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The endemic echinoids *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979, from the Santonian deposits of Korzkiew near Cracow (southern Poland); their ecology, taphonomy and evolutionary position

ABSTRACT: A relatively rich assemblage of the endemic echinoid species *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979, from the Santonian glauconitic marly clays exposed at Korzkiew near Cracow allowed to study its variability, life strategy, and taphonomy. The specimens of this species were well adapted to live in cohesive deposits, as they penetrated the sediment to a moderate depth, and fed on suspended material. A morphologic analysis of the tests, and stratigraphic ranges of the species, indicate that *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979, is a direct successor after *Micraster* (*Micraster*) *rogalae* NOWAK, 1909, within a separate branch of the evolutionary lineage of the genus *Micraster*. This endemic branch was developing since the Turonian as late as the Santonian/Campanian boundary.

INTRODUCTION

During the fieldwork in the years 1989-1990, undertaken by the author for his M. Sc. thesis (*see* KUDREWICZ 1991) under the supervision of Professor R. MARCINOWSKI, a special attention was paid to a Santonian deposit exposed at Korzkiew, and yielding ubiquitous echinoids. Most of them represent the endemic species *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979. The collected material allows to recognize the variability of this species, its ecology and taphonomy, as well as to conclude upon its phylogenic relationship. Thus, all these problems which were briefly outlined in the M. Sc. thesis (KUDREWICZ 1991), have been supplemented by further researches which realized in this contribution.

GEOLOGIC SETTING

At Korzkiew near Cracow, the exposed Cretaceous deposits represent an interval of the Upper Albian through Campanian which is featured by two stratigraphic gaps accented with abrasion surfaces (*see* Text-figs 1-2).

The Cretaceous deposits at Korzkiew have formerly been known from the exposure, situated as it was called "Above the castle" (Text-fig. 1, locality lettered *M*), where now only sandstone concretions of Albian age crop out, and where the collections of Santonian fossils came from (*see* HYNDA & MĄCZYŃSKA 1979, MAŁECKI 1980). Recently, a new section of Cretaceous deposits has been exposed, about 1400m to the former, and called "U Krzywdy" (arrowed *in* Text-fig. 1*A*).

The oldest deposits exposed in this new section (Text-fig. 2) are the Middle Cenomanian conglomerates capped with a thin stromatolite. These sediments are truncated by the first abrasion surface, and overlain by the Middle Turonian glauconitic marls (*see* KUDREWICZ 1991). These marls are truncated by the second abrasion surface, which is sculptured by the *Thalassinoides*-type burrows (*see* Text-figs 2-3) and fissures likely to be the neptunian dykes.

Above the Middle Turonian glauconitic marls, there occurs a layer of glauconitic marly clays containing numerous echinoids, as well as belemnites *Actinocamax verus* MILLER and *Gonioteuthis westfalica-granulata* (STOLLEY), indicative of presumably Middle Santonian age of the deposit. This very deposit fills both the *Thalassinoides*-type burrows and neptunian dykes penetrating the Middle Turonian substrate.

The Santonian glauconitic marly clays are a gray-green plastic rock which is composed of calcareous mud, clay minerals (illite and kaolinite) and quartz silt. The rock is grain supported, and the grain particles make about 70% of rock volume. Oval grains of glauconite, 0.1 - 1 mm in size, make about 30% of thin section surface. Calcareous detrital particles, composed of oval or circular grains (about 1 mm in size), reach up to 40%; grains of quartz (to 0.3 mm large), make about 2.5% (see Pl. 4, Fig. 1).

An assemblage of the echinoids from these glauconitic marly clays consists of the following species: *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979 — 77 specimens (i.e. 86% of the collection); *Conulus albogalerus* KLEIN, 1734 — 1 specimen; *Echinocorys vulgaris* BREYNIUS, 1734 — 2 specimens; *Echinocorys* sp. — 1 specimen.

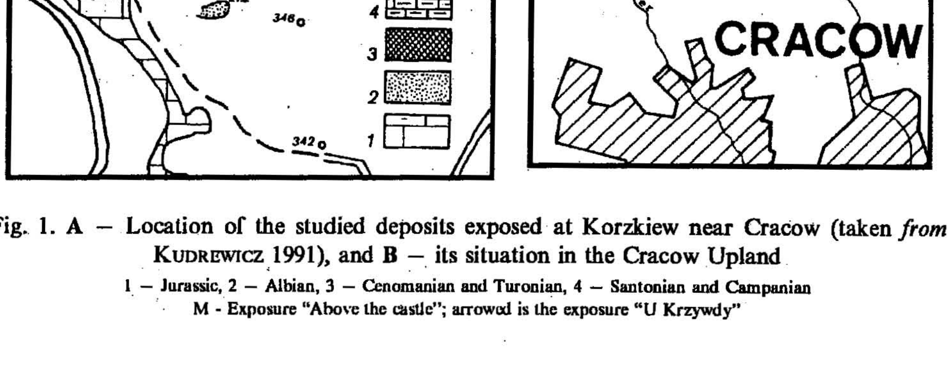

Fig. 1. A — Location of the studied deposits exposed at Korzkiew near Cracow (taken *from* KUDREWICZ 1991), and B — its situation in the Cracow Upland

1 — Jurassic, 2 — Albian, 3 — Cenomanian and Turonian, 4 — Santonian and Campanian
M - Exposure "Above the castle"; arrowed is the exposure "U Krzywdy"

The specimens of *Micraster* (*Micraster*) *maleckii* have rarely their tests well preserved, and the majority are preserved poorly, devoid of tests, or as moulds. The specimens rest in the rock in variable positions: 40% normal, as many reversed, and the rest on their side (*see* Text-fig. 3).

All the echinoid tests are filled with another kind of sediment than that they are resting in (*see* Text-fig. 5). Except of the calcareous mud, clay minerals (illite and kaolinite) and glauconite, there occur some minerals of the apatite group, but there is no quartz silt. The rock is mud supported and grain particles make less than 50%. Glauconite in the shape of oval or circular grains (0.4 - 0.9 mm in size) makes meanly 4.3% (with max. value of 10%). Organic particles consist of fragmented sponge spicules substituted with $CaCO_3$, benthic foraminifers, and planktic organisms. They make about 17% of thin sections in average (with max. value of 40%). Relationships between organic particles are varying. Some regularity is seen in greater concentration of organic particles in the oral parts of the echinoid tests. The rock is impregnated with finely dispersed and inequally concentrated chalcedony (*see* Pl. 4, Fig. 2). Some echinoid tests are completely phosphatized, but the others have more phosphates in their outer parts than in the center.

