

**ECHINOIDS FROM THE EARLY PALAEOCENE (DANIAN)
OF THE MAASTRICHT AREA (NE BELGIUM, SE NETHERLANDS):
PRELIMINARY RESULTS**

by

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Ham, R.W.J.M. van der. Echinoids from the Early Palaeocene (Danian) of the Maastricht area (NE Belgium, SE Netherlands): preliminary results.—Meded. Werkgr. Tert. Kwart. Geol., 25 (2-3): 127-161, 1 fig., 1 tab., 9 pls. Leiden, October 1988.

The echinoid fauna of the Geulhem Chalk Member (Houthem Formation, Early Palaeocene) is described and illustrated. It comprises twenty-eight species, twenty-one of which are regular. The material described was collected from two important sections in the Belgian and Dutch provinces of Limburg. The fauna is compared with that of time equivalent strata in the Mons Basin (S Belgium), and in Denmark and southern Sweden. As data presented are of a preliminary nature, no attempt is made to discuss the biostratigraphic value (spines of the genus *Tylocidaris* Pomel, 1883 in particular) of some species in this fauna.

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SAMENVATTING

Echinoiden uit het Vroeg Paleoceen (Danien) in de omgeving van Maastricht (NO België, ZO Nederland): voorlopige resultaten.

In de omgeving van Maastricht zijn momenteel twee ontsluitingen aanwezig in de Kalksteen van Geulhem (Vroeg Paleoceen, Danien, Formatie van Houthem): de voormalige groeve Curfs (Nederland) en het Albertkanaal (België). In de eerstgenoemde is alleen het onderste deel van de Kalksteen van Geulhem aanwezig, in de laatstgenoemde ook het bovenste deel. Dit artikel geeft een beschrijving van alle 28 zeegelsoorten (waaronder 21 regulaire) die in deze ontsluitingen in de Kalksteen van Geulhem zijn aangetroffen.

Speciale aandacht wordt besteed aan de zeeëgelfauna van het allerbovenste deel van de Kalksteen van Geulhem, dat van 1985 tot 1988 ontsloten was aan het Albertkanaal bij Kesselt. Dit deel leverde vele nieuwe soorten op voor het gebied; enkele hiervan zijn mogelijk nog niet beschreven.

In de vorm van een historisch overzicht wordt een samenvatting gegeven van de literatuur met betrekking tot de zeeëgels van de Kalksteen van Geulhem. Veel van de in het Maastrichtse Danien voorkomende soorten zijn ook aangetroffen in het Danien en Montien van het Mons Bekken, in het zuiden van België, en, in mindere mate, in het Danien van Denemarken en Zuid-Zweden.

Dit artikel beoogt een presentatie van voorlopige resultaten te zijn. Een aantal soorten kon nog niet worden gedetermineerd; enkele hiervan moeten mogelijk als nieuwe soorten beschreven worden. Voor een vijftal soorten is het nog niet mogelijk gebleken om het juiste genus te bepalen. Voor de vergelijking met de fauna's uit het Mons Bekken en Denemarken/Zuid-Zweden is bijna uitsluitend gebruik gemaakt van beschrijvingen van materiaal uit die gebieden; de correlaties dienen echter aan de hand van het materiaal zelf te worden gecontroleerd. Daarna is het eventueel mogelijk om het Maastrichtse materiaal te gebruiken voor stratigrafische correlaties.

INTRODUCTION

During the excavations carried out with the aim of broadening the Albertkanaal SW of Maastricht, the opportunity existed to sample the complete section of the Geulhem Chalk (Early Palaeocene, Danian) in the Maastricht area. The Albertkanaal section contains also the upper part of the Geulhem Chalk; in the former Curfs quarry, the only other accessible exposure of Early Palaeocene deposits in the environs of Maastricht, this part is probably absent. In 1985 Mr M.J. van Birgelen (Heerlen) discovered a probably yet unknown uppermost part of the Geulhem Chalk in the Albertkanaal section.

The soft, loamy chalk among the hard blocks in this uppermost Geulhem Chalk appeared to contain a rich macrofauna. As the excavations progressed rapidly and the occurrence of the deposit proved to be very local, intensive sampling was carried out by sieving during the winter of 1985/1986. Afterwards, only occasionally was it possible to sample this fauna. In the beginning of 1988 the deposits were levelled.

Special attention was paid to the well-preserved and very rich echinoid fauna. In this way, the number of species known from the Geulhem Chalk could be nearly tripled. Many of the new species were previously recorded from the Montian of Eure (France), from the Dano-Montian of the Mons region (S Belgium) and Zwartberg (NE Belgium), and from the Danian of Denmark/southern Sweden. Several species described earlier on very scanty material (holotypes only) from Caberg near Maastricht, and from Zwartberg, were collected in fairly large numbers. Some species could not be identified, and may thus be new to science.

This paper mainly deals with the echinoids from the uppermost Geulhem Chalk. They are treated in a preliminary way, as a final description would demand a time-devouring study of reference material, which is at the moment beyond the scope of the author. The paper also includes the echinoids from the lower parts of the Geulhem chalk, thus giving a state-of-affairs report of the echinoid fauna of the Early Palaeocene of the Maastricht area.

Most of the studied and figured specimens belong to the collection of Mr M.J. van Birgelen (Heerlen). A small part is in the collection of the author. One specimen is from the collection of Mr W.M. Felder (Vijlen), and another one from the M. Meijer collection in the Natuurhistorisch Museum at Maastricht.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the kind cooperation of Mr M.J. van Birgelen (Heerlen), Mr W.M. Felder (Vijlen), and Mr H. Peeters (Natuurhistorisch Museum, Maastricht), who made the echinoid material described in this paper available for study. He is much indebted to Mr J.W.M. Jagt (Venlo), who provided many useful suggestions.

LOCALITIES AND STRATIGRAPHY

The studied specimens originate from two localities (Fig. 1): the former Curfs quarry, a few hundred metres NW of the village of Berg (The Netherlands), and the Albertkanaal between Veldwezelt and Vroenhoven (Belgium), to the West of Maastricht. They all stem from the Geulhem Chalk (Early Palaeocene, Danian), which is the stratigraphically oldest unit of the Tertiary in the Maastricht area.

The Curfs section, representing the lower part of the Geulhem Chalk, measures about 6 m in height. Most of the echinoids were collected from the lowermost metre, mainly by sieving with a net (1 mm mesh) in water. Worn fragments of fauna elements from the underlying, transgressively eroded Maastrichtian were encountered only very rarely.

The Albertkanaal section, representing the complete Geulhem Chalk, measured about 12 m in height. Echinoids from the lower and upper part could be collected NE, E and SE of the village of Kesselt (Belgium), along both sides of the canal. The uppermost Geulhem Chalk was only present NE of Kesselt. It was exposed on the West bank of the canal, opposite of the stretch between the Dutch boundary-marks nr 86 and nr 87 on the East bank, just above the watermark. The rich echinoid fauna stems from an up to 1 m thick layer of soft, loamy chalk with embedded large, rounded blocks. The echinoids came from the soft material. The hard blocks contained many casts of Bivalvia and Gastropoda, and sometimes of Cephalopoda (Nautiloidea), but echinoid material was seen only very rarely in them. Sampling mostly took place by sieving with a net (1 mm mesh) in water. The 'echinoid layer' was overlain by an up to 1.5 m thick, chalky, poorly fossiliferous layer. This uppermost Geulhem Chalk was covered by a sandy deposit of probably Tongrian age.

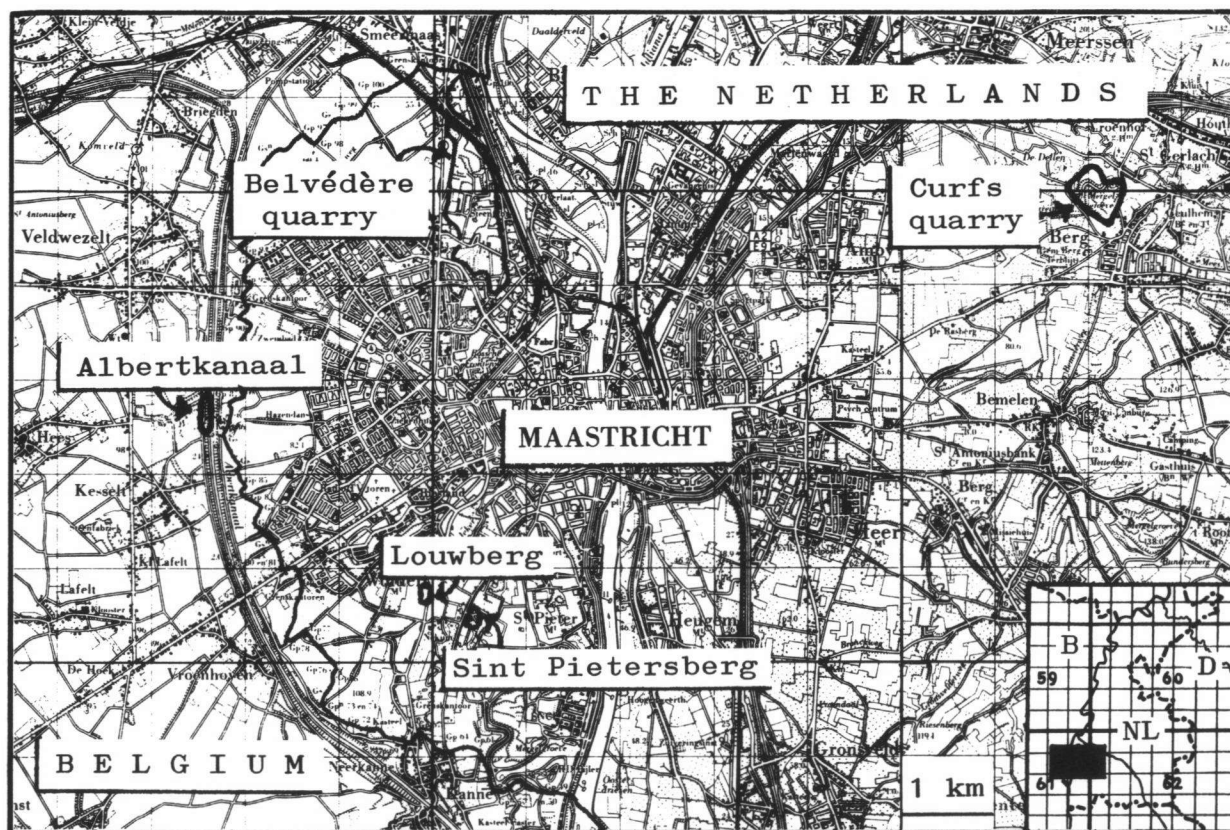


Fig. 1. Localities of former and present-day exposures of the Geulhem Chalk (Early Palaeocene, Danian) in the Maastricht area, based on parts of sheets 61 and 62 WEST of the topographical map 1 : 80.000 (Topografische Dienst, 1981).

HISTORY AND PREVIOUS LITERATURE

Hyposalenia heliophora (Desor, 1846) was the first echinoid to be described from Danian deposits in the Maastricht area. In the 'Paleontologie française', d'Orbigny (1855, 1856) and Cotteau (1866) described ? *Linthia breviscula*, *Procassidulus elongatus*, and *Goniopygus heberti* for the environs of Maastricht. In 1863 Cotteau mentioned the occurrence of *Tylocidaris hardouini* from this region. All these early data demonstrate that already in the nineteenth century Danian deposits in the Maastricht area were accessible for palaeontological study.

Nearly a century later, in the late nineteen fifties, Meijer discovered the presumed type localities of the species mentioned above. Besides the former Curfs quarry and the Albertkanaal, he knew two other localities where Danian strata had been found: the Louwberg, SW of Maastricht, and a small quarry at the western side of the Sint Pietersberg, S of Maastricht (Meijer, 1959). These localities (Fig. 1) are unknown to the author of the present paper. Probably, only the lowermost part of the Geulhem Chalk was represented there.

In a listing of exposures S of Maastricht, Felder (1963) treated the Danian stratigraphy of the Albertkanaal section, figuring several *Tylocidaris* spines.

Meijer (1965) listed 11 echinoid species for the 'Dano-Montian' in the neighbourhood of Maastricht (his *Procassidulus* sp., *P. chalmasi* and *P. aff. chalmasi* are *P. elongatus*, while his *Salenia* sp. proved to be a juvenile *Hyposalenia heliophora*). *Hyposalenia heliophora* and *Procassidulus elongatus* were considered by him as typical of his upper echinoid sequence of the Maastricht chalk. Rasmussen (1965) figured several cidaroid fragments, *Procassidulus elongatus*, and many other fossils from the 'Post-Maastrichtian' of the Albertkanaal and the former Curfs quarry.

In 1972, Engel described '*Phymosoma*' *maastrichtensis* for the Danian of the Belvédère quarry at Caberg, NW of Maastricht. This locality (Fig. 1) is the fifth of the known exposures of Danian deposits in the Maastricht area. Nowadays, however, Danian strata seem to have been excavated or at best inaccessible here.

