ECHINODERMS OF THE MÓJCZA LIMESTONE

ANDRZEJ PISERA

Pisera, A. 1994. Echinoderms of the Mójcza Limestone. — *In:* J. Dzik, E. Olempska, and A. Pisera. 1994. Ordovician carbonate platform ecosystem of the Holy Cross Mountains, Poland. *Palaeontologia Polonica* **53**, 283–307.

The material of disarticulated phosphatized echinoderm ossicles from the Ordovician Mójcza Limestone (at its type section at Mójcza, Holy Cross Mountains) is described. Because of the character of preservation, most of the ossicles have been assigned only to higher taxonomical groups; the most common are crinoid (camerates and inadunates) ossicles (mostly stem ossicles and brachials, but also thecal plates), and cystoid stems and plates (glyptocystid cystoids are dominant). Also common are asterozoan plates (mostly ambulacral and adambulacral) and stylophoran ossicles. Less common are fragments of eocrinoids and coronates. A doubtful holothurian plate has also been noted. Stratigraphic distribution of ossicles seems to have been primarily controlled by the processes of sedimentation and phosphatization. Numerous forms, especially among crinoids and supposed cystoids, are common with those from Baltoscandia, but stylophorans suggest southern European and perhaps also North American influences. Among the investigated material there are the oldest noted occurrences of *Bothriocidaris* and coronates, as well as the youngest known occurrence of epispire-bearing eocrinoids.

Key words: Echinodermata, Ordovician, Poland.

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INTRODUCTION

All the described material comes from the Ordovician limestone outcropping in a small quarry on the Skała hill near Mójcza village (south of Kielce, Holy Cross Mountains, southern Poland). The section of the Ordovician that is available for study is about 8 m thick. It includes the Bukówka Sandstone at the base, overlain by the Mójcza Limestone (which constitutes most of the section), and capped by Zalesie Formation (argillaceous limestones and marls). The section represents the interval from the Arenig through the Ashgill and is thus extremely condensed (see DZIK and PISERA 1994). The investigated echinoderms (nearly exclusively loose ossicles) have been found only in part of the section, mostly the Mójcza Limestone (see Text-figs 1–3), and they range from the *Pygodus serra* Zone (Llanvirn) to the *Amorphognathus superbus* Zone (Ashgill). For lithological description and sedimentological interpretation of the section see DZIK and PISERA (1993), and for conodont biostratigraphy see DZIK (1990, 1993). The investigated material, with one exception, resulted from acid resistant residue and is represented by phosphatic envelopes. In many samples the preservation is so excellent that it permits studies of the original stereom. The author has only disarticulated ossicles at his disposal, which does not allow, in most cases, for exact systematic assignment. The difficulty with dealing with such material follows also from the fact that, in most studies (with the notably exception of Asterozoa – see, for example, SPENCER 1914–1940), authors have neglected the details of particular ossicles while concentrating on their relation. It also seems that a considerable part of the material comes from young specimens, which are rarely described. It is also clear that percentages of particular types of ossicles in the material are biased by winnowing and/or preferential phosphatization, thus making reconstruction of the complete skeletons difficult.

This research has been financed by the Institute of Paleobiology, Polish Academy of Sciences, where all the material described herein is now housed.

Acknowledgements.— I would like to thank warmly Dr. Stephen K. DONOVAN (University of the West Indies, Kingston, Jamaica) for his critical reading the manuscript and improvement the language.

TAXONOMIC DESCRIPTIONS

CRINOIDS

Crinoids are represented mostly, as one may expect, by stem ossicles. However, brachials, pinnulars and thecal plates are also common. Whenever possible biological taxonomy is used in classification; parataxonomy used by Russian authors (see STUKALINA 1988 and literature herein) which has been recently adopted by DONOVAN (1986) in numerous papers is avoided as giving little biological information. In other cases descriptive terms are used.

Crinoid radial plate type A
(Pl. 59: 7)

Comments. — This is a wide heptagonal plate with a smooth brachial articulation surface from which two narrow ridges run, forming on inverted letter V; the remaining surface smooth. This plate strongly resembles radial plates of *Trochocrinites laevis* PORTLOCK (see RAMSBOTTOM 1961; DONOVAN 1984a) in shape and sculpture.

Distribution. — Sample MA-67; upper *Pygodus anserinus* Zone.

Crinoid radial plate type B
(Pl. 59: 8)

Comments. — This is a roughly pentagonal and rather thin plate with narrow articulation surface at the top; it resembles in shape and articulation surface radial plates of *Iocrinus shelvensis* RAMSBOTTOM (1961: Pl. 1: 3–8).

Distribution. — Samples MA-5 and MA-87; middle-upper *Amorphognathus tvaerensis* Zone.

Crinoid calyx folded plates
(Pl. 59: 1–6)

Comments. — Included herein are both radials (Pl. 59: 4–6) and other thecal plates (Pl. 59: 1–3) of similar morphology. They are folded plates with plate boundaries incised. They probably formed epispires in the cup. The outline varies from very broad to narrow, and the external surface can be sculptured or nearly smooth. These differences indicate that they represent more than one species or even genus. However, precise determination is difficult as cup plates of such morphology are known in various groups, both Camerata and Inadunata. Among inadunates very similar cup plates are known in *Dendrocrinus rugocyathus* RAMSBOTTOM (1961), as well as in the genus *Porocrinus* (see RAMSBOTTOM 1961: Pl. 5: 6; KOLATA 1975: Pl. 4: 5–6, 8; GUENSBURG 1984: Pl. 11: 3–5), where well-developed goniospires are usually also present; also, *Tetracionocrinus* bears similar sculpture, but without goniospires (see MOORE *et al.* 1978: Fig. 357, p. T563). In camerates similar folded cup plates are known in Rhodocrinitacea and Glyptocrinidae (see UBAGHS 1978; KOLATA 1982; GUENSBURG 1984).

Distribution. — Samples MA-58 to MA-89; uppermost *Pygodus serrus* Zone to uppermost *Amorphognathus tvaerensis* Zone.

Undetermined crinoid cup plates
(Pls 60: 14; 62: 9)

Comments. — These plates, of differing morphologies, resemble those found in various crinoids, but their morphology is too general to assign them more precisely.

Distribution. — Samples MA-99 and MA-76 respectively; *Amorphognathus tvaerensis* Zone and *Amorphognathus superbus* Zone.

Family Heterocrinidae ZITTEL, 1879
Genus *Ristnacrinus* ÖPIK, 1934
Ristnacrinus sp.
(Pl. 61: 9)

1966. *Ristnacrinus marinus* ÖPIK; YELTYSHEVA, p. 53, Pl. 2: 15–22.
1984. *Ristnacrinus* sp.; DONOVAN, p. 631, Text-fig. 4.
1985. *Ristnacrinus* sp.; DONOVAN, p. 349, Fig. 5.
1986. *Ristancrinus marinus* ÖPIK; HYNDA, p. 93, Text-fig. 36, Pl. 15: 1–2; *cum syn.*
1986. *Ristnacrinus* sp.; DONOVAN, p. 29, Pl. 3: 2–6, *cum syn.*
1988. *Ristnacrinus marinus* ÖPIK, 1934; STUKALINA, Pl. 14: 1–3.

Comments. — Round to elliptical columnals, usually barrel-shaped (convex latera) and smooth; articulation surface bearing median fulcral ridge, separating two ligament pits. A narrow elevated rim runs around margins. Specific attribution of such ossicles seems very difficult if not impossible as they are very similar in various species (DONOVAN 1985).

Distribution. — This type of columnal is widely distributed in the Middle and Upper Ordovician of Europe (Estonia, Sweden, Norway, France, Spain, and Great Britain – DONOVAN 1985; western part of East European Platform – HYNDA 1986; and Middle Asia and Kazakhstan – STUKALINA 1980, 1988). In the Mójcza Limestone they range from sample MA-43 to MA-85, i.e. lower *Pygodus serra* Zone to upper *Amorphognatus tvaerensis* Zone (see Text-fig. 1).

Ristnacrinus? *angulatus* YELTYSHEVA, 1966
(Pl. 61: 10)

1966. *Ristnacrinus angulatus* sp. n.; YELTYSHEVA, p. 55, Pl. 2: 5–10.
1986. *Ristnacrinus*? *angulatus* YELTYSHEVA; HYNDA, p. 94, Text-fig. 37, Pl. 15: 3–5.
1988. *Ristnacrinus*? *angulatus* YELTYSHEVA; STUKALINA, Pl. 8: 1–7.

Comments. — These are holomeric pentagonal columnals with more or less pronounced spine-like extensions of latera corners; lumen relatively large and circular. Articulation surface bearing wide median fulcral ridge separating deep ligament pits. A narrow elevated rim bearing more or less pronounced crenulation runs around the margin (which is best developed at the contact with median ridge). Assignment of this columnal to the genus *Ristnacrinus* ÖPIK is doubtful as it is based only on the synarthial type of articulation.

Distribution. — This type of columnal is known from the Middle Ordovician of Estonia and the St. Petersburg region of Russia, as well as the western part of the East European Platfrom (HYNDA 1986). In the Mójcza Limestone it ranges from sample MA-43 to MA-86, i.e., from lower *Pygodus serra* Zone to upper *Amporphognathus tvaerensis* Zone (see Text-fig. 1).

Schizocrinus? *kuckersiensis* YELTYSHEVA, 1966
(Pl. 61: 1–7)

1966. *Schizocrinus kuckersiensis* sp. n.; YELTYSHEVA, p. 57, Pl. 1: 13–17.
1986. *Schizocrinus kuckersiensis* YELTYSHEVA; HYNDA, p. 98, Fig. 39, Pl. 16: 1–4, *cum syn.*

Comments. — The ossicles here attributed come from a heteromorphic stem in which low, cylindrical columnals with smooth latera alternate with columnals which have flanged or spinose latera; they have wide pentalobate lumen and crenullae at the articular surface. They are attributed to the same species based on known examples of heteromorphic stems (smooth and sculptured columnals have the same articular facet morphology) as well as intergrading of spined and flanged forms. Based on their similarities with the genus *Schizocrinus* HALL, from the Ordovician of North America, this type of columnals from the Ordovician of the former Soviet Union has been also attributed to this genus (see HYNDA 1986). This assignment may be correct, as in my material I have found numerous crown plates of crinoids resembling some glyptocrinid species and comparison of latera morphology of glyptocrinid crinoids (see GUENSBURG 1984) shows features very similar to that in our material.

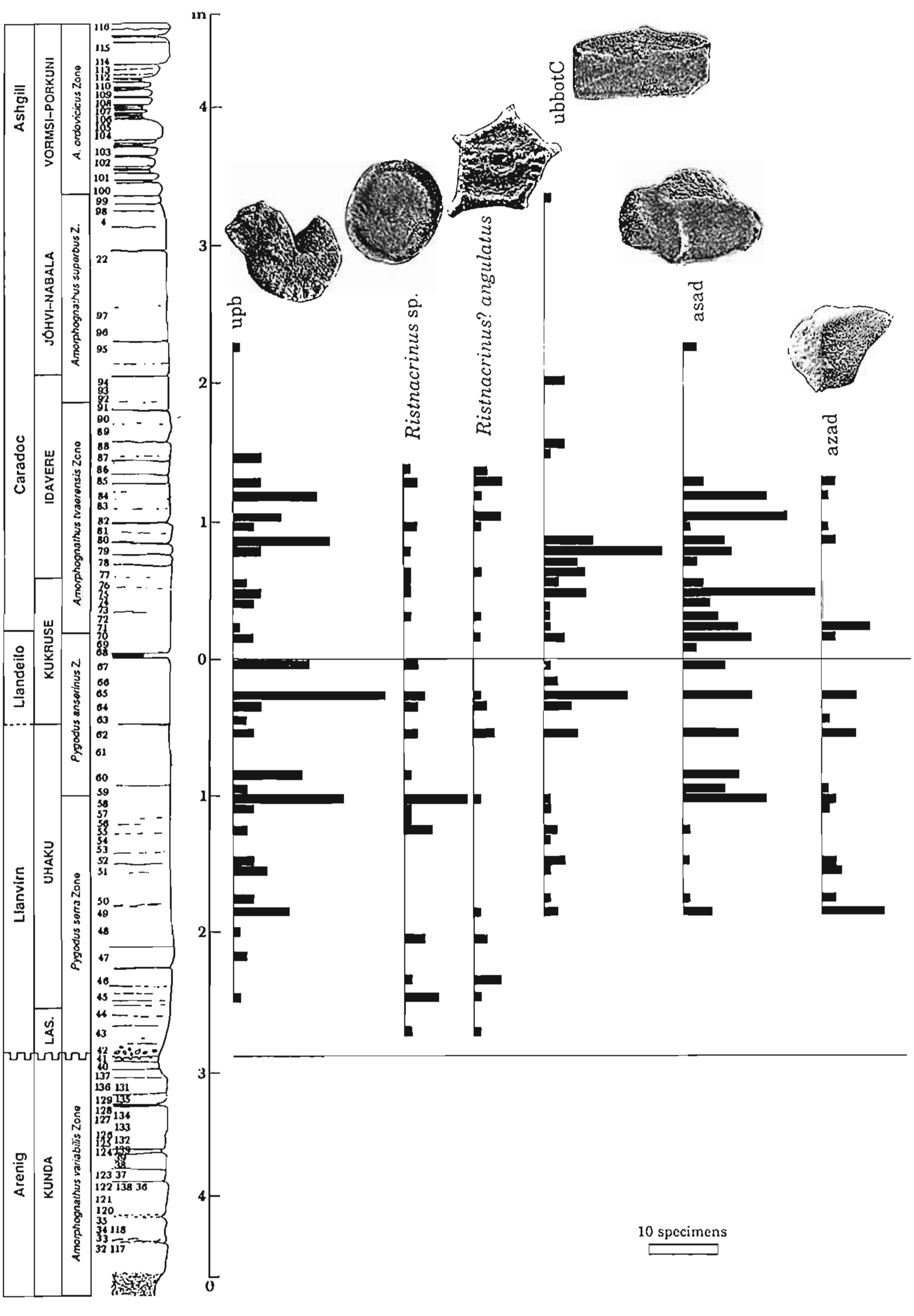

Fig. 1.
Frequency distribution of the most common pelmatozoan and eleutherozoan ossicles; upb – uniserial pinnulated brachial, ubbotC – undetermined biserial ?brachiolar ossicle type C, asad – asteroid adambulacral, azad – asterozoan adambulacral.

