Acta Geologica Polonica, Vol. 57 (2007), No. 1, pp. 1-87

Late Cretaceous (Turonian – Coniacian) irregular echinoids of western Kazakhstan (Mangyshlak) and southern Poland (Opole)

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ABSTRACT:

OLSZEWSKA-NEJBERT, D. 2007. Late Cretaceous (Turonian – Coniacian) irregular echinoids of western Kazakhstan (Mangyshlak) and southern Poland (Opole). *Acta Geologica Polonica*, **57** (1), 1-87. Warszawa.

During the Late Cretaceous, both Mangyshlak and the Opole area were part of the North European Province, and irregular echinoid faunas during the Turonian and Coniacian in both areas were dominated by holasteroids and spatangoids, in particular by *Plesiocorys*, *Echinocorys* and *Micraster*.

Almost 1,000 specimens from both areas have been studied. Taxonomically more varied are the faunas from Mangyshlak (15 species in 6 genera); the Opole assemblages comprise 9 species in 3 genera. One species, *Micraster* (*Micraster*) *praerogalae*, a transitional form between *Micraster* (*Micraster*) *cortestudinarium* (GOLDFUSS) and *Micraster* (*Micraster*) *rogalae* NOWAK, is described as new. *Micraster* (*Micraster*) *rogalae* is markedly diachronous within the North European Province, first appearing in the late Coniacian in Mangyshlak and reaching central and western Europe during the late Early Santonian. A similar pattern is revealed by a large morphotype of *Echinocorys* ex gr. *scutata* LESKE.

Palaeoecological and actualistic data show the taxa studied to have been shallow infaunal (*Catopygus*), shallow epifaunal [*Conulus* (*Conulus*) *subrotundus*], deeper infaunal [*Micraster* (*Micraster*)], deeper semi-infaunal [*Micraster* (*Gibbaster*), *Plesiocorys* (*Sternotaxis*) *plana*], deeper epifaunal [*Echinocorys*, *Plesiocorys* (*Plesiocorys*) *placenta*], and deeper infaunal (*Hemiaster*).

Echinoid bioevents described originally from the Salzgitter-Salder section (Lower Saxony, Germany) can also be recognised in the Opole area, but not further afield in Mangyshlak.

Key words: Irregular echinoids, Mangyshlak, Poland, Taxonomy, Palaeoecology, Upper Cretaceous, North European Province.

INTRODUCTION

Irregular echinoids first appeared in the Early Jurassic and diversified markedly during the Cretaceous and Cenozoic, attaining a near-worldwide distribution. In the Turonian and Coniacian (Late Cretaceous), the group was dominated by members of the orders Spatangoida and Holasteroida. The former is represented mainly by the genus *Micraster*, the latter by *Echinocorys*.

During the Late Cretaceous both Mangyshlak and the Opole area were situated in the North European Province, stretching from Ireland (i.e. the Atlantic coast) in the west to the western out-

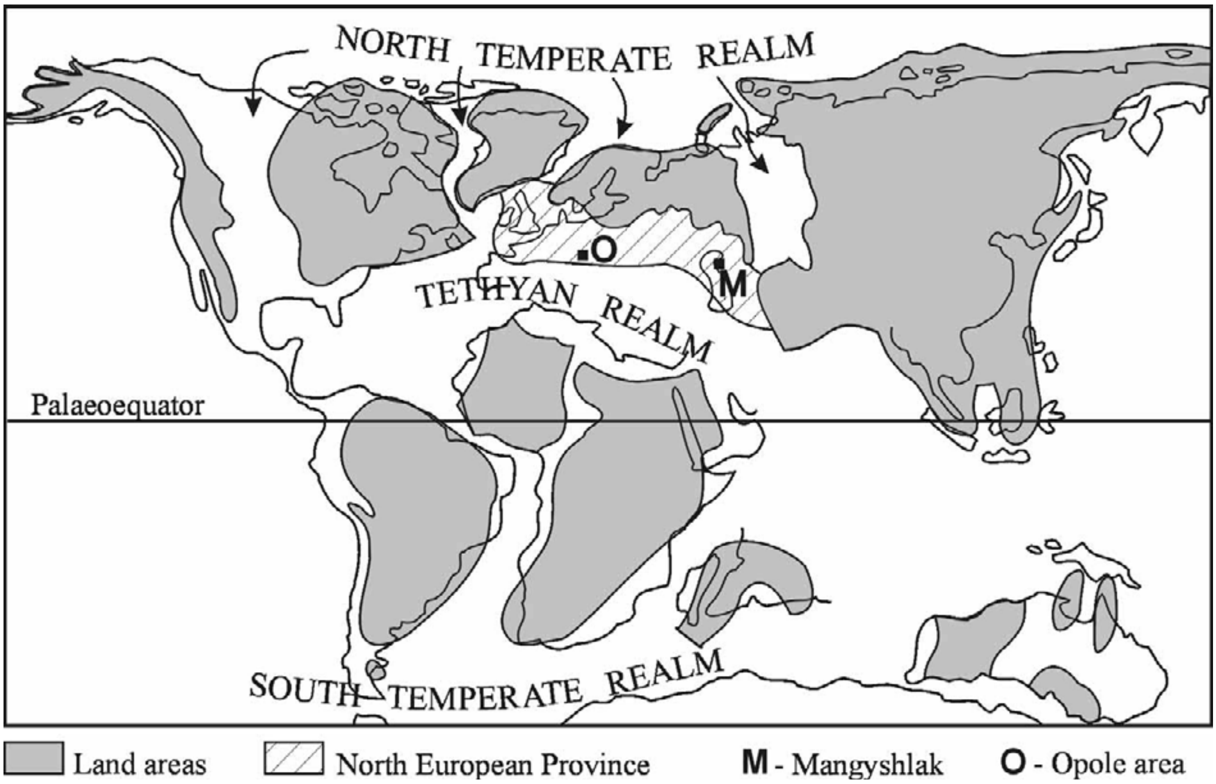

Fig. 1. Location of Mangyshlak and Opole in the North European Province on a palaeogeography map of the Late Cretaceous (after Tröger 1989)

skirts of Central Asia (e.g. Kauffman 1973). The Opole area represents the central-western part of this province, whereas Mangyshlak constitutes its marginal, south-easterly portion (see Text-fig. 1). Irregular echinoids from both these areas plus additional, comparative material from England, France, Germany and the Czech Republic, enable a comprehensive study of this group in the eastern part of the North European Province during the Turonian and Coniacian.

The echinoid collection studied comprises almost 1,000 specimens, most of them well enough preserved to be subjected to biometric and simple statistic analysis. Species well represented in this material are characterized statistically. In most cases, the mode of life of particular species as well as their ecological preference can be reconstructed.

Biozonation of sections studied follows Walaszczyk (1992, with additional comments by Walaszczyk 2000, Walaszczyk & Wood 1998, 1999) and Marcinowski & *al*. (1996).

Field work in the Opole area was carried out in 1991 and 1993-1995, and at Mangyshlak in 1992, within the framework of the Polish Scientific Expedition to that area, sponsored by the National Committee of Scientific Research, KBN, No. 6 6218 92 03, and organized and realized by Ryszard Marcinowski, Ireneusz Walaszczyk (both University of Warsaw), Ludmila Kopaevich (University of Moscow) and the author. Further collecting at Opole in 1995-1996 was possible thanks to a grant of the National Committee of the Scientific Research (KBN), No. 6 PO4D 008 09.

PREVIOUS STUDIES OF TURONIAN – CONIACIAN IRREGULAR ECHINOIDS FROM MANGYSHLAK AND OPOLE

Mangyshlak

The first record of Late Cretaceous echinoids from Mangyshlak was that by Semenov (1899), who recognized 32 species representing 14 orders of regular and irregular taxa. However, he did not illustrate any Turonian or Coniacian species. His *Holaster planus* (Semenov 1899, p. 15), from the Besakty section, is specifically indeterminate, and most probably is a Cenomanian species. Similarly, his *Micraster* sp. (cf. *cor anguinum*? AG.) (SEMENOV 1899, p. 15), from the Maastrichtian, must be a different species. MOSKVIN (1959) illustrated Late Cretaceous echinoids from the northern Caucasus and Crimea. Two of his species, i.e. *Holaster planus* MANTELL [described here as *Plesiocorys* (*Plesiocorys*) *placenta* (AGASSIZ)] from the Upper Turonian] and *Micraster rogalae* NOWAK from the upper Coniacian, are illustrated by specimens from Mangyshlak. In many subsequent papers on Late Cretaceous faunas from Mangyshlak, echinoids often appear in faunal lists only and systematic descriptions have never been given (see TRIFONOV & BURAGO 1960, TRIFONOV & VASILENKO 1963, ENDELMAN 1971, MOSKVIN & ENDELMAN 1972, SCHMIDT & *al*. 1973). Extensive lists were published by ENDELMAN (1971) and MOSKVIN & ENDELMAN (1972) in particular. The latter authors recognised 47 species from the Upper Cretaceous of Mangyshlak, most of them irregular, representing, according to them, the subfamilies Micrasterinae and Echinocorynae (order Spatangoida in MOSKVIN & ENDELMAN 1972); in comparison, representatives of the orders Holectypoida and Cassiduloida are rare. In addition, MOSKVIN & ENDELMAN (1972) emphasized the close relationship between echinoid faunas from Mangyshlak and those from the southern part of the Russian Platform (compare SAVCHINSKAYA 1967), the Fore-Carpathians (compare GINDA 1965, 1968) and the Crimea. SAVCHINSKAYA (1982) illustrated *Conulus subrotundus* and *Micraster rogalae* from Mangyshlak in her paper on echinoids of the Caspian Depression.

More recently, echinoids were listed from Mangyshlak, inclusive of range charts for selected sections by NAIDIN & *al*. (1984).

Opole

The first note on echinoid faunas from the Opole Cretaceous was published by ROEMER (1870), who described Cenomanian – Turonian deposits, collected numerous fossils, and recorded *Micraster leskei* D'ORBIGNY, *Ananchytes ovata* LAMBERT, and *Holaster planus* AGASSIZ; the latter species probably is *Plesiocorys* (*Sternotaxis*) *plana* (MANTELL). His *Ananchytes ovata* most likely represents *Echinocorys gravesi* (DESOR). QUENSTEDT (1872-1875) illustrated *Spatangus* cf. *subglobosus* and *Spatangus* cf. *planus*, which probably are conspecific with *Plesiocorys* (*Sternotaxis*) *plana. Holaster planus* MANTELL [probably *Plesiocorys* (*Sternotaxis*) *plana*] and *Micraster breviporus* AGASSIZ [probably *M.* (*Micraster*) *leskei*] were also listed by LEONHARD (1897), who compiled a monograph on Silesian fossils based on his own collections and in part used ROEMER'S (1870) material.

A complete echinoid list, ascribed roughly to inoceramid zones, was published subsequently by BIERNAT (1960), who identified the following species:

(i) Bolko Quarry: *Cidaris* sp., *Holaster planus* MANTELL and *Micraster cortestudinarium* AGASSIZ from the *Scaphites geinitzi* Zone, and *Micraster cortestudinarium* AGASSIZ from the *Inoceramus lamarcki* Zone;

(ii) Piast Quarry: *Micraster cortestudinarium* AGASSIZ from the *Inoceramus lamarcki* Zone;

(iii) Odra Quarry: *Micraster cortestudinarium* AGASSIZ from the *Scaphites geinitzi* Zone, *Ananchytes ovatus* LESKE? and *Micraster breviporus* AGASSIZ from the *Inoceramus lamarcki* Zone.

His *Micraster cortestudinarium* probably refers to *Micraster* (*M.*) *leskei*, and his *M. breviporus* is synonymous with *M.* (*M.*) *leskei*.

Micraster leskei and *Sternotaxis planus* [sic] were listed from the Opole Cretaceous by NASTAJ-SOBCZYK & TARKOWSKI (1989) from the upper part of the *Inoceramus lamarcki* Zone and from the *Inoceramus perplexus* (=*costellatus* of authors) Zone, in addition to *Micraster* (*Gibbaster*) sp. and *Echinocorys gravesi* DESOR from the latter zone. Descriptions and illustrations of *Sternotaxis plana*, *Echinocorys gravesi*, *Micraster leskei*, *M. corbovis* FORBES and *Micraster decipiens* (BAYLE) [= *M. cortestudinarium* here] were supplied by TARKOWSKI (1991). FOURAY & TARKOWSKI (1991) described *Micraster leskei* from the European Turonian, discussed its stratigraphical value, and studied the morphological range of variation of this taxon, considering *Micraster corbovis* FORBES to be a variety.

LOCALITIES IN MANGYSHLAK

Cretaceous and Cenozoic strata are exposed in limbs of the Central Mangyshlak Anticlinorium and the Tumgatchi Anticline, their axial portions being composed of Permo-Triassic and Jurassic

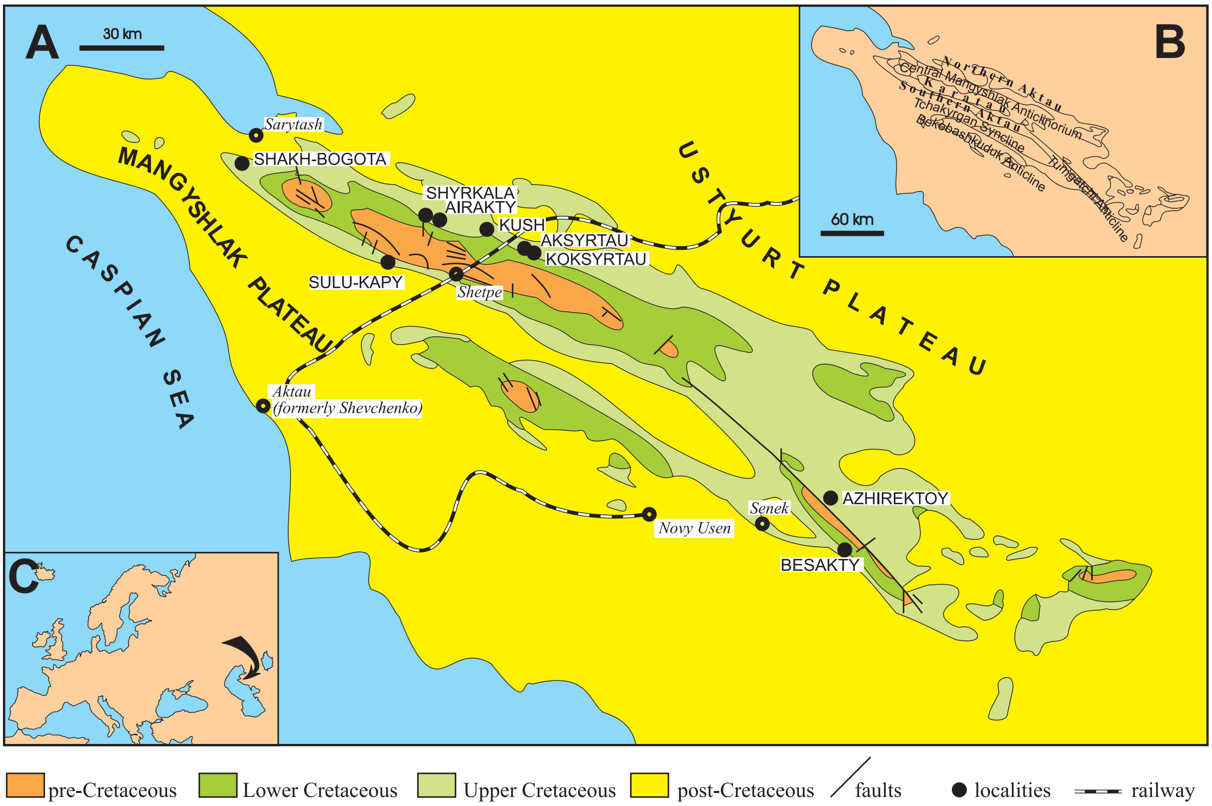

Fig. 2. Schematic geologic sketch-map of the study area in Mangyshlak (A – after BIESPALOV & *al*. 1965, simplified) with main geo-tectonic and geomorphologic units the area (B), and map of Europe and western Asia (C) [after MARCINOWSKI & *al.* 1996]

deposits (Text-fig. 2). The axial portion of the Central Mangyshlak Anticlinorium is called Karatau (meaning black mountains in Kazakh), its northern and southern limbs being known as Northern and Southern Aktau (meaning white mountains), respectively. For more details on the structure, regional geology and biostratigraphy of the Cretaceous in this area, reference is made to NAIDIN & *al*. (1984) and MARCINOWSKI & *al*. (1996).

Seven echinoid-bearing sections extend over a distance of about 250 km (Text-fig. 3, Pls 1-3); Shakh-Bogota, Shyrkala and Airakty, Kush, and Koksyrtau and Aksyrtau sections along Northern Aktau, and Sulu-Kapy along Southern Aktau, within the Central Mangyshlak Anticlinorium. Two sections represent limbs of the Tumgatchi Anticline: Azhirektoy in the northeast and Besakty in the southeast (MARCINOWSKI & *al*. 1996).

The main facies change, from siliciclastics in the Cenomanian – Middle Turonian, to carbonates in the Upper Turonian – Coniacian, triggered the relatively rapid and ‘explosive’ appearance of some groups of irregular echinoids (see also ENDELMAN 1971), first of all, members of the orders Holasteroida and Spatangoida.

Irregular echinoid faunas of the Turonian and Coniacian of Mangyshlak are dominated by the genera *Echinocorys* and *Micraster*. Less common is *Plesiocorys*, and *Conulus*, *Catopygus* and *Hemiaster* occur sporadically. A complete Upper Turonian – Coniacian succession is preserved only in the Shakh-Bogota section; this pinches out towards the most easterly sections of Azhirektoy and Besakty (see Text-figs 3, 4; for details on sections see Appendix). The Besakty section provides an exceptionally rich and diverse echinoid material. However, because of gaps and condensation there its original stratigraphical distribution can only be hinted at. An analysis of the echinoid succession of the Shakh-Bogota section has enabled a classification of the relative stratigraphic position of most specimens from the Azhirektoy and Besakty sections.

Detailed successions are provided in the Appendix; for additional data, reference is made to MARCINOWSKI & *al*. (1996).

LOCALITIES IN THE OPOLE AREA

The term 'Opole Cretaceous' (BIERNAT 1960) defines deposits of Cenomanian to Coniacian age, stretching nearly NW-SE along the Odra River from near Wrocław in the north, to the boundary with the Czech Republic in the south (Text-fig. 5), and resting on various Precambrian, Palaeozoic and Mesozoic rocks.

A comprehensive study of the Cretaceous exposed near Opole was presented by BIERNAT (1960), who described all of the main sections in the area, compiled a general Cretaceous succession, and noted the faunal content of particular units. Subsequently, ALEXANDROWICZ & RADWAN (1973) and ALEXANDROWICZ (1974) worked out a lithostratigraphical scheme, albeit an informal one, with microfaunal characteristics and age assignment.

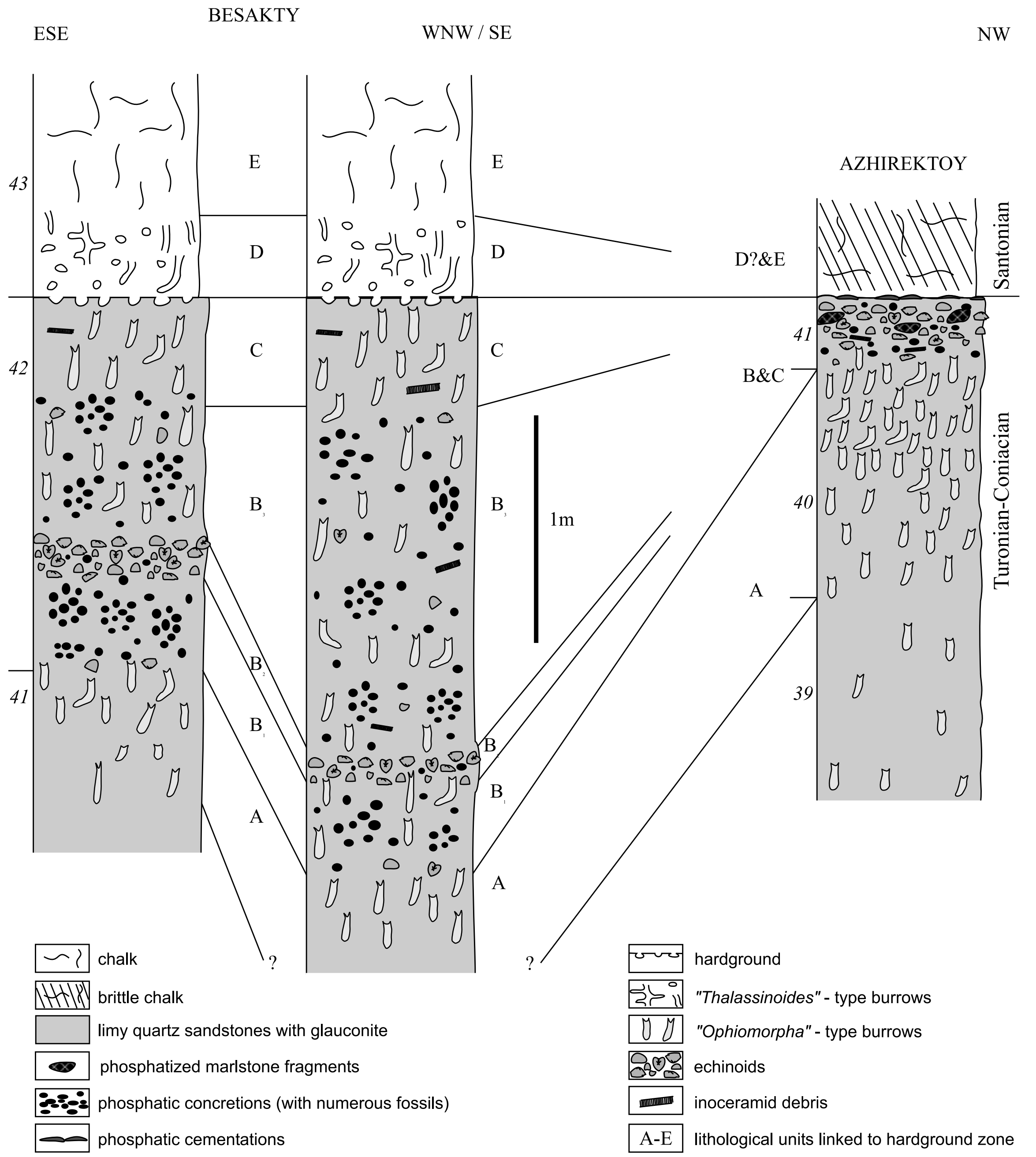

Fig. 4. Stratigraphic correlation of upper Turonian-Coniacian (Units B–C), with distribution of phosphatized echinoids in the hardground zone (Besakty and Azhirektoy sections)

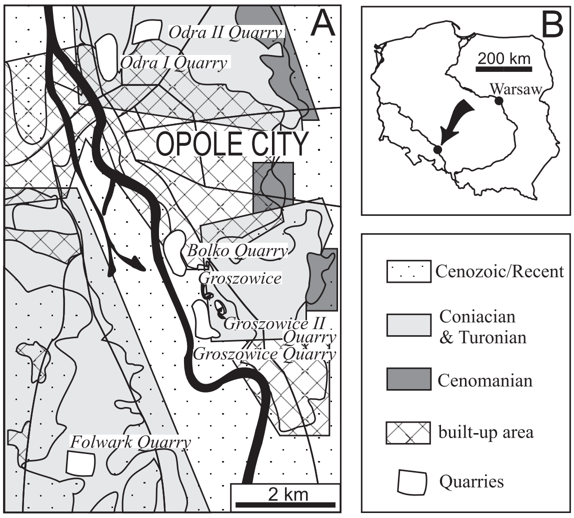

Fig. 5. Schematic geological map of the study area in Opole (A – after Biernat 1960 and Walaszczyk 1988, simplified), and position in Poland (B)

This scheme, subsequently used on numerous occasions, is as follows (Text-fig. 6): (1) Sands and sandstones, thickness ca. 50 m; (2) Lower Argillaceous Marls (= Lower Clayey Marls), thickness 8-12 m; (3) Lower Marls, thickness 10-17 m; (4) Marly Limestones, thickness 14-17 m; (5) Upper Marls, thickness 28-30 m; and (6) Upper Argillaceous Marls (= Upper Clayey Marls), thickness more than 30 m.

Sands and sandstones were dated as Cenomanian; the Lower Clayey Marls, Lower Marls, Marly Limestones, Upper Marls and Upper Clayey Marls in part were assigned to the Turonian and Coniacian.

Biozonations of the Opole Cretaceous are based primarily on inoceramid bivalves (see Walaszczyk 1988, 1992 and Tarkowski 1991). Zones proposed by Walaszczyk (1992) and in part revised by Walaszczyk & Wood (1998) are followed here.

Lithology and biostratigraphy

The lowermost Turonian (Lower Clayey Marls) of Opole is exposed at the Odra II Quarry. According to Walaszczyk (1988, 1992) and Tarkowski (1991), the exposed part of this unit belongs to the Middle Turonian *Inoceramus apicalis* Zone. Overlying are Lower Argillaceous Marls with thin clay layers (called Clay Horizon II) at the top (Text-fig. 6, Pls 4, 5 and Appendix; compare also Walaszczyk 1988, 1992), which belong to the *Inoceramus lamarcki* Zone (Middle Turonian). About 2 m below the top of this unit, there is a flood appearance of small inoceramids [*Inoceramus perplexus* Whitfield (= *I. costellatus* of authors, see Walaszczyk & Cobban 2000)], marking the base of the Upper Turonian (Walaszczyk 1992). The lower part of successive Marly Limestones unit, belongs to the *Inoceramus perplexus* Zone, whereas its upper part is assigned to the *Mytiloides scupini* Zone. In the lower part Marly Limestones occur two characteristic clay horizons, III and IV (see Walaszczyk 1988, 1992). The richest echinoid faunas are from this part of the succession (Text-fig. 6, Pls 4, 5A, see also Appendix).

The higher part of the succession is exposed southwest of Opole, at the Folwark Quarry (Pl. 5B), west of the Odra River. About 10 m of the upper part of the Marly Limestones unit are exposed here, followed by > 30 m of the Upper Marls unit (Text-fig. 6). The lower 16 m of the Upper Marls unit is assigned still to the *Mytiloides scupini* Zone (Walaszczyk 1992, Walaszczyk & Wood 1998). The first representatives of *Cremnoceramus waltersdorfensis waltersdorfensis* (Andert) appear suddenly in masses, just below the Turonian/Coniacian boundary. The boundary is marked by the FO of *Cremnoceramus deformis erectus* (Meek), index taxon for the lowermost Coniacian (Walaszczyk & Wood 1998, Walaszczyk & Cobban 2000). The Coniacian succession ranges up to the *Cremnoceramus crassus crassus*/*deformis deformis* Zone (Text-fig. 6).

The highest part of the Folwark Quarry section comprises soft, clayey marls of the Upper Argillaceous Marls. The youngest deposits of the Opole Cretaceous have been documented in boreholes; the fossil assemblage described by Radwańska (1969) from the Sady 1 borehole indicates Middle Coniacian (Walaszczyk 1992).

Detailed log description for the Odra, Bolko, Groszowice and Folwark quarries can be found in the Appendix.

MATERIAL AND REPOSITORIES

The material studied comprises almost 1,000 specimens, of which >500 have been analyzed biometrically. The material from Mangyshlak comprises about 600 specimens (of which about 400 have been analyzed biometrically). Material from the Opole area numbers >400 specimens, but most of them are poorly preserved and only 143 tests were good enough for biometric analysis.

Most of the specimens studied were collected by the author and are now housed at the Museum of the Faculty of Geology of the University of Warsaw (with the code IGPUW/E/01/000). Specimens from Westphalia (Germany), France and Wolin Island, borrowed from the Museum of the Earth (abbreviated MZ), as well as material from the Turonian and/or Coniacian of Beachy Head, England and of Kostomloty, Czech Republic, offered to the author by Ireneusz Walaszczyk (also with the code IGPUW/E/01/000), have proved very helpful.

Abbreviations:

IGPUW – Museum of the Faculty of Geology of the Warsaw University
NHM – The Natural History Museum, London
MZ – Muzeum Ziemi, Warszawa

SYSTEMATIC DESCRIPTIONS

The systematics down to the family level follow that of SMITH (1984), SMITH & WRIGHT (1999, 2000, 2003), and descriptive terminology used is that of DURHAM & WAGNER (1966).

Order Holectypoida DUNCAN, 1889
Suborder Echinoneina CLARK, 1925
Family Conulidae LAMBERT, 1911

Genus *Conulus* LESKE, 1778

TYPE SPECIES: *Conulus albogalerus* LESKE, 1778, by monotypy.

OCCURRENCE: Valanginian (Lower Cretaceous) to Maastrichtian (Upper Cretaceous) of Europe, northern Africa, Asia, and North America.

Subgenus *Conulus* (*Conulus*) LESKE, 1778

TYPE SPECIES: *Conulus albogalerus* LESKE, 1778, by monotypy.

OCCURRENCE: Valanginian-Hauterivian (Lower Cretaceous) to Maastrichtian (Upper Cretaceous) of Europe, northern Africa, Asia, and North America.

Conulus (*Conulus*) *subrotundus* MANTELL, 1822
(Text-fig. 7; Pl. 6, Fig. 1)

1822. *Conulus subrotundus*; G. MANTELL, p. 191, pl. 17, figs 15, 18.
1860. *Echinoconus subrotundus* D'ORBIGNY; A. D'ORBIGNY, p. 517, pl. 997, figs. 8-12.
1860. *Echinoconus subrotundus* D'ORBIGNY; G. COTTEAU & J. TRIGER, p. 283, pl. 47, fig. 4.
1860. *Echinoconus subrotundus* D'ORBIGNY; G. COTTEAU, p. 323, pl. 72, figs 1-5.
1870. *Galerites subrotundus* AGASSIZ; F. ROEMER, p. 351, Pl. 38, figs 5, 6.
1958. *Conulus subrotundus* (MANTELL); E. POPIEL-BARCZYK, p. 47, text-figs 2, 4-6; pl. 1, figs 1-12.
1958. *Conulus subrotundus* (MANTELL) var. *subglobosa*; E. POPIEL-BARCZYK, p. 52, text-fig. 7; pl. 2, figs 1-4.
1958. *Conulus subrotundus* (MANTELL) var. *conoidea*; E. POPIEL-BARCZYK, p. 53, text-fig. 8; pl. 2, figs 5-8.
1959. *Conulus subrotundus* MANTELL; M.M. MOSKVIN, p. 250, pl. 2, fig. 3.
1966. *Conulus subrotundus* (MANTELL); L. CAYEUX & O. DE VILLOUTREYS, p. 34, pl. 1, fig. 7.
1974. *Conulus subrotundus* (MANTELL); R. MARCINOWSKI, pl. 29, fig. 3.
1979. *Conulus subrotundus* (MANTELL); G.S. GONGADZE, p. 63, text-fig. 9; pl. 3, fig. 1.
1982. *Conulus subrotundus* (MANTELL); O.V. SAVCHINSKAYA, p. 235, pl. 25, figs 1-3.
1989. *Conulus subrotundus subrotundus* (MANTELL); S. MĄCZYŃSKA, p. 304, pl. 190, fig. 1.
1989. *Conulus subrotundus subglobosus* POPIEL-BARCZYK; S. MĄCZYŃSKA, p. 305, pl. 190, fig. 2.
1989. *Conulus subrotundus conoideus* POPIEL-BARCZYK; S. MĄCZYŃSKA, p. 305, pl. 190, fig. 3.
1995. *Conulus subrotundus* (MANTELL); J. GEYS, p. 141, pl. 1, figs 1-9.
1999. *Conulus* (*Conulus*) *subrotundus* MANTELL; A.B. SMITH & C.W. WRIGHT, p. 379, text-figs 137D-G, I-K, 140D, 143; pl. 121, figs 8-10; pl. 122, figs 1-8; pl. 123, figs 5-7; pl. 124, figs, 1-3 (with additional synonymy).
2005. *Conulus subrotundus* MANTELL; D. OLSZEWSKA-NEJBERT, text-fig. 4B.

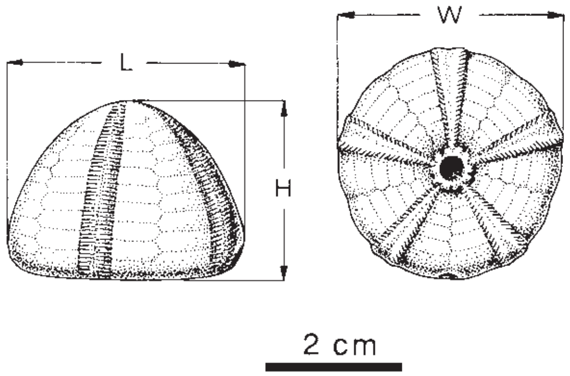

Fig. 7. Basic measurements in *Conulus* (*Conulus*) *subrotundus* MANTELL, 1822; L – length of mould, in mm; W – width of mould, in mm; H – height of mould, in mm

TYPE: The lectotype, designated by SMITH & WRIGHT (1999), is NHM 4693, the original of MANTELL (1822, pl. 17, figs 15, 18), from the Upper Chalk near Lewes, Sussex, England.

MATERIAL: Two poorly preserved phosphatic internal moulds (IGPUW/E/01/001-002), from Bed 42 at Besakty, Mangyshlak.

DESCRIPTION: **Shape and size**. Both specimens rather small (Table 1 and Text-fig. 7); shape of mould semicircular in lateral profile (Text-fig. 7 and Pl. 6, Fig. 1c), lateral sides moderately convex. Test/mould rather low with broad, flat base. Outline of base near circular.
Ambulacral zone (negative on mould). Ambulacra are narrow, non-petaloid with maximum width 2.8 mm, ambulacral plates arranged in groups of three.
Interambulacral zone. Interambulacra approximately three times wider than ambulacra, maximum width 7.8 mm measured at ambitus.
Peristome. Peristome small and circular in outline, situated centrally. Around peristome negative of perignathic girdle, at end of interambulacral zone two cavities representing negative of apophyses.
Periproct. Periproct poorly preserved, marginally, subambitally situated, visible both from oral surface and from posterior.

REMARKS: *Conulus* (*Conulus*) *subrotundus* from Besakty is most similar to *C. subrotundus* (MANTELL) var. *conoidea* as described by POPIEL-BARCZYK (1958) from the *Inoceramus labiatus* Zone (upper Lower Turonian) of Poręba Dzierżna and from the *Inoceramus lamarcki* Zone of Wielkanoc, both southern Poland. It also resembles *C. subrotundus* (MANTELL) var. *conoidea* described by SAVCHINSKAYA (1974) from the lower Upper Turonian of the Krynka Basin, southern Donbass (Ukraine).

OCCURRENCE: Mangyshlak, Upper Turonian to Coniacian of Besakty. Known from the entire North European Province: England, France, Belgium, Poland (Kraków area, Miechów and Wolbrom), Ukraine, northern Caucasus; also Turonian of Georgia. SMITH & WRIGHT (1999) recorded this species from Lower Turonian to Lower Campanian in England.

Order Cassiduloida CLAUS, 1880
Family Catopygidae LAMBERT, 1898

Genus *Catopygus* AGASSIZ, 1836

TYPE SPECIES: *Nucleolites carinatus* GOLDFUSS, 1829, by subsequent designation of COTTEAU (1869).

OCCURRENCE: Upper Jurassic (Kimmeridgian) to Upper Cretaceous (Maastrichtian); cosmopolitan.

Catopygus columbarius (LAMARCK, 1816)
(Text-figs 8, 9; Pl. 6, Figs 2, 3)

1816. *Nucleolites columbaria* LAMARCK, p. 27.
1972. *Catopygus obtusus* DESOR; S.S. MĄCZYŃSKA, p. 177, text-figs 8-15; pl. 2, figs 1-7.
2000. *Catopygus columbarius* (LAMARCK); A.B. SMITH & C.W. WRIGHT, p. 413, text-figs 162-164; pl. 133, figs 1-19; pl. 134, figs 1-28; pl. 135, figs 10-15 (with additional synonymy).

Number of the specimen	L [mm]	W [mm]	H [mm]	W/L*100	H/L*100	H/W*100
IGPUW/E/01/001	34.4	33.5	25.6	97.38	74.41	76.41
IGPUW/E/01/002	26.7	25.5	20.6	95.50	77.15	80.78

Table 1. Biometric data and simple ratios for *Conulus* (*Conulus*) *subrotundus* MANTELL, 1822

TYPE: The lectotype, designated by SMITH & WRIGHT (2000), is the specimen referred to by LAMARCK (1816, p. 27) as *Nucleolites columbaria*, from the Cenomanian of Le Mans, France.

MATERIAL: Four poorly to moderately preserved specimens: one from Bed 40 (IGPUW/E/01/003) (Middle Turonian) at Besakty; two from Bed 42 (IGPUW/E/01/004-005) at Besakty; and one from Bed 41 (IGPUW/E/001/006) at Azhirektoy.

DESCRIPTION: **Shape and size**. Rather small (Table 2 and Text-fig. 8) with highest point of test situated slightly posterior of centre. Ambital outline oval. Widest part of test posteriorly, approximately two-thirds of length from anterior. Aboral surface convex and adoral surface flat. In elongated profile, anterior edge gently rounded contrary to truncated posterior one. Ambitus relatively low.

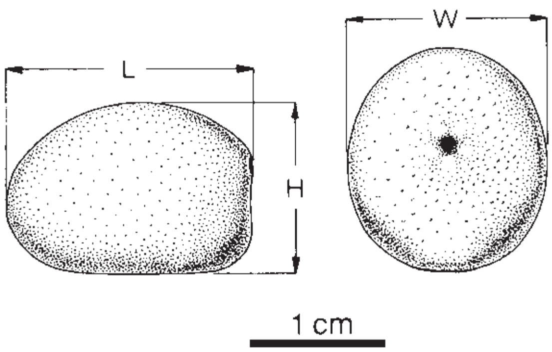

Fig. 8. Basic measurements in *Catopygus columbarius* (LAMARCK, 1816); L – length of mould, in mm; W – width of mould, in mm; H – height of mould, in mm

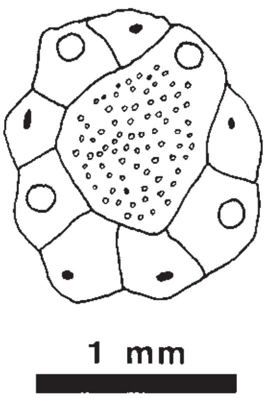

Fig. 9. Camera-lucida drawing of apical disc plating in *Catopygus columbarius* (LAMARCK, 1816) (IGPUW/E/01/005) Mangyshlak, Besakty

Apical disc. Apical disc visible only in one specimen; tetrabasal, slightly elongated, and a little anterior of centre. Madreporite large, several times larger than other genital plates, with numerous small hydropores. Other genital plates considerably smaller (Text-fig. 9), these and all ocular plates abutting madreporite plate.
Ambulacral zone. Ambulacra narrow, homeomorphic, composed of slightly marked petaloids (pseudopetaloids). Posterior pseudopetaloids slightly longer than others.
Interambulacral zone. Interambulacra relatively broad, much broader than ambulacra.
Peristome. Peristome rather small, anterior of centre, slightly elongated (slightly longer than wider), surrounded by prominent floscelle.
Periproct. Periproct slightly oval, situated high on anal field.
Tuberculation. All tubercles very small, scattered evenly over whole test.

OCCURRENCE: Middle Turonian of Besakty and Upper Turonian – Coniacian of Azhirektoy and Besakty; from Upper Aptian to Upper Cenomanian of Europe (SMITH &WRIGHT 2000), Turonian of France (MĄCZYŃSKA 1972).

Order Holasteroida DURHAM & MELVILLE, 1957
Family Holasteridae PICTET, 1857

Test measurements (in mm) and abbreviations applied to members of this family are shown in Text-figs 10 and 11. Simple ratios applied are as follows:

W/L*100 – characterizes outline of base of test; ratio between 85 to 95 characterizes circular, or

Number of specimen	L [mm]	W [mm]	H [mm]	W/L*100	H/L*100	H/W*100
IGPUW/E/01/004	17.0	15.2	11.4	89.41	67.06	75.00
IGPUW/E/01/005	12.5	11.3	9.9	90.40	79.20	87.61
IGPUW/E/01/003	16.7	15.2	11.6	91.02	69.46	76.32
IGPUW/E/01/006	16.2	14.6	10.6	90.12	65.43	72.60

Table 2. Biometric data and simple ratios for *Catopygus columbarius* (LAMARCK, 1816)

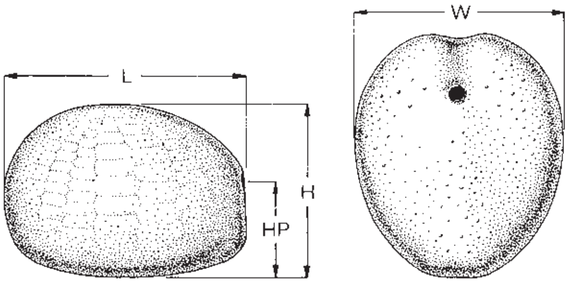

Fig. 10. Basic measurements in the genus *Plesiocorys* POMEL, 1883; L – length of test; W – width of test; H – height of test; HP – height of periproct from base

slightly oval, or oval outline, ratio < 85 characterizes oval-elongate outline;

H/L*100 – characterizes height of elongate profile; ratio > 80 characterizes tall-elongate profile, ratio between 70 to 80 characterizes moderately-tall profile, ratio < 70 characterizes low elongate profile;

H/W*100 – characterizes height of transverse profile; ratio > 90 characterizes tall profile, ratio between 80 to 90 characterizes moderate profile, the ratio < 80 characterizes low profile;

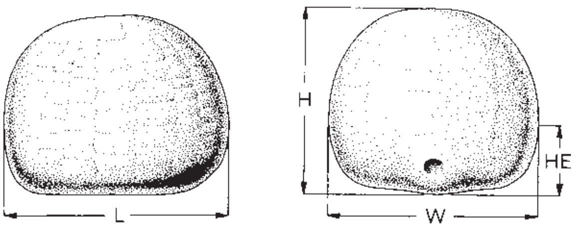

Fig. 11. Basic measurements in the genus *Echinocorys* LESKE, 1778; L – length of test; W – width of test; H – height of test; HE – height of ambitus

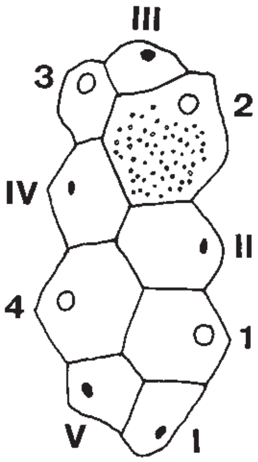

Fig. 12. Generalised apical disc of a holasteroid showing the Lovénian numbering of ocular plates (I-V) and genital plates (1-4, in which 2 is madreporite)

HE/H*100 – only in *Echinocorys*, characterizes shape of test, the higher this ratio the more convex the test; ratio > 30 characterizes shape of test strongly convex and lateral sides also strongly convex in relation to base;

HP/H*100 – only in *Plesiocorys* (*Sternotaxis*) *plana*, characterizes height of periproct in relation to height of test; the ratio < 50 indicating moderately-tall situated periproct.

In the case of large populations, biometric characters are shown in charts, and simple ratios in histograms. The apical disc is described using the Lovénian numbering system (Text-fig. 12).

Genus *Plesiocorys* POMEL, 1883

TYPE SPECIES: *Holaster placenta* AGASSIZ, in AGASSIZ & DESOR 1847, p. 27 (133), designated by WAGNER & DURHAM (1966, p. U533).

OCCURRENCE: Upper Cretaceous (Lower Turonian to Maastrichtian) of Europe and western Asia.

Subgenus *Plesiocorys* (*Sternotaxis*) LAMBERT, 1893

TYPE SPECIES: *Spatangus planus* MANTELL, 1822, p. 192, by original designation.

OCCURRENCE: Upper Cretaceous (Lower Turonian to Maastrichtian) of Europe and western Asia (Mangyshlak and Kopet-Dag).

Plesiocorys (*Sternotaxis*) *plana* (MANTELL, 1822)
(Text-figs 13, 14; Pl. 7, Figs 1-4)

1822. *Spatangus planus*; G. MANTELL, p. 192, pl. 17, figs 9, 21.
1876. *Holaster planus* (MANTELL) AGASSIZ; G. COTTEAU, p. 333, pl. 73, figs 1, ?2, 3, 4, ?5.
1870. *Holaster planus* AGASSIZ; F. ROEMER, p. 312, pl. 37, figs 1, 2.
1874. *Spatangus* cf. *subglobosus*; F.A. QUENSTEDT, p. 610, pl. 86, figs 2, 3.
1889. *Holaster planus* MANTELL; A. FRIČ, p. 99, fig. 128.
1964. *Sternotaxis planus* (MANTELL); G.N. DZHABAROV, p. 21, text-fig. 2; pl. 1, figs 1, 2.

1966. *Sternotaxis planus* (MANTELL); L. CAYEUX & O. DE VILLOUTREYS, p. 38, pl. 2, fig. 11.
1968. *Sternotaxis planus* (MANTELL); S.I. PASTERNAK & *al*., p. 208, pl. 43, figs 1, 2; pl. 44, figs 1, 2.
1974. *Sternotaxis planus* (MANTELL); O.V. SAVCHINSKAYA, p. 318, pl. 100, figs 9-12.
1989. *Sternotaxis planus* (MANTELL); S.S. MĄCZYŃSKA, p. 310, pl. 198, fig. 1.
1991. *Sternotaxis planus* (MANTELL); R. TARKOWSKI, p. 128, pl. 28, fig. 2.
2002. *Sternotaxis plana* (MANTELL); A.B. SMITH & C.W. WRIGHT, p. 285, pl. 58, figs 5-7.
2003. *Plesiocorys* (*Sternotaxis*) *plana* (MANTELL); A.B. SMITH & C.W. WRIGHT, p. 498, Text-figs 196C, 201-203; pl. 158, figs 1-11; pl. 159, figs 1-5 (with additional synonymy).

TYPE: Holotype, by monotypy, is specimen MHN 4740b of *Spatangus planus* figured by MANTELL (1822, pl. 17, figs 9, 21), from the Lower Chalk, near Lewes, Sussex, England.

MATERIAL: A single poorly preserved specimen from Bed 12 of Shakh-Bogota (IGPUW/E/-001/009); two moulds from Bed 37A of Koksyrtau-Aksyrtau (IGPUW/E/001/007-008); six poorly preserved, phosphatized specimens from Bed 42B of Besakty (IGPUW/E/001/010-015); seven incomplete specimens (IGPUW/E/001/016-022) and 49 very poorly preserved (more or less deformed) specimens (IGPUW/E/001/023-071) from the Marly Limestones at Odra I and II quarries; six incomplete specimens (IGPUW/E/001/072-077)

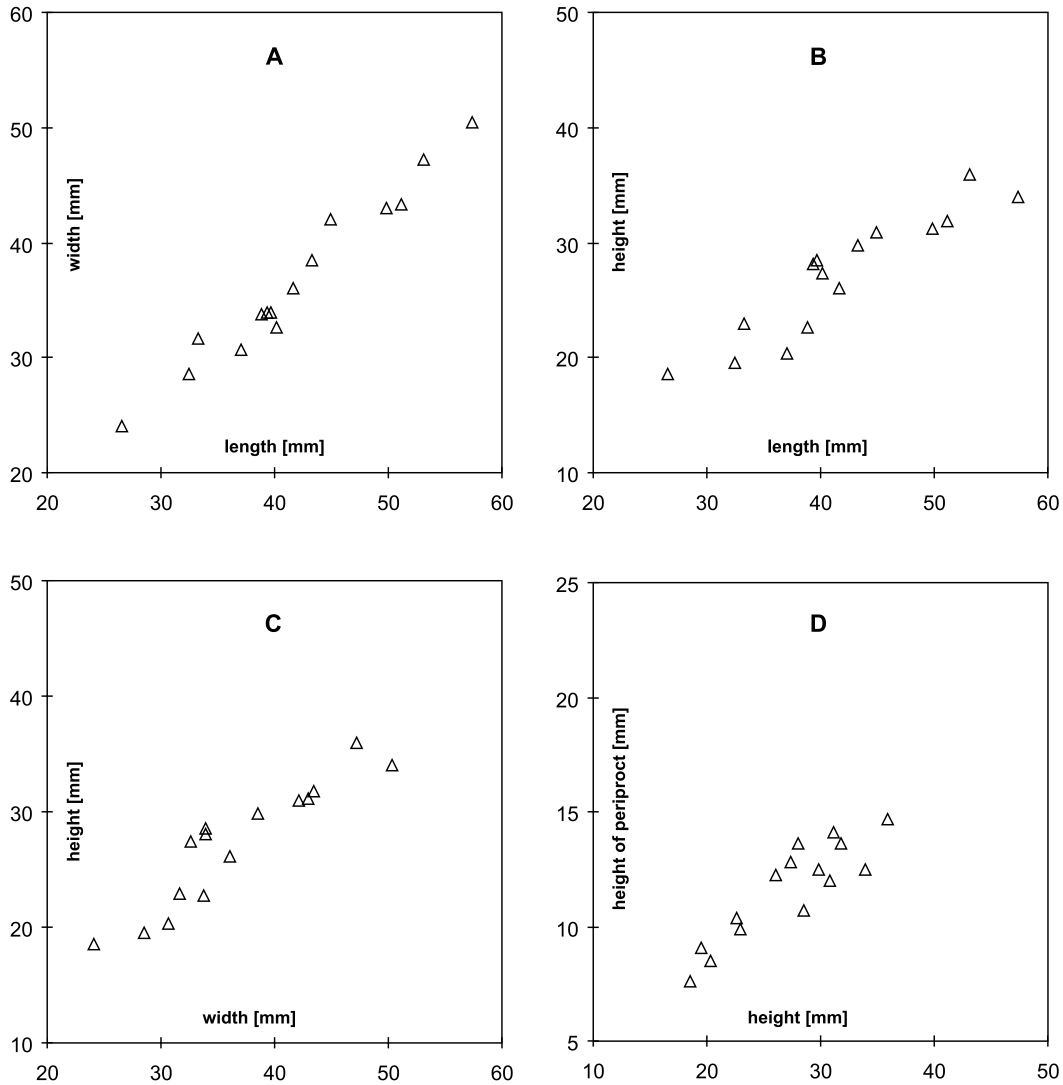

Fig. 13. Biometric data on *Plesiocorys* (*Sternotaxis*) *plana* (MANTELL, 1822) from the upper Turonian of Opole; A – scatter plot of length *versus* width; B – scatter plot of length *versus* height; C – scatter plot of width *versus* height; D – scatter plot of height *versus* height of periproct

Statistic	L [mm]	W [mm]	H [mm]	HP [mm]	W/L*100	H/L*100	H/W*100	HP/H*100
Minimum value	26.6	24.1	18.6	7.6	81.29	55.14	66.45	36.76
Maximum value	57.3	50.4	35.9	14.7	95.19	71.97	84.05	48.40
Mean value	41.89	36.67	27.18	11.61	87.65	65.08	74.29	42.94
Median	40.10	34.00	28.10	12.20	87.11	67.60	73.27	42.77
Standard Deviation	8.036	7.028	5.173	2.072	3.523	5.096	5.718	3.472

Table 3. Simple statistics of biometric data and simple ratios for *Plesiocorys* (*Sternotaxis*) *plana* (MANTELL, 1822) from Opole area; number of specimens N=15

and 59 very poorly preserved (more or less deformed) specimens (IGPUW/E/001/078-136) from the Lower Marls and Marly Limestones at Bolko quarry; three very poorly preserved (more or less deformed) specimens (IGPUW/E/001/137-139) from the Marly Limestones at Groszowice; one quite well-preserved (a mould with large fragments of test) specimen (IGPUW/E/001/140) and 4 very poorly preserved (more or less deformed) specimens (IGPUW/E/001/141-144) from the Marly Limestones at Folwark quarry. One-well preserved specimen (MZ VIII Ee 1466) from the Turonian of Trzciągowo (Wolin Island).

DESCRIPTION: **Shape and size**. Size quite variable (Table 3 and Text-fig. 13), slightly longer than broad, very thin shelled, and weakly cordate in outline. Transverse profile suboval. In elongate profile base, anterior and apical surfaces gently convex. Posterior truncated. Periproct at top of truncated area. Adoral surface uniformly and weakly convex. Anterior groove rather narrow, shallow, and weakly developed.

Apical disc. Apical disc elongate. Genital plates 2 and 3 separated from 1 and 4 by ocular plates II and IV.

Ambulacral zone. Paired ambulacra subpetaloid, but not sunken. Subpetaloid zone quite narrow, whereas zone below subpetaloid broader. Pores in ambulacra II and IV elongate-oval. In one pair, pores oriented horizontally or obliquely to each other. Pores in ambulacra I and V also elongate-oval but always oriented obliquely to each other in a pair.

Interambulacral zone. Interambulacra approximately twice as broad as ambulacra but only in subpetaloid area, whereas below this area the interambulacra are slightly broader than ambulacra.

Plastron. Plastron nearly flush, metasternous, with a single series of plates (Text-fig. 14).

Peristome. Peristome anteriorly and oval in outline, weakly sunken, approximately one-quarter of test length from anterior border.

Periproct. Periproct oval in outline, lying marginally at top of anal field, at less than half of test height.

Tuberculation. Tuberculation over aboral surface uniform and fine. On adoral size tuberculation visible only on plastron, where tubercles are relatively densely packed.

Fig. 14. Camera-lucida drawing of plastron in *Plesiocorys* (*Sternotaxis*) *plana* (MANTELL, 1822) (MZ VIII Ee 1466), Wolin

OCCURRENCE: Upper Turonian of Shakh-Bogota and Koksyrtau-Aksyrtau; also Upper Turonian – Coniacian of Besakty. Upper Turonian (commonly *Inoceramus perplexus* Zone) at Odra I and II, Bolko, and Groszowice quarries. Rare in the *Mytiloides scupini* Zone at Folwark Quarry. The first occurrence of species in the Middle Turonian of England, and is common in the Upper Turonian of the entire North European Province: England (*Sternotaxis plana* Zone), France, Czech Republic, Poland (Wolin Island, Wielkanoc near Wolbrom), Ukraine, Kopet-Dag.

Subgenus *Plesiocorys* (*Plesiocorys*) POMEL, 1883

TYPE SPECIES: *Holaster placenta* AGASSIZ, in AGASSIZ & DESOR 1847, p. 27 (133), designated by WAGNER & DURHAM (1966, p. U533).

OCCURRENCE: Upper Cretaceous (Upper Turonian to Lower Santonian) of Europe and western Asia (Mangyshlak).

Plesiocorys (*Plesiocorys*) *placenta* (AGASSIZ, in AGASSIZ & DESOR, 1847)
(Text-figs 15-17; Pl. 8, Figs 1, 2)

1847. *Holaster placenta* AGASSIZ; L. AGASSIZ & E. DESOR, p. 27 (133).
1972. *Sternotaxis ananchytoides* (ELBERT); G. ERNST, pl. 2, fig. 10.
2003. *Plesiocorys* (*Plesiocorys*) *placenta* (AGASSIZ, in AGASSIZ & DESOR, 1847); A.B. SMITH & C.W. WRIGHT, p. 510, text-fig. 202, 203, 208; pl. 163, figs 1-8; pl. 164, figs 1-12 (with additional synonymy).

TYPE: The holotype, by monotypy, is the specimen described by AGASSIZ, in AGASSIZ & DESOR 1847, p. 27 (133) from the Coniacian of Vernonnet, Eure, France. This is specimen M2 of the Agassiz Collection in the Neuchâtel Museum.

MATERIAL: Ten poorly to very poorly preserved specimens (IGPUW/E/001/145-154), mainly moulds, occasionally with test fragments attached, from the lower part of Bed 14 at Shakh-Bogota. A single, poorly preserved specimen (IGPUW/E/-001/155) from Bed 37B at Koksyrtau-Aksyrtau. Four quite well- and well-preserved, phosphatic moulds (IGPUW/E/001/156-159) from Bed 42B at Besakty.

DESCRIPTION: **Shape and size**. Tests or moulds moderately sized (Table 4 and Text-fig. 15), very thin. Test weakly cordate in outline. Aboral surface convex, and adoral one strongly flattened. Between aboral and adoral surfaces a sharp edge. Elongate profile convex on aboral side and flat on adoral side. From apical disc towards anterior edge arch very convex, making right angle with base. From apical disc towards posterior, arch more gentle (Pl. 8, Figs 1c, 2c). Transverse profile close to semicircle (Pl. 8, Figs 1d, 2d). Tallest point of test coincides with apical disc, shifted slightly to anterior border.

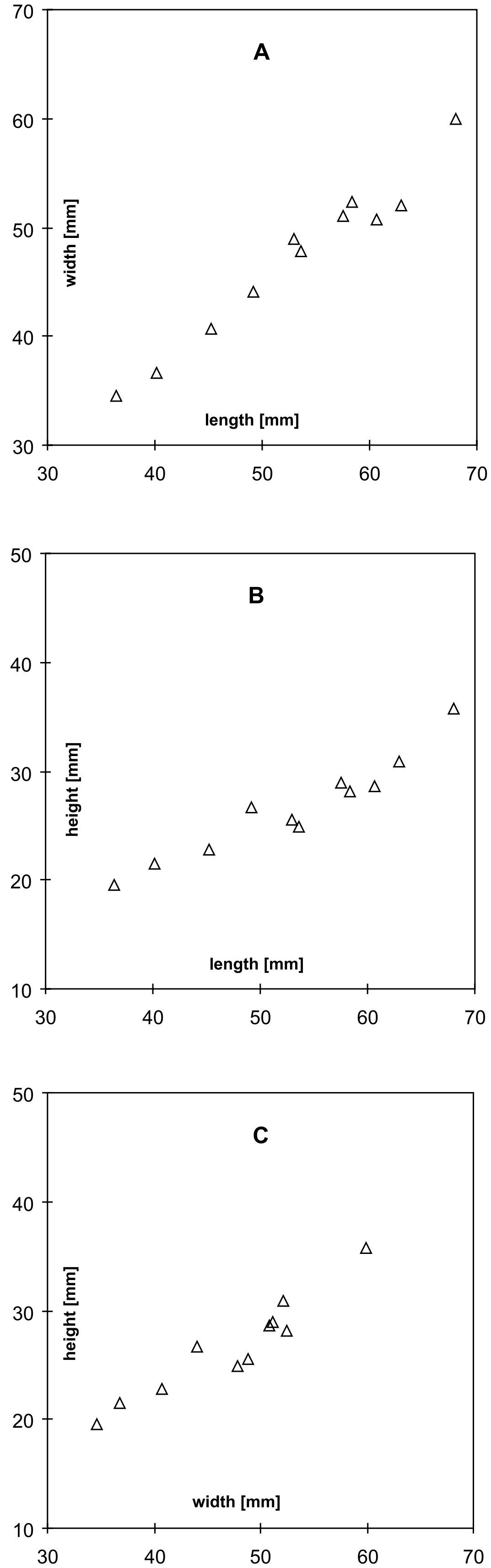

Fig. 15. Biometric data on *Plesiocorys* (*Plesiocorys*) *placenta* (AGASSIZ, in AGASSIZ & DESOR, 1847) from the upper Turonian of Mangyshlak; A – scatter plot of length *versus* width; B – scatter plot of length *versus* height; C – scatter plot of width *versus* height

Statistic	L [mm]	W [mm]	H [mm]	W/L*100	H/L*100	H/W*100
Minimum value	36.4	34.6	19.6	82.83	46.46	52.09
Maximum value	68.1	59.9	35.8	95.05	54.07	60.32
Mean value	53.19	47.19	26.67	89.15	50.36	56.52
Median	53.60	48.90	26.60	89.63	50.26	56.56
Standard Deviation	9.275	7.164	4.352	3.317	2.614	2.740

Table 4. Simple statistics of biometric data and simple ratios for *Plesiocorys* (*Plesiocorys*) *placenta* (AGASSIZ, in AGASSIZ & DESOR, 1847) from Mangyshlak; number of specimens N=11

Anterior groove narrow, very shallow, becoming flush adapically.

Apical disc. Apical disc elongate. Genital plates 1, 2 and 4 similar in size, genital plate 3 relatively smaller. Genital plates 2 and 3 separated from 1 and 4 by ocular plates II and IV (Text-fig. 16).

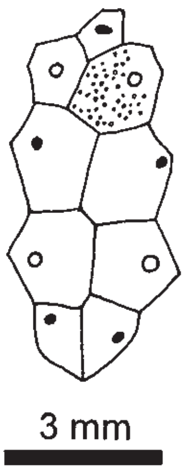

Fig. 16. Camera lucida drawings of apical disc plating in *Plesiocorys* (*Plesiocorys*) *placenta* (AGASSIZ, in AGASSIZ & DESOR, 1847), (IGPUW/E/01/159), Mangyshlak, Besakty

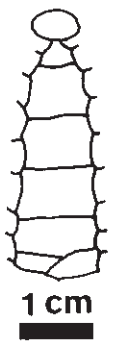

Fig. 17. Camera-lucida drawing of plastron in *Plesiocorys* (*Plesiocorys*) *placenta* (AGASSIZ, in AGASSIZ & DESOR, 1847), from Mangyshlak (after MOSKVIN 1959)

Ambulacral zone. Pores in ambulacra II and IV oval or circular. In one pair, pores are horizontal. Pores in ambulacra I and V oval. In one pair, pores 'en chevron'. Pores in ambulacrum III small, circular. In one pair, pores parallel to longer margin of ambulacral plates.

Interambulacral zone. At adapical field interambulacral zone approximately twice as broad as ambulacral zone, whereas interambulacra only slightly broader than ambulacra towards base edge.

Plastron. Plastron metasternous, with a single series of plates (Text-fig. 17).

Peristome. Peristome, lying anteriorly, quite large and oval in outline, weakly sunken, approximately at one-fifth to one-quarter of test length from anterior border.

Periproct. Periproct oval in outline, rather small, lying just above the ambitus (Pl. 8, Figs 1, 2)

Tuberculation. Tuberculation over aboral side uniform and fine granules widely scattered.

OCCURRENCE: Uppermost Turonian of the Shakh-Bogota and Koksyrtau-Aksyrtau and Upper Turonian to Coniacian of Besakty. Originally recorded from the Upper Turonian of Westphalia, Germany and the Coniacian of England and France.

Genus *Echinocorys* LESKE, 1778

TYPE SPECIES: *Echinocorys scutatus* LESKE, 1778, by subsequent designation of LAMBERT (1898).

OCCURRENCE: Middle Turonian to Upper Paleocene, worldwide.

REMARKS: The genus *Echinocorys* is rare in the Turonian. During the Coniacian – Maastrichtian the number of species and individuals considerably increased (LAMBERT 1903, SMISER 1935, HAYWARD 1940, MOSKVIN & SHIMANSKAYA 1977, JAGT 2000, SMITH & WRIGHT 2003). According to the opinion of several authors the genus *Echinocorys* represents a single large species complex in the Upper Cretaceous of England. WRIGHT (1864-1882) gave an extensive list of synonyms of this species under the informal (*nomen nudum*) name *Echinocorys vulgaris* BREYNIUS. However, this author distinguished a few varieties within *Echinocorys*, and pointed out that some of the varieties have an important stratigraphical significance, because they commonly occur within the particular lithostratigraphical units in the Upper Cretaceous of England.

WILLCOX (1953) and SMITH & WRIGHT (2003) also included all specimens of *Echinocorys* into one species, *Echinocorys scutata* LESKE; however, SMITH & WRIGHT (2003) also indicated some stratigraphically more useful forms (but not formally named) that occur in the British Chalk of England such as: *scutata*, *planodoma*, *elevata*, *gravesii*, *cincta*, *pyramidalis*, *ovata*, *subglobosa*, *conica*, *vulgaris*, and *depressa.* They noted that the forms recognized differ only in test shape. They do not rule out that more detailed palaeontological investigation can permit to divide these forms into separate species.

JAGT (2000) proposed to distinguish separate "species groups" characterized by different shapes of the *Echinocorys* test and linked to the different stratigraphical levels of the Upper Cretaceous (see also JAGT & *al*. 2004). According to the present author, except in cases where the species are and can be well distinguished (e.g. LAMBERT 1903; SMISER 1935; MOSKVIN & SHIMANSKAYA 1977), the concept by JAGT (2000) at present is more accurate, because his terminology allows to describe more precisely the variability of test shapes within *Echinocorys*. The concept of "species group" (ERNST & SCHULZ 1974; JAGT 2000; JAGT & *al*. 2004) is applied to material studied.

Echinocorys gravesi (DESOR, in AGASSIZ & DESOR, 1847)
(Text-figs 18, 19; Pl. 8, Fig. 3; Pl. 9, Figs 1, 2; Pl. 10, Figs 1, 2)

1847. *Ananchytes Gravesii* DESOR; L. AGASSIZ & E. DESOR, p. 135.
1870. *Annanchytes ovata* LAMBERT; F. ROEMER, p. 312, pl. 34, fig. 2.
1903. *Echinocorys gravesi* DESOR; J. LAMBERT, p. 48, pl. 1, figs 12-15.
non 1959. *Echinocorys gravesi* DESOR; M. M. MOSKVIN, p. 256, text-fig. 57; pl. 6, fig. 2 [=*Echinocorys* ex gr. *scutata* LESKE].
1964. *Echinocorys sphaericus* (SCHLÜTER); G.N. DZHABAROV, p. 23, pl. 1, fig. 2; pl. 2, fig. 1.
non 1964. *Echinocorys gravesi* (DESOR); G.N. DZHABAROV, p. 25, pl. 2, fig. 2 [=*Echinocorys* ex gr. *scutata* LESKE].
non 1964. *Echinocorys gravesi* (DESOR) var. *moskvini*; G. N. DZHABAROV, p. 26, pl. 2, fig. 3; pl. 3, fig. 1 [=*Echinocorys* ex gr. *scutata* LESKE].
non 1967. *Echinocorys gravesi* (DESOR); L. CAYEUX & O. DE VILLOUTREYS, p. 36, pl. 3, fig. 9 [=*Echinocorys* ex gr. *scutata* LESKE].
1972. *Echinocorys gravesi* (DESOR); G. ERNST, pl. 3, fig. 3; pl. 6, fig. 2.
1974. *Echinocorys sphaericus* (SCHLÜTER); O.V. SAVCHINSKAYA, p. 321, pl. 103, figs 9-11.
non 1974. *Echinocorys gravesi* DESOR; O.V. SAVCHINSKAYA, p. 321, pl. 103, figs 12-16 [=*Echinocorys* ex gr. *scutata* LESKE].
1991. *Echinocorys gravesi* (DESOR); R. TARKOWSKI, p. 129, pl. 28, fig. 1.

