

Ann. Naturhist. Mus. Wien	104 A	155–183	Wien, Mai 2003
---------------------------	-------	---------	----------------

The Echinodermata of the Langhian (Lower Badenian) of the Molasse Zone and the northern Vienna Basin (Austria)

by Andreas KROH¹

(With 4 textfigures and 5 plates)

Manuscript submitted on 19 July 2002,
the revised manuscript on 2 September 2002

Zusammenfassung

Die Echinodermenfauna des Unteren Badenium (Langhium) aus dem Nördlichen Niederösterreich wird vorgestellt. Zwei Fundkomplexe wurden untersucht: die Grunder Schichten von Grund und Umgebung und die Schilllagen von Niederleis. In den Grunder Schichten sind Echinodermenreste sehr selten, abgesehen von einem stark abgerollten *Eucidaris zeamays*-Stachel lieferten sie nur Stachelfragmente von Spatangoiden. Aus den Schilllagen von Niederleis, konnte hingegen eine reiche Echinodermenfauna, die abgesehen von Echiniden auch Asteriden und Crinoiden umfasst, nachgewiesen werden. Die Fauna der Schilllagen ist charakteristisch für Grobsandböden des flachen Subtidal und weist auf das Vorhandensein von Seegras- und/oder Makroalgen-Beständen hin. Aufgrund von Untersuchungen von MANDIC et al. (2002), wurde klar, dass es sich bei den untersuchten Schilllagen, die auch eine reiche Flachwasser-Molluskenfauna führen, um allochthone Vorkommen (proximale Tempestite) handelt, die in einer Wassertiefe zwischen 100 und 500 Metern abgelagert wurden. Vereinzelt vorkommende Stielglieder von Isocriniden (gestielten Seelilien) hingegen repräsentieren möglicherweise die autochthone Tiefwasser-Fauna.

Schlüsselwörter: Echinodermata, Niederleis, Grunder Schichten, Unteres Badenium, Mittelmiozän, Österreich, Zentrale Paratethys

Abstract

The echinoderm fauna of the Lower Badenian (Langhian) from the Molasse Zone and the northern Vienna Basin is described and illustrated. Two localities were studied: the Grund Formation, outcropping in the area around Grund and the shell beds of Niederleis, both in Lower Austria. Within the Grund Formation echinoderms are rare and poorly preserved, apart from a single, highly abraded *Eucidaris zeamays* spine, only fragmentary spatangoid spines were found. The echinoderm fauna of Niederleis, in contrast, is very rich and includes members of the classes Echinoidea, Asteroidea and Crinoidea. The fauna of this shell beds is characteristic of a shallow sublittoral, coarse sandy environment with sea grass and/or macroalgal patches. A study by MANDIC et al. (2002) showed that these shell beds are allochthonous and represent proximal tempestites deposited in a middle shelf environment between depth of 100 to 500 m. The isocrinid columnals found within the shell bed might represent the autochthonous deep water fauna which was incorporated into the shell bed during transport.

Keywords: Echinodermata, Niederleis, "Grund Beds", Lower Badenian, Middle Miocene, Austria, Central Paratethys

¹ Institut für Geologie und Paläontologie, Karl-Franzens-Universität Graz, Heinrichstraße 26, 8010 Graz, Österreich. – e-mail: discometra@gmx.at

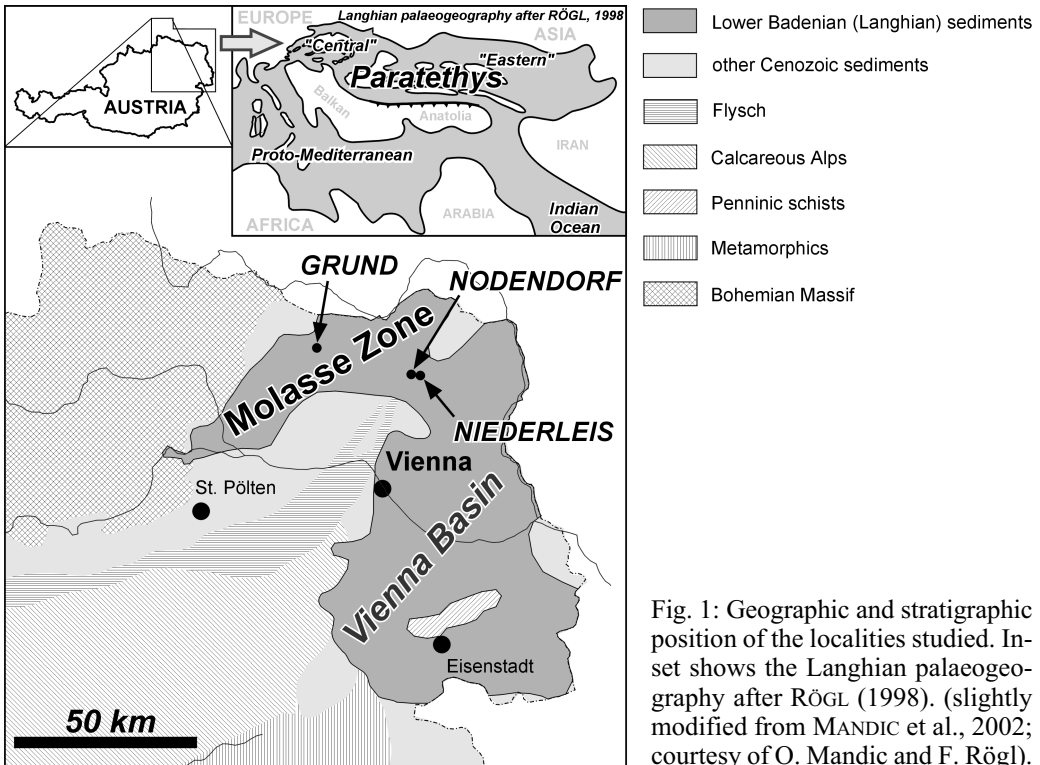


Fig. 1: Geographic and stratigraphic position of the localities studied. Inset shows the Langhian palaeogeography after RÖGL (1998). (slightly modified from MANDIC et al., 2002; courtesy of O. Mandic and F. Rögl).

Introduction

Despite to the long history of echinoderm research in Austria, with the first records dating back to 1830 (SEDGWICK & MURCHINSON 1831), our knowledge of Miocene echinoderms of Austria is still limited. Especially the spatial and temporal distribution of most taxa is poorly known. Moreover, earlier works (e.g. LAUBE 1871) considered only complete specimens; thus many taxa, recorded only by disarticulated ossicles or fragmentary material, were ignored. Since most echinoderms tend to disarticulate rapidly after death (compare e.g. data presented for regular echinoids by KIER 1977, and KIDWELL & BAUMILLER 1990), to consider only complete specimens would add considerable bias to the already biased fossil record. Moreover, although disarticulated echinoderms can often not be identified to species level, even higher-level taxa can be useful in palaeoecological and taphonomic studies (GORDON & DONOVAN 1992, NEBELSICK 1992, DONOVAN et al. 1993, DONOVAN 1996, KROH & HARZHAUSER 1999).

The use of fragmentary and disarticulated skeletal material was not well established in former times, because of the identification problems involved with these remains. These problems, however, may be overcome with the help of refined technical equipment, such as high-quality microscopes or the scanning electron microscope (SEM). With the help of macerated skeletons of extant echinoderms an accurate assignment of individual remains to families or genera is possible in most cases. This method yields a large amount of additional information, which was not available in former times.

The present paper is the second in a series of studies on Neogene echinoderms; the first reported on the echinoderm fauna from the Lower Miocene "Retz sands", with emphasis on the palaeoecology of the echinoid-bearing levels, as well as more global aspects, such as echinoid migration (KROH & HARZHAUSER 1999).

Study Area

The echinoderm faunas studied come from the Early Badenian (Langhian) time slice of the Molasse zone and the northern Vienna Basin. Two outcrops preserving marine sediments of this time slice were studied.

The first, Niederleis, lies approximately 3 km north-east of Ernstbrunn in Lower Austria and is situated at the western margin of the Northern Vienna Basin. There, small-scale tectonic depressions, formed by the subsidence of a single block of the Waschberg Zone (allochthonous Molasse) are filled with Lower Badenian sandy-clayey sediments of the late Early Lagenid Zone (MANDIC et al. 2002). The Waschberg Zone is a strongly sheared tectonic unit, comprising an incomplete sedimentary succession ranging from the Upper Jurassic to the Lower Miocene. At the south-east of the Leiser Hill, north-west of Niederleis, the Early Badenian transgression is documented by shallow-water conglomerates and limestones overlying the Upper Jurassic carbonates of the Waschberg Zone (MANDIC et al. 2002). Palaeogeographically, Niederleis is situated in the transitional zone between the Molasse Zone and the Northern Vienna Basin.

MANDIC et al. (2002) investigated two sections in the immediate vicinity of Niederleis, for the north-western section (Buschberg) they postulated a palaeo-water depth of approximately 100 metres and for the south-eastern section (Bahnhof) a depth between 100 to 500 m. Both estimates are based on plankton/benthos ratios of the foraminiferal fauna. This is in strong contrast to the composition of the molluscan fauna of the coquinas found within the sections, which indicate a palaeo-water depth between 0 to 30 m. However, sedimentological evidence indicates that the shell layers represent proximal tempestites (i.e. storm-induced downslope transport), explaining the presence of shallow-water mollusc assemblages in the deeper-water environment.

The second outcrop studied is the famous locality Grund, approximately 5 km north of Hollabrunn, Lower Austria. The Grund Formation, outcropping in this area, consists of medium sands with intercalations of greenish clays and dense shell beds. The age of the Grund Formation was subject to discussion for some time, but recent investigations by RÖGL et al. (2002) have allowed a correlation with the Lower Badenian, approximately the same time horizon as Niederleis (F. RÖGL, pers. comm. 08.07.2002). The shell beds have yielded a rich molluscan fauna of over 250 species (SIEBER 1949), most of which are characteristic of the shallow sublittoral. Taphonomic and sedimentological analysis of these shell beds clearly showed the allochthonous character of this deposits, as shown by HARZHAUSER et al. (1999). The intercalated pelitic layers, in contrast, yielded only a single molluscan species, the bivalve *Thyasira michelotti* (R. HÖRNES, 1875) and its burrows. This species lived in symbiosis with anaerobic bacteria, suggesting a dysaerobic environment for the pelites (ZUSCHIN et al. 2001).