Distribution. — This assemblage of columnals ranges in the Mójcza Limestone from the sample MA-43 to MA-94, i.e., from the lower *Pygodus serra* Zone to the lowermost *Amorphognathus superbus* Zone (see Text-fig. 2).

Holomeric crenulated columnals with round lumen
(Pl. 61: 8)

Comments. — These are medium-high, cylindrical, holomeric columnals with round narrow lumina and long, and thick crenullae on the articular surface; most probably they come from a homeomorphic stem. Similar columnals have been described by HYNDA (1986) as *Crenatocrinus biplex* (EICHWALD). EICHWALD's specimens come from the St. Petersburg region. Most probably these columnals belong to a camerate crinoid.

Distribution. — They are known from the uppermost and middle Ordovician of Volhynia (Ukraine) and the St. Petersburg region of Russia. In the Mójcza Limestone samples MA-48 to MA-85; lower *Pygodus serra* Zone to upper *Amorphognathus tvaerensis* Zone.

Pentameric crenulated columnals
(Pl. 61: 12–13)

Comments. — These are pentameric, pentagonal to pentagonal-rounded, medium-high columnals with smooth latera and wide pentagonal or pentastellate lumina, the corners of which point to the boundaries between meres (Angulata type of STUKALINA 1988); articular surface with long and strong radial crenellae. The investigated material resembles some morphospecies of *"Fascicrinus"* STUKALINA and *"Malovicrinus"* STUKALINA (see DONOVAN 1984c, 1986; STUKALINA 1988). The meric structure indicates that it belongs to an inadunate crinoid.

Distribution. — Samples MA-54 to MA-87, i.e., uppermost *Pygodus serra* Zone to the upper *Amorphognathus tvaerensis* Zone.

"Babanicrinus" sp.
(Pl. 61: 11)

Comments. — These are round columnals with smooth convex latera; lumen pentagonal and narrow; articulation surface divided into five depressions separated by thin and low ridges. There are several morphospecies of this parataxon established by STUKALINA (1988) and HYNDA (1986). Both authors suggest that those columnals are meric, but with meric sutures that are not visible on the latera. However, scanning electron microscopy suggests that they are holomeric columnals.

Distribution. — Middle Ordovician of East European Platform and Upper Ordovician of Kazakhstan (see HYNDA 1986; STUKALINA 1988); in the Mójcza Limestone sample MA-65; *Pygodus anserinus* Zone.

Uniserial pinnulated brachials
(Pl. 59: 13)

Comments. — There are numerous short, uniserial brachials with crenullae developed on near-dorsal surface bearing a large pinnular facet; lateral surface smooth. They resemble brachials of some inadunates (see GUENSBURG 1984: Pls 7: 5, 11, 13; 8: 2; BROWER and VENIUS 1982: Pl. 11). One should mention that pinnulation is rare in Ordovician inadunates.

Distribution. — Samples MA-46 to MA-95; lowermost *Pygodus serra* Zone to the lower *Amorphognathus superbus* Zone (see Text-fig. 1).

Holomeric pentagonal columnal
(Pl. 62: 1)

Comments. — This is a low, holometic, pentagonal columnal with a very wide rounded lumen. Articulation surface slightly depressed, bearing only traces of crenellae at the very edges; latera smooth. Generally it resembles proximal columnals of crinoids.

Distribution. — Sample MA-51; *Pygodus serra* Zone.

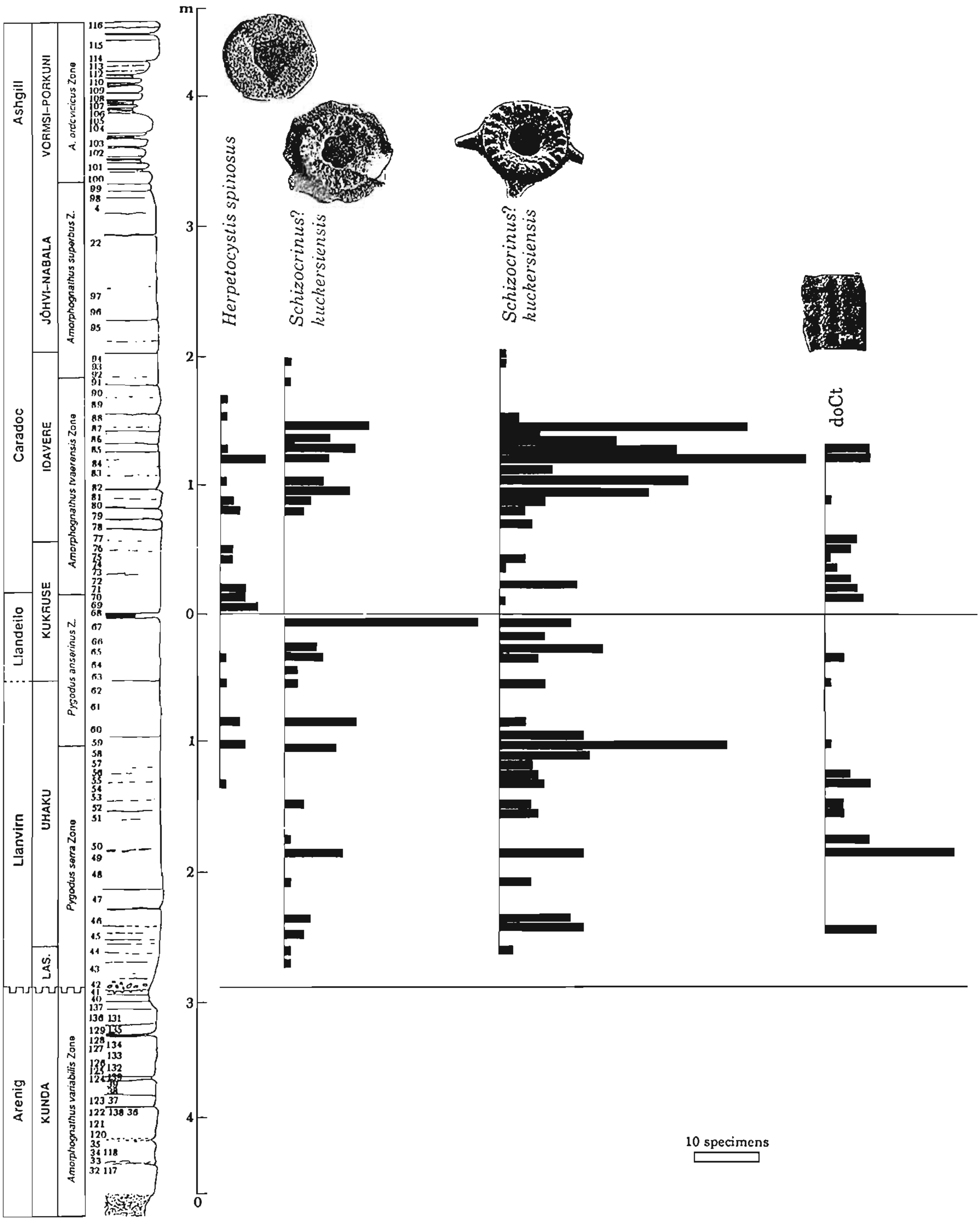

Fig. 2.
Frequency distribution of the most common pelmatozoan columnals and carpoid ossicles; doCt – distal ossicle of cornutan aulacophore.

Uniserial branched brachials
(Pl. 59: 11–12)

Comments. — These brachials are elongated, with a smooth outer surface and have a very strong lateral branch (nearly the same size as the main one); articulation surface smooth. They may belong to camerate crinoids.

Distribution. — Sample MA-5; middle *Amorphognathus tvaerensis* Zone.

Massive, sculptured brachials of ?calceocrinids
(Pl. 59: 14, 17–18)

Comments. — These are massive uniserial brachials with very characteristic pitted surface; one of them is an axillary (Pl. 59: 14). They closely resemble brachial ossicles of calceocrinid inadunates (see RAMSBOTTOM 1961: Pl. 2: 1–8).

Distribution. — Samples MA-51 and MA-78; upper *Pygodus serra* Zone and lower *Amorphognathus tvaerensis* Zone.

?Disparid brachials
(Pl. 60: 12, 18–19)

Comments. — These are elongated, semicircular in cross-section and more or less widening at both ends, brachials with narrow ambulacral grooves; articulation surface with two symmetrical ligamental fields, separated by a poorly developed ridge. Similar brachials are known in, for example, the Lower Ordovician *Tetragonocrinus pygmaeus* (EICHWALD) (see ARENDT 1985: Fig. 1g).

Distribution. — Samples MA-49 and MA-78; middle *Pygodus serra* Zone and lower *Amorphognathus tvaerensis* Zone.

Short delicate pinnular
(Pl. 60: 2)

Comments. — This is a singular, very small and short, V-shaped pinnular, most probably belonging to some camerate crinoid.

Distribution. — Sample MA-27; *Pygodus serra* Zone.

Massive tuberculated pinnulars
(Pl. 59: 10)

Comments. — These are long pinnulars with regularly distributed, strong tubercles on the outer surface; they are rounded in cross section with smooth articulation surface. Ventral side with groove bearing ledges for supporting the cover plates(?).

Distribution. — Samples MA-67 to MA-71; upper *Pygodus anserinus* Zone to lowermost *Amorphognathus tvaerensis* Zone.

Pinnulars with saw-like edges
(Pl. 59: 9)

Comments. — They are triangular in cross section with pitted surfaces and bear saw-like edges; most probably they belong to an undetermined camerate.

Distribution. — Samples MA-54 to MA-86; upper *Pygodus serra* Zone to upper *Amorphognathus tvaerensis* Zone.

?Ramules of undetermined crinoid
(Pl. 59: 15–16)

Comments. — These are elongated, semicircular in cross-section, with dorsal surface covered with fine granules. Ventral side displays well developed groove and ledges for supporting cover plates(?). Articulation surface smooth.

Distribution. — Samples MA-58 to MA-84; uppermost *Pygodus serra* Zone to middle *Amorphognathus tvaerensis* Zone.

CORONATES

Coronate radial
(Pl. 62: 16)

Comments. — This is approximately hexagonal plate bearing in the middle two prominent ridges forming V-like sculpture directed downward; traces of a delicate comarginal striation are also visible. The shape and sculpture of this plate closely resemble radial of *Paracystis ostrogothicus* SJÖBERG from the Middle Ordovician of Sweden (see REGNELL 1945: Text-fig. 24).

Distribution. — Sample MA-30 (upper *Amorphognathus variabilis* Zone), MA-5 and MA-80 (probably different species); middle *Amorphognathus tvaerensis* Zone. The specimen noted in the sample MA-30 is older than any noted in the literature coronate, as it comes definitely from the Lower Ordovician. The illustrated specimen is from the middle *Amorphognathus tvaerensis* Zone.

Coronate basal
(Pl. 62: 15)

Comments. — This is a thick and high heptagonal plate bearing in the middle a V-like sculpture and faint traces of comarginal sculpture; it resembles in shape and sculpture basals of *Stephanocrinus* and *Stephanoblastus* (see FAY 1978: Fig. 368; DONOVAN and PAUL 1985: Pls 62–63; BRETT *et al.* 1983).

Distribution. — Samples MA-35 (middle *Amorphognathus variabilis* Zone), MA-62 to MA-75; middle *Pygodus anserinus* Zone to lower *Amorphognathus tvaerensis* Zone. The presence of (not illustrated) coronate basal in the sample MA- 35 is the other oldest known occurrence of coronate echinoderms (see also above).

CYSTOIDS

Abundant stem fragments, thecal plates and brachiolar ossicles are common in most of the samples. In some cases the sculpture of the thecal plate is so characteristic that it allowed for generic attribution. The same concerns some stem fragments. Other holomeric stem ossicles, displaying various morphologies, never noted in crinoids, but resembling some known cystoid columnals, have been attributed by analogy to cystoids as well. In some cases, where they have been described by HYNDA (1986) within formal binomens then they are so used in the present paper; in other examples, only descriptive names are given.

Glyptocystitid cystoid thecal plate
(Pl. 64: 13)

Comments. — This is a hexagonal ridged plate with trace of ?stem insertion resembling thecal plates of Cheirocrinida (see KESLING 1968; PAUL 1984).

Distribution. — Sample MA-64; middle *Pygodus anserinus* Zone.

Proximal glyptocystitid columnal with spines
(Pl. 63: 3)

Comments. — This is an annular holomeric columnal with a very wide, round lumen, and bearing 4 to 5 triangular spines, symmetrically placed on their latera; in the middle of articulation facet it has an inner flange.

Distribution. — Samples MA-45 to MA-79; lower *Pygodus serra* Zone to middle *Amorphognatus tvaerensis* Zone.