Number of the specimen	L [mm]	W [mm]	H [mm]	HE [mm]	W/L *100	H/L *100	H/W *100	HE/H *100
IGPUW/E/01/160	63.1	53.5	48.7	19.3	84.78	77.18	91.03	39.63
IGPUW/E/01/161	62.6	57.8	46.7	16.7	92.33	74.60	80.79	35.76
IGPUW/E/01/162	58.1	-	49.5	18.9	-	85.20	-	38.18
MZ VIII Ee 1464/1 Wolin	50.1	43.5	45.7	17.1	86.82	91.21	105.05	37.42
MZ VIII Ee 1464/2 Wolin	48.2	42.3	43.6	16.1	87.75	90.46	103.07	36.93
MZ VIII Ee non numbering, Wolin	53.6	49.1	49.3	19.4	91.60	91.98	100.41	39.35
MZ VIII Ee non numbering, Wolin	56.4	50.5	48.6	17.5	89.54	86.17	96.24	36.01
MZ VIII Ee 1502/1 les Petites Dalles	46.1	41.0	35.7	11.6	88.94	77.44	87.07	32.49
MZ VIII Ee 1502/2 les Petites Dalles	47.0	42.6	40.1	12.7	90.64	85.32	94.13	31.67

Table 5. Biometric data and simple ratios for *Echinocorys gravesi* (DESOR, in AGASSIZ & DESOR, 1847)

TYPE: The holotype is specimen R 91 in the collection of Agassiz & Desor, from the Craie blanche of l'Oise, in the Neuchâtel Museum.

MATERAL: One poorly and three quite well-preserved specimens (IGPUW/E/001/160-163) from Odra I and II quarries. A single, poorly preserved test (IGPUW/E/001/164) from scree from Bolko, two very poorly preserved and deformed specimens (IGPUW/E/001/165-166) from Folwark. Four well-preserved specimens from Wolin Island (Museum of the Earth, nos MZ VIII Ee 1464/1-2, plus two unregistered tests). Two well-preserved specimens from Petites Dalles, north of Fécamp, Seine-Maritime (Museum of the Earth, nos MZ VIII Ee 1502/1-2).

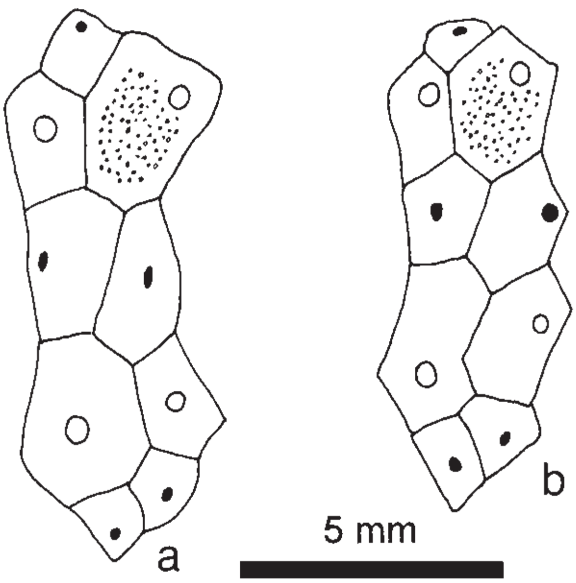

Fig. 18. Camera-lucida drawings of apical disc plating in *Echinocorys gravesi* (DESOR, in AGASSIZ & DESOR, 1847); a – MZ VIII Ee 1502/2, Petites Dalles; b – MZ VIII Ee 1464/2, Wolin

Fig. 19. Camera-lucida drawings of plastron in *Echinocorys gravesi* (DESOR, in AGASSIZ & DESOR, 1847), from Wolin; MZ VIII Ee 1464/1

DESCRIPTION: **Shape and size**. Tests medium- to large-sized (Table 5), oval in outline, slightly tapering posteriorly. Aboral surface much elevated, helmet-shaped. Base broad and flat with slightly convex plastron. Lateral profile strongly convex, with more convex anterior side than posterior side. In less typical specimens, lateral profile convex, nearly symmetrical from front to back (Pl. 9, Figs 1c, 2). Transverse profile tall and narrow. Ambitus situated fairly high, HE/H*100 ratio invariably > 30.

Apical disc. Apical disc elongate, comprising from 4 genital and 5 ocular plates. Genital plates 2 and 3 separate from 1 and 4 by ocular plates II and IV. Madreporite similar in size to genital plate 4 (Text-fig. 18). In two cases where it was possible to prepare camera-lucida drawings of apical disc, genital plate 4 bounded with ocular plates I and ocular plates V separated from genital plates 1.

Ambulacral zone. Ambulacral zone homeomorphic. Pores teardrop-shaped, tapering towards one another in pairs. Pores en chevron in two rows.

Interambulacral zone. Interambulacra slightly boarder than ambulacra.

Plastron. Plastron meridosternous, narrow (Text-fig. 19).

Peristome. Peristome anterior, transversely oval in outline. Weakly sunken.

Periproct. Periproct inframarginal, rather small, rounded or slightly oval in the outline.

Tuberculation. Aboral surface with fine and rare, widely scattered tubercles. Tubercles larger and clearer visible on adoral side on the inerambulacral areas, only on the plastron, tubercles relatively densely packed. Periplastronal areas tubercle-free.

REMARKS: *Echinocorys gravesi* appears in the Middle Turonian and this becomes commoner in the Late Turonian. Some forms, particulary earlier morphotypes of *E. gravesi*, are similar in shape to *Crassiholaster sphaericus* (SCHLÜTER); these occur in the *Inoceramus perplexus* Zone (lower Upper Turonian) in the Opole area. Forms found higher up section (*Mytiloides scupini* Zone) in this area more closely resemble *E. gravesi* as reported by LAMBERT (1903, p. 48, pl. 1, figs 12-15). In the present paper, typical representatives of *E. gravesi* are recorded from the Upper Turonian of Wolin and northern

France (Pl. 10, Figs 1, 2). DZHABAROV (1964, p. 23, pl. 1, fig. 2; pl. 2, fig. 1) and SAVCHINSKAYA (1974, p. 321, pl. 103, figs 9-11) described convex specimens from the Upper Turonian of Kopet-Dag and Donbass, respectively, as *Echinocorys sphaericus*. According to ERNST (1972), these specimens appear to be early forms of *E. gravesi*.

OCCURRENCE: Upper Turonian (*Inoceramus perplexus* Zone) of Odra I and II, Bolko, and Folwark and coeval levels in Wolin. Also known from the Middle Turonian to Lower Coniacian of Germany (Lower Saxony, Westphalia), and Upper Turonian to Lower Coniacian of England, France, Donbass, Kopet-Dag, plus Lower Coniacian of northern Spain.

Echinocorys ex gr. *scutata* LESKE, 1778
(Text-figs 20-30; Pl. 10, Fig. 3; Pl. 11, Figs 1-3; Pl. 12, Figs 1-4; Pl. 13, Figs 1-4; Pl. 14, Figs 1-4; Pl. 15, Figs 1-3)

1778. *Echinocorys scutatus* N.G. LESKE, p. 111, pl. 15, figs. A, B.
1881. *Echinocorys vulgaris* BREYNIUS, T. WRIGHT (*partly*), p. 328, pl. 77, figs 1-11.
1903. *Echinocorys vulgaris* variété *scutatus* LESKE; J. LAMBERT, p. 58.
1959. *Echinocorys gibbus* LAMARCK; M.M. MOSKVIN, p. 256, text-fig. 56; pl. 6, fig. 1.
1959. *Echinocorys gravesi* DESOR; M.M. MOSKVIN, p. 256, text-fig. 57; pl. 6, fig. 2.
1964. *Echinocorys gravesi* (DESOR); G.N. DZHABAROV, p. 25, pl. 2, fig. 2.
1964. *Echinocorys gravesi* (DESOR) var. *moskvini*; G.N. DZHABAROV, p. 26, pl. 2, fig. 3; pl. 3, fig. 1.
1966. *Echinocorys scutatus* LESKE; C.D. WAGNER & J.W. DURHAM, p. U528, fig. 416,*8*.
1967. *Echinocorys gravesi* (DESOR); L. CAYEUX & O. DE VILLOUTREYS, p. 36, pl. 3, fig. 9.
1968. *Echinocorys* cf. *conicus* AGASSIZ var. *minor* LAMBERT; S.I. PASTERNAK & *al*., p. 212, text-fig. 42; pl. 44, figs 6, 7.
1970. *Echinocorys scutata* LESKE; N.B. PEAKE & R.V. MELVILLE, p. 57, pl. 2, figs A, B.
1974. *Echinocorys gravesi* DESOR; O.V. SAVCHINSKAYA, p. 321, pl. 103, figs 12-16.
1974. *Echinocorys* ex gr. *scutata* LESKE; G. ERNST & M.-G. SCHULZ, p. 36, text-figs 12, 13; pl. 4, figs 1-4.
2002. *Echinocorys scutata* LESKE; A.B. SMITH & C.W. WRIGHT (pars), p. 287, text-fig. 13.1(A-D, I-J, K-L, O-P); pl. 59, figs 1, 2.
2003. *Echinocorys scutata* LESKE; A.B. SMITH & C.W. WRIGHT (pars), p. 531, text-fig. 218; pl. 168, figs 1-4, pl. 169, fig. 5; pl. 170, figs 1-3, 8-9; pl. 171, figs ?1-?3, 4-9.

TYPE: Neotype figured by PEAKE & MELVILLE (1970, pl. 2, figs A, B) is specimen NHM E.8721, from Fletcher's Pit, Gravesend, Kent, England; upper *Micraster coranguinum* Zone, Lower Santonian.

MATERIAL: 178 well-or fairly well-preserved, phosphatized specimens (IGPUW/E/001/167-344) from Bed 42 (unit B) and two poorly preserved specimens (IGPUW/E/001/345-346) from the top of Bed 42 (unit C) at Besakty; 21 poorly preserved, phosphatized specimens (IGPUW/E/001/347-367) from Bed 41 at Azhirektoy; 4 quite well-preserved specimens (IGPUW/E/001/368-371) from Bed 14 (*Cremnoceramus crassus crassus* Zone) at Shakh-Bogota. Two poorly preserved specimens (IGPUW/E/001/372-373) from the upper part of Bed 21 at Sulu-Kapy. A single internal mould (IGPUW/E/001/374) from Bed 21 at Kush. Two poorly preserved, incomplete specimens (IGPUW/E/001/375-376) from the *Cremnoceramus waltersdorfensis hannovrensis* + *C. crassus inconstans* + *C. crassus crassus*/ *deformis deformis* zones of Folwark Quarry.

DESCRIPTION: **Shape and size**. Tests small- to medium-sized (Text-fig. 21 and Table 6).

Statistic	L [mm]	W [mm]	H [mm]	HE [mm]	W/L*100	H/L*100	H/W*100	HE/H*100
Minimum value	27.5	24.4	20.4	4.9	79.73	61.18	72.80	15.17
Maximum value	57.3	48.9	40.8	14.0	92.05	91.24	101.08	40.88
Mean value	44.72	38.47	32.17	8.39	86.06	72.12	83.80	26.07
Median	44.85	38.50	32.15	8.15	86.08	71.83	83.60	25.75
Standard Deviation	4.895	4.123	3.488	1.937	2.223	4.939	5.357	5.076

Table 6. Simple statistics of biometric data and simple ratios for *Echinocorys* ex gr. *scutata* LESKE, 1778 from Besakty, Mangyshlak; number of specimens N=178

Several morphotypes (Text-fig. 20) are distinguished (compare ERNST & SCHULZ 1974), as follows:

(i) morphotype "*vulgaris*" (Text-fig. 20.1a-c; Pl. 9, Fig. 3; Pl. 10, Fig. 3; Pl. 11, Figs 1-3).

Moderately convex aboral surface and flattened adoral surface with quite sharp edge between them. Ambitus situated rather low, with HE/H*100 ratio sporadically exceeding 26. Base weakly elongate, slightly oval in outline.

(ii) morphotype "*planodoma*" (Text-fig. 20.2a-c; Pl. 12, Figs 1-3).

Sides of test almost vertical. Surface around apical area weakly convex, whereas apical disc with neighbouring area clearly flattened. Adoral surface flattened. Between aboral and adoral surfaces sharp edge. Ambitus situated high, with HE/H*100 ratio usually > 30. Base circular or very weakly oval in outline.

(iii) morphotype "*scutata*" (Text-fig. 20.3a-b; Pl. 13, Figs 1-3).

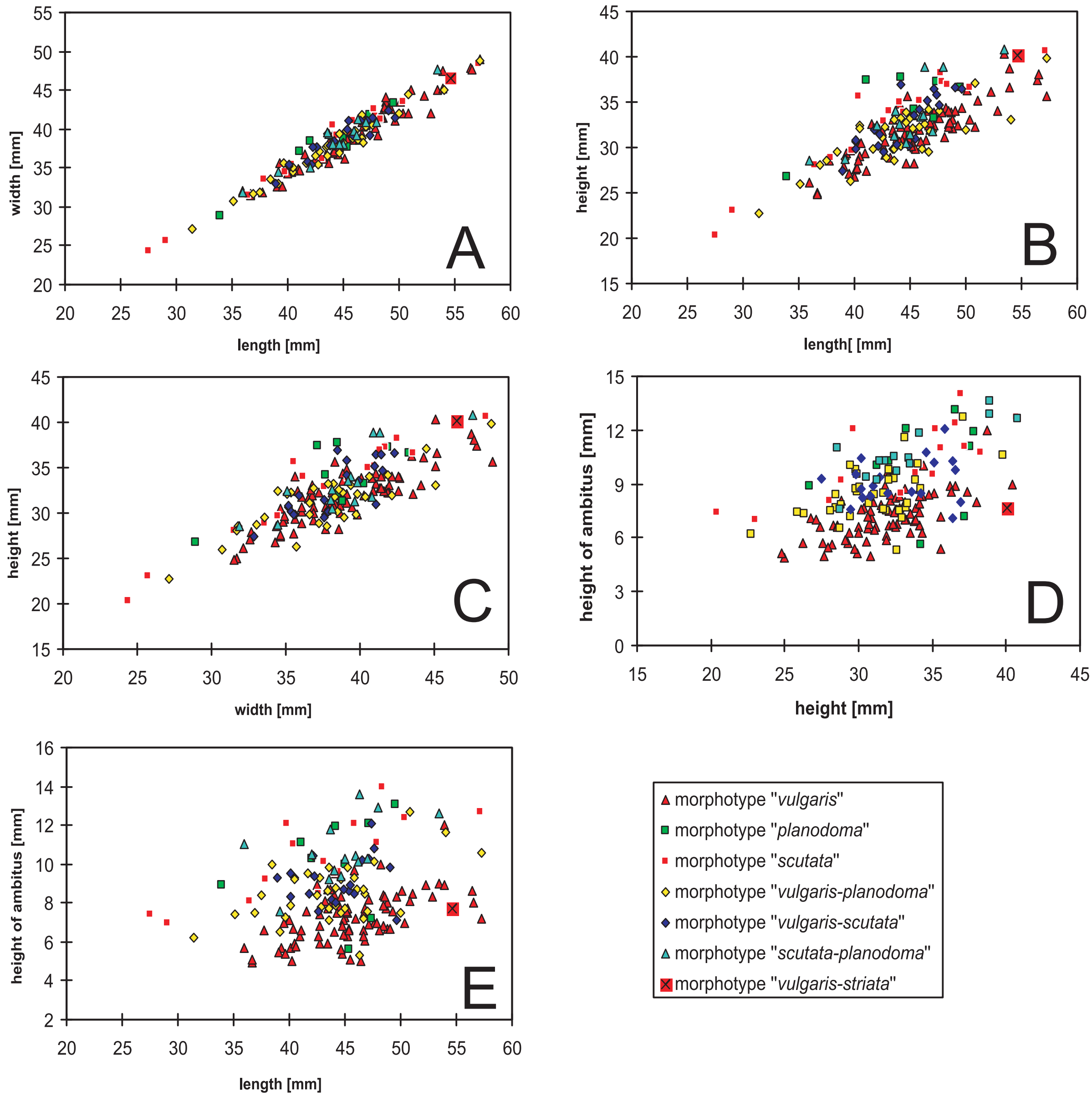

Fig. 21. Biometric data for *Echinocorys* ex gr. *scutata* LESKE, 1778, from Besakty in Mangyshlak; A – scatter plot of length *versus* width, B – scatter plot of length *versus* height, C – scatter plot of width *versus* height, D – scatter plot of height *versus* height of ambitus, E – scatter plot of length *versus* height of ambitus

Sides of test distinctly convex. Apical area slightly flattened, but in elongate and transverse profiles shows uniform arch with sides of test. Adoral surface flattened. Between aboral and adoral surfaces gentle arch. Ambitus situated high, with HE/H*100 ratio usually > 30. Base circular or occasionally very weakly oval in outline.

There are intermediate forms between these three morphotypes as follows:

(iv) intermediate morphotype "*vulgaris-planodoma*" (Text-fig. 20.4a-c; Pl. 14, Figs 1-4),

(v) intermediate morphotype "*vulgaris-scutata*" (Text-fig. 20.5a-c; Pl. 15, Figs 1-2),

(vi) intermediate morphotype "*scutata-planodoma*" (Text-fig. 20.6a-c; Pl. 12, Fig. 4; Pl. 13, Fig. 4).

ERNST & SCHULZ (1974) described the morphotype "*striata*", from the Santonian of Lägerdorf, northern Germany. In the Mangyshlak material studied only one intermediate form, i.e.

(vii) intermediate morphotype "*vulgaris-striata*" (Text-fig. 20.7a-c; Pl. 15, Fig. 3), was found, which has a subconical elongate and transverse profile, weakly convex area of apical disc, and sharp edge between aboral and adoral surfaces. Adoral surface flattened, and ambitus very low, with HE/H* 100 ratio being 19.2. Base oval-elongated.

Apical disc. Apical disc elongate, comprising 4 genital and 5 ocular plates. Genital plates 2 and 3 separated from 1 and 4 by ocular plates II and IV. The various morphotypes differ slightly in apical disc structure, although similar types of apical disc

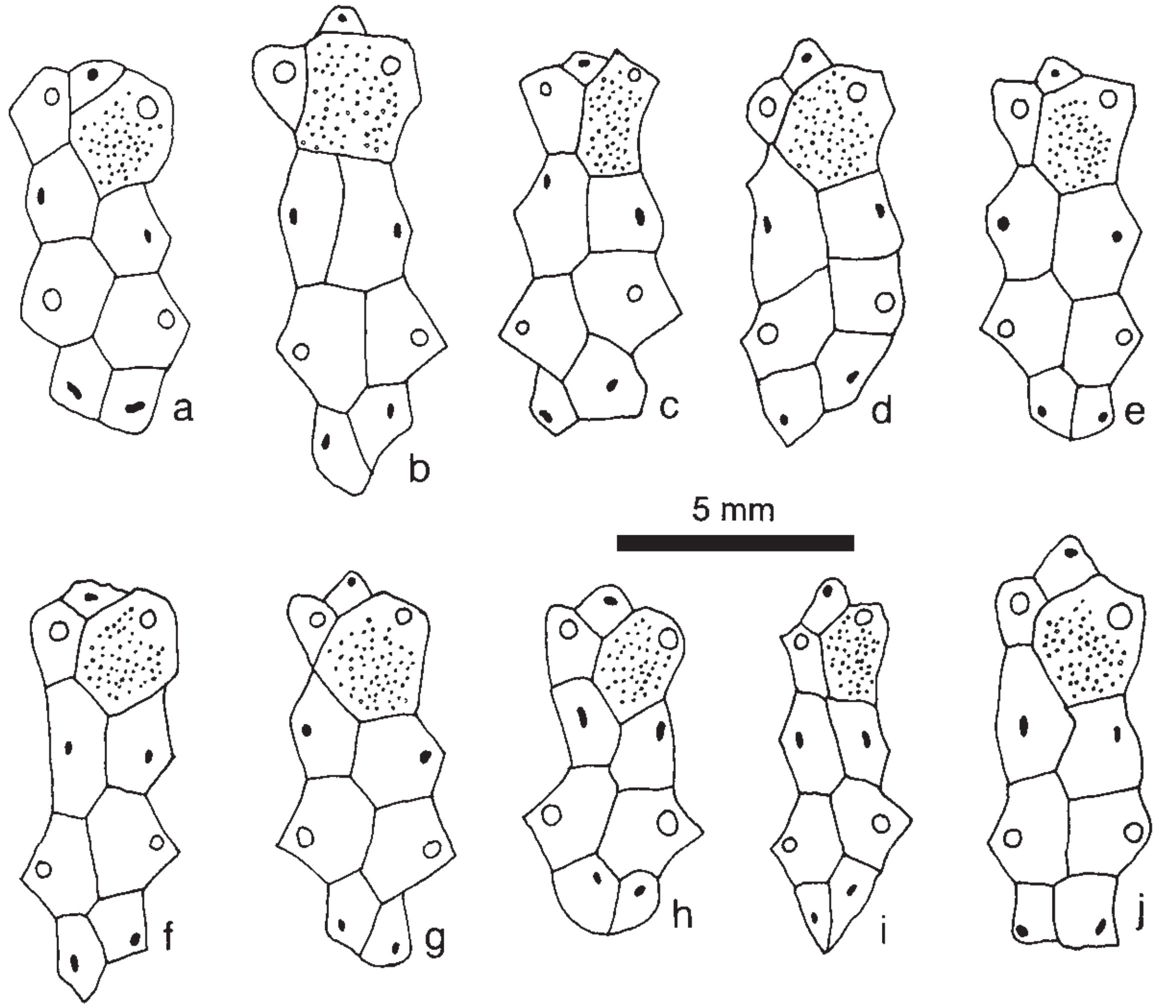

Fig. 22. Camera-lucida drawings of apical disc plating in *Echinocorys* ex gr. *scutata* LESKE, 1778; "*vulgaris*" morphotype, Mangyshlak. a – IGPUW/E/01/184, b – IGPUW/E/01/191, c – IGPUW/E/01/200, d – IGPUW/E/01/201, e – IGPUW/E/01/208, f – IGPUW/E/01/209, g – IGPUW/E/01/211, h – IGPUW/E/01/221, i – IGPUW/E/01/236, j – IGPUW/E/01/219

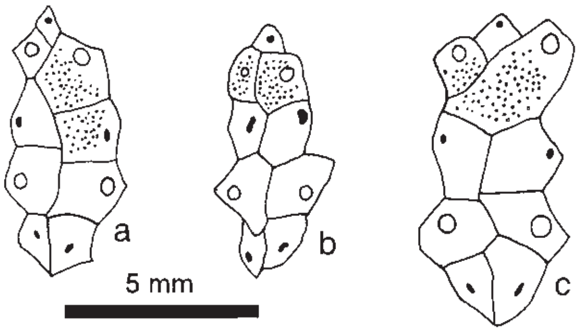

Fig. 23. Camera-lucida drawings of atypical apical disc plating in *Echinocorys* ex gr. *scutata* Leske, 1778; "*vulgaris*" morphotype, Mangyshlak; a – IGPUW/E/01/215, b – IGPUW/E/01/223, c – IGPUW/E/01/245

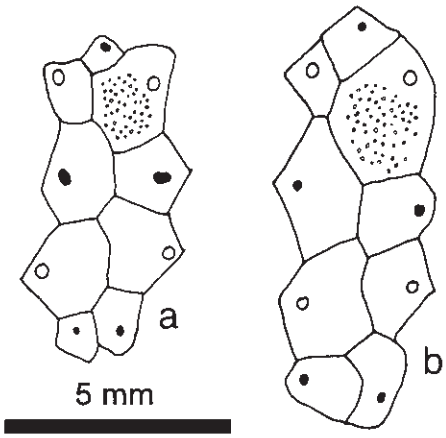

Fig. 24. Camera-lucida drawings of apical disc plating in *Echinocorys* ex gr. *scutata* Leske, 1778; "*planodoma*" morphotype, Mangyshlak; a – IGPUW/E/01/309, b – IGPUW/E/01/313

may occur in various morphotypes (Text-figs 22-28). For example, apical discs in which madreporite 2 separates genital plate 3 from ocular plate IV is found in the morphotypes "*vulgaris*" (Text-fig. 22b), "*scutata*" (Text-fig. 25a, d), "*vulgaris-planodoma*" (Text-fig. 26d). Similary, apical discs, in which genital plate 3 bounds at a very short distance with ocular plates IV is found in the morphotypes "*vulgaris*" (Text-fig. 22d), "*planodoma*" (Text-fig. 24b), "*vulgaris-planodoma*" (Text-fig. 26c), "*scutata-planodoma*" (Text-fig. 28d). Almost all morphotypes comprise specimens with apical discs, in which genital plate 1 bounds with ocular plates V and ocular plate I separated from genital plate 4 (Text-figs 22a, e, g, h; 23a; 25f; 26c, e; 27c; 28a, c). The most common apical disc, in which genital plate 4 bounds with ocular plate I and ocular plate V separated from genital plate 1 is found in every morphotype (Text-figs 22b-d, f, i, j; 23b, c; 24a, b; 25a-e; 26a, b, d, f; 27a, b; 28b, d, e). The madreporite is usually slightly larger or similar in size to other genital plates; only rarely is the madreporite distinctly larger (Text-figs 22b; 24a; 25b). Hydropores densely distributed on madreporite. Rarely, hydropores perforate also ocular plate II (Text-fig. 23a) or genital plate 3 (Text-fig. 23b, c) in morphotype "*vulgaris*".

Ambulacral zone. Ambulacral zone homeomorphic. Pores teardrop-shaped, tapered towards one another in pair, and en chevron.

Plastron. Plastron meridosternous, narrow, and similar in every type of morphotype (Text-fig. 29).

Peristome. Peristome anterior, transversely oval in outline, and weakly sunken.

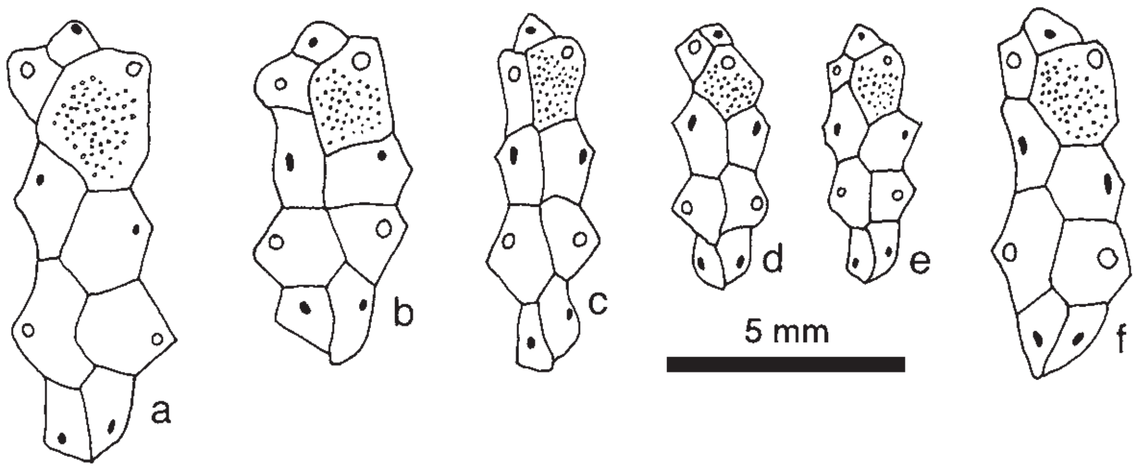

Fig. 25. Camera-lucida drawings of apical disc plating in *Echinocorys* ex gr. *scutata* Leske, 1778; "*scutata*" morphotype, Mangyshlak; a – IGPUW/E/01/315, b – IGPUW/E/01/320, c – IGPUW/E/01/325, d – IGPUW/E/01/326, e – IGPUW/E/01/327, f – IGPUW/E/01/330

Periproct. Periproct inframarginal, rounded or slightly oval in outline.

Tuberculation. Tuberculation weakly visible; fine and rare tubercles on aboral surface. Tubercles larger and more clearly visible on interambulacral zones on adoral side. Only on the plastron, are tubercles relatively densely packed. Periplastronal areas tubercle-free.

Simple statistical analysis

The mean values, simple ratios, and the small standard deviations of particular characters in the material from Besakty (Table 6) suggest this to be a homogeneous sample. There is good correlation between the characters: W and L, L and H, W and H (Table 7). Particularly close correlation occurs between L and W (r = 0.9714). The correlation coefficient between H and HE is rather low, r = 0.5273, and scatter plot of H versus HE gives a dispersed diagram. Althought the plots represented by particular morphotypes in part coincide, they do not differentiate in separated areas (Text-fig. 21D). The correlation between other characters (between HE and L and between the HE and W) indicates their independence. The chart of length versus height of ambitus (correlation coefficient r = 0.2835) gives a very scattered plot (Text-fig. 21E). However, there is a trend for the "*vulgaris*" morphotype to be situated in the lower part of the scatter diagram. Yet, the points corresponding to the "*planodoma*" and "*scutata*" morphotypes, situated in the upper part of diagram, coincide. Points corresponding to intermediate morphotype "*vulgaris-planodoma*" and "*vulgaris-scutata*" in part overlap with the area "*vulgaris*", and in part with the areas "*planodama*" and "*scutata*". The length and height of the test are independent of the height of the ambitus.

Characters and simple ratios	L	W	H	HE	W/L*100	H/L*100	H/W*100	HE/H*100
L	1	**0.9714**	**0.7988**	0.2835	-0.2069	-0.3344	-0.2753	-0.1311
W		1	**0.8213**	0.3338	0.0300	-0.2556	-0.2864	-0.0870
H			1	**0.5273**	0.0156	0.2963	0.3085	0.0411
HE				1	0.1786	0.3803	0.3310	**0.8648**
W/L*100					1	0.3498	-0.0293	0.1965
H/L*100						1	**0.9258**	0.2830
H/W*100							1	0.2204
HE/H*100								1

Table 7. Matrix correlation of biometric data and simple ratios for *Echinocorys* ex gr. *scutata* Leske, 1778, from Besakty, Mangyshlak; marked correlations are significant at $p<0.05$; number of specimens N=178

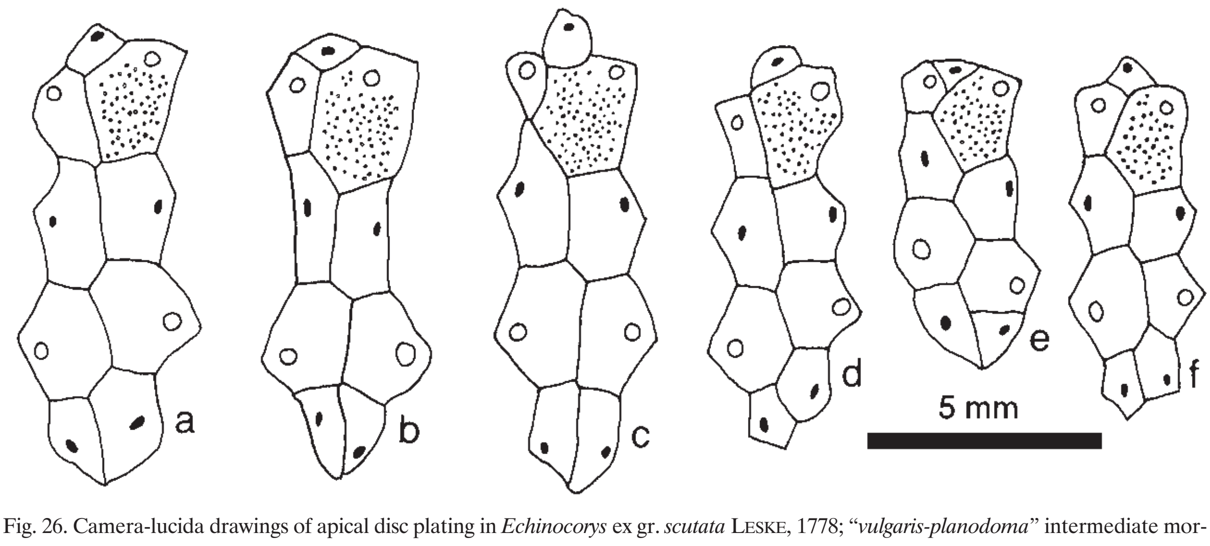

Fig. 26. Camera-lucida drawings of apical disc plating in *Echinocorys* ex gr. *scutata* Leske, 1778; "*vulgaris-planodoma*" intermediate morphotype, Mangyshlak; a – IGPUW/E/01/253, b – IGPUW/E/01/255, c – IGPUW/E/01/260, d – IGPUW/E/01/269, e – IGPUW/E/01/257, f – IGPUW/E/01/280

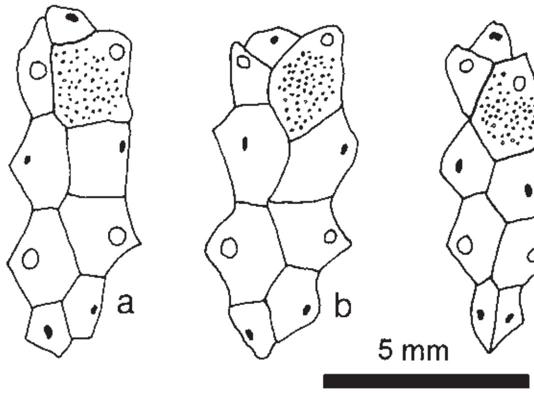

Fig. 27. Camera-lucida drawings of apical disc plating in *Echinocorys* ex gr. *scutata* LESKE, 1778; "*vulgaris-scutata*" intermediate morphotype, Mangyshlak; a –IGPUW/E/01/292, b – IGPUW/E/01/294, c – IGPUW/E/01/303

The frequency distribution of particular simple ratios (Text-fig. 30), examined with Kolmogorov-Smirnov test of goodness of fit, at the 95% confidence level, shows their distribution to be close to normal, additionally suggesting a homogeneous sample.

REMARKS: LESKE (1778) was the first to use the binomen *Echinocorys scutatus*, with masculine ending. HAYWARD (1940) corrected it to "*scutata*". ERNST & SCHULZ (1974) noted a wide range of variation in *Echinocorys* ex gr. *scutata*, first occurring in the Middle Coniacian. They distinguished several morphotypes and some of them they regarded as formal subspecies (e.g. *Echinocorys scutata scutata* LESKE, or *E. scutata vulgaris*

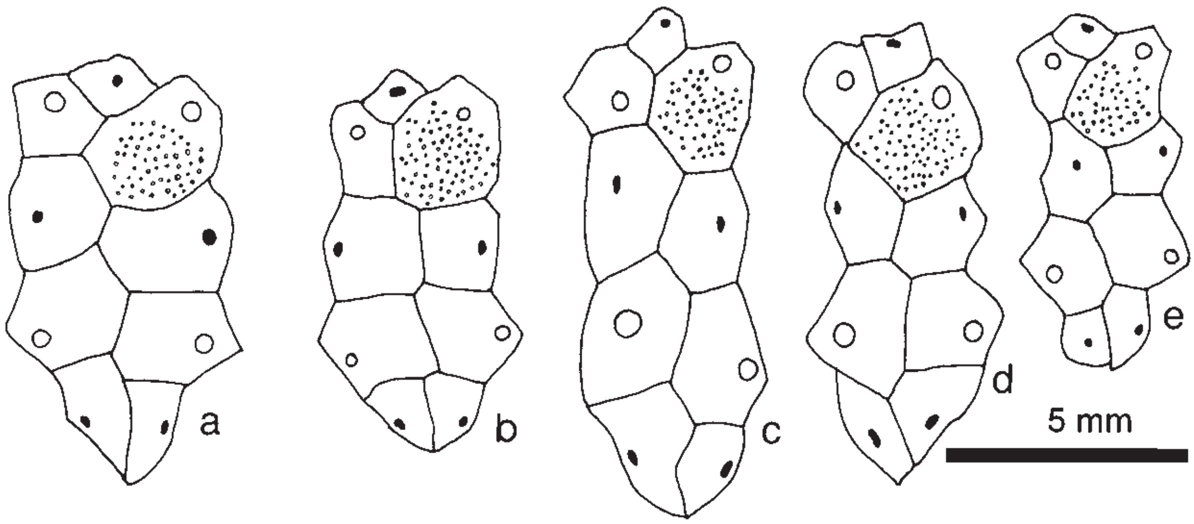

Fig. 28. Camera-lucida drawings of apical disc plating in *Echinocorys* ex gr. *scutata* LESKE, 1778; "*scutata-planodoma*" intermediate morphotype, Mangyshlak; a –IGPUW/E/01/332, b – IGPUW/E/01/336, c – IGPUW/E/01/333, d – IGPUW/E/01/340, e – IGPUW/E/01/334

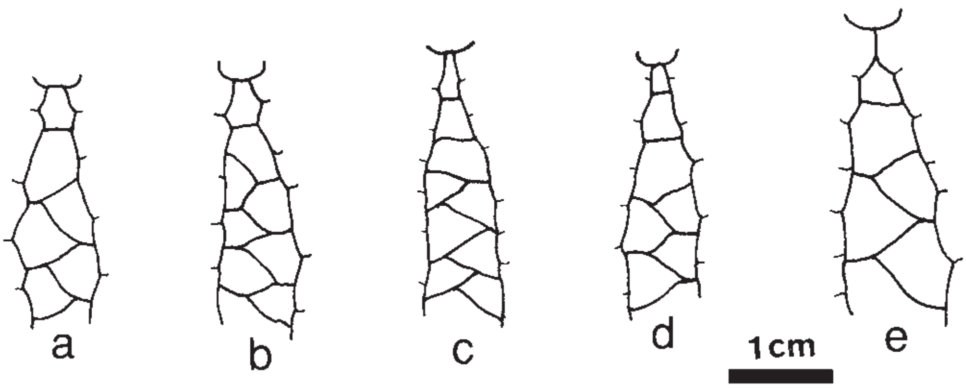

Fig. 29. Camera-lucida drawings of plastron plating in *Echinocorys* ex gr. *scutata* LESKE, 1778 of Mangyshlak; a – "*vulgaris*" morphotype, IGPUW/E/01/203; b – "*vulgaris*" morphotype, specimen No. IGPUW/E/01/234; c – "*vulgaris*" morphotype, IGPUW/E/01/227; d – "*scutata*" morphotype, IGPUW/E/01/323, e – "*vulgaris-planodoma*" morphotype, IGPUW/E/01/253

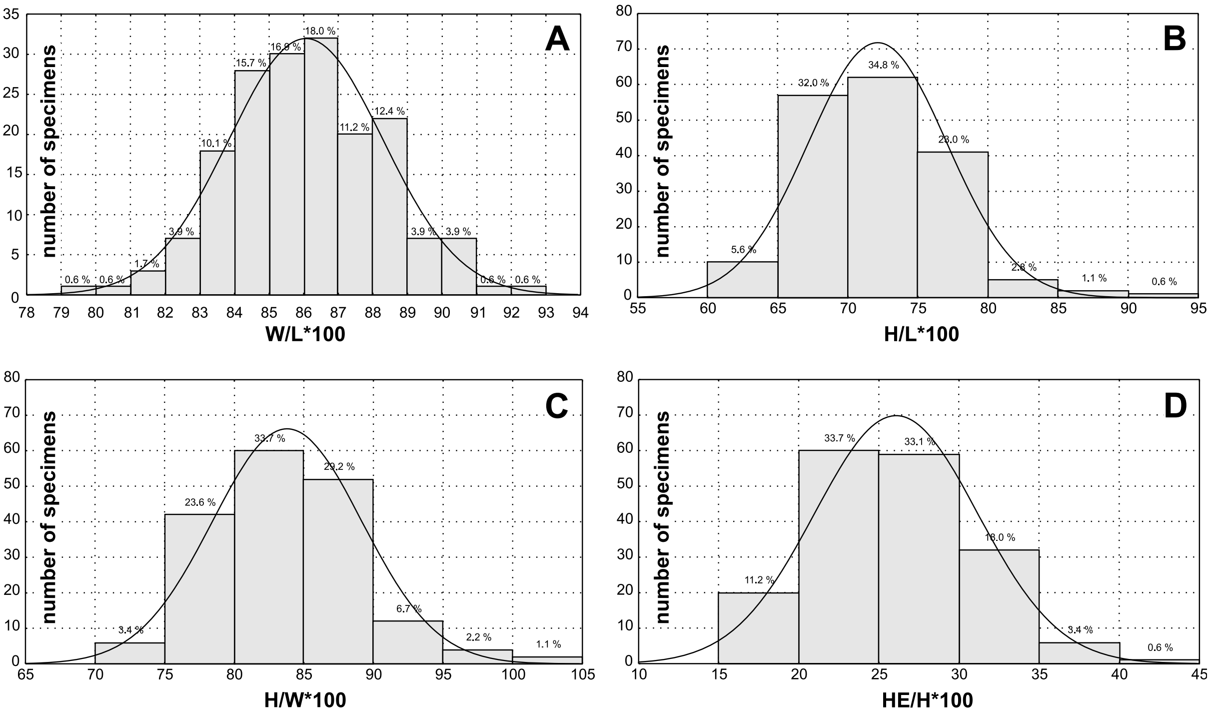

Fig. 30. Histograms of distribution of simple ratios in *Echinocorys* ex gr. *scutata* LESKE, 1778, from Besakty, Mangyshlak; A – W/L*100, B – H/L*100, C – H/W*100, D – HE/H*100

BREYNIUS), the others as morphotypes (e.g. "*planodoma*") only. SMITH & WRIGHT (2003) enclosed all specimens of *Echinocorys* from the Upper Cretaceous of England under the name *Echinocorys scutata* and distinguished 11 informal forms (*scutata*, *planodoma* with extreme forms named *depressula*, *elevata*, *gravesii*, *cincta*, *pyramidalis*, *ovata*, *subglobosa*, *conica*, *vulgaris*, *depressa*). Some of the forms illustrated by SMITH & WRIGHT (2003) are similar to morphotypes distinguished in this paper e.g. form *vulgaris* (SMITH & WRIGHT 2003, pl. 170, figs 1, 3, 8); the other forms are different. *E. scutata* form *depressula* extreme form of *planodoma* (SMITH & WRIGHT 2003, pl. 169, fig. 5) is exactly similar to *E. scutata* morphotype "*vulgaris-planodoma*" (Pl. 14, figs 1-4) and is nearly similar to *E.* ex gr. *scutata* type *vulgaris* of ERNST & SCHULZ (1974, pl. 4, fig. 3). *E. scutata* form *subglobosa* (SMITH & WRIGHT 2003, pl. 170, figs 2, 7, 9) is exactly similar to "*scutata*" morphotype (Pl. 13, figs 1-3) and resembles *E.* ex gr. *scutata* type *scutata* of ERNST & SCHULZ (1974, fig. 12.1). *E. scutata* form *ovata* (SMITH & WRIGHT 2003, pl. 171, figs 7-9) seems to be similar to "*vulgaris-scutata*" morphotype (Pl. 15, figs 1, 2). Moreover, it is remarkable that *E. scutata* form *planodoma* by SMITH & WRIGHT (2003, pl. 169, figs 1-4) is different from the same form by ERNST & SCHULZ (1974, fig. 12.6-7, pl. 4, figs 1, 2) and by the author of the present paper (Pl. 12, figs 1-3).

In Mangyshlak, in non-condensed sections most of the distinguished morphotypes co-occur in one interval of the section (Text-fig. 3). This means, that presumably the echinoids lived in the same time and in an environment without geographical barriers. Thus, consequently, I regard all varieties discussed herein ("*vulgaris*", "*planodoma*", "*scutata*", "*vulgaris-planodoma*", "*vulgaris-scutata*", "*scutata-planodoma*", "*vulgaris-striata*") only as morphotypes which cannot be treated as subspecies in the biological sense. Probably, they all, except of "*vulgaris-striata*", which seems to occur separately in the interval of the section directly above the interval containing the remaining morphotypes (Text-fig. 3), belong to a single species, *Echinocorys scutata*.

OCCURRENCE: Lower Coniacian (*Cremnoceramus* c. *crassus* Zone) at Shakh-Bogota, Middle and Upper Coniacian at Sulu-Kapy, Shyrkala-Airakty and condensed Upper Turonian – Coniacian of Azhirektoy and Besakty, plus Lower

Coniacian (*Cremnoceramus walt. hannovrensis* + *C. crassus inconstans* + *C. c. crassus*/*deformis deformis* zones) at Folwark. This species has also been reported from the Middle-Upper Coniacian and Santonian of the North European Province (England, France, Belgium, Germany, western Ukraine, Donbass, ?northern Caucasus, Kopet-Dag). ERNST & SCHULZ (1974) described a very similar *Echinocorys* ex gr. *scutata* fauna from the Middle Coniacian to Middle Santonian from Lägerdorf, northern Germany, with an acme in the Upper Coniacian and Lower Santonian. At Lägerdorf, the morphotype "*striata*" succeeds the morphotype "*vulgaris*" during the Middle Santonian.

Order Spatangoida CLAUS, 1876

The characters measured and abbreviations used for representatives of this order are shown in Text-figs 31 and 32.

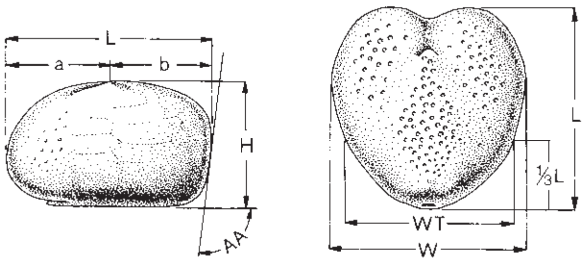

Fig. 31. Basic measurements in the genus *Micraster* AGASSIZ, 1836; L – length of the test (in mm); W – width of the test (in mm); H – height of the test (in mm); WT – width of the test measured at one third from posterior edge (in mm); AA – anal angle (in degrees); a – distance from central point of apical disc to anterior edge (in mm); b – distance from central point of apical disc to posterior edge (in mm).

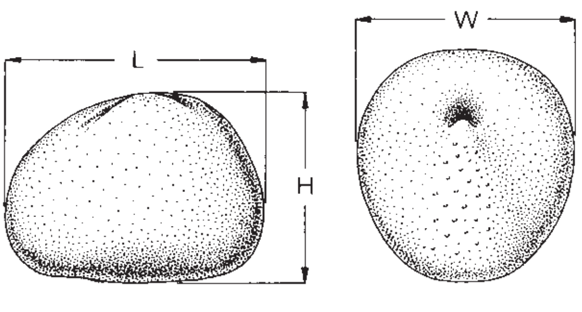

Fig. 32. Basic measurement in the genus *Hemiaster* AGASSIZ, in AGASSIZ & DESOR, 1847; L – length of the test (in mm); W – width of the test (in mm); H – height of the test (in mm)

Simple ratios:

W/L*100 – characterizes outline of test; ratio between 95 and 105 characterizes outline close to circular, ratio < 95 characterizes elongate outline;

H/L*100 – characterizes height of elongate profile; ratio > 70 characterizes tall, elongate profile, ratio between 50 and 70 characterizes moderately-tall profile, ratio < 50 characterizes low elongate profile;

H/W*100 – characterizes height of transverse profile; ratio > 75 characterizes tall profile, ratio between 55 and 75 characterizes moderately-tall profile, ratio < 55 characterizes low transverse profile;

WT/W*100 – additionally characterizes test outline, ratio >84 characterizes test close to oval,

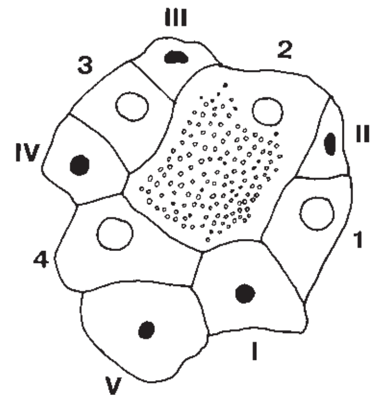

Fig. 33. Generalised apical disc of *Micraster* AGASSIZ, 1836, showing the Lovénian numbering of ocular (I-V) and genital plates (1-4, in which 2 is madreporite)

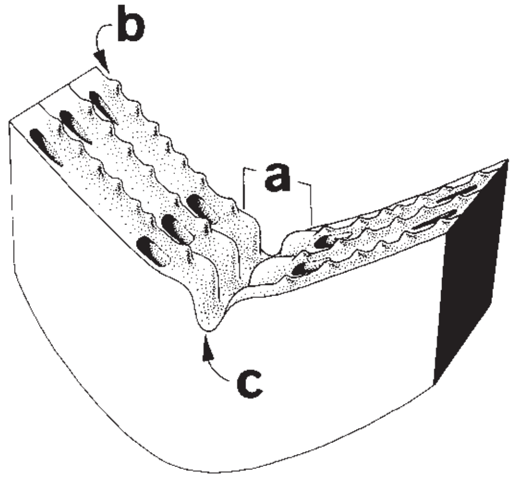

Fig. 34. Structure of petal (paired petal II) of the genus *Micraster* AGASSIZ, 1836, (compare also ERNST & SEIBERTZ 1977); a – interporiferous area, b – interporiferous ridge, c – ambulacral furrow

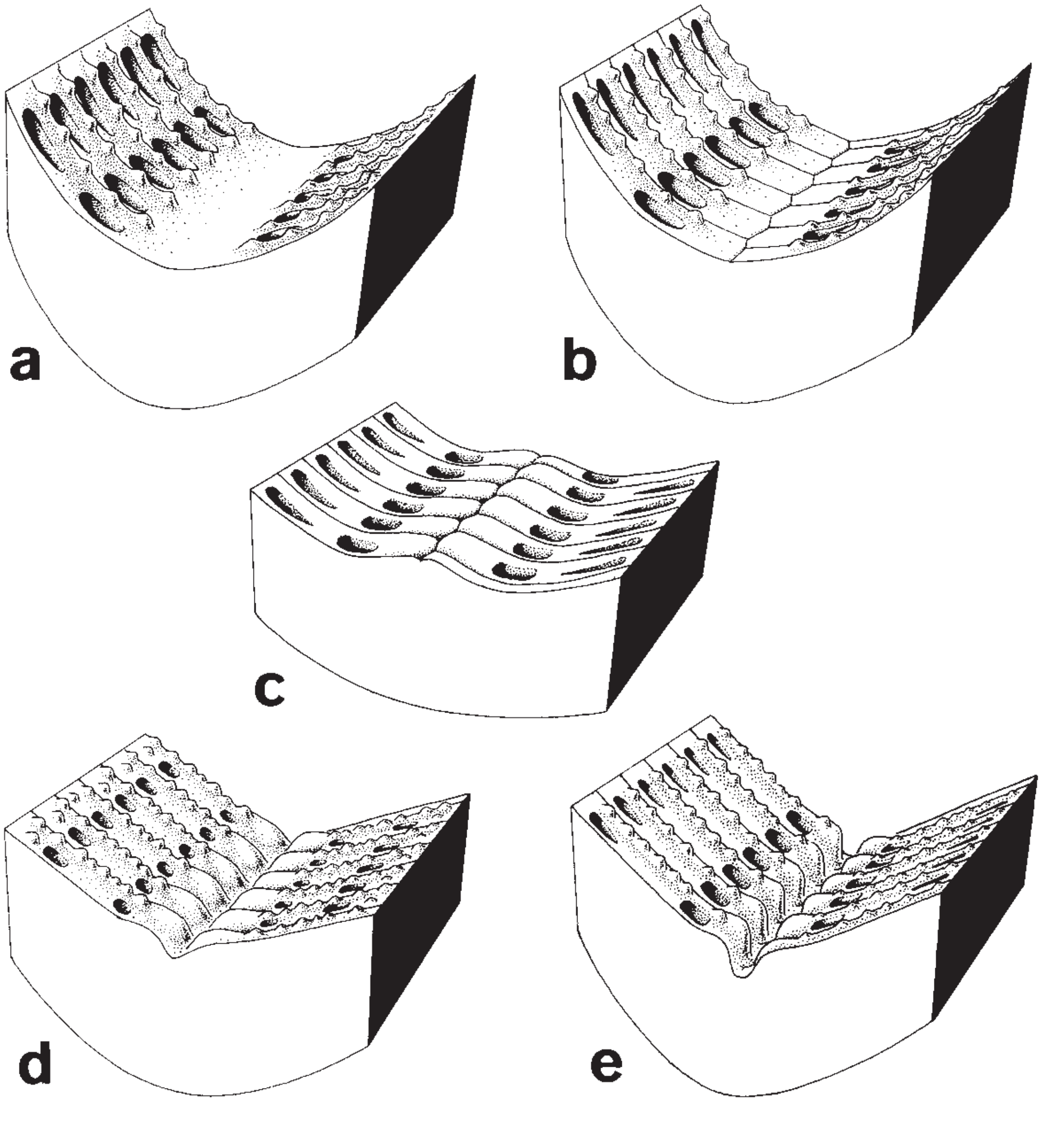

Fig. 35. Types of structure of petal (paired petal II) of the genus *Micraster* AGASSIZ, 1836; a – "smooth", b – "sutured", c – "inflated", d – "subdivided", e – "divided"

lower ratios, as a rule < 83, characterize pseudo-trapezoidal, oval-trapezoidal or circular-trapezoidal outline, whereas, more generally ratio < 80 characterizes cordiform or near-cordiform outline;

a/b*100 – characterizes placement of apical disc, ratio between 95 and 105 characterizes central or near-central position of apical disc, ratio < 95 characterizes position of apical disc moved anteriorly, ratio > 105 characterizes position of apical disc moved posteriorly.

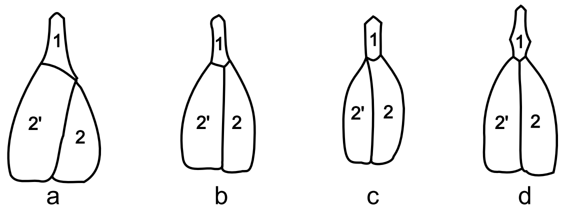

Fig. 36. Types of amphisternal plastron structure in the genera *Micraster* AGASSIZ, 1836 and *Hemiaster* AGASSIZ, in AGASSIZ & DESOR, 1847; a – semiamphisternal type 1, b – semiamphisternal type 2, c – semiamphisternal inverse type, d – euamphisternal; 1 – labral plate, 2' – left sternal plate, 2 – right sternal plate

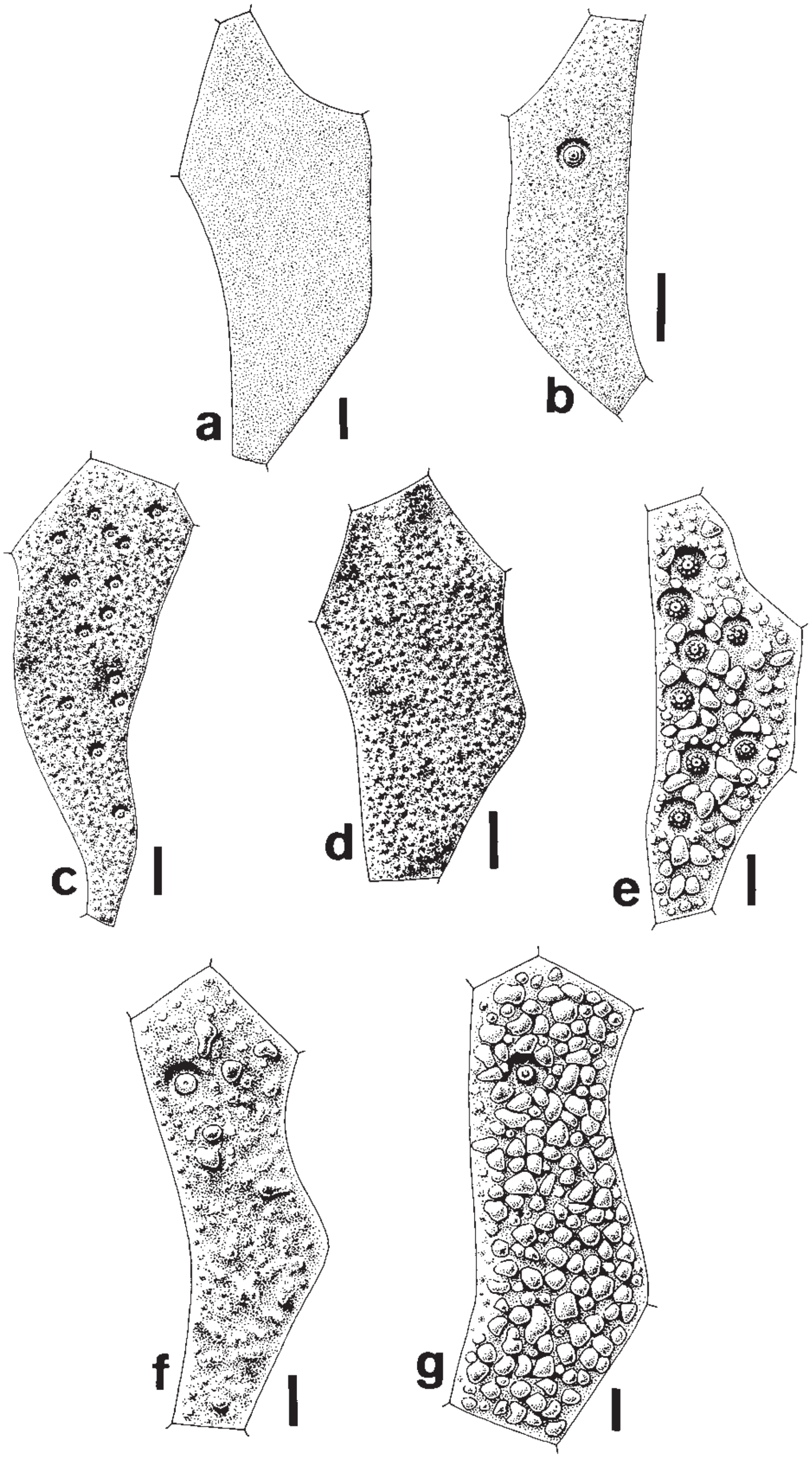

Fig. 37. Variations of periplastronal area in the genus *Micraster* AGASSIZ, 1836; a – “smooth”, b – “sandy”, c – “granular”, d – “coarsely-granular”, e – “tuberculate-mamillate”, f – “granular-mamillate”, g – “mamillate”; scale bar 1 mm

For large populations biometric characters are shown in charts, and simple ratios in histograms.

The apical disc is describe using the Lovénian numbering system (Text-fig. 33).

The structure of the ambulacral area is a variable character and the most interesting is petal structure (Text-fig. 34). It is possible to distinguish five different (compare ROWE 1899; ERNST 1970c, 1972; FOURAY 1981; DRUMMOND 1985; DRUMMOND & FOURAY 1985) evolutionary stages of petal development (Text-fig. 35):

(i) "smooth" – plate sutures in the interporiferous area badly or not visible, interporiferous ridge and ambulacral furrow not evolved;

(ii) "sutured" – clear suture visible;

(iii) "inflated" – median portion of petal with suture inflated, pore pairs situated outside inflated area;

(iv) "subdivided" – two rows of plates in the petal weakly divided, ambulacral furrow shallow;

(v) "divided" – two rows of plates in petal clearly divided, ambulacral furrow broad and relatively deep.

In addition, it is possible to distinguish four types of amphisternal plastron structure in the material studied (Text-fig. 36):

(i) semiamphisternal type 1 – suture between sternal plates 2' and 2 abuts right-hand corner of labral plate and divides plastron into two asymmetrical sternal plates, sternal plate 2' much larger than sternal plate 2;

(ii) semiamphisternal type 2 – suture between the sternal plates 2' and 2 abuts posterior of labral plate and divides plastron into two asymmetrical sternal plates, but asymmetry much less than in type 1;

(iii) semiamphisternal inversely type – this type is like a mirrored reflection of semiamphisternal plastron types 1 or 2, sternal plate 2' (much) smaller than sternal plate 2; this type very rare;

(iv) euamphisternal – suture between sternal plates 2' and 2 divides plastron into two symmetric sternal plates.

The structure of the periplastronal area is also different. FOURAY (1981), DRUMMOND (1985), DRUMMOND & FOURAY (1985) demonstrated the range of variations in periplastronal area of *Micraster*. This scheme, however, cannot be applied to material from the Mangyshlak and Opole Cretaceous. In my opinion, it is possible to distinguish seven variable 'types' of periplastronal area based on microscoping observation (Text-fig. 37).

(i) "smooth" – smooth; weak granulation rarely visible at large magnifications;

(ii) "sandy" – covered very fine granulation, reminiscent of surface covered with fine sand grains; rarely with tubercle;

(iii) "granular" – granulate, reminiscent of a surface covered with medium-grained sand; occasionally surface has numerous small tubercles;

(iv) "coarse-granular" – covered by coarse granulation, reminiscent of a surface covered with coarse-grained sand; tubercles rare;

(v) "tuberculate- mamillate" – covered by numerous large tubercules and large mamillae;

(vi) "granular- mamillate" – with coarse granules and mamillae, in some cases with rare tubercles;

(vii) "mamillate" – covered by large mamillae; occasionally with very rare tubercles.

The condensed Bed 42 (Text-fig. 4) at Besakty has yielded the most numerous and best-preserved specimens of *Micraster*. Statistical methods have proved not very helpful in separation of species of this genus from this section. The main characters in species recognition treated herein are: type of petal structure, type of plastron, structure of periplastron area, structure of apical disc, especially relationships of madreporite plate to other genital plates. The stratigraphical range of species of the genus examined herein is based on uncondensed sections, in particular Shakh-Bogota.

Family Micrasteridae LAMBERT, 1920
Genus *Micraster* AGASSIZ, 1836

TYPE SPECIES: *Spatangus Cor Anguinum* var. a *Anglicum* LESKE, 1778, by subsequent designation of POMEL (1883).

OCCURRENCE: The genus *Micraster* first occurs in the Cenomanian (Devon, England, e.g. SMITH 1988) and ranges through Paleocene (Danian) of Europe (e.g. SMITH & JEFFERY 2000), Mediterranean region, Asia (Georgia, Mangyshlak, Kopet-Dag), Madagascar, and Cuba.

Number of specimen	L [mm]	W [mm]	H [mm]	AA [^{o}]	WT [mm]	a [mm]	b [mm]
IGPUW/E/01/377	42.2	41.1	25.9	90	33.7	21.4	20.8
IGPUW/E/01/378	48.9	44.8	29.4	-	35.5	25.9	23.0
IGPUW/E/01/379	35.8	35.1	-	86	31.5	-	-
IGPUW/E/01/380	36.9	36.8	21.9	-	31.2	18.5	18.4

Table 8. Biometric data for *Micraster* cf. *distinctus* AGASSIZ & DESOR, 1947 from Bed 9, Shakh-Bogota, Mangyshlak

Micraster cf. *distinctus* AGASSIZ & DESOR, 1847
(Pl. 28, Fig. 1)

MATERIAL: Four poorly preserved, phosphatized moulds (IGPUW/E/001/337-380) from Bed 9 at Shakh-Bogota.

DESCRIPTION: **Shape and size**. Small to medium-sized (Table 8). Outline cordate, widest just above of ends of paired anterior petals. Elongated profile slightly convex from aboral side, very slightly convex, almost flattened from adoral side, transverse profile oval, more convex from aboral than from adoral side, anterior groove relatively narrow, slightly sunken, anal angle close to right or slightly smaller.

Ambulacral zone. Petals sunken considerably and relatively wide, posterior paired petals about 67% of anterior paired ones, unpaired ambulacrum III different from paired ambulacra because of lack of petal structure.

Peristome. Peristome oval in outline, situated relatively far from anterior border, no more, however, than one quarter length from anterior border.

Periproct. Periproct circular or oval in outline, lying high on anal field.

REMARKS: These moulds are similar to *Epiaster distinctus* (AGASSIZ) described by PASTERNAK & *al*. (1968) from the Upper Cenomanian of western Ukraine. The specimen illustrated by PASTERNAK & *al*. (1968, pl. 48, figs 1-3) has a smaller anal angle than specimens from Shakh-Bogota. SMITH (1988, pp 170-173, pl. 38, fig. 3; pl. 39, figs 1-4) described *Micraster distinctus* AGASSIZ & DESOR from the Lower Cenomanian of Wilmington (Devon, England). These specimens are of similar length and width but are taller and show a smaller (clearly acute) anal angle than specimens from Mangyshlak. The widest point of the test is moved anteriorly and the peristome is situated further from the anterior border than in the Mangyshlak specimens. Although *M.* cf. *distinctus* appears to fit the range of variations of *M. distinctus*, the limited number of specimens and their poor preservation do not allow an unequivocal conclusion.

OCCURRENCE: The stratigraphically condensed phosphatic horizon of Shakh-Bogota represents the Lower Cenomanian to, probably, lowermost Turonian.

Subgenus *Micraster* (*Micraster*) AGASSIZ, 1836

REMARKS: The typical feature of this subgenus is ambulacral heteromorphy. The unpaired ambulacrum differs from the paired ones, in being relatively narrow, non-petaloid, with pores small, rounded, and non-conjugated, whereas paired petals broad with rounded or transversely oval conjugated pores. A subanal fasciole is always present.

OCCURRENCE: *M*. (*Micraster*) is known from the Upper Cretaceous (Cenomanian through Maastrichtian) of Europe, the Mediterranean region, Asia (Georgia, Mangyshlak, Kopet-Dag), Madagascar, and Cuba.

Micraster (*Micraster*) *leskei* (DES MOULINS, 1837)
(Text-figs 38-45; Pl. 16, Figs 1-5; Pl. 17, Figs 1-5; Pl. 18, Figs 1-3; Pl. 19, Figs 1-6; Pl. 20, Figs 1-5; Pl. 21, Figs 1-4)

1734. *Spatangus Cor Anguinum* (*b*) *Norwagicum 2. Productum*; J.T. KLEIN, p. 33, pl. 23, figs E, F.
1853. *Micraster Leskei* D'ORBIGNY; A. D' ORBIGNY, p. 215, pl. 869, figs 1-8.
1874. *Micraster Leskii*; F.A. QUENSTEDT, p. 649, pl. 88, figs 2-4.
1874. *Micraster Leskii quadratus*; F.A. QUENSTEDT, p. 650, pl. 88, fig. 5.
1876. *Micraster breviporus* AGASSIZ; G. COTTEAU, p. 352, pl. 75, figs 1-5, 6?; pl. 76, figs 1-3.

