ossicles (*see* Pl. 6, Figs 13-14) which due to their development and presence of large crater-shaped tubercle near the aboral margin, resemble SupMM of *Astropecten granulatus* as illustrated by KACZMARSKA (1987, Pl. 1, Fig. 8), but they differ in the outline of their outer and intermarginal faces. The latter ossicles differ from those of *A. navodicensis* sp.n. by their inner face being concave, and by the presence of a large tubercle.

The second type is represented by 143 ossicles featured by a flat, wide articulation ridge, concave inner, and smooth outer face (*see* Pl. 6, Fig. 15). All these features allow to distinguish them from those of *Astropecten navodicensis* sp.n.

The third type consists of 43 massive, asymmetric ossicles (*see* Pl. 6, Fig. 16) which due to the shape of side-face outline and of articulation surface, resemble those from the Lower Oligocene illustrated by BLAKE (1973, p. 44, Pl. 13, Figs 13-14) as *Astropecten* sp.; they differ also by the presence of the tubercles on the outer face, and by the wider articulation ridge.

The fourth type is represented by 2 large, asymmetric ossicles featured by their outer face strongly convex, and the crater-shaped tubercle placed centrally (*see* Pl. 6, Fig. 17).

Inferomarginal ossicles (Pl. 6, Fig. 18), numbering 34, are relatively wide and low. Their outer face is covered by thickly positioned tiny tubercles, 3 to 5 of which are bigger, horseshoe-shaped, and situated along the distal margin. The last tubercle, placed near the abradial margin, is centrally placed and is the biggest. Inferomarginal face is concave. The ornamentation of their outer face resembles that of *Astropecten* sp. *A*, described from Korytnica by KACZMARSKA (1987, p. 137, Pl. 4, Fig. 1), from which they differ by their concave intermarginal surface.

Order **Valvatida** PERRIER, 1884
Suborder **Granulosina** PERRIER, 1894
Family **Goniasteridae** FORBES, 1841
Subfamily **Goniasterinae** FORBES, 1841
Genus *Ceramaster* VERRILL, 1899

Ceramaster polonicus sp.n.
(Plates 7-10)

HOLOTYPE: The specimen presented in Pls 8-9 and Pl. 10, Figs 13-16.

TYPE LOCALITY: Nawodzice, member 2 of the sand sequence.

TYPE HORIZON: Middle Miocene (Badenian = Langhian/Serravallian boundary interval).

DERIVATION OF THE NAME: Adjective, neo-Latinized – in reference to the country of the species occurrence.

DIAGNOSIS: The same number of SupMM and InfMM; inside the disc they correspond in position; variable number of arm ossicles slightly transpositioned one in respect to another; three pairs of distal SupMM touching each other along the radius; median MM flattened; central area of outer face slightly raised, surrounded by a more or less wide, irregular sunken edge, closely covered by fine granule-pits; arm MM very convex; central area of the ossicles enlarges in the distal direction.

MATERIAL: (1) Specimen with almost undisturbed arrangement of ossicles: MM (51 InfMM, 54 SupMM), Adambb, Actt; besides, exposed are 4 Ambb, 1 pedicellaria, many Abactt, granules, scales; this specimen is recognized as the **holotype** of the species; its dimensions are: R=45mm, r=30mm (R/r=1.5).

(2) Fragment of an arm with primary arrangement of MM (5 SupMM, 4 InfMM) having, moreover, 4 Ambb, 13 Adambb, 1 terminal, 1Act, and other small ossicles which cannot be precisely identified (*see* Pl. 10, Figs 1-6).

(3) Separate ossicles: 50MM, 14 Adambb, 39 Abactt, 3 Actt.

DESCRIPTION: The new species is a flat, medium-sized asteroid of a radiate shape, featured by 5 short, wide arms with pointless endings. The arms pass very smoothly into a large disc. The edge of the arms is higher than the disc. The frame is rounded, formed by the equal number of large, slightly protruding SupMM and InfMM, 14 from one tip of the arm to the other. SupMM and InfMM inside the disc correspond with each other in position; on the arms, MM No.*4* and No.*5*, and sometimes also No.*3* and No.*6*, are slightly dislocated in respect to each other. Three pairs of distal SupMM touch each other along the midline of the arm. Generally, SupMM and InfMM do not differ, only arm SupMM are a bit wider, better vaulted, and display a greater angle between intermarginal and inner faces than respective InfMM. Aboral surface is covered by paxillae. Oral surface is covered by multisided ossicles (mostly quadrangular), overlapping in the adradial and proximal direction, which compose rows parallel to the ambulacral grooves. The size of Actt diminishes in the distal direction; their outer face is covered with granules. Ambulacral groove is narrow and densely covered by tightly placed Adambb with adradially placed scales. The five tightly connected scales stick out in the direction of mouth. Pedicellariae are present on the aboral surface.

Marginal ossicles (Pl. 7, Figs 1-3; Pl. 10, Figs 1 and 11-12)

Dimensions of MM of the holotype (p – proximal, d – distal):

Ossicle	length (p-d) mm	width (p-d) mm	height mm
SupM No.*1*	4.5-4.0	6.2	3.7
InfM No.*1*	4.5-4.0	6.0	3.8
SupM No.*4*	4.0-3.5	7.5	5.0
InfM No.*4*	4.5-4.0	6.0	4.7
SupM No.*6*	2.7	5.5-3.0	4.1
InfM No.*6*	3.0	3.7-2.2	3.2
InfM No.*7*	1.5	2.1-1.0	–

Median SupMM and InfMM are low, flattened, wider than long; outer face is rectangular: proximal margin is a little longer than the distal one, slightly bent resembling an arch or obtuse angle with unequal arms; central area slightly raised, probably smooth (*see* Remarks), surrounded by more or less wide, irregular sunken edge, which is covered by densely placed small granules or shallow, circular granule-pits; triangular side face outline is surrounded by protruding ridge, looking as if continuing to neighboring faces; intermarginal face is large, flat or slightly concave, rectangular; abactinal side face (on SupMM) and actinal side face (on InfMM) are slightly concave, resembling a furrow; sometimes there are two smaller faces, which form a contact area for cover ossicles; inner face is flat or slightly convex. Closer to the apex of the arm, MM become more massive, strongly convex, asymmetric; shape of the outer face resembles a trapezium; central area occupies large place and, on the most distal ossicles, it is surrounded by one row of tiny pits. Ridge surrounding the side face gradually disappears on successive ossicles. Side face is flat or concave: distal face is smaller and more concave than the proximal one. Intermarginal face is divided into two parts (smaller and larger), which make a contact area for lower or upper marginals.

Terminal ossicle (Pl. 10, Fig. 3) is symmetric, massive and high; its length and width are (mm): 2.4 and 1.9; from the aboral and oral side it is deltoidal in outline, with proximal sides longer than distal ones; distal niche is large, separated from the proximal one, circular and deeper, by a narrowing formed by small, inside-directed edges; structures for attachment to the arm are large, oval, slightly concave; aboral surface is convex.

Ambulacral ossicles (Pl. 8, Fig. 1b; Pl. 10, Fig. 2) are asymmetric and high; length, width, and height of 3 ossicles are respectively (mm): 1.8, 4.4, –; 0.8, 2.6, 1.1; 1.0, 2.9, 1.3; distal concavity for podium is weak; ambulacral body is large, triangular; dentition consists of short horizontal slats; upper insertion for transverse muscles is weak, while lower one is relatively big, triangular; depressions for longitudinal muscles are oval: distal one placed on the aboral side, proximal one much smaller, and placed on the side face of the body; wing-like structures are small, semielliptical: proximal one is a little bigger than distal one and placed a bit higher; apophyse is prominent, shaped as a proximally bent slat; aboral ridge is rounded, abradially flattened; the angle between the plane of Amb/Adamb articulation and the ossicle axis is about 40°.

Adambulacral ossicles (Pl. 9, Fig. 1b-1c; Pl. 10, Figs 4-5) are quadrangled in shape; length, width, height of 3 ossicles are respectively (mm): 1.3, 2.1, 3.0; 1.0, 1.8, 2.2; 0.8, 1.5, 1.8; oral surface is rectangular, wider than long, slightly convex with the adradially devel-

oped ridge; adradial prominence is well developed; depression for muscle pm3 wide, dm1 high and narrow, limited by an articulation surface da2, which has the shape of a vertical roller; adradial surface is orally flat or slightly convex, and it becomes concave aborally; abradial surface is flat or slightly convex. Distal Adambb have insertion surfaces weaker, and these are higher, wider orally than aborally, and their outer face is more convex.

Scales (Pl. 10, Figs 13-16) have their length more or less the same as Adambb on which they are placed: cross-section is rectangular; one of the faces is curved, therefore the scale has larger cross-section surface at its top than at its base; in the basal part there is an oblong depression.

Actinal ossicles (Pl. 10, Figs 9-10) have length and width slightly larger than the adjacent Adambb; outer face is rectangular (near ambulacral grooves), multi-sized or oval, flat, covered thickly with granules or circular granule-pits; tongue-shaped aboral side of the ossicle is placed along the diagonal, and has concave contact surfaces with the overlapping Actt. Ossicles touching InfMM are higher and, when seen from the side, they are *L*-shaped with the oral part being its base.

Abactinal ossicles (Pl. 8, Fig. 1c; Pl. 10, Figs 6-8) are mainly of the same height; width and height of 3 ossicles are respectively (mm): 2.5, 1.5; 1.5, 1.5; 1.2, 1.5; basal part is flat or slightly convex, circular, oval or radiating (5-6 prominences); column is thick; tabula is well developed, multi-angled or oval, slightly convex or flat, covered with small, circular granule-pits. Traces of connections with neighboring ossicles can be seen on the side face.

