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## Asteroids from the Korytnica Basin (Middle Miocene; Holy Cross Mountains, Central Poland)

**ABSTRACT:** The assemblage of the asteroid remains from the Korytnica Basin (Middle Miocene; Holy Cross Mountains, Central Poland) contains ossicles belonging to the orders Paxillosida and Valvatida. The genus *Astropecten* is represented by four species: *Astropecten granulatus* WIENBERG RASMUSSEN, *Astropecten* sp. A, *Astropecten* sp. B, and *Astropecten* sp. C. The genus *Luidia* is represented by two species: *Luidia ciliaris* (PHILIPPI) and *L. alternata* (SAY). Moreover, the representatives of the family Goniasteridae are also present. The whole investigated assemblage indicates a tropical shallow-marine environment, and it shows certain affinities to the Recent asteroid fauna of the Indo-Pacific.

### INTRODUCTION

The asteroid remains are comparatively common in the Middle Miocene (Badenian) deposits in Poland. They were reported from the sandy sections exposed at Nawodzice (BAŁUK & RADWAŃSKI 1968) and Świński in the eastern part of the Holy Cross Mountains (RADWAŃSKI 1973) where wholly preserved asteroid skeletons occur (see BAŁUK & RADWAŃSKI 1968, Text-fig. 3; RADWAŃSKI 1970, Text-fig. 3, and 1977, Fig. 172/9), and from Niskowa near Nowy Sącz in the Carpathians (BAŁUK 1970) where loose, skeletal elements were found.

In the Korytnica Basin the asteroid ossicles were first recognized by KOWALEWSKI (1927; 1930, p. 70), who reported *Astropecten* sp. and/or *Luidia* sp. both in the Korytnica Clays and in the member overlying the clays, i. e. the marly sands with *Heterostegina* and other fossils (see BAŁUK & RADWAŃSKI 1977, Text-fig. 4). The presence of the *Astropecten* ossicles in the Korytnica Basin has also been stated by BAŁUK (1975), BAŁUK & RADWAŃSKI (1977), HOFFMAN (1977), RADWAŃSKA (1982), and GUTOWSKI (1984).

Among rich assemblages of diverse fossils in the Korytnica Basin, the asteroid ossicles are an accessory element (see BAŁUK & RADWAŃSKI

1977, HOFFMAN 1977). A systematic study has recently been undertaken by the present author (KACZMARSKA 1985), to recognize the morphology of isolated ossicles and their taxonomical attribution.

As it was recognized by BLAKE (1973), the morphology of certain skeletal ossicles of the asteroids may be useful in taxonomic studies. However, because of the scarcity of the comparative material, the present author has not been able to define the specific assignment of many ossicles, the taxonomy of which still remains open to discussion.

Any attempt to recognize the composition of the asteroid assemblages on the basis of isolated ossicles has not as yet been presented for the Tertiary sequences of Europe. The previous reports on the Tertiary asteroids in Europe concern larger fragments and more or less wholly preserved skeletons which are relatively very rare fossils in some Paleogene strata of northern and western Europe (FORBES 1852, WIENBERG RASMUSSEN 1972), in the Neogene of Italy (see SACCO 1893, DEL PRATO 1896), as well as in the Miocene of the Vienna Basin (HELLER 1858), Hungary and Rumania (VADÁSZ 1915), and the Ukraine, Soviet Union (KUDRIN 1957).

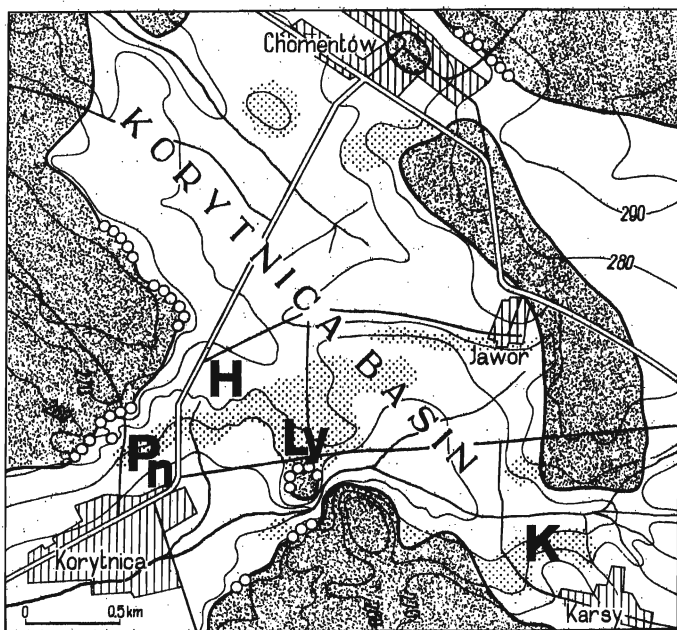


Fig. 1. Paleoenvironmental sketch of the Korytnica Basin, to show localities yielding the investigated assemblage of asteroids, both from the Korytnica Clays: Ly — Mt. Lysa, K — Karsy, Pn — Korytnica-Plebana, and from H — the overlying marly sands with *Heterostegina*. Within the sketch indicated are: marine area of the basin during the Middle Miocene (Badenian) transgression (blank), present-day outcrops of the Korytnica Clays (stippled), preserved fragments of littoral structures (circled), and land or island areas along the seashore (hachured); adopted from BAŁUK & RADWAŃSKI (1977, Text-fig. 2)

The investigated material comes from four localities in the Korytnica Basin (Text-fig. 1), and it was obtained during sifting the samples. All the ossicles are relatively well preserved and some of them, especially the marginals and ambulacrals, are very common in the sampled sites.

THE ASTEROID OSSICLES

The asteroid skeleton consists of many ossicles (see Text-figs 2—3). The most important are superomarginals and inferomarginals from the margin of the arm; the ambulacrals are supported by the adambulacrals and form an ambulacrals groove which is opened orally (Text-fig. 2). The specialized ossicles (mouth angle plates, circumoral ossicles, odontophores) are present in the oral region (Text-fig. 3). The surface of arms and of the disc is covered by actinals on the oral side, and by abactinals on the aboral side (Text-fig. 2). Very numerous spines, spinelets and tubercles are attached to the main ossicles.

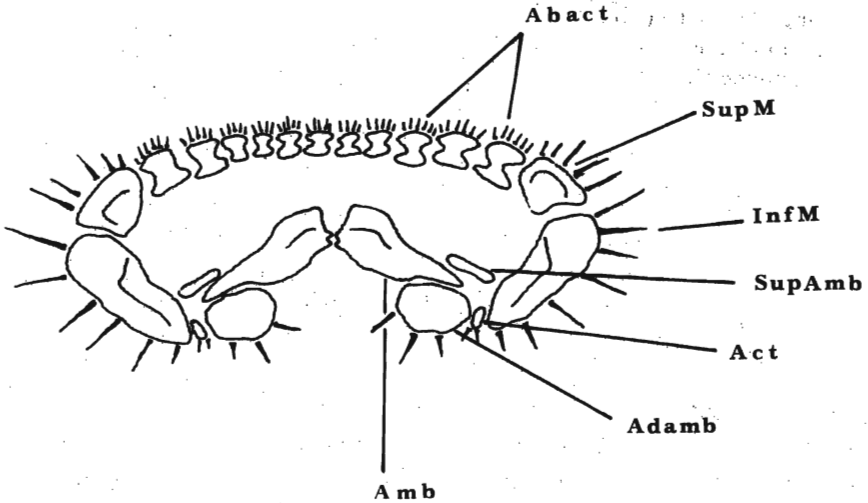


Fig. 2. Section through an idealized asteroid arm, to show the position of particular ossicles; **SupM** — superomarginals, **InfM** — inferomarginals, **Amb** — ambulacrals, **Adamb** — adambulacrals, **SupAmb** — superambulacrals, **Act** — actinals, **Abact** — abactinals (commonly, these are the paxillae)

The terminology, abbreviations and phrases used in the present paper, while describing the ossicles and/or their elements, follow those given by SPENCER & WRIGHT (1966), BLAKE (1973, 1980, 1981, 1983), and MÜLLER (1978). For a detailed description of circumoral ossicles

suggested are the new terms, such as the *adoral circumoral extension* ("zweiter Circumoralfortsatz" of MÜLLER 1978) and the *distal circumoral extension* ("erster Circumoralfortsatz" of MÜLLER 1978). For mouth