?1876. *Micraster tropidotus* AGASSIZ; G. COTTEAU, p. 358, pl. 76, fig. 4.
1878. *Micraster breviporus* AGASSIZ; TH. WRIGHT, p. 278, pl. 62A, fig. 3.
1887. *Micraster Sanctae Maurae* GAUTHIER; V. GAUTHIER, p. 227, pl. 4, figs 1-6.
1889. *Micraster breviporus* AGASSIZ; A. FRIČ, p. 99, fig. 127.
1899. *Micraster leskei* DESMOULINS; A.W. ROWE, p. 525, pl. 35, figs i1'-i5'; pl. 38, fig. 1.
1924. *Micraster Leskei* DESMOULINS, var. *joviniacensis*; J. LAMBERT & P. THIÉRY, p. 480, pl. 12, fig. 10.
1935. *Micraster leskei* DESMOULINS; J.S. SMISER, p. 80, pl. 7, fig. 3.
1936. *Micraster leskei* DESMOULINS; R. KONGIEL, p. 6, pl. 1, fig. 4; pl. 2, fig. 5.
1959. *"Micraster" leskei* DESMOULINS; M.M. MOSKVIN, p. 287, text-fig. 103; pl. 24, fig. 2.
1964. *Micraster leskei* DESMOULINS; G.N. DZHABAROV, p. 47, pl. 16, fig. 3; pl. 17, fig. 1.
1966. *Micraster leskei* (DESMOULINS); L. CAYEUX & O. DE VILLOUTREYS, p. 38, pl. 2, fig. 12.
1966. *Micraster leskei* (DESMOULINS); H. RAABE, p. 111, pl. 10, fig. ?2.
1968. *Micraster leskei* DESMOULINS; S.I. PASTERNAK & *al*., p. 218, text-fig. 47; pl. 49, figs 1-4.
1970c. *Micraster* (*Micraster*) *leskei* DESMOULINS; G. ERNST, pl. 17, fig. 2.
1972. *Micraster leskei* DESMOULINS; G. ERNST, pl. 5, fig. 1.
1974. *Micraster leskei* (DESMOULINS); O.V. SAVCHINSKAYA, p. 326, pl. 111, figs 5-9.
1974. *Micraster leskei* (DESMOULINS) var. *magna* NIETSCH; O.V. SAVCHINSKAYA, p. 326, pl. 112, figs 1-5.
1975. *Micraster leskei* (DES MOULINS); R.B. STOKES, p. 73, text-fig. 29p.
1977. *Micraster leskei* (DESMOULINS); R.B. STOKES, p. 812, pl. 108, figs 7-9.
1978. *Micraster leskei* (DESMOULINS); F. ROBASZYNSKI, pl. 1, figs 8-14.
1981. *Micraster leskei* DESMOULINS; M. FOURAY, p. 30, pl. 1, figs 11-16; pl. 2, figs 1-4; pl. 3, figs 1-4.
1984. *Micraster leskei* (DES MOULINS); B. DAVID & M. FOURAY, p. 467, figs 6, 8, 10.
1985. *Micraster leskei* (DES MOULINS); M. FOURAY & B. POMEROL, pl. 1, figs 1, 4, 7; pl. 2, figs 1, 8.
1991. *Micraster leskei* (DES MOULINS); R. TARKOWSKI, p. 130, pl. 26, figs 1-3.
1991. *Micraster leskei* (DES MOULINS); M. FOURAY & R. TARKOWSKI, p. 216, pl. 1, figs 1-6; pl. 2, figs 1, 2.
2002. *Micraster leskei* DESMOULINS; A.B. SMITH & C.W. WRIGHT, p. 293, pl. 60, figs 1-3.

TYPE: STOKES (1975) referred to the siliceous moulds figured by KLEIN (1734) under the name of *Spatangus Cor Anguinum* (*b*) *Norwagicum 2. Productum*. The collection of Klein is lost, however, and the type locality and type horizon of these specimens are unknown. According to FOURAY & TARKOWSKI (1991), the specimen decribed and illustrated by D'ORBIGNY (1853, p. 215, pl. 869, figs 1-8), under the name of *Micraster Leskei* D'ORBIGNY, from the Craie blanche (Turonian) of France, should be regarded as the type specimen.

MATERIAL: Three small well-preserved specimens (IGPUW/E/01/381-383) from Bed 12, and two medium-sized (IGPUW/E/01/385, 386) plus one large specimen (IGPUW/E/01/384) from the lower part of Bed 14 at Shakh-Bogota. Three poorly preserved, phosphatized moulds (IGPUW/E/01/509-511) from Bed 37A at Koksyratu/Aksyrtau. 118 well-preserved phosphatized specimens (IGPUW/E/01/387-504) from Bed 42 (unit B) at Besakty. Four poorly preserved, phosphatized specimens (IGPUW/E/01/505-508) from Bed 41 at Azhirektoy. 45 well- and moderately well-preserved specimens (IGPUW/E/01/512-556) and numerous very poorly preserved, mainly deformed moulds from the Odra I and II Quarries. 56 well- and moderately well-preserved specimens (IGPUW/E/01/557-612), plus numerous poorly preserved, usually deformed moulds from Bolko Quarry. 19 well- and moderately well-preserved specimens (IGPUW/E/01/613-631), and numerous poorly preserved, deformed moulds from Groszowice. Five well- and moderately-well preserved specimens (IGPUW/E/01/632-636) from the Turonian Chalk Rock of Beachy Head, southeast England.

DESCRIPTION: **Shape and size**. Tests variable in size (Tables 9-12 and Text-figs 38, 39), thickness of test depends on size and ontogenetic stage, small specimens have medium thick tests. Test outline also varies: from pseudotrapezoidal (Pl. 16, Figs 1a-b, 2a-b, 3a-b, 4a-b, 5a-b; Pl. 18, Figs 1a-b, 2a, 3; Pl. 19, Figs 3a-b, 4a-b, 5a-b, 6a-b), to oval-trapezoidal (Pl. 17, Figs 1a-b, 2a-b, 3a-b, 4a-b, 5a-b; Pl. 19, Figs 1a-b, 2a-b; Pl. 20, Figs 1a-b, 2a-b, 3a-b, 4a-b, 5a-b; Pl. 21, Figs 1a-b, 2a-b, 3a-b, 4a-b). Viewed from above, test widest at ends of anterior paired petals. Elongated profile moderately tall. In similar type of outline of test elongated profile consider-

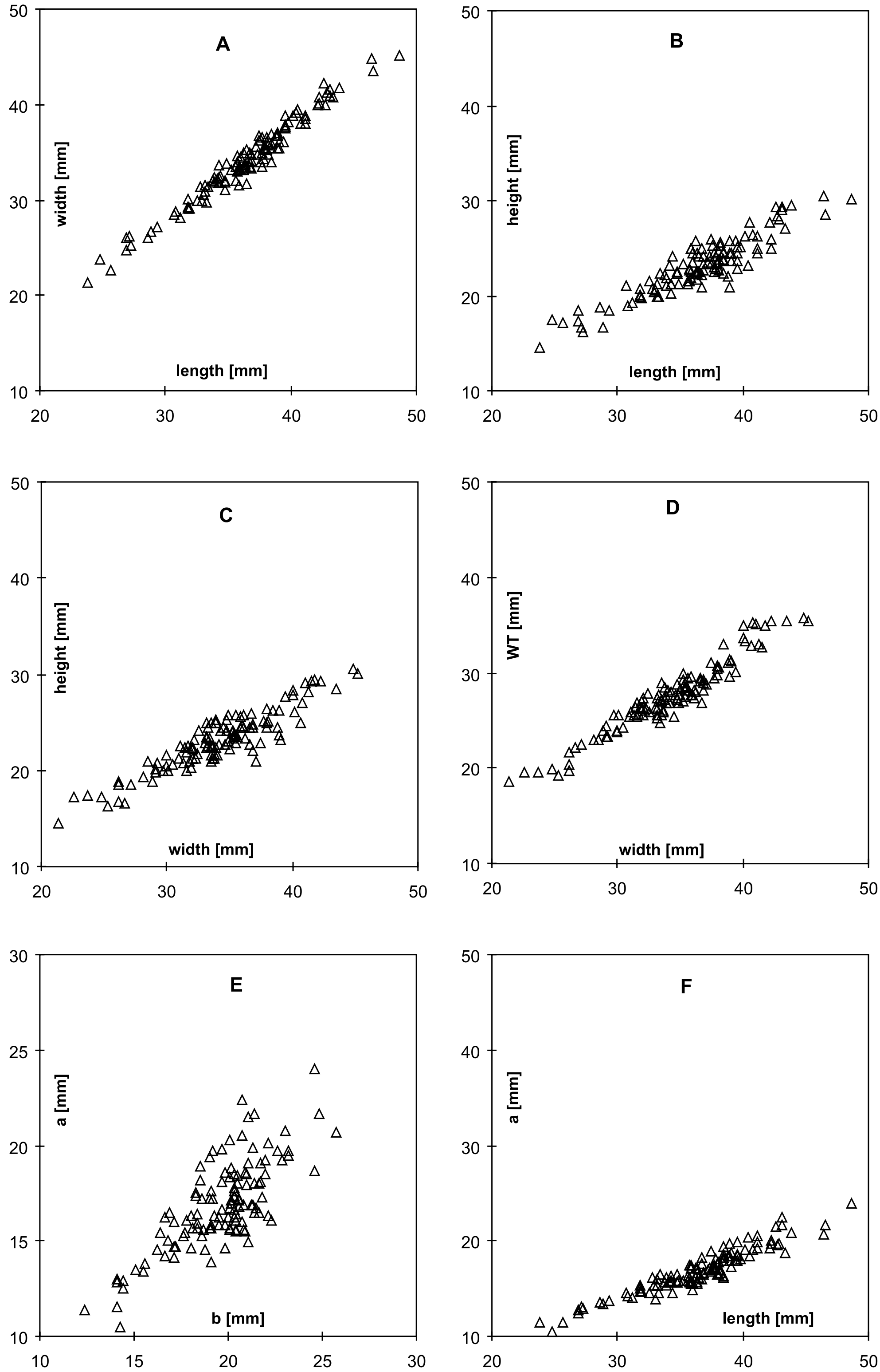

Fig. 38. Biometric data for *Micraster* (*Micraster*) *leskei* (DES MOULINS, 1837) from Besakty in Mangyshlak; A – scatter plot of length *versus* width, B – scatter plot of length *versus* height, C – scatter plot of width *versus* height, D – scatter plot of width *versus* WT (width of the test or mould measured in one third from posterior edge), E – scatter plot of distance b (distance from central point of apical disc to posterior edge) *versus* distance a (distance from central point of apical disc to anterior edge), F – scatter plot of distance length *versus* distance a

ably differentiated. It is possible to distinguish flattened, oval, slightly convex, or forms with a carina in elongated profile (Pl. 19, Figs 3c, 4c, 5c, 6c; Pl. 20, Figs 1c, 2c, 3c, 4c, 5c). Transverse section also differentiated between flattened to convex, slightly conical forms with carina. Adoral side very weakly convex. Anterior groove relatively narrow and slightly sunken. Anal angle slightly obtuse, in rare cases exceeding 100°.

Apical disc. Apical disc tetrabasal and ethmophract, positioned anteriorly. Ratio a/b*100 very rarely exceeds 100, and its mean values are 86.31 (median 85.63) for the Besakty sample, 84.1 (median 85.9) for the Odra I and II sample, 81.3 (median 80.6) for the Bolko sample, and 79.5 (median 80.6) for the Groszowice sample. Mean values and medians indicating for excentrally lying, moving anteriorally of apical disc. Shape of

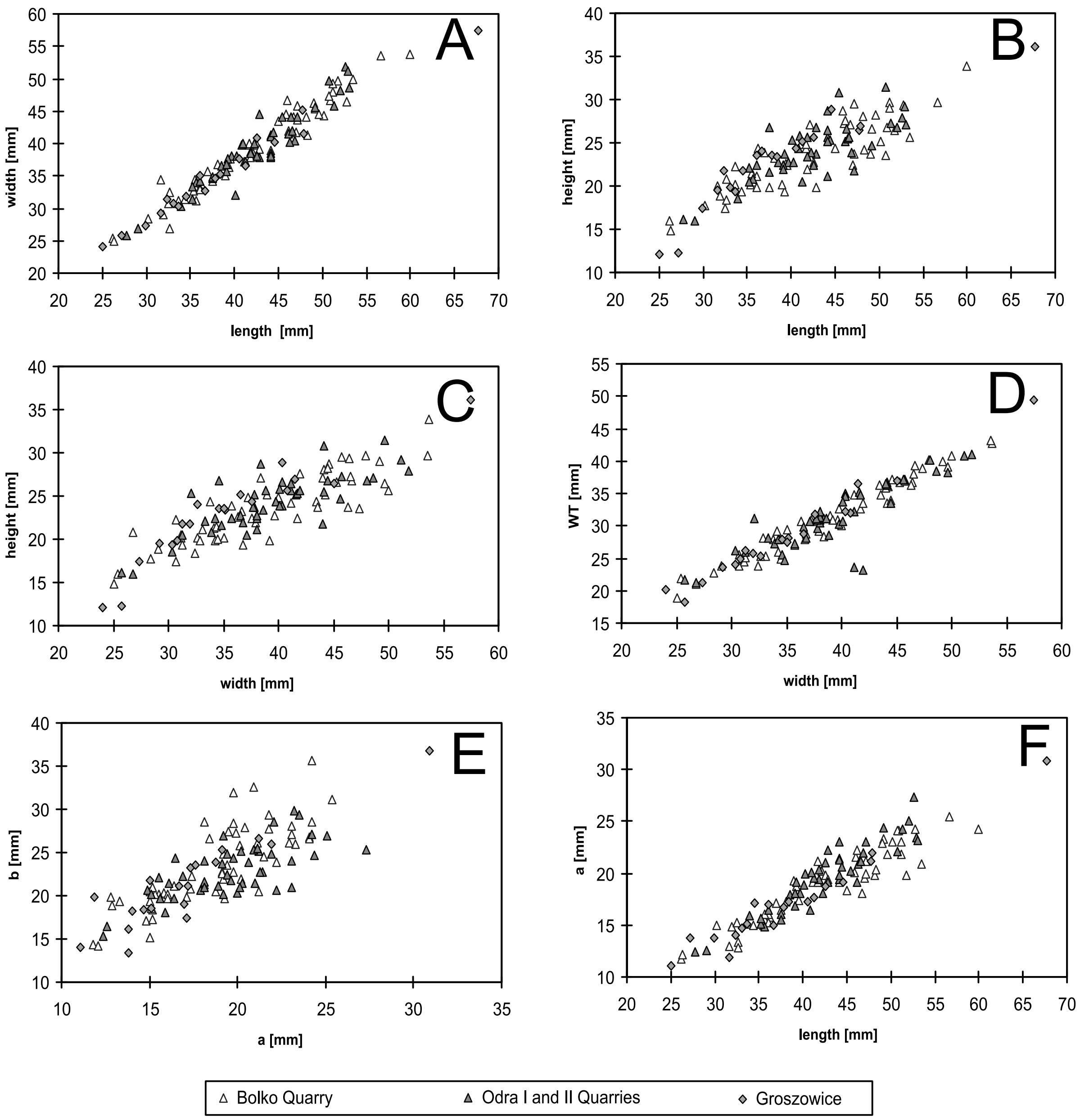

Fig. 39. Biometric data for *Micraster* (*Micraster*) *leskei* (DES MOULINS, 1837) from Opole; A – scatter plot of length *versus* width, B – scatter plot of length *versus* height, C – scatter plot of width *versus* height, D – scatter plot of width *versus* WT (width of the test or mould measured in one third from posterior edge), E – scatter plot of distance b (distance from central point of apical disc to posterior edge) *versus* distance a (distance from central point of apical disc to anterior edge), F – scatter plot of distance length *versus* distance a

apical disc circular to slightly elongate. In large specimens, always slightly elongate. Madreporite similar in size to other genital plates, and in contact with all of them. In most cases, madreporite 2 separated from ocular plates I and V by genital plates 1 and 4 (Text-figs 40, 41). In rare cases expansion of hydropores onto adjacent genital plates 1 occurs, a gonopore is absent from madreporite 2 (Text-fig. 42a), or genital plates 1 and 4 separated by madreporite 2 adjacent directly with ocular plate I (Text-fig. 42b-c).

Ambulacral zone. Ambulacra heteromorphic. Petals differ in length. Posterior petals about 57%-75% of anterior paired ones. Lower values about 57%-65% connected with small sized specimens. Transverse section by depression of petals arch in outline. Interporiferous area "smooth" or "sutured", or intermediate. Poriferous band in petal consisting of circular or rarely weakly oval pores. Sometimes pores in a pair differ, i.e. perradial pore weakly oval and adradial pore slightly larger, oval or teardrop-shaped. Interporiferous

Statictic	L [mm]	W [mm]	H [mm]	WT [mm]	AA [^{o}]	a [mm]	b [mm]	W/L *100	H/L *100	H/W *100	WT/W *100	a/b *100
Minimum value	23.8	21.4	14.5	18.6	90.5	10.5	12.4	86.85	53.73	56.33	73.30	70.62
Maximum value	48.6	45.2	30.5	35.8	111.5	24.0	25.7	99.30	70.99	76.11	87.25	108.21
Mean value	36.48	34.16	23.12	27.52	99.27	16.88	19.60	93.57	63.39	67.77	80.60	86.31
Median	36.70	34.10	23.15	27.40	99.00	16.65	20.10	93.47	63.09	67.81	80.34	85.63
Standard Deviation	4.420	4.449	3.016	3.654	3.956	2.314	2.385	2.397	3.282	3.617	2.996	7.512

Table 9. Simple statistics of biometric data and simple ratios for *Micraster* (*Micraster*) *leskei* (DES MOULINS, 1837) from Besakty, Mangyshlak; number of specimens N=118

Statistic	L [mm]	W [mm]	H [mm]	WT [mm]	AA [^{o}]	a [mm]	b [mm]	W/L *100	H/L *100	H/W *100	WT/W *100	a/b *100
Minimum value	27.7	25.8	16.0	21.2	90.0	12.4	15.3	80.05	46.07	49.32	55.13	67.62
Maximum value	53.1	51.8	31.5	41.1	103.0	27.3	29.9	103.73	71.47	78.82	96.88	110.00
Mean value	42.51	39.34	24.20	31.38	94.13	19.62	22.89	92.54	57.17	61.85	79.91	85.88
Median	42.50	38.60	24.40	31.10	94.00	19.80	22.40	92.87	57.18	61.31	81.05	84.13
Standard Deviation	5.804	5.745	3.230	4.973	2.948	3.202	3.081	4.142	4.977	5.604	6.619	10.043

Table 10. Simple statistics of biometric data and simple ratios for *Micraster* (*Micraster*) *leskei* (DES MOULINS, 1837) from Odra I and Odra II Quarries, Opole; number of specimens N=45

Statistic	L [mm]	W [mm]	H [mm]	WT [mm]	AA [^{o}]	a [mm]	b [mm]	W/L *100	H/L *100	H/W *100	WT/W *100	a/b *100
Minimum value	26.2	25.0	14.9	18.9	90.0	11.8	14.2	82.20	46.40	49.60	71.90	62.10
Maximum value	59.9	53.7	33.8	43.1	102.0	25.4	35.7	108.80	67.10	77.60	85.80	103.40
Mean value	41.93	38.98	23.53	31.20	94.14	18.63	23.30	93.08	56.51	60.78	79.98	80.65
Median	41.75	38.70	23.60	30.85	94.00	19.15	22.40	92.87	56.85	61.62	80.46	81.31
Standard Deviation	7.714	7.090	3.922	5.950	3.176	3.442	4.654	4.001	5.001	5.521	3.249	9.062

Table 11. Simple statistics of biometric data and simple ratios for *Micraster* (*Micraster*) *leskei* (DES MOULINS, 1837) from Bolko Quarry, Opole; number of specimens N=56

Statistic	L [mm]	W [mm]	H [mm]	WT [mm]	AA [^{o}]	a [mm]	b [mm]	W/L *100	H/L *100	H/W *100	WT/W *100	a/b *100
Minimum value	25.1	24.0	12.1	18.3	90.0	11.1	13.4	84.93	44.85	47.47	71.21	60.10
Maximum value	67.7	57.5	36.1	49.5	99.0	30.9	36.8	96.95	67.49	73.39	87.71	102.99
Mean value	38.35	35.13	22.73	28.43	92.65	17.06	21.28	92.09	59.24	64.39	80.56	80.74
Median	36.70	34.60	23.50	27.50	92.00	17.00	21.10	92.11	60.33	64.82	80.35	79.70
Standard Deviation	9.278	7.569	5.387	6.948	2.524	4.268	5.195	3.182	5.619	6.246	3.534	9.216

Table 12. Simple statistics of biometric data and simple ratios for *Micraster* (*Micraster*) *leskei* (DES MOULINS, 1837) from Groszowice, Opole area; number of specimens N=19

ridge not evolved or visible as four weakly evolved granules. Ambulacral furrow not evolved. Zone between poriferous band sometimes weakly granular. Unpaired ambulacrum III clearly different from paired ambulacra. Poriferous band consists of circular pores in a pair. Zone between poriferous band smooth or weakly granulated.

Interambulacral zone. Interambulacra much broader than ambulacra, covered by fine and rare tubercles on aboral side. Tubercles larger and denser when passing onto adoral side and on adoral side itself.

Plastron and labrum. Plastron semiamphisternal type 1 or type 2. In three cases, semiamphisternal inverse type (Pl. 16, Fig. 3b) has been observed. Labrum variable in shape: (a) triangular with broad base tapering to anterior, (b) relatively narrow, tall triangular with narrow base, or (c) triangular with equally longer sides. Number of tubercles on labrum rather small, maximum 6 or 7, chiefly lower.

Periplastronal zone. Periplastronal plates "sandy" in the most cases, rarely "smooth", always "sandy" in specimens from Mangyshlak.

Peristome. Peristome circular or weakly oval in outline, situated relatively far away from anterior border, totally opened or partly covered by labrum, in some cases around peristome visible peristomal ring.

Periproct. Periproct circular or weakly oval in outline on upper anal field.

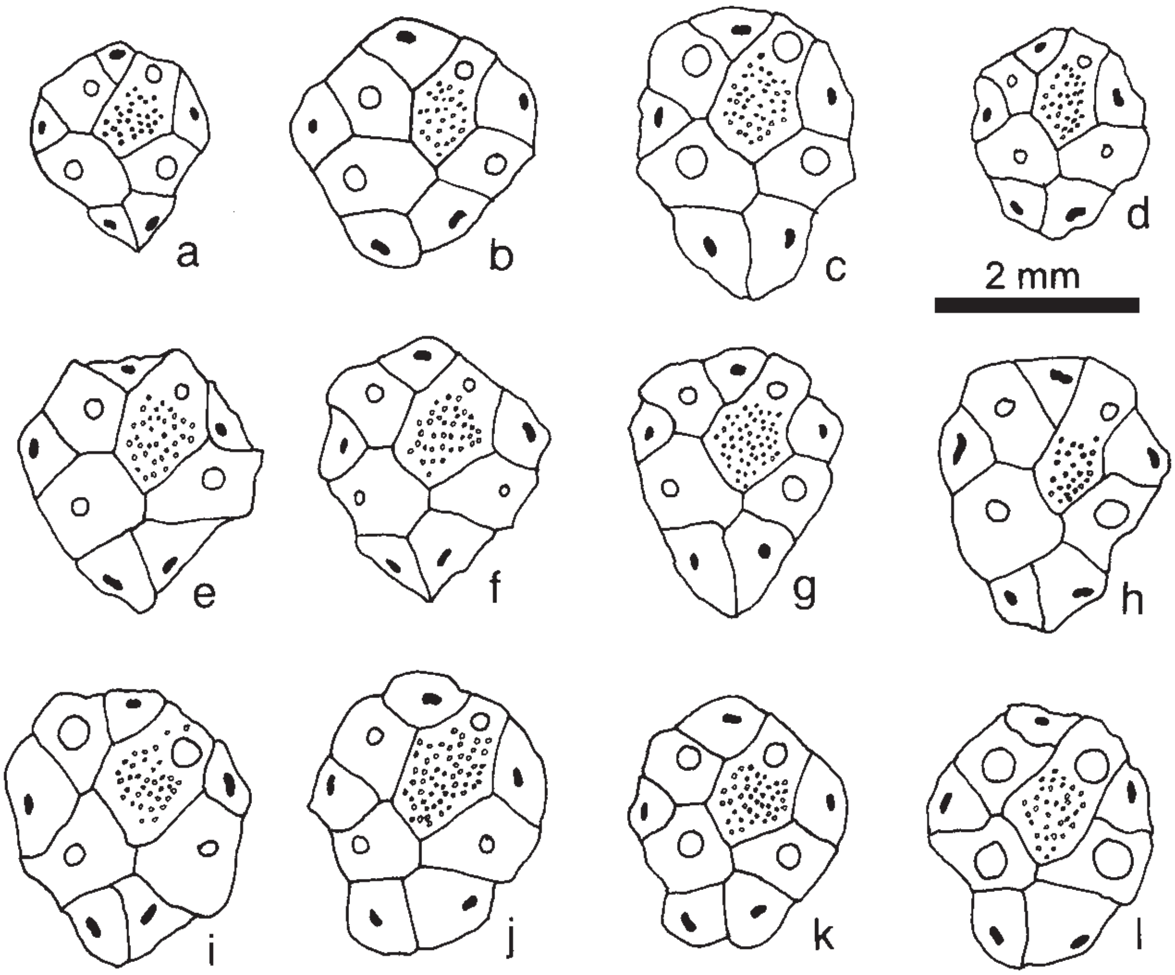

Fig. 40. Camera-lucida drawings of apical disc plating in *Micraster* (*Micraster*) *leskei* (DES MOULINS, 1837); a –IGPUW/E/01/381, Shakh-Bogota, Bed 12, Mangyshlak (compare Pl. 16, Fig. 1); b – IGPUW/E/01/382, Shakh-Bogota, Bed 12, Mangyshlak (compare Pl. 17, Fig. 1); c – IGPUW/E/01/489, Besakty, Mangyshlak (compare Pl. 17, Fig. 2); d – IGPUW/E/01/502, Besakty, Mangyshlak; e – IGPUW/E/01/634, Beachy Head, England (compare Pl. 16, Fig. 2); f – IGPUW/E/01/471, Besakty, Mangyshlak; g – IGPUW/E/01/482, Besakty, Mangyshlak; h – IGPUW/E/01/441, Besakty, Mangyshlak; i – IGPUW/E/01/427, Besakty, Mangyshlak; j – IGPUW/E/01/484, Besakty, Mangyshlak; k – IGPUW/E/01/487, Besakty, Mangyshlak; l – IGPUW/E/01/614, Groszowice, Opole

Subanal fasciole. Subanal fasciole rather poorly evolved, relatively narrow, consisting of dense, very fine tubercles carrying clavulae, well developed adorally, and disappearing when passing into anal field.

Tuberculation. Tuberculation variable. Aboral tubercles fine and scattered. Adoral tubercles larger and densely packed, being most numerous on plastron.

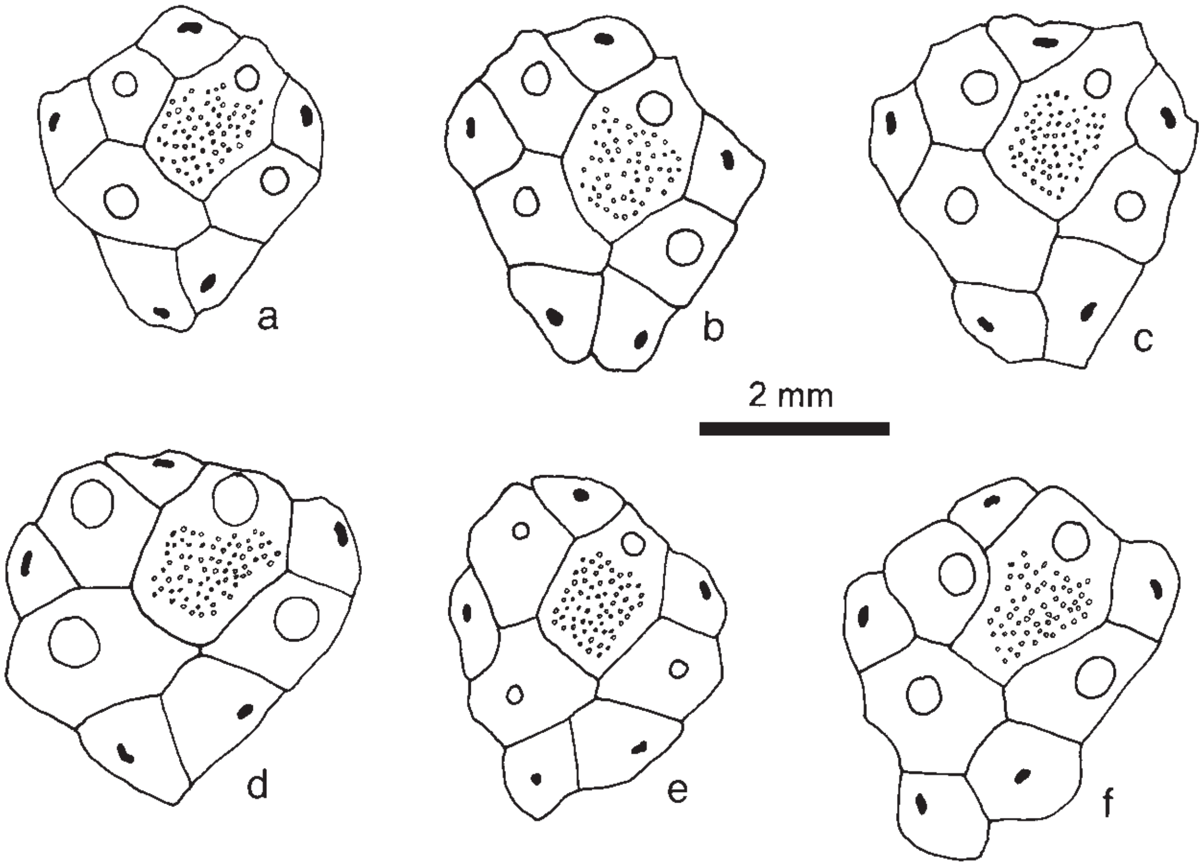

Fig. 41. Camera-lucida drawings of apical disc plating in *Micraster* (*Micraster*) *leskei* (DES MOULINS, 1837) from different places in the North European Province; a, d, e – Mangyshlak; b, f – Opole; c – Beachy Head, England; a – IGPUW/E/01/442, b – IGPUW/E/01/512; c – IGPUW/E/01/635, d – IGPUW/E/01/388, e – IGPUW/E/01/393, f – IGPUW/E/01/558

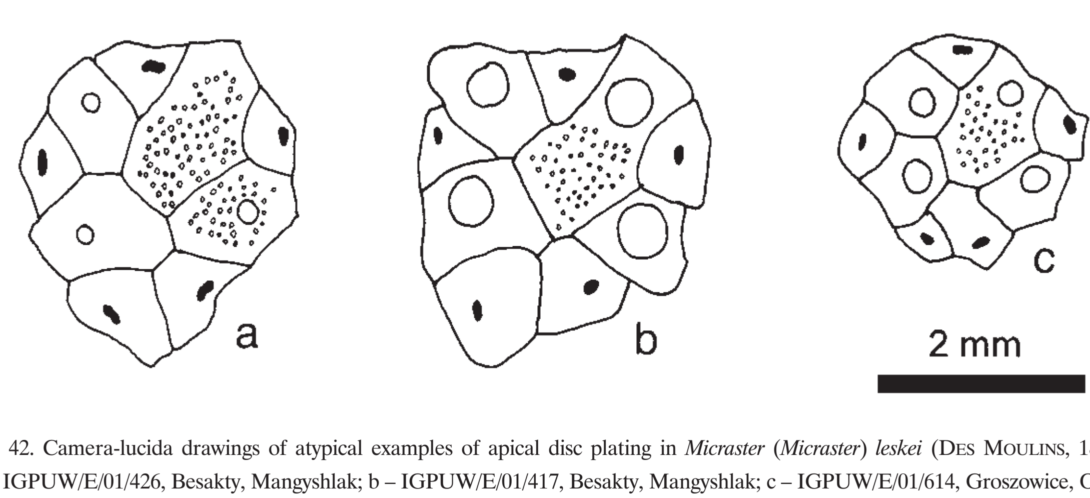

Fig. 42. Camera-lucida drawings of atypical examples of apical disc plating in *Micraster* (*Micraster*) *leskei* (DES MOULINS, 1837); a – IGPUW/E/01/426, Besakty, Mangyshlak; b – IGPUW/E/01/417, Besakty, Mangyshlak; c – IGPUW/E/01/614, Groszowice, Opole

Characters and simple ratios	L	W	H	WT	AA	a	b	W/L *100	H/L *100	H/W *100	WT/W *100	a/b *100
L	1	**0.9819**	**0.9171**	**0.9510**	0.0627	**0.9386**	**0.9423**	0.2628	-0.0495	-0.1757	-0.0907	0.1430
W		1	**0.9155**	**0.9601**	0.0342	**0.9345**	**0.9127**	0.4394	-0.0112	-0.2235	-0.1237	0.1788
H			1	**0.8864**	0.0203	**0.8382**	**0.8862**	0.3145	0.3496	0.1839	-0.0893	0.0648
WT				1	0.0814	**0.9221**	**0.8674**	0.3753	-0.0150	-0.1959	0.1558	0.2210
AA					1	0.0683	0.0499	-0.1194	-0.1049	-0.0460	0.1545	0.0389
a						1	**0.7690**	0.3072	-0.1068	-0.2523	-0.0249	0.4739
b							1	0.1889	0.0119	-0.0808	-0.1440	-0.1949
W/L*100								1	0.1744	-0.3133	-0.2351	0.2194
H/L*100									1	**0.8802**	-0.0222	-0.1876
H/W*100										1	0.0939	-0.2869
WT/W*100											1	0.1536
a/b*100												1

Table 13. Matrix correlation of biometric data and simple ratios for *Micraster* (*Micraster*) *leskei* (DES MOULINS, 1837) from Besakty, Mangyshlak; marked correlations are significant at $p<0.05$; number of specimens $N=118$

Characters and simple ratios	L	W	H	WT	AA	a	b	W/L *100	H/L *100	H/W *100	WT/W *100	a/b *100
L	1	**0.9495**	**0.7788**	**0.8496**	-0.0836	**0.9267**	**0.9206**	0.0289	-0.3484	-0.3481	-0.0727	0.2730
W		1	**0.7934**	**0.8546**	-0.0964	**0.8830**	**0.8709**	0.3397	-0.2513	-0.4161	-0.1586	0.2692
H			1	**0.6536**	-0.0774	**0.6629**	**0.7782**	0.1888	0.3130	0.2170	-0.1602	0.0740
WT				1	-0.0827	**0.8055**	**0.7634**	0.1705	-0.3043	-0.3732	0.3746	0.2802
AA					1	-0.0873	-0.0668	-0.0528	0.0022	0.0248	0.0175	-0.0360
a						1	**0.7064**	0.0339	-0.4092	-0.4064	-0.0322	**0.6123**
b							1	0.0193	-0.2311	-0.2333	-0.1035	-0.1220
W/L*100								1	0.2369	-0.2938	-0.3012	0.0334
H/L*100									1	**0.8573**	-0.1213	-0.3017
H/W*100										1	0.0547	-0.3002
WT/W*100											1	0.0724
a/b*100												1

Table 14. Matrix correlation of biometric data and simple ratios for *Micraster* (*Micraster*) *leskei* (DES MOULINS, 1837) from Odra I and Odra II Quarries, Opole; marked correlations are significant at $p<0.05$; number of specimens $N=45$

Characters and simple ratios	L	W	H	WT	AA	a	b	W/L *100	H/L *100	H/W *100	WT/W *100	a/b *100
L	1	**0.9756**	**0.8702**	**0.9617**	0.2934	**0.9357**	**0.9654**	-0.1695	-0.4470	-0.3644	0.1374	-0.1366
W		1	**0.8696**	**0.9799**	0.2538	**0.9072**	**0.9460**	0.0466	-0.3983	-0.4208	0.1075	-0.1504
H			1	**0.8553**	0.2188	**0.8156**	**0.8391**	-0.0653	0.0461	0.0721	0.1180	-0.1242
WT				1	0.2216	**0.9033**	**0.9258**	0.0116	-0.3937	-0.4011	0.3009	-0.1209
AA					1	0.2857	0.2750	-0.1897	-0.1992	-0.1077	-0.0545	-0.0412
a						1	**0.8113**	-0.1892	-0.4250	-0.3368	0.1708	0.2138
b							1	-0.1410	-0.4266	-0.3548	0.1015	-0.3845
W/L*100								1	0.2297	-0.2595	-0.1826	-0.0700
H/L*100									1	**0.8791**	-0.0499	0.0247
H/W*100										1	0.0278	0.0454
WT/W*100											1	0.1141
a/b*100												1

Table 15. Matrix correlation of biometric data and simple ratios for *Micraster* (*Micraster*) *leskei* (DES MOULINS, 1837) from Bolko Quarry, Opole; marked correlations are significant at $p<0.05$; number of specimens $N=56$

Characters and simple ratios	L	W	H	WT	AA	a	b	W/L *100	H/L *100	H/W *100	WT/W *100	a/b *100
L	1	**0.9894**	**0.9358**	**0.9854**	0.0079	**0.9761**	**0.9839**	**-0.6134**	0.0202	0.2282	0.4951	-0.0787
W		1	**0.9403**	**0.9888**	-0.0183	**0.9657**	**0.9734**	-0.4990	0.0562	0.2218	0.4792	-0.0765
H			1	**0.9257**	-0.0842	**0.8813**	**0.9471**	**-0.5429**	0.3659	**0.5359**	0.4667	-0.2229
WT				1	0.0032	**0.9604**	**0.9707**	**-0.5203**	0.0362	0.2093	**0.5994**	-0.0983
AA					1	0.0242	-0.0058	-0.0970	-0.3475	-0.2923	0.0327	0.1393
a						1	**0.9215**	**-0.5775**	-0.0692	0.1284	0.4487	0.1371
b							1	**-0.6210**	0.0929	0.3021	**0.5155**	-0.2532
W/L*100								1	0.0637	-0.2923	-0.3079	0.1394
H/L*100									1	**0.9355**	0.0668	-0.4314
H/W*100										1	0.1646	-0.4682
WT/W*100											1	-0.2961
a/b*100												1

Table 16. Matrix correlation of biometric data and simple ratios for *Micraster* (*Micraster*) *leskei* (DES MOULINS, 1837) from Groszowice, Opole; marked correlations are significant at p<0.05; number of specimens N=19

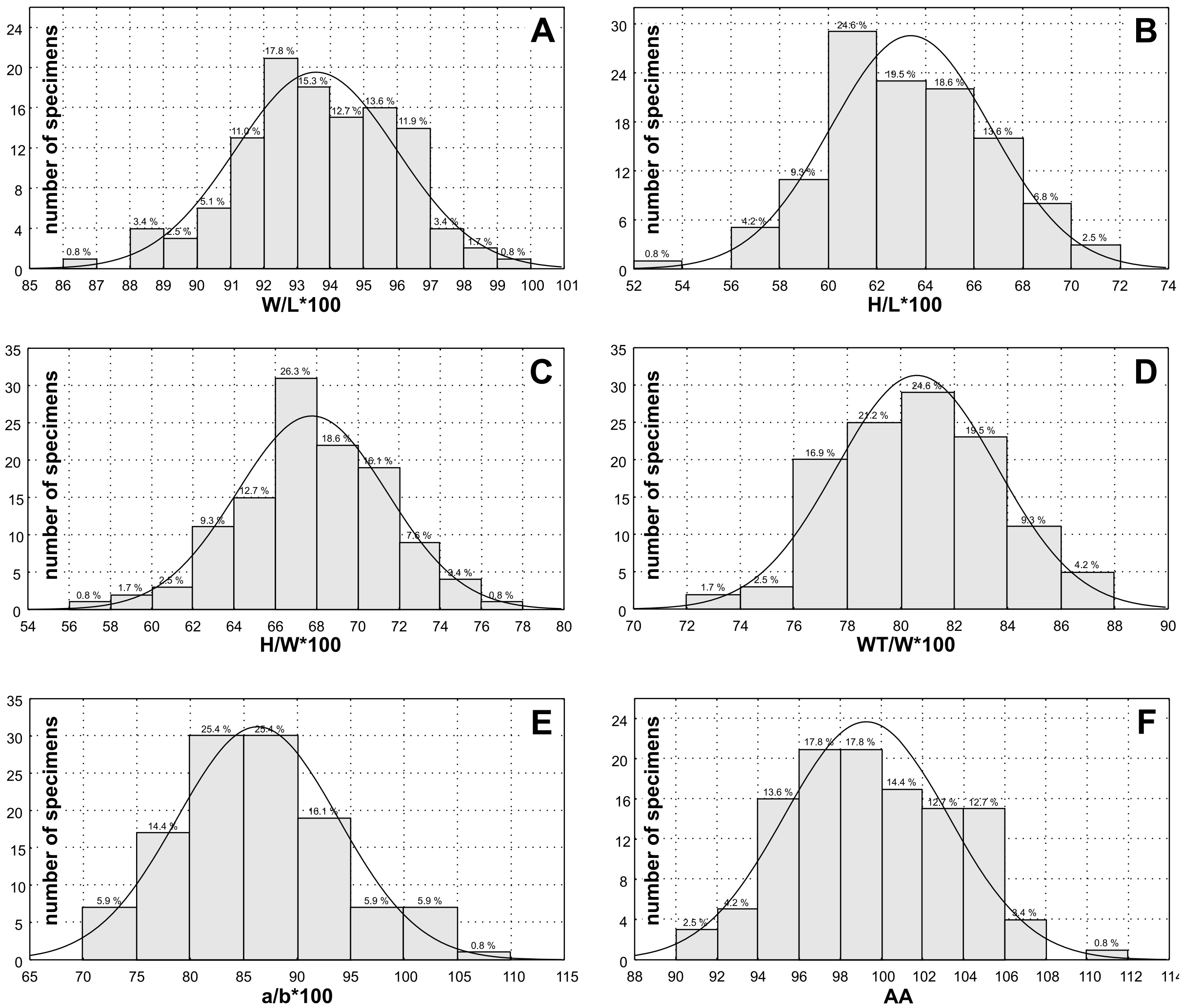

Fig. 43. Histograms of distribution of simple ratios and values of anal angle in *Micraster* (*Micraster*) *leskei* (DES MOULINS, 1837) from Besakty, Mangyshlak (sample N = 118); A – W/L*100, B – H/L*100, C – H/W*100, D – WT/W*100, E – a/b*100, F – anal angle

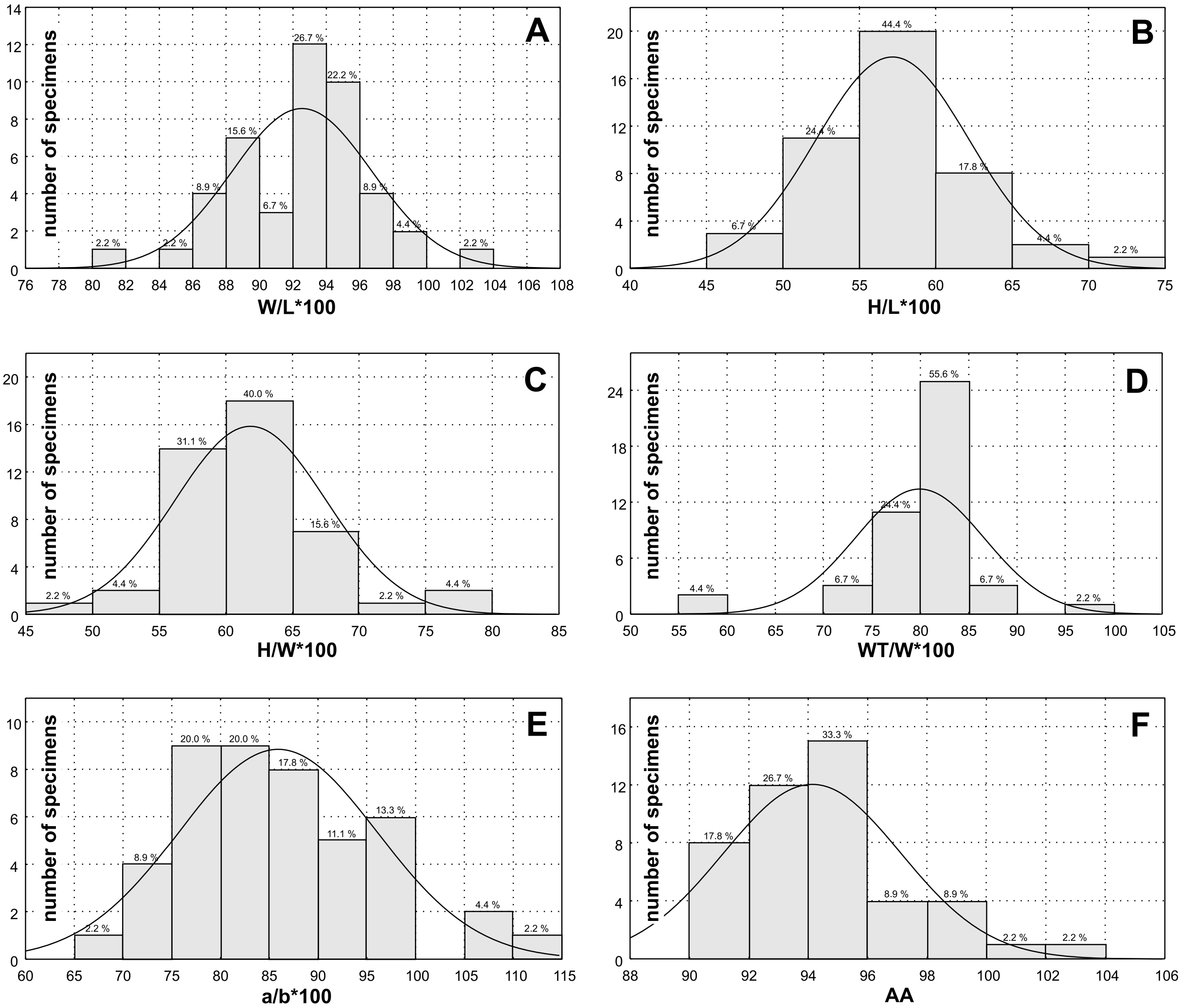

Fig. 44. Histograms of distribution of simple ratios and values of anal angle in *Micraster* (*Micraster*) *leskei* (DES MOULINS, 1837) from Odra I and II, Opole (sample N = 45); A – W/L*100, B – H/L*100, C – H/W*100, D – WT/W*100, E – a/b*100, F – anal angle

Simple statistic analysis

Basic statistics (Tables 9-12) indicate, that *Micraster* (*M.*) *leskei* from Mangyshlak (Besakty) are of lesser length and width than material from Opole, while the height is similar. Accordingly, ratios H/L*100 and H/W*100 are lower in samples from Opole than in those from Mangyshlak. However, ratios W/L*100 and WT/W*100 characterizing test outline are similar in the mean. The mean values of ratio a/b*100 are also similar in all samples and indicate that apical disc moved anteriorly. Simple statistics indicate high correlation between almost all parameters (Tables 13-16). The only independent parameter is anal angle. Particularly good correlation occurs between L and W. The correlation coefficient between H and L or between H and W attains lower values.

The frequency distribution of particular simple ratios (Text-figs 43-45), examined with Kolmogorov-Smirnov test of goodness of fit at the 95% confidence level, shows their distribution to be close to normal, suggesting homogeneous samples.

REMARKS: *Micraster* (*M.*) *leskei* from Mangyshlak is more advanced in its characters than is *M.* (*M.*) *leskei* from Opole. The former has better evolved granulation on the periplastronal zone, mostly “sandy”, and the plastron structure of semiamphisternal type 2 is the most frequently. The periplastronal zone in specimens from Opole are mainly “smooth” and the plastron of the semi-

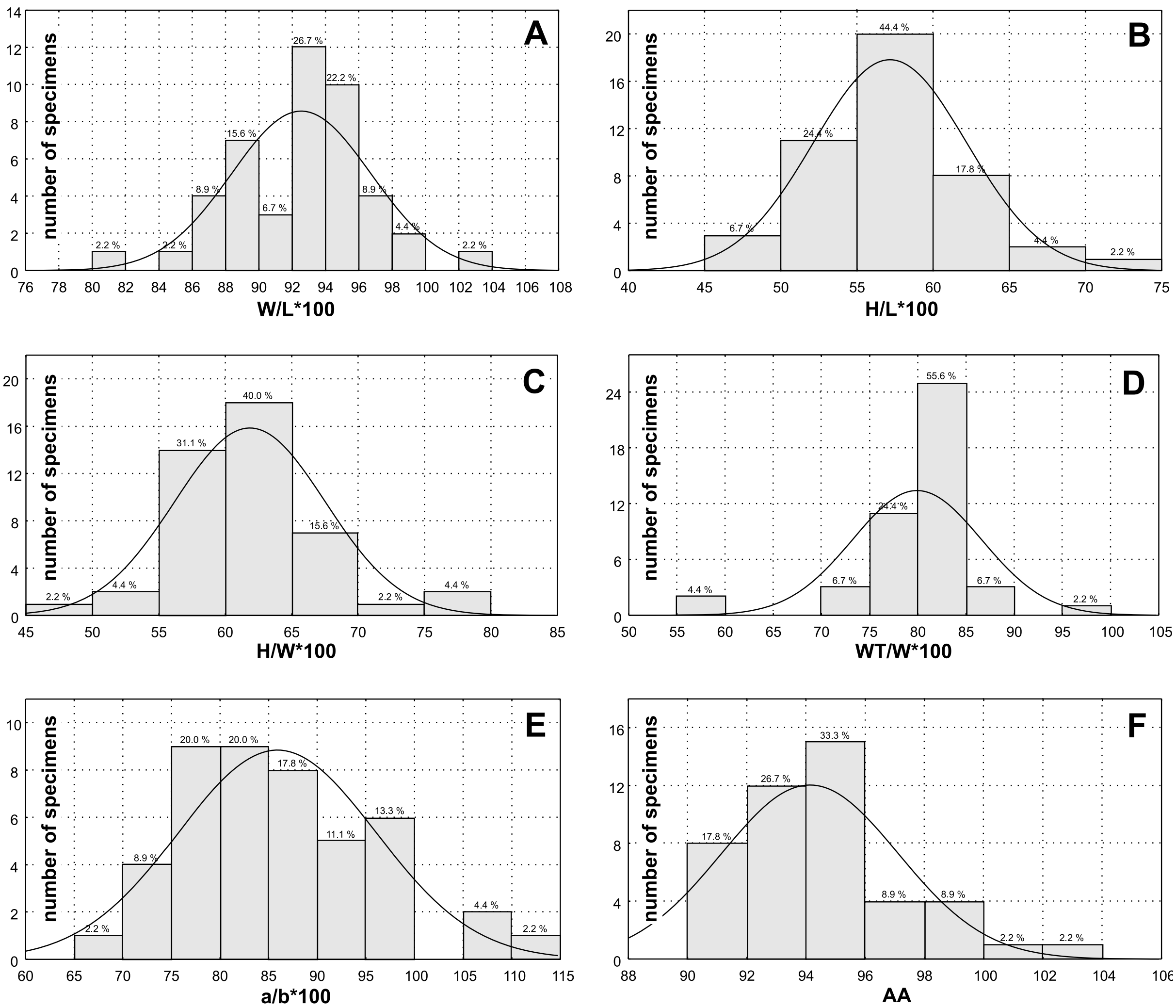

Fig. 45. Histograms of distribution of simple ratios and values of anal angle in *Micraster* (*Micraster*) *leskei* (DES MOULINS, 1837) from Bolko, Opole, (sample N = 56); A – W/L*100, B – H/L*100, C – H/W*100, D – WT/W*100, E – a/b*100, F – anal angle

amphisternal type 1; in addition specimens from Opole are larger than those from Mangyshlak. Despite, however, distinct morphological differences between the assemblages from Mangyshlak (Pl. 19, Figs 2-5; Pl. 20, Figs 1-5) and that from Opole (Pl. 19, Figs 1, 6; Pl. 21, Figs 1-4) a number of very similar, nearly identical morphotypes occur, which are further identical to morphotypes from the Upper Turonian of England (Pls 16-18). These identical morphotypes may represent oportunistic species, although this problem requires futher studies.

OCCURRENCE: Upper Turonian (*Inoceramus perplexus* Zone) at Shakh-Bogota, Upper Turonian at Koksyrtau-Aksyrtau, and condensed Upper Turonian – Coniacian at Azhirektoy and Besakty. Upper Turonian (*Inoceramus perplexus* Zone) of Odra I and II, and Bolko quarries, plus Groszowice. This species has been recorded from the North European Province: Middle and Upper Turonian of Germany, the Upper Turonian of France, England, Belgium, Czech Republic (Teplice area), southern Belorussia (Wolkowysk area), western Ukraine, Donbass, northern Caucasus and Kopet-Dag (western Turkmenistan).

Micraster (*Micraster*) *corbovis* FORBES, 1850
(Text-figs 46, 47; Pl. 22, Figs 1, 2; Pl. 23, Fig. 3)

1850. *Micraster cor-bovis* E. FORBES, p. 342, pl. 24, figs 3, 4.

1878. *Micraster corbovis* FORBES; TH. WRIGHT, p. 276, pl. 62A, figs 1, 2.
1899. *Micraster corbovis* FORBES; A.W. ROWE, p. 518, pl. 35, figs i1-i4, pl. 39, figs 2, 3.
1959. *"Micraster" corbovis* FORBES; M.M. MOSKVIN, p. 286, text-fig. 102; pl. 24, fig. 1.
1959. *Micraster subglobosus* M.M. MOSKVIN, p. 280, text-fig. 92; pl. 19, fig. 1.
1964. *Micraster corbovis* FORBES; G.N. DZHABAROV, p. 45, pl. 16, fig. 2.
1967. *Micraster corbovis* FORBES; L. CAYEUX, p. 39, pl. 4, fig. 13.
1968. *Micraster corbovis* FORBES; S.I. PASTERNAK & *al*., p. 217, text-fig. 46; pl. 48, figs 4-6.
1970c. *Micraster* (*Micraster*) *corbovis* FORBES; G. ERNST, pl. 17, fig. 1.
1974. *Micraster corbovis* FORBES; O.V. SAVCHINSKAYA, p. 327, pl. 110, figs 1-5; pl. 111, figs 1-4.
1975. *Micraster corbovis* FORBES; R.B. STOKES, p. 66.
1977. *Micraster corbovis* FORBES; R.B. STOKES, p. 810, pl. 106, figs 1-6.

TYPE: Holotype, by monotypy, is specimen NHM 30157 in the Dixon Collection, illustrated by FORBES (1850, pl. 24, figs 3, 4); from the *Sternotaxis planus* Zone of Sussex, England.

MATERIAL: Eight medium- and poorly preserved, phosphatized specimens (IGPUW/E/01/637-644) from Bed 42 (unit B) at Besakty. One moderately well-preserved specimen (IGPUW/E/01/645) from the *Inoceramus perplexus* Zone of Bolko Quarry. One well-preserved specimen, MZ VIII Ee – 649, from the Turonian of Opole.

DESCRIPTION: **Shape and size**. Test moderate to large size (Table 17, Text-fig. 46), very thin irrespective of size, oval and bulge-shaped in outline, ambitus tall. Lateral profile tall and oval, more convex on aboral than adoral side. Transverse profile also oval, close to elliptical. Anterior groove broad and shallow. Anal angle obtuse and exceeding 100°.

Apical disc. Tetrabasal and ethmophract positional anteriorly, mean value of a/b*100 ratio 85.94 (median 88.36). Apical disc slightly circular. Madreporite large in comparison to other genital plates, and in contact with ocular plates I, II, III, but separated from ocular plates IV and V (Text-fig. 47).

Ambulacral zone. Ambulacra heteromorphic. Petals very shallow and short in relation to test size (compare specimens in Pl. 22, Figs 1a, 3a to those of similar size of *M.* (*M.*) *leskei* in Pl. 18, Figs 1a, 2a). Posterior petals about 75% – 83% of anterior paired ones. Interporiferous area "smooth" in specimens from Opole, "sutured" or intermediate in specimens from Mangyshlak. Poriferous band in petal consists of oval pair of pores similar in size in a single pair, or pair of pores different in the same row. Perradial pore oval and adradial pore slightly larger and teardrop-shaped in outline. Interporiferous ridge not evolved, smooth, as is ambulacral furrow. Zone between poriferous row smooth. Unpaired ambulacrum III clearly different from paired ambulacra with poriferous band consisting of circular pores in one pair; zone between poriferous band weakly granulated.

Interambulacral zone. Interambulacra much broader than ambulacra, and covered by fine and rare tubercles on aboral side, tubercles larger and denser on adoral side.

Plastron and labrum. Plastron semiamphisternal type 1 or 2 (type 1 observed in only a single specimen from Opole) (Pl. 22, Fig. 2a). Labrum triangular close to isosceles triangle with broad base. Tubercles on labrum rather small, their maximum number being 4-5.

Periplastronal zone. Periplastronal plates "smooth" in specimens from Opole, and "sandy" in specimens from Mangyshlak.

Peristome. Peristome circular or weakly oval in outline, partly covered by labrum. Peristome relatively

Statistic	L [mm]	W [mm]	H [mm]	WT [mm]	AA [°]	a [mm]	b [mm]	W/L *100	H/L *100	H/W *100	WT/W *100	a/b *100
Minimum value	47.6	42.5	31.3	37.1	102.0	21.2	23.8	89.29	65.43	69.61	82.50	69.13
Maximum value	61.9	57.7	40.6	49.1	116.0	29.5	32.4	98.30	69.80	77.19	88.63	100.00
Mean value	55.04	51.11	37.30	43.60	106.81	25.39	29.65	92.82	67.79	73.09	85.32	85.94
Median	55.00	51.10	38.15	43.15	105.50	24.75	30.35	92.22	68.22	73.38	84.98	88.36
Standard Deviation	4.745	4.952	3.162	4.281	4.649	3.163	2.490	3.122	1.570	2.401	1.954	10.434

Table 17. Simple statistics of biometric data and simple ratios for *Micraster* (*Micraster*) *corbovis* FORBES, 1850, from Besakty, Mangyshlak; number of specimens N=8

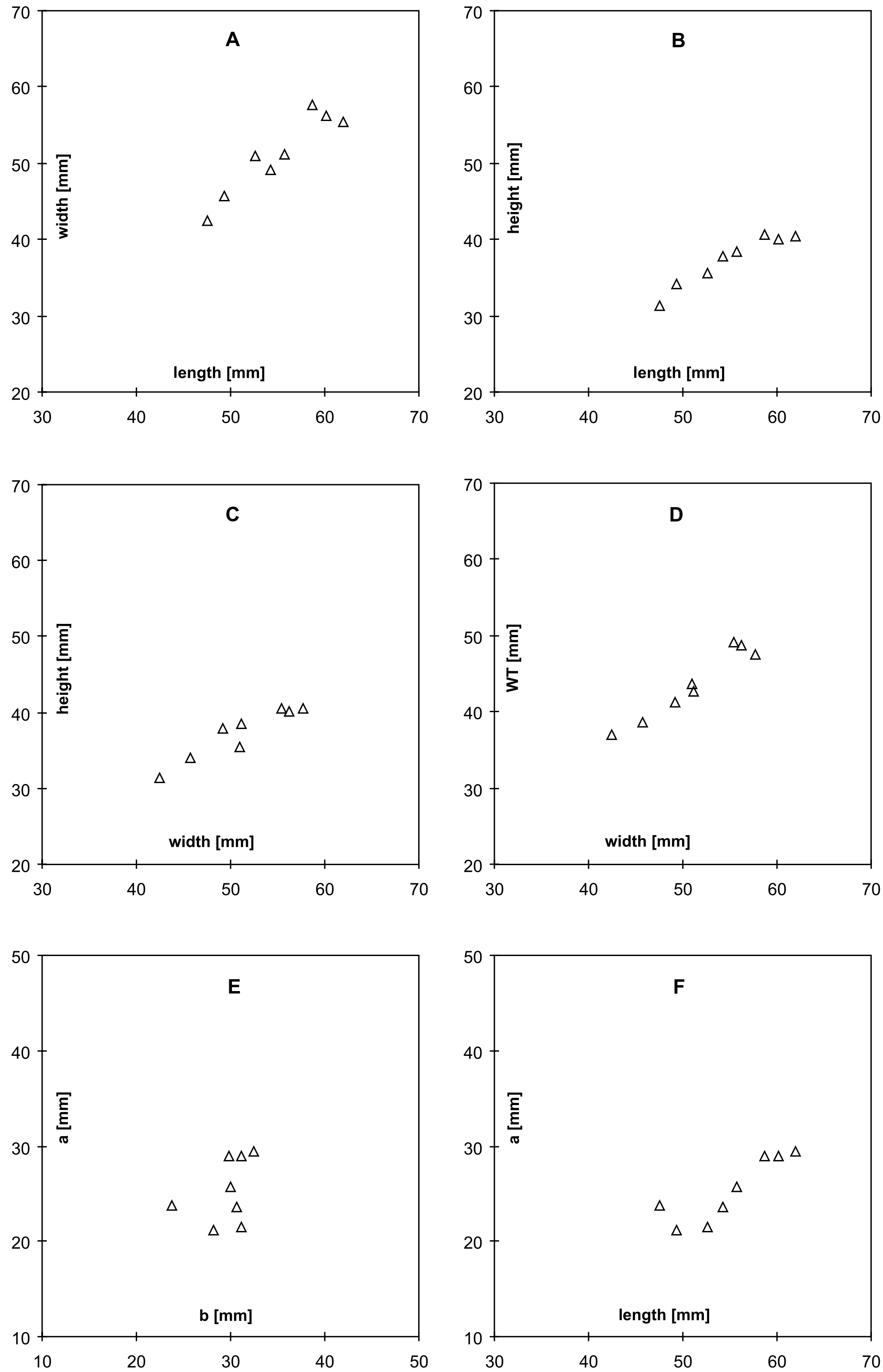

Fig. 46. Biometric data for *Micraster* (*Micraster*) *corbovis* Forbes, 1850, from Besakty, Mangyshlak; A – scatter plot of length *versus* width, B – scatter plot of length *versus* height, C – scatter plot of width *versus* height, D – scatter plot of width *versus* WT (width of the test or mould measured one third from posterior edge), E – scatter plot of distance b (distance from central point of apical disc to posterior edge) *versus* distance a (distance from central point of apical disc to anterior edge), F – scatter plot of distance length *versus* distance a

far away from anterior border, particulary so in specimens from Opole.

Periproct. Periproct circular or weakly oval in outline, lying high on anal field.

Subanal fasciole. Subanal fasciole not well evolved, relatively narrow, comprising dense, very fine tubercles for clavulae. Clear on adoral side, then passes to anal field forming closed ring. Sometimes on anal field it is not well developed.

Tuberculation. Tuberculation of whole test variable, aboral tubercles fine and scattered, and adoral tubercles larger and densely packed, being most numerous on plastron.

REMARKS: *Micraster* (*M.*) *corbovis* is closest to large specimens of *M.* (*M.*) *leskei*, yet differs from that species in being more bulge-shaped and in having a thinner test, and shorter paired petals. Although FOURAY & TARKOWSKI (1991) regarded *M.* (*M.*) *corbovis* as a variety of *M.* (*M.*) *leskei*, a comparison of large specimens of both species would discard such an interpretation (see also below).

In England, two morphotypes of *M.* (*M.*) *corbovis* have been distinguished (STOKES 1977). The first one, from the *Terebratulina lata* and *Sternotaxis planus* zones, is typified by a lateral profile, which shows that the maximum height is close to the anterior border, the size not attaining more than 50 mm in length, the anterior slope steep and the slope from apical disc to posterior border rather gentle in lateral profile (STOKES 1977; pl. 106, figs 4-6). The rare second one, from the *S. planus* Zone, shows large size (up to 80 mm), a bulge-shaped outline, and a gently convex aboral side (STOKES 1977; pl. 106, figs 1-3). The specimens from Opole and Mangyshlak are comparable to the stratigraphically younger second type.

M. (*M.*) *corbovis* appears later than *M.* (*M.*) *leskei* in the Opole area. It agrees with opinion of ERNST (1970c, 1972), who regarded *M.* (*M.*) *corbovis* as a side branch distinct from the mainline of Micrasterinae. *M.* (*M.*) *corbovis* represents a short-time form which decreased until the end of Turonian (ERNST 1970c, fig. 4).

OCCURRENCE: Condensed deposits of Upper Turonian to Coniacian at Besakty. Very rare in the Upper Turonian (*Inoceramus perplexus* Zone) at Bolko Quarry. Rare specimens of *Micraster* (*M.*) *corbovis* are known from the Middle and Upper Turonian of northern Germany and England, the Upper Turonian of France, western Ukraine, Donbass, northern Caucasus and Kopet-Dag.

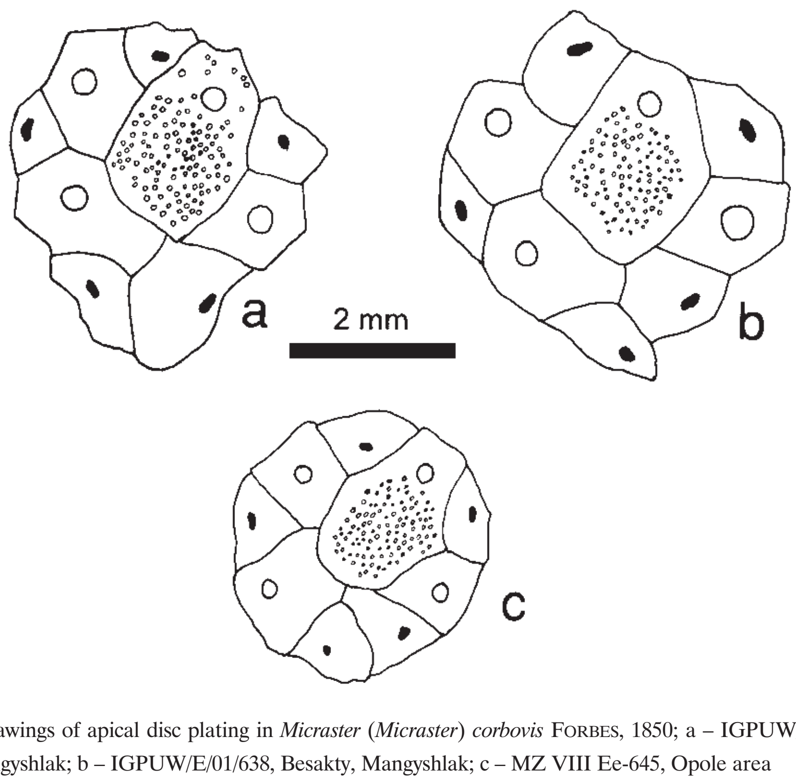

Fig. 47. Camera-lucida drawings of apical disc plating in *Micraster* (*Micraster*) *corbovis* FORBES, 1850; a – IGPUW/E/01/637, Besakty, Mangyshlak; b – IGPUW/E/01/638, Besakty, Mangyshlak; c – MZ VIII Ee-645, Opole area

Micraster (*Micraster*) *normanniae* BUCAILLE, 1883
(Text-figs 48, 49; Pl. 23, Figs 1, 2)

1883. *Micraster normanniae* E. BUCAILLE, p. 29, pl. 6, figs 1-7.
1967. *Micraster normanniae* (BUCAILLE); L. CAYEUX & O. DE VILLOUTREYS , p. 35, pl. 3, fig. 8.
1975. *Micraster normanniae* BUCAILLE; R.B. STOKES, p. 75, text-fig. 29s.
1977. *Micraster normanniae* BUCAILLE; R.B. STOKES, p. 812, pl. 107, figs 1-3, 7-9.
1981. *Micraster normanniae* BUCAILLE; M. FOURAY, p. 37, pl. 3, figs 5-7; pl. 4, figs 5, 6.
1984. *Micraster decipiens* (BAYLE) morphe *normanniae* BUCAILLE; B. DAVID & M. FOURAY, p. 468, fig. 16.
1985. *Micraster decipiens* (BAYLE) morphe *normanniae* BUCAILLE; M. FOURAY & B. POMEROL, pl. 1, figs 2, 5, 8.