Pedicellaria (Pl. 8, Fig. 1b) is relatively large (2mm long); its two parts resemble an open bivalve shell.

REMARKS: The rarity of fossil skeletons, which could be assigned to the genus *Ceramaster*, and a lack of any resemblance to the present-day and/or fossil goniasterid species described in the literature, allow the Authoress to create a new species, *Ceramaster polonicus* sp.n.

The extremely well preserved specimen recognized as the holotype of the newly established species, *Ceramaster polonicus* sp.n., was originally assigned by its finders (BAŁUK & RADWAŃSKI 1968, p. 450) generally to the family Goniasteridae. Subsequently, KACZMARSKA (1987, p. 141) noticed its resemblance to the representatives of the genus *Ceramaster* VERRILL, 1899.

The comparison of the size of MM from a fragment of the arm with the holotype marginals allows to conclude that this fragment belonged to a specimen with dimensions close to those of the holotype. Moreover, in the collection there are loose median MM which are either smaller or bigger than median MM of the holotype. Because of their resemblance, SupMM and InfMM, have been described together; if found loose they cannot be differentiated. In the description of MM, their central area was noted as probably smooth, since the outer face of these ossicles is pitted by sand grains. After removing them, there remain small hollows which mask the real sculpture, that is a lack or presence of the granules.

The loose marginal ossicles resemble those presented by KACZMARSKA (1987, p. 141, Pl. 7, Figs 2-3) from the Korytnica Basin and assigned to the family Goniasteridae. However, median MM of the studied specimens differ from the latter ones since their width is greater than length (*see* KACZMARSKA 1987, Pl. 7, Fig. 3).

Because of a distinct resemblance of the collected loose MM to the holotype marginals, they have been ascribed herein to the same species, although such an assessment

may remain very arbitrary. This is apparent from the diagnosis of the genus *Ceramaster* VERRILL, 1899, given by SPENCER & WRIGHT (1966, p. *U57*), according to which its marginal ossicles may have the same shape and ornamentation as those of the genus *Metopaster* SLADEN, 1893. The differences between these genera lie in the having by *Metopaster* a smaller number of MM between the tips of the arms, and that ultimate SupMM correspond with the greater number of InfMM; these features, obviously, cannot be recognized when only loose material is available.

Loose cover ossicles, because of their resemblance to Actt and Abactt of the holotype, are herein assigned also to the newly established species, *Ceramaster polonicus* sp.n.

Goniasteridae, gen. et sp. indet.
(Pl. 11 and Pl. 12, Figs 1-7)

MATERIAL: 6 MM, 8 Ambb, 6 mouth-angle plates, 14 cover ossicles.

DESCRIPTION and REMARKS:

Marginal ossicles (Pl. 11, Figs 1-3) represent two types.

To the first type belong 5 slightly asymmetric, relatively low ossicles (Pl. 11, Figs 1-2) that resemble, due to the development of their elements, median MM of *Ceramaster polonicus* sp.n., but differ by the outline of the outer face, square-like in shape. These features make them similar to the marginal described by KACZMARSKA (1987, p. 141, Pl. 7, Fig. 3) from the Korytnica Basin, and assigned to the family Goniasteridae.

To the second type belongs one ossicle (*see* Pl. 11, Fig. 3) which has outer face convex, distally bent under the angle of 90°, where it is concave; smooth, raised central area is surrounded by a sunken edge covered with circular pits (very well-preserved row of pits touches the central area); inner face is weak, positioned at a great angle to either the actinal or abactinal side face; intermarginal and side faces are slightly concave. Because of a step of the outer face the studied ossicle resembles a radial SupM of *Chomataster rectus* SCHULZ & WEITSCHAT from the Lower Campanian of northwest Germany (*see* SCHULZ & WEITSCHAT 1975, p. 277, Pl. 31, Fig. 3).

Ambulacral ossicles (Pl. 11, Figs 5-7) represent 3 types.

The first type is represented by 6 asymmetric, delicate ossicles (*see* Pl. 11, Fig. 6) that slightly resemble Ambb of *Ceramaster polonicus* sp.n. The differences are in the development of wing-like structures (weak, semielliptical and symmetricallly positioned), the more distinct distal concavity for ambulacral podium and the apophyse, which looks like a protruding slat, adradially thicker.

To the second type belongs one asymmetric, delicate ossicle (*see* Pl. 11, Fig. 5) with triangular, adradially flattened ambulacral body; dentition is composed of irregularly positioned tubercles and horizontal slats; upper insertion for transverse muscles is weak, very prolonged, lower one is large, triangular; oral groove is shallow and narrow; imprints of longitudinal muscles are oval – proximal one is small, present on the side face of the ambulacral body, distal one is big and visible on the aboral side, where additionally there is a big oval hollow; wing-like structures are small, semielliptical, proximal one is adradially transpositioned towards the distal wing-like structure; apophyse is slat-shaped, protruding; aboral ridge is low, rounded, strongly flattened on its abradial part.

To the third type belongs one symmetric, relatively short ossicle (*see* Pl. 11, Fig. 7) with weakly marked concavities for ambulacral podia. It has rectangular ambulacral body; dentition is well developed, composed of horizontal, irregular slats; there is a long deep insertion for longitudinal muscles on the aboral face; lower insertion for transverse mus-

cles is large, triangular; oral groove is very shallow; wing-like structures are small, semi-elliptical, symmetrically placed; apophyse is prominent: tubercle-shaped in the adradial part, slat-shaped in the abradial one. Aboral ridge is very protrudent on the level of concavities for podia, rounded, abradially flattened.

The above distinguished 3 types of Ambb are assigned to the family Goniasteridae due to the development of apophyses, and the value of the angle between the ossicle axis and Amb/Adamb contact surface. The ambulacral groove of representatives of the order Valvatida is narrow and very solid; therefore, the angle between the ossicle axis and contact surface of Amb/Adamb is quite big, and the apophyse runs along the adambulacral notch (BLAKE 1983; *fide* KACZMARSKA 1987, pp. 141-142).

Mouth-angle plates (Pl. 11, Fig. 4 and Pl. 12, Fig. 1) represent 2 types.

To the first type belong 5 ossicles (*see* Pl. 11, Fig. 4) which have triangular shape, main body prolonged, and proximally sharpened, but distally rounded; its abradial face is slightly concave: depression for muscle is oval, distally marked; near the oral ridge, opposite the first ambulacral articulation bar, there is a vertically prolonged loculus, limited on proximal and distal side by ridges; on outer face of the main body, in its distal part, there is a deep depression (muscle insertion?), limited by a ridge placed along the oral edge (there are 4 small loculuses over this ridge); oral surface is triangular; first ambulacral articulation bar is prominent, rectangular near its basis, and on its proximal side there is a relatively deep notch with a sharp slat. These ossicles resemble those of *Metopaster recurvatus* SPENCER from the Lower Maastrichtian (MÜLLER 1963, p. 430, Fig. 567/17-18). The differences concern the development of the first ambulacral articulation bar and the appearance of outer and inner faces of the main body.

To the second type belongs one small ossicle (*see* Pl. 12, Fig. 1) with the distally and proximally rounded main body. It has distal part bent inwards with a deep loculus (muscle insertion) on the adradial side; oral edge is rounded; first ambulacral articulation bar is slightly bent in the distal direction. This specimen resembles, in its shape, the mouth-angle plate of *Pycinaster angustatus* (FORBES, 1848) from the Campanian of northwest Germany (*see* SCHULZ & WEITSCHAT 1971, Pl. 26, Fig. 6), from which it differs by its size, shape of the first ambulacral articulation bar, and by a lack of the loculus near the oral ridge on the abradial side.

Cover ossicles (Pl. 12, Figs 2-7) represent 5 types.

To the first type belongs one relatively large ossicle (*see* Pl. 12, Fig. 7) which has outer face rectangular and flat, side-face rhomb-like, slightly concave. To the second type belongs one ossicle (Pl. 12, Fig. 6) featured by the rectangular, slightly concave outer face with centrally placed tubercles; its inner part is prolonged horizontally, triangularly shaped, with distinct surfaces of the contact with neighboring ossicles. The third type consists of 10 low ossicles (*see* Pl. 12, Figs 3-4) multi-sized, with outer face covered with circular loculuses, and inner one flat; side-face outlines groove-shaped. To the fourth type belongs one ossicle (*see* Pl. 12, Fig. 5) which has the following surfaces: outer one convex, inner one concave, side-faces – flat and concave. To the fifth type belongs one ossicle spool-shaped (*see* Pl. 12, Fig. 2); its outer face is slightly convex with big hollows, and inner one slightly concave with a tubercle placed centrally; column is relatively thick.

Asteroid indeterminate ossicles (Pl. 12, Figs 8-16)

Taxonomically unrecognized asteroid material contains different ossicles (*see* Pl. 12, Figs 8-16), which characteristics is presented below.

The Ambb ossicles are of three types (Pl. 12, Figs 11, 14, and 16), and named herein as *A*, *B*, and *C*. The type *B* ossicle (Pl. 12, Fig. 14) probably belonged to an asteroid that had 4 rows of podia inside ambulacral groove; Ambb of these asteroids are very delicate, thickly placed, and their concavities (also in Amb *B*) are in different distance from the top of the ossicle (*see* HYMAN 1955, MÜLLER 1963).

The terminals are of 3 types (Pl. 12, Figs 8-9 and 15) and called herein as *A*, *B*, and *C*. The type *B* (Pl. 12, Fig. 9) resembles the terminal presented from the Korytnica Basin by KACZMARSKA (1987, Pl. 8, Fig. 4).