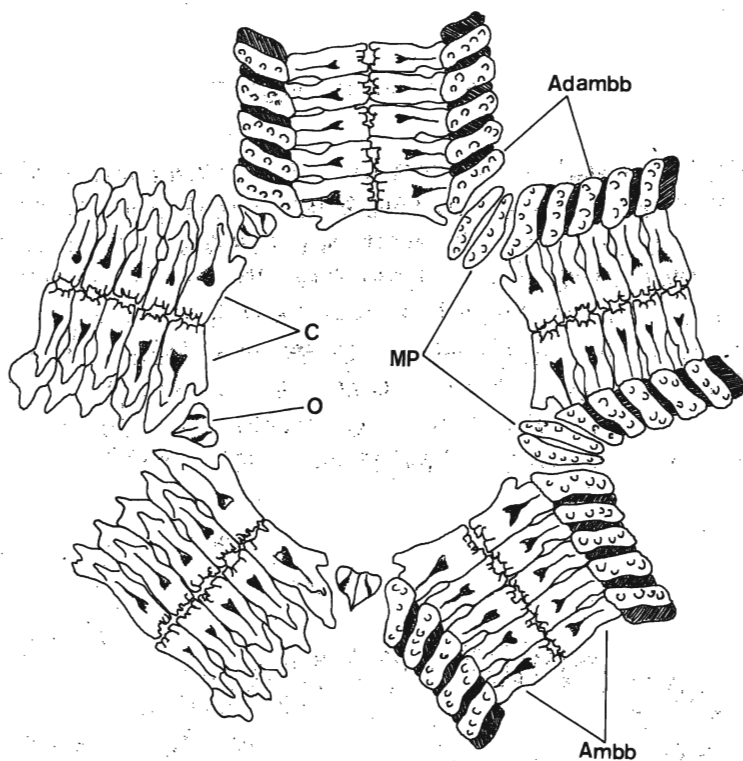


Fig. 3. Position of ossicles in the oral region of an asteroid (oral view; at left, adambulacrals and mouth angle plates partly removed): **Ambb** — ambulacrals, **Adambb** — adambulacrals, **MP** — mouth angle plates, **C** — circumorals, **O** — odontophore

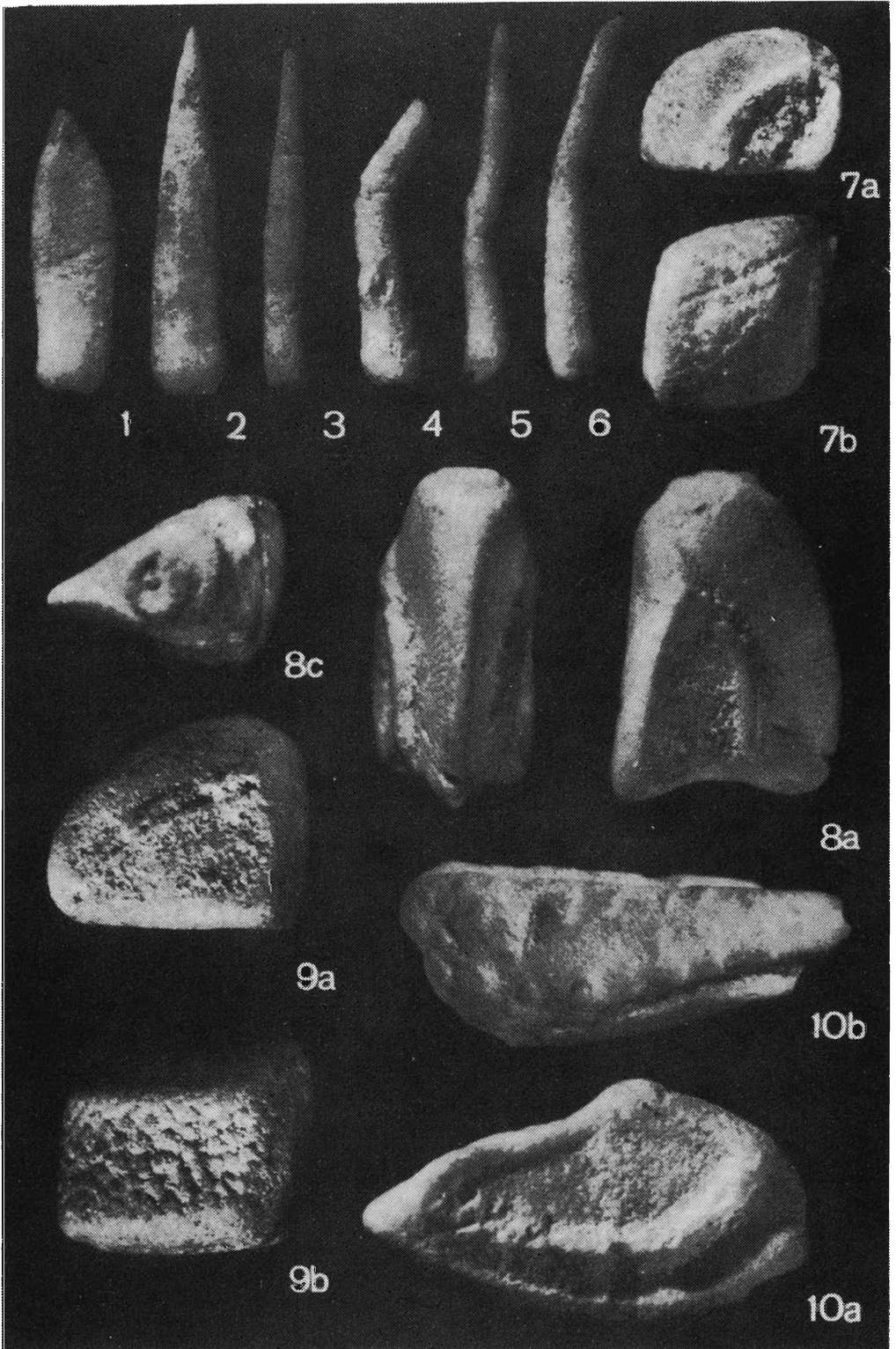
angle plates suggested are the terms: the *outer face* for the laterally directed face of the ossicle in its furrow view, and the *inner face* for the face directed toward the opposite member of the mouth-angle ossicle pair.