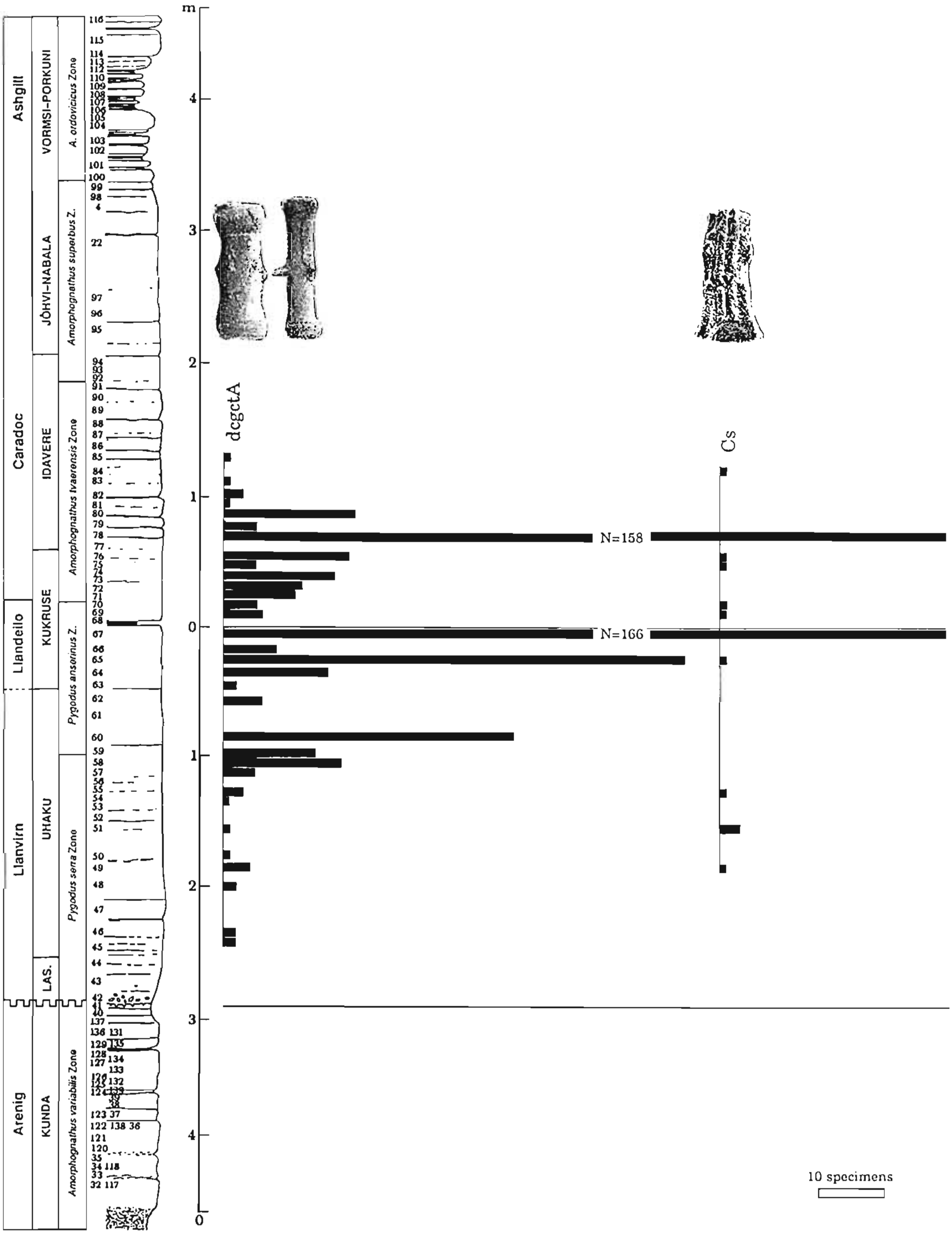

Fig. 3.
Frequency distribution of the most common cystoid and carpoid ossicles; dcgctA – distal columnal of glyptocystitid cystoid type A, Cs – cornutan stylocone.

Distal columnal of glyptocystitid cystoid type A
(Pl. 63: 10–12)

Comments. — This is the most common type of a cystoid columnal in the whole Mójcza section. These columnals are high, cylindrical and smooth with concave latera. On some of the columnal lateral surfaces there are nodes or spines placed equatorially (Pl. 63: 11–12); both articulation surfaces are slightly concave and smooth, with extremely narrow lumina (Pl. 63: 10). I was not able to assign them to any particular genus, but these columnals resemble macrocystellid and pleurocystitid distal columnals (compare PAUL 1984).

Distribution. — Samples MA-45 to MA-85; lower *Pygodus serra* Zone to upper *Amorphognathus tvaerensis* Zone (see Text-fig. 3).

Glyptocystitid distal columnal type B
(Pl. 63: 18)

Comments. — This is high, cylindrical columnal bearing an equatorial zone of thick tubercles and sculptured with delicate longitudinal striae; it resembles distal columnals of glyptocystitid cystoids.

Distribution. — Sample MA-80; *Amorphognathus tvaerensis* Zone.

Glyptocystitid, smooth, ring-like columnals
(Pl. 63: 1–2)

Comments. — These are ring-shaped columnals with a wide lumen; they have an outer elevated rim and an inner sunken facet of approximately the same width; they have smooth latera. Except for lacking lateral ornamentation they are very similar to proximal columnals of macrocystellid or pleurocystitid cystoids.

Distribution. — Samples MA-49 to MA-78; middle *Pygodus serra* Zone to lower *Amorphognathus tvaerensis* Zone.

Glyptocystitid proximal columnal with ribs
(Pl. 63: 4)

Comments. — These are low, ring-like, holomeric columnals with a wide round lumen and a wide perilumen; latera covered with narrow vertical ribs. Such type of columnals is typical of the proximal part of the stem of various glyptocystitid cystoids.

Distribution. — Samples MA-45 to MA-99; lowermost *Pygodus serra* Zone to uppermost *Amorphognathus superbus* Zone.

Genus *Asperellacystis* STUKALINA *et* HINTS, 1987

Type species: *Asperellacystis asperellus* STUKALINA *et* HINTS, 1987.

Asperellacystis cinctus HYNDA, 1986
(Pl. 63: 13–15, 17)

1986. *Aspirellocystis cinctus* sp. n.; HYNDA, p. 72, Pl. 12: 4–7.

Comments. — Holomeric elongated columnals bearing a downward directed flange with spines in the middle or lower latus; lumen round and relatively wide. Articulation surface wide, with median fulcral ridge and deep ligament pits; margin surrounded by more or less developed narrow rim. One articulation surface (probably upper one) is always smaller than the other one. This columnal type resembles vaguely columnals of some extant bourgeticrinids, while articulation facets are similar to those found in cirri of extant isocrinids and comatulids (the fact drawn to my attention by Dr. S.K. DONOVAN); these are, however, clearly independent developments.

No cystoid known to me has the stem composed of such columnals; thus the assignment of these forms by STUKALINA (*in litt.* – see HYNDA 1986) to cystoids must be conditional.

Distribution. — Middle Ordovician of western part of East European Platform; other morphospecies of *Asperellacystis* are known from the Ordovician of Baltic States (HYNDA 1986; STUKALINA and HINTS 1987). In the Mójcza Limestone sample MA-99; uppermost *Amorphognathus superbus* Zone.

Vialovicystis sp.
(Pl. 63: 16)

Comments. — These are cylindrical, holomeric columnals telescopically arranged and differing strongly in length. Lumen narrow, margin covered with a narrow rim or with several small protuberances; latera smooth. The investigated material differs from *Vialovicystis gradatus* HYNDA in lacking a periluminal elevated rim, and in the presence of protuberances at the margin. This type of columnals has been attributed to cystoids based mostly on their telescopic nature, typical of many glyptocystid cystoids.

Distribution. — Samples MA-45 to MA-99; middle *Pygodus serra* Zone to uppermost *Amorphognathus superbus* Zone.

Vialovicystis gradatus HYNDA, 1984
(Pl. 63: 5)

1984. *Vialovicystis gradatus* sp. n.; HYNDA, p. 58, Figs 1–3.
1986. *Vialovicystis gradatus* HYNDA; HYNDA, p. 71, Pl. 12: 1–3.

Comments. — This is a low, round cylindrical columnal with a slightly larger diameter at one end than the other; articulation surface shows round and relatively large lumen bordered with narrow elevated ring; similar ring borders the edge of the surface. Lateral surface smooth.

Distribution. — HYNDA (1986) reported the occurrence of this type of stem from the Middle Ordovician of the western part of the East European Platform; in the Mójcza Limestone sample MA-84; middle *Amorphognathus tvaerensis* Zone.

Herpetocystis spinosus HYNDA, 1986
(Pl. 63: 9)

1986. *Herpetocystis spinosus* sp. n.; HYNDA, p. 74, Pl. 12: 9–11.

Comments. — These are cylindrical, trimeric columnals with large, triangular lumina and short spines or nodes on lateral surfaces. Articular surface flat and smooth. This type of columnal has been attributed (HYNDA 1986) to the genus *Herpetocystis* (diploporite cystoid) described by TERMIER and TERMIER (1970, 1972) from the Ashgill of Morocco. Such assignment is based on their trilobate lumen; the differences are, however, so great that this attribution seems very unsure, if not false.

Distribution. — This morphospecies is also known from the uppermost Lower and Middle Ordovician from the western part of the East European Platform, while other, only sligthly different morphospecies, occur in the Middle and Upper Ordovician of Estonia, Middle and Southern Urals, Central Kazakhstan and southern Tian-Shan (HYNDA 1986). In the Mójcza Limestone samples MA-54 to MA-85; upper *Pygodus serra* Zone to upper *Amorphognathus tvaerensis* Zone (see Text-fig. 2).

Large globular diploporite cystoids

Comments. — In the investigated material, there are several poorly preserved (mostly without test), up to 3 cm in diameter, globular thecae; no pores have been observed due to the effects of preservation, and the theca seems nearly smooth. Most probably these fossils are the same as *Echinosphaerites* sp. illustrated from Mójcza by BEDNARCZYK (1966). However, in both cases their preservation is too poor for more precise attribution. Their diploporite cystoid nature is nevertheless undoubted.

Distribution. — The specimens have been collected from the scree, but they come definitely from the above the bentonite layer.

Sphaeronites (*Peritaphros*) sp.
(Text-fig. 4)

Comments. — The author has a fragment of globular theca without oral region; it displays polygonal peripores (and as such can be assigned to subgenus *Peritaphros* – see PAUL 1973; PAUL and

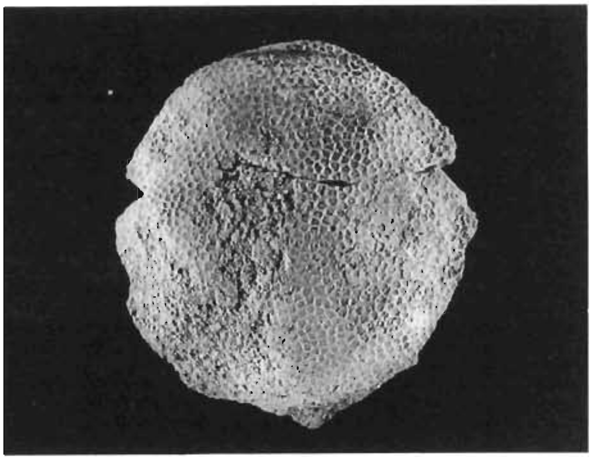

Fig. 4.
Sphaeronites (Peritaphros) sp., scree (above the bentonite layer – *Amorphognathus tvaerensis* Zone or higher), × 2.

BOCKELIE 1983; BOCKELIE 1984). It is, however, too poorly preserved and fragmentary to determine it to the species level.

Distribution. — The specimen has been collected from the scree; however, it definitely comes from the above of bentonite layer (*Amorphognathus tvaerensis* Zone or higher).

Haplosphaeronis sp.
(Pl. 64: 17)

Comments. — This is a small fragment of thecal plate densely covered with a dumb-bell shaped diplopores having raised periporal rim, the feature characteristic for the genus *Haplosphaeronis* (see PAUL 1973; BOCKELIE 1984).

Distribution. — Sample MA-5; middle *Amorphognathus tvaerensis* Zone.

Eucystis sp.
(Pl. 64: 16)

Comments. — This is a fragment of smooth perioral plate with a small singular brachiolar facet closely resembling some *Eucystis* species (see PAUL 1973; BOCKELIE 1984).

Distribution. — Sample MA-78; lower *Amorphognathus tvaerensis* Zone.

Diloporite thecal plates
(Pl. 64: 14–15, 18)

Comments. — These are fragmentarily preserved thecal plates bearing well developed rimmed diplopores. As they show substantial differences in their shape and distribution (these being specific characters – see PAUL 1973; BOCKELIE 1984) there is no doubt that they belong to different (probably 3) species. Some (Pl. 64: 14 and 18 especially) strongly resemble some *Eucystis* species.

Distribution. — Samples MA-80 to MA-84; middle *Amorphognathus tvaerensis* Zone.

EOCRINOIDS

There are two types of ossicles assigned to eocrinoids – thecal plates with epispires (resembling especially *Gogia*) and basal marginals(?) of *Batherocystis*. The problem is in the fact that the plates with epispires are known only from the Cambrian, and no eocrinoids with epispires are known to occur above the Lower Ordovician, while the investigated material is of the Middle Ordovician age.

Eocrinoid thecal plates with epispires
(Pl. 65: 1–7)

Comments. — These are common, thick, penta- to heptagonal plates bearing well developed epispires which are surrounded, in most cases, with a narrow elevated ledge, and are of different size. In the center the surfaces of plates are covered with various tubercles, ridges or even spines (Pl. 65: 2–3). They closely resemble thecal plates of some eocrinoids, especially of the Cambrian genus *Gogia* (see SPRINKLE 1973; DURHAM 1978: Pl. 1: 7–8); also loose plates of such type are regarded as representing eocrinoids (compare SPRINKLE 1973: Pl. 25; JELL *et al.* 1985: Fig. 6M–P).

However, some of the investigated plates resemble also the Cambrian ?*Stromatocystites* sp. and *Edriodiscus primotica* (HENDERSON *et* SHERGOLD) plates from Australia (JELL *et al.* 1985: Fig. 7). As the described plates show some variability, most probably they represent more than one form.

Distribution. — Samples MA-65 to MA-99; *Pygodus anserinus* to *Amorphognathus superbus* Zone.

Rhipidocystid eocrinoid basal marginals?
(Pl. 65: 12–13)

Comments. — These are massive, oblong ossicles with two large and one very small articulation surfaces, and outer surfaces sculptured with delicate pits. Such massive plates with similar sculpture are known to occur in rhipidocystid eocrinoid *Batherocystis* (UBAGHS 1967b: Fig. 319) as well as *Petalocystites* (see SPRINKLE 1973: Pl. 32, Figs 4–10, 17–18).

Distribution. — Samples MA-30 to MA-65; *Amorphognathus variabilis* to *Pygodus anserinus* Zones.

?Eocrinoid thecal plate with epispires
(Pl. 65: 9)

Comments. — This is an oval plate with deep, groove-like ?epispires. It resembles supposedly eocrinoid plate illustrated by SPRINKLE (1973: Pl. 25: 22) as well as some stromatocystitid isolated plates illustrated by JELL *et al.* (1985: Fig. 6E–H). It is included within the eocrinoids as it bears epispires.