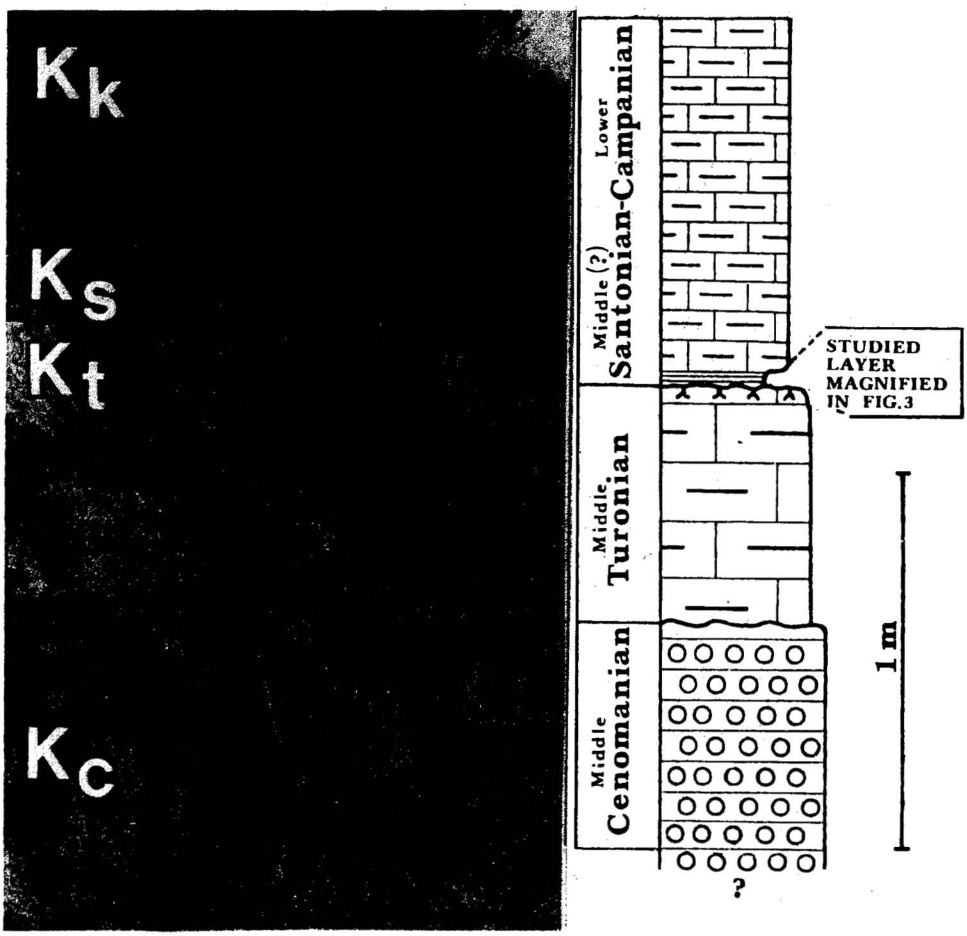

Fig. 2. Scenery of the exposure at Korzkiew near Cracow, to show the section exposed; photo by the Author

K_c - Middle Cenomanian, K_t - Middle Turonian, K_s - Middle(?) Santonian, K_k - Lower Campanian

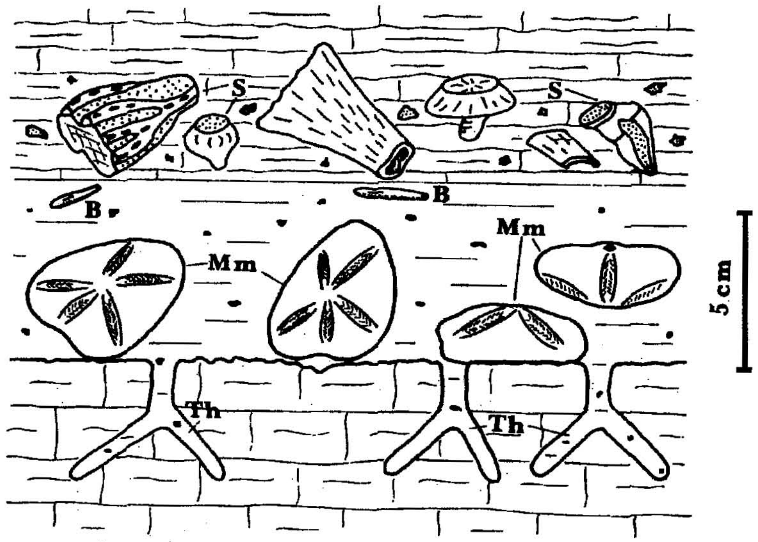

Fig. 3. Distribution of fossils in the Middle(?) Santonian glauconitic marly clays at Korzkiew near Cracow (magnified part of the section presented in Text-fig. 2)
Mm — *Micraster (Micraster) maleckii* MĄCZYŃSKA, 1979; **B** — belemnites *Gonioteuthis westfalica-granulata* (STOLLEY, 1892) and *Actinocamax verus* MILLER, 1823; **S** — sponges; **Th** — *Thalassinoides*-type burrows

The beds overlying gray glauconitic marly clays begin with a layer replete with silicified and phosphatized sponges, all of which are broken and bear traces of redeposition (*see* Text-fig. 3; *and* MAŁECKI 1980).

SYSTEMATIC ACCOUNT

Order **Spatangoida** CLAUS, 1876
Suborder **Micrasterina** A.G. FISCHER, 1966
Family **Micrasteridae** LAMBERT, 1920

Genus *Micraster* L. AGASSIZ, 1836
Subgenus *Micraster* L. AGASSIZ, 1836

Micraster (Micraster) maleckii MĄCZYŃSKA, 1979
(Plates 1-3)

1979. *Micraster (Micraster) maleckii* sp. n. MĄCZYŃSKA; V.A. HYNDA & S. MĄCZYŃSKA, p. 22; Pl. 1, Figs 1-2; Pl. 2, Figs 1-3; Pl. 3, Figs 1-2.

1984. *Micraster (Micraster) maleckii* MĄCZYŃSKA, 1979; S. MĄCZYŃSKA *in* L. MALINOWSKA [*Ed.*], p. 456; Pl. 214, Figs 1-3.

MATERIAL: 77 well preserved specimens, some of them with complete and nearly complete test; 6 of them are recognized as juvenile forms.

DESCRIPTION: Tests averaging 52.54 mm in length, 53.49 mm in width and 30.26 mm in height. Values of W/L and H/L indexes mean 1.018 and 0.577 (*see* Text-fig. 4). Test oval to heart-shaped in outline. Anterior groove wide and not too deep. Longitudinal profile uniformly convex; base large and flat. Transverse profile conical, slightly flattened. Apex slightly depressed.

Apical system ethmophract, slightly elongated, formed by 4 genital and 5 ocular plates with a large madreporite, sometimes overgrowing the genital plates. Madrepores very fine.