TYPE: Holotype is the specimen figured by BUCAILLE (1883, pl. 6, figs 1-7), from the “lit tubulé” in the cliffs at Pollet, Seine Maritime, France; from the Upper Cretaceous, probably Turonian; housed in the Muséum d’Histoire naturelle de Rouen, Bucaille Collection.

MATERIAL: Ten medium- and well-preserved, phosphatic specimens (IGPUW/E/01/646-655) from Bed 42 (unit B) at Besakty. One very poorly preserved specimen (IGPUW/E/01/656) from scree from *Mytiloides scupini* Zone and two very poorly preserved, deformed specimens (IGPUW/E/01/657-658) from the *Cremnoceramus waltersdorfensis waltersdorfensis* Zone at Folwark Quarry.

DESCRIPTION: **Shape and size**. Test of moderate size (Table 18, Text-fig. 48), thick or moderately thick, trapezoidal or cordate in outline. Elongate profile moderate in height, weakly convex on aboral side, and flattened in some cases, very flat on adoral side. Transverse profile close to flattened-oval. Maximum width close to anterior, approximately one fifth to one quarter length from anterior. Viewed from aboral side maximum width above ends of anterior paired petals. Anterior groove well developed and moderately sunken. Anal angle obtuse, about 100°.
Apical disc. Apical disc tetrabasal and ethmophract, weakly anteriorly. In rare cases, central, exceptionally posteriorly. Mean value of a/b*100 ratio 93.67 (median 92.19). Shape of apical disc slightly circular or weakly elongated (Text-fig. 49). Madreporite slightly larger than other genital plates or similar in size to genital plate 4, and in contact with ocular plates II, III and, usually, separated from ocular plates I, IV, and V (Text-fig. 49a, c-f). In a single specimen, ocular plate IV in contact with madreporite (Text-fig. 49b).
Ambulacral zone. Ambulacra heteromorphic. Petals differ in length, posterior petals about 75% – 83% of anterior paired ones. Petals sunken and section by petal weakly arched shaped. Interporiferous area “sutured”. In some specimens, midline of petals intermediate to inflated type. Poriferous band in petal consists of oval pair of pores similar in size in single pair, or pair of pores different in same row. Perradial pore oval and adradial pore teardrop-shaped in outline. Interporiferous ridge fine, of up to 6 granules. Ambulacral furrow absent or weakly evolved in specimens where midline of petals intermediate to inflated. Zone between poriferous band finely granulated. Unpaired ambulacrum III clearly different from paired ambulacra, with poriferous band consisting of circular pores in single pair. Between every pair of pores a small granule. Zone between poriferous band weakly granulated. Between two rows of plates a clear suture.
Interambulacral zone. Interambulacra much broader than ambulacra. Intensively covered by tubercles.
Plastron and labrum. Plastron of semiamphisternal type 2, labrum narrow, covered by tubercles in two asymmetric rows.

Statistic	L [mm]	W [mm]	H [mm]	WT [mm]	AA [°]	a [mm]	b [mm]	W/L *100	H/L *100	H/W *100	WT/W *100	a/b *100
Minimum value	35.7	34.9	21.7	27.5	94.0	15.4	20.3	92.14	56.75	58.63	75.63	75.86
Maximum value	49.6	45.7	29.2	35.6	105.0	24.1	25.5	97.76	65.30	69.76	85.61	110.43
Mean value	43.80	41.55	26.64	33.05	99.55	21.17	22.63	94.98	60.87	64.11	79.60	93.67
Median	43.75	41.60	26.60	33.35	99.50	21.15	22.90	94.63	60.97	64.30	79.03	92.19
Standard Deviation	3.514	2.762	2.109	2.207	3.341	2.383	1.677	1.849	2.316	2.749	3.174	9.797

Table 18. Simple statistics of biometric data and simple ratios for *Micraster* (*Micraster*) *normanniae* BUCAILLE, 1883, from Besakty, Mangyshlak; number of specimens N=10

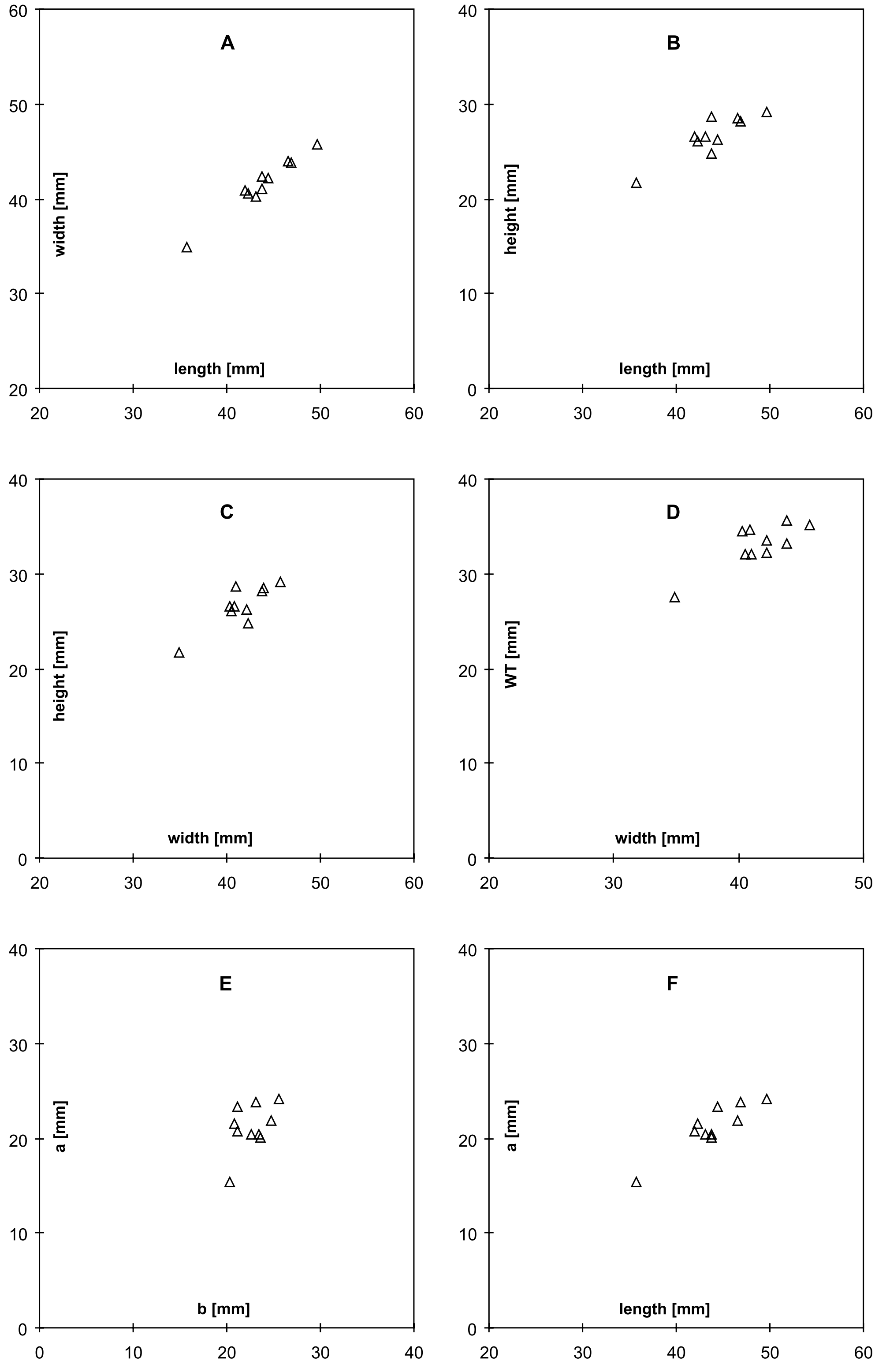

Fig. 48. Biometric data for *Micraster* (*Micraster*) *normanniae* BUCAILLE, 1883, from Besakty, Mangyshlak; A – scatter plot of length *versus* width, B – scatter plot of length *versus* height, C – scatter plot of width *versus* height, D – scatter plot of width *versus* WT (width of the test or mould measured one third from posterior edge), E – scatter plot of distance b (distance from central point of apical disc to posterior edge) *versus* distance a (distance from central point of apical disc to anterior edge), F – scatter plot of distance length *versus* distance a

Periplastronal zone. Periplastronal area transitional between “sandy” and “granular”.
Peristome. Peristome oval in outline, covered partly by labrum and situated relatively far from anterior border.
Periproct. Periproct oval, in upper part of anal field.
Subanal fasciole. Subanal fasciole well developed, relatively narrow on adoral side, slightly wider on anal field, forming closed ring, comprising densely packed, very fine tubercles for clavulae.
Tuberculation. Tuberculation of whole test variable. On aboral side, chiefly on interambulacral zones, tubercles fine and scattered. Adoral tubercles larger and more densely packed, being numerous on plastron.

REMARKS: Specimens which are cordate in outline(e.g. from Bed C14 at Folwark Quarry), agree with the description and illustration of the type specimen (see BUCAILLE 1883, pl. 6, figs 1-7) from the cliffs at Pollet, Seine Maritime, France (STOKES 1977, pl. 107, figs 7-9). The other specimens (from Marly Limestones Unit at Folwark Quarry and from Mangyshlak) differ in being more trapezoidal in shape. However, in both cases the maximum test width is clearly anteriorly, which is a very characteristic feature of this species. STOKES (1977, pl. 107, figs 1-3) illustrated a trapezoidal specimen which is similar to specimens of *Micraster normanniae* from Mangyshlak and Folwark. STOKES (1977) also noted transitional forms between *Micraster leskei* and *M. normanniae* from England. It is impossible to record reliably the same on the basis of material from Mangyshlak. It is feasible that some specimens referred to as *M.* (*M.*) *leskei* herein actually are transitional forms to *M.* (*M.*) *normanniae*, but the closer similarity to *M.* (*M.*) *leskei* has led me to assign them to that species. DRUMMOND (1985) distinguished two forms of *M. normanniae*: “*normanniae sensu stricto*” and “*normanniae cordata*”. Unfortunately, he did not illustrate these forms. One can only suspect that his form “*normanniae cordata*” contains forms with more cordate test outline, and follow the forms “*normanniae* s.s.” in the English White Chalk (DRUMMOND 1985).

OCCURRENCE: Condensed Upper Turonian – Coniacian deposits at Besakty. *Mytiloides scupini*

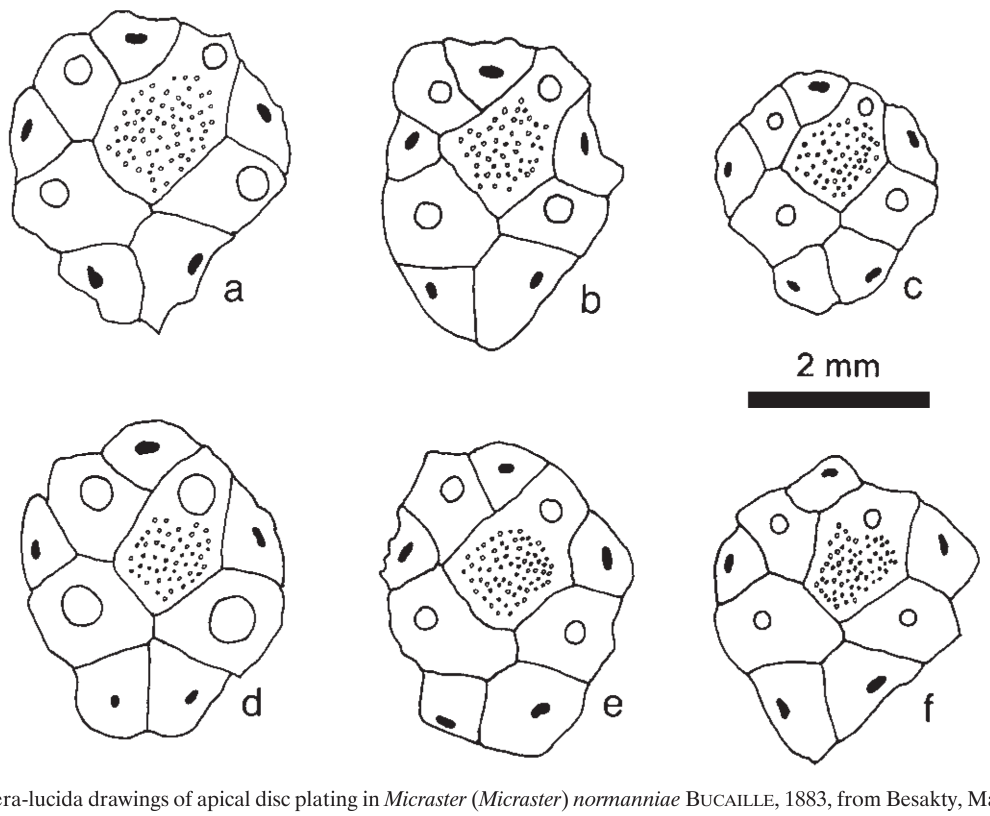

Fig. 49. Camera-lucida drawings of apical disc plating in *Micraster* (*Micraster*) *normanniae* BUCAILLE, 1883, from Besakty, Mangyshlak; a – IGPUW/E/01/651, b – IGPUW/E/01/652, c – IGPUW/E/01/655, d – IGPUW/E/01/648, e – IGPUW/E/01/650, f – IGPUW/E/01/653

and *Cremnoceramus walt. waltersdorfensis* zones (Upper Turonian) at Folwark Quarry. Rare in the North European Province: upper Upper Turonian and Lower Coniacian of England and France. Rare occurrences in the Upper Turonian of northern Spain (KÜCHLER & ERNST 1989).

Micraster (*Micraster*) *cortestudinarium* (GOLDFUSS, 1829)
(Text-figs 50-52; Pl. 24, Figs 1-4; Pl. 25, Figs 1-4; Pl. 26, Figs 1, 2)

1829. *Spatangus cor testudinarium* A. GOLDFUSS, p. 156, pl. 48, fig. 5.
1874. *Spatangus cor-testudinarium*; F.A. QUENSTEDT, p. 646, pl. 87, fig. 30.
1876. *Micraster cortestudinarium* AGASSIZ; G. COTTEAU, p. 498, pl. 83, figs 1-3.
1878. *Micraster cortestudinarium* GOLDFUSS; TH. WRIGHT, p. 335, pl. 76, figs 1, 2.
1889. *Micraster* cf. *cortestudinarium* GOLDFUSS; A. FRIČ, p. 99, fig. 126.
1899. *Micraster cortestudinarium* GOLDFUSS; A.W. ROWE, p. 534, pl. 35, figs iii, v.
?1934. *Micraster cor testudinarium* GOLDFUSS; H. ANDERT, p. 76, pl. 18, figs 19, 20.
1959. *Micraster cortestudinarium* GOLDFUSS; M.M. MOSKVIN, p. 280, text-fig. 93; pl. 19, fig. 2; pl. 20, fig. 1.
1964. *Micraster cortestudinarium* (GOLDFUSS); G.N. DZHABAROV, p. 50, pl. 17, fig. 2.
1964. *Micraster carinatus* G.N. DZHABAROV, p. 53, pl. 18, fig. 1.
1967. *Micraster decipiens* (BAYLE); L. CAYEUX & O. DE VILLOUTREYS, p. 30, pl. 2, figs 7, 7[a], 7[b], 7[c], 7B, 7B[a], 7B[b]; pl. 3, figs 7C, 7C[a].
1968. *Micraster cortestudinarium* (GOLDFUSS); S.I. PASTERNAK & *al*., p. 219, text-fig. 48; pl. 49, figs 5-9.
1970c. *Micraster* (*Micraster*) *cortestudinarium* (GOLDFUSS); G. ERNST, pl. 17, fig. 3.
1972. *Micraster cortestudinarium* (GOLDFUSS); G. ERNST, pl. 5, fig. 2.
1974. *Micraster cortestudinarium* GOLDFUSS; O.W. SAVCHINSKAYA, p. 327, pl. 113, figs 1-6.
1975. *Micraster cortestudinarium* GOLDFUSS; R.B. STOKES, p. 67, text-fig. 29h.
1975. *Micraster decipiens* (BAYLE); R.B. STOKES, p. 68.
1977. *Micraster decipiens* (BAYLE); R.B. STOKES, p. 810, pl. 108, figs 1-4.
1978. *Micraster decipiens* (BAYLE); F. ROBASZYNSKI, pl. 1, figs 1-4.
1981. *Micraster decipiens* BAYLE; M. FOURAY, p. 38, pl. 3, figs 8-10.
1984. *Micraster decipiens* (BAYLE); B. DAVID & M. FOURAY, p. 469, figs 7, 9.
1985. *Micraster decipiens* (BAYLE); M. FOURAY & B. POMEROL, pl. 1, figs 3, 6, 9; pl. 2, figs 2-5.
1991. *Micraster decipiens* (BAYLE); R. TARKOWSKI, p. 130, pl. 27, fig. 1.
2002. *Micraster cortestudinarium* (GOLDFUSS); A.B. SMITH & C.W. WRIGHT, p. 293, pl. 60, figs 4, 5.

TYPE: Lectotype, designated by STOKES (1975), is the specimen illustrated by GOLDFUSS (1829, pl. 48, fig. 5 a-c) under the name of *Spatangus cor testudinarium*. Possible source localities, according to GOLDFUSS (1829), are Quedlinburg, Coesfeld and Maastricht. WOOD & *al*. (1984) noted that the sediment preserved inside one syntype, i. e. recrystallised chalk, indicates a provenance either from the Anglo-Paris Basin or from the chalk of Lüneburg. A provenance from Quedlinburg may be excluded (WOOD & *al*. 1984).

MATERIAL: Twenty-seven medium- and well-preserved, phosphatic specimens (IGPUW/E/01/659-669, 742-757) from Bed 42 (unit B) at Besakty. Four poorly- and moderately well-preserved, phosphatic specimens (IGPUW/E/01/758-761) from Bed 41 at Azhirektoy. One poorly preserved specimen (IGPUW/E/01/762) from the *Cremnoceramus deformis deformis* Zone and two poorly preserved specimens (IGPUW/E/01/763, 764) from the *C. crassus crassus* Zone, Bed 14 at Shakh-Bogota. A single poorly preserved specimen (IGPUW/E/01/765) from the top of Bed 20 at Sulu-Kapy. One well-preserved specimen (IGPUW/E/01/693) from Bed 21 at Kush. One poorly (IGPUW/E/01/694) and one moderately well-preserved specimen (IGPUW/E/01/695) from the *Cremnoceramus deformis erectus* and *Cremnoceramus walt. hannovrensis* + *C. crassus inconstans* + *C. crassus crassus*/ *deformis deformis* zones boundary, and numerous very poorly preserved specimens from latter zone at Folwark Quarry. One well-preserved specimen (IGPUW/E/01/696) from Beachy Head in England.

DESCRIPTION: **Shape and size**. In general of moderate size (Table 19 and Text-fig. 50), with a

Statistic	L [mm]	W [mm]	H [mm]	WT [mm]	AA [°]	a [mm]	b [mm]	W/L *100	H/L *100	H/W *100	WT/W *100	a/b *100
Minimum value	38.3	35.8	23.0	29.3	90.5	17.5	18.6	92.42	59.13	61.33	76.72	76.35
Maximum value	52.9	52.3	34.4	42.6	106.0	25.3	27.6	100.46	74.54	76.46	86.03	109.14
Mean value	45.41	43.93	29.90	36.03	98.22	21.71	23.70	96.73	65.84	68.07	82.07	92.15
Median	45.60	44.10	30.10	35.90	98.00	22.00	23.80	96.90	66.06	67.08	82.37	91.02
Standard Deviation	3.820	3.869	3.057	3.120	4.177	2.017	2.377	2.177	3.835	3.801	2.537	9.134

Table 19. Simple statistics of biometric data and simple ratios for *Micraster* (*Micraster*) *cortestudinarium* (GOLDFUSS, 1829) from Besakty, Mangyshlak; number of specimens N=27

single large-sized specimen (length 64.9 mm, width 64.3 mm, height 37.9 mm) from Bed C20 at Folwark Quarry.Test thick or moderately thick. Relatively wide morphological range of variations. In general, test circular-cordiform (Pl. 24, Figs 3a-b, 4a-b; Pl. 25, Figs 2a-b, 4a-b; Pl. 26, Figs 1a-b, 2a-b); rarely circular-trapezoidal (Pl. 24, Figs 1a-b, 2a-b), or oval-cordiform (Pl. 25, Figs 1a-b, 3a-b). Mean value of W/L*100 ratio is 96.73, median 96.90, which indicates a roughly circular outline. Viewed from aboral side maximum test width below ends of anterior paired petals. Test in lateral section moderately tall in specimens from Mangyshlak, and relatively low in specimens from Opole, weakly convex from aboral side. Transverse section convex, with symmetric, gently arched shape from aboral side. Anterior groove broad, clearly sunken. Anal angle obtuse, close to 100°.

Apical disc. Apical disc tetrabasal and ethmophract, slightly sunken, moved anteriorly. Mean value a/b*100 is 92.15, median 91.02 in Besakty. Rarely, apical disc centrally or nearly centrally, roughly circular or slightly elongate in outline. Madreporite much larger than other genital plates and usually in contact with ocular plates II, III, IV, separated from ocular plates I, V (Text-fig. 51a, b). Sometimes, madreporite abuts ocular plates II, III and separated from ocular plates I, IV, V (Text-fig. 51c, d). In a single specimen, madreporite in contact with ocular plates I, II, III and separated from ocular plates IV, V (Text-fig. 51e). Madreporite in another specimen in contact with ocular plates II, III, V, and separated from ocular plates I, IV (Text-fig. 51f). In all cases where ocular plates I and V separated from madreporite by genital plates 1 and 4, genital plates abut (Text-fig. 51a-d); ocular plate I tends to separate genital plate 1 from 4.

Ambulacral zone. Ambulacra heteromorphic, petals different in length. Posterior petals about 63% – 78% of anterior paired ones. Interporiferous area "inflated". Rarely specimens intermediate from "sutured" to "inflated" occur. Poriferous band in petal consists of oval or oval-elongate, or teardrop-shaped pore pair. Usulally, in one row perradial pores smaller and oval, adradial pores larger, oval-elongate or teardrop-shaped. Interporiferous ridge either absent or consisting of a few fine granules. Ambulacral furrow shallow and weakly developed. Zone between poriferous band smooth or fine granulate. Unpaired ambulacrum III clearly different from paired ambulacra, poriferous band consists of circular pores, between every pair of pores small granule, zone between poriferous band weakly granulate, clear suture between two rows of plates.

Interambulacral zone. Interambulacra uniformly covered by tubercles.

Plastron and labrum. Plastron euamphisternal, rarely semiamphisternal type 2, with slight asymmetry of sternal plates, labral plate usually narrow, triangular (close to isosceles triangle) with narrow base, tubercles on labrum irregularly spaced.

Periplastronal zone. Periplastronal plates "sandy", transitional to "granular".

Peristome. Peristome oval in outline, partialy or completely covered by labrum, situated relatively far from anterior border.

Periproct. Periproct circular or oval, high on anal field.

Subanal fasciole. Subanal fasciole well-developed, moderately broad, forming closed ring, with more or less constant width, comprising densely spaced, very fine tubercles for clavulae.

Tuberculation. Tuberculation of whole test variable. On aboral side tubercles not so large, but distinct and relatively densely spaced. Adoral tubercles much larger and densely packed, being most numerous on plastron.

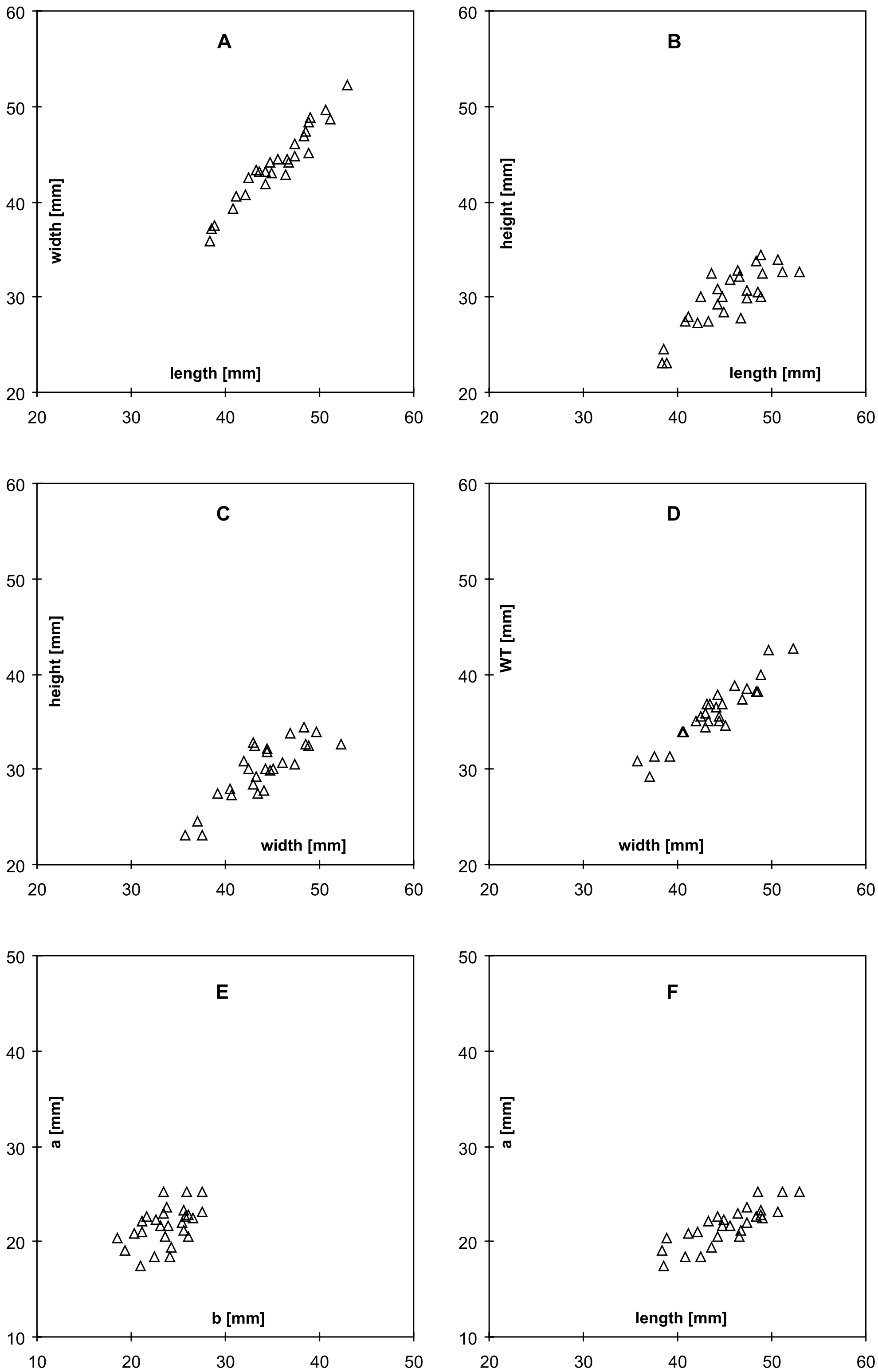

Fig. 50. Biometric data for *Micraster* (*Micraster*) *cortestudinarium* (GOLDFUSS, 1829), from Besakty, Mangyshlak; A – scatter plot of length *versus* width, B – scatter plot of length *versus* height, C – scatter plot of width *versus* height, D – scatter plot of width *versus* WT (width of the test or mould measured one third from posterior edge), E – scatter plot of distance b (distance from central point of apical disc to posterior edge) *versus* distance a (distance from central point of apical disc to anterior edge), F – scatter plot of distance length *versus* distance a

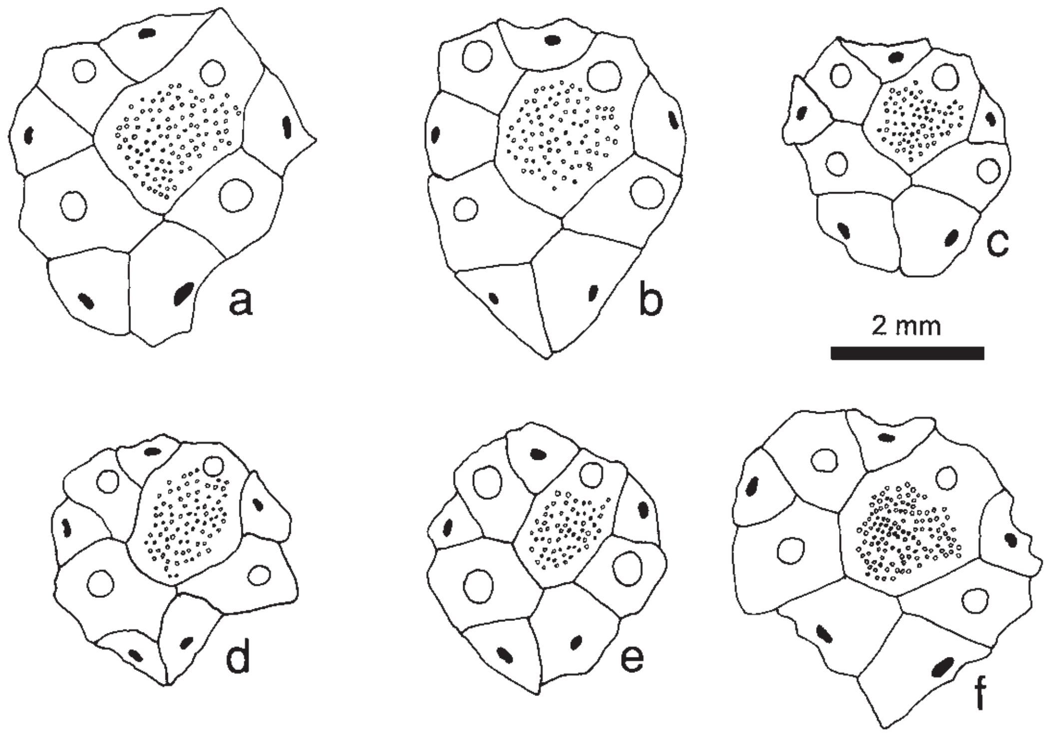

Fig. 51. Camera-lucida drawings of apical disc plating in *Micraster* (*Micraster*) *cortestudinarium* (GOLDFUSS, 1829); a – IGPUW/E/01/696, Beachy Head of England; b – IGPUW/E/01/665, Besakty, Mangyshlak; c – IGPUW/E/01/749, Besakty, Mangyshlak; d – IGPUW/E/01/663, Besakty, Mangyshlak; e – IGPUW/E/01/750, Besakty, Mangyshlak; f – IGPUW/E/01/693, Kush, Mangyshlak

Simple statistical analysis

The basic simple statistics shows small standard deviations (Table 19). The medians are close to mean values. There is a high correlation between almost all characters (Table 20), with the exception of the anal angle which seems to be the only independent character.

The frequency distribution of particular simple ratios (Text-fig. 52) examined with the Kolmogorov-Smirnov test of goodness of fit at the 95% confidence level, shows their distribution to be close to normal, additionally suggesting the homogeneity of samples.

REMARKS: *Micraster* (*M.*) *cortestudinarium* differs

Characters and simple ratios	L	W	H	WT	AA	a	b	W/L *100	H/L *100	H/W *100	WT/W *100	a/b *100
L	1	**0.9661**	**0.8281**	**0.8637**	0.3938	**0.8444**	**0.8906**	0.0465	0.0560	0.0445	-0.3390	-0.1380
W		1	**0.8413**	**0.9372**	0.3549	**0.7953**	**0.8778**	0.3019	0.1289	0.0167	-0.2332	-0.1686
H			1	**0.7548**	0.3870	**0.5936**	**0.8271**	0.2065	**0.6045**	**0.5532**	-0.2958	-0.3144
WT				1	0.3572	**0.7293**	**0.7691**	0.4327	0.1214	-0.0450	0.1191	-0.1065
AA					1	0.4543	0.2473	-0.1045	0.1088	0.1585	-0.0214	0.1760
a						1	**0.5083**	-0.0421	-0.1467	-0.1268	-0.2093	0.4121
b							1	0.1105	0.2144	0.1791	-0.3672	**-0.5716**
W/L*100								1	0.3097	-0.0825	0.3348	-0.1473
H/L*100									1	**0.9217**	-0.0444	-0.3776
H/W*100										1	-0.1853	-0.3259
WT/W*100											1	0.2177
a/b*100												1

Table 20. Matrix correlation of biometric data and simple ratios for *Micraster* (*Micraster*) *cortestudinarium* (GOLDFUSS, 1829) from Besakty, Mangyshlak; marked correlations are significant at $p<0.05$; number of specimens $N=27$

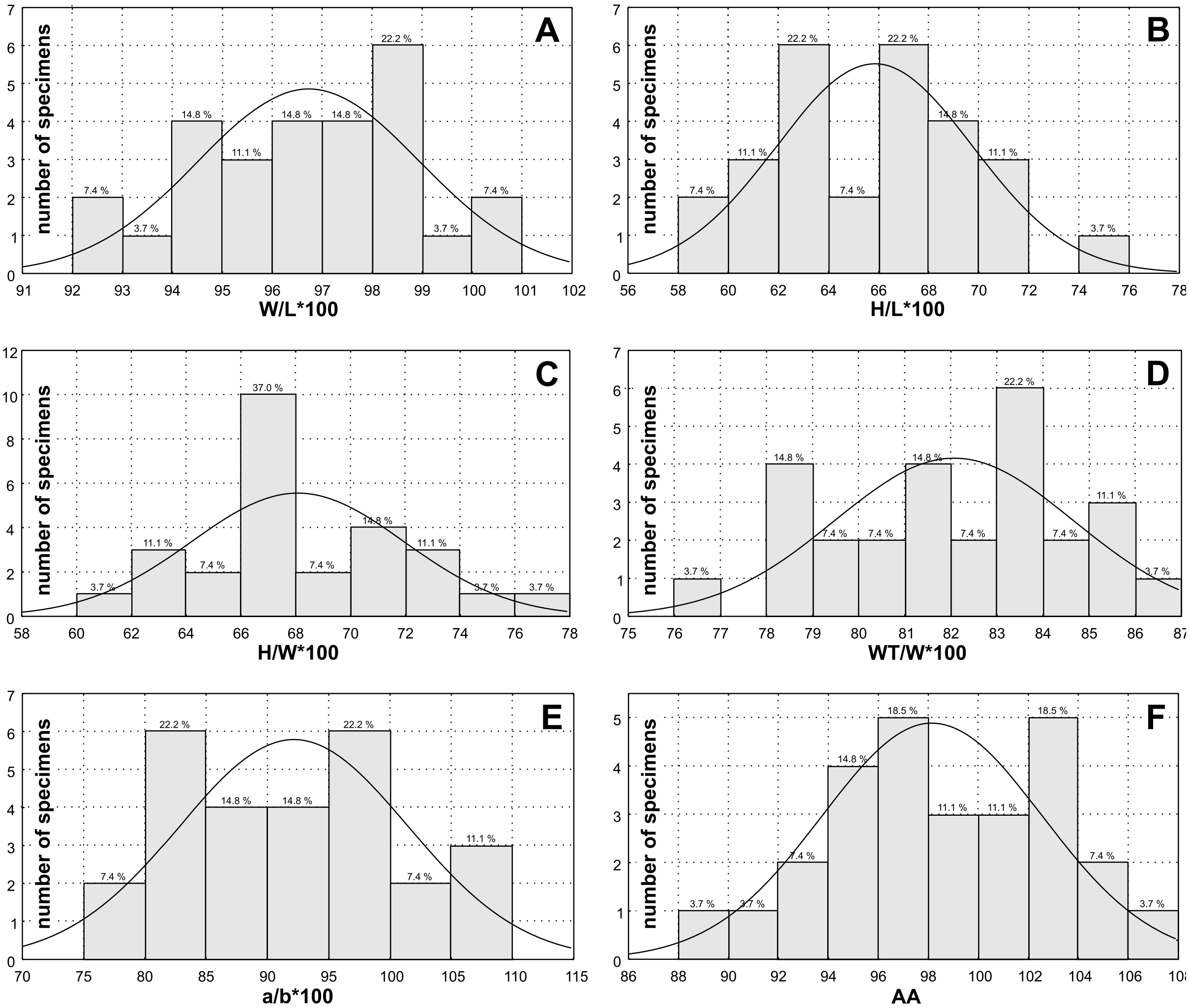

Fig. 52. Histograms of distribution of the simple ratios and values of anal angle in *Micraster* (*Micraster*) *cortestudinarium* (GOLDFUSS, 1829), from Besakty, Mangyshlak (sample N = 27); A – W/L*100, B – H/L*100, C – H/W*100, D – WT/W*100, E –a/b*100, F – anal angle

from *M.* (*M.*) *leskei* and *M.* (*M.*) *normanniae* in being more circular-cordate in shape. Its maximum width is located more posteriorly and its tuberculation is better developed. On the aboral side, the tubercles are larger and more densely spaced. The type of interporiferous area is “inflated”; this does not occur in *M.* (*M.*) *leskei*, nor in *M.* (*M.*) *normanniae*, which also lack a euamphisternal plastron. Only the semiamphisternal type 2 plastron appears in all three cited taxa. In such cases, other characters, such as shape of test, “granular” periplastronal zone, or “inflated” interporiferous area, permit to distinguish *M.* (*M.*) *cortestudinarium*, which also has a much larger madreporite, considerably larger than other genital plates, whereas the madreporite of *M.* (*M.*) *leskei* and *M.* (*M.*) *normanniae* is similar or slightly larger in size to other genital plates.

I agree with ROWE (1899), and WOOD & *al.* (1984), that *Micraster decipiens* fits well the concept of *M.* (*M.*) *cortestudinarium* and, consequently, include it in the synonymy of the latter. STOKES (1975) regarded *M. cortestudinarium* and *M. decipiens* to be distinct species typical of Central Europe and the Anglo-Paris Basin, respectively.

Thanks to the late Prof. Gundolf ERNST, I received a plaster cast of a syntype of *Spatangus cortestudinarium* of GOLDFUSS (1829). This shows a close similarity to English Chalk specimens (Pl. 26, Fig. 1), and both these and GOLDFUSS’s syntype are close to material from Opole (Pl. 26, Fig. 2, compare also TARKOWSKI 1991, pl. 27, fig. 1). This would suggest that *M. decipiens* occurred outside the Anglo-Paris Basin as well and thus could no longer be considered endemic.

OCCURRENCE: Lower Coniacian (*Cremnoceramus deformis deformis – C. crassus crassus* Zone) at Shakh-Bogota, Coniacian at Sulu-Kapy and Kush. Condensed Upper Turonian-Coniacian at Azhirektoy and Besakty. Lower Coniacian (*Cremnoceramus deformis erectus* Zone and *Cremnoceramus walt. hannovrensis + C. crassus inconstans + C. crassus crassus / deformis deformis*) at Folwark Quarry. This species is widely known from the North European Province: uppermost Turonian and Coniacian of England, Coniacian of France, Germany, western Ukraine, Donbass, and northern Caucasus. Also known from the Coniacian of northern Spain (KÜCHLER & ERNST 1989), and from the northern periphery of Mediterranean Province of Georgia.

Micraster (*Micraster*) *cayeusi* PARENT, 1892
(Pl. 30, Fig. 1)

1892. *Micraster Cayeusi* H. PARENT, p. 13, pl. 2, fig. 2.
1974. *Micraster cayeusi* PARENT; G. ERNST & M.-G. SCHULZ, p. 34, text-fig. 11; pl. 2, fig. 5.

TYPE: Holotype, by monotypy, is the specimen illustrated by PARENT (1892, pl. 2, fig. 2), from Ennequin near Lille (France), Craie blanche, Coniacian, *Micraster cortestudinarium*/*Inoceramus involutus* Zone.

MATERIAL: A single slightly deformed, quite well-preserved specimen (IGPUW/E/01/670), and another poorly preserved test (IGPUW/E/01/671) from the *Cremnoceramus walt. hannovrensis + C. crassus inconstans + C. crassus crassus / deformis deformis* Zone at Folwark Quarry.

DESCRIPTION: **Shape and size**. Test of moderate size (Table 21), moderately thick, circular in outline. Viewed from aboral side maximum test width situated at ends of anterior paired petals or just below. Elongate section moderate in height, convex from aboral side and flattened adoral side. Transverse section also convex from aboral side. Anterior groove narrow and shallow. Anal angle almost 90° in one specimen or slightly obtuse in the second one. The obtuse angle can be a result of post-mortem compactional deformation (Pl. 30. Fig. 1c).

Apical disc. Apical disc central, in one case, a/b*100 ratio being 96.65. In the second specimen, is eccentric, moved posteriorly, a/b*100 ratio being 108.37.

Ambulacral zone. Ambulacra heteromorphic. Petals very weakly sunken. Posterior petals about 75% of anterior paired ones. Interporiferous area poorly preserved and probably "inflated", with a tendency to "subdivided", poriferous band in petal consists of two different pores in single pair; perradial pores circular or slightly oval, adradial pores elongate and teardrop-shaped; interporiferous ridge poorly preserved; ambulacral furrow very poorly developed; zone between poriferous band poorly preserved. Unpaired ambulacrum III clearly different from paired ambulacra, with poriferous band consisting of circular pores in one pair, zone between poriferous band weakly granulated, between two rows of plates occurs a clear suture.

Interambulacral zone. Interambulacra uniformly covered moderately dense, fine tubercles.

Plastron and labrum. Plastron semiamphisternal type 1, with large sternal plates, labral plate narrow and two longer edges of labrum quite parallel to each other, labrum covered by tubercles in two symmetric rows.

Periplastronal zone. Periplastronal area "coarse-granular" with rare tubercles.

Peristome. Peristome ovalo-elongate in outline and completely covered by labrum, situated close to anterior border.

Periproct. Periproct circular or slightly oval in outline, high on anal field.

Subanal fasciole. Subanal fasciole very poorly preserved, moderately broad, forming a closed ring, consisting of dense, very fine tubercles for clavulae.

Tuberculation. Tuberculation of whole test variable. On aboral side tubercles fine and rare, scattered. Adoral tubercles larger and densely packed, being most numerous on plastron.

Number of specimen	L [mm]	W [mm]	H [mm]	AA [°]	a [mm]	b [mm]	W/L *100	H/L *100	H/W *100	a/b *100
IGPUW/E/01/670	?41.1	43.8	23.6	-	?20.2	?20.9	106.57	57.42	53.88	?96.65
IGPUW/E/01/671	44.8	45.2	28.1	90	23.3	21.5	100.89	62.72	62.17	108.37

Table 21. Biometric data and simple ratios for *Micraster* (*Micraster*) *cayeusi* PARENT, 1892

OCCURRENCE: Lower Coniacian (upper part of *Cremnoceramus walt. hannovrensis* + *C. crassus inconstans* + *C. crassus crassus* / *deformis deformis* Zone) at Folwark Quarry. This species is very rarely reported from the western part of North European Province, with records from the Coniacian of France and northern Germany (*Cremnoceramus involutus*/*Micraster bucailli* Zone).

Micraster (*Micraster*) *bucailli* PARENT, 1892
(Text-fig. 53; Pl. 30, Fig. 2)

1892. *Micraster Bucailli* H. PARENT, p. 15, pl. 1, fig. 1.
1974. *Micraster bucailli* PARENT; G. ERNST & M.-G. SCHULZ, p. 28, text-figs 7, 8a, 9a-c; pl. 1, figs 1, 2; pl. 2, figs 1, 4.
1975. *Micraster bucaillei* PARENT; R.B. STOKES, p. 63.

TYPE: Holotype, by monotypy, is the specimen illustrated by PARENT (1892, pl. 1, fig. 1), from the Coniacian, *Micraster cortestudinarium*/*Inoceramus involutus* Zone of Ennequin near Lille.

MATERIAL: A single, moderately preserved specimen (IGPUW/E/01/672), from Bed 42 (unit B_3) at Besakty.

DESCRIPTIONS: **Shape and size**. Test of moderate in size; length 46.9 mm, width 42.5 mm, height 34.6 mm, WT 33.1 mm, distance a 23.2 mm, distance b 23.7 mm; test thick; cordiform in outline, and elongated; W/L*100 ratio is 90.6; WT/W*100 ratio is 77.9. Viewed from aboral side maximum test width situated at level of ends of anterior paired petals. Lateral profile high, with H/L*100 ratio being 73.8. In lateral profile, from apical disc towards anterior edge, arch weakly convex and quite abrupt; from apical disc towards posterior, arch much gently. Adoral side weakly convex. Transverse profile high and cone-shaped with convex sides, H/W*100 ratio is 81.4. Anterior groove of moderate breadth and moderately sunken. Anal angle obtuse (108°).

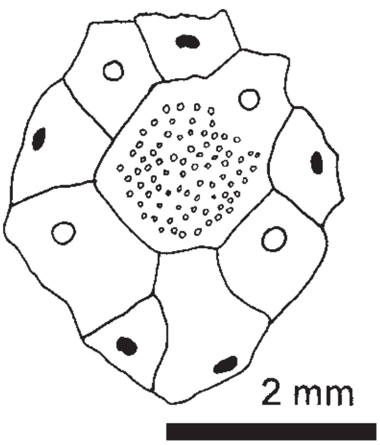

Fig. 53. Camera-lucida drawing of apical disc plating in *Micraster* (*Micraster*) *bucailli* PARENT, 1892, IGPUW/E/01/672 from Besakty, Mangyshlak

Apical disc. Apical disc tetrabasal and ethmophract, located centrally, a/b*100 ratio is 97.9, and roughly circular. Madreporite large and almost twice as larger as next large genital plate 4 (Text-fig. 53). Madreporite in contact with ocular plates I, II, III, IV, and separated only from ocular plate V.

Ambulacral zone. Ambulacra heteromorphic. Petals weakly sunken; posterior petals about 78% of anterior paired ones; interporiferous area "subdivided", poriferous band in petal consists of oval or teardrop-shaped pore pair obliquely in one pair; interporiferous ridge developed as granules; ambulacral furrow clear and moderately sunken; zone between poriferous band finely granulated. Unpaired ambulacrum III clearly different from paired ambulacra; with poriferous band consisting of circular pores in one pair, between every pair there is a clear granule; zone III, i.e. zone between poriferous band and field around poriferous band, granulated; a clear suture occurs between two rows of plates.

Interambulacral zone. Interambulacra uniformly covered by tubercles.

Plastron and labrum. Plastron euamphisternal, labral plate is narrow and club-shaped, slightly broader at anterior side, and densely covered by tubercles.

Periplastronal zone. The periplastronal area "granular-mamillate".

Peristome. Peristome oval-elongate in outline, completely covered by labrum; end of the reconstructed labrum agrees with the anterior edge; peristome situated at extreme anterior border.

Periproct. Periproct circular or slightly oval, high on anal field.

Subanal fasciole. Subanal fasciole well developed, broad, forming closed ring of dense, very fine tubercles for clavulae.

Tuberculation. Tuberculation of whole test variable. On aboral side tubercles fine and scattered; adoral tubercles much larger and more densely packed, and most numerous on plastron.

OCCURRENCE: Probably Upper Coniacian in condensed Upper Turonian – Coniacian at Besakty section. Rare in the North European Province: *Volviceramus involutus* Zone (Middle Coniacian) of France and Middle Coniacian to Lower Santonian of northern Germany.

Micraster (*Micraster*) *coranguinum* (LESKE, 1778)
(Pl. 30, Fig. 3)

1734. *Spatangus Cor-anguinum* (*a*) *Anglicum*; J.T. KLEIN, p. 33, pl. 23, figs A, B.
1778. *Spatangus Cor Anguinum* Var. a *Anglicum*; N.G. LESKE, p. 221, pl. 23, figs C, D.
1829. *Spatangus coranguinum* LAMARCK; A. GOLDFUSS, p. 157, pl. 48, fig. 6.
1853. *Micraster cor-anguinum* AGASSIZ; A. D'ORBIGNY, p. 207, pl. 867, figs ?1-?8; pl. 868, figs ?3, ?4.
1869. *Micraster cor-anguinum* AGASSIZ; G. COTTEAU & J. TRIGER, p. 326, pl. 55, figs 5-10.
1874. *Spatangus* (*Micraster*) *cor-anguinum*; F.A. QUENSTEDT, p. 644, pl. 87, figs 28, ?33.
1876. *Micraster coranguinum* AGASSIZ; G. COTTEAU, p. 501, pl. 83, figs 4,5.
1878. *Micraster cor-anguinum* KLEIN; TH. WRIGHT, p. 271, pl. 62, figs 1-3, 5.
1959. *Micraster coranguinum* KLEIN; M.M. MOSKVIN, p. 281, text-fig. 94; pl. 20, fig. 2.
1964. *Micraster coranguinum* (KLEIN); G.N. DZHABAROV, p. 55, pl. 18, ?fig. 2.
1966. *Micraster coranguinum* (KLEIN); G. ERNST, p. 124.
1966. *Micraster* (*Micraster*) *coranguinum* (LESKE); A.G. FISCHER, p. U581, text-fig. 467,2.
1968. *Micraster coranguinum* (KLEIN); S.S. MĄCZYŃSKA, p. 108, text-pl. 2, figs 1, 2; text-pl. 3, fig. 3; pl. 3, figs 1-3.
1968. *Micraster coranguinum* (KLEIN); S.I. PASTERNAK & *al.*, p. 221, text-fig. 49; pl. 50, figs 1-4.
1969. *Micraster coranguinum* (KLEIN); L. CAYEUX, p. 37, pl. 1, figs 5-9.
1974. *Micraster coranguinum* LESKE; G. ERNST & M.-G. SCHULZ, p. 30, text-figs 7, 8b-c, 9d-e; pl. 1, fig. 3; pl. 2, fig. 2.
1974. *Micraster coranguinum* (KLEIN); O.V. SAVCHINSKAYA, p. 328, pl. 113, figs 7-10.
1975. *Micraster coranguinum* (LESKE); R.B. STOKES, p. 64, text-fig. 29d; pl. 2, figs 1-3.
1993. *Micraster coranguinum* (LESKE); E.P.F. ROSE & N. E. CROSS, text-figs 1, 5, 6.
1994. *Micraster coranguinum* (LESKE); N.E. CROSS & E.P. F. ROSE, text-fig. 1.
2002. *Micraster coranguinum* (LESKE); A.B. SMITH & C. W. WRIGHT, p. 293, pl. 60, figs 6-8.

TYPE: STOKES (1975) indicated for siliceous moulds figured by KLEIN (1734, p. 33, pl. 23, figs A, B) under the name *Spatangus Cor-anguinum* (*a*) *Anglicum*. The collection of KLEIN is lost and type locality and type horizon of these specimens are unknown.

MATERIAL: Three medium-preserved specimens (IGPUW/E/01/673-675) from the top of Bed 15 at Shakh-Bogota. A single poorly preserved specimen (IGPUW/E/01/676) from Bed 21 at Sulu-Kapy.

DESCRIPTION: **Shape and size**. Test of moderate size (Table 22) and moderate thickness, oval-cordiform in outline. W/L*100 ratio is 92.9. Viewed from aboral side, maximum test width situated just below ends of anterior paired petals. Elongate profile moderately high. H/L*100 ratio is 68.51; convex from aboral side; weakly convex or nearly flattened from adoral side. Transverse profile also moderately high, with H/W*100 ratio being 73.75, lateral sides convex. Anterior groove narrow and moderately sunken. Anal angle obtuse being 101^{o} in the best-preserved specimen.
Apical disc. Apical disc not preserved, but located centrally, a/b*100 ratio is 99.56.
Ambulacral zone. Ambulacra heteromorphic; petals weakly sunken. Transverse section by petals V-shaped; posterior petals about 77% of anterior paired ones; interporiferous area "subdivided"; poriferous band in petal consists of oval pores, similar in size; interporiferous ridge developed as fine

Number of specimen	L [mm]	W [mm]	H [mm]	a [mm]	b [mm]
IGPUW/E/01/673	45.1	41.9	30.9	22.5	22.6
IGPUW/E/01/674	52.4	-	-	-	-

Table 22. Biometric data and simple ratios for *Micraster* (*Micraster*) *coranguinum* (LESKE, 1778), Mangyshlak

granules; zone between poriferous band finely granulated; ambulacral furrow shallow. Unpaired ambulacrum III clearly different from paired ambulacra, with poriferous band consisting of circular pores in one pair; whole field III covered by granules and tubercles; a clear suture between two rows of plates.

Interambulacral zone. Interambulacra quite densely covered by tubercles.

Plastron and labrum. Plastron euamphisternal; labral plate narrow and club-shaped, slightly broader at anterior side, and densely covered by tubercles.

Periplastronal zone. Periplastronal area "tuberculate-mamillate".

Peristome. Peristome oval-elongate in outline, completely covered by labrum, and situated very close to anterior border.

Periproct. Periproct high on anal field.

Subanal fasciole. Subanal fasciole well developed, broad and forming closed ring of densely arranged miliary tubercles.

Tuberculation. Tuberculation of whole test quite rich; on aboral side fine, densely spaced tubercles; adoral tubercles also densely packed but larger, most numerous on plastron.

REMARKS: *Micraster* (*M.*) *coranguinum* is closest to *M.* (*M.*) *bucailli* but is, however, more oval in outline and, more importantly, differs in peristome and labrum features.

OCCURRENCE: Upper Coniacian (*Magadiceramus subquadratus* Zone) at Shakh-Bogota and ?Middle Coniacian at Sulu-Kapy. This species is widespread in the North European Province: Upper Coniacian – Santonian of England, France, and Germany; Coniacian of western Ukraine and Donbass; Upper Coniacian – Santonian of Northern Caucasus and Kopet-Dag; Santonian of Poland (Kraków area). Known also from the Upper Coniacian – Santonian of the northern periphery of the Mediterranean Province (Georgia).

Micraster (*Micraster*) *praerogalae* sp. nov.
(Text-fig. 54; Pl. 27, Fig. 1)

HOLOTYPE: IGPUW/E/01/677 illustrated in Pl. 27, Fig. 1; housed in the Museum of the Faculty of Geology, University of Warsaw.

PARATYPE: IGPUW/E/01/678.

TYPE LOCALITY: Shakh-Bogota, about 15 km south of Sarytash, Mangyshlak.

TYPE HORIZON: Upper Coniacian, *Magadiceramus subquadratus* Zone.

DERIVATION OF THE NAME: ancestor of the species *Micraster* (*M.*) *rogalae* NOWAK.

DIAGNOSIS: Large-sized, test oval-cordiform in outline, length exceeding width, apical disc lying eccentrically, moved anteriorly, type of interporiferous area "subdivided", type of periplastron "granular-mamillate".

MATERIAL: A single well-preserved specimen (IGPUW/E/01/677) from the upper part of Bed 15 at Shakh-Bogota, and a second moderately well-

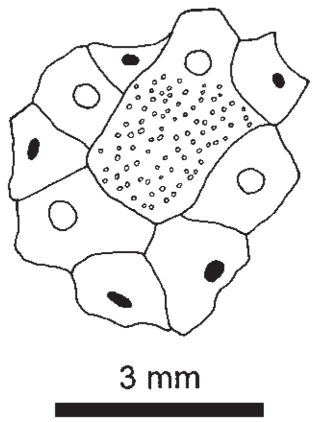

Fig. 54. Camera-lucida drawing of apical disc plating in *Micraster* (*Micraster*) *praerogalae* sp. nov., holotype No. 677 from Shakh-Bogota, Mangyshlak

Number of specimen	L [mm]	W [mm]	H [mm]	WT [mm]	AA [°]	a [mm]	b [mm]	W/L *100	H/L *100	H/W *100	WT/W *100	a/b *100
IGPUW/E/01/677	68.2	63.8	36.6	51.1	95.0	33.1	35.1	93.5	53.1	57.4	80.1	94.3
IGPUW/E/01/678	70.9	66.1	36.9	48.1	98.0	33.9	37.0	93.2	52.0	55.8	72.8	91.6

Table 23. Biometric data and simple ratios for *Micraster* (*Micraster*) *praerogalae* sp. nov., Mangyshlak

preserved test (IGPUW/E/01/678) from the top of Bed 21 at Kush (type series).

DESCRIPTIONS: **Shape and size**. Test of large size (Table 23 and Text-fig. 55) and thick, oval-cordiform in outline. Viewed from aboral side maximum test width situated well below level of ends of anterior paired petals. Elongate profile moderately high, aboral side convex, forming weak arch, however, posterior slightly more convex than anterior; adoral side weakly convex. Transverse profile also moderately high, slightly convex from aboral side, weakly convex or nearly flattened from adoral side. Anterior groove moderately broad and clearly sunken. Anal angle slightly obtuse, but in neither specimen is it 100°.

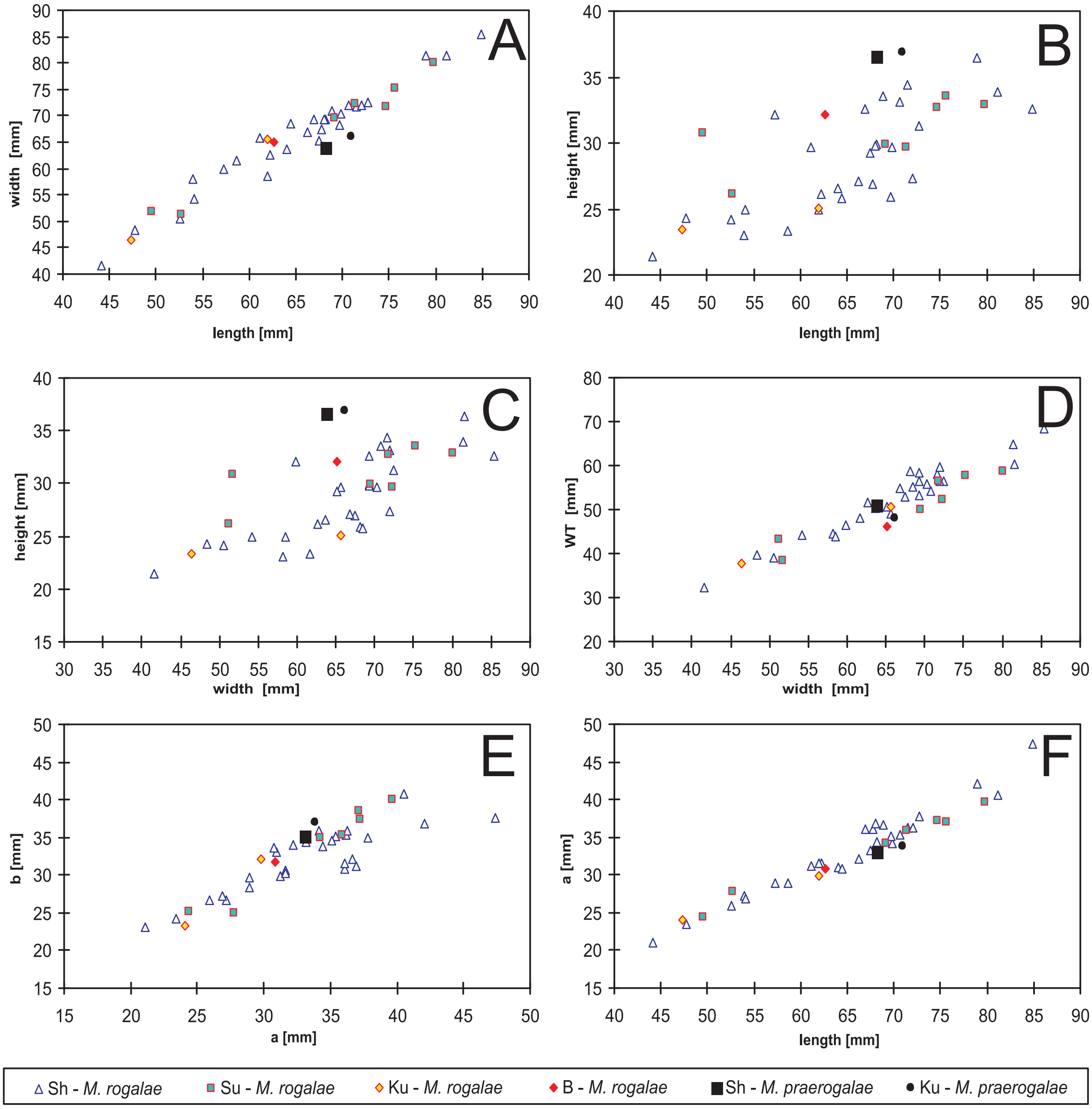

Fig. 55. Biometric data for *Micraster* (*Micraster*) *rogalae* NOWAK, 1909, and *Micraster* (*Micraster*) *praerogalae* sp. nov. from the upper Coniacian of Mangyshlak; A – scatter plot of length *versus* width, B – scatter plot of length *versus* height, C – scatter plot of width *versus* height, D – scatter plot of width *versus* WT (width of the test or mould measured one third from posterior edge), E – scatter plot of distance b (distance from central point of apical disc to posterior edge) *versus* distance a (distance from central point of apical disc to anterior edge), F – scatter plot of distance length *versus* distance a

Apical disc. Apical disc tetrabasal and ethmophract, situated eccentrically and moved anteriorly, roughly circular; madreporite large and at least twice larger than next large genital plate 4 (Text-fig. 54); madreporite in contact with ocular plates I, II, III, IV, and separated only from ocular plate V.

Ambulacral zone. Ambulacra heteromorphic, petals clearly sunken. All petals relatively long, posterior petals about 72% of anterior paired ones; transverse section of petals V-shaped; interporiferous area "subdivided"; poriferous band in petal consists of oval pores different in size in one pair, perradial pores smaller than adradial ones; pores situated relatively far apart in a pair; interporiferous ridge developed as several granules; ambulacral furrow shallow but clear; zone between poriferous band finely granulated, with small tubercles. Unpaired ambulacrum III clearly different from paired ambulacra; poriferous band consists of circular pores in one pair, between every one pair of pores occur a large granule; whole field III covered by granules; between two rows of plates occurs a clear suture.

Interambulacral zone. Interambulacra covered by rare tubercles.

Plastron and labrum. Plastron euamphisternal, with large sternal plates; labrum triangular, close to isosceles triangle, with broad base, densely covered by tubercles.

Periplastronal zone. Periplastronal area "granular-mamillate".

Peristome. Peristome oval in outline, almost all covered by labrum, and situated relatively far from anterior border.

Periproct. Periproct circular or slightly oval, high on anal field.

Subanal fasciole. Subanal fasciole well developed, broad, forming closed ring of densely miliary tubercles.

Tuberculation. Tuberculation of whole test variable; on aboral side tubercles of moderate and moderately dense; adoral tubercles large and densely packed, being particulary frequent on plastron.

REMARKS: *Micraster* (*M.*) *praerogalae* sp. nov. differs from *M.* (*M.*) *cortestudinarium* in being larger showing a more advanced type of interporiferous area ("subdivided"), an abundance of tubercules in periplastronal zones, in having relatively longer petals in relation to test size, and in having the madreporite larger than other genital plates. From *M.* (*M.*) *rogalae* NOWAK, the new species differs in showing a more elongate oval-cordiform test outline (lower W/L*100 ratio) and greater relative height (H/L*100 ratio showing a higher value). Its apical disc is situated eccentrically, moved anteriorly, whereas in *M.* (*M.*) *rogalae*, as a rule, it is situated centrally or almost centrally. Its types of interporiferous area ("subdivided") and periplastronal area ("granular-mamillate") are less advanced than in *M.* (*M.*) *rogalae* which shows a "divided" type of interporiferous area and "mamillate" periplastronal area.

OCCURRENCE: Mangyshlak, Upper Coniacian (*Magadiceramus subquadratus*) Zone.

Micraster (*Micraster*) *rogalae* NOWAK, 1909
(Text-figs 55-57; Pl. 27, Fig. 2; Pl. 28, Figs 2, 3; Pl. 29, Figs 1, 2)

1909. *Micraster rogalae* J. NOWAK, p. 876, pl. 46, figs 1, 2.
1911. *Micraster* (*Gibbaster*) *belgicus* J. LAMBERT, p. 5, pl. 1, figs 1-4.
1935. *Gibbaster belgicus* LAMBERT (*Micraster*); J.S. SMISER, p. 83.
1959. "*Micraster*" *rogalae* NOWAK; M.M. MOSKVIN, p. 288, text-fig. 104; pl. 24, fig. 3; pl. 25, figs 1, 2.
1963. *Micraster rogalae* NOWAK; G. ERNST, pl. 14, figs 1, 2.
1966. *Micraster rogalae* NOWAK; G. ERNST, p. 125.
1968. *Micraster rogalae* NOWAK; S.I. PASTERNAK & *al.*, p. 222, pl. 50, figs 5, 6.
1974. *Micraster rogalae* NOWAK; G. ERNST & M.-G. SCHULZ, p. 32, text-figs 7, 10; pl. 2, fig. 3; pl. 3, figs 1-4.
1975. *Micraster rogalae* NOWAK; R.B. STOKES, p. 77.
1979. *Micraster rogalae* NOWAK; V.A. HYNDA & S. MĄCZYŃSKA, p. 23, text-figs 3, 4; pl. 3, fig. 3; pl. 4, fig. 1; pl. 5, figs 1-3; pl. 6, fig. 1.
1982. *Micraster rogalae* NOWAK; O.V. SAVCHINSKAYA, p. 239, pl. 29, fig. 2.