In 1982, Geys dealt with the synonymy, the morphology, and the distribution of *Salenidia danica* and *Hyposalenia heliophora*, discussing their potential as index fossils for Danian strata in the Maastricht area.

Jagt (1985) provided a detailed account of the stratigraphical and palaeontological aspects of the Danian sections at the Albertkanaal and the former Curfs quarry. He considered the possibility of using *Tylocidaris* spines for stratigraphical and correlational purposes. A list of fossils was presented in which he added *Typocidaris serrata* (Desor, 1858) (see *Stereocidaris* sp. in this paper) to the echinoid species known to Meijer (1965).

The remarkable echinoid fauna of the uppermost Geulhem chalk at the Albertkanaal was first reported in a brief communication by van Birgelen & van der Ham (1986). In 1987, van der Ham *et al.* furnished very concise descriptions of the echinoids from the Danian of the Maastricht area. They figured most of them, and gave photographs of the excavations at the Albertkanaal and collecting activities in the uppermost part of the Geulhem Chalk.

SYSTEMATIC DESCRIPTIONS

The classification of the families is according to Smith (1984).

Classis Echinoidea Leske, 1778
Subclassis Cidaroidea Claus, 1880
Ordo Cidaroida Claus, 1880
Familia Cidaridae Gray, 1825
Genus *Stereocidaris* Pomel, 1883

***Stereocidaris forchhammeri* (Desor, 1846)**

Plate 1, Figs 1-3

Figured specimens—Fig. 1: van Birgelen collection, nr 846, from the former Curfs quarry near Berg, lower part of the Geulhem Chalk; Figs 2-3: van der Ham collection, nr 285, from the Albertkanaal near Kesselt, uppermost part of the Geulhem Chalk.

Description—Only test fragments (up to 2/5: Figs 2-3) and isolated interambulacral plates (with or without ambulacral plates attached) are known. Sutural pits present. Interambulacral plates about

isodiametric, four or five in one series, up to 15 mm in diameter, with only few granules outside the ring of secondary tubercles; primary tubercles perforate, noncrenulate or adapically slightly crenulate. Ambulacral plates in small specimens with one tubercle and a few small granules, in large specimens with two tubercles and a few granules. '*Cidaris*' sp. indet. 4 (van der Ham *et al.*, 1987) may represent the spine.

Distribution—Entire Geulhem Chalk. Common. Also occurring in the Maastrichtian (Kunrade, Nekum, and Meerssen Chalks).

Discussion—This species was described by Desor, as *Cidaris forchhammeri*, for the Danian of Fakse (Denmark). According to Ravn (1928) it is very similar to his *Typocidaris rosenkrantzi*, differing only in the spines. However, the latter species differs also in having more granules outside the ring of secondary tubercles (see *Stereocidaris* sp.). *Stereocidaris forchhammeri* was recorded by Cotteau (1879, including spines) and Lambert (1898), as *Cidaris tombecki* Desor, 1855, for the 'Calcaire grossier de Mons' of the Mons region (S Belgium). Meijer (1965) mentioned the species for the 'Tuffeau de Ciplly' of the same area. The species also occurs in the 'Calcaire pisolithique' of Eure, France (Sorignet, 1850; Lambert, 1908). According to Geys (1987) it belongs to the genus *Typocidaris* Pomel, 1883, and is confined to the Danian.

Stereocidaris sp.

Plate 1, Fig. 4

Figured specimen—Van der Ham collection, nr 285, from the Albertkanaal near Kesselt, uppermost part of the Geulhem Chalk.

Description—Similar to *Stereocidaris forchhammeri*, but with more granules outside the ring of secondary tubercles.

Distribution—Entire Geulhem Chalk. Rather rare. Possibly also present in the Maastrichtian.

Discussion—This species closely resembles *Stereocidaris rosenkrantzi*, described as a *Typocidaris* by Ravn (1928) from the Danian of several localities in Denmark. However, the typical, distally broadened

Plate 1. Cidaroida.

Figs 1-3. *Stereocidaris forchhammeri* (Desor, 1846).

1: interambulacrum with attached ambulacral plates (1/5 part of test), lateral view, x 3.

2 and 3: 2/5 part of test, lateral views, x 3.

Fig. 4. *Stereocidaris* sp., interambulacrum with attached ambulacral plates, lateral view, x 3.

Fig. 5. '*Cidaris*' sp., three interambulacral plates with attached ambulacral plates, x 3.

Fig. 6. '*Cidaris distincta*' Sorignet, 1850, three interambulacral plates with attached ambulacral plates, x 3.

Fig. 7. *Temnocidaris danica* (Desor, 1855), three interambulacral plates, x 2.

Fig. 8. '*Cidaris*' sp. indet., spine, x 2.

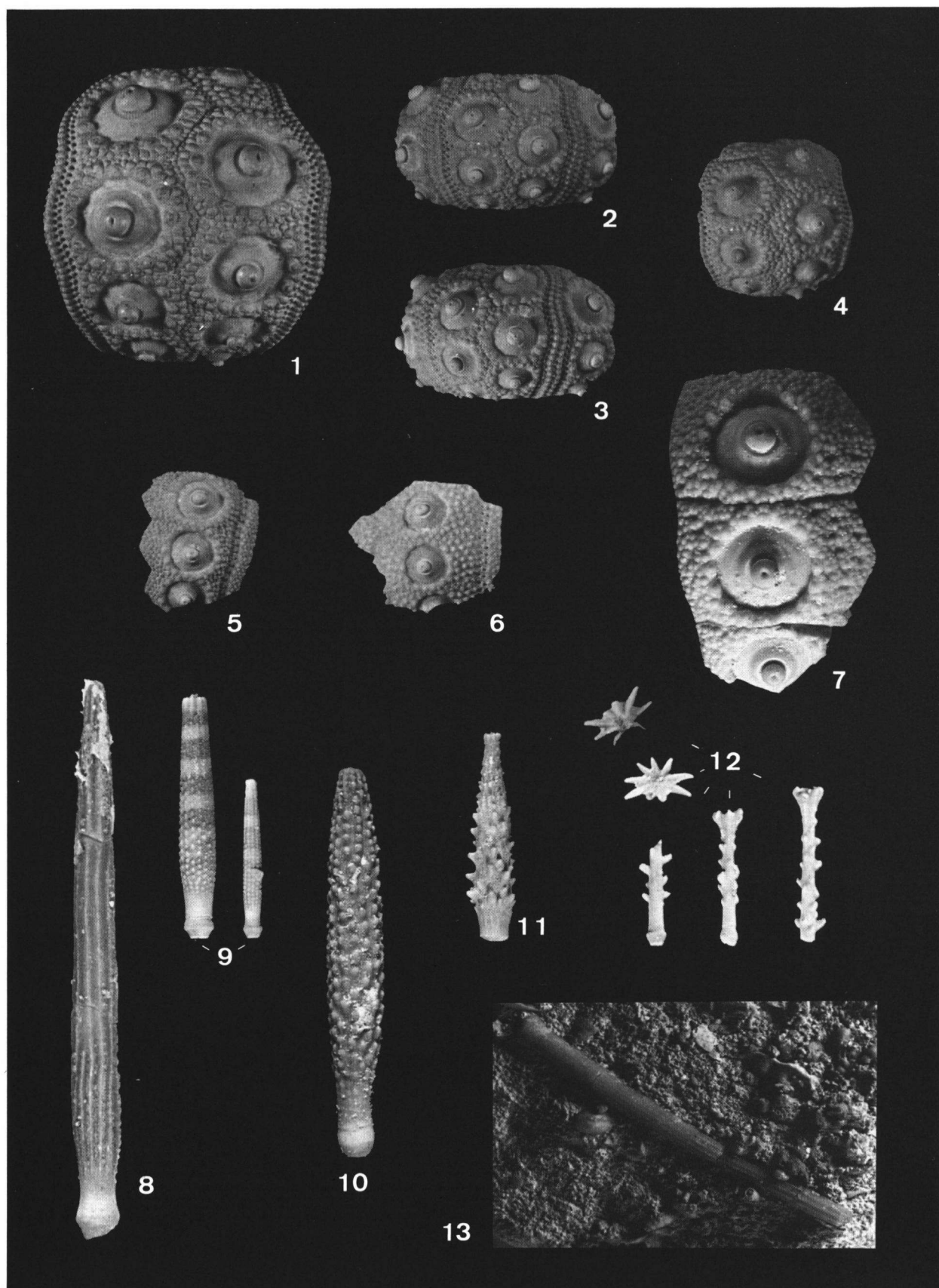
Fig. 9. '*Cidaris*' sp. indet., two spines, x 2.

Fig. 10. '*Cidaris*' sp. indet., spine, x 2.

Fig. 11. '*Cidaris*' sp. indet., spine, x 2.

Fig. 12. '*Cidaris*' sp. indet., three spines (left broken off) and one isolated apex (top: proximal side, bottom: distal side), x 3.

Fig. 13. '*Cidaris*' sp. indet., spine, x 2.



spines have not been found in the Maastricht region. Probably identical to *Typocidaris serrata* (Desor, 1858) of Geys (1987).

Genus *Temnocidaris* Cotteau, 1863

***Temnocidaris danica* (Desor, 1855)**

Plate 1, Fig. 7

Figured specimen—Van Birgelen collection, nr 681, from the Albertkanaal near Kesselt, lower part of the Geulhem Chalk.

Description—Only test fragments and isolated interambulacral plates (with or without ambulacral plates attached) are known. Pits scattered, in the interambulacrals as well as in the ambulacrals. Interambulacral plates slightly oblong, up to 18 mm long, with outside the ring of secondary tubercles many granules in rows separated by narrow grooves; primary tubercles perforate, noncrenulate or adapically slightly crenulate. Ambulacral plates with a single row of three or four tubercles. '*Cidaris*' sp. indet. 2 and *C.* sp. indet. 3 of van der Ham *et al.* (1987) may represent the spine.

Distribution—Entire Geulhem Chalk. Common, but rather rare in the uppermost part.

Discussion—This species was described by Desor, as *Cidaris danica*, for the Danian of Fakse (Denmark). Ravn (1928) mentioned it for many more localities in Denmark. *Temnocidaris danica* was reported from the 'Poudingue de la Malogne' of the Mons region (S Belgium) by Lambert (1898). Material of *Temnocidaris* from the Maastrichtian of the Maastricht area (van der Ham *et al.*, 1987) was recorded by Geys (1987) as *Temnocidaris baylei* Cotteau, 1863.

Genus '*Cidaris*' s. lat.

'*Cidaris*' *distincta* Sorignet, 1850

Plate 1, Fig. 6

Figured specimen—Van Birgelen collection, nr 432VV, from the Albertkanaal near Kesselt.

Description—Only test fragments and dissociated interambulacral plates (mostly with ambulacral plates attached) are known. Pits not apparent. Interambulacral plates oblong, up to 6 mm long, outside the ring of secondary tubercles sparsely covered with granules; primary tubercles perforate, noncrenulate. Ambulacral plates with a single row of three tubercles. Spine probably represented by '*Cidaris*' sp. indet. 7 (van der Ham *et al.*, 1987).

Distribution—Geulhem Chalk, uppermost part. Rare.

Discussion—'*Cidaris*' *distincta* was described for the 'Senonien' of Eure (France). The description included a spine similar to '*Cidaris*' sp. indet. 7 (see van der Ham *et al.*, 1987). Material of the species from the 'Calcaire grossier de Mons' of the Mons region (S Belgium) was figured by Cotteau (1879) and Smiser (1935). Its generic position has yet to be determined.

'*Cidaris*' sp.
Plate 1, Fig. 5

Figured specimen—Van Birgelen collection, nr 432VV, from the Albertkanaal near Kesselt.

Description—Only test fragments and isolated interambulacral plates (mostly with ambulacral plates attached) are known. Interambulacral plates oblong, up to 5.5 mm long, with scattered pits, outside the ring of secondary tubercles rather densely covered with many granules; primary tubercles perforate, noncrenulate. Ambulacral plates with double rows of three or four tubercles.

Distribution—Geulhem Chalk, uppermost part. Rare. *Discussion*—This species resembles '*Cidaris*' *distincta*, but differs in the pattern of the ambulacral tubercles and the density of the interambulacral granules. Likewise, its generic position has yet to be determined.

'*Cidaris*' spp. indet.
Plate 1, Figs 8-13

Figured specimens—Figs 8 and 10: van Birgelen collection, nr 681, from the Albertkanaal near Kesselt, lower part of the Geulhem Chalk; Figs 9 and 12: van Birgelen collection, nrs 432FF and 432SS, from the Albertkanaal near Kesselt, uppermost part of the Geulhem Chalk; Fig. 11: van der Ham collection, nr 285, from the Albertkanaal near Kesselt, uppermost part of the Geulhem Chalk; Fig. 13: van der Ham collection, nr 205, from the Albertkanaal near Kesselt, lower part of the Geulhem Chalk.

Description—The Danian of the Maastricht region yields a large variety of cidaroid spines. Geys (1987) rightly stressed that it would be inopportune to introduce new taxa on the basis of spines only. Indeed, several species may possess (nearly) identical spines or one species may have quite different spines. Below, several characteristic forms are presented, which should be looked upon as morphospecies.