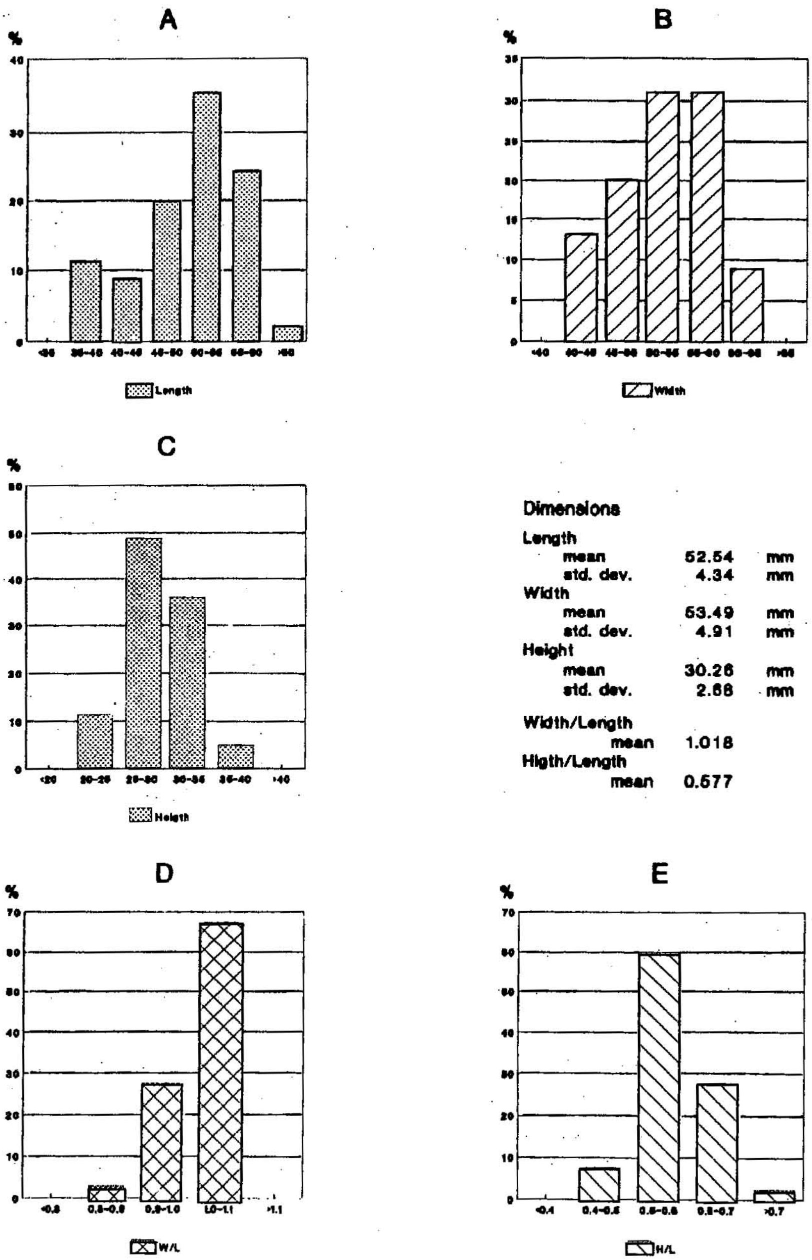

Fig. 4. Dimensions of tests of *Micraster (Micraster) maleckii* MĄCZYŃSKA, 1979, from Korzkiew and their statistical distributions

Ambulacra heteromorphic. Petals large, varying in length, the paired posterior shorter than the anterior ones. Plastron amphisternal. Labrum plate wide and large. Peristome transversally oval. Periproct large, circular or ovally elongated, situated in the upper part of the anal area.

Subanal fasciola well developed, composed of very fine granules arranged in the form of a closed ring. Ornamentation of the test uniform and better developed on the adoral surface.

OCCURRENCE: Endemic species of the Cracow area; recorded from the Santonian of Korzkiew and Januszowice (HYNDA & MĄCZYŃSKA 1979), and Lower Campanian of Januszowice (*see* KUDREWICZ 1991).

ECOLOGY

The specimens of the species *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979, adapted to live in a cohesive sediment. They especially protected their stone canal and ambulacral system against silting, by developing a large madreporite overgrowing the genital plates and featured by numerous, very small madrepores.

The investigated species *Micraster* (*Micraster*) *maleckii* is thus thought to have lived endobenthically in the unconsolidated sediment (*see* Text-fig. 5*A*). Since the Recent Spatangoida from the Adriatic echinofacies *Echinocardium* + *Spatangus* live at depths of 12 to over 20 meters (ERNST 1973), it may be assumed that the discussed species inhabited the comparable depths.

The flattening value of the test, expressed by H/L index, bespeaks what was the sediment penetration depth (*see* SMITH 1984), as the more flattened forms penetrated deeper than the more conical ones. The development of the subanal fasciola is concomitant with the evolutionary flattening of the test (*see* ERNST 1972, SMITH 1984). As the H/L index indicates, the specimens of *Micraster* (*Micraster*) *maleckii* did not burrow so deeply as its evolutionary ancestors, although they had well developed subanal fasciola, surely owing to large dimensions of their body (*see* GOLDRING & STEPHENSON 1970).

As the food source and kind of feeding of the endobenthic echinoids determine the size of the anterior groove and the developing of the labrum plate (NICHOLS 1959, SMITH 1984), it is to indicate that the specimens of *Micraster* (*Micraster*) *maleckii* have a wide but rather shallow groove and the well developed labrum plate. It may thus be supposed that the major part of their food came from suspension and was carried into the mouth along the anterior groove (*see* NICHOLS 1959).

Similarly as in the other *Micraster* assemblages (*cf.* ERNST 1970a), no other fully endobenthic echinoids were found in association with the discussed species *Micraster* (*Micraster*) *maleckii*. The collected specimens (*see* Pl. 1, Fig. 2 and Pl. 4, Fig. 3) of *Conulus albogalerus* KLEIN and *Echinocorys vulgaris* BREYNIUS lived rather epibenthically (*see* ERNST 1970a).