Material and Methods

The Niederleis material stems from an old bulk sample (taken 15.08.1865) kept at the Natural History Museum Vienna and from bulk samples of excavations made in 2000 by Harzhauser, Mandic and Zuschin (MANDIC et al. 2002). The Grund material comes from a bulk sample collected in an abandoned wine cellar next to the road between Grund and Guntersdorf. The bulk samples were washed using H_2O_2 for disaggregation and then wet-sieved. Ossicles were picked from the residue using a binocular microscope. Material used for SEM analysis was again cleaned with H_2O_2 and in an ultrasonic bath. Ossicles of extant specimens for comparison were immersed in Sodiumhypochlorite solution (30%) to remove soft tissues and then ultrasonically cleaned in water. All material used in the present study is deposited at the Natural History Museum Vienna (NHMW), except extant comparison material of *Genocidaris maculata* and *Asthenosoma iijimai* kindly lent by the United States National Museum (USNM). The abbreviation NÖ used in this study stands for Niederösterreich (Lower Austria).

Systematics

Class Echinoidea LESKE, 1778

Order Cidaroida CLAUS, 1880

Family Cidaridae GRAY, 1825

Subfamily Cidarinae GRAY, 1825

Genus *Eucidaris* POMEL, 1883

Eucidaris zeamays (SISMONDA, 1842) (pl. 1, figs. 1-11)

- * 1842 *Cidarites zea-mays* mihi. – SISMONDA: 391 [based on spines]
- . 1901 *Cidaris zeamais* SISM. – AIRAGHI: 167-168; pl. 19, figs. 49-57
- . 1915 *Cidaris zeamays* SISM. – VADÁSZ: 105; pl. 8 (2), fig. 17
- . 1915 *Cidaris* cfr. *zeamays* SISM. – VADÁSZ: 105; pl. 8 (2), fig. 15
- . 1966 *Cidaris* cfr. *zeamays* SISM. – KÓKAY: 83
- . 1977 *Cidaris* cf. *desmoulinsi* SISMONDA, 1842 – MACZYŃSKA: 194; pl. 1, figs. 7, 13
- . 1984 *Plegiocidaris zeamaïs* (SISMONDA, 1842) – PHILIPPE: 86; pl. 5, fig. 11
- . 1987 *Cidaris zeamais* SISMONDA, 1842 – MACZYŃSKA: 146, 148; pl. 1, fig. 1
- . 1987 *Cyathocidaris avenionensis* (DESMOULINS, 1837) – MACZYŃSKA: 145-146, 148; pl. 1, figs. 4-7; pl. 2, figs. 1a-d
- . 1988 *Cidaris zeamais* SISMONDA, 1841 – MACZYŃSKA: 60; pl. 1, figs. 1-3
- . 1989 *Eucidaris zeamais* – PHILIPPE: 27; tab. 1
- . 1993 *Cidaris zeamais* SISMONDA, 1842 – MACZYŃSKA: 105; pl. 1, fig. 1; pl. 6, figs. 1a, 4
- . 1993 *Cyathocidaris avenionensis* (DESMOULINS, 1837) – MACZYŃSKA: 106; pl. 1, figs. 3-4; pl. 6, fig. 1c
- . 1996 *Cidaris zeamais* SISMONDA, 1842 – MACZYŃSKA: 40; pl. 1, fig. 1
- . 1996 *Cyathocidaris avenionensis* (DESMOULINS, 1837) – MACZYŃSKA: 40-41; pl. 1, figs. 2-3
- . 1998 *Eucidaris zeamais* (SISMONDA, 1842) – PHILIPPE: 44-46; pl. 4, figs. 8-15

M a t e r i a l: Niederleis, NÖ: 10 interambulacral plates (NHMW 2002z0087/0048-49, 2002z0087/00052), 166 primary spines (NHMW 2002z0087/0040-47, 2002z0087/0050, 2002z0088/0002, 2002z0089/0006) and 1 genital plate (NHMW 2002z0087/0051).

Grund, NÖ: 1 primary spine (NHMW 2002z0086/0001).

Description: This species is characterised by its short, stout spines, which are ornamented by closely spaced, longitudinal rows of large granules. At regular intervals these granules are enlarged and form two to three whorls along the shaft. Towards the tip, the size of the granules decreases and they grade into longitudinal ridges, which form a small crown at the tip of the spine. The acetabulum has a noncrenulate margin. The spines from Niederleis show a characteristic coloration pattern: they are banded with broad dark and thin light bands, the latter coinciding with the whorls of the ornamentation and the base. Extant species of the genus (e.g. *E. metularia* from the Red Sea) show a similar spine coloration, suggesting that this pattern is a remnant of the original coloration.

The interambulacral plates are small and pentagonal, with a large perforate, noncrenulate primary tubercle. The areoles are well defined, but contiguous below and above in ambital plates and surrounded by a ring of scrobicular tubercles, which are slightly larger than the secondary tubercles.

Remarks: This species, which is very common in the Badenian of the Central Paratethys, has only recently been placed into the genus *Eucidaris* (PHILIPPE 1984, but see also PHILIPPE 1998), a genus currently restricted to tropical environments (FELL 1966a). Spines and test fragments/individual plates have usually been treated as separate species (e.g. MACZYŃSKA 1987, 1993, 1996) since only disarticulated material was available. MACZYŃSKA placed the spines into this species, but erroneously identified co-occurring test fragments as *Cyathocidaris avenionensis*. Based on comparisons with extant material of *E. metularia* and *E. tribuloides* and the morphology of the fossils, both spines and test fragments can clearly be assigned to the same species. Moreover, at some localities (Rauchstallbrunngraben, near Baden, Lower Austria; Wiesfleck, Burgenland) this species is very abundant and the only cidaroid represented.

Distribution: Lower to Upper Badenian (Langhian to Lower Serravallian) of the Central Paratethys (Eisenstadt-Sopron Basin, Fore-Carpathian Basin, Great Hungarian Basin, Molasse Zone, Styrian Basin, Transylvanian Basin and Vienna Basin) and Burdigalian to ?Langhian of the Mediterranean (Aquitanian Basin, Piemont Basin, Rhône Basin and Sardinia).

***Cidaroida* indet. (pl. 2, figs. 6-7)**

Material: Niederleis, NÖ: 4 fragmentary primary spines (NHMW 2002z0087/0006-8).

Description: The spines are relatively slender and ornamented by short thorns arranged in longitudinal rows. These rows are well separated from each other by distinct grooves. The base of the spines is slightly enlarged and the acetabulum has a noncrenulate margin.

Remarks: The spine fragments considered here are clearly different from spines of *E. zeamays*, in being much larger, with a proportionally larger base and different ornament. They could, however, not be identified to genus or species due to their fragmentary nature. Similar spines were described under the name "*Cidaris schwabenau*" by LAUBE (1871) from the Upper Badenian of St. Margarethen.

Subclass Euechinoidea BRONN, 1860

Infraclass Acroechinoidea SMITH, 1981

Cohort Diadematacea DUNCAN, 1889

Order Diadematoida DUNCAN, 1889

Family Diadematidae GRAY, 1855

Diadematidae indet. (pl. 2, figs. 1-5)

M a t e r i a l : Niederleis, NÖ: 3 interambulacral plates (NHMW 2002z0087/0021, 2002z0087/00023), 1 ambulacral plate (NHMW 2002z0089/0002), 12 spine fragments (NHMW 2002z0087/0018-20, 2002z0087/0022).

D e s c r i p t i o n :

A m b u l a c r a l p l a t e (pl. 2, fig. 5): The plate bears one perforate, crenulate tubercle in the middle of the plate. No inner tubercles are present. The plate bears three ambulacral pores and is of the diadematoid compound type.

I n t e r a m b u l a c r a l p l a t e s (pl. 2, fig. 4): Each plate bears a single, large, perforate, crenulate primary tubercle. Along the margin of the plates small secondary tubercles are present. The remaining surface of the plates is smooth and lacks details.

S p i n e s (pl. 2, figs. 1-3): The spines are hollow and show spinous processes arranged in spirals, producing a verticillate pattern along the shaft. The bases of the spines are distinctly separated from the shaft by a prominent, oblique crenulated ring.

R e m a r k s : The large crenulate, perforate tubercles and the hollow, verticillate spines are typical of members of the family Diadematidae (FELL 1966b, SMITH 1980). In general, fossil diadematid spines from the Paratethys and the Mediterranean were related to the genus *Centrostephanus* and several species were even differentiated (VADÁSZ 1915, MACZYŃSKA 1977, 1987, 1993; PHILIPPE, 1998). However, although spines of several extant diadematid genera were compared with the fossil specimens, it was impossible to associate them with any of the genera due to the limited number of extant species available and the low diagnostic potential of the spines. Probably comparison of the coronal plate would be more promising, but this was impossible due to the limited material and poor preservation of the fossil specimens.

D i s t r i b u t i o n : The family Diadematidae is known from the Lower Jurassic to Recent (FELL 1966b), and although diadematid spines are common in Miocene sediments of the Central Paratethys, they are rarely mentioned and/or described. From Austria diadematids were reported only from the Eggenburgian (Burdigalian) of the Retz area, Lower Austria by KROH & HARZHAUSER (1999) and from the Badenian of the Vienna Basin (REUSS 1860). Diadematid spines are also known from the Lower Badenian (Langhian) of Poland (MACZYŃSKA 1977, 1987, 1988, 1993), Hungary and Romania (VADÁSZ 1915).

Cohort Echinacea CLAUS, 1876

Superorder Camarodonta JACKSON, 1912

Order Temnopleuroidea MORTENSEN, 1942

Family Temnopleuridae A. AGASSIZ, 1872

Genus *Genocidaris* A. AGASSIZ, 1869***Genocidaris catenata* (DESOR, 1846) (pl. 3, figs. 1-6)**

- * 1846 [*Echinus* (*Psammechinus*)] *catenatus* DESOR. – DESOR in AGASSIZ & DESOR: 369
- . 1910 *Arbacina catenata* DESOR (*Psammechinus*), 1846. – LAMBERT: 27-28; pl. 1, figs. 52-58
- . 1910 *Arbacina tenera* DE LORIO, 1902 – LAMBERT: 28-29; pl. 1, figs. 59-62
- . 1910 *Arbacina Savini* LAMBERT. – LAMBERT: 30; pl. 1, figs. 71-73
- . 1915 *Arbacina tenera* LOR. – VADÁSZ: 108-109.
- . 1943 *Arbacina catenata* (DESOR) – MORTENSEN: 366; fig. 224a
- . 1993 *Arbacina catenata* (DESOR, 1847) – MACZYŃSKA: 108; pl. 2, fig. 1a-c
- . 1998 *Arbacina catenata* (DESOR, 1846) – PHILIPPE: 55-58; pl. 7, figs. 1-8; pl. 8, figs. 1-2
- ? 1999 *Arbacina* sp. – KROH & HARZHAUSER: 156-158; fig. 4; pl. 7, figs. 5-7

Material: Niederleis, NÖ: 6 test fragments (NHMW 2002z0087/0053, 2002z0089/0053, 2002z0090/0003-6).