Distribution. — Sample MA-78; *Amorphognathus tvaerensis* Zone.

ASTEROZOANS

There are quite numerous ossicles with complicated morphology, which without doubt belong to asterozoans. In many cases, however, I was not able to recognize conclusively their position within the skeleton and thus their assignment to this group is questionable. It seems, however, that both asteroids and ophiuroids are represented in the investigated material. This is a first record of both groups from the Ordovician of Poland.

Asterozoan adambulacralia
(Pl. 66: 1–2)

Comments. — These are numerous ossicles, rather flat and smooth, closely resembling adambulacralia of some Ophiuroidea (see SPENCER 1914–1940; SPENCER and WRIGHT 1966), as well as Recent asteroids (see BLAKE 1973). They cannot be assigned more specifically.

Distribution. — Samples MA-49 to MA-85; *Pygodus serra* to *Amorphognathus tvaerensis* Zone (see Text-fig. 1).

Asteroid adambulacralia
(Pl. 66: 5–6)

Comments. — These massive, smooth ossicles are among the most common and can be compared only with some asterozoan plates, most probably adambulacral, but the general morphology does not allow for a more precise assignment.

Distribution. — Samples MA-49 to MA-95; *Pygodus serra* to *Amorphognathus superbus* Zones (see Text-fig. 1).

Asterozoan ambulacral plate type A
(Pl. 66: 9–11)

Comments. — These complicated, shaft-like ossicles closely resemble ambulacral plates of some fossil ophiuroids (see SPENCER 1914–1940) but also the Recent asteroid *Luidia* (see BLAKE 1973).

Distribution. — Samples MA-70 to MA-88; uppermost *Pygodus serra* Zone to upper *Amorphognatus tvaerensis* Zone.

Asterozoan ambulacral plate type B
(Pl. 66: 3)

Comments. — This is a multiangular, irregular plate resembling some asteroid ambulacral ossicles (see SPENCER 1914–1940: Text-figs 5, 8–9).

Distribution. — Sample MA-78; *Amorphognathus tvaerensis* Zone.

Asterozoan mouth plate
(Pl. 66: 12)

Comments. — This plate closely resembles the mouth plate of the ophiuroid *Taeniaster* (see SPENCER 1914–1940: Text-fig. 319), but as morphology of other elements of this type is poorly known, one cannot be sure about its position.

Distribution. — Samples MA-71 to MA-95; *Amorphognathus tvaerensis* to *Amorphognathus superbus* Zones.

Salteraster abactinals
(Pl. 66: 15–16)

Comments. — These are irregularly hexagonal plates with long paxillary shafts in the top-center, closely resembling abactinals of *Salteratser* sp. cf. *S. grandis* illustrated by GUENSBURG (1984).

Distribution. — Samples MA-52 to MA-95; *Pygodus serra* Zone to *Amorphognathus superbus* Zone.

Asteroid abactinals
(Pl. 62: 10–11)

Comments. — These are narrow, irregularly quadrangular plates with very long paxillary shafts. They are so much different in general shape that they have to represent different species from those assigned to *Salteraster* (see above).

Distribution. — Sample MA-95; *Amorphognathus superbus* Zone.

Asteroid disk ossicle type A
(Pl. 66: 17)

Comments. — This is a star-like pentagonal, strongly convex ossicle with deeply pitted central portion; it most probably represents a disk ossicle.

Distribution. — Sample MA-82; *Amorphognathus tvaerensis* Zone.

Asteroid disk ossicle type B
(Pl. 66: 19)

Comments. — This is a massive, pentagonal plate with a strongly convex central portion which bears several small pits.

Distribution. — Sample MA-62; *Pygodus anserinus* Zone.

Asteroid disk(?) ossicles type C
(Pl. 65: 14–15)

Comments. — These are thick, irregular ossicles with clear incisions of the margins, and bearing varying numbers of tubercles (sometimes with a pit at the top, thus suggesting that they supported spines). They closely resemble disk ossicles of Silurian *Neopalaeaster* (see RASMUSSEN 1952).

Distribution. — Samples MA-6 and MA-84; *Amorphognathus tvaerensis* Zone.

Asteroid disk(?) ossicles type D
(Pl. 65: 10–11)

Comments. — These are very thick, strongly convex, multiangular to stellate plates sculptured with thick nodes or ridges. They have very characteristic radial structures (central shaft with narrow, radial canals perpendicular to it) in their center. I was not able to find similar structures in any asterozoan plates, but morphology of plates can be only compared with asteroid disk ossicles.

Distribution. — Samples MA-49 to MA-5; *Pygodus serra* Zone to *Amorphognathus tvaerensis* Zone.

Asteroid marginal and disk ossicles(?)
(Pls 62: 5; 66: 13–14, 18)

Comments. — These are massive, multiangular plates with strongly convex upper surface covered with nodes or showing traces of spine attachment, and flat to concave lateral articulation surfaces; they can be only compared with marginals and/or disk plates of asteroids.

Distribution. — Samples MA-5, 78, 99; *Amorphognathus tvaerensis* Zone and *Amorphognathus superbus* Zone.

Asterozoan spine
(Pl. 60: 13)

Comments. — This is a delicate spine-like ossicle which can be only attributed to an undetermined asteroid or ophiuroid.

Distribution. — Sample MA-78; *Amorphognathus tvaerensis* Zone.

Undetermined asterozoan ossicles
(Pl. 66: 4, 7–8)

Comments. — These include several plates of complicated morphology which approach some ambulacrals and/or mouth plates of asterozoans.

Distribution. — Samples MA-67, 78, 79; *Pygodus anserinus* Zone to *Amorphognathus tvaerensis* Zone.

ECHINOIDS

Bothriocidaris? sp.
(Pls 61: 16; 62: 6)

Comments. — There is one fragment (Pl. 61: 16) of interambulacral plate with two perforate tubercles (compare with, for example, MÄNNIL 1962: Pl. 2: 1). The other plate (Pl. 62: 6) shows three major perforated tubercles in one row, surrounded by several secondary tubercles which are poorly expressed. Both plates are too poorly preserved to allow for precise assignment. See also comments concerning bothriocidaroids below.

Distribution. — Samples MA-71 and MA-82; *Amorphognathus tvaerensis* Zone.

Neobothriocidaris sp. cf. *N. minor* PAUL, 1967
(Pl. 61: 15)

cf. 1967 *Neobothriocidaris minor* sp. n.; PAUL, p. 535, Text-fig. 4.

Comments. — There is one fragmentarily preserved perforated plate, with one primary mamelon, a poorly developed secondary mamelon, and a well-developed peripodial rim. It closely resembles *Neobothriocidaris minor* PAUL, 1967 (Text-fig. 4), but in my specimen the secondary mamelon is located on the right, and not the left, side as in the PAUL's specimen. It should be mentioned here that according to SMITH (1984) bothriocidaroids in phylogenetic terms are stem holothuroids rather than echinoids.

Distribution. — Sample MA-27; *Pygodus serra* Zone.

Echinocystitoid? ambulacral plate
(Pl. 61: 14)

Comments. — This is an irregularly hexagonal plate with a pore pair located in the middle of the plate, which resembles some ambulacral plates of the Echinocystitoida (see KIER 1966).

Distribution. — Sample MA-71; *Amorphognathus tvaerensis* Zone.

HOLOTHURIANS?

Holothurian? sclerite
(Pl. 60: 1)

Comments. — There are few irregular perforated plates closely resembling *Thuroholia* spp., which are supposedly holothurian sclerites (see GUTSCHICK 1954; HYNDA 1986). This taxon was recently reported from Poland by SZTEJN (1989).

Distribution. — This morphology of plate occurs only in the marly limestones (sample MA-100; boundary of *Amorphognathus superbus* and *A. ordovicicus* Zones, Zalesie Formation) from the above of the Mójcza Limestone.

STYLOPHORANS

There are several types of ossicles, representing both aulacophore ossicles as well as marginals, which are assigned to this group. They are so characteristic that there is no doubt about their systematic position. More problematic are variously sculptured plates which I regard as centralia. Some of them (which are stellate) resemble, at the first sight, thecal plates of cheirocrinid cystoids (see, for example, Pl. 61: 1–3), but they differ in the absence of rhombs and in having only radial (pointing to the plate corners) ridges on their surface, as well as in having concave plate boundaries (if not damaged). They also slightly resemble thecal plates known from the eocrinoid *Gogia*(?) *radiata* SPRINKLE (which, however, bears well-developed epispires absent in the Polish material). Thus, based on comparison with centralia of *Nevadaecystis americana* (UBAGHS) from the uppermost Cambrian of Nevada, I regard them as stylophoran thecal plates.

Nevadaecystis? sp.
(Pl. 64: 5–8)

Comments. — These are stellate, convex plates bearing from 4 to 11 very prominent ridges of unequal length, and slightly less strongly developed comarginal, concentric ridges (growth lines?). Plate boundaries between radial ridges are concave. They are so close to the integument plates of *Nevadaecystis americana* (UBAGHS) (uppermost Cambrian of Nevada; see UBAGHS 1963) that most probably they belong to the same genus.

Distribution. — Sample MA-99; *Amorphognathus superbus* Zone.

Cornutan centralia type A
(Pl. 64: 1–4)

Comments. — There are strongly convex multiangular plates bearing 4 to 6 radial ridges (pointing to the plate corners). The surface between ridges is covered with strong rounded nodes. Plate boundaries concave, indicating a rather loose arrangement in the theca.

Distribution. — Samples MA-49 to MA-85; *Pygodus serra* Zone to *Amorphognathus tvaerensis* Zone.

Cornutan centralia type B
(Pl. 64: 9–12)

Comments. — There are strongly convex plates bearing 3 to 4 prominent radial ridges running from the apex to the corners of the plate; plate boundaries concave, surface covered with more or less strong and irregular pits. As there are some differences in the sculpture, most probably they belong to more than one species.

Distribution. — Samples MA-59 to MA-84; *Pygodus anserinus* to *Amorphognathus tvaerensis* Zone.

Cornutan centralia type C
(Pl. 67: 1–4)

Comments. — There are thin, oval to polygonal plates from the theca strongly sculptured with rounded pits of different size. They closely resemble plates of *Galliaecystis ligniersi* UBAGHS (see UBAGHS 1969: Pls 12: 1, 4; 13: 4).

Distribution. — Samples MA-67 to MA-79; *Pygodus anserinus* Zone to *Amorphognathus tvaerensis* Zone.

Cornutan stylocone
(Pl. 67: 6)

Comments. — These are semicylindrical ossicles, expanded at one end which bears a wide cavity; surface with a median furrow and transverse channels well visible; they perfectly fit the morphology of stylophore of Cornuta (see UBAGHS 1967a: Fig. 343–2a; 1969: Fig. 13). In the investigated material there are numerous ossicles of this type. As there are some differences in their shapes, it may be expected that more than one species is represented.

Distribution. — Samples MA-49 to MA-84; *Pygodus serra* Zone to *Amorphognathus tvaerensis* Zone (see Text-fig. 3).

Distal ossicles of cornutan aulacophore
(Pl. 67: 7–8)

Comments. — These are semicylindrical ossicles with a rounded lower face. The upper face bears a median furrow, bordered by narrow ridges which are cut by transverse channels leading to the lateral depressions. Articulation surface nearly flat, except for two poorly-developed lateral ridges on one end and similar depressions on the other. This morphology perfectly fits the shape of distal aulacophore ossicles of Cornuta (see UBAGHS 1967a: Fig. 343–3; 1969: Fig. 14).

Distribution. — Samples MA-49 to MA-85; *Pygodus serra* Zone to *Amorphognathus tvaerensis* Zone (see Text-fig. 2).

Cover plate of cornutan aulacophore
(Pl. 67: 9)

Comments. — This is a thin and flat ossicle resembling a scale and bearing a characteristic sculpture of irregular ribs which fits very well with the morphology of aulacophore cover plates of *Scotiaecystis griffei* UBAGHS (see UBAGHS 1969: Fig. 25–3a).

Distribution. — Sample MA-84; *Amorphognathus tvaerensis* Zone.

Cornutan marginal ossicle
(Pl. 67: 5)

Comments. — This is a massive ossicle with two articulation surfaces at its extremities and bearing a massive, spine-like outgrowths. It resembles M3 marginals in the genera *Cothurnocystis*, *Scotiaecystis* and *Galiaecystis* (see UBAGHS 1967a, 1969).

Distribution. — Sample MA-62; *Pygodus anserinus* Zone.

PELMATOZOAN COLUMNALS

Barrel-shaped spinose columnals
(Pl. 62: 4)

Comments. — These are medium high, barrel-shaped holomeric columnals bearing equatorially five massive, regularly distributed, spines; articulation surface concave, lumen very narrow.

Distribution. — Samples MA-49 to MA-82; *Pygodus serra* to *Amorphognathus tvaerensis* Zones.

Spinose columnal with quadrangular lumen
(Pl. 62: 3)

Comments. — This is a medium high, round holomeric columnal, bearing on latera irregularly distributed (that is, at various heights), numerous blunt, massive spines of various lengths. Axial canal wide, quadrangular, articulation surface smooth and flat.

Distribution. — Samples MA-65 to MA-67; *Pygodus anserinus* Zone.

Undetermined ribbed holomeric columnals
(Pl. 63: 19–21)

Comments. — These are high, rounded, holomeric columnals with thick vertical, longitudinal ribs on the latera. Ribs sometimes bear more or less pronounced (equatorially located) nodes. Lumen round and relatively wide, articulation surface smooth.

Distribution. — Samples MA-45 to MA-82; middle *Pygodus serra* Zone to middle *Amorphognathus tvaerensis* Zone.

Various undetermined pelmatozoan holomeric columnals
(Pls 62: 2, 12; 63: 6–8)

Comments. — These include a variety of higher than wide, holomeric columnals with round lumina of various width, with spinose latera (Pls 62: 2, 12; 63: 6). This type resembles mostly distal columnals of glyptocystid cystoids. Other columnals, which are very low with smooth latera (Pl. 63: 7–8) are difficult to attribute, but do not belong to crinoids.

Distribution. — See explanation of plates.