Fig. 8: long spine, up to 75 mm long, cylindrical or widest near the base, with knobby, toothed, or smooth, sharp ridges. Common. It possibly represents the spine of *Temnocidaris danica*, and corresponds to '*Cidaris*' sp. indet. 2 and sp. indet. 3 in van der Ham *et al.* (1987) and *Cidaris faujasii* Desor, 1855.

Figs 9 and 10: rather plump spine, up to 55 mm long, widest near the base, sometimes with coloured bands, rather heavily knobbed; knobs mostly in regular rows, often at one side larger and less regularly arranged in rows. Common. It possibly represents the spines of *Stereocidaris forchhammeri*, and corresponds to '*Cidaris*' sp. indet. 4 in van der Ham *et al.* (1987).

Fig. 11: plump spine, up to 20 mm long, widest near the base, with distinct knobs or teeth in mostly irregular rows, apically broadened. Rare. It corresponds to '*Cidaris*' sp. indet. 6 in van der Ham *et al.* (1987).

Fig. 12: small, slender spine, up to 10 mm long, very distinctly toothed, with a broadened, mostly toothed apex. Rather rare. It possibly represents the spine of '*Cidaris*' *distincta*, and corresponds to '*Cidaris*' sp. indet. 7 in van der Ham *et al.* (1987).

Fig. 13: long, about cylindrical spine, up to 36 mm long, smooth or with very faint knobs in rows. Rather rare. It corresponds to 'Cidaris' sp. indet. 5 in van der Ham *et al.* (1987).

Familia Psychocidaridae Ikeda, 1936

Genus *Tylocidaris* Pomel, 1883

***Tylocidaris bruennichi* Ravn, 1928**

Plate 2, Figs 1-6

Figured specimens—Van der Ham collection, nr 285, from the Albertkanaal near Kesselt.

Description—Only one small (9 mm in diameter), complete test is known; 1/5 parts are not rare. Interambulacral plates five or six in one series, slightly oblong, up to 9 mm long, with outside the ring of secondary tubercles few but distinct granules; primary tubercles relatively large, imperforate, noncrenulate. Ambulacral plates with one tubercle and one or two small granules. Spines up to 18 mm long, plump, apically acute and often crested.

Distribution—Geulhem Chalk, upper part. Common.

Discussion—*Tylocidaris bruennichi* was described (spines only) as *Tylocidaris vexillifera* Schlüter, 1892 var. *bruennichi* for the Danian of several localities in Denmark. Rasmussen (1965) figured spines from the Danian of the Mons region (S Belgium) and the Maastricht area. Meijer (1965) mentioned the species for the 'Tuffeau de Ciply' of the Mons region. *Balanocidaris schlueteri* Lambert, 1911, from the Maastrichtian (?) of that area, is probably identical to *Tylocidaris bruennichi*. *Tylocidaris ravni* Brotzen, 1960, from the Danian of S Sweden is also very similar. Coronal parts of *T. bruennichi* are indistinguishable from those of *T. hardouini*.

Plate 2. Cidaroida, Diadematoida

Figs 1-6. *Tylocidaris bruennichi* Ravn, 1928.

1-3: apical, lateral, and oral view, x 3.

4: interambulacral plate, x 3.

5: interambulacrum with attached ambulacral plates (1/5 part of test), lateral view, x 3.

6: four spines, x 2.

Figs 7-9. *Tylocidaris hardouini* (Desor, 1855).

7: interambulacrum with attached ambulacral plates, lateral view, x 3.

8: lower part of interambulacrum with attached ambulacral plates, lateral-oral view, x 3.

9: five spines, x 2.

Figs 10-15. *Palaeodiadema* sp.

10: two ambulacral plates, x 3.

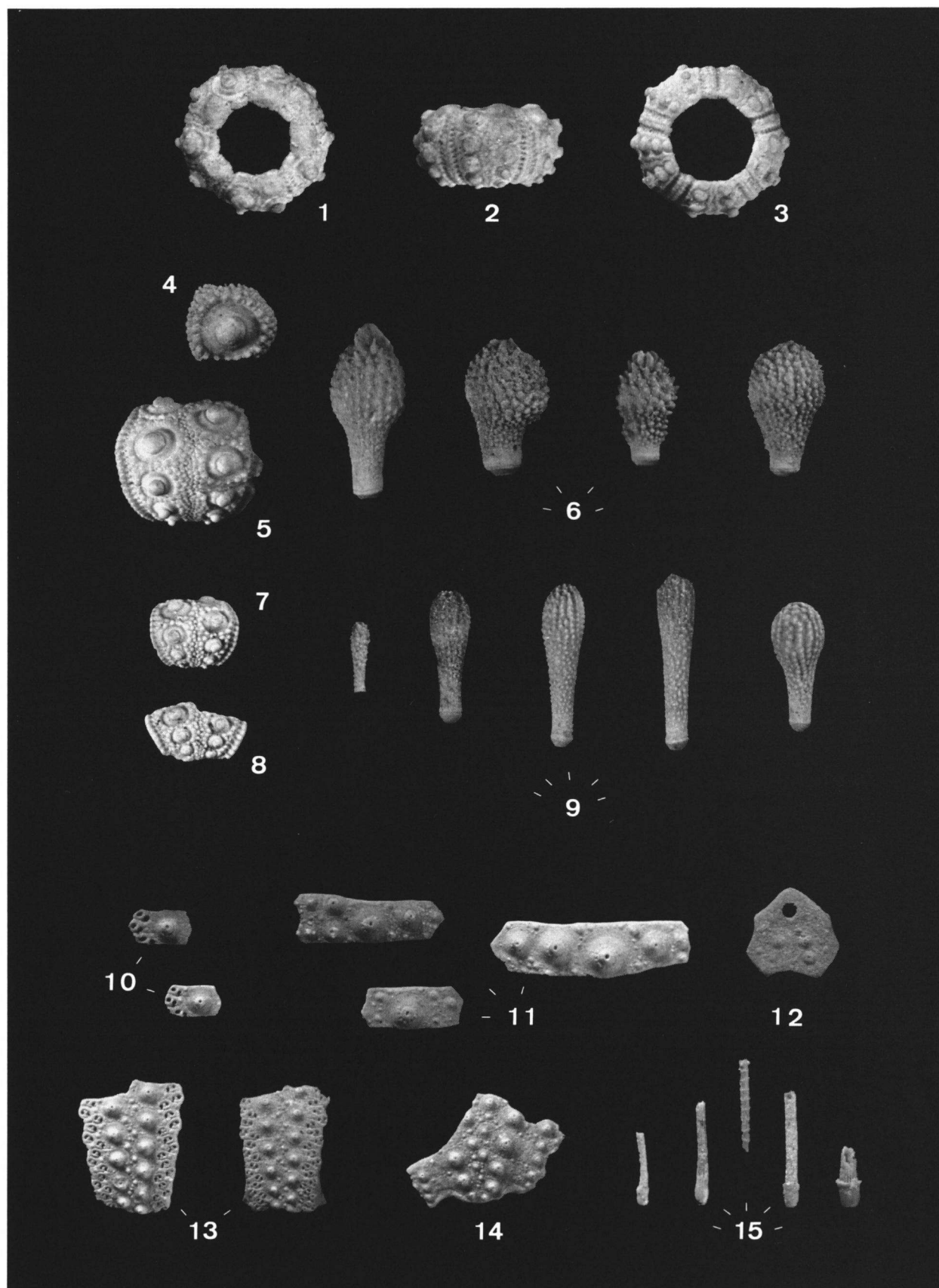
11: three interambulacral plates, x 3.

12: genital plate, x 3.

13: adoral parts of two ambulacra, x 3.

14: adoral part of interambulacrum, x 3.

15: fragments of five spines, x 3.



Tylocidaris hardouini (Desor, 1855)

Plate 2, Figs 7-9

Figured specimens—Van der Ham collection, nr 436, from the Albertkanaal near Kesselt.

Description—Complete tests unknown; 1/5 parts are not rare. Interambulacral and ambulacral plates similar to those of *Tylocidaris bruennichi*. Spines up to 20 mm long, slender, club-shaped; apex mostly rounded.

Distribution—Geulhem Chalk, lower part. Common.

Discussion—*Tylocidaris hardouini* was described (spines only) as *Balanocidaris hardouini*, for the Danian of the Mons Basin (S Belgium). Lambert (1897) and Meijer (1965) reported the species for the 'Poudingue de la Malogne' of that area. Brotzen (1960) mentioned the possibility of Desor's species being identical with *Tylocidaris abildgaardi* Ravn, 1928. However, the latter is distinctly less slender. *Tylocidaris hardouini* closely resembles *Tylocidaris oedumi* Brännich Nielsen, 1938 from Denmark, figured by Wind (1954); the specimens of the latter species figured by Brotzen, from S Sweden, are less close. Coronal parts of *Tylocidaris hardouini* are indistinguishable from those of *Tylocidaris bruennichi*.

Subclassis Euechinoidea Bronn, 1860

Ordo Diadematoidea Duncan, 1889

Familia Diadematidae Gray, 1855

Genus *Palaeodiadema* Pomel, 1887

Palaeodiadema sp.

Plate 2, Figs 10-15

Figured specimens—Fig. 10 (bottom), Fig. 11 (right), Fig. 13 (left), Fig. 14, and Fig. 15 (first, second, and fourth): van Birgelen collection, nr 432H; other specimens: van der Ham collection, nr 285, all from the Albertkanaal near Kesselt, the uppermost part of the Geulhem Chalk.

Description—Only known from fragments, isolated plates, and spines. Ambulacral plates up to 8 mm long, trigeminate, with one primary tubercle and one or a few granules. Genital plates with a few small tubercles and granules. Interambulacral plates up to 11 mm long, with one primary tubercle, up to five secondary tubercles, and scattered granules. Gill slits shallow. Tubercles perforate, crenulate. Spines up to 1.7 mm in diameter, hollow, verticillate (in unworn state), sometimes slightly curved.

Distribution—Entire Geulhem Chalk. Rather common.

Discussion—Diadematooid echinoids were recorded for the first time from the Maastricht region by van der Ham *et al.* (1987). The genus *Palaeodiadema* appears to be present in Maastrichtian as well as in Danian deposits. Several species seem to be involved. The Danian material is probably homogeneous. Further study has to include a thorough comparison with Maastrichtian and Danian material from Denmark (Ravn, 1928) and Rügen, German Democratic Republic (Kutscher, 1985), which is known as *Palaeodiadema multiforme* Ravn, 1928.

Ordo Salenioida Delage & Hérouard, 1903

Familia Saleniidae L. Agassiz, 1838

Genus *Salenia* Gray, 1835

Salenia belgica Lambert, 1898

Plate 3, Figs 1-4

Figured specimen—Van Birgelen collection, nr 491, from the former Curfs quarry near Berg.

Description—Test up to 13 mm in diameter. Apical system rather convex, consisting of 11 smooth plates; sutures with small pits; periproct in the I-3 axis. About five interambulacral plates in one series. Ambulacral plates with two pore pairs, up to 11 in one series. Peristome rather small. Gill slits indistinct.

Distribution—Geulhem Chalk, lower part. Rather common.

Discussion—*Salenia belgica* was described for the 'Poudingue de la Malogne' of the Mons region (S Belgium). Geys (1979) mentioned 'St. Symphorien Gravel, Maastrichtian' as type stratum, but Meijer (1965) encountered the species in the 'Tuffeau de Ciply' of the same region, which is of Danian age. Geys also assigned a Maastrichtian age to specimens from Dutch Limburg (Gulpen Chalk). However, *Salenia belgica* is clearly confined to the Danian of the Maastricht region. The holotype is probably also of Danian age. Geys (1982) figured a specimen of *Salenia belgica* from the Geulhem Chalk of the Albertkanaal as *Salenia minima* Desor, 1846.

Genus *Salenidia* Pomel, 1883

Salenidia danica Ravn, 1928

Plate 3, Figs 5-8

Figured specimen —Van Birgelen collection, nr 339, from the Albertkanaal near Kesselt, lower part of the Geulhem Chalk.

Description—Test up to 5.5 mm in diameter. Apical system slightly convex, consisting of 11 plates with a shallow, radiating sculpture (in unworn state); sutures hardly visible, without pits; periproct in the I-3 axis. About five interambulacral plates in one series. Ambulacral plates for the greater part with one pore pair, up to eight in one series. Peristome large. Gill slits indistinct.

Distribution—Entire Geulhem Chalk. Rather common, but rare in the uppermost part.

Discussion—Geys (1982) treated the material from the Maastricht area under *Salenia minima* Desor, 1846. He had probably studied worn specimens (mixed with specimens of *Salenia belgica*), as well-preserved tests possess a sculptured apical system instead of a smooth one. Actually, the material from the Maastricht area displays a much closer resemblance to *Salenidia danica* from the Danian of Saltholm (Denmark). Eventually it may turn out that *Salenia minima*, which was described for the 'Tuffeau de Ciply' of the Mons region (S Belgium), had a sculptured apical system in unworn state as well (van der Ham *et al.*, 1987) and is identical to *Salenidia danica*. Meijer (1965) reported *Salenia minima* from the 'Poudingue de la Malogne' in the Mons region. Smiser (1935) figured it as *Goniopygus minor*.