The other ossicles are represented by various madreporites (Pl. 12, Figs 12-13) that vary in the arrangement of grooves on their outer surface, as well as by some circumorals (Pl. 12, Fig. 10).

TAXONOMIC PROBLEM OF THE SPECIES *ASTROPECTEN GRANULATUS*

While searching in the references to this study, the Authoress has recognized that the species name for the isolated ossicles from the Eocene deposits of England, used by WIENBERG RASMUSSEN (1972, pp. 38-40 and Pl. 3, Figs 5-8), to designate a new species "*Astropecten granulatus* WIENBERG RASMUSSEN, 1972", is preoccupied (*see* MÜLLER & TROSCHEL 1842) by the name of the present-day species *Astropecten granulatus* MÜLLER & TROSCHEL, 1842, living along the coasts of Australia, East India, the Philippines, and South Africa (*see* DILWYN JOHN 1948).

In fact, it is quite surprising that WIENBERG RASMUSSEN (1972) used the discussed name for a different fossil species, while the present-day species bearing this preoccupied name, *Astropecten granulatus* MÜLLER & TROSCHEL, 1842, has often been reported in the literature (*see* full data *in* DILWYN JOHN 1948, p. 486).

The species name *Astropecten granulatus* WIENBERG RASMUSSEN, 1972, as being a younger homonym, in thus replaced herein by a new name, *Astropecten anglicus* nom.n., which refers to the occurrence of the species in the fossil sequence of England.

FINAL REMARKS

The studied starfish assemblage from the Nawodzice Sands enriches the list of unique biota dispersed throughout the Middle Miocene (Badenian) sequence of the Fore-Carpathian and adjacent areas in Poland. All data on other occurrences of the Middle Miocene (Badenian) starfishes in these areas, with a special emphasis to the Korytnica Basin, were concisely surveyed by KACZMARSKA (1985,

1987), who also presented a review of reports on the Tertiary fully preserved starfishes in Europe. A taxonomic comment on the *Luidia* findings of KACZMARSKA (1987) was offered by JAGT (1991).

The ecological and biogeographic conclusions on the studied assemblage from the Nawodzice Sands are consistent with those given by KACZMARSKA (1987) for specimens from the Korytnica Basin. The feeding biology and biotope behavior of *Astropecten navodicensis* sp.n. is thought the same as of modern species of that genus (*cf.* CHRISTENSEN 1970).

A general impression is involved that the studied assemblage from the Nawodzice Sands is well compatible to the recognized environmental conditions of that Middle Miocene area, typified by the shallow, open-marine, tropical and/or subtropical waters with distinct influences of the Indo-Pacific bioprovince.

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PLATE 1

Astropecten navodicensis sp.n.

1 — Specimen with outspread arms (*1a* oral, *1b* aboral view), × 2; Fig. 1a – formerly illustrated as *Astropecten* sp. by RADWAŃSKI (1977, p. 748, Fig. 172/*9*)

2 — Specimen with aborally bent arms, nearly into a tulip-like form (*2a-2b* oral views of arms, *2c* oral view of the disc); × 3

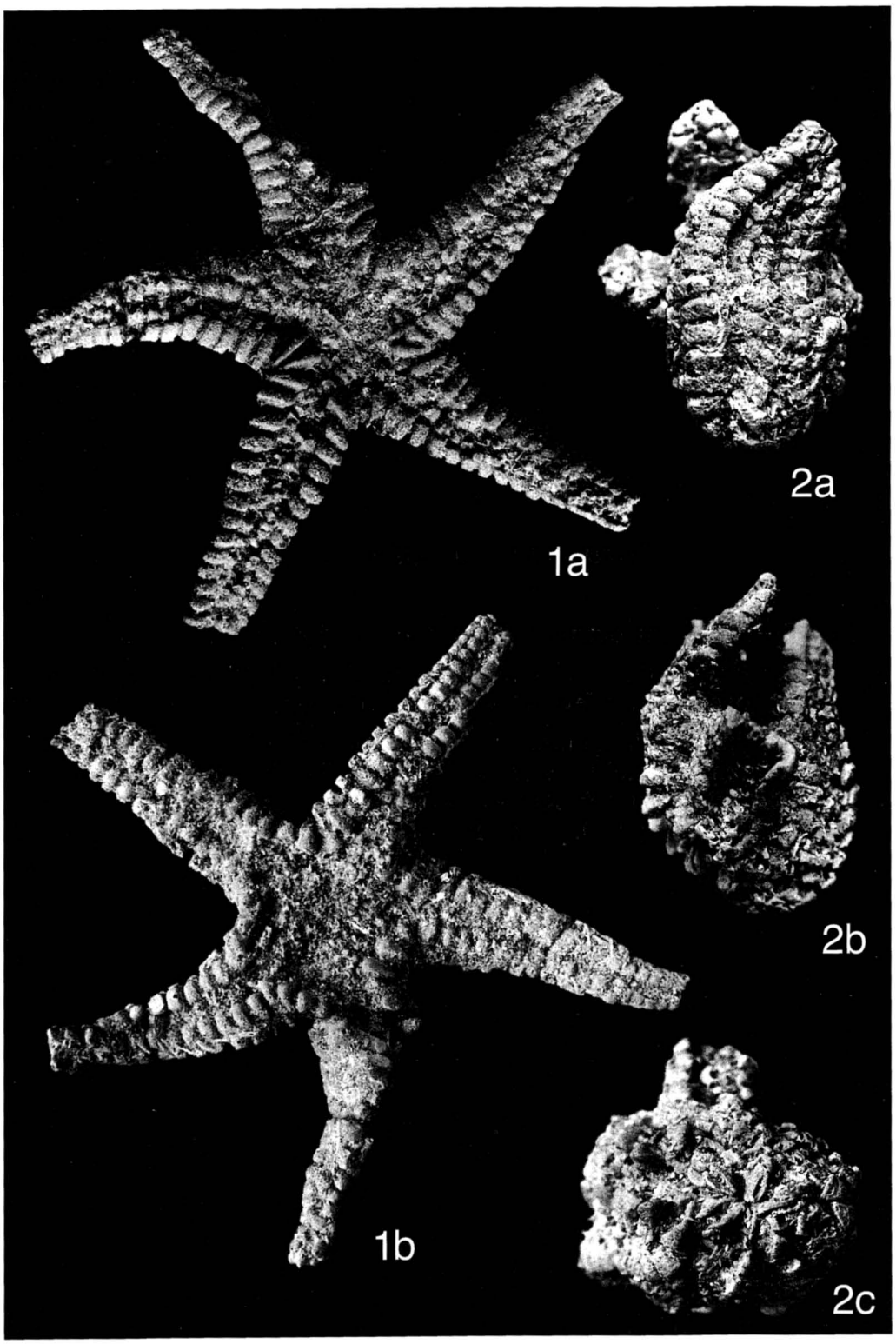

2a
1a
2b
1b
2c

PLATE 2

Astropecten navodicensis sp.n.

1 — Specimen with outspeared arms (*1a* oral, *1b* aboral view); × 1.7

2 — Specimen with heavily twisted arms (*2a* oral view of ambulacral groove, *2b* oral view, arrow indicates the circumoral ossicle); × 3

3 — Specimen with upraised arms into a tulip-like form (*3a* oral view of arms, *3b* oral view of the disc); × 3; Fig. 3a – formerly illustrated by BAŁUK & RADWAŃSKI (1968, p. 456, Fig. 3/*10a*) and RADWAŃSKI (1970, p. 383, Fig. 3/*j*)