UNDETERMINED ECHINODERM OSSICLES

Undetermined biserial brachiolae ossicle type A
(Pl. 67: 16–17)

Comments. — These are massive plates, rounded at dorsal side and not sculptured on the dorsal surface. These ossicles are from biserial brachiolae with simple zig-zag suture. All articulation surfaces are smooth. The ventral groove is simple and bears no ledge which can be suggestive of existence of cover plates. Such brachiolar ossicles may belong to cystoids or eocrinoids.

Distribution. — Sample MA-49; *Pygodus serra* Zone.

Undetermined biserial brachiolae ossicle type B
(Pl. 67: 18–19)

Comments. — These are massive ossicles very similar to those described as type A. They differ only in being L-shaped in cross section, not rounded on the dorsal side and bearing strong tubercles on the exterior.

Distribution. — Samples MA-62 and MA-78; *Pygodus anserinus* Zone to *Amorphognathus tvaerensis* Zone.

Undetermined biserial ?brachiolae ossicle type C
(Pl. 67: 14–15)

Comments. — These are relatively delicate plates with clearly developed growth lines on the exterior and with an L-shaped cross section. Ossicles fit together along a zig-zag line into a brachiolar-like appendage. The inner side bears a narrow ledge at the ?bottom; transverse articulation surface flat. Most probably these represent brachioles of some diploporite cystoids. For example, rectangular brachiolar facets resemble those of the genus *Haplosphaeronis* (see BOCKELIE 1984: Text-fig. 20).

Distribution. — Samples MA-49 to MA-99; *Pygodus serra* Zone to *Pygodus superbus* Zone (see Text-fig. 1).

Undetermined plates type A
(Pl. 67: 10–11)

Comments. — These are massive plates, trapezoidal in outline showing traces of growth line on one (?inner) side, while the other one bears two closely placed, wide nodes located near the shortest horizontal margin. They resemble oral plates of some diploporite cystoids (see BOCKELIE 1984: Pls 3: 1; 5: 1).

Distribution. — Sample MA-78; *Amorphognathus tvaerensis* Zone.

Undetermined plate type B
(Pl. 67: 12–13)

Comments. — These are rectangular to trapezoidal, thin plates bearing clear growth lines on one (?inner) side; the other one bears two nodes bordered by shallow pits near the shorter horizontal margin. These plates resemble slightly those described above, and perhaps are also oral plates of some cystoid.

Distribution. — Samples MA-47 to MA-95; *Pygodus serra* Zone to *Amorphognathus superbus* Zone.

Undetermined ?cover plates type C
(Pl. 62: 7–8)

Comments. — These are massive plates, clinoform in transverse section and bearing prominent growth line on one side. The other surface shows two deep pits on sides and a median, vertical furrow between them. They generally resemble previously described plates and perhaps belong to the same group, i.e., the cystoids; however, some superficial resemblance to cyclocystoid marginals may be also noted.

Distribution. — Samples MA-80, MA-84; *Amorphognathus tvaerensis* Zone.

Thecal plates of unknown affinity, type A
(Pl. 60: 16–17)

Comments. — These are massive, multiangular plates, but approaching a rectangular outline, with the outer surface sculptured with deep pits. On the inner side very characteristic, parallel longitudinal ledges are prominent. They may belong to some unknown crinoid cup.

Distribution. — Sample MA-78; middle *Amorphognathus tvaerensis* Zone.

Thecal plates of unknown affinity, type B
(Pl. 60: 4)

Comments. — These ossicles are triangular in outline with one surface smooth and the other with a triangular depressed area at the base. The rest of the ossicle is covered with several thick radial ribs.

Distribution. — Samples MA-8 and MA-50; middle *Pygodus serra* Zone.

Thecal plate of unknown affinity, type C
(Pl. 60: 3)

Comments. — This is a slightly trapezoidal, thick plate, convex on the outside and with a pitted surface. It may represent the cup plate of an inadunate crinoid.

Distribution. — Sample MA-46; lower *Pygodus serra* Zone.

Thecal plate of unknown affinity, type D
(Pl. 60: 15)

Comments. — This is a trapezoidal plate with concave inner and convex outer surface, bearing no special structures on the articulation surfaces. It most probably belongs to some inadunate crinoid.

Distribution. — Sample MA-64; *Pygodus anserinus* Zone.

Thecal plate of unknown affinity, type E
(Pl. 60: 7)

Comments. — This is a thick, multiangular plate bearing three elevated and narrow areas on the outer surface. It is widened at one end and surrounded by a narrow rim, which strongly resembles the peripores of diplorite cystoids. However, there are no pores visible.

Distribution. — Sample MA-6; lower *Amorphognathus tvaerensis* Zone.

Thecal plate of unknown affinity, type F
(Pls 60: 6; 62: 13)

Comments. — These are thick, multiangular plates. On the outer surface one or two narrow elevated areas are surrounded by a narrow rim. These resemble the peripores of diploporite cystoids, but bear only one pore at the end of each elevated area.

Distribution. — Samples MA-59 to MA-84; *Pygodus anserinus* Zone to *Amorphognathus tvaerensis* Zones.

Thecal plate of unknown affinity, type G
(Pl. 60: 8)

Comments. — This is a narrow, convex, hexagonal plate with a strongly sculptured surface. It most probably belongs to some crinoid.

Distribution. — Sample MA-5; *Amorphognathus tvaerensis* Zone.

Thecal plate of unknown affinity, type H
(Pl. 60: 11)

Comments. — This is a large, convex, smooth, hexagonal, elongated plate which most probably represents some inadunate crinoid cup plate.

Distribution. — Sample MA-78; *Amorphognathus tvaerensis* Zone.

Thecal plate of unknown affinity, type I
(Pl. 60: 5)

Comments. — This is a thin, pentagonal plate bearing five prominent radial ridges. Such morphology is known in both crinoids and asterozoans.

Distribution. — Sample MA-75; *Amorphognathus tvaerensis* Zone.

Thecal plate of unknown affinity, type J
(Pl. 65: 16)

Comments. — This is nearly round thecal plate bearing five radial folds. It resembles some plates found in crinoids, but the morphology is too general to allow for a precise assignment.

Distribution. — Sample MA-64; *Pygodus anserinus* Zone.

Indeterminate echinoderm plates
(Pls 60: 9–10; 62: 14, 17–18; 65: 8, 17–18)

Comments. — These are plates of various morphologies which I was not able to associate with any particular group or function. They represent the largest "class" of ossicles present in the investigated material, but not illustrated here, which I was unable to classify. For the distribution of the illustrated ossicles, see the explanations of the plates.

FINAL REMARKS

For the purpose of a faunal dynamic study, the most common types of ossicles have been counted in each sample and their frequency plotted against a stratigraphic column (see Text-figs 1–3). Unfortunately, no pattern in frequency distribution has been found which can be interpreted in biological terms. There is no indication of the *Nemagraptus gracilis* transgressive event, which can be seen in the distribution of conodonts (see DZIK 1994, and DZIK and PISERA 1993) and sedimentation of the bentonite resulted in no change in echinoderm assemblage composition. The only drastic change (not indicated on the figures) is seen, as is the case with other groups, in sample MA-99, where several plates interpreted as cornutan centralia (known from North America) and strange flanged telescopic columnals assigned to cystoids (known from the Baltic province) appeared, which are unknown below. A further surprising observation concerns the morphological stability of certain common ossicles [such as *Ristnacrinus* sp. (Text-fig. 1), and other crinoids (Text-fig. 2), as well as cystoid stem ossicles (Text-fig. 3), and supposedly brachiolar ossicles], which show no changes over three or more geological stages. On the other hand the observed frequency distribution (the highest frequency in the middle of the section and low or absence in the upper and lower part) should be interpreted in terms of preservation potential rather than real change in living specimen frequency. It is supported by thin section observation, where samples from the middle of the section show the best developed phosphate envelopes.

With respect to the groups which were recognized, some attributions may be questioned, but the existing literature gives very little support for interpretation of disassociated ossicles. Nevertheless, the presence in the investigated material of all important Ordovican groups, that is, camerate and inadunate crinoids, echinoids, coronates, stylophorans, cystoids, eocrinoids and asterozoans, can be granted. One has to mention that up until today only cystoids (see BEDNARCZYK 1966) and doubtful holothurians (see SZTEJN 1989) have been reported from the Polish Ordovician.

Based on such material, it is also difficult to speak about paleobiogeographical relationships. The strongest connections, as may be expected, are visible with the Baltic province. It is well shown by crinoids (stem ossicles) as well as by cystoids and echinoids (compare especially with HYNDA 1986). Nonetheless, there are certain groups, such as stylophorans (the presence of supposedly *Nevadaecystis*) and eocrinoids, which indicate some relationships with the south European and North American provinces. However, they are not determined precisely enough to be very certain about this deduction. The presence of supposed *Trochocrinites* indicates a connection with British Isles, exactly with their part north of the Iapetus Suture and thus representing also North American faunal province (see DONOVAN 1989). Ostracodes (OLEMPSKA 1994) also show taxa known in various Ordovician provinces; many of the ostracodes are new, thus the situation may be similar with echinoderms. Many other potentially useful ossicles cannot be determined because of a lack of literature data describing details of particular plates which compose the whole animal.

There are also some interesting findings, concerning the stratigraphical range of particular groups. It seems generally that their stratigraphical range is extended in comparison with previous reports. The best example are the eocrinoid plates with epispires; before, eocrinoids with epispires were known from the Cambrian and lowermost Ordovician only (SPRINKLE 1973). The other case is with coronates and *Bothriocidaris*, determined in this study, which in the Mójcza Limestone appear much earlier than previously reported. Similar features have been found to be characteristic for ostracodes (OLEMPSKA 1994). All this suggests that the known ranges of some groups, based in most cases on well-preserved specimens, may be treated as very much reduced. Such a situation could be expected as in fact findings of entire specimens should be regarded rather as "fossil Lagerstätten" than the norm (DONOVAN 1991). This conclusion may be of some importance for evolutionary considerations.

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PLATE 59

Figs 1–6. Folded crinoid calyx plates; 1, undetermined calyx plate, MA-78, × 42; 2, undetermined calyx plate, MA-5, × 27; 3, undetermined calyx plate, MA-5, × 45; 4, radial, MA-5, × 30; 5, radial, MA-5, × 60; 6, radial, MA-84, × 24.

Fig. 7. Crinoid (probably *Trochocrinites*) radial plate type A, MA-67, × 36.

Fig. 8. Crinoid radial plate type B (similar to *Iocrinus shelvensis* RAMSBOTTOM, 1961), MA-5, × 45.

Fig. 9. Pinnular with saw-like edges, MA-54, × 36.

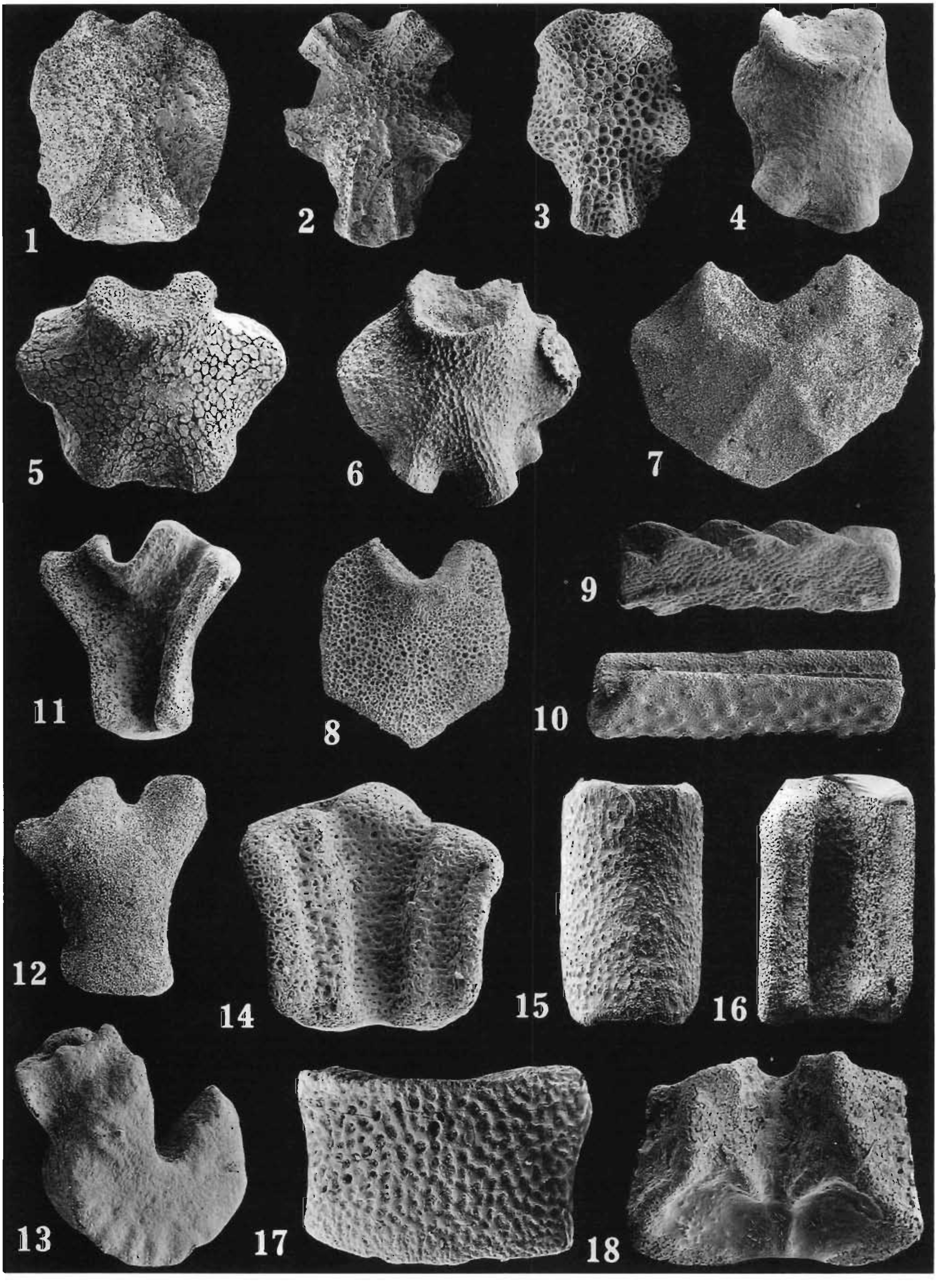
Fig. 10. Massive tuberculated pinnular, MA-67, × 36.