Description:

Size and shape: The test is very small, hemispherical with a circular outline. In profile, the test is domed, with a tumid ambitus.

Ambulacra: The ambulacra are about two-third to half the width of the interambulacra. Each plate bears one large imperforate, noncrenulate marginal tubercle with a distinct boss and a globular mamelon with undercut neck. The bases of the marginal tubercles are distinctly indented (see Text-fig. 2). Along the adapical and perradial border of each ambulacral plate, several imperforate, noncrenulate inner tubercles are seen. Two to three of these situated along the adapical sutures of the plates are distinctly enlarged, the remaining ones are small. Each ambulacral plate bears three P2 isopores (compare SMITH 1978), and is of the echinoid compound type.

Interambulacra: Each interambulacral plate bears one large imperforate, noncrenulate primary tubercle very similar to the marginal tubercles of the ambulacra, the bases of the primary tubercles being indented as well. The secondary and miliary tuberculation is dense, consisting of small noncrenulate, imperforate tubercles.

Peristome: The peristome seems to have been about half the width of the test diameter and shows shallow gill slits.

Remarks: The specimens lack sutural depressions, which MORTENSEN (1943) regarded as a diagnostic feature for the genus *Arbacina*. Although such depressions can easily be obscured by growth of cement, this is certainly not the case in the studied material, which is, albeit fragmentary, fairly well preserved and shows no signs of syntaxial rim cement. Moreover, the specimens clearly show indentations in the margin of the primary and marginal spine bases, a feature not present in *Arbacina*. Consequently this species is here reassigned to the genus *Genocidaris*, which is closely related to *Arbacina*, but distinguished by the presence of indentations in the bases of the primary and marginal tubercles and the lack of sutural depressions in the horizontal sutures (MORTENSEN, 1943: 358). Up to now this genus included a single extant species: *G. maculata* A. AGASSIZ, 1869, restricted to the Atlantic Ocean and the Mediterranean Sea. For fossil

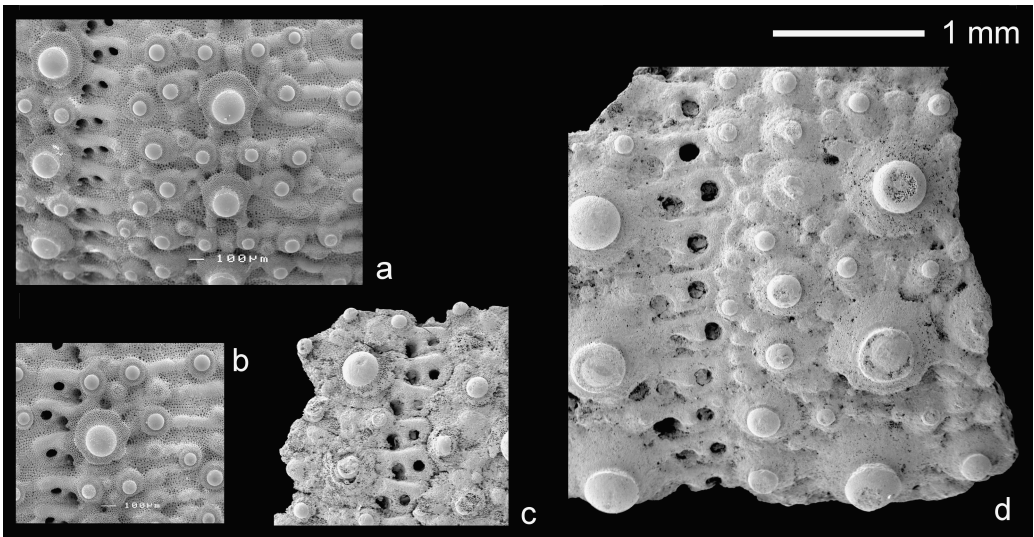


Fig. 2: Comparison of extant *Genocidaris maculata* A.AGASSIZ, 1869 (a-b: USNM E12092, Gulf of Mexico, off Florida Keys, Florida) with *Genocidaris catenata* (DESOR, 1846) (c-d: Niederleis, NÖ; c: NHMW 2002z0087/0053; d: NHMW 2002z0090/0003). Note the presence of indentations in the base of the primary and marginal tubercles in both species.

specimens from the Pliocene of Castell'Arquato, Italy the subspecies *G. maculata pli-orecens* BORGHI, 1995 was established (BORGHI, 1995). The apical disc of *G. catenata* is known in specimens from the Rhône Basin (PHILIPPE, 1998: pl. 7, figs. 7a-b, 8); it is dicyclic and very similar to that of *G. maculata*.

In a recent revision of the echinoids of the Rhône Basin, PHILIPPE (1998) synonymised *Arbacina tenera* DE LORIO, 1902 and *A. savini* LAMBERT, 1910 with this species.

Distribution: Lower to Upper Badenian (Langhian to Lower Serravallian) of the Central Paratethys (Eisenstadt-Sopron Basin, Fore-Carpathian Basin, Great Hungarian Basin and Vienna Basin) (VADÁSZ 1915, MACZYŃSKA 1993; pers. obs.) and Burdigalian to ?Langhian of the Mediterranean (Egypt, Rhône Basin and Sardinia) (COTTREAU 1913, LAMBERT 1915, FOURTAU 1920, PHILIPPE 1998).

Family Toxopneustidae TROSCHER, 1872

Genus *Schizechinus* POMEL, 1869

Schizechinus sp. (pl. 3, figs. 7-10)

Material: Niederleis, NÖ: 15 test fragments (NHMW 2002z0087/0057-62, 2002z0089/0008, 2002z0090/0007-8).

Description:

Ambulacra (pl. 3, fig. 10): The ambulacra consist of trigeminate plates of the echinoid compound type. The pores are partitioned isopores and are arranged in arcs of

three, forming a zigzag pattern. Each plate bears one large noncrenulate, imperforate marginal tubercle with undercut mamelon and several smaller inner tubercles.

I n t e r a m b u l a c r a (pl. 3, figs. 7-9): Each interambulacral plate bears one large noncrenulate, imperforate primary tubercle with undercut mamelon. The secondary tubercles besides the primary tubercles are distinctly enlarged, forming a horizontal row. On many plates there are two enlarged secondary tubercles arranged in a vertical row adradially of the primary tubercle. "Normal" secondary tubercles and miliary tubercles are spread loosely among the larger tubercles, but are commonest along the adapical border of each plate.

P e r i s t o m e: The peristome shows moderately deep gill slits.

R e m a r k s: Although the material is highly fragmentary it can be assigned to the genus *Schizechinus* without much doubt, based on a comparison with specimens of *Schizechinus* from Winden and St. Margarethen (Burgenland, Austria), where this genus is fairly common and where specimens preserving apical disc, associated spines and jaws are known (compare e.g. SCHMID et al. 2001: pl. 2; pl. 3, fig. 1). Diagnostic features are the tuberculation pattern, the arrangement of the ambulacral pores and the presence of moderately deep gill slits.

D i s t r i b u t i o n: The genus *Schizechinus* is known from the Miocene to Pliocene of the Mediterranean and the Paratethys (FELL & PAWSON 1966). In Austria it is known from the Badenian (Langhian-Serravallian) of the Vienna Basin, the Eisenstadt-Sopron Basin and the Danube Basin (LAUBE 1871, SCHMID et al. 2001, pers. obs.).

Genus *Tripneustes* L. AGASSIZ, 1841

***Tripneustes* sp.** (pl. 2, figs. 8-10)

M a t e r i a l: Niederleis, NÖ: 3 spine fragments (NHMW 2002z0087/0066-68).

D e s c r i p t i o n: The spine fragments examined are striate, with small granules on the ridges. The base of the spine is about as wide as the basal part of the shaft, only the ring is wider. In two of the spine fragments the base is heavily corroded, revealing a stacked pattern of tubes similar to the shaft.

R e m a r k s: The specimens studied are all proximal spine fragments and are closely similar to the basal part of spines of *Tripneustes* (see Text-fig. 3a, c). There is also some similarity to the basal part of oral spines of echinothuriids. In this group oral and aboral spines are differentiated. The oral spines are rather long and terminate in a trumpet-shaped tip. Along the spine four zones with different microstructures can be distinguished (at least in the genus *Asthenosoma*): a) the distal trumpet-shaped hoof with a smooth outer surface, b) a transitional zone which is striated, with minute teeth along the ridges, c) a striated zone which is distinctly verticillate and d) a striated basal part with smooth or slightly granulated ridges (RÉGIS & THOMASSIN 1984 and pers. obs. on *Asthenosoma ijimai* YOSHIWARA, USNM E10669). However, the milled ring of echinothuriid spines is much more prominent and the verticillate part of the spines starts relatively close to the base, features not observed in the spines studied. Moreover, echinothuriid spines are hollow or filled with a porous mesh, whereas the investigated spines are more or less solid, without central cavity or a very small one.

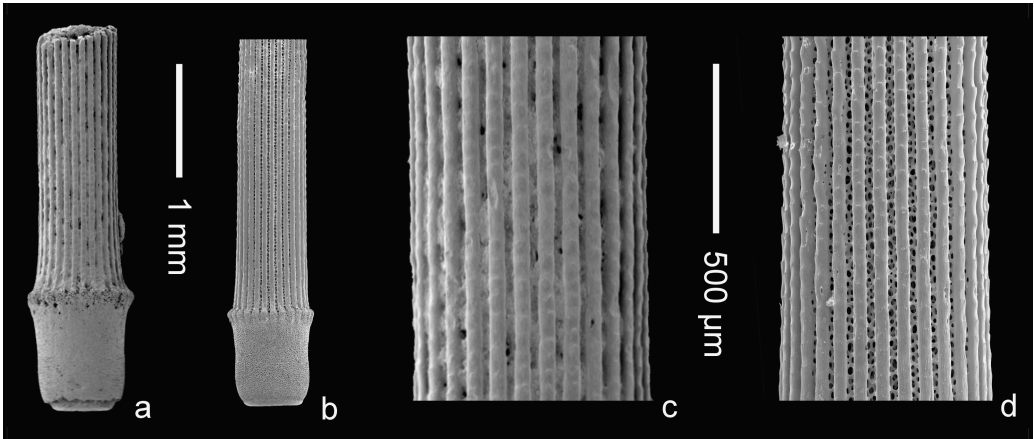


Fig. 3: Comparison of fossil *Tripneustes* sp. spines (Niederleis, NÖ; a, c: NHMW 2002z0087/0066) with spines of extant *Tripneustes ventricosus* (LAMARCK, 1816) (b, d: ?Caribbean Sea).

