

MACHAERIDIANS, CHITONS, AND CONCHIFERAN MOLLUSCS OF THE MÓJCZA LIMESTONE

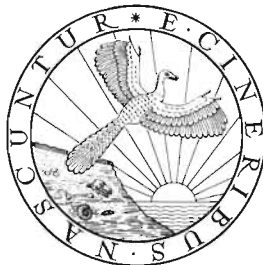
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Phosphate coated originally aragonitic mollusc shells and calcitic machaeridian sclerites contribute significantly to fossil assemblages of the extremely condensed Mójcza Limestone, providing an almost continuous record of the faunal dynamics of these groups from the end of Arenig to the beginning of Ashgill. Except for the topmost bed, which contains a relatively warm-water fauna, the Mójcza Limestone and the overlying Zalesie Formation contain molluscs of Gondwanan affinities, presumably cold-water. Machaeridians are represented by at least six lineages. Four lineages of septemchitonid polyplacophorans, twelve bellerophontids and gastropods, five rostroconchs and bivalves, and eleven hyoliths continue across significant parts of the section. *Aulacolepos elongatum* sp. n., *Sarkachiton kielcensis* gen. et sp. n., Solenocarididae fam. n., *Bursata santacruzensis* sp. n., and *Mojczatheca triangularis* gen. et sp. n. are proposed.

Key words: Machaeridia, Polyplacophora, gastropods, hyoliths, Ordovician, larval development, evolution.

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INTRODUCTION

The most celebrated issue in paleontology of the earliest Phanerozoic is the allegedly sudden appearance of numerous skeletal fossils at the base of the Cambrian. The reported earliest Cambrian fossil assemblages are mostly composed of secondarily phosphatized and originally phosphatic minute fossils, the so called "small shelly fossils" (see BENGTON *et al.* 1990 for recent reviews). Paradoxically, the same kind of punctuated occurrence and preservation of minute skeletal fossils in the Ordovician and Silurian, known for decades, remains almost unnoticed, except for students of the Baltic Ordovician geology. The pattern of distribution of "small shelly fossils" in the whole early Paleozoic suggests that their abundance in some horizons (including the Tommotian) was controlled by preservational factors and had little to do with biological evolution. The widely accepted opinion that the suddenness of the basal Cambrian faunal change was a unique evolutionary event resulted mostly from concentration of micropaleontological research on the basal Cambrian rocks, as contrasted with neglect of similar faunas in the Ordovician.

Occurrences of Cambrian, Ordovician, and Silurian phosphatic microfossils are generally restricted in time and space, being confined to narrow horizons in some geographic regions. The cephalopod limestone rock facies is their most typical source. In all cases they are associated with numerous sedimentary discontinuities, at which skeletal detritus was exposed long enough to the action of sea water to undergo phosphatization (DZIK and PISERA 1994). In this respect the rocks of the Arenig in the Baltic region and the Tommotian of the Siberian Platform are closely similar. Phosphatic nuclei

of minute shells, the most common way of preservation of microfossils in both regions, frequently fill cavities in hard-grounds, and only locally in areas where sediment was deposited at higher rate, can adult specimens of the same species be found (DZIK 1991). In some extreme cases almost all the organic detritus seems to be enveloped in thin phosphatic linings, and in such strata any benthic microfossils are rare or virtually lacking. This is the case with the Chinese Meishucun assemblage of the basal Cambrian (QIAN and BENGTSON 1989), the Polish Ordovician Mójcza assemblage, but also the Silurian Kok assemblage of the Carnic Alps.

It seems crucial for better understanding of the early Phanerozoic metazoan evolution to have more data on faunal assemblages post-dating the basal Cambrian "small shelly fossils" assemblages but corresponding to them in respect to the mode of preservation. Phosphatized and phosphate-covered microfossils of molluscan and problematic affinities from the Mójcza Limestone represent such a "small shelly fossils" assemblages of Ordovician age. They are the subject of the present paper.

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TAXONOMIC DESCRIPTIONS

Class **Machaeridia** WITHERS, 1926
Order **Turrilepadida** PILSBRY, 1916

In the Cambrian, along with the first true polyplacophoran molluscs, several other groups of fossil organisms are known which had bodies covered with an armor of sclerotized plates or scales. The only larger group of this kind in the Ordovician are the machaeridians, probable successors of the Cambrian tommotiids (BENGTSON 1970). Zoological affinities of the Machaeridia remain unclear (possibly they are primitive articulates, as discussed below) but an alternative molluscan connection cannot be definitely excluded (DZIK 1986).

The elongated body of the post-Cambrian turrilepadid machaeridians was covered with four rows of calcitic (instead of phosphatic in the possibly related Cambrian tommotiids) sclerites (BENGTSON 1978). At least in the most primitive family of the turrilepadids, the Plumulitidae JELL, 1979, the two first body segments had probably only the medial pair of the sclerites and the subsequent three had their lateral sclerites morphologically different from the following thoracic segments (JELL 1979). This apparent tagmation may suggest affinities of the Machaeridia to the articulates rather than molluscs. In the most primitive arthropods the anterior part of the body was tagmatized in a similar way. The two first segments form the sensorial tagma in the arthropods (ocular and antennular segments), while the following three differ morphologically and functionally from the rest of the body representing the primary oral segments (second antennae, mandibles, and first maxillae).

Of special interest for understanding the nature of the machaeridian sclerites is new data on the micromorphology of their surfaces (Pl. 52: 10–12). The radial ornamentation appears not to be a special feature of only the Carboniferous machaeridians (ELIAS 1958). It characterizes at least all the turrilepadids and lepidocoleids. In the Ordovician forms, as well as in Silurian *Aulakolepos* from the Carnic Alps, there are radial microfissures that transect complex system of concentric microrugae, developed especially well in the furrows separating rugae. Margins of the rugae at least in *Mojczalepas* are smooth, except for that radial microfissures continue across them.

Distribution. — The Ordovician species of the Machaeridia are generally long-ranging. In the Mójcza Limestone particular species of *Deltacoleus* and *Mojczalepas* occur virtually throughout the whole section, from the top of the Arenig to the Early Ashgill without any identifiable changes in the morphology of their sclerites (Text-fig. 1). They usually co-occur with each other. Remarkable is their

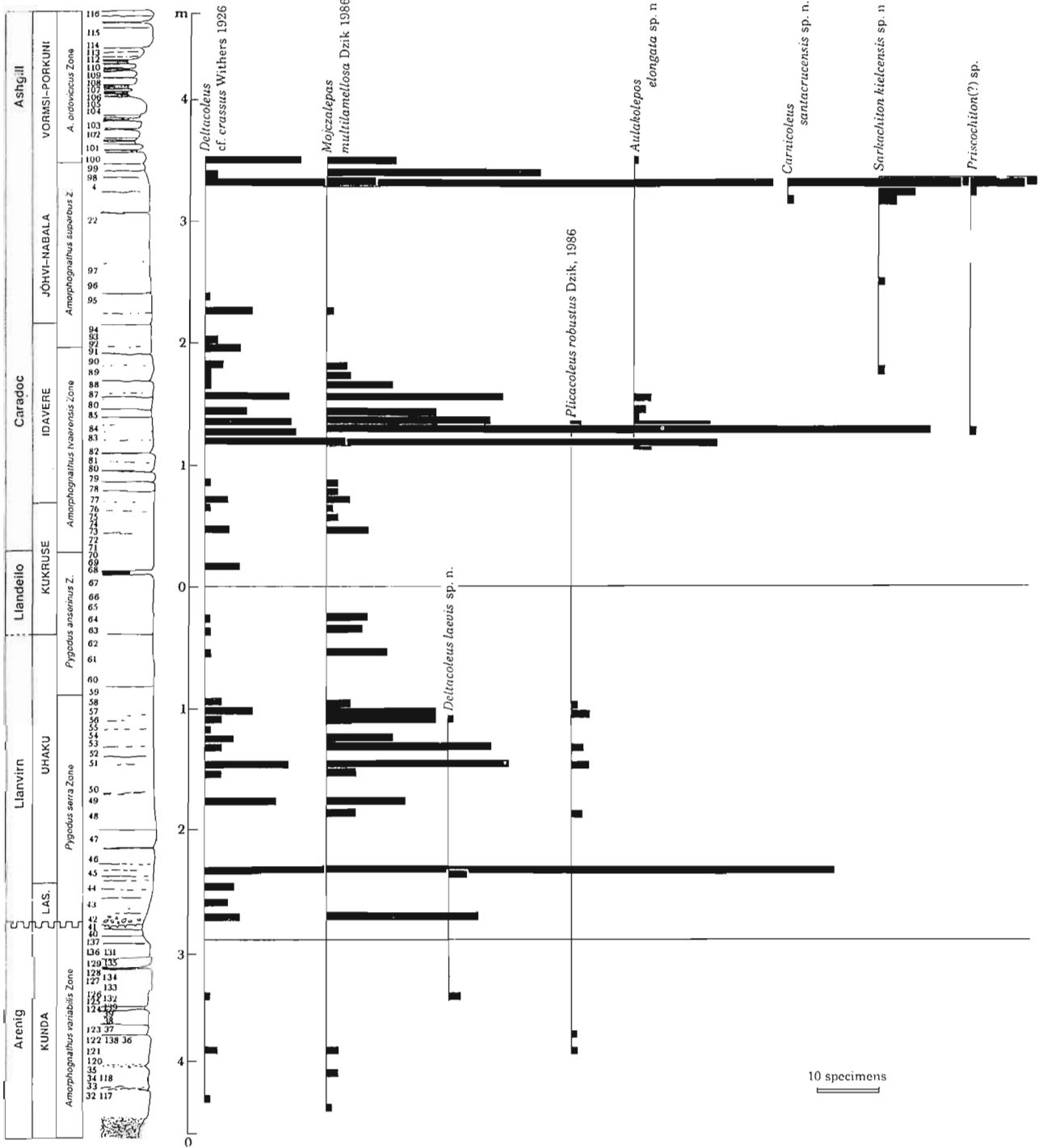


Fig. 1.

Distribution of machaeridians and polyplacophorans in the Mójcza Limestone section at Mójcza, Holy Cross Mountains, Poland.

abundance in beds from about 1.3 m to 1.7 m above the bentonite where four genera are represented in great numbers of specimens. This is also the level of the last occurrence of the robust *Plicacoleus* and the first appearance of the delicate, tubular *Aulakolepos*.

Family **Turrilepadidae** CLARKE, 1896

Diagnosis. — Elongated, box-shaped body with about 30 transverse sets of paired angular dorsal sclerites and smaller, flat lateral sclerites; sclerites thick walled, each with a distinct muscle scar (modified after DZIK 1986; see also ADRAIN *et al.* 1991 for different treatment).

Genus *Mojczalepas* DZIK, 1986

Type species: *Mojczalepas multilamellosa* DZIK, 1986.

Diagnosis. — Dorsal sclerites with concave inner and convex outer areas and relatively deep and wide medial sinus at the anterior margin.

Remarks. — As pointed out by ADRAIN *et al.* (1991) except for two species of *Turrilepas* no other turrilepadid is known with an articulated skeleton. Preservation of individual sclerites is rarely satisfactory and this concerns also the Mójcza sclerites of *Mojczalepas*. However, the dense high rugae at the surface of sclerites makes them quite distinct from cooccurring species of *Deltacoleus* and this alone seems to substantiate their generic distinctiveness.

Massive acute sclerites with a medial furrow cooccur rarely with *Mojczalepas* sclerites in some samples from Baltic erratic boulders (DZIK 1986) and deep boreholes at the margin of the East European Platform, but they have not been identified in Mójcza. This weakens the original suggestion that the scleritome of *Mojczalepas* was different from that of *Deltacoleus* in having also lateral sclerites. Actually they remain unknown in both these genera. The validity of the genus has been questioned by ADRAIN *et al.* (1991), who generally believe that machaeridian taxa should be based only on articulated specimens. Nevertheless, I continue to use this name for the type species because it is morphologically distinct from cooccurring machaeridians in the ornamentation of its sclerites, more distinct than it is usual for species of the same genus in this group.

Mojczalepas multilamellosa DZIK, 1986
(Pl. 52: 4, 6–7, 12; Text-fig. 2a)

1986: *Mojczalepas multilamellosa* sp. n.; DZIK, p. 132, Figs 5A–B, 6A, 8C.

Holotype: ZPAL V.XII/2: Fig. 5A–B in DZIK (1986), Pl. 52: 4 here.

Type horizon and locality: Late Llanvirn of the Mójcza Limestone at its type locality (sample MA-29), *E. reclinatus* or *E. robustus* Subzone.

Diagnosis. — Sclerites ornamented with densely spaced, high rugae. Outer area of dorsal sclerites with semicircular lobe at the anterior margin, inner area with medial shallow sinus and marginal narrow lobe (after DZIK 1986).

Distribution. — From the base of the Mójcza Limestone (latest Arenig), to the base of the Zalesie Formation (Early Ashgill) in the Mójcza section; Llanvirn and Llandeilo of the Baltic region.

Genus *Deltacoleus* WITHERS, 1926

Type species: *Deltacoleus crassus* WITHERS, 1926.

Deltacoleus cf. *crassus* WITHERS, 1926
(Pl. 52: 8–10; Text-fig. 2c–d)

Remarks. — Species identity of these turrilepadids remains uncertain. Their sclerites are clearly separated from cooccurring *Mojczalepas* by a morphologic hiatus. They may represent more than one species that differ from each other in features difficult to identify in this mode of preservation (see DZIK 1986: Fig. 8).

Distribution. — From the base of the Mójcza Limestone (latest Arenig), to the base of the Zalesie Formation (Early Ashgill) in the Mójcza section; Llanvirn to Late Caradoc of the Baltic region.

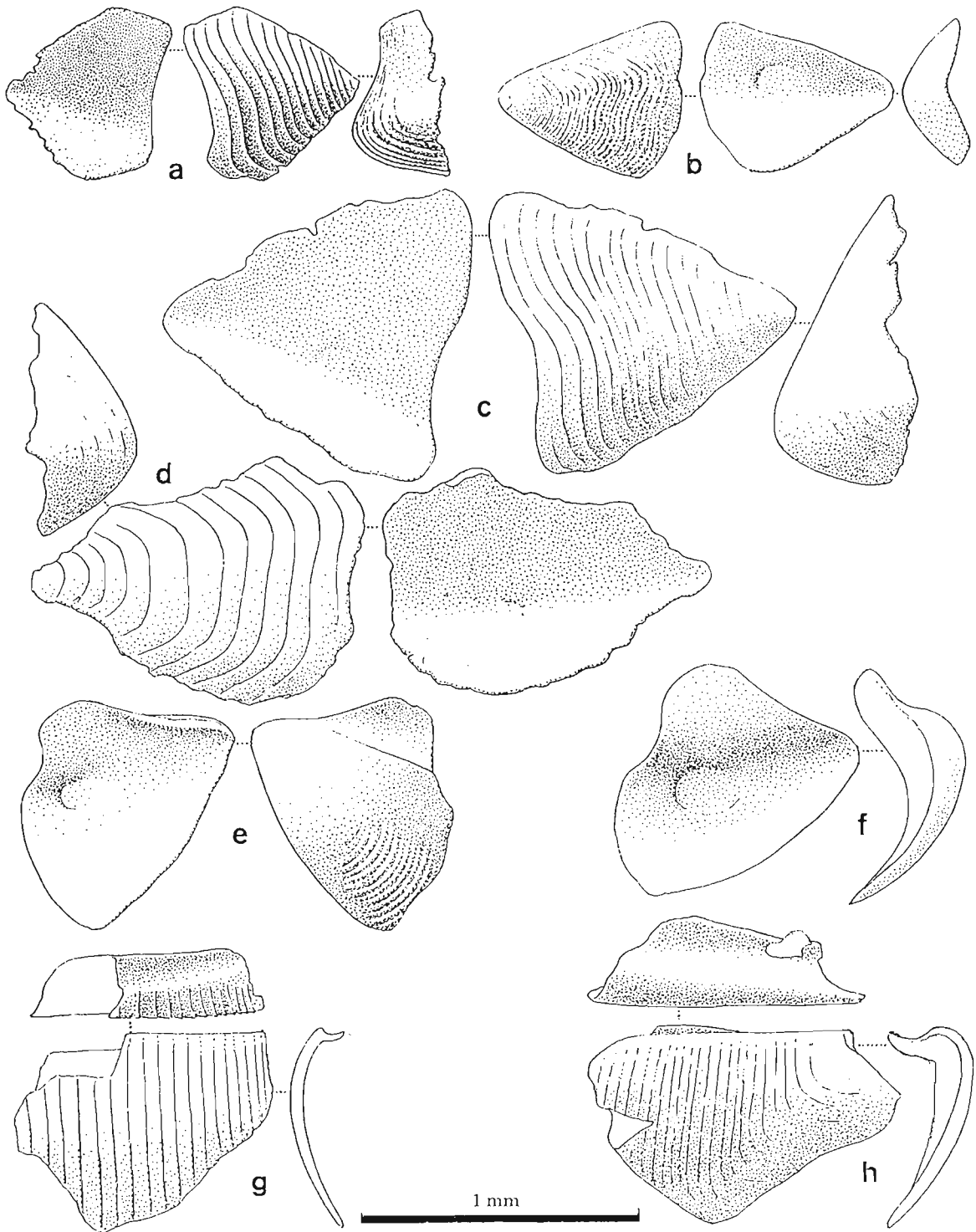


Fig. 2.

a. *Mojczalepas multilamellosa* DZIK, 1986; dorsal sclerite from sample MA-29 (loose block, *E. robustus* Zone, Llanvirn) (see also Pl. 52: 6). b. *Deltacoleus laevis* sp. n.; dorsal? sclerite from sample MA-43 (see also Pl. 52: 5). c, d. *Deltacoleus* cf. *crassus* WITHERS, 1926; dorsal sclerites from sample MA-99 (see also Pl. 52: 8–9). e–f. *Plicacoleus robustus* DZIK, 1986; dorsal sclerites from sample MA-52 (see also Pl. 52: 2). g–h. *Aulakolepos elongatum* sp. n.; dorsal sclerites from sample MA-85 (see also Pl. 53: 2–3).

Deltacoleus laevis sp. n.
(Pl. 52: 5; Text-fig. 2b)

Holotype: ZPAL V.XII/26; Pl. 52: 5.

Type horizon and locality: Llanvirn (sample MA-43, 0.2 m above the discontinuity) of the Mójcza Limestone at its type section, *E. reclinatus* Zone.

Diagnosis. — Dorsal sclerites with densely distributed but low rugae.

Remarks. — Although rare, sclerites of this species are easy to distinguish because of their smooth (especially under light microscope) appearance. They are also less convex and thinner than in other cooccurring turrilepadids. A possibility that these are actually lateral sclerites of some other turrilepadids cannot be excluded, but it is not likely because of an angular bending along their midline (lateral sclerites in better known turrilepadid machaeridians are usually almost flat).

Distribution. — From the base of the Mójcza Limestone to 1.0 m above the discontinuity in the type section (latest Arenig to latest Llanvirn).

Family **Lepidocoleidae** CLARKE, 1896

Diagnosis. — Strongly elongated, laterally compressed body with up to 60 semicylindrical sets of sclerites. Large dorsal sclerites meet ventrally in closed position. Lateral sclerites reduced in size or lacking.

Genus *Plicacoleus* DZIK, 1986

Type species: *Plicacoleus robustus* DZIK, 1986.

Diagnosis. — Dorsal sclerites thick-walled, with very convex outer area separated by a prominent crest from the wing shaped inner area. Sclerites weakly ornamented. (Modified after DZIK 1986.)

Plicacoleus robustus DZIK, 1986
(Pl. 52: 1–3; Text-fig. 2e–f)

1986. *Plicacoleus robustus* sp. n.; DZIK, p. 132, Figs 6E, 9A–B.

Holotype: ZPAL V.XII/3, Fig. 9A–B in DZIK (1986), here Pl. 52: 1a–b.

Type horizon and locality: Late Llanvirn of the Mójcza Limestone at its type locality (sample MA-29), *E. reclinatus* or *E. robustus* Zone.

Distribution. — From the base to 1.3 m above the bentonite layer in the Mójcza section (latest Arenig to Early Caradoc), Llanvirn and Llandeilo of the Baltic region.

Genus *Aulakolepos* WOLBURG, 1938

Type species: *Aulakolepos gleidorfense* WOLBURG, 1938.

Diagnosis. — Dorsal sclerites with thin walls, a narrow concave dorsal area and wide lateral area, regularly convex in dorso-ventral plane.

Aulakolepos elongatum sp. n.
(Pls 52: 11; 53: 1–3; Text-fig. 2g–h)

Holotype: ZPAL V.XII/12; Pl. 53: 1.

Type horizon and locality: Early Caradoc of the Mójcza Limestone at its type locality (sample MA-85; 1.5 m above the bentonite), *A. tvaerensis* Zone.

Diagnosis. — Dorsal sclerites with higher longitudinal than dorso-ventral dimension, ornamented with sparse but regularly spaced rugae.