Figs 11–12. Uniserial branched brachial; 11, dorsal view, MA-73, × 60; 12, ventral view, MA-73, × 60.

Fig. 13. Uniserial pinnulated (?inadunate) brachial, MA-5, × 60.

Figs 14, 17–18. Brachials of ?calceocrinids, MA-78, × 60; 14, ventral view of axillare, MA-51, × 60; 17, dorsal view of a ?IBr1, MA-78, × 60; 18, ventral view of a ?IBr1, MA-78, × 42.

Figs 15–16. ?Ramules of undetermined crinoid; 15, dorsal view, MA-78, × 36; 16, ventral view, MA-78, × 36.



PISERA: ECHINODERMS OF THE MÓJCZA LIMESTONE

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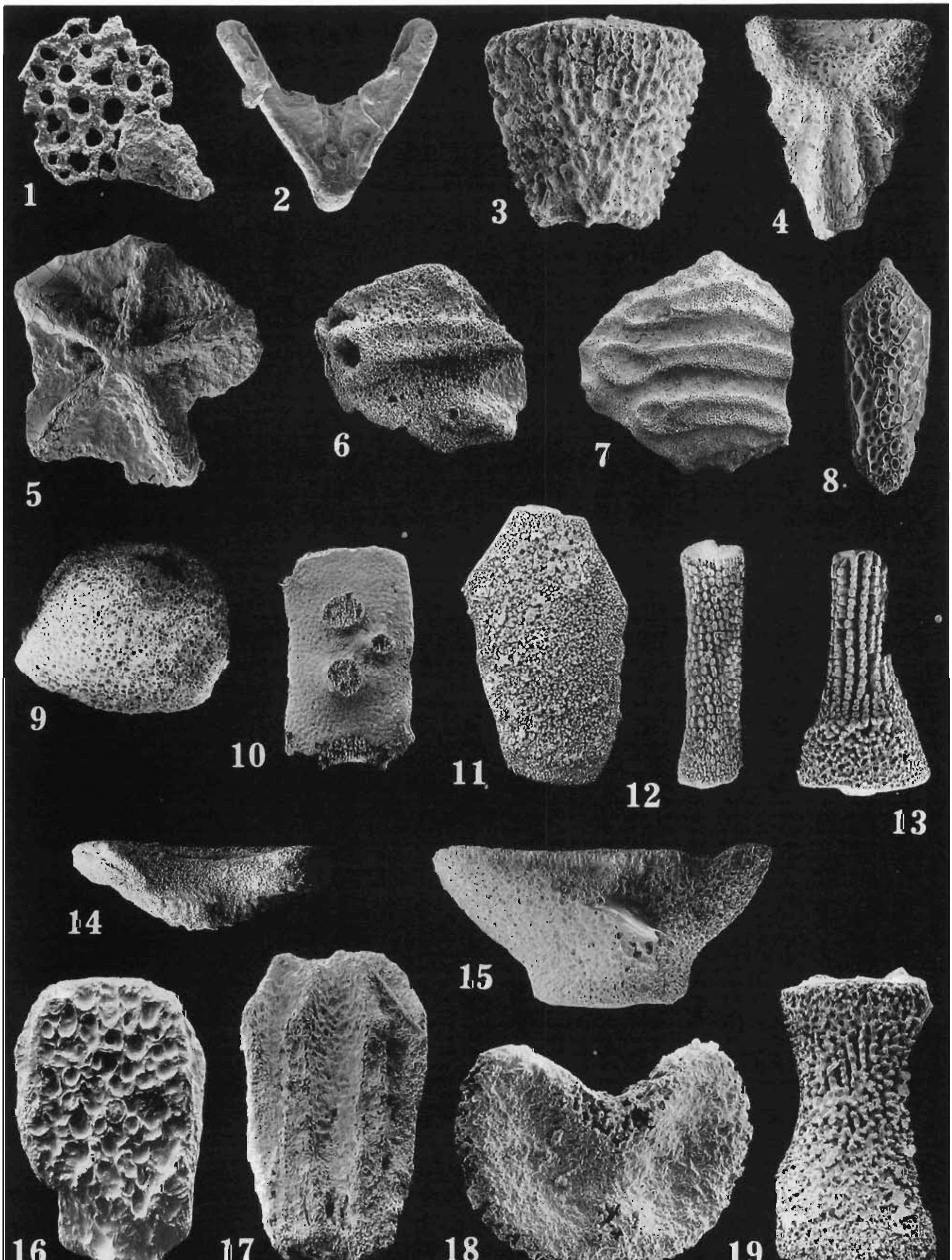
PLATE 60

Fig. 1. Holothurian? sclerite; MA-100, × 60.
Fig. 2. Short, delicate crinoid pinnular; MA-27, × 45.
Fig. 3. Thecal plate of unknown affinity, type C, MA-46, × 60.
Fig. 4. Thecal plate of unknown affinity, type B, MA-08, × 45.
Fig. 5. Plate of unknown affinity type I; MA-75, × 90.
Fig. 6. Thecal plate of unknown affinity, type F; MA-78, × 36.
Fig. 7. Thecal plate of unknown affinity, type E; MA-6, × 30.
Fig. 8. Thecal plate of unknown affinity, type G; MA-5, × 21.
Figs 9–10. Undetermined echinoderm plates; 9. MA-49, × 60; 10. MA-82, × 60.
Fig. 11. Thecal plate of unknown affinity, type H; MA-78, × 30.
Figs 12, 18–19. ?Disparid brachials, 12, dorsal view, MA-49, × 30; 18, articulation surface, MA-78, × 120; 19, dorsal view, MA-78, × 45.
Fig. 13. Asterozoan spine; MA-78, × 36.
Fig. 14. Undetermined crinoid cup plate, MA-99, × 30.
Fig. 15. Thecal plate of unknonwn affinity, type D; MA-64, × 60.
Figs 16–17. Thecal platę of unknown affinity, type A; 16, outer view, MA-78, × 30; 17, inner view, MA-78, × 30.



PISERA: ECHINODERMS OF THE MÓJCZA LIMESTONE

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PLATE 61

Figs 1–7. *Schizocrinus? kuckersensis* YELTYSHEVA, 1966; ossicles of various morphology from a heteromorphic stem, articulation surface view; 1, MA-84, × 45; 2, MA-84, × 45; 3, MA-84, × 36; 4, MA-5, × 30; 5, MA-84, × 60; 6, MA-65, × 60; 7, MA-84, × 45.

Fig. 8. Crenulated holomeric columnal (resembling *Crenatocrinus biplex* EICHWALD, 1861, MA-65, × 42

Fig. 9. *Ristnacrinus* sp. articulation surface; MA-60, × 36.

Fig. 10. *Ristnacrinus? angulatus* YELTYSHEVA, 1966, articulation surface view; MA-46, × 60.

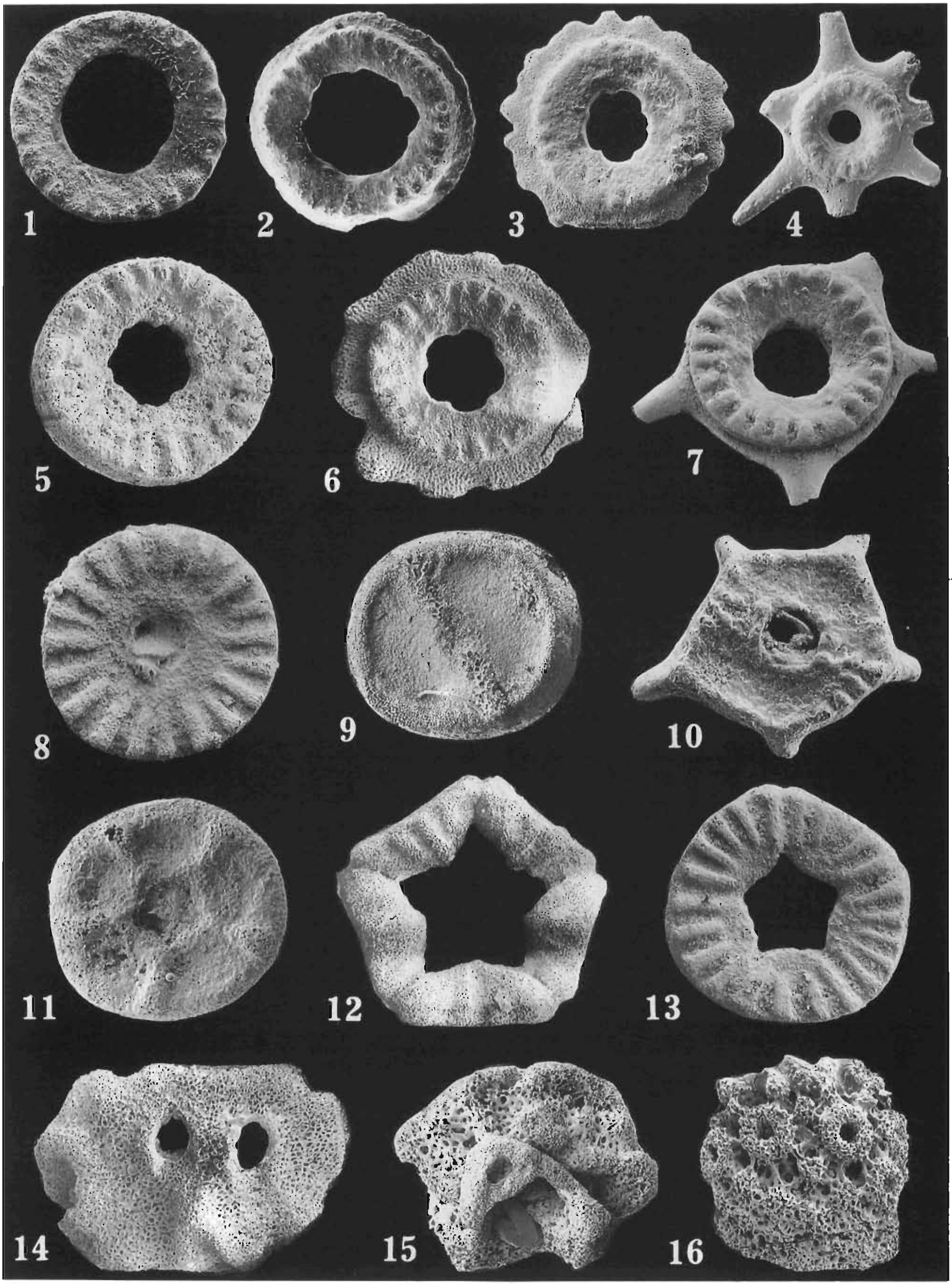
Fig. 11.Columnal of *"Babanicrinus"* sp., MA-78, × 60.

Figs 12–13. Pentameric crenulated columnals; 12, MA-5, × 60; 13, MA-65, × 45.

Fig. 14. Echinocystitid? ambulacral plate, MA-71, × 60.

Fig. 15. *Neobothriocidaris* sp. cf. *Neobothriocidaris minor* PAUL, 1976, MA-27, × 36.

Fig. 16. *Bothriocidaris?* sp., MA-71, × 84.



PISERA: ECHINODERMS OF THE MÓJCZA LIMESTONE

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PLATE 62

Fig. 1. Crinoid holomeric pentagonal columnal, MA-51, × 42.

Figs 2, 12. Undetermined holomeric spinose pelmatozoan columnals (most probably cystoid); 2, MA-87, × 45; 12, MA-65, × 36.

Fig. 3. Spinose columnal with quadrangular lumen, MA-65, × 60.

Fig. 4. Barrel shaped spinose columnal, MA-65, × 60.

Fig. 5. Asteroid? marginal or disk plate; MA-78, × 36.

Fig. 6. *Bothriocidaris*? sp. MA-82, × 45.

Figs 7–8. Undetermined? cover plates type C; 7. ?outer view, MA-80, × 45; 8.?Inner view, MA-84, × 45.

Fig. 9. Undetermined crinoid cup plate, MA-76, × 36.

Figs 10–11. Asteroid abactinals; 10, upper view, MA- 95, × 60; 11, side view, MA-95, × 60.