Salenidia selandica Ravn, 1928

Plate 3, Figs 9-12

Figured specimen—Van Birgelen collection, nr 432J, from the Albertkanaal near Kesselt.

Description—Test up to 10 mm in diameter. Apical system nearly flat, consisting of 11 almost smooth plates; sutures with small pits; periproct in the I-3 axis. About six interambulacral plates in one

series. Ambulacral plates with one pore pair, up to 22 in one series. Peristome rather large. Gill slits small but distinct.

Distribution—Geulhem Chalk, uppermost part. Fairly common.

Discussion—*Salenidia selandica* was recorded for the first time from the Maastricht region by van der Ham *et al.* (1987). The species was described for the Danian of several localities in Denmark. One specimen is known from the Mons region (Ciply, carrière André, Tuffeau de Ciply; van Birgelen collection 358).

Genus *Hyposalenia* Desor, 1856

Hyposalenia heliophora (Desor, 1846)

Plate 3, Figs 13-16

Figured specimen—Van Birgelen collection, nr 432K, from the Albertkanaal near Kesselt, uppermost part of the Geulhem Chalk.

Description—Test up to 12 mm in diameter. Apical system rather flat (in juvenile specimens rather convex), consisting of 11 plates with a pronounced, radiating sculpture which obscures the sutures; periproct in the III-5 axis. About six interambulacral plates in one series. Ambulacral plates with two pore pairs, up to 16 in one series. Interambulacral tubercles with a relatively small mamelon. Peristome small. Gill slits distinct. Spines slender, cylindrical, and smooth.

Discussion—The species was first described, as *Salenia heliophora*, for the Danian of the Maastricht region. Cotteau (1875) and Meijer (1965) reported it from the 'Poudingue de la Malogne' of the Mons region (S Belgium). Possibly, *Peltastes ultimus* Ravn, 1928, from the Danian of Saltholm (Denmark), is identical (see also Meijer, 1965).

Ordo Phymosomatoida Mortensen, 1904

Familia Phymosomatidae Pomel, 1883

Genus *Phymosoma* Haime, 1853

Phymosoma sp.

Plate 4, Figs 1-4

Figured specimens—Figs 1, 2 and 4: van Birgelen collection, nr 432U; Fig. 3: van der Ham collection, nr 285. Both from the Albertkanaal near Kesselt.

Description—Test flattened, up to about 35 mm in diameter. Periproct pentagonal. Poriferous zones biserial adapically and adorally. Up to ten ambulacral plates in one series, each with about five pore

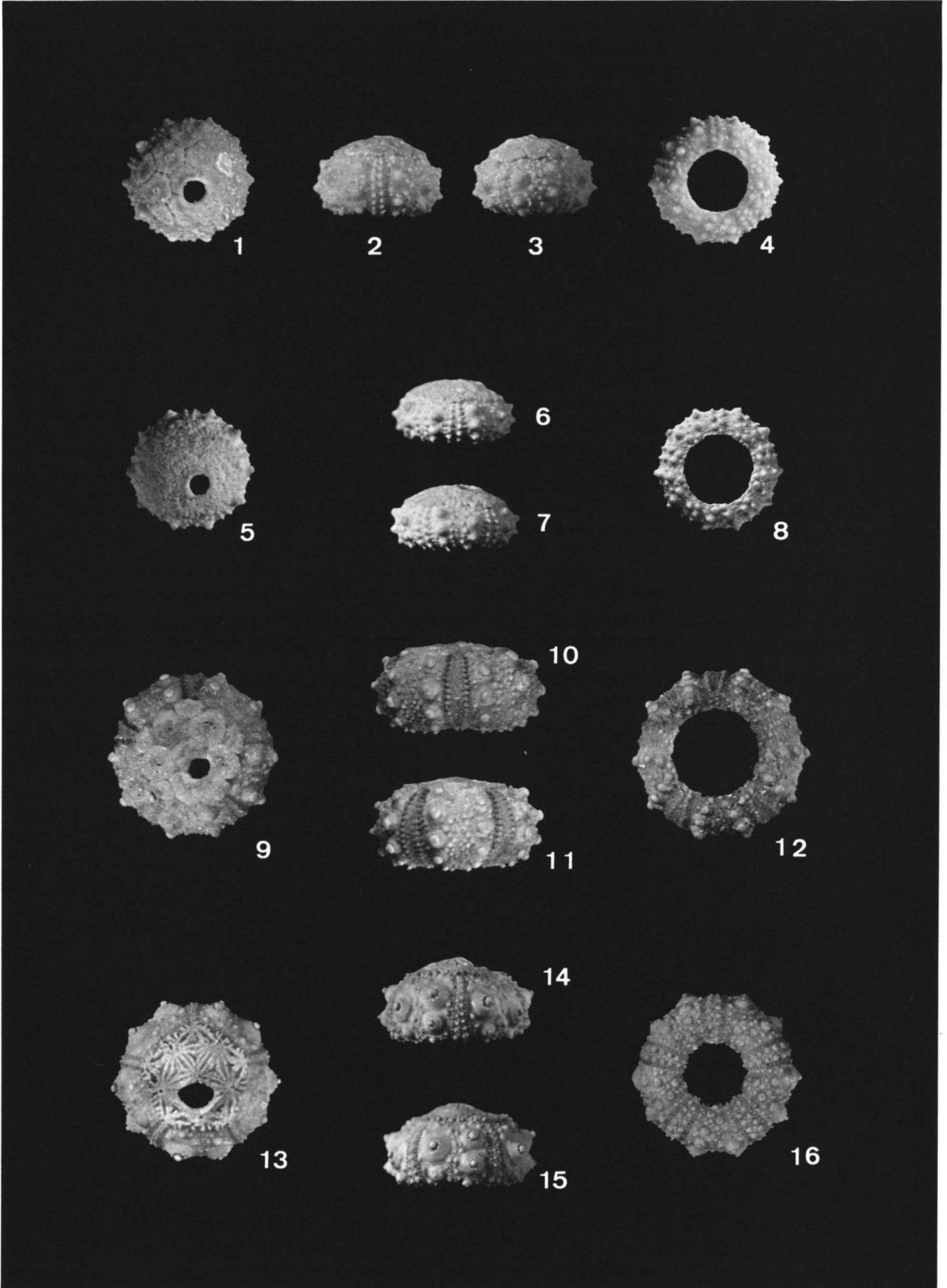
Plate 3. Salenioida

Figs 1-4. *Salenia belgica* Lambert, 1898, apical, ambulacral, interambulacral, and oral view, x 3.

Figs 5-8. *Salenidia danica* Ravn, 1928, apical, ambulacral, interambulacral, and oral view, x 5.

Figs 9-12. *Salenidia selandica* Ravn, 1928, apical, ambulacral, interambulacral, and oral view, x 3.

Figs 13-16. *Hyposalenia heliophora* (Desor, 1846), apical, ambulacral, interambulacral, and oral view, x 3.



pairs. Up to ten interambulacral plates in one series, each with up to three small, secondary tubercles; scrobicules in one series confluent or separated by a single row of granules. Primary tubercles imperforate, crenulate. Peristome hardly sunken, with distinct gill slits.

Distribution—Geulhem Chalk, uppermost part. Rare.

Discussion—This species resembles *Phymosoma corneti* (Cotteau, 1875), from the 'Poudingue de la Malogne' of the Mons region (S Belgium). It differs in having biserial poriferous zones instead of simple ones adorally. It corresponds to *Phymosoma* sp. 2 in van der Ham *et al.* (1987).

'Phymosoma' maastrichtensis Engel, 1972

Plate 4, Figs 5-8

Figured specimens—Van Birgelen collection, nr 432R, from the Albertkanaal near Kesselt.

Description—Test rather high, up to about 23 mm in diameter. Periproct irregularly circular. Poriferous zones simple adapically, biserial adorally. Up to 15 ambulacral plates in one series, each with about five pore pairs. Up to 13 interambulacral plates in one series, each with three small, secondary tubercles which constitute oblique rows of three; scrobicules in one series confluent or separated by a single row of granules. Primary tubercles imperforate, noncrenulate (Engel, however, noticed in the holotype 'distinct traces of crenulation' in two tubercles). Peristome slightly sunken, with small gill slits.

Distribution—Geulhem Chalk, uppermost part. Rather rare.

Discussion—As *Phymosoma* has biserial poriferous zones adapically, Engel's species cannot be referred to this genus. Because of its present obscure systematic position, the species is here provisionally indicated as '*Phymosoma*' *maastrichtensis* (see also van der Ham *et al.*, 1987). The noncrenulate tubercles suggest inclusion in the family Stomechinidae Pomel, 1883 (see also next species). The holotype (about 1/5 part of a test), from the Danian (according to Engel the Maastrichtian) of the Belvédère quarry at Caberg near Maastricht, was until recently the only known specimen.

Phymosomatoida sp.

Plate 4, Figs 9-11

Figured specimens—Fig. 9: van der Ham collection, nr 285; Figs 10 and 11: van Birgelen collection, nr 432O. Both from the Albertkanaal near Kesselt.

Plate 4. *Phymosomatoida*

Figs 1-4. *Phymosoma* sp.

1, 2, and 4: apical, lateral, and oral view, x 2.

3: lower part of interambulacrum with adjacent ambulacral plates, x 3.

Figs 5-8. '*Phymosoma*' *maastrichtensis* Engel, 1972.

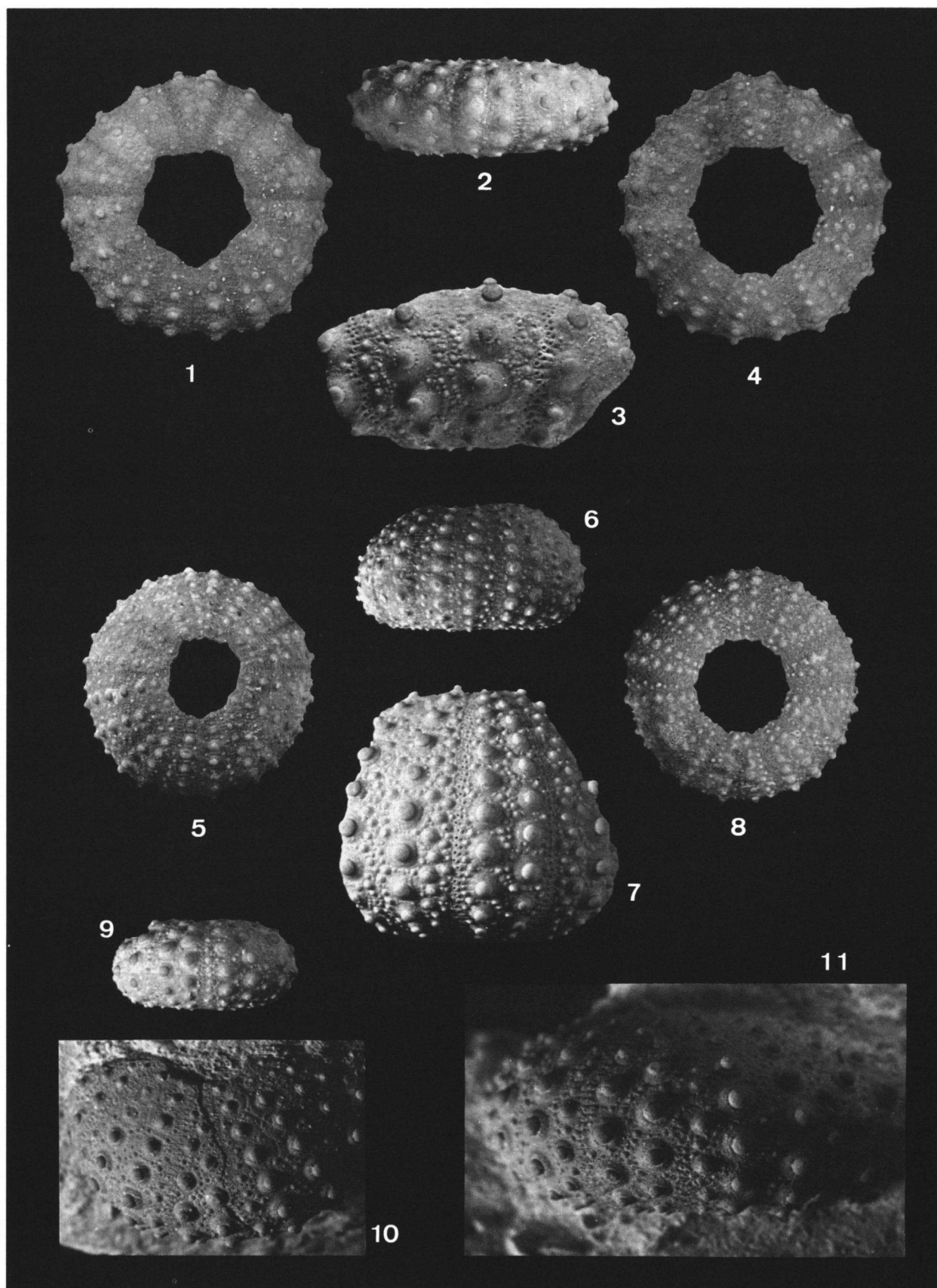
5, 6, and 8: apical, lateral, and oral view, x 2

7: ambulacrum with parts of the adjacent interambulacra, lateral view, x 4.