Description. — All the available dorsal sclerites from Mójcza are incomplete but the course of rugae at the external surface of the sclerites allows us to restore their shape. It appears then that they were of rectangular shape, with almost strictly transversely straight anterior margin and gently convex, cylindrical appearance. Sclerite length was somewhat longer than its height. The surface rugation was

relatively dense but low with rather distinct concentric micro-furrows (Pl. 52: 11), which makes this species different from undescribed late Silurian species of the Carnic Alps.

Remarks. — The Mójcza populations of *Aulakolepos* are hardly different from those from the Llanvirn of the Baltic area (see DZIK 1986) and all probably represent the oldest known species of the genus. From geologically younger species of the genus (see BENGTON 1977) *A. elongatum* sp. n. differs in having more elongated sclerites. In this respect it resembles the cooccurring, usually split in halves, intermediate sclerites of the chiton *Bursata*. They can be safely distinguished only if the convex dorsal area, typical for the lepidocoleids, is preserved.

Distribution. — From about 1.0 m above the bentonite in the Mójcza Limestone to the base of the Zalesie Formation in the Mójcza section (Early Caradoc to Early Asgill).

Phylum **Mollusca** CUVIER, 1797

Subphylum **Amphineura** IHERING, 1877

Class **Polyplacophora** DE BLAINVILLE, 1816

Distribution. — Phosphatized valves of chitons are restricted in their distribution to the upper part of the Mójcza Limestone, practically being confined to the uppermost bed (Text-fig. 1). Only a few specimens have been found below it, the oldest one in the late *A. tvaerensis* Zone of the Early Caradoc (sample MA-85). In the topmost layer of latest Caradoc or early Ashgill age (sample MA-99) four species are represented, the most common being *Sarkachiton kielcensis* sp. n. *Bursata santacrucensis* sp. n. is the second in number, while *Priscochiton* sp. and *Chelodes* sp. are quite rare.

Order **Septemchitonida** BERGENHAYN, 1955

Family **Septemchitonidae** BERGENHAYN, 1955

Emended diagnosis. — Valves V-shaped in cross section and with smooth inner surface, the tail valve being of similar length as the intermediate ones.

Remarks. — ROLFE (1981) showed that the septemchitonids, despite of their name, actually possessed eight valves and that the enigmatic Late Ordovician *Solenocaris* is related to them. Isolated, phosphatized valves from the Mójcza Limestone and from the Silurian Kok Formation of the Carnic Alps suggest that within the order Septemchitonida two rather distinct groups can be distinguished. *Septemchiton* and its proposed ancestor from the Early Ordovician, *Sarkachiton* gen. n., show body organization more or less similar to other Paleozoic chitons, differing mostly in their high, angularly bent valves, and thus roughly triangular transverse cross section of the body. *Bursata*, representative of the group of *Solenocaris*, appears to be a very unusual polyplacophoran with the ventral opening of its scleritome slit-like (in Ordovician *B. santacrucensis* sp. n.). In its probable Silurian successor *Carnicoleus gazdzickii* DZIK, 1986 the valves were almost completely closed ventrally. The foot was thus reduced and the animal was hardly able to creep over substrate, as usual for typical polyplacophorans. In the place of the foot an aplacophoran-type furrow must have developed to transfer food and oxygen with passing water. This apparent anatomical similarity to Recent aplacophorans puts in question their generally accepted ancestral position in the phylogenetic tree of the molluscs (SCHELEMA 1988; HASZPRUNAR 1992).

Genera included: *Priscochiton* DALL, 1882, *Sarkachiton* gen. n., *Septemchiton* BERGENHAYN, 1955.

Genus *Sarkachiton* gen. n.

Type species: *Helminthochiton aequivoca* ROBSON, 1913.

Diagnosis. — Intermediate valves relatively short and thick, with their length only slightly exceeding height. Interior of the tail valve with a conical cavity penetrating to its apex.

Remarks. — From *Paleochiton* SMITH, 1960 (possibly synonymous with *Ivoechiton* SMITH, 1960 and *Eochiton* SMITH, 1960) the new genus differs in the highly V-shaped cross section of the valves, typical for the Septemchitonidae. From *Septemchiton*, as well as other advanced Septemchitonida it differs in that the tail valve has its apex in the midlength as well as in much shorter intermediate

valves. The structure of the tail valve seems to be a trait of relationship to (perhaps descendance from) the Late Cambrian Mattheviidae (see DZIK 1986). Among several specimens of the type species housed at the Narodni Muzeum, Prague, at least two are articulated, but not more than four valves are in the original arrangement. The head valve has not been found and its shape given in the reconstruction of the whole armor (DZIK 1986: Fig. 14C) is quite conjectural.

Species included: *S. aequivoca*, *S. kielcensis* sp. n.

Sarkachiton kielcensis sp. n.

(Pl. 53: 8–10; Text-fig. 3c–g)

Holotype: Specimen ZPAL V.XII/10, Pl. 53: 9a–b (also DZIK 1986: Fig. 15).

1986. *Septemchiton* aff. *aequivoca* (ROBSON 1913); DZIK, Fig. 15 (note that actual magnification is not $\times 100$, as given in figure explanations but about $\times 65$; figure size was reduced by the printer).

Type horizon and locality: Mójca Limestone, 1.5 m above the bentonite (sample MA-5), *A. tvaerensis* Zone, Early Caradoc.

Diagnosis. — Length of intermediate valves similar to height, all valves thin-walled, surface ornamented with prominent tubercles pointing backward. Probable tail valve approximately two times as long as high.

Remarks. — The new species resembles in the valve morphology *S. aequivoca* ROBSON, 1913 from the Šárka Formation (Early Llanvirn). The Bohemian species has, however, much thicker valves and especially the tail valve resembles in its internal organization the Cambrian chitons *Matthevia* (see DZIK 1986). Tail valves of *S. kielcensis* sp. n., known from the Early Caradoc of the Lesieniec 1 borehole at the margin of the East European Platform, are similar in external shape to those of *S. aequivoca* but without any deep internal cavities. The species, with its relatively thin and elongated valves, may thus appear transitional between Early Ordovician *S. aequivoca* and typical *Septemchiton* of the Late Ordovician (see ROLFE 1981).

Distribution. — Upper part of the Mójca Limestone (from 1.5 m above the bentonite to the top; Early to Late Caradoc), Late Llanvirn of the Baltic area.

Genus *Priscochiton* DALL, 1882

Type species: *Chiton canadensis* BILLINGS, 1865.

Priscochiton? sp.

(Text-fig. 3a–b)

Remarks. — In the shape of its valves the species is intermediate between *Septemchiton* and *Chelodes* being high angular in transverse section and roughly triangular in outline. From the type species of the genus that occurs in the Early Caradoc Leray-Rockland beds of Canada (WILSON 1951: p. 16: Pl. 1: 1–3) it differs in being much narrower and higher. Its valves are even more acutely vaulted than in the associated *S. kielcensis* and this feature allows easy distinction of even very fragmentary specimens. The only two known specimens of *P. canadensis* are considered by WILSON (1951) to represent the head valves. It is tempting to match the Mójca specimens, with their triangular lateral outline, with the co-occurring rhomboid valves of *Sarkachiton* as more anteriorly located valves. It seems unlikely, however, that they represented the same armor. Even if this would be the case a presence of an additional valve, a small one of the kind identified by ROLFE (1981) has to be assumed.

Distribution. — This is a relatively rare species in the Mójca Limestone, restricted to its upper part (from 1.5 m above the bentonite to the top; Early to Late Caradoc).

Family *Solenocarididae* fam. n.

Diagnosis. — Valves U-shaped in cross section with pseudoporous (aesthetae?) wall, strongly elongated, especially the acute tail valve.

Genera included. — *Bursata* RHOADS, 1962, *Carnicoleus* DZIK, 1986, *Solenocaris* YOUNG in YOUNG and YOUNG, 1868.

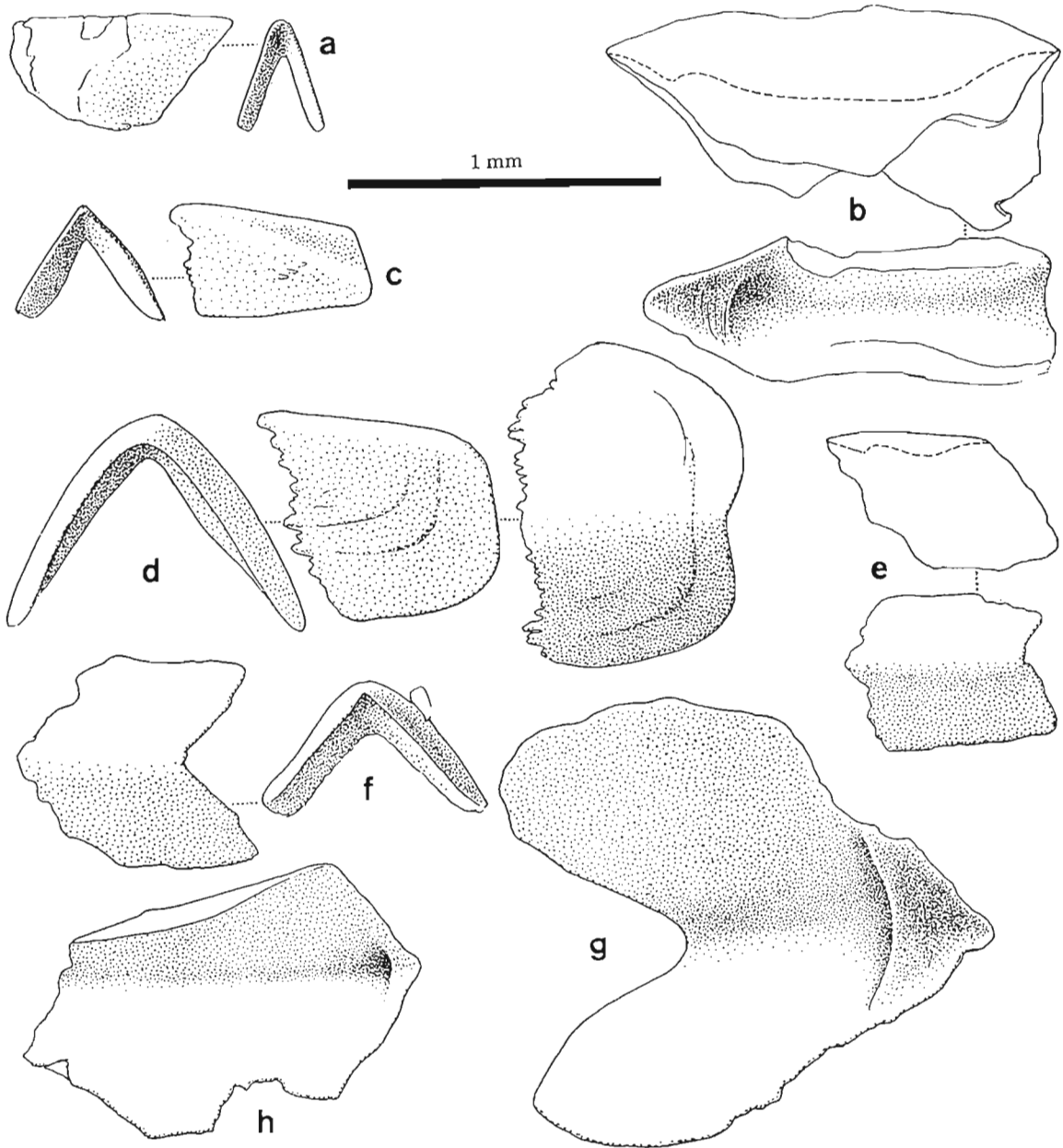


Fig. 3.

a–b. *Priscochiton?* sp.; intermediate valves from sample MA-99. c–g. *Sarkachiton kielcensis* sp. n.; intermediate valves from sample MA-99.

Genus *Bursata* RHOADS, 1962

Type species: *Bursata iowaensis* RHOADS, 1962.

Remarks. — Before complete valves had been found in the Mójcza Limestone, the main source of information on skeletal morphology of the solenocaridid Septemchitonida were medially split intermediate valves of *Carnicoleus* from the Ludlow Kok Formation of the Carnic Alps (DZIK 1986; more recently also complete intermediate and tail valves have been identified). In such a mode of fragmentation they are very similar to dorsal sclerites of *Aulakolepos*, and because of this similarity the genus was then provisionally included in the machaeridian family Lepidocoleidae. As now under-

stood, *Bursata* is transitional between *Septemchiton* and *Solenocaris*, being closer to the latter genus in its vermiform shape and strong elongation of valves, more or less approaching each other ventrally.

Bursata santacrucensis sp. n.
(Pl. 53: 4–7; Text-fig. 4a–i)

Holotype: Tail valve ZPAL V.XII/18, Pl. 53: 7.

Type horizon and locality: Topmost bed of the Mójcza Limestone in its type locality.

Diagnosis. — Tubular body with relatively short intermediate valves, the tail valve triangular in lateral profile, almost three times longer than high. Surface ornamented with indistinct and irregularly distributed growth lines.

Remarks. — Like the type species of the genus, *B. santacrucensis* sp. n. has the internal surface of its valves pitted with numerous pseudopores (RHOADS 1962), which are typical also for the Silurian *Carnicoleus*. The Mójcza species differs from slightly younger *B. iowensis* of the Maquoketa Shale in less elongated body (see RHOADS 1962; SANDERS 1966). Intermediate valves of the new species do not seem to differ in elongation from the type species of *Septemchiton* (see ROLFE 1981), and some very short valves (Pl. 53: 6; Text-fig. 4a) may, by analogy, represent its cephalic valves. The associated tail valves are, however, quite different from those of *Septemchiton*, being of *Solenocaris* appearance, even if much shorter than in *S. solenoides* YOUNG *et* YOUNG (see ROLFE 1981). "*Anatifopsis*" *elongata* HADDING, 1913 from the Late Llanvirn to Early Caradoc of the Baltic area (HADDING 1913, 1915; ROLFE 1981; SMITH and HOARE 1987) seems to be a related species but the cross section of its intermediate valves as well as the shape of its tail valve remains unknown, which leaves uncertainty whether it belongs to *Bursata* or *Septemchiton*.

Distribution. — Topmost bed of the Mójcza Limestone in its type locality (sample MA-04: 1 specimen, sample MA-99: 29 specimens), Late Caradoc.

Order **Chelodida** BERGENHAYN, 1943
Family **Chelodidae** BERGENHAYN, 1943
Genus *Chelodes* DAVIDSON *et* KING, 1874

Type species: *Chelodes bergmani* DAVIDSON *et* KING, 1874.

Chelodes sp.
(Pl. 53: 11a–b)

Remarks. — The valves of *Chelodes* from Mójcza are of rather generalized morphology. They may represent a new species which is hard to compare with other Ordovician species of the genus (BERGENHAYN 1960; RUNNEGAR *et al.* 1979) because of rather limited published evidence on the morphologic variability of valves within the scleritome.

Distribution. — Only the topmost bed of the Mójcza Limestone at its type locality (sample MA-99: 6 specimens), Late Caradoc.

Subphylum **Cyrtosoma** RUNNEGAR *et* POJETA, 1974

Conchiferan molluscs are known from the Mójcza Limestone almost exclusively from phosphatic linings and nuclei of juvenile conchs. Only a single macroscopic specimen of a possible monoplacophoran has been found in the basal part of the section (see Pl. 6: 14 in DZIK and PISERA 1994). This makes any taxonomic judgement very difficult, as presumably similar juvenile stages characterized species that were quite different at the adult stages. The lack of any published data on similar assemblages with adult shells represented makes it even more problematic. Possibly, the Mójcza gastropods represent a new fauna of the Early Paleozoic. All the taxonomic decisions presented below are thus only tentative and many generic names are used solely to indicate similarity in the shell form.

The Mójcza Limestone assemblages of the cyrtosome molluscs are different ecologically from those of the coeval Baltic cephalopod limestone. While in the Baltic Ordovician the abundance of minute phosphatic steinkerns of gastropod, hyoliths, and bellerophonid conchs (see HYNDA 1986)

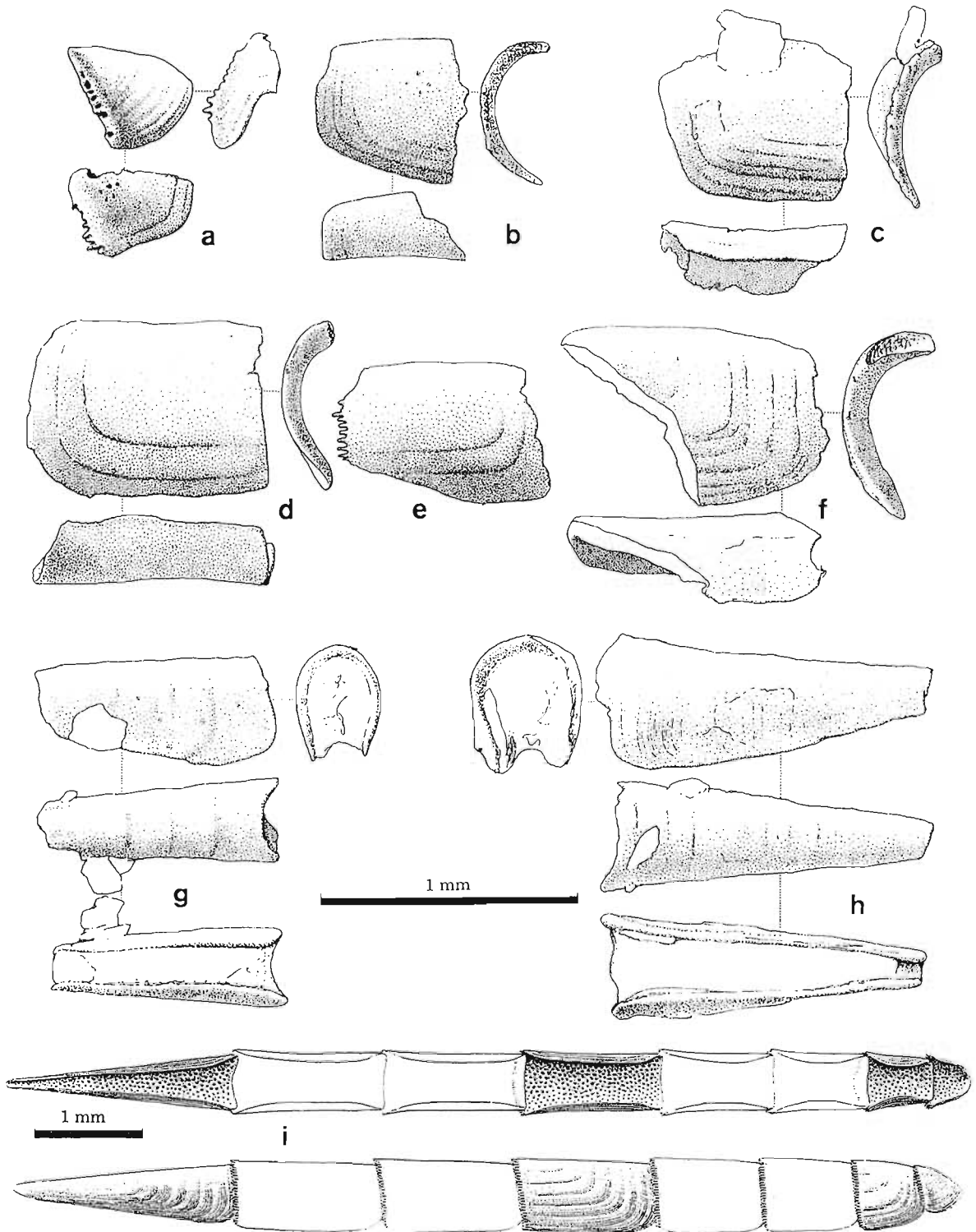


Fig. 4.

a-i. *Bursata santacruzensis* sp. n.; head (a), anterior intermediate (b, c), medial intermediate (d-f), and tail (g-h) valves from sample MA-99; reconstruction of the armor from ventral and lateral sides (i).

seems to be a result of an increased mortality at the metamorphosis of the veliger larvae and settlement (DZIK 1978), in Mójcza most gastropod specimens represent apical parts of juvenile teleoconchs. This was evidently caused by an extremely low rate of sedimentation that resulted in the destruction of any objects too large to be covered with the sediment in reasonable time (see DZIK and PISERA 1994). In effect virtually no macrofossil can be found in the Mójcza Limestone, which is not the case with the Baltic cephalopod limestones.

Distribution. — Two distinct mollusc faunas can be distinguished in the Mójcza Limestone (Text-fig. 14). The older one, represented in almost the whole section except for the topmost bed, is of a very low diversity and clear Bohemian affinities. Two Gondwanan, cold-water molluscs prevail, the bellerophontid *Modestospira* and sinistrally coiled *Mimospira* (see JELL *et al.* 1984; FRYDA 1988). It is quite unlike the younger assemblage of the topmost Mójcza Limestone, which is of high diversity, with many species contributing to it at similar percentage. The only other area in which at least similar forms can be identified is the North American Midcontinent (see WILSON 1951; ROHR 1980). The younger Mójcza fauna seems to be unique in being dominated by smooth-shelled gastropods. Even if the bellerophontids from this assemblage are possibly congeneric with those of the coeval strata of Canada, any of the typical Midcontinent gastropods are missing. This concerns especially prominently ornamented, supposedly warm-water forms.