Distribution: The genus *Tripneustes* is known from the Miocene to the present day (FELL & PAWSON 1966). In Austria it is known from the Badenian (Langhian-Serravallian) of Kalksburg in the Vienna Basin (TAUBER 1951).

Echinacea indet. (pl. 4, figs. 1-14)

Material: Niederleis, NÖ: 77 rotulae type 1 (NHMW 2002z0087/0031-36, NHMW 2002z0089/0005), 1 rotula type 2 (NHMW 2002z0087/0026), 4 primary spines type 1 (NHMW 2002z0087/0027-30), 1 primary spine type 2 (NHMW 2002z0087/0024), 12 demipyramids (NHMW 2002z0087/0025, 2002z0089/0003-4, 2002z0090/0002).

Description:

Rotula type 1 (pl. 4, figs. 7-11, 14): Rather large, thick rotula, with a distinctly triangular part at the distal end. The proximal end is bluntly pointed with a central indentation.

Rotula type 2 (pl. 4, figs. 12-13): Smaller, thin rotula, with a trapezoid part at the distal end. The proximal end is broad with a wide central indentation.

Primary spine type 1 (pl. 4, figs. 1-4): Striated spines with a distinct milled ring and a noncrenulate acetabulum.

Primary spine type 2 (pl. 4, fig. 5): Striated spines with indistinct milled ring, blunt shaft and a noncrenulate acetabulum.

Demipyramids (pl. 4, fig. 6): Typical camarodont demipyramid.

Remarks: The spines and lantern elements belong to echinacean echinoids. On the basis of a comparison with fossil (*Schizechinus dux* (LAUBE, 1871)) and extant (*Genocidaris maculata*) material it is possible to tentatively refer part of those elements to specific taxa. The type 1 rotula and spines are very similar to those of *Schizechinus dux*.

from Winden and St. Margarthen (Burgenland, Austria) and are referred to *Schizechinus* sp., of which also test fragments were found (see above). The type 2 rotula is very similar to those of extant *Genocidaris maculata* and are referred to *G. catenata*, of which also test fragments were found (see above). The demipyramids could not be related to any specific taxon considered in the present study.

Cohort Irregularia LATREILLE, 1825

Superorder Microstomata, SMITH, 1984

Series Neognathostomata SMITH, 1981

Order Cassiduloida CLAUS, 1880

?Family Echinolampadidae GRAY, 1851

?Genus *Echinolampas* GRAY, 1825

***Echinolampas?* sp.** (pl. 4, fig. 15)

M a t e r i a l : Niederleis, NÖ: 5 test fragments (NHMW 2002z0087/0037-39).

R e m a r k s : The material available is highly fragmentary and abraded and consists of a few small (5 mm in greatest length) test fragments. On account of tuberculation and the lack of any internal support structures, the fragments are placed in the order Cassiduloida. Although they lack features diagnostic for family or even genus level, they are tentatively assigned to the genus *Echinolampas*, since all other Miocene cassiduloids of the Central Paratethys are very rare and/or have a different tuberculation pattern.

Series Atelostomata ZITTEL, 1879

Order Spatangoida CLAUS, 1876

Spatangoida indet. (pl. 4, fig. 16)

M a t e r i a l : Niederleis, NÖ: 4 test fragments (NHMW 2002z0087/0063-65). - Grund, NÖ: numerous spine fragments.

R e m a r k s : The highly fragmentary material of Niederleis is attributed to the order Spatangoida on account of its tuberculation, but a more specific determination is impossible. In bulk samples from the Grund Formation spines of spatangoids are very common, but due to their lack of diagnostic features, however, a more precise allocation is impossible.

Class Asteroidea DE BLAINVILLE, 1830

Order Forcipulatida PERRIER, 1884

?Family Asteriidae GRAY, 1840

Asteriidae? indet. (pl. 2, figs. 11-14)

M a t e r i a l : Niederleis, NÖ: 3 actinal ossicles (NHMW 2002z0087/0003-5).

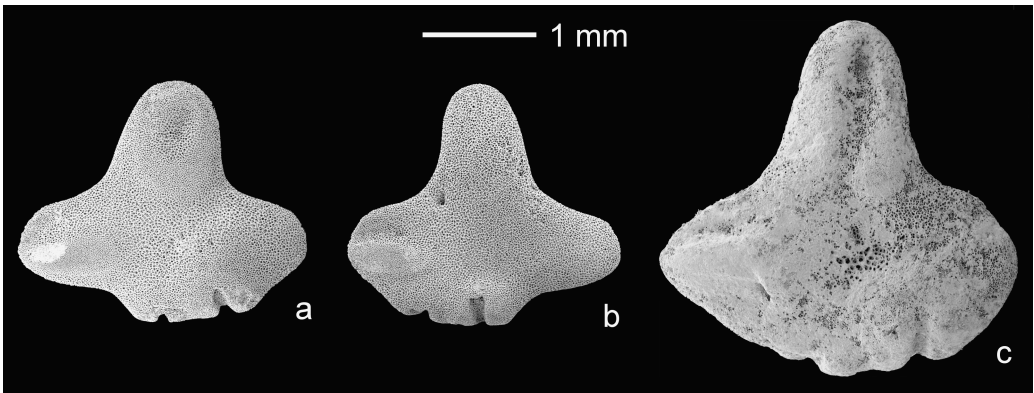


Fig. 4: Comparison of actinal ossicles of extant *Marthasterias glacialis* (LINNÉ, 1758) (a-b: Norway; NHMW 12039) with fossil ones of Asteriidae? indet. (Niederleis, NÖ; c: NHMW 2002z0087/004).

Description: The ossicles are flattened and club- to broad T-shaped in outline. On the outer side there is a distinct groove in the long flange (pl. 2, figs. 11, 13). The inner side shows a central pit. The ventral margin of the ossicles is indented.

Remarks: The studied ossicles are actinals (body wall ossicles between the ambulacral and inframarginal series) and are very similar to those found in extant asteriids (compare FISHER 1930). Several different extant species of *Asterias* in the collection of the NHM Vienna have been compared with the fossil material and revealed close similarities. However, most of them showed spine-bases on the actinals, a feature not observed in the fossil specimens. Another group with superficially similar ossicles are the Ophidiasteridae, but their ossicles have the shape of a broad cross. Until more material, especially also other ossicles, are available the specimens are tentatively placed in the family Asteriidae.

Distribution: The family Asteriidae is known from the Lower Jurassic to Recent (SPENCER & WRIGHT 1966). This is the first record of this group from the Miocene of Austria.

Class Crinoidea MILLER, 1821

Subclass Articulata ZITTEL, 1879

Order Isocrinida SIEVERTS-DORECK, 1952

Family Isocrinidae GISLÉN, 1924

?Genus *Isocrinus* von MEYER in AGASSIZ, 1836

***Isocrinus?* sp.** (pl. 5, figs. 9-11)

Material: Niederleis, NÖ: 2 columnals (1 nodal and 1 internodal; NHMW 2002z0087/00054-55).

Description: The columnals are small (about 1.5 – 2 mm in diameter) and pentagonal-stellate in outline. The nodal bears 5 large, elliptical cirrus sockets, which are

almost as high as the nodal. The articulation of the columnals consists of marginal and adradial crenulae forming five elliptical petals.

R e m a r k s : Since the main taxonomic features in isocrinid genera are found in the crown (e.g. branching pattern, articulation types, ...) it is difficult to identify isolated columnals. The material considered is tentatively referred to *Isocrinus* because of its articulation pattern (compare also OJI 1990, who reported similar, albeit larger columnals from the Miocene of Japan).

Crinoidea indet. (pl. 5, figs. 1-8, 12-14)

M a t e r i a l : Niederleis, NÖ: 23 brachials (NHMW 2002z0087/0008-12, NHMW 2002z0087/00016, NHMW 2002z0089/0001, NHMW 2002z00900001) and 36 cirrals (NHMW 2002z0087/0013-15, 17).

D e s c r i p t i o n :

B r a c h i a l s (pl. 5, figs. 1-8): The brachials are rather large (width up to 2.5 mm, height: 3 mm, thickness: 0.5 to 1.5 mm) and U-shaped outline. The dorsal side is rounded and bears small, vertical ridges in some specimens. The articulations are mainly oblique muscular articulations, but straight muscular and syzygial articulations are also present. The attachment scar for the pinnulae, if present, lies ventrally and is as wide as the brachial is thick.

C i r r i (pl. 5, figs. 12-14): The cirri are rather large, massive and of low cylindrical shape. The axial canal is relatively narrow and lies slightly ventrally of the centre. The distal and the proximal articulation surface are roughly parallel to each other and are inclined to the axis of the ossicle. The distal articulation surface bears a distinct articulation ridge, which is perforated by the axial canal. On the proximal articulation surface the axial canal lies in a shallow depression and the articulation ridge is not so prominent as the distal one.

R e m a r k s : Although well preserved it is difficult to attribute the studied ossicles to a specific group of crinoids, partly because no or only few diagnostic features are preserved on isolated brachials and cirri, and partly because of the lack of extant specimens for comparison. It is quite possible that they belong to the isocrinid described above, but until more and especially articulated material becomes available a more specific determination is left open.

Biostratigraphy and Palaeoecology

The biostratigraphical value of the echinoderm taxa studied is very low, in part because most taxa could not be identified to species level, and because many echinoderm species have a rather long temporal occurrence. The two echinoids identified to species level (*Eucidaris zeamays* and *Genocidaris catenata*) have also been recorded from the Burdigalian to Langhian of the Mediterranean and the Langhian to Serravallian of the Central Paratethys.