TYPE: Holotype, by monotypy, is specimen Ee 631, figured by NOWAK (1909, pl. 46, figs 1, 2), housed in the Museum of the Earth in Warsaw; from the Coniacian of the Halicz area, western Ukraine.

MATERIAL: Twenty-eight moderately and well-preserved (IGPUW/E/01/679-692, 697-710), and five poorly preserved specimens (IGPUW/E/01/710-715) from the top of Bed 15 at Shakh-Bogota. Seven moderately (IGPUW/E/01/720-723, 733-735) and well-, and four poorly (IGPUW/E/01/736-739) preserved specimens from the top of Bed 21 at Sulu-Kapy. Two moderately well-preserved specimens (IGPUW/E/01/740-741) from the top of Bed 21 at Kush. One poorly preserved specimen (IGPUW/E/01/717) from the topmost of Bed 42 (topmost unit C) at Besakty. One moderately preserved specimen (IGPUW/E/01/716) from the boundary between Beds 42 and 43 at Besakty.

DESCRIPTIONS: **Shape and size**. Tests usually large- and occasionally moderate in size (Table 24 and Text-fig. 55), and thick. Most specimens equally wide as long, width mean value W/L*100 ratio being 100.93. Test circular-cordiform in outline (Pl. 27, Fig. 2a-b; Pl. 29, Fig. 1a-b) or close to circular (Pl. 28, Figs 2a-b, 3; Pl. 29, Fig. 2a-b), relatively low in height. Viewed from aboral side maximum test width situated much below level of ends of anterior paired petals. Elongate profile clearly flattened, very weakly convex from aboral side, and flattened from adoral side. Transverse profile relatively low (mean value H/W*100 ratio merely 44.358), very weakly convex from aboral side and flattened from adoral side. Anterior groove broad and relatively shallow. Anal angle always obtuse and mean value exceeding 102°.

Apical disc. Apical disc tetrabasal and ethmophract, slightly sunken, located centrally or slightly moved posteriorly, roughly circular or weakly elongated; madreporite large and at least twice as large as next largest genital plate 4, usually in contact with ocular plates I, II, III, IV, and separated only from ocular plates V by genital plate 4 and ocular plate I (Text-fig. 56a-b); in one specimen where madreporite is small, hydropores expand on genital plate 1 (Text-fig. 56d); in another specimen madreporite and genital plate 1 form one large

Statistic	L [mm]	W [mm]	H [mm]	WT [mm]	AA [°]	a [mm]	b [mm]	W/L *100	H/L *100	H/W *100	WT/W *100	a/b *100
Minimum value	44.1	41.6	21.4	32.1	92.5	21.1	23.0	94.30	37.20	37.70	70.80	91.40
Maximum value	84.9	85.4	36.4	68.4	112.0	47.4	40.7	107.80	62.20	59.60	85.90	126.40
Mean value	65.04	65.64	28.85	51.42	103.30	32.90	32.15	100.93	44.75	44.36	78.39	102.24
Median	67.25	67.80	29.70	52.45	103.50	33.65	32.65	100.58	43.51	43.22	78.19	100.98
Standard Deviation	9.738	9.908	3.818	7.861	4.763	5.479	4.567	3.274	5.078	4.910	3.554	7.900

Table 24. Simple statistics of biometric data and simple ratios for *Micraster* (*Micraster*) *rogalae* NOWAK, 1909, from Mangyshlak; number of specimens N=38

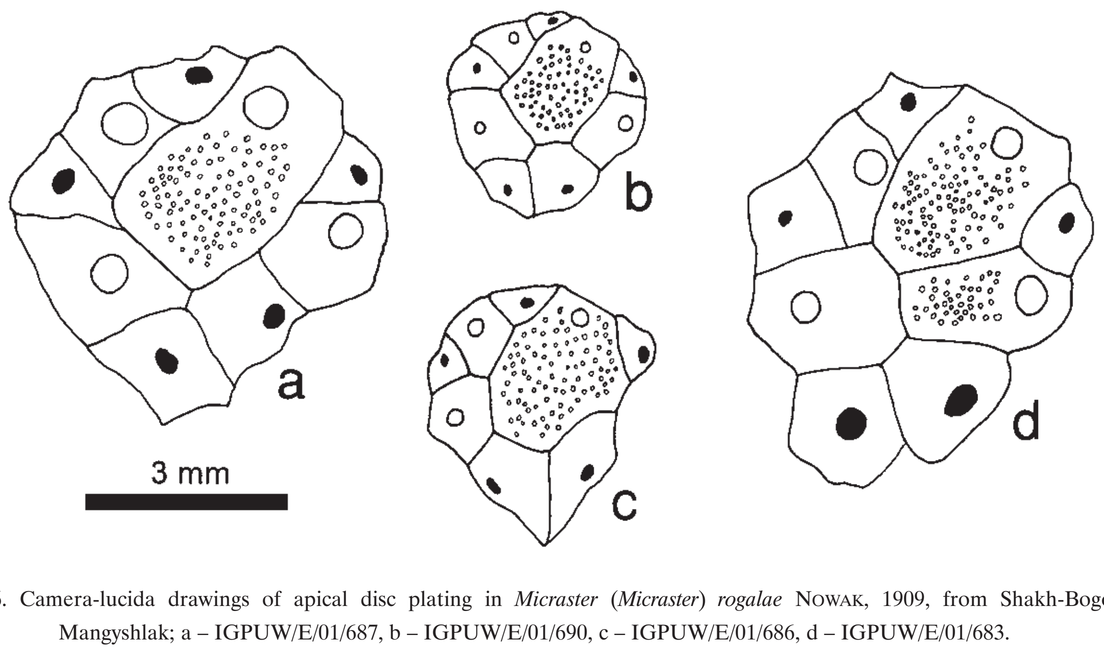

Fig. 56. Camera-lucida drawings of apical disc plating in *Micraster* (*Micraster*) *rogalae* NOWAK, 1909, from Shakh-Bogota, Mangyshlak; a – IGPUW/E/01/687, b – IGPUW/E/01/690, c – IGPUW/E/01/686, d – IGPUW/E/01/683.

plate covered by hydropores (Text-fig. 56c); gonopores small and not exceeding 0.5 mm; hydropores much finer.

Ambulacral zone. Ambulacra heteromorphic, petals quite long, clearly sunken. Posterior petals about 66% – 78% of anterior paired ones.; transverse section by petals V-shape letter; interporiferous area "subdivided" or "divided"; pair of pores in poriferous band different, perradial pores oval in outline and smaller than adradial ones; adradial pores oval or tear–drop-shaped; interporiferous ridge developed as granules; ambulacral furrow moderately deep in "subdivided" type and quite deep and clear in "divided" type; zone between poriferous band richly granulated with small tubercles. Unpaired ambulacrum III clearly different from paired ambulacra; poriferous band consists of circular pores in one pair; whole field III covered by granules and fine tubercles; a clear suture occurs between two rows of plates.

Interambulacral zone. Interambulacra uniformly covered by fine tubercles.

Plastron and labrum. Plastron euamphisternal, with large sternal plates; labrum wide, slightly tapering to anterior edge, and densely covered by tubercles.

Periplastronal zone. Periplastronal area "mamillate", rich in large mamillae with rare tubercles.

Peristome. Peristome oval in outline, and almost completely covered by labrum, situated relatively far from anterior border.

Periproct. Periproct circular or slightly oval, and high on anal field.

Subanal fasciole. Subanal fasciole very well developed, broad and forms large closed ring of dense very fine tubercles for clavulae.

Tuberculation. Tuberculation of whole test variable; on aboral side tubercles fine and uniformly scattered; adoral tubercles larger and densely packed, particularly on plastron.

Simple statistical analysis

The standard deviations of measured characters of L (length) and W (width) are quite large (Table 24). However, the standard deviation W/L*100 ratio is small. The correlation matrix (Table 25) indicates a high correlation of almost all parameters. Of interest is a high correlation of AA (anal angle) with L, W, WT (width of the test or mould measured at one third from posterior edge), parameter a (distance from central point of apical disc to anterior edge) and parameter b (distance from central point of apical disc to posterior edge). In other species of the genus *Micraster* the anal angle is independent of other parameters. In *Micraster* (*M*.) *rogalae* the anal angle increases along with growth of the test (the correlation coefficient between L and AA, and between W and AA being 0.7668 and 0.7355, respectively).

The frequency distribution of particular simple ratios (Text-fig. 57), examined with Kolmogorov-Smirnov test of goodness of fit at the 95% confidence level, shows their distribution to be close to normal, additionally suggesting the homogeneity of samples.

Characters and simple ratios	L	W	H	WT	AA	a	b	W/L *100	H/L *100	H/W *100	WT/W *100	a/b *100
L	1	**0.9804**	**0.7315**	**0.9489**	**0.7668**	**0.9745**	**0.9631**	-0.0076	**-0.5230**	**-0.5417**	-0.0697	0.3432
W		1	**0.7497**	**0.9538**	**0.7355**	**0.9578**	**0.9412**	0.1878	-0.4774	**-0.5522**	-0.1187	0.3469
H			1	**0.6521**	0.4640	**0.7393**	**0.6728**	0.1578	0.1895	0.1294	-0.2934	0.3680
WT				1	**0.7643**	**0.9326**	**0.9045**	0.1144	**-0.5469**	**-0.6006**	0.1825	0.3623
AA					1	**0.7782**	**0.7014**	-0.0723	**-0.5087**	**-0.5087**	0.1366	0.4105
a						1	**0.8780**	-0.0011	-0.4729	-0.4931	-0.0476	**0.5435**
b							1	-0.0150	**-0.5477**	**-0.5634**	-0.0915	0.0798
W/L*100								1	0.1848	-0.1062	-0.2449	0.0284
H/L*100									1	**0.9570**	-0.2464	-0.0253
H/W*100										1	-0.1756	-0.0412
WT/W*100											1	0.0791
a/b*100												1

Table 25. Matrix correlation of biometric data and simple ratios for *Micraster* (*Micraster*) *rogalae* NOWAK, 1909, from Mangyshlak; marked correlations are significant at $p<0.05$; number of specimens N=38

REMARKS: *Micraster* (*M.*) *rogalae* was erected by NOWAK (1909) on the basis of a single specimen from the Upper Cretaceous of Halych (Halicz in Polish), western Ukraine. The same lithological unit with holotype of *M.* (*M.*) *rogalae* provided also *Inoceramus involutus* SOWERBY (see NOWAK 1909, pl. 46, figs 4, 5), the inoceramid which first appears in the middle Coniacian but ranges higher into the upper Coniacian (TRÖGER 1974, 1989; WALASZCZYK & WOOD 1999, WALASZCZYK & COBBAN 2006). In later studies of the Ukrainian succession (PASTERNAK & *al*. 1968, HYNDA & MĄCZYŃSKA 1979), it was stated that the holotype most probably came from the Upper Coniacian (= Middle and Upper as currently understood), and not from the Santonian, as STOKES (1975) said.

STOKES (1975) included *Micraster* (*Gibbaster*) *belgicus* from the Santonian of Frameries, Belgium, into the synonymy of *M.* (*M.*) *rogalae*. LAMBERT (1911) and SMISER (1935), and later HYNDA & MĄCZYŃSKA (1979), regarded *M. belgicus* to belong to *Micraster* (*Gibbaster*). According to LAMBERT (1911), *M.* (*G.*) *belgicus* differed from *M.* (*M.*) *rogalae* in having a shallower anterior groove. Thanks to Prof. J. GEYS (Department of Biology, Arctic Ecology & Paleobiology, University of Antwerpen), I could examine two specimens, one of them the holotype of *M.* (*G.*) *belgicus*, housed at the Institut Royal des Sciences Naturelles de Belgique at Brussels, Belgium. In *M.* (*M.*) *rogalae* from Mangyshlak, however, the depth of the anterior groove increases with test size. The holotype of *M.* (*M.*) *rogalae* is the

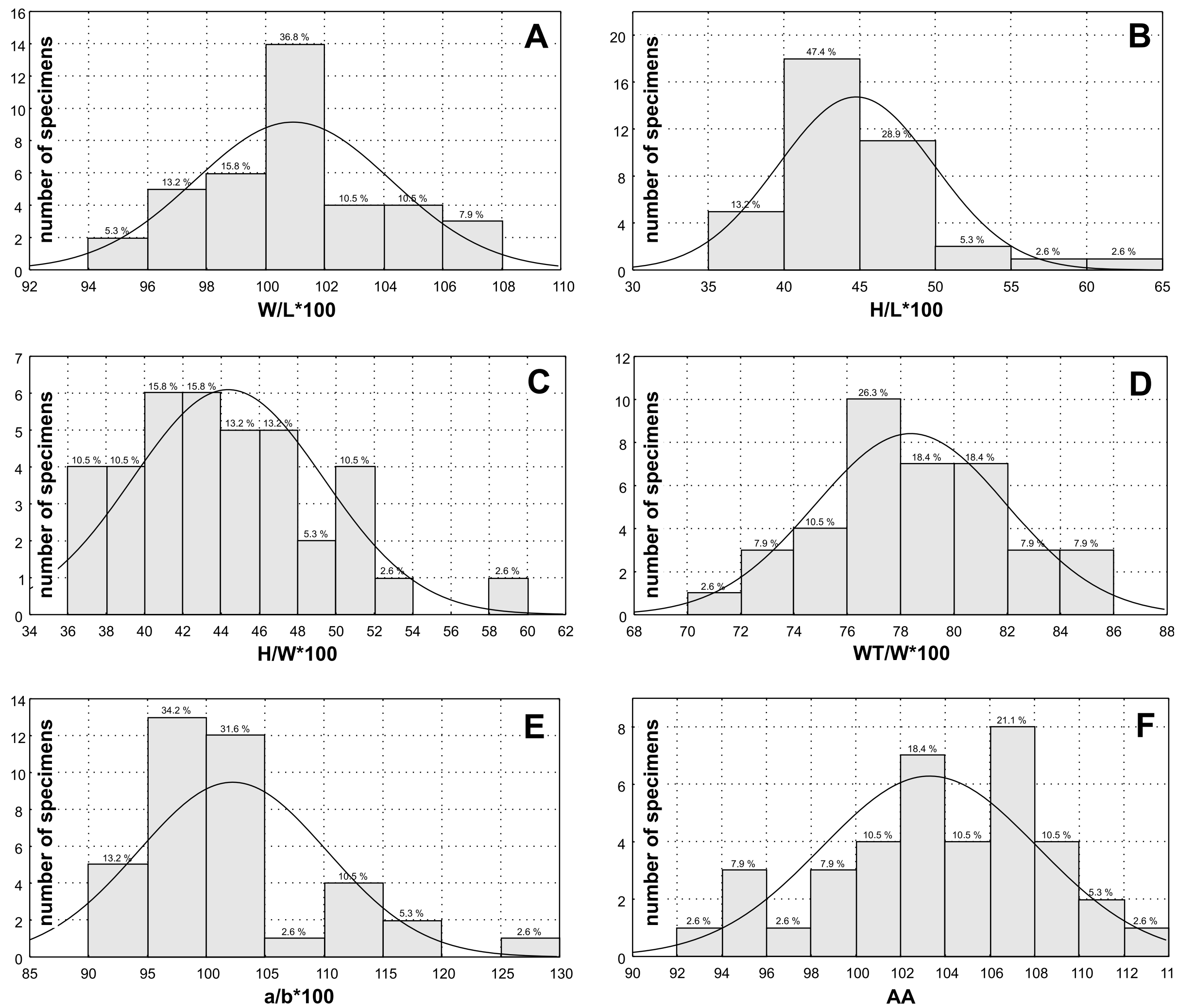

Fig. 57. Histograms of distribution of the simple ratios and values of anal angle in *Micraster* (*Micraster*) *rogalae* NOWAK, 1909, of Mangyshlak (sample N = 38); A – W/L*100, B – H/L*100, C – H/W*100, D – WT/W*100, E –a/b*100, F – anal angle

largest micrasterid known: length 88 mm, width 90 mm, height 35 mm (see also HYNDA & MĄCZYŃSKA 1979). The holotype of *M.* (*G.*) *belgicus*, which is of smaller size than that of *M.* (*M.*) *rogalae*, fits well with the range of variations of the latter.

M. (*M.*) *rogalae* differs from *M.* (*M.*) *praerogalae* sp. nov. in a more circular test shape (W/L*100 ratio attaining higher values in the former species); in being relatively lower. As a rule, in *M.* (*M.*) *rogalae*, the apical disc is situated centrally or near centrally, while in *M.* (*M.*) *prerogalae* sp. nov., it is situated eccentrically (moved anteriorly). The type of interporiferous area in *M.* (*M.*) *rogalae* (as a rule, "divided") and periplastronal area ("mamillate") are more advanced than in *M.* (*M.*) *praerogalae* sp. nov. which has interporiferous area "subdivided" and a "granular-mamillate" periplastronal area.

OCCURRENCE: Upper Coniacian at Shakh-Bogota, Sulu-Kapy, Shyrkala-Airakty, Kush, Koksyrtau-Aksyrtau, Besakty and Coniacian/Santonian boundary at Besakty. This species is known from the North European Province: Middle or Upper Coniacian of Halych, western Ukraine; ?Middle Santonian of Ulina Wielka near Wolbrom, southern Poland; upper Lower Santonian to lower Upper Santonian of Lägerdorf, northern Germany; Santonian of the Frameries area, Belgium.

Subgenus *Micraster* (*Gibbaster*) GAUTHIER, 1887

TYPE SPECIES: *Micraster fastigatus* GAUTHIER, 1887, by original designation

REMARKS: The forms belonging to subgenus *M.* (*Gibbaster*) are high, subconical or conical in shape, with deep anterior groove, periproct relatively to the height of the test lies much lower (well below mid-height in posterior view) than in the subgenus *M.* (*Micraster*), the frontal ambulacrum is similar in structure to paired ones. Subanal fasciole is missing or in very rare specimens are visible very fine concentrations of very small miliaries on the adoral side, resembling an initial (incipient) subanal fasciole corresponding to protofasciole sensu NÉRAUDEAU & *al.* (1998).

OCCURRENCE: Subgenus *M.* (*Gibbaster*) is known from the Upper Cretaceous (Turonian through Maastrichtian) of Europe, northern Africa, Madagascar, central Asia (Georgia, Mangyshlak, Kopet-Dag), and Mexico.

Micraster (*Gibbaster*) *brevis* DESOR, in AGASSIZ & DESOR, 1847
(Text-fig. 58; Pl. 30, Fig. 4; Pl. 31, Figs 1-3)

1847. *Micraster brevis* DESOR; L. AGASSIZ & E. DESOR, p. 129.
1869. *Epiaster brevis*; C. SCHLÜTER, p. 240, pl. 2, fig. 2.
1887. *Epiaster renati* GAUTHIER; V. GAUTHIER, p. 239, pl. 5, figs 3-5.
1970c. *Micraster* (*Gibbaster*) *brevis* DESOR; G. ERNST, pl. 18, figs 1, 2.
1972. *Micraster* (*Gibbaster*) aff. *brevis*; G. ERNST, pl. 2, fig. 6.
1975. *Micraster brevis* DESOR; R.B. STOKES, p. 62, text-fig. 29b.

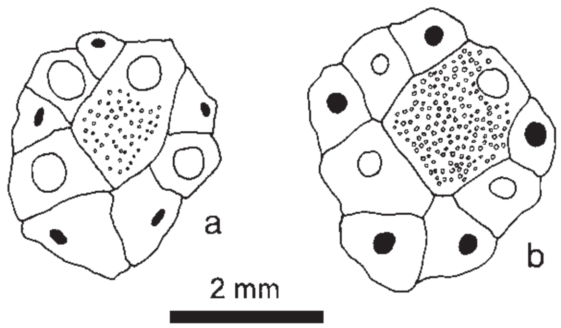

Fig. 58. Camera-lucida drawings of apical disc plating in *Micraster* (*Gibbaster*) *brevis* DESOR, in AGASSIZ & DESOR, 1847; a – IGPUW/E/01/720, Folwark, Opole; b – MZ VIII Ee-645, Westphalia, Germany

Number of specimen	L [mm]	W [mm]	H [mm]	AA [°]	W/L*100	H/L*100	H/W*100
IGPUW/E/01/720	?44.4	?39.6	?38.1	-	?89.19	?85.81	?96.21
IGPUW/E/01/719	43.3	42.8	32.4	97.0	98.84	74.83	75.70
MZ VIII Ee – 645 Westphalia	55.7	56.6	40.2	96.0	101.61	72.17	71.02
IGPUW/E/01/724	52.1	52.0	39.4	98.0	99.81	75.62	75.77

Table 26. Biometric data and simple ratios for *Micraster* (*Gibbaster*) *brevis* DESOR, in AGASSIZ & DESOR, 1847, from Folwark Quarry, Westphalia and Kostomloty

TYPE: Holotype, by monotypy, is mould no. R 69, in the collection of Agassiz and Desor, Craie à *Hippurites* of Corbières, France, Museum in Neuchâtel.

MATERIAL: Two moderately well-preserved (IGPUW/E/01/719,720) and numerous poorly preserved, deformed specimens from *Cremnoceramus walt. hannovrensis* + *C. crassus inconstans* + *C. crassus crassus* / *deformis deformis* Zone at Folwark Quarry. One well-preserved specimen, MZ VIII Ee - 645 from Westfalen, Germany. Another well-preserved (IGPUW/E/01/724) and two deformed specimens (IGPUW/E/01/725, 726) from the *Cremnoceramus deformis deformis* Zone at Kostomloty, Czech Republic.

DESCRIPTIONS: **Shape and size**. Test medium in size (Table 26) and of moderate thickness, circular-cordiform in outline. Elongate profile high, from apical disc towards anterior edge arch weakly convex and abrupt, and from apical disc towards posterior arch more gentle and less abrupt. Transverse profile high and cone-shaped, with slightly convex sides and broad base. Anterior groove moderate broad and shallow. Anal angle obtuse and not exceeding 100°.
Apical disc. Apical disc tetrabasal and ethmophract, slightly sunken, located centrally, and roughly circular; madreporite 1.5 times larger than next largest genital plate 4 (Text-fig. 58), at contact with ocular plates I, II, III, IV, and separated only from ocular plate V (Text-fig. 58a) or in contact with ocular plates I, II, III, and separated from ocular plates IV and V (Text-fig. 58b).
Ambulacral zone. Ambulacra homeomorphic; petals weakly sunken, quite long. Posterior petals about 64% – 76% of anterior paired ones. Transverse section of petals V-shaped letter; interporiferous area weakly "inflated"; pair of pores in poriferous band different, perradial pores circular or slightly oval in outline and smaller than adradial pores, adradial pores oval or teardrop-shaped; interporiferous ridge poorly developed; zone between poriferous band very finely granulated. Unpaired ambulacrum III consists of petal shorter than paired petals; poriferous band consists of circular or oval pores in one pair; zone between poriferous band also very finely granulated.
Interambulacral zone. Interambulacra densely covered by fine tubercles.
Plastron and labrum. Plastron semiamphisternal type 2 with slight asymmetry of large sternal plates; labral plate narrow, two longer edges of labrum parallel to each other; labrum covered by tubercles in two asymmetric rows.
Periplastronal zone. Periplastronal area "granular" passing into "coarsely sandy", with numerous small tubercles.
Peristome. Peristome oval in outline, partly covered by labrum, and situated far from anterior border.
Periproct. Periproct circular or slightly oval, low on anal field, at c.a. 1/3 of test height.
Subanal fasciole. Subanal fasciole absent, however, in some specimens possess isolated area covered by densely packed, very fine miliaries, resembling an initial (incipient) subanal fasciole correspod to protofasciole sensu NÉRAUDEAU & *al*. (1998).
Tuberculation. Tuberculation of whole test variable; on aboral side tubercles fine and quite dense; tubercles increase in size towards base of test; adoral tubercles larger and densely packed, being most numerous on plastron.

REMARKS: The subanal fasciole is absent the specimens included in *M.* (*Gibbaster*) *brevis* DESOR. However, in the specimens from Folwark Quarry of the Opole Cretaceous and from Kostomloty (Czech Republic) on the adoral side observed small area covered by concentrated very fine miliaries correspond to protofasciole sensu NÉRAUDEAU & *al*. (1998). They do not form a regular subanal fasciole like in specimens belonging to the subgenus *M.* (*Micraster*), where the subanal fasciole is clearly evolved (at least) on the adoral side and correspond to mainly parafasciole sensu NÉRAUDEAU & *al*. (1998).

OCCURRENCE: Lower Coniacian (*Cremnoceramus walt. hannovrensis* + *C. crassus inconstans* + *C. crassus crassus* / *deformis deformis* Zone) at Folwark Quarry. Western part of North European Province: Coniacian of France, Lower Saxony and Westphalia (Germany), and Czech Republic.

STOKES (1975) showed *M. brevis* as a species of his Pyrenean Province. ERNST (1970c, 1972) noted that species from Germany. The author agrees with ERNST (1970c, 1972) with the concept of *M.* (*Gibbaster*) *brevis* and the present paper shows that geographic distribution that species is wider in the North European Province contrary to the opinion of STOKES (1975).

Suborder Hemiasterina FISCHER in MOORE, 1966
Family Hemiasteridae CLARK, 1917

Genus *Hemiaster* AGASSIZ, in AGASSIZ & DESOR, 1847

TYPE SPECIES: *Spatangus bufo* BRONGNIART, 1822, by subsequent designation of SAVIN (1903).

OCCURRENCE: Aptian to Recent, cosmopolitan.

Hemiaster simakovi SCHMIDT, in SCHMIDT & SIMAKOV, 1953
(Pl. 6, Figs 4-7)

1953. *Hemiaster simakovi* O.I. SCHMIDT in O.I. SCHMIDT & S.N. SIMAKOV, p. 63, text-fig. 24; pl. 4, figs 2-6.
1962. *Hemiaster simakovi* SCHMIDT; O.I. SCHMIDT, p. 290, pl. 4, figs 1-5.

TYPE: Holotype is the specimen illustrated by SCHMIDT (in SCHMIDT & SIMAKOV 1953, pl. 4, figs 2-6) from the Turonian of the south-western part of the Gissar Mountains, Akrabat of Tadzhik (formerly Soviet Union).

MATERIAL: Four poorly preserved phosphatic internal moulds (IGPUW/E/01/727-730) from Bed 42 (unit B) at Besakty; two poorly preserved phosphatic moulds (IGPUW/E/01/731-732) from Bed 37A at Koksyrtau/Aksyrtau.

DESCRIPTION: **Shape and size**. Tests small in size (Table 27), squat and oval or weakly oval in outline, with length slightly exceeding width; ambitus situated high in relation to height. Lateral profile convex, from aboral side posterior arch situated higher than anterior arch and consisting of carina. Transverse section oval. Anterior groove very shallow. Anal angle < 90°.

Apical disc. Apical disc eccentric, and moved posteriorly.
Ambulacral zone. Posterior paired petals very short, about 40-45% of anterior paired petals; petal on unpaired ambulacrum III longest, about 120-130% of anterior petal.
Plastron and labrum. Plastron weakly visible, in two specimens semiamphisternal type 2; labrum narrow, triangular in shape, and covered by rare tubercles.
Periplastronal zone. Periplastronal area probably "sandy".
Peristome. Peristome oval in outline, situated relatively close to anterior border, opened.
Periproct. Periproct circular or weakly oval in outline, high on anal field.
Tuberculation. Tuberculation visible only in two specimens with preserved remains of test on adoral side; rather rare tubercles on plastron.

OCCURRENCE: Upper Turonian at Koksyrtau/Aksyrtau and condensed upper Turonian-Coniacian at Besakty. Known also from the upper Turonian of Gissar Mountains and the upper Turonian to lower Coniacian of the Tadzhik Depression.

REMARKS ON PALAEOECOLOGY AND PALAEOGEOGRAPHY

Controls on distribution of Recent echinoids

Of about 800 living species of echinoid, most prefer littoral and shallow shelf zones. More than 150 species are recorded between high and low tides (littoral zone), and in excess 360 species occur in the highest 100 m below the littoral zone (DURHAM 1966). In deeper settings, the number of species gradually decreases, and from below 4,000 m, only 10 to 12 species are known, and below 6,000 m only 2 or 3 species were found (ERNST & SEIBERTZ 1977). Most echinoid species live between

Number of the specimen	L [mm]	W [mm]	H [mm]	W/L*100	H/L*100	H/W*100
IGPUW/E/01/727	19.8	18.4	14.3	92.93	72.22	77.72
IGPUW/E/01/728	16.5	15.9	12.1	96.36	73.33	76.10
IGPUW/E/01/729	14.6	13.9	9.5	95.20	65.07	68.34
IGPUW/E/01/730	13.1	12.6	9.6	96.18	73.28	76.19
IGPUW/E/01/731	18.5	17.4	13.3	94.05	71.89	76.44
IGPUW/E/01/732	21.8	21.2	-	97.25	-	-

Table 27. Biometric data and simple ratios for *Hemiaster simakovi* SCHMIDT, in SCHMIDT & SIMAKOV, 1953, Mangyshlak

rather narrow depth limits (e.g. SMITH & *al*. 2006). Only few taxa tolerate wider depth limits, such as *Echinus elegans* DÜBEN & KOREN, which lives between 50 and 1,710 m (MORTENSEN 1943). Deep-sea basins can be traversed by most of the echinoid species only during the larval stage.

Another factor controlling echinoid distribution is temperature. Many extant echinoids prefer warm waters and are numerous only near the equator, e.g., *Echinometra mathaei* (DE BLAINVILLE). There are also echinoids linked only to the colder waters, e.g., *Pourtalesia jeffreysi* WYVILLE THOMSON. However, there also are rare echinoids which live in the Atlantic from northern Europe to central or even southern Africa, e.g. *Brissopsis lyrifera* (FORBES) and *Spatangus purpureus* MÜLLER. The wide geographic range of these species is linked to the available substrate rather than to temperature (ERNST & SEIBERTZ 1977). But most echinoids are restricted to a low range of temperature, which is an effective barrier for the spread of echinoids. Recent Arctic and Antarctic echinoid assemblages are completely distinct faunas (FECHTER 1970).

The next important factor is substrate. Most regular echinoids prefer nearshore, hard rocky to coarsely clastic substrates covered by algae, an important food item. Irregular echinoids are more abundant in quiet-water environments such as the more seaward and deeper parts of seas: in finer sands, marly or limy mud habitats. They burrow into the sediment to feed. Echinoids tend to avoid clay or marly clay sea floors, because, the fine suspensed clay clogs pores of their water vascular system (ERNST & SEIBERTZ 1977).

Recent studies of echinoids in the Mediterranean (ERNST & *al*. 1973) have yielded clear examples of the fact that echinoid biocoenoses depend on substrate type, water movement, exposure, bathymetry and algal crusts. ERNST & *al*. (1973) described four echinoid zones in the upper sublittoral of the Mediterranean:

(i) *Arbacia* + *Paracentrotus* Zone, on rocky bottoms, depth range 0-3 m;

(ii) *Paracentrotus* Zone, on boulder bottoms, depth range 3-8 m;

(iii) *Sphaerechinus* Zone, on coarse and very coarse gravelly sediments, depth range 8-12 m;

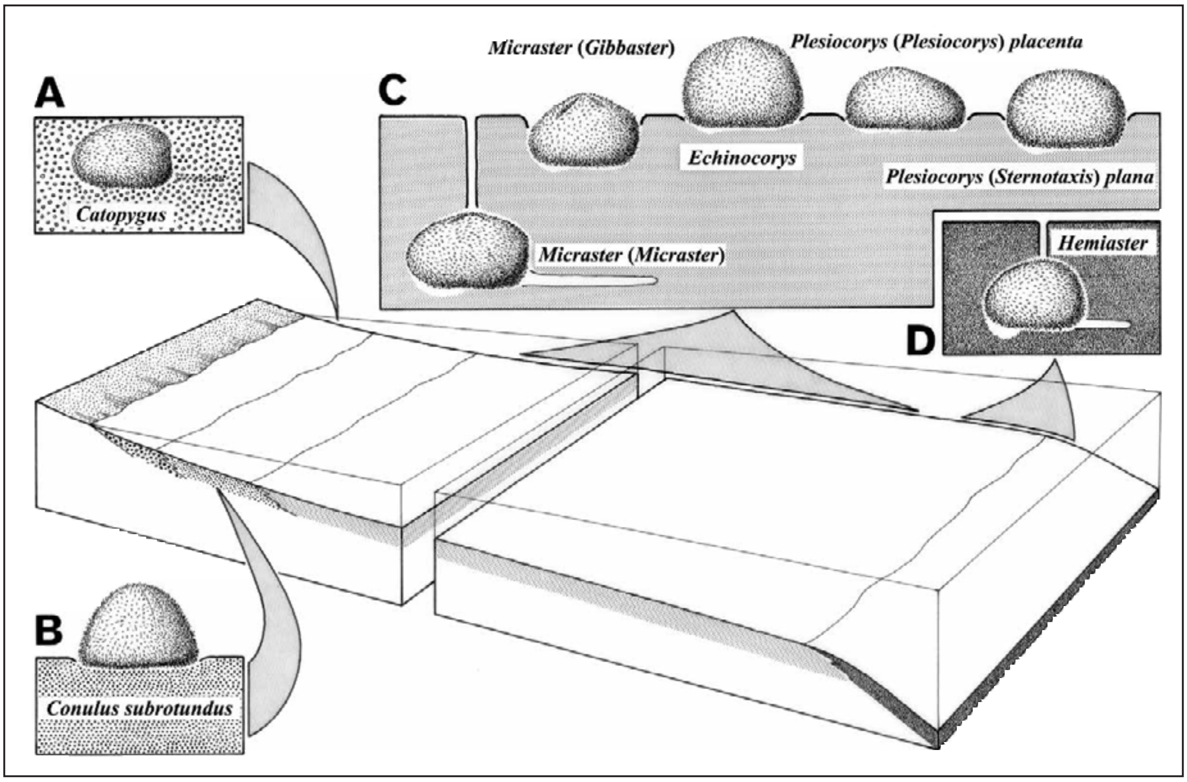

Fig. 59. Palaeoenvironments of irregular echinoids during the Turonian and Coniacian, detailed description in text; A – coarse- and very coarse-grained sediments; bioclastic, gravel and coarse sandy facies; B – sandy, calcarenite facies; C – fine-grained, chalky and marly chalky facies; D – deeper shelf and higher part of continental slope facies with increasing component of mud and clay

(iv) *Echinocardium* + *Spatangus* Zone, on calcarenic sediments, depth range 12-20 m.

The type of sea floor and degree of firmness of bottom sediments, currents, and source for feeding clearly influence colonisation by the different echinoid assemblages in a variety of condition (ERNST & *al*. 1973). Consequently, Recent echinoids show a large degree of provincialism (MORTENSEN 1951).

Palaeoecological interpretation of Cretaceous forms studied

Seven (sub) genera of irregular echinoid from the Turonian and Coniacian of Mangyshlak are described herein, *Conulus*, *Catopygus*, *Plesiocorys* (*Sternotaxis*), *Plesiocorys* (*Plesiocorys*), *Echinocorys*, *Micraster* (*Micraster*), and *Hemiaster*; only four are known from coeval beds in the Opole area: *Plesiocorys* (*Sternotaxis*), *Echinocorys*, *Micraster* (*Micraster*), and *Micraster* (*Gibbaster*).

Genus *Conulus*

The features of the *Conulus* (*C.*) *subrotundus* MANTELL include oval, flattened and conical morphotypes of the genus *Conulus*. HAWKINS (1919) regarded that the genus *Conulus* lived generally deeper than *Pyrina* and *Echinoneus*. However, *Conulus* is widely known in calcarenitic rocks of Turonian age (POPIEL-BARCZYK 1958, ERNST 1967, ERNST & *al*. 1979, KUDREWICZ & OLSZEWSKA-NEJBERT 1997, OLSZEWSKA-NEJBERT 2005). SMITH (1988), suggested that *Conulus* changed its mode of life; earlier forms, such as moderately depressed *Conulus castanea* (BRONGNIART), were not really adapted for burrowing and may have emerged periodically to forage, but the characters of *Conulus* (*C.*) *subrotundus* (being much higher, with more rounded profile with a flat base, with fairly scattered adapical tubercles, and rarer miliary tubercles) indicate its epifaunal mode of life (Text-fig. 59B), living on unconsolidated sediment feeding on detached algal debris and small benthic organisms on the see floor (SMITH & *al*. 2006)

Genus *Catopygus*

SMITH (1988) and SMITH & *al.* (2006) analyzed characters of *Catopygus* from the Cenomanian of England and suggested that it was an infaunal, unselected bulk sediment swallower in shallow-water clastic habitats.

Summing up, it is possible to assume, that *Catopygus columbarius* from the Turonian of Mangyshlak, could have lived infaunally, shallowly buried in a relatively coarse, sandy substrate (Text-fig. 59A).

Holasteroida – genera *Plesiocorys* and *Echinocorys*

Genus *Plesiocorys*

The genus *Plesiocorys* belongs to subepibenthonic deposit feeders (see *Sternotaxis* in ERNST & SEIBERTZ 1977), feeding on accumulations of organic debris at the sediment-water interface (SMITH & *al*. 2006). The study material from Mangyshlak and Opole Cretaceous comprises two species: *Plesiocorys* (*Sternotaxis*) *plana* and *P.* (*Plesiocorys*) *placenta*. The frontal ambulacrum of *P.* (*S.*) *plana* is clearer and more sunken than of *P.* (*P.*) *placenta*, what could suggest its better usage as a passageway for food to the mouth (unfortunately in none of the specimens of *P.* (*S.*) *plana* the test on the sunken frontal ambulacrum is preserved, which is necessary to describe the function of tube feet). The periproct of *P.* (*S.*) *plana* is situated marginally, relatively high to the height of the test (Pl. 7, Figs 1c, 2c, 3c, 4c), whereas in *P.* (*P.*) *placenta* it is situated inframarginally (Pl. 8, Figs 1c, 2c). Some of the characters of *P.* (*P.*) *placenta*, such as very shallow frontal ambulacrum, inframarginal periproct, the sharp edge between the aboral and adoral surface, the large and flattened base, indicate difficulties to adaptation for deep burrowing. The morphological characters listed of the tests show that *P.* (*S.*) *plana* could rather be a semi-infaunal form (or a shallow burrower, lacking respiratory shaft), whereas *P.* (*P.*) *placenta* represented an epifaunal form (Text-fig. 59C).

Genus *Echinocorys*

The genus *Echinocorys*, similar to *Micraster*, belongs to deposit feeders although it, similar to *Plesiocorys*, is epibenthonic (ERNST & SEIBERTZ 1977; JAGT & MICHELS 1994), living on soft, chalky substrate (Text-fig. 59C). Several characters, such as shape and tuberculation of the test, large wide flattened base, the lack of the anterior groove on the ambulacral III, and of the fascioles, and the character of ambulacral pores (indicating respiratory function) on the adoral side (SMITH 1980a, b, 1988; JAGT & MICHELS 1994), confirm its epibenthic mode of life. This interpretation is not commonly accepted, and KONGIEL (1949), e.g., suggested a burrowing mode of life of the genus, although based on weakly evolved tubercles on the aboral side of the test, rare asymmetric tubercles, and the lack of fascioles in *Echinocorys*, KONGIEL (1949) suggested it to be an ineffective, shallow burrower.

The shape of the test in the genus *Echinocorys* is particularly sensitive for lithofacies. In the material from Germany, from pure limy lithotopes, the genus is larger and higher on average than its representatives from marly limestones, or silty to arenitic limy marls (ERNST 1970b). Test height decreases with relative increase of clay or sand content in the substrate. *Echinocorys* seems to have been much more sensitive to facies changes than infaunal *Micraster* (compare ERNST & SEIBERTZ 1977).

Genus *Micraster*

Micraster (*Micraster*) was a deposit feeder. Test morphological features show an adaptation to a very fine-grained sediment (NICHOLS 1959a; SMITH 1984; SMITH & *al*. 2006) and an infaunal mode of life (Text-fig. 59C).

Micraster (*Gibbaster*) is more pyramidal in shape with subanal protofasciole, and the periproct is situated relatively low. These characters indicate a seminfaunal mode of life (Text-fig. 59C) similar to Recent *Spatangus raschi* LOVÉN (NICHOLS 1959b).

Genus *Hemiaster*

A single *Hemiaster* species, *Hemiaster simakovi* SCHMIDT, was found in a condensed succession of Bed 42 at Besakty, and in reduced upper Turonian at Koksyratu-Aksyrtau, where it co-occurs with *Plesiocorys* (*Sternotaxis*) and *Micraster*. The species *Hemiaster simakovi* SCHMIDT could belong to the mud-dwellers, living at same depths as or slightly deeper than genus *Micraster*. It is possibly that *Hemiaster simakovi* SCHMIDT lived in the upper part of bathyal zone (Text-fig. 59D). During the Cretaceous most of representatives of the genus *Hemiaster* lived near the Equator (SMITH 1984) and were connected with Tethys Sea (NÉRAUDEAU 1993, 1994). In the Turonian they were scarce in the northern temperate and boreal province (NÉRAUDEAU 1994). The genus *Hemiaster* seems to have retained its mode of life throughout its whole long timespan (Early Cretaceous to Recent) (SMITH 1988; JAGT & MICHELS 1994; NÉRAUDEAU 1993, 1994).

PALAEOBIOGEOGRAPHY, BIOSTRATIGRAPHY AND BIOEVENTS

During the Late Cretaceous, both Mangyshlak and the Opole area were part of the North European Province (*sensu* KAUFFMAN 1973) (Text-figs 1 and 60). Facies across an extensive European Cretaceous sea, its latitudinal extension with stable and equable temperatures favoured the wide geographical distribution of many echinoid species. STOKES (1975), on the basis of *Micraster*, distinguished some smaller palaeogeographical units in western and central Europe but these have not gained wider acceptance (ERNST & SEIBERTZ 1977). Simultaneously, the widening Atlantic Ocean during the Turonian and particularly Coniacian, led to an increased differentiation between European and North American faunas (ERNST & SEIBERTZ 1977).

Irregular echinoids of Turonian and Coniacian age from the North European Province are mainly Holasteroida and Spatangoida, *Plesiocorys* (*Sternotaxis*), *Echinocorys*, and *Micraster* (see KÜCHLER & ERNST 1989). In Mangyshlak (Text-fig. 61), *Echinocorys* represents 42% and *Micraster* ca. 51%. Minor components are *Plesiocorys* (ca. 5%) and *Hemiaster* (1%). Also rare are representatives of the genera *Conulus* and *Catopygus* (ca. 1%). Less differentiated is the assemblage from the Opole area (Text-fig. 61). The commonest genus, *Micraster*, represents ca. 71%.The two other genera, *Plesiocorys* (*Sternotaxis*) and *Echinocorys*, represent ca. 23% and 6% of the fauna, respectively.

The most characteristic elements of these faunas are representatives of the genus *Micraster*, which correspond well to coeval faunas from western Europe. KÜCHLER & ERNST (1989) noted the morphological plasticity of the genus with the development of many local forms, but also underlined the similarity and isochroneity of general phylogenetic trends of this group during the Turonian and Coniacian in western Europe. Evolutionary pathway of plastron, periplastron, and the structure of petals, the displacement of the peristome to the anterior edge, etc., are similar in different places of North European Province (com-

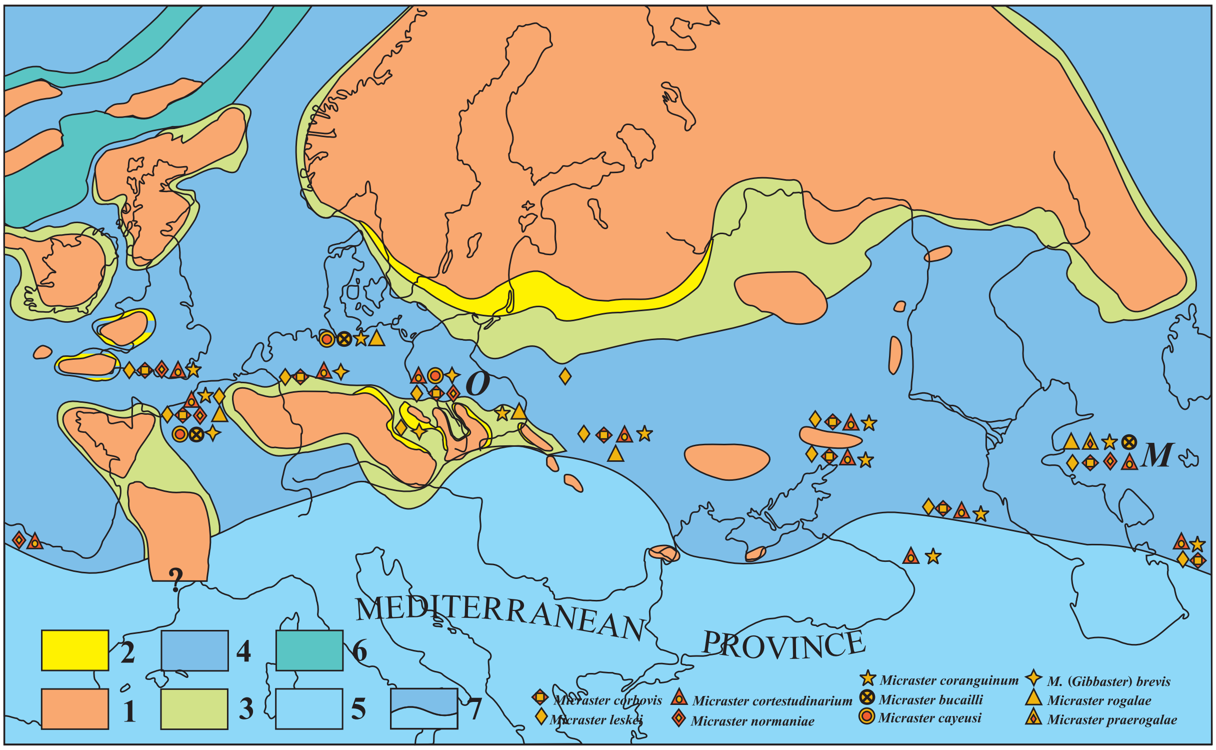

Fig. 60. Turonian-Santonian palaeogeography with simplified distribution of facies in the North European Province (after NAIDIN 1959; KAUFFMAN 1973; ZIEGLER 1990; modified) with distribution of echinoids of the genus *Micraster*; 1 – Land areas; 2 – Deltaic, coastal and shallow-marine clastic facies (sands and conglomerates, sands and shales); 3 – Shallow-marine facies (sands, marls, carbonate marls, marly carbonates, carbonates); 4 – Mainly shallow-carbonate marine facies (marly carbonates, carbonates, chalk, white chalk, carbonate shales); 5 – Approximate area of Mediterranean Province (without indication of facies); 6 – Deeper marine shale facies (the area of rift); 7 – Position of the future Alpine deformation front; M – Mangyshlak, O – Opole

pare ERNST 1970c; FOURAY 1981; DRUMMOND 1985; DRUMMOND & FOURAY 1985). The same evolutionary trends are also found in *Micraster* faunas from Mangyshlak and Opole.

Micraster (*M.*) *leskei*, the oldest element of the main *Micraster* lineage (ERNST 1970c), seems to be

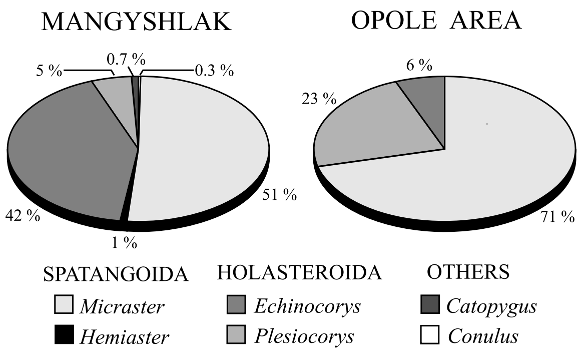

Fig. 61. Percentages (pie diagram) of particular genera of irregular echinoid in the Turonian and Coniacian deposits of Mangyshlak and Opole

limited to the North European Province. It first appears in the Middle Turonian (*Inoceramus lamarcki* Zone) of Germany (ERNST 1967, 1970a, c), while in England, very rare specimens are noted in the *Rhynchonella cuvierii* Zone (ROWE 1899; NICHOLS 1959a). Generally, however, *M.* (*M.*) *leskei* is common in the Upper Turonian, across the North European Province (Text-fig. 60). In the Opole area, *M.* (*M.*) *leskei* first appears near the Middle/Upper Turonian boundary, whereas in Mangyshlak it occurs higher in the Upper Turonian. In Mangyshlak, however, with the exception of the Besakty section, sections are characterized by a stratigraphic gap encompassing the entire Middle Turonian (MARCINOWSKI & *al.* 1996 and Text-fig. 3 herein); *M.* (*M.*) *leskei* from Mangyshlak shows more advanced morphological test characters than representatives from western Europe (ERNST 1970c, 1972; FOURAY 1981) and from Opole.

About 7 to 9 m above the Middle/Upper Turonian boundary there is an acme of *M.* (*M.*)

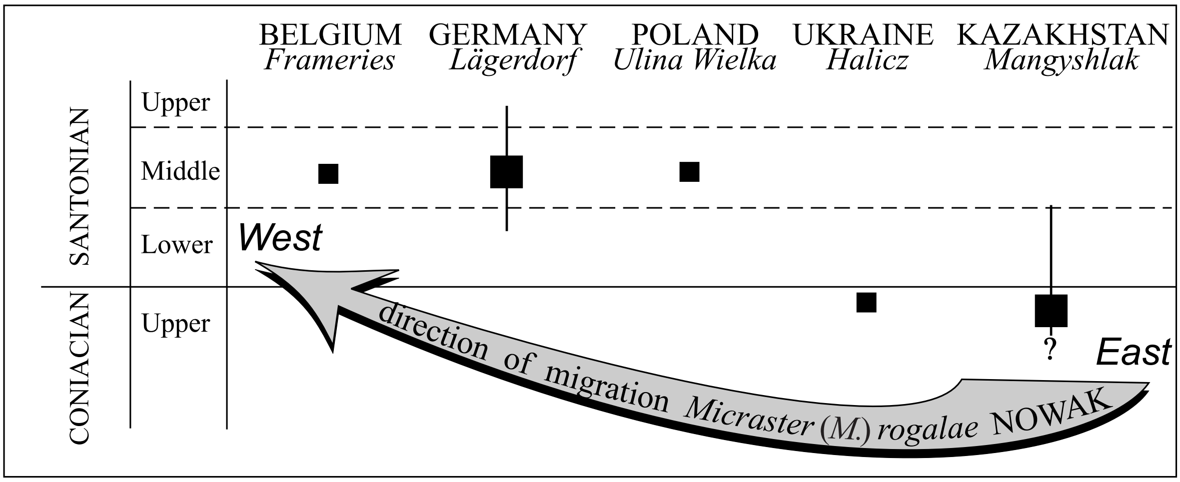

Fig. 62. Stratigraphic and geographic distribution of *Micraster* (*Micraster*) *rogalae* NOWAK, 1909

leskei in the sections exposed at Odra II and Bolko quarries (Text-fig. 6). Here, it is accompanied by rare *Plesiocorys* (*Sternotaxis*) *plana*, and abundant ammonites (WALASZCZYK 1988, 1992). In the *Inoceramus perplexus* (=*I. costellatus* of authors) Zone of the Upper Turonian of northwest Germany, the *Hyphantoceras* Event yields *Micraster* ex gr. *corbovis* FORBES, and the underlying horizon contains *Plesiocorys* (*Sternotaxis*) (ERNST & *al.* 1983; WOOD & *al.* 1984). These levels correspond, most probably, to the two horizons with acme occurrences of *M.* (*M.*) *leskei* and heteromorph ammonites, here described as *M. leskei* bioevents I and II, within the *Inoceramus perplexus* Zone in the Opole area (Text-figs 6, 64; Pls 4 and 5a).

Successive members of the main *Micraster* lineage are more widely distributed. The *praecursor* (*sensu* KÜCHLER & ERNST 1989) – *cortestudinarium* group first appears in the uppermost Turonian and Coniacian of northern Spain (KÜCHLER & ERNST 1989), at the southern margin of the North European Province. Moreover, *M.* (*M.*) *cortestudinarium* and *Micraster* (*M.*) *coranguinum* range outside the North European Province (Text-fig. 60), being known also from the Coniacian of Georgia (MOSKVIN 1959; GONGADZE 1979).

The *M. cortestudinarium* Bioevent within the *Cremnoceramus walt. hannovrensis* + *C. crassus inconstans* + *C. c. crassus*/*d. deformis* Zone at Folwark, probably corresponds to the *cortestudinarium* ecoevent in the Salzgitter-Salder section, Lower Saxony, Germany (WOOD & *al.* 1984).

Micraster (*Gibbaster*) *brevis* occurs in the lower Coniacian of Opole but is not noted from Mangyshlak. The subgenus *M.* (*Gibbaster*) appears confined to the western part of the North European Province and North Africa, at least during the Turonian and Coniacian. An acme of this species is noted as the *M.* (*G.*) *brevis* Bioevent at Folwark section in the Lower Coniacian *Cremnoceramus walt. hannovrensis* + *C. crassus inconstans* + *C.* c. *crassus*/*d. deformis* Zone. This seems to be isochronous with the *Isomicraster* Ecoevent at the Salzgitter-Salder section (WOOD & *al.* 1984).

A very interesting pattern is shown by *Micraster* (*M.*) *rogalae*. This species appears in Mangyshlak in the uppermost Coniacian, with a distinct acme, and ranges up to the Lower Santonian (= *M. rogalae* Bioevent) (MOSKVIN 1959; SCHMIDT & *al.* 1973; SAVCHINSKAYA 1982; MARCINOWSKI & *al.* 1996). Outside Mangyshlak, it is reported from the Upper Coniacian of western Ukraine (NOWAK 1909; PASTERNAK & *al.* 1968) and from the Middle(?) Santonian of southern Poland (SUJKOWSKI 1926; HYNDA & MĄCZYŃSKA 1979). In Poland, *M.* (*M.*) *rogalae* is accompanied by the belemnite, *Goniotheutis westfalica* (SCHLÜTER) (SUJKOWSKI 1926), which indicates the upper lower and Middle Santonian (ERNST 1964; ERNST & SCHULZ 1974). In western Europe, *M.* (*M.*) *rogalae* is noted from the upper Lower Santonian to the lower Upper Santonian of northern Germany, and from the Santonian of Frameries, Belgium (STOKES 1975), with an acme in the Middle Santonian (ERNST 1963; 1966; ERNST & SCHULZ 1974). The species thus reveals a marked diachronism within the boundaries of the North European Province (OLSZEWSKA 1995): it first appeared in the east and spread

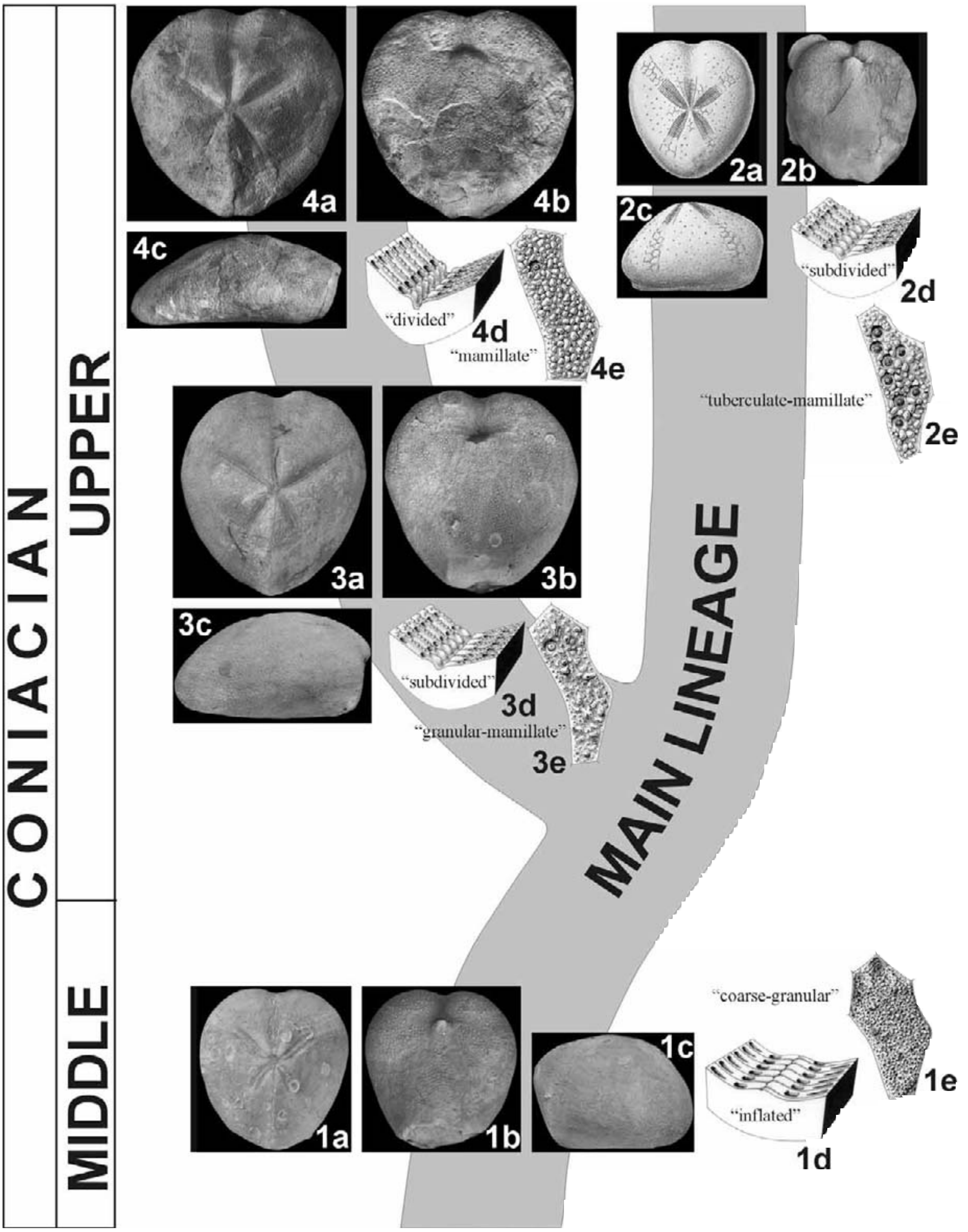

Fig. 63. Evolution of part of main lineage of the genus *Micraster* (*Micraster* (*M.*) *cortestudinarium* to *Micraster* (*M.*) *coranguinum*) and the side branch (*Micraster* (*M.*) *praerogalae* to *Micraster* (*M.*) *rogalae*) in Coniacian deposits of the Mangyshlak (compare Ernst 1972); 1 – *Micraster* (*M.*) *cortestudinarium* (advanced form) from the middle Coniacian of Kush; 2 – *Micraster* (*M.*) *coranguinum* from the upper Coniacian of Shakh-Bogota; 3 – *Micraster* (*M.*) *praerogalae* from the upper Coniacian of Shakh-Bogota; 4 – *Micraster* (*M.*) *rogalae* from the top of the upper Coniacian of Shakh-Bogota; a – aboral view, b – adoral view, c – lateral view, d – type of interporiferous area (after Rowe 1899), e – type of periplastronal area

towards the west (Text-fig. 62). In two places the species occurs abundantly, but horizons of mass occurrence observed in particular regions are apparently not synchronous. In Mangyshlak, *M.* (*M.*) *rogalae* NOWAK is abundant within the upper part Upper Coniacian (= *M. rogalae* Bioevent), whereas at Lägerdorf, Germany, its acme falls in the Middle Santonian (ERNST 1966; ERNST & SCHULZ 1974). These data, as well as the occurrence in Mangyshlak of the species *Micraster* (*M.*) *praerogalae* sp. nov., a transitional form between *M.* (*M.*) *rogalae* and *M.* (*M.*) *cortestudinarium*, indicate that the species migrated towards the west. The easterly origin of the species and its subsequent migration towards the west explains the difficulties in placing *M.* (*M.*) *rogalae* within the evolutionary tree which ERNST (1972) faced. The intermediate form *M.* (*M.*) *praerogalae* sp. nov., known exclusively from the upper Upper Coniacian of Mangyshlak (Text-fig. 63).

Hemiaster simakovi represents a member of a southerly fauna in Mangyshlak. Rare specimens of this species occur in the Turonian at Koksyrtau-Aksyrtau, and in the condensed Upper Turonian – Coniacian Bed 42 at Besakty. Outside the North European Province, the species is known from the Upper Turonian and ?Lower Coniacian of Tadzhik Depression (Tadzhik Republic) and Gissar Mountains (Tadzhik Republic) (SCHMIDT & SIMAKOV 1953; SCHMIDT 1962). The characters such as: slightly depressed anterior and posterior petals, very shallow frontal groove, asymmetric sternal plates, posterior face without concavity, refer this specimens to primitive hemiasterids, only apical disc moved posteriorly is more advanced character (NÉRAUDEAU 1994).

The genus *Echinocorys* is a cosmopolitan form (WAGNER & DURHAM 1966; MOSKVIN & SHIMANSKAYA 1977; SMITH & WRIGHT 2003). It first appeared in the Turonian (SMITH & WRIGHT 2003), evolved slowly in the Late Turonian, and then radiated rapidly during the Coniacian to Maastrichtian (ERNST 1972; ERNST & SEIBERTZ 1977; MOSKVIN & SHIMANSKAYA 1977). Numerous cases of iterative evolution in the *Echinocorys* lineage cause difficulties with proper recognition of particular species (ERNST 1972) and their use in chronostratigraphical correlations (ERNST & SEIBERTZ 1977).

A number of well-preserved *Echinocorys* tests come from Bed 42 at Besakty (Mangyshlak). The material shows a wide range of morphological variation, similar to that seen at Lägerdorf, northern Germany, as reported by ERNST & SCHULZ (1974). The large morphotype of *Echinocorys* ex gr. *scutata* occurred in the Lower and Middle Coniacian in Mangyshlak, whereas, at Lägerdorf, it appeared in the uppermost Coniacian and continued into the Early Santonian. Similar Middle Coniacian representatives of *Echinocorys* are noted in Kopet-Dag (DZHABAROV 1964), south of Mangyshlak. The evolution and morphotypical differentiation of *E.* ex gr. *scutata* thus were similar in the entire North European Province, but not synchronous, similar to the migratory pattern of the *Micraster rogalae*.

Echinocorys is very rare in the Opole area. In the Turonian there is a form very similar to forms described as *Echinocorys sphaericus*, reported from Donbass (SAVCHINSKAYA 1974), northern Caucausus (MOSKVIN 1959), and Kopet-Dag (DZHABAROV 1964). ERNST (1972) referred to those forms as early forms of *Echinocorys gravesi*. More typical *E. gravesi* appears in the upper Upper Turonian of Opole, and the first, rare representatives of *E.* ex gr. *scutata* appear in the Lower Coniacian.

Plesiocorys (*Sternotaxis*) *plana* is widely known in the entire North European Province and is commonly referred to as an index taxon for the Upper Turonian (ROWE 1899; DZHABAROV 1964; STOKES 1975, 1977; POMEROL 1985; MORTIMORE 1986; SMITH & WRIGHT 2003). Rare representatives of this species appear in the lower Upper Turonian *Inoceramus perplexus* Zone of Mangyshlak. It is quite common in coeval strata in the Opole area, but becomes rare higher up section, in the *Mytiloides scupini* Zone at Folwark Quarry. In the upper Upper Turonian of Mangyshlak a common echinoid species is *Plesiocorys* (*Plesiocorys*) *placenta*, which is not noted from the Opole Cretaceous. Besides Mangyshlak, *Plesiocorys* (*Plesiocorys*) *placenta*; this is not known from Opole, but has, however, been noted from Coniacian of Germany (ELBERT 1902; ERNST 1972) and England (SMITH & WRIGHT 2003), which indicates its fairly wide distribution within the North European Province.

Conulus (*C.*) *subrotundus* is common in the Turonian of the North European Province, but appears limited to shallow, calcarenitic facies (HAWKINS 1919; POPIEL-BARCZYK 1958; ERNST 1967; ERNST & *al.* 1979; SMITH 1988; KUDREWICZ & OLSZEWSKA-NEJBERT 1997; OLSZEWSKA-NEJBERT 2005).

Catopygus columbarius is rare in the North European Province. In addition to Mangyshlak, this species is known from the Aptian-Cenomanian of Europe (SMITH & WRIGHT 2000), and Turonian of France (MĄCZYŃSKA 1972). Its rare occurrence is probably linked to its special facies requirements, having preferred coarse-grained substrates, which were rare in the North European Province, where fine-grained carbonates (coccolith and foraminiferal oozes) predominated.

FINAL REMARKS

Irregular echinoid faunas from the Turonian – Coniacian of Mangyshlak are almost identical to those occurring in the entire Northern Realm and certainly in the North European Province, including England, France, Belgium, Germany, the Czech Republic, Poland, Belorussia, Ukraine, northern Caucasus, and Kopet-Dag.

The occurrence of *Hemiaster simakovi* indicates rare invasions of southerly species into Mangyshlak. These elements do not appear in the Opole area; however, another species of the genus *Hemiaster* is known from North European Province, rare in Turonian, more frequent in higher Cretaceous strata (NÉRAUDEAU 1994 and references therein).

The analysis of echinoid species from Mangyshlak and from Opole indicates a large morphological variability of the echinoid fauna in the entire province and, at the same time, a constant distribution of particular morphotypes throughout the area. The province seems also to be quite homogenous in the vertical, stratigraphical succession of particular faunas, although some of the morphotypes clearly display some diachronism in the appearance. Thus, the succession of Turonian and Coniacian species of the genus *Micraster* is very similar in Opole, western Europe (ERNST 1970c, 1972; ERNST & SEIBERTZ 1977; FOURAY & DRUMMOND 1985; KÜCHLER & ERNST 1989), and in Mangyshlak. However, the earliest representatives of *Micraster* (*M.*) *leskei*, the first member of the *Micraster* lineage, and of its successor, *M.* (*M.*) *corbovis* (see ERNST 1970c), make their first appearance in western Europe and later occur east: earliest Late Turonian in Opole, and Late Turonian in Mangyshlak. This pattern may be explained by diachronism in the appearance of carbonate facies between western and eastern Europe; the latter is required for rapid and explosive appearance of spatangoids and holasteroids. The change from siliciclastic to carbonate took place in Mangyshlak late in the Turonian, which is much later than in western Europe. The subsequent phylogenetic pathway of the *Micraster* lineage, i.e. *M.* (*M.*) *leskei* – *M.* (*M.*) *normanniae* – *M.* (*M.*) *cortestudinarium* – *M.* (*M.*) *coranguinum*, occurred under already unified facies conditions, and the appearance of particular taxa is most probably isochronous (or almost isochronous) in the entire North European Province.