Within the *Mimospira* – *Modestospira* dominated part of the Mójcza section, two subunits can be distinguished. In the lower part of the section up to about 1.5 m above the discontinuity surface, virtually all specimens of the phosphatized molluscs belong to these two genera. Interestingly, both of them are also known from the Bohemian Klabava Formation (FRYDA 1989) which is similar to the Mójcza Limestone in containing also an assemblage of presumably cold-water conodonts (DZIK 1984). The Klabava Formation is significantly older than the base of the Mójcza Limestone.

Above a barren horizon, close to the top of the Mójcza Limestone, several new molluscs appear marking the introduction of the younger Mójcza fauna. Even if some older elements seem to survive the change, they are of very minor importance, being subdued by smooth-shelled gastropods of generalized shape but very high species diversity. *Modestospira* is lacking in the assemblage but instead, several bellerophontids of possibly North American affinities have been identified.

In the overlying Zalesie Formation again only *Mimospira* and rare, undeterminable holopeids(?) occur. This seems to mark a reestablishing of the cold water regime after a brief warming at the end of the sedimentation of the Mójcza Limestone.

Class Monoplacophora KNIGHT 1952
Order Bellerophontida ULRICH *et* SCOFIELD, 1897

Remarks. — It is still a matter of dispute whether all or only some of the bellerophontids are monoplacophorans (see HORNÝ 1991; PEEL 1991).

Family **Bucaniidae** ULRICH *et* SCOFIELD, 1897
Genus *Modestospira* YOCHELSON, 1964

Type species: *Modestospira poulсени* YOCHELSON, 1964.

Modestospira sp.
(Pl. 55: 1–3; Text-fig. 5a–c)

1978. *Modestospira* sp.; DZIK, Fig. 4D.

1981. *Modestospira* sp.; DZIK, Fig. 4C.

Remarks. — Presumably larval shells of this kind are quite common in the lower half of the Mójcza Limestone. They seem to represent a single lineage possibly directly related to *Modestospira polonica* (GÜRICH, 1901) from the underlying Bukówka Sandstone (see YOCHELSON 1964) which, in turn, may be a derivative of the somewhat older Bohemian species *M. mergli* FRYDA 1989 (see FRYDA, 1989). In the Bornholm strata coeval to the lower part of the Mójcza Limestone *M. poulсени* occurs.

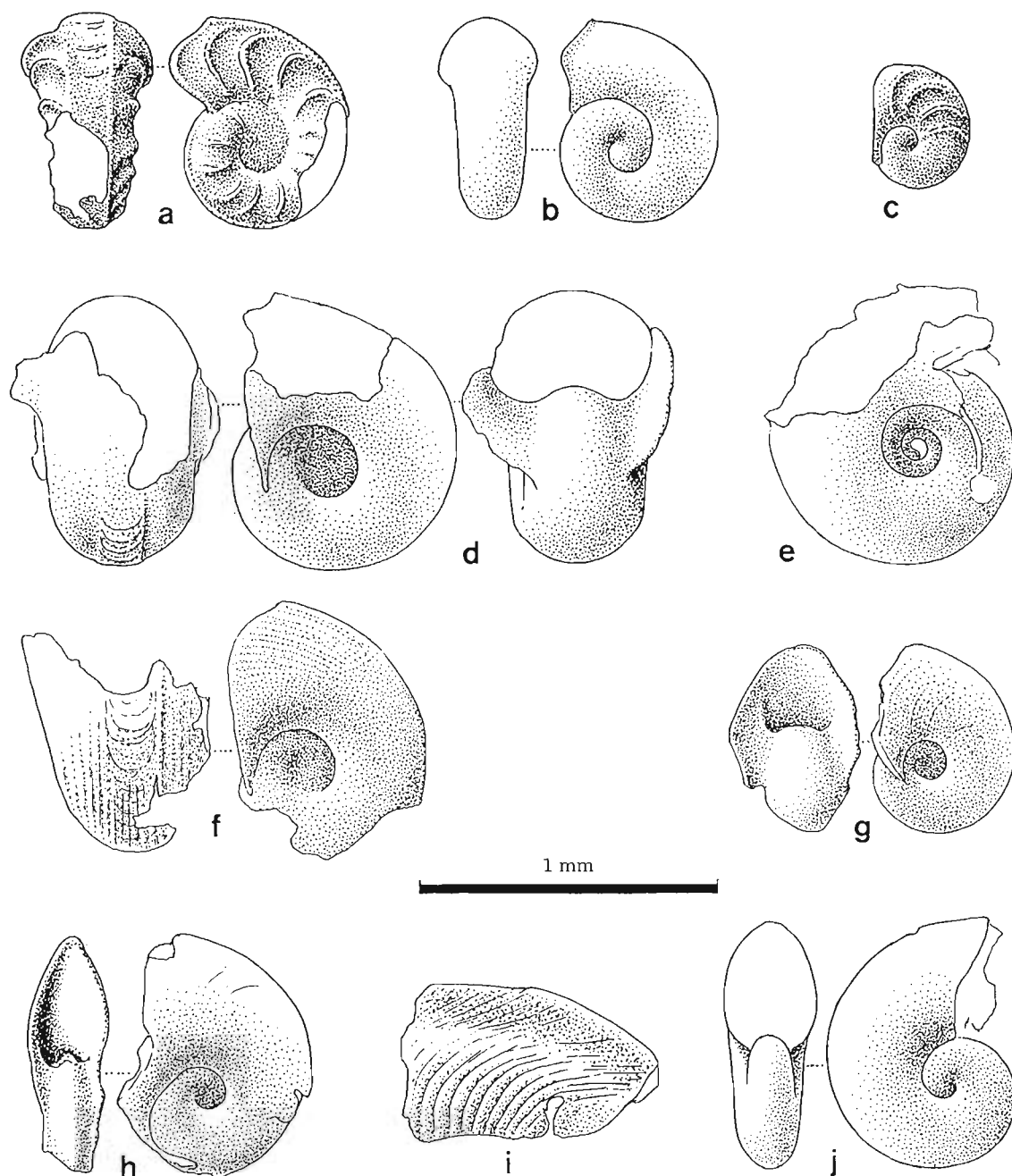


Fig. 5.

a–c. *Modestospira* sp.; partially exfoliated phosphatic envelope of a juvenile conch from sample MA-45 (a), nucleus and phosphatic envelope of juvenile conchs from sample MA-58 (b, c). d–f. *Kokenospira* sp. [cf. *K. esthona* (KOKEN)] or *Tetranota* sp.; phosphatic envelopes of juvenile conchs from sample MA-99 (f, see also Pl. 55: 5). g. *Cyrtodiscus?* sp.; phosphatic envelope of a juvenile conch from sample MA-99 (see also Pl. 55: 7). h–j. *Tropidodiscus* sp.; phosphatic envelopes and nucleus of juvenile conchs from sample MA-99 (i, h, see also Pl. 55: 4, 6).

In the lack of adult stages in the Mójcza material it is not possible to decide whether they are conspecific or not.

The embryonic shell of *Modestospira* was smooth, ornamented only with indistinct growth lines (Pl. 55: 2–3). The ornamentation typical for the genus appears suddenly at the second coil. The frequently occurring complete specimens with about 1.5 coils are perhaps veliger conchs (Pl. 55: 1)

but the evidence for an increase in mortality at this stage is very weak. The proposed veliger conchs have the selenizone distinctly separated by spiral ridges, like small specimens of *M. mergli* and *Peelerophon oehlerti* (BERGERON, 1889). Larger specimens of *P. oehlerti* show a much more angularly shaped incision in the aperture, which makes them closely similar to the adults of *Modestospira polonica* (see Pl. 6: 10–13 in DZIK and PISERA 1994). A generic distinction of *P. oehlerti* from the species of *Modestospira* seems thus rather doubtful.

Distribution. — Very common in the middle part of the Mójcza Limestone (139 juvenile specimens), from the discontinuity surface up to 1.5 m above the bentonite (Llanvirn to Early Caradoc).

Genus *Kokenospira* BASSLER, 1915

Type species: *Bucanella esthona* KOKEN, 1889.

Kokenospira sp. [cf. *K. esthona* (KOKEN, 1889)] or *Tetranota* sp.
(Pl. 55: 5a–b; Text-fig. 5d–f)

Remarks. — The most typical bellerophontid conchs for the top of the Mójcza Limestone (sample MA-99) are globular and spirally ornamented. Similar forms are common also in the Baltic cephalopod limestones (DZIK 1978; HYNDA 1986) where they can be matched with adult specimens of *Kokenospira*. This is not possible in Mójcza so the real affinity of the juveniles remains unknown. If the ribbing pattern of the juveniles continued to later stages, it would result in a morphology close to that of *K. esthona* (see KNIGHT 1941: Pl. 8: 2a–b). Another similar form is the Midcontinent *Tetranota*, especially *T. bisulcata* (HALL) from the Early Caradoc Leray-Rockland beds of Canada (see WILSON 1951: p. 30, Pl. 55: 1–2).

Distribution. — Top of the Mójcza Limestone (Late Caradoc, samples MA-4, 98, 99: 64 specimens) and at the bentonite (Llandeilo, samples MA-67–69: 7 specimens). Perhaps these are populations of different species.

Family **Tropidodiscidae** KNIGHT, 1956

Genus *Cyrtodiscus* PERNER, 1903

Type species: *Oxydiscus (Cyrtodiscus) procer* PERNER, 1903.

Cyrtodiscus? sp.
(Pl. 55: 7, ?14; Text-fig. 5g)

Remarks. — These rare discoidal but rather globose specimens are hard to determine even at the generic level. A fragment of a somewhat older conch (ZPAL Ga1/83; Pl. 55: 14) may represent the same species but its pleurotomariid nature cannot be excluded. *Trematodiscus? disculus* (BILLINGS) from the Cobourg beds of Canada (WILSON 1951: p. 32, Pl. 4: 24–25) is somewhat similar to the Mójcza juveniles.

Distribution. — Only 5 specimens in the topmost bed of the Mójcza Limestone (Late Caradoc, sample MA-99).

Genus *Tropidodiscus* MEEK *et* WORTHEN, 1866

Type species: *Bellerophon curvilineatus* CONRAD, 1842.

Tropidodiscus sp.
(Pl. 55: 4, 6; Text-fig. 5h–j)

Remarks. — These flat discoidal conchs with a deeply incised ventral sinus cannot be determined specifically at the ontogenetic stages represented in the Mójcza material. They presumably represent the cosmopolitan genus *Tropidodiscus*. Similar species of the genus can be found both in Bohemia (HORNÝ 1963) and the Baltic region (HYNDA 1986).

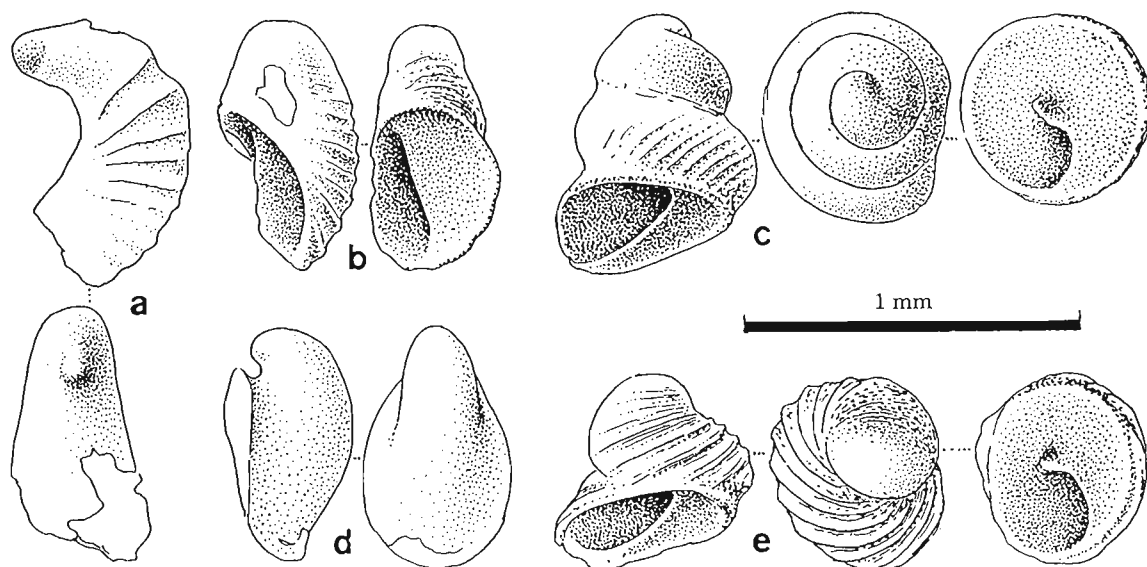


Fig. 6.

a–e. *Mimospira* sp.; envelope of a pathologic(?) specimen from sample MA-43 (a); early postembryonic conch from sample MA-34 (b); juvenile specimens with different shapes of embryonic parts from sample MA-45 (c, e); nucleus possibly representing a newly hatched larval conch of this species, prior to developing the columella, from sample MA-95 (d).

Distribution. — Top of the Mójcza Limestone (Late Caradoc, sample MA-99: 6 specimens). Possibly represented also by singular specimens in the Late Llanvirn part of the section (sample MA-58) and close to its base (sample MA-37).

Order *Mimospirida* DZIK, 1983

Remarks. — These are originally sinistral gastropods that probably developed independently of other, originally dextral ones, already in the earliest Cambrian (LINSLEY and KIER 1984). Whether they are to be classified as gastropods or monoplacophorans is a matter of convention. I place them here among monoplacophorans just to indicate their uncertain taxonomic position.

Family *Clisospiridae* MILLER, 1889

Genus *Mimospira* KOKEN, 1925

Type species: *Mimospira helmhackeri* PERNER, 1900.

Mimospira sp.

(Pl. 55: 8–12; Text-fig. 6a–e)

1983. *Mimospira* sp.; DZIK, Fig. 3A–E.

Remarks. — Like the Baltic populations of the genus (DZIK 1983), the *Mimospira* specimens in Mójcza show an extraordinary variability in the shape of their apical parts and the shell ornamentation. The embryonic shell in *Mimospira* is ornamented only with growth lines. In some samples (MA-25, 95) nuclei of possibly newly hatched larval shells occur. They are virtually symmetrical bilaterally and without any columella. In specimens a little older (sample MA-34) the columella develops forming a slightly oblique shelf that covers half of the conch aperture. Only after this stage regular coiling starts. The basal part of the shell remains completely smooth, evidently it was covered with soft tissue. A single specimen of an unusual horn-like shape (Text-fig. 6a; sample MA-43) seems to represent a malformation of *Mimospira* rather than a new mollusc group.

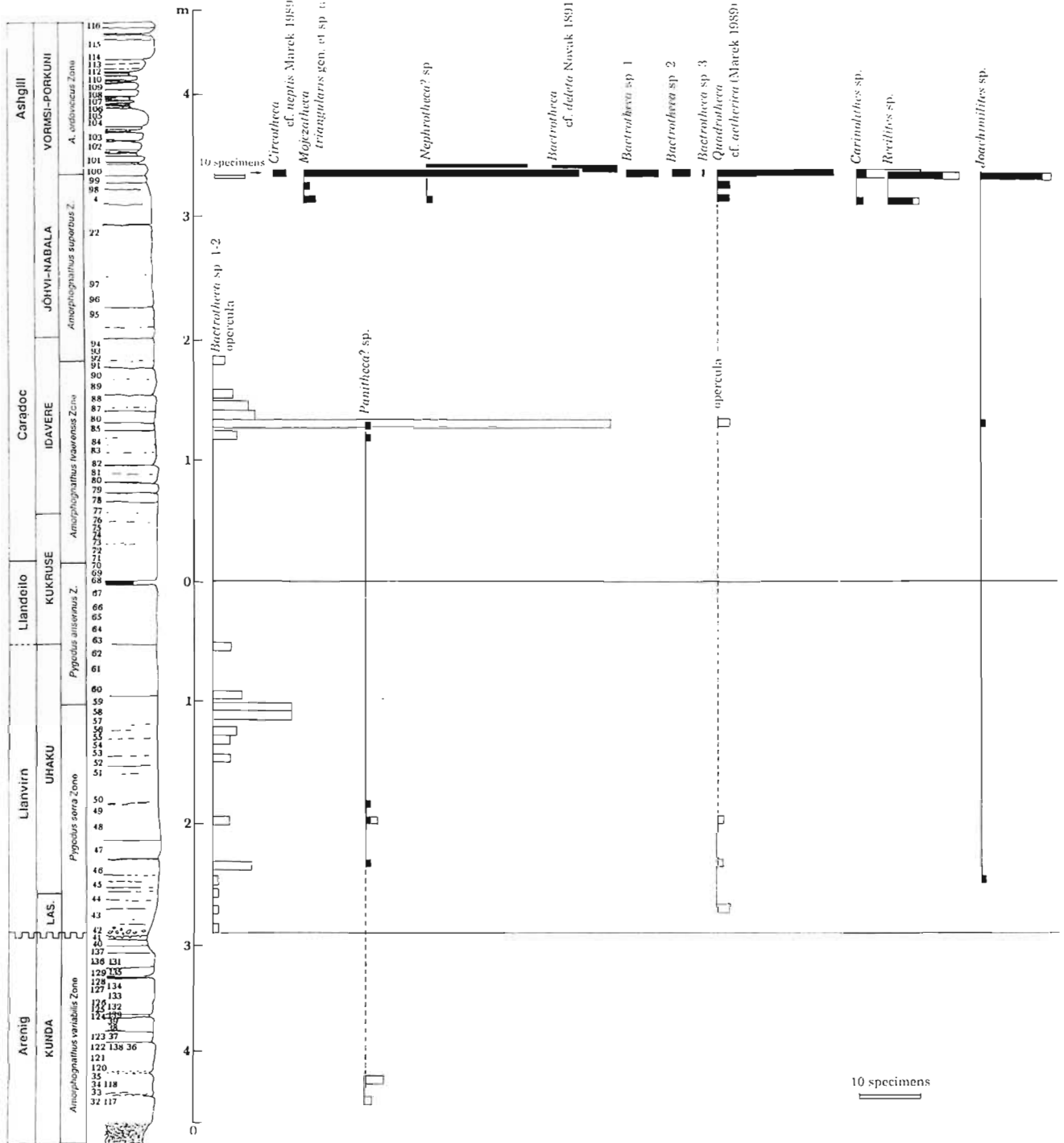


Fig. 7.

Distribution of hyoliths in the Mójca Limestone section at Mójca, Holy Cross Mountains, Poland.

The surface ornamentation of the *Mimospira* conchs from Mójca is generally coarse and very variable in each sample. Without biometrics, which is rather hard to do with the variously preserved Mójca material, I am not able to recognize any apparent evolutionary change in the section. Relationships to the Baltic species defined on the basis of adult specimens by WÄNGBERG-ERIKSSON (1979) are not clear.

Distribution. — Occurs throughout the section, both in the Mójcza Limestone and the Zalesie Formation. Most common in the interval between the discontinuity surface and bentonite.

Class **Hyalitha** MAREK, 1963

Hyaloliths are exclusively Paleozoic organisms with conical aragonitic shells of cross-lamellar microstructure (RUNNEGAR *et al.* 1975) closed with a calcareous operculum. Their embryonic and larval conchs are of variable but typically molluscan morphology (DZIK 1978). The opercula, with a complex inner side (MAREK 1966), are calcified in a way closely similar to that in the neritid gastropods and show analogies to them also in the distribution of the muscular attachments and processes (DZIK 1980). Intestines of hyaloliths may be preserved filled with sediment (MAREK 1966; RUNNEGAR *et al.* 1975; MESHKOVA and SYSSOIEV 1981; BABCOCK and ROBISON 1988) and this, together with the flattening of a one side of their shells, indicate that they spent most of their life lying passively on the sea bottom in a way similar to the Recent turrnellid gastropods. A paired dorsal muscle attachment scar, located in proximity of the aperture, fits spatially the pair of clavicles at the operculum. Despite relatively well known morphology, relationships of the hyaloliths are still hotly disputed (see YOCHELSON 1987).

Like many other tall conical shells the hyalolith conchs also have their apical parts separated by diaphragms. The periodic secretion of the diaphragms, as in cephalopods, sometimes results in a periodicity in the thickening of the conch wall and in the preservation of a series of the muscle scars. A strange feature of the hyalolithid diaphragms is the variability of their shapes. Usually they are more or less flat, sometimes with pointed structures deforming their centers. This seems to be of little taxonomic importance, and generally the morphology of the hyalolith conchs has a limited value in distinguishing genera, especially among the hyalolithids (MAREK 1966).

Distribution. — In the Mójcza Limestone the hyaloliths are common fossils but, from some unknown reason, except for the topmost bed only their phosphatized opercula occur in greater numbers, the conchs being known only from few fragments (Text-fig. 7). Almost all of these opercula belong to the orthothecid hyaloliths. Even if in the topmost bed quite a diverse assemblage of the hyaloliths appears, it is still dominated by the orthothecids. This is unlike all other known hyalolith assemblages of the Ordovician, even the most similar fauna of the Králův Dvůr Formation of Bohemia (MAREK 1989).