Figs 9-11. *Phymosomatoida* sp.

9: part of test, lateral view, x 2.

10 and 11: part of test, apical (x 2) and lateral (x 3) view.



Description—Test rather flattened, up to 29 mm in diameter. Periproct probably irregularly circular. Poriferous zones simple adapically, biserial adorally. Up to 12 ambulacral plates in one series, each with five or six pore pairs. Up to 12 interambulacral plates in one series, each with one large and one small, secondary tubercle; scrobicules in one series confluent or separated by a single row of granules. Primary tubercles imperforate, noncrenulate. Peristome hardly sunken, with indistinct gill slits.

Distribution—Geulhem Chalk, uppermost part. Rather rare.

Discussion—This species resembles '*Phymosoma*' *maastrichtensis*; it differs in its pattern of secondary tuberculation, its more flattened shape, and in its lower number of primary tubercles per series. As these tubercles are likewise noncrenulate, it may prove to belong to the Stomechinidae too. The species corresponds to *Phymosomatoida* sp. 2 in van der Ham *et al.* (1987).

Phymosomatoida sp.
Plate 5, Figs 1-5

Figured specimens—Van Birgelen collection, nr 432P, from the Albertkanaal near Kesselt.

Description—Test rather flattened, up to 20 mm in diameter. Periproct pentagonal. Poriferous zones simple throughout. Up to ten ambulacral plates in one series, each with about five pore pairs; adapical scrobicules small, separated by many granules. Up to 12 interambulacral plates in one series, at the oral side of the test with one or two small, secondary tubercles; scrobicules in one series confluent or separated by one or two rows of granules. Primary tubercles imperforate, crenulate. Peristome sunken, with distinct gill slits.

Distribution—Geulhem Chalk, uppermost part. Rather common.

Discussion—This species is distinctive on account of the dense granulation in the adapical part of the test and the relatively small size of the adapical tubercles. It corresponds to *Phymosomatoida* sp. 3 in van der Ham *et al.* (1987).

Phymosomatoida sp.
Plate 5, Figs 6-8

Figured specimen—Van Birgelen collection, nr 432Q, from the Albertkanaal near Kesselt, uppermost part of the Geulhem Chalk.

Plate 5. Phymosomatoida, Temnopleuroidea

Figs 1-5. *Phymosomatoida* sp.

1-3: apical (x 2), lateral (x 4), and oral (x 2) view.

4 and 5: apical and oral view, x 2.

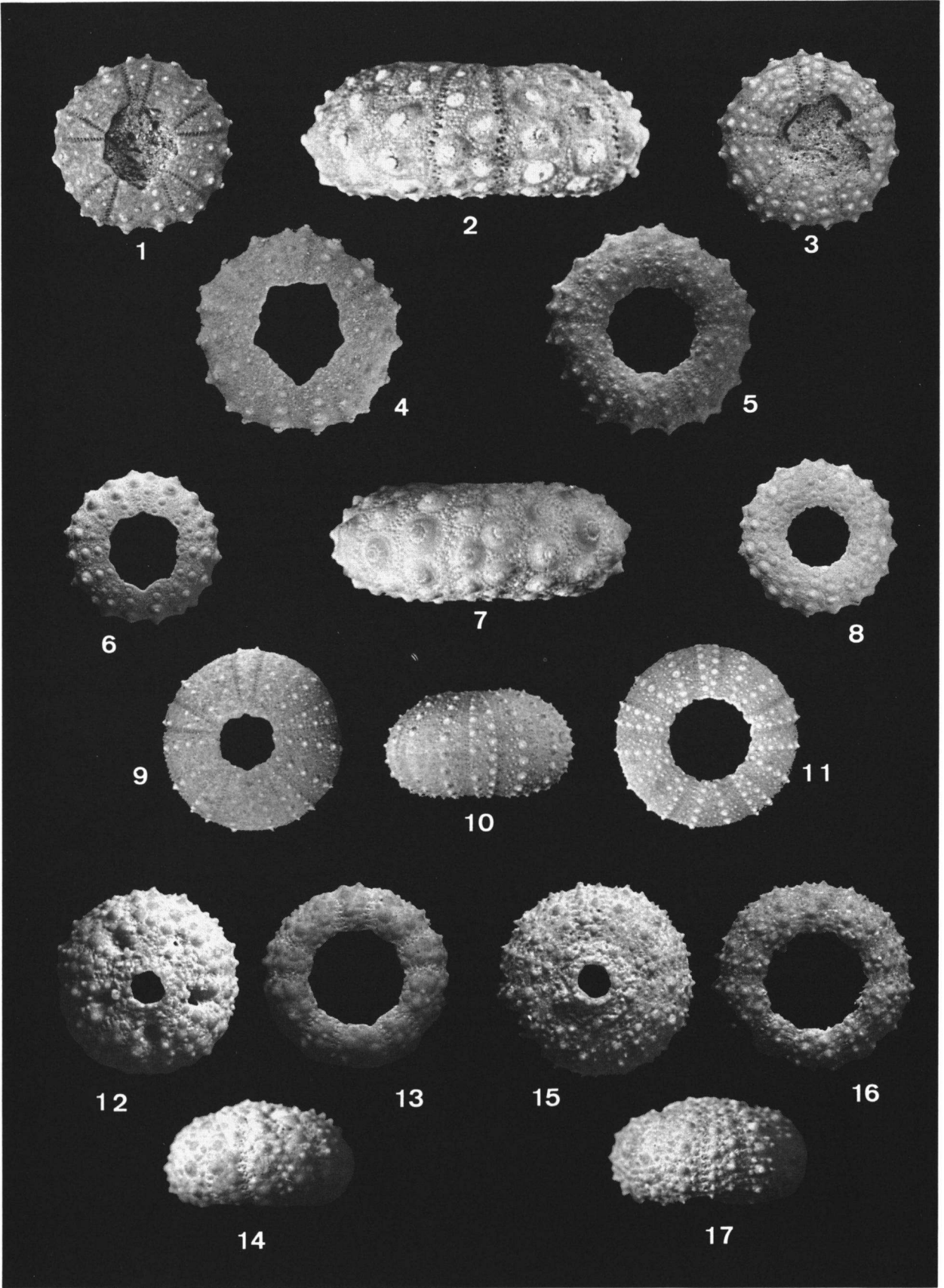
Figs 6-8. *Phymosomatoida* sp., apical (x 2), lateral (x 4), and oral (x 2) view

Figs 9-11. ? *Phymosomatoida* sp., apical, lateral, and oral view, x 2).

Figs 12-17. Gen. et sp. aff. ? *Arbacina*

12-14: female specimen, apical, lateral, and oral view, x 5.

15-17: male specimen, apical, lateral, and oral view, x 5.



Description—Test rather flattened, up to 26 mm in diameter. Periproct irregularly circular; however, in one large (26 mm in diameter) specimen a distinctly pentagonal periproct was observed. Poriferous zones simple throughout. Up to ten ambulacral plates in one series, each with about five pore pairs. Up to ten interambulacral plates in one series, at the oral side of the test each with up to two very small, secondary tubercles; scrobicules in one series confluent or separated by one or two rows of granules. Primary tubercles imperforate, crenulate. Peristome hardly sunken, with small gill slits.

Distribution—Entire Geulhem Chalk. Rather common in the uppermost part, but rare in the lower part.

Discussion—This species is rather close to *Rachiosoma grossouvrei* Lambert, 1898, from the 'Poudingue de la Malogne' of the Mons region (S Belgium). It corresponds to *Phymosomatoida* sp. 4 in van der Ham *et al.* (1987).

Familia Arbaciidae Gray, 1855

Genus *Goniopygus* L. Agassiz, 1838

***Goniopygus heberti* Cotteau, 1866**

Plate 6, Figs 15-18

Figured specimen—Van Birgelen collection, no, 432C, from the Albertkanaal near Kesselt.

Description—Species does probably not display any sexual dimorphism. Test up to 7 mm in diameter. Apical system slightly convex, consisting of ten sculptured plates; sutures pitted; pits three to six per suture, in short grooves, which perpendicularly cross a suture; periproct nearly central, bordered by three depressions, each of which harbours a small tubercle. Poriferous zones simple throughout; ambulacral plates trigeminate. Interambulacral depressions absent. Gill slits small. Tubercles imperforate, noncrenulate, up to nine in each ambulacrum and up to six in each interambulacrum; secondary tuberculation sparse. Spines: see *Goniopygus* sp.(spp.) indet.

Distribution—Geulhem Chalk, uppermost part. Rather common.

Discussion—*Goniopygus heberti* was described for the 'Etage sénonien supérieur (danien)' of the Maastricht region. The species closely resembles *Goniopygus* sp. from the uppermost part of the

Plate 6. *Phymosomatoida*

Figs 1-14. *Goniopygus minor* Sorignet 1850

1-3: female specimen, apical, apical-lateral, and oral view, x 2

4: detail of Fig. 2, x 4.5

5-7: male specimen, apical, apical-lateral, and oral view, x 2

8: detail of Fig. 6, x 4.5

9-11: female specimen, apical, lateral, and oral view, x 3.

12-14: male specimen, apical, lateral, and oral view, x 3.

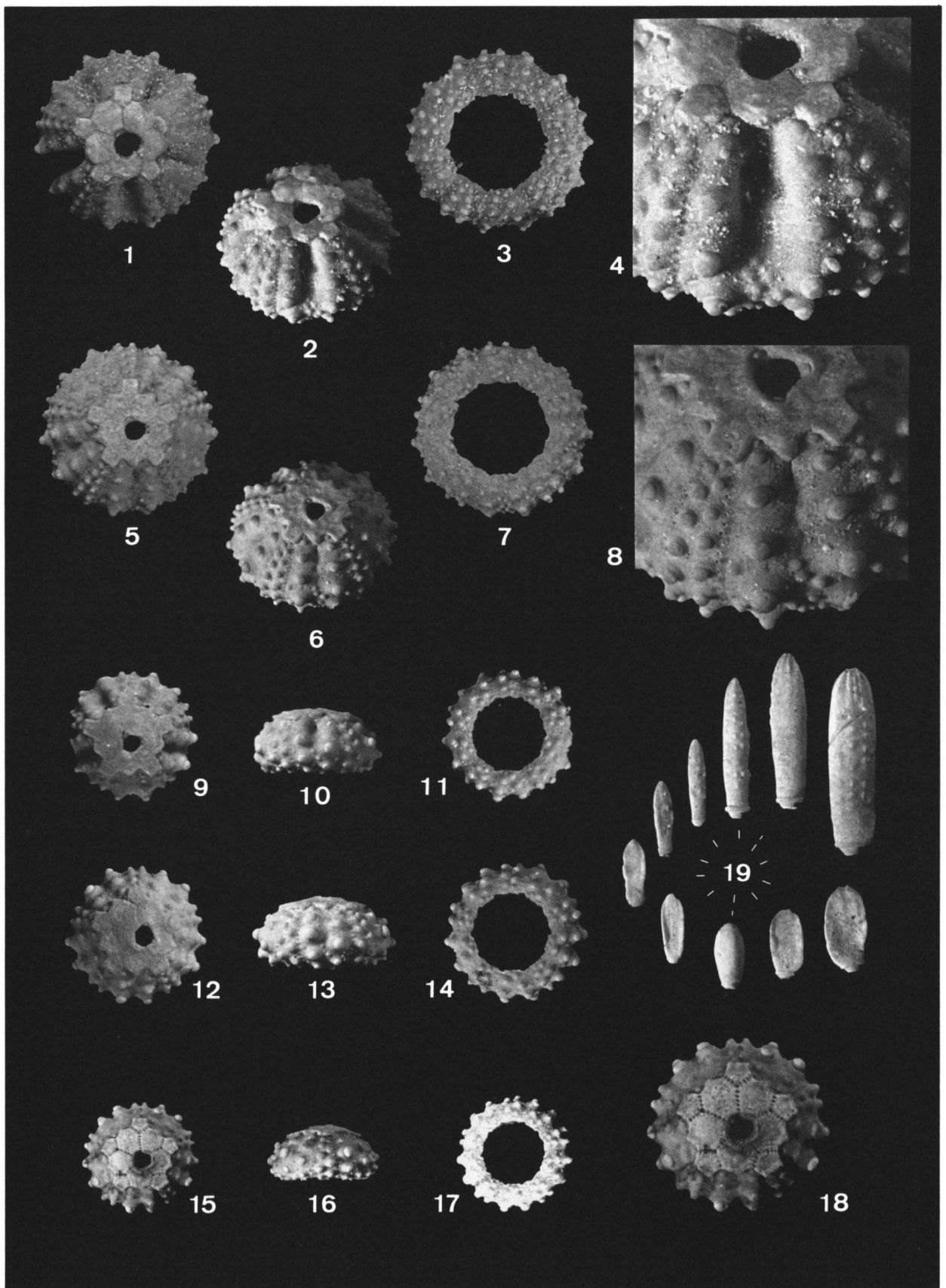
Figs 15-18. *Goniopygus heberti* Cotteau, 1866.