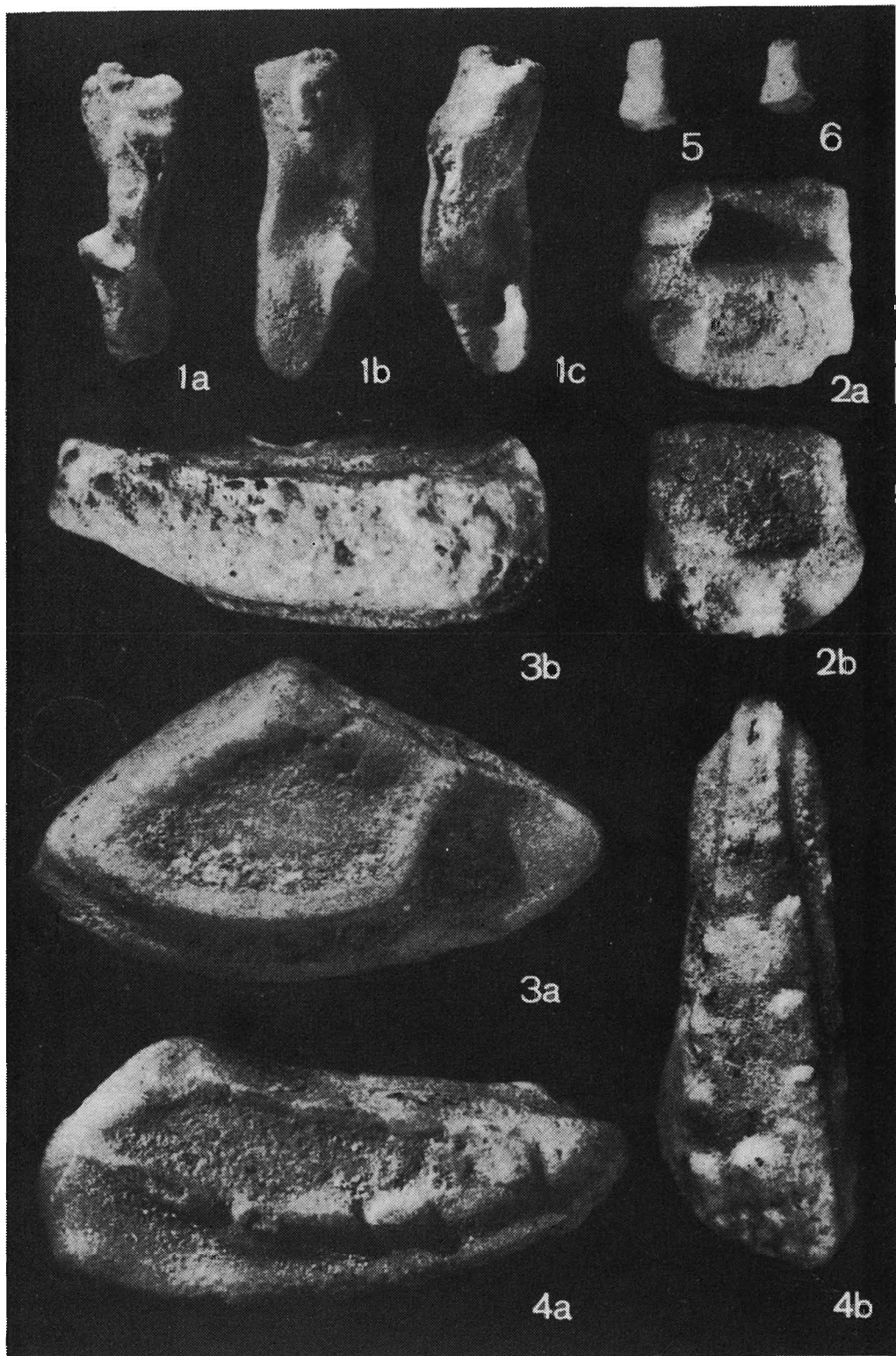
#### PLATE I

#### *Astropecten granulatus* WIENBERG RASMUSSEN, 1972

1 — Scale, 2-3 — spines, 4-6 — repaired ("regenerated") spines, 7-9 — SupMM (a lateral, b abradial, c aboral views), 10 — InfM (10a lateral, 10b oral view)

All photos  $\times 10$ ; taken by K. ZIELIŃSKA





## SYSTEMATIC ACCOUNT

## Order Paxillosida PERRIER, 1894

## Suborder Diplozonina SPENCER &amp; WRIGHT, 1966

## Family Astropectenidae GRAY, 1840

Genus *Astropecten* GRAY, 1840*Astropecten granulatus* WIENBERG RASMUSSEN, 1972

(Pls 1—3)

1972. *Astropecten granulatus* n. sp.; H. WIENBERG RASMUSSEN, pp. 38—40, Pl. 3, Figs 5—8.

MATERIAL: 121 superomarginals, 180 inferomarginals, 117 ambulacrals, 19 adambulacrals, 2 superambulacrals, 3 mouth angle plates, 5 circumorals, 1 odontophore, 13 terminals, 23 paxillae, 1 madreporite, 73 spines, spinelets and scales from the Korytnica Clays\*; 36 superomarginals, 8 inferomarginals and 1 ambulacral ossicle from the marly sands.

## DESCRIPTION

**Superomarginal ossicles** (Pl. 1, Figs 7—9) are massive, high, narrow (height 3.7—5.5 mm, width 2.8—4.2 mm), triangular in side-face outline; outer face convex, covered by small, densely spaced spine-bases with one larger spine-base located near the aboral margin; on side faces large fasciolar surfaces covered by small fasciolar spine-bases; articulation area quarter-circular in shape; articulation ridge well developed; intermarginal face concave; inner face flat or concave; ossicles from the distal fragment of the arm are less symmetrical, lower and long; interbrachial SupMM cuneate.

**Inferomarginal ossicles** (Pl. 1, Fig. 10 and Pl. 2, Figs 3—4) are large, massive, wide and low (height 5.0 mm, width 7.5 mm), triangular to ovate in side-face outline; outer face covered by very small spine-bases, and a row of about five large spine-bases continues along the distal margin, the base near the intermarginal margin being the largest; on side face a large articulation area; articulation ridge prominent, may be disjunct; vertical ridge distinct; intermarginal face short and convex; inner face long and flat with a weak superambulacral boss.

**Ambulacral ossicles** (Pl. 2, Fig. 1) are asymmetrical, wide and short (width 4.2—7.7 mm, length 1.2—2.0 mm); ambulacral body trapezoid; dentition well developed, consists of horizontal lateral slats and vertical medial slats; lower insertion for transverse muscles (UG) small, triangular; oral groove deep and narrow; oral apophyse weak; winglike structures (GG) asymmetrical; proximal GG (pGG)

\* A larger group of these ossicles, which may be ascribed to one individual, was contained in a shell of the gastropod *Ancilla glandiformis* (LAMARCK), acting as a preservational trap. This group consists of: 1 superomarginal, 2 inferomarginals, 4 fragments of marginals, 3 ambulacrals (all left), 11 adambulacrals (8 left and 3 right), 2 superambulacrals, 23 paxillae, 73 spines, spinelets and scales, as well as 12 unidentified fragments.

## PLATE 2

*Astropecten granulatus* WIENBERG RASMUSSEN, 1972

1—Left Amb (*1a* oral, *1b* distal, *1c* proximal view), 2—right Adamb (*2a* proximal, *2b* distal view); 3—4—InfMM (*a* lateral, *b* oral views), 5—6—paxillae

All photos  $\times 10$ ; 1—4 taken by K. ZIELIŃSKA. 5—6 by L. ŁUSZCZEWSKA. M. Sc.

weak, U-shaped, opens orally, distal: GG (*dGG*) semielliptical, flattened; surface on the proximal and distal sides of the ambulacral body for articulation with neighboring *Ambb* (*N*) prominent, ovate; aboral ridge high.

**Adambulacral ossicles** (Pl. 2, Fig. 2) are small (height 2.2–3.2 mm, width 1.7–3.3 mm), rectangular in side-face outline; adradial prominence distinct, *pa1* cuneate; both *pa2* and *pa3* semicircular; *pa4* triangular and high; *pm1* narrow and high; *pm2* and *pm3* wide, deep, trapezoid; both *da1* and *da2* weak; *dml* wide; oral face covered by spine-bases.

**Superambulacral ossicles** are very small (width 2.0 mm, length 1.0 mm), trapezoid, flattened.

**Mouth angle plates** (Pl. 3, Fig. 3) are large ossicles (height 2.0 mm, length 3.0 mm), with their main body rectangular; outer face convex, with a broad adoral blade, bears numerous spine-bases; inner face concave, with two dentitions: adoral consists of irregular slats, distal consists of vertical slats; first ambulacral articulation bar low and broad.

**Circumoral ossicles** (Pl. 3, Figs 5–6) are large and massive, long and wide (width 5.4 mm, length 1.6 mm), with their body large; dentition well developed consists of horizontal lateral slats and vertical medial slats; insertion for transverse muscles small, triangular; adoral circumoral extension rather weak; distal circumoral extension wide and high.

**Odontophores** (Pl. 3, Fig. 4) are relatively large ossicles (width 3.5 mm, length 4.0), triangular in outline, symmetrical; distal part of ossicle forms a wedge-shaped extension; oral face concave, lateral edges bent inward; aboral face convex.

**Terminal ossicles** (Pl. 3, Fig. 2) are relatively large (width 2.0 mm, length 2.3 mm), rectangular to trapezoid; outer face covered by small, densely spaced spine-bases; proximal niche shallow, gradually widened; distal niche narrow and deep; aboral face divided by the longitudinal median concavity; lateral edges short, obliquely truncate with crescent-shaped structures for attachment to the arm.

**Paxillae** (Pl. 2, Figs 5–6) are fine but high ossicles (height 2.0–3.0 mm); basal part ovate, sometimes with radial extensions, convex; column of the paxilla conical; aboral terminus of the ossicle (tabula) rounded.

**Madreporite** (Pl. 3, Fig. 1) is round (diameter 2.2 mm), with its outer convex, bearing three intersecting systems of parallel grooves; on inner face an elongate opening with fragments of the cellar forms the stone canal.

**Spines** (Pl. 1, Figs 2–6) are predominantly ovate and round in section (dimensioned 2.5–6.0 mm). Long, flattened spines are called herein the scales (Pl. 1, Fig. 1). Some of the spines are repaired (see Pl. 1, Figs 4–6) during the animal's life ("regenerated" as called formerly, see BAŁUK & RADWAŃSKI 1984, p. 215).

**REMARKS:** The investigated SupMM, InfMM, *Ambb* and terminals resemble those of the Eocene species *Astropecten granulatus* WIENBERG RASMUSSEN. The terminals are however rather trapezoid instead of hexagonal, as these referred to by WIENBERG RASMUSSEN (1972).