Order **Circothecida** SYSSOIEV, 1968

Diagnosis. — Conchs with “ventral” surface not flattened; opercula with prominent cardinal processes and a circular rim sometimes showing incipient differentiation into clavicles.

Family **Circothecidae** MISSARZHEVSKY, 1968

Diagnosis. — Conchs with circular or oval cross sections.

Genus *Circotheca* SYSSOIEV, 1958

Type species: *Hyalithes (Orthotheca) stylus* HOLM, 1893.

Remarks. — The type species of the genus is Late Cambrian in age. Its operculum bears two prominent cardinal processes (HOLM 1893: Pl. 6: 6–9). Morphologically similar Early Cambrian hyaloliths had quite different opercula and it remains unclear whether the Middle Ordovician Baltic species with tubular conchs can be classified in this genus even if their larval shells are similar to those of the type species of *Circotheca* (compare DZIK 1980: Figs 3C and 7). The generic identification of the Mójcza species is thus also conjectural.

Circotheca cf. *neptis* MAREK, 1989 (Pl. 54: 1; Text-fig. 8a, i)

1989. *Circotheca neptis* sp. n.; MAREK, p. 41, Pl. 1: 1–2.

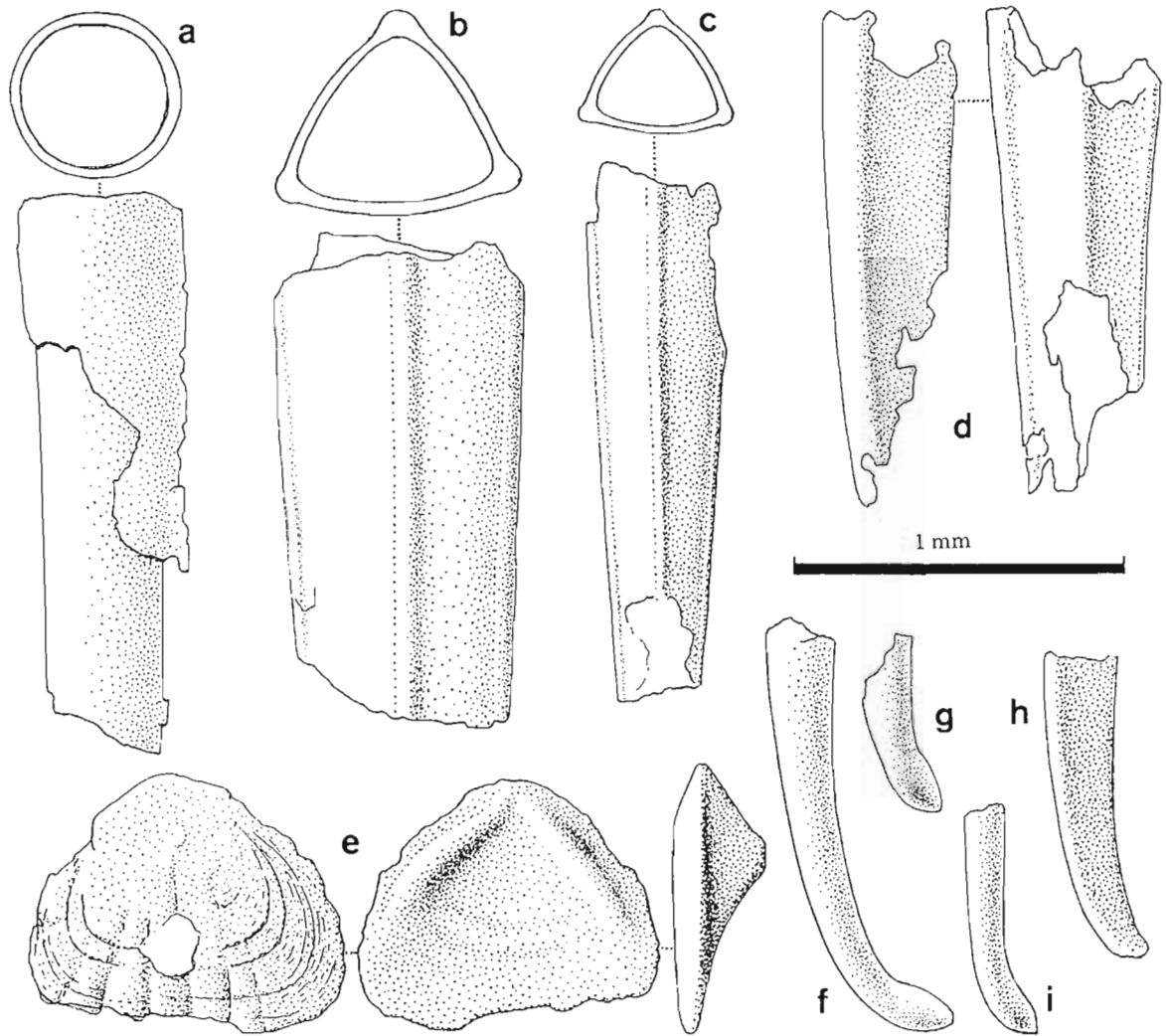


Fig. 8.

a, i. *Circotheca* cf. *neptis* MAREK, 1989; partially exfoliated phosphatic envelope of a conch from sample MA-99 (a, see also Pl. 54: 1); nucleus of the apical part of a conch possibly belonging to this species, same sample (i). b–h. *Mojczatheca triangularis* gen. et sp. n.; conchs from sample MA-99 (b–c, h) and MA-4 (d); operculum possibly belonging to the species, sample MA-99 (e; see also Pl. 54: 8); nuclei of apices from the same sample (f–g).

Remarks. — The fragmentary tubular conchs with a transverse aperture and virtually circular cross section from the sample MA-99 may represent hyoliths of this genus, most probably the almost coeval Bohemian species from the Kraluv Dvur Formation. Neither the apical parts of the conch nor opercula have been identified in the Mójcza material.

Distribution. — Late Caradoc, 4 conch fragments in sample MA-99.

Family ?*Tetrathecidae* SYSSOIEV, 1968

Genus *Mojczatheca* gen. n.

Type species: *M. triangularis* sp. n.

Diagnosis. — Elongated, gently curved conchs with regularly triangular cross section, flanks and venter being gently convex. Operculum flat, with wide cardinal processes.

Remarks. — The morphology of the embryonic conch almost identical with that of *Circotheca* suggests an evolutionary proximity to this genus. Conchs of the early Cambrian *Gracilitheca* Sys-

SOIEV, 1968 also have an acutely triangular cross section but they are wide and have a typically orthothecid concave venter.

Species included: Only the type species. Perhaps also the specimen from the Late Cambrian of the Baltic region identified as a juvenile of *Decoritheca excavata* (HOLM, 1893) by DZIK (1980: Fig. 8B) represents a species of the genus, which requires that associated apices belong to another form. HINZ (1987: p. 72, Pl. 14: 37–38, Text-fig. 3I) identified morphologically undistinguishable shell fragments from the Early Cambrian of England as *Anabarites compositus* MISSARZHEVSKY, 1969, but any similarity of at least the Mójcza material to these problematic fossils is rather superficial.

Mojczatheca triangularis sp. n.
(Pl. 54: 22, ?8a, b; Text-fig. 8b–h)

Holotype: Fragmentary conch ZPAL GaI/45 (Pl. 54: 22).

Type horizon and locality: Top of the Mójcza Limestone in its type section, Late Caradoc.

Diagnosis. — As for the genus.

Description. — The thickenings at the three edges of the conch form its sole longitudinal ornament. Growth lines are not apparent but they seem to show a strictly transverse course. With a decreasing diameter towards the apex the conch flanks became more and more convex and the apical part seems to be almost circular in cross section (at least its interior, as shown by phosphatic nuclei). The conch is generally gently bent; only its tip curves strongly towards the dorsum. The embryonic conch is elongated, with a mucro, approximately 0.12 mm in diameter.

The only operculum that matches the aperture of *Mojczatheca* conchs (Pl. 54: 8a–b) is completely flat from the outside (even its embryonic part). From the inside its dorsolateral sides are bordered by long bases of the cardinal processes, that are triangular in profile but incompletely preserved. The medial area is gently concave.

Remarks. — This is the most unusual of the Mójcza hyoliths. Its highly elongated conch with the strictly regular, triangular cross section makes it unlike any other hyoliths.

Distribution. — Late Caradoc, topmost beds of the Mójcza Limestone, 90 conchs from the sample MA-99, 1 from MA-98 and 2 from MA-4; the single operculum from MA-99 may also belong here.

Order **Orthothecida** MAREK, 1966

Diagnosis. — Conchs with a flat or concave ventral surface; opercula with large, flat cardinal processes but without any clavicles. In hyoliths of this order a tightly sigmoidal, sediment-filled intestine is known to occur while any mineralized appendages (helens) are missing.

Family **Orthothecidae** SYSSOIEV, 1958

Diagnosis. — Conchs with flat or concave ventral surface and transverse aperture.

Genus *Nephrotheca* MAREK, 1966

Type species: *Orthotheca sarkaensis* NOVAK, 1891.

Diagnosis. — Shell elongate, kidney-shaped in cross section. Wide cardinal processes nearly reaching lateral margins of the operculum (modified after MAREK 1966).

Remarks. — Except for the single specimen tentatively attributed to *Mojczatheca*, no operculum with *Nephrotheca*-like cardinal processes (see MAREK 1966, 1967) has been found in the Mójcza Limestone. Opercula occurring abundantly in the lower part of the section invariably bear long cardinal processes of *Bactrotheca*-type. They are associated with fragments of conchs with ornamentation identical with that of coeval Baltic "*Orthotheca*" *dens* HOLM, 1893, closely similar to the Bohemian type species of *Nephrotheca*. It is not unusual among hyoliths that conchs of similar generalized morphology have very different, taxonomically diagnostic opercula. Therefore any attributions of the Mójcza hyoliths to *Nephrotheca* are highly tentative.

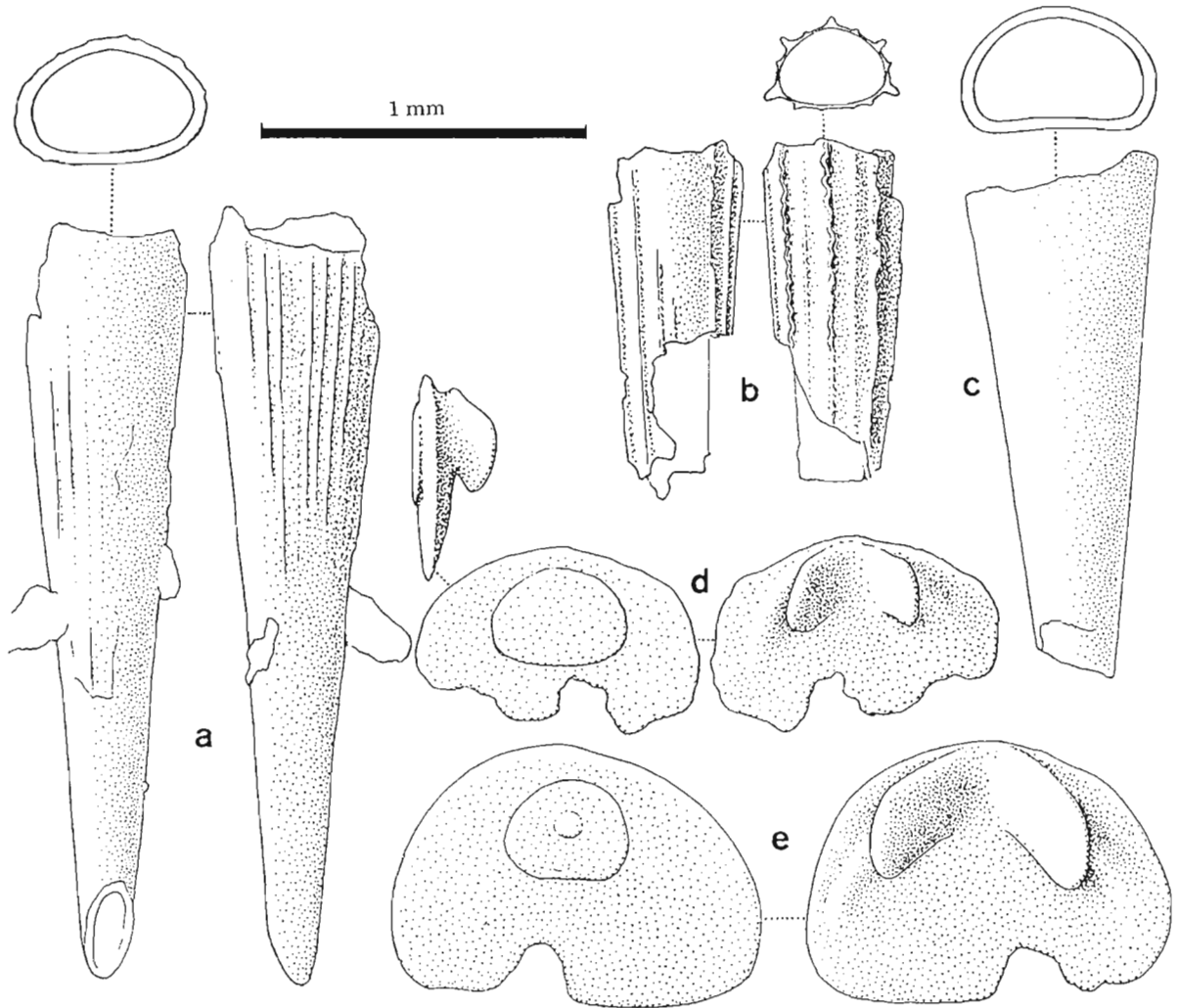


Fig. 9.

a. *Bactrotheca* cf. *deleta* NOVAK, 1891; phosphatic envelope of a conch from sample MA-99. b. *Bactrotheca* sp. 3; conch from sample MA-99. c. *Nephrotheca*? sp.; conch from sample MA-99. d–e. *Panitheca*? sp.; opercula possibly belonging to the species from sample MA-118 (d) and MA-34 (e).

Nephrotheca? sp.

(Pl. 54: 3, 21; Text-fig. 9c)

Remarks. — These orthothecids differ from associated species in almost smooth conchs with concave venter. An indistinct longitudinal striation can be discerned only under SEM (Pl. 54: 3). Another feature that makes this species distinct is a relatively wide apical angle at later ontogenetic stages.

Distribution. — Late Caradoc, sample MA-99: 32 conchs, sample MA-4: single nucleus.

Genus *Panitheca* MAREK, 1967

Type species: *Panitheca collector* MAREK, 1967, Zahořany Formation.

Panitheca? sp. (aff. "*Orthotheca*" *dens* HOLM, 1893)

(Text-fig. 9d–e)

Remarks. — The conch fragments with dense, basally undulated riblets from samples MA-5, 10, 46, 49, 84 may belong here. Identical ornamentation occurs in Bohemian *Panitheca collector* but no

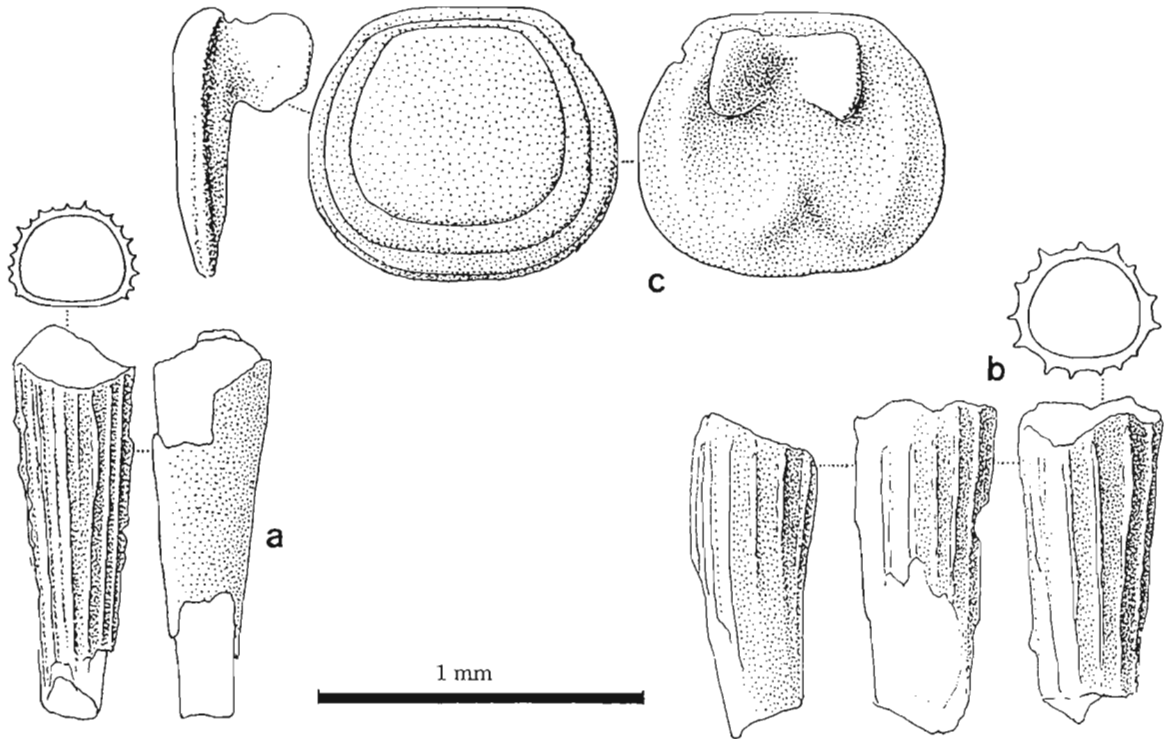


Fig. 10.

a. *Bactrotheca* sp. 2.; conch from sample MA-99 (see also Pl. 54: 14). b–c. *Bactrotheca* sp. 1; conch from sample MA-99 (b; see also Pl. 54: 12) and possibly conspecific operculum from sample MA-86 (c).

specimen in the Mójcza material is preserved well enough to show the cross-section, which is diagnostic for the genus.

Possibly opercula with gently convex dorsal margin from samples MA-8, 33, 34, 118 represent one of the two above described orthothecid species. If this is the case these species hardly belong to *Nephrotheca* or *Panithea*.

Genus *Bactrotheca* NOVAK, 1891

Type species: *Hyolithes teres* BARRANDE, 1867.

Diagnosis. — Conchs with rounded trapezoidal cross-section.

Bactrotheca cf. *deleta* NOVAK, 1891 (Pl. 54: 23; Text-fig. 9a)

Remarks. — The conchs attributed here are more elongated than in preceding species and ornamented with numerous longitudinal ribs, a little more densely distributed at the ventral side. Their cross sections are gently rounded dorsally but their ventral surface is also a little convex, as in the following species. The opercula from samples MA-8, 33, 34, 118, closely similar to those of *B. deleta* from the Králův Dvůr Formation (MAREK 1989: Pl. 1: 10), may belong to this species.

Distribution. — 22 conchs in sample MA-99.

Bactrotheca sp. 1 (Pl. 54: 5–6, 10–12; Text-fig. 10b–c)

1978. *Circotheca* sp.; DZIK, Fig. 7D.

Remarks. — This species differs from *B. cf. deleta* in its more robust ornamentation and in much higher conchs with a convex venter. Judging from its cross section most of the opercula of *Bactrotheca* in the Mójcza Limestone represent this species.

Distribution. — 11 conchs in sample MA-99; numerous opercula occurring throughout the section.

Bactrotheca sp. 2
(Pl. 54: 14; Text-fig. 10a)

Remarks. — Unlike the above two species, this one has a smooth venter and strongly ornamented dorsum of the conch. The conch cross section is rounded trapezoidal.

Distribution. — 6 specimens in sample MA-99.

Bactrotheca sp. 3
(Pl. 54: 13; Text-fig. 9b)

Remarks. — The strong, basally undulated main ribs separated by more delicate, numerous intercalary ribs make this species distinct from the associated orthothecids.

Distribution. — Single specime in sample MA-99 and some shell fragments.

Genus *Quadrotheca* SYSSOIEV, 1958

Type species: *Hyalithes (Orthotheca) quadrangularis* HOLM, 1893.

Diagnosis. — Conchs with trapezoidal cross section with thickened corners.

Quadrotheca cf. aethERICA (MAREK, 1989)
(Pl. 54: 4, 7, 9; Text-fig. 11a–g)

Remarks. — None of the Mójcza specimens show any remnants of longitudinal ornament, so it seems that the shell surface was almost smooth. The conchs of *Bactrotheca aethERICA* MAREK from the Králův Dvůr Formation at early ontogenetic stages show strongly thickened corners, a typical feature of the *Quadrotheca*, that disappears later in the ontogeny (MAREK 1989: Pl. 1: 11). Its operculum is of an almost identical morphology as in the prominently ornamented *Q.?* *rediviva* MAREK from the Zahořany Formation of Bohemia (MAREK 1967).