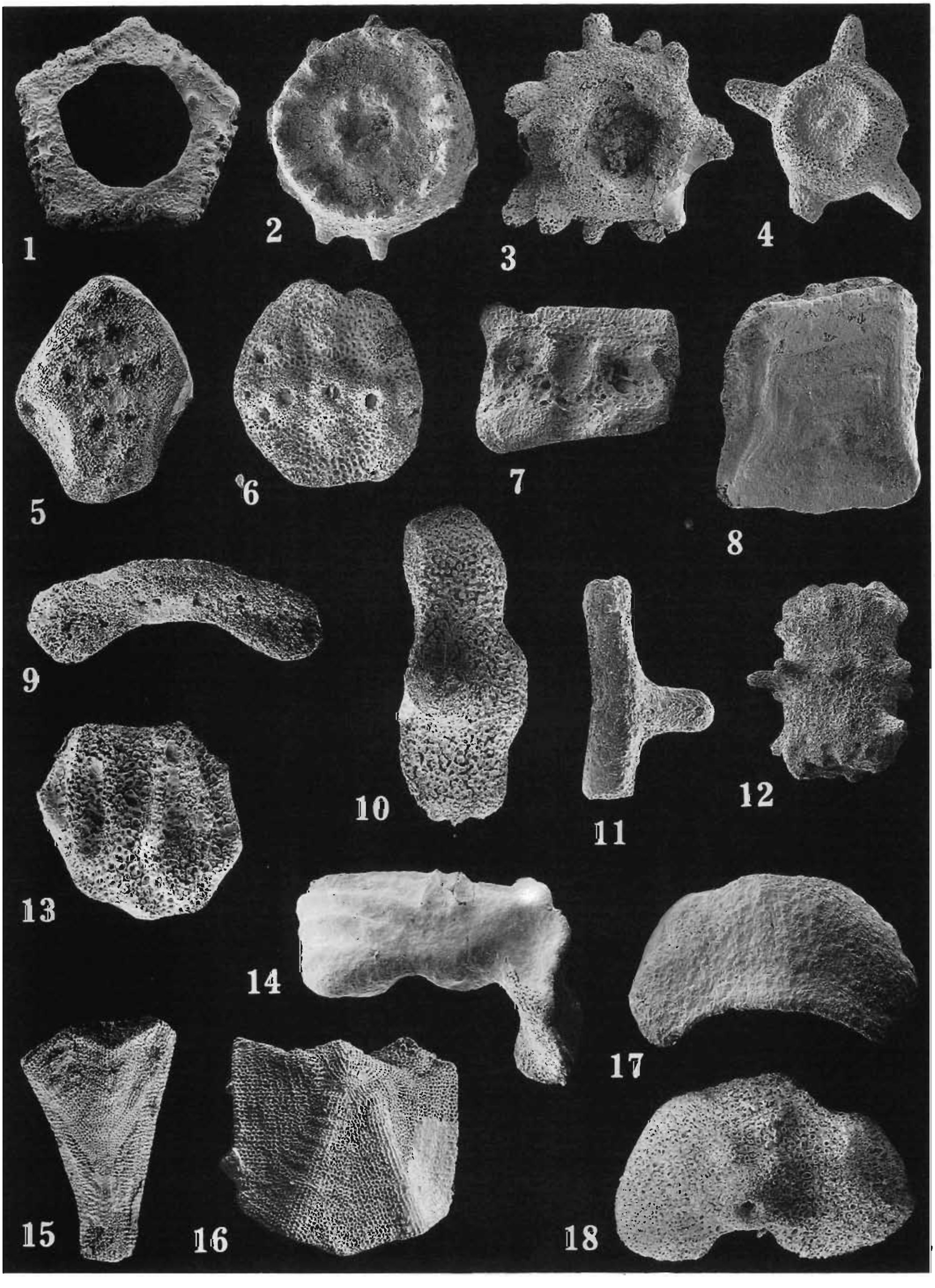
Fig. 13. Thecal plate of unknown affinity, type F; MA-76, × 45.

Fig. 14. Undetermined echinoderm plate, MA-79, × 42.

Fig. 15. Coronate basal, MA-65, × 60.

Fig. 16. Coronate radial, MA-5, × 60.

Figs 17–18. Undetermined echinoderm plates; 17, MA-67, × 42; 18, MA-67, × 60.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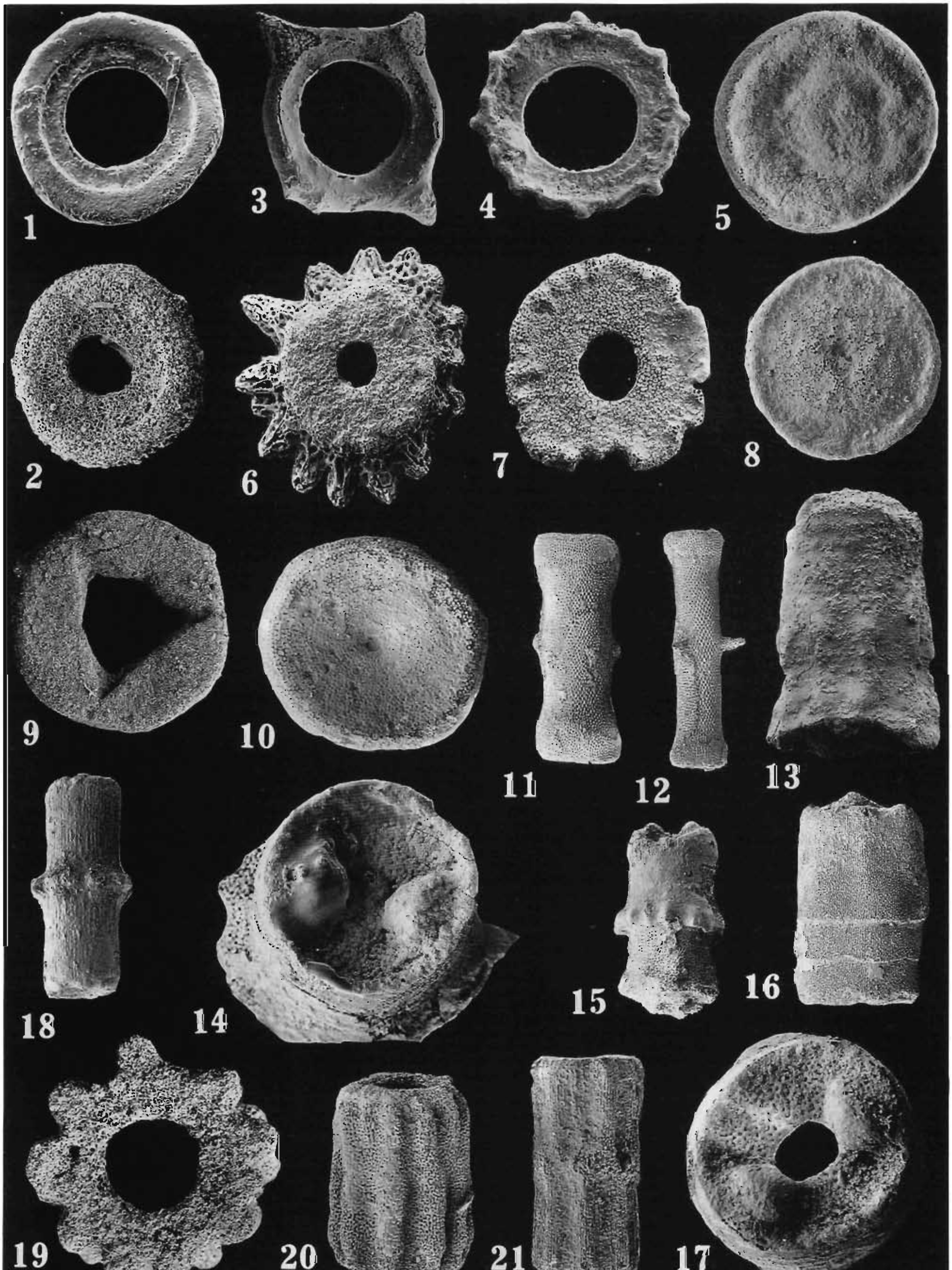
PISERA: ECHINODERMS OF THE MÓJCZA LIMESTONE

PLATE 63

Figs 1–2. Glyptocystid cystoid smooth ring-like proximal columnals; 1, MA-52, × 60; 2, MA-78, × 45.
Fig. 3. Proximal glyptocystitid columnal with spines, MA-49, × 90.
Fig. 4. Proximal annular columnal with ribs of glyptocystid cystoid, MA-99, × 120.
Fig. 5. *Vialovicystis gradatus* HYNDA 1984, articulation surface; MA-84, × 60.
Fig. 6. Spinose pelmatozoan holomeric columnal (probably distal columnal of glyptocystitid cystoid), MA-76, × 60.
Fig. 7. Unrecognized flat pelmatozoan columnal, MA-78, × 45.
Fig. 8. Low and smooth holomeric pelamatozoan columnal (most probably proximal rhombiferan cystoid columnal), MA-78, × 36.
Fig. 9. *Herpetocystis spinosus* HYNDA 1986, articulation surface; MA-5, × 36.
Figs 10–12. Distal columnals of glyptocystid cystoid (the most common cystoid columnl in my material) type A; 10, articulation surface, MA-58, × 60; 11, lateral view, MA-67, × 36; 12, lateral view, MA-80, × 36.
Figs 13–15, 17. *Asperellacystis cinctus* HYNDA, 1986, 13, lateral view; MA-99, × 60; 14, upper articulation surface; MA-99; × 120; 15, lateral view; MA-99, × 60; 17, MA-99, × 90.
Fig. 16. *Vialovicystis* sp.; MA-78, × 45.
Fig. 18. Glyptocystid cystoid distal columnal type B; MA- 80, × 36.
Figs 19–20. Ribbed columnal of unknown pelmatozoan (?rhombiferan cystoid); 19, articulation surface, MA-65, × 84; 20, lateral view, MA-49, × 60.
Fig. 21. Ribbed columnal of unknown pelmatozoan (probably rhombiferan cystoid) MA-76, × 60.



PISERA: ECHINODERMS OF THE MÓJCZA LIMESTONE

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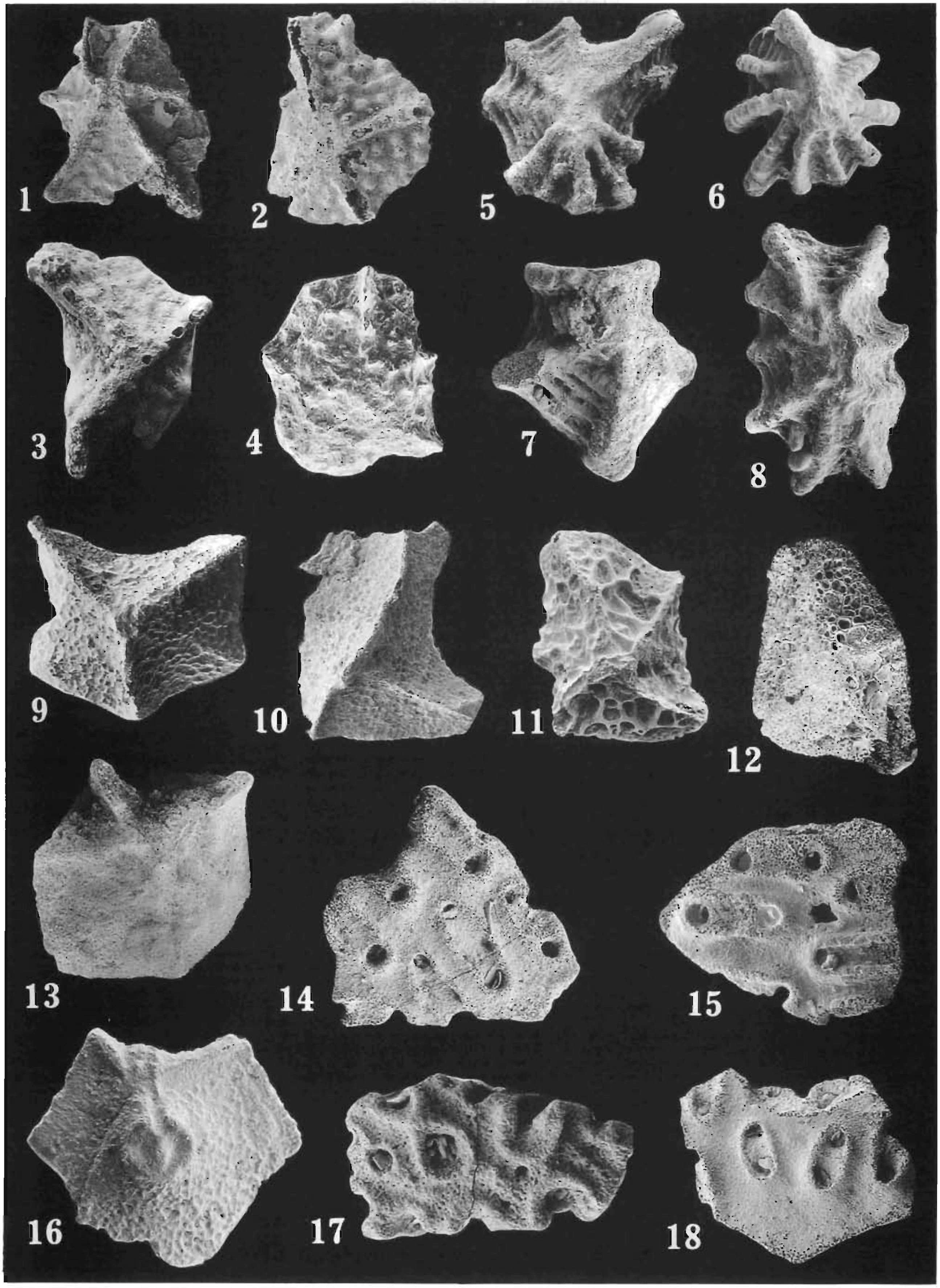
PLATE 64

Figs 1–4. Cornutan centralia type A; 1, MA-65, × 30; 2, MA-67, × 36; 3, MA-78, × 45; 4, MA-99, × 36.
Figs 5–8. *Nevadaecystis*? sp. 5, MA-99, × 36; 6, MA-76, × 36; 7, MA-99, × 36; 8, MA-99, × 36.
Figs 9–12. Cornutan centralia type B; 9, MA-78, × 45; 10, MA-84, × 42; 11, MA-59, × 45; 12, MA-59, × 30.
Fig. 13. Glyptocystitid thecal plate; MA-64, × 60.
Figs 14–18. Diploporite thecal plates. 14, MA-5, × 27; 15, MA-5, × 30; 16, *Eucystis* sp. MA-78, × 30; 17, *Haplosphaeronis*? sp. MA-5, × 36; 18, MA-5, × 30.



PISERA: ECHINODERMS OF THE MÓJCZA LIMESTONE

PLATE 65

Figs 1–7. Eocrinoidhecal plates with epispires; 1, MA-99, × 45; 2, MA-76, × 60; 3, MA-76, × 45; 4, MA-76, × 45; 5, MA-65, × 60; 6, MA-78, × 24; 7, MA-65, × 36.

Fig. 8. Undetermined ?thecal plate; MA-58, × 45.

Fig. 9. ?Eocrinoid thecal plate with epispires; MA-78, × 30.

Figs 10–11. Asteroid(?) disk ossicles (type D) with characteristic stellate inner structures; 10, MA-67, × 60; 11, MA-5, × 36.