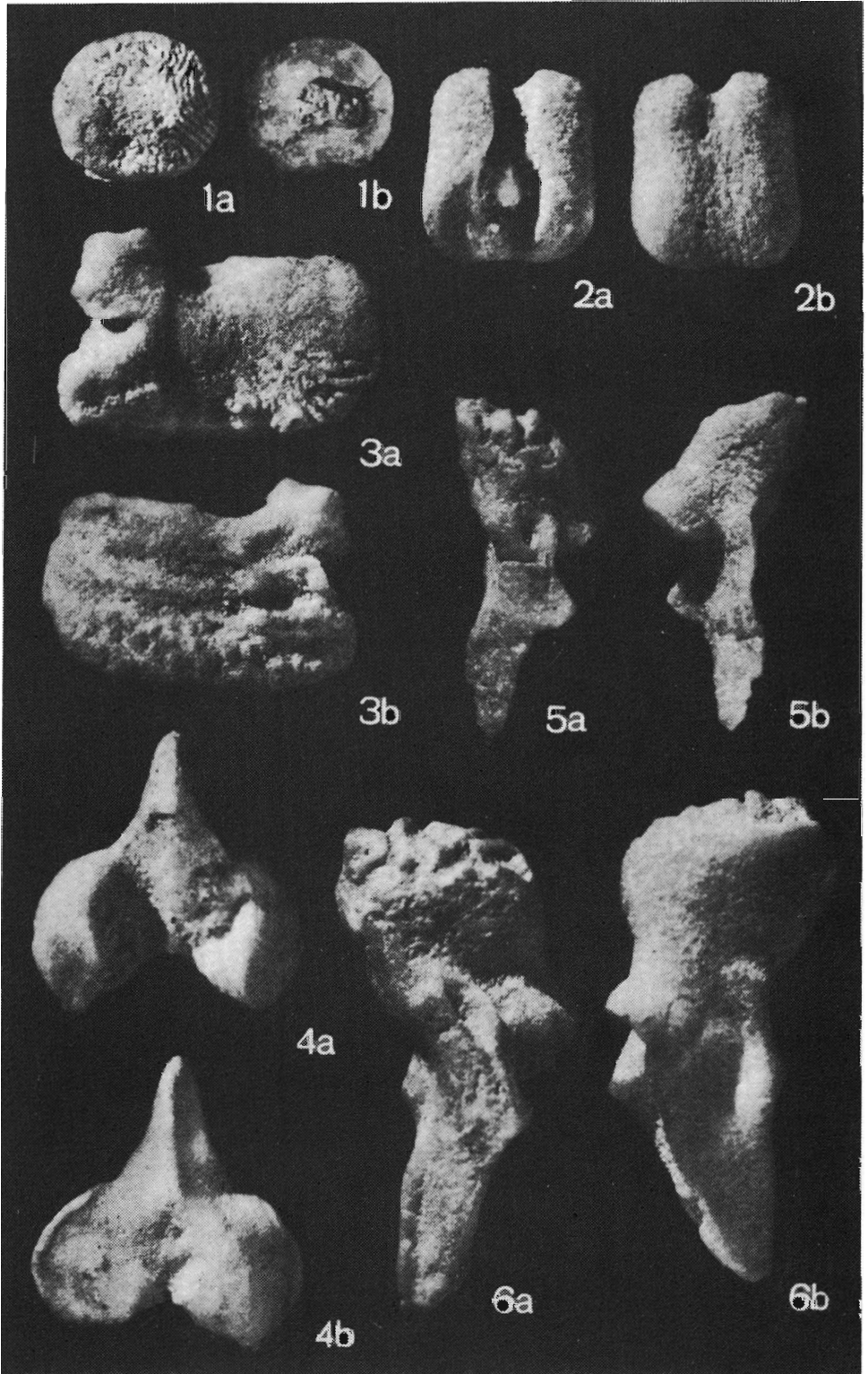
PLATE 3

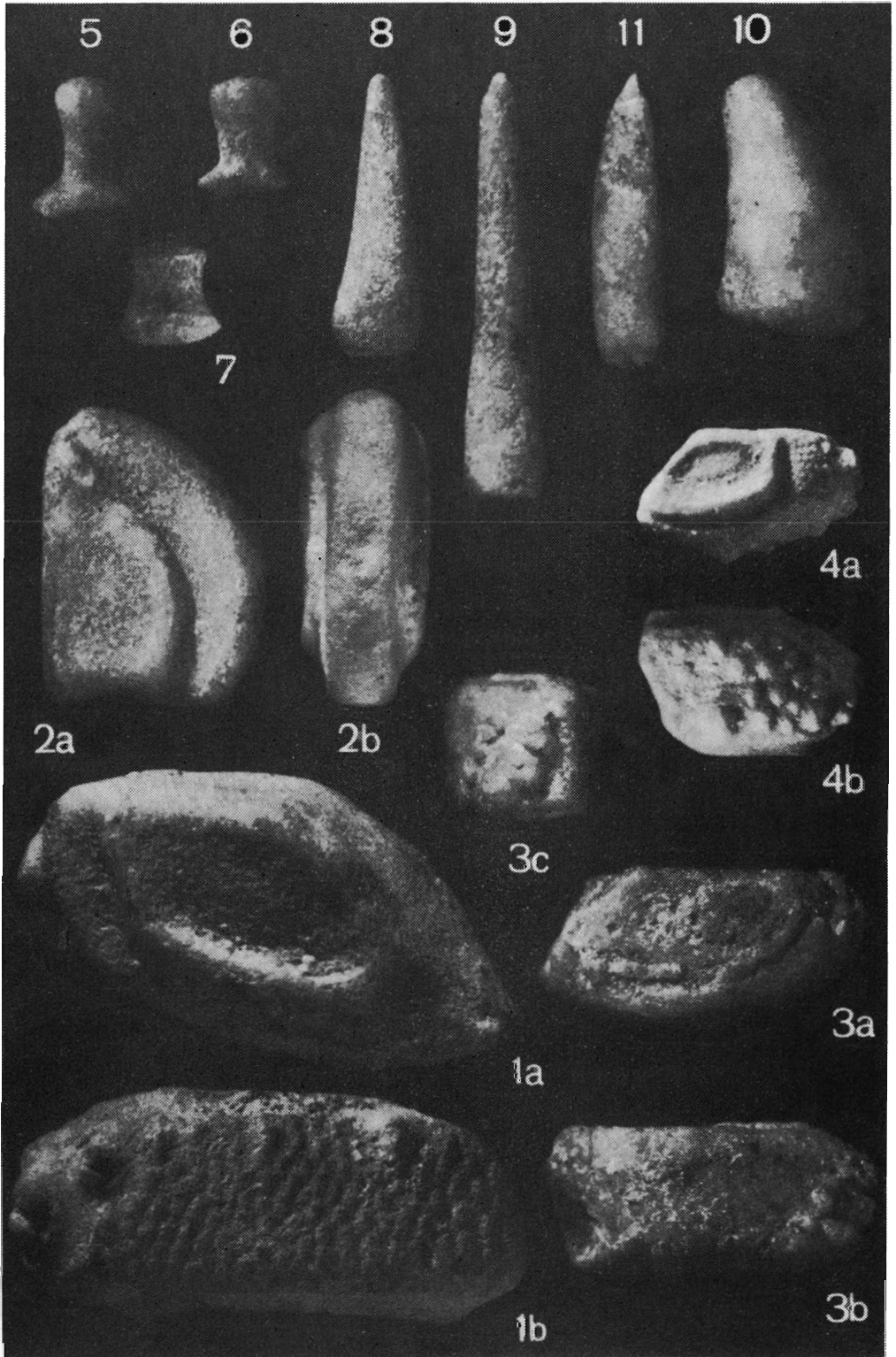
*Astropecten granulatus* WIENBERG RASMUSSEN, 1972

1 — Madreporite (*1a* aboral, *1b* oral view), 2 — terminal ossicle (*2a* oral, *2b* aboral view), 3 — mouth angle plate (*3a* inner, *3b* outer view), 4 — odontophore (*4a* oral, *4b* aboral view), 5–6 — circumorals (*a* oral, *b* aboral views)

All photos  $\times 10$ ; taken by K. ZIELIŃSKA







On the other hand, SupMM, InfMM, Ambb, Adambb and mouth angle plates resemble also those of the modern species *Astropecten armatus* GRAY (see BLAKE 1973, pp. 4—5, Figs 2N-O and p. 42, Pl. 14, Figs 36—55), from which they differ in some minor details. In InfMM abradial region is smaller than in *A. armatus*; ambulacral bodies differ from those of *A. armatus* in their trapezoid instead of rectangular outline, dGG differ in their semielliptical instead of subrectangular outline, and mouth angle plates differ in their rectangular instead of quadrangle outline.