Numerous opercula from the Mójcza Limestone show a complete spectrum of shapes from a wide one of *Quadrotheca*-type to a high associated with *Bactrotheca*. This was the basis of synonymizing several genera of the orthothecids (DZIK 1980) but only the strict correlation of conchs with opercula may corroborate this proposal.

Distribution. — Conchs of *Quadrotheca* are known only from the topmost strata of the Mójcza Limestone, in the sample MA-99 represented by 38 specimens, MA-98 and MA-4, 2 specimens in each. The opercula that potentially may belong to the genus are even more widely distributed but there are some problems with discrimination of opercula belonging to *Quadrotheca* and *Bactrotheca*.

Order **Hyalithida** MATTHEW, 1899

Diagnosis. — Mineralized appendages (helens) present. Conch with roundedly subtrigonal cross-section; the ventral margin of the conch aperture protruding (ligula); operculum with small cardinal processes and massive clavicles.

Family **Hyalithidae** NICHOLSON, 1872

Diagnosis. — One pair of clavicles.

Genus *Joachimilites* MAREK, 1967

Type species: *Joachimilites novaki* MAREK, 1967, Zahořany Formation (Caradoc).

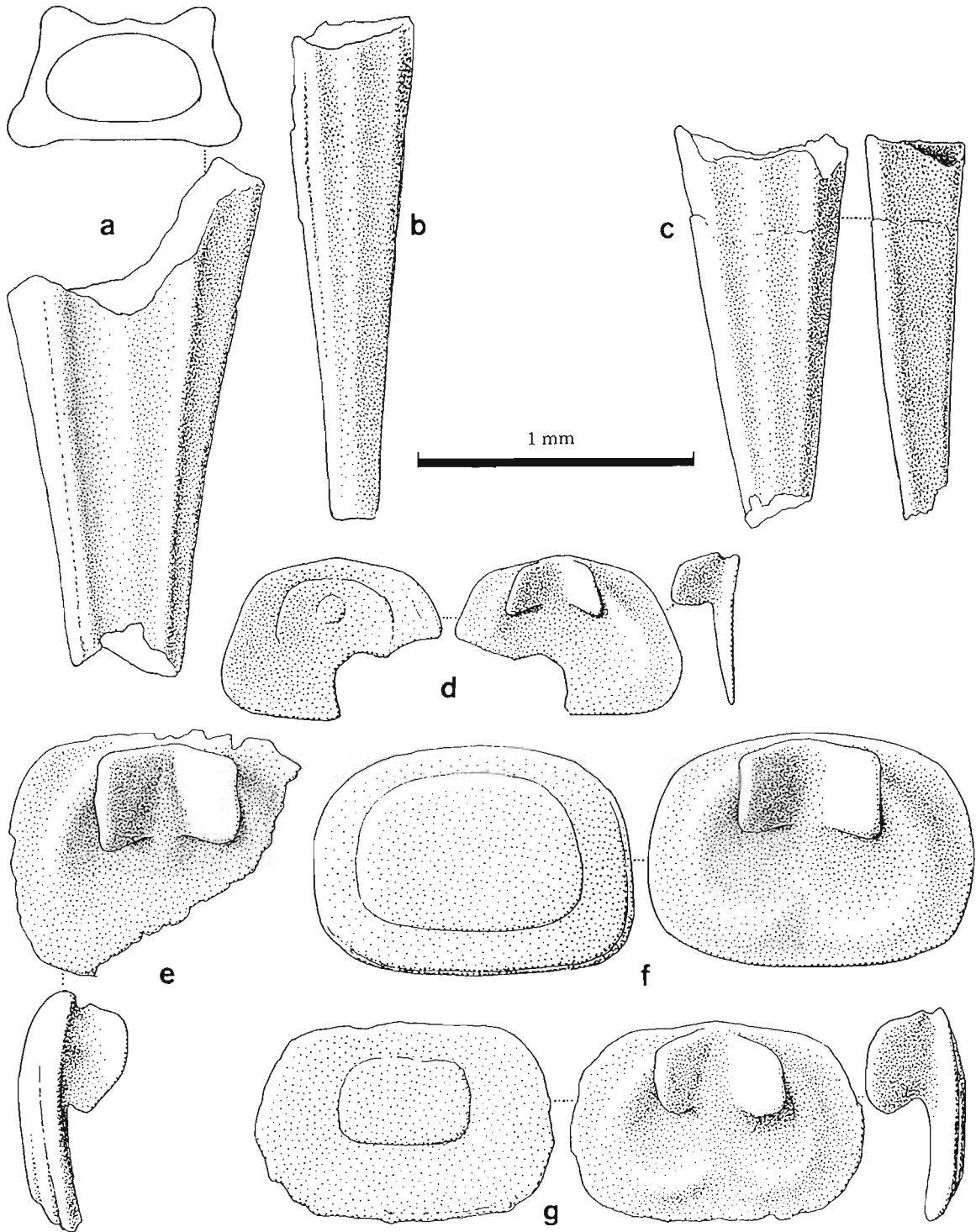


Fig. 11.

a-g. *Quadrotheca* cf. *aethetica* (MAREK, 1989); conchs from sample MA-99 (a, b) and MA-4 (c); possibly conspecific opercula from sample MA-85 (d), MA-43 (e, g), and MA-46 (f; see also Pl. 54: 7).

Diagnosis. — Operculum with one pair of long, simple cardinal processes diverging at an acute angle. Central process ridge-like, cardinal teeth present (modified after MAREK 1967).

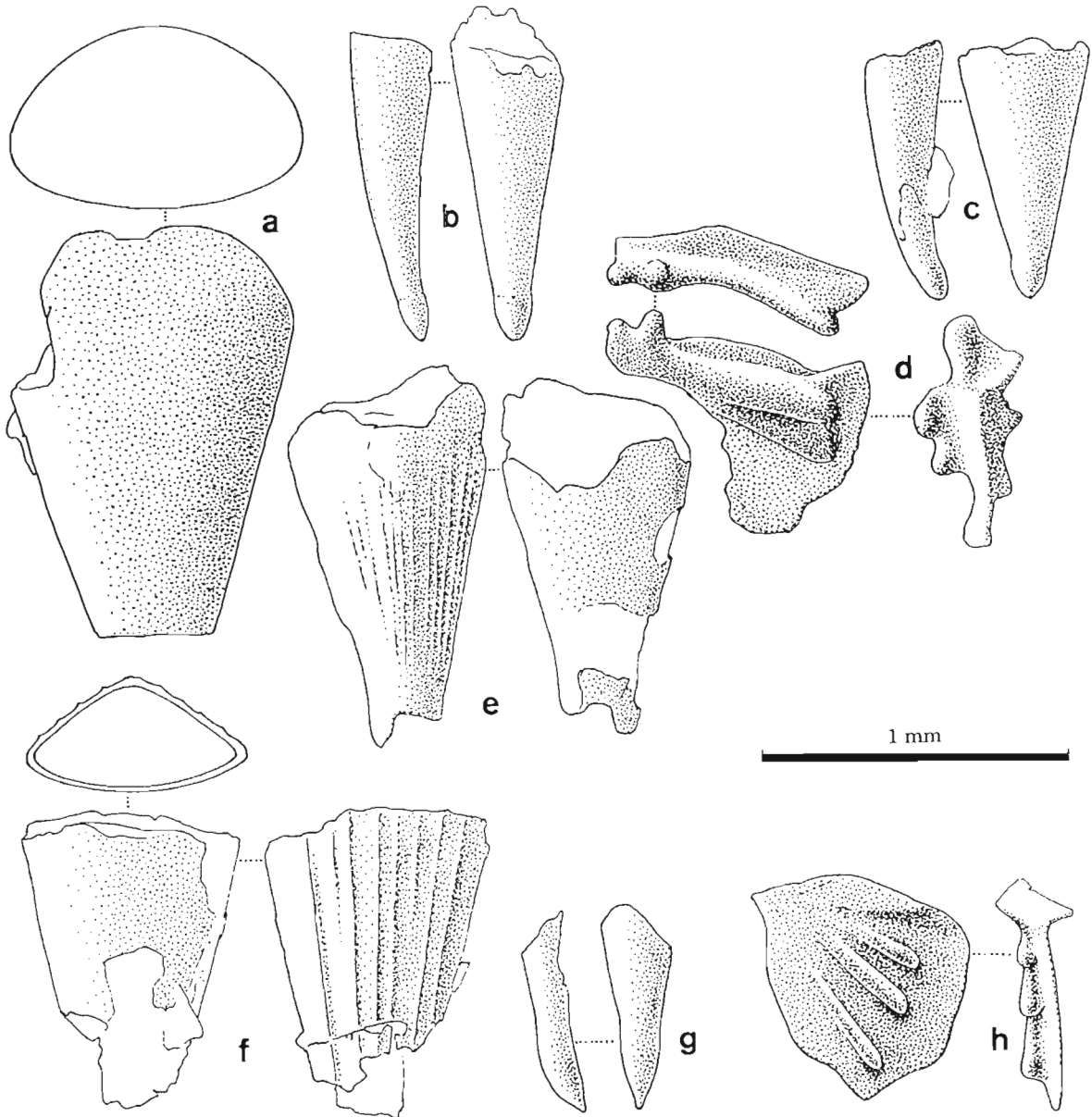


Fig. 12.

a–d. *Joachimilites* sp.; conch from sample MA-99 (a); phosphatic envelopes of apical parts, samples MA-85 and MA-45 (b–c); operculum from sample MA-99 (d; see also Pl. 54: 19). **e–h.** *Recilites* sp.; conchs from sample MA-99 (e, f; see also Pl. 54: 17); nucleus of the apex from the same sample (g); operculum, same sample (h; see also Pl. 54: 18).

Joachimilites sp.

(Pl. 54: 15, 19; Text-fig. 12a–d)

Remarks. — Two fragmentary opercula from the sample MA-99 resemble those of *J. novaki* in the shape of clavicles with an additional basal ridge and narrow cardinal processes (only their bases are preserved). This does not prove the generic affiliation because the dorsal part, which in *Joachimilites* bears structures distinguishing it from the related genus *Elegantilites* MAREK, 1966 (see also KASE *et al.* 1987), remains unknown. It is also difficult to match these opercula with the associated conchs. Perhaps those with a rounded cross section and curved apex belong to the same species. They

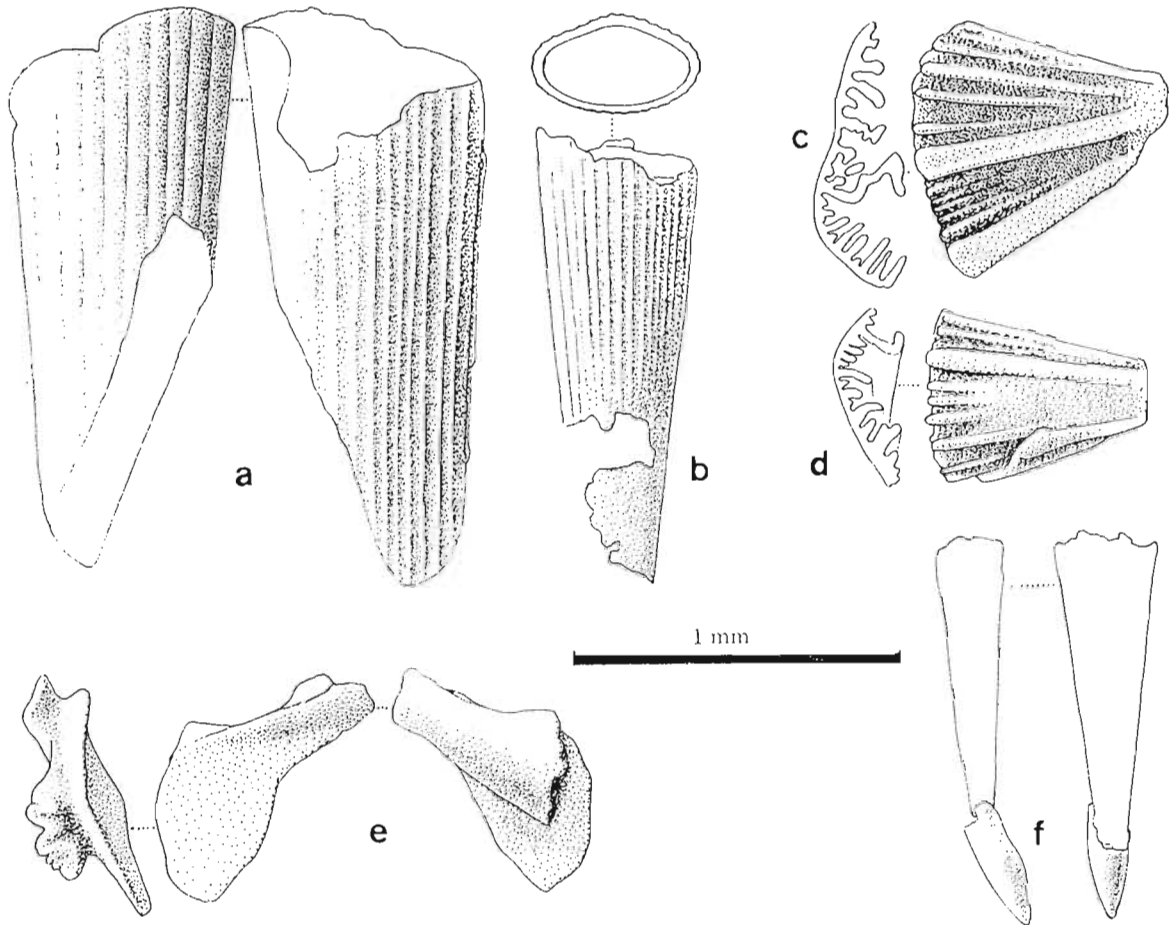


Fig. 13.

a–f. *Carinolithes* sp.; conchs from sample MA-99 (a–b); opercula from the same sample (c–e); conch apex, same sample (f).

differ from the Bohemian species of *Joachimilites* (MAREK 1967, 1989) in having a much larger apical angle. In this respect they rather resemble coeval species tentatively attributed to *Elegantilites* by MAREK (1967, 1983).

Distribution. — Along with the opercula mentioned above, 21 conchs in the sample MA-99, and singular specimens from MA-45 and 85.

Genus *Carinolithes* SYSSOIEV, 1958

Type species: *Hyalithes pennatulus* HOLM, 1893.

Diagnosis. — Operculum platyclavicate, cardinal processes fused. Conch with low angular dorsal side and strongly convex venter.

Carinolithes sp.

(Pl. 54: 2, 20; Text-fig. 13a–f)

Remarks. — Fragmented septate clavicles of these hyoliths resemble corals. Complete opercula with clavicles of this kind are known from Bohemia (MAREK 1967, 1974), erratic boulders of Baltic origin and from boreholes at the SW margin of the East European Platform. In the specimens from the erratic boulder E-085 of Late Llanvirn age (DZIK 1978: Figs 3, 7E), the cardinal processes are still recognizable, being connected with a prominent medial process. In approximately coeval operculum

from the Lesieniec I borehole, NE Poland (sample 129), the cardinal processes are fused into an arch bordering the dorsal margin of the operculum.

A conch associated with opercula in the sample MA-99, which can be tentatively matched with the opercula under discussion, differs quite significantly from both the Baltic type species and Bohemian *C.? tantulus* MAREK 1967 from the Libeň Formation. Its most characteristic feature is a flat dorsum and longitudinal ribbing. In these respects it resembles a little "*Hyolithes* sp. No. 12" of HOLM (1893) of Early Llanvirn age but even in this species of *Carinolithes* ribs are restricted to the lateral sides of the conch. A closely related, if not conspecific, species of *Carinolithes* with a completely ribbed conch, more prominently at the dorsal surface and delicately at the venter, occurs in erratic boulders of the Backsteinkalk type. Unfortunately, in this form ontogenetic stages comparable to those represented in the Mójcza Limestone are unknown.

Distribution. — 18 fragments of opercula (mostly clavicles) in sample MA-99, 3 fragmentary conchs in the same sample and another one in sample MA-4.

Family **Pauxillitidae** MAREK, 1967

Diagnosis. — Operculum with more than one pair of clavicles.

Genus *Recilites* MAREK, 1967

Type species: *Hyolithes solitarius* BARRANDE, 1867.

Diagnosis. — Conch of low-subtrigonal section. Operculum triclavicate, cardinal processes broad and short, central process broad and dentate (modified after MAREK 1967).

Recilites sp.

(Pl. 54: 16–18; Text-fig. 12e–h)

1978. *Leolites* sp.; DZIK, Fig. 7A.

Remarks. — An almost complete mould of the external surface of operculum from the sample MA-99 shows a morphology closely similar to that of *R. solitarium*, with fused cardinal processes. Associated juvenile conchs are less similar to those of the type species of the genus, in being ornamented by less densely distributed ribs, as in *Leolites paucicostatus* MAREK from the Králův Dvůr Formation (MAREK 1989). It is hard to say whether this is an expression of early ontogenetic stage or of specific distinctiveness.

Distribution. — Fragmentary opercula in samples MA-4 and MA-99, a complete nucleus in the latter sample; 18 conchs in MA-99 and 4 in MA-4.

Class **Gastropoda** CUVIER, 1797

All the Mójcza and coeval Baltic gastropods have relatively loosely coiled protoconchs, usually with distinct growth lines indicative of an early calcification. Among the Recent archaeogastropods only the neritids preserved the primitive early calcification and the resulting presence of growth lines at the surface of both the embryonic and larval shells (BANDEL 1982) although already in the Triassic they were much more tightly coiled (BANDEL 1992) than in any of the known early Paleozoic gastropods. Although the morphology of embryonic and larval shells is known in supposed Devonian relative of the neritids *Naticonema* (DZIK 1978), similarities are remote. This well exposes the difficulties in the attribution of Ordovician gastropods to higher-rank zoological groups (see HASZ-PRUNAR 1988 for discussion on classification).

The most remarkable feature of the Mójcza gastropod fauna is a rather low diversity of protoconch morphologies when compared with the coeval Baltic faunas. The whole assemblage seems thus to be represented by species related to each other. It is highly probable that most of them belong to yet unnamed genera. Therefore, in reviewing the Mójcza gastropods only their tentative generic assignments are given, without any reference to higher-rank taxonomy.

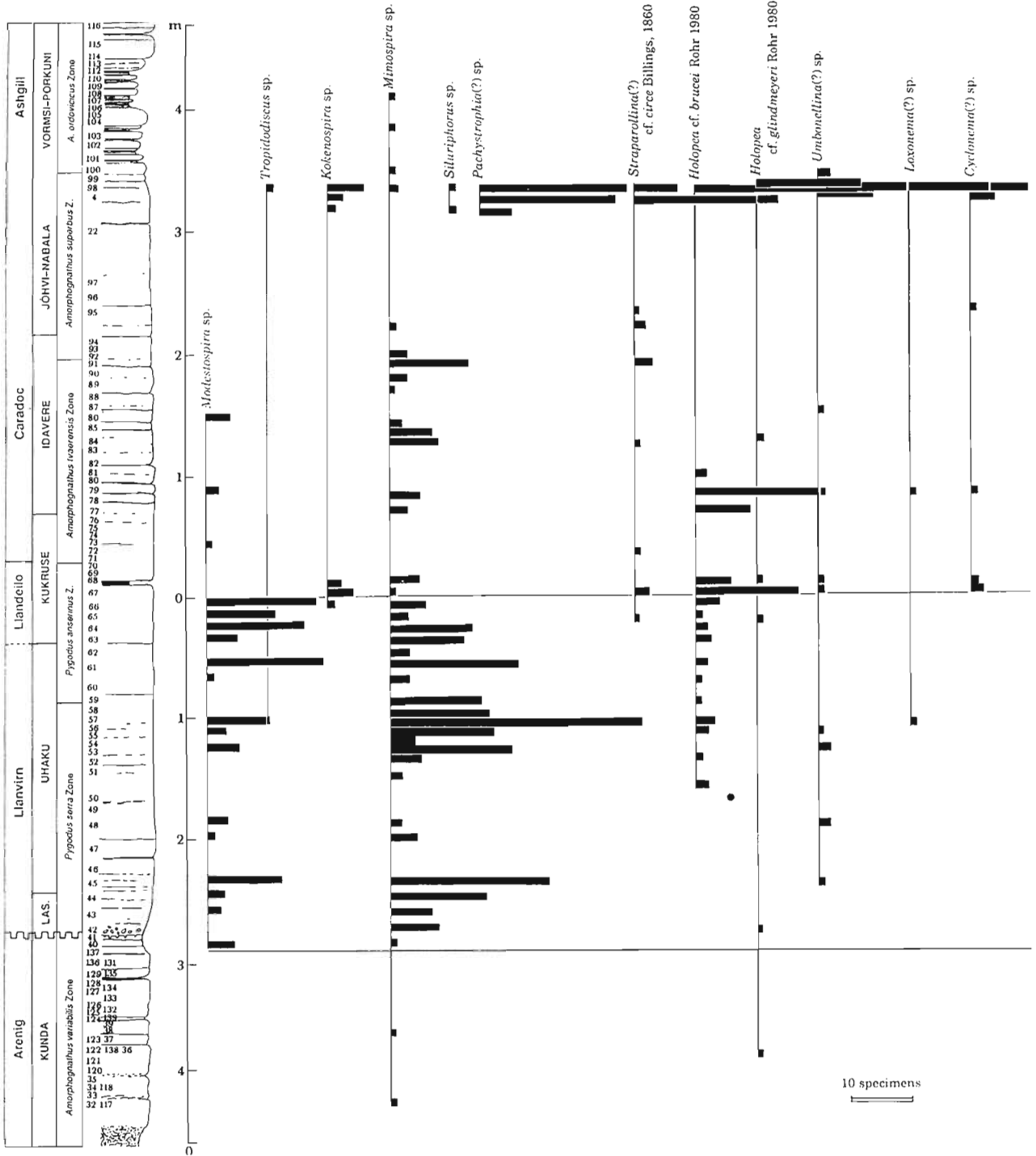


Fig. 14.