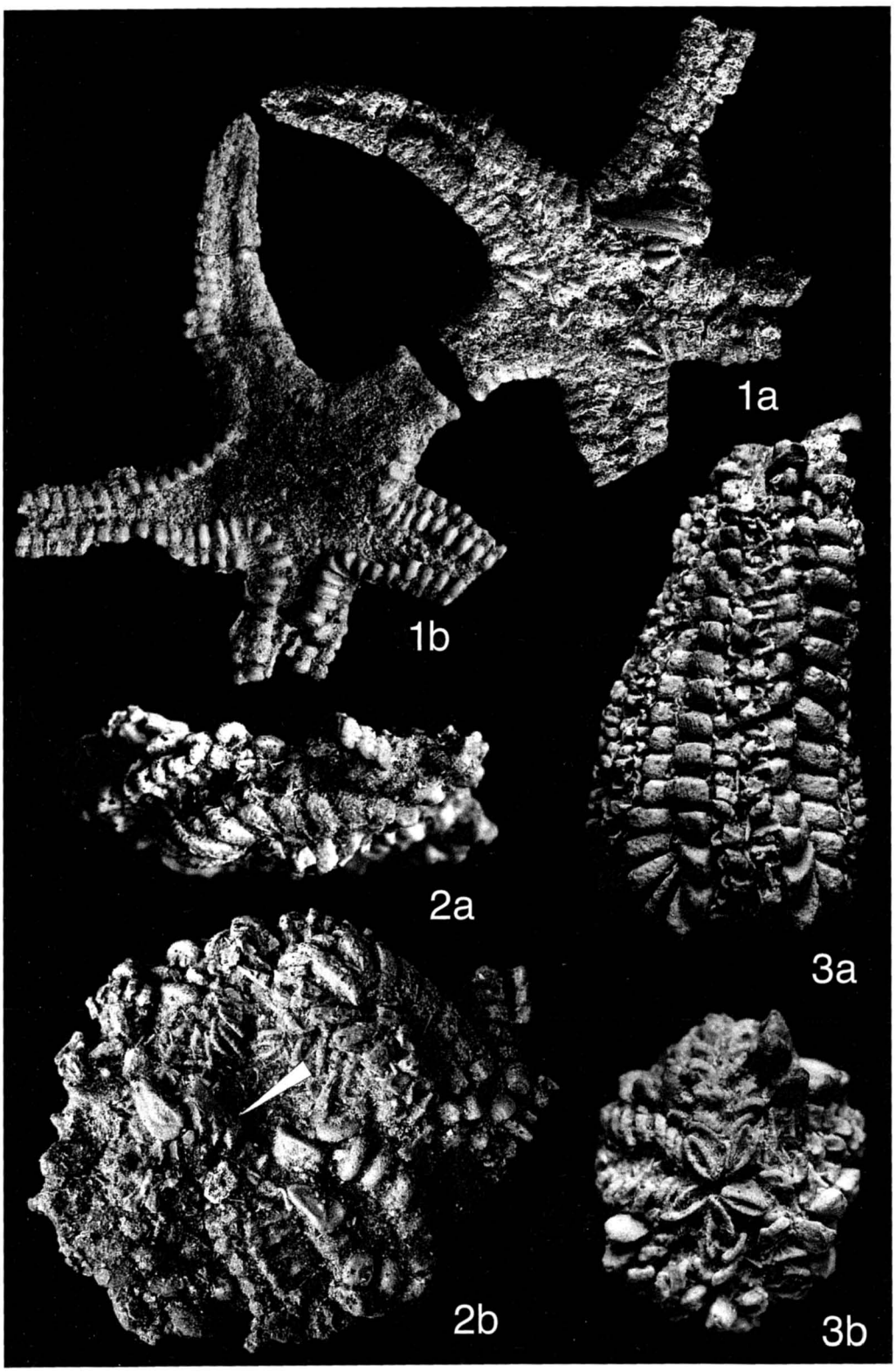

1a
1b
2a
3a
2b
3b

PLATE 3

Astropecten navodicensis sp.n.

1 — Specimen with twisted arms (*1a* aboral, *1b* oral view); × 3

2 — Fragment of the arm (*2a* proximal, *2b* aboral, *2c* abradial, *2d* oral view: arrows indicate proximal direction); × 6

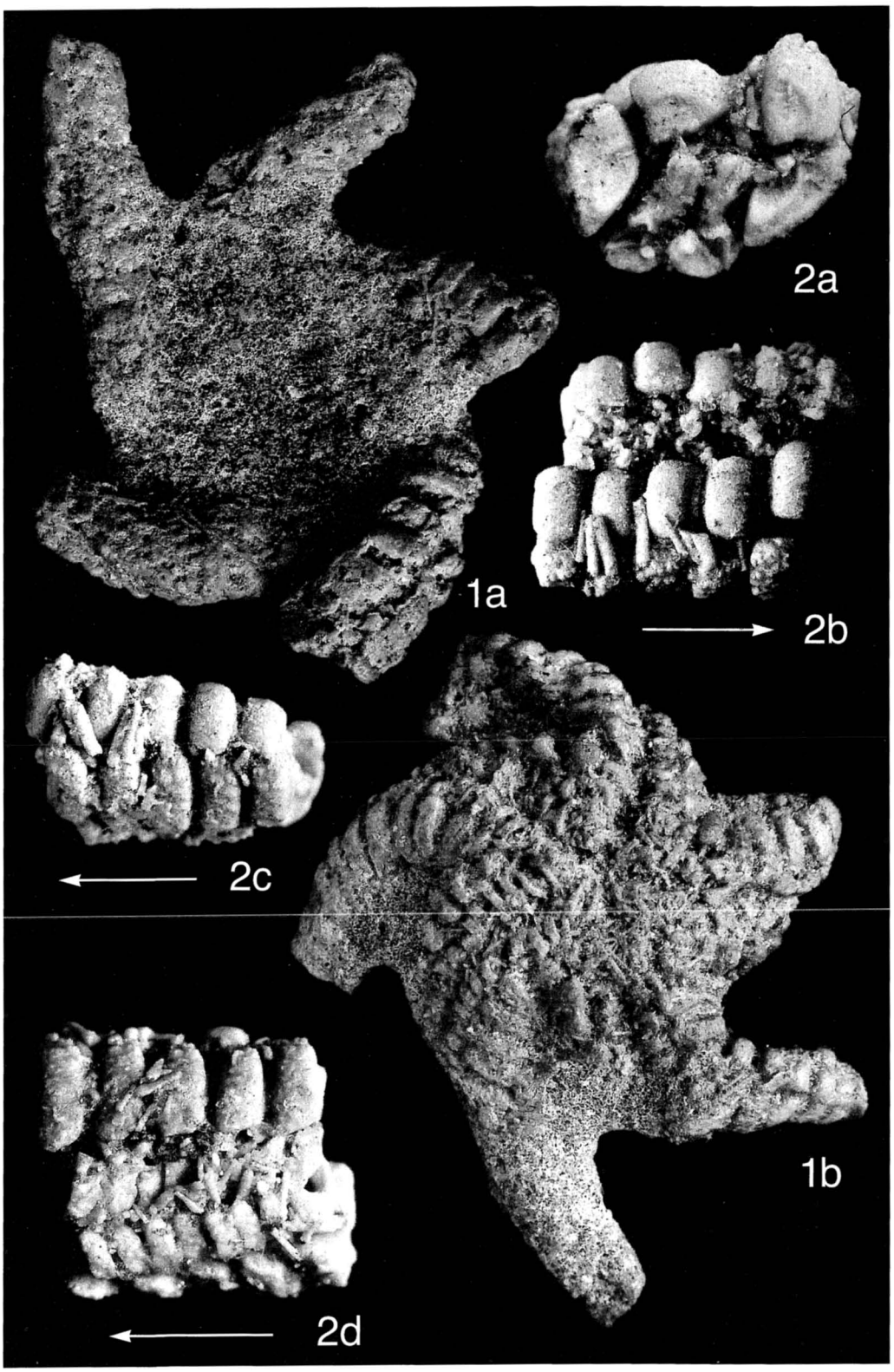

2a
1a
2b
2c
1b
2d

PLATE 4

Astropecten navodicensis sp.n.

1 — Specimen with outspread arms (*1a* aboral, *1b* oral view); × 1.6

2 — Fragment of ambulacral groove (*2a* abradial, *2b* distal, *2c* abora *2d* oral view: arrows indicate proximal direction); × 10

3 — Ossicles connected confusedly; ×10

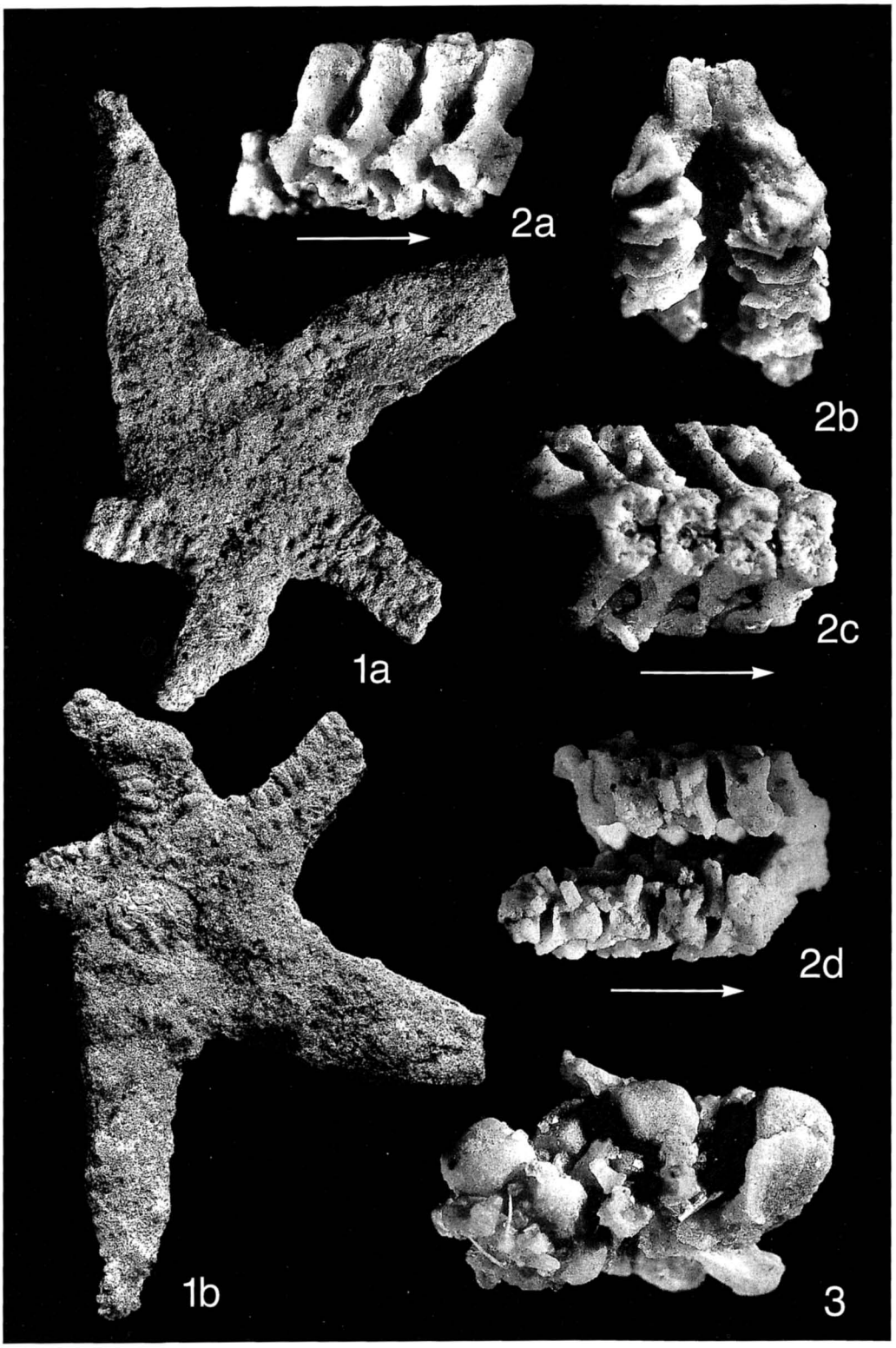

2a
2b
2c
1a
2d
1b
3

PLATE 5

Astropecten navodicensis sp.n.