*Astropecten* sp. A

(Pl. 4, Figs 1 and 2)

**MATERIAL:** 379 superomarginals and 33 interomarginals from the Korytnica Clays; 16 interomarginals from the marly sands.

**DESCRIPTION**

**Superomarginal ossicles** (Pl. 4, Fig. 2) are massive, high, narrow (height 2.5—4.0 mm, width 3.5—4.0 mm); outer face convex, smooth; on side faces a large fasciolar surface; articulation area large; articulation ridge well developed; intermarginal face concave; inner face flat. Distinguished from SupMM of *Astropecten granulatus* WIENBERG RASMUSSEN by their smooth outer face.

**Inferomarginal ossicles** (Pl. 4, Fig. 1) are large, massive, wide and low (height 3.8 mm, width 3.8 mm); triangular to ovate in side-face outline; outer face covered by very small spine-bases; row of three or four large spine-bases near the distal margin, the base near intermarginal margins is the largest and located more centrally; on side face a large articulation area; articulation ridge well developed; intermarginal face large and flat; on inner face a moderately prominent superambulacral boss. Distinguished from InfM of *Astropecten granulatus* WIENBERG RASMUSSEN by their spine-bases distribution.

**REMARKS:** The investigated ossicles resemble those of the modern species *Astropecten californicus* FISHER (see BLAKE 1973, pp. 42—43, Pl. 14, Figs 1—12), from which SupMM differ in their weakly concave intermarginal face, and InfMM in their spine-bases distribution.

PLATE 4

*Astropecten* sp. A

1 — InfM (1a lateral, 1b oral view), 2 — SupM (2a lateral, 2b oral view)

*Astropecten* sp. B

3 — InfM (3a lateral, 3b oral, 3c abradial view)

*Astropecten* sp. C

4 — InfM (4a lateral, 4b oral view)

Asteroid undetermined ossicles

5-7 — Paxillae, 8-10 — spines, 11 — scale

All photos ×10; taken by K. ZIELIŃSKA

*Astropecten* sp. B

(Pl. 4, Fig. 3)

MATERIAL: 18 inferomarginals from the Korytnica Clays.

## DESCRIPTION

**Inferomarginal ossicles** (Pl. 4, Fig. 3) are massive, wide and low (height 2.5 mm, width 4.8 mm), almost quadrangled in side-face outline; outer face covered by very small spine-bases; row of three enlarged spine-bases near the distal margin and six large spine-bases in two rows along the intermarginal margin; on side face a very large articulation area; articulation ridge well developed; intermarginal face very wide and flat; on inner face a weak superambulacral boss. Distinguished from InfMM of other *Astropecten* species from the Korytnica Clays by their spine-bases distribution.

**REMARKS:** The investigated ossicles show similar ornamentation as those of the Danian species *Astropecten postornatus* WIENBERG RASMUSSEN, 1945 (see WIENBERG RASMUSSEN 1972, pp. 37—38 and Pl. 3, Fig. 4a—4b), but they differ in their almost quadrangled instead of subtriangular outline.

*Astropecten* sp. C

(Pl. 4, Fig. 4)

MATERIAL: 863 inferomarginals from the Korytnica Clays.

## DESCRIPTION

**Inferomarginal ossicles** (Pl. 4, Fig. 4) are massive, wide and low (height 3.8—6.0 mm, width 5.5—6.5 mm), triangular to ovate in side-face outline, similar to those of *Astropecten* sp. B; outer face covered by small spine-bases; row of about five large spine-bases, curving from the proximal aboral corner, continues toward the abradial end of the distal margin of the outer face; second row of spine-bases along the proximal margin; on side face a large articulation area; articulation ridge well developed; intermarginal face convex; inner face flat. Distinguished from InfMM of other *Astropecten* species from the Korytnica Clays by their spine-bases distribution.

## PLATE 5.

*Luidia* sp. div.

1-4 — Paxillae (*a* aboral, *b* lateral views; 3 is div. in lateral view), 5 — mouth angle plate (*5a* inner, *5b* outer view)

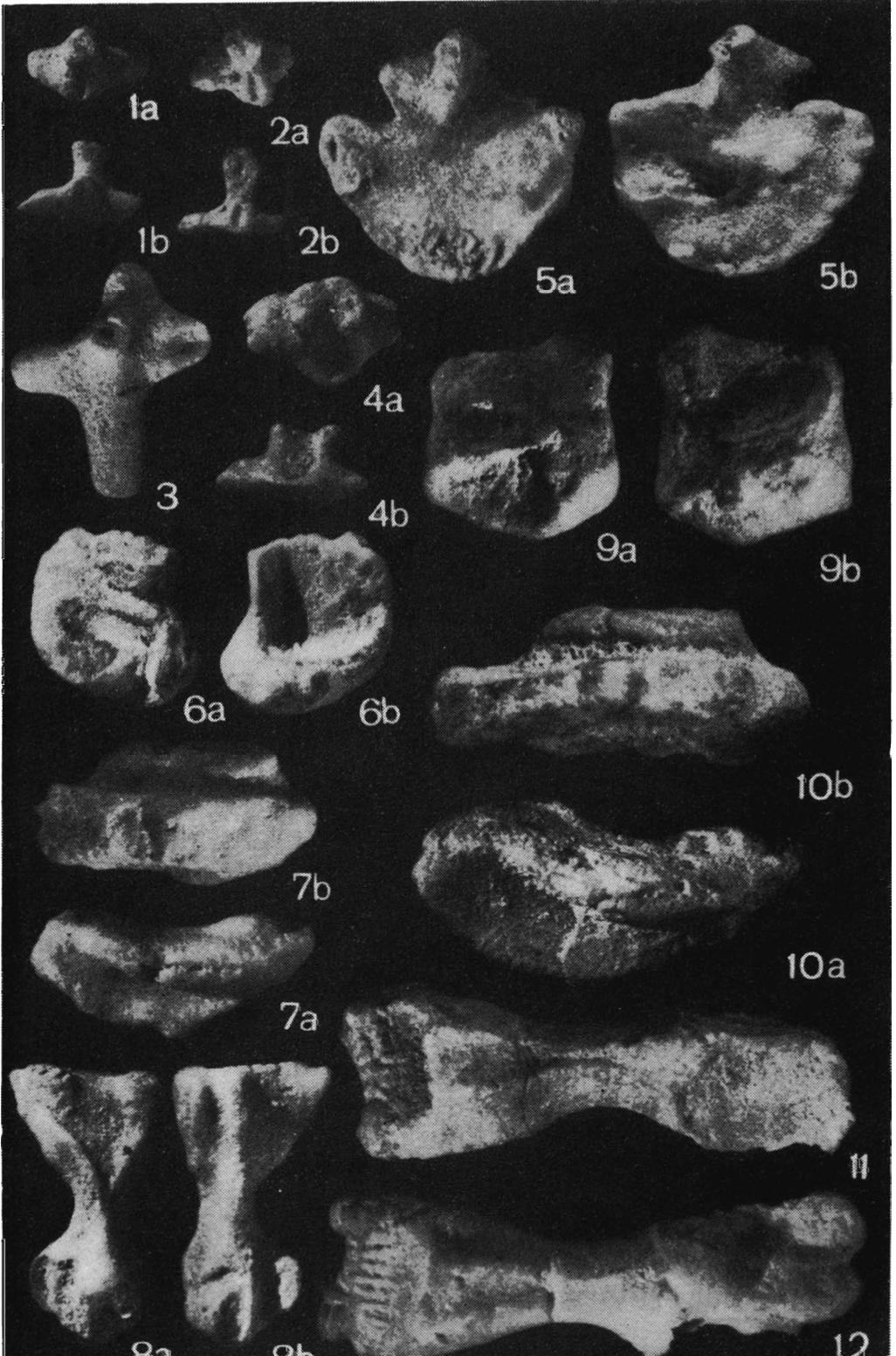
*Luidia ciliaris* (PHILIPPI, 1837)