Distribution of monoplacophorans and gastropods in the Mójcza Limestone section at Mójcza, Holy Cross Mountains, Poland.

Distribution. — In the basal part of the Mójcza Limestone true dextrally-coiled gastropods are virtually missing (Text-fig. 14). Beginning from the level 1.5 m above the discontinuity surface, some simple, smooth-shelled gastropods appear in greater number, but up to the bentonite layer they are of minor importance. Only with the general change in the fossil assemblages observable immediately

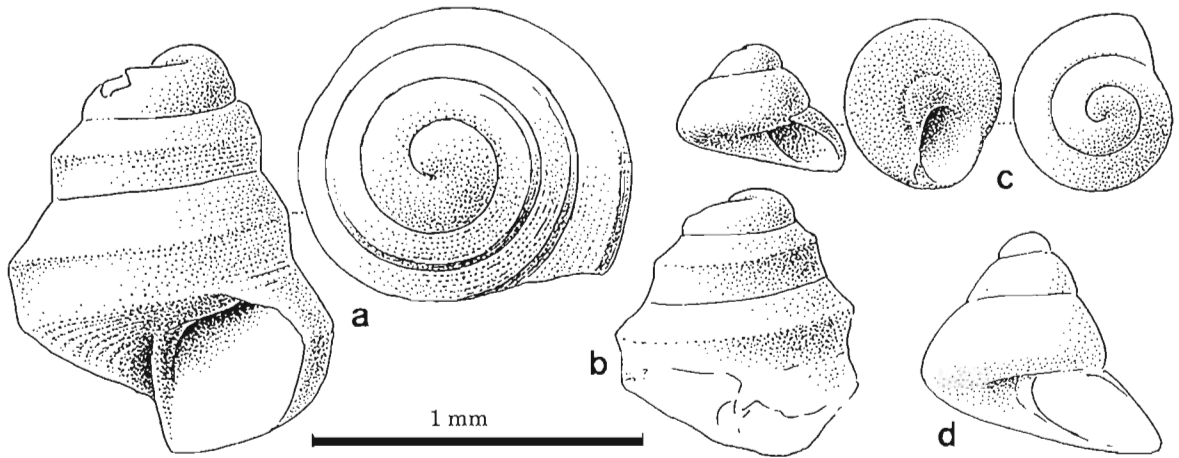


Fig. 15.

a–b. *Cyclonema?* sp.; conchs from sample MA-99. c–d. *Siluriphorus* sp.; conchs from sample MA-99.

above the bentonite layer, does the holoepid gastropods begin to dominate. This seems to continue, despite the poor record in the middle, up to about 1.0 m above the bentonite where the previous structure of the community seems to be restored. This topmost Llandeilo-Early Caradoc event may be related to the *Nemagraptus gracilis* warm period that resulted in a eustatic event and a decrease in the geographic extent of the Mediterranean faunal elements.

A characteristic feature of the Mójcza assemblage of gastropods is the domination of smooth-shelled *Straparollus*-like forms, while any pleurotomariids and murchisoniids are virtually absent. In the best known coeval faunas from the equatorial North American Midcontinent (WILSON 1951), temperate Baltic area (KOKEN 1925; YOCHELSON 1962), as well as from the high-latitude Bohemian (PERNER 1903) and South French massives (BABIN *et al.* 1982), such gastropods contribute only subordinately to assemblages. Somewhat unexpectedly the Baltic gastropod faunas are not similar to any of the Mójcza ones, although some rare species closely related to those of the older fauna probably occurred there, too. The Baltic gastropod faunas in the Middle Ordovician were dominated by the euomphalids and pleurotomariids, which seem to be rare, perhaps even missing in Mójcza. In the assemblages of juvenile gastropod conchs from the Baltic area (see DZIK 1978; HYNDA 1986), as well as from Spitsbergen (alleged “worms” of BOCKELIE and YOCHELSON 1979), embryonic shell morphologies are represented that are unknown in Mójcza. Perhaps the generally low taxonomic diversity of the older mollusc fauna should be blamed for this, but even in the diverse gastropod assemblage from the top of the Mójcza Limestone almost all species represent the same kind of early ontogeny.

Genus *Umbonellina* KOKEN, 1925

Type species: *Umbonellina infrasilurica* KOKEN, 1925.

Umbonellina? sp.

(Pl. 55: 13, 15; Text-fig. 16e–f)

Remarks. — These globose shells with a narrow apex of the coil and open umbilicus resemble later *Naticonema* in shape. They differ from other gastropods of the Mójcza Limestone in having a somewhat more loosely coiled protoconch with small subspherical apex. Conchs of this kind continue throughout the whole Mójcza section possibly representing several species of the same genus, which is also suggested by some variability in the coiling of the first whorl (see Pl. 55: 13 and 15). Similar in shape are also the larval shells from Volhynia named *Holopea? pusilla* by HYNDA (1986). The only adult gastropod from the Baltic Ordovician that remotely resembles the Mójcza form is *Umbonellina infrasilurica* KOKEN (see KOKEN 1925: p. 203, Pl. 32: 10–12). Perhaps *Straparollina eurydice* BILLINGS from the Leray-Rockland beds of Canada (WILSON 1951) is related to the Mójcza species. It changes

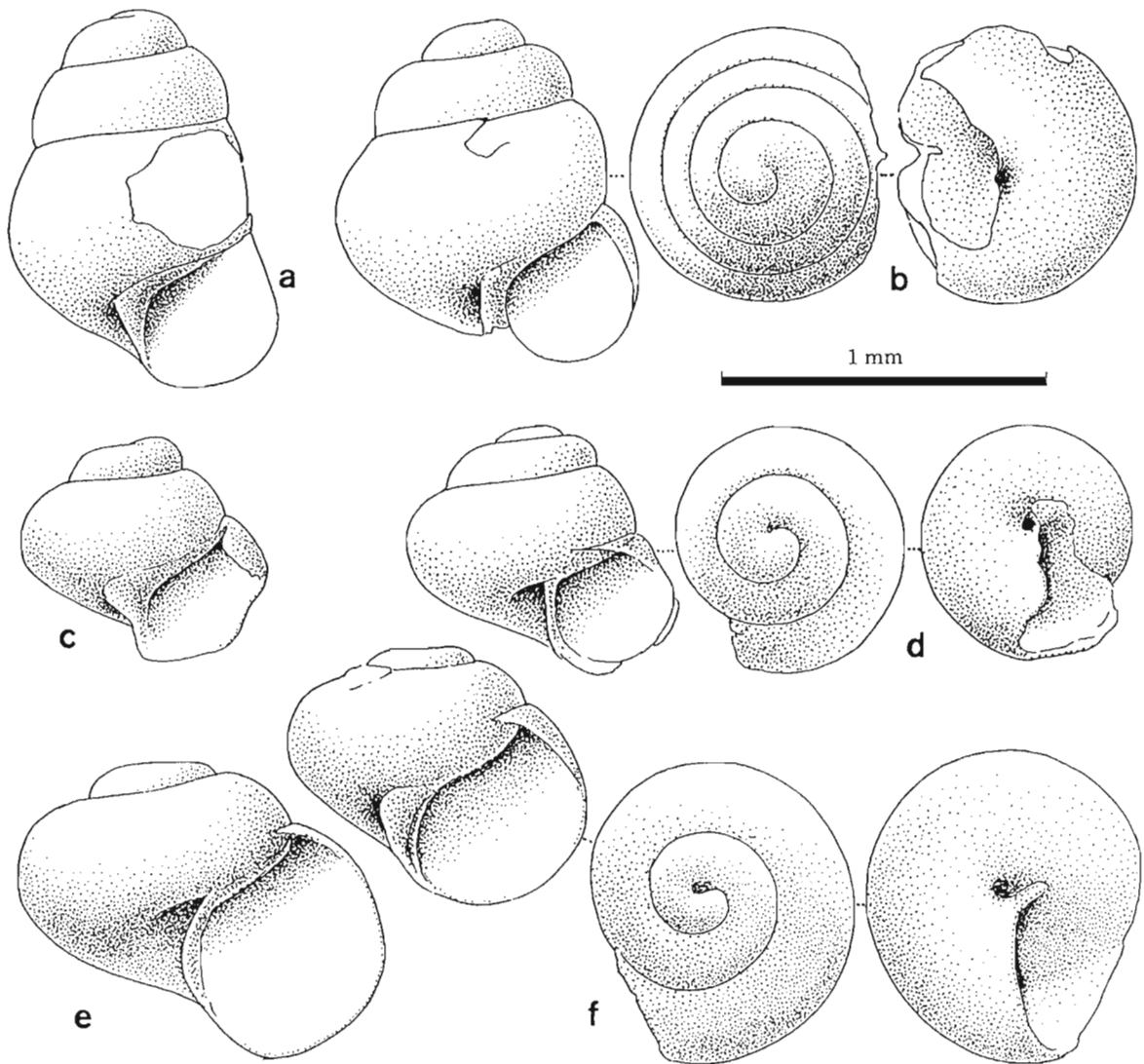


Fig. 16.

a–b. *Loxonema?* sp.; conchs from sample MA-99. c–d. *Holopea* cf. *glindmeyeri* ROHR, 1980; conchs from sample MA-99. e–f. *Umbonellina?* sp.; nucleus and phosphatic envelope of a conch from the sample MA-99.

its shape during ontogeny to high-trochiform. Another Canadian species with a similar juvenile shape that is preserved also in adults, is *Holopea informis* WILSON from the Lowville beds.

Distribution. — Rare in the part of the Mójcza Limestone above the discontinuity surface.

Genus *Gyronema* ULRICH in ULRICH and SCOFIELD, 1897

Type species: *Trochonema* (*Gyronema*) *pulchellum* ULRICH in ULRICH and SCOFIELD, 1897.

Remarks. — Two distinct groups seem to be represented among the highly trochoidal conchs with a spiral striation occurring in the topmost strata of the Mójcza Limestone. They differ in the prominence of the ornamentation, and these with more prominent ribs may belong to a species of *Trochonema* (a pleurotomariid) or *Gyronema* (a holopeid). No specimen has been found with the apex preserved well enough to compare its embryonic shell with those of the coeval pleurotomariids and holopeids.

Gyronema? sp.
(Pl. 56: 3)

Remarks. — The conch surface is prominently ribbed in this species. The character of ribbing is hardly discernible at the surface of the nuclei, and only rare, fragmentary specimens with the phosphatic coating can be attributed to this species.

Distribution. — Fragmentary specimens in the topmost beds of the Mójcza Limestone.

Genus *Cyclonema* HALL, 1859

Type species: *Pleurotomaria bilix* CONRAD, 1842.

Cyclonema? sp.
(Pl. 56: 1–2, 5; Text-fig. 15a–b)

Remarks. — Usually the thick phosphatic coatings obscure the spiral ornamentation in conchs of this species, which are then recognizable only owing to an angulation at the middle of the exposed part of every whorl of the spire. Nuclei are practically unidentifiable. It is also not clear to what degree the ornamentation changes in the ontogeny.

This is the only species in the Mójcza assemblage in which a clear difference in ornamentation between embryonic and post-embryonic conch is discernible, the latter being ornamented by both the growth lines and a spiral striation. The embryonic conch seems to be completely smooth but this may be due to the thickness of the phosphatic coatings that obliterates a delicate ornament. No significant change in the ornamentation that would correspond to the metamorphosis is visible.

Distribution. — Common in the topmost beds of the Mójcza Limestone (Late Caradoc, samples MA-98, 99: 103 specimens) tentatively identified nuclei rarely occur from the level of the bentonite (Llandeilo-Caradoc).

Genus *Holopea* HALL, 1847

Type species: *Holopea symmetrica* HALL, 1847.

Remarks. — At least four species (perhaps even genera) are represented in the uppermost Mójcza Limestone by smooth conchs with a widely open umbilicus. The morphologic boundaries between these species are difficult to indicate precisely. All the forms vary in the height of the spire, size of the apex, convexity of whorls, and diameter of the umbilicus. Unfortunately, the mode of preservation does not allow us to treat the material biometrically. Most of the specimens have their external phosphatic linings at least partly exfoliated, which makes any measurements unreliable. The proposed subdivisions are thus based on a rather subjective assessment that transitional forms are infrequent and the distribution of characters is multimodal.

Purely on the basis of a general shape similarity they are classified here as the holopeids, an assignment that is by no means certain. Perhaps only the highest trochoidal form deserves the generic name *Holopea*.

BANDEL (1992) identified in the alleged late Triassic platyceratid "*Orthonychia*" *alata* (LAUBE, 1869) a larval shell of the neritid type. Ironically, larval shells of this kind are unknown from the Early Paleozoic and even that of the Devonian neritid *Naticopsis* is very different (DZIK 1978). Possibly, "*O.*" *alata* is rather an advanced neritid than a true platyceratid.

Holopea cf. *glindmeyeri* ROHR, 1980
(Pl. 56: 4, 11; Text-fig. 16c–d)

Remarks. — This is the highest trochoidal form among the supposed Mójcza holopeids, being similar in shape to *Holopea symmetrica* HALL (KNIGHT 1941: Pl. 51: 6) and *H. glindmeyeri* ROHR (ROHR 1980: Pl. 9: 4–18) from the late Middle Ordovician of North America. Similar in shape (but similarity in this particular case means just comparable simplicity) is also *Holopella vesiculosa* (BARRANDE) (PERNER 1903: Pl. 63: 1–5).

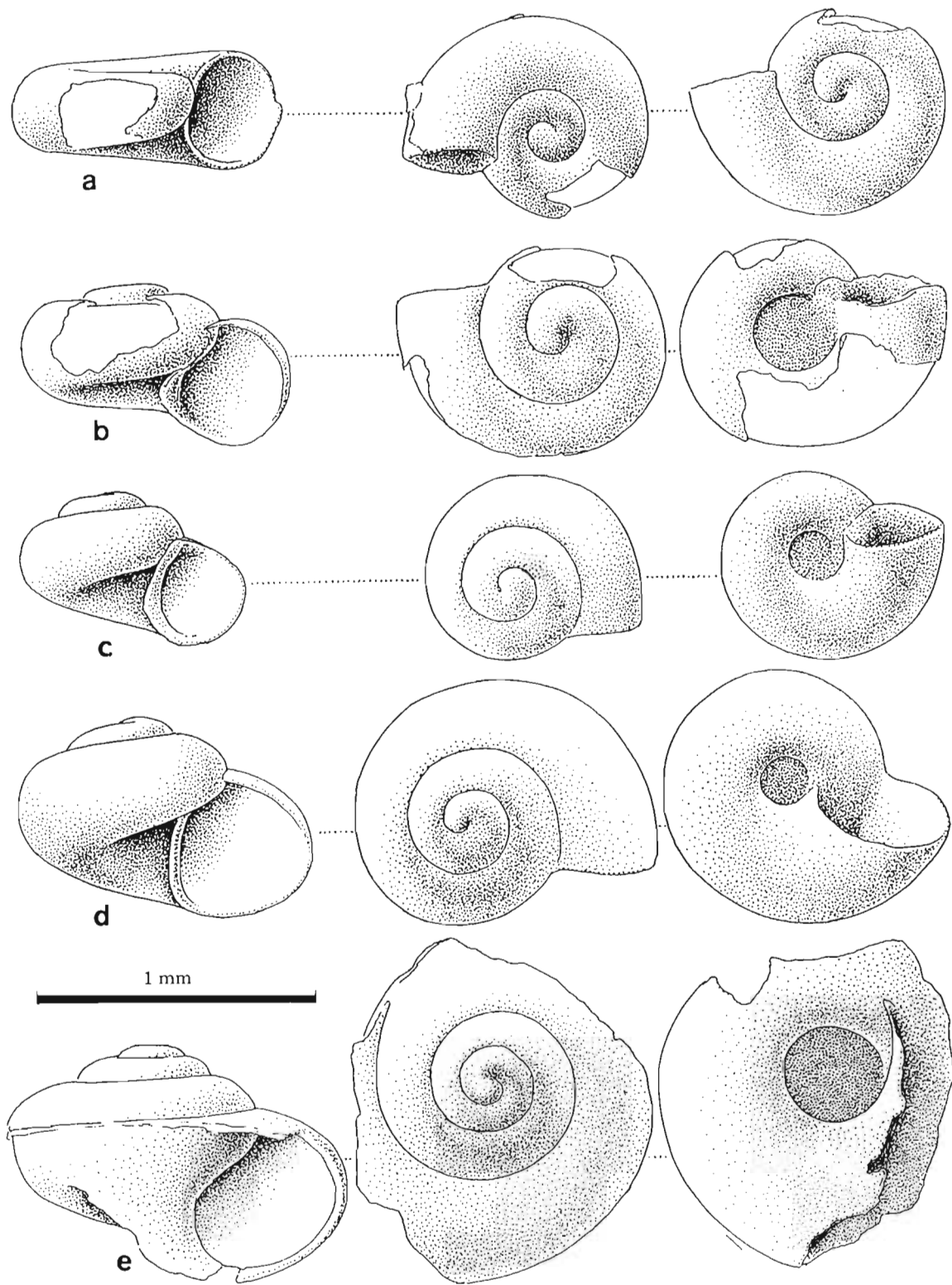


Fig. 17.

a. *Pachystrophia?* sp.; conch from sample MA-99. b–c. *Straparollina?* cf. *circe* BILLINGS, 1860; conchs from sample MA-99. d–e. *Holopea* cf. *brucei* ROHR, 1980; conchs from sample MA-99.

Distribution. — Species common in the topmost beds of the Mójcza Limestone (samples MA-4, 99: 173 specimens). Morphologically undistinguishable singular specimens occur throughout the whole section.

Holopea cf. *brucei* ROHR, 1980
(Pl. 56: 6, 9; Text-fig. 17d–e)

Remarks. — The species next in the degree of opening of the umbilicus may be related to *H. brucei* ROHR from the Middle Ordovician of California (ROHR 1980: Pl. 9: 25–27). At least superficially it resembles also Silurian *Umbospira nigricans* PERNER (see KNIGHT 1941: Pl. 26: 2a–c). However, the aperture does not seem to possess any sinus that would substantiate its assignment to the pleurotomariids. Another similar but also superficially known species is *Straparollus borkholmen-sis* KOKEN (KOKEN 1925: p. 132, Pl. 16: 8; VOSTOKOVA 1955: Pl. 4: 9) and *S. vortex* EICHWALD (VOSTOKOVA 1955: Pl. 4: 2) from the Ashgill of Estonia.

Distribution. — This is the only holopeid morphology that occurs abundantly not only at the top of the Mójcza Limestone (292 specimens in sample MA-99) but also in the middle of the section from about 1.5 m above the discontinuity to 1.0 m above the bentonite.

Genus *Straparollina* BILLINGS, 1865

Type species: *Straparollina pelagica* BILLINGS, 1865.

Straparollina(?) cf. *circe* BILLINGS, 1860
(Pl. 56: 7–8; Text-fig. 17b–c)

Remarks. — Even wider umbilicus, lower spire, and more rounded whorls characterize this species which resembles the Late Paleozoic species of *Straparollus*. Conchs of *S. circe* BILLINGS from the Early Caradoc Leray-Rockland beds of Canada (WILSON 1951) are virtually identical in shape, which does not seem to change strongly in the ontogeny. Superficially similar are species from the Ordovician of Norway and California attributed to *Helicotoma* by YOCHELSON (1962) and ROHR (1980). Perhaps *H.?* *norvegica* (KOKEN), Ashgill in age, is related to the Mójcza species, but only nuclei of adult conchs are known (YOCHELSON 1962: p. 157, Pl. 4: 1–2, 5, 7).

Distribution. — Common in the topmost beds of the Mójcza Limestone (sample MA-98, 99: 88 specimens) not uncommon in strata above the bentonite.

Genus *Pachystrophia* PERNER, 1903

Type species: *Eomphalus devexus* EICHWALD, 1859.

Pachystrophia(?) sp.
(Pl. 56: 9–10; Text-fig. 17a)

Remarks. — The extremely low-spined, almost planispiral gastropod species from the Mójcza Limestone was initially classified as *Leseurilla* (DZIK 1978). It was assumed that the angulation, typical for *Leseurilla* and other early euomphalids, develops later in ontogeny. This has not been supported by observations on additional, slightly older specimens. Moreover, the larval conch morphology recently identified in *Eccyliomphalus*, a close relative of *Leseurilla* is almost uncoiled and indicates affinities of the group to early pleurotomariids.