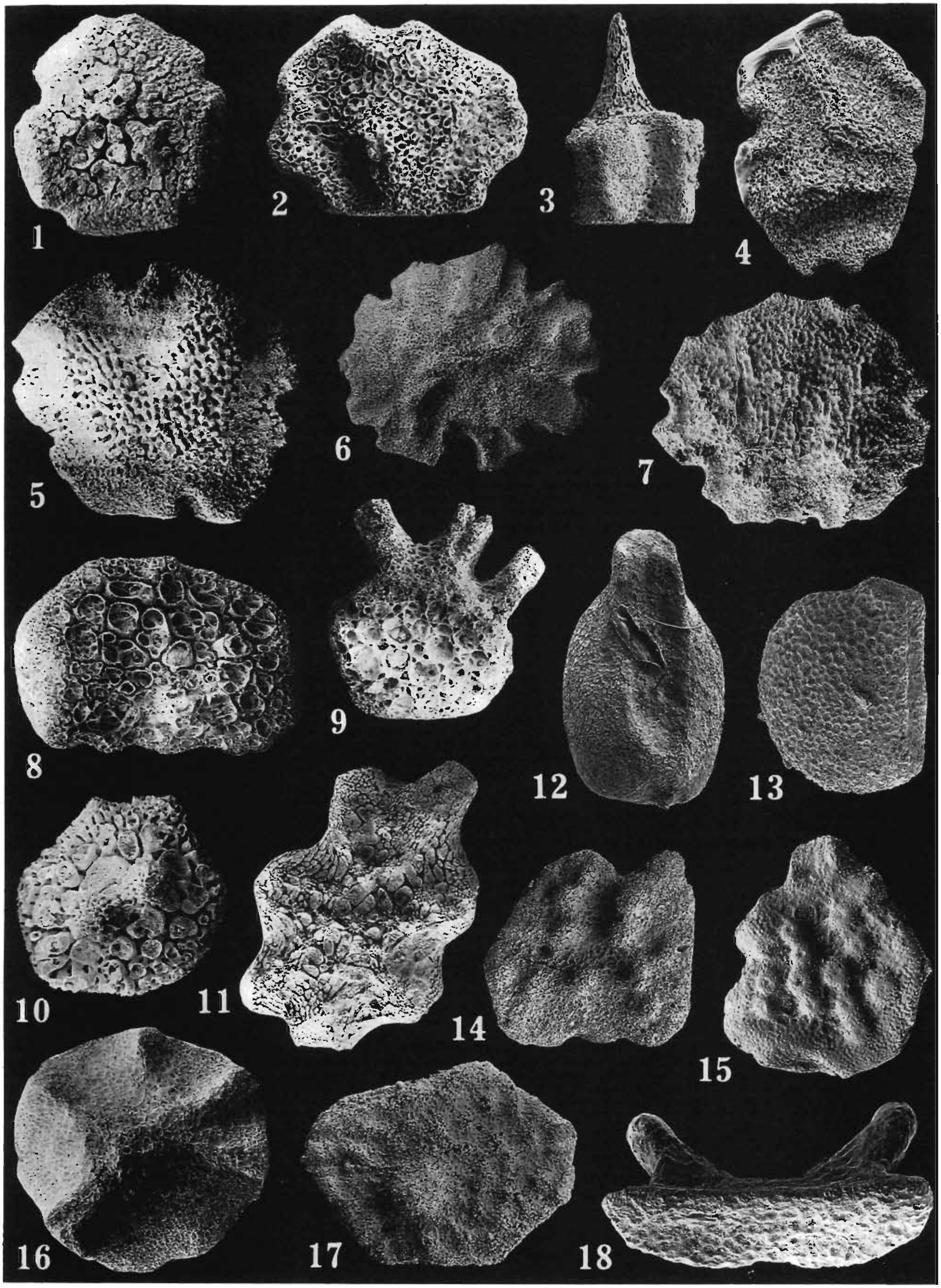
Figs 12–13. Rhipidocystid eocrinoid basal marginals?; 12, view of two surfaces of articulation with other plates, MA-30, × 45; 13, lateral view, MA-65, × 60.

Figs 14–15. Asteroid ?disk ossicles type C; 14, MA-6, × 36; 15, MA-84, × 33.

Fig. 16. Undetermined thecal plate, type J; MA-64, × 60.

Fig. 17. Undetermined ?thecal plate; A 65, × 60.

Fig. 18. Undetermined plate; MA-87, × 60.



PISERA: ECHINODERMS OF THE MÓJCZA LIMESTONE

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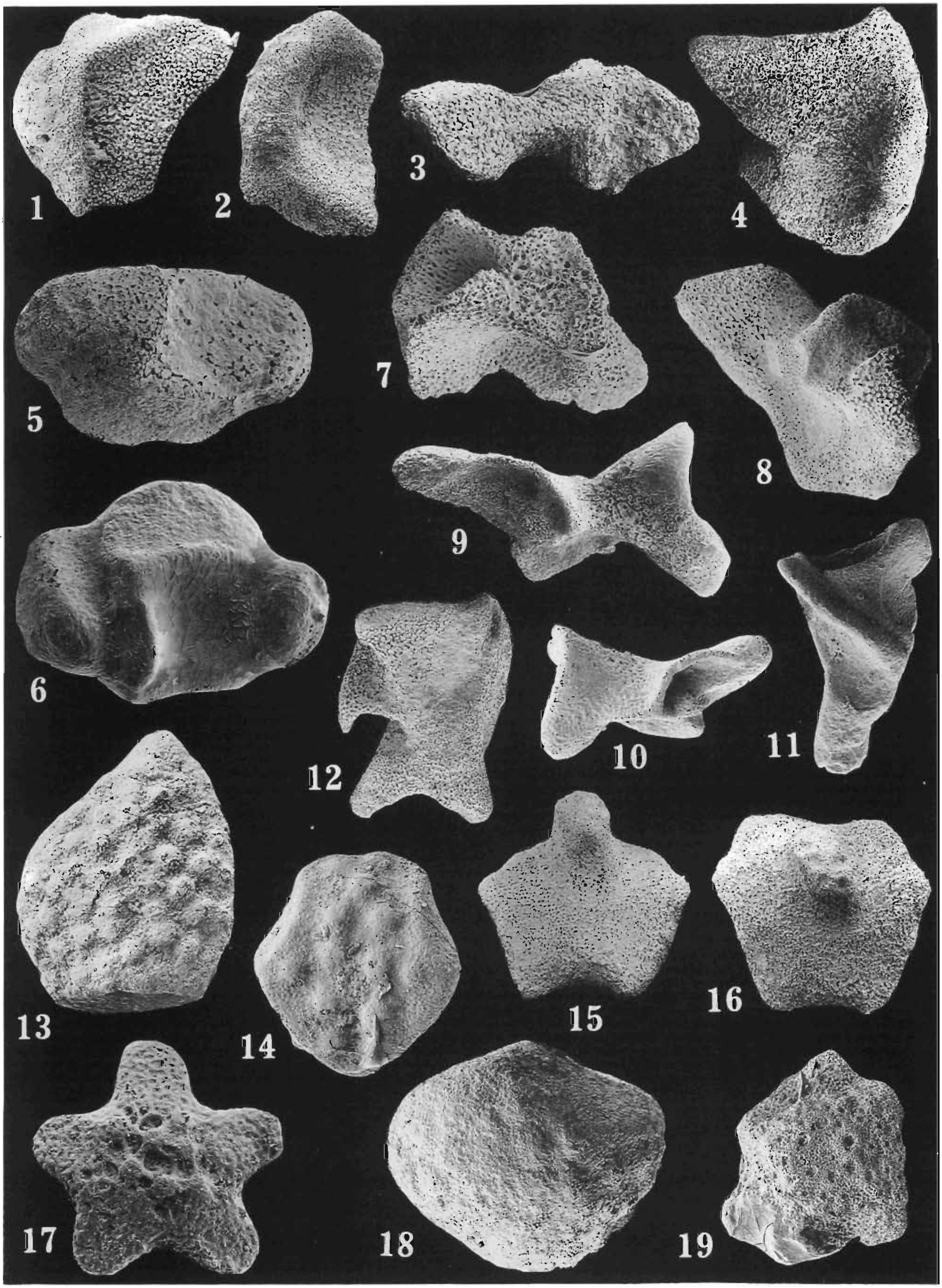
PLATE 66

Figs 1–2. Asterozoan adambulacralia; 1, one side view, MA-78, × 36; 2, opposite side view, MA-78, × 36.
Fig. 3. Asterozoan ambulacral plate type B; MA-78, × 30.
Figs 4, 7, 8. Undetermined asterozoan ossicles; 4, MA-67, × 45 7, MA-78, × 60; 8, MA-79, × 60.
Figs 5–6. Asteroid adambulacralia; 5, one side view, MA-49, × 60; 6, opposite side view, MA-84, × 36.
Figs 9–11. Asteroid ambulacral type A; 9, MA-79, × 60; 10, MA-59, × 60; 11, MA-99, × 36.
Fig. 12. Asterozoan mouth plate; MA-5, × 36.
Figs 13–14. Asteroid(?) marginals and/or disk ossicles; 13, MA-5, × 70; 14, MA-5, × 45.
Figs 15–16. *Salteraster* abactinals; 15, MA-67, × 36; 16, MA-67, × 36.
Fig. 17. Asteroid disk ossicle type A; MA-82, × 60.
Fig. 18. Asteroid(?) disk ossicle; MA-99, × 45.
Fig. 19. Asteroid disk ossicle type B; MA-62, × 36.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PISERA: ECHINODERMS OF THE MÓJCZA LIMESTONE

PLATE 67

Figs 1–4. Cornutan centralia type C, 1, MA-67, × 60; 2, MA-79, × 30; 3, MA-75, × 42; 4, MA-79, × 45.

Fig. 5. Cornutan marginal ossicle, MA-62, × 21.

Fig. 6. Cornutan stylocone, MA-52, × 36.

Figs 7–8. Distal ossicles of cornutan aulacophore; 7, MA-73, × 36; 8, MA-72, × 60.

Fig. 9. Cover plate of cornutan aulacophore, MA-84, × 45.

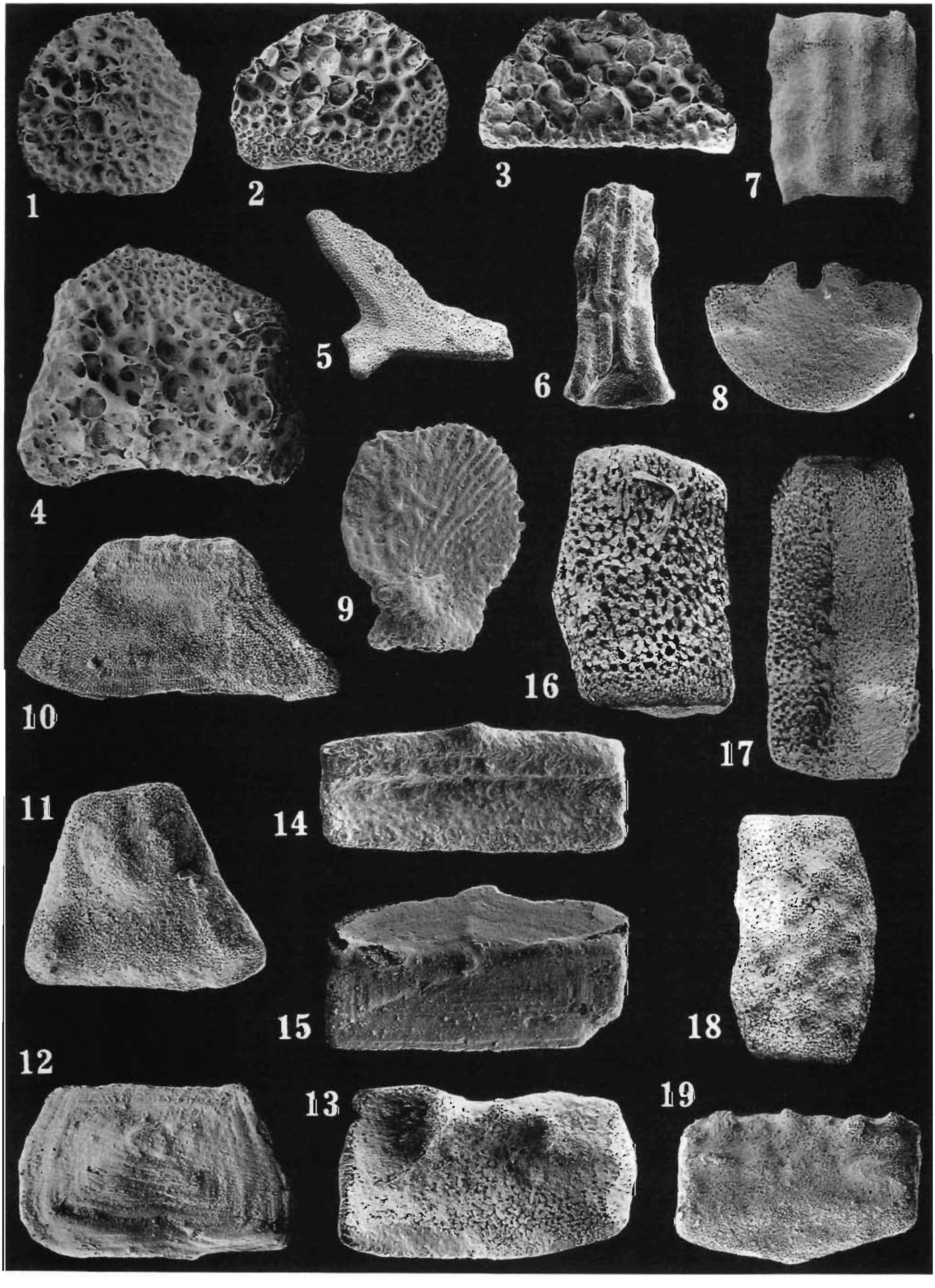
Figs 10–11. Undetermined ?cover plate type A; 10, ?inner view, MA-78, × 45; 11, ?outer view, MA-78, × 45.

Figs 12–13. Undeteremined plates type B; 12. ?inner view, MA-78, × 60; 13, ?outer view, MA-78, × 60.

Figs 14–15. Undetermined biserial ?brachiolae ossicles type C; 14, ventral view MA-65, × 42; 15, dorsal view, MA-65, × 36.

Figs 16–17. Undetermined biserial brachiolae ossicles, type A 16, dorso-lateral view, MA-49, × 60; 17, ventro-lateral view, showing surfaces of articulation with other ossicles, MA-49, × 60.

Figs 18–19. Undetermined biserial brachiolar ossicles type B, 18, dorso-lateral view, MA-78, × 60; 19, dorsal view (visible edges of articulation with other ossicles) MA-62, × 45.



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