The potential value of echinoderms in palaeoecology and palaeoenvironmental reconstruction, however, is much greater, as shown by numerous studies on echinoids (e.g.:

ERNST 1970, CROFT & SHAAK 1985, NÉRAUDEAU & FLOQUET 1991, JAGT & MICHELS 1994, NÉRAUDEAU et al. 2001, SCHMID et al. 2001). They are especially useful, when also fragmentary and disarticulated material is considered (e.g.: GORDON & DONOVAN 1992, NEBELSICK 1992, DONOVAN et al. 1993, DONOVAN 1996, KROH & HARZHAUSER 1999) due to the fact that species, recorded only by such isolated ossicles, are also recognised, which otherwise would not have been.

The present assemblage from Niederleis is a typical shallow-water echinoderm fauna: The commonest species found is *Eucidaris zeamays*, which was recorded by isolated plates and spines. Extant species of *Eucidaris* are especially abundant from the intertidal down to 20–30 metres (KIER & GRANT 1965, NEBELSICK 1992, HICKMAN 1998). *E. tribuloides* is usually observed on sandy or rocky bottoms, within turtle grass or on rocks in crevices or beneath sponges or corals; but not on clean sand, where sea grass or algae are absent; its distribution coincides with that of *Tripneustes ventricosus* (KIER & GRANT, 1965). *E. metularia* lives on a variety of hard and soft substrates and is especially common on sand with coral patches, in coral reefs and coral carpets (NEBELSICK, 1992). *Schizechinus* sp., of which test fragments, spines and pieces of the lantern were found, is closely related to extant *Sphaerechinus*. In the Mediterranean *Sphaerechinus granularis* lives between 1 to 120 metres water depth, but is commonest between 8–12 metres, on coarse sandy to gravel bottoms with sea grass (RIEDL 1983, ERNST 1973). According to ERNST (1973), however, water depth is not relevant for the distribution of this echinoid, instead it is controlled by the presence of suitable substrates and most important the presence of macroalgae on which the urchin feeds. *Genocidaris catenata* is morphologically very similar to the extant *G. maculata*, which is found on sands with coralline algae and muddy sands with *Peyssonnelia* between 12 to 500 metres water depth in the Mediterranean (RIEDL 1983). Extant diadematids inhabit a wide range of substrates, ranging from exposed rocks to clean sands and coral reefs (KIER & GRANT 1965, RIEDL 1983, NEBELSICK 1992, HICKMAN 1998). In the Northern Bay of Safaga, Red Sea, fragments of *Diadema setosum* are widely distributed (although not very numerous) and are most frequent in moderately sorted, medium sands in the sand with coral patches bottom facies and terrigenous sedimentary facies (NEBELSICK 1992). The fragments of *Tripneustes* sp., *Echinolampas*? sp. and *Spatangoida* indet. were found in rather low number and are in most cases heavily abraded, whereas the remains of all other taxa reported are usually very well preserved, a fact which suggests that the former specimens were transported into this environment.

Summarising the data presented above, a shallow sublittoral coarse sandy environment with sea grass and/or macroalgal patches in a depth between 10 to 30 m water depth is suggested for the echinoderm fauna recovered from the bulk samples of Niederleis. This is in good agreement with the data presented for the gastropods from this locality (MANDIC et al. 2002). Note, however, that the bulk sample comes from one of the common shell beds present in the sections of Niederleis, which represent proximal tempestites and were deposited in a middle shelf environment with inferred palaeodepth between 100 and 500 m (MANDIC et al. 2002). The isocrinid columnals found within the sample might represent the autochthonous deep-water fauna, since extant isocrinids occur mostly between 200 to 1,000 metres (BREIMER 1978, OJI 1985), which was incorporated into the shell bed during the transport.

Acknowledgements

This study was supported by the Austrian Science Foundation, project No. P-14366-Bio to Werner E. Piller (University of Graz). The opportunities to do my research at the Geological-Palaeontological Department of the Vienna Natural History Museum and to access the collections of the Institute of Palaeontology, University of Vienna are gratefully acknowledged. I wish to express my thanks to John Jagt (NHM Maastricht) for his critical review, to James H. Nebelsick (Univ. Tübingen) for improving the English, and to the following people for valuable discussion and support during this study: Cynthia Ahearn (US National Museum), Daniel Blake (Univ. Illinois), Rosalinde Esberger (NHM Vienna), Andy Gale (NHM London), Mathias Harzhauser (NHM Vienna), Hans Hess (Binningen, Switzerland), Oleg Mandic (Univ. Vienna), Tatsuo Oji (Univ. Tokyo), Ortwin Schultz (NHM Vienna), Helmut Sattmann (NHM Vienna), Andrew Smith (NHM London), Loïc Villier (Univ. Bourgogne, Dijon), Gerhard Wanzenböck (Gainfarn, Austria), and Martin Zuschin (Univ. Vienna).

References

- AGASSIZ, L. & DESOR, P.J.E. (1846-1847): Catalogue raisonné des familles, des genres, et des espèces de la classe des échinodermes. – Ann. Sci. Nat. (3), Zool. **6** (1846):305-374, **7** (1847):129-168, **8** (1847): 5-35, 355-380. – Paris.
- AIRAGHI, C. (1901): Echinidi terziari del Piemonte e della Liguria. – Palaeontogr. Ital., **7**: 149-219. – Pisa.
- BORGHI, E. (1995): Echinodermi fossili del Parmense-Piacentino. Segnalazione di una nuova forma affine *Genocidaris maculata* A. Agassiz, 1869. – Bibliotheca, Studi di scienze naturali, **5**: 1-14. – Piacenza & Vigevano
- BREIMER, A. (1978): Ecology of Recent crinoids. – In: MOORE, R.C. & TEICHERT, C. (eds.): Treatise on Invertebrate Paleontology, T. Echinodermata. 2 (1). – T316-T330. – Lawrence, KS & Boulder, CO (GSA & Univ. Kansas Press).
- COTTREAU, J. (1913): Les Échinides néogènes du Bassin Méditerranéen. – Ann. Inst. Océanogr. Monaco, **6/3**: 1-192. – Monaco.
- CROFT, M. & SHAAK, G.D. (1985): Ecology and Stratigraphy of the Echinoids of the Ocala Limestone (Late Eocene). – Tulane Studies Geol. Paleont., **18/4**: 127-143. – New Orleans, LOU.
- DONOVAN, S.K. (1996): Use of the SEM in interpreting ancient faunas of sea urchins. – European Microscopy and Analysis, 1996/7: 29. – Bookham, Surrey.
- , GORDON, C.M., VELTKAMP, C.J. & SCOTT, A.D. (1993): Crinoids, asteroids, and ophiuroids in the Jamaican fossil record. – In: WRIGHT, R.M. & ROBINSON, E. (eds.): Biostratigraphy of Jamaica. – Mem. Geol. Soc. America, **182**: 125-130. – Boulder, CO.
- ERNST, G. (1970): Faziesgebundenheit und Ökomorphologie bei irregulären Echiniden der nord-westdeutschen Oberkreide. – Paläont. Z., **44/1-2**: 41-62. – Stuttgart.
- (1973): Aktuopaläontologie und Merkmalsvariabilität bei mediterranen Echiniden und Rückschlüsse auf die Ökologie und Artumgrenzung fossiler Formen. – Paläont. Z., **47/3-4**: 188-216. – Stuttgart.
- FELL, H.B. (1966a): Cidaroids. – In: MOORE, R.C. (ed.): Treatise on Invertebrate Paleontology, U. Echinodermata. 3 (1). – : U312-U340. – Boulder, CO & Lawrence, Kansas (GSA & Univ. Kansas Press).

- (1966b): Diadematacea. – In: MOORE, R.C. (ed.): Treatise on Invertebrate Paleontology, U. Echinodermata, **3** (1): U340-U366. – Boulder, CO & Lawrence, Kansas (GSA & Univ. Kansas Press).
- & PAWSON, D.L. (1966): Echinacea. – In: MOORE, R.C. (ed.): Treatise on Invertebrate Paleontology, U. Echinodermata, **3** (2): U367-U440. – Boulder, CO & Lawrence, KS (GSA & Univ. Kansas Press).
- FISHER, W.K. (1930): Asteroidea of the North Pacific and Adjacent Waters. Part 3. Forcipulata (Concluded). – Smiths. Inst. US Natl. Mus. Bull., **76**: 1-356. – Washington, D.C.
- FOURTAU, R. (1920): Catalogue des Invertébrés fossiles de l'Égypte. Terrains Tertiaires. 2^{de} partie: Echinodermes Néogènes. – 100 pp. – Cairo (Geological Survey of Egypt).
- GORDON, C.M. & DONOVAN, S.K. (1992): Disarticulated echinoid ossicles in paleoecology and taphonomy: the last interglacial Falmouth Formation of Jamaica. – *Palaios*, **7**: 157-166. – Bloomington, IN.
- HARZHAUSER, M., MANDIC, O., ZUSCHIN, M., PERVESLER, P. & ROETZEL, R. (1999): Allochthone Mollusken-Schille aus der Grund-Formation (Unteres Badenium) in einer *Thyasiridae*-Fazies. – In: ROETZEL, R. (ed.): Arbeitstagung Geologische Bundesanstalt 1999: 223-224. – Wien (GBA).
- HICKMAN, C.P. (1998): A Field Guide to Sea Stars and other Echinoderms of Galápagos. – 83 pp. – Lexington, Virginia (Sugar Spring Press).
- JAGT, J.W.M. & MICHELS, G.P.H. (1994): The palaeobiology of a late Maastrichtian echinoid fauna from Haccourt (Liège, NE Belgium). – In: DAVID, B., GUILLE, A., FÉRAL, J.-P. & ROUX, M. (eds.): Echinoderms through Time. – Proc. of the 8th Internat. Echinoderm Conf. Dijon/France, 6-10 Sept. 1993: 719-724. – Rotterdam (A. A. Balkema).
- KIDWELL, S.M. & BAUMILLER, T. (1990): Experimental disintegration of regular echinoids: Roles of temperature, oxygen, and decay thresholds. – *Paleobiology*, **16/3**: 247-271. – Lawrence, KS.
- KIER, P.M. (1977): The poor fossil record of the regular echinoids. – *Paleobiology*, **3**: 168-174. – Lawrence, KS.
- & GRANT, R.E. (1965): Echinoid distribution and habits, Key Largo Coral Reef Preserve, Florida. – Smiths. Misc. Collns., **149**: 1-68. – Washington DC.
- KÓKAY, J. (1966): A Herend - Márkói Barnaköszénterület földtani és öslénytani vizsgálata. – Geol. Hung., Ser. Palaeont., **36**: 1-149. – Budapest.
- KROH, A. & HARZHAUSER, M. (1999): An Echinoderm Fauna from the Lower Miocene of Austria: Paleocology and Implications for Central Paratethys Paleobiogeography. – *Ann. Naturhist. Mus. Wien*, **101A**: 145-191. – Wien.
- LAMBERT, J.M. (1910): Description des échinides des terrains néogènes du bassin Rhône. fasc.1. – *Mém. Soc. Paléont. Suisse*, **37**: 1-48. – Genève.
- (1915): Description des échinides des terrains néogènes du bassin Rhône. fasc.4. – *Mém. Soc. Paléont. Suisse*, **41**: 155-240. – Genève.
- LAUBE, G.C. (1871): Die Echinoiden der oesterreichisch-ungarischen oberen Tertiaerablagerungen. – *Abh. kaiserl.-königl. Geol. Reichsanst.*, **5/3**: 55-74. – Wien.
- MAĆZYŃSKA, S. (1977): Echinoids from the Korytnica basin (Middle Miocene; Holy Cross Mountains, Poland). – *Acta Geol. Polonica*, **27/2**: 193-200. – Warszawa.