Statistical distribution of body size of *Micraster* (*Micraster*) *maleckii* from Korzkiew is close to monomodal symmetric distribution, but it is lacking small and very small forms. A low representation of the smallest forms can be the

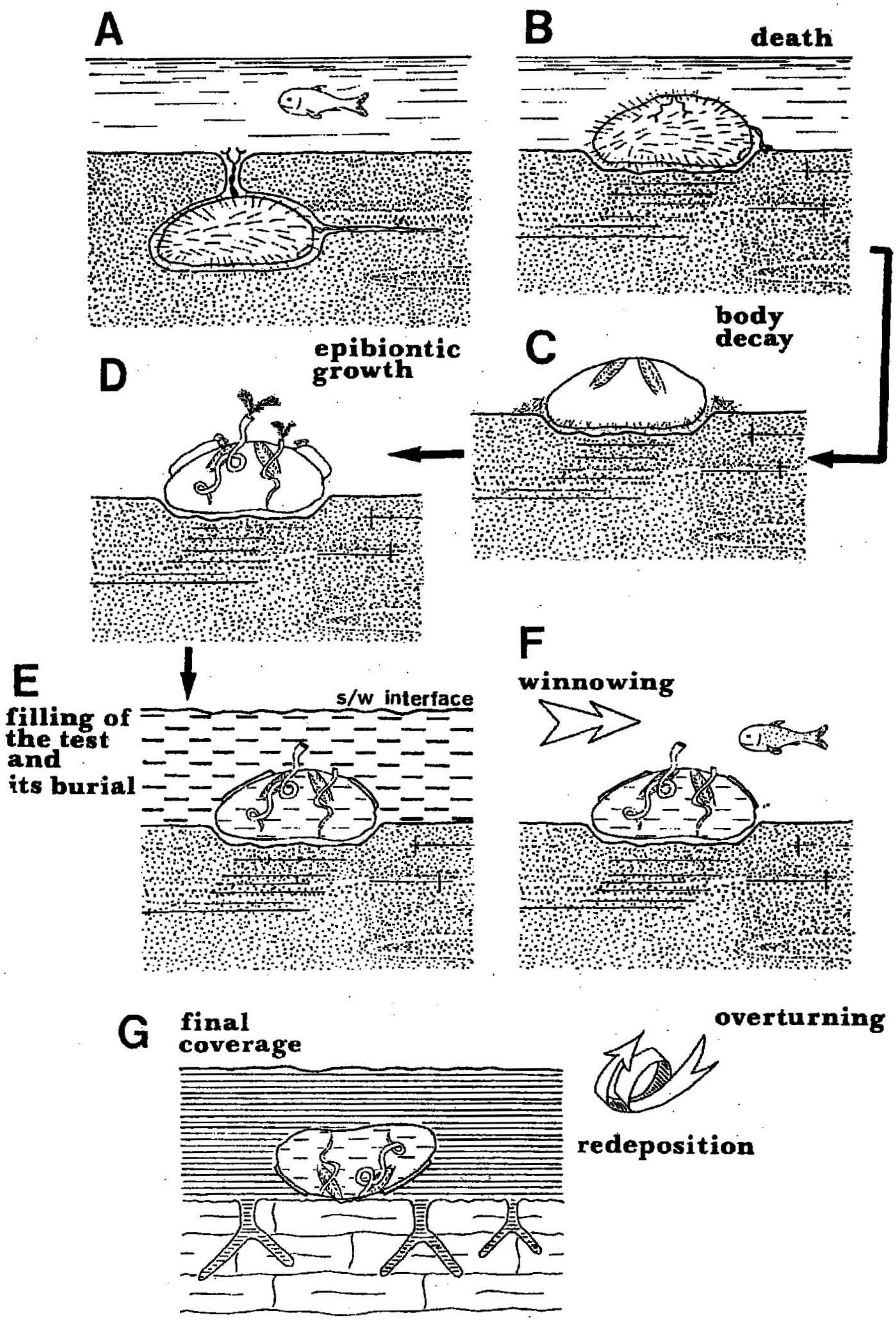

Fig. 5. Taphonomy of *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979, from Korzkiew; detailed explanation in the text

effect of other environmental and feeding preferences by young and adult forms. The phenomenon of inhabiting different biotopes by young and adult echinoids was observed in some Recent assemblages (*see* ERNST 1973).

TAPHONOMY

The preservation state of the specimens *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979, namely a lack of traces of crushing or drilling by the predators, speaks about the senescence as a predominant reason of their death. It is likely that these echinoids came onto the deposit surface quite before their death (*see* Text-fig. 5*B*). The sudden death as an effect of coverage by the sediment is excluded (*see* SMITH 1984), because the spines, periproctal plates and in most cases apical system plates have been lost before the burial.

After the death, echinoid remains were rather not damaged by scavengers, and the tests filled by the gas products were suspended and transported in the water, as it concerns the Recent cases (*see* ERNST 1973).

After decomposition of the skin and loosing the spines (Text-fig. 5*C*), and in the case of the floating specimens after their settling, the echinoid tests were overgrown by numerous epibenthic organisms (*see* Text-fig. 5*D*). The attached shells and/or traces of attachment of the bivalves *Atreta* sp. are observed on 40% of the collected specimens. About 20% specimens bear traces of adherence of the polychaetes, mostly of the serpulids, which were settling both on the outer surface as well as inside the tests (*see* Pl. 3, Figs 2a-2b). Later, the tests were filled and buried by the marly sediment (Text-fig. 5*E*).

The buried echinoid tests have subsequently been exhumed due to winnowing (Text-fig. 5*F*) and redeposited into local depressions of the bottom, where the decaying organic material was concentrated. In such places, in conditions of oxygen minimum and ascended pH, gel composed of organic material and rich in phosphates was formed. These phosphates were liberated in desintegration processes of albumins and RNA with participation of denitrifying bacteria (*see* PIPER & CODISPOTI *in* SCHOPF 1980). In slightly alcaline conditions phosphates reacted with $CaCO_3$ forming calcium phosphates (*see* GOLONKA & RAJCHEL 1972, KRAJEWSKI 1984). A process of substitution carbonate ions with phosphate ones in marly material filling the echinoid tests, resulted in a total phosphatization of these fossils still lying uncovered on the bottom.

When the sedimentation returned, the phosphatized echinoid tests and their infilling were buried again within the clay-marly deposit (Text-fig. 5*G*). Under the sediment surface diagenetic processes were in progress, some kinds of apatite-group minerals crystallizated, and silification took place.