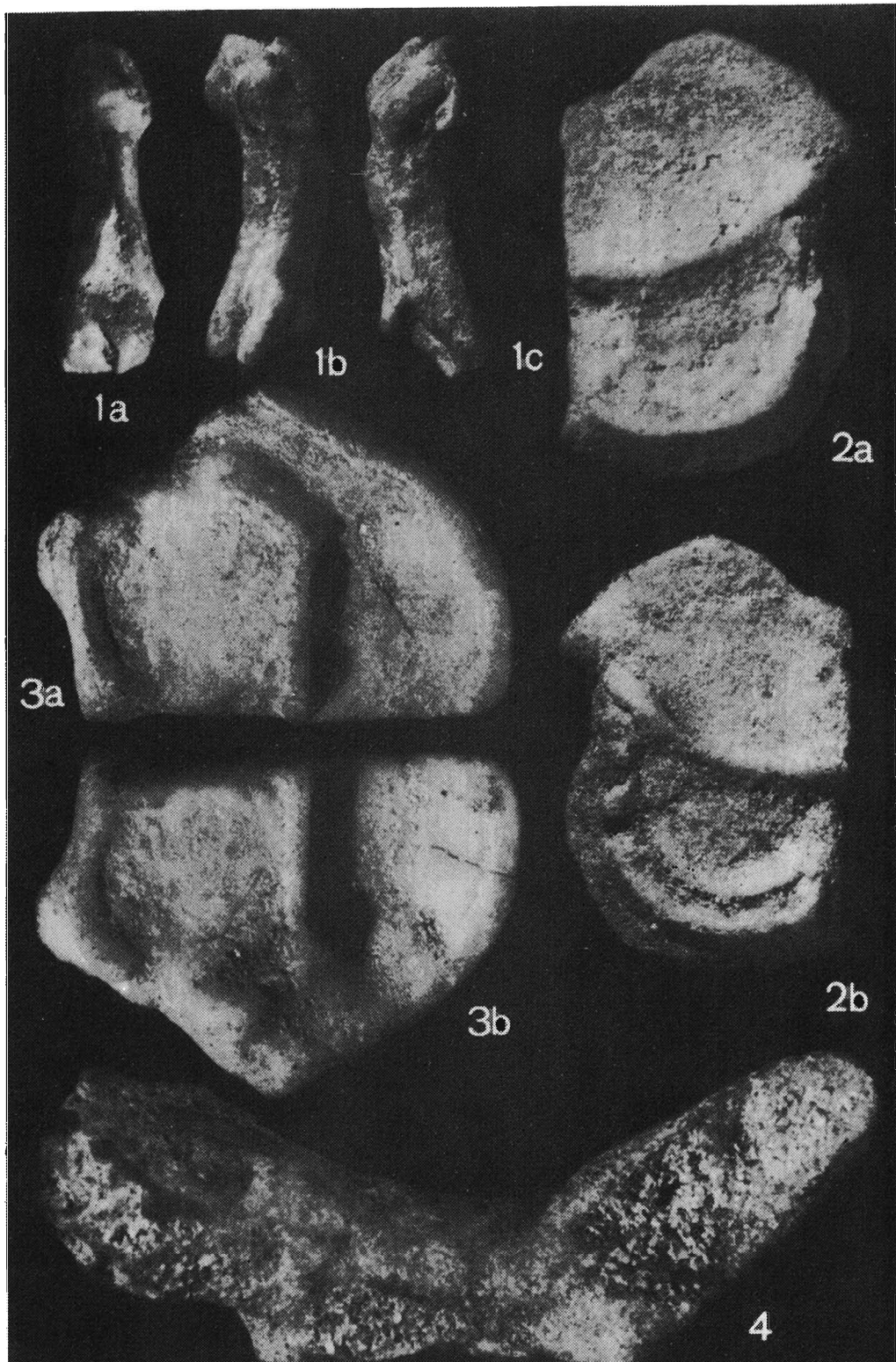
6 — Adamb (*6a* proximal, *6b* distal view), 7 — InfM (*7a* lateral, *7b* oral view), 8 — left Amb (*8a* oral, *8b* aboral view)

*Luidia alternata* (SAY, 1825)

9 — Adamb (*9a* proximal, *9b* distal view), 10 — InfM (*10a* lateral, *10b* oral view), 11 — right Amb (oral view), 12 — left Amb (oral view)

All photos ×10; taken by K. ZIĘLIŃSKA





Family *Luidiidae* VERRILL, 1899Genus *Luidia* FORBES, 1839*Luidia ciliaris* (PHILIPPI, 1837)

(Pl. 5, Figs 6—8)

1837. *Asterias ciliaris* PHILIPPI; R. A. PHILIPPI, p. 194.1972. *Luidia ciliaris* (PHILIPPI); D. B. BLAKE, p. 307, Text-fig. 1.1973. *Luidia ciliaris* (PHILIPPI); D. B. BLAKE, p. 40, Pl. 10, Figs 1—26.

MATERIAL: 574 inferomarginals, 485 ambulacrals, 17 adambulacrals from the Korytnica Clays.

## DESCRIPTION

**Inferomarginal ossicles** (Pl. 5, Fig. 7) are rather small (height 3.0 mm, width 3.6 mm), crescent-shaped, without any distinct inner-face step; moderately prominent superambulacrals boss; outer face convex with three large spine-bases; distal articulation ridge large, angular; proximal articulation ridge rather weak.

**Ambulacrals ossicles** (Pl. 5, Fig. 8) are almost symmetrical (width 4.2 mm, length 2.1 mm); ambulacrals body triangular; dentition weakly developed with a medial gap; *UG* small, triangular; oral groove shallow; oral apophyse prominent; adambulacrals notch deep, angular; *GG* almost symmetrical; *N* low elongate; aboral ridge low, rounded.

**Adambulacrals ossicles** (Pl. 5, Fig. 6) are small (height 2.3 mm, width 1.9 mm), rectangular; *pa1* angular; both *pa2* and *pa3* small; *pa4* triangular; *pm1* wide; *dm1* relatively large; oral surface rounded, with weak spine-bases.

REMARKS: The investigated ossicles agree well with those of the modern species referred to in the synonymy.

*Luidia alternata* (SAY, 1825)

(Pl. 5, Figs 9—12)

1973. *Luidia alternata* (SAY); D. B. BLAKE, pp. 33—34, Pl. 6, Figs 25—42.

MATERIAL: 57 inferomarginals, 23 ambulacrals, 4 adambulacrals from the Korytnica Clays.

## DESCRIPTION

**Inferomarginal ossicles** (Pl. 5, Fig. 10) are high (height 5.1 mm, width 5.0 mm), semielliptical, with an inner-face step; superambulacrals boss prominent; abradial region large, elliptical; outer face with two large spine-bases; distal articulation ridge large, trapezoid. Distinguished from *InfMM* of *L. ciliaris* by the number and position of spine-bases, and outline of the distal articulation ridge.

**Ambulacrals ossicles** (Pl. 5, Figs 11—12) are moderately massive (width 4.5—7.7 mm, length 1.5—2.4 mm); ambulacrals body trapezoid; dentition consists of vertical slats, lateral slats enlarged; *UG* small, triangular; oral groove shallow; oral

## PLATE 6

## Goniasteridae, gen. et sp. indet.

1—Amb (*1a* oral, *1b* distal, *1c* proximal view), 2—left Adamb (*2a* distal, *2b* proximal view), 3—right Adamb (*3a* proximal, *3b* distal view), 4—Amb (lateral view)

All photos  $\times 10$ ; taken by K. ZIELIŃSKA

apophyse prominent; GG asymmetrical; margins parallel; pGG taper abradially, dGG taper adradially; adambulacral notch curved; N moderately prominent, ovate; aboral ridge low, rounded. Distinguished from *Ambb* of *L. ciliaris* by asymmetrical GG and the appearance of dentition.

**Adambulacral ossicles** (Pl. 5, Fig. 9) are quadrate (height 3.6 mm, width 3.2 mm); adradial prominence distinct; *pa1* cuneate; both *pa2* and *pa3* weak; *pa4* triangular and high; both *pm2* and *pm3* broad and triangular; oral margin wide and rounded; oral surface covered by spine-bases. Distinguished from *Adambb* of other investigated *Luidia* species by their quadrate outline and triangular *pm3*.

REMARKS: The investigated ossicles agree well with those of the modern species referred to in the synonymy.

*Luidia* sp. div.

(Pl. 5, Figs 1—5)

MATERIAL: 16 mouth angle plates and 56 paxillae from the Korytnica Clays.

DESCRIPTION

**Mouth angle plates** (Pl. 5, Fig. 5) are large (height 3.5 mm, length 4.0 mm), with their main body of subcircular shape; outer face with a broad adoral blade, bears numerous spine-bases; inner face with two dentitions (adoral and medial) composed of irregular slats; first ambulacral bar low and broad, directed adorally.

**Paxillae** (Pl. 5, Figs 1—4) have their basal parts (width 2.7 — 3.5 mm, length 3.5 — 4.0 mm) cross-shaped and the columella not very high (rarely preserved; if broken it leaves an ovate scar).