- (1987): A supplementary account on the echinoids from the Korytnica Basin (Middle Miocene; Holy Cross Mountains, Central Poland). – *Acta Geol. Polonica*, **37/3-4**: 145-153. – Warszawa.
- (1988): Echinoids from the Middle Miocene (Badenian) sands from southern Poland. – *Prace Muz. Ziemi*, **40**: 59-64. – Warszawa.
- (1993): Echinoids from the Pińczów Limestones (Middle Miocene; Holy Cross Mountains, Central Poland). – *Acta Geol. Polonica*, **43/1-2**: 103-114. – Warszawa.
- (1996): Middle Miocene (Badenian) echinoids from Niechobrz near Rzeszów (southern Poland). – *Prace Muz. Ziemi*, **43**: 39-46. – Warszawa.
- MANDIC, O., HARZHAUSER, M., SPEZZAFERRI, S. & ZUSCHIN, M. (2002): The paleoenvironment of an early Middle Miocene Paratethys sequence in NE Austria with special emphasis on paleoecology of mollusks and foraminifera. – *Geobios, Mémoire spécial* **24**: 193-206. – Lyon.
- MORTENSEN, T. (1943): A Monograph of the Echinoidea, III, 2 Camarodonta. – vii+533 pp. – Copenhagen (C. A. Reitzel).
- NEBELSICK, J.H. (1992): Echinoid distribution by fragment identification in the Northern Bay of Safaga, Red Sea, Egypt. – *Palaios*, **7**: 316-328. – Bloomington, IN
- NÉRAUDEAU, D. & FLOQUET, M. (1991): Les échinides Hemiasteridae: marqueurs écologiques de la plateforme castillane et navarro-cantabre (Espagne) au Crétacé supérieur. – *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, **88**: 265-281. – Amsterdam.
- , GOUBERT, E., LACOUR, D. & ROUCHY, J.M. (2001): Changing biodiversity of Mediterranean irregular echinoids from the Messinian to Present-Day. – *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, **175**: 43-60. – Amsterdam.
- OJI, T. (1985): Early Cretaceous *Isocrinus* from Northeast Japan. – *Palaeontology*, **28/4**: 629-642. – London.
- (1990): Miocene Isocrinidae (stalked crinoids) from Japan and their biogeographic implication. – *Trans. Proc. Palaeont. Soc. Japan, N. S.*, **157**: 412-429. – Tokyo.
- PHILIPPE, M. (1984): Echinides. – In: POUYET, S. (ed.): La faune du faciès "marnes bleues", Burdigalien du Bassin de Faucon-Mollans-Malaucène (Sud-Est de la France). – *Nouv. Arch. Mus. Hist. Nat. Lyon*, **22**: 85-91. – Lyon.
- (1989): Révision des Echinides miocènes du Bassin du Rhône: résultats d'ordre systématique. – *Actes 6ème Sémin. intern. Echinodermes, Les Embiez, 1988; Vie Marine, Hors Serie* **10**: 24-35. – Marseille.
- (1998): Les Échinides Miocènes du Bassin du Rhône: révision systématique. – *Nouvelles Archives du Muséum d'Histoire Naturelle de Lyon*, **36/1+2**: 3-241, 249-441. – Lyon.
- RÉGIS, M.B. & THOMASSIN, B.A. (1985): Macro- and microstructure of the primary spines in *Asthenosoma varium* Grube (Echinothuridae: Echinoidea): Affinities with the Diadematidae and Toxopneustidae. – In: KEEGAN, B.F. & O'CONNER, B.D.S. (eds.): *Echinodermata - Proceed. 5th Internat. Echinoderm Conf., Galway, 24-29 Sept. 1984.* – : 321-332. – Rotterdam (A. A. Balkema).
- REUSS, A.E. (1860): Die marinen Tertiärschichten Böhmens und ihre Versteinerungen. – *Sitzber. kaiserl. Akad. Wiss., Math.-naturwiss. Cl., Abt. I*, **39**: 207-288. – Wien.
- RIEDL, R. (ed.) (1983): *Fauna und Flora des Mittelmeeres*. 3. Aufl. – 836 pp. – Hamburg (Paul Parey Verlag).

- RÖGL, F. (1998): Palaeogeographic Considerations for Mediterranean and Paratethys Seaways (Oligocene to Miocene). – Ann. Naturhist. Mus. Wien, **99A**: 279-310. – Wien.
- , SPEZZAFERRI, S. & CORIC, S. (2002): Micropaleontology and biostratigraphy of the Karpatian-Badenian transition (Early-Middle Miocene boundary) in Austria (Central Paratethys). – Cour. Forsch.-Inst. Senckenb., **237**: 47-67. – Frankfurt/Main.
- SCHMID, H.-P., HARZHAUSER, M. & KROH, A. (2001): Hypoxic Events on a Middle Miocene Carbonate Platform of the Central Paratethys (Austria, Badanian, 14 Ma). – Ann. Naturhist. Mus. Wien, **102A**: 1-50. – Wien.
- SEDGWICK, A. & MURCHINSON, R.I. (1831): A Sketch of the Structure of the Eastern Alps; with Sections through the Newer Formations on the Northern Flanks of the Chain, and through the Tertiary Deposits of Styria, &c. &c. – Trans. Geol. Soc. London, (2. Ser.) **3**: 301-420. – London.
- SIEBER, R. (1949): Eine Fauna der Grunder Schichten von Guntersdorf und Immendorf in Niederösterreich (Bezirk Hollabrunn). – Verh. Geol. Bundesanstalt, 1946: 107-122. – Wien.
- SISMONDA, E. (1842): Appendice alla Monografia degli Echinidi Fossili del Piemonte. – Mem. R. Accad. Sci. Torino, (Ser. 2) **4**: 385-394. – Torino.
- SMITH, A.B. (1978): A functional classification of the coronal pores of regular echinoids. – Palaeontology, **21**/4: 759-789. – London.
- (1980): The structure and arrangement of echinoid tubercles. – Phil. trans. roy. Soc. London, (B) **289**: 1-54. – London.
- SPENCER, W.K. & WRIGHT, C.W. (1966): Asterozoans. – In: MOORE, R.C. (ed.): Treatise on Invertebrate Paleontology, U. Echinodermata. 3 (1). – : U4-U107. – Boulder, CO & Lawrence, KS (GSA & Univ. Kansas Press).
- TAUBER, A.F. (1951): *Tripneustes ventricosus austriacus* nov. ssp. ein tropischer Seeigel aus dem Torton des Wiener Beckens. – Sitzber. Österr. Akad. Wiss. Wien, math.-naturw. Kl., Abt. I, **160**/3-4: 303-320. – Wien.
- VADÁSZ, M.E. (1915): Die mediterranen Echinodermen Ungarns. – Geol. Hung., **1**/2: 79-253. – Budapest.
- ZUSCHIN, M., HARZHAUSER, M. & PERVESLER, P. (2001): Fossil Evidence for Chemoautotrophic Bacterial Symbiosis in the Thyasirid Bivalve *Thyasira michelottii* From the Middle Miocene (Badenium) of Austria. – Hist. Biol., **15**: 123-134. – London

Plates

Plate 1

- Fig. 1: *Eucidaris zeamays* (SISMONDA, 1842), primary spine (NHMW2002z0087/0040)
- Fig. 2: *Eucidaris zeamays* (SISMONDA, 1842), primary spine (NHMW2002z0087/0041)
- Fig. 3: *Eucidaris zeamays* (SISMONDA, 1842), primary spine (NHMW2002z0087/0042)
- Fig. 4: *Eucidaris zeamays* (SISMONDA, 1842), primary spine (NHMW2002z0087/0043)
- Fig. 5: *Eucidaris zeamays* (SISMONDA, 1842), primary spine (NHMW2002z0087/0044)
- Fig. 6: *Eucidaris zeamays* (SISMONDA, 1842), primary spine (NHMW2002z0087/0045)
- Fig. 7: *Eucidaris zeamays* (SISMONDA, 1842), primary spine (NHMW2002z0087/0046)
- Fig. 8: *Eucidaris zeamays* (SISMONDA, 1842), primary spine (NHMW2002z0087/0047)
- Fig. 9: *Eucidaris zeamays* (SISMONDA, 1842), primary spine, detail of ornament (NHMW2002z0087/0044) same specimen as fig. 5
- Fig. 10: *Eucidaris zeamays* (SISMONDA, 1842), interambulacral plate (NHMW2002z0087/0048)
- Fig. 11: *Eucidaris zeamays* (SISMONDA, 1842), interambulacral plate (NHMW2002z0087/0049)

all figures, except fig. 9, given in the same magnification, scale bar equals 1 mm