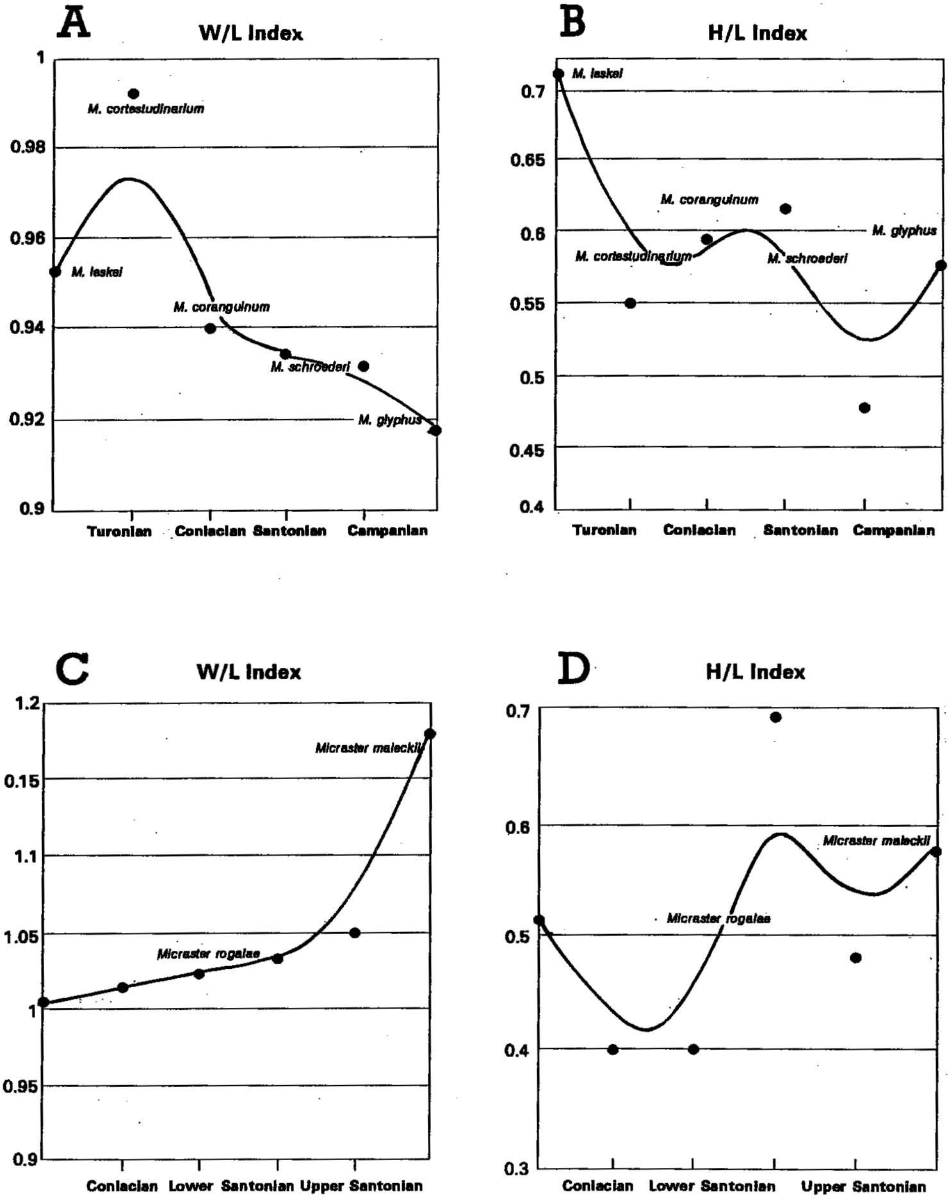

Fig. 6. Variation of values of W/L and H/L indexes in the evolutionary lines of the genus *Micraster*
A, B — The *Micraster* Main Line, **C, D** — The *Rogalae-maleckii* Line; points represent mean values
Species succession in the *Micraster* Main Line *after* ERNST (1970b, 1972); measurements *after* MĄCZYŃSKA (1968, 1984, and *in* HYNDA & MĄCZYŃSKA 1979) and Author's own data

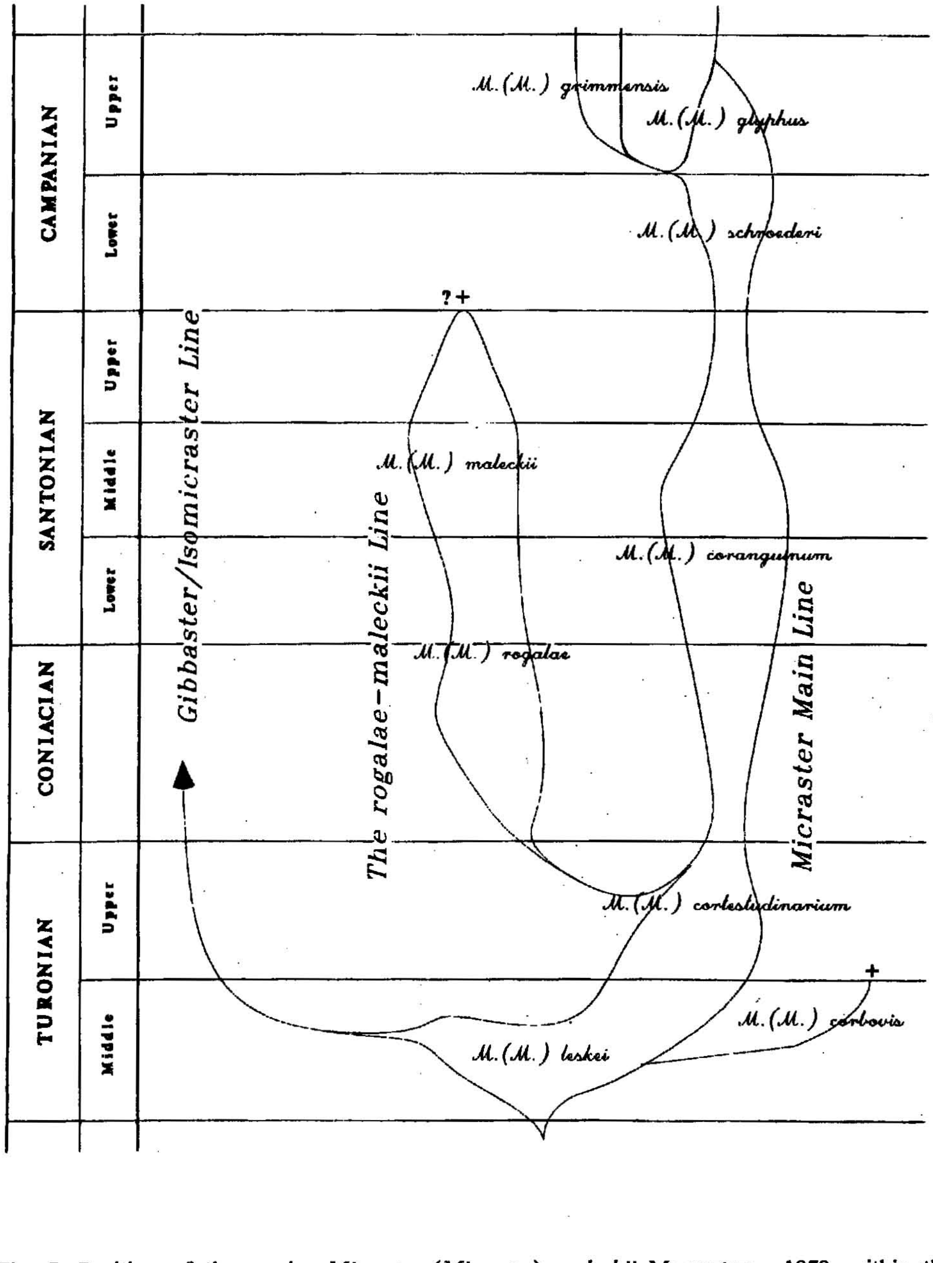

Fig. 7. Position of the species *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979, within the evolutionary lineages of the genus *Micraster*; adopted *from* ERNST (1970b, 1972)

EVOLUTION

The comparison of W/L and H/L indexes between the *Micraster* Main Line and the *Rogalae* Line, the both constructed by ERNST (1970b, 1972), indicate that the species (*see* NOWAK 1909, HYNDA & MĄCZYŃSKA 1979) *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979, and *Micraster* (*Micraster*) *rogalae* NOWAK, 1909, differ only in size and value of W/L and H/L index. The W/L index varies consequently in the *Rogalae* Line (*see* Text-fig. 6*A*,*C*) and variation of H/L indexes is very similar in both lines (*see* Text-fig. 6*B*,*D*). The peristome of *Micraster* (*Micraster*) *maleckii* is situated a bit nearer to the anterior part of the test as it is in *Micraster* (*Micraster*) *rogalae*, what corresponds with a peristome-moving-forward trend observed in the *Micraster* Main Line (*see* NICHOLS 1959, ERNST 1970b, SMITH 1984).