For *Micraster* (*M.*) *rogalae*, regarded as an offshoot of the main *Micraster* lineage (ERNST 1970c, 1972), Mangyshlak seems to be the area of origin because: (i) *M.* (*M.*) *rogalae* appeared here first in the latest Coniacian, marking a very distinct acme: the *M. rogalae* Bioevent, whereas, in western Europe it is noted in the late Early Santonian with an acme in the Middle Santonian (ERNST & SCHULZ 1974); (ii) the species *Micraster* (*M.*) *praerogalae* sp. nov., which is transitional between *Micraster* (*M.*) *cortestudinarium* and *Micraster* (*M.*) *rogalae* appears in Mangyshlak. These data indicate for diachronism for both: the appearance and mass occurrence of *Micraster* (*M.*) *rogalae*, and westward migration in the North European Province (Text-fig. 62).

Echinoid mass occurrences with bioevent character occur as follows:

(i) at the bottom of a layer, where sedimentation changed from more clayey (clayey marls) to a higher carbonate component (marly limestone): the *Micraster leskei* Bioevent I at the Odra I & II and Bolko Quarries; the *Micraster leskei* Bioevent II at Odra I & II and Bolko Quarries, and at Groszowice (Text-fig. 6);

(ii) at the top of a limestone layer (marly limestone or pelitic limestone), just prior to the change of sedimentation from more carbonate into more clayey or terrigenous clastic (marls, clayey marls, sandy marls): *Micraster cortestudinarium* Bioevent at Folwark Quarry (Text-fig. 6); *Micraster rogalae* Bioevent at Shakh-Bogota, Shyrkala-Airakty, and Kush (Text-fig. 3), this change was connected with decreased sedimentation and/or winnowing of soft sediments, the infaunally buried *Micraster* were exposure at the bottom and covered by epibionts;

(iii) just below a firmground or hardground which indicate decreased sedimentation and/or winnowing of soft sediment (the echinoids were exposed on the bottom and covered by epibionts):

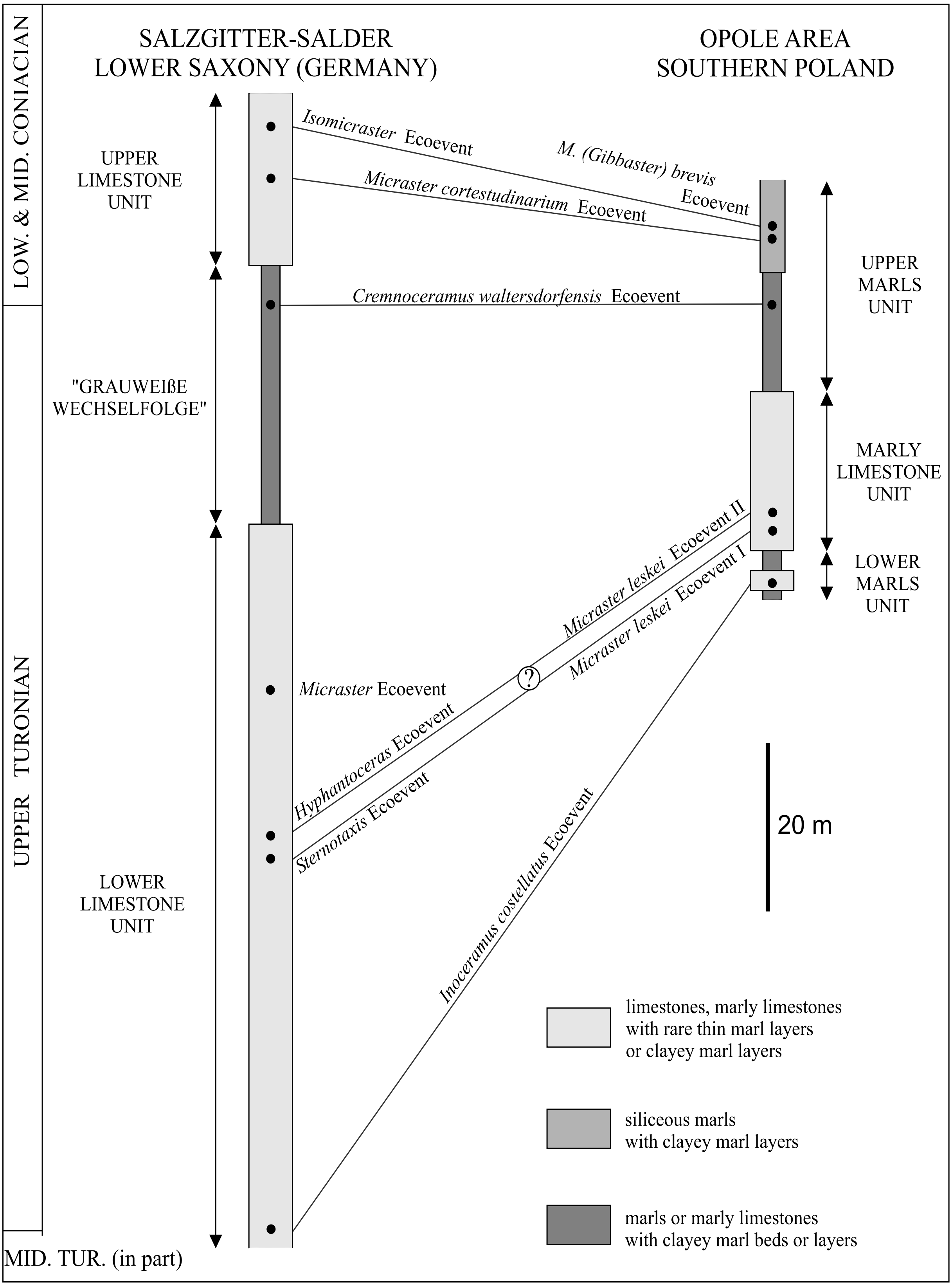

Fig. 64. Correlation of bioevents in Opole with bioevents at Salzgitter-Salder, Lower Saxony (after Wood & *al*. 1984; inoceramid bioevents of Opole after Walaszczyk 1992; with modification after Walaszczyk & Wood 1998)

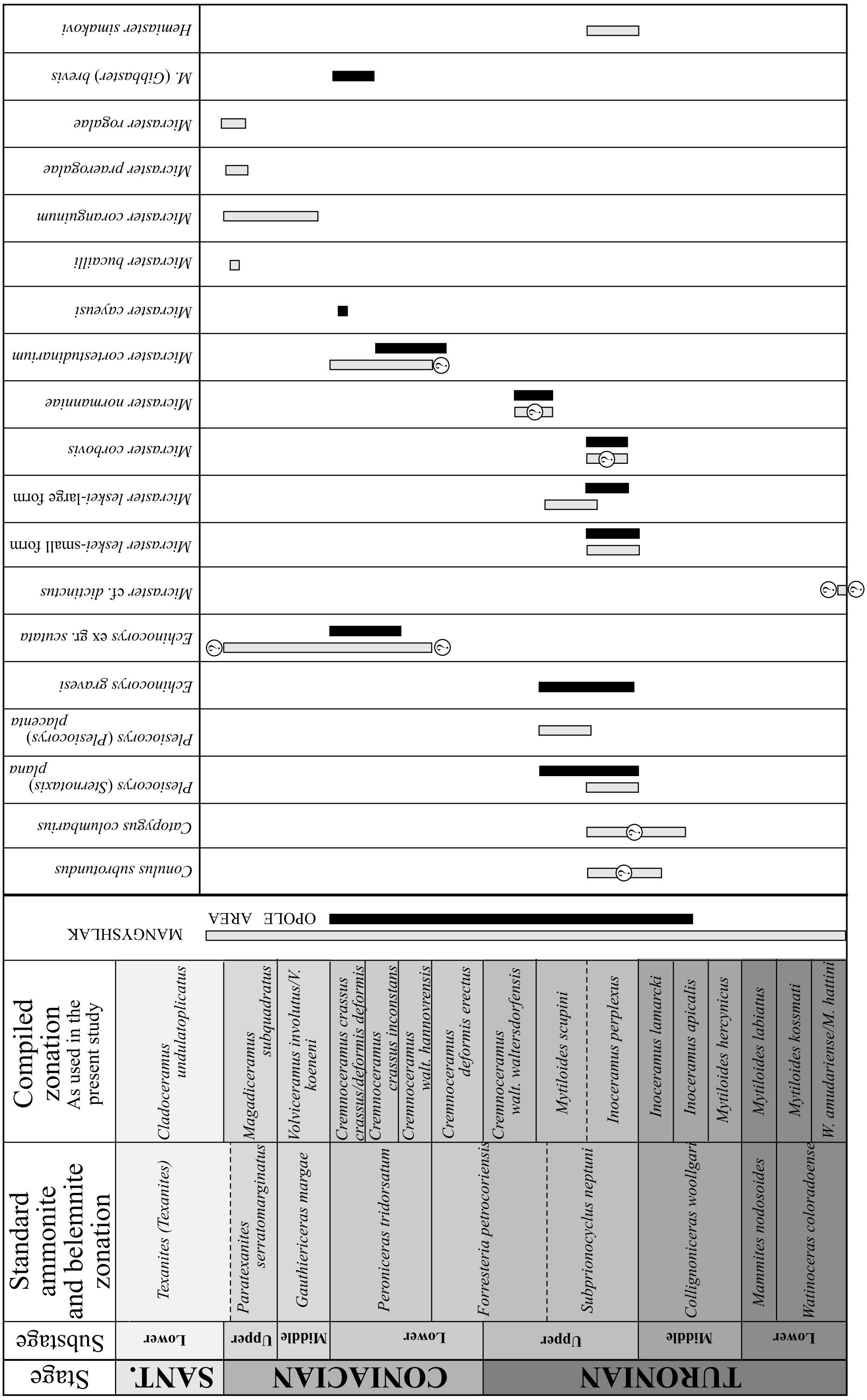

Fig. 65. Stratigraphic range of irregular echinoids from Mangyshlak and Opole (biostratigraphy after WALASZCZYK 1992; MARCINOWSKI & *al*. 1996; WALASZCZYK & WOOD, 1998, 1999; KENNEDY & WALASZCZYK 2004)

Micraster rogalae Bioevent at Sulu-Kapy and Koksyrtau-Aksyrtau (Text-fig. 3);

(iv) within a layer; just below and above the echinoid biohorizon appear irregular intercalations of clayey marls: *M.* (*Gibbaster*) *brevis* Bioevent at Folwark Quarry (Text-fig. 6).

All acme occurrences of echinoids are connected with a change in character of sedimentation, and three last cases (ii, iii, iv) with a clearly decreased rate of sedimentation. At the time, the amount of organic component probably increased in relation to the carbonate component, which yielded good food supply for deposit-feeding echinoids. An increase in clay component or the development of firm- or hardgrounds halted the evolution of echinoid population. In the first case (i) this is also connected with the change in sedimentation rate, and echinoids occurred at the bottom of a layer. After more clayey sedimentation (clayey marls), followed sedimentation of increased carbonate content (marly limestone), which provided enough food for echinoid acmes. The sedimentary environment was tranquil and optimal for biotic acme. This interpretation is supported by the mass occurrence of heteromorph ammonites in the layer discussed (compare MARCINOWSKI & WIEDMANN 1990). Such optimal conditions changed rapidly, because up to the section (a dozen or so centimetres above the bottom of the layer) infauna and epifauna occur very rarely.

The bioevents noted in the Opole area have the character of biochronohorizons, and seem to be valuable for correlation with bioevents in Lower Saxony (Text-fig. 64). In the upper Turonian, the *Inoceramus costellatus* Bioevent occur in both regions, and *Micraster leskei* Bioevents I and II, with several *Hyphantoceras* accompanying them seem to represent the ?*Sternotaxis* Horizon and *Hyphantoceras* Bioevent, respectively at the Salzgitter-Salder (Text-fig. 64). In the Lower Coniacian, the *Cremnoceramus waltersdorfensis* Bioevent and *Micraster cortestudinarium* Bioevent are similar in both regions, while the *M.* (*Gibbaster*) *brevis* Bioevent of the Opole area corresponds to the *Isomicraster* Bioevent in Lower Saxony (Text-fig. 64).

The analysis of irregular echinoid occurrences in Mangyshlak and in the Opole area make it possible to designate of the age range of echinoids on the basis of the standard ammonite/belemnite and inoceramid zonations (Text-fig. 65).

Acknowledgements

This paper is a revised version of my Ph.D. thesis, prepared under supervision of R. MARCINOWSKI at the Geological Faculty of the Warsaw University. I express my best thanks to I. WALASZCZYK for helpful remarks, co-operation during field work, presentation of specimens of echinoids from England and the Czech Republic; to L.F. KOPAEVICH for discussion and assistance during the expedition in Mangyshlak; to Dr. S. MĄCZYŃSKA, for fruitful advice and remarks, to Professor A. RADWAŃSKI, for helpful remarks and scientific discussion, to Docent T. MARYAŃSKA and Professor W. BAŁUK, for critical reviews of my dissertation and for valuable suggestions and comments.

Thanks to all the workers of the Museum of the Earth for their kindness and patience, specially to Dr. B. STUDENCKA; to late Professor G. ERNST for valuable suggestions, to Professor J. GEYS for the possibility to study the collection of Upper Cretaceous echinoids of Belgium, housed at the Institut Royal des Sciences Naturelles de Belgique (Brussels), and to Professor R.B. STOKES for helpful remarks about *Micraster* problems.

I am also grateful for helpful remarks to M. BĄBEL, M. MACHALSKI, B. WAKSMUNDZKI, S. SKOMPSKI, M. ŻYWIECKI, and J. ZROBEK; additional thanks are to B. WAKSMUNDZKI for the line drawings of part of the figures, and to Mr. S. KOLANOWSKI for photos.

Special and very warm thanks to John W. M. JAGT for critical review and a lot of very helpful comments and remarks, and to a second anonymous reviewer for critical reading of an earlier typescript.

Last, but not least heartfelt thanks to my husband Krzysztof NEJBERT, for help during field work in the Opole area, and for assistance with all computer problems.

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Manuscript submitted: 18th July 2002
Revision version accepted: 14th November 2006

APPENDIX

Details on echinoid occurrences in source sections in Mangyshlak and Opole

MANGYSHLAK

Individual sections are presented briefly going from NW to SE (Text-fig. 2). Numerals denoting particular lithologic units are after MARCINOWSKI & *al*. (1996), and refer only to individual sections. The characteristic of particular beds are in MARCINOWSKI & *al*. (1996); here only data on echinoid distribution are provided.

Shakh-Bogota: This section exposes an almost complete Turonian – Coniacian sequence (Text-figs 2-3).

Lower Turonian

Bed 9 (Phosphatic Horizon IV), thickness 0.3-0.9 m, bipartite. Four specimens of echinoid were collected from this bed. All are black phosphatic moulds, without any test preserved. Although external test features cannot be observed, the heart-shaped outline, type of longitudinal section, structure and depth of petals suggest placement in *Micraster* (Pl. 28, Fig. 1). It is the stratigraphically oldest find of this genus in Mangyshlak and seems to be one of the earliest occurrences of the genus over all. The specimens are similar to *Micraster* cf. *distinctus*, and not resembling the small *Micraster* (*M.*) *leskei*, known from the higher Upper Turonian interval (Bed 12), in the same section.

Bed 10, thickness 20-38 m. Unfossiliferous.

Upper Turonian – Middle Coniacian

Bed 11 (Phosphatic Horizon V), thickness 0.8 m.

Bed 12, thickness 0.8 m. Firmground horizon, with relatively common small *Micraster* (*M.*) *leskei* and rare *Plesiocorys* (*Sternotaxis*) *plana* (MANTELL). NAIDIN & *al*. (1984) reported from this unit *M. leskei* and *Cardiaster* cf. *peroni* LAMBERT.

Bed 13, thickness 1 m. Hardground horizon.

Bed 14, thickness 23 m. In the lower part of the bed, about 2-3 m above the hardground (Bed 13) occur numerous echinoids in a unit of 0.8 m thickness (Pl. 1B). Despite their very poor preservation, the following taxa are recognised: *Plesiocorys* (*Plesiocorys*) *placenta*, *Echinocorys* sp., *Micraster* (*M.*) *leskei*, large forms (Pl. 18, Fig. 3), and *Micraster* sp. NAIDIN & *al*. (1984) reported from the same unit also *Micraster cortestudinarium*. The common occurrence of echinoids is connected with two local omission surfaces represented by initial hardgrounds: 2.3 m and 3.1 m above Bed 13. Between these echinoids are rather rare. The similar tendency in size of *M.* (*M.*) *leskei*, from small below to large above has been reported from the Upper Turonian of England and France (STOKES 1975, 1977; FOURAY 1981; DRUMMOND 1985; DAVID & FOURAY 1984; FOURAY & POMEROL 1985; MORTIMORE 1986), but it does not appear in Turonian strata of the Opole area (see also TARKOWSKI 1991).

The next relatively common occurrence of echinoids is noted 17-20 m above the hardground in the Lower Coniacian (see also MARCINOWSKI & *al*. 1996). *Echinocorys* ex gr. *scutata* represented by morphotype "*vulgaris*", and transitional morphotypes between "*vulgaris*" and "*planodoma*". Rare representatives of *M.*(*M.*) *cortestudinarium* are also observed. NAIDIN & *al*. (1984) reported from the same unit *Echinocorys gravesi*, *Echinocorys* cf. *rossiensis*, *Micraster* cf. *coranguinum*, and *Sternotaxis planus*. In my opinion, NAIDIN & *al*.'s (1984) *E. gravesi* and *E.* cf. *rossiensis* most probably belong to *E.* ex gr. *scutata* as here understood.

Upper Coniacian

Bed 15, thickness 17 m. From about 1.5 m below the top of the unit comes *Micraster* (*M.*) *praerogalae* sp. nov. At the top of the unit there is a horizon with common *Micraster* (*M.*) *rogalae* NOWAK [*M. rogalae* Event] and less frequent *Micraster* (*M.*) *coranguinum*. The mass occurrence of *M.* (*M.*) *rogalae* is connected with the topmost bed of white limestone in the unit. The overlying deposits (Bed 16, Santonian) change to light-grey, marly limestones rhythmites. This change probably is connected with slower sedimentation and caused the acme occurrence of *M.* (*M.*) *rogalae* at the latest Coniacian in Mangyshlak. NAIDIN & *al*. (1984) reported *M. rogalae* in the uppermost Coniacian and Lower Santonian; however, they reported *M.* cf. *rogalae* in the Upper Coniacian, and *Echinocorys* cf. *vulgaris* (=*E.* ex gr. *scutata* in this paper) in the Lower Santonian.

Sulu-Kapy: Compared to Shakh-Bogota the Upper Turonian and Coniacian strata are partially condensed, but still relatively complete (in comparison to sections further to the SE). The echinoids are from Coniacian deposits (Text-fig. 3).

Coniacian

Bed 20, thickness 8.3 m. At the top of the bed, there is a single *Micraster* (*M.*) *cortestudinarium*.

Bed 21, thickness 8.2 m. Poorly bedded white limestones, with firmground at the top. From the middle part of this unit come rare and poorly preserved *Micraster* (*M.*) *coranguinum*, and *Echinocorys* ex gr. *scutata*, "*vulgaris*" morphotype. At the top, 1.5-0.5 m below the firmground, appears a horizon with mass occurrence of *Micraster* (*M.*) *rogalae* [*M. rogalae* Event] and rarer *E.* ex gr. *scutata*, "*vulgaris-striata*" morphotype. NAIDIN & *al*. (1984) reported *M. rogalae* and *M. coranguinum* from, just below the firmground. However, they referred this interval to the Lower Santonian. MARCINOWSKI & *al*. (1996) put the Coniacian/Santonian boundary higher, above the firmground. The acme occurrence of *M.* (*M.*) *rogalae*, consequently, appears at the level similar to Shakh-Bogota, in the topmost Coniacian. It is interesting that mass occurrence of *M.* (*M.*) *rogalae* is just below slow and break of sedimentation (below firmground).

Shyrkala-Airakty: This section records the eastward tendency in gradual thickness reduction the Upper Turonian-Coniacian succession (Text-fig. 3).

Upper Turonian

Bed 25 (Phosphatic Horizon V), thickness 3 m.

Bed 26, thickness 2 m. In the uppermost part occur frequent indeterminate echinoids.

Coniacian

Bed 27, thickness 20 m. In the topmost part of this unit, ca. 0.3 m below the top, there is a horizon with frequent *Micraster* (*M.*) *rogalae* [*M. rogalae* Event]. They disappear above, at the facies change to green-grey marls of the Santonian (Bed 28).

Kush: The lithological succession is very close to that in the Shyrkala-Airakty section (Text-fig. 3).

Upper Turonian

Bed 19 (Phosphatic Horizon V), thickness 0.8 m.

Bed 20, thickness 0.7 m. Yellow-green, sandy-glauconitic marls, bioturbated, with hardground horizon at top.

Coniacian

Bed 21, thickness 14 m. In the middle part of this unit occur rare *Echinocorys* ex gr. *scutata*, "*planodoma*" morphotype and advanced forms of *Micraster* (*M.*) *cortestudinarium*. The echinoids appear just below an omission surface. In topmost part of the unit occur single *Micraster* (*M.*) *praerogalae* sp. nov., and very common *Micraster* (*M.*) *rogalae* [*M. rogalae* Event]. Similar to the Shyrkala/Airakty section, echinoids disappear at the facies change to the green-grey, limy marls of the Santonian (Bed 22).

Koksyrtau-Aksyrtau

Upper Turonian

Bed 36 (Phosphatic Horizon V), thickness 0.5 m.

Bed 37, 1.1 m thick. The bed is subdivided into units A and B (Text-fig. 3). Bed 37A represents a composite hardground. The rare, slightly posphatizated echinoids are represented by *Plesiocorys* (*Sternotaxis*) *plana*, *Micraster* (*M.*) *leskei* and *Hemiaster simakovi*. Bed 37B, of late Turonian age, yields very rare *Plesiocorys* (*Plesiocorys*) *placenta*.

Coniacian

Bed 38, thickness 0.4 m.

Bed 39, thickness 8 m.

From the Aksyrtau section the following echinoids were reported by NAIDIN & *al*. (1984): *Micraster* cf. *cortestudinarium* in the Upper Turonian and lower Lower Coniacian; *Micraster* cf. *coranguinum* in the upper Upper Turonian to Lower Santonian; *Micraster rogalae* and *Echinocorys* cf. *vulgaris* from the middle Lower Santonian. MARCINOWSKI & *al*. (1996) placed the Coniacian/Santonian boundary higher than NAIDIN & *al*. (1984) at Koksyrtau-Aksyrtau. All echinoids reported by NAIDIN & *al*. (1984) in the Lower Santonian already appear as follows:

(i) *E.* cf. *vulgaris* in the Middle and Upper Coniacian; (ii) *M.* cf. *coranguinum* in the Coniacian; (iii) *Micraster rogalae* in the Upper Coniacian and Lower Santonian.

SCHMIDT & *al*. (1973) distinguished a *Micraster leskei* Zone (about 2 m thickness) in the Aksyrtau section as equivalent of the *Hyphantoceras reussianum* Zone in western Kopet-Dag. They reported from this zone: *M. leskei*, *Micraster corbovis*, *Micraster cortestudinarium*, *Cardiaster peroni*, *Conulus subrotundus*, *Hemiaster turonensis*, *Sternotaxis planus* and *Phymosoma regulare* AGASSIZ. The same authors reported *M. coranguinum* in the Upper Coniacian and *M. rogalae* in the Upper Coniacian and Lower Santonian. SCHMIDT & *al*. (1973) distinguished a *M. rogalae* Zone (thickness about 9.5 m) above the *Micraster leskei* Zone. *M. rogalae* Zone *sensu* SCHMIDT & *al*. (1973) comprises the Upper Coniacian (*Inoceramus involutus* beds) and lowermost Santonian.

Micraster (*M.*) *rogalae* occurs in the Aksyrtau section in the uppermost Coniacian, similar to Shakh-Bogota, Sulu-Kapy, Shyrkala-Airakty, and Kush. *M.* (*M.*) *rogalae* appears in Mangyshlak in the latest Coniacian. The acme zone of this species (=*M. rogalae* Event) in Mangyshlak always occurs just below an episode of decreased sedimentation, accompanying a change of sedimentation from carbonate to more clayey-sandy (Shakh-Bogota, Shyrkala-Airakty, and Kush) or just below a hardground surface (Sulu-Kapy, and Koksyrtau-Aksyrtau).

Azhirektoy: The section was completed within the northern limb of the Tumgatchi Anticline (Text-figs 2, 3). The Upper Turonian – Coniacian is enclosed within phosphatic bed and associated hardground horizon (Bed 41, Text-figs 3, 4).

Middle Turonian – Coniacian

Bed 41 (Phosphatic Horizon V), 0.3-0.4 m thick. Represented are *Echinocorys* ex gr. *scutata*, morphotypes "*vulgaris*", "*planodoma*", "*vulgaris-planodoma*", and "*vulgaris-striata*", *Micraster* (*M.*) *leskei*, *Micraster* (*M.*) *cortestudinarium*, *Catopygus columbarius*. Comparison with the echinoid succession in more complete sections (first of all Shakh-Bogota) suggests that species collected here represent an interval spanning the Upper Turonian to the Middle Coniacian.

Besakty: The Besakty section is part of the southern limb of the Tumgatchi Anticline (Text-figs 2, 3). Similar to the Azhirektoy section, Besakty represents a very condensed record of Upper Turonian to Coniacian. It is the only section where, at least partially, uncondensed Middle Turonian sandstones are preserved (Bed 41). The Upper Turonian – Coniacian is enclosed by a composite hardground horizon (Bed 42), where strong condensation is indicated by an exceptionally rich fauna of ammonites, echinoids, inoceramids, and belemnites (MARCINOWSKI & *al*. 1996). Irregular echinoids are especially rich in this condensed bed (see Text-figs 3, 4).

Middle Turonian

Bed 40, Phosphatic Horizons IVb & Va, thickness 0.2 m. Single *Catopygus columbarius* was found in dark- to light-brown phosphatic concretions dated as latest Cenomanian – Middle Turonian (cf. MARCINOWSKI & *al*. 1996).

Bed 41, thickness 4.5 m. Grey-green, poorly cemented, fine-grained, quartz limy sandstones with glauconite.

Upper Turonian – Coniacian

Bed 42: Phosphatic Horizon Vb with a hardground at its top, 0.8-1.8 m thick. Bed 42 yields the richest assemblage of echinoids of all of Mangyshlak. It is possible to correlate Bed 42 with the Azhirektoy section (Text-fig. 4).

Bed 42, and under- and overlying deposits are divided herein into several lithological units (Text-fig. 4, Pl. 3). **Unit A** [=the top of Bed 41 in MARCINOWSKI & *al*. 1996], light-green, poorly cemented, fine-grained quartz limy sandstones, gradually more limy and harder upwards.
Unit B [= Bed 42A in MARCINOWSKI & *al*. 1996], 50-150 cm thick bed of green, moderately cemented, fine-grained, limy quartz sandstone with glauconite and numerous phosphatic concretions, strongly bioturbated, and with numerous *Ophiomorpha*-type burrows. Phosphatised fossils are represented by echinoids (most numerous), ammonites, gastropods, bivalves, shark and ray teeth (MARCINOWSKI & *al*. 1996; RADWAŃSKI & MARCINOWSKI 1996). Representatives of genera *Echinocorys* and *Micraster* predominate, much less frequent is *Plesiocorys* (*Sternotaxis*), or *Plesiocorys* (*Plesiocorys*) and sporadic *Conulus*, *Catopygus*, and *Hemiaster*. Unit B is subdivided into three subunits B_1, B_2, and B_3 on the basis of echinoid content. B_2, about 20-30 cm thick, is a quite regular horizon packed with echinoids (Text-fig. 4, Pl. 3B). Below and above that horizon, in B_1 and B_3 respectively, echinoids are less common and scattered. The tests are not oriented, and of various states of preservation. Besides well-preserved specimens with intact or almost intact test, most of them have test partly preserved and several of them occur as moulds. Echinoids are infilled by light-grey, strongly phosphatized limestones. The following species occur in unit B: *Plesiocorys* (*Sternotaxis*) *plana*, *Plesiocorys* (*Plesiocorys*) *placenta*, *Echinocorys* ex gr. *scutata*, morphotypes "*vulgaris*", "*planodoma*", "*scutata*", "*vulgaris-planodoma*", "*vulgaris-scutata*", "*scutata-planodoma*", and a single specimen "*vulgaris-striata*" only in subunit B_3, *Micraster* (*M.*) *leskei*, *Micraster* (*M.*) *corbovis*, *Micraster* (*M.*) *normanniae*, *Micraster* (*M.*) *cortestudinarium*, a single specimen of *Micraster* (*M.*) *bucailli* only in subunit B_3, *Hemiaster simakovi*, *Conulus* (*C.*) *subrotundus*,

Catopygus columbarius, and representatives of regular echinoids of the genus *Gauthieria*.

Unit C [Bed 42B in MARCINOWSKI & *al*. 1996], 30-40 cm thick. Rare echinoids in a poor state of preservation are found just below the top of the bed: *Echinocorys* ex gr. *scutata*, morphotype "*vulgaris-striata*" and *Micraster* (*M.*) *rogalae*.

Santonian

Unit D [= bottom part of Bed 43 in MARCINOWSKI & *al*. 1996], 30 cm thick. At the bottom of the unit a single *Micraster* (*M.*) *rogalae* was found.

Unit E, white chalk without macrofossils and bioturbations.

OPOLE

Odra Quarries: The Odra I and II quarries are situated in the northern part of the city of Opole (Text-fig. 5). The section comprises the Middle and lower Upper Turonian (WALASZCZYK 1988, 1992), and is about 27.5 m thick (Text-fig. 6, Pl. 5A).

The following remarks are based on an analysis of the echinoid distribution at the Odra II and Odra I Quarries:

(i) the echinoids are connected chiefly with layers of marly limestones, in clayey marls or marls the echinoids do not occur or appear in very low numbers;

(ii) the echinoid acmes occur at the bottom of marly limestone layer, which seems to be connected with changes in character of sedimentation. At the bottom part of layers the echinoids could occur just the clayey sedimentation passed gradually to more limy character. The increasing rate of sedimentation was not be favourable to the echinoid acme on the sea bottom;

(iii) the association of numerous heteromorphic ammonites and echinoids at the same horizons manifest the biotic optima of these epibenthonic and benthonic organisms and similar environment requirements for these groups. The heteromorphic ammonites prefer the marly or clayey deposits under quiet conditions of sedimentation (compare MARCINOWSKI 1980; MARCINOWSKI & WIEDMANN 1985, 1990);

(iv) representatives of species of *Echinocorys* are rare in the section of Odra II and Odra I Quarries, but when it does occur it is situated in the middle part of the layer. Probably the epifaunal *Echinocorys* better tolerated a higher rate of sedimentation of limy ooze, than infaunal *Micraster* (*Micraster*) or semiepifaunal *Plesiocorys* (*Sternotaxis*) *plana*.

Middle Turonian

Bed Od1, 2.2 m thick; dark grey, massive when fresh, platy on weathered surfaces, clayey marls, with numerous pyritic concretions, sometimes pyritic burrows (compare KUTYBA 1977; KĘDZIERSKI & UCHMAN 2001) rare small terebratulids, oysters, echinoid spines and subordinate inoceramids, (*Inoceramus apicalis* WOODS) (see WALASZCZYK 1988).

Bed Od2, 0.3 m thick; grey marls

Bed Od3, 0.5 m thick; dark grey, clayey marls similar to marls of Layer Od 1

Beds Od4–Od15, 11.15 m thick; Lower Marls; thick bedded grey or light-grey, moderately hard marls, with thin intercalation of dark grey, clayey marls. Particular rhythms are slightly irregular, and vary in thickness from 70 to 230 cm. About 2-3 m above the bottom of Bed Od4 there is an inoceramid accumulation with numerous *Inoceramus* ex gr. *lamarcki* PARKINSON. The first appearance of this species is noted at the bottom of Bed Od4, and coincides with the base of the Lower Marls, and thus the lower boundary of the *Inoceramus lamarcki* Zone is placed herein (WALASZCZYK 1988, 1992).

Middle/Upper Turonian boundary

Bed Od16, thickness 1 m, the pronounced, hard, white-grey marl layer with numerous pyritic concretions in the bottom and in the top of layer. The acme occurrence (bio-event) of *Inoceramus perplexus* WHITFIELD in the upper half of Bed Od16 marks the boundary between the *Inoceramus lamarcki* Zone (Middle Turonian) and *Inoceramus perplexus* Zone (Upper Turonian) (Text-fig. 6; WALASZCZYK 1992).

Upper Turonian

Bed Od17, Clay Layer I (Cl-1 in WALASZCZYK 1988, 1992), thickness 0.4 m, well individualized clayey marl horizon, visible not only at the Odra II Quarry and stable all over the study area.

Beds Od18–Od19, thickness 1.45 m, moderate and thick layered light-grey, moderately hard marls.

Bed Od20, Clay Layer II (Cl-2 in WALASZCZYK 1988, 1992), thickness 0.2 m, well individualized clayey marl horizon, visible not only at the Odra II Quarry and stable all over the studied area.

The layers Od16–Od20 belong to the upper part of the Lower Marls Unit of ALEXANDROWICZ & RADWAN (1973).

Bed Od21, thickness 2.1 m, light-grey to yellowish, hard, layered marly limestones, irregular layered clearly visible on weathered faces, in the upper half of layer visible non-continuous layers of inoceramid debris while at the top of Bed Od21 occur layered accumulations of large inoceramid shells, continuing laterally at a distance of some tens of metres. The layer Od21 starts the last lithologic unit at the Odra II Quarry, the Marly Limestones Unit.

Beds Od22–Od25, thickness 1.9 m, moderate to thick layers (from 30 to 80 cm), light to slightly yellow marly limestones, with thin intercalation (from 4 to 8 cm) of dark grey marls. In Bed23 occur large specimens of *Echinocorys gravesi*, and in Bed25 *Micraster* (*M.*) *leskei* in very low numbers.

Bed Od26, Clay Layer III (Cl-3 in WALASZCZYK 1988, 1992), 0.2 m thick, well individualized clayey marl horizon, visible not only at the Odra II Quarry and stable all over the area studied.

Bed Od27, 1.5 m thick, light-grey to slightly yellow, hard, marly limestones. At the bottom of the layer there is an echinoid acme with predominant *Micraster* (*M.*) *leskei*, represented by small and medium-sized forms, and *Plesiocorys* (*Sternotaxis*) *plana*. In the middle part of layer the echinoids are low in number, *Echinocorys gravesi* was collected here. Together with echinoids co-occur numerous heteromorph ammonites of the genera *Hyphantoceras*, *Scaphites*, *Sciponoceras*.

Bed Od28, Clay Layer IV (Cl-4 in WALASZCZYK 1988, 1992), 0.15 m thick, well individualized clayey marl horizon, platy on weathered face, visible not only at the Odra II Quarry and stable all over the studied area. A single deformed *M.* (*M.*) *leskei* was collected.

Bed Od29, 0.35 m thick, light-grey to slightly yellow, hard, marly limestones. At the bottom of the layer there is again an echinoid acme with predominant *M.* (*M.*) *leskei* together with heteromorph ammonites (KACZOROWSKI 1997).

Bed Od30, 0.05 m thick, dark grey, clayey marls.

Bed Od31, light-grey to slightly yellow, hard, layered marly limestones, irregular layered clearly visible on weathered face.

Bolko Quarry: The Bolko Quarry is situated in the southern part of Opole City east of the Odra River (Text-fig. 5). The section exposed comprises the Middle and lower Upper Turonian (WALASZCZYK 1988, 1992), and is about 16 m thick (Text-fig. 6, Pl. 4). In the quarry (i) echinoids are associated chiefly with layers of marly limestones, in marls they are low in number, and in clayey marls they are absent; and (ii) echinoid and heteromorph ammonite acmes are connected with bottom of layers during the change of sedimentation into the most limy.

Middle Turonian

Beds Bo1–Bo6, thickness 2.5 m, part of the Lower Marls Unit sequence of ALEXANDROWICZ & RADWAN (1973), succession of thick-layered grey or light-grey, moderately hard marls (up to 90 cm in thickness) slightly bioturbated, with thin and moderately thick intercalations of dark grey, clayey marls (from 5 mm to 30 cm in thickness).

Middle/Upper Turonian boundary

Bed Bo7, thickness 1 m, pronounced, hard, white-grey marl layer with numerous pyritic concretions. Acme (bioevent) of *Inoceramus perplexus* in the upper half of Bed Bo7 marks the boundary between the *Inoceramus lamarcki* Zone (Middle Turonian) and *I. perplexus* Zone (Upper Turonian) (Text-fig. 6; see also WALASZCZYK 1992). Small- and medium-sized specimens of *Micraster* (*M.*) *leskei* occur in this layer. Bed Bo7 corresponds to Bed Od16 at Odra II Quarry.

Upper Turonian

Bed Bo8, Clay Layer I (Cl-1 in WALASZCZYK 1988, 1992), thickness 0.3 m, well-individualized clayey marl horizon (Text-fig. 6, Pl. 4A), corresponds to Bed Od17 at Odra II Quarry.

Beds Bo9–Bo11, thickness 1.5 m, moderate- and thick-layered light-grey, moderately hard marls, with thin (a few cm) intercalations of dark grey, clayey marls. The particular rhythms are not very regular, and they vary in thickness from 20 to 60 cm in the light-grey marls. In Bed

Bo9 a single *Micraster* (*M.*) *corbovis* was found (see Pl. 22, Fig. 2).

Bed Bo12, Clay Layer II (Cl-2 in WALASZCZYK 1988, 1992), thickness 0.2 m, well-individualized clayey marl horizon (see Pl. 4A), corresponds to Bed Od20 at Odra II Quarry.

The Beds Bo1–Bo12 belong to the upper part of the Lower Marls Unit of ALEXANDROWICZ & RADWAN (1973).

Beds Bo13–Bo19, 4.3 m thick, light-grey to slightly yellow, hard, layered marly limestones, irregular layered clearly visible on weathered faces, with thin intercalations of dark-grey, clayey marls. Beds of marly limestone are not very regular, and they vary in thickness from 30 to 120 cm, and from few mm to 20 cm in dark grey, clayey marl beds. In Beds Bo13, Bo14, and Bo17 occur rare *Plesiocorys* (*Sternotaxis*) *plana*, as well as *Micraster* (*M.*) *leskei* in Bed Bo14. In Bed Bo14 are visible non-continuous layers of inoceramid debris while at the bottom and top of Bed Bo17 occur accumulations of inoceramid debris.

Bed Bo13 is the highest lithologic unit at Bolko Quarry, the Marly Limestones Unit.

Bed Bo20, Clay Layer III (Cl-3 in WALASZCZYK 1988, 1992), thickness 0.15 m, well-individualized clayey marl horizon (Pl. 4B), corresponds to Bed Od26 at Odra II Quarry.

Bed Bo21, thickness 1.6 m, light-grey to slightly yellow, hard, marly limestones. At the bottom of the bed there is an echinoid acme (Bioevent I) with predominant *M.* (*M.*) *leskei*, represented by small-, medium, and large-size forms. Together with echinoids occur numerous heteromorph ammonites similar to bed Od27 at Odra II Quarry.

Bed Bo22, Clay Layer IV (Cl-4 in WALASZCZYK 1988, 1992), 0.15 m thick, well-individualized clayey marl horizon, corresponds to Bed Od28 at Odra II Quarry.

Bed Bo23, 0.55 m thick, light-grey to slightly yellow, hard, marly limestones. At the bottom of the bed there also is an echinoid acme (Bioevent II) with predominant *Micraster* (*M.*) *leskei*, represented by small- and medium-sized forms, and *Plesiocorys* (*Sternotaxis*) *plana*. Numerous heteromorph ammonites occur with echinoids.

Bed Bo24, 0.05 m thick, dark-grey, clayey marls.

Beds Bo25–Bo28, 2.8 m thick, light-grey to slightly yellow, thick layered, hard, marly limestones. At the top of Bed Bo27 a large ammonite of the genus of *Lewesiceras* (Pl. 4B).

Groszowice II Quarry: The Groszowice II Quarry is situated close to abandoned Groszowice Quarry, in the southern part of Opole City east of the Odra River (Text-fig. 5). The exploitation of marls at Groszowice II Quarry started at the beginning of 1990s. The section comprises the Middle and lower Upper Turonian and is about 7.5 m thick (Text-fig. 6).

Middle Turonian

Bed Gr02, thickness unknown, the visible upper part of the layer is 0.4 m, light-grey, moderately hard marls.

Middle/Upper Turonian boundary

Beds Gr01–Gr1, 1.15 m thick, a pronounced, hard, white-grey marl layer with numerous pyritic concretions. This layer corresponds to Bed Od16 and Bo7 at Odra II Quarry and Bolko Quarry, respectively. Consequently, the boundary between the *Inoceramus lamarcki* Zone (Middle Turonian) and *Inoceramus perplexus* Zone (Upper Turonian) is situated in these layers.

Upper Turonian, Inoceramus perplexus *Zone*

Bed Gr2, thickness 0.6 m, grey moderately hard marls.

Bed Gr3, Clay Layer I, thickness 0.25 m, well-individualized clayey marl horizon, corresponds to Bed Od17 at Odra II Quarry and Layer Bo8 at Bolko Quarry.

Beds Gr4–Gr6, succession of thick and moderate layered grey marls, with moderate intercalation of dark grey, clayey marls (20 cm in thick). In Bed Gr4 occur rare, strongly broken echinoids of *Micraster*. At the bottom of Bed Gr6 inoceramid debris was noted.

Bed Gr7, Clay Layer II, thickness 0.2 m, well-individualized clayey marl horizon, corresponds to Bed Od20 at Odra II Quarry and Bed Bo12 at Bolko Quarry.

The Beds Gr02–Gr7 belong to the upper part of the Lower Marls Unit of ALEXANDROWICZ & RADWAN (1973).

Beds Gr8–Gr9, thickness 2.4 m, light-grey to slightly yellow, hard, layered marly limestones, irregular layered clearly visible on weathered faces. At the bottom of Bed Gr8 are visible non-continuous layers of inoceramid debris. The sequence belong to the Marly Limestones Unit of ALEXANDROWICZ & RADWAN (1973).

Groszowice: The Groszowice outcrop is situated about 200 m north of Groszowice II Quarry (Text-figs 5, 6), in the southern face of a cuesta. The section comprises the Upper Turonian, about 5 m thick (Text-fig. 6). The sequence represents the strongly weathered Marly Limestone Unit of ALEXANDROWICZ & RADWAN (1973).

Upper Turonian

Beds Go07, Go06, Go05, Go04, thickness 1.6 m, light-grey to slightly yellow, hard, layered marly limestones, irregular layered clearly visible on weathered faces.

Bed Go03, Clay Layer III, thickness 0.07 m, clayey marl horizon, probably corresponds to Bed Od26 at Odra II Quarry and Bed Bo20 at Bolko Quarry.

Beds Go02, Go01, Go1, thickness 1 m, succession of thick layered (from 30 cm to 70 cm) light-grey to slightly yellow, hard, layered marly limestones, irregular layered clearly visible on weathered faces, with thin intercalation (5 cm) of dark grey, clayey marls. A single large specimen of *Micraster* (*M.*) *leskei* was found in Bed Go02.

Bed Go2, thickness 0.08 m, Clay Layer IV, thickness 0.07 m, clayey marl horizon, probably corresponds to Bed Od28 at Odra II Quarry and Bed Bo22 at Bolko Quarry.

Bed Go3, thickness 0.35 m, light-grey to slightly yellow, hard, layered marly limestones, irregularly layered clearly visible on weathered faces. At the bottom of the layer there is an echinoid acme with predominant *Micraster* (*M.*) *leskei*, represented by small- and medium-sized forms, and *Plesiocorys* (*Sternotaxis*) *plana*. In the middle part of the layer echinoids are rare. With echinoids at the bottom of the layer occur numerous heteromorph ammonites of the genera *Hyphantoceras*, *Scaphites*, *Bostrychoceras* similar to Odra II and I, and Bolko quarries.

Bed Go4, thickness 0.1 m, dark-grey, clayey marls.

Beds Go5–Go6, thickness 2.1 m, light-grey to slightly yellow, hard, layered marly limestones, irregular layered clearly visible on weathered faces. Rare *Micraster* (*M.*) *leskei*, represented by small- and medium-sized forms, and *Plesiocorys* (*Sternotaxis*) *plana* were found here.

Folwark Quarry: The upper part of the Cretaceous sequence near Opole is exposed in the large Folwark Quarry lying between the villages of Chrząszczyce and Folwark, west of the Odra River (Text-fig. 5). The section comprises the Upper Turonian and Lower Coniacian (WALASZCZYK 1992, WALASZCZYK & WOOD 1998) about 44 m thick (Text-fig. 6).

Upper Turonian

Beds A**05, A04, A03, A02, A01, A1**, thickness 8.9 m, succession of thick layered, light-grey, hard, marly limestones, with very thin intercalation of grey/dark-grey, marls/clayey marls. The particular rhythms are not very regular, and they vary in thickness from 30 to 220 cm in the light-grey marly limestones. The marls/clayey marls intercalations are more regular and attain no more than few millimetres. Echinoids are quite frequent in these layers but are in very poor state of preservation. Rare *Plesiocorys* (*Sternotaxis*) sp. occur at the bottom of Bed A03. Common fragments of *Echinocorys* sp. together with inoceramid and brachiopod debris appear in layer A01. Numerous echinoids of the genera *Plesiocorys*, *Echinocorys* and *Micraster* were found in the rubble of marly limestone, but only rare specimens are relatively well-preserved to be identified as *Plesiocorys* (*Sternotaxis*) *plana* and *Micraster* (*M.*) *normanniae*.

Beds A05, A04, A03, A02, A01, A1 belong to upper part of the Marly Limestone Unit (Text-fig. 6) of ALEXANDROWICZ & RADWAN (1973)

Beds A2–A27 and C1–C13, thickness 15.1 m, succession of moderate and thick layered grey or light-grey, moderately hard marls, with thin, or moderate or thick intercalation of dark grey, clayey marls. The particular rhythms are not very regular, and they vary in thickness from 20 to 105 cm in the grey or light-grey marls, and from 4 cm to 70 cm in dark grey, clayey marl layers. In the middle part of Bed A15 was found a single, deformed *Echinocorys gravesi* and frequent ossicles of the genus *Echinocorys*. Bed A17 yields frequent strongly compacted echinoids of the genus *Echinocorys*. In the topmost Bed A25 appears inoceramid debris and in Bed A26 occur echinoids, so strongly deformed that it is possible to determine only that they belong to family Holasteridae. The overlying Bed A27 yields numerous fragments of test of *Micraster* and inoceramid debris. A single *Echinocorys gravesi* was found in

Bed C7. It is the highest occurrence of this species in the Opole area. Quite rare fragments of tests of *Micraster* sp. occur in Bed C9. The topmost part of Beds A3, A5, A11, A19, A21, and A25 is strongly bioturbated.

The Beds A2–A27 and C1–C13 belong to the lower part of the Upper Marls Unit of ALEXANDROWICZ & RADWAN (1973).

Bed C14, thickness 0.5 m, light-grey, moderately hard marls, in the upper part of the Bed C14 there is an inoceramid acme with a rich assemblage of *Cremnoceramus walt. waltersdorfensis* (ANDERT), and coincident with the base of the Lower Coniacian (WALASZCZYK 1992). In this layer, besides inoceramids, occurs *Micraster* (*M.*) *normanniae* BUCAILLE.

Lower Coniacian

Bed C15, thickness 0.12 m, dark grey, slightly clayey marls.

Beds C16–C20, thickness 4.2 m, succession of thick layered grey or light-grey, moderately hard marls. The particular rhythms vary in thickness from 35 to 140 cm. Rare *Micraster* (*M.*) *cortestudinarium* occur in Beds C19 and C20

Beds C21–C33, thickness 6 m, succession of moderate and thick layered light-grey, hard slightly siliceous marls, with thin, or moderate, intercalation of dark grey, clayey marls. The particular rhythms are not very regular, and they vary in thickness from 30 to 120 cm in the light-grey siliceous marls, and from 8 to 28 cm in dark grey, clayey marl layers. In Beds C21 and C29 occurs much inoceramid debris.

Bed C34, thickness 0.6 m, light-grey, hard, slightly siliceous marls. In the middle part of the layer occur inoceramid debris with fragments of thick shell of up to 1 cm in size. At the top of the layer there is echinoid acme (Text-fig. 6) with *Micraster* (*M.*) *cortestudinarium*, represented by numerous deformed tests. Echinoids are quite regularly distributed and in life position; seem to indicate bioevent *M. cortestudinarium*.

Beds C35–C40, thickness 2.15 m, succession of thick layered light-grey, hard slightly siliceous marls, with thin intercalation of dark grey, clayey marls. The particular rhythms vary in thickness from 45 to 85 cm in the light-grey siliceous marls, and from 5 to 10 cm in dark grey, clayey marl layers.

Bed C41, thickness 1.4 m, light-grey, hard, slightly siliceous marls, the layer showing a tripartite character emphasized by very thin, irregular intercalations of clayey marls. Between these intercalations, in the middle part of the layer, numerous *Micraster* (*Gibbaster*) *brevis* were found (Text-fig. 6); interpreted as a bioevent. Inoceramid debris appear above the echinoid horizon.

Beds C42–C49, thickness 3.7 m, succession of moderate and thick layered light-grey, hard slightly siliceous marls, with thin intercalation (from 6 to 10 cm) of dark grey, clayey marls. The particular rhythms vary in thickness from 20 to 110 cm in the light-grey siliceous marls. Rare echinoids, poorly preserved, were found in this part of the section, representing *Echinocorys* and *Micraster* (Text-fig. 6). At the top of layer C43 occurs *Micraster* (*M.*) *cayeusi*, rarely noted (ERNST & SCHULZ 1974).

Beds C14–C49 belong to the upper part of the Upper Marls Unit of ALEXANDROWICZ & RADWAN (1973).

Bed C50, thickness 0.5 m, the hard siliceous marls are overlain by soft, clayey marls of the Upper Clayey Unit of ALEXANDROWICZ & RADWAN (1973) exposed in the north-western corner of the quarry. Rare *Echinocorys* ex gr. *scutata*, morphotype "*vulgaris*" were found in this layer.

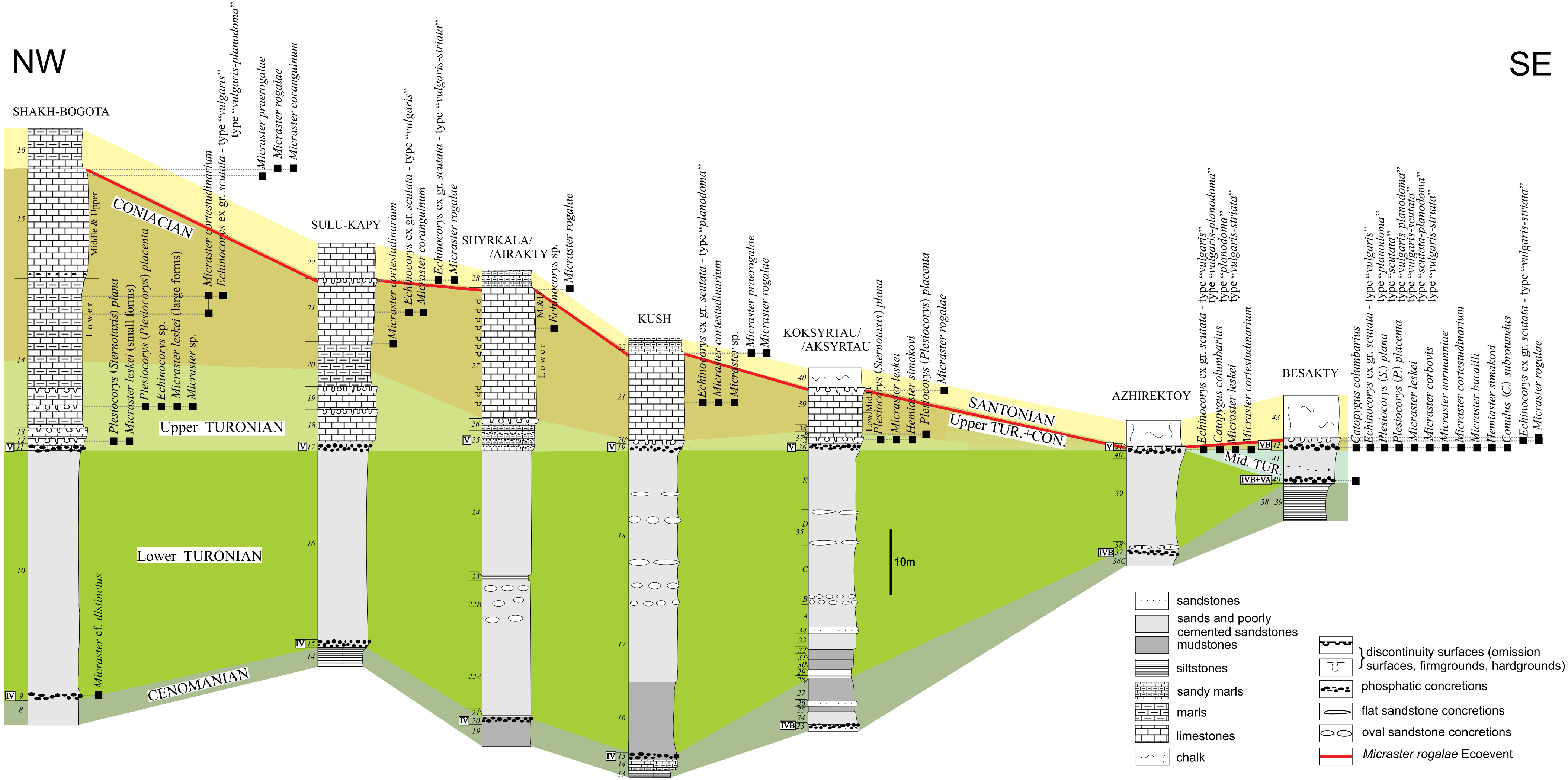


Fig. 3. Correlation of Turonian and Coniacian deposits of Mangyshlak (after MARCINOWSKI & *al.* 1996) with distribution of irregular echinoid taxa. The change of clastic deposits to carbonate rocks occurs at the lower/upper Turonian boundary

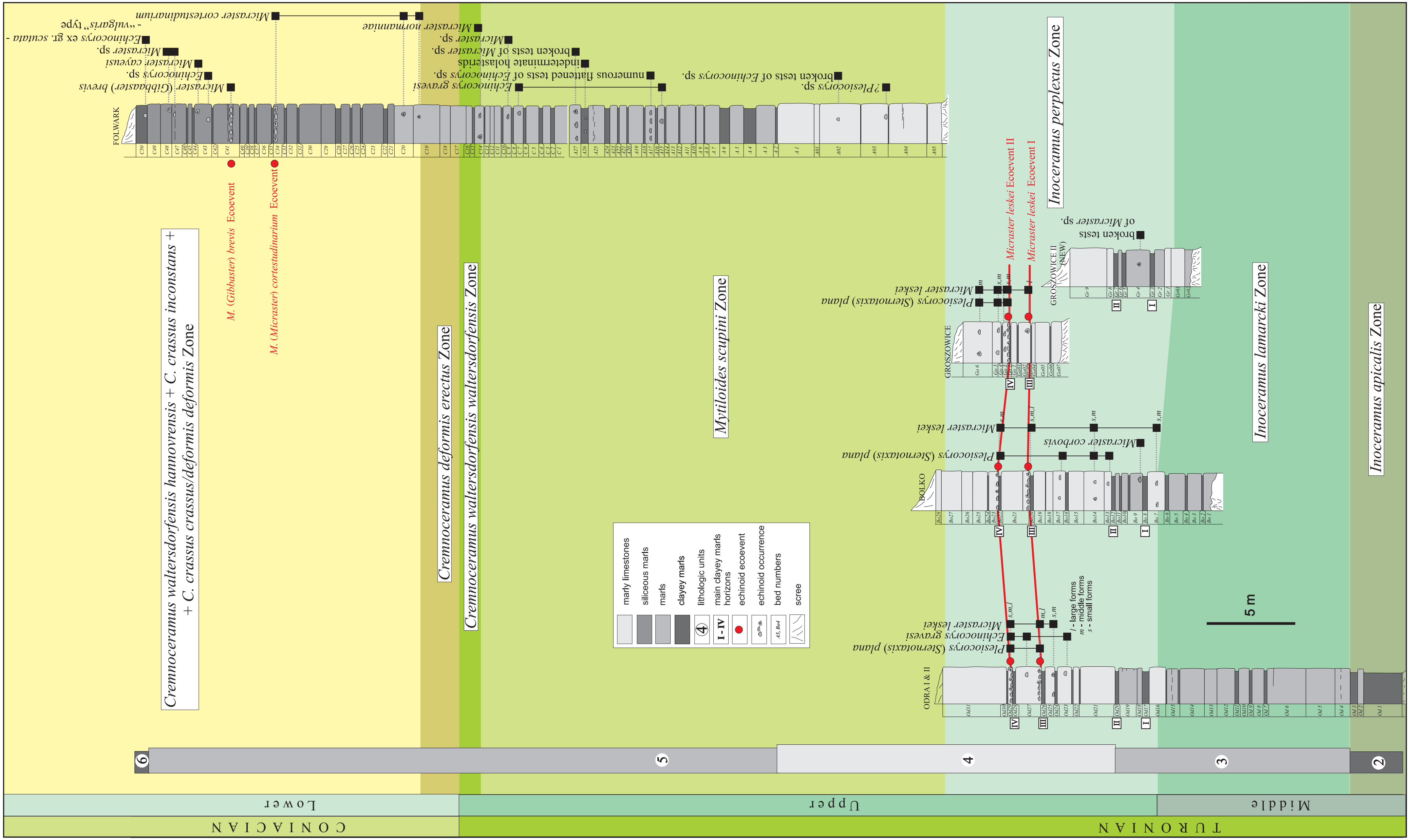


Fig. 6. Correlation of Turonian and Coniacian deposits in Opole with distribution of irregular echinoid taxa. At the middle/upper Turonian boundary appears the first bed with increasedlime components; lithology units 2 – 6 after ALEXANDROWICZ & RADWAN (1973), and ALEXANDROWICZ (1974); biostratigraphy after WALASZCZYK (1992); WALASZCZYK & WOOD (1998, 1999); WALASZCZYK & COBBAN (2000); KENNEDY & WALASZCZYK (2004)

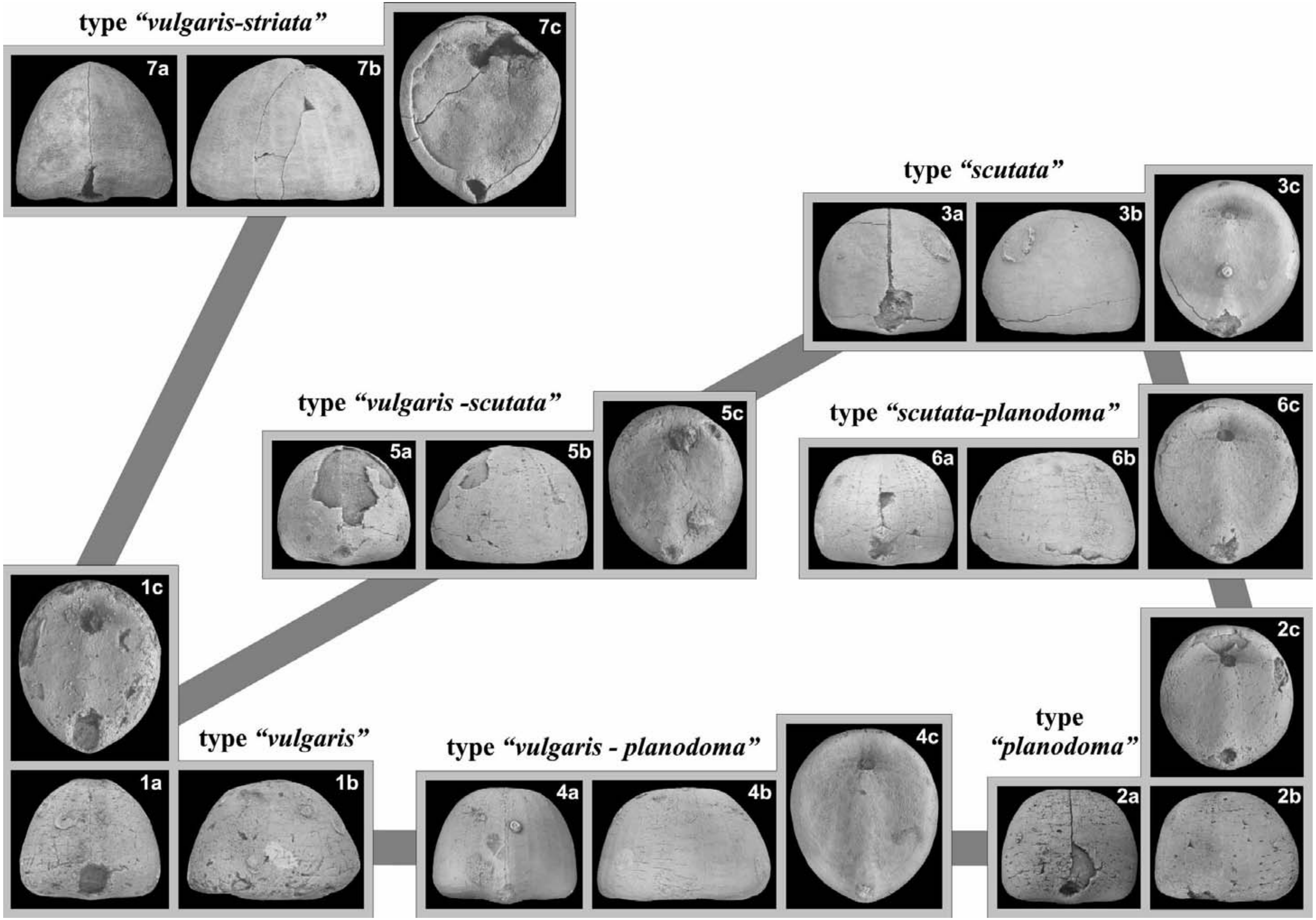


Fig. 20. Morphological variability of *Echinocorys* ex gr. *scutata* LESKE, 1778 (compare ERNST & SCHULZ 1974) from stratigraphically condensed upper Turonian-Coniacian deposits of Besakty, Mangyshlak; the scheme is not related to time; a – posterior side, b – lateral side, c – adoral side

PLATE 1

A – Lower Turonian-lower Santonian succession in Shakh-Bogota Valley, view to the south; a – light-green, fine-grained sands and sandstones, lower Turonian; b – firmground, upper Turonian; c – hardground, upper Turonian, d – rhythmites with alternating well-bedded marls and limestones; upper Turonian; e – rhythmites with alternating well-bedded marls and limestones in lower part and white limestones in upper part, Coniacian; f – rhythmites with alternating well-bedded marls and limestones; Santonian. Red line indicates the *Micraster rogalae* Bioevent in topmost Coniacian.

B – Upper Turonian succession (Beds 11-13, and Bed 14 in part) with levels yielding numerous irregular echinoids in Shakh-Bogota Valley.


A
f
e
d
c
b
a

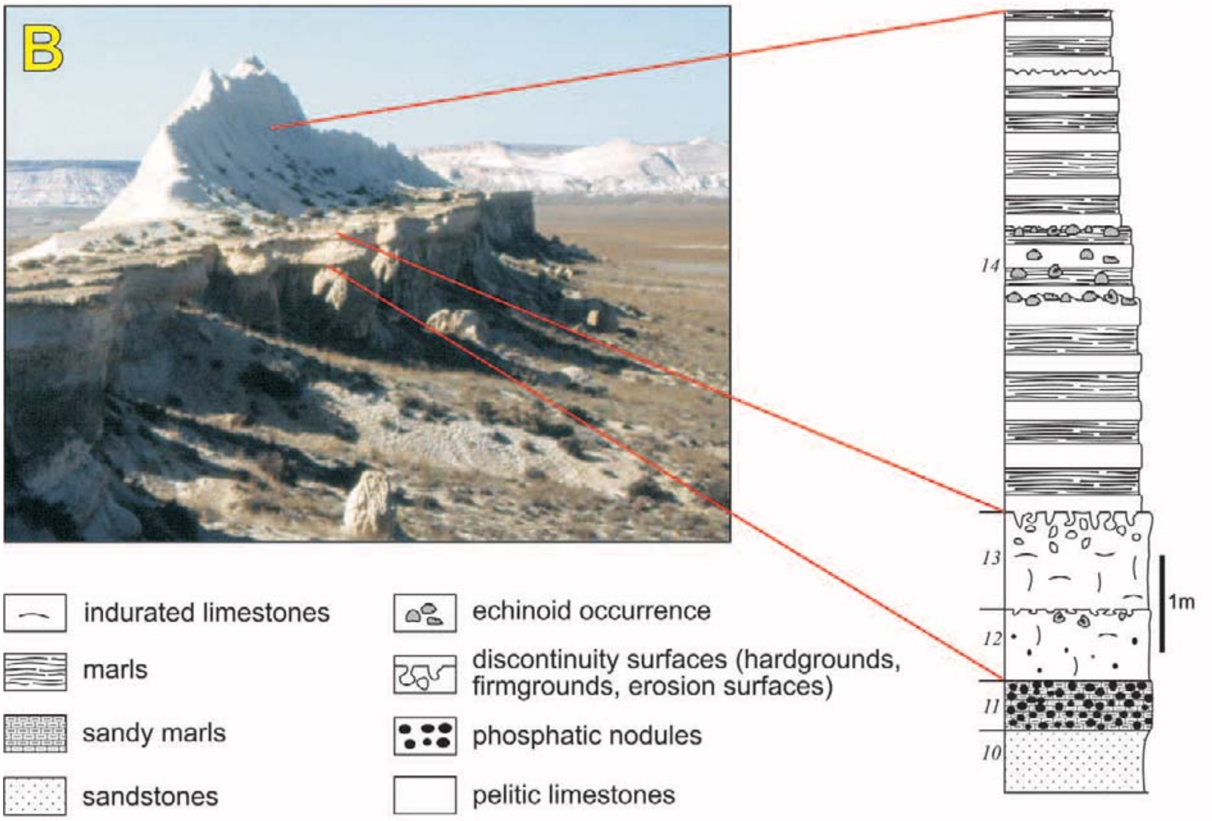

B
14
13
12
11
10
1m
indurated limestones
marls
sandy marls
sandstones
echinoid occurrence
discontinuity surfaces (hardgrounds, firmgrounds, erosion surfaces)
phosphatic nodules
pelitic limestones

PLATE 2

Stratigraphically condensed upper Turonian-Coniacian deposits (Bed 41) and Santonian white chalk at Azhirektoy

A – View to the south; a – strongly cemented and ferrigenous hardground with fault disturbances within the Phosphatic Horizon V, Upper Turonian – Coniacian; b – white chalk, Santonian.