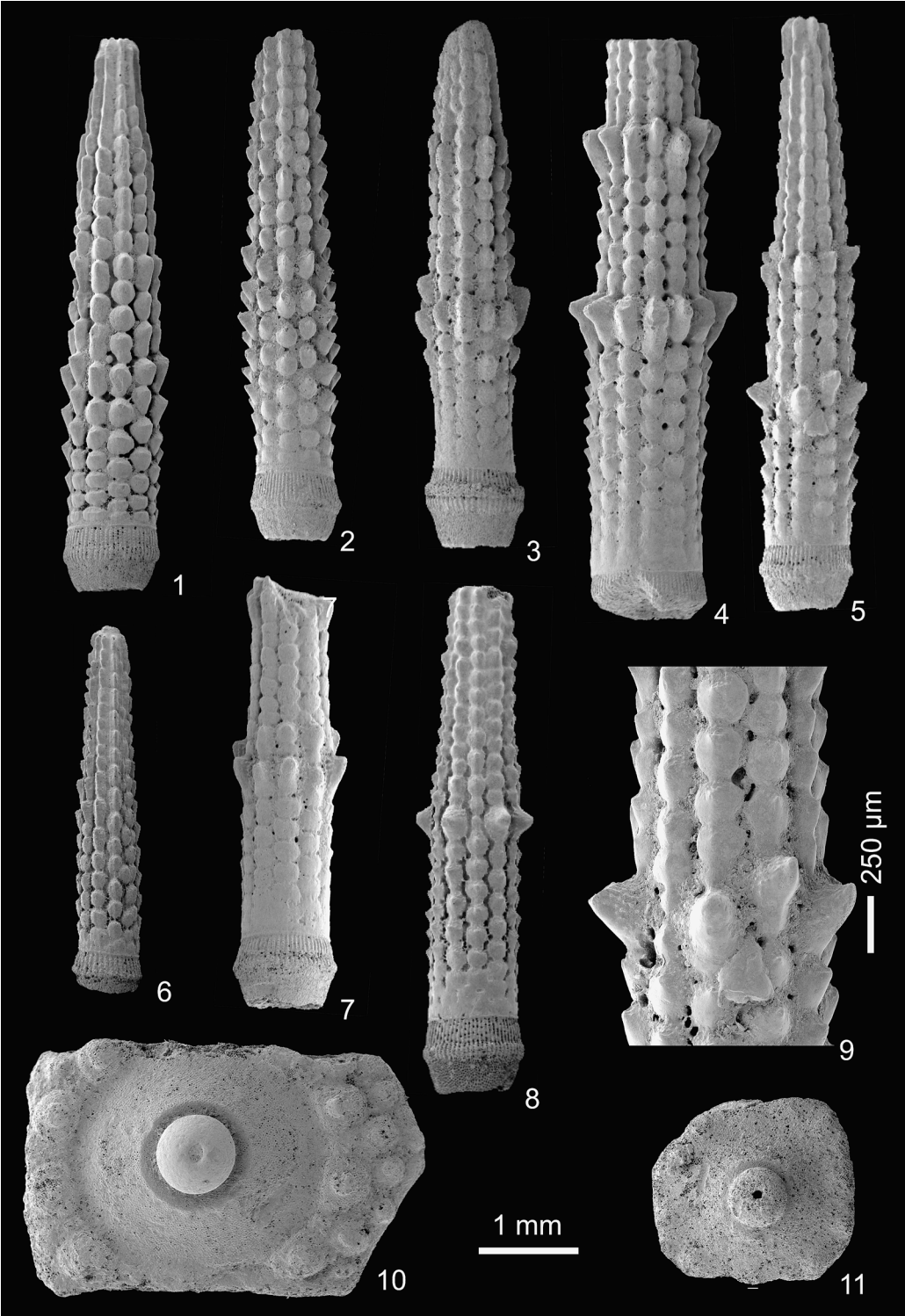


Plate 2

- Fig. 1: **Diadematidae indet.**, base of a primary spine
(NHMW2002z0087/0018)
- Fig. 2: **Diadematidae indet.**, base of a primary spine
(NHMW2002z0087/0019)
- Fig. 3: **Diadematidae indet.**, primary spine
(NHMW2002z0087/0020)
- Fig. 4: **Diadematidae indet.**, interambulacral plate
(NHMW2002z0087/0021)
- Fig. 5: **Diadematidae indet.**, ambulacral plate
(NHMW2002z0089/0002)
- Fig. 6: **Cidaroida indet.**, base of a primary spine
(NHMW2002z0087/0006)
- Fig. 7: **Cidaroida indet.**, small primary spine
(NHMW2002z0087/0007)
- Fig. 8: ***Tripneustes* sp.**, base of a primary spine
(NHMW2002z0087/0066)
- Fig. 9: ***Tripneustes* sp.**, base of a primary spine
(NHMW2002z0087/0067)
- Fig. 10: ***Tripneustes* sp.**, base of a primary spine
(NHMW2002z0087/0068)
- Fig. 11: **Asteriidae? indet.**, actinal, outer view
(NHMW2002z0087/0003)
- Fig. 12: **Asteriidae? indet.**, actinal, inner view
(NHMW2002z0087/0003)
- Fig. 13: **Asteriidae? indet.**, actinal, outer view
(NHMW2002z0087/0004)
- Fig. 14: **Asteriidae? indet.**, actinal, inner view
(NHMW2002z0087/0004)
- all figures given in the same magnification, scale bar equals 1 mm

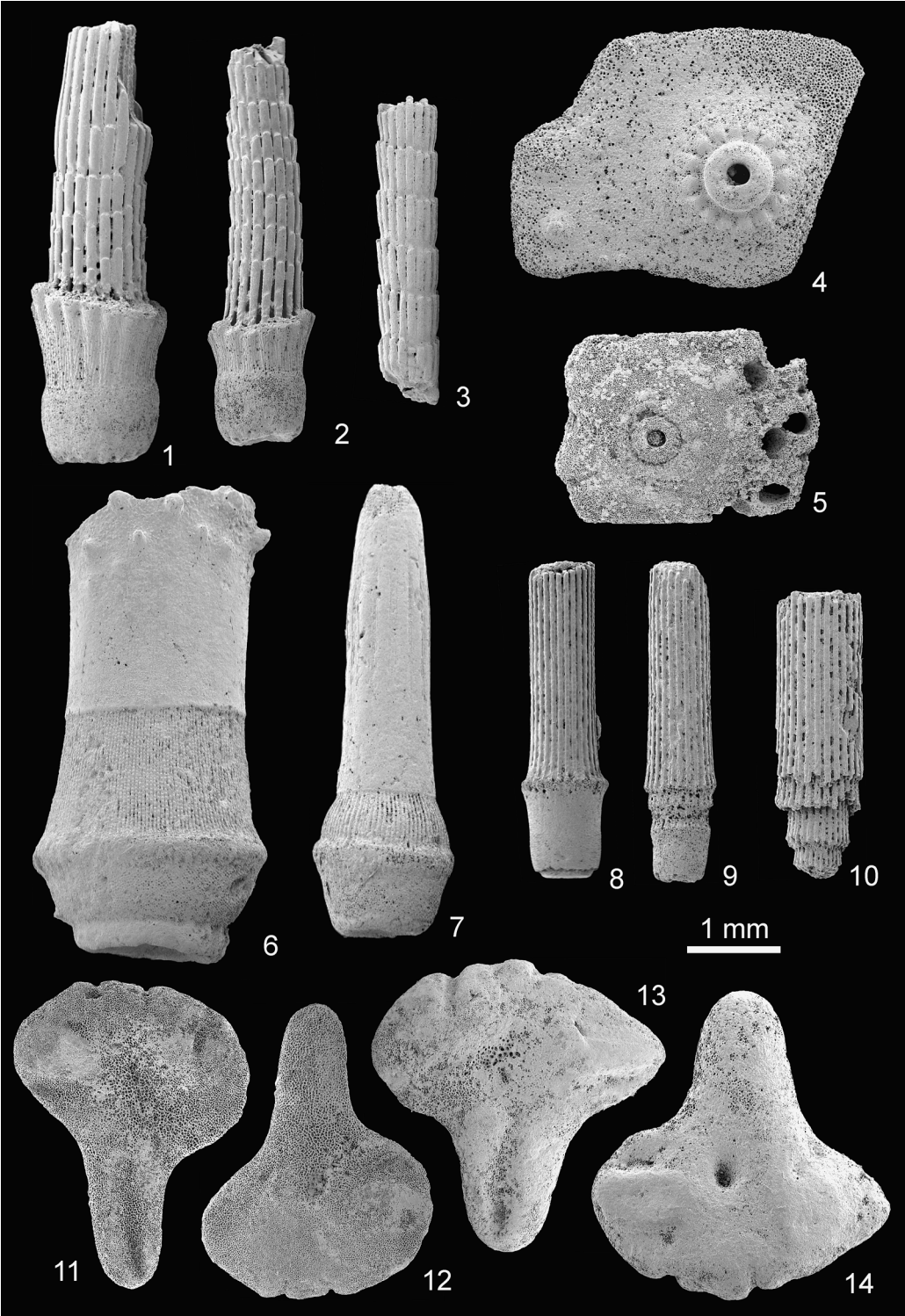


Plate 3

- Fig. 1: *Genocidaris catenata* (DESOR, 1846), ambital test fragment (NHMW2002z0087/0053)
- Fig. 2: *Genocidaris catenata* (DESOR, 1846), ambital test fragment (NHMW2002z0090/0003)
- Fig. 3: *Genocidaris catenata* (DESOR, 1846), ambital test fragment (NHMW2002z0090/0004)
- Fig. 4: *Genocidaris catenata* (DESOR, 1846), ambital test fragment (NHMW2002z0089/0007)
- Fig. 5: *Genocidaris catenata* (DESOR, 1846), adoral test fragment (NHMW2002z0090/0005)
- Fig. 6: *Genocidaris catenata* (DESOR, 1846), detail of the ambulacral pores (NHMW2002z0090/0003), same specimen as fig. 2
- Fig. 7: *Schizechinus* sp., adapical interambulacral plate (NHMW2002z0087/0057)
- Fig. 8: *Schizechinus* sp., ambital interambulacral plate (NHMW2002z0090/0007)
- Fig. 9: *Schizechinus* sp., adoral test fragment (NHMW2002z0087/0058)
- Fig. 10: *Schizechinus* sp., adoral ambulacral plates (NHMW2002z0087/0059)
- all figures, except fig. 6, given in the same magnification, scale bar equals 1 mm