REMARKS: The investigated mouth angle plates resemble those of the modern species *L. phragma* CLARK (see BLAKE 1973, Text-fig. 1L-M), but they differ in their subcircular instead of subtriangular outline.

The investigated paxillae are similar to specimens from the Miocene deposits of Hungary, referred by VADÁSZ (1915, p. 95, Text-fig. 8) as "calcareous corpuscles" (*Kalkkörperchen*) of *Asterias*. BLAKE (1973, Pls 4—5 and 10—11) described similar ossicles as paxillae of diverse species of *Luidia*.

Order Valvatida PERRIER, 1884

Suborder Granulosina PERRIER, 1894

Family Goniasteridae FORBES, 1841

Goniasteridae, gen. et sp. indet.

(Pls 6—7)

MATERIAL: 84 marginals, 10 ambulacrals, 72 adambulacrals, 3 mouth angle plates, 4 circumorals, 52 actinals and abactinals from the Korytnica Clays; 14 adambulacrals from the marly sands.

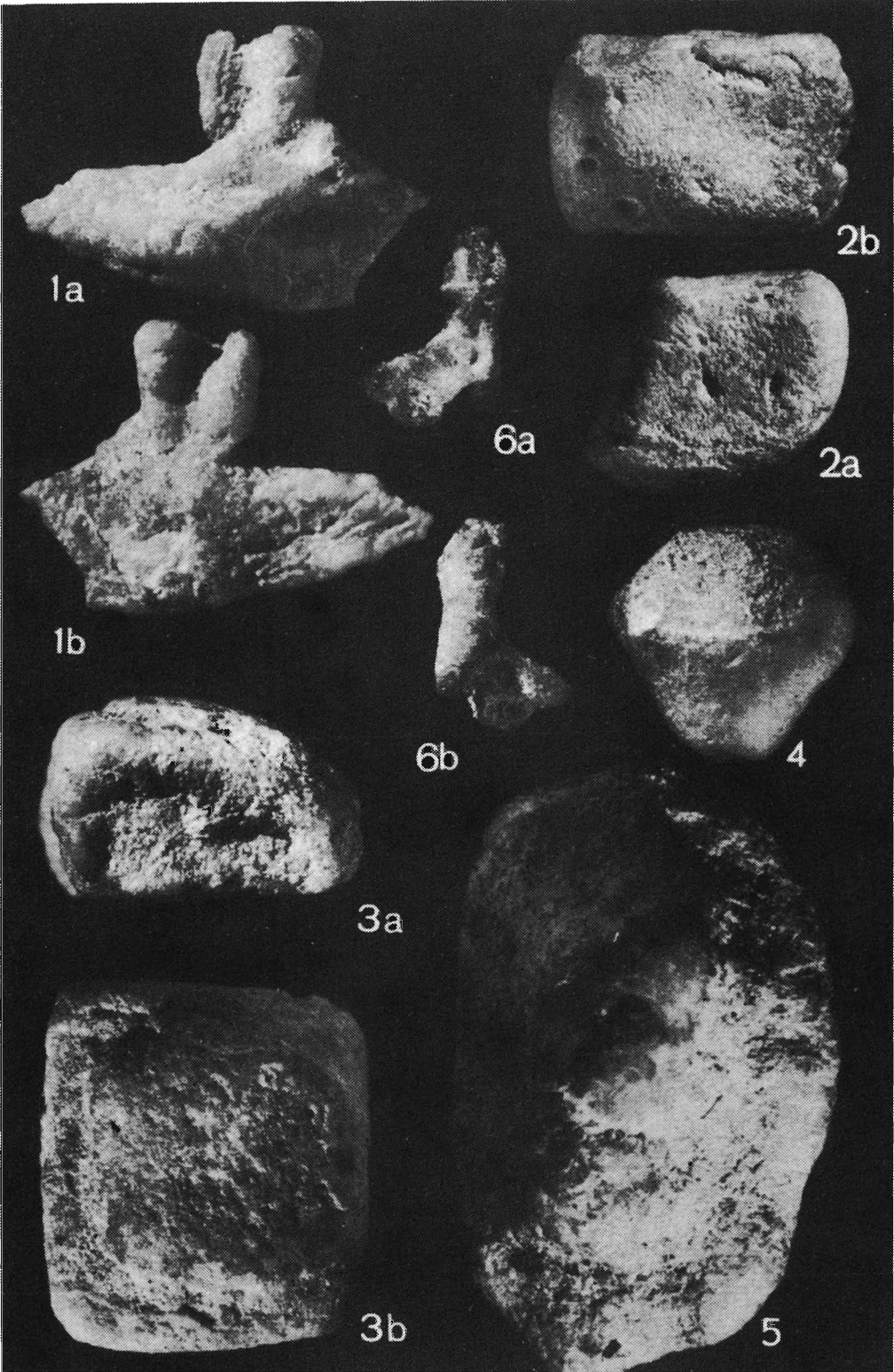
PLATE 7

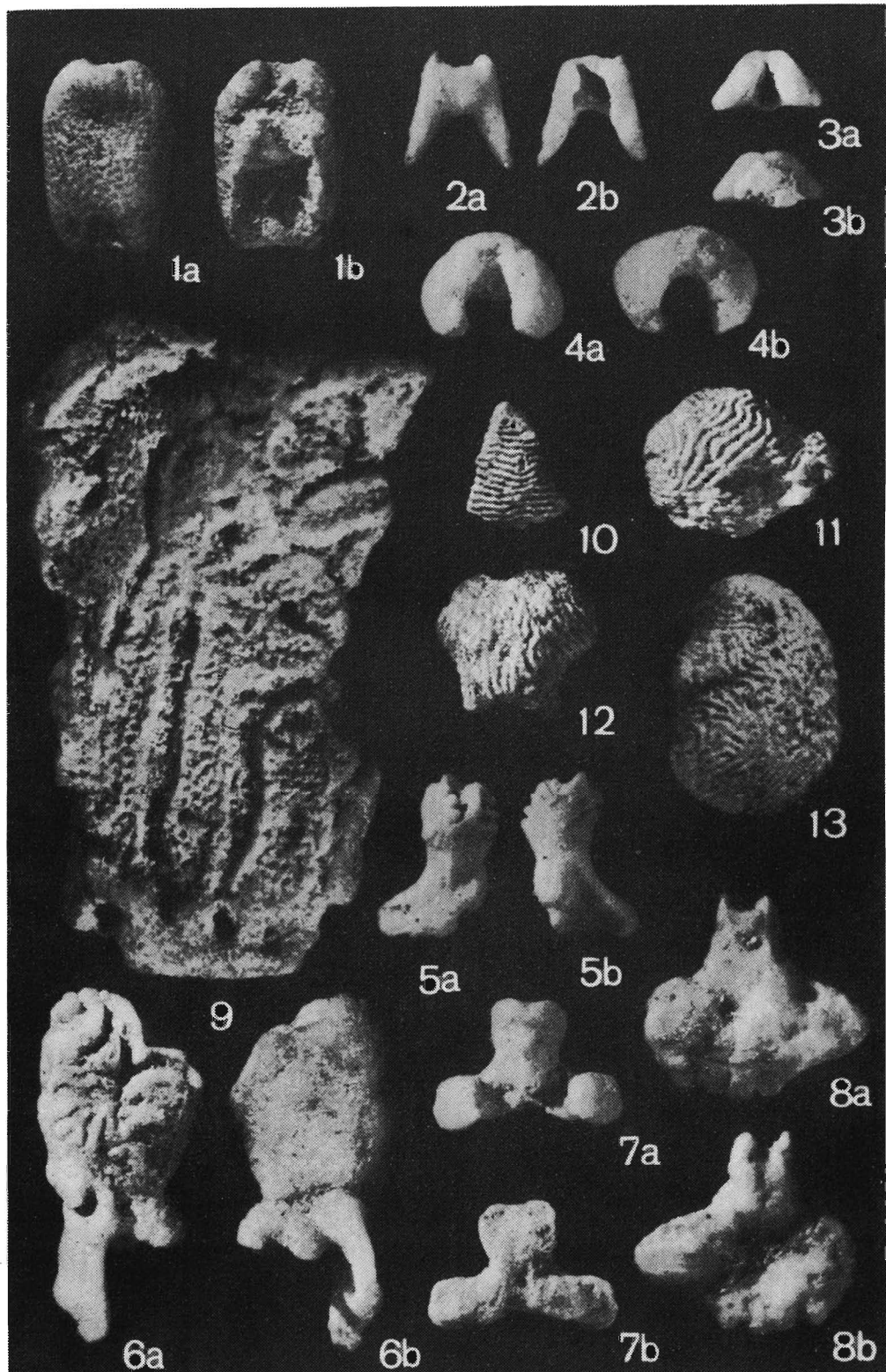
Goniasteridae, gen. et sp. indet.