15-17: apical, lateral, and oral view, x 3.

18: same apical view as Fig. 15, but x 5.

Figs 19. *Goniopygus* sp. (spp.).

Ten spines, 'flattening' from the upper right counter-clockwise to the lower right; upper spaced arrow: smooth side of a slightly flattened spine, lower spaced arrow: convex side of a flattened spine. All x 3.



Maastrichtian (Meerssen Chalk) of the Maastricht area. It differs in having three to six pits per suture instead of two or three.

Goniopygus minor Sorignet, 1850

Plate 6, Figs 1-14

Figured specimens—Figs 1-8: van Birgelen collection, nr 432A; figs 9-14: van der Ham collection, nr 285. All from the Albertkanaal near Kesselt.

Description—Species exhibits sexual dimorphism. Test up to 17 mm in diameter. Apical system flat to slightly convex, consisting of ten smooth plates; sutures not pitted; periproct nearly central, bordered by three depressions, each of which harbours a small tubercle. Poriferous zones simple, adorally somewhat expanding in large specimens; ambulacral plates trigeminate. Adapical part of interambulacra in females distinctly depressed (brood pouches?), with a gonopore at the bottom. Males without or (in large specimens) with very slight interambulacral depressions, which are mostly situated more adorally than in females; male gonopores smaller or absent. Gill slits small. Tubercles imperforate, noncrenulate, up to ten in each ambulacrum and up to nine in each interambulacrum; secondary tuberculation sparse. Spines: see *Goniopygus* sp.(spp.) indet.

Distribution—Geulhem Chalk, uppermost part. Rather common. Males and females in about equal numbers.

Discussion—*Goniopygus minor* was described for the 'Etage sénonien sup. (danién)' of Eure (France). The species is probably restricted to Dano-Montian deposits. Cotteau (1879) reported *Goniopygus minor* from the 'Calcaire grossier de Mons' of the Mons region (S Belgium). Maastrichtian records (Geys, 1981) are probably based on specimens of *Goniopygus* sp. (van der Ham *et al.*, 1987), or specimens which, from a stratigraphical point of view, lacked reliable data (Zwartberg coal-mines). Geys (1981) considered *Goniopygus minor* and *G. heberti* conspecific. However, these species are certainly distinct in size and apical system. The difference between their apical systems does not seem to be brought about by progressing age (size) and/or abrasion, as small, unworn specimens display an apical system with smooth plates and nonpitted sutures as well. These are considered to be juveniles of *Goniopygus minor*. Large specimens never show pitted sutures. *G. eravillensis* Arnaud, 1889, cited by Geys (1981) for 'unspecified Maastrichtian' of the Zwartberg coal-mines (Belgium, about 20 km NW of Maastricht), is almost certainly based on material of *G. minor*. Smiser (1935) figured *G. minor* as *Salenia minima*.

Goniopygus sp.(spp.) indet.

Plate 6, Fig. 19

Figured specimens—Van der Ham collection, nr 285, from the Albertkanaal near Kesselt.

Description—Spines, up to 11 mm long. Slightly flattened. One side smooth, the other with three to five series of knobs. Apex grooved all around. Annulus very finely striate. A continuous series can be laid out with large, slightly flattened spines and small, much more flattened ones with every transition; these latter spines probably had a special function at a special position, *e.g.* around the peristome, the periproct, or the presumed brood pouches (van der Ham *et al.*, 1987).

Distribution—Geulhem Chalk, uppermost part. Common.

Discussion—*Goniopygus* indet. may represent the spines of either *G. minor* or *G. heberti*, or of both. Lambert (1908) figured a similar spine from France under *Goniopygus minor*. Cotteau (1879) figured a rather different spine from the 'Calcaire grossier de Mons' of the Mons region (S Belgium) together with tests of *G. minor*.

Ordo ? Phymosomatoida

? Phymosomatoida sp.

Plate 5, Figs 9-11

Figured specimen—Van Birgelen collection, nr 432N, from the Albertkanaal near Kesselt, uppermost part of the Geulhem Chalk.

Description—Test rather high, up to 16 mm in diameter; however, many fragments indicate a much larger size, up to about 30 mm. Periproct small, irregularly circular. Poriferous zones straight, simple throughout. Up to 13 ambulacral plates in one series, each with three pore pairs. Up to 13 interambulacral plates in one series. Primary tubercles small, imperforate, crenulate; secondary tubercles absent or very small. All plates covered by a sparse granulation. Peristome hardly sunken, with distinct gill slits.

Distribution—Geulhem Chalk, uppermost part. Rather common.

Discussion—On the basis of overall morphology, the species was provisionally referred to the Phymosomatoida (van der Ham *et al.*, 1987). A very faint sculpture on some fragments may justify a place in the Temnopleuroida (family Temnopleuridae). The species corresponds to Phymosomatoida ? sp. 2 in van der Ham *et al.* (1987).

Ordo Temnopleuroida Mortensen, 1942

Familia Temnopleuridae A. Agassiz, 1872

Genus *Arbacina* Pomel, 1869

Gen. et sp. aff. ? *Arbacina*

Plate 5, Figs 12-17

Figured specimens—Van Birgelen collection, nr 432M, from the Albertkanaal near Kesselt.

Description—Species exhibits sexual dimorphism. Test up to 7 mm in diameter. Apical system dicyclic, pentagonal; the inner whorl with a raised border surrounding the periproct. Poriferous zones simple throughout; ambulacral plates trigeminate. Females with a depression (brood pouch ?) in the apical part of each interambulacrum; each depression has a gonopore and is partly covered by a lobe originating from the adjacent inner whorl plate of the apical system (in Fig. 12 broken off in the lowermost one). Males (lacking interambulacral depressions) also have these lobes, but gonopores could not be detected. Gill slits small but distinct. Tubercles imperforate, noncrenulate, up to eight in each series, primary tubercles being situated in the lower half of all plates; secondary tuberculation rather dense. Sutural pits are probably absent, but traces of sculpture could be demonstrated in one specimen.

Distribution—Geulhem Chalk, uppermost part. Rare. Males and females in about equal numbers.

Discussion—This species was mentioned for the first time for the Maastricht area as *Temnopleuroida* ? sp., by van der Ham *et al.* (1987). As traces of sculpture could be demonstrated, the species has been referred to the *Temnopleuroida* with more evidence in this paper. Its imperforate tubercles place it among the *Temnopleuridae*. It may be near to *Arbacina*.

Ordo Hololectypoida Duncan, 1889

Familia Conulidae Lambert, 1911

Genus *Pygopyrina* Pomel, 1883

'*Pygopyrina*' houzeaui (Cotteau, 1875)

Plate 7, Figs 1-4

Figured specimen—W.M. Felder collection, nr MK770, from the former Curfs quarry near Berg.

Description—Test up to 31 mm long. Ambitus about circular. Apical system with four gonopores. Ambulacral plates unequal; pore pairs in arcs of three, each pair very oblique. Peristome slightly oblique and depressed. Tubercles scrobiculate, adorally more crowded than adapically.

Distribution—Geulhem Chalk, lower part. Rare.

Discussion—The type of this species stems from the 'Poudingue de la Malogne' of the Mons region (S Belgium). Also Meijer (1965) encountered it in the 'Poudingue'. Cotteau referred the species to the genus *Pyrina* Desmoulins, 1835. Smiser (1935) transferred the species to *Pygorhynchus* L. Agassiz, 1839 (*Cassiduloida* !) and Meijer (1965) to *Pygopyrina*. However, the latter genus is rather different, and at present known only up to the Cenomanian. Therefore, the species is indicated as '*Pygopyrina*' *houzeaui* (see also van der Ham *et al.*, 1987). Further study must ascertain its systematic position. The figured (type ?) specimen of '*Pygopyrina*' *conica* (Smiser, 1935), from the 'Poudingue de la Malogne' of the Mons region, is rather close to '*Pygopyrina*' *houzeaui*. *Pyrina montainvillainensis* Sorignet, 1850, from the 'Calcaire pisolitique' of Eure (France) is very near too (see also Lambert, 1908). *Globator subovalis*, described by Ravn (1927) as *Pseudopyrina subovalis*, from the Danian of Aggersborggaard (Denmark), may be identical (see also Meijer, 1965).

'*Pygopyrina*' ovalis (Smiser, 1935)

Plate 7, Figs 5-8

Figured specimen—Van Birgelen collection, nr 432D, from the Albertkanaal near Kesselt.

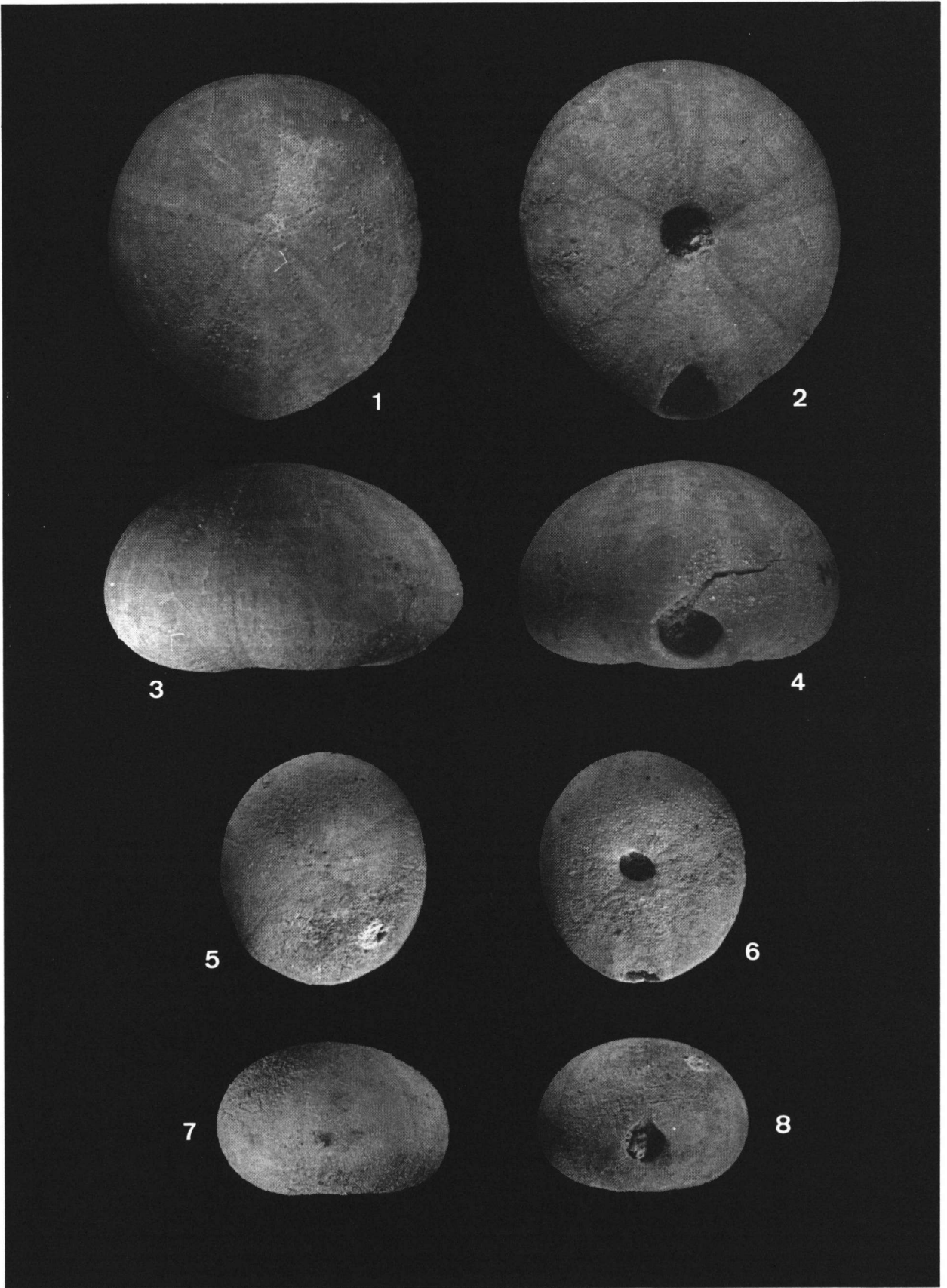
Description—Test up to 20 mm long, resembling '*Pygopyrina*' *houzeaui*, but differing in its more oblong shape, its larger height/width ratio, its less depressed and more distinctly oblique peristome, its higher situated periproct, and its less oblique pore pairs.

Distribution—Geulhem Chalk, uppermost part. Rare.