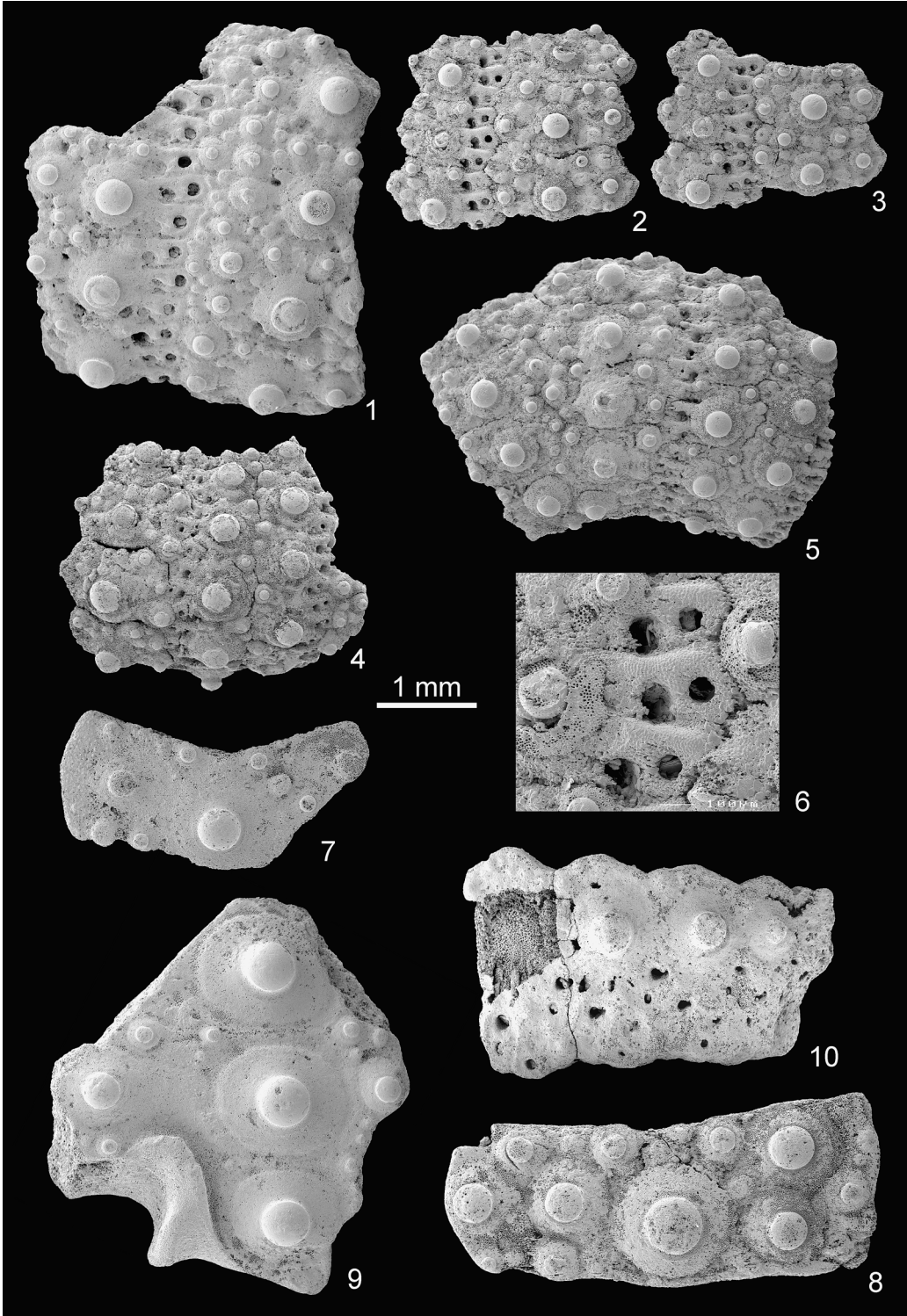


Plate 4

- Fig. 1: **Echinacea indet. (?Schizechinus sp.)**, primary spine (NHMW2002z0087/0027)
- Fig. 2: **Echinacea indet. (?Schizechinus sp.)**, primary spine (NHMW2002z0087/0028)
- Fig. 3: **Echinacea indet. (?Schizechinus sp.)**, primary spine (NHMW2002z0087/0029)
- Fig. 4: **Echinacea indet. (?Schizechinus sp.)**, primary spine (NHMW2002z0087/0030)
- Fig. 5: **Echinacea indet.**, primary spine (NHMW2002z0087/0024)
- Fig. 6: **Echinacea indet.**, demipyramid (NHMW2002z0089/0003)
- Fig. 7: **Echinacea indet. (?Schizechinus sp.)**, rotula (NHMW2002z0087/0031)
- Fig. 8: **Echinacea indet. (?Schizechinus sp.)**, rotula (NHMW2002z0087/0032)
- Fig. 9: **Echinacea indet. (?Schizechinus sp.)**, rotula (NHMW2002z0087/0033)
- Fig. 10: **Echinacea indet. (?Schizechinus sp.)**, rotula (NHMW2002z0087/0034)
- Fig. 11: **Echinacea indet. (?Schizechinus sp.)**, rotula (NHMW2002z0087/0035)
- Fig. 12: **Echinacea indet. (?Genocidaris catenata (DESOR, 1846))**, rotula (NHMW2002z0087/0026)
- Fig. 13: **Echinacea indet. (?Genocidaris catenata (DESOR, 1846))**, rotula, lateral view (NHMW2002z0087/0026), same specimen as fig. 12
- Fig. 14: **Echinacea indet. (?Schizechinus sp.)**, rotula, lateral view (NHMW2002z0087/0033), same specimen as fig. 9
- Fig. 15: **Echinolampas? sp.**, test fragment (NHMW2002z0087/0037)
- Fig. 16: **Spatangoida indet.**, test fragment (NHMW2002z0087/0063)

all figures given in the same magnification, scale bar equals 1 mm

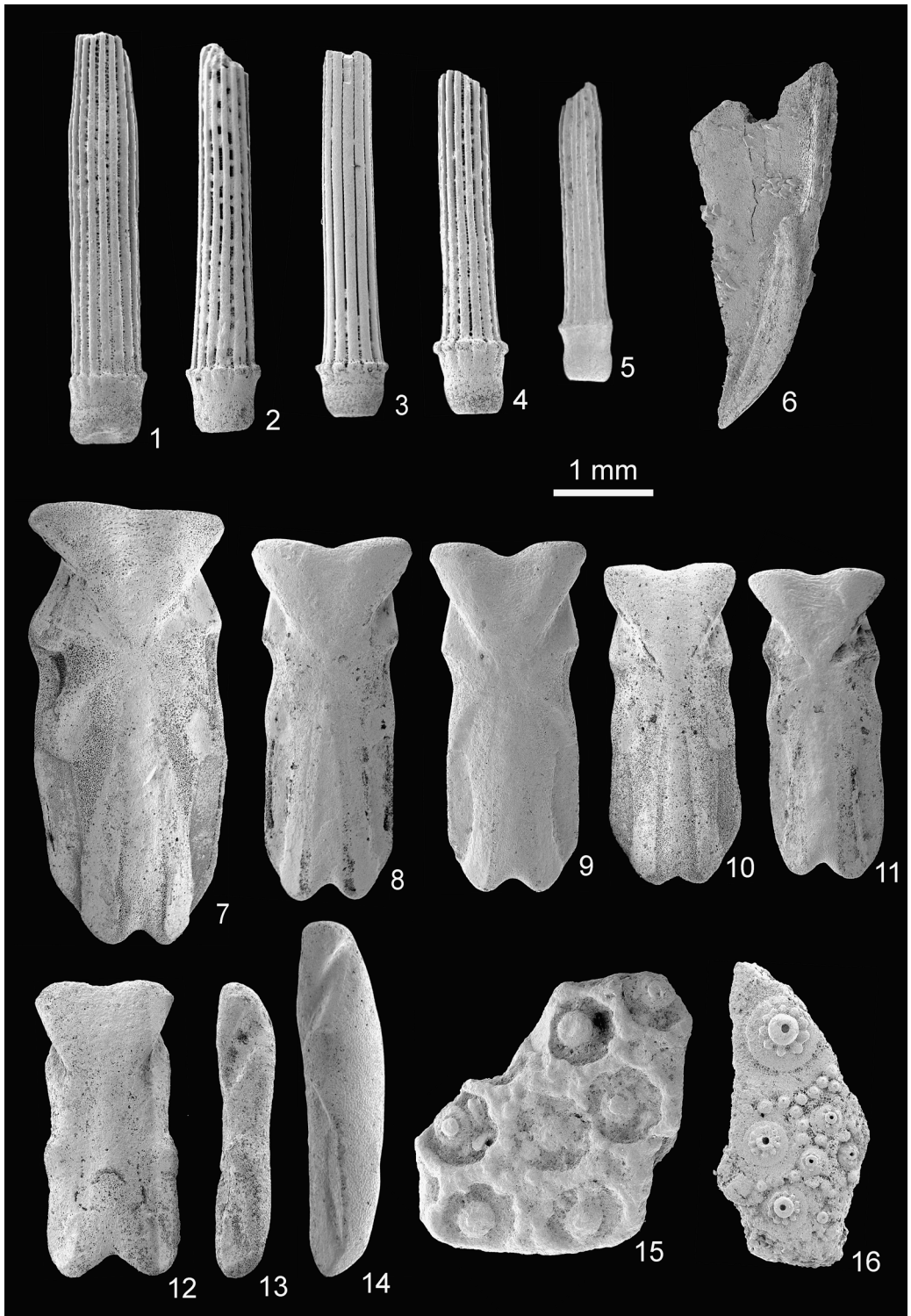


Plate 5

- Fig. 1-2: **Crinoidea indet.**, muscular brachial
(NHMW2002z0087/0009)
- Fig. 3-4: **Crinoidea indet.**, syzygial brachial
(NHMW2002z0087/0010)
- Fig. 5-6: **Crinoidea indet.**, syzygial brachial
(NHMW2002z0087/0011)
- Fig. 7-8: **Crinoidea indet.**, muscular brachial
(NHMW2002z0087/0012)
- Fig. 9: ***Isocrinus?* sp.**, columnal (internodal)
(NHMW2002z0087/0054)
- Fig. 10: ***Isocrinus?* sp.**, columnal (nodal)
(NHMW2002z0087/0055)
- Fig. 11: ***Isocrinus?* sp.**, columnal (nodal), lateral view to show cirral socket
(NHMW2002z0087/0055), same specimen as fig. 10
- Fig. 12: **Crinoidea indet.**, cirral
(NHMW2002z0087/0013)
- Fig. 13: **Crinoidea indet.**, cirral, lateral view
(NHMW2002z0087/0014)
- Fig. 14: **Crinoidea indet.**, cirral
(NHMW2002z0087/0015)

all figures given in the same magnification, scale bar equals 1 mm