Actually, any euomphalid affinities of this species and, consequently, its attribution to *Pachystrophia*, are also not very likely, but I am not able to find any better taxonomic placement for it.

The embryonic conch is smooth in this species, as in other Mójcza gastropods. Usually no significant change in the ornamentation that could correspond to hatching or metamorphosis is discernible. In some specimens growth lines appear suddenly (Pl. 56: 10) but whether this corresponds to the boundary between the embryonic and larval conchs remains unclear.

Distribution. — Topmost beds of the Mójcza Limestone (Late Caradoc, samples MA-4, 98, 99: 270 specimens).

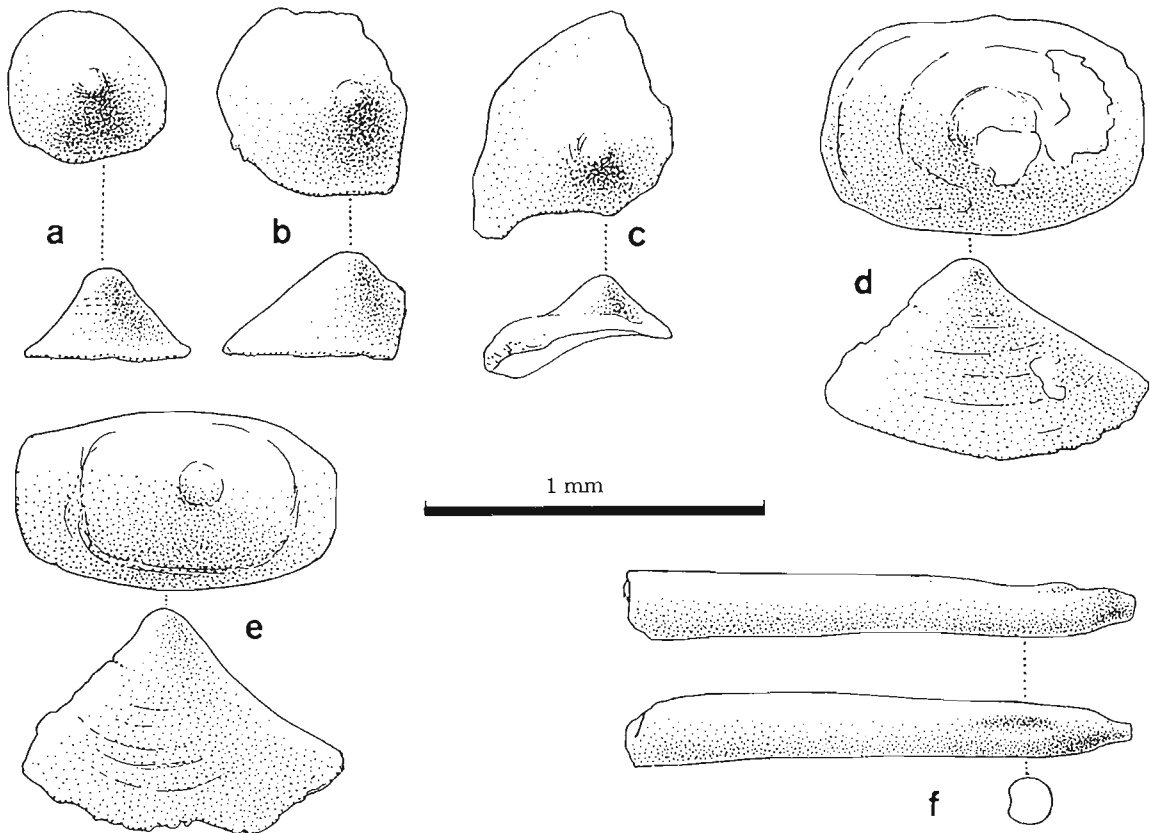


Fig. 18.

a–e. *Rostroconch* gen. et sp. indet.; phosphatic envelopes of early postembryonic(?) conchs from sample MA-85 (a–c); juvenile conchs from sample MA-84 (d–e). f. *Jinonicella* sp.; nucleus from sample MA-99.

Genus *Loxonema* PHILLIPS, 1841

Type species: *Terebra? sinuosa* SOWERBY, 1839.

Loxonema? sp.

(Pl. 56: 12; Text-fig. 16a–b)

Remarks. — The species represented by narrowly coiled, acute juvenile conchs may belong to the loxonematids. Similar, generalized larval conch morphologies are common in the Silurian and even in the late Carboniferous (see HERCHOLZ 1992). *Subulites*, although its adult conch is of similar appearance, fundamentally differs from them in having loosely coiled first whorl (see BOCKELIE and YOCHELSON's 1979 "worm tube" on their Fig. 5C), resembling in this respect rather coeval eccyliomphalids.

The Triassic loxonematids described by BANDEL (1991) do not show any closer similarity to this Ordovician species.

Distribution. — The topmost bed in the Mójcza Limestone (sample MA-99: 136 specimens), singular specimens in strata below may also represent the same lineage.

Genus *Siluriphorus* COSSMANN, 1918

Type species: *Trochus gotlandicus* LINDSTRÖM, 1884.

Siluriphorus sp.
(Text-fig. 15c–d.)

Remarks. — Only 8 specimens of this *Mimospira*-like, but dextrally coiled, gastropod have been found. The shell surface is almost smooth, the base is flat with a callus closing the umbilicus. The only other Ordovician pseudophorid from the Ashgill of Alaska (ROHR and BLODGETT 1985) is narrowly umbilicate, thus presumably more primitive than the Mójcza species, which is now the oldest known representative of its genus.

Distribution. — Topmost beds of the Mójcza Limestone (samples MA-4, 99: 9 specimens).

Subphylum **Diasoma** RUNNEGAR *et* POJETA, 1974

Class ?**Rostroconchia** POJETA *et al.*, 1972

Order ?**Ribeiriida** KOBAYASHI, 1954

Gen. et sp. indet.

(Text-fig. 18a–e)

Remarks. — Two cup-like fossils from the sample MA-84 resemble somewhat the early ribeiriid rostroconchs in having a laterally compressed aperture. Except for the presence of clear growth lines and a circular shape of the earlier ontogenetic stages little can be observed in these specimens. Smaller specimens from the stratigraphically following sample MA-85 are almost circular in outline, flat conical. No apparent change in ornamentation that could correspond to the embryonic and larval stages is visible, so even the molluscan nature of these fossils remains uncertain.

Distribution. — Early Caradoc of the Mójcza Limestone.

Incertae classis

Order **Jinonicellida** POKORNÝ, 1978

Remarks. — These peculiar molluscs with subspherical embryonic, curved or spirally coiled (*Janospira*) larval conch (POKORNÝ 1979), and tubular teleoconch may be successors of Cambrian *Yochelcionella* (RUNNEGAR 1977). They are not uncommon in the Early Paleozoic, occurring in the Ordovician of Spitsbergen, NE Poland, Volhynia (Ukraine), and the Holy Cross Mountains, and the Silurian of Bohemia and the Carnic Alps.

Family **Jinonicellidae** POKORNÝ, 1978

Genus *Jinonicella* POKORNÝ, 1978

Type species: *Jinonicella kolebabai* POKORNÝ, 1978.

Jinonicella sp.
(Text-fig. 18f)

Remarks. — Rare nuclei of tubular conchs that preserve elongated depressions close to the tip occur in the topmost bed of the Mójcza Limestone. Such steinkerns were identified by HYNDA (1986: p. 48, Pl. 8: 3–4) as belonging to *J. kolebabai*. This species identity would require that the protoconch was separated by a calcareous septum from the tubular part of the shell and the depression is the only sign of its former presence.

Distribution. — Only in the topmost bed of the Mójcza Limestone (sample MA-99: 7 specimens).

Class **Bivalvia** LINNAEUS, 1758

Distribution. — Bivalves are extremely rare in the Mójcza Limestone. Except for the top of the formation (sample MA-99) only a few fragmentary juvenile specimens have been found, all in the upper part of the section.

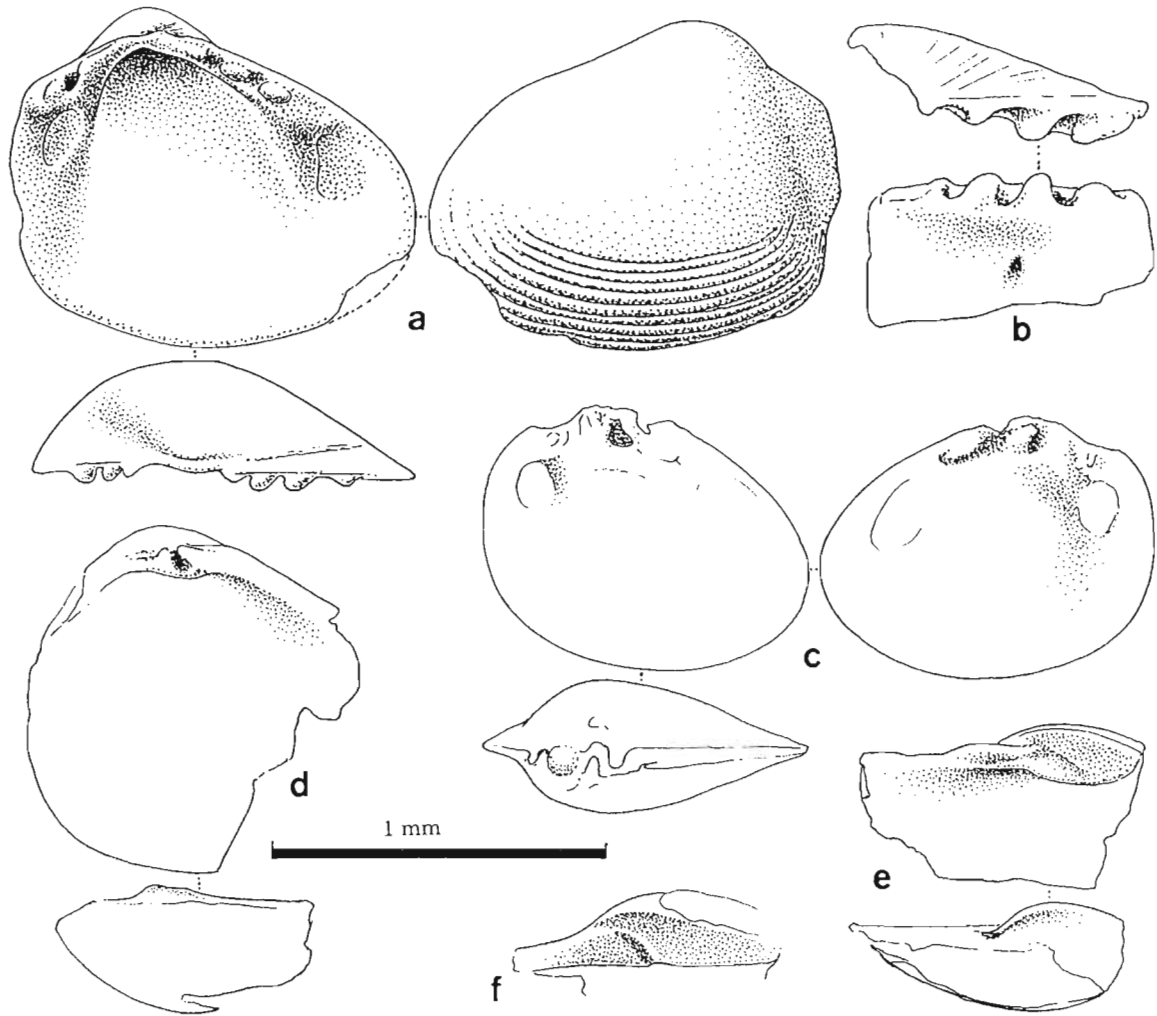


Fig. 19.

a–b. *Deceptrix?* sp.; valves from sample MA-99. c–d. *Nuculoidea?* sp.; nucleus of articulated valves and phosphatic envelope with probably obliterated hinge, sample MA-99. e–f. *Modiolopsis?* sp.; fragmentary phosphatic envelopes of the hinge area, sample MA-99.

Order **Nuculida** DALL, 1889
 Family **Ctenodontidae** WOHRMANN, 1893
 Genus *Deceptrix* FUCHS, 1919

Type species: *D. carinata* FUCHS, 1919.

Deceptrix? sp.
 (Pl. 56: 13; Text-fig. 19a–b)

Remarks. — Both conch form and dentition are similar to those of other Ordovician species of *Deceptrix* (see POJETA 1971: Pl. 5). All the collected specimens represent juvenile postlarval stage with several teeth developed at the hinge margin.

Distribution. — Topmost bed of the Mójcza Limestone (sample MA-99: 22 specimens, MA-98: 5 fragmentary valves, MA-04: 2 valve fragments); perhaps also closed valves from 1.0 m above the bentonite (sample MA-80) belong to this genus.

Family **Nuculidae** GRAY, 1824
 Genus *Nuculoidea* WILLIAMS *et* BREGER, 1916
Nuculoidea? sp.
 (Pl. 56: 14; Text-fig. 19c–d)

Remarks. — The hinge is composed of two teeth anteriorly and a one posteriorly of a depression that may correspond to the resilifer. If this is true the specimens may represent early postlarval shells of a nuculid with the hinge still rather simple at this stage of ontogeny.

Distribution. — Topmost bed of the Mójcza Limestone (sample MA-99), 18 specimens.

Order **Mytilida** FERRUSAC, 1822
 Family **Modiomorphidae** MILLER, 1877
 Genus *Modiolopsis* HALL, 1847

Type species: *Pterinea modiolaris* CONRAD, 1838.

Modiolopsis? sp.
 (Text-fig. 19e–f)

Remarks. — A fragment of the right valve hinge with a shelf-like protrusion seems to represent this genus (see POJETA 1971: Pl. 14: 3). Two additional hinge fragments that are more difficult to interpret may belong here, too.

Distribution. — Topmost bed of the Mójcza Limestone (sample MA-99), 3 specimens.

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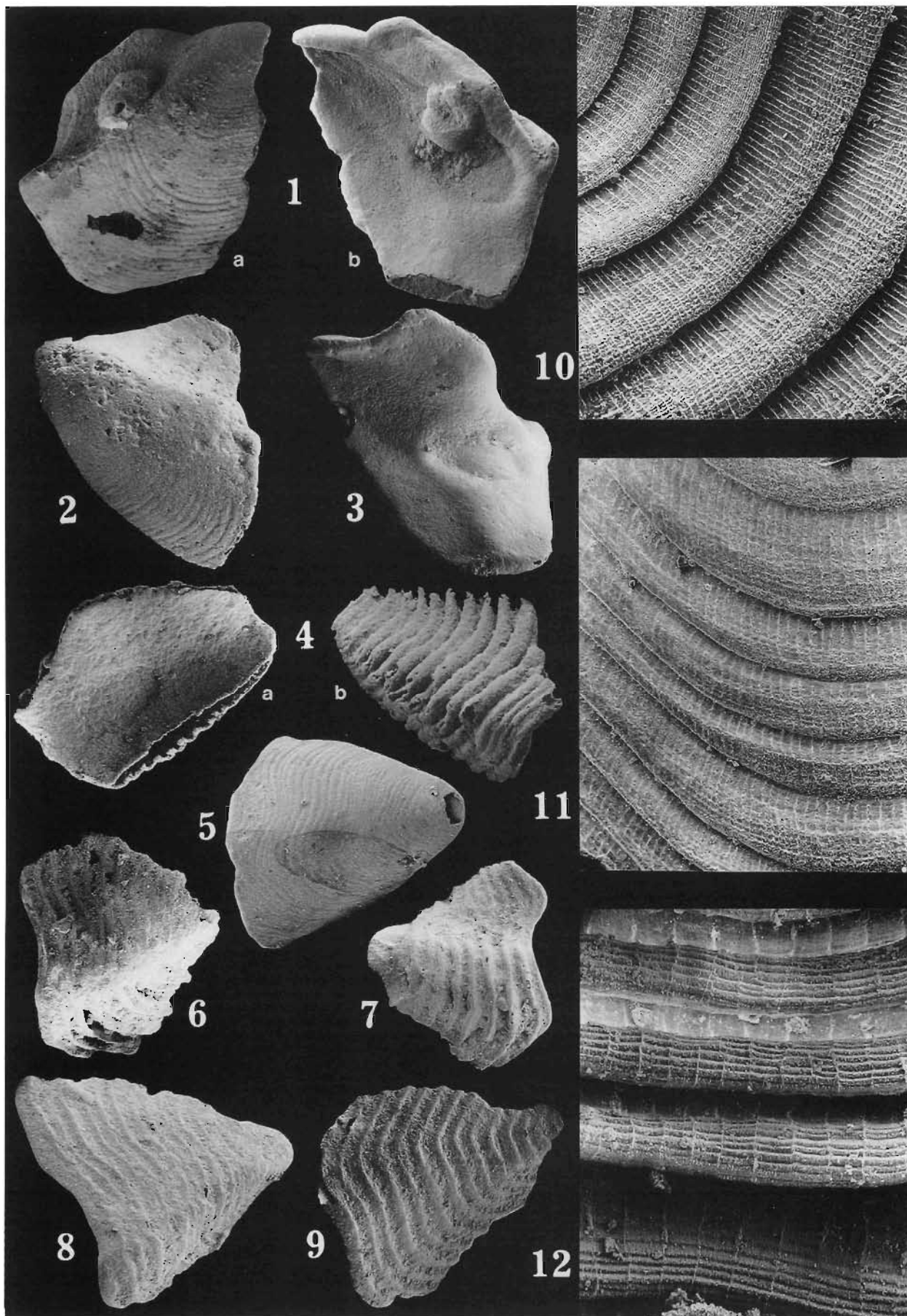
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PLATE 52

<i>Plicacoleus robustus</i> DZIK, 1986	220
Fig. 1. Dorsal sclerite ZPAL V.XII/3, sample MA-29, <i>E. robustus</i> Zone, Llanvirn, × 60.	
Fig. 2. Dorsal sclerite ZPAL V.XII/21, sample MA-52, × 60.	
Fig. 3. ZPAL V.XII/22, sample MA-52, × 60.	
<i>Mojczalepas multilamellosa</i> DZIK, 1986	218
Fig. 4a–b. Holotype ZPAL V.XII/2, sample MA-29, <i>E. robustus</i> Zone, Llanvirn, × 60.	
Fig. 6. Dorsal sclerite ZPAL V.XII/23, sample MA-99, × 60.	
Fig. 7. Dorsal sclerite ZPAL V.XII/24, sample MA-85, × 60.	
Fig. 12. Dorsal sclerite ZPAL V.XII/25, sample MA-85, interior of a phosphatic lining showing negative print of surface morphology of the sclerite, × 230.	
<i>Deltacoleus laevis</i> sp. n.	220
Fig. 5. Holotype, dorsal sclerite ZPAL V.XII/26, sample MA-43, × 60.	
<i>Deltacoleus</i> cf. <i>crassus</i> WITHERS, 1926	218
Fig. 8. Dorsal sclerite ZPAL V.XII/30, sample MA-99, × 60.	
Fig. 9. Dorsal sclerite ZPAL V.XII/27, sample MA-99, × 60.	
Fig. 10. Dorsal sclerite ZPAL V.XII/28, sample MA-99, interior of a phosphatic lining showing negative print of the surface morphology of the sclerite, × 230.	
<i>Aulakolepos elongatum</i> sp. n.	220
Fig. 11. ZPAL V.XII/29, sample MA-99, interior of a phosphatic lining showing negative print of the surface morphology of the sclerite, × 230.	