B – Close-up views of the hardground, arrowed are numerous phosphatized echinoids in the lower part of Bed 41.

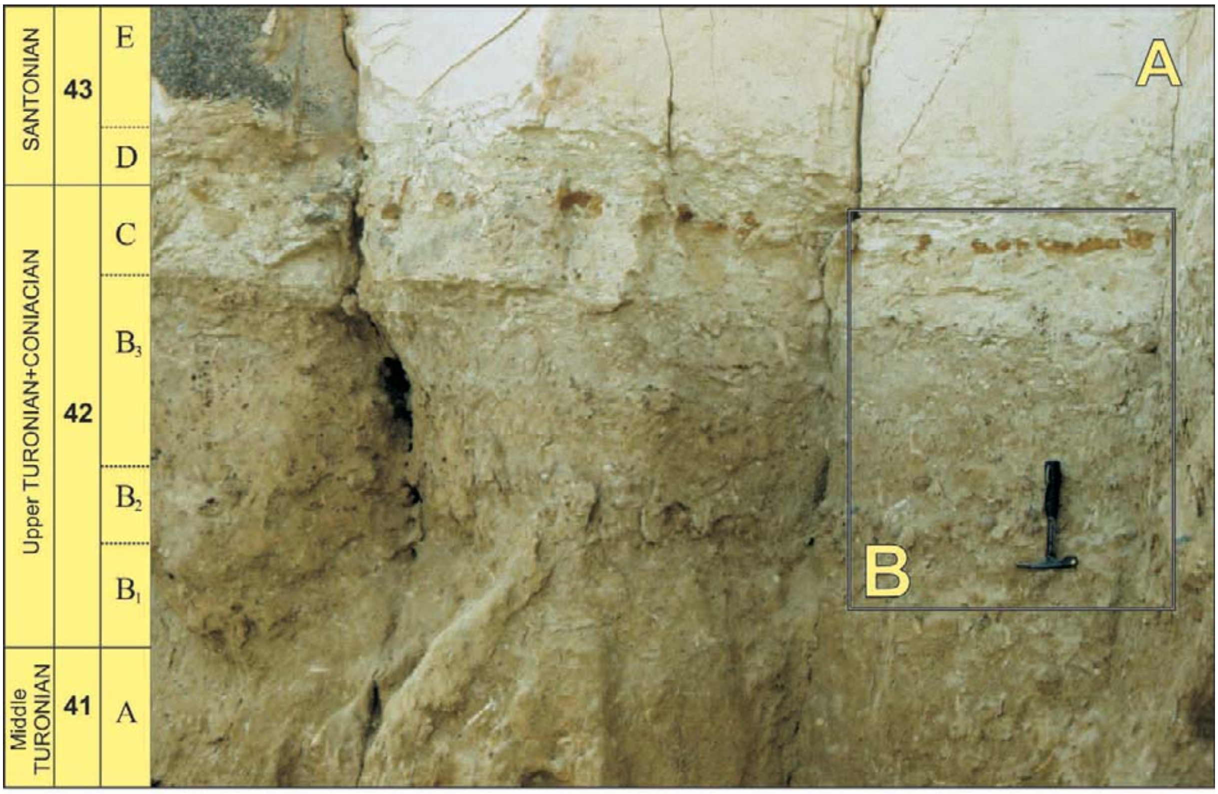

A
b
a
B

PLATE 3

Part of the hardground zone at Besakty

A – distribution of hardground zone for lithologic units, corresponded to Text-fig. 4, with stratigraphic column.

B – distribution of echinoids in Unit B, with numerous fossils in Subunit B_2.



Thalassinoides - type burrows

Ophiomorpha - type burrows

phosphorite

echinoids

hiatus concretions with phosphatic and/or ferruginous mineralization

PLATE 4

General view of middle and upper Turonian deposits at Bolko Quarry (year 1995)

A – lower working level, I and II main clay horizons, view of the north-eastern wall

B – upper working level, III and IV main clay horizons, view of the eastern wall; e – arrowed numerous occurrence of the *Micraster leskei* at the bottom of Bed Bo 21 (I *Micraster leskei* Bioevent) and bottom of Bed Bo 23 (II *Micraster leskei* bio-event), L – large ammonite (*Lewesiceras*) at the top of Bed Bo 27.

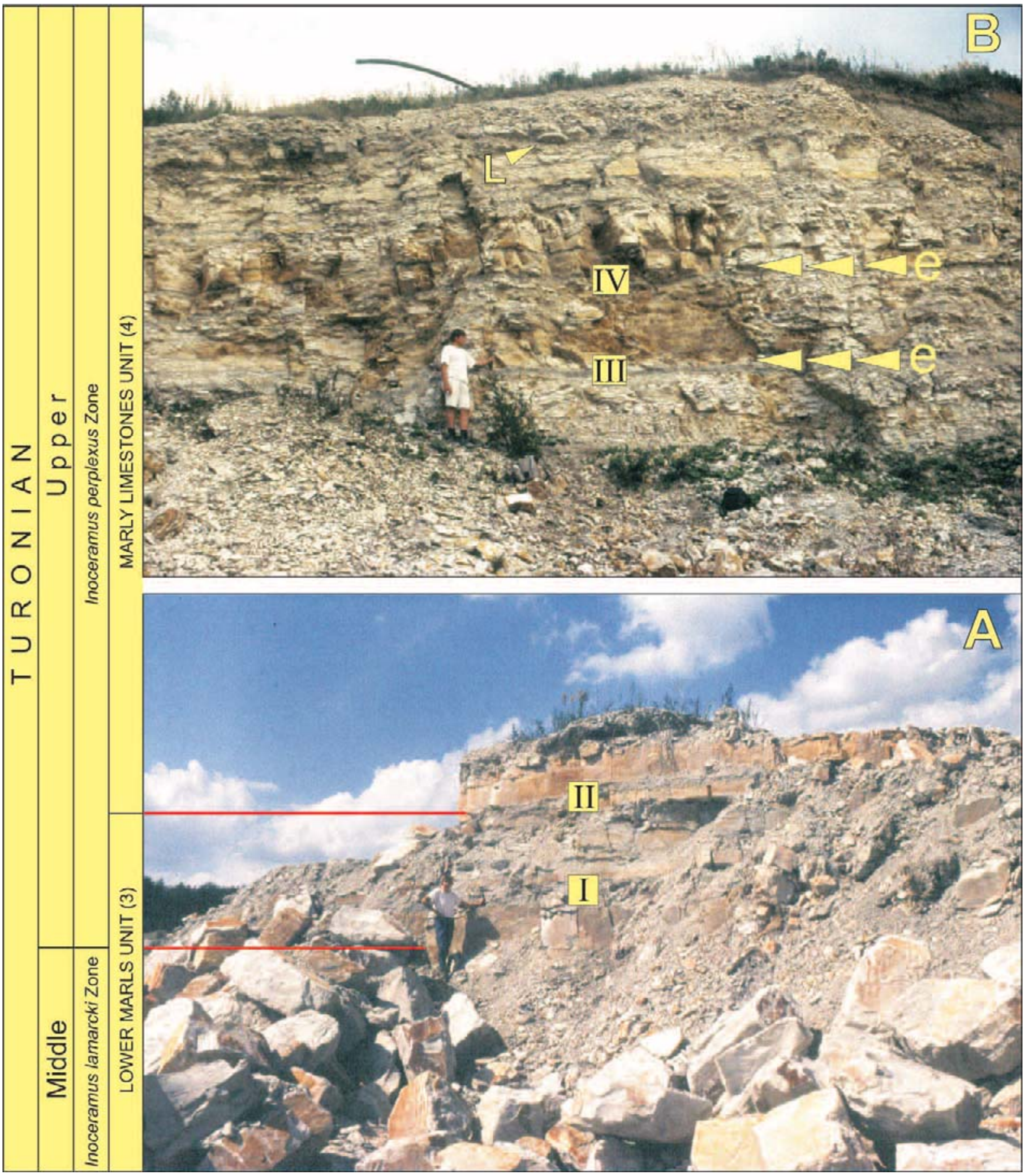
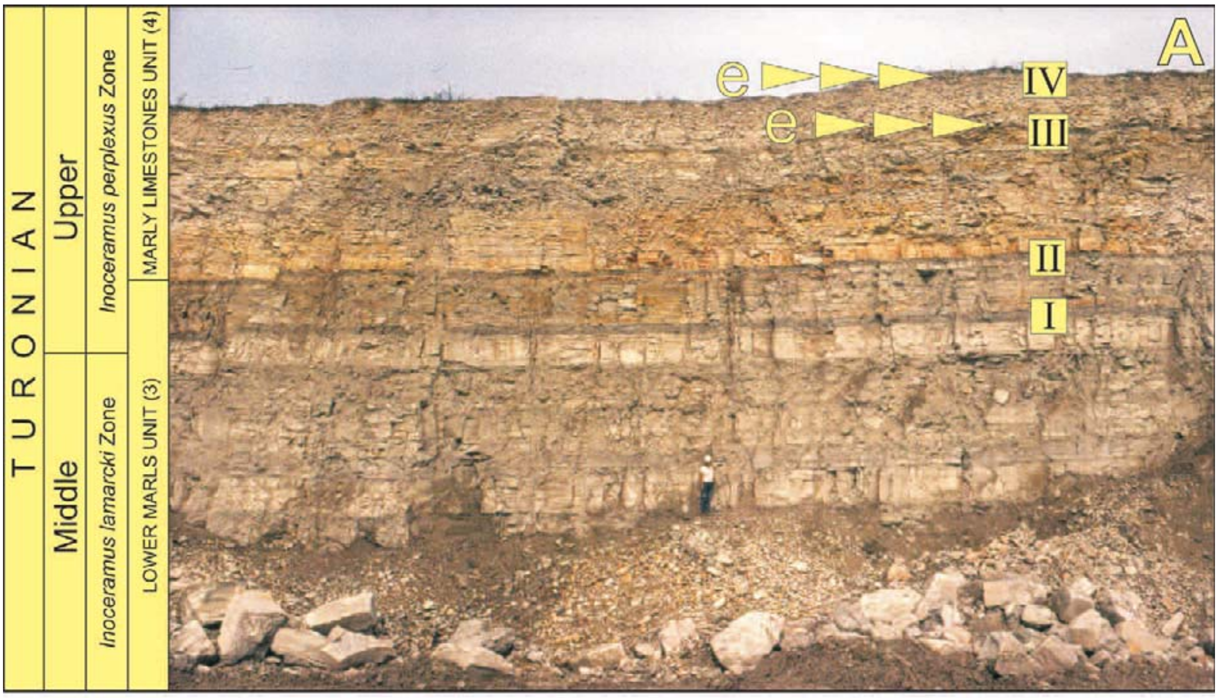

TURONIAN
Upper
Middle
Inoceramus perplexus Zone
Inoceramus lamarcki Zone
MARLY LIMESTONES UNIT (4)
LOWER MARLS UNIT (3)
B
L
IV
III
e
e
A
II
I

PLATE 5

A – view of the northern wall of Odra II Quarry (year 1995) with middle and upper Turonian deposits; I, II, III, IV – main clay horizons; arrowed horizons with numerous *Micraster leskei*.

B – lower working level at Folwark Quarry (year 1995); boundary between Marly Limestone Unit (MLU – Lithologic Unit 4) and Upper Marly Unit (UPU – Lithologic Unit 5); September 1994.


TURONIAN
Middle
Upper
Inoceramus lamarcki Zone
Inoceramus perplexus Zone
LOWER MARLS UNIT (3)
MARLY LIMESTONES UNIT (4)
A
e
e
IV
III
II
I


B
UMU
MLU

PLATE 6

1 – *Conulus* (*Conulus*) *subrotundus* MANTELL, 1822; IGPUW/E/01/001, probably upper Turonian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak; × 1.

2, 3 – *Catopygus columbarius* (LAMARCK, 1816); IGPUW/E/01/004, probably upper Turonian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak; 1 – × 1; 2 – × 2.

4-7 – *Hemiaster simakovi* SCHMIDT, in SCHMIDT & SIMAKOV, 1953; 4, 5 – IGPUW/E/01/727, probably upper Turonian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak; 4 – × 1; 5 – × 2; 6, 7 – IGPUW/E/01/731, upper Turonian of Aksyrtau, Mangyshlak; 6 – × 1; 7 – × 2.

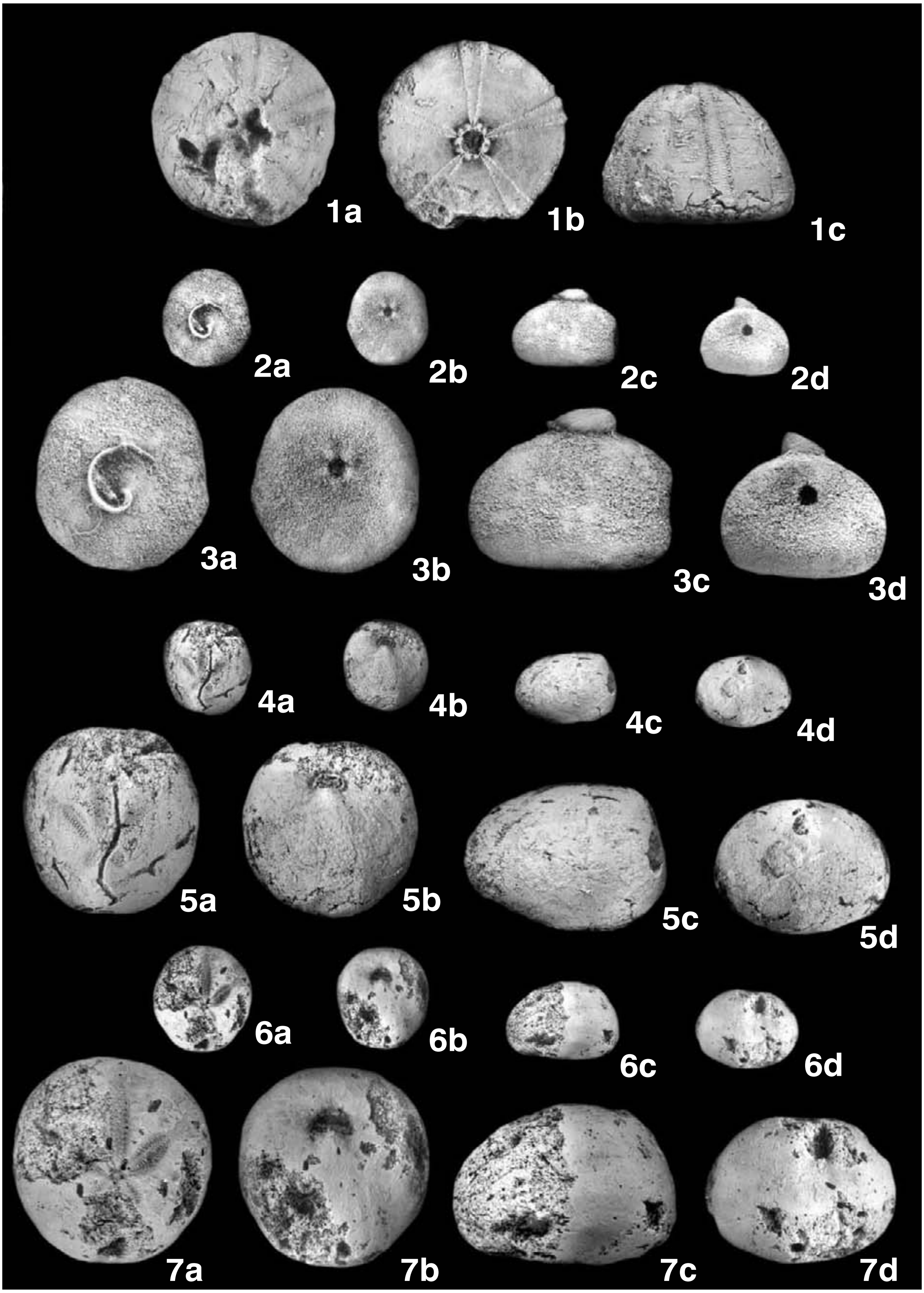

1a
1b
1c
2a
2b
2c
2d
3a
3b
3c
3d
4a
4b
4c
4d
5a
5b
5c
5d
6a
6b
6c
6d
7a
7b
7c
7d

PLATE 7

Plesiocorys (*Sternotaxis*) *plana* (MANTELL, 1822)

1 – IGPUW/E/01/009, upper Turonian of Aksyrtau, Mangyshlak.

2 – IGPUW/E/01/140, upper Turonian (*Mytiloides scupini* Zone) of Folwark, Opole.

3 – MZ VIII Ee 1466, upper Turonian of Trzciągowo, Wolin, Poland.

4 – IGPUW/E/01/072, upper Turonian (*Inoceramus perplexus* Zone) of Bolko, Opole.

a – aboral side, b – adoral side, c – lateral side, d – posterior side; arrows indicate position of periproct; all figures are natural size

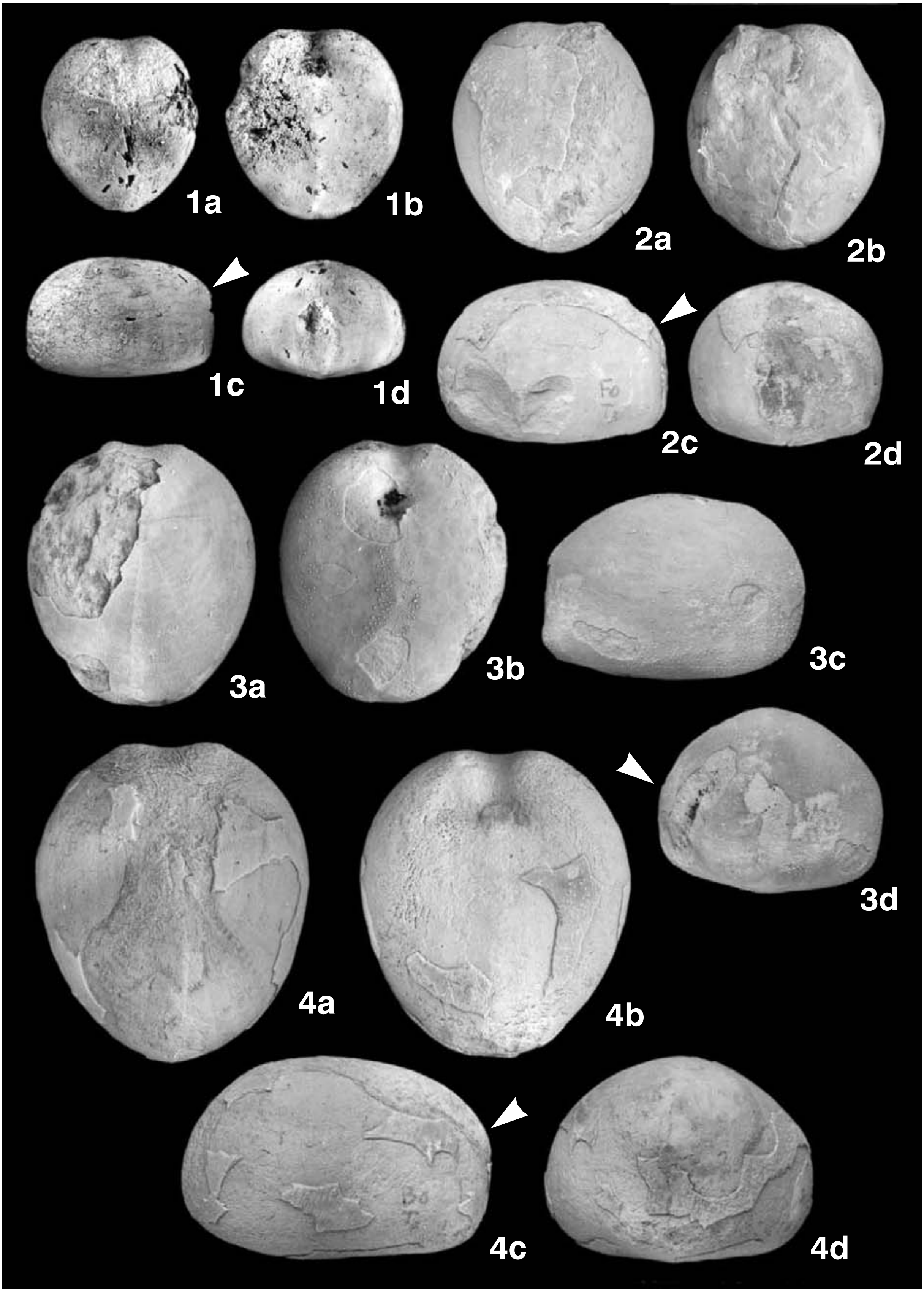

1a
1b
2a
2b
1c
1d
2c
2d
3a
3b
3c
3d
4a
4b
4c
4d

PLATE 8

1, 2 – *Plesiocorys (Plesiocorys) placenta* (AGASSIZ, in AGASSIZ & DESOR, 1847), probably upper upper Turonian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak; 1 – IGPUW/E/01/156; 2 – IGPUW/E/01/158

3 – *Echinocorys gravesi* (DESOR, in AGASSIZ & DESOR, 1847), IGPUW/E/01/160, upper Turonian (*Inoceramus perplexus* Zone) of Odra I.

a – aboral side, b – adoral side, c – lateral side, d – posterior side; arrows indicate position of periproct; all figures are natural size

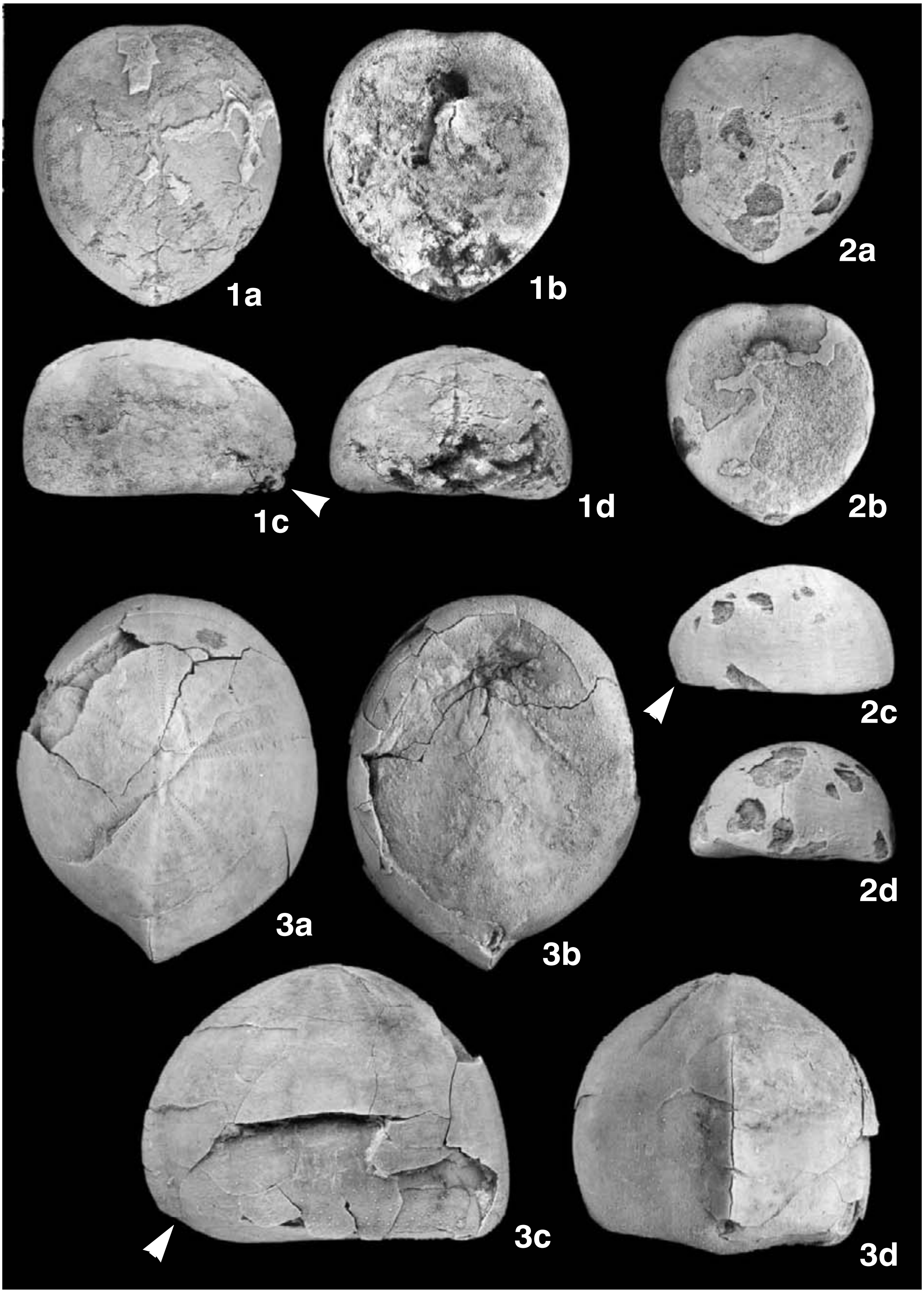

1a
1b
2a
1c
1d
2b
2c
3a
3b
2d
3c
3d

PLATE 9

1, 2 – *Echinocorys gravesi* (DESOR, in AGASSIZ & DESOR, 1847), upper Turonian (*Inoceramus perplexus* Zone) of Odra II; 1 – IGPUW/E/01/161; 1a – aboral side, 1b – adoral side, 1c – lateral side, 1d – posterior side; 2 – IGPUW/E/01/162; lateral side.

3 – *Echinocorys* ex gr. *scutata* LESKE, 1778; IGPUW/E/01/375, "*vulgaris*" morphotype; lower Coniacian (*Cremnoceramus waltersdorfenis hannovrensis* + *C. crassus inconstans* + *C. crassus crassus*/ *deformis deformis* zones) of Folwark; adoral side.

Arrows indicate position of periproct; all figures are natural size

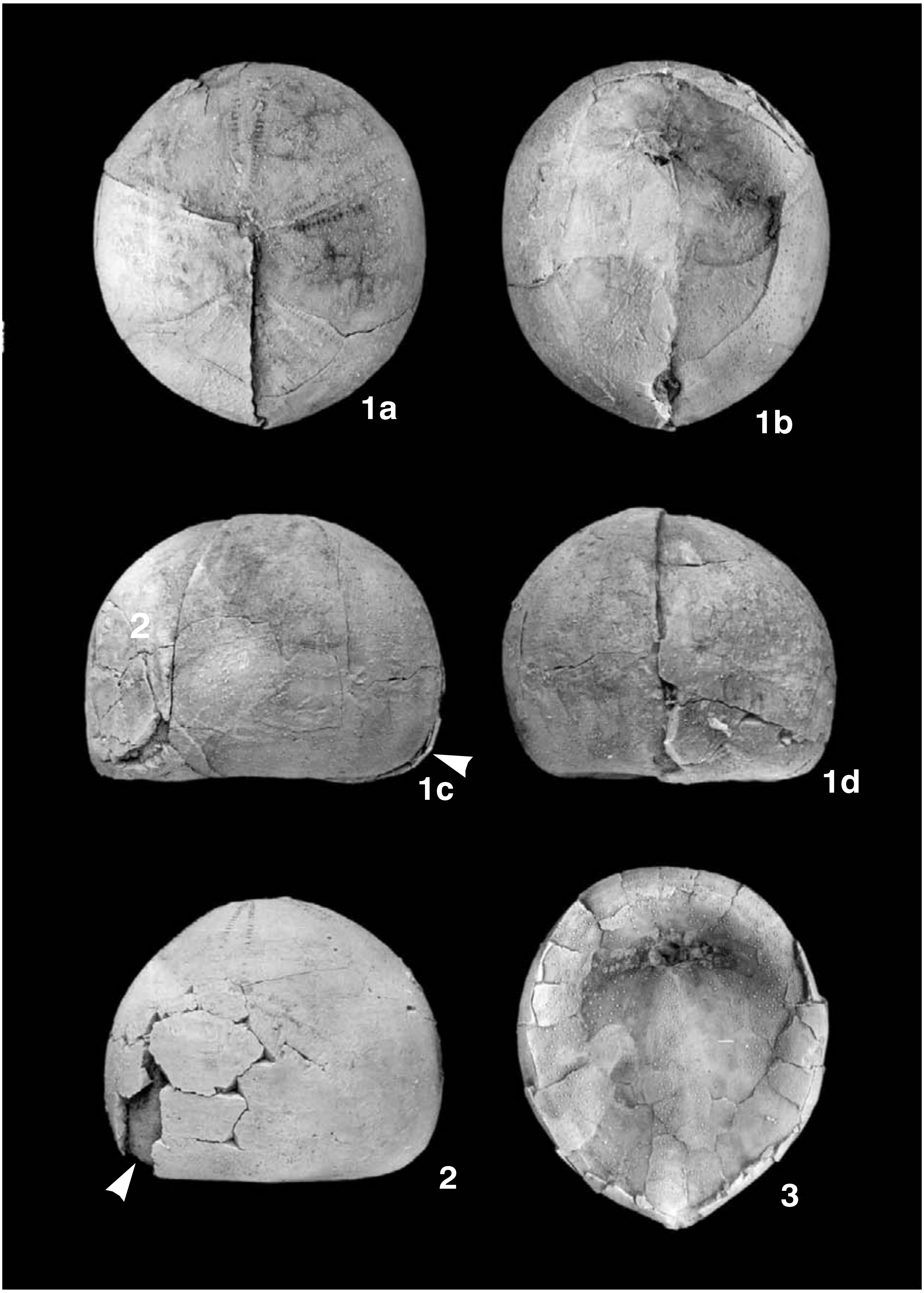

1a
1b
2
1c
1d
2
3

PLATE 10

1, 2 – *Echinocorys gravesi* (DESOR, in AGASSIZ & DESOR, 1847); Turonian; 1 – MZ VIII Ee 1502/2; les Petites Dalles, northern France; 2 – MZ VIII Ee 1464/1; Wicko of Wolin, Poland.

3 – *Echinocorys* ex gr. *scutata* LESKE, 1778; IGPUW/E/01/180, "*vulgaris*" morphotype; probably middle Coniacian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak.

a – aboral side, b – adoral side, c – lateral side, d – posterior side; arrows indicate position of periproct; all figures are natural size

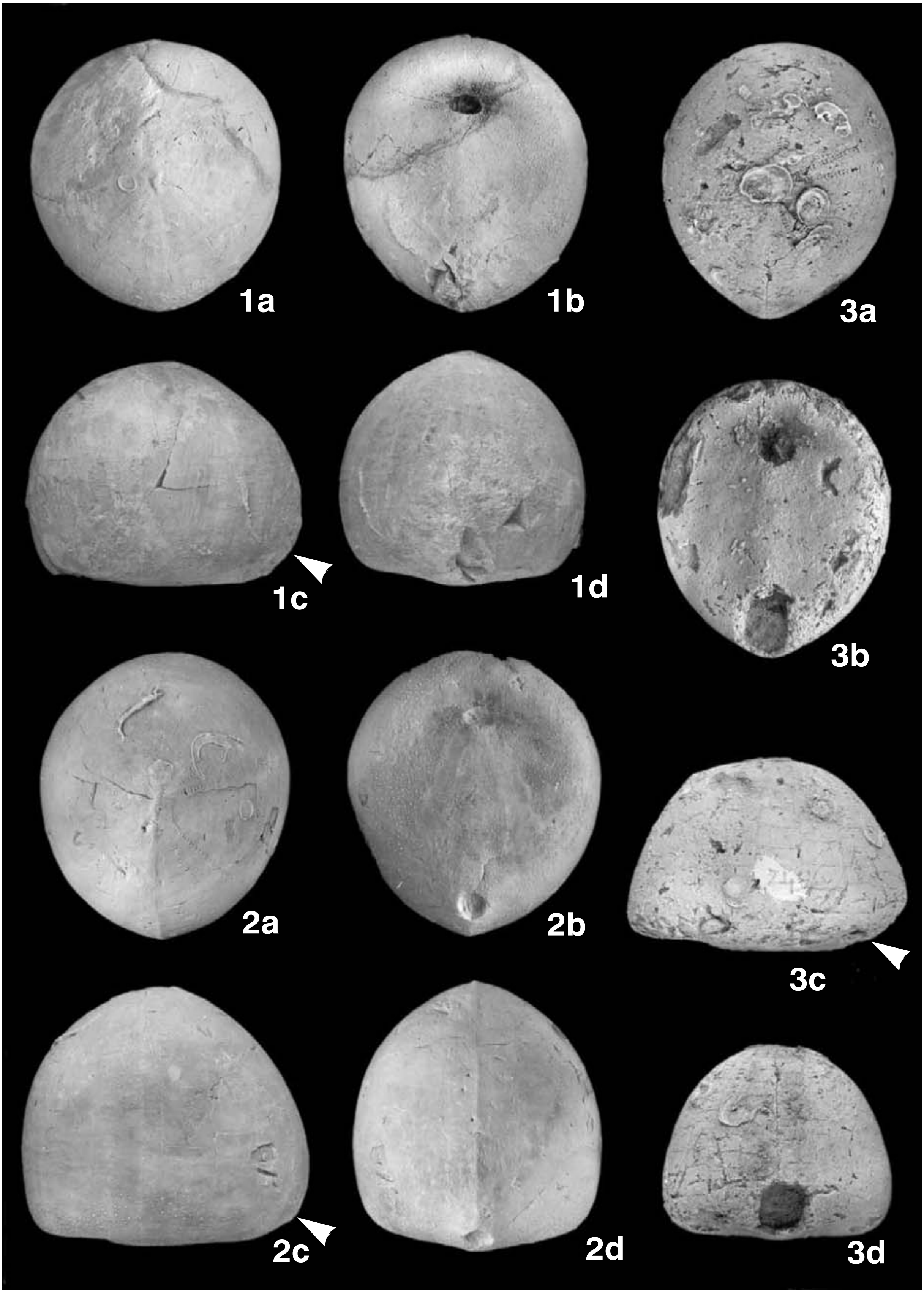

1a
1b
3a
1c
1d
3b
2a
2b
3c
2c
2d
3d

PLATE 11

Echinocorys ex gr. *scutata* LESKE, 1778; "*vulgaris*" morphotype

1, 2 – Probably middle Coniacian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak; 1 – IGPUW/E/01/208; 2 – IGPUW/E/01/189.

3 – IGPUW/E/01/368; Middle Coniacian of Shakh-Bogota, Mangyshlak.

a – aboral side, b – adoral side, c – lateral side, d – posterior side; arrows indicate position of periproct; all figures are natural size

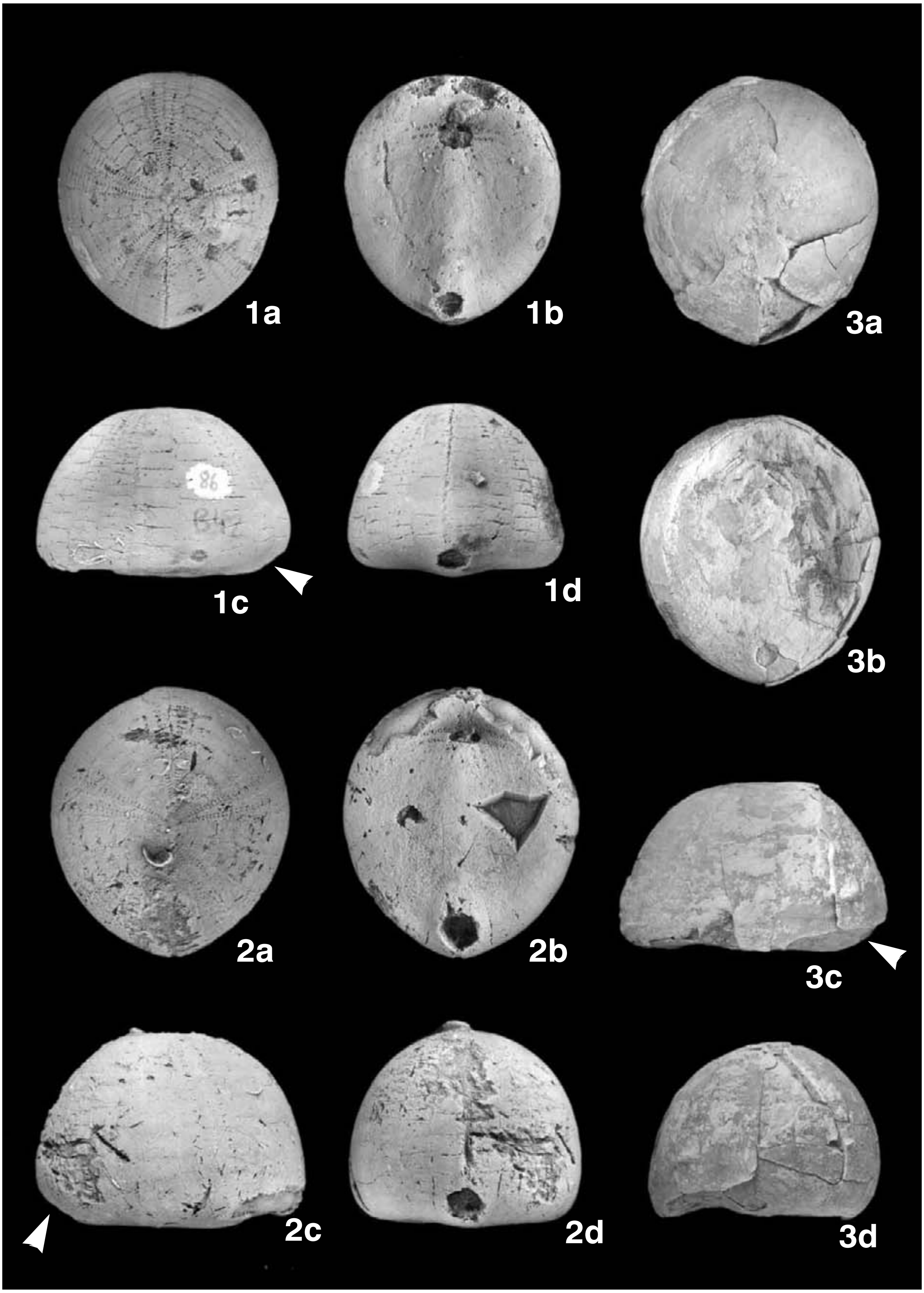

1a
1b
3a
86
1c
1d
3b
2a
2b
3c
2c
2d
3d

PLATE 12

Echinocorys ex gr. *scutata* LESKE, 1778; probably middle Coniacian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak;

1-3 – "*planodoma*" morphotype; 1 – IGPUW/E/01/309; 2 – IGPUW/E/01/312; 3 – IGPUW/E/01/311

4 – IGPUW/E/01/332; "*scutata-planodoma*" intermediate morphotype, note *Ancistrocrania* on the lateral side.

a – aboral side, b – adoral side, c – lateral side, d – posterior side; arrows indicate position of periproct; all figures are natural size

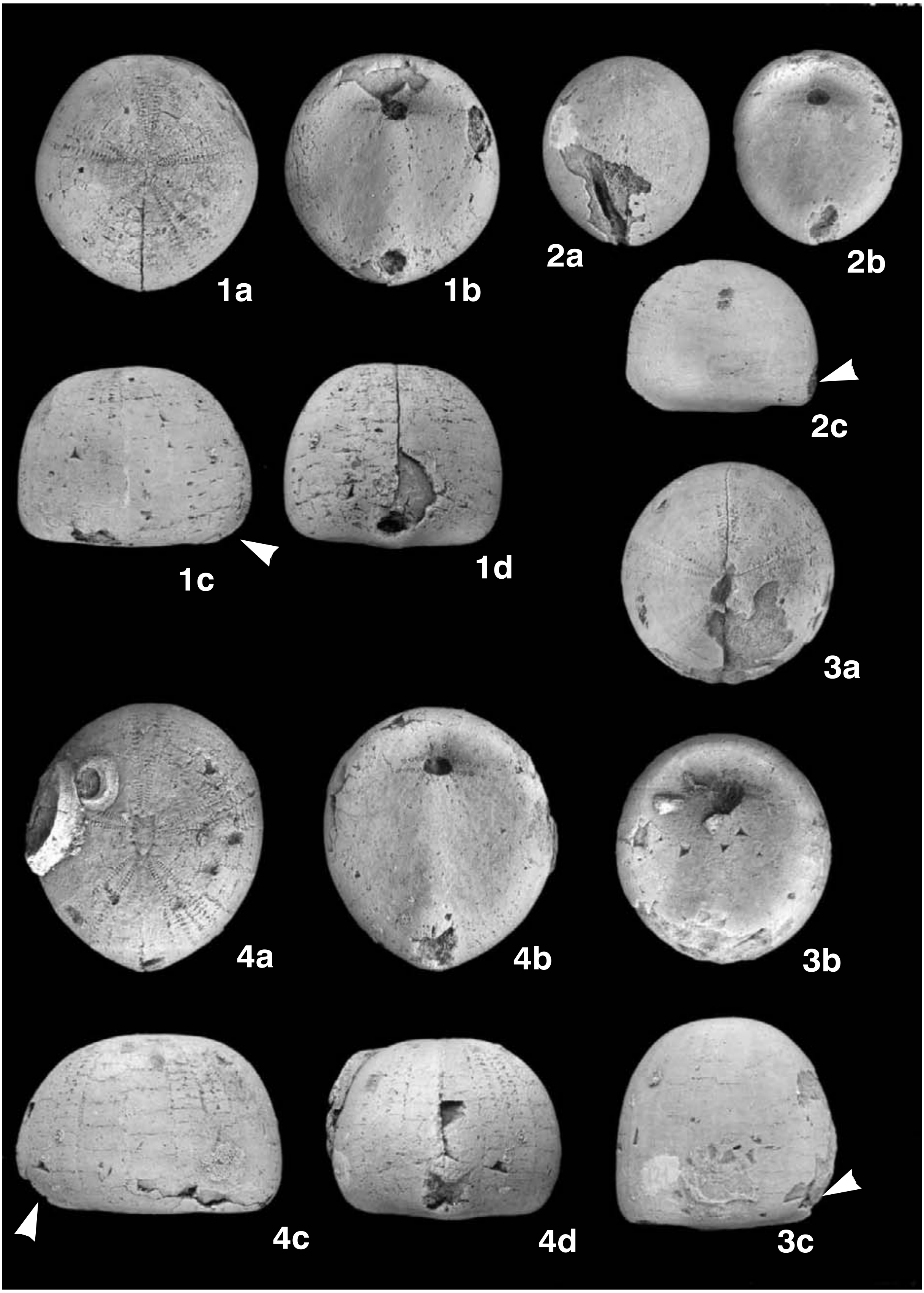

1a
1b
2a
2b
2c
1c
1d
3a
4a
4b
3b
4c
4d
3c

PLATE 13

Echinocorys ex gr. *scutata* LESKE, 1778; probably middle Coniacian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak

1-3 – "*scutata*" morphotype; 1 – IGPUW/E/01/327; 2 – IGPUW/E/01/318; 3 – IGPUW/E/01/322

4 – IGPUW/E/01/334; "*scutata-planodoma*" intermediate morphotype.

a – aboral side, b – adoral side, c – lateral side, d – posterior side; arrows indicate position of periproct; all figures are natural size

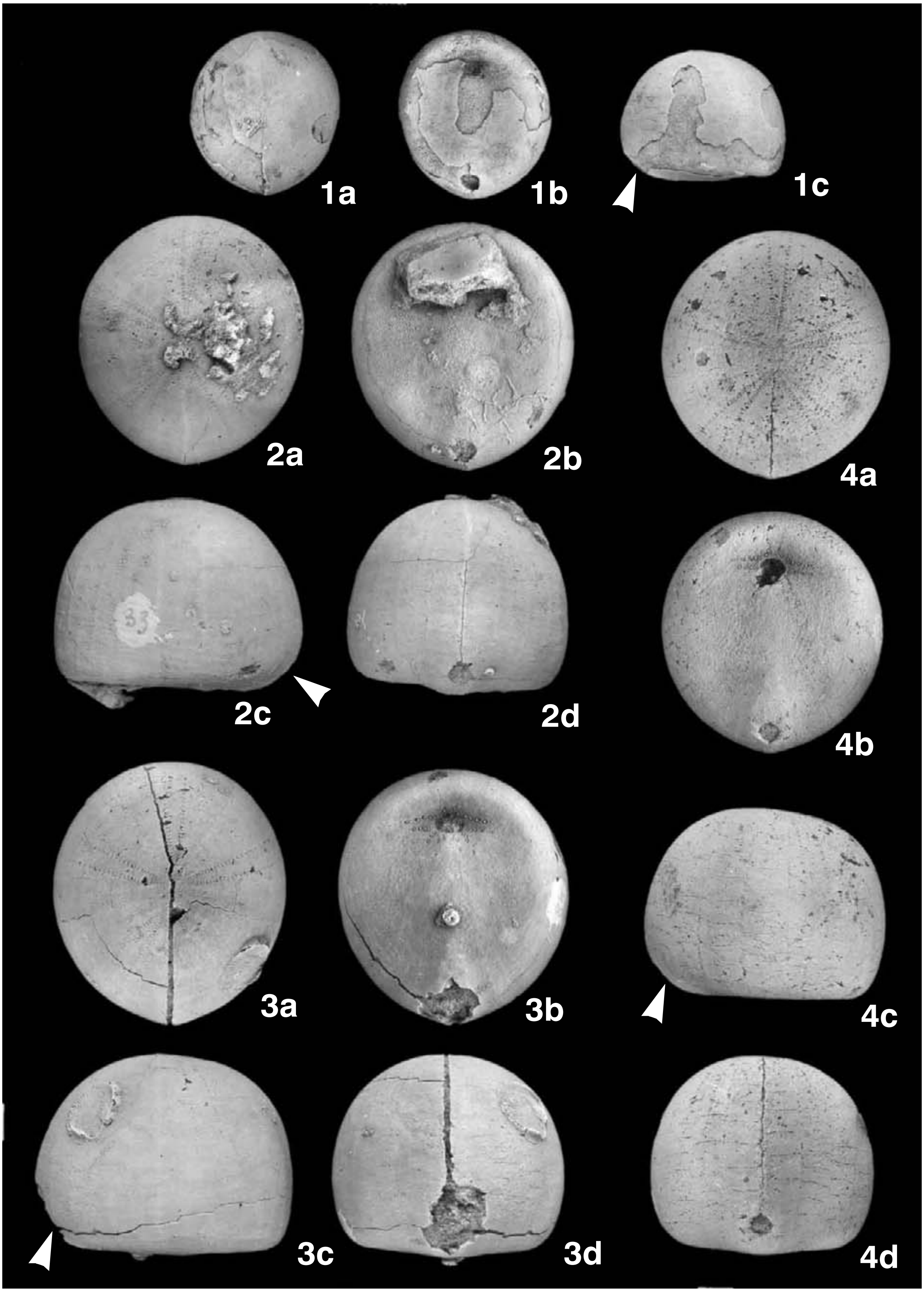

1a
1b
1c
2a
2b
4a
2c
2d
4b
3a
3b
4c
3c
3d
4d

PLATE 14

Echinocorys ex gr. *scutata* LESKE, 1778; "*vulgaris-planodoma*" intermediate morphotype

1-3 – Probably middle Coniacian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak; 1 – IGPUW/E/01/280; 2 – IGPUW/E/01/258; 3 – IGPUW/E/01/253

4 – IGPUW/E/01/369; middle Coniacian of Shakh-Bogota.

a – aboral side, b – adoral side, c – lateral side, d – posterior side; arrows indicate position of periproct; all figures are natural size

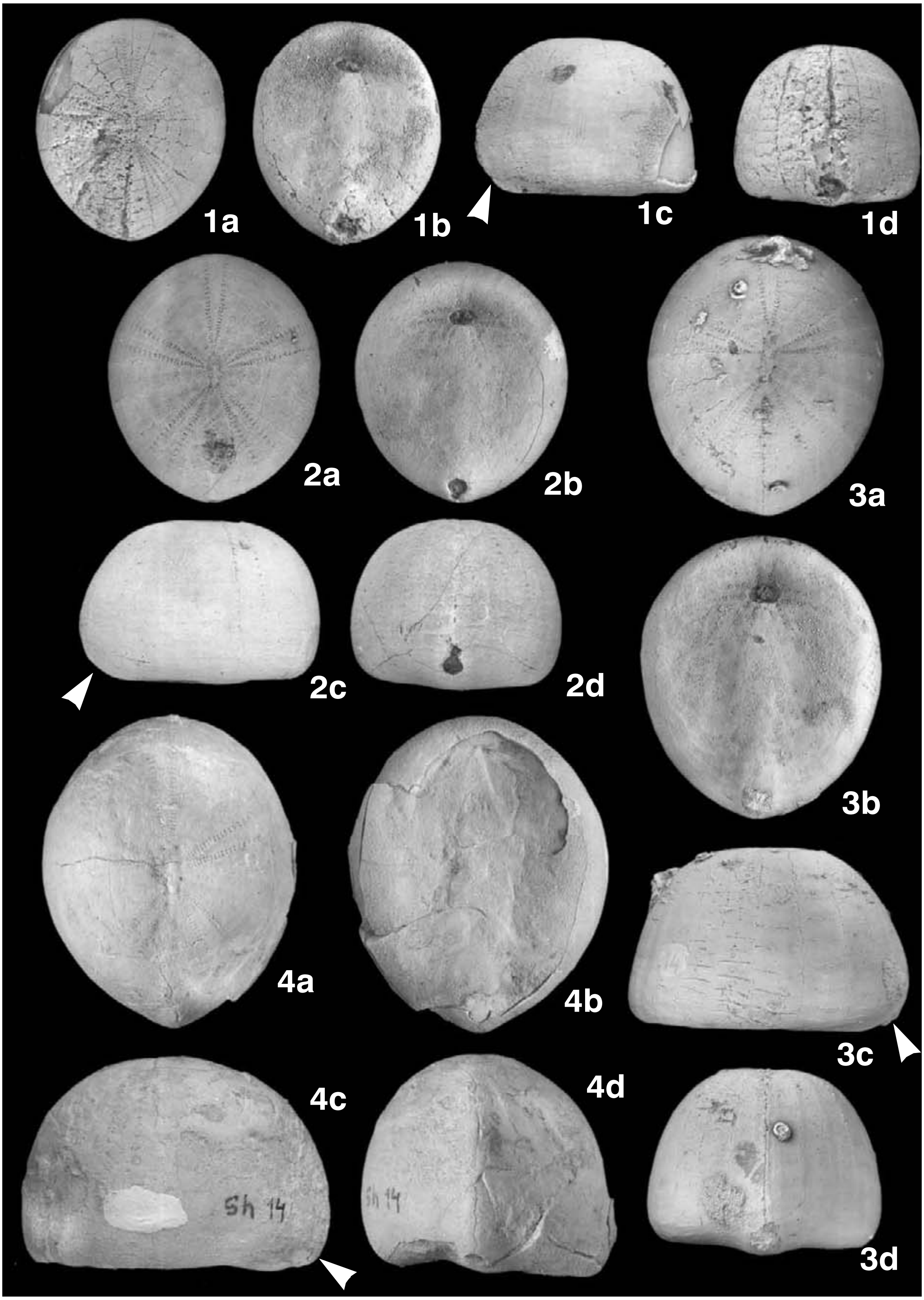

1a
1b
1c
1d
2a
2b
3a
2c
2d
3b
4a
4b
3c
4c
4d
Sh 14
Sh 14
14
3d

PLATE 15

Echinocorys ex gr. *scutata* LESKE, 1778; Besakty of Mangyshlak

1, 2 – "*vulgaris-scutata*" intermediate morphotype; probably middle Coniacian, condensed upper Turonian-Coniacian of Bed 42 (Unit B); 1 – IGPUW/E/01/290; 2 – IGPUW/E/01/286.

3 – IGPUW/E/01/344; "*vulgaris-striata*" intermediate morphotype; probably upper Coniacian, condensed upper Turonian-Coniacian of Bed 42 (Unit B_3).

a – aboral side, b – adoral side, c – lateral side, d – posterior side; arrows indicate position of periproct; all figures are natural size

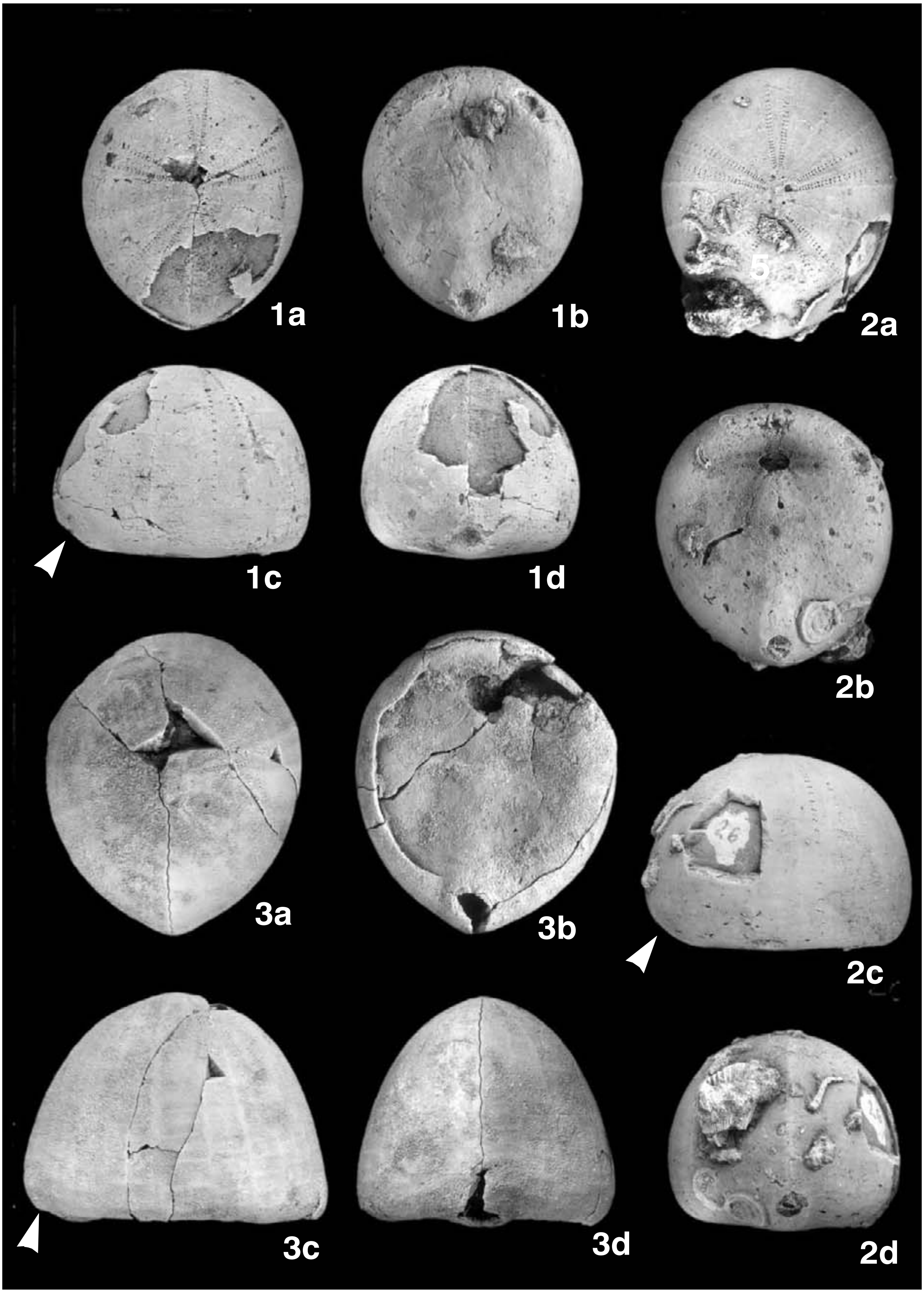

1a
1b
2a
1c
1d
2b
3a
3b
2c
3c
3d
2d

PLATE 16

Micraster (*Micraster*) *leskei* (DES MOULINS, 1837); examples of pseudotrapezoidal specimens from different regions of the North European Province

1 – IGPUW/E/01/381; upper Turonian of Shakh-Bogota, Mangyshlak.

2 – IGPUW/E/01/634; upper Turonian of Beachy Head, England.

3 – IGPUW/E/01/417; 3b – semiamphisternal inverse type of plastron; probably upper Turonian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak.

4 – IGPUW/E/01/393; probably upper Turonian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak.

5 – IGPUW/E/01/519; upper Turonian (*Inoceramus perplexus* Zone) of Odra II, Opole.

a – aboral side, b – adoral side, c – lateral side, d – posterior side; all figures are natural size

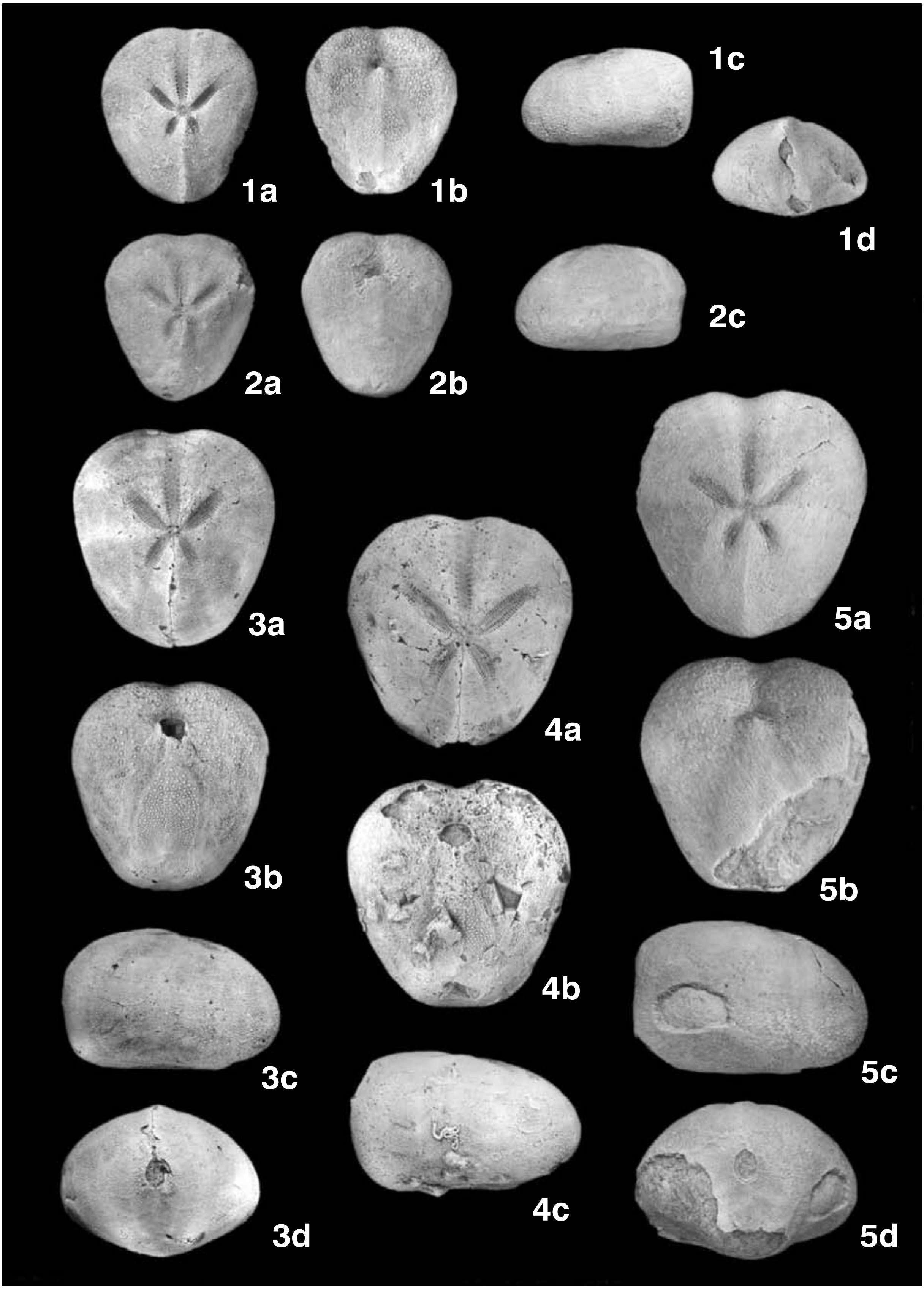

1a
1b
1c
1d
2a
2b
2c
3a
3b
3c
3d
4a
4b
4c
5a
5b
5c
5d

PLATE 17

Micraster (*Micraster*) *leskei* (DES MOULINS, 1837); examples of oval-trapezoidal specimens from different regions of the North European Province

1 – IGPUW/E/01/382; upper Turonian of Shakh-Bogota, Mangyshlak.

2 – IGPUW/E/01/489; probably upper Turonian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak.

3 – IGPUW/E/01/440; probably upper Turonian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak.

4 – IGPUW/E/01/566; upper Turonian (*Inoceramus perplexus* Zone) of Bolko, Opole.

5 – IGPUW/E/01/635; upper Turonian of Beachy Head, England.

a – aboral side, b – adoral side, c – lateral side, d – posterior side; all figures are natural size

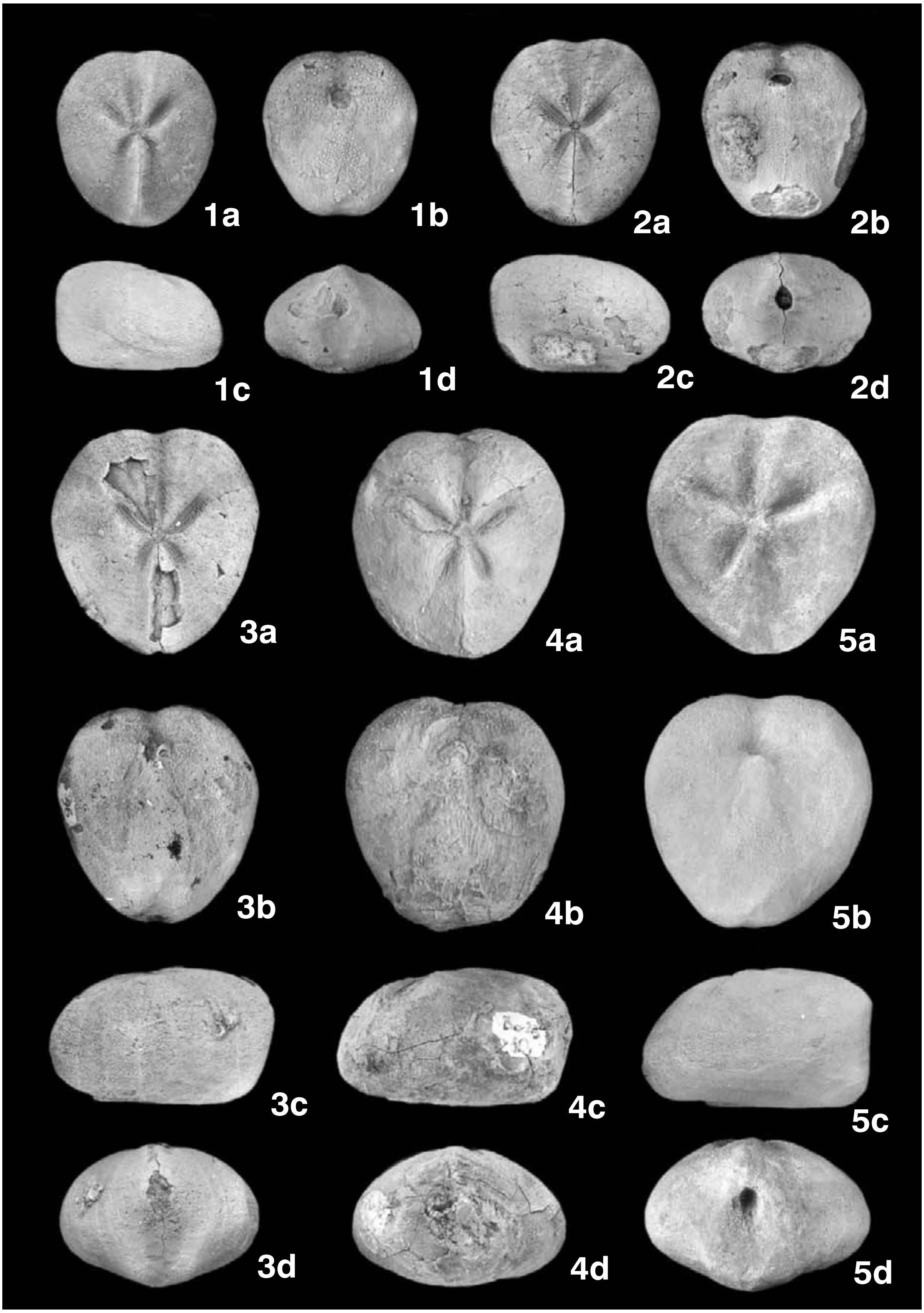

1a
1b
2a
2b
1c
1d
2c
2d
3a
4a
5a
3b
4b
5b
3c
4c
5c
3d
4d
5d

PLATE 18

Micraster (*Micraster*) *leskei* (DES MOULINS, 1837); examples of large morphologically similar specimens from different regions of the North European Province; upper Turonian

1 – IGPUW/E/01/632; Beachy Head, England; 1a – aboral side, 1b – adoral side, 1c – lateral side.

2 – IGPUW/E/01/558; *Inoceramus perplexus* Zone of Bolko, Opole; 2a – aboral side, 2b – lateral side.

3 – IGPUW/E/01/384; Shakh-Bogota, Mangyshlak; adoral side.