1—Mouth angle plate (*1a* outer, *1b* inner view), 2—InfM (*2a* lateral, *2b* oral view), 3—SupM (*3a* lateral, *3b* abradial view), 4—abactinal ossicle (lateral view), 5—abactinal ossicle (oral view), 6—circumoral (*6a* oral, *6b* aboral view)

All photos  $\times 10$ ; taken by K. ZIELIŃSKA







## DESCRIPTION

**Marginal ossicles** (Pl. 7, Figs 2—3) are massive (height 4.3 — 6.5 mm, width 3.0 — 4.5 mm), triangular in shape; outer face convex with a rectangular protuberance and sometimes with irregularly spaced elongate or circular depressions (alveolae ?); side-face articulation ridge lacking; inner face flat or convex; intermarginal face flat or concave.

**Ambulacral ossicles** (Pl. 6, Figs 1 and 4) are rather small (width 5.1 mm, length 1.5 mm); ambulacral body rectangular to trapezoid; dentition well developed, composed of irregular slats; *UG* large and triangular; oral apophyse prominent; adambulacral notch curved; *N* large, prominent; the angle between the plane of adambulacral/ambulacral articulation and the ossicle axis about 40°.

**Adambulacral ossicles** (Pl. 6, Figs 2—3) are large (height 4.5 — 6.5 mm, width 3.0 — 4.6 mm), quadrangled in shape, with a distinct adradial prominence; *pal* forms an oblique groove; *pad* angular; both *pm2* and *pm3* broad; *dm1* broad; both *dm2* and *dm3* ridge-shaped; oral surface wide, rounded, covered by fine spine-bases.

**Mouth angle plates** (Pl. 7, Fig. 1) are relatively large (height 4.5 — 5.6 mm, length 6.3 — 7.7 mm), with their main body triangular; outer face with a large, elongate adoral blade, deep and broad first adambulacral articulation surface, it bears a row of spine-bases; inner face concave, with two swellings (first one in the adoral part, second one in the medial part of the ossicle); first ambulacral articulation bar prominent, directed adorally.

**Circumoral ossicles** (Pl. 7, Fig. 6) are massive (width 3.0 mm, length 2.0 mm), with their main body large, massive, rectangular; dentition well developed, composed of irregular slats; adoral circumoral extension small, distal circumoral extension broad, flattened.

**Actinal and abactinal ossicles** (Pl. 7, Figs 4—5) vary in size (height 3.0 — 6.0 mm) and shape (ovate, quadrangle, hexagonal); their outer terminus is convex, either smooth or covered by fine depressions.

**REMARKS:** The investigated marginals, actinals and abactinals are similar to those of a completely preserved specimen from the coeval Middle Miocene deposits exposed at Nawodzice, and which resembles the modern genus *Ceramaster* and has been assigned to the family Goniasteridae FORBES by BAŁUK & RADWAŃSKI (1968, p. 450).

BLAKE (1983) studied the morphology of ossicles related to the ambulacral furrow in the Valvatida and recognized some characteristic features of their skeletons. These features concern: (i) The value of angle between the plane of Amb/Adamb articulation and the ossicle axis; and (ii) Solid structure of the ambulacral furrow, which is realized due to closely spaced adambulacrals. On the ground of

## PLATE 8

## Asteroid undetermined ossicles

- 1— Terminal A (*1a* oral, *1b* aboral view), 2— terminal B (*2a* oral, *2b* aboral view),  
 3— terminal C (*3a* oral, *3b* aboral view), 4— terminal D (*4a* oral, *4b* distal view),  
 5— circumoral B (*5a* oral, *5b* aboral view), 6— circumoral A (*6a* oral, *6b* aboral view),  
 7— odontophore (*7a* oral, *7b* aboral view), 8— mouth angle plate (*8a* outer, *8b* inner  
 view), 9-13— madreporites

these features the present author suggests the family assignment of the investigated Ambb and Adambb, as that of the Goniasteridae. The associated circumoral ossicles have been assigned identically owing to their dentition similar to those of the ambulacral ossicles.

The investigated mouth angle plates resemble those of *Metopaster tumidus* SPENCER from the Lower Maastrichtian of the Isle of Rügen (see MÜLLER 1978, p. 478, Text-fig. 573 t-u), but they are smaller and devoid of ornamentation.

### Asteroidea indet.

#### Order and family unrecognizable

The taxonomically unrecognizable material contains diverse ossicles, some of which worth to be presented (see Pl. 4, Figs 5—11 and Pl. 8, Figs 1—13).

The terminal ossicles are of four types, called herein A, B, C, and D (Pl. 8, Figs 1—4). The only one of the type A (Pl. 8, Fig. 1) resembles that described by VADÁSZ (1915, p. 95, Text-fig. 6), from the Miocene deposits of Hungary, as a terminal ossicle of *Asterias* or *Goniaster*, but it differs in its rather ovate instead of elongate outline.

The circumoral ossicles are of two types, called herein A and B (Pl. 8, Figs 5—6). Present are also the odontophores (Pl. 8, Fig. 7), mouth angle plates (Pl. 8, Fig. 8) and madreporites (Pl. 8, Figs 9—13). Small ossicles are represented by paxillae (Pl. 4, Figs 5—7), spines (Pl. 4, Figs 8—10), and scales (Pl. 4, Fig. 11). The spines are much variable both in their size (3.0—7.5 mm) and shape of the section (triangular, ovate, semicircular, circular); some of them are repaired to the same extent as those of *Astropecten granulatus* WIENBERG RASMUSSEN (see Pl. 1, Figs 4—6).

#### REMARKS ON ECOLOGY AND BIOGEOGRAPHY

The environmental conditions, such as extremely shallow depths, normal salinity, well ventilated water (for details see BAŁUK & RADWAŃSKI 1977) during the sedimentation in the Korytnica Basin appeared rather convenient for the asteroids, which became here relatively abundant.

The modern *Astropecten* and *Luidia* have similar habits and habitats, as they live in shallow waters on unconsolidated substrates and burrow beneath the surface. They are predators, feeding mainly upon different mollusks, small crustaceans and other echinoderms (see HYMAN 1955, CHRISTENSEN 1970, BLAKE 1982). Contrary to that, the representatives of the Valvatida are small-particle feeders with stout skeleton; they also prefer warm, shallow waters.

The composition of the asteroid assemblage from the Korytnica Basin shows certain affinities to the Recent asteroid fauna of the tropical Indo-Pacific, while its generic composition is taken into account. In the Indo-Pacific region the representatives of the orders Valvatida and the Paxillosida predominate (see BLAKE 1983). Such tropical Indo-Pacific affinities of diverse organic communities have formerly been indicated in the Korytnica Basin by BAŁUK & RADWAŃSKI (1977).

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The investigated specimens are deposited in the collection of the Institute of Geology, University of Warsaw.

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## ROZGWIAZDY Z BASENU KORYTNICY

### (Streszczenie)

Przedmiotem pracy jest analiza zespołu szczątków rozgwiazd pochodzących z Basenu Korytnicy (patrz fig. 1—3 oraz pl. 1—8). Większość tych szczątków, których liczba sięga około 3800 różnych płytek szkieletowych, została oznaczona do poziomu gatunku, chociaż dla niektórych szczątków możliwe było rozpoznanie wyłącznie wyższych jednostek taksonomicznych.

Rodzaj *Astropecten* w badanym materiale reprezentowany jest przez 4 gatunki: *Astropecten granulatus* WIENBERG RASMUSSEN, 1972, *Astropecten* sp. A, *Astropecten* sp. B, oraz *Astropecten* sp. C. Wśród szczątków rodzaju *Luidia* wyróżnić można dwa gatunki znane dotychczas tylko z faun dzisiejszych — *Luidia ciliaris* (PHILIPPI, 1837) oraz *L. alternata* (SAY, 1825), a także szereg form gatunkowo nieoznaczalnych. Blżej nieoznaczalne są również wszystkie szczątki należące do rodziny Goniasteridae FORBES, 1841.

Skład badanego zespołu rozgwiazd wskazuje na środowisko płytkich wód strefy tropikalnej i wykazuje pewne podobieństwo do fauny dzisiejszych rozgwiazd z obszaru indo-pacyficznego.