Plate 7. Hololectypoida

Figs 1-4. '*Pygopyrina*' *houzeaui* (Cotteau, 1875), apical, oral, lateral (left), and posterior view, x 2.

Figs 5-8. '*Pygopyrina*' *ovalis* (Smiser, 1935), apical, oral, lateral (left), and posterior view, x 2.



Discussion—Smiser described the species as a *Pygorhynchus* L. Agassiz, 1839 (Cassiduloidea !), for the Maastrichtian of the Zwartberg coal-mines (Belgium, about 20 km NW of Maastricht). However, Smiser was mistaken when he established its stratigraphic as well as its systematic position. The stratigraphical level of the type stratum is almost certainly Danian. At the moment its true systematic position remains unsettled. Because of the resemblance with '*Pygopyrina*' *houzeaui*, the species has been provisionally transferred to the genus *Pygopyrina* (compare van der Ham *et al.*, 1987). *Globator ravnii* Brünnich Nielsen, 1926, from the Danian of several localities in Denmark, may be identical. The '*Pygopyrina*' of plate 4, fig. 8 in Smiser (1935), from the 'Poudingue de la Malogne' of the Mons region (S Belgium), is closer to '*Pygopyrina*' *ovalis* than to '*Pygopyrina*' *houzeaui*.

Ordo Cassiduloidea Claus, 1880

Familia Cassidulidae L. Agassiz & Desor, 1847

Genus *Nucleopygus* L. Agassiz, 1840

***Nucleopygus oblongus* (Smiser, 1935)**

Plate 8, Figs 4-8

Figured specimens—Van Birgelen collection, nr 432F, from the Albertkanaal near Kesselt.

Description—Test up to 12 mm, sometimes up to 23 mm long. Apical system with four gonopores. Poriferous zones short and straight. Peristome depressed, broadly pentagonal, vertical sides densely covered with granules, in large specimens with indistinct bourrelets. Periproct nearly marginal, with a faint, short anal groove. Tubercles of about equal size, scrobiculate.

Distribution—Geulhem Chalk, uppermost part. Rather common.

Discussion—Smiser described the species, as *Phyllobrissus oblongus*, from the top of the Maastrichtian of the Zwartberg coal-mines (Belgium, about 20 km NW of Maastricht). However, Smiser was mistaken when he established its stratigraphic as well as its systematic position. The stratigraphical level of the type stratum is almost certainly Danian. As the species is more closely related to *Nucleopygus scrobiculatus* (Goldfuss, 1829) (type species of *Nucleopygus*) than to *Phyllobrissus gresslyi* (L. Agassiz, 1839) (type species of *Phyllobrissus* Cotteau, 1859), the species has been transferred to *Nucleopygus* (see also van der Ham *et al.*, 1987). Possibly, a very young specimen reported by Smiser (1935) as *Nucleopygus scrobiculatus* for the 'Calcaire grossier de Mons' of the Mons region (S Belgium) represents *Nucleopygus oblongus*.

Genus *Procassidulus* Lambert, 1918

Plate 8. Cassiduloidea

Figs 1-3. *Plagiochasma analis* (L. Agassiz, 1847), apical, lateral (right), and oral view, x 2.

Figs 4-8. *Nucleopygus oblongus* (Smiser, 1935).

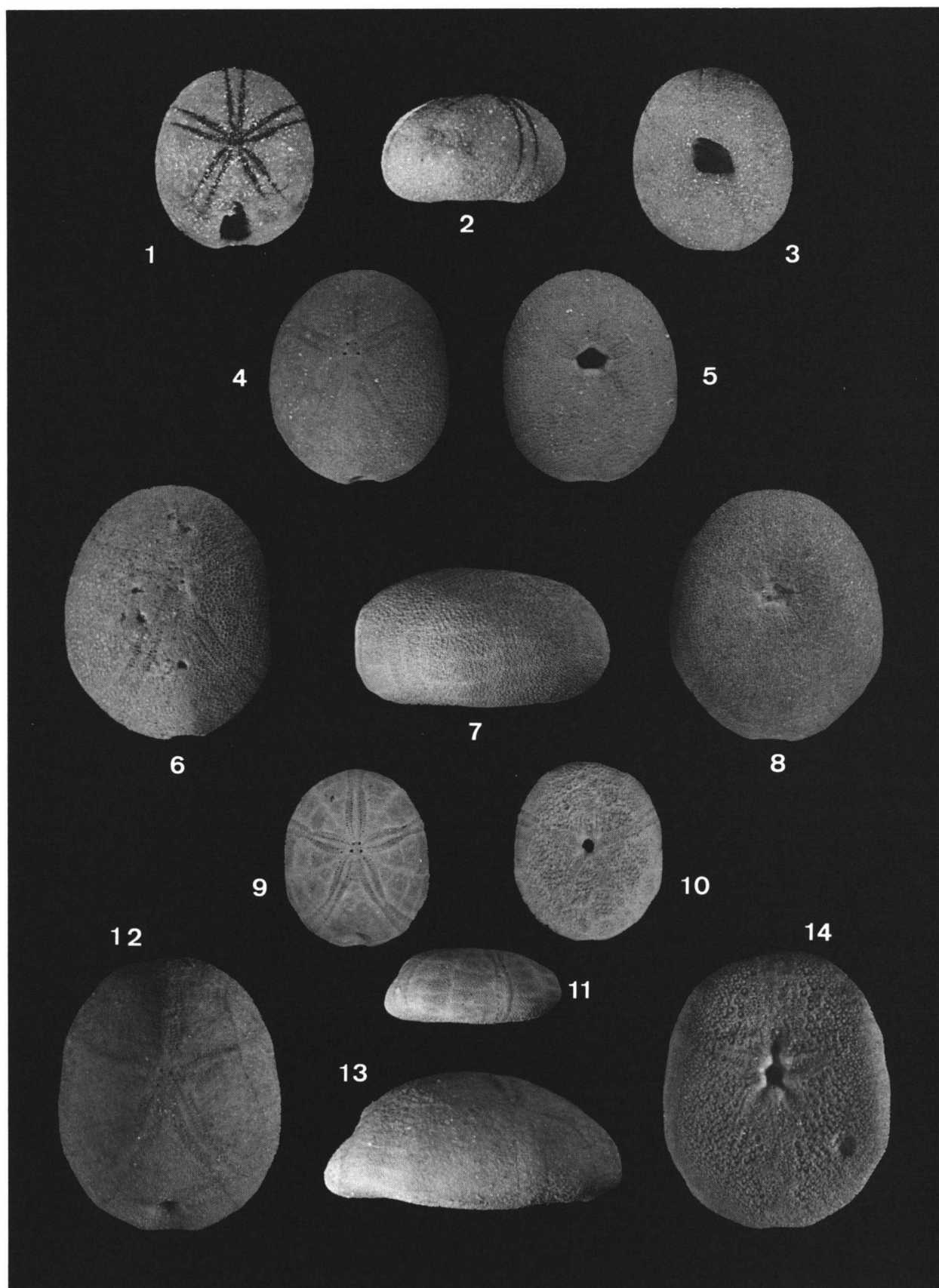
4 and 5: apical and oral view, x 2.

6-8: apical, lateral (right), and oral view, x 2.

Figs 9-14. *Procassidulus elongatus* d'Orbigny, 1856.

9-11: apical, oral, and lateral (right) view, x 2.

12-14: apical, lateral (right), and oral view, x 2.



Procassidulus elongatus d'Orbigny, 1856

Plate 8, Figs 9-14

Figured specimens—Van Birgelen collection, nr 432G, from the Albertkanaal near Kesselt, uppermost part of the Geulhem Chalk.

Description—Test up to 12 mm, sometimes up to 25 mm long. Apical system with four gonopores. Pore pairs in superficial petals. Oral side somewhat convex. Peristome small, faintly pentagonal, with distinct bourrelets. Periproct supramarginal, with a short but distinct anal groove, not deviating from the median axis. Oral side with a polymorphous, coarse tuberculation, which changes at the ambitus into a fine, homogeneous tuberculation. All tubercles scrobiculate.

Distribution—Entire Geulhem Chalk. Rather common.

Discussion—The species has been described for the Mons region, S Belgium ('Poudingue de la Malogne') as well as for the Maastricht area ('Terrain crétacé supérieur'). Cotteau (1879) reported it from the 'Calcaire grossier de Mons' of the Mons region, and Smiser (1935), as *Procassidulus chalmasi* Lambert, 1908, for the same deposit of the Eisden coal-mines (Belgium, about 15 km N of Maastricht). Meijer (1965) included it in his enumeration of the echinoids in the Maastricht region as *Procassidulus chalmasi*, *Procassidulus* aff. *chalmasi* and *Procassidulus* sp., probably unaware of the wide range of variability of the species. Rasmussen (1965) figured the species as *Procassidulus lapiscancri* (Leske, 1778), for the 'Tuffeau de Ciply' (Mons region), which is of Danian age. Engel (undated) eventually referred to it as *Procassidulus elongatus*. The species resembles *Procassidulus lapiscancri*. It differs in its more oblong shape and the more marginally situated periproct, which does not deviate from the median axis. It is very close to *Stigmatopygus bervillei* Desor, 1857, from the 'Calcaire pisolithique' of Eure, France (see also Lambert, 1908).

Familia Nucleolitidae L. Agassiz & Desor, 1847

Genus *Plagiochasma* Pomel, 1883

Plagiochasma analis (L. Agassiz, 1847)

Plate 8, Figs 1-3

Figured specimen—Van Birgelen collection, nr 432E, from the Albertkanaal near Kesselt, uppermost part of the Geulhem Chalk.

Description—Test up to 19 mm long. Apical system with four gonopores. Poriferous zones long and straight. Peristome oblique, depressed. Periproct large, oblong, without anal groove. Tubercles large and scrobiculate adorally, smaller and less distinctly scrobiculate adapically.

Distribution—Entire Geulhem Chalk. Rather rare.

Discussion—Agassiz described the species as *Nucleolites analis* for the 'Poudingue de la Malogne' of the Mons region (S Belgium). Also Meijer (1965) encountered it in this stratum, in the same area. Smiser (1935) wrongly referred this deposit to the base of the Maastrichtian. Lambert (1898) figured a specimen of *Plagiochasma analis* as *Lychnidius* (= *Nucleopygus*) *scrobiculatus* (Goldfuss, 1829).

Ordo Spatangoida Claus, 1876

Familia Schizasteridae Lambert, 1905

Genus *Linthia* Desor, 1853

***Linthia* sp. (spp.)**

Plate 9, Figs 1-5

Figured specimens—Figs 1-3: van Birgelen collection, nr 345, from the Albertkanaal between Vroenhoven and Kesselt, lower part of the Geulhem Chalk; Fig. 4: van der Ham collection, nr 285, from the Albertkanaal near Kesselt, uppermost part of the Geulhem Chalk; Fig. 5: van Birgelen collection, nr 432I, from the Albertkanaal near Kesselt, uppermost part of the Geulhem Chalk.

Description—Test very fragile, up to 41 mm long; however, several fragments suggest a much larger size. Apical system ethmolytic, with four gonopores. Ambulacrum III rather strongly depressed, distinctly indenting the frontal ambitus. Petals moderately to strongly depressed; posterior petals one third to one half of the length of the anterior ones; poriferous zones somewhat broader than the interporiferous zone. Peripetalous and latero-anal fascioles well-developed. Tubercles nonscrobiculate.

Distribution—Entire Geulhem Chalk. Rather common. Unbroken tests are rare.

Discussion—Probably, several species are represented in the Danian of the Maastricht region. Especially in the uppermost part of its range, the material is very heterogeneous. Further study requires a larger amount of complete tests or a time-devouring inspection of the numerous fragments. Eventually some fragments (like that of Fig. 4) may prove to belong to some other schizasterid genus. Up to now, *Linthia houzeaui* Cotteau, 1879, from the 'Calcaire grossier de Mons' of the Mons region (S Belgium) and of the Eisden coal-mines, Belgium, about 15 km N of Maastricht (Smiser, 1935), has not been recognised among the available material. In this species the posterior petals are somewhat shorter than to nearly equal to the anterior petals.

? ***Linthia breviuscula* (d'Orbigny, 1855)**

Plate 9, figs 6-8

Figured specimen—Meijer collection, nr 862, from the side of the road between Geulhem and Berg.

Description—Test relatively thick, up to 8 mm long. Apical system ethmolytic, probably with four gonopores. Ambulacrum III and petals slightly depressed; posterior petals about half the length of the anterior petals; interporiferous zone very narrow. Fascioles and tubercles not discernable, due to recrystallization.

Distribution—Very rare; only one, maybe two specimens known. The figured specimen stems from the filling of a perforation in the hardground at the top of the Maastrichtian; originally probably from the lowermost part of the Geulhem Chalk (according to M. Meijer, the collector of the specimen).

Discussion—D'Orbigny described the species, as *Hemiaster breviuscula*, for the 'craie blanche' of the environs of Maastricht. However, *Hemiaster* L. Agassiz, 1847 has an ethmophract apical system, whereas in it is ethmolytic in the present specimen. For that reason and on the basis of overall shape and morphology, the species has been provisionally transferred to the genus *Linthia* (see van der Ham *et al.*, 1987). The specimen has still to be compared with the holotype, in order to ascertain the above assignment.