The above given comparisons allow to recognize that *Micraster* (*Micraster*) *maleckii* is a direct successor after *Micraster* (*Micraster*) *rogalae* in a separate evolutionary line continuing from the Turonian/Coniacian boundary to the Lower Campanian (Text-fig. 7). The species *Micraster* (*Micraster*) *maleckii* is herein regarded as one evolved from the species *Micraster* (*Micraster*) *rogalae*, to adapt to the stressed environmental conditions that have prevailed in marginal parts of the Santonian sea. This evolutionary line is herein called the *Rogalae-maleckii* Line.

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ENDEMICZNE JEŻOWCE *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA Z SANTONU KORZKWI

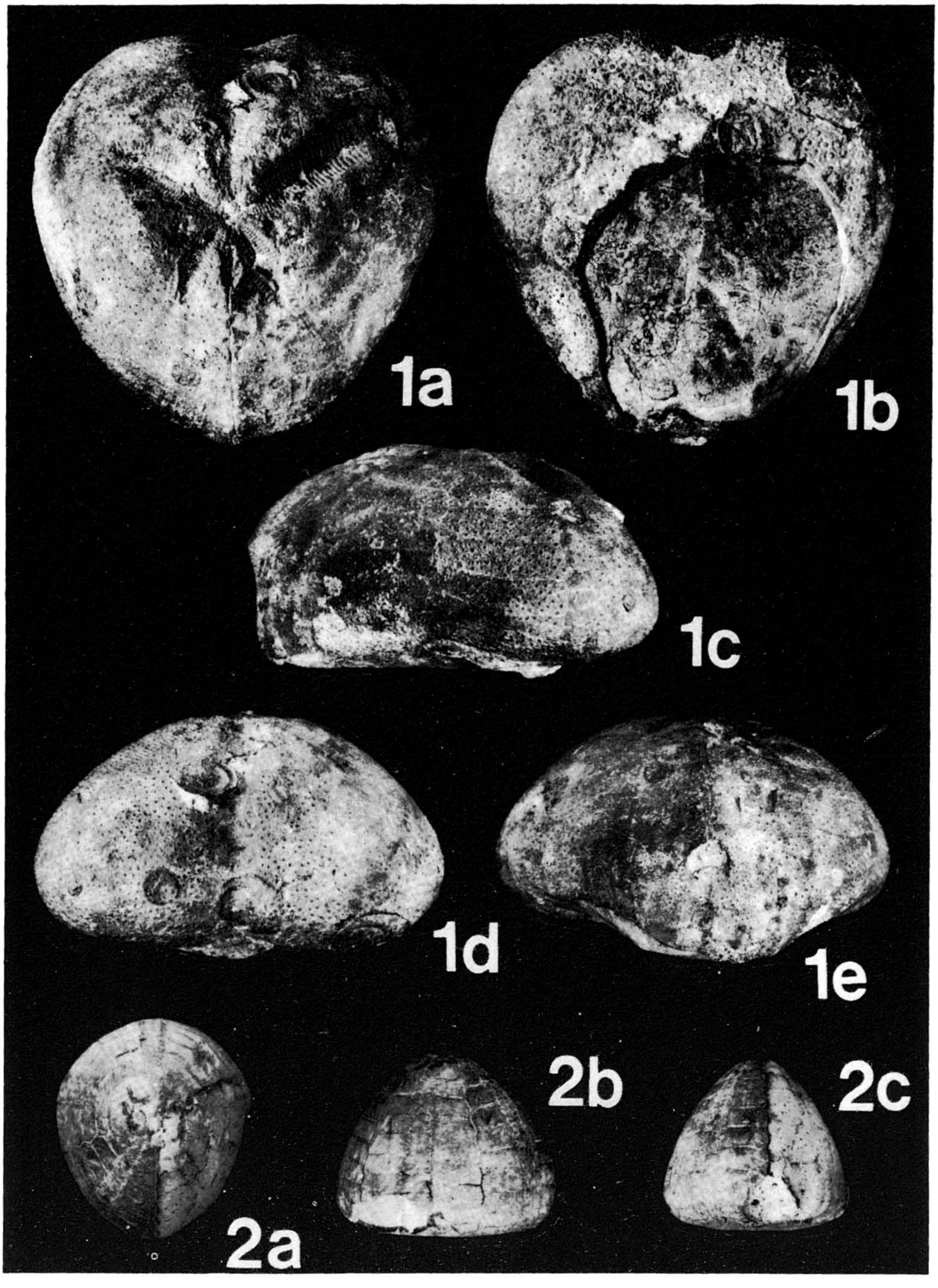
(Streszczenie)

Zebrana w czasie wykonywania pracy magisterskiej (KUDREWICZ 1991) kolekcja jeżowców *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979, z nowego odsłonięcia osadów santonu w Korzkwi koło Krakowa, gdzie występują one masowo (*patrz* fig. 1-3 oraz pl. 1-4) stała się podstawą szerszej analizy tego endemicznego gatunku.

Morfologia pancerza badanych jeżowców (*patrz* fig. 4) wskazuje na ich daleko idące przystosowanie do życia w osadzie kohezyjnym, co wyrażało się niezbyt głęboką penetracją osadu i odżywianiem się pokarmem pochodzącym z zawiesiny.

Po śmierci jeżowców szczątki ich ulegały rozkładowi na dnie i były porastane m.in. przez wieloszczety i małże. Po okresowym zagrzebaniu w osadzie, były wymiatane i redeponowane, zaś w miejscu złożenia ulegały fosfatyzacji. Ostatecznie przykryte osadem ilasto-marglistym (*patrz* fig. 5) podlegały dalszym przemianom diagenetycznym, m.in. częściowej sylifikacji.

Analiza morfologii pancerzy oraz interpretacja przystosowania ekologicznego i rozprzestrzenienia wiekowego wskazuje na bezpośrednie następstwo gatunku *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979, po gatunku *Micraster* (*Micraster*) *rogalae* NOWAK, 1909, w bocznej (endemicznej) linii ewolucyjnej rodzaju *Micraster* rozpoznanej przez ERNSTA (1970), a sięgającej od turonu do kampanu (*patrz* fig. 6-7).