1 — **Holotype**: an overall view of the specimen; exposed are the disc and fragments of three arms (oral view of the ambulacral groove); × 3

Figs **2-16** — Isolated ossicles of various specimens; all × 10
Figs **4**, **6-8**, **11-14**, **16** — Ossicles belonging to the **holotype** (*see* Fig. 1 of this Plate)

2 — Right SupM and InfM (abradial view), **3** — Right SupM, InfM, and paxillae (distal view), **4** — Left InfM (*4a* oral, *4b* distal view), **5** — Right InfM (*5a* oral, *5b* distal view), **6** — Interbrachial InfM (*6a* oral, *6b* lateral view), **7** — Interbrachial SupM (*7a* abradial, *7b* lateral view), **8** — Right SupM (*8a* distal, *8b* abradial view), **9-10** — Terminal ossicles (*9a*, *10a* aboral; *9b*, *10b* oral views), **11** — Left Adamb (*11a* oblique proximal, *11b* oblique distal view), **12** — Left proximal Adamb (*12a* oblique proximal, *12b* oblique distal view), **13** — Left Amb (*13a* oral, *13b* proximal, *13c* aboral, *13d* distal view), **14** — Left proximal Amb (*14a* oral, *14b* proximal, *14c* aboral view), **15** — Left circumoral ossicle (*15a* aboral, *15b* oral view), **16** — Mouth-angle plate (*16a* adradial, *16b* abradial view)

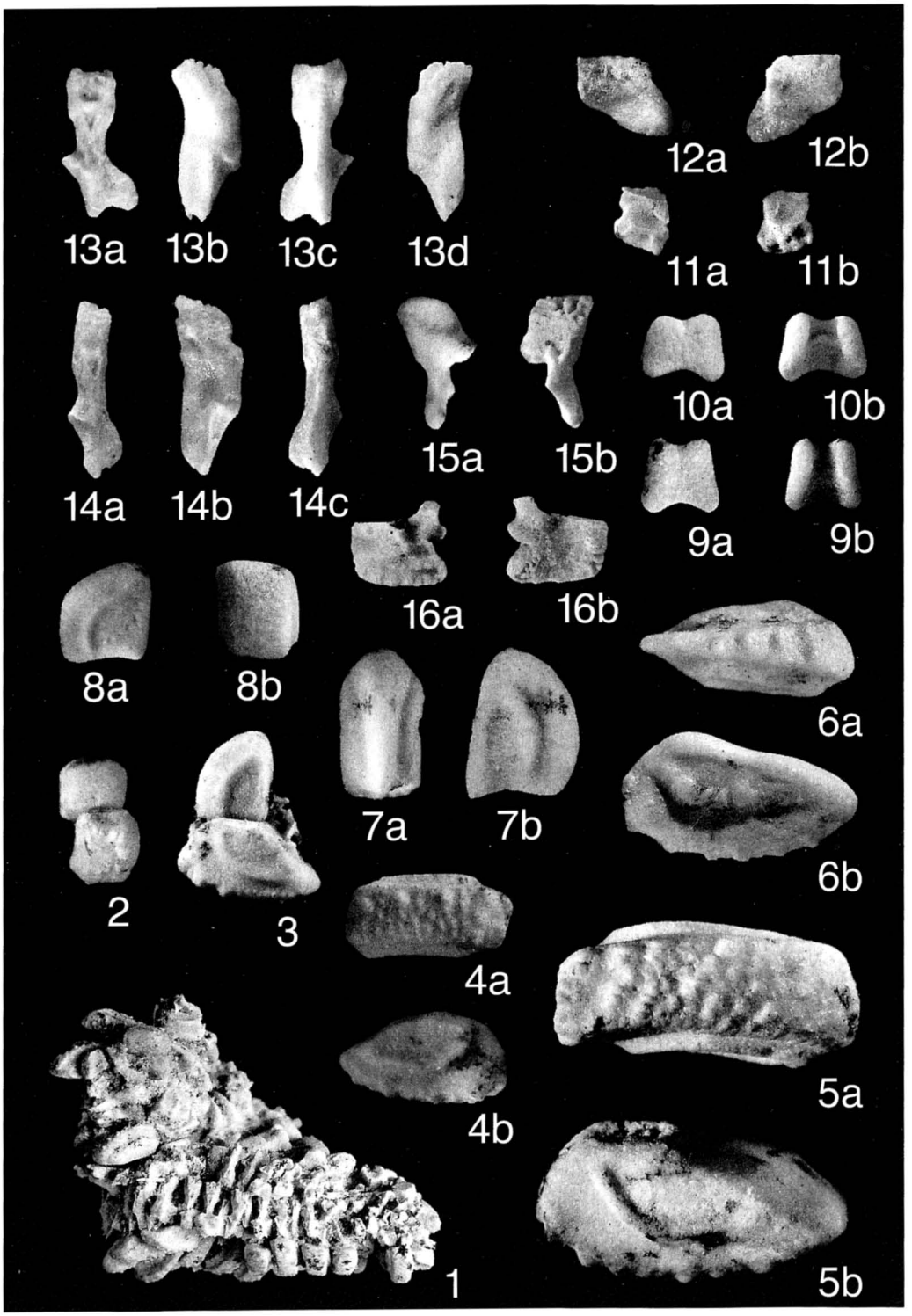

13a
13b
13c
13d
12a
12b
11a
11b
14a
14b
14c
15a
15b
10a
10b
9a
9b
16a
16b
8a
8b
6a
7a
7b
6b
2
3
4a
5a
4b
1
5b

PLATE 6

Astropecten navodicensis sp.n.

1-5 — Scales; **6-8** — Spines; **9** — SupAmb of the **holotype** (lateral view); **10-12** — Paxillae of the **holotype** (*a* lateral, *b* aboral views); all × 10

Astropecten sp.

13-15 — Interbrachial SupMM (*a* lateral, *b* abradial, *c* aboral views); **16-17** — SupMM (*a* lateral, *b* abradial views); **18** — InfM (*18a* lateral, *18b* oral view); all × 10