BIOSTRATIGRAPHICAL AND BIOGEOGRAPHICAL NOTES

Tab. 1, column 1 summarizes the stratigraphical distribution of the Danian echinoids (spines excluded) from the Maastricht area. Occurrence in the lower part of the Geulhem Chalk (localities: former Curfs quarry and Albertkanaal) is indicated at the left-hand side of the column, while occurrence in the upper part (including the uppermost part) of the Geulhem Chalk (locality: Albertkanaal) is shown at the right-hand side. Only 4 species are confined to the lower part of the Geulhem Chalk, 14 are limited to the upper part, while 10 occur in both parts. Most of the genera (as far as they could be identified) pass the Maastrichtian/Danian boundary, which fits the conclusion of Stokes (1979) for spatangoid echinoids. Only a single species, *Stereocidaris forchhammeri* (maybe also a second one: *Stereocidaris* sp.), crosses the boundary, which may reflect the considerable gap between the Maastrichtian and the Danian deposits in the Maastricht area. Gravesen (1979) and Asgaard (1979) described a similar pattern for the regular and the irregular echinoids respectively from the Late Maastrichtian and Early Danian of Denmark. A remarkable difference between the Maastrichtian and Danian echinoid faunas in the Maastricht area is shown by the changing ratio Regularia/Irregularia. In the Geulhem Chalk three out of four species are regular echinoids, whereas in the Maastrichtian this group is always less well-represented. Especially the increase of Cidaroida and the decrease of Cassiduloida, Holasteroida, and Spatangoida contribute to this ratio change.

In the discussions in the systematic part of this paper, mention is made of the occurrence of species from the Maastricht area in the Dano-Montian of southern Belgium (Mons region) and the Danian of Denmark/southern Sweden. Column 2 of Tab. 1 shows the stratigraphical distribution of species from the Mons region. The Dano-Montian can be split into a Danian and a Montian part, according to Godfriaux & Marlière (1971) and Anderson (1982). Presence in the Danian ('Tuffeau de Cipl'y', including its basal layer, the 'Poudingue de la Malogne') is shown at the left-hand side, presence in the Montian ('Calcaire grossier de Mons') at the right-hand side. Tentative correlations are indicated by question-marks. It appears that the Maastricht area and the Mons region have at least 12 species in common. The resemblance is especially apparent for the 'Tuffeau de Cipl'y': 10 species in common. '*Cidaris*' *distincta* and *Goniopygus minor*, which in the Mons region are confined to the Montian, occur in the Maastricht area in the uppermost Geulhem Chalk. Two additional species, *Stereocidaris forchhammeri* and *Procassidulus elongatus*, which occur in the Danian as well as in the Montian, have long ranges (entire Geulhem Chalk) in the Maastricht area as well.

Attention must be paid here to the data of Smiser (1935) and Geys (1981) concerning the Dano-Montian species found in the shafts of coal-mines near Eisden and Zwartberg (Belgium, 15 km N and 20 km NW of Maastricht respectively). From Zwartberg, Smiser described '*Pygopyrina*' *ovalis* and *Nucleopygus oblongus*, while Geys reported *Goniopygus minor* from that locality. Although both referred to Maastrichtian deposits, these species almost certainly stem from the post-Maastrichtian, probably

Plate 9. Spatangoida

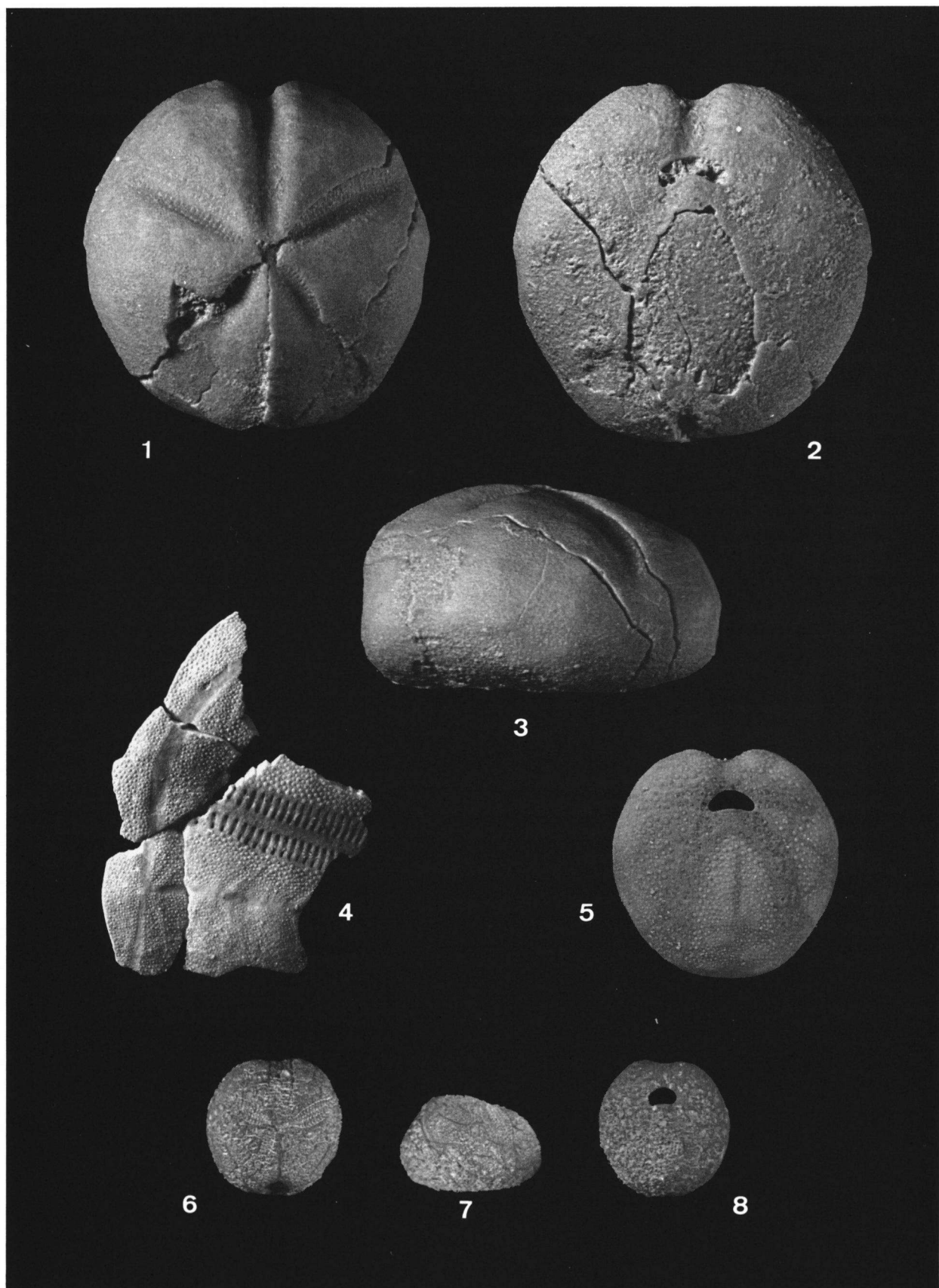
Figs 1-5. *Linthia* sp. (spp.).

1-3: apical, oral, and lateral (right) view, x 2.

4: distal part of petal in ambulacrum IV with parts of fascioles, x 2.

5: oral view of an apically damaged test, x 2.

Figs 6-8. ? *Linthia breviuscula* (d'Orbigny, 1855), apical, lateral (right), and oral view, x 3.



	1 Maas- tricht area	2 Mons region	3 Denmark/ S Sweden
<i>Stereocidaris forchhammeri</i> (Desor, 1846)	+ +	+ +	+
<i>Stereocidaris</i> sp.	+ +	- +	?
<i>Temnocidaris danica</i> (Desor, 1855)	+ +	+ -	+
' <i>Cidaris</i> ' <i>distincta</i> Sorignet, 1850	- +	- +	-
' <i>Cidaris</i> ' sp.	- +	- -	-
<i>Tylocidaris bruennichi</i> Ravn, 1928	- +	+ -	+
<i>Tylocidaris hardouini</i> (Desor, 1855)	+ -	+ -	?
<i>Palaeodiadema</i> sp.	+ +	- -	-
<i>Salenia belgica</i> Lambert, 1898	+ -	+ -	-
<i>Salenidia danica</i> Ravn, 1928	+ +	? -	+
<i>Salenidia selandica</i> Ravn, 1928	- +	+ -	+
<i>Hyposalenia heliophora</i> (Desor, 1846)	+ +	+ -	?
<i>Phymosoma</i> sp.	- +	? -	-
' <i>Phymosoma</i> ' <i>maastrichtensis</i> Engel, 1972	- +	- -	-
<i>Phymosomatoida</i> sp.	- +	- -	-
<i>Phymosomatoida</i> sp.	- +	- -	-
<i>Phymosomatoida</i> sp.	+ +	? -	-
<i>Goniopygus heberti</i> Cotteau, 1866	- +	- -	-
<i>Goniopygus minor</i> Sorignet, 1850	- +	- +	-
? <i>Phymosomatoida</i> sp.	- +	- -	-
Gen. et sp. aff. ? <i>Arbacina</i>	- +	- -	-
' <i>Pygopyrina</i> ' <i>houzeau</i> (Cotteau, 1875)	+ -	+ -	?
' <i>Pygopyrina</i> ' <i>ovalis</i> (Smiser, 1935)	- +	? -	?
<i>Nucleopygus oblongus</i> (Smiser, 1935)	- +	- ?	-
<i>Procassidulus elongatus</i> d'Orbigny, 1856	+ +	+ +	-
<i>Plagiochasma analis</i> (L. Agassiz, 1847)	+ +	+ -	-
<i>Linthia</i> sp.	+ +	- -	-
? <i>Linthia breviscula</i> (d'Orbigny, 1855)	+ -	- -	-

Table 1. Stratigraphical and geographical distribution of Danian echinoids from the Maastricht area. Further explanation in text (see Biostratigraphical and biogeographical notes).

from an equivalent of the uppermost Geulhem Chalk in the Maastricht area. From Eisdén, Smiser described *Isopneustes eysdenensis* and *I. montensis*, in addition to recording *Procassidulus elongatus*, *Echinanthus corneti* Cotteau, 1879, and *Linthia houzeau* Cotteau, 1879. Both *Isopneustes* species and the *Linthia* are probably absent from the Maastricht area. The Eisdén specimen of *Echinanthus corneti* figured by Smiser, is very dissimilar to those from the type locality (Mons). Fragments which may be matched with the Eisdén specimen were collected in the uppermost Geulhem Chalk, but as the material is very incomplete, no description has been included in the systematic part of this paper. The species known from Eisdén may indeed originate from Montian deposits, as Smiser mentioned ('Calcaire grossier de Mons'). *Procassidulus elongatus*, the only Eisdén species which is also known with certainty from the Maastricht area, ranges in the Mons region from the Danian to the Montian.

Column 3 of Tab. 1 shows the occurrence of several species from the Maastricht area in the Danian of Denmark and southern Sweden. The two regions have at least five species in common.

At least four species are shared by the Maastricht area, the Mons region, and Denmark/southern Sweden. Ten species are up to now only known from the Maastricht area. Some of these may have been endemic to the Early Palaeocene Maastricht Basin.

An echinoid fauna remarkably similar to that of the Maastricht and Mons regions is found in the Montian ('Calcaire pisolithique') of Eure in the Paris Basin, France (Sorignet, 1850; Lambert, 1908). *Stereocidaris forchhammeri* and *Goniopygus minor* are among this fauna, while *Pyrina montainvillensis* Sorignet, 1850 and *Stigmatopygus bevillei* Desor, 1857 are close to '*Pygopyrina*' *houzeaui* and *Procassidulus elongatus* respectively.

CONCLUSION AND SUGGESTIONS FOR FURTHER STUDY

The echinoid fauna from the Geulhem Chalk of the Maastricht area demonstrates a clear relationship with the echinoid faunas from the Danian of Denmark/southern Sweden, the Dano-Montian of Eisdén/Zwartberg (NE Belgium) and the Mons region (S Belgium), and the Montian of Eure (France). The closest affinity exists with the fauna of the 'Tuffeau de Ciplé' (Danian) of the Mons region, especially with its base, the 'Poudingue de la Malogne'. However, the uppermost Geulhem Chalk also yields several Montian elements, sharing these with the Montian of Eisdén, the Mons region, and Eure. The echinoid fauna of the Geulhem Chalk also contains a considerable endemic element.

Further study of the echinoid fauna from the Geulhem Chalk should include first and foremost the identification of especially the phymosomatoid species. Secondly, material of a number of species has to be compared with the type specimens to confirm the assignments; the generic position of several species has to be changed. Subsequently, the relations between the faunas of the Maastricht area and those of other regions, which in this paper were deduced for the greater part from a comparison with descriptions of material from those regions, have to be checked with actual specimens.

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Manuscript received 17 August 1988