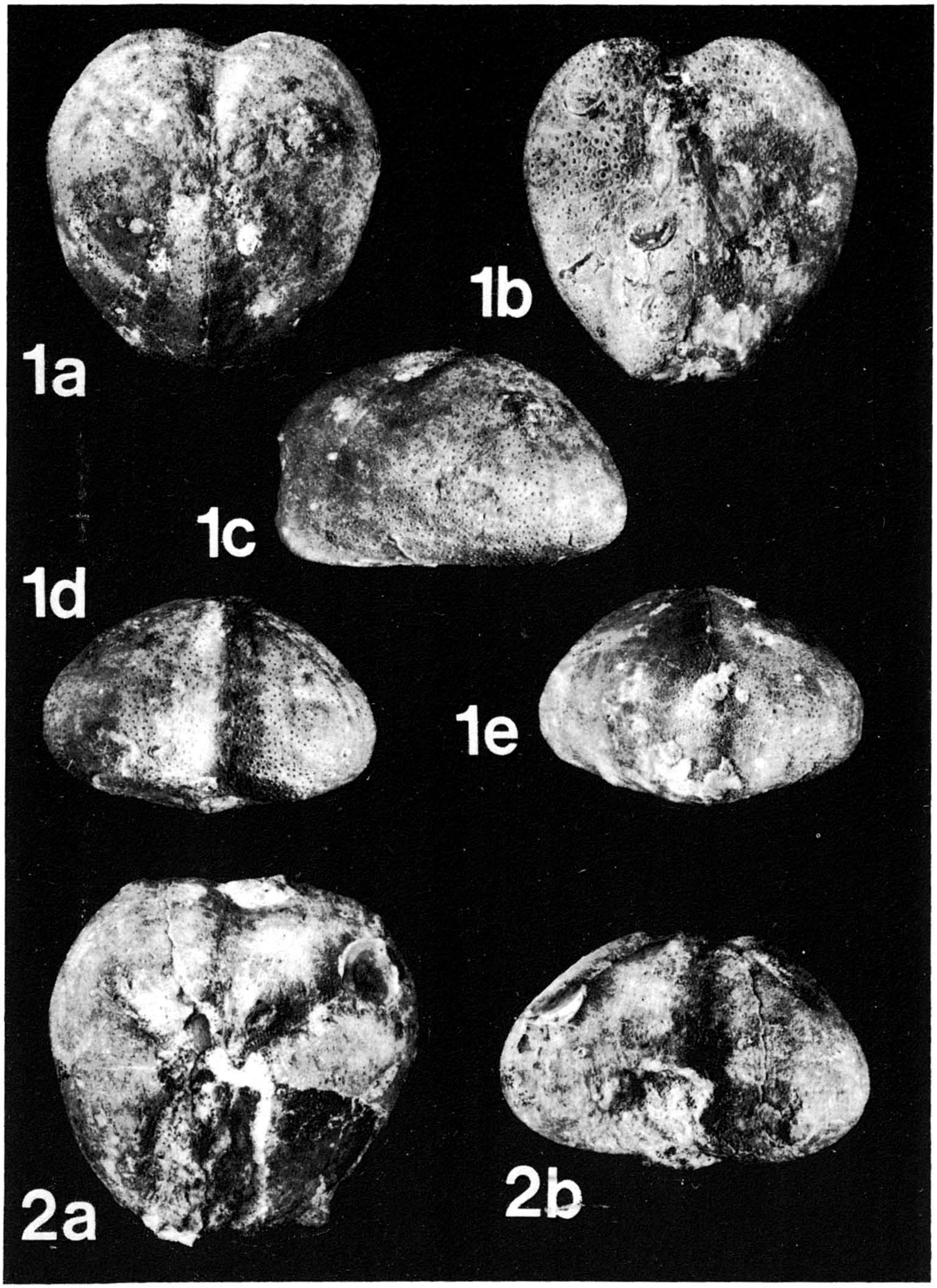


Middle(?) Santonian echinoids from Korzkiew

1 — *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979; one of the largest specimens, with numerous attachment traces of bivalves *Atreta* sp. and serpulids (in Fig. 1a settled in A1 and A3 ambulacra); 1a - aboral, 1b - adoral, 1c - lateral, 1d - anterior, 1e - posterior view

2 — *Conulus albogalerus* KLEIN, 1734; 2a - aboral, 2b - lateral, 2c - posterior view