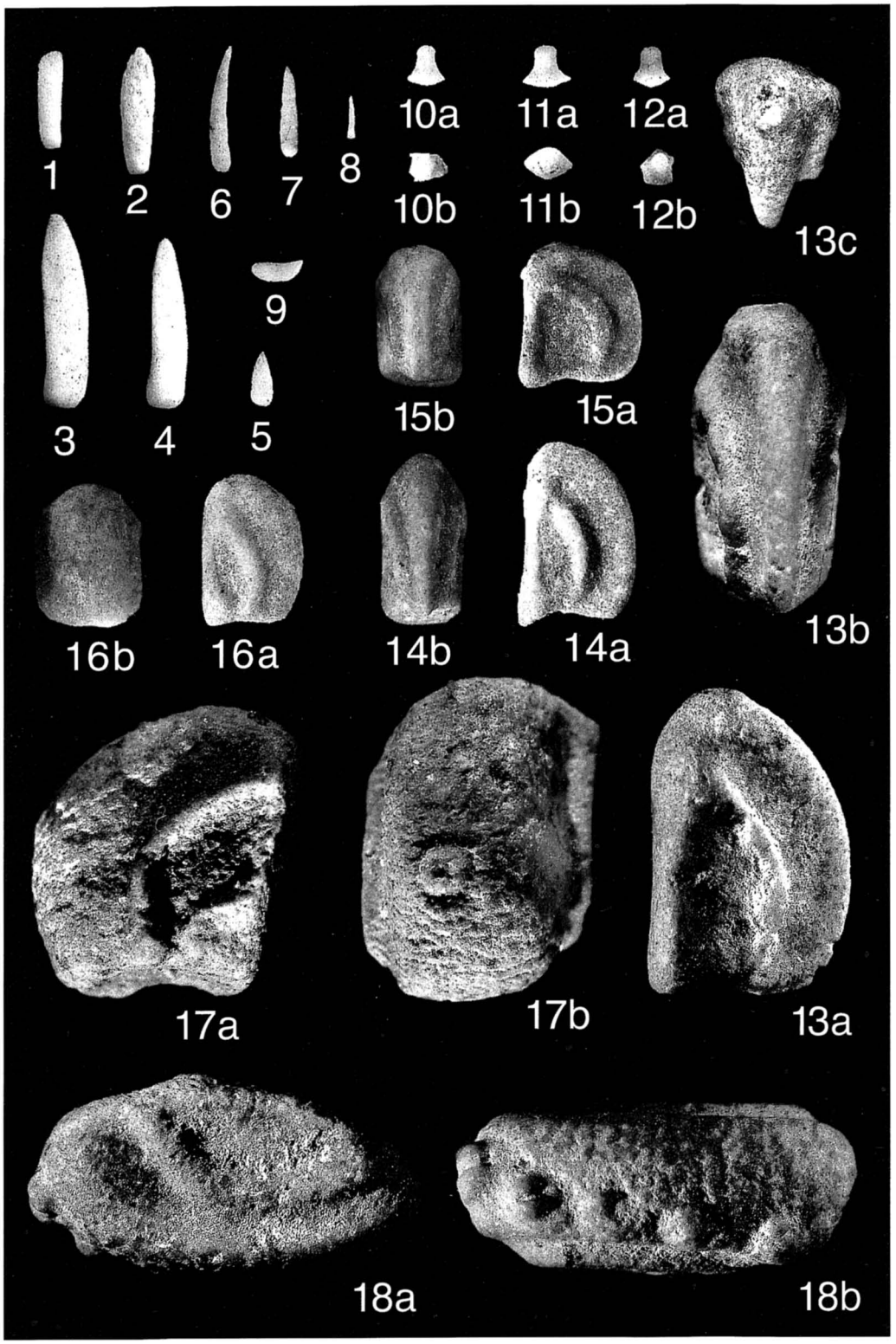
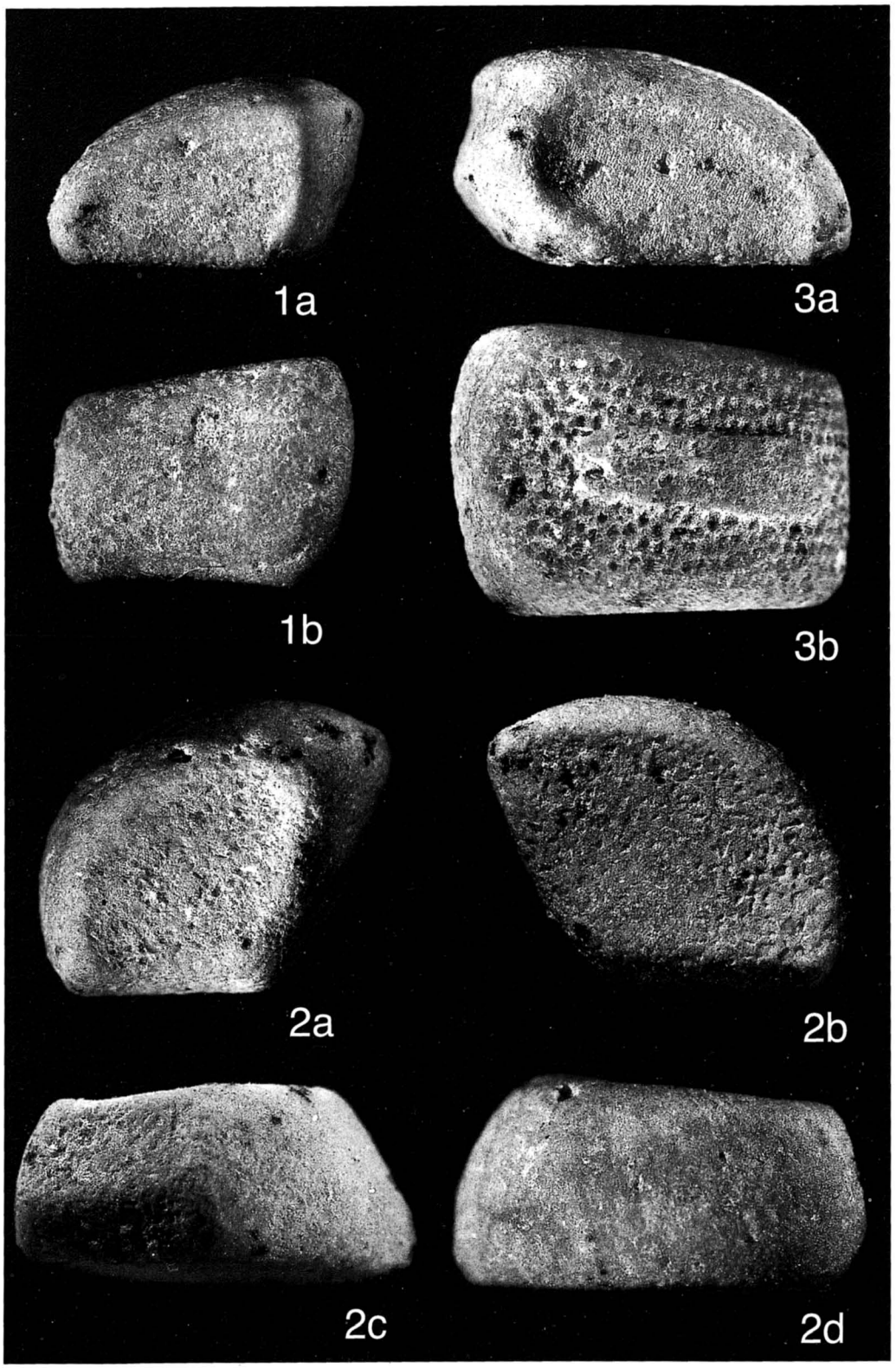

1
2
6
7
8
10a
10b
11a
11b
12a
12b
13c
3
4
9
5
15b
15a
16b
16a
14b
14a
13b
17a
17b
13a
18a
18b

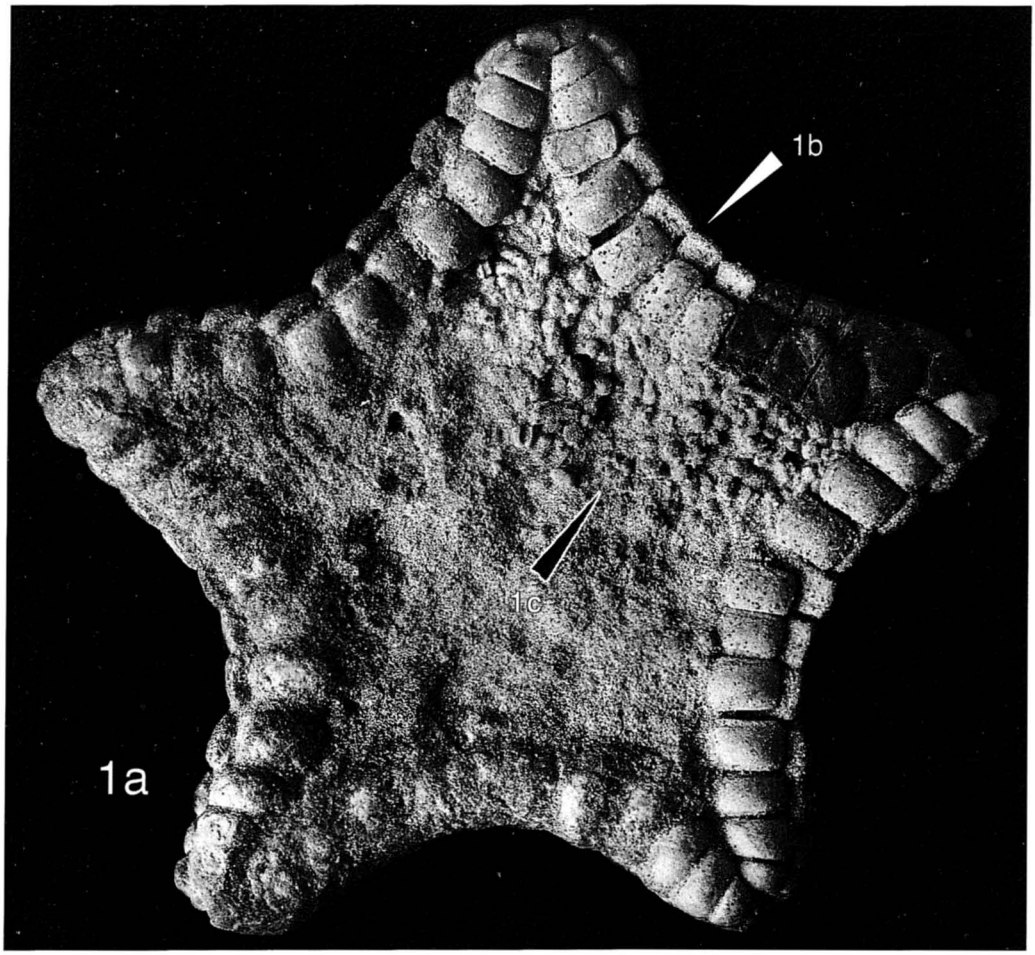
PLATE 7

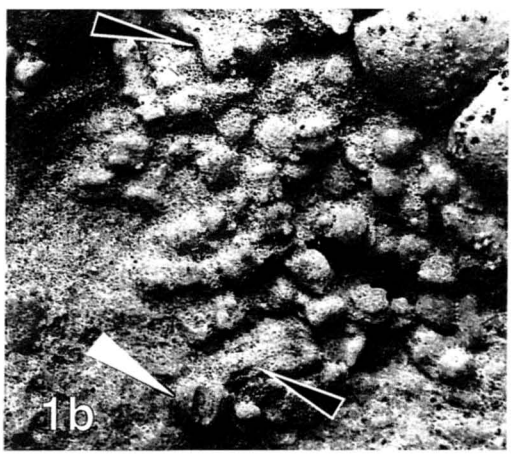
Ceramaster polonicus sp.n.