All figures are natural size

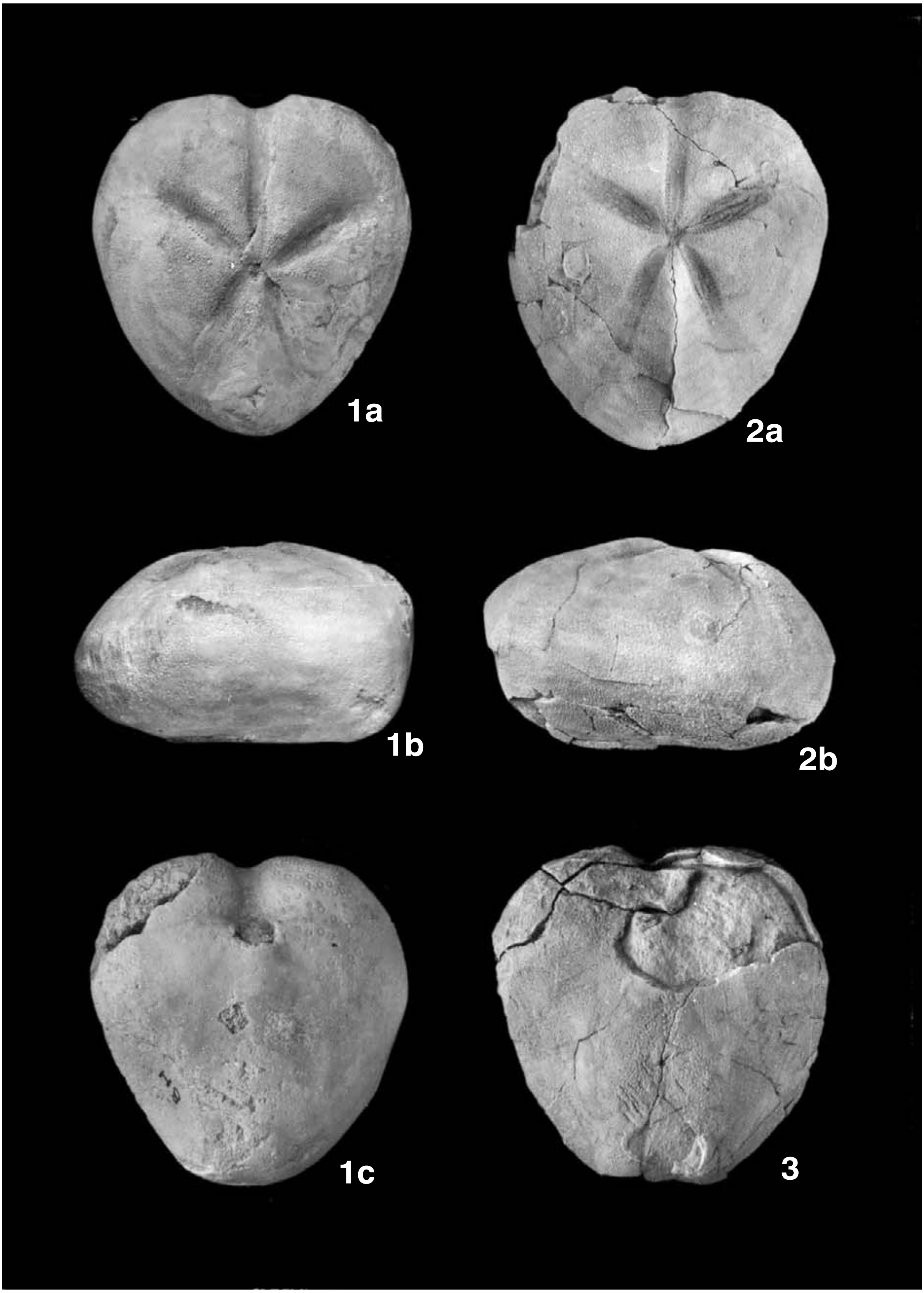

1a
2a
1b
2b
1c
3

PLATE 19

Micraster (*Micraster*) *leskei* (DES MOULINS, 1837)

1 – IGPUW/E/01/614; upper Turonian (*Inoceramus perplexus* Zone) at Groszowice, Opole.

2-5 – Probably upper Turonian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak; 2 – IGPUW/E/01/494

3-6 – Examples of specimens with pseudotrapezoidal ambitus and various lateral profiles from different regions of the North European Province; 3 – IGPUW/E/01/460, specimen with carina; 4 – IGPUW/E/01/450, specimen with oval lateral profile; 5 – IGPUW/E/01/453, tall specimen with convex aboral side; 6 – IGPUW/E/01/559, tall specimen with maximum height at apical disc; upper Turonian, (*Inoceramus perplexus* Zone) of Bolko, Opole.

a – aboral side, b – adoral side, c – lateral side, d – posterior side; all figures are natural size

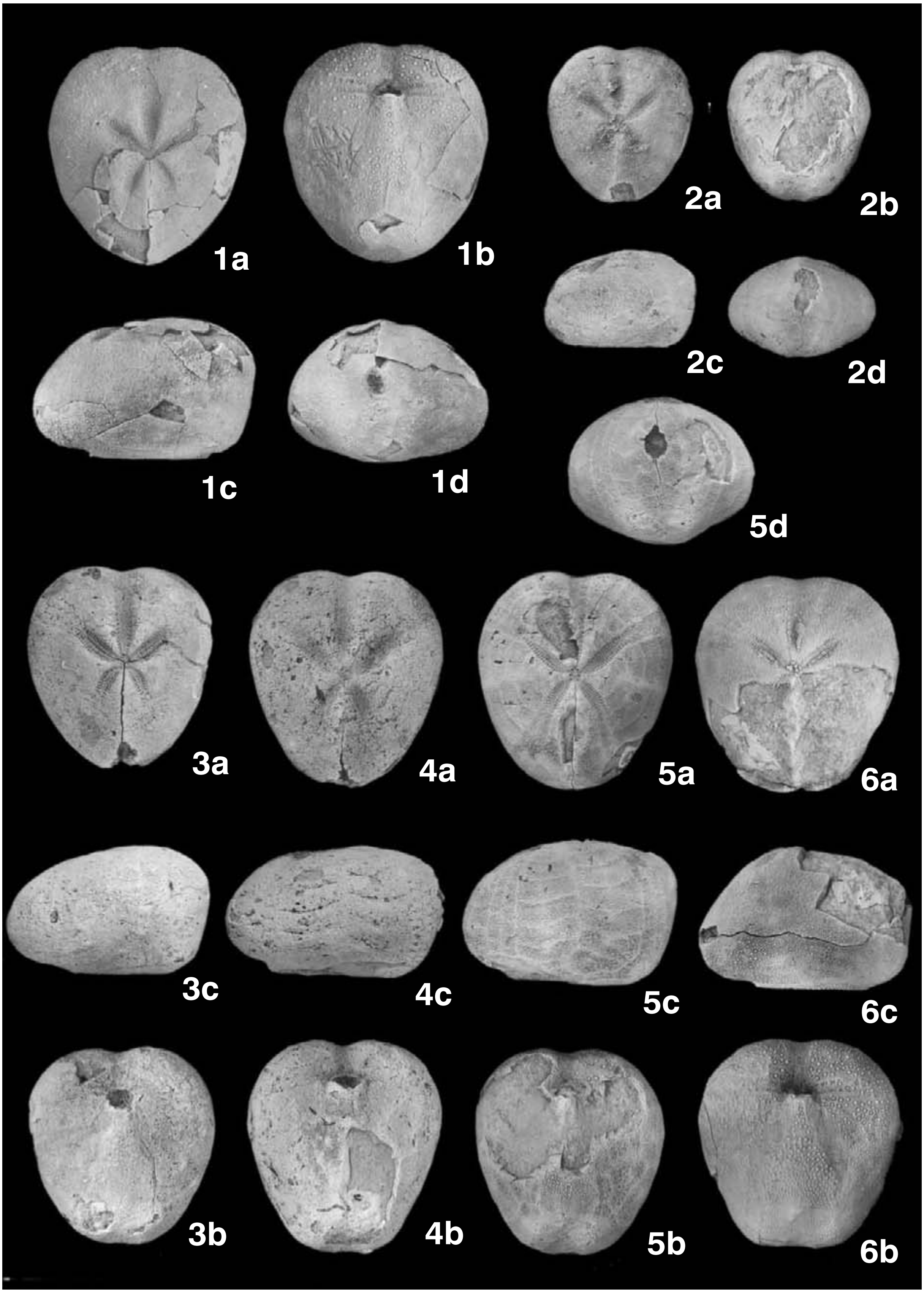

1a
1b
2a
2b
2c
2d
1c
1d
5d
3a
4a
5a
6a
3c
4c
5c
6c
3b
4b
5b
6b

PLATE 20

Micraster (*Micraster*) *leskei* (DES MOULINS, 1837); examples of specimens with oval-trapezoidal ambitus and various lateral profiles; probably upper Turonian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak

1 – IGPUW/E/01/455, specimen with slightly convex lateral profile

2 – IGPUW/E/01/474, specimen with convex lateral profile

3 – IGPUW/E/01/438, another specimen with convex lateral profile

4 – IGPUW/E/01/419, specimen with carina in lateral profile

5 – IGPUW/E/01/420, specimen with flattened lateral profile

a – aboral side, b – adoral side, c – lateral side, d – posterior side; all figures are natural size

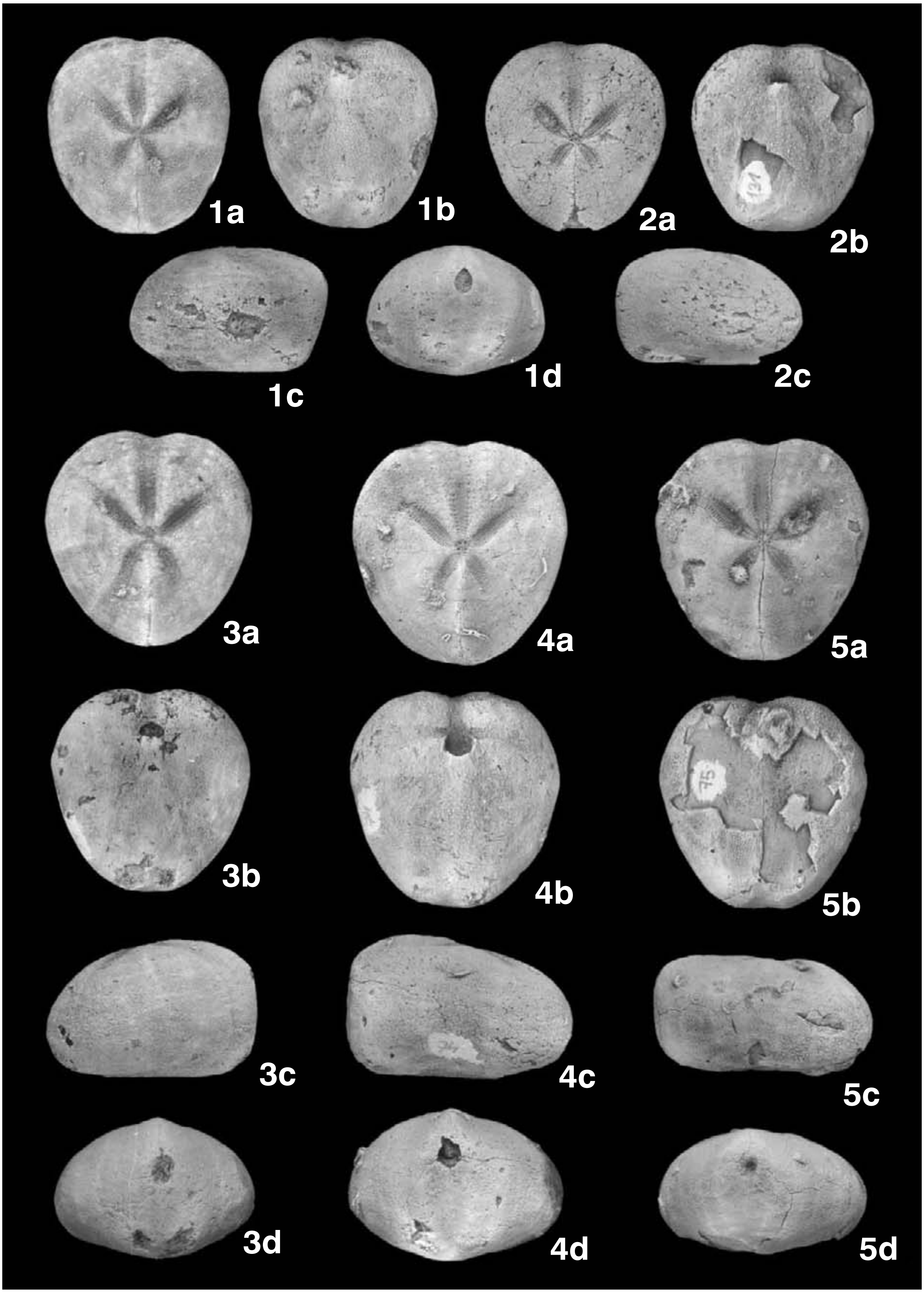

1a
1b
2a
2b
1c
1d
2c
3a
4a
5a
3b
4b
5b
3c
4c
5c
3d
4d
5d

PLATE 21

Micraster (*Micraster*) *leskei* (DES MOULINS, 1837); upper Turonian (*Inoceramus perplexus* Zone) of Opole.

1 – IGPUW/E/01/615, Groszowice

2 – IGPUW/E/01/516, Odra II

3 – IGPUW/E/01/512, Odra II

4 – IGPUW/E/01/557, Bolko

a – aboral side, b – adoral side, c – lateral side, d – posterior side; all figures are natural size

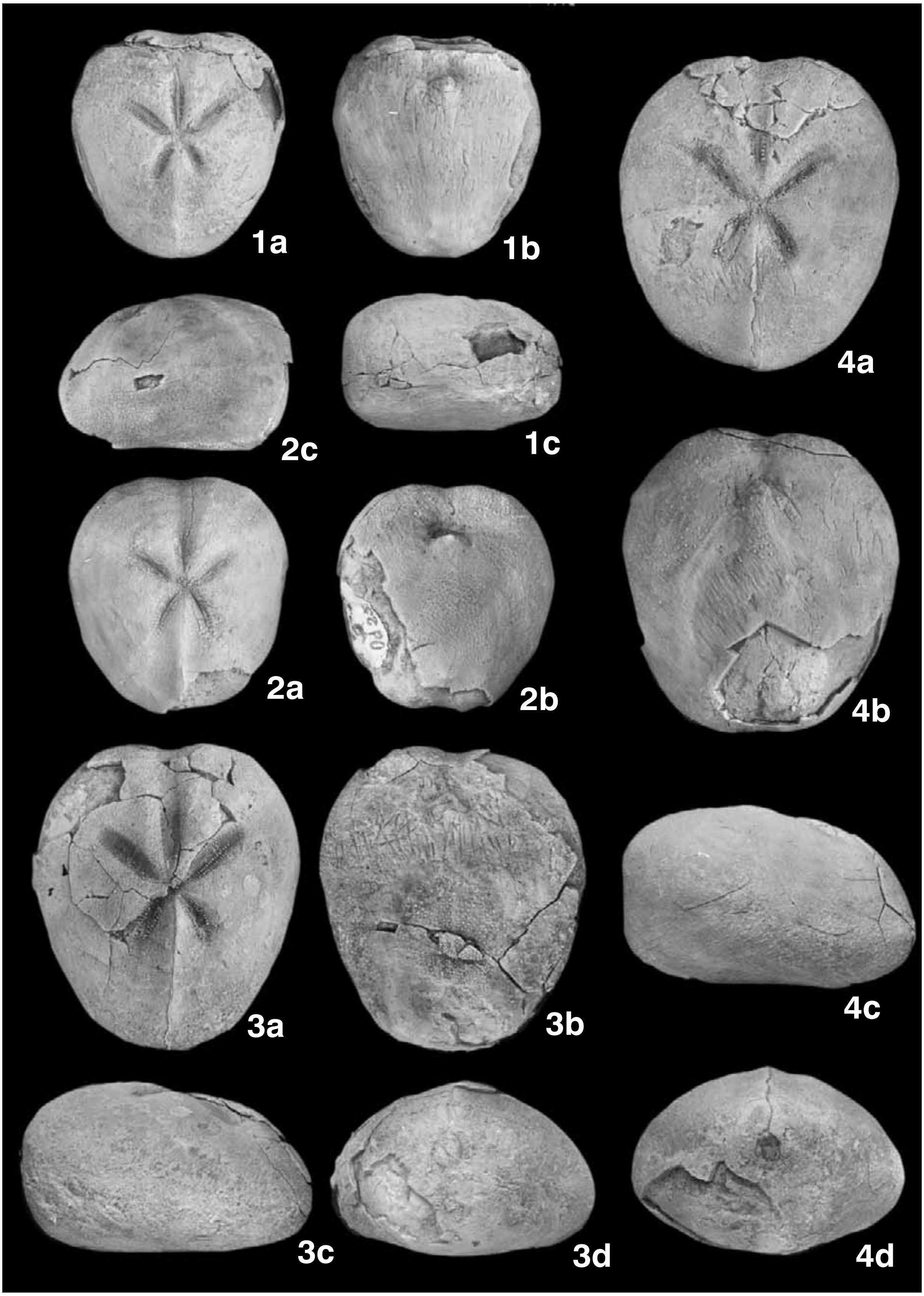

1a
1b
4a
2c
1c
2a
2b
4b
3a
3b
4c
3c
3d
4d

PLATE 22

Micraster (*Micraster*) *corbovis* FORBES, 1850

1 – MZ VIII Ee-649; upper Turonian of Opole; 1a – aboral side, 1b – adoral side, 1c – lateral side, 1d – posterior side.

2 – IGPUW/E/01/645; upper Turonian (*Inoceramus perplexus* Zone) of Bolko, Opole; 2a – adoral side, 2b – lateral side.

3 – IGPUW/E/01/637; probably upper Turonian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak; 3a – aboral side, 3b – lateral side

All figures are natural size

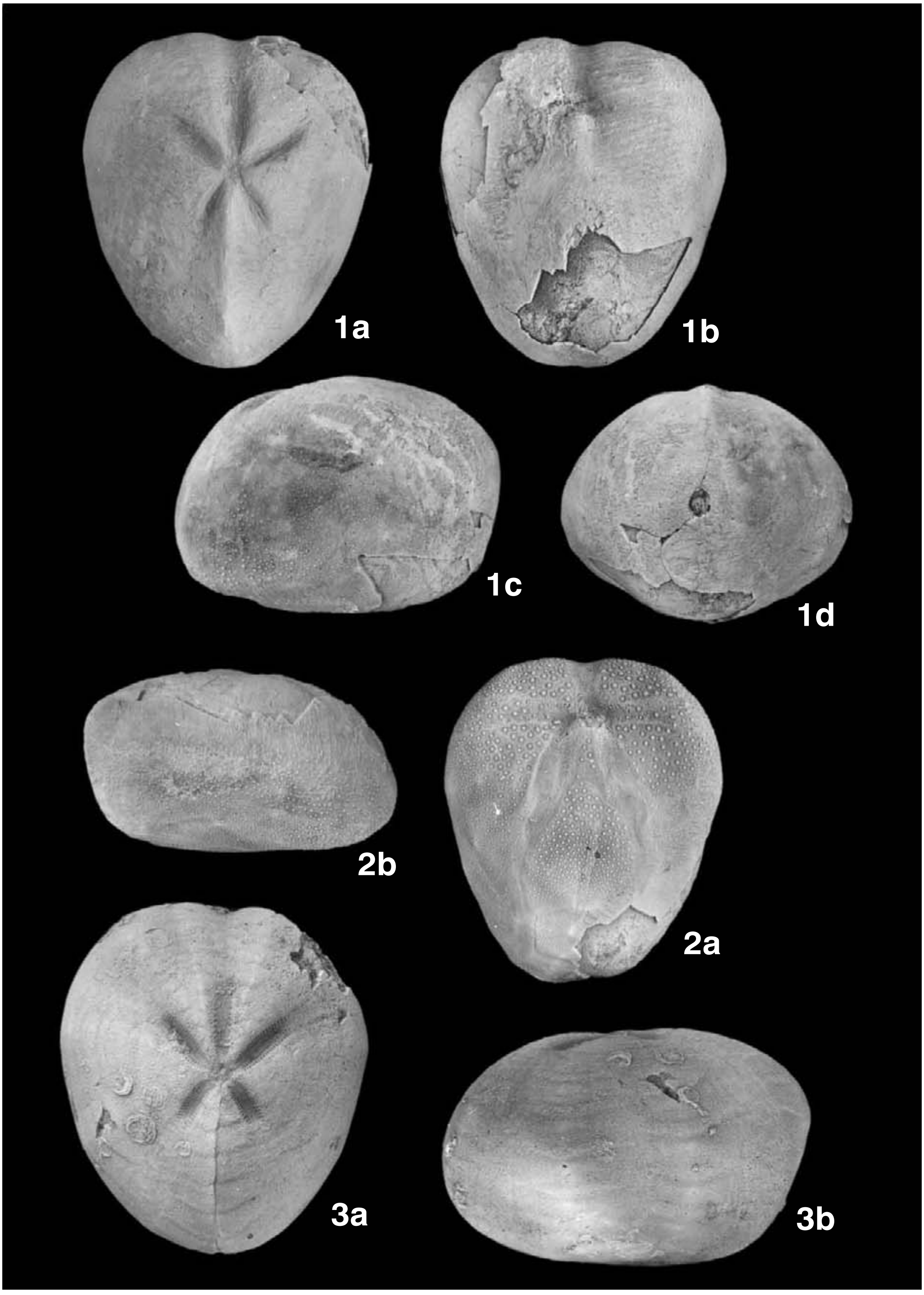

1a
1b
1c
1d
2b
2a
3a
3b

PLATE 23

1, 2 – *Micraster* (*Micraster*) *normanniae* BUCAILLE, 1883; condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak; 1 – IGPUW/E/01/651; 2 – IGPUW/E/01/652; 1a, 2a – aboral side, 1b, 2b – adoral side, 1c, 2c – lateral side, 1d, 2d – posterior side.

3 – *Micraster* (*Micraster*) *corbovis* FORBES, 1850; IGPUW/E/01/639; probably upper Turonian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak; 3a – adoral side, 3b – lateral side, 3c – posterior side.

All figures are natural size

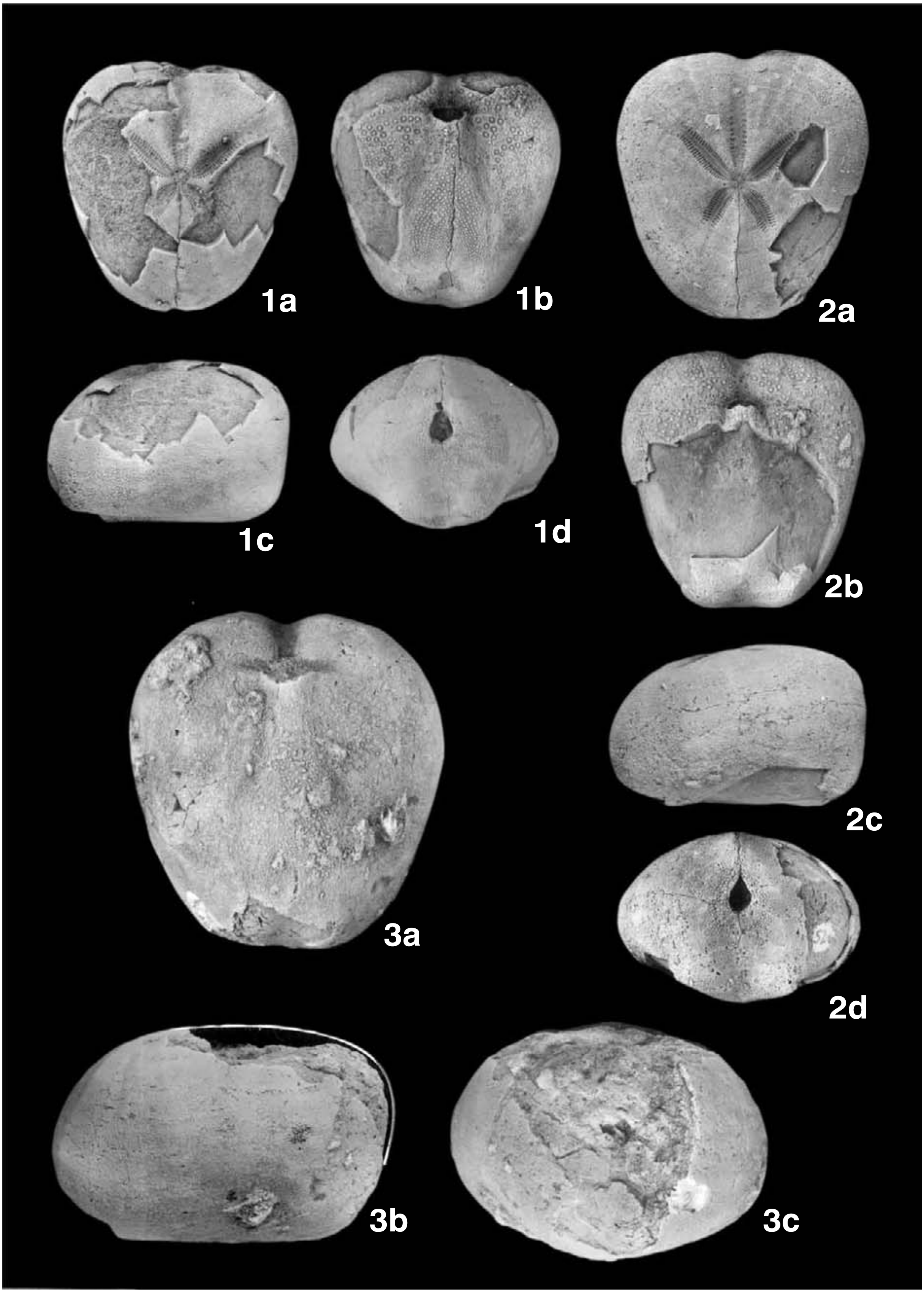

1a
1b
2a
1c
1d
2b
3a
2c
2d
3b
3c

PLATE 24

Micraster (*Micraster*) *cortestudinarium* (GOLDFUSS, 1829); condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B), Mangyshlak

1 – IGPUW/E/01/753

2 – IGPUW/E/01/750

3 – IGPUW/E/01/665

4 – IGPUW/E/01/664

a – aboral side, b – adoral side, c – lateral side, d – posterior side; all figures are natural size

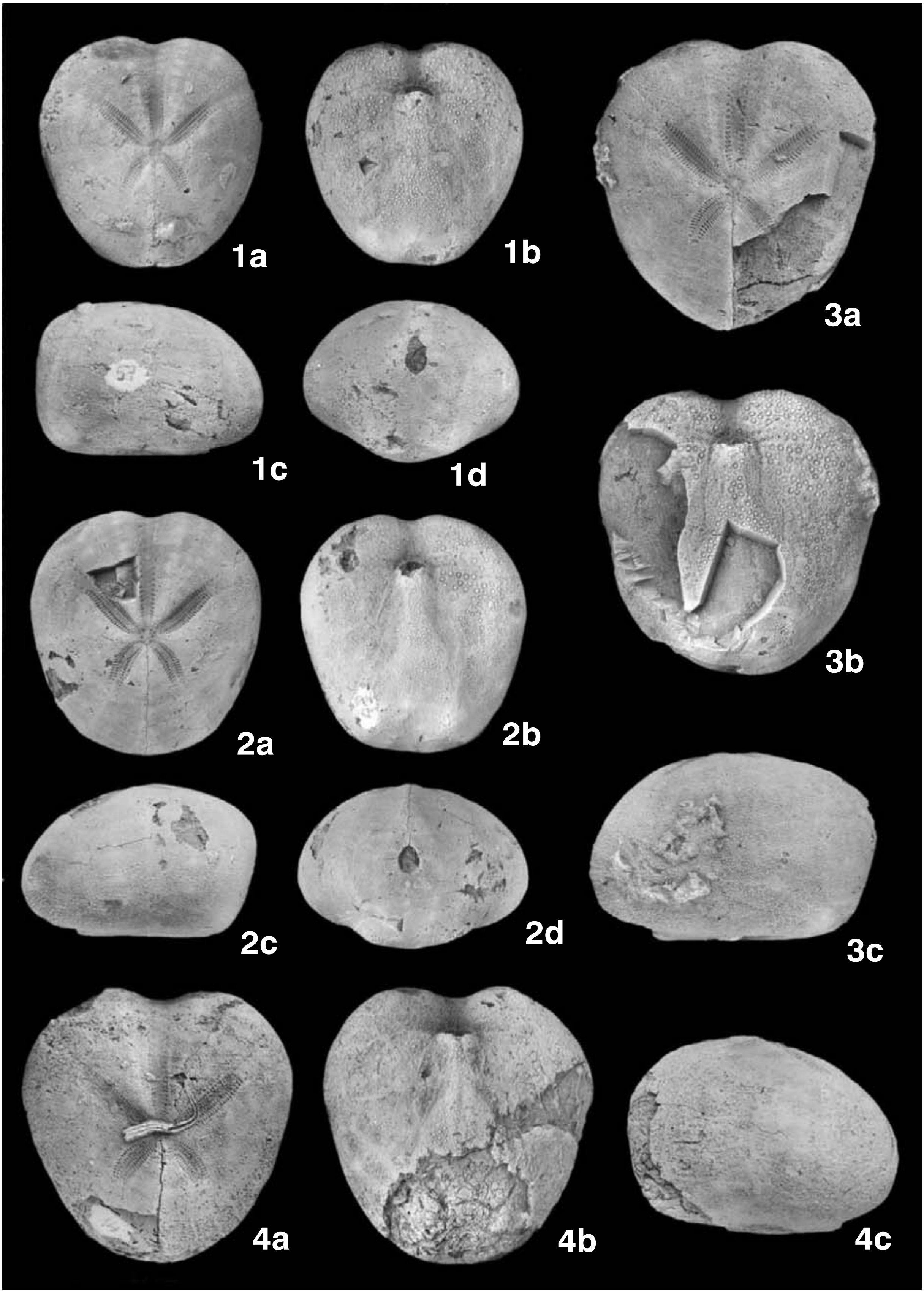

1a
1b
3a
1c
1d
3b
2a
2b
2c
2d
3c
4a
4b
4c

PLATE 25

Micraster (*Micraster*) *cortestudinarium* (GOLDFUSS, 1829), Mangyshlak

1-3 – stratigraphically condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B); 1 – IGPUW/E/01/742; 2 – IGPUW/E/01/745; 3 – IGPUW/E/01/659

4 – IGPUW/E/01/693; middle Coniacian of Kush.

a – aboral side, b – adoral side, c – lateral side, d – posterior side; all figures are natural size

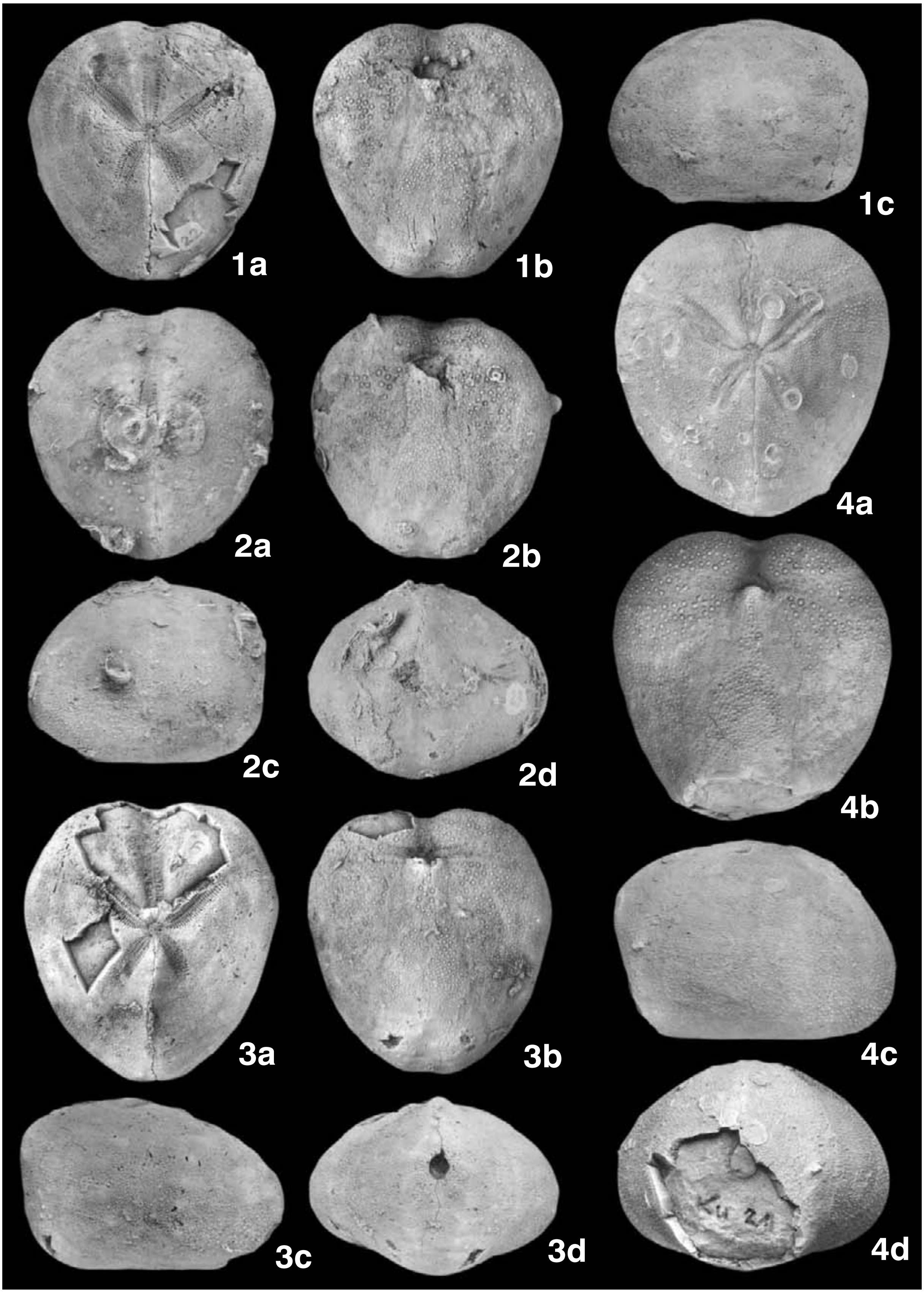

1a
1b
1c
2a
2b
4a
2c
2d
4b
3a
3b
4c
3c
3d
4d

PLATE 26

Micraster (*Micraster*) *cortestudinarium* (GOLDFUSS, 1829)

1 – IGPUW/E/01/696; upper Turonian of Beachy Head, England.

2 – IGPUW/E/01/694; lower Coniacian (*Cremnoceramus waltersdorfensis hannovrensis* + *C. crassus inconstans* + *C. crassus crassus*/ *deformis deformis* Zone) of Folwark, Opole area.

a – aboral side, b – adoral side, c – lateral side, d – posterior side; all figures are natural size

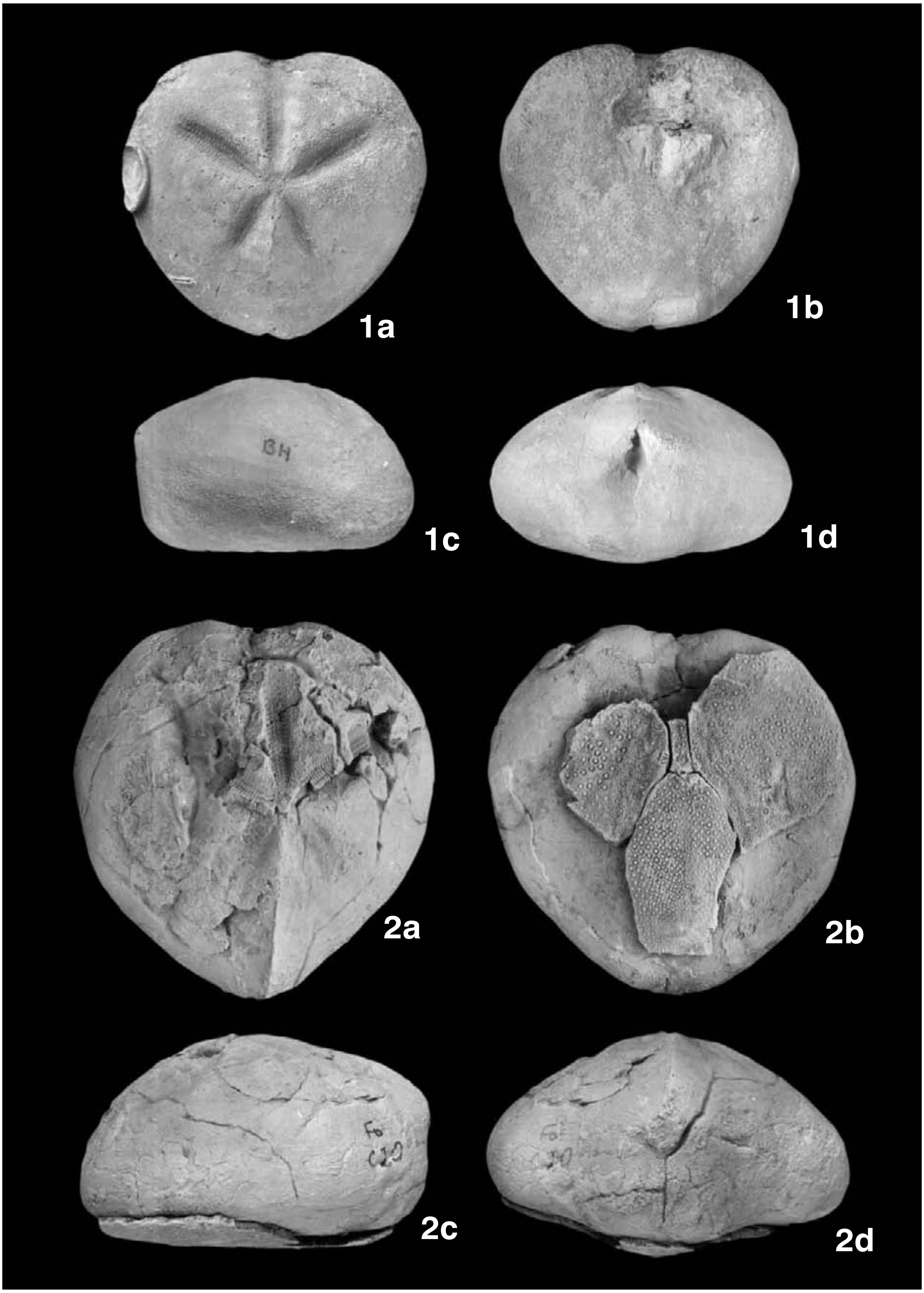

1a
1b
BH
1c
1d
2a
2b
Fo
C20
2c
Fo
C20
2d

PLATE 27

1 – *Micraster* (*Micraster*) *praerogalae* sp. nov., holotype; IGPUW/E/01/677; upper Coniacian of Shakh-Bogota, Mangyshlak.

2 – *Micraster* (*Micraster*) *rogalae* NOWAK, 1909; IGPUW/E/01/679; uppermost Coniacian of Shakh-Bogota, Mangyshlak.

a – aboral side, b – adoral side, c – lateral side, d – posterior side; all figures are natural size

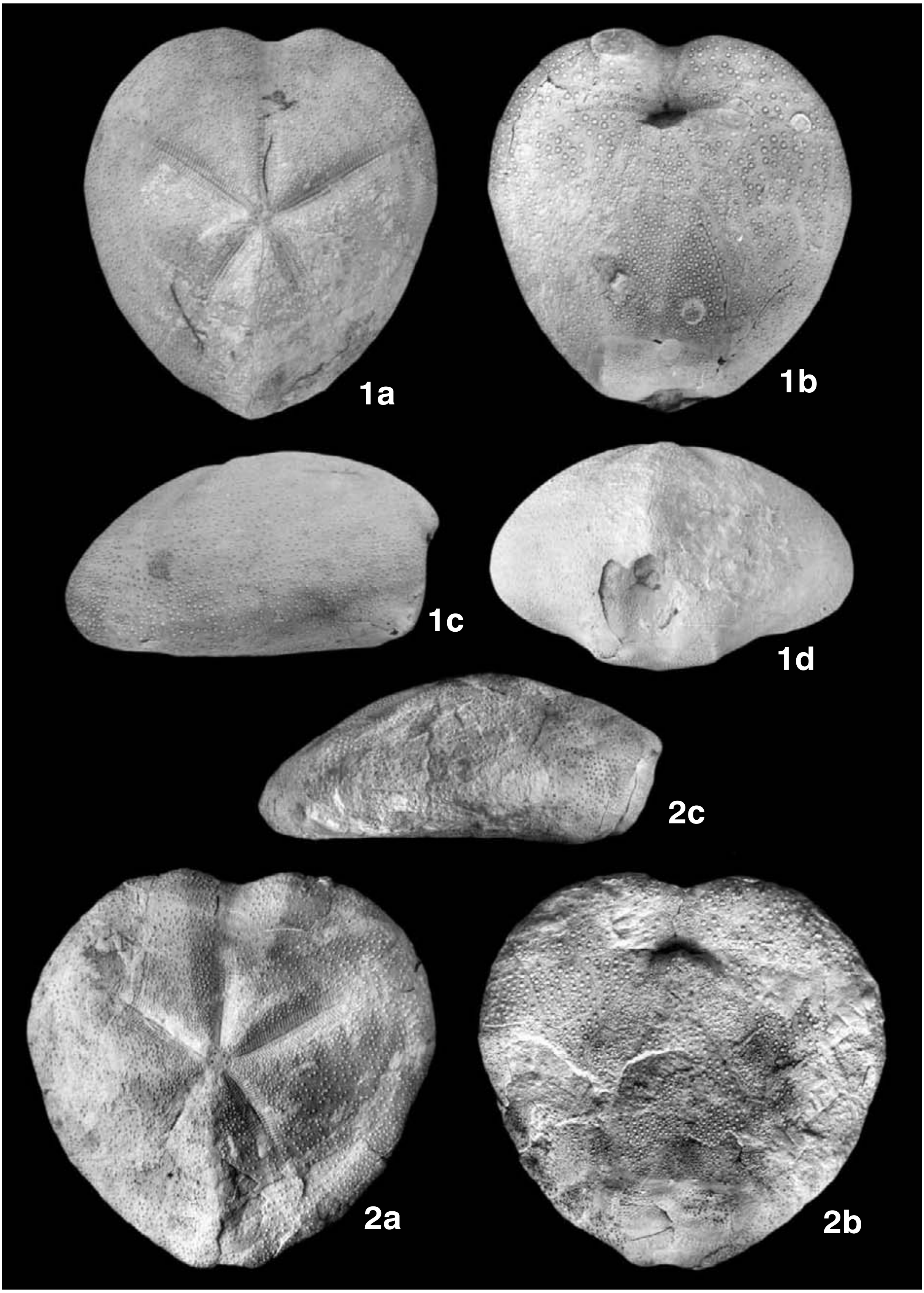

1a
1b
1c
1d
2c
2a
2b

PLATE 28

1 – *Micraster* cf. *distinctus* AGASSIZ & DESOR, 1847; IGPUW/E/01/377, internal mould; condensed lower Cenomanian-lower lower Turonian Bed 9 of Shakh-Bogota, Mangyshlak; 1a – aboral side, 1b – adoral side, 1c – lateral side.

2-3 – *Micraster* (*Micraster*) *rogalae* NOWAK, 1909; uppermost Coniacian of Shakh-Bogota, Mangyshlak
2 – IGPUW/E/01/681; 2a – aboral side, 2b – adoral side, 2c – lateral side
3 – IGPUW/E/01/682; adoral side.

All figures are natural size

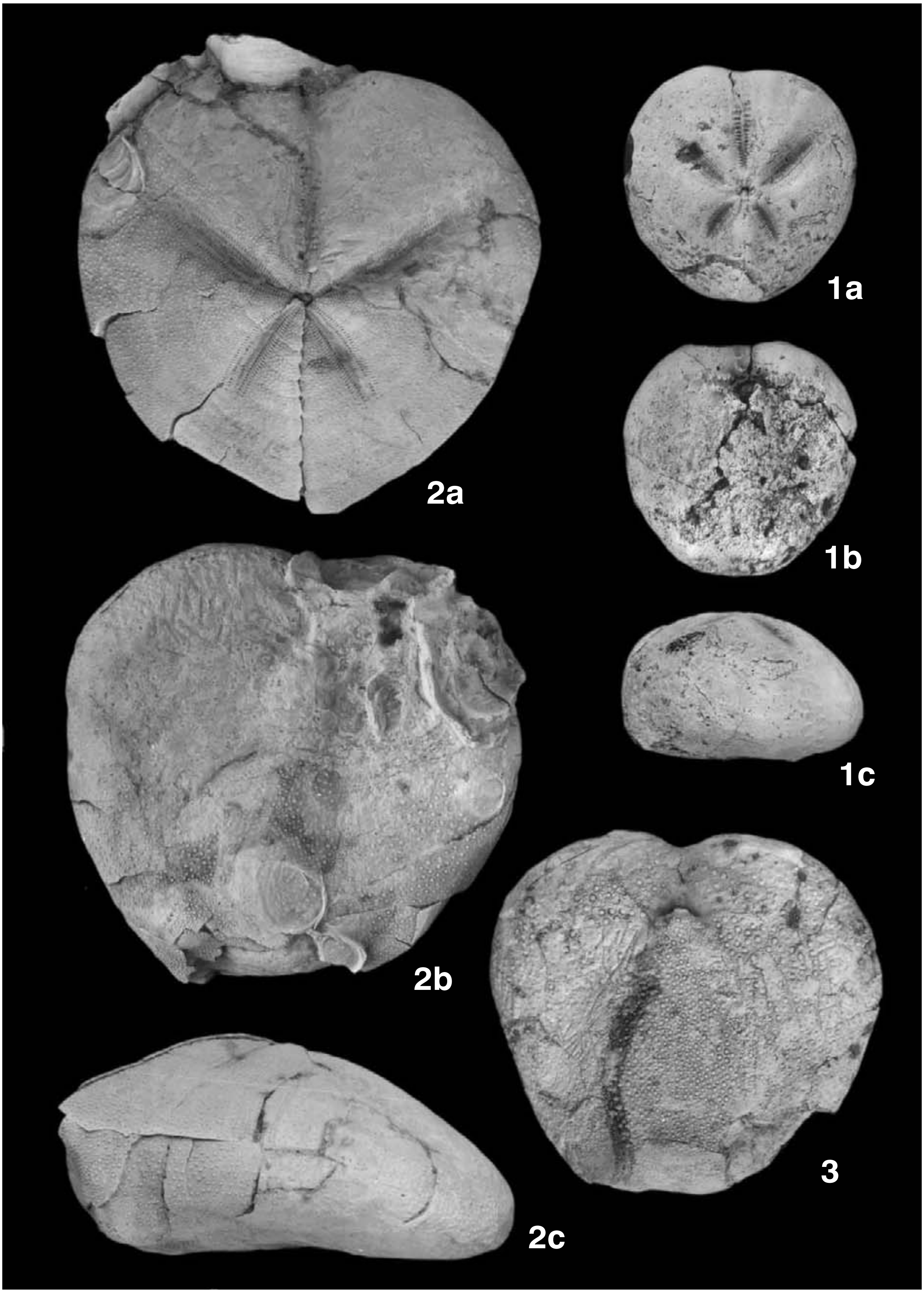

1a
1b
1c
2a
2b
2c
3

PLATE 29

Micraster (*Micraster*) *rogalae* NOWAK, 1909; Mangyshlak

1 – IGPUW/E/01/716; Coniacian/Santonian boundary of Besakty.

2 – IGPUW/E/01/683; uppermost Coniacian of Shakh-Bogota.

a - aboral side, b - adoral side, c - lateral side; all figures are natural size

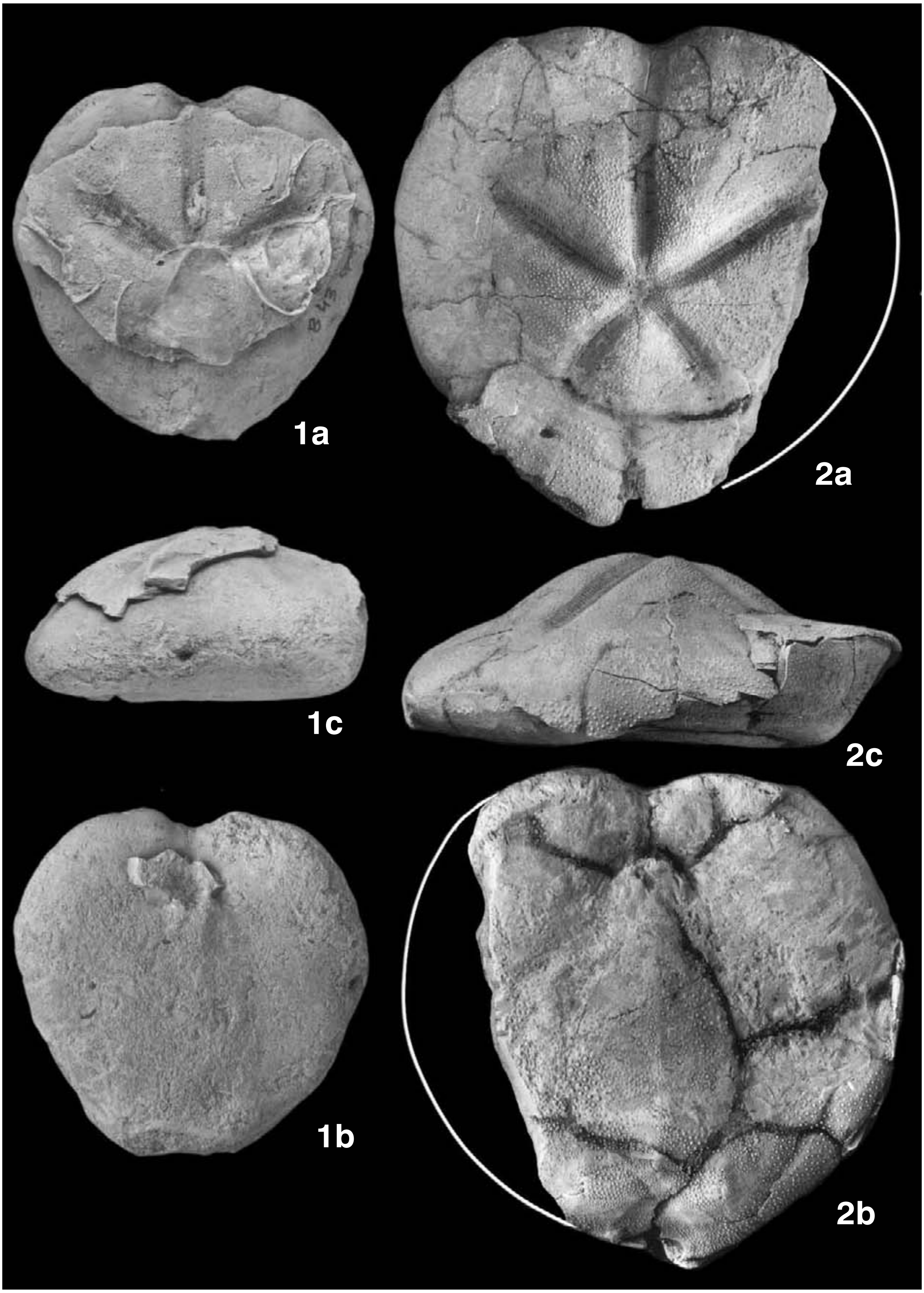

1a
2a
1c
2c
1b
2b

PLATE 30

1 – *Micraster* (*Micraster*) *cayeusi* PARENT, 1892; IGPUW/E/01/670; lower Coniacian (*Cremnoceramus waltersdorfensis hannovrensis* + *C. crassus inconstans* + *C. crassus crassus/ deformis deformis* Zone) of Folwark, Opole; 1a – aboral side, 1b – adoral side, 1c – lateral side, 1d – posterior side.

2 – *Micraster* (*Micraster*) *bucailli* PARENT, 1892; IGPUW/E/01/672; probably upper Coniacian, condensed upper Turonian-Coniacian of Besakty, Bed 42 (Unit B_3), Mangyshlak; 2a – aboral side, 2b – adoral side, 2c – lateral side, 2d – posterior side.

3 – *Micraster* (*Micraster*) *coranguinum* (LESKE, 1778); IGPUW/E/01/673; uppermost Coniacian of Shakh-Bogota; 3a – adoral side, 3b – lateral side, note *Pycnodonte*.

4 – *Micraster* (*Gibbaster*) *brevis* DESOR, in AGASSIZ & DESOR, 1847; IGPUW/E/01/719; lower Coniacian (*Cremnoceramus waltersdorfensis hannovrensis* + *C. crassus inconstans* + *C. crassus crassus/deformis deformis* Zone) of Folwark, Opole; 4a – aboral side, 4b – adoral side, 4c – lateral side, 4d – posterior side.

All figures are natural size

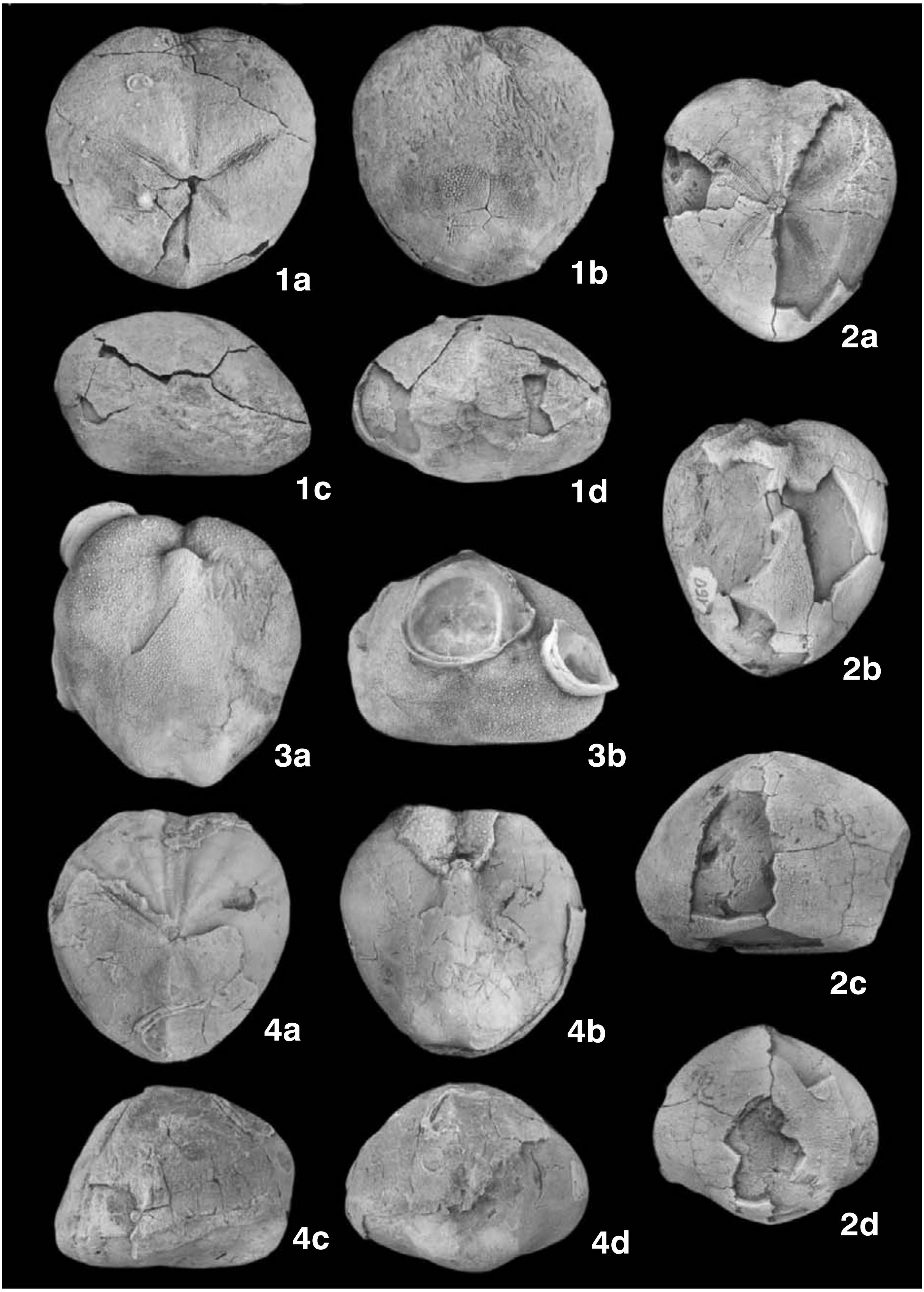

1a
1b
2a
1c
1d
2b
3a
3b
4a
4b
2c
4c
4d
2d

PLATE 31

Micraster (*Gibbaster*) *brevis* DESOR, in AGASSIZ & DESOR, 1847

1 – IGPUW/E/01/720; lower Coniacian (*Cremnoceramus waltersdorfensis hannovrensis* + *C. crassus inconstans* + *C. crassus crassus*/ *deformis deformis* Zone) of Folwark, Opole.

2 – IGPUW/E/01/724; lower Coniacian, (*Cremnoceramus deformis deformis* Zone) at Kostomloty, Czech Republic, note craniids on adoral side.

3 – MZ VIII Ee - 645; ?Coniacian of Westphalia, Germany.

a – aboral side, b – adoral side, c – lateral side, d – posterior side; all figures are natural size

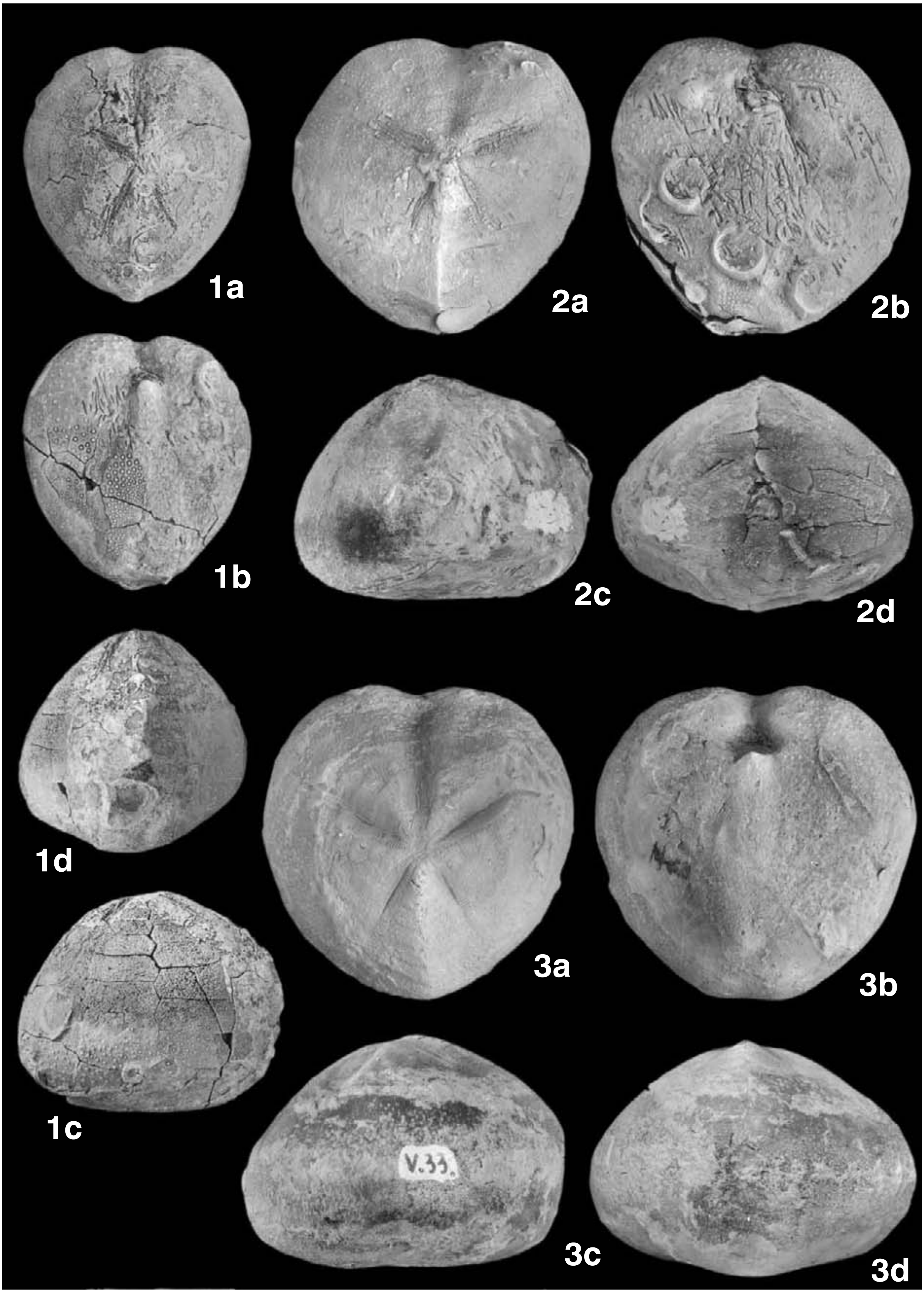

1a
2a
2b
1b
2c
2d
1d
3a
3b
1c
V.33.
3c
3d

PLATE 32

Endo- and epibionts associated with echinoid tests; Besakty, Bed 42, Mangyshlak

1 – Bryozoan *Stomatopora* sp. on adoral side of *Echinocorys* ex gr. *scutata* LESKE, IGPUW/E/01/318.

2 – *Membranipora* sp. and predation traces of gastropods (?) on the aboral side of *Echinocorys* ex gr. *scutata* LESKE, IGPUW/E/01/181.

3 – *Rogerella mathieui* SAINT-SEINE frequently presumed pores after ambulacral feet on *Echinocorys* ex gr. *scutata* LESKE, IGPUW/E/01/320.

4 – *Centrichnus eccentricus* BROMLEY & MARTINELL (etching traces of the byssus of anomiid bivalves) on lateral side of *Echinocorys* ex gr. *scutata* LESKE, IGPUW/E/01/211.

5 – *Hyotissa semiplana* (SOWERBY) on latero-posterior side of *Echinocorys* ex gr. *scutata* LESKE, IGPUW/E/01/243.

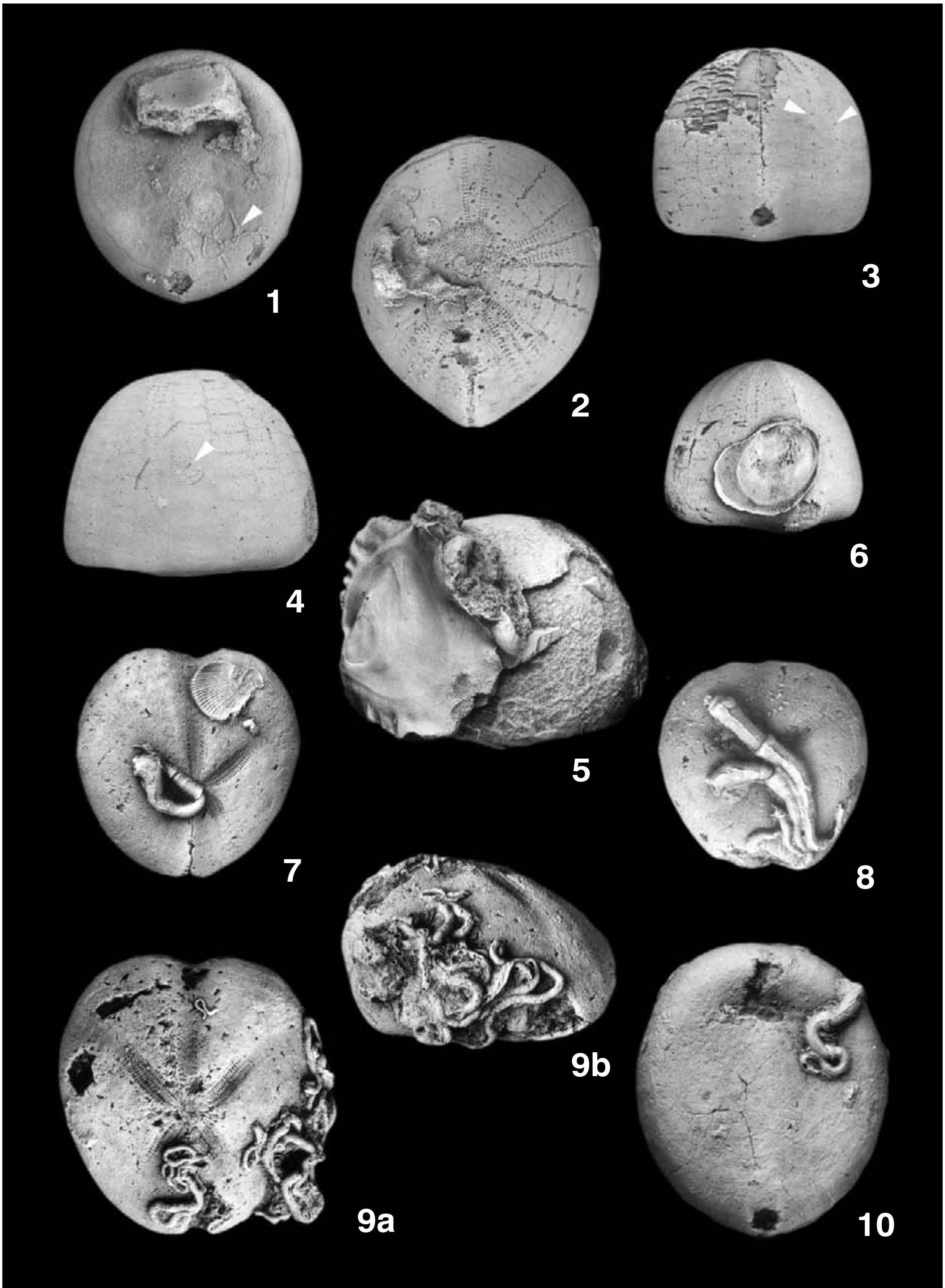
6 – "*Pycnodonte*" sp. on later-posterior side of *Echinocorys* ex gr. *scutata* LESKE, IGPUW/E/01/244.

7 – *Spondylus* sp. and *Proliserpula tumida* REGENHARDT on aboral side of *Micraster* (*Micraster*) *cortestudinarium* (GOLDFUSS), IGPUW/E/01/756.

8 – *Proliserpula tumida* REGENHARDT on aboral side of *Micraster* (*Micraster*) *leskei* (DES MOULINS), IGPUW/E/01/504.

9 – *Cycloserpula gordialis* (SCHLOTHEIM) on *Micraster* (*Micraster*) *cortestudinarium* (GOLDFUSS), IGPUW/E/01/755; a – view from aboral side, b – view from lateral side.

10 – *Proliserpula tumida* REGENHARDT on adoral side of *Echinocorys* ex gr. *scutata* LESKE, IGPUW/E/01/313.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