All photos in nat. size; taken by S. KOLANOWSKI

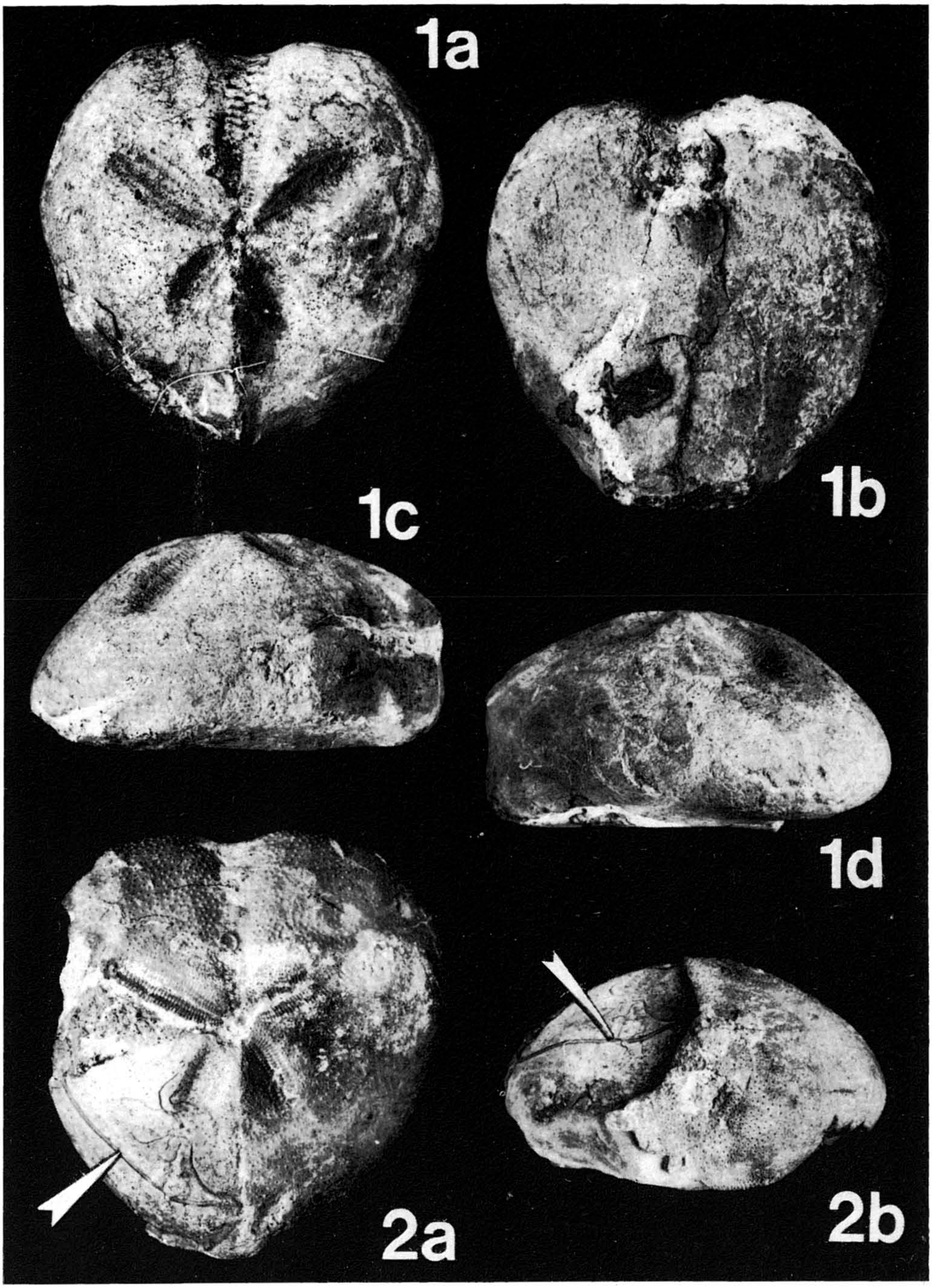


Middle(?) Santonian echinoids from Korzkiew

1 – *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979; one of the smallest specimens, with epibionthic bivalves *Atreta* sp. on the adoral side; 1a - aboral, 1b - adoral, 1c - lateral, 1d - anterior, 1e - posterior view

2 – Epibionthic bivalves *Atreta* sp. on a corroded test of *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979; 2a - aboral, 2b - anterior view

All photos in nat. size; taken by S. KOLANOWSKI

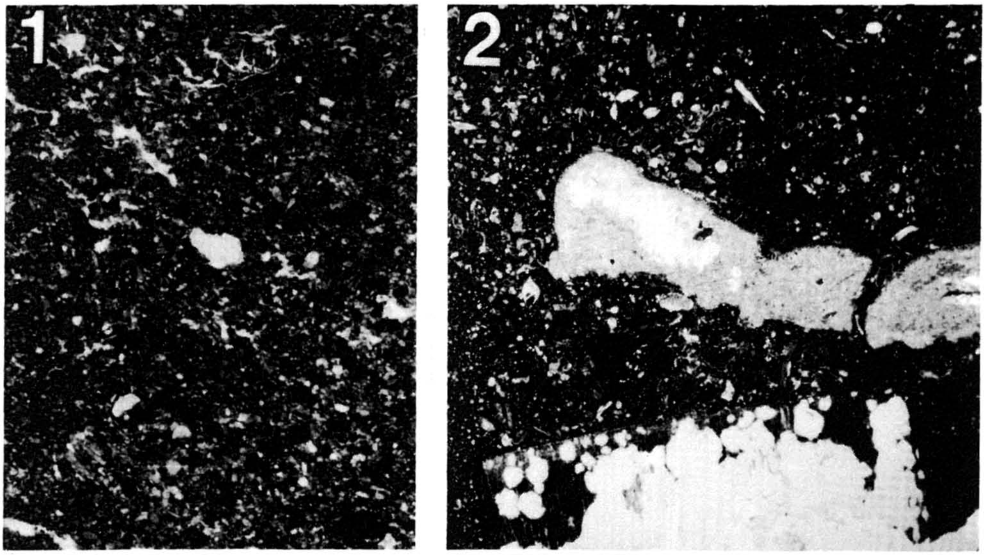


Middle(?) Santonian echinoids from Korzkiew

1 — *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979 - internal mould; 1a - aboral, 1b - adoral, 1c - left lateral, 1d - right lateral view

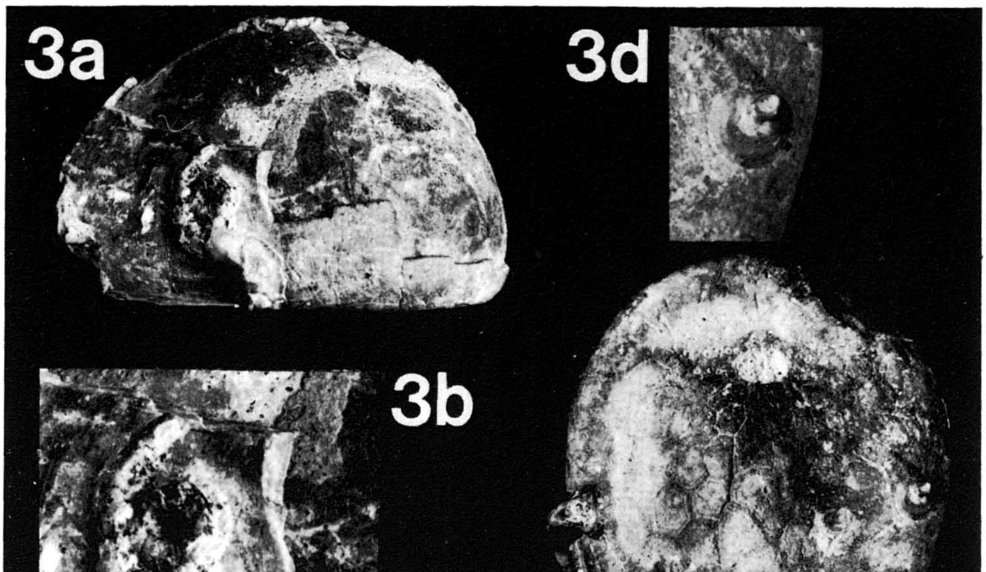
2 — *Micraster* (*Micraster*) *maleckii* MĄCZYŃSKA, 1979, with attachment traces of serpulids inside the test (arrowed on the mould) and on the test (in iA2 interambulacrum); 2a - aboral, 2b - posterior view

All photos in nat. size; taken by S. KOLANOWSKI



Middle(?) Santonian echinoid-bearing deposits from Korzkiew

1 – General view of the glauconitic marly clays; black small grains - glauconite; taken by the Author, × 7
2 – Filling of a *Micraster* test with phosphatized and silificated fragments of its test (white spots in the fragmented test - chalcedony); in the right part, numerous foraminifers; black grains - glauconite; taken by the Author, × 7



Middle(?) Santonian echinoid from Korzkiew

3 – *Echinocorys vulgaris* BREYNIUS, 1734, with epibionthic serpulids: 3a - lateral right view, nat. size; 3b - close-up × 2; 3c - adoral view, nat. size; 3d - close-up × 2; photos by S. KOLANOWSKI