1 — Arm marginal (*1a* lateral, *1b* outer view), **2** — Arm marginal (*2a* distal, *2b* proximal, *2c* intermarginal and inner, *2d* outer view), **3** — Median marginal (*3a* lateral, *3b* outer view)

All photos are taken × 10

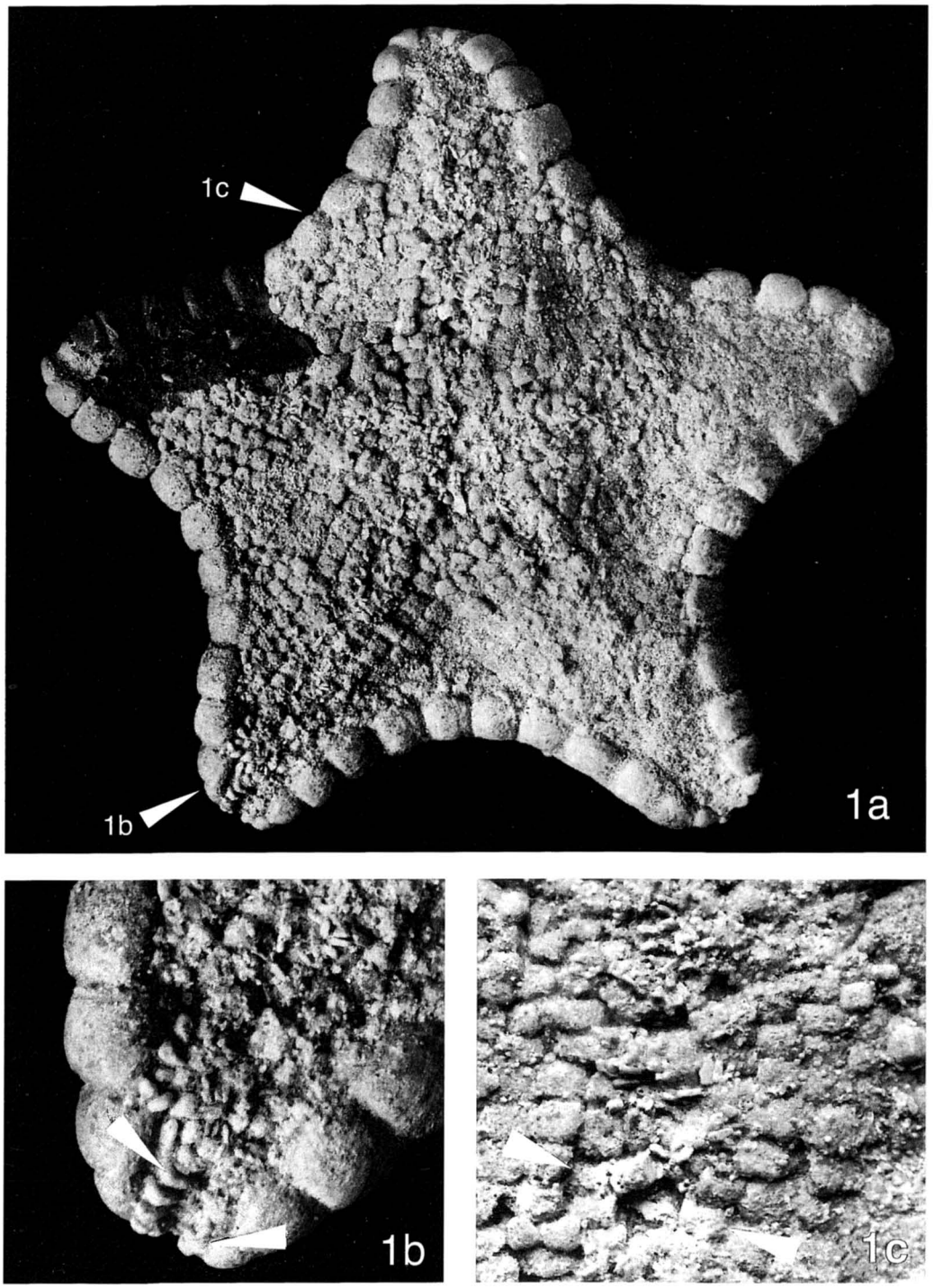

1a
3a
1b
3b
2a
2b
2c
2d





Ceramaster polonicus sp.n.

1a — Aboral view of the **holotype** with outspread arms, × 1.4; **1b** — Close-up of the disc, to indicate the ambulacral ossicles (*black arrows*) and pedicellaria (*white arrow*), × 3; **1c** — Close-up of the disc, to show abactinal ossicles, × 3



Ceramaster polonicus sp.n.

1a — Oral view of the **holotype**, × 1.4; **1b** — Close-up of the arm apex, to show the adambulacral ossicles (*arrowed*), × 3; **1c** — Close-up of the disc, to show the adambulacral ossicles (*arrowed*), × 3

PLATE 10

Ceramaster polonicus sp.n.

1 — Fragment of the arm: SupMM (upper row) and InfMM (lower row) in abradial view, × 2

2-6 — Close-ups of ossicles from a fragment of the arm (shown in Fig. 1)

2 — Left Amb (*2a* oral, *2b* aboral, *2c* proximal view), **3** — Terminal ossicle (*3a* aboral, *3b* oral, *3c* lateral view), **4** — Distal Adamb (distal or proximal view), **5** — Right proximal Adamb (*5a* proximal, *5b* oral view), **6** — Abactinal ossicle (*6a* lateral, *6b* aboral, *6c* oral view)

7-8 — Abactinal ossicles of other specimens (*a* lateral, *b* aboral, *c* oral views)

9 — Actinal ossicle adjacent to InfM (*9a* lateral, *9b* oral view)

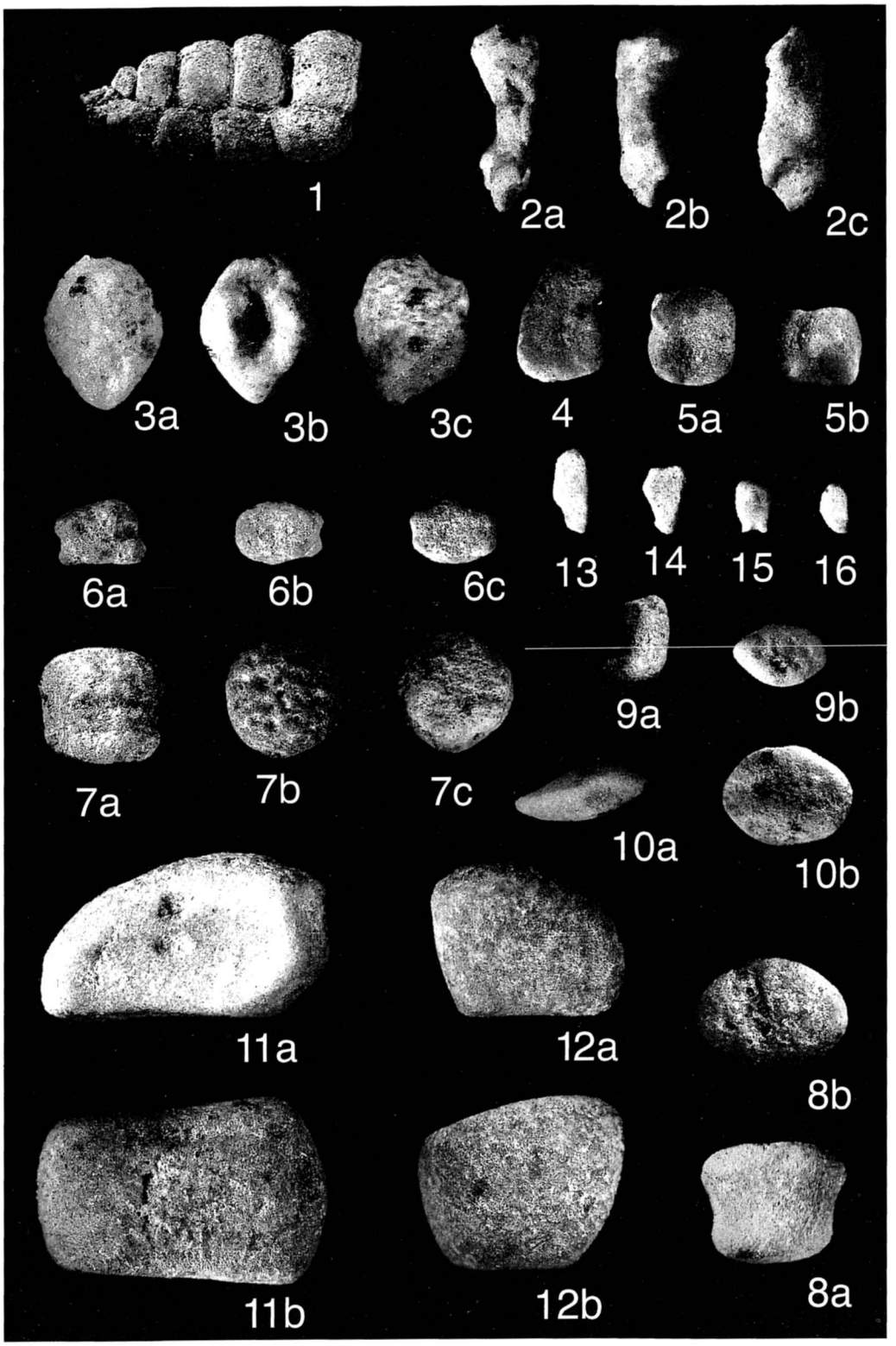
10 — Actinal ossicle (*10a* lateral, *10b* oral view)

11 — Median marginal (*11a* lateral, *11b* outer view)

12 — Arm marginal (*12a* proximal, *12b* outer view)

13-16 — Close-up of scales from the **holotype**

All photos (except Fig. 1) are taken × 10


1
2a
2b
2c
3a
3b
3c
4
5a
5b
6a
6b
6c
13
14
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16
9a
9b
7a
7b
7c
10a
10b
11a
12a
8b
11b
12b
8a

PLATE 11

Goniasteridae, gen. et sp. indet.