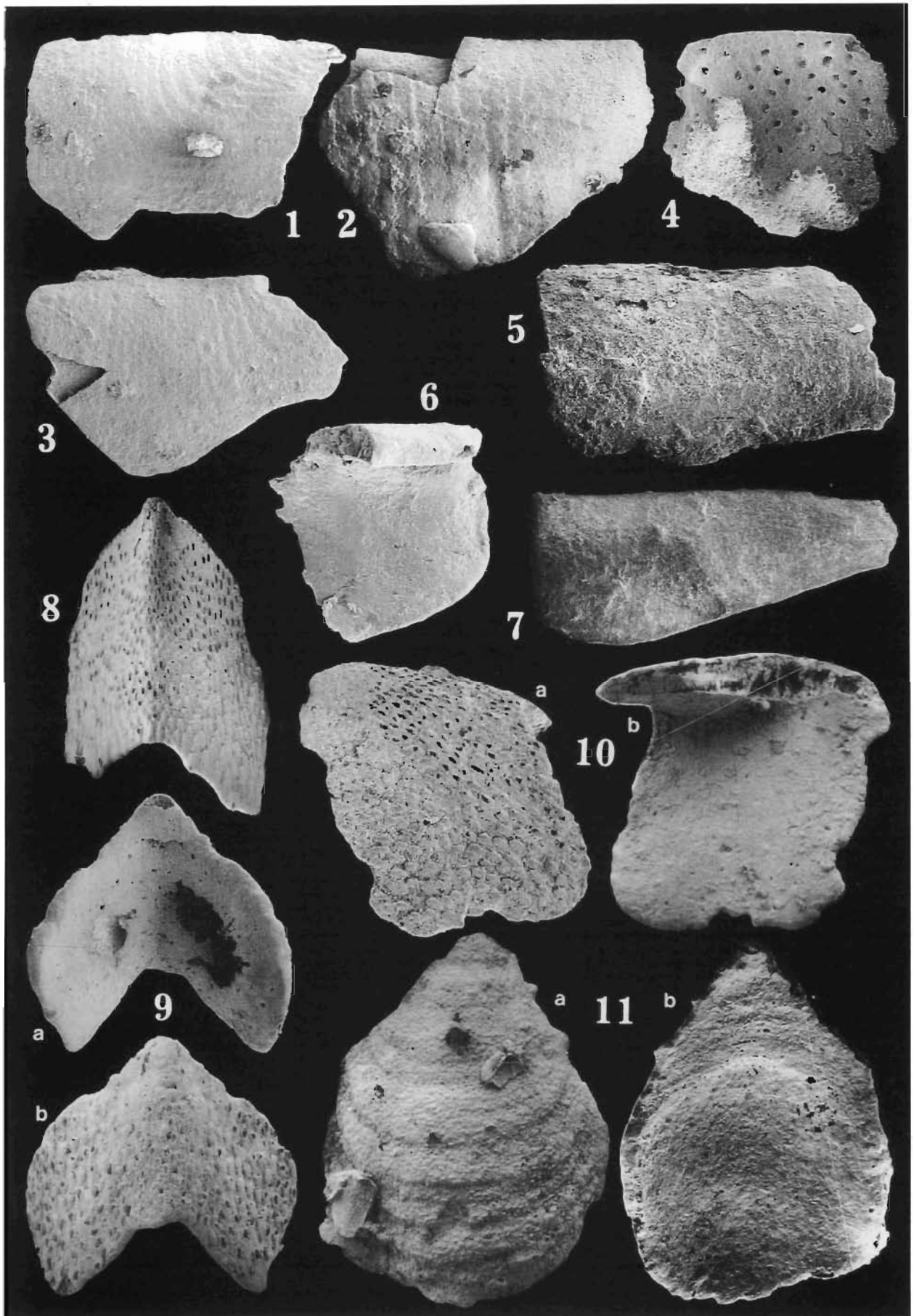


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PLATE 53

<i>Aulakolepos elongatum</i> sp. n.	220
Fig. 1. Holotype ZPAL V.XII/12, sample MA-85, × 60.	
Fig. 2. Dorsal sclerite ZPAL V.XII/13, sample MA-99, × 60.	
Fig. 3. Dorsal sclerite ZPAL V.XII/14, sample MA-85, × 60.	
<i>Bursata santacrucensis</i> sp. n.	224
Fig. 4. Intermediate valve ZPAL V.XII/15, inner side, sample MA-99, × 60.	
Fig. 5. Intermediate valve ZPAL V.XII/16, sample MA-99, × 60.	
Fig. 6. Intermediate valve ZPAL V.XII/17, sample MA-99, × 60.	
Fig. 7. Holotype, tail valve ZPAL V.XII/18, sample MA-99, × 60.	
<i>Sarkachiton kielcensis</i> sp. n.	222
Fig. 8. Intermediate valve ZPAL V.XII/19, sample MA-99, × 75.	
Fig. 9a–b. Holotype, intermediate valve ZPAL V.XII/10, sample MA-4, Late Caradoc, × 60.	
Fig. 10a–b. Intermediate valve ZPAL V.XII/20, sample MA-99, × 75.	
<i>Chelodes</i> sp.	224
Fig. 11a–b. Intermediate valve ZPAL V.XII/11, sample MA-4, × 75.	

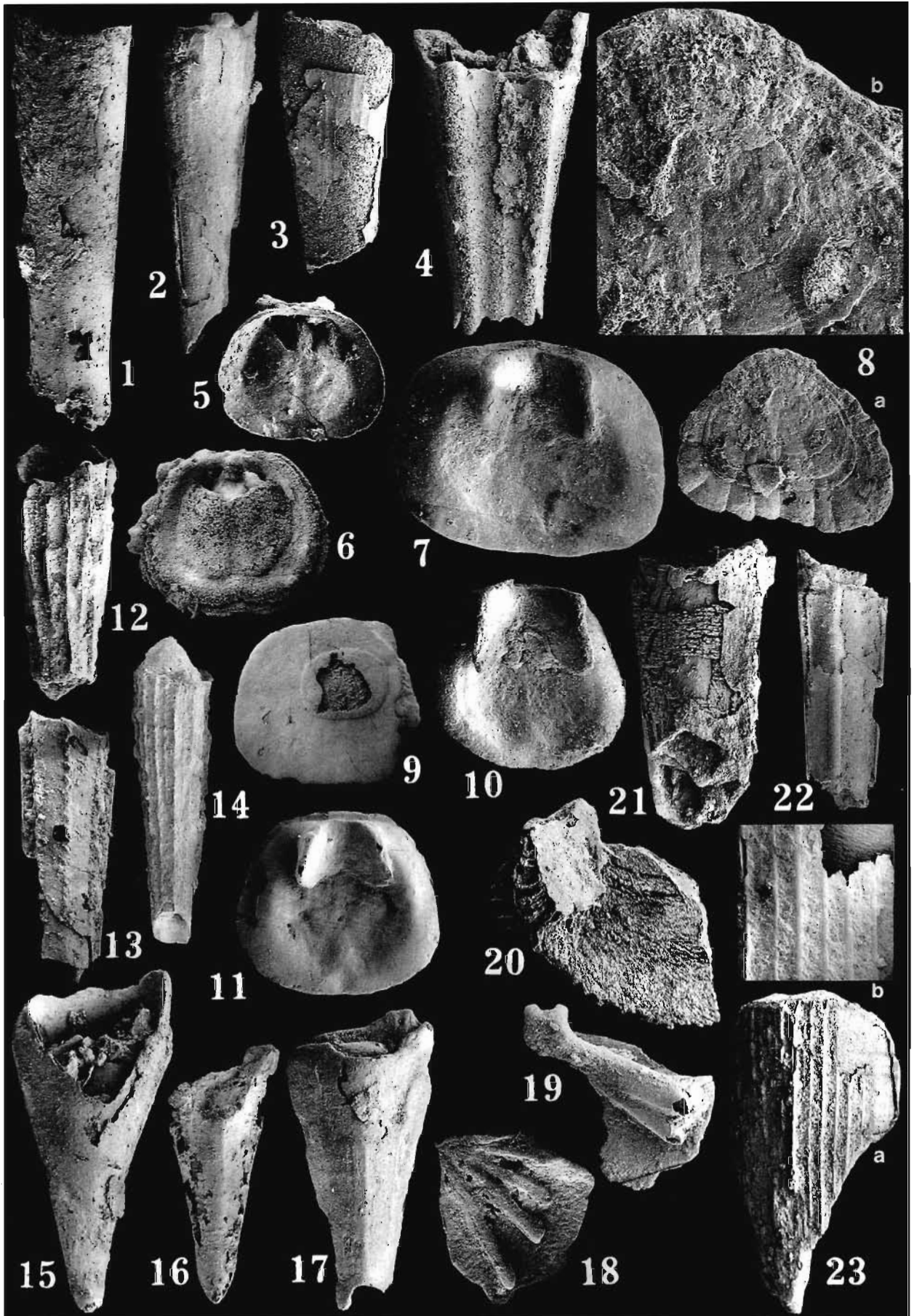


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PLATE 54

<i>Circotheca cf. neptis</i> MAREK, 1989	231
Fig. 1. Conch ZPAL Gal/47 with partially exfoliated phosphatic envelope, sample MA-99, × 40.	
<i>Carinolites</i> sp.	239
Fig. 2. Conch ZPAL Gal/ with partially exfoliated phosphatic envelope from ventral side, sample MA-99, × 60.	
Fig. 20. Operculum ZPAL Gal/54, sample MA-99, × 50.	
<i>Nephrotheca?</i> sp.	234
Fig. 3. Conch ZPAL Gal/38, sample MA-99, oblique ventral view, × 60.	
Fig. 21. Conch ZPAL Gal/40 with partially exfoliated envelope and phosphatized shell wall, sample MA-99, dorsal view, × 60.	
<i>Quadrotheca cf. aethetica</i> (MAREK, 1989)	236
Fig. 4. Conch ZPAL Gal/44 with phosphatized walls, sample MA-99, dorsal view, × 60.	
Figs 7, 9. Opercula ZPAL Gal/58,23, samples MA-99, 29, respectively, × 60.	
<i>Mojczatheca triangularis</i> gen. et sp. n.	233
Fig. 8. Operculum ZPAL Gal/55, sample MA-99, a × 60, b × 150.	
Fig. 22. Holotype, conch ZPAL Gal/45 with partially exfoliated phosphatic envelope, from dorsal side, sample MA-99, × 60.	
<i>Bactrotheca</i> sp. 1	235
Fig. 12. Conch ZPAL Gal/43, sample MA-99, dorsal view, × 60.	
Figs 5–6, 10–11. Opercula ZPAL Gal/56, 24, 23, 57, 25, samples MA-59, 18, 57, 30, respectively, all × 60.	
<i>Bactrotheca</i> sp. 3	236
Fig. 13. Conch ZPAL Gal/45, sample MA-99, dorsal view, × 60.	
<i>Bactrotheca</i> sp. 2	236
Fig. 14. Conch ZPAL Gal/42, sample MA-99, dorsal view, × 60.	
<i>Joachimilites</i> sp.	238
Fig. 15. Conch ZPAL Gal/39, sample MA-99, dorsal view, × 60.	
Fig. 19. Operculum ZPAL Gal/52, sample MA-99, × 60.	
<i>Recilites</i> sp.	240
Figs 16–17. Conchs ZPAL Gal/49, 48, sample MA-99, dorsal view, × 60.	
Fig. 18. Operculum ZPAL Gal/53, sample MA-99, × 60.	
<i>Bactrotheca cf. deleta</i> NOVAK, 1891	235
Fig. 23. Conch ZPAL Gal/37, sample MA-99, dorsal view, a × 60, b × 120.	

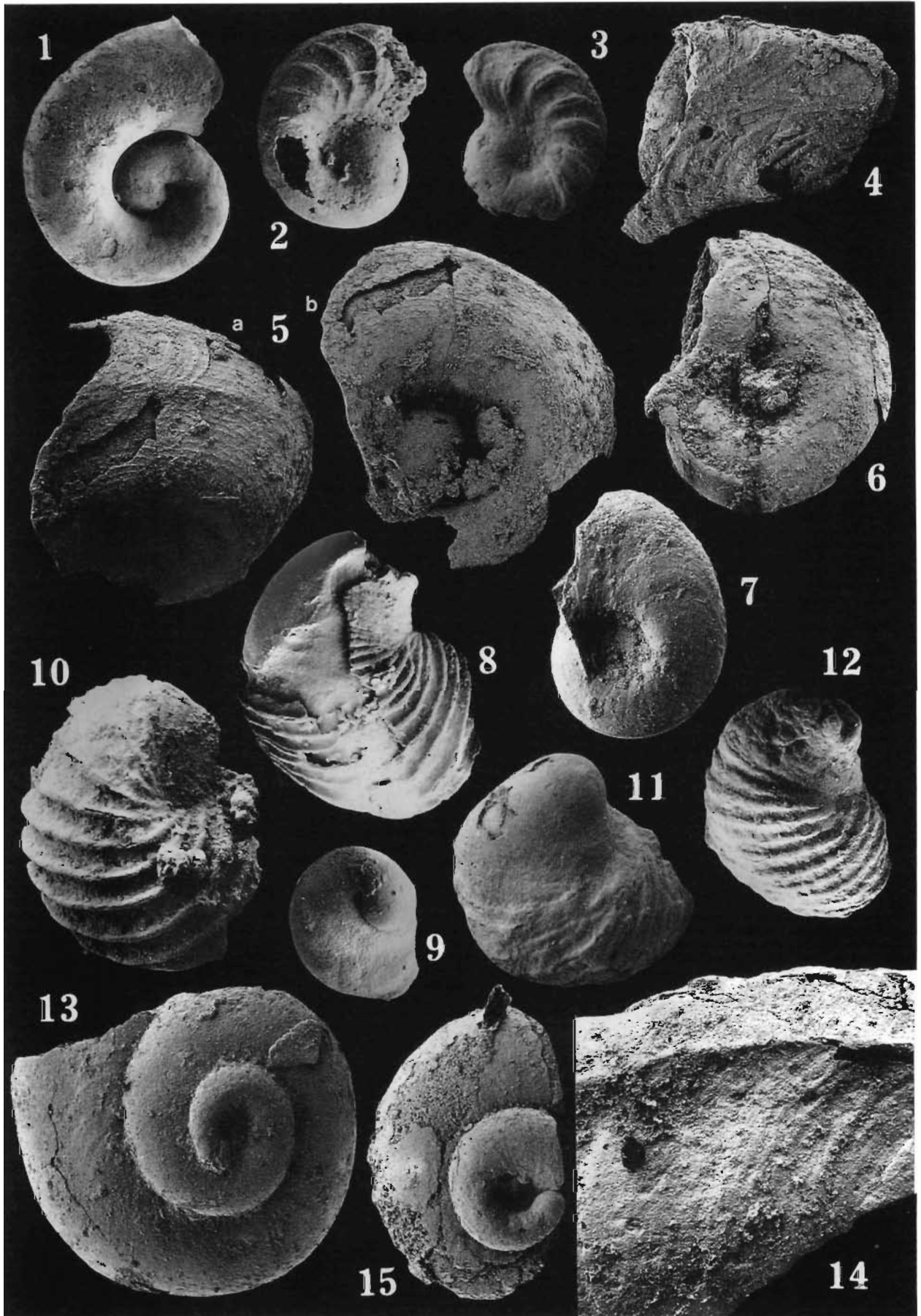


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PLATE 55

<i>Modestospira</i> sp.	226
Fig. 1. Phosphatic nucleus of a mature veliger(?) conch Ga 1/01, sample MA-5, × 60.	
Fig. 2. Phosphatic envelope Ga 1/037 of early postembryonic (veliger?) conch, sample MA-5, × 60.	
Fig. 3. Phosphatized early postembryonic (veliger?) conch Ga 1/, sample MA-4, × 60.	
<i>Tropidodiscus</i> sp.	228
Fig. 4. Fragmentary conch Ga 1/80, sample MA-99, × 60.	
Fig. 6. Ga 1/81, sample MA-99, × 60.	
<i>Kokenospira</i> sp. [cf. <i>K. esthona</i> (KOKEN)] or <i>Tetranota</i> sp.	228
Fig. 5a–b. Ga 1/62, sample MA-99, × 60.	
<i>Cyrtodiscus?</i> sp.	228
Fig. 7. Phosphatized conch Ga 1/82, sample MA-99, × 60.	
Fig. 14. Ga 1/83, sample MA-99, the specimen may represent a fragmentary pleurotomariid conch, × 60.	
<i>Mimospira</i> sp.	229
Fig. 8. Partially exfoliated envelope Ga 1/36, sample MA-20, × 60.	
Fig. 9. Phosphatic nucleus Ga 1/33, sample MA-10, × 60.	
Fig. 10. Conch in phosphatic envelope Ga 1/35, sample MA-4, × 60.	
Fig. 11. Ga 1/34, sample MA-29, × 60.	
Fig. 12. Phosphatized conch Ga 1/32, sample MA-15, × 60.	
<i>Umbonellina?</i> sp.	242
Fig. 13. Conch in phosphatic envelope Ga 1/68, sample MA-99, × 60.	
Fig. 15. Partially exfoliated envelope Ga 1/69, sample MA-99, × 60.	

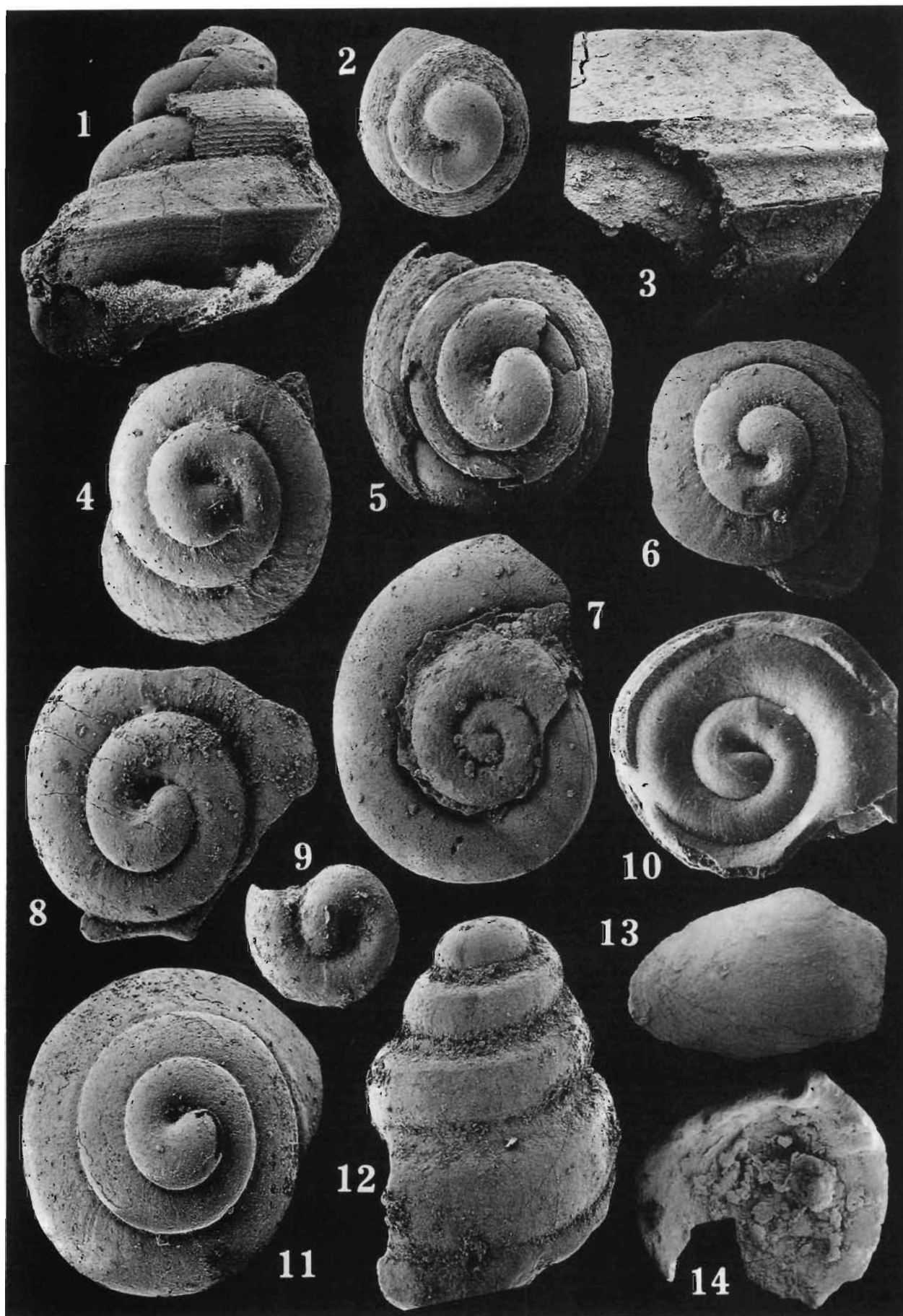


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PLATE 56

<i>Cyclonema?</i> sp.	244
Fig. 1. Partially exfoliated phosphatized conch Ga 1/77, sample MA-99, × 60.	
Fig. 2. Apex with distinct embryonic conch Ga 1/75, sample MA-99, × 60.	
Fig. 5. Partially exfoliated envelope Ga 1/79, sample MA-99, × 60.	
<i>Gyronema?</i> sp.	244
Fig. 3. Ga 1/78, sample MA-99, × 60.	
<i>Holopea</i> cf. <i>glindmeyeri</i> ROHR, 1980	246
Fig. 4. Ga 1/72, sample MA-99, × 60.	
Fig. 11. Ga 1/71, sample MA-99, × 60.	
<i>Holopea</i> cf. <i>brucei</i> ROHR, 1980	246
Fig. 6. Ga 1/67, sample MA-99, × 60.	
Fig. 9. Ga 1/73, sample MA-99, × 60.	
<i>Straparollina?</i> cf. <i>circe</i> BILLINGS, 1860	246
Fig. 7. Ga 1/61, sample MA-99, × 60.	
Fig. 8. Ga 1/70, sample MA-99, × 60.	
<i>Pachystrophia?</i> sp.	246
Fig. 9. Ga 1/73, sample MA-99, × 60.	
Fig. 10. Ga 1/2, sample MA-4, × 60.	
<i>Loxonema?</i> sp.	247
Fig. 12. Ga 1/76, sample MA-99, × 60.	
<i>Deceptrix?</i> sp.	249
Fig. 13. Left valve ZPAL Ga 1/, sample MA-4, × 60.	
<i>Nuculoidea?</i> sp.	250
Fig. 14. Right valve ZPAL Ga 1/, sample MA-4, × 60.	



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