1-2 — Marginal ossicles (*a* outer, *b* lateral views), **3** — Marginal ossicle (*3a* outer distal, *3b* outer oral or aboral, *3c* lateral view), **4** — Mouth--angle plate (*4a* adradial, *4b* abradial view), **5** — Right Amb (*5a* aboral, *5b* oral, *5c* proximal view), **6** — Right Amb (*6a* aboral, *6b* oral, *6c* distal view), **7** — Amb (*7a* aboral, *7b* oral, *7c* lateral view)

All photos are taken × 10

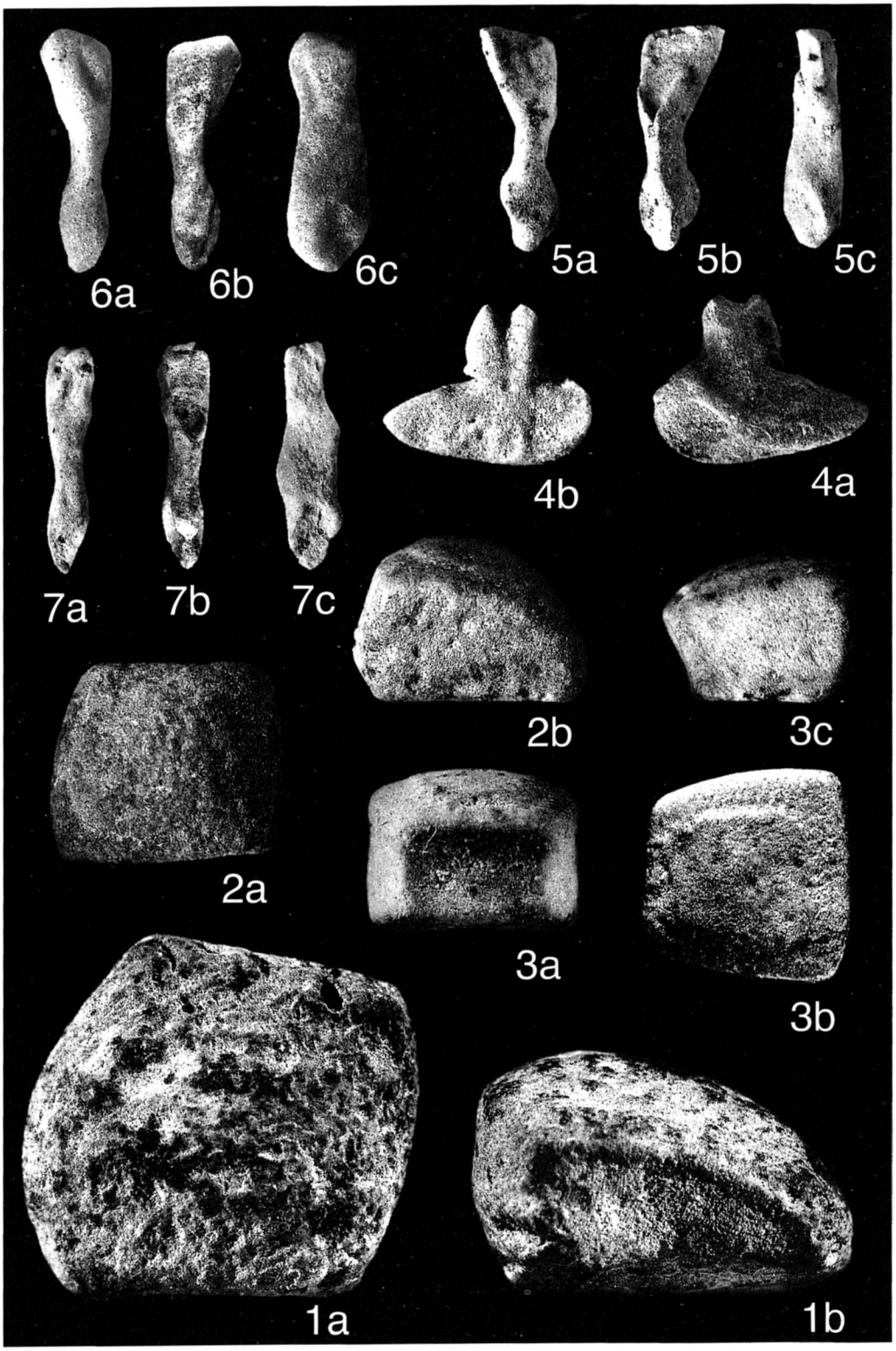

6a
6b
6c
5a
5b
5c
7a
7b
7c
4b
4a
2b
3c
2a
3a
3b
1a
1b

PLATE 12

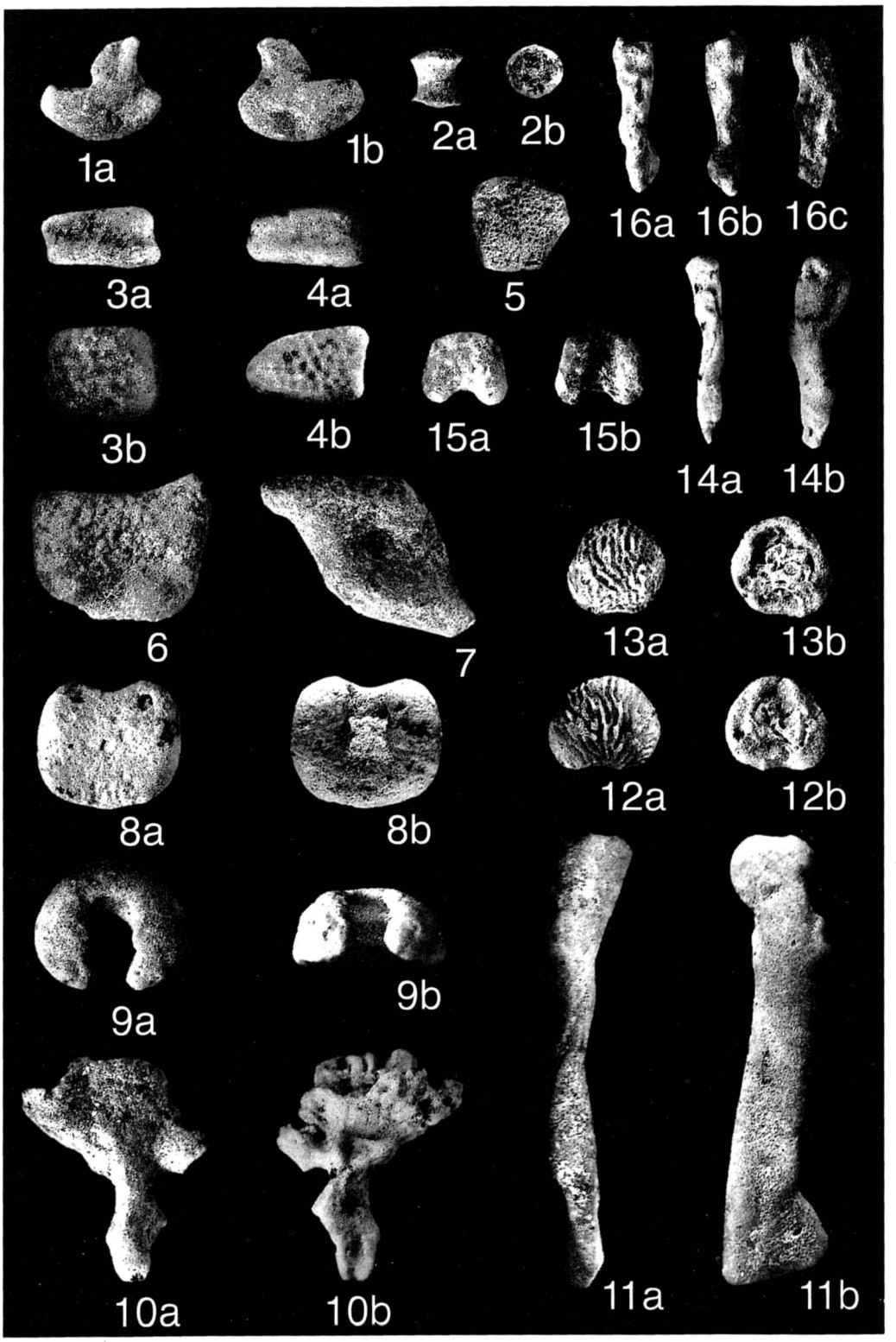
Goniasteridae, gen. et sp. indet.

1 — Mouth-angle plate (*1a* abradial, *1b* adradial view), **2** — Cover ossicle (*2a* lateral, *2b* outer view), **3-4** — Cover ossicles (*a* lateral, *b* outer views), **5-6** — Cover ossicles (outer views), **7** — Cover ossicle (lateral view)

Asteroid indeterminate ossicles

8 — Terminal *A* ossicle (*8a* aboral, *8b* oral view), **9** — Terminal *B* ossicle (*9a* distal, *9b* oral view), **10** — Circumoral ossicle (*10a* aboral, *10b* oral view), **11** — Amb *A* ossicle (*11a* oral, *11b* lateral view), **12-13** — Madreporites (*a* aboral, *b* oral views), **14** — Amb *B* ossicle (*14a* oral, *14b* lateral view), **15** — Terminal *C* ossicle (*15a* aboral, *15b* oral view), **16** — Amb *C* ossicle (*16a* oral, *16b* aboral, *16c* lateral view)

All photos are taken × 10


1a
1b
2a
2b
16a
16b
16c
3a
4a
5
3b
4b
15a
15b
14a
14b
6
7
13a
13b
8a
8b
12a
12b
9a
9b
10a
10b
11a
11b